

NOTICE

All drawings located at the end of the document.

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TECHNICAL MEMORANDUM NO. 9

**HUMAN HEALTH RISK ASSESSMENT
903 PAD, MOUND, AND EAST TRENCHES AREAS
OPERABLE UNIT NO. 2
CHEMICALS OF CONCERN**

DRAFT FINAL

ROCKY FLATS PLANT

**U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado**

**DOCUMENT CLASSIFICATION
REVIEW WAIVER PER
CLASSIFICATION OFFICE**

**ENVIRONMENTAL MANAGEMENT DEPARTMENT
December 1993**

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INTRODUCTION

This Chemicals of Concern Technical Memorandum is presented as part of the Baseline Risk Assessment (BRA) for the 903 Pad, Mound Area, and East Trenches Area, otherwise known as Operable Unit 2 (OU-2), located at Rocky Flats Plant. The BRA, which consists of the Human Health Risk Assessment (HHRA) and the Environmental Evaluation, will be included in the Phase II RCRA Facility Investigation/Remedial Investigation (RFI/RI) report for OU-2. The RFI/RI is being conducted pursuant to the U.S. Department of Energy (DOE) Environmental Restoration Program; a Compliance Agreement between DOE, the U.S. Environmental Protection Agency (EPA), and the State of Colorado Department of Health (CDH); and the Federal Facility Agreement and Consent Order (Interagency Agreement), signed in 1991.

This technical memorandum has been developed to address the selection of chemicals of concern to be evaluated in the BRA, in particular the HHRA. The identification of chemicals of concern will also help focus the efforts of the environmental evaluation, environmental transport modeling, description of the nature and extent of contamination, and remedy selection.

The HHRA will evaluate potential human health risks for on-site and off-site receptors under current land use and probable future land use conditions, assuming no remedial action takes place at OU-2. Chemicals of concern are organic chemicals, metals, or radionuclides that are site-related (i.e., potentially related to releases of wastes or waste sources in OU-2), that exceed background range, and that could be a significant threat to human health or the environment under the exposure conditions evaluated. Chemicals of concern are identified for each medium (e.g., groundwater, soil) through which exposure to site-related chemicals could occur. Therefore, the selection of chemicals of concern supports the quantification of risk from exposure to chemicals via the exposure pathways identified in the Exposure Scenarios Technical Memorandum No. 5 (DOE 1993a).

This technical memorandum focuses on selecting chemicals of concern in groundwater, subsurface soil, and surface soil, which were the media sampled during the Phase I and Phase II RFI/RI at OU-2. Indirect exposure to OU-2 contaminants can also occur through air and surface water if soil or groundwater contaminants are released to these media. Concentrations of chemicals of concern in air and surface water will be estimated using fate and transport modeling.

This technical memorandum describes the process for selecting chemicals of concern detected in groundwater, subsurface soil, and surface soil at OU-2 and summarizes the chemicals of concern for each medium. The general process to select potential chemicals of concern is described in Section 2.0. Sections 3.0, 4.0, and 5.0 present decision criteria specific to each medium and identify the chemicals of concern selected for each medium. References used in this document are listed in Section 6.0.

Appendix A, "Background Comparison for Metals and Radionuclides," describes the statistical methodology used to compare OU-2 data to background data and includes tables showing the results of the statistical tests. Statistical tests were used to identify metals and radionuclides whose concentrations exceed background levels and which may therefore be site-related. These metals and radionuclides are retained for further evaluation as potential chemicals of concern.

Appendix B, "Risk-Based Evaluation of Infrequently Detected Chemicals," presents the screening of infrequently detected compounds (<5 percent detection frequency) to identify those that merit further evaluation as special-case chemicals of concern.

Appendix C contains a copy of the OU-2 report titled "Domestic Water Supply Simulations," September 10, 1992. This document supports evaluating the No. 1 Sandstone lithologic unit for hypothetical on-site ingestion of groundwater. Other lithologic units (alluvium, colluvium, and valley fill) have insufficient water to support a domestic well.

Appendix D, "Dissolved Metals and Radionuclides, No. 1 Sandstone, Background Comparison," contains results of the statistical comparison to background data for dissolved metals and radionuclides in the No. 1 Sandstone groundwater. These results are used to support the discussion of the significance of certain total (unfiltered) metals results from this unit.

CHEMICALS OF CONCERN SELECTION PROCESS

The general methodology for selecting chemicals of concern for OU-2 is presented in Figure 2-1, Criteria for Identifying Chemicals of Concern. The process is intended to identify chemicals in each medium that appear to be associated with waste releases or sources in OU-2 that could have adverse impacts on public health under exposure scenarios involving that medium. In this way, the risk assessment is focussed on OU-2 constituents that are potential health hazards. Inorganic compounds whose concentrations are within background range or that are minor constituents (e.g., rarely detected and/or of low toxicity) are excluded from the risk assessment. Organic compounds that would contribute negligibly or not at all to overall risk are identified but are not included in the quantitative risk assessment. It is important that the chemicals of concern be carefully selected so that risk is not underestimated and so as not to distract from the dominant risks associated with the OU.

This selection process was based on guidance presented in Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part A (EPA 1989). The background comparison methodology was based on the Final Background Geochemical Characterization Report, Rocky Flats Plant (EG&G 1992) and on standard statistical evaluation techniques.

The steps shown in Figure 2-1 and described in the following sections were applied to select chemicals of concern for all three media sampled during the remedial investigation (groundwater, subsurface soil, and surface soil). Details of the application of the process for each medium are presented in Sections 3.0 (groundwater), 4.0 (subsurface soil), and 5.0 (surface soil).

The individual steps shown in Figure 2-1 are identified below. Each step is described in more detail in Subsections 2.1 through 2.5.

Step 1 - Site-Specific Chemical Analysis Roster

Table 2-1 is the Site-Specific Chemical Analysis Roster (SSCAR) for the Phase II sampling program at OU-2. Analytical results for all detected compounds in the following analyte groups are included in the data set for evaluation as potential chemicals of concern for risk assessment: metals (target analyte list and "other metals"), radionuclides, and organics.

Step 2 - Data Evaluation

The analytical results from the OU-2 sampling program were reviewed and compiled in a database by the validation contractor. Data validation was performed for some but not all of the data prior to use. The database was then reviewed for its suitability for selecting chemicals of concern. For example, data qualifiers were considered and quality control samples were removed from the database.

Step 3 - Background Comparison (Metals and Radionuclides)

Analytical results for metals and radionuclides were compared to background levels derived from data for groundwater and subsurface soils reported in the Background Geochemical Characterization Report (EG&G 1992) and from background surface soil samples collected in the Rock Creek area during the 1991 OU-1 Phase III investigation and the 1993 OU-2 Phase II investigation. Metals and radionuclides whose concentrations did not exceed background levels were eliminated from further consideration as potential chemicals of concern. The following criteria were used to evaluate whether a metal or radionuclide exceeded background levels:

- a. Analytical results for metals and radionuclides were compared to the 95 percent upper tolerance limit (95% UTL) of the background data. If less than 5 percent of the results exceeded the 95% UTL, the constituent was considered to be within background range. Analysis of variance (ANOVA) was used to confirm this assessment.
- b. The OU-2 data for metals and radionuclides were compared to background data using parametric or nonparametric ANOVA. If no statistical difference was found, the analyte was considered to be within background range.
- c. Spatial/temporal evaluation of analytes that appeared to exceed background by one or more of the statistical tests was performed to identify analytes that are unlikely to be OU-2 contaminants.

Step 4 - Eliminate Essential Nutrients and Anions

Constituents such as calcium, potassium, iron, and carbonate were eliminated from further consideration as chemicals of concern due to low toxicity and because they are usually not waste-related.

Step 5 - Detection Frequency

All detected organic target analytes were separated into two groups based on detection frequency. Compounds detected at 5 percent or greater detection frequency were evaluated further in Step 6. Contaminants detected below 5 percent frequency were evaluated in Steps 8 and 9.

Step 6 - Concentration/Toxicity Screen

A concentration/toxicity screen, using maximum detected concentrations and EPA-established toxicity factors, was performed for all organic chemicals with a detection frequency equal to or greater than 5 percent, and for metals and radionuclides that exceed background levels. The concentration/toxicity screen identified those compounds that are likely to contribute 99 percent or more of the total risk. These compounds are identified as chemicals of concern for quantitative evaluation in the risk assessment.

EPA-established toxicity factors are not available for some of the target analytes. Therefore, these analytes cannot be included in the concentration/toxicity screens, in other toxicity-based screens, or in the quantitative risk assessment. OU-2 contaminants without toxicity factors were identified for each medium (surface and subsurface soil and groundwater) and are listed in each section. The potential impact of these compounds on overall risk will be addressed qualitatively in the human health risk assessment.

Step 7 - Chemicals of Concern

Organic compounds, metals, and radionuclides that contribute to 99 percent of a total risk factor, based on Step 6, were retained as chemicals of concern for quantitative evaluation in the human health risk assessment.

Step 8 - Evaluation of Infrequently Detected Compounds

The maximum concentration of each organic compound detected at less than 5 percent frequency was compared to a screening-level concentration equivalent to 1000 times a health risk-based concentration (RBC). This step identifies infrequently detected compounds that could contribute significantly to risk if exposure were to occur.

Step 9 - Spatial and Temporal Evaluation of Infrequently Detected but Potentially Hazardous Compounds

Infrequently detected organic compounds whose maximum concentration exceeded 1000 times the RBC were evaluated for spatial and temporal distribution of the detected values. If the compounds appeared to be related to waste sources or if spatial and temporal distribution indicated that the constituent is of potential concern for current or future exposures, these chemicals were retained as "special-case" chemicals of concern.

Step 10 - Special Case Chemicals of Concern

Compounds whose maximum concentration exceeded the screening values (Step 8) and with significant spatial and temporal distributions (e.g., detected in association with elevated concentrations of other chemicals of concern) (Step 9), as well as certain inorganic compounds with highly localized, source-related occurrences of concentrations above background, were retained as "special case" chemicals of concern. Their impact on overall risk will be addressed separately in the risk assessment.

Step 11 - Professional Judgment

Chemicals or radionuclides that were eliminated as chemicals of concern by the above criteria may be retained on the basis of professional judgment.

2.1 DATA EVALUATION

2.1.1 Media-Specific Data Sets

Analytical data from environmental samples collected during OU-2 field sampling programs and RFP site-wide sampling programs were used to characterize contamination in OU-2. Table 2-2, OU-2 Analytical Data File Summary, presents the data files used to select chemicals of concern

for OU-2. The data sets used for evaluation of groundwater, subsurface soils, and surface soils are described below:

Groundwater

Groundwater samples are collected from RFP monitoring wells on a quarterly basis under a plant-wide groundwater sampling program. For the plant-wide monitoring program, samples were collected from a large group of accessible wells in OU-2, including wells installed during OU-2 Phase I and Phase II investigations, and wells installed during other investigations conducted in 1986 and 1989.

Lithologic identifications for the groundwater monitoring data were determined, and only wells completed in the Upper Hydrostratigraphic Unit (UHSU) were included in the groundwater data set for the selection of chemicals of concern. The UHSU includes the alluvium, colluvium, valley fill, the uppermost Arapahoe Sandstone (No. 1 Sandstone) and weathered claystone of the Arapahoe and/or Laramie formations. The OU-2 bedrock investigation (DOE 1993b) will address any potential contamination of the Lower Hydrostratigraphic Unit (LHSU). Chemicals of concern for assessing human health risk from on-site groundwater ingestion were selected from analytes detected in the No. 1 Sandstone. This approach is based on the finding, presented in the OU-2 Water Supply Simulations document (Appendix C), that the No. 1 Sandstone is the only lithologic unit within the UHSU that could support a domestic water well. Groundwater data from all units in the UHSU were used for evaluating migration of contaminants in groundwater to potential exposure points in Woman Creek and Walnut Creek.

The data used for evaluation of contaminant concentrations in the UHSU were taken from samples collected from the second quarter of 1991 through the third quarter of 1992, and received from RFEDS by March 15, 1993. The second quarter of 1991 was the first quarterly groundwater sampling event for which SOPs and a validation criteria were in place. Samples collected prior to the second quarter of 1991 were inconsistently collected and validated. In general, the groundwater samples were analyzed for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides/PCBs, metals, radionuclides, and water-quality parameters.

Subsurface Soils

Data used to evaluate OU-2 contamination in subsurface soils were taken from four sources:

- OU-2 Phase I field investigation conducted in 1987
- OU-2 Phase II field investigation conducted in 1991 to 1993
- Boreholes drilled for a seismic evaluation conducted in 1989
- Well abandonment and replacement program conducted in 1992

Available analytical results from the above field investigations received from RFEDS by March 15, 1993 have been used in characterizing OU-2 contamination. For the background comparison and selection of chemicals of concern, results from subsurface soil samples collected below the water table (high groundwater levels) were not included in the data set in order to avoid including constituents present due to cross-contamination by groundwater.

Surface Soils

Data used to evaluate OU-2 contamination in surface soils were taken from two sources:

- OU-2 Phase II investigations in 1991 (CDH and modified RFP methods)
- OU-2 Phase II investigations in 1993 (RFP method)

The surface soils collected in 1991 were analyzed for radionuclides only. Those samples collected using the CDH method were analyzed for americium, plutonium, and uranium. Surface soils collected during the 1991 sampling event using the modified RFP method were analyzed for americium and plutonium.

Samples collected during the 1993 field investigation using the RFP method were analyzed for metals, radionuclides (except for americium, plutonium, and uranium), SVOCs, and pesticides/PCBs.

2.1.2 Data Review and Editing

Some chemical analytical results received from Rocky Flats Environmental Data System (RFEDS) had not been validated. Nonvalidated data were integrated with validated data received from Quantalex Laboratory. If nonvalidated and validated data for the same sample were found in the database, the nonvalidated data were eliminated. Data that had not yet been through the validation process were used if no validated data were available.

The next step in the data evaluation process was to remove quality control samples, such as blanks, spikes, and rinsates, from the database. Data qualifiers for chemicals (e.g., B, E, D and R) were identified and the following revisions to the database were made:

- E qualified data (exceeded calibration range) were replaced with the associated D qualified data (diluted to within calibration range). The E qualifier for metal analytical results indicates that the reported value was estimated due to interference. These data were used as reported.
- The B qualifier for a metal result signifies that the reported concentration is greater than the instrument detection limit but less than the Contract Required Quantitation Limit (CRQL) for that analyte. These data were used as reported (B-qualified organic data are addressed separately in Section 2.1.3.)
- R-qualified data (not usable according to EPA criteria) were eliminated. R-qualified results represent a very small fraction of the entire data set and only appear in validated data.

Data qualified with J or U were used as follows:

- Analytical results were J qualified if the compound was positively identified below the quantitation limit. The result was considered an estimate because of the uncertainty associated with detected concentrations at low levels. Data qualified with a J were used as reported.
- A U qualifier assigned to an analytical result indicates that the analyzed chemical was not detected above the sample quantitation limit. The U qualifier was the primary mechanism used for evaluating detection frequency for the organic and inorganic constituents. The U-qualified data were used as nondetects for detection frequency determination, but one-half the reporting limit was used as the concentration in the statistical evaluations (background comparison).

Sometimes multiple analytical results for a given sample were reported in the RFEDS database. Circumstances that may have resulted in multiple results being reported and the action taken during review of the database include:

- Validated and nonvalidated results were reported for the same sample: In all cases where a validated and nonvalidated sample result were reported, the result from the validated record was retained in the database.
- Multiple validated results received for the same sample: The record that contained the most information or had the most recent validation date was retained.
- Results from multiple dilutions were reported for the same sample: Multiple dilutions were reported for the analyses for volatile and semivolatile organics due to one or more analytes exceeding the calibration range for the initial analysis. In cases where the result was flagged with an E qualifier by the laboratory, the action taken was as described above. In cases where nondetects were reported for an analyte in both the initial and diluted samples, the value with the lower detection limit was retained. In cases where the results were reported as detected in both the initial and diluted samples, the higher value was retained in the database.
- Results from both an initial analysis and a re-analysis or re-extraction were reported for the same sample: For nonvalidated results, the reason for the re-analysis or re-extraction were not reported (e.g., calibration, surrogates, internal standard errors) and it was not possible to determine if the problem requiring the re-analysis was corrected or if the re-analysis was performed within holding times. Therefore, in cases where nondetects were reported for an analyte in both the initial and re-analyzed samples, the value with the lower detection limit was retained. In cases where the results were reported as detected in both the initial and re-analyzed samples, the higher value was retained in the database.

For radionuclides, negative values were considered nondetect (and set equal to zero), and values less than the laboratory reporting limit were used as positive results or nondetects in accordance with qualifiers assigned during data validation.

2.1.3 Use of B-Qualified Results for Organics

The B qualifier assigned to an organic compound (volatile, semivolatile, pesticide, or polychlorinated biphenyl [PCB]) signifies that the compound was found in both the sample and the associated laboratory blank. For validated data, if the reported sample concentration of a compound that is not a common laboratory contaminant was greater than five times the

concentration in the blank, the sample result was used as reported. If less than five times the blank concentration, the sample result was qualified with a U by the validation contractor and the result reported as nondetect at the reported value. If the sample concentration of a compound that is a common laboratory contaminant (e.g., acetone, methylene chloride, 2-butanone, bis([2-ethylhexyl]) phthalate) was greater than ten times the concentration in the blank, the analytical result was used as reported. If not, the result was qualified with a U by the validation contractor and the result reported as nondetect at the reported value.

Nonvalidated, B-qualified sample results were also contained in the original database received from the validation contractor. However, data for the associated laboratory blanks or rinsate blanks were not included or received during development of the working database for selection of chemicals of concern. Because the effect of blank contamination on the B-qualified results could not be assessed, the nonvalidated B-qualified results were not included in the working database for selection of chemicals of concern. The exclusion of these nonvalidated B-qualified results from the working database does not adversely affect the usability of the data for selection of chemicals of concern for the following reasons:

- (1) Relatively few results were excluded (388 results, or less than 1 percent of the total number of analytical results).
- (2) About 85 percent of the nonvalidated B-qualified results were for the common laboratory contaminants acetone, methylene chloride, and phthalates; about 10 percent of the B-qualified results were for other volatile organics in groundwater samples that were also detected in laboratory or rinsate blanks; and about 5 percent were B-qualified results for N-nitrosodiphenylamine in subsurface soils. Therefore, most of the removed results are for compounds that are not likely to be chemicals of concern in risk assessment.
- (3) In the validated data set, most B-qualified results for common laboratory contaminants were changed to U-qualified results (nondetect) during validation. Therefore, it is probable that most of the other B-qualified results for these compounds would also be qualified as nondetect.

The largest effect of removing the nonvalidated B-qualified results from the database for selecting chemicals of concern is to change the frequency of detection of compounds that are common laboratory contaminants by a small percentage because the total number of results for each analyte is reduced by the number of nonvalidated B-qualified results excluded from the working data set. This is not considered to adversely affect the identification of site-related chemicals of concern for risk assessment.

Further assessment of the excluded B-qualified data was undertaken by the remedial investigation contractor to verify this conclusion and to assign an arbitrary data qualifier to each nonvalidated B-qualified result reflecting whether the result was assessed to be nondetect (ND) or a real value (RV). The results of this assessment are summarized in Table 2-3. The assessment of these sample results was made on the basis of blank data, when available; when blank data were not available the assessment was based on comparison to nominal detection limits. As discussed below, the assessment supports the conclusion that exclusion of the nonvalidated B-qualified results has no effect on the selection of COCs for OU-2.

The nonvalidated B-qualified results were assessed using the following criteria:

- Where method blank data were available, the sample concentration was compared to the amount reported in the blank. For common laboratory contaminants (acetone, methylene chloride, 2-butanone, and the phthalates), if the sample concentration exceeded ten times the concentration in the blank, the chemical was deemed to be present in the sample and was assigned the code RV. If the sample concentration was less than ten times the blank concentration, the sample concentration was attributed to laboratory contamination and was assigned the code ND. For chemicals other than common laboratory contaminants that were detected in the associated method blank, the same assessment procedure was applied except that a factor of five instead of ten was used; the codes ND and RV were assigned as appropriate.
- The method blanks and their associated samples were matched primarily by laboratory batch ID, test code, and analysis date. In cases of multiple result records in the method blank data set, the highest reported concentration was used to compare to the B-qualified sample result. An analysis time was not provided in the method blank data set, and in some cases the analysis dates were not an exact match. In these cases, a method blank with an analysis date one day before or one day after the sample date was chosen, and if necessary, the highest reported concentration was used.
- Where method blank data were not available, the nominal detection limit for the chemical in question was assumed as the concentration present in the associated blank and the "times ten" and "times five" rules were applied as described above. Sample results were then assigned the codes ND or RV as appropriate. The

nominal detection limits were taken from General Radiochemistry and Routine Analytical Services Protocol or GRRASP (EG&G 1991).

Nonvalidated B-qualified results consisted of VOCs analyzed by EPA Method 502.2 for UHSU groundwater (there is no established validation procedure for this method), VOCs analyzed by CLP/SOW methodology for the 1991, 1992, and 1993 boreholes, and SVOCs for the 1987 boreholes. Validation cannot be performed for the method 502.2 VOC results and is not expected to be performed for the 1987 borehole data (the Rocky Flats quality assurance program had not been established at that time).

As shown in Table 2-3, the assessment of the UHSU groundwater data resulted in 12 occurrences of common laboratory contaminants (4 acetone results and 8 methylene chloride results) that were assessed as nondetect (ND). There were also 7 occurrences of other chemicals that were attributed to laboratory contamination and assessed as nondetect; these included 3 occurrences each of chloroform and trichloroethylene (TCE) and 1 occurrence each of carbon tetrachloride and hexachlorobutadiene.

Other nonvalidated B-qualified results in groundwater samples consisted of 35 occurrences of other organic contaminants (chlorinated solvents, alkylated benzenes, and styrene) that were deemed to be present in the sample and assessed as RV. These included 8 occurrences tetrachloroethane (PCE), 5 occurrences of TCE, 12 occurrences of sec-butylbenzene, and 1 occurrence each of 1,1-dichloroethene, 1,2-dichloroethane, 1,2,3-trichlorobenzene, n-butylbenzene, tert-butylbenzene, and styrene. The concentration range for these chemicals in the nonvalidated B-qualified results are shown in Table 2-4. These few results do not significantly affect the frequency of detection of potential chemicals of concern, and the concentrations of the chlorinated solvents are lower than the maximum concentrations in other samples used in the screening process to identify chemicals of concern. Therefore the absence of these samples from the working data base does not influence the results of the selection process. The alkylated benzenes do not have EPA toxicity factors; compounds without these factors are addressed qualitatively in the risk assessment.

The assessment of the soil borehole VOC data resulted in 160 occurrences of acetone and methylene chloride that were deemed not present in the samples (assigned code ND), and 3 occurrences of acetone and 2 occurrences of methylene chloride that were not attributed to laboratory contamination (assigned code RV).

Finally, the assessment of 1987 soil borehole data resulted in 168 occurrences of bis(2-ethylhexyl)phthalate, di-n-butylphthalate, and N-nitrosodiphenylamine that were deemed not present in the samples (assigned code ND) and 1 occurrence of bis(2-ethylhexyl)phthalate that was not attributed to laboratory contamination (assigned code RV).

In summary, assessment of the nonvalidated B-qualified data support the conclusion that their exclusion from the working data set has no effect on the selection of chemicals of concern for OU-2. As shown in Table 2-3, most of the results were for common laboratory contaminants, and most of the results, whether common laboratory contaminants or not, were assessed as nondetect (ND) based on the criteria described above. Thirty-five B-qualified results in groundwater were for potential chemicals of concern, such as chlorinated solvents, and were assigned the code RV (i.e., positive results not attributable to laboratory contamination). These solvents were detected in other groundwater samples and were therefore included in concentration/toxicity screens or other risk-based screens to identify chemicals of concern for quantitative risk assessment. The concentrations of these chemicals in the nonvalidated B-qualified samples were lower than those detected in other samples, and therefore the excluded nonvalidated B-qualified results has no effect on the selection of COCs.

2.2 BACKGROUND COMPARISON FOR INORGANIC COMPOUNDS

OU-2 sample results for metals and radionuclides in soil and groundwater were compared to background data to determine which inorganic constituents exceeded background range and, therefore may be related to waste sources in OU-2. (Essential nutrients, such as iron, potassium, calcium, sodium, and magnesium, and anions with low toxicity, such as carbonate, bicarbonate, chloride, sulfate, nitrate, fluoride, bromide, silica, ammonium, and orthophosphate, were eliminated from consideration as potential chemicals of concern and were not included in the background comparison.) Appendix A describes the details of the approach used to compare OU-2 sample results with background concentrations. The results of the statistical comparison are presented in Tables A-1 through A-16 in Appendix A.

2.3 FREQUENCY OF DETECTION

All detected volatiles, semivolatiles, pesticides, and PCBs were evaluated for frequency of detection. Compounds detected at a frequency of 5 percent or greater were considered potential chemicals of concern. These compounds were included in concentration/toxicity screens to identify compounds that could contribute significantly to total risk (see Section 2.4). Compounds detected at less than 5 percent frequency (for example, in fewer than 2 of 40

samples or in fewer than 5 of 100 samples) can be eliminated from further consideration because the compound is not characteristic of site contamination and the potential for exposure is low. Nevertheless, concentrations of infrequently detected organic compounds were further evaluated as described in Section 2.5 (and Steps 8, 9, and 10 of Figure 2-1) to identify those that could contribute significantly to risk if routine exposure were to occur.

2.4 CONCENTRATION/TOXICITY SCREEN

Concentration/toxicity screens were performed for each chemical detected at 5 percent frequency or greater in each medium of concern (groundwater, subsurface soils, and surface soils). The purpose of applying the screen is to focus the risk assessment on the chief contributors to potential risk. To perform the screen, each chemical in a medium (such as groundwater) is scored according to its maximum detected concentration and toxicity to obtain a risk factor. The risk factor for noncarcinogenic effects is the maximum concentration divided by the EPA Reference Dose (RfD) for that chemical. The risk factor for carcinogenic effects (and for radionuclides) is the concentration (activity) multiplied by the EPA cancer slope factor for that chemical. The chemical-specific risk factors are summed to calculate total risk factors for the noncarcinogenic, carcinogenic, and radioactive chemicals of potential concern in each medium. The ratio of the risk factor for each chemical to the total risk factor is called a risk index and approximates the relative risk associated with each chemical in the medium. Separate concentration/toxicity screens are performed for carcinogenic and noncarcinogenic effects of organic compounds and metals and for carcinogenic effects of radionuclides.

EPA-recommended toxicity factors (RfDs and cancer slope factors) were used in the concentration/toxicity screens (Step 6, Figure 2-1) and in the calculation of risk-based concentrations (Step 9, Figure 2-1). Slope factors and RfDs were determined from IRIS (EPA 1993a), and HEAST (EPA 1993b and earlier editions in special cases) and are listed in Tables 2-5 and 2-6. Chemicals of potential concern that do not have EPA-established toxicity factors cannot be evaluated quantitatively in the concentration/toxicity screens or in the risk assessment. These are listed in each section for each medium. However, their potential contribution to risk will be evaluated qualitatively in the risk assessment.

Chemicals with very low risk indexes compared to other chemicals in the medium were eliminated from further consideration because of their very low potential to contribute to overall risk. In this step of the selection process, all chemicals that comprise 99 percent of the total risk factor were considered chemicals of concern for evaluation in the quantitative risk assessment. This approach greatly reduces the number of chemicals to be carried through a risk assessment.

However, the approach is conservative (health protective) because it retains some chemicals that contribute as little as 1 percent of the total potential risk. In most cases, only a few chemicals contribute the majority of risk from each medium.

2.5 EVALUATION OF INFREQUENTLY DETECTED COMPOUNDS

Chemicals detected infrequently (in less than 5 percent of all samples in the medium) can usually be eliminated from consideration as chemicals of concern because they are not characteristic of site contamination and the potential for exposure is low. However, these compounds were further screened so as not to neglect an infrequently detected compound that could contribute significantly to risk if routine exposure were to occur. In this analysis, maximum measured concentrations were compared to screening levels equivalent to 1000 x RBCs. This analysis, summarized below, is presented in detail in Appendix B.

For screening purposes, RBCs were defined as chemical concentrations associated with an excess cancer risk of 10^{-6} (1 in 1 million) or a hazard index for noncarcinogenic effects of 1.0, assuming residential exposures. Any infrequently detected chemical measured at a concentration greater than 1000 times the respective RBC was identified as representing a potentially significant health threat if exposure were to occur and was included in the list of OU-2 "special case" chemicals of concern for evaluation in the risk assessment.

RBCs were calculated assuming a residential exposure scenario, using conservative exposure assumptions, and using standard toxicity values (RfDs and SFs) published by EPA. RBCs for chemicals in surface and subsurface soils were calculated assuming multiple pathway exposure (ingestion, dermal contact, and inhalation of particulates). RBCs for chemicals in groundwater were calculated based on ingestion only, since this was assumed to be the chief groundwater exposure route. The exposure parameters used to calculate RBCs are presented in Appendix B. They are the same as those presented in the Exposure Scenarios Technical Memorandum No. 5 (DOE 1993a). Toxicity values used to calculate RBCs are listed in Table 2-5.

**TABLE 2-1
ROCKY FLATS PLANT OU-2
SITE-SPECIFIC CHEMICAL ANALYSIS ROSTER
PHASE II OU-2 SAMPLING PARAMETERS**

TOTAL METALS	INDICATORS	OTHER METALS
Target Analyte List	<u>Soil</u>	<u>Groundwater</u>
<u>Soil</u>	Dissolved Organic Carbon	Molybdenum
Aluminum	Total Organic Carbon	Strontium
Antimony		Cesium
Arsenic	OTHER PARAMETERS	Lithium
Barium	Total Petroleum Hydrocarbons	Tin
Beryllium		FIELD PARAMETERS
Cadmium	METALS	<u>Groundwater</u>
Calcium	Target Analyte List	pH
Chromium	<u>Groundwater</u>	Specific Conductance
Cobalt	(Total and Dissolved Metals)	Temperature
Copper	Aluminium	Dissolved Oxygen
Iron	Antimony	
Lead	Arsenic	INDICATORS
Magnesium	Barium	<u>Groundwater</u>
Manganese	Beryllium	Total Organic Carbon
Mercury	Cadmium	Dissolved Organic Carbon
Nickel	Calcium	pH
Potassium	Chromium	ANIONS
Selenium	Cobalt	<u>Groundwater</u>
Silver	Copper	Carbonate
Sodium	Iron	Bicarbonate
Thallium	Lead	Chloride
Vanadium	Magnesium	Sulfate
Zinc	Manganese	Nitrate (as N)
	Mercury	Cyanide
OTHER METALS	Nickel	Fluoride
<u>Soil</u>	Potassium	Bromide
Molybdenum	Selenium	Silica (as Si and SiO ₂)
Strontium	Silver	Ammonium
Cesium	Sodium	Orthophosphate
Lithium	Thallium	
Tin	Vanadium	OTHER PARAMETERS
	Zinc	Total Petroleum Hydrocarbons
OTHER INORGANICS		
<u>Soil</u>		
pH		
Sulfide		
Nitrate-Nitrite (as N)		
Percent Solids		
Cyanide		
Moisture Content		
Orthophosphate		
Bromide		
Ammonium		
Silica (as Si and SiO ₂)		

TABLE 2-1
(Continued)

ORGANICS: VOLATILES	ORGANICS: PESTICIDES/PCBs	TOTAL RADIONUCLIDES
Target Compound List	Target Compound List	
<u>Soil and Groundwater</u>	<u>Soil and Groundwater</u>	<u>Soil</u>
Chloromethane	alpha-BHC	Gross Alpha
Bromomethane	beta-BHC	Gross Beta
Vinyl Chloride	delta-BHC	Uranium-233, 234, 235, and 238
Chloroethane	gamma-BHC (Lindane)	Americium-241
Methylene Chloride	Heptachlor	Plutonium-239 and 240
Acetone	Aldrin	Tritium
Carbon Disulfide	Heptchlor Epoxide	Strontium-89,90
1,1-Dichloroethene	Endosulfan I	Cesium-137
1,1-Dichloroethane	Dieldrin	Radium-226, 228
Total 1,2-Dichloroethene	4,4'-DDE	DISSOLVED RADIONUCLIDES
Chloroform	Endrin	<u>Groundwater</u>
1,2-Dichloroethane	Endosulfan II	Gross Alpha
2-Butanone	4,4'-DDD	Gross Beta
1,1,1-Trichloroethane	Endosulfan Sulfate	Uranium-233, 234, 235, and 238
Carbon Tetrachloride	4,4'-DDT	Tritium
Vinyl Acetate	Endrin Ketone	Strontium-89, 90
Bromodichloromethane	Methoxychlor	Cesium-137
1,1,2,2-Tetrachloroethane	alpha-Chlordane	Radium-226 and 228
1,2-Dichloropropane	gamma-Chlordane	Tritium
Trans-1,3-Dichloropropene	Toxaphene	TOTAL RADIONUCLIDES
Trichloroethene	Aroclor-1016	<u>Groundwater</u>
Dibromochloromethane	Aroclor-1221	Plutonium-239 and 240
1,1,2-Trichloroethane	Aroclor-1232	Americium-241
Benzene	Aroclor-1242	Tritium
cis-1,3-Dichloropropene	Aroclor-1248	
Bromoform	Aroclor-1254	
2-Hexanone	Aroclor-1260	
4-Methyl-2-pentanone	SURFACE SOIL PARAMETERS	
Tetrachloroethene	Total Organic Carbon	
Toluene	Carbonate	
Chlorobenzene	pH	
Ethyl Benzene	Specific Conductance	
Styrene	Plutonium-239 and 240	
Total Xylenes	Americium-241	

**TABLE 2-1
(Concluded)**

ORGANICS: SEMI-VOLATILES		
Target Compound List		
<u>Soil and Groundwater</u>		
Phenol	Hexachlorobutadiene	N-nitrosodiphenylamine
bis(2-Chloroethyl)ether	4-Chloro-3-methylphenol(para-chloro-	4-Bromophenyl Phenyl Ether
2-Chlorophenol	2-Methylnapthalene	Hexachlorobenzene
1,3-Dichlorobenzene	Hexachlorocyclopentadiene	Pentachlorophenol
1,4-Dichlorobenzene	2,4,6-Trichlorophenol	Phenanthrene
Benzyl Alcohol	2,4,5-Trichlorophenol	Anthracene
1,2-Dichlorobenzene	2-Chloronaphthalene	Di-n-butylphthalate
2-Methylphenol	2-Nitroaniline	Fluoranthene
bis(2-Chloroisopropyl)ether	Dimethylphthalate	Pyrene
4-Methylphenol	Acenaphthlene	Butyl Benzylphthalate
N-Nitroso-Dipropylamine	3-Nitroaniline	3,3'-Dichlorobenzidine
Hexachloroethane	Acenaphthene	Benzo(a)anthracene
Nitrobenzene	2,4-Dinitrophenol	bis(2-ethylhexyl)phthalate
Isophorone	4-Nitrophenol	Chrysene
2-Nitrophenol	Dibenzofuran	Di-n-octyl Phthalate
2,4-Dimethylphenol	2,4-Dinitrotoluene	Benzo(b)fluoranthene
Benzoic Acid	2,6-Dinitrotoluene	Benzo(k)fluoranthene
bis(2-Chloroethoxy)methane	Diethylphthalate	Benzo(a)pyrene
2,4-Dichlorophenol	4-Chlorophenyl Phenyl Ether	Indeno(1,2,3-cd)pyrene
1,2,4-Trichlorobenzene	Fluorene	Dibenz(a,h)anthracene
Naphthalene	4-Nitroaniline	Benzo(g,h,i)perylene
4-Chloroaniline	4,6-Dinitro-2-methylphenol	

TABLE 2-2
ROCKY FLATS PLANT OU-2
ANALYTICAL DATA FILE SUMMARY

Data File	Data Description: Borehole	Collected By	Data Used for Chemicals of Concern
BH_IN87A.XLS	Inorganics 1987 (pH, solids, cyanide, etc.)	Weston	All subsurface soil data from above high water table.
BH_M87AN.XLS	Metals 1987	Weston	
BH_M91AN.XLS	Metals 1991-1992	W-C	
BH_P87A.XLS	Pesticides 1987	Weston	
BH_P91AN.XLS	Pesticides 1991-1992	W-C	
BH_R87AN.XLS	Radionuclides 1987	Weston	
BH_R91AN.XLS	Radionuclides 1991-1992	W-C	
BH_S87A.XLS	Semi-volatiles 1987	Weston	
BH_S91AN.XLS	Semi-volatiles 1991-1992	W-C	
BH_V87A.XLS	Volatile Organics 1987	Weston	
BH_V91AN.XLS	Volatile Organics 1991-1992	W-C	
BH_W91AN.XLS	Inorganics 1991-1992 (pH, solids, cyanide, etc.)	W-C	
Data File	Data Description: Groundwater	Collected By	Data Used for Chemicals of Concern
GW_P192N.XLS	Pesticides	Site-Wide Program (IT)	1st and 2nd Quarter 1992
GW_U91L.XLS	Pesticides	Site-Wide Program (IT)	2nd through 4th Quarter 1991
GW_R192D.XLS	Dissolved Radionuclides	Site-Wide Program (IT)	1st and 2nd Quarter 1992
GW_R192T.XLS	Total Radionuclides	Site-Wide Program (IT)	1st and 2nd Quarter 1992
GW_R792D.XLS	Dissolved Radionuclides	Site-Wide Program (IT)	3rd Quarter 1992
GW_R792T.XLS	Total Radionuclides	Site-Wide Program (IT)	3rd Quarter 1992
GW_R90D.XLS	Dissolved Radionuclides	Site-Wide Program (IT)	Not Used
GW_R90T.XLS	Total Radionuclides	Site-Wide Program (IT)	Not Used
GW_R91D.XLS	Dissolved Radionuclides	Site-Wide Program (IT)	2nd through 4th Quarter 1991
GW_R91T.XLS	Total Radionuclides	Site-Wide Program (IT)	2nd through 4th Quarter 1991
GW_S192N.XLS	Semi-Volatiles	Site-Wide Program (IT)	1st and 2nd Quarter 1992
GW_U91L.XLS	Volatiles	Site-Wide Program (IT)	4th Quarter 1991
GW_V192N.XLS	Volatiles	Site-Wide Program (IT)	1st and 2nd Quarter 1992
GW_V792N.XLS	Volatiles	Site-Wide Program (IT)	3rd Quarter 1992
GW_U90.XLS	Volatiles	Site-Wide Program (IT)	Not Used
GW_U91.XLS	Volatiles	Site-Wide Program (IT)	2nd through 4th Quarter 1991
GW_W192N.XLS	Water Quality Parameters	Site-Wide Program (IT)	Not Used
GW_W792N.XLS	Water Quality Parameters	Site-Wide Program (IT)	Not Used
GW_U90.XLS	Water Quality Parameters	Site-Wide Program (IT)	Not Used
GW_U91.XLS	Water Quality Parameters	Site-Wide Program (IT)	Not Used
CHEMS4.XLS	Metals	Site-Wide Program (IT)	2nd Qtr 1991 - 3rd Qtr 1992
Data File	Data Description: Surficial Soil	Collected By	Data Used for Chemicals of Concern
SS93FLT2.XLS	1993 data not including background (met. rads, sv, pest)	W-C	All
SS_FT.XLS	1991 data (rads)	Stoller/W-C	All

**TABLE 2-3
ASSESSMENT OF NONVALIDATED B-QUALIFIED DATA**

	UHSU Groundwater (2nd 91 - 3rd 92)	Borehole
Volatile Organics		
Total Nonvalidated B Results	54	165
Assessment Code		
ND	19	160
RV	35	5
Acetone ND	4	77
Acetone RV	0	3
MeCl2 ND	8	83
MeCl2 RV	0	2
Other ND	7	0
Other RV **	35	0
Semivolatiles		
Total Nonvalidated B Results	0	169 *
Assessment Code		
ND		168
RV		1
BEHP ND		85
BEHP RV		1
DNBP ND		63
DNBP RV		0
Other ND (N-nitrosodiphenylamine)		20
Other RV		0

- * 1987 borehole data.
- ** Data Summary for Non Laboratory Contaminants is shown in Table 2-4.
- B Blank qualified non-validated result.
- ND Not detected.
- RV Real value.
- BEHP Bis(2-ethylhexyl)phthalate.
- DNBP di-n-Butylphthalate

TABLE 2-4
DATA SUMMARY FOR CHEMICALS OTHER THAN
LABORATORY CONTAMINANTS REPORTED IN NON-VALIDATED
B-QUALIFIED GROUNDWATER SAMPLES (1)

Nonvalidated B-Qualified Chemical	Number of Positive Results (1)	Concentration Range ug/L
tetrachloroethene	8	0.28 - 1200
trichloroethene	5	4.2 - 140
sec-butylbenzene	12	0.4 - 370
1,1-dichloroethene	1	3.9
1,2-dichloroethane	1	85
1,2,3-trichlorobenzene	1	0.28
n-butylbenzene	1	250
tert-butylbenzene	1	170
styrene	1	10

(1) "Other RV" results for UHSU Groundwater shown in Table 2-3.

**TABLE 2-5
ROCKY FLATS OU-2
TOXICITY FACTORS FOR
ORGANIC COMPOUNDS AND METALS**

Analyte	Oral Slope Factor 1/(mg/kg/day)	Chronic Oral RfD (mg/kg/day)	Inhalation Slope Factor 1/(mg/kg/day)	Chronic Inhalation RfD (mg/kg/day)	EPA Cancer Weight of Evidence
1,1,1,2-Tetrachloroethane	2.6E-02 (1)	3.0E-02 (1)	2.6E-02 (1)	-	C
1,1,1-Trichloroethane	-	9.0E-02 (4)	-	3.0E-01 (4)	-
1,1,2,2-Tetrachloroethane	2.0E-01 (1)	-	2.0E-01 (1)	-	C
1,1,2-Trichloroethane	5.7E-02 (1)	4.0E-03 (1)	5.7E-02 (1)	-	C
1,1-Dichloroethane	-	1.0E-01 (2)	-	1.4E-01 (3)	C
1,1-Dichloroethene	6.0E-01 (1)	9.0E-03 (1)	1.7E-01 (1)	-	C
1,2,3-Trichloropropane	-	6.0E-03 (1)	-	-	-
1,2,4-Trichlorobenzene	-	1.0E-02 (1)	-	3.0E-03 (3)	-
1,2-Dibromo-3-chloropropane	1.4E+00 (2)	-	6.9E-07 (2)	5.0E-05 (1)	B2
1,2-Dibromoethane	8.5E+01 (1)	-	7.6E-01 (2)	-	B2
1,2-Dichlorobenzene	-	9.0E-02 (1)	-	4.0E-02 (4)	-
1,2-Dichloroethane	9.1E-02 (1)	-	9.1E-02 (1)	-	B2
1,2-Dichloroethene	-	9.0E-03 (2)	-	-	-
cis-1,2-Dichloroethene	-	1.0E-02 (2)	-	-	-
trans-1,2-Dichloroethene	-	2.0E-02 (1)	-	-	-
1,2-Dichloropropane	-	-	-	1.0E-03 (1)	-
1,2-Dimethylbenzene (o-xylene)	-	2.0E+0 (1)	-	-	-
1,3-Dimethylbenzene (m-xylene)	-	2.0E+0 (1)	-	-	-
cis-1,3-Dichloropropene*	1.8E-01 (2)	3.0E-04 (1)	1.3E-01 (2)	5.0E-03 (1)	B2
1,4-Dichlorobenzene	2.4E-02 (2)	-	-	2.0E-01 (2)	C
2-Butanone	-	6.0E-01 (1)	-	3.0E-01 (1)	-
4,4'-DDT	3.4E-01 (1)	5.0E-04 (1)	3.4E-01 (1)	-	B2
4-Methyl-2-pentanone	-	5.0E-02 (2)	-	2.0E-02 (3)	-
Acenaphthene	-	6.0E-02 (1)	-	-	-
Acetone	-	1.0E-01 (1)	-	-	-
Anthracene	-	3.0E-01 (1)	-	-	-
Antimony	-	4.0E-04 (1)	-	-	-
Aroclor-1254	7.7E+00 (1)	-	-	-	B2
Arsenic	1.7E+00 (1)	3.0E-04 (1)	1.5E+01 (1)	-	A
Barium	-	7.0E-02 (1)	-	1.4E-04 (3)	-
Benzene	2.9E-02 (1)	-	2.9E-02 (2)	-	A
Benzo(a)anthracene	7.3E-01 (6)	-	-	-	B2
Benzo(a)pyrene	7.3E+00 (6)	-	6.1E+00 (2)	-	B2
Benzo(b)fluoranthene	7.3E-01 (6)	-	-	-	B2
Benzo(k)fluoranthene	7.3E-01 (6)	-	-	-	B2
Benzoic acid	-	4.0E+00 (1)	-	-	-
Beryllium	-	5E-1 (2)	8.4E-10 (1)	-	B2
Bis(2-ethylhexyl)phthalate	1.4E-02 (1)	2.0E-02 (1)	-	-	B2
Bromodichloromethane	6.2E-02 (1)	2.0E-02 (1)	-	-	B2
Bromoform	7.9E-03 (1)	2.0E-02 (1)	3.9E-03 (2)	-	B2
Butyl benzylphthalate	-	2.0E-01 (1)	-	-	-

TABLE 2-5
(Continued)

Analyte	Oral Slope Factor 1/(mg/kg/day)	Chronic Oral RfD (mg/kg/day)	Inhalation Slope Factor 1/(mg/kg/day)	Chronic Inhalation RfD (mg/kg/day)	EPA Cancer Weight of Evidence
Cadmium (food)	-	1.0E-03 (1)	6.3E+00 (1)	-	B1
Cadmium (water)	-	5.0E-04 (1)	6.3E+00 (1)	-	B1
Carbon tetrachloride	1.3E-01(1)	7.0E-04 (1)	5.2E-02 (1)	-	B2
Chlorobenzene	-	2.0E-02 (1)	-	5.0E-03 (3)	-
Chloroethane	-	-	-	3.0E+00 (1)	-
Chloroform	6.1E-03 (1)	1.0E-02 (1)	8.0E-02 (1)	-	B2
Chloromethane	1.3E-02 (2)	-	6.3E-03 (2)	-	C
Chlorotoluene, o-	-	2.0E-02 (1)	-	-	-
Chromium III	-	1.0E+00 (1)	-	-	-
Chrysene	7.3E-02 (6)	-	-	-	B2
Cumene	-	4.0E-02 (1)	-	3.0E-03 (2)	-
Cyanide	-	2.0E-02 (1)	-	-	-
Di-n-butylphthalate	-	1.0E+01 (1)	-	-	-
Di-n-octylphthalate	-	2.0E-02 (2)	-	-	-
Dibromomethane	-	1.0E-02 (5)	-	-	-
Dichlorodifluoromethane	-	2.0E-01 (1)	-	5.0E-02 (3)	-
Diethyl phthalate	-	8.0E-01 (1)	-	-	-
Ethylbenzene	-	1.0E-01 (1)	-	3.0E-01 (1)	-
Fluoranthene	-	4.0E-02 (1)	-	-	-
Fluorene	-	4.0E-02 (1)	-	-	-
Heptachlor epoxide	9.1E+00 (1)	1.3E-05 (1)	9.1E+00 (1)	-	B2
Hexachlorobutadiene	7.8E-02 (1)	2.0E-04 (2)	7.8E-02 (2)	-	C
Hexachloroethane	1.4E-02 (1)	1.0E-03 (1)	1.4E-02 (1)	-	C
Indeno(1,2,3-cd)pyrene	7.3E-01 (6)	-	-	-	B2
Manganese (food)	-	1.4E-01 (2)	-	1.1E-04 (1)	-
Managanese (water)	-	5.0E-03 (2)	-	-	-
Mercury	-	3.0E-04 (2)	-	9.0E-05 (2)	-
Methylene chloride	7.5E-03 (1)	6.0E-02 (1)	1.6E-03 (1)	9.0E-01 (2)	B2
Molybdenum	-	5.0E-03 (1)	-	-	-
N-nitrosodiphenylamine	4.9E-03 (1)	-	-	-	B2
Naphthalene	-	4.0E-02 (8)	-	-	-
Nickel	-	2.0E-2 (2)	-	-	-
Pentachlorophenol	1.2E-01(1)	3.0E-02 (1)	-	-	B2
Pyrene	-	3.0E-02 (1)	-	-	-
Selenium	-	5.0E-3 (2)	-	-	-
Silver	-	5.0E-03 (1)	-	-	-
Strontium	-	6.0E-01 (2)	-	-	-
Styrene	-	2.0E-01 (1)	-	3.0E-01 (1)	-

**TABLE 2-5
(Concluded)**

Analyte	Oral Slope Factor 1/(mg/kg/day)	Chronic Oral RfD (mg/kg/day)	Inhalation Slope Factor 1/(mg/kg/day)	Chronic Inhalation RfD (mg/kg/day)	EPA Cancer Weight of Evidence
Tetrachloroethene	5.2E-02 (7)	1.0E-02 (1)	2.0E-03 (7)	-	B2
Thallium (oxide)	-	7.0E-05 (2)	-	-	-
Tin	-	6.0E-02 (2)	-	-	-
Toluene	-	2.0E-01 (1)	-	1.1E-01 (1)	-
Trichloroethene	1.1E-02 (7)	-	6.0E-03 (7)	-	B2
Xylene, p-**	-	2.0E+00 (1)	-	-	-
Vinyl chloride	1.9E+0 (1)	-	3.0E-01 (1)	-	A
Zinc	-	9.0E-01(4)	-	3.0E-01 (4)	-

Sources:

1 = IRIS

2 = HEAST 1993

3 = HEAST 1993 Table 2

4 = HEAST 1992

5 = HEAST 1991

6 = EPA Region IV Guidance, February 1992

7 = Joan S. Dollarhide, Superfund Health Risk Technical Support Center. "Carcinogenicity Characterization of Perchloroethylene (PERC) and Trichloroethylene (TCE) (Luke Air Force Base, Arizona). ECAO.

8 = Provisional value. USEPA. ECAO.

* Values are for 1,3-dichloropropene. No data for individual isomer.

** o- and m-xylenes are listed as 1,2- and 1,3-dimethylbenzene.

A = Human carcinogen

B1 = Probable human carcinogen (limited human data)

B2 = Probable human carcinogen (animal data only)

C = Possible human carcinogen

- = Not classifiable or not carcinogenic

**TABLE 2-6
ROCKY FLATS PLANT OU-2
SLOPE FACTORS
FOR RADIONUCLIDES**

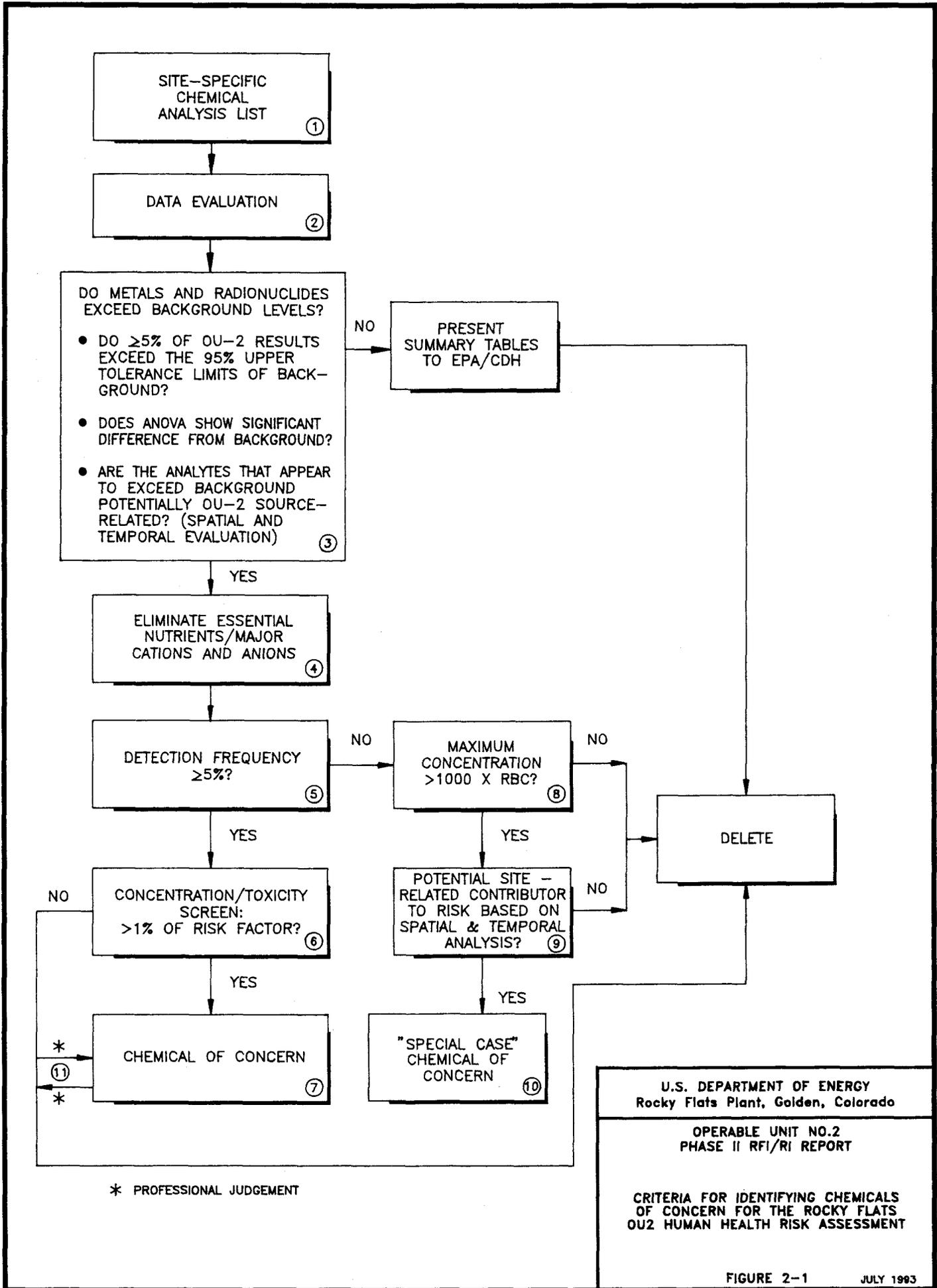
Analyte	Oral Slope Factor (Risk/pCi)	Inhalation Slope Factor (Risk/pCi)	External Slope Factor (Risk/yr/pCi/g)	EPA Cancer Weight of Evidence
Americium-241	2.4E-10	3.2E-08	4.9E-09	A
Cesium-134	4.1E-11	2.8E-11	5.2E-06	A
Cesium-137 +D	2.8E-11	1.9E-11	2.0E-06	A
Plutonium-238	2.2E-10	3.9E-08	2.8E-11	A
Plutonium-239	2.3E-10	3.8E-08	1.7E-11	A
Plutonium-240	2.3E-10	3.8E-08	2.7E-11	A
Radium-226 +D	1.2E-10	3.0E-09	6.0E-06	A
Radium-228 +D	1.0E-10	6.6E-10	2.9E-06	A
Strontium-89	3.0E-12	2.9E-12	4.7E-10	A
Strontium-90 +D	3.6E-11	6.2E-11	0.0E+00	A
Tritium	5.4E-14	7.8E-14	0.0E+00	A
Uranium-233,234 *	1.6E-11	2.6E-08	3.0E-11	A
Uranium-235 +D	1.6E-11	2.5E-08	2.4E-07	A
Uranium-238 +D	2.8E-11	5.2E-08	3.6E-08	A

Source: HEAST 1993.

A = Class A (human) carcinogen.

* = Slope factors shown are for U-234.

+D = Risks from radioactive decay products included.



* PROFESSIONAL JUDGEMENT

U.S. DEPARTMENT OF ENERGY
 Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO.2
 PHASE II RFI/RI REPORT

CRITERIA FOR IDENTIFYING CHEMICALS
 OF CONCERN FOR THE ROCKY FLATS
 OU2 HUMAN HEALTH RISK ASSESSMENT

GROUNDWATER CHEMICALS OF CONCERN

3.1 DATA EVALUATION

Chemicals of concern in groundwater were selected using the data sets identified in Table 2-2. Samples collected in the 2nd through 4th quarter 1991 and the 1st through 3rd quarter 1992 were used to evaluate volatile organic compounds, pesticides, PCBs, metals, and radionuclides. Samples collected in the 4th quarter 1992 and the 1st and 2nd quarters 1992 were used to evaluate semivolatile organic compounds (semivolatile data were not available prior to 4th quarter 1991; no 3rd quarter 1992 data were received for semivolatiles). Monitoring well locations are shown in Figure 3-1.

The data received from RFEDs were reviewed and edited using the steps and criteria outlined in Section 2.1 to develop a data set of environmental samples for further evaluation. Groundwater data were then divided into two sets for selection of chemicals of concern: (1) analytical results from wells screened in the No. 1 Sandstone and (2) analytical results from all UHSU wells (i.e., wells screened in alluvium, colluvium, valley fill, and the Arapahoe No. 1 Sandstone and weathered claystone). The No. 1 Sandstone could support a drinking water well; under a hypothetical future residential development scenario, future residents could be exposed to OU-2 contaminants through ingestion of water from the No. 1 Sandstone. Therefore, analytical results from the No. 1 Sandstone are used to select chemicals of concern for an on-site residential groundwater ingestion scenario to be evaluated in the risk assessment.

The alluvium, colluvium, and valley fill are relatively thin and discontinuous, and colluvium occurs only on slopes; these units have low yields and are only intermittently saturated (see Appendix C). These units cannot provide drinking water and were therefore not included as exposure media for on-site residential groundwater ingestion exposures. However, analytical results from samples collected from monitoring wells in the alluvium, colluvium, valley fill, and the Arapahoe No. 1 Sandstone and weathered claystone were used to evaluate contaminant migration through groundwater to surface water in Woman Creek and Walnut Creek.

A note on methylene chloride: Methylene chloride was detected in about 26 percent of the groundwater samples in concentrations ranging from 0.2 µg/L to 3900 µg/L. Review of analytical results for methylene chloride in groundwater suggests that methylene chloride is not an environmental contaminant at the high concentrations reported for some samples.

Methylene chloride is a common laboratory contaminant, as is acetone and bis(2-ethylhexyl)phthalate. The methylene chloride results are given special attention since the compound is relatively toxic and could be identified as a chemical of concern if included in a concentration/toxicity screen. If the identification were inaccurate (i.e., if the methylene chloride probably results from laboratory procedures rather than waste sources), this could result in omitting other compounds from the risk assessment that are actual environmental contaminants.

The highest results for methylene chloride were reported from 1991 wells sampled in the 4th quarter 1991 and 1st quarter of 1992. These samples were analyzed by EPA Method 502.2, but the data were not validated because of the absence of an established validation process for this method. Concentrations in these samples ranged from approximately 4 to 3900 $\mu\text{g}/\text{L}$. In subsequent sampling rounds in these wells, methylene chloride was either nondetect or, in a few cases, detected at much lower concentrations. For example, in samples from well 7391 methylene chloride was reported at 3900 $\mu\text{g}/\text{L}$ in 1st quarter 1992 and at 8 $\mu\text{g}/\text{L}$ in 2nd quarter 1992 (both analyzed by Method 502.2). In samples from well 11691, it was reported at 3000 $\mu\text{g}/\text{L}$ in 1st quarter 1992 but was nondetect in the 3rd quarter 1992 (detection limit = 0.2 $\mu\text{g}/\text{L}$). In two samples from well 12691 collected in 1st quarter 1992, methylene chloride was reported at a concentration of 140 $\mu\text{g}/\text{L}$ in one sample and was nondetect in the other (detection limit = 0.01 $\mu\text{g}/\text{L}$). This pattern is consistent for most of the wells sampled and analyzed by this method.

Because methylene chloride was usually not detected in subsequent sampling rounds where a previous high concentration was reported, methylene chloride is not considered a groundwater contaminant in these wells. There is no evidence of a plume of methylene chloride contamination, because other positive results are not spatially related. In order to address the possibility that methylene chloride is a local contaminant in some source areas, methylene chloride is included in concentration/toxicity screens to identify chemicals of concern using the maximum concentration reported in a well where methylene chloride was detected in more than one sampling round (but excluding the results from well 7391, which were 3900 $\mu\text{g}/\text{L}$ in one sampling round and 8 $\mu\text{g}/\text{L}$ the next). The concentration used in the concentration/toxicity screen is 38 $\mu\text{g}/\text{L}$, detected in well 3687 in the 1st quarter 1992. Methylene chloride was reported in subsequent samples from this well at concentrations of 5 and 11 $\mu\text{g}/\text{L}$.

3.2 BACKGROUND COMPARISON FOR INORGANIC COMPOUNDS

The comparison of OU-2 data for metals and radionuclides detected in groundwater to background data is presented in Appendix A. The results are summarized in Tables 3-1 through 3-4. Tables 3-1 and 3-2 show the results for total (unfiltered) metals and radionuclides in the OU-2 No. 1 Sandstone compared to data from bedrock background wells (see explanation in Appendix A). Tables 3-3 and 3-4 show the results for dissolved (filtered fraction) metals and radionuclides in the OU-2 UHSU compared to data from UHSU background wells. Total inorganics in No. 1 Sandstone were evaluated as potential chemicals of concern for risk associated with on-site groundwater ingestion, and dissolved inorganics were evaluated in the UHSU for migration of contaminants in groundwater. Metals and radionuclides that exceeded background and that were identified as probable OU-2 contaminants based on data evaluation were included in concentration/toxicity screens to select chemicals of concern for use in risk assessment.

Metals and radionuclides were eliminated from further consideration (i.e., were considered to be within background range) if less than 5 percent of the OU-2 data exceeded the 95% UTL of background and if the parametric or nonparametric ANOVA analysis showed no significant difference from background ($p < 0.05$). Metals and radionuclides that appeared to exceed background by one or both of the tests were retained for further evaluation of the spatial and temporal distribution of elevated concentrations to identify probable OU-2 contaminants. This was done in order to eliminate analytes from further consideration that are not actual site contaminants. It is important that risk assessment and the selection of remedies be focussed on actual site contaminants that could threaten public health or the environment rather than on naturally occurring elements or trace contaminants that may be detected infrequently at elevated concentrations but are not characteristic of site contamination.

3.2.1 No. 1 Sandstone

Tables 3-1 and 3-2 show the results of the background comparison for total (unfiltered) metals and radionuclides in the No. 1 Sandstone. The total fraction is assessed for this unit because the No. 1 Sandstone groundwater is evaluated for direct ingestion exposures and EPA guidance recommends using concentrations measured in unfiltered samples to assess risks for groundwater ingestion.

Total Metals

Table 3-1 shows the results of the background comparison for total metals in No. 1 Sandstone. On the basis of both statistical tests, the following metals were concluded not to exceed background levels: antimony, beryllium, cadmium, cesium, chromium, cobalt, copper, lithium, molybdenum, nickel, selenium, silver, thallium, tin, vanadium, and zinc. Cyanide was retained for further evaluation although it may not be a waste-related contaminant. Cyanide concentrations in the No. 1 Sandstone exceeded the background UTL of 6 $\mu\text{g/L}$ (background maximum = 8.5 $\mu\text{g/L}$) in 7 of 59 samples (12 percent). The observed concentrations were relatively low, ranging from 7 $\mu\text{g/L}$ to 20.7 $\mu\text{g/L}$; only three of these results exceeded the background maximum. The seven slightly elevated concentrations were detected once each in seven separate wells (that is, other sampling rounds at these wells did not show elevated concentrations of this ion). The evidence to support identifying cyanide as a potential OU-2 contaminant is not strong. Nevertheless, cyanide is included in a concentration/toxicity screen to identify chemicals of concern for quantitative risk assessment.

On the basis of spatial, temporal, and other data evaluation, the following inorganic compounds are not considered contaminants in the No. 1 Sandstone: aluminum, arsenic, barium, lead, manganese, mercury, and strontium. The reasons are discussed below.

No. 1 Sandstone Total Metals Eliminated as Contaminants on the Basis of Spatial/Temporal Evaluation

Aluminum: Elevated concentrations of total aluminum (up to 128,000 $\mu\text{g/L}$) were detected in numerous samples from wells screened in the No. 1 Sandstone. Aluminum is a ubiquitous and naturally occurring element in soils and water. Many of these samples also contained elevated concentrations of iron and other rock-forming elements. The elevated aluminum concentrations are probably associated with the physical characteristics of the samples (e.g., suspended solids) rather than to chemical releases in OU-2 because the dissolved-phase concentrations (see Appendix D) were below background range. Since there is no evidence of a dissolved-phase plume, aluminum is not considered a contaminant in the No. 1 Sandstone groundwater.

Arsenic: Arsenic was detected in 77 percent of the No. 1 Sandstone unfiltered groundwater samples. Arsenic is a common, naturally occurring constituent in soils and groundwater. Arsenic was detected in concentrations above the background UTL of 7 $\mu\text{g/L}$ in only 5 of 79 samples from the No. 1 Sandstone (the background maximum is also 7 $\mu\text{g/L}$). Concentrations

above the background UTL ranged from 8 to 11.4 $\mu\text{g/L}$; these are not greatly above background levels. The maximum concentration of 11.4 $\mu\text{g/L}$ was observed in a sample from well 12191, which is located in the Northeast Trenches Area near Trench T-3 (IHSS 110). Arsenic was also detected above the background UTL in two other samples from wells that are in the Northeast Trenches Area but are not associated with trenches: wells 3691 (8.3 $\mu\text{g/L}$) and well 3791 (8 $\mu\text{g/L}$). However, concentrations above background UTL in these wells were observed in only one of six sampling rounds and are, therefore temporally isolated. Furthermore, arsenic was not detected above background in well 3391, which is located downgradient of well 12191 and upgradient of wells 3691 and 3791. The other detection of arsenic above the background UTL was at well 10991 (9.4 $\mu\text{g/L}$). This well is located in the East Spray Fields. This is the only No. 1 Sandstone well in the area. Alluvial wells in the area did not contain elevated concentrations of arsenic (with the exception of a temporally isolated observation of 9 $\mu\text{g/L}$ in well 5191). Based on the spatial and temporal distribution and infrequency of observations above the background UTL, arsenic is not considered a contaminant in No. 1 Sandstone groundwater.

Barium: Barium appears to exceed background levels by both statistical comparisons (UTL and nonparametric ANOVA). It was detected in unfiltered samples from the No. 1 Sandstone in concentrations ranging from 99 to 3,090 $\mu\text{g/L}$ (background 95% UTL = 1,050 $\mu\text{g/L}$ and background maximum = 1,810 $\mu\text{g/L}$) and was found in elevated concentrations in several wells located near source areas. Barium is a naturally occurring constituent of native soil and rock, and it is unlikely that barium in groundwater is due to leaching from barium-containing wastes (no evidence of barium-containing wastes was found in subsurface soil investigations in OU-2). It is possible, though, that under some environmental conditions, barium might leach from native materials in the presence of an organic contaminant plume; if so, it could be considered a waste-related potential chemical of concern. The association of elevated barium concentrations with organic contamination was evaluated to assess this possibility. The evaluation was performed for filtered and unfiltered sample results for all UHSU wells; the results are summarized in Table 3-3A. The table shows that the percentage of barium results that exceeded the background UTL are approximately the same in wells in areas associated with VOC plumes and in wells outside the areas associated with VOC plumes. For example, in filtered samples, elevated barium results occurred in 39 percent of the wells with VOC contamination and in 44 percent of the wells with little or no organic contamination. Results in unfiltered samples show a slightly higher occurrence of elevated results in wells that have VOC contamination (18 percent vs. 9 percent). This variation in the unfiltered results is not considered significant.

Since elevated barium concentrations are nearly as likely to occur in areas not associated with VOC contamination as in areas that have VOC contamination, barium is not considered a site-related chemical of concern and is eliminated from further evaluation. The cause of the apparent differences between background and OU-2 barium concentrations is uncertain; however, it may result from the particular physical and perhaps chemical characteristics of the native material in which many of the OU-2 wells are screened.

Lead: Elevated concentrations of total lead (up to 171 $\mu\text{g/L}$) were detected in samples from several wells screened in the No. 1 Sandstone in the Northeast Trenches Area, in the Mound Area, and west of the 903 Pad. However, most of these samples also contained elevated concentrations of total iron, aluminum, and lithium, which are common rock-forming elements. Dissolved concentrations of these elements were not elevated above background levels (see Appendix D), and there is no evidence of a dissolved-phase plume. For example, at two wells with elevated total lead concentrations (well 11891 at 171 $\mu\text{g/L}$ and in well 3691 at 86 $\mu\text{g/L}$), dissolved lead was not detected at a reporting limit of 3 $\mu\text{g/L}$. In addition, lead concentrations are within background levels in soils (see Tables 4-1A and 5-2). The elevated total lead concentrations in the groundwater samples are likely to be naturally occurring and related to suspended solids in the water samples rather than to leaching resulting from OU-2 contamination because there is no evidence of a dissolved-phase plume or of elevated lead concentrations in soils.

Manganese: Manganese appears to exceed background levels by both statistical comparisons. It was detected in unfiltered samples from the No. 1 Sandstone in concentrations ranging from 9 to 4,920 $\mu\text{g/L}$ (background 95% UTL = 438 $\mu\text{g/L}$ and background maximum = 710 $\mu\text{g/L}$) and was found in elevated concentrations in several wells located near source areas. Manganese is a common constituent of native soil and rock, and manganese oxide precipitates are observable in soil and rock at Rocky Flats. Although it is unlikely that manganese in groundwater is due to leaching from wastes, it is possible that under some environmental conditions manganese might leach from native materials in the presence of an organic contaminant plume; if so, it could be considered a waste-related potential chemical of concern. An evaluation like that done for barium (described above) was performed to assess the association of elevated manganese concentrations with organic contamination. Table 3-3A shows that the percentage of manganese results in UHSU wells that exceeded the background UTL are approximately the same in wells in areas associated with VOC plumes and in wells outside areas associated with VOC plumes. For example, in filtered samples, elevated manganese results occurred in 26 percent of the wells with VOC contamination and in 12 percent of the wells with little or no organic contamination. Only 13 percent and 7 percent of

the samples with and without VOC contamination, respectively, had concentrations above two times the background UTL. In unfiltered samples with and without VOC contamination, 15 percent and 12 percent, respectively, had concentrations exceeding two times the background UTL.

Since elevated manganese concentrations occur in areas of no VOC contamination as well as in areas that have VOC contamination, manganese is not considered a site-related chemical of concern and is eliminated from further evaluation. The cause of the apparent differences between background and OU-2 manganese concentrations is uncertain; however, it may result from the particular physical and perhaps chemical characteristics of the native material in which the OU-2 wells are screened. It is interesting to note that manganese concentrations above the background UTL are also found in the Lower Hydrostatic Unit (which is not being evaluated in the risk assessment), where little or no VOC contamination is found (DOE 1993c).

Mercury: Mercury was detected in 15 percent of the samples analyzed (maximum concentration = 0.8 $\mu\text{g/L}$). The maximum concentration was detected in well 5691 in the NE Trench Area. The background UTL is 0.2 $\mu\text{g/L}$. Mercury was also detected in three wells (2387, 1791, and 1491) in the Mound Area, in concentrations ranging from 0.27 to 0.62 $\mu\text{g/L}$; these wells are screened in the No. 1 Sandstone. However, the upper paired wells were nondetect for mercury at a reporting limit of 0.2 $\mu\text{g/L}$. Dissolved-phase mercury was not elevated above background levels, and there is no evidence of a contaminant plume. Mercury is not considered a contaminant in groundwater because (1) the elevated concentrations are low (0.25 to 0.8 $\mu\text{g/L}$), (2) dissolved-phase concentrations are within background levels, (3) elevated concentrations occur in some wells screened at the base of the No. 1 Sandstone but not in paired wells screened near the top of the sandstone, and (4) only one well (11691 in the NE Trench Area) had mercury detected in more than one sampling event.

Strontium: Concentrations for total strontium were somewhat elevated in 6 percent of the samples collected from wells screened in the No. 1 Sandstone. Elevated concentrations ranged from 1010 $\mu\text{g/L}$ to 1370 $\mu\text{g/L}$ (background UTL = 921 $\mu\text{g/L}$). Strontium was detected at somewhat elevated concentrations in some wells potentially related to source areas. These latter wells include well 1491 at the 903 Pad (1040 $\mu\text{g/L}$) and well 291 near the inner East Gate (1070 $\mu\text{g/L}$). Comparable concentrations also occur in wells that are unrelated to source areas (such as wells 286 and 41591, both at Indiana Avenue). The filtered fraction was also elevated in most samples where total strontium was elevated. Because strontium is found in wells unrelated to source areas at concentrations comparable to those found near source areas, maximum concentrations are only somewhat above background, and there is no evidence of a

total or dissolved-phase plume, strontium is not considered a contaminant in No. 1 Sandstone groundwater.

Radionuclides

Table 3-2 summarizes the background comparison for total radionuclides in the No. 1 Sandstone. Radionuclides considered to be OU-2 contaminants in the No. 1 Sandstone based on the statistical comparison to background data are americium-241 and plutonium-239,240.

Cesium-137 was detected at activities above the background UTL of 0.83 pCi/L in 7 of 49 (14 percent of) No. 1 Sandstone unfiltered groundwater samples analyzed for this radionuclide. However, the nonparametric ANOVA does not show a significant difference between background and OU-2 data. Further review of the analytical results supports the conclusion that cesium-137 is within background levels. The "elevated" results only slightly exceed the UTL. For example, the maximum activity of 1.66 pCi/L (well 12191 at Trench T-3) is only twice the UTL and is not much higher than the background maximum of 1.35 pCi/L. Other elevated levels ranged from 0.9 to 1.2 pCi/L, which are below the background maximum and only slightly exceed the background UTL. Activities above the UTL were detected only once in three to five sampling events, except in well 12491, where two of five samples had activities (0.9 and 1.2 pCi/L) that exceeded the background UTL. Well 12491 is located northeast of the Northeast Trenches and is screened at the base of the No. 1 Sandstone. Wells upgradient of 12491 did not contain elevated activities of this radionuclide, indicating that there is not an upgradient source for cesium-137 in this well. Because the cesium-137 activities do not significantly exceed the background UTL, the maximum OU-2 and background activities are comparable, and elevated levels are usually not found in more than one sampling event, cesium-137 is not considered to exceed background levels and is not considered an OU-2 contaminant.

Total (unfiltered) concentrations of radium-226, strontium-89,90, and the uranium isotopes do not exceed background levels in the No. 1 Sandstone using both statistical tests, and these are not considered groundwater contaminants. Only four unfiltered samples were analyzed for the uranium and strontium isotopes.

3.2.2 UHSU

Tables 3-3 and 3-4 show the results of the background comparison for dissolved metals and radionuclides in the UHSU, including the No. 1 Sandstone. Dissolved-phase constituents are assessed in the UHSU rather than total (unfiltered) results because dissolved-phase

contaminants may be transported in groundwater to exposure points in Woman or Walnut Creeks.

Dissolved Metals

On the basis of the statistical tests, the following metals were concluded not to exceed background levels: aluminum, arsenic, beryllium, cadmium, cesium, cobalt, copper, lead, lithium, mercury, molybdenum, selenium, silver, thallium, tin, and vanadium. On the basis of spatial and temporal evaluation, the following metals are not considered site-related contaminants in the UHSU: antimony, barium, chromium, manganese, nickel, strontium, and zinc. The reasons are discussed below.

UHSU

Dissolved Metals Eliminated as Contaminants on the Basis of Spatial/Temporal Evaluation

Antimony: Antimony concentrations are evenly distributed and unrelated to source areas. Detected concentrations range from 8 to 88 $\mu\text{g/L}$; the maximum value was detected at well 286 at Indiana Street. Other detected values were below the 95% UTL of background (46 $\mu\text{g/L}$) and appear to have no relationship to source areas.

Barium: Although barium appears to exceed background levels by the statistical comparisons, the concentrations of this element detected in UHSU wells are probably naturally occurring and are not likely to be related to groundwater contamination. As shown in Table 3-3A, elevated concentrations occur with approximately the same frequency in wells associated with VOC contamination and those not associated with VOC contamination. Barium is therefore eliminated from further consideration as a chemical of concern in groundwater. The reasoning and evidence for this conclusion are discussed in more detail in the previous section 3.2.1 for Total Metals in the No. 1 Sandstone wells.

Chromium: Only six percent of the results exceeded the background UTL of 14 $\mu\text{g/L}$ and chromium did not exceed background by the nonparametric ANOVA test. The OU-2 maximum detected value of 23 $\mu\text{g/L}$ is equivalent to the background maximum (also 23 $\mu\text{g/L}$), and the background mean (6 $\mu\text{g/L}$) exceeds the OU-2 mean (5 $\mu\text{g/L}$). Five samples with concentrations above the UTL (15 to 23 $\mu\text{g/L}$) were from wells in the NE Trenches Area (wells 2587, 3686, 3687, 4286). However, only well 3687 had more than one sampling event with a concentration that exceeded the background UTL, there is no evidence of a plume of elevated chromium, and

all concentrations are relatively low and are below the maximum value detected in background samples. Therefore, chromium is not retained as a potential chemical of concern in the UHSU.

Manganese: Although manganese appears to exceed background levels by the statistical comparisons, the concentrations of this element detected in UHSU wells are probably naturally occurring and unrelated to groundwater contamination. As shown in Table 3-3A, elevated concentrations occur with approximately the same frequency in wells associated with VOC contamination and those not associated with VOC contamination. Manganese is therefore not considered a waste-related contaminant and is eliminated from further consideration as a chemical of concern in groundwater. The reasoning and evidence for this conclusion are discussed in more detail in the previous section 3.2.1 for Total Metals in the No. 1 Sandstone wells.

Nickel: Eight sample results (6 percent) exceeded the background UTL of 25 $\mu\text{g/L}$. Elevated concentrations of nickel were detected in four samples from well 2987 (239 to 1210 $\mu\text{g/L}$), one sample each from well 3686 (287 $\mu\text{g/L}$) and well 6586 (65 $\mu\text{g/L}$), and in two samples from well 286 at Indiana Street (46 and 50 $\mu\text{g/L}$). The elevated concentrations do not appear to be associated with source areas in OU-2 or with a contaminant plume. Other detected values ranged from 2 to 25 $\mu\text{g/L}$, which are equal to or below the background UTL of 25 $\mu\text{g/L}$. Because elevated concentrations occurred in only three wells within OU-2 (not counting well 286 at Indiana Street), all of which are screened in the colluvium or valley fill, and because elevated concentrations do not appear to be associated with source areas, nickel is not considered a contaminant in the UHSU.

Strontium: Only 2 percent of the strontium results exceeded the background UTL of 2148 $\mu\text{g/L}$ (background maximum = 8730 $\mu\text{g/L}$). The highest concentrations of strontium were detected in samples collected from wells 286 and 41591 at Indiana Street (2000 to 2290 $\mu\text{g/L}$), in well 7391 near a source trench (about 3000 $\mu\text{g/L}$ in two samples), and in well 3686 (2020 $\mu\text{g/L}$), which is screened in the valley fill in Walnut Creek. Strontium is otherwise evenly distributed throughout OU-2 in concentrations of less than 1000 $\mu\text{g/L}$. Because strontium was detected in comparable concentrations in wells near source areas and at locations distant from source areas, it is not considered an OU-2 contaminant.

Zinc: Zinc was detected above the background UTL concentration of 51 $\mu\text{g/L}$ in only 3 of nearly 200 samples, and zinc does not exceed background by the UTL comparison. The maximum concentration of 759 $\mu\text{g/L}$ was observed in well 05691. This extreme concentration appears to have biased the nonparametric ANOVA. Other elevated concentrations were

56 µg/L in well 2387 and 157 g/L in well 12987; these concentrations are near or below the background maximum of 137 µg/L. Concentrations exceeding the UTL were observed only once in several sampling rounds and do not appear to be related to known source areas. Zinc is not considered a contaminant in groundwater in OU-2.

Dissolved Radionuclides

Table 3-4 summarizes the background comparison for dissolved radionuclides in the UHSU. For a number of the analytes, few background data were available for comparison. Americium-241 and plutonium-239,240 are considered potential contaminants in UHSU groundwater.

Other radionuclides were eliminated from further consideration for the reasons discussed below.

UHSU

Dissolved Radionuclides Eliminated as Contaminants on the Basis of Spatial/Temporal or Other Data Evaluation

Cesium-137: Cesium-137 was detected in only 2 of 11 filtered samples at activities of 0.25 pCi/L (well 11691) and 0.5 pCi/L (well 3091). No filtered background results are available for comparison. The few OU-2 data available do not support identifying cesium-137 as a groundwater contaminant. (The background UTL calculated for total [unfiltered] cesium-137 in the No. 1 Sandstone is 0.83 pCi/L. The filtered sample results are below this value, suggesting that dissolved-phase cesium-137 is not a groundwater contaminant).

Radium-226: Radium-226 was detected in UHSU groundwater (filtered fraction) in activities ranging from 0.15 to 2.8 pCi/L. The background UTL is 1.8 pCi/L and the background maximum value is 3 pCi/L. Only 2 percent of the OU-2 data (i.e., one result) exceeded the background UTL, but this result (2.8 pCi/L) was below the background maximum. Therefore, radium-226 is not considered an OU-2 contaminant.

Strontium-89,90: Strontium-89,90 was detected in UHSU groundwater (filtered fraction) in activities ranging from 0.009 to 2.1 pCi/L. Seven percent of the sample results exceeded the background UTL of 0.82 pCi/L. Activities exceeding the background UTL occurred in only one of several sampling events per well. Because the occurrences of elevated concentrations are temporally isolated events, this radionuclide is not considered a contaminant in OU-2 groundwater.

Tritium: Tritium occurs both in background water samples and in OU-2 samples. It was detected above the background UTL of 334 pCi/L in 14, or approximately 8 percent, of the OU-2 samples. The tritium activities above the background UTL were widely distributed across OU-2. Nine of the 14 elevated results were below the background maximum of 561 pCi/L. In the other 5 samples, tritium levels ranged from 607 pCi/L to 2,641 pCi/L. The highest activities were observed in September 1991 sampling round in well 1587 (east of the 903 Pad) and in well 1487 (near Woman Creek). The elevated levels of tritium were observed during only one sampling event at all wells, with the exception of well 3586, located west of the B series ponds, where two samples had activities of 350 and 439 pCi/L, which slightly exceeded the background UTL of 334 pCi/L. Since somewhat elevated tritium levels were scattered across OU-2 and with one exception, were only observed in a single sampling round at each well, tritium is not considered to be a site-related contaminant in OU-2.

Uranium-233,234: Uranium-233,234 did not exceed background by either statistical test. Dissolved-phase U-233,234 was detected in UHSU groundwater in activities ranging from 0.18 to 43 pCi/L. None of these results exceed the background UTL of 53 pCi/L. The background maximum was 200 pCi/L, but most background sample results were less than 18 pCi/L. OU-2 data are consistent with the background data, in that most of the OU-2 results were below 11 pCi/L, with four results in the 20 to 24 pCi/L range, and the maximum at 43 pCi/L. U-233,234 results appear to be within background levels and the isotopes are not considered contaminants in groundwater.

Uranium-235: Uranium-235, like uranium-233,234, was not detected in any sample above the background UTL of 1.7 pCi/L. The background maximum was 4.8 pCi/L, but most background activities were less than 1 pCi/L. The OU-2 maximum was 1.5 pCi/L, but most OU-2 activities were also less than 1 pCi/L. Uranium-235 appears to be within background levels and is not considered a contaminant in groundwater.

Uranium-238: Uranium-238 did not exceed background levels by either statistical test. It was detected above the background UTL of 37 pCi/L in only one sample from well 7391 (76 pCi/L). This well is located south of Trench T-2. Background maximum result is 136 pCi/L (all background results greater than 16 pCi/L were measured in well 205589). Since only a single result exceeded the background UTL, U-238 is not considered a site-related contaminant in OU-2.

3.3 FREQUENCY OF DETECTION

Organic compounds detected at a frequency of 5 percent or greater were considered potential chemicals of concern. These compounds are listed in Tables 3-5 (No. 1 Sandstone) and 3-6 (UHSU) and are included in the concentration/toxicity screens for groundwater. Frequency of detection was evaluated separately for the No. 1 Sandstone and UHSU for consistency with the evaluation of metals and radionuclides.

Infrequently detected compounds (detected at less than 5 percent frequency) are listed in Tables 3-7 and 3-8. Concentrations of infrequently detected organic compounds were further evaluated as described in Section 3.5 to identify "special case" chemicals of concern for evaluation in the risk assessment.

3.4 CONCENTRATION/TOXICITY SCREENS

Concentration/toxicity screens were used to identify chemicals of concern in groundwater to be evaluated in the quantitative human health risk assessment. The screening process permits selecting chemicals, based on concentration and toxicity, that could contribute significantly to risk and identifies chemicals that can be eliminated from further consideration because they contribute insignificantly to overall risk. The screen was performed for all inorganic constituents identified as potential contaminants after the background comparison and spatial/temporal assessment discussed in Section 3.2 and for all organic compounds detected at a frequency of 5 percent or greater. The concentration/toxicity screen process was explained in Section 2.4. In performing the concentration/toxicity screens for organic compounds detected in groundwater, if both inhalation and oral toxicity factors were available for organic compounds, the toxicity value that resulted in the highest relative risk value (or "risk index") was used. For evaluation of metals and radionuclides in groundwater, only oral slope factors were used because they do not volatilize and, therefore are not inhaled.

Results of the screen for the No. 1 Sandstone are shown in Tables 3-9 (Noncarcinogenic Effects), 3-10 (Carcinogenic Effects), and 3-11 (Radionuclides). Results of the screen for the UHSU are shown in Tables 3-12 (Noncarcinogenic Effects), 3-13 (Carcinogenic Effects), and 3-14 (Radionuclides). All chemicals that comprise 99 percent of the total risk factor are identified as chemicals of concern to be evaluated in the risk assessment.

Carbon tetrachloride, chloroform, tetrachlorethene, trichloroethene, americium-241, and plutonium-239,240 were identified as chemicals of concern in groundwater for both the No. 1

Sandstone and the UHSU as a whole. 1,1-Dichloroethene is an additional chemical of concern in the UHSU.

3.5 EVALUATION OF INFREQUENTLY DETECTED COMPOUNDS

As stated in Section 3.2, compounds detected at less than 5 percent frequency can usually be eliminated from further consideration because the potential for exposure is low. However, these compounds were further screened so as not to neglect infrequently detected compounds that could contribute significantly to risk if exposure were to occur. In this screen, maximum concentrations of infrequently detected compounds were compared to risk-based screening values using the approach outlined in Section 2.5 and described in greater detail in Appendix B. Complete results of the evaluation are shown in Table B-6. The evaluation shows that the following three infrequently detected compounds have maximum concentrations that exceeded the screening values used in the analysis:

- 1,2-dibromoethane
- cis-1,3-dichloropropene
- vinyl chloride

The compound 1,2-dibromoethane was detected in 2 of 170 groundwater samples at concentrations of 1.8 $\mu\text{g/L}$ (well 6691 in the 903 Pad) and at 13 $\mu\text{g/L}$ (well 7391, IHSS 109, south of the 903 pad). Well 6691 is screened in the Rocky Flats alluvium, and well 7391 is screened in the colluvium. Both wells are in or near contaminant source areas where other solvents have been detected. The samples with positive results were collected in May 1992. These wells were also sampled in November 1992 (4th quarter) and 1,2-dibromoethane was not detected, although reporting limits were elevated, so the results are inconclusive. 1,2-Dibromoethane is not characteristic of groundwater contamination at OU-2 because it is so infrequently detected. However, it is identified as a special-case chemical of concern and its potential impact on overall risk will be evaluated in the risk assessment.

Vinyl chloride was detected at approximately 4 percent frequency of detection (10 samples out of about 280). The highest concentrations (380 to 860 $\mu\text{g/L}$) were detected in several samples collected at well 3586. This well is located at the northern boundary of OU-2 near the discharge from the Protected Area and near a seep that is being investigated under a separate program. Vinyl chloride was not detected in OU-2 upgradient of this well. Therefore, vinyl chloride

detected in this well is probably not related to source areas in OU-2. Vinyl chloride was detected in much lower concentrations (2 to 3 $\mu\text{g}/\text{L}$) in samples from well 7391, where it is co-located with other solvents. Vinyl chloride is included as a special-case chemical of concern for OU-2.

The compound cis-1,3-dichloropropene was detected in three of 281 samples at concentrations of 0.56 $\mu\text{g}/\text{L}$ (well 6691 in the 903 Pad), 13 $\mu\text{g}/\text{L}$ (well 12691 in the Northeast Trenches Area), and 1700 $\mu\text{g}/\text{L}$ (well 7391 south of the 903 Pad). The samples with positive results were collected in the first quarter of 1992. This compound was nondetect in subsequent sampling rounds. Nevertheless, it will be evaluated in the risk assessment as a special-case chemical of concern.

3.6 SUMMARY OF CHEMICALS OF CONCERN IN GROUNDWATER

Summary lists of chemicals of concern identified by the concentration/toxicity screens are shown in Tables 3-15 (No. 1 Sandstone) and 3-16 (UHSU).

Some chemicals detected in groundwater do not have EPA-established toxicity factors and cannot be evaluated in the concentration/toxicity screen or other risk-based screening for infrequently detected compounds. These chemicals are listed in Table 3-17. They will be evaluated qualitatively in the risk assessment.

TABLE 3-1
ROCKY FLATS PLANT OU-2
SUMMARY OF BACKGROUND COMPARISON
TOTAL METALS IN GROUNDWATER, µg/L
NO. 1 SANDSTONE

Analyte	% Data		ANOVA		Potential Contaminant?		Spatial /Temporal / Other (See Text)	Consider Further?
	(1)	(2)	(3)	(4)	No	Yes		
Aluminum	82	<0.05	X	X			Widely distributed; low dissolved concentrations.	No
Antimony	0	0.63	X					No
Arsenic	6	<0.05	X	X			No spatial or temporal significance.	No
Barium	12	<0.05	X	X			Elevated total and dissolved concentrations in many wells.	Yes
Beryllium	0	0.08	X					No
Cadmium	0	0.89	X					No
Cesium	0	0.21	X					No
Chromium	0	<0.05	X					No
Cobalt	0	<0.05	X					No
Copper	0	0.28	X					No
Cyanide	12	0.88		?			Several elevated results; uncertain spatial/temporal significance	Yes
Lead	65	<0.05	X	X			Widely distributed; low dissolved conc.; no dissolved plume.	No
Lithium	0	<0.05	X					No
Manganese	40	<0.05	X	X			Elevated total and dissolved concentrations in many wells.	Yes
Mercury	15	<0.05	X				Erratic hits, low frequency, no dissolved plume.	No
Molybdenum	0	0.22	X					No
Nickel	0	0.72	X					No
Selenium	0	<0.05	X					No
Silver	0	<0.05	X					No
Strontium	6	<0.05	X	X			Elevated concentrations found far from source areas.	No
Thallium	0	0.56	X					No
Tin	0	0.28	X					No
Vanadium	0	<0.05	X					No
Zinc	0	<0.05	X					No

- (1) From Table A-1.
(2) Table A-9. p < 0.05 is considered significant.
(3) < 5% data exceeds 95% UTL and p > 0.05. ? Either > 5% data exceeds 95% UTL or p < 0.05.
(4) > 5% data exceeds 95% UTL and p < 0.05. * Background mean equals or exceeds OU-2 mean.

TABLE 3-2
ROCKY FLATS PLANT OU-2
SUMMARY OF BACKGROUND COMPARISON
TOTAL RADIONUCLIDES IN GROUNDWATER, pCi/L
NO. 1 SANDSTONE

Analyte	DF		% Data		ANOVA		Potential Contaminant?		Spatial/Temporal/Other (See Text)	Consider Further?
	(1)	(2)	(1)	(2)	p (2)	No (3)	Yes (4)			
Americium-241	86/93	12	12	<0.05			X		Results only slightly > UTL; no spatial or temporal pattern	Yes
Cesium-137	49/49	14	14	0.06		?				No
Plutonium-239,240	100/102	64	64	<0.05			X			Yes
Radium-226	1/1	0	0	0.16		X				No
Strontium-89,90	1/4	0	0	0.86		X				No
Uranium-233,234	4/4	0	0	0.8 *		X				No
Uranium-235	4/4	0	0	0.42 *		X				No
Uranium-238	4/4	0	0	0.91 *		X				No

- (1) From Table A-2.
- (2) Table A-10. $p < 0.05$ is considered significant.
- (3) $< 5\%$ data exceeds 95% UTL and $p > 0.05$
- (4) $> 5\%$ data exceeds 95% UTL and $p < 0.05$
- ? Either $> 5\%$ data exceeds 95% UTL or $p < 0.05$.
- * Background mean equals or exceeds OU2 mean.

TABLE 3-3
ROCKY FLATS PLANT OU-2
SUMMARY OF BACKGROUND COMPARISON
DISSOLVED METALS IN GROUNDWATER, µg/L
UHSU

Analyte	% Data		ANOVA p (2)	Potential Contaminant?		Spatial/Temporal/Other (See Text)	Consider Further?
	> 95% UTL (1)	< 0.05 (2)		No (3)	Yes (4)		
Aluminum	0	0.58 *		X		Evenly distributed; unrelated to source areas	No
Antimony	9	<0.05			X		No
Arsenic	1	0.37 *		X			No
Barium	40	<0.05			X	Elevated dissolved concentrations in wells near source areas.	Yes
Beryllium	0	0.59 *		X			No
Cadmium	2	0.44		X			No
Cesium	0	<0.05 *		X		OU-2 max = bknd max; most results > UTL occur in only one sample round.	No
Chromium	6	<0.05 *			?		No
Cobalt	0	0.86 *		X			No
Copper	2	<0.05 *		X			No
Lead	0	<0.05 *		X			No
Lithium	0	<0.05 *		X			No
Manganese	23	<0.05			X	Elevated dissolved concentrations in wells near source areas.	Yes
Mercury	0	0.14 *		X			No
Molybdenum	1	0.26 *		X			No
Nickel	6	0.16			?	Comparable concentrations at source areas and non-source areas.	No
Selenium	0	<0.05 *		X			No
Silver	0	<0.05 *		X			No
Strontium	2	<0.05			?	Comparable concentrations at source areas and non-source areas.	No
Thallium	0	0.83		X			No
Tin	0	<0.05 *		X			No
Vanadium	0	<0.05 *		X		ANOVA biased by OU-2 extreme value; no relation to source areas.	No
Zinc	3	<0.05			?		No

- (1) From Table A-3.
(2) Table A-11. p < 0.05 is considered significant.
(3) <5% data exceeds 95% UTL and ? Either >5% data exceeds 95% UTL or p < 0.05
(4) > 5% data exceeds 95% UTL and * Background mean equals or exceeds OU-2 mean.

TABLE 3-3A
BARIUM AND MANGANESE EXCEEDANCES OF BACKGROUND
UTL IN UHSU WELLS

		Filtered Samples		Unfiltered Samples	
		In VOC Plume	Outside VOC Plume *	In VOC Plume	Outside VOC Plume *
Barium	Number of results	158	41	153	34
	% results < UTL	61	56	82	91
	% results > UTL	39	44	18	9
	% results > 2 X UTL	1	0	9	6
Manganese	Number of results	158	41	150	33
	% results < UTL	76	88	70	82
	% results > UTL	26	12	30	18
	% results > 2 X UTL	13	7	15	12

* Wells with little or no VOC contamination are 6191, 3986, 6291, 6391, 6491, 0386, 0286, 6786, 2591, 13391, 41591, 2987, 1491, 12091, 1391, 1791, 1891, 12291, 2387, and 4386.

TABLE 3-4
ROCKY FLATS PLANT OU-2
SUMMARY OF BACKGROUND COMPARISON
DISSOLVED RADIONUCLIDES IN GROUNDWATER, pCi/L
UHSU

Analyte	DF (1)	% Data > 95% UTL (1)	ANOVA p (2)	Potential Contaminant?		Spatial/Temporal/Other (See Text)	Consider Further?
				No (3)	Yes (4)		
Americium 241	10/10	30	0.74		?	Probable contaminant.	Yes
Cesium 137	2/11	-	-		?	Few data to support identification as contaminant	No
Plutonium 239,240	10/10	-	-		?	Probable contaminant.	Yes
Radium 226	52/53	2	<0.05		?	OU-2 results < bknd max	No
Strontium 89,90	165/184	7	0.99		?	Results > bknd UTL are temporally isolated.	No
Tritium	181/181	8	0.06		?	Several elevated results; no spatial/temporal significance.	No
Uranium 233,234	230/230	0	<0.05 *	X		All results below background UTL.	No
Uranium 235	179/197	0	0.05 *	X		All results below background UTL.	No
Uranium 238	224/224	1	<0.05 *	X		All results below but one below background UTL.	No

- (1) From Table A-4.
- (2) Table A-12. p < 0.05 is considered significant.
- (3) <5% data exceeds 95% UTL and p > 0.05
- (4) > 5% data exceeds 95% UTL and p < 0.05
- ? Either > 5% data exceeds 95% UTL or p < 0.05.
- * Background mean equals or exceeds OU2 mean.
- Analysis not performed. See Tables A-4 and A-12.

TABLE 3-5
ROCKY FLATS PLANT OU-2
ORGANIC COMPOUNDS DETECTED AT
5% OR GREATER FREQUENCY
NO. 1 SANDSTONE GROUNDWATER

Chemical	Maximum Concentration mg/L	Detection Frequency %
1,1,1,2-Tetrachloroethane	0.0026	6
1,1,1-Trichloroethane	0.13	39
1,1,2,2-Tetrachloroethane	0.0024	6
1,1-Dichloroethane	0.0034	26
1,1-Dichloroethene	0.036	34
1,1-Dichloropropene	0.0016	5
1,2-Dichloroethene	0.054	39
cis-1,2-Dichloroethene	0.3	51
trans-1,2-Dichloroethene	0.025	13
Acetone	0.16	9
Benzene	0.001	6
Bromochloromethane	0.03	5
Bromodichloromethane	0.018	9
Carbon tetrachloride	4.5	63
Chloroform	1.1	65
Methylene chloride	3	40
Naphthalene	0.044	10
n-Butyl benzene	0.0013	5
p-Cymene	0.00076	6
Tetrachloroethene	13	79
Toluene	0.013	11
Trichloroethene	94	72
Bis (2-ethylhexyl) phthalate	0.017	33
Benzoic acid	0.056	6
Diethyl phthalate	0.31	26
Di-n-butyl phthalate	0.003	6

**TABLE 3-6
ROCKY FLATS PLANT OU-2
ORGANIC COMPOUNDS DETECTED AT 5%
OR GREATER FREQUENCY
UHSU GROUNDWATER**

Chemical	Maximum Concentration mg/L	Detection Frequency %
1,1,1-Trichloroethane	0.54	24
1,1-Dichloroethane	0.19	15
1,1-Dichloroethene	0.26	23
1,2-Dichloroethene	0.17	32
cis-1,2-Dichloroethene	1.4	46
trans-1,2-Dichloroethene	0.03	11
Benzene	0.005	5
Bromodichloromethane	0.02	7
Carbon tetrachloride	17	57
Chloroform	1.7	58
Methylene chloride	3.9	26
Tetrachloroethene	13	67
Toluene	0.01	9
Trichloroethene	94	62
Bis(2-ethylhexyl)phthalate	0.017	38
Diethylphthalate	0.31	20
Naphthalene	0.09	13
Heptachlor epoxide*	0.00007	*

* Reported in 1 of 2 samples analyzed.

TABLE 3-7
ROCKY FLATS PLANT OU-2
ORGANIC COMPOUNDS DETECTED AT
LESS THAN 5% FREQUENCY
NO. 1 SANDSTONE GROUNDWATER

	Maximum Concentration mg/L	Detection Frequency %
1,1,2-Trichloroethane	0.0006	3
1,2,3-Trichlorobenzene	0.00003	3
1,2,4-Trichlorobenzene	0.0003	1
1,2-Dichloroethane	0.001	3
cis-1,3-Dichloropropene	0.013	2
1,3-Dimethylbenzene	0.0002	3
1,2,4-Trimethylbenzene	0.0001	3
1,3,5-Trimethylbenzene	0.00009	3
4-Methyl-2-pentanone	0.01	4
Carbon disulfide	0.0008	4
Chlorobenzene	0.016	2
Chloroethane	0.043	2
Chloromethane	0.00029	2
Dibromomethane	0.065	2
Dichlorodifluoromethane	0.00058	3
Ethylbenzene	0.015	2
Hexachlorobutadiene	0.0012	4
sec-Butylbenzene	0.00024	3
Styrene	0.014	3
Total xylene	0.053	3
Trichlorofluoromethane	0.00057	4

TABLE 3-8
ROCKY FLATS PLANT OU-2
ORGANIC COMPOUNDS DETECTED AT
LESS THAN 5% FREQUENCY
UHSU GROUNDWATER

Chemical	Maximum Concentration mg/L	Detection Frequency %
1,1,1,2-Tetrachloroethane	0.003	3
1,1,2,2-Tetrachloroethane	0.18	3
1,1,2-Trichloroethane	0.02	2
1,1-Dichloropropene	0.002	2
1,2,3-Trichlorobenzene	0.0003	2
1,2,3-Trichloropropane	0.002	2
1,2,4-Trichlorobenzene	0.002	2
1,2-Dibromoethane	0.01	1
1,2-Dichlorobenzene	0.0001	<1
1,2-Dichloroethane	0.0073	3
1,2-Dichloropropane	0.02	<1
1,2-Dimethylbenzene (o-xylene)	0.0002	3
1,2,4-Trimethylbenzene	0.0001	2
1,3-Dichlorobenzene	0.002	2
1,3-Dichloropropane	0.0003	1
cis-1,3-Dichloropropene	1.7	1
1,3-Dimethylbenzene (m-xylene)	0.0003	2
1,3,5-Trimethylbenzene	0.001	1
1,4-Dichlorobenzene	0.0003	1
2-Hexanone	0.005	2
4-Methyl-2-pentanone	0.01	2
Acetone	0.16	4
Benzoic acid	0.056	4
Bromobenzene	0.0003	1
Bromoform	0.006	1
n-Butylbenzene	0.001	2
Chlorobenzene	0.02	1
Chloroethane	0.04	1
Chloromethane	0.005	1
o-Chlorotoluene	0.003	<1
p-Chlorotoluene	0.0003	<1
p-Cymene	0.0008	4

**TABLE 3-8
(Concluded)**

	Maximum Concentration mg/L	Detection Frequency %
Dibromomethane	1.7	2
Dichlorodifluoromethane	0.0006	1
Ethylbenzene	0.02	2
Hexachlorobutadiene	0.0012	3
1,2-Dibromo-3-chloropropane	0.004	1
sec-Butylbenzene	0.2	3
sec-Dichloropropane	0.01	1
Styrene	0.01	3
tert-Butylbenzene	0.0004	1
Vinyl chloride	0.86	3
Di-n-butylphthalate	0.003	4

TABLE 3-9
ROCKY FLATS OU-2
CONCENTRATION/TOXICITY SCREEN
NO. 1 SANDSTONE GROUNDWATER
NONCARCINOGENS
(Organics and Total Metals)

Chemical	Max Valu (mg/L)	Inhalation RfD	Oral RfD	Risk Factor	Risk Index	Rank	Cumulative Percent
carbon tetrachloride	4.5	n/a	7.0E-04	6.4E+03	8.1E-01	1	81.5
tetrachloroethene	13	n/a	1.0E-02	1.3E+03	1.6E-01	2	98.0
chloroform	1.1	n/a	1.0E-02	1.1E+02	1.4E-02	3	99.4
cis-1,2-dichloroethene	0.3	n/a	1.0E-02	3.0E+01	3.8E-03	4	99.8
1,2-dichloroethene	0.054	n/a	9.0E-03	6.0E+00	7.6E-04	5	99.8
1,1-dichloroethene	0.036	n/a	9.0E-03	4.0E+00	5.1E-04	6	99.9
acetone	0.16	n/a	1.0E-01	1.6E+00	2.0E-04	7	99.9
1,1,1-trichloroethane	0.13	3.0E-01	9.0E-02	1.4E+00	1.8E-04	8	99.9
trans-1,2-dichloroethene	0.025	n/a	2.0E-02	1.3E+00	1.6E-04	9	99.9
naphthalene	0.044	n/a	4.0E-02	1.1E+00	1.4E-04	10	99.9
cyanide	0.02	n/a	2.0E-02	1.0E+00	1.3E-04	11	100.0
bromodichloromethane	0.018	n/a	2.0E-02	9.0E-01	1.1E-04	12	100.0
bis(2-ethylhexyl)phthalate	0.017	n/a	2.0E-02	8.5E-01	1.1E-04	13	100.0
methylene chloride	0.04	9.0E-01	6.0E-02	6.7E-01	8.5E-05	14	100.0
diethyl phthalate	0.31	n/a	8.0E-01	3.9E-01	4.9E-05	15	100.0
toluene	0.013	1.1E-01	2.0E-01	1.2E-01	1.5E-05	16	100.0
1,1,1,2-tetrachloroethane	0.0026	n/a	3.0E-02	8.7E-02	1.1E-05	17	100.0
1,1-dichloroethane	0.0034	1.4E-01	1.0E-01	3.4E-02	4.3E-06	18	100.0
benzoic acid	0.056	n/a	4.0E+00	1.4E-02	1.8E-06	19	100.0
di-n-butylphthalate	0.003	n/a	1.0E+01	3.0E-04	3.8E-08	20	100.0
Total Risk Factor				7.9E+03			

RfDs are in units of mg/kg-day. See Table 2-5 for references.
n/a = not available.

TABLE 3-10
ROCKY FLATS OU-2
CONCENTRATION/TOXICITY SCREEN
NO. 1 SANDSTONE GROUNDWATER
CARCINOGENS
(Organics and Total Metals)

Chemical	Max Value (mg/L)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	Rank	Cumulative Percent
trichloroethene	94	6.0E-03	1.1E-02	1.0E+00	4.3E-01	1	43.0
tetrachloroethene	13	2.0E-03	5.2E-02	6.8E-01	2.8E-01	2	71.1
carbon tetrachloride	4.5	5.3E-02	1.3E-01	5.9E-01	2.4E-01	3	95.4
chloroform	1.1	8.0E-02	6.1E-03	8.8E-02	3.7E-02	4	99.0
1,1-dichloroethene	0.036	1.8E-01	6.0E-01	2.2E-02	9.0E-03	5	99.9
bromodichloromethane	0.018	n/a	6.2E-02	1.1E-03	4.6E-04	6	100.0
methylene chloride	0.04	1.6E-03	7.5E-03	3.0E-04	1.2E-04	7	100.0
bis(2-ethylhexyl)phthalate	0.017	n/a	1.4E-02	2.4E-04	9.9E-05	8	100.0
1,1,1,2-tetrachloroethane	0.0026	2.6E-02	2.6E-02	6.8E-05	2.8E-05	9	100.0
benzene	0.001	2.9E-02	2.9E-02	2.9E-05	1.2E-05	10	100.0
Total Risk Factor				2.4E+00			

Slope factors are in units of 1/(mg/kg-day). See Table 2-5 for references.
n/a = not available.

TABLE 3-11
ROCKY FLATS OU-2
CONCENTRATION/TOXICITY SCREEN
NO. 1 SANDSTONE GROUNDWATER
TOTAL RADIONUCLIDES

Chemical	Max Value (pCi/L)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	Rank	Cumulative Percent
plutonium-239,240	5.02	n/a	2.3E-10	1.2E-09	8.2E-01	1	81.5
americium-241	1.09	n/a	2.4E-10	2.6E-10	1.8E-01	2	100.0
Total Risk Factor				1.4E-09			

Slope factors are in units of 1/pCi. See Table 2-6 for references.
n/a = not applicable.

TABLE 3-12
ROCKY FLATS OU-2
CONCENTRATION/TOXICITY SCREEN
UHSU GROUNDWATER
NONCARCINOGENS
(Organics and Dissolved Metals)

Chemical	Max Value (mg/L)	Inhalation RfD	Oral RfD	Risk Factor	Risk Index	Rank	Cumulative Percent
carbon tetrachloride	17	n/a	7.0E-04	2.4E+04	9.3E-01	1	93.1
tetrachloroethene	14	n/a	1.0E-02	1.4E+03	5.4E-02	2	98.4
chloroform	1.7	n/a	1.0E-02	1.7E+02	6.5E-03	3	99.1
cis-1,2-dichloroethene	1.4	n/a	1.0E-02	1.4E+02	5.4E-03	4	99.6
1,1-dichloroethene	0.26	n/a	9.0E-03	2.9E+01	1.1E-03	5	99.9
1,1,1-trichloroethane	0.54	3.0E-01	9.0E-02	6.0E+00	2.3E-04	6	100.0
naphthalene	0.09	n/a	4.0E-02	2.3E+00	8.6E-05	7	100.0
1,1-dichloroethane	0.19	1.4E-01	1.0E-01	1.9E+00	7.3E-05	8	100.0
trans-1,2-dichloroethene	0.03	n/a	2.0E-02	1.5E+00	5.8E-05	9	100.0
bromodichloromethane	0.02	n/a	2.0E-02	1.0E+00	3.8E-05	10	100.0
cyanide	0.02	n/a	2.0E-02	1.0E+00	3.8E-05	11	100.0
bis(2-ethylhexyl)phthalate	0.017	n/a	2.0E-02	8.5E-01	3.3E-05	12	100.0
methylene chloride	0.04	9.0E-01	6.0E-02	6.7E-01	2.6E-05	13	100.0
diethyl phthalate	0.31	n/a	8.0E-01	3.9E-01	1.5E-05	14	100.0
toluene	0.01	1.1E-01	2.0E-01	9.1E-02	3.5E-06	15	100.0
Total Risk Factor				2.6E+04			

RfDs are in units of mg/kg-day. See Table 2-5 for references.
n/a = not available.

**TABLE 3-13
ROCKY FLATS OU-2
CONCENTRATION/TOXICITY SCREEN
UHSU GROUNDWATER
CARCINOGENS
(Organics and Dissolved Metals)**

Chemical	Max Value (mg/L)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	Rank	Cumulative Percent
trichloroethene	94	6.0E-03	1.1E-02	1.0E+00	4.1E-01	1	41.2
tetrachloroethene	13	2.0E-03	5.2E-02	6.8E-01	2.7E-01	2	68.1
carbon tetrachloride	4.5	5.3E-02	1.3E-01	5.9E-01	2.3E-01	3	91.4
1,1-dichloroethene	0.2	1.8E-01	6.0E-01	1.2E-01	4.8E-02	4	96.2
chloroform	1.1	8.0E-02	6.1E-03	8.8E-02	3.5E-02	5	99.7
bromodichloromethane	0.1	n/a	6.2E-02	6.2E-03	2.5E-03	6	99.9
1,1,1,2-tetrachloroethane	0.05	2.6E-02	2.6E-02	1.3E-03	5.2E-04	7	100.0
methylene chloride	0.04	1.6E-03	7.5E-03	3.0E-04	1.2E-04	8	100.0
bis(2-ethylhexyl)phthalate	0.017	n/a	1.4E-02	2.4E-04	9.5E-05	9	100.0
benzene	0.005	2.9E-02	2.9E-02	1.5E-04	5.8E-05	10	100.0
Total Risk Factor				2.5E+00			

Slope factors are in units of 1/(mg/kg-day). See Table 2-5 for references.
n/a = not available.

**TABLE 3-14
ROCKY FLATS OU-2
CONCENTRATION/TOXICITY SCREEN
UHSU GROUNDWATER
DISSOLVED RADIONUCLIDES**

Chemical	Max Value (pCi/L)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	Rank	Cumulative Percent
americium-241	21.3	n/a	2.4E-10	5.1E-09	9.7E-01	1	96.5
plutonium-239,240	0.8	n/a	2.3E-10	1.8E-10	3.5E-02	2	100.0
Total Risk Factor				5.3E-09			

Slope factors are in units of 1/pCi. See Table 2-6 for references.
n/a - not applicable.

TABLE 3-15
ROCKY FLATS PLANT OU-2
CHEMICALS OF CONCERN
NO. 1 SANDSTONE GROUNDWATER

Organic Compounds	Radionuclides
Carbon tetrachloride	Americium-241
Chloroform	Plutonium-239,240
Tetrachloroethene	
Trichloroethene	

**TABLE 3-16
ROCKY FLATS PLANT OU-2
CHEMICALS OF CONCERN
UHSU GROUNDWATER**

Organic Compounds	Radionuclides
Carbon tetrachloride	Americum-241
Chloroform	Plutonium-239,240
1,1-Dichloroethene	
Tetrachloroethene	
Trichloroethene	

SPECIAL CASE CHEMICALS OF CONCERN (1)

1,2-Dibromoethane
cis-1,3-Dichloropropene
Vinyl chloride

- (1) Special case chemicals of concern are infrequently detected and are not OU-2-wide contaminants, but they occur in potentially hazardous concentrations in highly localized waste-related areas. These were identified using the risk-based screen for infrequently detected organic compounds described in Appendix B. Special case chemicals of concern and their impact on overall risk will be evaluated separately in the risk assessment.

**TABLE 3-17
ROCKY FLATS PLANT
DETECTED ORGANIC COMPOUNDS
WITHOUT EPA TOXICITY FACTORS
GROUNDWATER**

1,1-Dichloropropene
1,2,4-Trichlorobenzene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
1,3-Dichlorobenzene
2-Hexanone
Bromochloromethane
n-Butylbenzene
n-Propylbenzene
p-Phlorotoluene
p-Cymene
Phenanthrene
sec-Butylbenzene
sec-Dichloropropane
Tetrabutylbenzene

SUBSURFACE SOIL CHEMICALS OF CONCERN

4.1 DATA EVALUATION

Chemicals of concern in subsurface soil were selected using the data set identified in Table 2-2. This includes borehole samples collected in 1987 under the OU-2 Phase I investigation and in 1991-1992 under the OU-2 Phase II investigation. Borehole samples were analyzed for VOCs, SVOCs, pesticides, metals, and radionuclides. Borehole locations are shown in Figure 4-1.

The data received from RFEDs were reviewed and edited using the steps and criteria outlined in Section 2.1 to develop a data set for further evaluation. The data set used to identify potential chemicals of concern for exposure to subsurface soils was restricted to samples collected above the water table to avoid the possibility of including chemicals that result from cross-contamination by groundwater. (However, the Phase II RFI/RI report describes the extent of contamination in the entire soil column, including the saturated zone.)

Several common laboratory contaminants detected in subsurface soil samples (bis(2-ethylhexyl)phthalate, di-n-butylphthalate, methylene chloride, and acetone) were evaluated to judge whether their occurrence may be due to cross-contamination from sampling or analytical procedures. If these compounds are found in consistently low concentrations regardless of sampling location, it is likely that they are not related to chemical releases from plant operations but are field or laboratory contaminants and can be eliminated from further consideration as chemicals of concern. The evaluation of these compounds follows:

Bis(2-ethylhexyl)phthalate and di-n-butylphthalate: Bis(2-ethylhexyl)phthalate (BEHP) was detected in 47 percent of the subsurface soil samples, and di-n-butylphthalate (DNBP) was detected in only 10 percent of the samples. Although in many cases the concentrations were estimated values below the detection limit (330 $\mu\text{g}/\text{kg}$), in other cases, elevated concentrations of BEHP ranging from 400 to 12,000 $\mu\text{g}/\text{kg}$ were detected in spatially related sampling locations, suggesting that BEHP may be an environmental contaminant in these areas. For example, BEHP was consistently detected in a series of borings in the Mound Area (borings 3287, 3287, 3387, 3487, 3587, 3687, 3787, and 3887). DNBP was also detected in a number of these borings, but in much lower concentrations (40 to 100 $\mu\text{g}/\text{kg}$).

BEHP was consistently detected in three borings in the Northeast Trenches Area: boring 10191 in Trench T-3 (5500 $\mu\text{g}/\text{kg}$), boring 4387 in Trench T-4 (360 and 420 $\mu\text{g}/\text{kg}$), and boring 4587 (770 and 880 $\mu\text{g}/\text{kg}$). BEHP was also consistently detected in several borings in and south of the 903 Pad, in concentrations ranging from 540 to 1600 $\mu\text{g}/\text{kg}$.

The 1987 borehole data have not been validated. Therefore, it is not known whether the BEHP and DNBP detected in these samples result from field or laboratory contamination. Because of this uncertainty, BEHP and DNBP are considered to be possible OU-2 contaminants in subsurface soil and are included in concentration/toxicity screens for this medium.

Methylene Chloride: Methylene chloride was detected in about 30 percent of the subsurface soil samples. Detected concentrations range from 1 $\mu\text{g}/\text{kg}$ to 37 $\mu\text{g}/\text{kg}$. About two-thirds of the results were B or J qualified (typical reporting limit was 5 $\mu\text{g}/\text{kg}$; some samples with positive results had reporting limits of 25 $\mu\text{g}/\text{kg}$).

At these low concentrations, methylene chloride is not of particular concern for adverse health effects, and its presence may or may not be due to environmental contamination in OU-2. Nevertheless, it is included in the concentration/toxicity screens to identify chemicals of concern for subsurface soils. Based on the screens (Tables 4-5 and 4-6) methylene chloride is not a chemical of concern in soils in OU-2.

Acetone: Concentrations of acetone ranging from 3 to 340 $\mu\text{g}/\text{kg}$ (and one J-qualified result of 26,000 $\mu\text{g}/\text{kg}$) were observed in subsurface soil samples collected in the Northeast Trenches Area. Acetone was also detected in concentrations ranging from 19 to 500 $\mu\text{g}/\text{kg}$ (reporting limit = 25 $\mu\text{g}/\text{kg}$) in numerous subsurface soil samples in the Mound Area. However, most of these samples did not contain measurable concentrations of other VOCs, and, therefore acetone is considered to be a probable laboratory contaminant in these samples.

Historical information indicates that acetone still bottoms were located in the 903 Pad Area. However, acetone was detected in only a few samples taken from this area at concentrations at less than 50 $\mu\text{g}/\text{kg}$. Therefore, it is unlikely that acetone is an environmental contaminant in the 903 Pad.

In conclusion, acetone appears to be a minor contaminant, and may be a result of laboratory contamination. For example, it is detected in a number of samples where no other VOCs are detected; this suggests the possibility of laboratory contamination. In some areas (e.g., Southeast Trenches and Mound Area) it is detected in fairly consistent concentrations regardless

of depth (data not shown). This pattern is not indicative of a concentration gradient resulting from chemical releases. The single high detection of 26,000 $\mu\text{g}/\text{kg}$ (reporting limit = 25,000 $\mu\text{g}/\text{kg}$) was in a sample that was diluted 5000 times because of high concentrations of chlorinated solvents. The acetone reported in this sample could be due to laboratory contamination (although the result was not B qualified).

Even though it is uncertain whether acetone is a site-related contaminant in OU-2, it is included in the concentration/toxicity screen for noncarcinogenic effects at its maximum reported concentration of 26,000 $\mu\text{g}/\text{kg}$. This is a highly conservative approach, because this concentration is not characteristic of subsurface soils. Based on the results of the concentration/toxicity screen, acetone is not a chemical of concern in subsurface soils in OU-2.

4.2 BACKGROUND COMPARISON FOR INORGANIC COMPOUNDS

Tables 4-1A, B and C, and 4-2 summarize the results of comparing concentrations of metals and radionuclides in borehole samples to background levels. Metals and radionuclides that did not exceed background levels were eliminated from further consideration as potential chemicals of concern. The background comparison process is described in Appendix A.

4.2.1 Metals

On the basis of the statistical tests, the following metals do not appear to exceed background levels (i.e., the metal did not exceed background by using both the UTL and nonparametric ANOVA tests): aluminum, barium, beryllium, chromium, cobalt, copper, lead, lithium, manganese, nickel, selenium, silver, tin, vanadium, and zinc. Antimony, arsenic, cadmium, cesium, mercury, molybdenum, strontium, and thallium appear to exceed background by one or both tests.

Of the metals mentioned above, only strontium is retained as a probable OU-2 contaminant and included in a concentration/toxicity screen to identify chemicals of concern. Strontium was detected in 12 subsurface soil samples above the background UTL of 127 mg/kg. Concentrations of strontium above the background UTL ranged from 133 to 246 mg/kg. The maximum concentration was detected in borehole 319789 from a depth of 0 to 3 feet. Eight of the 12 strontium detections above background were obtained from boreholes in the Southeast Trenches Area from a depth of less than 10 feet (the approximate maximum depth of a trench). Two strontium detections were obtained from boreholes located beneath the 903 Pad (IHSS

112) and the other two detections were located in the Mound Area (IHSS 113). All elevated results were in samples collected from a depth of less than 10 feet.

Although strontium did not have a high frequency of detection, it was detected in several samples in both 1987 and later boreholes at concentrations above the background UTL in known disposal trenches. Therefore, strontium is considered a potential OU-2 contaminant in subsurface soils.

Subsurface Soils
Metals Eliminated as Contaminants
on the Basis of Data Evaluation

Antimony, cesium, mercury, molybdenum, and thallium exceeded background by one statistical test but not by another. These metals are eliminated from further consideration for the reasons outlined below. Arsenic and cadmium concentrations exceed background levels in numerous samples. However, data review strongly suggests that these metals may be waste-related in only a few instances. The distribution of arsenic and cadmium in subsurface soils is also discussed below.

Antimony: Antimony was detected at concentrations above the background UTL of 12 mg/kg in only two subsurface soil samples collected in the 903 Pad area. Detected concentrations were 16 and 24 mg/kg. Background maximum was 16 mg/kg, with a detection frequency of 16 percent. Based on the overall low frequency of detection (4 percent), the fact that only two results exceeded the background UTL, and that antimony did not exceed background by the ANOVA test, antimony is not considered an OU-2 contaminant in subsurface soils.

Arsenic: Arsenic was detected in 42 OU-2 subsurface soil samples above the background UTL of 12 mg/kg. (The background maximum was 42 mg/kg; all but two of the background sample results were at or below 11 mg/kg.) Concentrations of arsenic in OU-2 samples above the UTL ranged from 13 to 37 mg/kg. Distribution of elevated concentrations of arsenic in subsurface soils is shown by IHSS area in Figures 4-2 through 4-5. Some elevated concentrations may be related to metal-bearing wastes deposited in trenches. For example, the maximum arsenic concentration of 37 mg/kg was detected at a depth of 0 to 2 feet in Trench T-3 in the Northeast Trenches Area (BH3987, IHSS 110); arsenic at a concentration of 25 mg/kg was also detected in this borehole at a depth of 14.5 to 17 feet. Elevated arsenic concentrations (23 to 30 mg/kg) were also detected in three samples from Trench T-7 (IHSS 111.4) and one sample from Trench T-8 (IHSS 111.5) in the Southeast Trenches Area.

Other occurrences of elevated arsenic concentrations are scattered throughout OU-2. Data review suggests that the apparent widespread occurrences of elevated arsenic concentrations may not be associated with contamination but may be related to unknown characteristics of the 1987 sampling and analysis program. Nearly all of the elevated arsenic results (38 results out of 42) were observed in samples collected in 1987 sampling program; these data are unvalidated because the Rocky Flats quality assurance program had not yet been established. Only 4 elevated arsenic results were observed in post-1987 sampling. This information is summarized in Table 4-1B. Post-1987 samples collected near locations previously sampled during the 1987 sampling program did not confirm the presence of elevated concentrations. Furthermore, where several samples in a borehole have concentrations above the background UTL, concentrations tend to be relatively constant with depth (up to 32 feet), indicating the absence of localized contaminant sources (e.g., at the surface or buried within trenches). In addition, some of the highest concentrations were detected at depths of 20 to 44 feet, which are probably below potential sources in trenches (trenches are estimated to have depths of 5 to 10 feet). It is also noteworthy that arsenic was not identified as a contaminant in groundwater.

It is concluded that most of the occurrences of elevated arsenic concentrations are probably not associated with waste releases in OU-2 and may be an artefact of the 1987 sampling and analytical program. However, at a few specific locations (Trenches T-3 and possibly T-7 and T-8), arsenic may be related to disposal of metal-bearing wastes and therefore arsenic should be evaluated as a potential special-case chemical of concern. Special-case chemicals of concern are identified by comparing the maximum concentration to a risk-based screening value (see Appendix B). If the maximum concentration exceeds the screening value, the contaminant could pose a significant health risk if exposure were to occur and would be evaluated in the risk assessment. Results of the screen are shown in Table B-7 and B-8. Since the maximum concentration did not exceed the screening values, arsenic is not identified as a special-case chemical of concern and is not evaluated further in the risk assessment.

Cadmium: Cadmium was detected in approximately 40 percent of the OU-2 subsurface soil samples in concentrations above the background UTL of 1 mg/kg. Concentrations above background UTL ranged from 1.1 to 10 mg/kg. The maximum concentration of cadmium (10 mg/kg) was detected in borehole 10291 (Trench T-4, IHSS 111.1) at a depth of 2 to 8 feet. It is possible that cadmium is elevated in this interval due to deposits of metal-bearing wastes (several other metals were also elevated in this sample).

However, as with arsenic, most occurrences of apparently elevated cadmium are probably not waste-related and cadmium is not considered a chemical of concern for OU-2. Cadmium results above background UTL are displayed by IHSS area in Figures 4-2 through 4-5. Cadmium detections above the background UTL occurred predominantly in the 1987 borehole samples and in very few of the post-1987 samples. Cadmium was detected above the background UTL in 65 to 91 percent of the 1987 borehole samples, depending on the IHSS area, but in only 2 to 9 percent of the post-1987 samples (see Table 4-1C). In most boreholes, cadmium concentrations were fairly constant with depth (up to 50 feet), indicating that the cadmium concentrations are not related to localized surface sources or to waste materials in trenches, which have estimated depths of 5 to 10 feet.

It is concluded that most of the occurrences of elevated cadmium concentrations are probably not associated with waste releases in OU-2 and may be an artefact of the 1987 sampling and analytical program. However, at a few specific locations, such as Trench T-4, cadmium may be related to disposal of metal-bearing wastes. Therefore cadmium is evaluated as a potential special-case chemical of concern. Special-case chemicals of concern are identified by comparing the maximum concentration to a risk-based screening value (see Appendix B). If the maximum concentration exceeds the screening value, the contaminant could pose a significant health risk if exposure were to occur and the contaminant would be evaluated in the risk assessment. Results of the screen are shown in Tables B-7 and B-8. Since the maximum concentration of cadmium did not exceed the screening values, it is not identified as a special-case chemical of concern and is not evaluated further in the risk assessment.

Cesium: Cesium is eliminated from further consideration because it is below background by the ANOVA test, and the results that exceeded the background UTL were non-detect (one-half reporting limits).

Mercury: Mercury was detected in about 20 percent of the samples analyzed, in concentrations ranging from 0.06 to 0.49 mg/kg (detection limit = 0.1 mg/kg), with one elevated concentration of 114 mg/kg detected in a 0 to 10-foot composite sample from borehole 2987. This borehole is located west of the 903 Pad and is unrelated to known source areas. Background UTL is 1 mg/kg and the background maximum is 6 mg/kg. Because all OU-2 results are below the background UTL, except for the one extreme value (unvalidated 1987 data) at a location unrelated to known source areas, mercury is not considered a contaminant in OU-2.

Molybdenum: Molybdenum is eliminated from further consideration because it is below background by the ANOVA test and the results that exceeded the background UTL were non-detect (one-half reporting limits).

Thallium: Thallium is eliminated from further consideration as a contaminant in subsurface soils because all of the results were below the background UTL of 3 mg/kg and the OU-2 mean concentration of 1 mg/kg is comparable to the background mean of 0.8 mg/kg.

4.2.2 Radionuclides

Table 4-2 summarizes the background comparison radionuclides in subsurface soils. For a number of the analytes, few background data were available for comparison. Radium-226, strontium-89,90 and strontium 90 did not exceed background based on both statistical comparisons and were eliminated from further consideration on that basis. Americium-241, plutonium-239,240, and cesium-137 are probable contaminants based on the percentage of results (33% to 78%) that exceed the background UTLs. Nearly all elevated tritium results (17 samples) occurred in trenches in the Southeast Trenches Area or at the 903 Pad; therefore, tritium is retained as a probable contaminant in subsurface soils. For the reasons outlined below, uranium-233,234, uranium-235, and uranium-238 were retained as special-case contaminants, and radium-228 was eliminated from further consideration.

Uranium-233,234: Uranium-233,234 was detected in two borehole samples (1 percent) above the background UTL of 2.5 pCi/g. Activities above background UTL ranged from 14.35 to 191.7 pCi/g. The maximum activity was obtained from borehole 10291 from a depth of 2 to 8 feet. Source borehole 10291 is located in Trench T-4 (IHSS 111.1). Borehole 10191, which is located in Trench T-3 (IHSS 111.0), had a level of 14.35 pCi/g from a depth of 4.2 to 8.0 feet. Review of the data indicates that uranium-233,234 is not a contaminant characteristic of OU-2 soils. However, it may be a local contaminant in Trenches T-3 and T-4 and is retained as a special-case chemical of concern for evaluation in the risk assessment.

Uranium-235: Uranium-235 was also detected in two borehole samples above the background UTL of 0.2 pCi/g. Uranium-235 activities in boreholes 10191 and 10291 were 0.75 pCi/g and 11.5 pCi/g, respectively. Both detections were from the uppermost composite sample. Due to the low frequency of elevated activities, it is not considered a contaminant characteristic of subsurface soils in OU-2. However, uranium-235 may be a local contaminant in Trenches T-3 and T-4 and is retained as a special-case chemical of concern for evaluation in the risk assessment.

Uranium-238: Although only a small percentage (3%) of results for uranium-238 exceeded the background UTL (1.5 pCi/g), the elevated concentrations ranged from 2 to 133 pCi/g and were detected in the 903 Pad Area and at Trenches T-3 and T-4 in the Northeast Trenches Area; therefore, uranium-238 is retained as a special-case chemical of concern at these Trenches.

Radium-228: Radium-228 was detected in six borehole samples (9 percent) above the background UTL of 2.0 pCi/g. Activities above background UTL range from 2.044 to 2.6 pCi/g. Because the maximum level (2.6 pCi/g) is not substantially higher than the background UTL (2.0 pCi/g) or the background maximum (2.2 pCi/g), radium-228 is not considered a contaminant in subsurface soil in OU-2.

4.3 FREQUENCY OF DETECTION

Organic compounds detected at a frequency of 5 percent or greater were considered potential chemicals of concern and are listed in Table 4-3. These compounds are included in the concentration/toxicity screens for subsurface soils (Section 4.4).

Compounds detected in subsurface soils at less than 5 percent frequency are listed in Table 4-4. The potential for exposure to infrequently detected compounds is low. Nevertheless, concentrations of infrequently detected organic compounds were further evaluated as described in Section 4.5 to identify those that could contribute significantly to risk if exposure were to occur.

4.4 CONCENTRATION/TOXICITY SCREENS

Concentration/toxicity screens were used to identify chemicals, based on concentration and toxicity, that could contribute significantly to risk and to eliminate chemicals from quantitative evaluation in the risk assessment that contribute insignificantly to risk. The screen was performed on chemicals detected above background and at a frequency of 5 percent or greater. The concentration/toxicity screen process was explained in Section 2.4. Results of the screen for borehole data are shown in Tables 4-5 (Noncarcinogenic Effects), 4-6 (Carcinogenic Effects), and 4-7 (Radionuclides). Chemicals of concern are summarized in Table 4-8. All chemicals that comprise approximately 99 percent of the total risk factor are identified as chemicals of concern to be evaluated in the risk assessment.

Compounds without EPA-established toxicity factors cannot be assessed and are not included in the concentration/toxicity screen. Table 4-9 identifies the compounds for which EPA has not

established toxicity factors. These compounds will be addressed qualitatively in the risk assessment.

4.5 EVALUATION OF INFREQUENTLY DETECTED COMPOUNDS

Compounds detected at less than 5 percent frequency may be eliminated from further consideration because the potential for exposure is low. However, these compounds were further screened so as not to neglect infrequently detected compounds that could contribute significantly to risk if exposure were to occur. In this screen, maximum concentrations of infrequently detected compounds were compared to risk-based screening values using the approach outlined in Section 2.5 and described in greater detail in Appendix B.

Results of the comparison are shown in Tables B-7 and B-8. No infrequently detected compounds in subsurface soils were present at concentrations greater than the screening values used in the analysis.

4.6 SUMMARY OF CHEMICALS OF CONCERN IN SUBSURFACE SOIL

OU-2 chemicals of concern in subsurface soil identified by the approach described above are listed in Table 4-8. These are tetrachloroethene, americium-241, and plutonium-239,240. Special-case chemicals of concern are uranium-233,234, uranium-235, and uranium-238, based on the occurrence of elevated concentrations in samples from 903 Pad Area, the Northeast Trenches Area.

TABLE 4-1
ROCKY FLATS PLANT OU-2
SUMMARY OF BACKGROUND COMPARISON
METALS IN SUBSURFACE SOIL, mg/kg

Analyte	% Data > 95% UTL (1)	ANOVA p (2)	Potential Contaminant?		Spatial/Temporal/Other (See Text)	Consider Further?
			No (3)	Yes (4)		
Aluminum	0	0.63	X		4% detection frequency; 2 results > bknd UTL.	No
Antimony	5	0.43				No
Arsenic	11	<0.05	X	X		Yes
Barium	2	<0.05*	X			No
Beryllium	0.4	<0.05*	X			No
Cadmium	36	<0.05*		X		Yes
Cesium	7	<0.05*	?		Results > bknd UTL are non-detect (half det. limit).	No
Chromium	1	<0.05*	X			No
Cobalt	2	<0.05*	X			No
Copper	1	<0.05*	X			No
Lead	1	<0.05*	X			No
Lithium	1	0.91	X			No
Manganese	1	0.91	X			No
Mercury	1	<0.05	?		3 hits above bknd UTL. Results >UTL are non-detect (half det. limit).	No
Molybdenum	7	0.75	?			No
Nickel	0.4	<0.05*	X			No
Selenium	0	<0.05*	X			No
Silver	1	<0.05*	X			No
Strontium	5	<0.05*		X	Probable contaminant in source areas OU-2 max = 1; bknd UTL = 3.	Yes
Thallium	0	<0.05	?			No
Tin	0	0.31	X			No
Vanadium	0	<0.05*	X			No
Zinc	2	<0.05*	X			No

(1) From Table A-5.
(2) Table A-13. $p < 0.05$ is considered significant.
(3) <5% data exceeds 95% UTL and $p > 0.05$
(4) > 5% data exceeds 95% UTL and $p < 0.05$

? Either >5% data exceeds 95% UTL or $p < 0.05$
* Background mean is equal to or exceeds OU-2 mean.

TABLE 4-1 B
ARSENIC IN SUBSURFACE SOILS

	1987	Post 1987
<u>903 Pad</u>	<u>Samples</u>	<u>Samples</u>
Number of samples	34	107
Number of detects	32	99
Number of results above background 95% UTL	3	1
Percent of results above background 95% UTL	9	1
Range of values above 95% UTL, mg/kg	14-20	14
 <u>Mound Area</u>		
Number of samples	39	11
Number of detects	39	6
Number of results above background 95% UTL	7	1
Percent of results above background 95% UTL	18	9
Range of values above 95% UTL, mg/kg	13-20	13
 <u>Northeast Trenches</u>		
Number of samples	61	43
Number of detects	54	38
Number of results above background 95% UTL	14	0
Percent of results above background 95% UTL	23	0
Range of values above 95% UTL, mg/kg	13-37	-
 <u>Southeast Trenches</u>		
Number of samples	69	84
Number of detects	64	73
Number of results above background 95% UTL	14	2
Percent of results above background 95% UTL	20	2
Range of values above 95% UTL, mg/kg	13-31	18
 <u>Totals</u>		
Number of samples	206	245
Number of detects	192	215
Number of results above background 95% UTL	38	4
Percent of results above background 95% UTL	18	2
Range of values above 95% UTL, mg/kg	13-37	13-18

95% UTL of background = 12 mg/kg.

Background maximum = 42 mg/kg.

Detection frequency in background samples = 68 percent.

Reporting limit = 2 mg/kg.

TABLE 4-1C

CADMIUM IN SUBSURFACE SOILS

<u>903 Pad</u>	<u>1987</u>	<u>post 1987</u>
Number of samples	34	96
Number of detects	30	8
Number of results above background 95% UTL	31	9
Percent of results above background 95% UTL	91	9
Range of values above 95% UTL, mg/kg	1.2-5.4	1.3-1.4
 <u>Mound Area</u>		
Number of samples	39	11
Number of detects	27	1
Number of results above background 95% UTL	27	1
Percent of results above background 95% UTL	67	9
Range of values above 95% UTL, mg/kg	1.1-3.7	1.4
 <u>Northeast Trenches</u>		
Number of samples	61	39
Number of detects	51	10
Number of results above background 95% UTL	51	1
Percent of results above background 95% UTL	84	3
Range of values above 95% UTL, mg/kg	1.1-6.2	10.5
 <u>Southeast Trenches</u>		
Number of samples	69	58
Number of detects	48	1
Number of results above background 95% UTL	46	1
Percent of results above background 95% UTL	65	2
Range of values above 95% UTL, mg/kg	1.1-5.6	1.4
 <u>Totals</u>		
Number of samples	206	204
Number of detects	159	18
Number of results above background 95% UTL	155	12
Percent of results above background 95% utl	75	6
Range of values above 95% UTL, mg/kg	1.1-6.2	1.3-10.5

95% UTL of background = 1 mg/kg (reporting limit).

Detection frequency in background samples = 6 percent.

TABLE 4-2
ROCKY FLATS PLANT OU-2
SUMMARY OF BACKGROUND COMPARISON
RADIONUCLIDES IN SUBSURFACE SOIL, pCi/g

Analyte	% Data > 95% UTL (1)	ANOVA p (2)	Potential Contaminant?		Spatial/Temporal/Other (See Text)	Consider Further?
			No (3)	Yes (4)		
Americium-241	61	0.28		X	Probable contaminant based on UTL comparison. Possible contaminant based on UTL comparison.	Yes
Cesium-137	44	0.94		X		Yes
Plutonium- 239, 240	53	<0.05		X		Yes
Radium-226	3	<0.05*	X		OU-2 max = 2.6 pCi/g; bknd UTL = 2.0 pCi/g. OU-2 mean <bknd mean	No
Radium-228	8	0.81		?		No
Strontium-89,90	0	<0.05*	X			No
Strontium-90	(5)	-	X		Max equivalent to bknd UTL for Sr-89,90. Contaminant at 903 Pad and SE Trenches	No
Tritium (pCi/L)	10	0.83		X		Yes
Uranium-233,234	2	0.3		?	2 results >bknd UTL at Trenches T-3, T-4. 2 results >bknd UTL at Trenches T-3, T-4.	Special Case
Uranium-235	2	<0.05*		?		Special Case
Uranium-238	4	0.39		?	Detected at 903 Pad and Trenches T-3, T-4	Special Case

- (1) From Table A-6.
- (2) Table A-14. $p < 0.05$ is considered significant.
- (3) <5% data exceeds 95% UTL and $p > 0.05$
- (4) > 5% data exceeds 95% UTL and $p < 0.05$
- (5) 5% of Sr-90 results exceeds 95% UTL for Sr-89,90 (0.09 pCi/g), but maximum Sr-90 result (1.1 pCi/g) is not significantly above background.
- ? Either > 5% data exceeds 95% UTL or $p < 0.05$
- * Background mean is equal to or exceeds OU2 mean
- Statistical test could not be made.

**TABLE 4-3
ROCKY FLATS PLANT OU-2
ORGANIC COMPOUNDS DETECTED AT
5% OR GREATER FREQUENCY
SUBSURFACE SOIL**

	Maximum Concentration, mg/kg	Detection Frequency %
Acetone	26	34
Methylene chloride	0.037	32
1,2-Dichloroethane	0.120	12
2-Butanone	0.15	7
1,1,1-Trichloroethane	13	7
Trichloroethene	120	5
Toluene	1.1	34
Tetrachloroethene	13000	11
Total xylenes	0.23	5
Bis(2-ethylhexyl)phthalate	12	47
N-Nitrosodiphenylamine	0.37	18
Di-n-butyl phthalate	3.4	10

TABLE 4-4
ROCKY FLATS PLANT OU-2
ORGANIC COMPOUNDS DETECTED AT
LESS THAN 5% FREQUENCY
SUBSURFACE SOIL

	Maximum Concentration mg/kg	Detection Frequency %
1,1,2-Trichloroethane	0.027	0.7
1,1-Dichloroethane	0.008	0.3
1,2-Dichloroethane	0.09	2
2-Chloroethylvinylether	0.031	0.7
Benzene	0.012	0.3
Bromomethane	0.006	0.3
Carbon tetrachloride	140	4
Chloroethane	0.050	0.3
Chloroform	8.8	3
Cis-1,3-dichloropropene	0.006	0.3
Ethylbenzene	0.78	1
Styrene	0.17	0.3
Aroclor-1254	8.9	2
4,4'-DDT	0.14	0.35
Pentachlorophenol	0.095	0.7
1,4-Dichlorobenzene	0.043	0.4
Fluoranthene	1.0	1.8
Pyrene	1.3	2.2
Di-n-octyl phthalate	0.26	0.4
Phenanthrene	2.7	1.8
2-Methylnaphthalene	8.1	1
Acenaphthene	0.28	0.7
Benzo(a)pyrene	0.48	0.7
Chrysene	0.42	0.7
Naphthalene	2.0	0.7
Benzoic Acid	0.4	0.4

TABLE 4-5
ROCKY FLATS PLANT OU-2
CONCENTRATION/TOXICITY SCREEN
SUBSURFACE SOIL
NONCARCINOGENS
(Organics and Metals)

Chemical	Max Value (mg/kg)	Inhalation RfD	Oral RfD	Risk Factor	Risk Index	Rank	Cumulative Percent
tetrachloroethene	13000	n/a	1.0E-02	1.3E+06	1.0E+00	1	99.9
bis(2-ethylhexyl)phthalate	12	n/a	2.0E-02	6.0E+02	4.6E-04	2	99.9
strontium	246	n/a	6.0E-01	4.1E+02	3.2E-04	3	100.0
acetone	26	n/a	1.0E-01	2.6E+02	2.0E-04	4	100.0
1,1,1-trichlorethane	13	3.0E-01	9.0E-02	1.4E+02	1.1E-04	5	100.0
toluene	1.4	1.1E-01	2.0E-01	1.3E+01	9.8E-06	6	100.0
2-butanone	0.21	3.0E-01	6.0E-01	7.0E-01	5.4E-07	7	100.0
methylene chloride	0.037	9.0E-01	6.0E-02	6.2E-01	4.7E-07	8	100.0
di-n-butylphthalate	3.4	n/a	1.0E+01	3.4E-01	2.6E-07	9	100.0
total xylenes	0.23	n/a	2.0E+00	1.2E-01	8.8E-08	10	100.0
Total Risk Factor				1.3E+06			

RfDs are in units of mg/kg-day. See Table 2-5 for references.
n/a = not available.

**TABLE 4-6
ROCKY FLATS OU-2
CONCENTRATION/TOXICITY SCREEN
SUBSURFACE SOIL
CARCINOGENS
(Organics and Metals)**

Chemical	Max Value (mg/kg)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	Rank	Cumulative Percent
tetrachloroethene	13000	1.8E-03	5.2E-02	6.8E+02	1.0E+00	1	99.8
trichloroethene	120	6.0E-03	1.1E-02	1.3E+00	1.9E-03	2	100.0
bis(2-ethylhexyl)phthalate	12	n/a	1.4E-02	1.7E-01	2.5E-04	3	100.0
1,2-dichloroethane	0.12	9.1E-02	9.1E-02	1.1E-02	1.6E-05	4	100.0
N-nitrosodiphenylamine	0.37	n/a	4.9E-03	1.8E-03	2.7E-06	5	100.0
methylene chloride	0.037	1.6E-03	7.5E-03	2.8E-04	4.1E-07	6	100.0
Total Risk Factor				6.8E+02			

Slope factors are in units of 1/(mg/kg-day). See Table 2-5 for references.
n/a = not available.

**TABLE 4-7
ROCKY FLATS OU-2
CONCENTRATION/TOXICITY SCREEN
SUBSURFACE SOIL
RADIONUCLIDES**

Chemical	Max Value (pCi/g)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	Rank	Cumulative Percent
plutonium-239/240(1)	68	3.8E-08	2.3E-10	2.6E-06	9.2E-01	1	91.8
americium-241(1)	7	3.2E-08	2.4E-10	2.3E-07	8.2E-02	2	100.0
tritium (1) (pCi/L)	1500	7.8E-14	5.4E-14	1.2E-10	4.2E-05	3	100.0
cesium-137(1)	2.4	1.9E-11	2.8E-11	6.7E-11	2.4E-05	4	100.0
Total Risk Factor				2.8E-06			

Slope factors are in units of 1/pCi. See Table 2-6 for references.

**TABLE 4-8
ROCKY FLATS PLANT OU-2
CHEMICALS OF CONCERN
SUBSURFACE SOIL**

Organic Compounds	Radionuclides
Tetrachloroethene	Americium-241 Plutonium-239,240

**SPECIAL CASE
CHEMICALS OF CONCERN (1)**

Compound	Location
Uranium-233,234	Trenches T-3 and T-4
Uranium-235	Trenches T-3 and T-4
Uranium-238	903 Pad and Trenches T-3 and T-4

- (1) Special case chemicals of concern are infrequently detected and are not OU-2 wide contaminants. The uranium isotopes were identified as special case chemicals of concern because the infrequent elevated concentrations were located near source areas and because uranium is a potential significant contributor to risk. The effect of uranium at these locations on overall risk will be evaluated separately in the risk assessment.

**TABLE 4-9
DETECTED COMPOUNDS WITHOUT EPA
TOXICITY FACTORS
SUBSURFACE SOIL**

2-Methylnaphthalene

4-Methylphenol

Benzo(ghi)perylene

5.1 DATA EVALUATION

Chemicals of concern in surface soil were selected using the data set identified in Table 2-2. This includes surface soil samples collected in 1991 (radionuclides only) and in 1993. Surface soil samples were analyzed for semivolatiles, pesticides, metals, and radionuclides. Sampling locations are shown in Figures 5-1 through 5-3.

The occurrences of benzoic acid, polycyclic aromatic hydrocarbons (PAHs), and bis(2-ethylhexyl)phthalate detected in surface soil samples were evaluated to judge whether or not their presence is likely to be due to waste releases in OU-2. This evaluation is described below.

- Benzoic Acid

Benzoic acid was detected in 88 percent of the surface soil samples obtained within OU-2. Benzoic acid concentrations were all estimated at well below the reporting limit of 1,600 $\mu\text{g}/\text{kg}$. Benzoic acid results range from about 40 to 700 $\mu\text{g}/\text{kg}$ (most fell between 100 and 300 $\mu\text{g}/\text{kg}$) and are evenly distributed across OU-2 with no relationship to source areas (see Figure 5-3). In addition, benzoic acid was also detected in 58 percent of the background data within the range of 40 to 230 $\mu\text{g}/\text{kg}$. The range of concentrations of benzoic acid in OU-2 is similar to the range of background concentrations. It is probable the reported results in background and OU-2 samples are laboratory artifacts. False positives for this compound are common due to cross-contamination from glassware and the chromatographic instruments, and this chemical has been removed from the CLP Statement of Work. Benzoic acid is not considered as a waste-related contaminant in OU-2.

- PAHs

Several polycyclic aromatic hydrocarbons (PAHs) were detected in many of the 39 surface soil samples collected in OU-2. Of the 40 samples, 6 were at biased sampling locations (IHSSs) and 34 were random (grid-based) samples collected across OU-2. The sampling locations and concentrations are shown in Figure 5-3. Concentrations of PAHs measured in the biased samples were comparable to those measured in the random samples. For

example, Table 5-1 shows that benzo(a)anthracene ranged from 41 to 130 in $\mu\text{g}/\text{kg}$ in the random samples and from 51 to 160 $\mu\text{g}/\text{kg}$ in the biased samples. The ranges are similar for other PAHs detected in OU-2 surface soil samples (see Table 5-1).

PAHs are common products of hydrocarbon combustion, including vehicle emissions and burning of coal, wood, tobacco, and petroleum-based fuels. Because similar PAHs levels are found in random and in biased samples, the detected PAHs are probably related to normal activities that occur at any developed industrial area and are not related to waste disposal activities in OU-2, with the possible exception of PAHs detected in the former Reactive Metal Destruction Site (IHSS 140, sample plot 376, SS200193). At this location, individual PAHs were detected in concentrations ranging from 69 $\mu\text{g}/\text{kg}$ (benzo(k)-fluoranthene) to 390 $\mu\text{g}/\text{kg}$ (fluoranthene). Random sample plot 45 (SS200093) is located approximately 200 feet west of the old Pallet Burn Site (IHSS 154); PAHs detected there may or may not be related to historic burns at the IHSS.

Since PAHs might be related to waste-disposal activities at one or two locations in OU-2, they were evaluated in the risk-based screen (Appendix B) to identify special-case chemicals of concern, which are infrequently detected waste-related contaminants that could contribute significantly to risk if exposure were to occur. The results of the screen are shown in Tables B-7 and B-8. The evaluation shows that maximum concentrations of PAHs detected in OU-2 samples do not exceed risk-based screening levels. Therefore none of the PAHs are special-case chemicals of concern.

- Bis(2-ethylhexyl)phthalate

Bis(2-ethylhexyl)phthalate was detected in 9 of 40 (23 percent of) surface soil samples widely distributed across OU-2, including locations distant from source areas. Concentrations in most samples ranged from 49 to 110 $\mu\text{g}/\text{kg}$ (detection limit = 330 $\mu\text{g}/\text{kg}$), and one sample had a concentration of 510 $\mu\text{g}/\text{kg}$. In background samples, bis(2-ethylhexyl)phthalate was detected in 22 percent of the samples in concentrations ranging from 35 to 140 $\mu\text{g}/\text{kg}$. Since the distribution of OU-2 results and background results are similar, and since this compound is a common field and laboratory contaminant, it is concluded that bis(2-ethylhexyl)phthalate in OU-2 samples is not related to waste releases, and it is not considered an OU-2 contaminant.

5.2 BACKGROUND COMPARISON FOR INORGANIC COMPOUNDS

Tables 5-2 and 5-3 summarize the results of comparing concentrations of metals and radionuclides in OU-2 surface soil samples to background levels. Background surface soil data consist of analytical results from samples collected at 18 locations in the Rock Creek area. Nine of the sites were sampled in February 1992 and the remaining nine sites were sampled in March 1993. All background samples were collected using the RFP method, a composite method in which the top 2 inches of soil are collected. The OU-2 samples were collected during three sampling events. Samples analyzed for uranium were collected during Summer 1991 by the CDH method, a method in which the top 1/4 inch of soil is collected. Samples analyzed for plutonium and americium were collected in Fall 1991 using the RFP method. Additional samples for other radionuclides and metals were collected by the RFP method in March 1993. Metals and radionuclides that did not exceed background levels were eliminated from further consideration as potential chemicals of concern. The background comparison process is described in Appendix A.

5.2.1 Metals

Most metals do not exceed background using both statistical tests (UTL and ANOVA; see Table 5-2), and these are not considered further. However, beryllium, cadmium, selenium, thallium, and tin appear to exceed background by the ANOVA test. Nevertheless, these metals are not considered to be OU-2 contaminants in surface soils for the reasons outlined below.

Beryllium: Beryllium was detected in 1 of 40 samples (3 percent detection frequency) at a concentration of 1.3 mg/kg, which is below the background maximum of 2.5 mg/kg, and below the background UTL of 3.56 mg/kg. Therefore, beryllium is not considered a contaminant of concern in surface soils in OU-2.

Cadmium: Cadmium was detected in 5 of 40 samples. None of the cadmium results exceeded the background UTL of 3.4 mg/kg, and the maximum cadmium concentration detected in OU-2 samples (2.2 mg/kg) is below the background maximum (2.5 mg/kg).

Selenium: Selenium was detected in 3 of 40 samples. Only one selenium result (0.9 mg/kg) exceeded the background UTL of 0.8 mg/kg, and the maximum detected concentration (0.9 mg/kg) is less than the background maximum (1.0 mg/kg). Therefore, selenium is not considered a contaminant in OU-2 surface soil.

Thallium: Thallium is not considered an OU-2 contaminant because it was detected in only 1 of 40 samples (3 percent detection frequency) at a concentration of 0.5 mg/kg, which is below the background UTL of 1.1 mg/kg and below the background maximum of 1 mg/kg.

Tin: Tin was detected in 16 of 40 samples. In one of the 16 samples it was detected at a concentration of 93 mg/kg, which is above the background UTL of 56 mg/kg. This sample was collected near Indiana Street. Therefore, tin is not considered a contaminant in OU-2 because the only sample result that exceeded the background UTL was detected at a location unrelated to source areas.

In conclusion, metals are not considered contaminants in surface soils in OU-2.

5.2.2 Radionuclides

The radionuclides cesium-137, radium-228, and strontium-89,90 do not exceed background levels, based on results of both statistical tests (Table 5-3). The radionuclides americium-241 and plutonium-239 are considered OU-2 contaminants. Radium-226 is not considered an OU-2 contaminant (see below). The uranium isotopes (233, 234, 238, and 239) are considered further as possible OU-2 contaminants based on spatial evaluation of the data, as described below.

Radium-226: Radium-226 was detected in all 24 surface soil samples analyzed for radionuclides, but only one sample had an activity (11.8 mg/kg) that exceeded the background UTL of 1.3 mg/kg. This sample was collected in plot 8180 near Indiana Street, distant from OU-2 source areas. Because the elevated level found in only one sample distant from OU-2 source areas, radium-226 is not considered an OU-2 contaminant.

Uranium isotopes: The uranium isotopes exceed background levels by the UTL comparison (over 20 percent of the data exceeded background UTLs), but population differences between OU-2 data and background were not significant by the ANOVA test ($p < 0.05$). Spatial evaluation shows that elevated activities of the analytes uranium-233,234, -235, -238, and -238,239 occur in an area east of the 903 Pad. These are considered potential OU-2 contaminants and are retained for further evaluation as potential chemicals of concern in a concentration/toxicity screen.

5.3 FREQUENCY OF DETECTION

Of the organic analytes, benzoic acid, bis(2-ethylhexyl)phthalate, and the PAHs benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene were detected in surface soils at a frequency of 5 percent or greater. These compounds are listed in Table 5-4. None of these compounds are likely to be related to waste sources in OU-2, as described in Section 5.1, and, therefore are not considered to be OU-2 contaminants.

Organic compounds detected in surface soils at less than 5 percent frequency are listed in Table 5-5. These include benzo(ghi)perylene, benzo(k)fluoranthene, indeno(1,2,3-cd) pyrene, PCBs, DDT, and delta-BHC. The potential for exposure to infrequently detected compounds is low. Nevertheless, concentrations of these compounds were further evaluated in a risk-based screen as described in Section 5.5.

5.4 CONCENTRATION/TOXICITY SCREENS

No site-related organic compounds or metals were identified in surface soils with the exception of the infrequently detected organic compounds that are evaluated in Section 5.5 and chromium (a "special case" chemical of concern). Therefore, a concentration/toxicity screen was performed only for radionuclides of potential concern. The concentration/toxicity screen process was explained in Section 2.4. Results of the screen for radionuclides in surface soil are shown in Table 5-6. Plutonium-239,240 contributes over 98 percent of the total risk factor. Americium-241 contributes approximately 1 percent of the total risk factor. The uranium isotopes contribute insignificantly to the total risk factor and are eliminated as chemicals of concern in surface soils. Table 5-7 summarizes the chemicals of concern in surface soils. All chemicals that comprise 99 percent of the total risk factor are identified as chemicals of concern to be evaluated in the risk assessment.

5.5 EVALUATION OF INFREQUENTLY DETECTED COMPOUNDS

Compounds detected at less than 5 percent frequency may be eliminated from further consideration because they are not characteristic of contamination and because the potential for exposure is low. However, these compounds were further screened so as not to neglect infrequently detected compounds that could contribute significantly to risk if exposure were to occur. In this screen, maximum concentrations of infrequently detected compounds (4,4-DDT, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, and PCBs) were compared to risk-based

screening values using the approach outlined in Section 2.5 and described in greater detail in Appendix B. Complete results of the evaluation are shown in Tables B-7 and B-8. The infrequently detected compounds in surface soils were not present at concentrations greater than the screening values, and therefore they do not warrant inclusion in the risk assessment. Benzo(ghi)perylene and delta-BHC are not included in the risk-based screen because the EPA has not established toxicity factors for these compounds.

5.6 SUMMARY OF CHEMICALS OF CONCERN IN SURFACE SOIL

Chemicals of concern in surface soils in OU-2 are plutonium-239, 249 and americium-241. The concentration/toxicity screen shows that uranium isotopes contribute an insignificant fraction of potential overall risk and they are eliminated from further evaluation in risk assessment.

**TABLE 5-1
ROCKY FLATS PLANT OU-2
CONCENTRATION RANGES OF SELECTED PAHs AT
RANDOM AND BIASED SURFACE SOIL
SAMPLING LOCATIONS**

	Detected Concentrations ⁽¹⁾ $\mu\text{g}/\text{kg}$	
	Random (grid-based)	Biased (IHSSs)
Benzo(a)anthracene	41 - 130	51 - 160
Benzo(a)pyrene	48 - 140	68 - 160
Benzo(b)fluoranthene	90 - 200	38 - 240
Pyrene	54 - 260	98 - 350

⁽¹⁾Detected concentrations are all estimated values below the reporting limit (330 $\mu\text{g}/\text{kg}$).

Source: Figure 5-3

TABLE 5-2
ROCKY FLATS PLANT OU-2
SUMMARY OF BACKGROUND COMPARISON
METALS IN SURFACE SOIL, mg/kg

Analyte	% Data > 95% UTL (1)	ANOVA p(2)	Potential Contaminant?		Spatial/Temporal/Other (See Text)	Consider Further?
			No (3)	Yes (4)		
Aluminum	0	0.14*	X			No
Antimony	0	-	X			No
Arsenic	0	<0.01*	X			No
Barium	0	<0.01*	X			No
Beryllium	0	0.05	X			No
Cadmium	0	0.02		?	OU2 Max (2.2 mg/kg) < bknd max (2.5 mg/kg)	No
Cesium	0	-	X			No
Chromium	4.8	0.05	X			No
Cobalt	0	0.90	X			No
Copper	0	0.06	X			No
Lead	4.8	0.82	X			No
Lithium	4.8	<0.01*	X			No
Manganese	0	0.14	X			No
Mercury	0	-	X			No
Molybdenum	0	0.18	X			No
Nickel	2.4	0.73	X			No
Selenium	2.4	<0.01		?	OU2 Max (0.9 mg/kg) < bknd max (1.0 mg/kg)	No
Silver	0	-	X			No
Strontium	4.8	0.92	X			No
Thallium	0	<0.01		?	Detected in 1 of 40 samples at 0.5 mg/kg.	No
Tin	2.4	<0.01		?	1 result > bknd UTL, at Indiana St.	No
Vanadium	2.4	0.34	X			No
Zinc	0	0.30	X			No

(1) From Table A-7.

(2) Table A-15. p < 0.05 is considered significant.

(3) <5% data exceeds 95% UTL and p > 0.05

(4) > 5% data exceeds 95% UTL and p < 0.05

? Either > 5% data exceeds 95% UTL or p < 0.05

* Background mean is equal to or exceeds OU2 mean.

TABLE 5-3
ROCKY FLATS PLANT OU-2
SUMMARY OF BACKGROUND COMPARISON
RADIONUCLIDES IN SURFACE SOIL, pCi/g

Analyte	% Data		ANOVA		Potential Contaminant?		Spatial/Temporal/Other (See Text)	Consider Further?
	(1)	(2)	(3)	(4)	No (3)	Yes (4)		
Americium 241	95	<0.01		X			Probable contaminant	Yes
Cesium 137	0	<0.01*	X					No
Plutonium 239,240	100	-	?	X			Probable contaminant	Yes
Radium 226	12	0.11					3 results > bknd, max at Indiana St.	No
Radium 228	0	0.66	X					No
Strontium 89,90	4	0.55	X					No
Uranium 233/234	28	0.15		X			Probable contaminant based on UTL test and spatial analysis	Yes
Uranium 235	22	0.39		X			Probable contaminant based on UTL test and spatial analysis	Yes
Uranium 238	23	0.085		X			Probable contaminant based on UTL test and spatial analysis	Yes
Uranium 233,238,239	NE	NE		?			Probable contaminant based on spatial analysis	Yes

(1) From Table A-8.

(2) Table A-16. $p < 0.05$ is considered significant

(3) <5% data exceeds 95% UTL and $p > 0.05$

(4) > 5% data exceeds 95% UTL and $p < 0.05$

* Background mean exceeds OU2 mean

NE = Not evaluated; no background analyses for this analyte group.

Either > 5% data exceeds 95% UTL or $p < 0.05$

Test not performed because OU-2 data clearly exceed background. See Tables A-8 and A-15.

**TABLE 5-4
ROCKY FLATS PLANT OU-2
ORGANIC COMPOUNDS DETECTED AT
5% OR GREATER FREQUENCY
SURFACE SOIL**

	Maximum Concentration (mg/kg)	Detection Frequency %
Benzo(a)anthracene	0.16	17
Benzo(a)pyrene	0.16	17
Benzo(b)fluoranthene	0.24	17
Benzoic Acid	0.7	88
Bis(2-ethylhexyl) phthalate	0.51	21
Chrysene	0.2	23
Fluoranthene	0.39	38
Phenanthrene	0.23	25
Pyrene	0.35	46

**TABLE 5-5
ROCKY FLATS PLANT OU-2
ORGANIC COMPOUNDS DETECTED AT
LESS THAN 5% FREQUENCY
SURFACE SOIL**

	Maximum Concentration mg/kg	Detection Frequency %
Benzo(g,h,i)perylene	0.061	4
Benzo(k)fluoranthene	0.076	4
Di-n-butyl phthalate	1.0	2
Indeno(1,2,3-cd)perylene	0.83	4
4,4'-DDT	0.026	2
Aroclor-1254	0.97	4
Aroclor-1260	0.66	4
delta-BHC	0.023	2

**TABLE 5-6
ROCKY FLATS OU-2
CONCENTRATION/TOXICITY SCREEN
SURFACE SOIL
RADIONUCLIDES**

Chemical	Max Value (pCi/g)	Inhalation Slope Factor	Oral Slope Factor	Risk Factor	Risk Index	Rank	Cumulative Percent
plutonium-239,240	7300	3.8E-08	2.3E-10	2.8E-04	9.9E-01	1	98.6
americium-241	110	3.2E-08	2.4E-10	3.5E-06	1.3E-02	2	99.8
uranium-233,238,239	7.74	2.7E-08	1.6E-11	2.1E-07	7.4E-04	3	99.9
uranium-238	7.26	2.4E-08	1.6E-11	1.7E-07	6.2E-04	4	100.0
uranium-233,234	3.58	2.7E-08	1.6E-11	9.7E-08	3.4E-04	5	100.0
uranium-235	0.68	2.5E-08	1.6E-11	1.7E-08	6.0E-05	6	100.0
Total Risk Factor				2.8E-04			

Slope factors are in units of 1/pCi. See Table 2-6 for references.

**TABLE 5-7
ROCKY FLATS PLANT OU-2
CHEMICALS OF CONCERN
SURFACE SOIL**

Plutonium-239,240
Americium-241

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APPENDIX A
BACKGROUND COMPARISON
FOR METALS AND RADIONUCLIDES

APPENDIX A
BACKGROUND COMPARISON
FOR METALS AND RADIONUCLIDES

Concentrations of metals and radionuclides detected in groundwater, subsurface soil, and surface soil in OU-2 were compared to background concentrations to help distinguish inorganic compounds that are naturally occurring in OU-2 from those that occur in elevated concentrations due to chemical releases in OU-2. Background concentrations for groundwater and subsurface soil were taken from the Final Background Geochemical Characterization Report, Rocky Flats Plant (EG&G 1992). Background concentrations for surface soil were determined from samples collected in the Rock Creek area in 1991 and 1993.

The procedures applied in the background comparison are shown in the flow chart in Figure A-1. Each step is described below.

Step 1 - Categorize OU-2 Samples and Background Data

For the groundwater, OU-2 results and background results were classified by the lithologic unit in which the well screen was set so that a background comparison could be made for the UHSU as a whole and for the Arapahoe No. 1 Sandstone separately. The OU-2 UHSU is comprised of Rocky Flats Alluvium (RFA), Valley Fill Alluvium (VFA), colluvium, Arapahoe No. 1 Sandstone and weathered claystone of the Arapahoe and/or Laramie Formations. The UHSU is the principal pathway of potential contaminant migration in groundwater to surface seeps and to potential exposure points in Woman Creek and Walnut Creeks. The aggregated OU-2 UHSU results were compared to aggregated background groundwater results collected from the Rocky Flats Alluvium, Valley Fill Alluvium, colluvium, and Arapahoe/Laramie sandstones and claystones as reported in the Background Geochemical Characterization Report (EG&G 1992). Dissolved-phase metals and radionuclides were used in this comparison.

The No. 1 Sandstone in OU-2 is the only lithologic unit within the UHSU that has sufficient yields to support a domestic water well (see Appendix C). Therefore, the No. 1 Sandstone portion of the UHSU is considered the exposure medium for hypothetical on-site groundwater ingestion. The No. 1 Sandstone is a channel deposit of limited depositional extent, which is not present in the designated background area. Therefore, OU-2 No. 1 Sandstone results were compared to background groundwater results collected from the Arapahoe/Laramie sandstones

and claystones. Total (unfiltered) results for metals and radionuclides were used in this comparison.

For subsurface soils, all OU-2 borehole soil results collected above the water table were aggregated and compared to an aggregated background borehole data set consisting of all background subsurface soil results. OU-2 samples collected below the water table were not included in the data set for background comparison in order to avoid including inorganic constituents resulting from cross-contamination by groundwater.

The OU-2 surface soil data collected using the RFP method during the 1991 and 1993 sampling events were used for the background comparison with the exception of the uranium isotope data. The OU-2 RFP method data were used in order to be comparable with the background soil data, which was collected using the RFP method. Uranium isotope data collected using the CDH method during the 1991 sampling event were used in the background comparison because no uranium results for RFP-method data were available.

Step 2 - Comparison to Background Tolerance Limits.

Analytical results for each detected inorganic analyte were compared to the 95% upper tolerance limit (UTL) of the background results. If 5 percent or more of the data exceeded the UTL, the compound was retained for further evaluation. If less than 5 percent of the data exceeded the UTL, the compound was considered to be within background range, although further evaluation by analyses of variance (ANOVA) may be performed. Tolerance limits define a range that contains at least P percent of a population with a probability (p) (level of confidence). A probability is associated with the tolerance limits since they are estimated from the data set and, therefore, have some level of uncertainty associated with them. For the tolerance limit to be useful in decision making, both "p" and "P" are chosen to be large, in this case $p=0.95$ and $P=95$ percent. A one-sided tolerance limit is appropriate for analytes for which an increase over background may be indicative of potential contamination. If less than 5 percent of the OU-2 results for a given analyte exceeded the upper 95% tolerance limit (UTL) of the background results, then the OU-2 and background populations were considered to be similar. Consequently, these analytes can be deleted from the list of potential contaminants based on background comparison. If 5 percent or more of the OU-2 results exceed the background UTL, Step 3 is performed. The comparison to UTL was performed using one-half

the detection limit as the concentration in samples in which the compound was reported as nondetect.

Step 3 - Percentage of Nondetections

If there are more than 50% nondetections in the grouped background and OU-2 observations, the Wilcoxon Rank Sum test or the Kruskal-Wallis test is an appropriate analysis. The Kruskal-Wallis test is an extension of the Wilcoxon Rank Sum test to more than one population.

Step 4 - Wilcoxon Rank Sum Test

The Wilcoxon Rank Sum test or the Kruskal-Wallis test may be used if there are more than 50% nondetections in the grouped background and OU-2 data. In the background comparison performed for this technical memorandum, data were evaluated using either the nonparametric ANOVA (Kruskal-Wallis) or the parametric ANOVA (Steps 5 through 8). ANOVA requires at least three observations from the nonbackground area.

Step 5 - Distribution of Data

Were the data normally distributed? In using ANOVA it is necessary to identify sample distributions (Step 5) and equality of variances (Step 6) to determine whether nonparametric (Step 7) or parametric (Step 8) ANOVA methods should be used. Nondetections were included using a value equal to one-half of the detection limit.

The distribution of the data was evaluated using the Shapiro-Wilks test or the Lilliefors variation of the Kolmogov-Smirnoff test. If the data were normally distributed, Step 6 was performed next. If the data were not normally distributed, a logarithmic transformation was performed and the distribution test was applied to the transformed data. If the transformed data were normally distributed, the parametric ANOVA was used to assess difference from background. If the transformed data were not normally distributed, then nonparametric statistical methods (Step 7) were used for evaluating the data. Variance is a measure of dispersion of a set of observations around the mean of a random variable. If the variances of the background and OU-2 populations are equal, and the data are normally distributed (Step 5), then parametric one-way ANOVA tests are used.

Step 6 - Equality of Variance

Are the variances of the background and the OU-2 data equal? (This step only applies to normally distributed data.)

Step 7 - Nonparametric Test

If data are not normally distributed or the variances are not equal, the Kruskal-Wallis nonparametric ANOVA is used. The nonparametric ANOVA evaluates differences in the mean rankings of the data (rather than the raw data or transformations of the raw data).

Step 8 - Parametric Test

If both the background and OU-2 data are normally distributed and the variances are equal, then a parametric ANOVA test is used.

Use of Nondetect Values in Calculations: For metals, the UTL and ANOVA tests were performed using one-half the detection limit as the concentration in samples in which the analyte was not detected. For radionuclides, zero values and negative results were not included in the calculation.

The tables on the following pages present the results of the background comparisons for metals and radionuclides in groundwater, subsurface soil, and surface soil.

- Table A-1 95% UTL Comparison: Dissolved Metals in Groundwater
- Table A-2 95% UTL Comparison: Total Metals in Groundwater (No. 1 Sandstone only)
- Table A-3 95% UTL Comparison: Total Radionuclides in Groundwater (No. 1 Sandstone)
- Table A-4 95% UTL Comparison: Dissolved Radionuclides in Groundwater (UHSU)
- Table A-5 95% UTL Comparison: Metals in Subsurface Soil
- Table A-6 95% UTL Comparison: Radionuclides in Subsurface Soil
- Table A-7 95% UTL Comparison: Metals in Surface Soil
- Table A-8 95% UTL Comparison: Radionuclides in Surface Soil
- Table A-9 ANOVA Comparison: Total Metals in Groundwater (No. 1 Sandstone)
- Table A-10 ANOVA Comparison: Dissolved Metals in Groundwater (UHSU)
- Table A-11 ANOVA Comparison: Total Radionuclides in Groundwater (No. 1 Sandstone)
- Table A-12 ANOVA Comparison: Dissolved Radionuclides in Groundwater
- Table A-13 ANOVA Comparison: Metals in Subsurface Soil

Table A-14 ANOVA Comparison: Radionuclides in Subsurface Soil

Table A-15 ANOVA Comparison: Metals in Surface Soil

Table A-16 ANOVA Comparison: Radionuclides in Surface Soil

TABLE A-1
ROCKY FLATS PLANT OU-2
95% UTL COMPARISON
TOTAL METALS IN GROUNDWATER, µg/L
NO. 1 SANDSTONE

Analyte	OU-2 Detected			Bknd Max	Background 95% UTL(1)	% of OU-2 data > 95% UTL (2)
	Min	Max	Approx. DF %			
Aluminum	870	128,000	100	7,000	6,262	82
Antimony	10	297	20	1,610	933	0
Arsenic	1	11	77	7	7	6
Barium	99	3,090	100	1,810	1,050	12
Beryllium	1	19	63	160	89	0
Cadmium	1	11	36	1,720	951	0
Cesium	30	80	9	500 (ND)	800	0
Chromium	4	209	75	1,590	881	0
Cobalt	3	99	68	1,620	905	0
Copper	4	206	83	1,750	972	0
Cyanide	1	21	44	8	6	12
Lead	1	171	99	15	10	65
Lithium	4	84	93	100	89	0
Manganese	9	4,920	100	710	438	40
Mercury	0	1	15	ND	0	15
Molybdenum	3	26	49	1,600	915	0
Nickel	4	188	85	1,660	925	0
Selenium	1	6	50	80	49	0
Silver	2	4	13	300	163	0
Strontium	262	1,370	99	1,110	921	6
Thallium	1	3	15	2	8	0
Tin	14	87	21	100 (ND)	168	0
Vanadium	7	345	100	1,670	929	0
Zinc	14	839	98	1,800	1,023	0

- (1) Calculated using data from Arapahoe/Laramie formation wells reported in the Background Geochemical Characterization Report, Rocky Flats Plant, EG&G, 1992.
- (2) UTL comparison is performed using one-half the detection limit for results reported as non-detect. Therefore, the maximum detected value in OU-2 can be below the 95% UTL of background even though the UTL comparison shows that a certain percentage of OU-2 data (i.e., reporting limits for non-detects) exceeds the 95% UTL of background.

DF = Detection frequency based on edited database of August 1993. DF is approximate because continuing quality review of the database may result in minor changes to the number of results.

ND = Not detected

TABLE A-2
ROCKY FLATS PLANT OU-2
95% UTL COMPARISON
TOTAL RADIONUCLIDES IN GROUNDWATER, pCi/L
NO. 1 SANDSTONE

Analyte	OU-2 Detected			Bknd	Bknd 95%	% of OU-2 data
	Min	Max	Approx. DF	Max	UTL (1)	>95% UTL
Americium-241	0.001	1.09	86/93	0.08	0.044	12
Cesium-137	0.04	1.66	49/49	0.89*	0.83	14
Plutonium-239, 240	0.0005	5.02	100/102	0.009	0.007	64
Strontium-89, 90(2)	0.39	0.39	1/4	0.17	0.44	0
Tritium	ND	-	0/12	1350	2786	0
Uranium-233, 234	3.7	8.2	4/4	17.5	24	0
Uranium-235	0.06	0.28	4/4	0.75	1.05	0
Uranium-238	2	6.4	4/4	10.6	2.5	0

(1) Calculated using data from Arapahoe/Laramie formation wells reported in the Background Geochemical Characterization Report, Rocky Flats Plant, EG&G 1992.

(2) Only 3 background data points and 4 OU-2 data points (3 of the 4 are ND)

DF = Detection frequency (no. detects/no. samples), based on edited database of August 1993.

ND = not detected

- No data

TABLE A-3
ROCKY FLATS PLANT OU-2
95% UTL COMPARISON
DISSOLVED METALS IN GROUNDWATER, µg/L
USHU

Analyte	OU-2 Detected			Bknd Max	Background 95% UTL(1)	% of OU-2 data >95% UTL (2)
	Min	Max	Approx. DF %			
Aluminum	20	367	74	8610	1318	0
Antimony	8	88	17	60 (ND)	46	9
Arsenic	1	8	11	15	7	1
Barium	23	675	100	203	169	40
Beryllium	1	3	4	5 (ND)	3	0
Cadmium	1	98	11	9	5	2
Cesium	30	120	20	2500 (ND)	1177	0
Chromium	3	23	24	23	14	6
Cobalt	3	13	6	50 (ND)	28	0
Copper	1	19	25	25 (ND)	17	2
Lead	1	10	6	64	13	0
Lithium	2	127	79	281	149	0
Manganese	1	3940	73	934	216	23
Mercury	0.21	0.32	3	1.2	0.38	0
Molybdenum	2	67	45	114	61	1
Nickel	2	1210	31	40 (ND)	25	6
Selenium	1	168	36	607	290	0
Silver	2	25	9	13600	2133	0
Strontium	240	3040	99	8730	2148	2
Thallium	1	2	6	328	4	0
Tin	12	89	10	8830	1367	0
Vanadium	3	12	69	57	28	0
Zinc	1	759	67	137	51	3

- (1) Calculated using data from RFA, VFA, colluvial, and Arapahoe/Laramie formation wells reported in the Background Geochemical Characterization Report, Rocky Flats Plant, EG&G 1992.
- (2) UTL comparison is performed using one-half the detection limit for results reported as non-detect. Therefore, the maximum detected value in OU-2 can be below the 95% UTL of background even though the UTL comparison shows that a certain percentage of OU-2 data exceeds the 95% UTL of background.

DF = Detection frequency based on edited database of August 1993. DF is approximate because continuing quality review of the database may result in minor changes to the number of results.

TABLE A-4
ROCKY FLATS PLANT OU-2
95% UTL COMPARISON
DISSOLVED RADIONUCLIDES IN GROUNDWATER, pCi/L
UHSU

Analyte	OU-2 Detected			Bknd	Bknd 95%	% OU2 data
	Min	Max	Approx. DF	Max	UTL (1)	> 95% UTL
Americium-241	0.001	21.3	10/10	0.28	0.10	30
Cesium-137	0.25	0.53	2/11	--	NE	*
Plutonium-239, 240	0.0003	0.81	10/10	0.11(2)	NE	*
Radium-226	0.12	1.3	52/53	3.0	1.84	0
Strontium-89,90	0.009	1.8	165/184	1.5	0.82	6.5
Tritium	0.96	1753	181/181	561	333	8
Uranium-233, 234	0.18	42.62	230/230	199.5	53	0
Uranium-235	0.02	1.2	179/197	4.8	1.7	0
Uranium-238	0.17	22.2	224/224	135.6	37	0

(1) Calculated using data from RFA, VFA, colluvial, and Arapahoe/Laramie formation wells reported in the Background Geochemical Characterization Report, Rocky Flats Plant, EG&G 1992.

(2) One data point .

DF = Detection frequency (no. detects/no. samples), based on edited database of August 1993.

NE = not evaluated. Data insufficient to calculate 95% UTL.

* Comparison cannot be made

TABLE A-5
ROCKY FLATS PLANT OU-2
95% UTL COMPARISON
METALS IN SUBSURFACE SOIL, mg/kg

Analyte	OU-2 Detected			Bknd	Background	% of OU-2 data
	Min	Max	Approx. DF %	Max	95% UTL(1)	> 95% UTL (2)
Aluminum	1,190	27,900	100	102,000	31,979	0
Antimony	4	24	4	16	12	5
Arsenic	1	37	94	42	12	11
Barium	10	589	83	777	270	2
Beryllium	0	23	47	24	13	0.4
Cadmium	1	10	45	2	1	36
Cesium	1	5	91	274	208	7
Chromium	2	127	98	176	61	1
Cobalt	1	78	55	30	15	2
Copper	3	132	84	123	35	1
Lead	1	86	99	40	27	1
Lithium	1	25	91	83	24	1
Manganese	4	1,610	100	3,330	822	1
Mercury	0	114	20	6	1	1
Molybdenum	1	19	33	68	31	7
Nickel	4	63	79	193	57	0.4
Selenium	0	2	7	14	4.5	0
Silver	1	96	13	41	22.5	1
Strontium	4	246	82	242	127	5
Thallium	0	1	12	10	3	0
Tin	22	53	24	441	268	0
Vanadium	4	53	97	283	80	0
Zinc	4	437	98	486	131	2

- (1) Calculated using borehole data reported in Background Geochemical Characterization Report, Rocky Flats Plant, EG&G 1992.
- (2) UTL Comparison is performed using one-half the detection limit for results reported as non-detect. Therefore, the maximum detected value in OU-2 can be below the 95% UTL of background even though the UTL comparison shows that a certain percentage of OU-2 data (i.e., reporting limits for non-detects) exceeds the 95% UTL of background.

DF = Detection frequency based on edited database of August 1993. DF is approximate because continuing quality review of the database may result in minor changes to the number of results.

TABLE A-6
ROCKY FLATS PLANT OU-2
95% UTL COMPARISON
RADIONUCLIDES IN SUBSURFACE SOIL, pCi/g

Analyte	OU-2 Detected			Bknd	Bknd 95%	% of OU-2 data
	Min	Max	Approx. DF %	Max	UTL (1)	>95% UTL
Americium-241	0.0009	22	83	0.01	0.01	61
Cesium-137	0.005	2.4	66	0.2	0.3	44
Plutonium-239,240	0.006	68	78	0.03	0.02	53
Radium-226	0.32	1.9	90	1.3	1.3	3
Radium-228	0.52	2.6	100	2.2	2.0	8
Strontium-89, 90	0.002	0.8	73	1.2	0.9	0
Strontium-90	0.01	1.1	100	-	-	5 (2)
Tritium (pCi/L)	9.63	1500	74	440	366	10
Uranium-233,234	0.04	192	100	8.9	2.5	2
Uranium-235	0	11.5	88	0.3	0.2	2
Uranium-238	0.09	113	100	3.2	1.5	4

- (1) Calculated using borhole data reported in Background Geochemical Characterization Report, Rocky Flats Plant, EG&G, 1992
- (2) 5% of the strontium-90 data points exceeds the 95% UTL concentration for strontium-89,90. However, there is no significant difference between the strontium-89,90 maximum (1.1 pCi/g) and the background levels for strontium-89,90 (95% UTL = 0.9 pCi/g).
- DF = Detection frequency based on edited database of August 1993. DF is approximate because continuing quality review of the database may result in minor changes to the number of results.
- No Data

TABLE A-7
ROCKY FLATS PLANT OU-2
95% UTL COMPARISON
METALS IN SURFACE SOIL, mg/kg

Analyte	OU-2 Detected			Bknd	Bknd 95%	% of OU-2 data
	Min	Max	Approx. DF%	Max	UTL (1)	>95% UTL(2)
Aluminum	6,170	17,900	100	21,800	22,514	0
Antimony	ND	-	0	25	16.16	0
Arsenic	1.5	6.1	100	8.7	10.13	0
Barium	71.7	190	100	470	405.96	0
Beryllium	*	1.3	3	2.5	3.56	0
Cadmium	1.3	2.2	13	2.5	3.44	0
Cesium	ND	-	0	250	198.92	0
Chromium	8.5	29.5	100	22	23.46	4.8
Cobalt	4.3	9.6	100	24	17.10	0
Copper	5	16.4	100	24	24.18	0
Lead	14.7	63.4	100	51	53.53	4.8
Lithium	4.5	22.9	100	18	18	4.8
Manganese	192	1,110	100	2,220	1,327.28	0
Mercury	ND	-	0	0.1	0.17	0
Molybdenum	*	5.3	3	20	27.76	0
Nickel	6.1	21.6	100	19	21.04	2.4
Selenium	0.47	0.9	8	1	0.8	2.4
Silver	ND	-	0	5	3.33	0
Strontium	15	100	100	109	81.55	4.8
Thallium	*	0.5	3	1	1.14	0
Tin	24	93.3	40	50	56.74	2.4
Vanadium	17.5	51.1	100	47	50.63	2.4
Zinc	33.8	89.3	100	94	92.78	0

(1) Calculated using data from samples collected in the Rock Creek area in 1991 and 1993.

(2) UTL comparison is performed using one-half the detection limit for results reported as non-detect. Therefore, the maximum detected value in OU-2 can be below the 95% UTL of background even though the UTL comparison shows that a certain percentage of OU-2 data (i.e., reporting limit for non-detects) exceeds the 95% UTL of background.

DF = Detection frequency based on edited database of August 1993. DF is approximate because continuing quality review of the database may result in minor changes to the number of results.

ND = not detected.

* Only detected in 1 of 40 samples. Result is shown as maximum.

**TABLE A-8
ROCKY FLATS PLANT OU-2
95% UTL COMPARISON
RADIONUCLIDES IN SURFACE SOIL, pCi/g**

Analyte	OU-2 Detected			Bknd	Bknd 95%	% of OU-2 data
	Min	Max	Approx. DF%	Max	UTL (1)	>95% UTL
Americium-241	0.01	110	43	0.04	0.042	95
Cesium-137	0.16	1.8	96	2.5	2.62	0
Plutonium-239, 240	0.3	7,300	52	0.1	0.10	100
Radium-226	0.6	11.8	100	1.1	1.28	12
Radium-228	1.3	3.5	100	2.9	3.57	0
Strontium-89/90	0.2	3.5	96	1.0	1.46	4
Uranium-233, 234	0.8	3.6	99	1.47	1.50	28
Uranium 235	0.01	0.68	78	0.15	0.09	22
Uranium 238	0.89	7.3	78	1.52	1.62	23
Uranium 233, 238, 239	1.09	7.7	40	-	NE	*

(1) Calculated using data from samples collected in the Rock Creek area in 1991 and 1993.

DF = Detection frequency based on edited database of August 1993. DF is approximate because continuing quality review of the database may result in minor changes to the number of results.

NE = Not evaluated. No background analysis for this analyte group.

* Comparison cannot be made.

TABLE A-9
ROCKY FLATS PLANT OU-2
ANOVA COMPARISON
TOTAL METALS IN GROUNDWATER, µg/L
NO. 1 SANDSTONE

Analyte	Background (1)		OU-2 Data		Norm Dist?	Test(2)	Result (Chi-Square)	P =	Significantly Different?	Bknd Mean = /> OU2 Mean(3)	Consider Further?
	Arith. Mean	SD	Arith. Mean	SD							
Aluminum	1,383	2,108	18,702	26,247	No	Kruskal	41.52	<0.01	Y	N	Y
Antimony	170	354	47	160	No	Kruskal	0.23	0.63	N	Y	N
Arsenic	5	0.8	4	2	No	Kruskal	5.63	0.02	Y	Y	N
Barium	181	376	434	510	No	Kruskal	38.68	<0.01	Y	N	Y
Beryllium	10	34	4	16	No	Kruskal	4.48	<0.03	Y	Y	N
Cadmium	84	375	20	174	No	Kruskal	0.02	0.89	N	Y	N
Cesium	439	157	416	152	No	Kruskal	1.55	0.21	N	Y	N
Chromium	82	345	41	159	No	Kruskal	10.73	<0.01	Y	Y	N
Cobalt	98	349	36	159	No	Kruskal	6.20	0.01	Y	Y	N
Copper	96	379	45	175	No	Kruskal	1.15	0.28	N	Y	N
Cyanide	5	0.6	5	3	No	Kruskal	0.02	0.88	N	Y	N
Lead	3	3	21	30	No	Kruskal	34.19	<0.01	Y	N	Y
Lithium	33	25	25	21	Yes	ANOVA	4.28	0.04	Y	Y	N
Manganese	75	157	528	832	No	Kruskal	33.71	<0.01	Y	N	Y
Mercury	ND	-	0.16	0.11	No	Kruskal	1.08	0.30	N	N	N
Molybdenum	127	341	58	161	No	Kruskal	1.53	0.22	N	Y	N
Nickel	98	358	46	165	No	Kruskal	0.13	0.72	N	Y	N
Selenium	8	18	3	8	No	Kruskal	4.98	0.03	Y	Y	N

TABLE A-9
(Concluded)

Analyte	Background (1)		OU-2 Data		Norm Dist?	Test(2)	Result (Chi-Square)	P =	Significantly Different?	Bknd Mean = /> OU2 Mean(3)	Consider Further?
	Arith. Mean	SD	Arith. Mean	SD							
Silver	19	64	8	31	No	Kruskal	8.73	<0.01	Y	Y	N
Strontium	361	242	503	223	Yes	ANOVA	24.90	<0.01	Y	N	Y
Thallium	4	2	4	2	No	Kruskal	0.34	0.56	N	Y	N
Tin	82	35	75	37	No	Kruskal	1.18	0.28	N	Y	N
Vanadium	93	362	66	174	No	Kruskal	17.03	<0.01	Y	Y	N
Zinc	127	387	133	219	No	Kruskal	14.13	<0.01	Y	N	Y

(1) Background data are from bedrock (Arapahoe/Laramie formation) wells. There is no No. 1 Sandstone in the background sampling area.

(2) ANOVA comparison is used on normally distributed data. The Kruskal analysis is used on non-normally distributed data.

(3) If the background mean is higher than OU-2 mean, a statistically significant difference (P < 0.05) is not applicable.

ND = non-detected

- No data

TABLE A-10
ROCKY FLATS PLANT OU-2
ANOVA COMPARISON
TOTAL RADIONUCLIDES IN GROUNDWATER, pCi/L
NO. 1 SANDSTONE

Analyte	Background(1)		OU-2 Data		Norm Dist?	Test(2)	Result (Chi-Square)	P =	Significantly Different?	Bknd Mean = /> OU2 Mean(3)	Consider Further?
	Arith. Mean	SD	Arith. Mean	SD							
Americium-241	0.01	0.02	0.04	0.14	No	Kruskal	5.06	0.02	Y	N	Y
Cesium-137	0.29	0.230	0.46	0.38	Yes	ANOVA	3.54	0.06	N	N	N
Radium-226	0.51	0.39	(4)	-	No	Kruskal	2.00	0.16	N	-	N
Plutonium-239, 240	0.003	0.002	0.13	0.58	No	Kruskal	30.89	<0.01	Y	N	Y
Strontium-89,90	0.11	0.05	0.16	0.16	No	Kruskal	0.03	0.86	N	N	N
Uranium-233, 234	6	6	5	2	Yes	ANOVA	0.64	0.80	N	Y	N
Uranium-235	0.28	0.26	0.16	0.12	Yes	ANOVA	0.71	0.42	N	Y	N
Uranium-238	4	5	3	2	Yes	ANOVA	0.02	0.91	N	Y	N

- (1) Background data are from bedrock (Arapahoe/Laramie formation) wells. There is no No. 1 Sandstone in the background sampling area.
(2) ANOVA comparison is used on normally distributed data. The Kruskal analysis is used on non-normally distributed data.
(3) If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference (P<0.05) is not applicable.
(4) One data point
No data

TABLE A-11
ROCKY FLATS PLANT OU-2
ANOVA COMPARISON
DISSOLVED METALS IN GROUNDWATER, µg/L
UHSU

Analyte	Background(1)		OU-2 Data			Norm Dist?	Test(2)	Result (Chi-Square)	P =	Significantly Different?	BKG Mean ≥OU2 Mean(3)	Consider Further?
	Arith. Mean	SD	Arith. Mean	SD	Count							
Aluminum	106	630	56	42	42	No	Kruskal	0.30	0.58	N	Y	N
Antimony	22	11	26	11	11	No	Kruskal	6.69	<0.01	Y	N	Y
Arsenic	4	2	4	2	2	No	Kruskal	0.81	0.37	N	Y	N
Barium	84	34	161	75	75	No	Kruskal	159.0	<0.01	Y	N	Y
Beryllium	2	1	2	1	1	No	Kruskal	0.30	0.59	N	Y	N
Cadmium	2	1	3	7	7	No	Kruskal	0.59	0.44	N	N	N
Cesium	417	221	349	179	179	No	Kruskal	3.87	<0.01	Y	Y	N
Chromium	6	3	5	4	4	No	Kruskal	9.71	<0.01	Y	Y	N
Cobalt	19	10	19	10	10	No	Kruskal	0.03	0.86	N	Y	N
Copper	10	4	8	5	5	No	Kruskal	6.52	0.01	Y	Y	N
Lead	3	6	1	1	1	No	Kruskal	29.96	<0.01	Y	Y	N
Lithium	41	55	16	23	23	No	Kruskal	36.22	<0.01	Y	Y	N
Manganese	34	96	216	536	536	No	Kruskal	28.66	<0.01	Y	N	Y
Mercury	0.10	0.11	0.09	0.04	0.04	No	Kruskal	2.23	0.14	N	Y	N
Molybdenum	48	45	42	45	45	No	Kruskal	1.26	0.26	N	Y	N
Nickel	14	8	31	107	107	No	Kruskal	1.95	0.16	N	N	N
Selenium	12	55	5	20	20	No	Kruskal	13.74	<0.01	Y	Y	N
Silver	89	1068	4	2	2	No	Kruskal	20.33	<0.01	Y	Y	N

**TABLE A-11
(Concluded)**

Analyte	Background(1)		OU-2 Data		Norm Dist?	Test(2)	Result (Chi-Square)	P =	Significantly Different?	BKG Mean \geq OU2 Mean(3)	Consider Further?
	Arith. Mean	SD	Arith. Mean	SD							
Strontium	436	891	566	409	No	Kruskal	73.5	<0.01	Y	N	Y
Thallium	5	13	4	2	No	Kruskal	0.05	0.83	N	Y	N
Tin	106	671	75	40	No	Kruskal	15.18	<0.01	Y	Y	N
Vanadium	13	11	8	7	No	Kruskal	9.69	<0.01	Y	Y	N
Zinc	14	19	16	58	No	Kruskal	7.74	<0.01	Y	N	Y

(1) Background data are from VFA, RFA, colluvial, and bedrock (Arapahoe/Laramie formation) wells.

(2) The Kruskal analysis is done on non-normally distributed data.

(3) If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference ($P < 0.05$) is not applicable.

TABLE A-12
ROCKY FLATS PLANT OU-2
ANOVA COMPARISON
DISSOLVED RADIONUCLIDES IN GROUNDWATER, pCi/L
UHSU

Analyte	Background(1)		OU-2 Data		Norm Dist?	Test (2)	Result (Chi-Square)	P =	Significantly Different?	BKG Mean > OU2 Mean (3)	Consider Further?
	Arith. Mean	SD	Arith. Mean	SD							
Americium-241	0.02	0.01	2	7	No	Kruskal	0.11	0.74	N	N	N
Cesium-137	-	-	0.22	0.11	No	Kruskal	-	-	-	-	Y
Plutonium-239, 240	(4)	(4)	0.11	0.25	No	Kruskal	(4)	(4)	(4)	Y	Y
Radium-226	0.4	0.62	0.57	0.39	No	Kruskal	15.52	<0.01	Y	N	Y
Strontium-89,90	0.36	0.24	0.4	0.33	No	Kruskal	0.01	0.99	N	N	N
Tritium	139	102	175	171	No	Kruskal	3.59	0.06	N	N	N
Uranium-233, 234	6	24	5	5	No	Kruskal	47.95	<0.01	Y	Y	N
Uranium-235	0.28	0.74	0.17	0.20	No	Kruskal	3.74	0.053	N	Y	N
Uranium-238	4	16.7	4	7	No	Kruskal	50.56	<0.01	N	Y	N

(1) Background data are from VFA, RFA, colluvial, and bedrock (Arapahoe/Laramie formation) wells.

(2) The Kruskal analysis is performed on non-normally distributed data.

(3) If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference (P<0.05) is not applicable.

(4) One background data point. ANOVA not performed.

- No data

TABLE A-13
ROCKY FLATS PLANT OU-2
ANOVA COMPARISON
METALS IN SUBSURFACE SOIL, mg/kg

Analyte	Background		OU-2 Data		Norm Dist?	Test	Result (Chi-Square)	P =	Significantly Different?	Blend Mean => OU2 Mean(1)	Consider Further?
	Arith. Mean	SD	Arith. Mean	SD							
Aluminum	11,567	10,637	10,471	4,663	No	Kruskal	0.23	0.63	N	Y	N
Antimony	6	3	8	10	No	Kruskal	0.63	0.43	N	N	N
Arsenic	4	4	6	5	No	Kruskal	35.77	<0.01	Y	N	Y
Barium	95	91	76	65	No	Kruskal	7.97	<0.01	Y	Y	N
Beryllium	4	4	0.73	1	No	Kruskal	212.45	<0.01	Y	Y	N
Cadmium	0.7	0.4	1	1	No	Kruskal	7.79	<0.01	Y	N	Y
Cesium	115	49	38	127	No	Kruskal	139.77	<0.01	Y	Y	N
Chromium	17	23	13	11	No	Kruskal	9.65	<0.01	Y	Y	N
Cobalt	7	4	6	5	No	Kruskal	13.55	<0.01	Y	Y	N
Copper	13	12	10	10	No	Kruskal	13.21	<0.01	Y	Y	N
Lead	12	8	8	8	No	Kruskal	29.67	<0.01	Y	Y	N
Lithium	9	8	9	4	No	Kruskal	0.01	0.91	N	Y	N
Manganese	206	321	187	175	No	Kruskal	0.01	0.91	N	Y	N
Mercury	0.26	0.58	0.51	7	No	Kruskal	109.51	<0.01	Y	N	Y
Molybdenum	14	9	16	13	No	Kruskal	0.10	0.75	N	N	N
Nickel	20	20	12	7	No	Kruskal	26.62	<0.01	Y	Y	N
Selenium	1	2	0.5	0.11	No	Kruskal	110.22	<0.01	Y	Y	N
Silver	5	9	2	7	No	Kruskal	100.70	<0.01	Y	Y	N
Strontium	48	41	40	40	No	Kruskal	10.67	<0.01	Y	Y	N
Thallium	0.82	1.1	1	0.24	No	Kruskal	9.59	<0.01	Y	N	Y
Tin	65	106	31	24	No	Kruskal	1.01	0.31	N	Y	N
Vanadium	29	27	24	10	No	Kruskal	4.82	0.03	Y	Y	N
Zinc	40	48	30	33	No	Kruskal	11.28	<0.01	Y	Y	N

(1) If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference (P<0.05) is not applicable.

TABLE A-14
ROCKY FLATS PLANT OU-2
ANOVA COMPARISON
RADIONUCLIDES IN SUBSURFACE SOIL, pCi/g
VADOSE ZONE

Analyte	Background		OU-2 Data				Norm Dist?	Test	Result (Chi-Square)	P =	Significantly Different?	Bknd Mean => OU2 Mean (I)	Consider Further?
	Arith. Mean	SD	Arith. Mean	SD	SD								
Americium-241	0.01	0	0.20	0.79	0.06	No	Kruskal	3.53	0.06	N	N	Y (2)	
Cesium-137	0.13	0.05	0.49	0.61	0.89	No	Kruskal	0.02	0.89	N	N	N	
Plutonium-239,240	0.01	0.005	1.65	7.16	<0.01	No	Kruskal	9.18	<0.01	Y	N	Y	
Radium-226	0.79	0.25	0.59	0.28	<0.01	No	Kruskal	35.57	<0.01	Y	Y	N	
Radium-228	1.38	0.31	1.39	0.44	0.94	No	Kruskal	0.005	0.94	N	N	N	
Strontium-89,90	0.37	0.27	0.22	0.17	<0.01	No	Kruskal	10.62	<0.01	Y	Y	N	
Strontium-90	-	-	0.46	0.17	-	No	Kruskal	-	-	-	-	N	
Tritium (pCi/L)	168	103.1	93.8	135.5	<0.01	No	Kruskal	47.19	<0.01	Y	Y	N	
Uranium-233, 234	0.80	0.87	1.24	11.67	<0.01	No	Kruskal	36.05	<0.01	Y	N	Y	
Uranium-235	0.12	0.05	0.15	1.07	<0.01	No	Kruskal	47.09	<0.01	Y	N	Y	
Uranium 235, 236	-	-	0.06	0.06	-	No	Kruskal	-	-	-	-	N(3)	
Uranium-238	0.76	0.37	1.05	7.02	<0.01	No	Kruskal	27.31	<0.01	Y	N	Y	

(1) If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference (P<0.05) is not applicable.
(2) Americium 241 is retained for further evaluation even though P>0.05. Background samples had only four positive results at 0.01 pCi/g.
(3) Mean concentration of Uranium 235, 236 is lower than background mean for Uranium 235. Therefore, Uranium 235, 236 is not considered further.

TABLE A-15
 ROCKY FLATS PLANT OU-2
 ANOVA COMPARISON
 METALS IN SURFACE SOIL, mg/kg

Analyte	Background		OU-2 Data		Norm Dist?	Test(1)	Result (Chi-Square)	P =	Significantly Different?	Bknd Mean => OU2 Mean(2)	Consider Further?
	Arith. Mean	SD	Arith. Mean	SD							
Aluminum	12,636	4,370	11,305	2,855	Yes	ANOVA	2.24	0.14	N	Y	N
Antimony	14	10	ND	-	-	-	-	-	-	-	N
Arsenic	6	2	4	1	Yes	ANOVA	27.99	<0.01	Y	Y	N
Barium	196	93	126	27	Yes	ANOVA	21.06	<0.01	Y	Y	N
Beryllium	2	0.89	2	0.84	No	Kruskal	3.98	0.05	Y	Y	N
Cadmium	1	0.9	2	0.84	No	Kruskal	5.68	0.02	Y	N	Y
Cesium	114	123	ND	-	-	-	-	-	-	-	N
Chromium	15	4	13	4	No	Kruskal	3.74	0.05	N	Y	N
Cobalt	8	4	7	2	No	Kruskal	0.02	0.90	N	Y	N
Copper	14	5	12	3	Yes	ANOVA	3.72	0.06	N	Y	N
Lead	37	7	37	12	Yes	ANOVA	0.05	0.82	N	Y	N
Lithium	11	3	9	4	No	Kruskal	7.27	<0.01	Y	Y	N
Molybdenum	15	6	13	6	No	Kruskal	1.79	0.18	N	Y	N
Manganese	402	409	315	157	No	Kruskal	2.17	0.14	N	Y	N
Mercury	0.08	0.03	ND	-	-	-	-	-	-	-	N
Nickel	11	4	12	3	Yes	ANOVA	0.12	0.73	N	N	N
Selenium	0.59	0.20	0.88	0.22	No	Kruskal	15.81	<0.01	Y	N	Y
Silver	3	2	ND	-	-	-	-	-	-	-	N
Strontium	39	19	39	19	No	Kruskal	0.01	0.92	N	Y	N
Thallium	0.76	0.33	0.98	0.11	No	Kruskal	11.18	<0.01	Y	N	Y
Tin	30	12	40	14	No	Kruskal	10.19	<0.01	Y	N	Y
Vanadium	32	8	30	8	Yes	ANOVA	0.93	0.34	N	Y	N
Zinc	56	16	53	11	No	Kruskal	1.07	0.30	N	Y	N

(1) ANOVA comparison is used on normally distributed data. The Kruskal analysis is used on non-normally distributed data.
 (2) If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference (P<0.05) is not applicable.
 ND = not detected.
 - no data

TABLE A-16
ROCKY FLATS PLANT OU-2
ANOVA COMPARISON
RADIONUCLIDES IN SURFACE SOIL, pCi/g

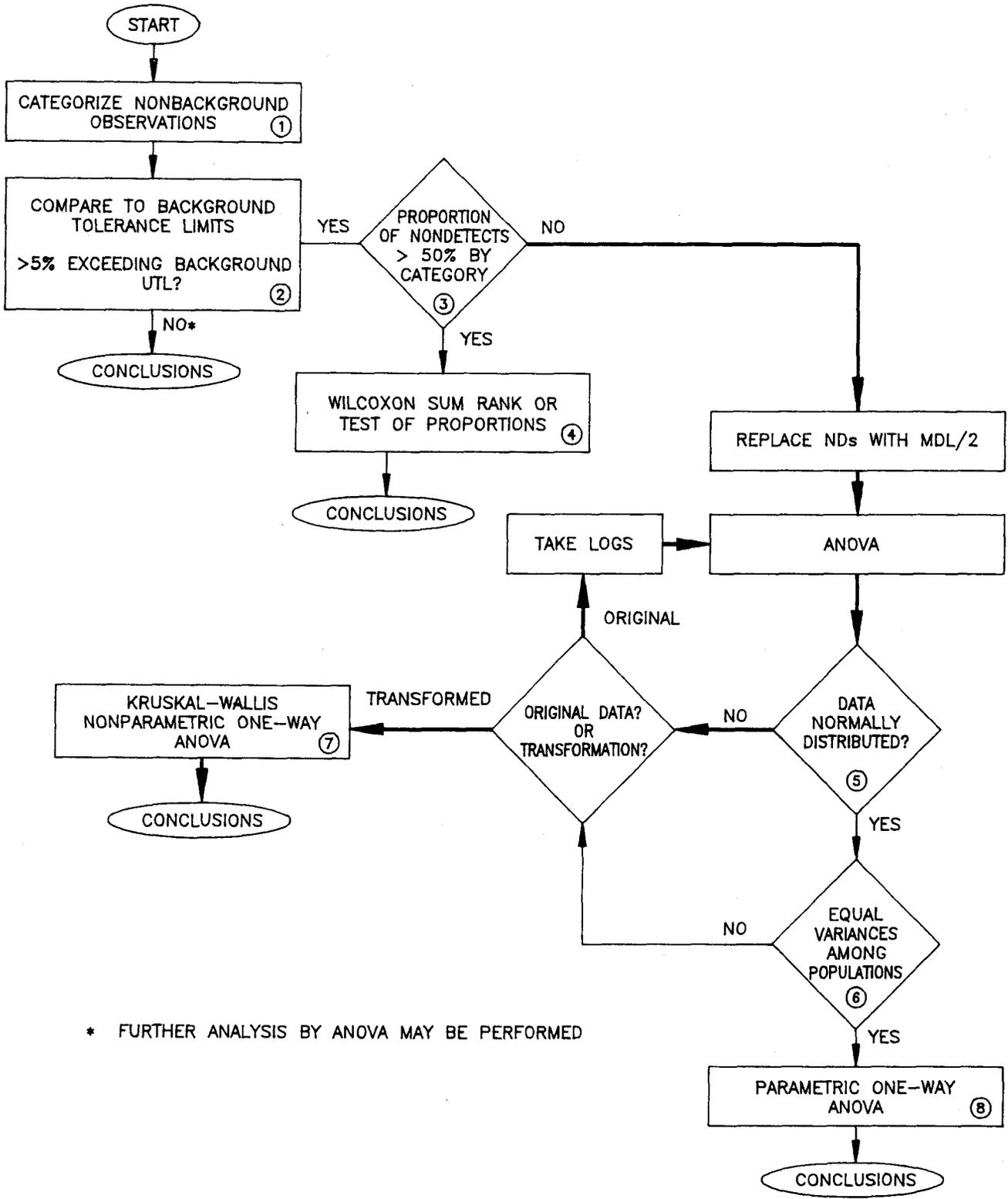
Analyte	Background		OU-2 Data		Norm Dist?	Test(1)	Result (Chi-Square)	P =	Significantly Different?	Bkrd Mean => OU2 Mean(2)	Consider Further?
	Arith. Mean	SD	Arith. Mean	SD							
Americium-241	0.019	0.0096	15.71	27.25	No	Kruskal	33.18	<0.01	Y	N	Y
Cesium-137	1.39	0.48	0.81	0.48	Yes	ANOVA	13.01	<0.01	Y	Y	N
Plutonium-239, 240	0.05	0.02	546	2,027	No	-	(3)	-	-	N	Y
Radium-226	0.93	0.13	1.42	2.12	No	Kruskal	2.56	0.11	N	N	N
Radium-228	2.14	0.53	2.05	0.56	Yes	ANOVA	0.19	0.66	N	Y	N
Strontium-89,90	0.57	0.33	0.61	0.64	Yes	ANOVA	0.36	0.55	N	N	N
Uranium-233,234	1.16	0.14	1.49	0.64	No	Kruskal	2.08	0.15	N	N	N
Uranium-235	0.06	0.04	0.08	0.10	No	Kruskal	0.74	0.39	N	N	N
Uranium-235,236	-	-	0.12	0.06	-	-	-	-	-	-	Y
Uranium-238	1.17	0.19	1.43	0.80	No	Kruskal	2.97	0.085	N	N	N
Uranium-233,238,239	-	-	2.80	1.50	-	-	-	-	-	-	Y

(1) ANOVA comparison is used on normally distributed data. The Kruskal analysis is used on non-normally distributed data.

(2) If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference (P<0.05) is not applicable.

(3) Chi-square tests were not performed for plutonium 239,240 because OU-2 results clearly exceed background.

- NO data



* FURTHER ANALYSIS BY ANOVA MAY BE PERFORMED

U.S. DEPARTMENT OF ENERGY
 Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO.2
 PHASE II RFI/RI REPORT

SELECTION OF STATISTICAL METHOD
 FOR COMPARISON OF BACKGROUND
 AND NONBACKGROUND POPULATIONS

FIGURE A-1 JULY 1993
 RFSSCAL1

APPENDIX B
RISK-BASED EVALUATION OF INFREQUENTLY DETECTED CHEMICALS

APPENDIX B

RISK-BASED EVALUATION OF INFREQUENTLY DETECTED CHEMICALS

B.1 PURPOSE AND APPROACH

The chemicals of concern evaluated in a quantitative human health risk assessment are the subset of all site-related chemicals that are thought to pose the greatest potential risk to human health. The determination that these chemicals may pose the greatest potential risk is generally based on an evaluation of the following three criteria:

- The inherent toxicity of the chemical;
- The concentrations of the chemical found on-site; and
- The potential for human exposure to the chemical (e.g., whether or not the chemical is widely distributed across the site or could readily migrate from the site)

In general, compounds found at low frequency (<5% of all samples) are not included as chemicals of concern because the potential for human exposure is limited. However, all infrequently detected compounds were evaluated according to the procedures shown in Figure 2-1 so as not to neglect infrequently detected chemicals that could contribute significantly to risk if they were co-located with other potentially hazardous compounds at source areas or at locations where routine exposure could occur.

This evaluation examines those organic chemicals that were initially excluded from the chemicals of concern based on low frequency of detection, using a health-based screening approach. A screening evaluation was performed for all low-frequency chemicals for which toxicity values were available. As a benchmark, it was assumed that any infrequently detected chemical whose maximum concentration was greater than 1000 times a risk-based concentration (RBC) based on a target hazard index (HI) of 1.0 or target excess cancer risk of 10^{-6} (1 in 1,000,000) warrants further evaluation. The purpose is to identify those infrequently detected chemicals that may pose an unacceptable health risk (cancer or non-cancer) if chronic exposure were to occur. These chemicals are retained for separate evaluation in the risk assessment as "special case" chemicals of concern. Since they are not characteristic of contamination in OU-2, risk will be assessed separately at the locations where the special case chemicals are found.

RBCs were calculated assuming a residential exposure scenario, using site-specific exposure assumptions, and using standard toxicity values (RfDs and SFs) established by EPA. For surface soils and subsurface soils, multiple pathway exposure was assumed (ingestion, dermal contact, and inhalation of particulates) in calculating RBCs. Exposure was evaluated for ingestion only for groundwater, since this was assumed to be the only major groundwater exposure route. The parameters used to evaluate potential exposure (and to calculate intake factors) are presented in Tables B-1 through B-4. These parameters were presented in the Exposure Assessment Technical Memorandum No. 5 (DOE 1993). Toxicity values were derived from IRIS (EPA 1993) and HEAST (EPA 1991a, 1992a, 1993b), and are summarized in Tables 2-3 and 2-4. For purposes of calculating multiple-pathway RBCs, 10 percent is used as an upperbound estimate of dermal absorption rate of organic compounds adhered to soil. (Chemical-specific values will be used to estimate risks from dermal exposure to chemicals of concern in the risk assessment for OU-2.) RBCs were then multiplied by 1000 to generate the screening concentrations for use in the evaluation.

B.2 GROUNDWATER

Twenty-six VOCs and SVOCs were reported at low frequency (<5% detection) in groundwater samples. Table B-6 presents a comparison of the maximum detected concentrations to the health-based screening criteria (both cancer and non-cancer) and presents the equations used to develop the screening concentrations. Chemicals whose maximum detected concentration was greater than 1000 times either the cancer or non-cancer RBCs were retained for further evaluation as potential chemicals of concern. Based on the comparison to screening-level concentrations, two chemicals, 1,2-dibromoethane and vinyl chloride, were identified as requiring further evaluation in the human health risk assessment as potential chemicals of concern (see Section 3.5).

B.3 SOIL

Potentially site-related organic compounds detected at less than 5 percent frequency in subsurface soil samples and in surface soils are listed in Tables B-7 and B-8. Table B-7 (carcinogenic effects) presents a comparison of the maximum detected concentrations in subsurface and surface soils to the health-based screening criteria (carcinogens) and presents the equations used to develop the screening concentrations. Table B-8 presents a similar comparison for noncarcinogenic effects.

As with groundwater, chemicals whose maximum detected concentration was greater than 1000 times either the cancer or noncancer risk-based screening concentration were retained for further evaluation as potential chemicals of concern. Based on this evaluation, no infrequently detected chemicals found in surface or subsurface soils failed the screening evaluation (i.e., none were identified as special case chemicals of concern).

References

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**TABLE B-1
ROCKY FLATS PLANT OU-2
UHSU GROUNDWATER INGESTION
HYPOTHETICAL FUTURE ON-SITE RESIDENT**

Intake Factor = $\frac{IR \times EF \times ED \times FI}{BW \times AT}$		
	Parameter	RME
IR :	Intake rate (l/day) ⁽¹⁾	2.0
EF :	Exposure frequency (days/year) ⁽¹⁾	350
ED:	Exposure duration (years) ⁽¹⁾	30
FI:	Fraction ingested from contaminated source	1.0
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550
IF:	Intake Factor (L/kg-day)	
	Noncarcinogenic	0.027
	Carcinogenic	0.0117

⁽¹⁾ Source: EPA 1991c.

TABLE B-2
ROCKY FLATS PLANT OU-2
SOIL INGESTION
HYPOTHETICAL FUTURE ON-SITE RESIDENT
(ADULT AND CHILD)⁽¹⁾

Noncarcinogenic:

$$\text{Intake Factor} = \left[\frac{(200 \text{ mg/day} \times 350 \text{ day/yr} \times 6 \text{ yr})}{15 \text{ kg} \times 365 \text{ day/yr}} + \frac{(100 \text{ mg/day} \times 350 \text{ day/yr} \times 24 \text{ yr})}{70 \text{ kg} \times 365 \text{ day/yr}} \right] \times 0.5 \times 10^{-6} \text{ kg/mg/30 yr}$$

Carcinogenic:

$$\text{Intake Factor} = \left[\frac{(200 \text{ mg/day} \times 350 \text{ day/yr} \times 6 \text{ yr})}{15 \text{ kg} \times 365 \text{ day/yr}} + \frac{(100 \text{ mg/day} \times 350 \text{ day/yr} \times 24 \text{ yr})}{70 \text{ kg} \times 365 \text{ day/yr}} \right] \times 0.5 \times 10^{-6} \text{ kg/mg/70 yr}$$

Parameter		RME	
		Adult	Child
IR:	Ingestion rate (mg/day) ⁽¹⁾	100	200
FI:	Fraction ingested from contaminated source ⁽²⁾	0.5	0.5
ME:	Matrix effect ⁽³⁾	1.0	1.0
EF:	Exposure frequency (days/year) ⁽⁴⁾	350	350
ED:	Exposure duration (years) ⁽⁵⁾	24	6
CF:	Conversion factor (kg/mg)	10 ⁻⁶	10 ⁻⁶
BW:	Body weight (kg)	70	15
AT:	Averaging time (days)		
	Noncarcinogenic	10,950	
	Carcinogenic	25,550	
IF:	Intake Factor (kg/kg-day)		
	Noncarcinogenic	1.8 x 10 ⁻⁶	
	Carcinogenic	7.8 x 10 ⁻⁷	

(1) The calculation of a 30-year residential exposure to soil is divided into two parts. First, a six-year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg). Second, a 24-year exposure duration is assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) and an adult body weight (70 kg) (EPA 1991c).

(2) The FI assumes that 50 percent of the soil ingested daily is from the contaminated source.

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect of 1.0 (100 percent absorption) is used as a conservative value for screening purposes.

(4) EPA 1991c.

(5) Thirty-year residential exposure. EPA 1991c.

TABLE B-3
ROCKY FLATS PLANT OU-2
DERMAL CONTACT WITH SURFACE SOIL
HYPOTHETICAL FUTURE ON-SITE RESIDENT

Intake Factor = $\frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$		
	Parameter	RME
SA:	Surface area (cm ²) ⁽¹⁾	2,910
AB:	Absorption factor ⁽²⁾	0.1
AF:	Adherence factor (mg/cm ²) ⁽³⁾	0.5
FC:	Fraction contacted from contaminated source ⁽⁴⁾	0.5
EF:	Exposure frequency (days/year) ⁽⁵⁾	350
ED:	Exposure duration (years) ⁽⁶⁾	30
CF:	Conversion factor (kg/mg)	10 ⁻⁶
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550
IF:	Intake Factor (kg/kg-day)	
	Noncarcinogenic	1.0 x 10 ⁻⁶
	Carcinogenic	4.3 x 10 ⁻⁷

- ⁽¹⁾ The surface area is equivalent to face, forearms, and hands, or 15 percent of total body surface (EPA 1989).
- ⁽²⁾ Dermal absorption of metals from a soil matrix is considered negligible. For screening purposes, the absorption factor for semivolatiles, volatiles, and other organics is assumed to be 10 percent (see Table B-8).
- ⁽³⁾ Source: Sedman 1989.
- ⁽⁴⁾ The FC assumes that residents are at home for 16 hours per day and are at work, school, or other locations for 8 hours per day.
- ⁽⁵⁾ Assumes that residents take 15 days per year vacation (EPA 1991c).
- ⁽⁶⁾ Source: EPA 1991c.

TABLE B-4
ROCKY FLATS PLANT OU-2
INHALATION OF PARTICULATES
HYPOTHETICAL FUTURE ON-SITE RESIDENT

Intake Factor = $\frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$		
	Parameter	RME
IR =	Inhalation rate (m ³ /hr) ⁽¹⁾	0.83
ET =	Exposure time (hours/day)	24
EF =	Exposure frequency (days/year) ⁽²⁾	350
ED =	Exposure duration (years) ⁽²⁾	30
DF =	Deposition factor ⁽³⁾	0.75
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550
IF:	Intake Factor (m ³ /kg-day)	
	Noncarcinogenic	2.0 x 10 ⁻¹
	Carcinogenic	8.8 x 10 ⁻²

⁽¹⁾ Equivalent to 20 m³/day (EPA 1991c).

⁽²⁾ EPA 1991c.

⁽³⁾ Seventy-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all chemicals in that fraction are absorbed (Cowherd 1985).

TABLE B-6
COMPARISON TO RISK-BASED SCREENING CONCENTRATIONS
GROUNDWATER: COMPOUNDS AT LESS THAN 5% FREQUENCY OF DETECTION
CARCINOGENIC AND NON-CARCINOGENIC EFFECTS

Equations: $Cs-c = Risk / (IForal-c \times SForal)$
 $Cs-nc = (HI \times RfDoral) / IForal-nc$

Where:
 Cs-c = Cancer Risk-Based Screening Concentration
 Cs-nc = Non-cancer Risk-Based Screening Concentration
 Risk = Target Cancer Risk Level of 1 E-6 (1 in 1 million)
 HI = Target Hazard Index = 1
 IForal-c = Oral Intake Factor for Carcinogens (Table B-1)
 IForal-nc = Oral Intake Factor for Noncarcinogens (Table B-1)
 SForal = Oral Slope Factor
 RfDoral = Oral Reference Dose
 RBC-c = Risk-based concentration at 1E-6 target excess cancer risk
 RBC-nc = Risk based concentration at HI = 1

CHEMICAL	SForal (mg/kg-d) ⁻¹	RfDoral mg/kg-d	IForal-c L/kg-d	RBC-c mg/L	IForal-nc L/kg-d	RBC-nc mg/L	CS-c 1000 x RBC-c	Cs-nc 1000 x RBC-nc	Maximum Conc. mg/L	Maximum Conc. > Cs
1,1,2,2-tetrachloroethane	2.0E-01	-	1.17E-02	4.3E-04	2.7E-02	-	4.3E-01	-	1.80E-01	NO
1,1,2-trichloroethane	5.7E-02	4.0E-03	1.17E-02	1.5E-03	2.7E-02	1.5E-01	1.5E+00	1.5E+02	2.10E-02	NO
1,2,3-trichloropropane	-	6.0E-03	1.17E-02	-	2.7E-02	2.2E-01	-	2.2E+02	2.00E-03	NO
1,2,4-trichlorobenzene	-	1.0E-02	1.17E-02	-	2.7E-02	3.6E-01	-	3.6E+02	2.00E-03	NO
1,2-dibromoethane	8.5E+01	-	1.17E-02	1.0E-06	2.7E-02	-	1.0E-03	-	1.30E-02	YES
1,2-dichlorobenzene	-	9.0E-02	1.17E-02	-	2.7E-02	3.3E+00	-	3.3E+03	1.00E-04	NO
1,2-dichloroethane	9.1E-02	-	1.17E-02	9.4E-04	2.7E-02	-	9.4E-01	-	7.30E-03	NO
1,2-dimethylbenzene (o-xylene)	-	2.0E+00	1.17E-02	-	2.7E-02	7.3E+01	-	7.3E+04	2.00E-04	NO
1,3-dimethylbenzene (m-xylene)	-	2.0E+00	1.17E-02	-	2.7E-02	7.3E+01	-	7.3E+04	3.00E-04	NO
1,4-dichlorobenzene	2.4E-02	-	1.17E-02	3.6E-03	2.7E-02	-	3.6E+00	-	3.00E-04	NO
4-methyl-2-pentanone	-	5.0E-02	1.17E-02	-	2.7E-02	1.8E+00	-	1.8E+03	1.00E-02	NO
bromoform	7.9E-03	2.0E-02	1.17E-02	1.1E-02	2.7E-02	7.3E-01	1.1E+01	7.3E+02	6.00E-03	NO
chlorobenzene	-	2.0E-02	1.17E-02	-	2.7E-02	7.3E-01	-	7.3E+02	2.00E-02	NO
chloromethane	1.3E-02	-	1.17E-02	6.6E-03	2.7E-02	-	6.6E+00	-	5.00E-03	NO
cis-1,3-dichloropropene	1.8E-01	3.0E-04	1.17E-02	4.7E-04	2.7E-02	1.1E-02	4.7E-01	1.1E+01	1.70E+00	YES
dibromomethane	-	1.0E-02	1.17E-02	-	2.7E-02	3.6E-01	-	3.6E+02	1.70E+00	NO
dichlorodifluoromethane	-	2.0E-01	1.17E-02	-	2.7E-02	7.3E+00	-	7.3E+03	6.00E-04	NO
ethylbenzene	-	1.0E-01	1.17E-02	-	2.7E-02	3.6E+00	-	3.6E+03	2.00E-02	NO
hexachlorobutadiene	7.8E-02	2.0E-04	1.17E-02	1.1E-03	2.7E-02	7.3E+00	1.1E+00	7.3E+00	1.20E-03	NO
o-chlorotoluene	-	2.0E-02	1.17E-02	-	2.7E-02	7.3E-01	-	7.3E+02	3.00E-03	NO
1,2-dibromo-3-chloropropane	1.4E+00	-	1.17E-02	6.1E-05	2.7E-02	-	6.1E-02	-	4.20E-03	NO
styrene	-	2.0E-01	1.17E-02	-	2.7E-02	7.3E+00	-	7.3E+03	1.00E-02	NO
vinyl chloride	1.9E+00	-	1.17E-02	4.5E-05	2.7E-02	-	4.5E-02	-	8.60E-01	YES
di-n-butylphthalate	-	1.0E+01	1.17E-02	-	2.7E-02	3.6E+02	-	3.6E+05	3.00E-03	NO

TABLE B-7
COMPARISON TO RISK-BASED SCREENING CONCENTRATIONS
SOIL: COMPOUNDS AT LESS THAN 5% FREQUENCY
CARCINOGENIC EFFECTS

Where:
Cs = Screening concentration in soil (mg/kg)
Risk = Target cancer risk level
SF oral = Slope Factor for oral route
SF inh = Slope Factor for inhalation exposure route
IForal = Oral Intake Factor (Table B-2)

Equation: $Cs = Risk / ((IForal + IFderm) \times SF \text{ oral}) + (PM \text{ IFinh} \times SF \text{ inh})$

IFderm = Dermal Exposure Intake Factor (Table B-3)
PM Air = $37 \mu\text{g}/\text{m}^3$ (site-specific, assumed 100% PM10)
PM IFinh = Inhalation Exposure Intake Factor (Table B-4), PM air concentration.
RBC = Risk-based screening concentration at 1 E-6 target cancer risk level.

CHEMICAL	IFderm kg/kg-d	IForal kg/kg-d	PM Air Conc. kg/m ³	PM IFinh kg/kg-d	SF oral (mg/kg- day^{-1}) ⁻¹	SF inh (mg/kg- day^{-1}) ⁻¹	RBC (mg/kg)	Cs (1000 X RBC) (mg/kg)	Maximum Conc. (mg/kg)	Maximum Conc. > Cs?
Subsurface Soil										
arsenic	0	7.8E-07	3.7E-08	3.3E-09	1.8E+00	1.5E-01	7.3E-01	7.3E+02	3.7E+01	NO
cadmium	0	7.8E-07	3.7E-08	3.3E-09	-	6.3E+00	4.9E+01	4.9E+04	1.1E+01	NO
benzene	4.3E-07	7.8E-07	0	0	2.9E-02	2.9E-02	2.8E+01	2.8E+04	1.2E-02	NO
chloroform	4.3E-07	7.8E-07	0	0	6.1E-03	8.0E-02	1.4E+02	1.4E+05	8.8E+00	NO
carbon tetrachloride	4.3E-07	7.8E-07	0	0	1.3E-01	5.3E-02	6.4E+00	6.4E+03	1.4E+02	NO
pentachlorophenol	4.3E-07	7.8E-07	3.7E-08	3.3E-09	1.2E-02	-	6.9E+01	6.9E+04	9.5E-02	NO
dis-1,3-dichloropropene	4.3E-07	7.8E-07	0	0	1.8E-01	1.3E-01	4.6E+00	4.6E+03	6.0E-03	NO
1,4-dichlorobenzene	4.3E-07	7.8E-07	0	0	2.4E-02	-	3.4E+01	3.4E+04	4.3E-02	NO
benzo(b)pyrene	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.3E+00	-	1.1E-01	1.1E+02	4.8E-01	NO
chrysene	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.3E-02	-	1.1E-01	1.1E+04	4.2E-01	NO
benzo(a)anthracene	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.3E-01	-	1.1E+00	1.1E+03	5.3E-01	NO
benzo(b)fluoranthene	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.3E-01	-	1.1E+00	1.1E+03	8.2E-01	NO
hexachlorobutadiene	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.8E-02	7.8E-02	1.1E+01	1.1E+04	1.7E-01	NO
hexachloroethane	4.3E-07	7.8E-07	3.7E-08	3.3E-09	1.4E-02	1.4E-02	5.9E+01	5.9E+04	1.1E+00	NO
indeno(1,2,3-c,d)pyrene	4.3E-07	7.8E-07	3.7E-08	3.3E-09	5.8E-01	-	1.4E+00	1.4E+03	3.3E-01	NO
4,4'-DDT	4.3E-07	7.8E-07	3.7E-08	3.3E-09	3.4E-01	3.4E-01	2.4E+00	2.4E+03	1.4E-01	NO
Aroclor-1254	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.7E+00	-	1.1E-01	1.1E+02	8.9E+00	NO
Surface Soil										
Aroclor 1254	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.7E+00	-	1.1E-01	1.1E+02	9.7E-01	NO
Aroclor 1260	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.7E+00	-	1.1E-01	1.1E+02	6.6E-01	NO
4,4'-DDT	4.3E-07	7.8E-07	3.7E-08	3.3E-09	3.4E-01	3.4E-01	2.4E+00	2.4E+03	2.6E-02	NO
benzo(a)anthracene	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.3E-01	-	1.1E+00	1.1E+03	1.6E-01	NO
benzo(b)pyrene	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.3E+00	-	1.1E-01	1.1E+02	1.6E-01	NO
benzo(b)fluoranthene	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.3E-01	-	1.1E+00	1.1E+03	2.4E-01	NO
benzo(e)fluoranthene	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.3E-01	-	1.1E+00	1.1E+03	7.6E-02	NO
chrysene	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.3E-02	-	1.1E-01	1.1E+04	2.0E-01	NO
indeno(1,2,3-cd)pyrene	4.3E-07	7.8E-07	3.7E-08	3.3E-09	7.3E-01	-	1.1E+00	1.1E+03	8.3E-02	NO

TABLE B-8
COMPARISON TO RISK-BASED SCREENING CONCENTRATIONS
SOIL: COMPOUNDS AT LESS THAN 5% FREQUENCY
NON-CARCINOGENIC EFFECTS

Equation: $Cs = (HI) / [(IF_{oral} + IF_{derm}) / (RD_{oral}) + (PM\ IF_{inh} / RD_{inh})]$

Where:

Cs = Screening concentration in soil (mg/kg)
HI = Target Hazard Index
IF_{oral} = Oral Intake Factor
IF_{derm} = Dermal Exposure Intake Factor
PM IF_{inh} = Inhalation Exposure Intake Factor x PM air concentration

RD_{oral} = Oral Reference Dose, mg/kg-day
RD_{inh} = Inhalation Reference Dose, mg/kg-day
PM Air = 37µg/m³ (site-specific value assumed to be 100% PM10)
RBC = Risk-based screening concentration at (target) HI=1.

CHEMICALS	IF _{derm} kg/kg-d	IF _{oral} kg/kg-d	PM Air Conc. kg/m ³	PM IF _{inh} kg/kg-d	Oral RD	Inhalation RD	RBC (mg/kg)	Cs (1000 X RBC) (mg/kg)	Maximum Conc. (mg/kg)	Maximum Conc. > Cs?
Subsurface Soil										
arsenic	0	1.80E-06	3.70E-08	7.59E-09	3.00E-04		1.67E+02	1.67E+05	3.70E+01	NO
cadmium	0	1.80E-06	3.70E-08	7.59E-09	1.00E-03		5.56E+02	5.56E+05	1.05E+01	NO
chloroethane	1.00E-06	1.80E-06	3.70E-08	7.59E-09		3	3.95E+08	3.95E+11	5.00E-02	NO
chloroform	1.00E-06	1.80E-06	3.70E-08	7.59E-09	1.00E-02		3.57E+03	3.57E+06	8.80E+00	NO
cis-1,3-dichloropropene	1.00E-06	1.80E-06	3.70E-08	7.59E-09	3.00E-04	5.00E-03	1.07E+02	1.07E+05	6.00E-03	NO
ethylbenzene	1.00E-06	1.80E-06	3.70E-08	7.59E-09	1.00E-01	3.00E-01	3.57E+04	3.57E+07	7.80E-01	NO
styrene	1.00E-06	1.80E-06	3.70E-08	7.59E-09	2.00E-01	3.00E-01	7.13E+04	7.13E+07	1.70E-02	NO
carbon tetrachloride	1.00E-06	1.80E-06	3.70E-08	7.59E-09	7.00E-04		2.50E+02	2.50E+05	1.40E+02	NO
1,2-dichloroethene	1.00E-06	1.80E-06	3.70E-08	7.59E-09	9.00E-03		3.21E+03	3.21E+06	9.00E-02	NO
pentachlorophenol	1.00E-06	1.80E-06	3.70E-08	7.59E-09	3.00E-02		1.07E+04	1.07E+07	9.50E-02	NO
fluoranthene	1.00E-06	1.80E-06	3.70E-08	7.59E-09	4.00E-02		1.43E+04	1.43E+07	1.00E+00	NO
pyrene	1.00E-06	1.80E-06	3.70E-08	7.59E-09	3.00E-02		1.07E+04	1.07E+07	1.30E+00	NO
1,4-dichlorobenzene	1.00E-06	1.80E-06	3.70E-08	7.59E-09		2.00E-01	2.64E+07	2.64E+10	4.30E-02	NO
acenaphthene	1.00E-06	1.80E-06	3.70E-08	7.59E-09	6.00E-02		2.14E+04	2.14E+07	2.80E-01	NO
di-n-octyl phthalate	1.00E-06	1.80E-06	3.70E-08	7.59E-09	2.00E-02		7.14E+03	7.14E+06	2.60E-01	NO
naphthalene	1.00E-06	1.80E-06	3.70E-08	7.59E-09	4.00E-02		1.43E+04	1.43E+07	2.00E+00	NO
benzoic acid	1.00E-06	1.80E-06	3.70E-08	7.59E-09	4.00E+00		1.43E+06	1.43E+09	4.00E-01	NO
anthracene	1.00E-06	1.80E-06	3.70E-08	7.59E-09	3.00E-01		1.07E+05	1.07E+08	2.60E-01	NO
butyl benzyl phthalate	1.00E-06	1.80E-06	3.70E-08	7.59E-09	2.00E-01		7.14E+04	7.14E+07	5.20E-01	NO
diethyl phthalate	1.00E-06	1.80E-06	3.70E-08	7.59E-09	8.00E-01		2.86E+05	2.86E+08	5.20E-02	NO
hexachloroethane	1.00E-06	1.80E-06	3.70E-08	7.59E-09	1.00E-03		3.57E+02	3.57E+05	1.10E+00	NO
hexachlorobutadiene	1.00E-06	1.80E-06	3.70E-08	7.59E-09	2.00E-04		7.14E+01	7.14E+04	1.70E-01	NO
4,4'-DDT	1.00E-06	1.80E-06	3.70E-08	7.59E-09	5.00E-04		1.79E+02	1.79E+05	1.40E-01	NO
Surface soil										
fluoranthene	1.00E-06	1.80E-06	3.70E-08	7.59E-09	4.00E-02		1.43E+04	1.43E+07	3.90E-01	NO
pyrene	1.00E-06	1.80E-06	3.70E-08	7.59E-09	3.00E-02		1.07E+04	1.07E+07	3.50E-01	NO

OU-2 DOMESTIC WATER SUPPLY SIMULATIONS

**The results of computer simulations of domestic
water production capabilities from subsurface units beneath
OU-2 at the Rocky Flats Plant, Golden, Colorado**

**This work was performed by the Earth Resources Division
for the Remediation Programs Division
in support of risk analysis studies.**

September 10, 1992

INTRODUCTION

To investigate the water production capabilities of the near surface hydrostratigraphic units beneath Operable-unit 2 at the Rocky Flats Plant several transient pumping computer simulations were performed. These simulations were designed to determine whether these units could produce sufficient water to supply a hypothetical four-member household. A daily pumping requirement of 240 gallons per day (gpd) was assumed based on a daily water requirement of 60 gallons per person.

Independent simulations were performed for three different hydrostratigraphic units. Models were constructed for the Rocky Flats Alluvium, hillslope colluvial materials, and an unconfined Arapahoe sandstone unit representing the #1 sandstone beneath OU-2. The Rocky Flats Alluvium and hillslope colluvial materials were not considered reliable water sources but were included in the simulations since they comprise the upper-most hydrostratigraphic units and have been impacted by plant activities. The Arapahoe sandstone unit was included because it was considered to be the best prospect for producing water from the Arapahoe Formation. The claystones of the Arapahoe formation were not considered good prospects for water and as such were not modeled.

METHOD

Simulations were performed using the USGS MODFLOW groundwater flow simulation package (McDonald and Harbaugh, 1988). Input parameters common to all simulations are listed in table 1. Separate simulations were done for the Rocky Flats Alluvium, hillslope colluvium and the Arapahoe sand unit. A listing of the input parameters for these simulations are given in tables 2, 3, and 4. Simulations were run using a daily time-frame until the pumping-well grid cell went dry or the end of the simulation (365 days) was reached.

Each day of the transient simulation was divided into two periods and each period was divided into two timesteps. The first 2.7 hours of each day was used as a pumping period. It was assumed that the household maintained water storage capabilities and that this pumping period was used to replenish the water storage

system. A pumping rate of 1.5 gpm was used. This rate is below the 3-5 gpm rate commonly used for domestic wells and as such is conservative. The pumping period was based on the total daily water requirement (240 gal.) and the pumping rate (1.5 gpm)

$$240 \text{ gal}/(1.5 \text{ gal/min} \cdot 60 \text{ min/hr}) = 2.7 \text{ hrs}$$

The remaining 21.3 hours of each day allowed water level recovery to take place.

The pumping well was located at the center of the grid cell array. A variable grid spacing ranging from 5 feet at the well to 50 feet at the boundaries was used to provide realistic drawdown conditions near the well. The grid spacing for each scenario are given in tables 2, 3, and 4.

Boundary conditions were either constant head (equal to the initial head) or no-flow depending on the scenario. For the Rocky Flats Alluvium and hillslope colluvium scenarios constant head boundaries were used at all boundaries. For the Arapahoe sandstone simulation the modeling grid was intended to represent a discontinuous channel sand deposit. To implement this configuration no-flow boundaries were placed along two parallel sides of the grid with constant head boundaries along the other two sides.

Table 1
Modeling parameters common to all scenarios

PARAMETER	VALUE	SOURCE
Water Requirement	240 gpd	Based on 60 gal/person/day
Pumping Rate	1.5 gpm	Assumed
Pumping Time per Day	2.7 hrs	Based on pumping rate
X to Y Anisotropy	1 (isotropic)	Assumed

ROCKY FLATS ALLUVIUM SCENARIO

Scenario specific parameters for the Rocky Flats Alluvium simulation are given in table 2. The modeling grid for this scenario consisted of a 19 by 19 grid cell array with the pumping well at the center of the grid and constant head boundaries (equal to the initial head) along each edge of the grid. The grid spacing in feet for the x and y directions increased from the well as follows 5_{well}-7-10-15-25-35-50-50-50-50_{boundary} (see figure 1). The hydraulic conductivity value comes from the recent OU-2 aquifer pump testing program. The value used represents the geometric mean of the results from two test locations. The specific yield came from lab analyses of core samples and example values from the literature for fine-grained materials (Fetter, 1980, pg. 68). The initial saturated thickness represents the historical average for well 1787 which is within OU-2. During initial pump test planning this well was observed to have the greatest alluvial saturated thickness and therefore should represent the most reliable OU-2 alluvial water source.

Table 2
Modeling Parameters for Rocky Flats Alluvium

PARAMETER	VALUE	SOURCE
Hydraulic Conductivity	1.6 ft/day	OU-2 pumping test
Specific Yield	0.10	Lab analyses/literature
Grid Spacing (variable)	from 5 to 50 ft	Assumed
Hydrogeologic Unit Condition	Unconfined	On-site observation
Initial Saturated Thickness	7.2 ft	Observation wells
Boundary Conditions	Constant head	Assumed

Results

For the Rocky Flats Alluvium scenario the pumping-well grid cell went dry within one to two hours after pumping started on the first day of the simulation. These results are consistent with the low pumping rates (0.3 - 0.056 gpm) required during field pump testing to avoid excessive drawdown.

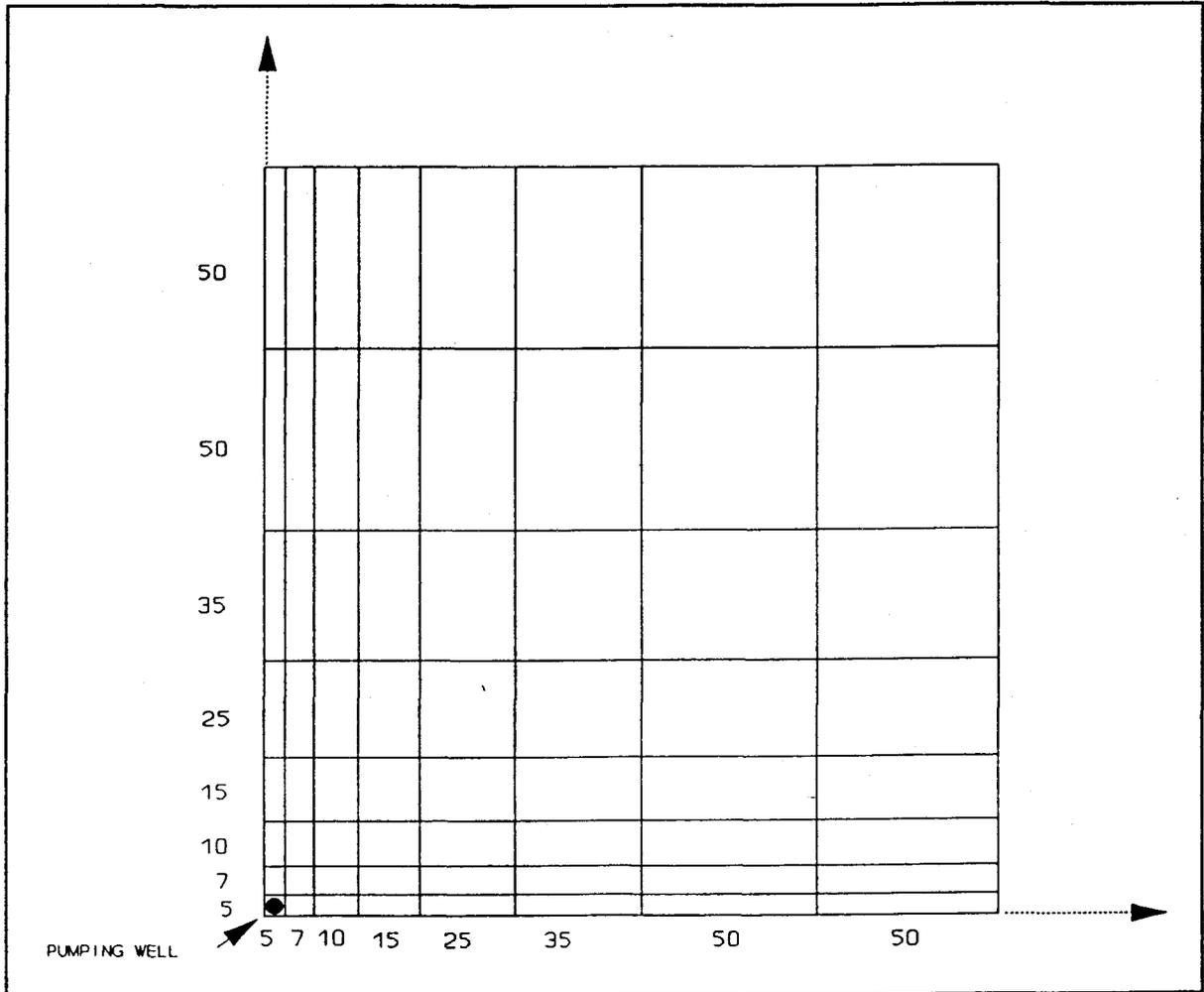


Figure 1. Figure shows 1/4 (upper right-hand quadrant) of an example model grid. In model well is at center of grid. Grid spacings in feet. The number of grid nodes for each model may differ, but grid spacings are similar. Not to scale.

HILLSLOPE COLLUVIUM SCENARIO

Scenario specific parameters for the hillslope colluvium simulation are given in table 3. The modeling grid for this scenario consisted of a 19 by 19 grid cell array with the pumping well at the center of the grid and constant head boundaries (equal to the initial head) along each edge of the grid. The grid spacing in feet in the x and y directions increased from the well as follows 5_{well}-7-10-15-25-35-50-50-50-50_{boundary} (see figure 1). Because there were no hydraulic conductivity values for OU-2 colluvium, data from slug-tests in colluvial material from OU-1 were used. These values should be representative of conditions in OU-2 since OU-1 and OU-2 are physically adjacent to each other. The specific yield came from lab analyses of core samples and example values from the literature for fine-grained materials (Fetter, 1980, pg. 68). The initial saturated thickness represents the average for well 0687 which is within OU-2. Comparisons of water level data indicate this well has historically had relatively large saturated thicknesses and would therefore represent conditions most promising for OU-2 colluvial water production.

Table 3
Modeling Parameters for Hillslope Colluvium

PARAMETER	VALUE	SOURCE
Hydraulic Conductivity	0.17 ft/day	OU-1 field testing
Specific Yield	0.10	Lab analyses/literature
Grid Spacing (variable)	from 5 to 50 ft	Assumed
Hydrogeologic Unit Character	Unconfined	On-site observation
Initial Saturated Thickness	3.6 ft	Observation wells
Boundary Conditions	Constant head	Assumed

Results

For the hillslope colluvium scenario the pumping-well grid cell went dry within one hour after pumping started on the first day of the simulation. This is consistent with the low hydraulic conductivity and small saturated thickness observed for colluvial materials.

ARAPAHOE SANDSTONE SCENARIO

Scenario specific parameters for the Arapahoe Sandstone simulation are given in table 4. The modeling grid for this scenario consisted of a grid cell array of 23 rows by 31 columns with the pumping well at the center of the grid. The rectangular shape of the modeling grid represents the elongate physical shape of the sandstone unit as reconstructed from borehole information. Constant head boundaries (equal to the initial head) were used along the first and last columns of the grid with no-flow boundaries set along the other two edges. The grid spacing in feet in the x and y directions increased from the well as follows 5_{well}-7-10-15-25-35-50-50- ... -50_{boundary} (see figure 1). The hydraulic conductivity value came from OU-2 aquifer pump testing. The specific yield is assumed equal to the effective porosity computed for this sandstone from the OU-2 tracer test program. The initial saturated thickness represents the historic average for well 3687 which was included in the OU-2 aquifer test program for the #1 Arapahoe Sandstone.

Table 4
Modeling Parameters for Arapahoe Sandstone

PARAMETER	VALUE	SOURCE
Hydraulic Conductivity	1.1 ft/day	OU-2 field testing
Specific Yield	0.12	OU-2 tracer testing
Grid Spacing (variable)	from 5 to 50 ft	Assumed
Hydrogeologic Unit Condition	Unconfined	On-site observation
Initial Saturated Thickness	33.7 ft	Observation wells
Boundary Conditions	Constant head & No flow	Assumed

Results

For the Arapahoe Sandstone scenario the pumping well was able to meet the water requirement without dewatering the pumping-well grid cell. The maximum draw down observed at the pumping well after 365 days was 3.2 feet indicating that the aquifer was not highly stressed at this pumping rate. These results are consistent

with OU-2 aquifer testing that resulted in approximately seven feet of draw down after five days of continuous pumping at 1.6 gpm.

SUMMARY OF FINDINGS

Based on groundwater flow simulation results neither the Rocky Flats Alluvium nor the hillslope colluvium materials within OU-2 are capable of producing sufficient water to support a four-member household consuming 240 gallons per day. Using a 2.7 hour daily pumping period and a rate of 1.5 gpm, both the alluvium and the colluvium wells would be pumped dry within one day (table 5). In contrast, a well within the Arapahoe sandstone beneath OU-2 would appear to provide a reliable water resource at the required rates given above. The well grid-point in this simulation experienced only minimal drawdown after one year of daily-pumping cycles.

Table 5

Summary of simulation results

FORMATION	WATER PRODUCTION DAYS
Rocky Flats Alluvium	< 1
Hillslope Colluvium	< 1
Arapahoe Sandstone	> 365

To investigate the water resource potential for the OU-2 Arapahoe sandstone unit the total water available from this unit was computed (table 6). The average spatial dimensions of the sandstone unit were taken from isopach maps constructed from well and borehole information. The average saturated thickness is an assumed value derived from observational water level data and sandstone thickness information. The specific yield is assumed equal to the effective porosity as used

above.

Assuming an annual water requirement of 2,920 cubic feet (equivalent to 60 gal/day • 365 days) there appears to be sufficient water volume in the sand to support ten four-person families for approximately 54 years (6,300,000 cu ft / (2,920 cu ft/person/year • 40 persons) = 53.9 years). This assumes complete desaturation of the aquifer (which is virtually impossible) and does not account for any external recharge to the aquifer.

Table 6

Arapahoe Sandstone Water Resource Evaluation

DESCRIPTION	VALUE	UNITS
Length of sand	4,200	ft
Width of sand	500	ft
Sat. thickness of sand	25	ft
Total saturated sand vol	52,500,000	cu ft
Specific yield	0.12	
Total water volume	6,300,000	cu ft
Daily water need	60	gal/person/day
Daily water need	8	cu ft/person/day
Annual water need	2,920	cu ft/person/year
Available water	2,158	person/years

References

Fetter, C.W. Jr., 1980, Applied Hydrogeology, Merrill Publishing Company, Columbus, 488 p.

McDonald, Michael G. and Harbaugh, Arlen W., 1988, Techniques of Water-Resources Investigations of the United States Geological Survey, Book 6, Chapter A1, A Modular Three-dimensional Finite-difference Groundwater Flow Model.

APPENDIX D
BACKGROUND COMPARISON FOR DISSOLVED METALS AND RADIONUCLIDES
NO. 1 SANDSTONE

TABLE D-1
ROCKY FLATS PLANT OU-2
95% UTL COMPARISON
DISSOLVED METALS IN GROUNDWATER, µg/L
NO. 1 SANDSTONE

Analyte	OU-2 Detected			Bknd Max	Background 95% UTL(1)	% of OU-2 data > 95% UTL(2)
	Min	Max	Approx. DF			
Aluminum	8.6	367	85	3,780	1,050	0
Antimony	9	56	15	36	44	2
Arsenic	1	1	6	15	8	0
Barium	82	352	100	182	152	59
Beryllium	1	3	5	3.5	4	0
Cadmium	1	98	13	7	4	2
Cesium	30	100	19	1,250	870	0
Chromium	3	23	19	16	11	5
Cobalt	3	3	1	25	40	0
Copper	2	9	19	175	55	0
Lead	1	2	5	22	10	0
Lithium	2	38	79	249	129	0
Manganese	1	1,240	68	440	158	20
Mercury	0.21	0.25	2	1.2	0.5	0
Molybdenum	3	16	36	114	125	0
Nickel	2	23	22	20	31	0
Selenium	1	10	48	76	31	0
Silver	2	4	7	12.5	12	0
Strontium	253	744	98	1,910	1,040	0
Thallium	1	2	6	5	8	0
Tin	14	34	7	100	137	0
Vanadium	3	10	76	25	35	0
Zinc	2	56	69	120	47	4

- (1) Calculated using data from Arapahoe/Laramie formation wells reported in the Background Geochemical Characterization Report, Rocky Flats Plant. EG&G 1992.
- (2) UTL comparison is performed using the detection limit for results reported as non-detect. Therefore, the maximum detected value in OU-2 can be below the 95% UTL of background even though the UTL comparison shows that a certain percentage of OU-2 data exceeds the 95% UTL of background.

DF = Detection frequency based on working database of August 1993. Detection frequency is approximate because continuing quality review of the database may result in minor changes to the number of results.

TABLE D-2
ROCKY FLATS PLANT OU-2
95% UTL COMPARISON
DISSOLVED RADIONUCLIDES IN GROUNDWATER, pCi/L
NO. 1 SANDSTONE

Analyte	OU-2 Detected (1)			Bknd	Bknd 95%	% OU-2 data
	Min	Max	DF	Max	UTL (2)	> 95% UTL
Americium-241	0.005	0.04	4/4	-	NE	*
Cesium-137	0.6	0.5	2/4	-	NE	*
Plutonium-239,240	0.006	0.006	4.4	-	NE	*
Radium-226	0.3	1.0	19/19	2.9	3.86	0
Strontium-89,90	0.009	1.6	87/95	1.3	0.9	6.3
Tritium	6.7	736	73/73	413	357	11
Uranium-233,234	0.67	12	101/101	16	12.00	1
Uranium-235	0.02	0.43	75/81	0.4	0.33	2
Uranium-238	0.4	9.4	97/97	10	7.7	1

(1) Based on edited database of August 1993.

(2) Calculated using data from Arapahoe/Laramie formation wells reported in the Background Geochemical Char Report, Rocky Flats Plant, EG&G 1992.

DF = Detection frequency (no. detects/no. samples), based on edited database of August 1993.

NE = not evaluated.. Data insufficient to calculate 95% UTL.

* Comparison cannot be made.

TABLE D-3
ROCKY FLATS PLANT OU-2
ANOVA COMPARISON
DISSOLVED METALS IN GROUNDWATER, µg/L
NO. 1 SANDSTONE

Analyte	Background(1)		OU-2 Data		Norm Dist?	Test(2)	Result (Chi-Square)	P =	Significantly Different?	Bknd Mean = /> OU2 Mean(3)	Consider Further?
	Arith. Mean	SD	Arith. Mean	SD							
Aluminum	111	468	59	51	No	Kruskal	0.83	0.36	N	Y	N
Antimony	21	11	25	9	No	Kruskal	3.28	0.07	N	N	N
Arsenic	4	2	4	2	No	Kruskal	2.36	0.12	N	Y	N
Barium	86	33	167	52	No	Kruskal	78.28	<0.01	Y	N	Y
Beryllium	2	1	2	0.78	No	Kruskal	1.31	0.25	N	Y	N
Cadmium	2	1	3	10	No	Kruskal	0.02	0.88	N	N	N
Cesium	386	237	363	181	No	Kruskal	0.11	0.75	N	Y	N
Chromium	6	3	5	3	No	Kruskal	2.17	0.14	N	Y	N
Cobalt	19	10	21	9	No	Kruskal	1.03	0.31	N	N	N
Copper	13	21	9	5	No	Kruskal	1.74	0.19	N	Y	N
Lead	3	4	1	0.34	No	Kruskal	10.11	<0.01	Y	Y	N
Lithium	38	45	13	14	No	Kruskal	32.22	<0.01	Y	Y	N
Manganese	22	67	104	213	No	Kruskal	4.76	0.03	Y	N	Y
Mercury	0.12	0.17	0.09	0.04	No	Kruskal	2.51	0.11	N	Y	N
Molybdenum	41	42	53	47	No	Kruskal	0.18	0.67	N	N	N
Nickel	15	8	15	7	No	Kruskal	0.07	0.80	N	Y	N
Selenium	6	12	2	1	No	Kruskal	4.74	0.03	Y	Y	N
Silver	6	3	4	2	No	Kruskal	3.15	0.08	N	Y	N

TABLE D-3
(Concluded)

Analyte	Background(1)		OU-2 Data		Norm Dist?	Test(2)	Result (Chi-Square)	P =	Significantly Different?	Bknd Mean = /> OU2 Mean(3)	Consider Further?
	Arith. Mean	SD	Arith. Mean	SD							
Strontium	397	231	447	115	No	Kruskal	18.72	<0.01	Y	N	Y
Thallium	4	2	4	2	No	Kruskal	0.55	0.46	N	Y	N
Tin	54	41	79	38	No	Kruskal	11.69	<0.01	Y	N	Y
Vanadium	15	10	7	6	No	Kruskal	13.05	<0.01	Y	Y	N
Zinc	13	17	11	11	No	Kruskal	4.23	0.04	Y	Y	N

(1) Background data are from bedrock (Arapahoe/Laramie formation) wells. There is no No. 1 Sandstone in the background sampling area.

(2) The Kruskal analysis is used on non-normally distributed data.

(3) If the background mean is equal to or higher than OU-2 mean, a statistically significant difference (P<0.05) is not applicable.

TABLE D-4
 ROCKY FLATS PLANT OU-2
 ANOVA COMPARISON
 DISSOLVED RADIONUCLIDES IN GROUNDWATER, pCi/L
 NO. 1 SANDSTONE

Analyte	Background (1)		OU-2 Data				Test (2)	Result (Chi-Square)	P =	Significant y Different?	BKG Mean >OU2 Mean (3)	Consider Further?	
	Arith. Mean	SD	Arith. Mean	SD	Norm Dist?								
Americium-241	-(4)	-	0.02	0.02	No	Kruskal	0.50	0.48	N	-	-	?	
Cesium-137	-	-	0.28	0.19	No	Kruskal	-	-	-	-	-	Y	
Plutonium-239, 240	-	-	<0.01	<0.01	No	Kruskal	-	-	-	-	-	Y	
Radium-226	0.71	1	0.58	0.16	No	Kruskal	5.76	0.02	Y	Y	Y	N	
Strontium-89,90	0.34	0.26	0.38	0.30	No	Kruskal	0.17	0.68	N	N	N	N	
Tritium	130	104	202	150	No	Kruskal	7.09	<0.01	Y	N	N	Y	
Uranium-233, 234	3	4	3	2	No	Kruskal	4.03	0.04	Y	Y	Y	N	
Uranium-235	0.13	0.09	0.12	0.08	No	Kruskal	0.12	0.73	N	N	Y	N	
Uranium-238	2	3	2	1	No	Kruskal	8.31	<0.01	Y	Y	Y	N	
Total Radioactive Cesium	-	-	0.60	0.52	-	-	-	-	-	-	-	-	?

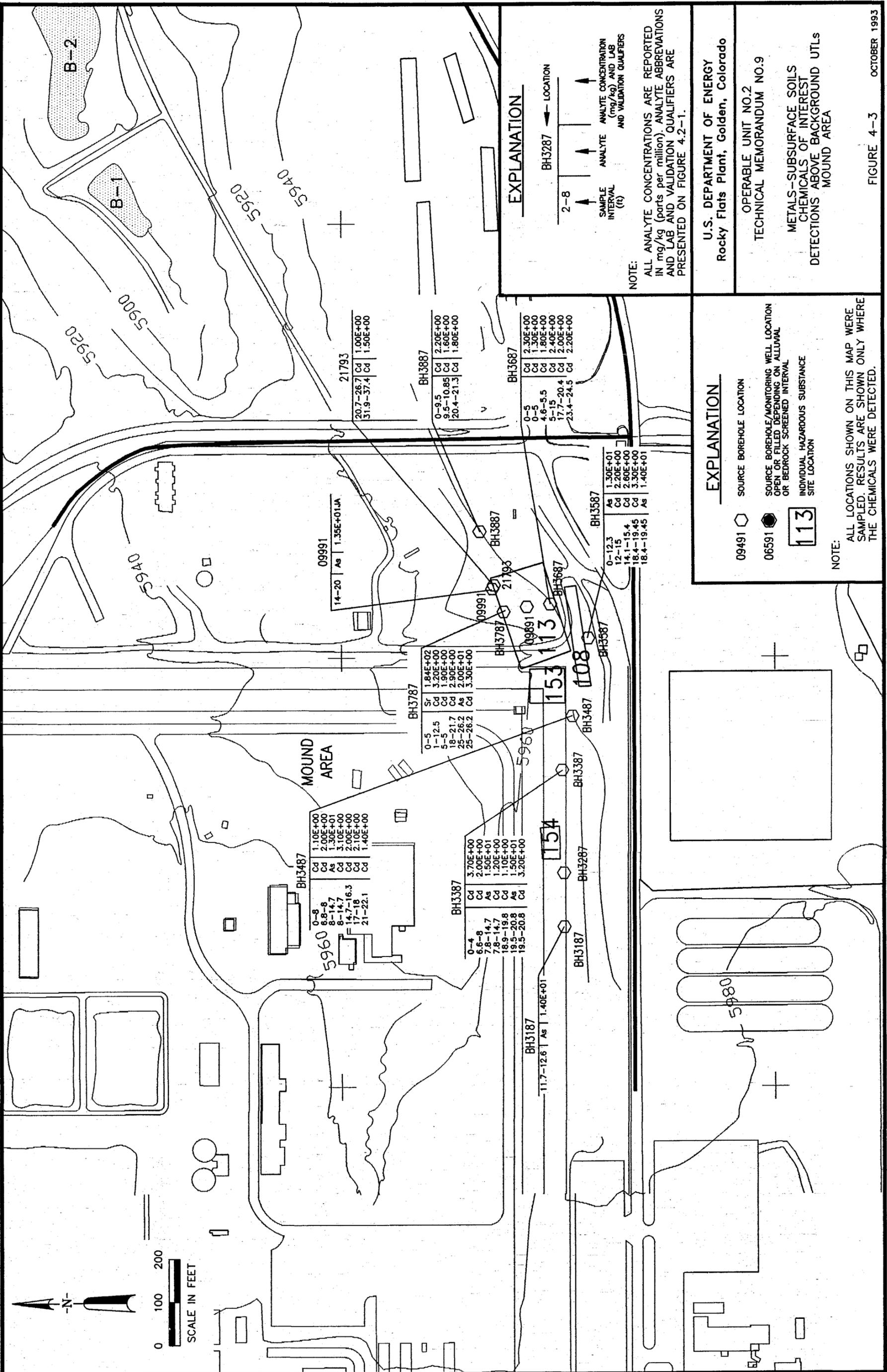
(1) Background data are from bedrock (Arapahoe/Laramie formation) wells. There is no No. 1 Sandstone in the background sampling area.

(2) The Kruskal analysis is performed on non-normally distributed data.

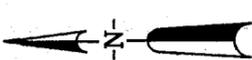
(3) If the background mean is higher than OU-2 data mean, a statistically significant difference (P<0.05) is not applicable.

(4) One background data point.

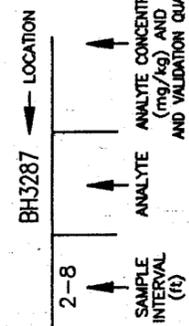
- No data



0 100 200
SCALE IN FEET

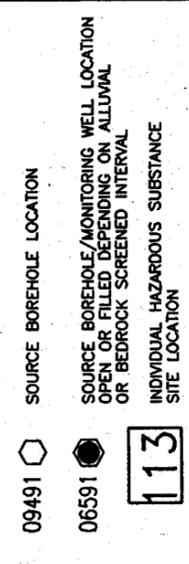


EXPLANATION



NOTE:
ALL ANALYTE CONCENTRATIONS ARE REPORTED IN mg/kg (parts per million). ANALYTE ABBREVIATIONS AND LAB AND VALIDATION QUALIFIERS ARE PRESENTED ON FIGURE 4.2-1.

EXPLANATION

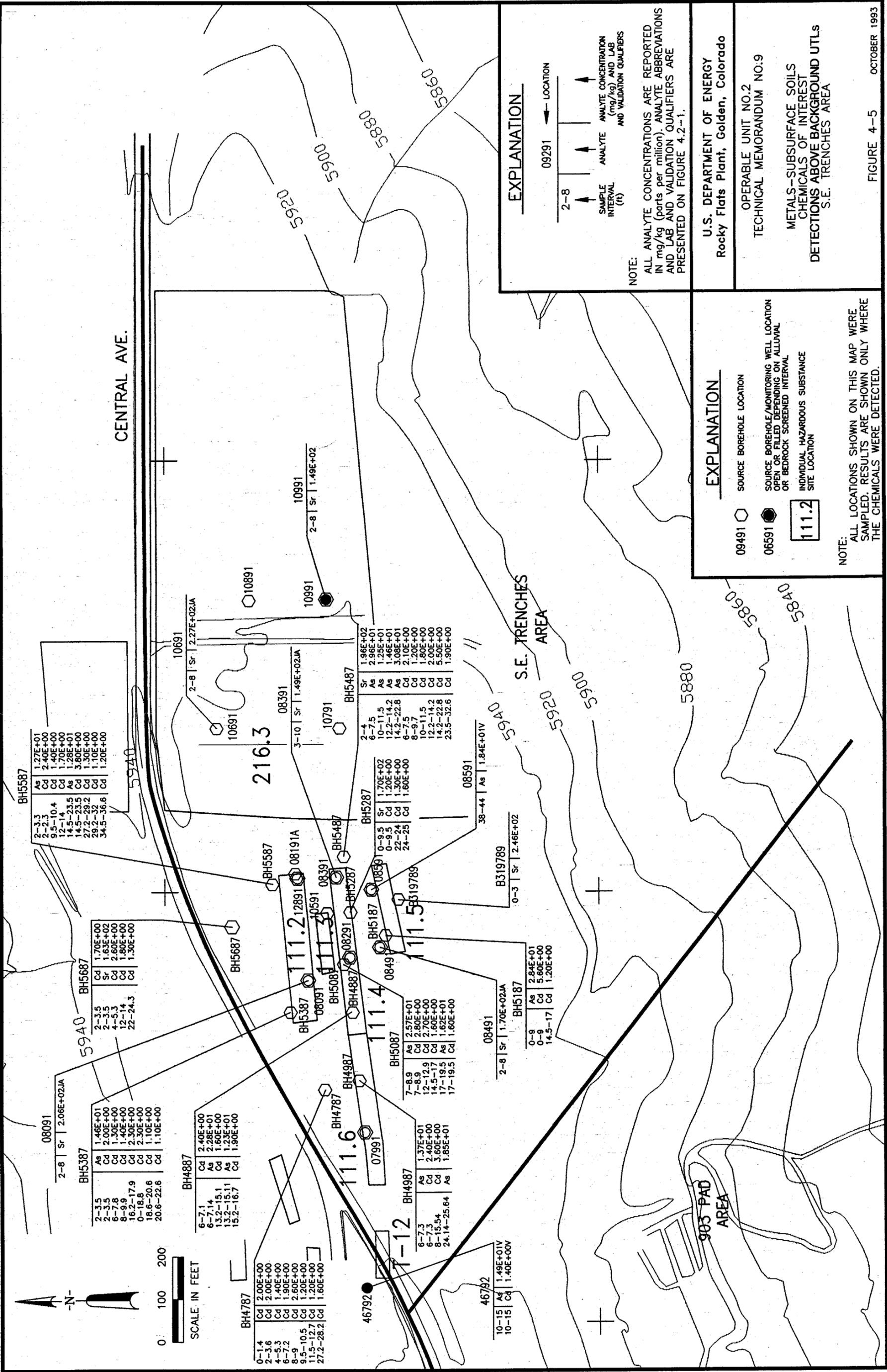


NOTE:
ALL LOCATIONS SHOWN ON THIS MAP WERE SAMPLED. RESULTS ARE SHOWN ONLY WHERE THE CHEMICALS WERE DETECTED.

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO.2
TECHNICAL MEMORANDUM NO.9

METALS-SUBSURFACE SOILS
CHEMICALS OF INTEREST
DETECTIONS ABOVE BACKGROUND UTILS
MOUND AREA



EXPLANATION

09291 ← LOCATION

2-8 ↑ SAMPLE INTERVAL (ft)

↑ ANALYTE

↑ ANALYTE CONCENTRATION (mg/kg) AND LAB AND VALIDATION QUALIFIERS

NOTE:
ALL ANALYTE CONCENTRATIONS ARE REPORTED IN mg/kg (parts per million). ANALYTE ABBREVIATIONS AND LAB AND VALIDATION QUALIFIERS ARE PRESENTED ON FIGURE 4.2-1.

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO.2
TECHNICAL MEMORANDUM NO.9

METALS-SUBSURFACE SOILS
CHEMICALS OF INTEREST
DETECTIONS ABOVE BACKGROUND UTILS
S.E. TRENCHES AREA

EXPLANATION

○ 09491 SOURCE BOREHOLE LOCATION

● 06591 SOURCE BOREHOLE/MONITORING WELL LOCATION OPEN OR FILLED DEPENDING ON ALLUVAL OR BEDROCK SCREENED INTERVAL

111.2 □ INDIVIDUAL HAZARDOUS SUBSTANCE SITE LOCATION

NOTE:
ALL LOCATIONS SHOWN ON THIS MAP WERE SAMPLED. RESULTS ARE SHOWN ONLY WHERE THE CHEMICALS WERE DETECTED.

EXPLANATION

- 10-ACRE SAMPLING PLOT LOCATION
- 2.5-ACRE SAMPLING PLOT LOCATION
- 10-ACRE PLOT NOT SAMPLED
- 2.5-ACRE PLOT NOT SAMPLED
- SURFACE WATER SAMPLING LOCATION

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO.2
CHEMICALS OF CONCERN
TECHNICAL MEMORANDUM NO.9

1991 RADIONUCLIDE SURFICIAL
SOIL SAMPLING PLOT LOCATIONS

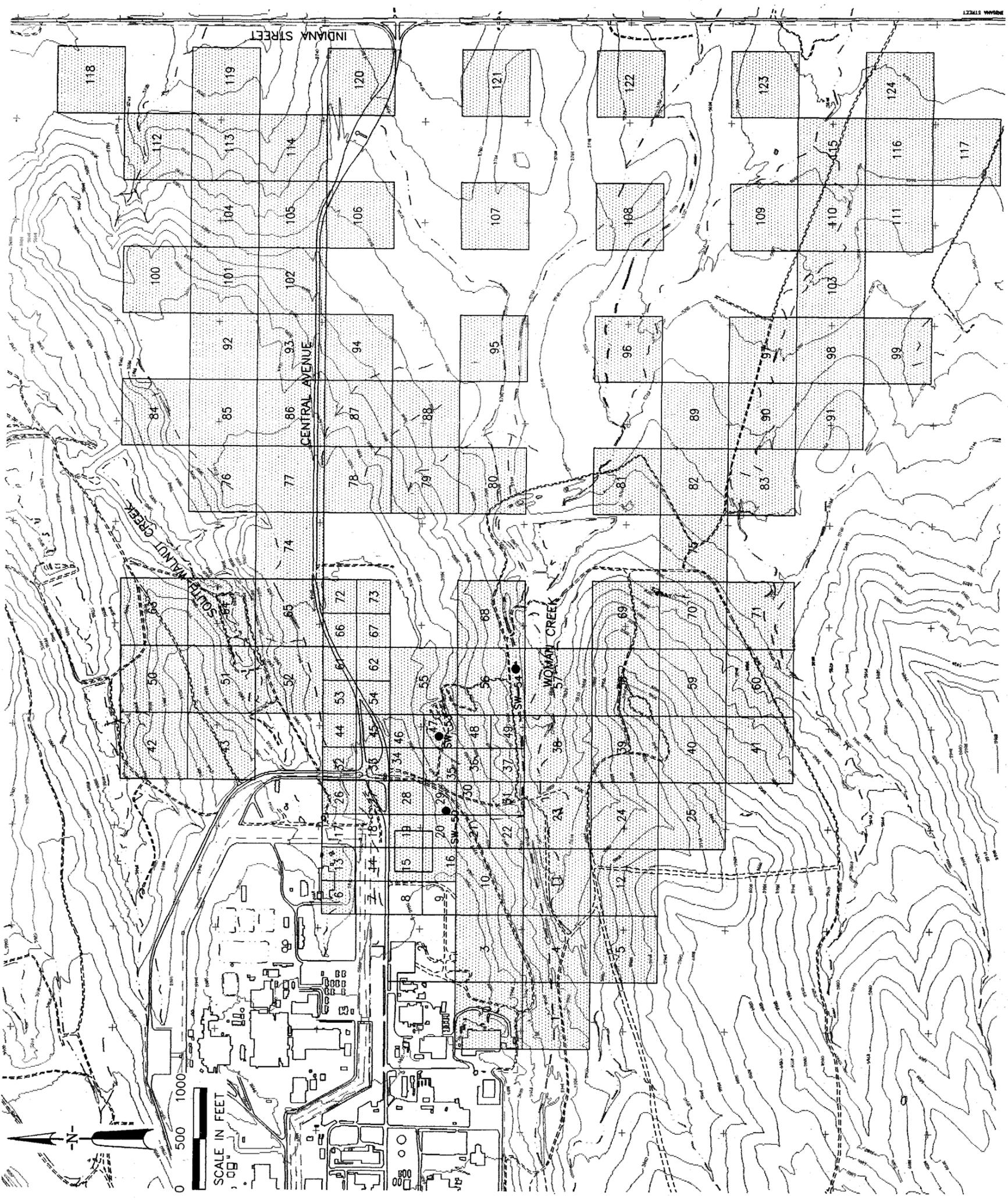


FIGURE 5-1 AUGUST 1993
N1271064 1-1000

EXPLANATION

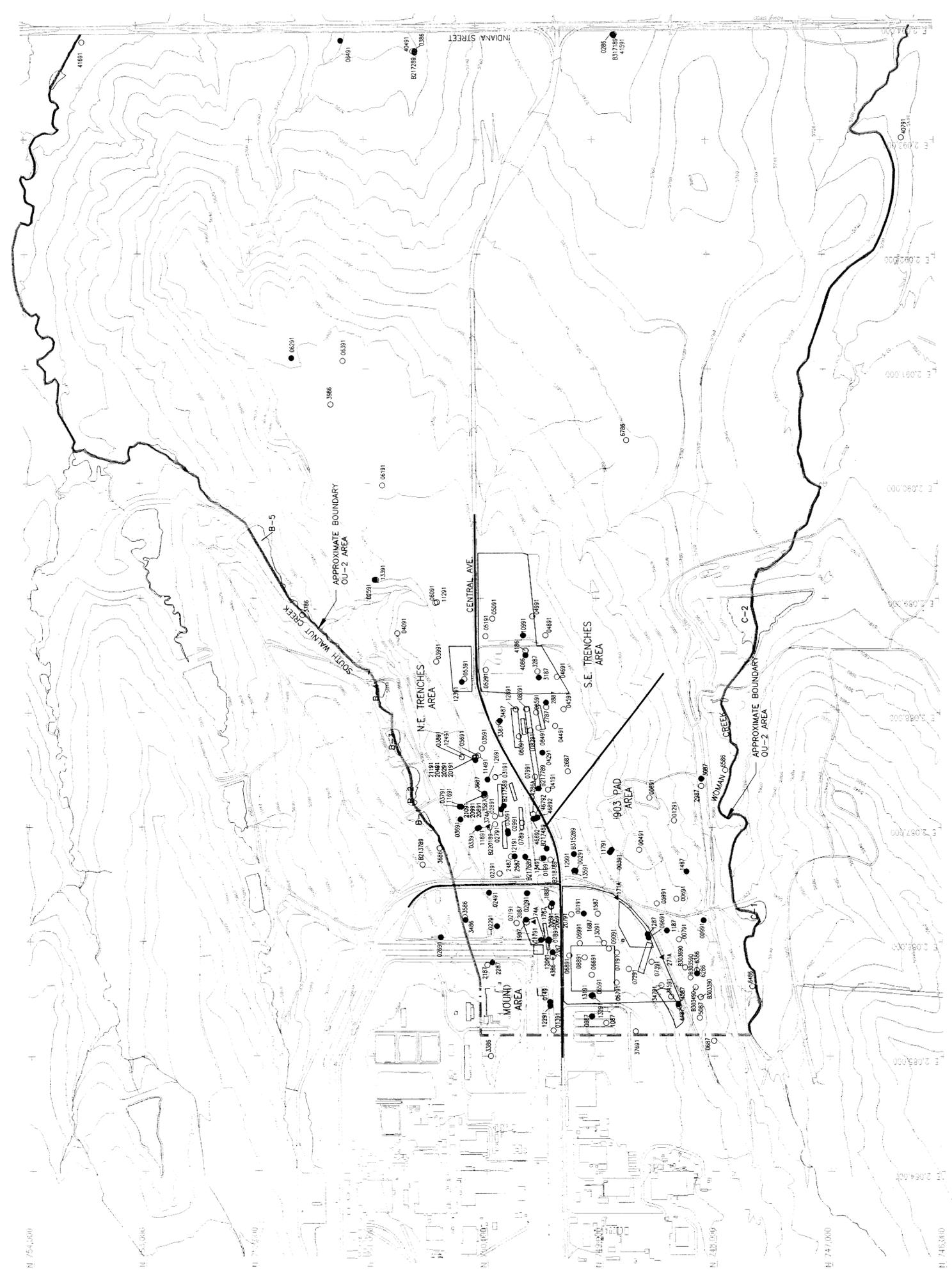
- 3786 ○ 1986-1990 ALLUVIAL MONITORING WELL
- 3087 ● 1986-1990 BEDROCK MONITORING WELL
- 00191 ○ 1991-1992 ALLUVIAL MONITORING WELL
- 12891 ● 1991-1992 BEDROCK MONITORING WELL
- 20591 -□- 1991 TEST WELL CLUSTER
- 4288A ○ ABANDONED MONITORING WELL
- 174A ▲ 1971-1974 MONITORING WELL
- INDIVIDUAL HAZARDOUS SUBSTANCE SITE LOCATION
- APPROXIMATE BOUNDARY OF OU-2 STUDY AREA



SCALE : 1 INCH = 500 FEET
 1000' 0 1000'
 CONTOUR INTERVAL = 20'

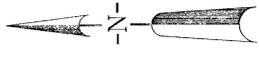
U.S. DEPARTMENT OF ENERGY
 Rocky Flats Plant, Golden, Colorado
 OPERABLE UNIT NO.2
 CHEMICALS OF CONCERN
 TECHNICAL MEMORANDUM NO.9

OU-2 MONITORING WELL LOCATIONS
 (HISTORICAL, PHASE II, AND OTHER INVESTIGATIONS)



EXPLANATION

- BH187 O 1987 BOREHOLE LOCATION
- B31788 O 1989-1990 BOREHOLE LOCATION
- 09481 O 1991-1992 BOREHOLE LOCATION
- 0191A O ABANDONED MONITORING WELL INSTALLATION ATTEMPT
- INDIVIDUAL HAZARDOUS SUBSTANCE SITE LOCATION
- APPROXIMATE BOUNDARY OF OU-2 STUDY AREA



SCALE : 1 INCH = 500 FEET

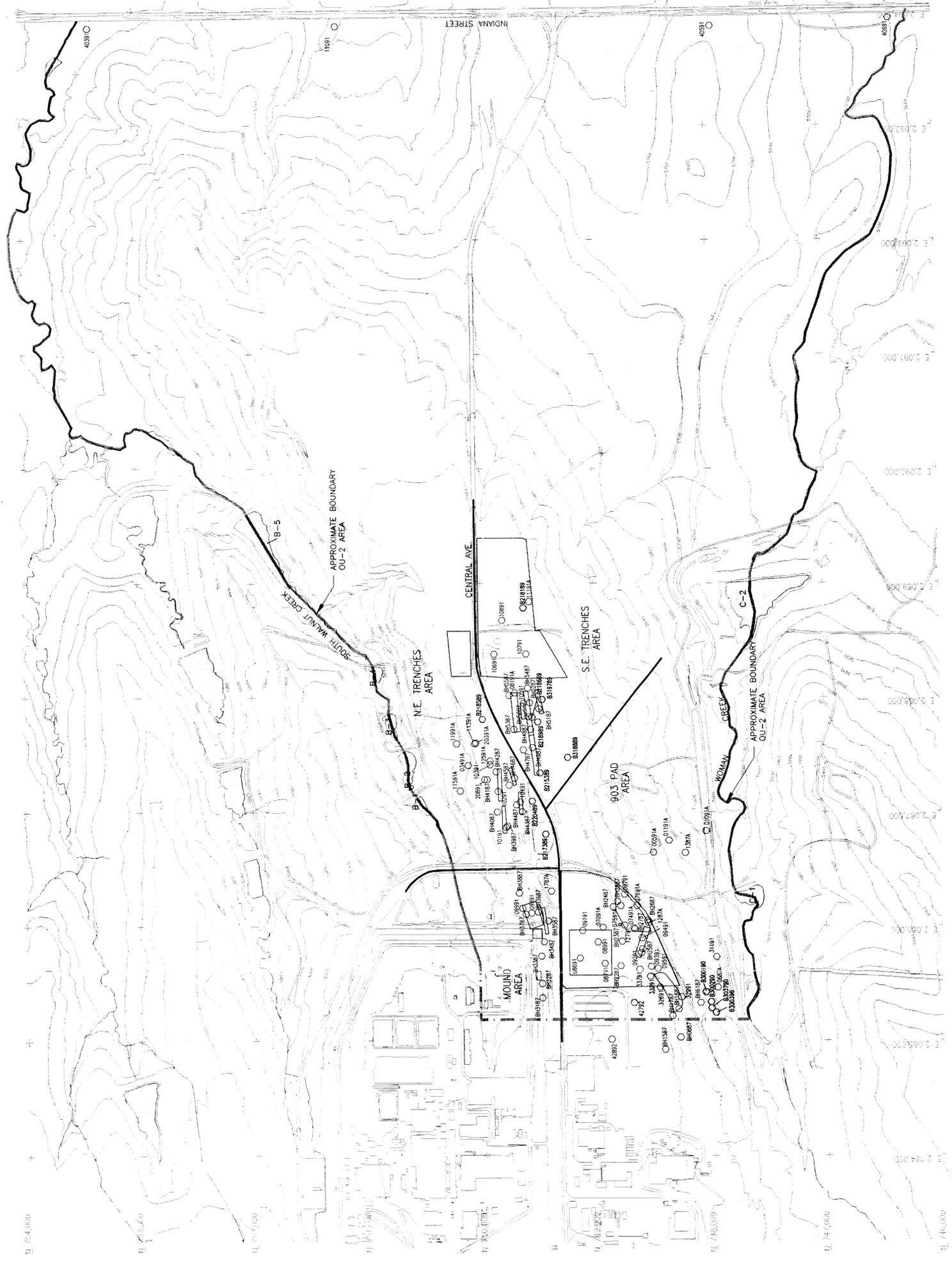
1000' 0 1000'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO.2
CHEMICALS OF CONCERN
TECHNICAL MEMORANDUM NO.9

OU-2 BOREHOLE LOCATIONS
(HISTORICAL, PHASE II, AND OTHER INVESTIGATIONS)



EXPLANATION

- 50' x 100' PLOT
- BIASED SURFICIAL SOIL SAMPLING PLOT LOCATION
- GRID-BASED SURFICIAL SOIL SAMPLING PLOT LOCATION

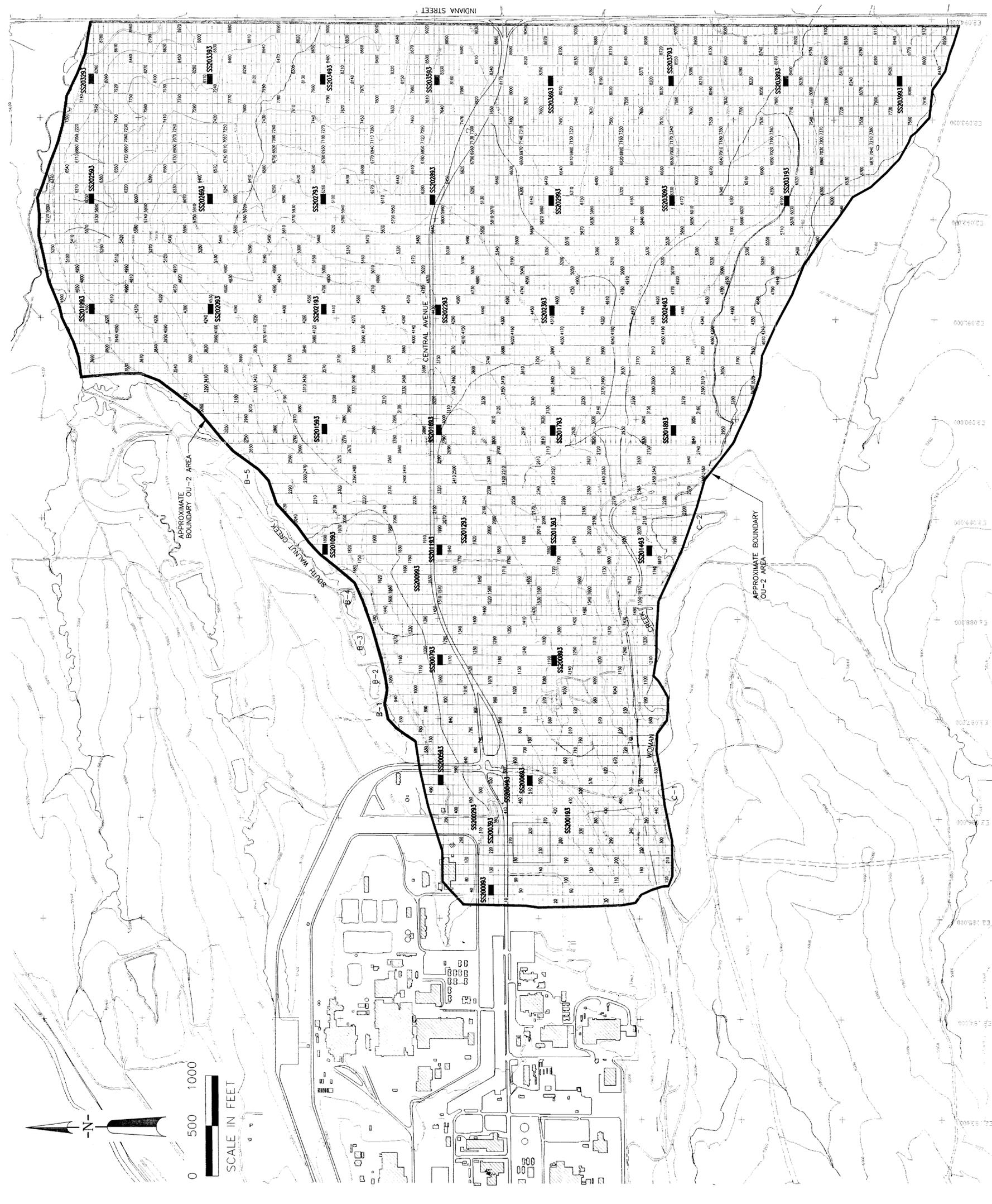
8619
SS200193

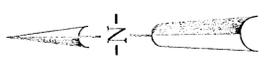
SS200093

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO.2
CHEMICALS OF CONCERN
TECHNICAL MEMORANDUM NO.9

1993 SURFICIAL SOIL SAMPLING
PLOT LOCATIONS





0 250 500
SCALE IN FEET

EXPLANATION

- BIASED SAMPLING PLOT LOCATION
- GRID-BASED SAMPLING PLOT LOCATION
- 507 (SS200493) → LOCATION PROPOSED (ACTUAL)
BENZO(F)FLUORANTHENE | 1.1E+02J
- ↑ ANALYTE
- ↑ ANALYTE CONCENTRATION
(µg/kg) AND LAB
AND VALIDATION QUALIFIERS

ANALYTE ABBREVIATIONS AND LAB AND VALIDATION QUALIFIERS ARE PRESENTED ON THE LEGEND PAGE FIGURE 4.2-1

NOTE:
ALL LOCATIONS SHOWN ON THIS MAP WERE SAMPLED.
RESULTS ARE SHOWN ONLY WHERE THE CHEMICALS
WERE DETECTED.

CONTOUR INTERVAL = 40'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT NO.2
TECHNICAL MEMORANDUM NO. 9

SEMIVOLATILE ORGANIC
COMPOUNDS DETECTED IN
SURFACE SOILS
DRAWN (RFP METHOD)

