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Engineering Evaluation/Cost Analysis
Groundwater Interim Removal Action
LEHR Environmental Restoration
Davis, California

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OFFICE OF ENVIRONMENTAL HEALTH AND SAFETY
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April 11, 1997

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Re: Final Engineering Evaluation/Cost Analysis (EE/CA) Report

Dear Mr. Austin, Ms. Ficklin, Ms. Timm, and Mr. Hsu:

Enclosed please find a copy of the Final Engineering Evaluation/Cost Analysis Report for the anticipated groundwater Interim Removal Action (IRA) at the LEHR and South Campus Disposal Sites. This report has been prepared at your request and incorporates comments received on the draft EE/CA that was issued in January 1997. The comments and corresponding responses to the draft EE/CA have been incorporated as Appendix A to this Final EE/CA.

In addition to distribution to the LEHR/SCDS Remedial Project Managers, this Final EE/CA will also be re-noticed for public comment for 30 days. Comments received by UC Davis to the Final EE/CA will be addressed in the groundwater IRA Removal Action Work Plan.

If you have any questions about the enclosed document, please call me at (916) 752-6041. Written comments on the EE/CA Report can be sent to my attention at the following address:

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ENGINEERING EVALUATION/COST ANALYSIS
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LIST OF ACRONYMS AND ABBREVIATIONS

ARARs	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
ATC	Authority to Construct
(T-)BACT	(Toxic-)Best Available Control Technology
bgs	below ground surface
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DOE	(US) Department of Energy
DWR	(State of California) Department of Water Resources
EE/CA	Engineering Evaluation/Cost Analysis
gpm	gallons per minute
HSU	hydrostratigraphic unit
IRA	Interim Removal Action
LEHR	Laboratory for Energy-related Health Research
MCLs	Maximum Contaminant Levels
mgd	million gallons per day
mg/L	milligrams per liter
NCP	National Oil and Hazardous Substances Pollution and Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NSR	(Yolo-Solano Air Quality Management District) New Source Review
pCi/L	picocuries per liter
PNL	Pacific Northwest Laboratories
PNNL	Pacific Northwest National Laboratories
PRG	Preliminary Remediation Goal
ppb	parts per billion
PTO	Permit to Operate
RO	reverse osmosis
ROG	Reactive Organic Gases
RWQCB	Regional Water Quality Control Board
SCDS	South Campus Disposal Site
SVOC	semi-volatile organic compound
SWAT	Solid Wastewater Quality Assessment Test
SWRCB	State Water Resources Control Board
TAC	Toxic Air Contaminant
TBC	To-Be-Considered Criteria
TDS	Total Dissolved Solids
UC Davis	University of California, Davis
UIC	Underground Injection Control
USEPA	United States Environmental Protection Agency
UTL	upper tolerance limits
VOC	volatile organic compound
WDR	Waste Discharge Requirement
WWTP	Wastewater Treatment Plant
YSAQMD	Yolo-Solano Air Quality Management District
μg/L	micrograms per liter

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0.0 EXECUTIVE SUMMARY

This Engineering Evaluation/Cost Analysis (EE/CA) Report has been prepared for the anticipated groundwater Interim Removal Action (IRA) at the Laboratory for Energy-related Health Research/ Davis South Campus Disposal Site (Site) at the University of California, Davis (UC Davis). The groundwater IRA is considered a non-time critical Removal Action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program currently being conducted at the Site. In general, the IRA is being conducted to prevent, minimize, or mitigate potential damage to public health and the environment. The EE/CA focuses on evaluating alternatives for capturing, treating, and disposing of groundwater that is pumped from the second hydrostratigraphic unit (HSU) at a location downgradient of site sources. As an interim and non-time critical removal action, the anticipated groundwater IRA as defined in this EE/CA is limited in scope and is not intended to be the final long-term remedy for groundwater impacts at LEHR/SCDS.

The EE/CA supplements and refines ideas and analyses presented in three previous documents prepared for the groundwater IRA. UC Davis prepared a Conceptual Work Plan (UC Davis, 1995), proposing the groundwater IRA to the U.S. Environmental Protection Agency (US EPA) and other regulatory oversite agencies in November 1995. An Assessment of Remedial Options (Dames & Moore, 1996a), presented a review of remedial alternatives that intercept and treat volatile organic compounds (VOCs) in groundwater at the UC Davis property boundary. Alternatives screened in the Assessment of Remedial Options were developed for further analysis in the Technical Memorandum/Work Plan for Pre-design Activities (Dames & Moore, 1996b). The results of these pre-design activities are presented in this EE/CA report in support of the remedial action evaluation and the UC Davis recommendations. Each of the documents preceding this EE/CA has been refined based on comments received from site regulatory oversight agencies and members of the public. The Remedial Action Objectives stipulated for the IRA are presented below.

- To prevent, minimize, or mitigate potential threat to public health or the environment.
- To eliminate or substantially decrease potential offsite migration of constituents of concern in HSU-2 at the Site through plume containment and without impacting potential site source areas.
- To substantially reduce the overall mass of constituents of concern in HSU-2 groundwater.
- To provide information on aquifer response and effects of long-term pumping.
- To provide information on the quality of extracted groundwater.

- To provide operational data which will aid in assessment of groundwater treatment effectiveness and the need for further groundwater remedial action.

- To provide data on reinjection effectiveness.

Evaluation of groundwater impacts at the Site, which include quarterly groundwater monitoring and several phases of in-situ groundwater sample collection, have identified chloroform (and associated VOCs), hexavalent chromium and chromium, nitrate, TDS, and tritium as the primary constituents of concern. Chloroform in HSU-2 extends approximately 2,000 feet beyond the UC Davis property boundary. Chloroform, hexavalent chromium, nitrate, and TDS are reported at elevated concentrations in HSU-1 in the areas up- and downgradient of extraction well EW2-1 (see Figure 3). Tritium is relatively localized in HSU-1, and at lower concentrations in HSU-2 near monitoring wells UCD1-13 and UCD2-14, upgradient of extraction well EW2-1.

Background groundwater quality conditions were evaluated from three sources: water quality data from municipal, domestic and irrigation wells in the Davis area; data collected as part of the Site neighbor's well sampling program; and data from upgradient monitoring wells UCD1-18 and UCD2-17 as part of the Site groundwater monitoring program. The background data indicate that concentrations of several key Site constituents, such as nitrate, hexavalent chromium, and TDS, vary greatly.

The anticipated quality of extracted groundwater was estimated based on samples collected and analyzed from extraction well EW2-1. In general, this estimate is consistent with Site groundwater monitoring and hydropunch data and is representative of HSU-2 conditions in the vicinity of the extraction well. However, the quality of extracted water could change during the IRA as a result of prolonged extraction or seasonal stresses on HSU-2. Continued groundwater monitoring will play a key role in tracking potential changes in water quality during operation of the IRA. A monitoring plan will be implemented to provide data for evaluation of system effectiveness. The plan will include contingencies to address potential problems or non-compliance issues.

Aquifer pumping tests and analyses were conducted, as planned and described in the Technical Memorandum/Work Plan (Dames & Moore, 1996b). One potential extraction well (EW2-1) and four observation wells were installed to facilitate completion of these tests. A constant-rate pumping test was run at a pumping rate of 270 gallons per minute (gpm) for a period of 48 hours. Drawdown was observed in all observation and monitoring wells used for the test, including wells located up to 1,500 feet away from the pumping well. Based on analysis of pumping test results, estimates of transmissivity and leakage factors were made.

Based on the results of the aquifer pumping test and an analysis of the stresses and responses to the aquifer system at the Site, groundwater flow was numerically modeled. Two steady-state, three-dimensional flow models — one depicting winter recharge, and one depicting summer withdrawal — were constructed using the software MODFLOW. Pumping scenarios were selected with the calibrated flow models using the particle tracking software MODPATH. Evaluations were performed for both winter and summer conditions to identify appropriate well locations and pumping rates for injection and extraction, such that the groundwater plume (as defined by the 1-part-per-billion contour for chloroform) would be captured. For the winter simulations, operation of extraction well EW2-1 at approximately 120 gpm appears adequate for capturing the groundwater plume upgradient of extraction well EW2-1. Injection at location IW2-1 at approximately 120 gpm also appears adequate for plume capture. For summer simulations, without operation of irrigation well 22N, operation of EW2-1 at approximately 190 gpm appeared adequate for capturing the groundwater plume upgradient of extraction well EW2-1. Injection at location IW2-1 at approximately 190 gpm also appears adequate for plume capture. A portion of the water which will have been treated and reinjected, ranging from approximately 8 percent in the summer to approximately 34 percent in the winter, will not be recaptured by extraction well EW2-1.

The feasibility of extraction, discharge, and treatment technologies required to provide hydraulic containment and treatment of groundwater in the IRA was first evaluated based on three screening criteria: effectiveness; implementability; and cost of the action. Two extraction elements — a one-well and a two-well option — were analyzed and only the one-well option was retained for further analysis. Four discharge options — reinjection, the UC Davis WWTP, Putah Creek, and agricultural land — were considered in the screening. Only one option, reinjection, was retained for further analysis. Four treatment options — air stripping of VOCs, ion exchange, bone char carbon, and reverse osmosis — were evaluated. Two technologies — air stripping of VOCs and reverse osmosis — were retained for further analysis.

The screening of extraction, discharge, and treatment alternatives resulted in two combined alternatives being carried forward for detailed assessment: Alternative 1, Extraction with VOC removal and reinjection; and Alternative 2, Extraction with VOC, nitrate, hexavalent chromium and TDS removal and reinjection. The two options were different with respect to the level of treatment and cost. The degree and level of treatment will be dependent on the required quality of the extracted groundwater and the discharge limits to be established by the regulatory agencies at the point of injection. Alternative 2 would allow for the treatment of some general mineral parameters (mostly salts) that would result in an incremental decrease in these salts. Most of these salts are already below drinking water standards in extracted groundwater. A cost comparison between the two options showed that the incremental improvement in water quality with the significant additional cost offered by Alternative 2, versus Alternative 1, was not feasible or effective.

Based on a more detailed analysis of Alternatives 1 and 2, as prescribed in the NCP, Alternative 1 is recommended. Alternative 1 was selected for the following reasons:

- decreasing the concentration of nitrate, hexavalent chromium, and TDS would require treatment by reverse osmosis (RO) which would result in a significant increase in capital and operation and maintenance (O&M) costs (approximately $1.4 million over five years);
- treatment by reverse osmosis would result in only an incremental improvement in water quality to potentially meet local background water quality values;
- treatment by RO results in a concentrated salt solution that must be then disposed of as a waste stream; and
- time constraints to perform additional field testing, design, and equipment procurement for treatment of nitrate, hexavalent chromium, and TDS will affect the schedule for implementation of the IRA.

The viability of Alternative 1 is further supported by the ability of the proposed IRA extraction and reinjection system to recapture a majority of the reinjected water, the completeness of the groundwater monitoring system at the Site, and the opportunity to address any additional concerns in the final remedy.

A schedule for implementing the IRA has been developed with the goal of initiating system start-up by the end of 1997. Upon release of this final EE/CA, the US EPA will complete the IRA Action Memorandum, and UC Davis will complete a Remedial Action Work Plan. Design of the system has been initiated and will consist of 50% and 100% design documents. Upon approval of regulatory and design documents, bidding and system construction will be conducted.

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GROUNDWATER INTERIM REMOVAL ACTION
LEHR ENVIRONMENTAL RESTORATION
DAVIS, CALIFORNIA

1.0 INTRODUCTION

This Engineering Evaluation/Cost Analysis (EE/CA) Report has been prepared for the anticipated groundwater Interim Removal Action (IRA) at the former Laboratory for Energy-related Health Research (LEHR) and the South Campus Disposal Site (SCDS) (together referred to as the Site) at the University of California, Davis (UC Davis), California (Figure 1). This EE/CA Report identifies the objectives for the anticipated groundwater IRA at the Site and presents an analysis of likely remedial alternatives that satisfy these objectives.

This EE/CA Report, and work leading up to this report, were conducted at the request of UC Davis and based on the UC Davis conceptual work plan submitted to the United States Environmental Protection Agency (US EPA) on November 30, 1995. The conceptual work plan outlined steps to implement a groundwater IRA that addresses VOC impacts in groundwater beneath and downgradient of the Site. Because downgradient impacts extend offsite east of the Site, the resulting groundwater IRA is being considered a non-time critical Removal Action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). As required by CERCLA, the IRA will be conducted in order to prevent, minimize, or mitigate potential damage to public health and the environment, and an EE/CA will be completed to analyze remedial alternatives for the removal action. As an interim and non-time critical removal action, the anticipated groundwater IRA as defined in this EE/CA is limited in scope and is not intended to be the final long-term remedy for groundwater impacts at LEHR/SCDS.

This EE/CA has been prepared to comply with CERCLA, and with section 330.415, "Removal Action," of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and in accordance with US EPA Guidance for Conducting Non-Time Critical Removal Actions (US EPA, 1993). When the results of this document are approved, an Action Memorandum will be prepared by the US EPA and other regulatory agencies to authorize the groundwater IRA. Upon authorization, the recommendations of this EE/CA Report will form the conceptual basis for the design and implementation of the groundwater IRA, and a Technical Memorandum presenting design plans will be prepared.

1.1 Purpose and Scope of EE/CA Report

The purpose of this EE/CA Report is to present background data and information that is relevant to IRA activities, to identify and describe the IRA objectives, and to identify and evaluate remedial alternatives that satisfy the objectives of the IRA. The scope of the IRA and range of potential

remedial alternatives has been narrowed during the preparation of and comment to three previous Site documents: the conceptual work plan (UC Davis, November 1995); the Assessment of Remedial Options (Dames & Moore, 1996a); and the Technical Memorandum/Work Plan for Pre-design Activities (Dames & Moore, 1996b). The Assessment of Remedial Options addressed alternatives that intercept and treat the VOC-impacted groundwater plume at the UC Davis property boundary. The Technical Memorandum presented plans and procedures for the pre-design activities, including additional analysis of groundwater extraction and treatment selections, and of discharge alternatives for the groundwater IRA. This EE/CA report, therefore, builds on the earlier work conducted for the IRA by refining the scope and objectives of the action, and by recommending a remedial alternative.

As a result of previous assessments, this report focuses on evaluating alternatives for capturing, treating, and disposing of groundwater that is pumped from the second hydrostratigraphic unit (HSU-2). Existing hydrogeologic information and new data collected during aquifer testing are analyzed to refine groundwater extraction locations and volumes. Existing and new groundwater quality data are compiled to estimate the quality of extracted groundwater and to evaluate treatment and discharge alternatives. Remedial action objectives are presented with applicable requirements in order to establish the rationale and basis for the groundwater IRA. This report presents an analysis of the remedial alternatives using three CERCLA removal action criteria: (1) effectiveness; (2) implementability; and (3) cost. The analysis forms the basis for recommending an extraction, treatment and discharge scenario that will serve as the conceptual remedial system design.

1.2 Organization and Content

This EE/CA Report is organized into ten chapters, including this introduction. Chapter 2.0 presents a description of the Site and a summary of background information. Chapter 3.0 describes the hydrogeology of the Site and includes the conceptual hydrogeology model updated with recently collected data, and a summary of groundwater flow model simulations. Chapter 4.0 presents a summary of relevant groundwater quality data including new chemical information collected during recent aquifer testing. Chapter 5.0 presents the remedial action objectives for the groundwater IRA. Chapter 6.0 identifies and screens removal action remedial alternatives and Chapter 7.0 presents an analysis of the alternatives and discusses recommended alternatives. Chapter 8.0 presents conclusions, and Chapter 9.0 discusses the proposed schedule for implementation. References are included in Chapter 10.0.

2.0 SITE DESCRIPTION AND BACKGROUND

This chapter presents a review of Site description and background information that is relevant to the groundwater IRA. This review focuses on data collected during previous groundwater investigations and on information necessary for the evaluation of interim groundwater remedial alternatives. As such, information reviewed for this EE/CA does not include soil or waste characterization data, and does not focus on groundwater information near the probable source areas. A detailed description of the Site and its history and of data collected as part of both soil and groundwater investigations have been presented in several previous Site documents, including the Initial Assessment Survey (Rockwell, 1984), the Environmental Survey Preliminary Report (DOE, March 1988), the Groundwater and Soils Investigation (Wahler Associates, 1989) the Phase II Site Characterization Report (Dames & Moore, 1993), the Field Activity Report (PNNL, 1995c), and the DOE Areas Characterization Report (Weiss Associates, 1997). In addition, Annual Water Monitoring Reports have been published for the DOE since 1994.

2.1 Site Description

The Site is located in Solano County approximately one and one-half miles south of the main UC Davis campus and the town of Davis, California (Figure 1). The Site encompasses approximately 15 acres and is located on and immediately surrounded by UC Davis property to the north and west. The South Fork of Putah Creek borders the Site to the south, and privately-owned land borders the Site to the east. Currently, the Site consists of one- and two-story laboratory and office buildings, and animal-handling facilities in a rural-type setting. Most of the buildings are currently used by UC Davis as part of the Institute of Toxicology and Environmental Health (ITEH) research facility. Of the 15 acres, approximately 45 percent (6.75 acres) is paved with asphalt or concrete, or covered by structures. Approximately 30 percent (4.5 acres) of the Site is unpaved and kept relatively free of vegetation. Former dog pen areas occupy approximately 20 percent (3 acres) of the Site, and approximately 5 percent (0.75 acres) is heavily vegetated with large deep-rooted vegetation.

The Site consists of a variety of landfills, subsurface disposal areas, and waste treatment systems. The responsibility for the investigation and clean-up of various sites areas is currently being divided between the DOE and UC Davis. Although the exact division has not yet been officially agreed upon, it is likely that investigation and clean-up of areas associated with the former LEHR facility will be conducted by the DOE, and that investigation and clean-up of areas designated as SCDS will be conducted by UC Davis. UC Davis has agreed to take the lead role for groundwater investigation and remediation. A brief summary of the LEHR/SCDS areas is presented in section 2.2.1 below. This EE/CA report refers to both LEHR and SCDS as "the Site."

2.1.1 Surrounding Area

Private land is adjacent to and surrounds UC Davis property in the vicinity of the Site. Most of the private land is used for agricultural purposes and includes approximately thirty-four groundwater wells within one mile of the Site that are used primarily for either irrigation or domestic purposes (Dames & Moore, 1990). Approximately 40 percent of the surrounding area is irrigated for agriculture, with major crops including vegetables, fruits, nuts, and grains. The use of groundwater for irrigation in the area typically begins in late spring and continues through late summer.

The regional topography surrounding the Site is typical of the broad, relatively flat-lying Sacramento Valley. The Site is situated on relatively flat-lying land termed the Putah Plain (California DWR, 1978), with an average elevation at the Site of approximately 50 feet above mean sea level, and relief across the Site of approximately two feet. The greatest relief in the vicinity at the Site occurs as a result of the levee (the local high point) and channel (local low point) for Putah Creek, located south of the Site. The land surface slope in the vicinity of the Site is approximately 0.001 foot/linear foot (5 feet per mile) to the east/northeast toward the Sacramento River. The Site is not within the 100-year flood plain as defined in the 1982 Flood Insurance Maps (Federal Emergency Management Agency, 1982).

2.1.2 Surface Water

The South Fork of Putah Creek (Putah Creek) is the principal surface water feature of the region and forms the southern border of the Site. Putah Creek flows eastward from Lake Berryessa, located approximately 20 miles west of the Site, and ultimately empties into the Yolo Bypass approximately 8 miles east of the Site.

Flow in Putah Creek is regulated by releases from Monticello Dam at Lake Berryessa and from the Solano Diversion Dam. Putah Creek also receives water from the following sources:

- Runoff from adjacent agricultural land;
- Stormwater from UC Davis;
- UC Davis Putah Creek Research Facility;
- UC Davis Aquatic Center Fishery;
- UC Davis Aquatic Weed Control Laboratory; and
- Treated effluent from the UC Davis Wastewater Treatment Plant (WWTP) via an outfall pipeline upstream of the Site.

Flow in Putah Creek varies widely during the course of the year from high flows and flood conditions during the winter rainy season, to dry or low-flow conditions in the summer. Putah Creek is a losing stream, and during dry years, flow in many parts of the creek ceases. The bottom

of the creek channel is approximately 25 feet lower in elevation relative to the Site. Near the Site, water is present in the creek all year long due in large part to discharge from the nearby UC Davis wastewater treatment plant outfall (average daily flow of 1.6 million gallons per day).

2.1.3 Meteorology

The climate in the region of the Site is temperate, with mild winters and long summers. The mean annual precipitation in the vicinity (at the National Oceanic and Atmospheric Administration station Davis 2WSW) is 17.0 inches, most of which occurs between October and April (National Climatic Data Centers, 1992). The 100-year, 24-hour storm event for this station is 4.45 inches, and the 10-year return period event is 3.15 inches.

The prevailing wind direction in the Davis area is from the south, reflecting frequent incursion of marine air through the Carquinez Strait into the Sacramento Valley. Changes in wind direction are common, with flows from the northwest occurring diurnally. Several times a year, strong winds blow from the north, generally following the passage of Pacific Ocean storm systems.

2.2 Site Environmental Background

UC Davis conducted radiological studies on laboratory animals for the DOE from the 1950s to 1988. The initial studies, conducted for the US Atomic Energy Commission (now DOE), involved the x-irradiation of beagles at the UC Davis main campus. Full-scale experimental use of radioactive materials, including strontium-90 and radium-226, began at LEHR in 1960, and research continued at LEHR until 1988. In the initial stages of operation at LEHR, waste was handled through a central handling facility on the main campus. However, waste handling for LEHR-generated waste was transferred to LEHR in the early 1960s. Radioactive waste was primarily handled through two onsite processing systems, or disposal into a variety of disposal pits and trenches. Prior to and during research activities conducted at LEHR, municipal, laboratory, and construction wastes generated by the University were disposed into three different UC Davis landfills, and a series of burial trenches and pits located within and near the Site boundaries. These disposal areas are summarized below.

2.2.1 Potential Source Areas

During the 30-year operation of the Site, a variety of wastes were generated and disposed of onsite. The wastes, which included radioactive, biological, chemical, municipal, and laboratory wastes, were disposed of using several different processes and into several disposal areas. A brief summary of waste-generating processes and waste disposal areas with the potential to impact groundwater are presented below and in Figure 2.

- ***Imhoff System (LEHR)*** — From 1960 to 1987, effluent from strontium-90 experiments was processed through an Imhoff sewage treatment system. The Imhoff system used a series of settling tanks and cation exchange columns to treat waste prior to discharge to leach fields.

- ***Radium-226 System (LEHR)*** — The radium-226 processing system consisted of septic tanks, dry wells, and a leach trench that were used to process waste from radium-226 experiments.

- ***Domestic Septic Tanks (LEHR)*** — Six of seven onsite septic tanks were reported to have received all liquid wastes from the LEHR facility except for strontium-90 and radium-226 project wastes. The LEHR facility was connected to the main UC Davis wastewater treatment plant in 1971 and the on-site systems were not used by LEHR thereafter.

- ***Southwest Trenches (LEHR)***— Low-level radioactive solid waste generated by DOE-sponsored research at LEHR was reportedly disposed in trenches located in the southwest corner of the Site.

- ***Southern Disposal Area (SCDS)***— UC Davis and possibly LEHR waste was reportedly disposed in two east-west oriented trenches located south of the main dog pen area.

- ***Waste Burial Holes (SCDS)*** — Forty-nine burial pits located south of the smaller, eastern dog pens were reported to be used by UC Davis to dispose of radioactive waste.

- ***Eastern Trenches (SCDS)*** — Five to seven north-south trending trenches located between Landfill Unit #2 and the cobalt-60 field were reportedly used for disposal of chemical and laboratory wastes.

- ***Landfill Unit #1 (SCDS)*** — The oldest of the three inactive disposal units is presently covered by the Cobalt-60 Field. Disposal reportedly began in this unit in the 1940s and ceased in the 1950s. General campus wastes, sewage sludge, and possibly chemical wastes appear to have been disposed at the landfill unit.

- ***Landfill Unit #2 (SCDS)*** — Landfill Unit #2 was operated from 1956 to 1967, and consisted of twelve east-west oriented disposal pits. This unit is partially covered with the eastern dog pens. Types of wastes disposed at this Site were reported to include general refuse, animal parts, ash from the UC Davis incinerator, and some liquid chemicals.

- ***Landfill Unit #3 (SCDS)*** — UC Davis operated this unit which is located east of the Site, from 1963 to 1967. Wastes were placed in two large, pit-like excavations and covered with

a soil cap. Types of waste were reported to include general municipal and campus waste, construction debris, and laboratory waste.

- ***Dog Pens (LEHR)*** — Two out-door dog pen areas containing approximately 350 separate pens were located at LEHR. These pens housed the dogs from the strontium-90 and radium-226 studies.

2.2.2 Summary of Site Groundwater Investigations

The investigation of groundwater impacts at the Site began in 1987. Groundwater investigations at the Site have primarily consisted of installing monitoring wells and collecting Hydropunch water samples from the two shallow water-bearing zones that occur beneath the Site. The shallow zone, or first hydrostratigraphic unit (HSU-1), consists of predominantly fine-grained clay, silt, and sand that extends from the water table to between 76 and 88 feet below ground surface (bgs). Wells completed in HSU-1 are identified with a "1" (e.g., UCD1-13). The second, deeper zone, or second HSU (HSU-2), consists of sand and gravel that extends from the bottom of HSU-1 to between 114 and 130 feet bgs. Wells completed in the HSU-2 are identified with a "2" (e.g., UCD2-17 or EW2-1). Figure 3 presents Site monitoring and extraction well locations. This section presents a brief summary of previous groundwater investigations at the Site. A detailed discussion of Site hydrogeology is presented below in Chapter 3.0; a discussion of Site groundwater quality is presented in Chapter 4.0.

2.2.2.1 Well Installations

Investigations of groundwater at the Site began with the Phase I Groundwater and Soils Investigations conducted by Wahler and Associates in 1987 to 1989 (Wahler & Associates, 1988, 1989). During the Phase I investigations, wells UCD1-1 through UCD1-8 were installed into HSU-1. Well UCD2-7 was installed into HSU-2. Five additional groundwater monitoring wells were installed in 1989 as part of a Solid Wastewater Quality Assessment Test (SWAT – Dames & Moore, 1990). Wells UCD1-10, UCD1-11, UCD1-12, and UCD1-13 were installed in HSU-1, and well UCD2-14 was installed into HSU-2.

The LEHR Phase II Site Investigation was conducted beginning in 1990 and included the redevelopment of Phase I wells, the destruction of well UCD1-2 because it was installed through waste in landfill unit #2, and the installation of 10 new monitoring wells located upgradient (UCD1-18 and UCD2-17) and downgradient of potential source areas. The new monitoring wells included seven wells (UCD1-18 through UCD1-24) installed in HSU-1, and three wells (UCD2-15, UCD2-16, and UCD2-17) installed in HSU-2.

In 1995 and 1996, nine monitoring wells and one extraction well were installed during work conducted for the LEHR RI/FS and predesign work for the IRA. HSU-1 wells UCD1-25 and UCD1-34 and HSU-2 wells UCD2-26, and UCD2-35 were installed as part of the RI/FS to evaluate interaction between groundwater and nearby Putah Creek, and to collect additional data downgradient of the Site within the plume of chloroform-impacted water. In addition, well UCD2-27 was installed as a multi-port West Bay system that allows groundwater samples to be collected from several depth-discrete intervals completed within HSU-1 and HSU-2. Monitoring wells UCD1-28, UCD2-29, UCD2-30, and UCD2-31, and extraction well EW2-1 were installed in September 1996 to conduct aquifer testing for the IRA. Well EW2-1 was installed in HSU-2 as a fully penetrating extraction well for the eventual IRA and to collect data to estimate physical parameters and groundwater quality for IRA system design.

2.2.2.2 Water Monitoring

Groundwater monitoring at the Site began with two rounds of sampling under the initial Phase I investigations, and a round of sampling for the Solid Waste Water Quality Assessment Test (SWAT). Quarterly groundwater monitoring of 18 of the 24 Site monitoring wells began in November 1990 as part of the Phase II Site Characterization and is ongoing at the Site. Samples collected for quarterly monitoring are analyzed for a variety of inorganic, organic, and radiologic parameters, and water level measurements are recorded. As new wells are installed under the RI/FS and IRA programs, they are incorporated into the quarterly monitoring program. In addition to monitoring wells, three surface water locations along Putah Creek are also monitored quarterly. The Putah Creek samples are collected from one location upstream of the Site, one location downstream of the Site and one location at the UC Davis wastewater treatment plant outfall. Quarterly monitoring data for the Site are reported in quarterly data transmittals and summarized in yearly annual reports.

In addition to data collected from the installation and sampling of Site monitoring wells, four phases of Hydropunch sampling have been conducted on and around the Site. The purpose of the Hydropunch sampling has been to further delineate impacts from Site constituents of concern (chloroform, nitrate, hexavalent chromium, and tritium) to help select locations for new monitoring wells at various stages of the LEHR Environmental Site Restoration Program. Hydropunch sampling has focused on areas downgradient and offsite of source areas to evaluate the extent of impacts in HSU-1 and HSU-2. Hydropunch sampling has provided data from the HSU-1 and HSU-2 immediately surrounding the Site and south of Putah Creek (Fall and Spring 1991); from HSU-1 and HSU-2 in areas north and east (downgradient) of the Site (Fall 1994); and from downgradient areas off UC Davis property in HSU-2 (Summer 1995 and Fall 1996).

3.0 SITE HYDROGEOLOGY

Groundwater investigations conducted at the Site since 1987 have been used to develop an understanding of Site stratigraphy and hydrogeology. Based on the results of these investigations a conceptual hydrogeologic model has been developed to understand the processes and factors affecting groundwater flow in the Site vicinity. To support design of the groundwater IRA system, a groundwater flow model has also been developed based on the conceptual hydrogeologic model. The groundwater flow model was used to evaluate groundwater extraction and reinjection alternatives. A description of regional hydrogeology, the conceptual hydrogeologic model, and the groundwater flow model are provided in this chapter.

3.1 Regional Geology

As described in the previous chapter, the Site and the surrounding area are located on the geomorphic unit termed "low-alluvial plains and fans" (California DWR, 1978), specifically the Putah Plain. This unit represents the distal portions of alluvial fan deposits associated with Putah Creek that are referred to as the Putah Creek Fan (Mann, 1992). Sediments that form these alluvial fan deposits consist primarily of silts and clays with coarse-grained sediments occurring locally. The Putah Creek Fan was formed by a creek that changed course many times throughout this area. The sands and gravels were deposited during high velocity flows at times of floods. Outside the ribbon-like strips of coarse channel deposits, lower velocity waters deposited silts and clays. The age of these deposits ranges from late Pleistocene to Recent. The thickness of the alluvial fan deposits is reported to be between 140 feet (Mann, 1992) and 180 feet (California DWR, 1978).

Underlying the Putah Creek Fan is the Plio-Pleistocene Tehama Formation that was folded or tilted and then eroded prior to the deposition of the alluvial material of the Putah Creek Fan (Mann, 1992). The Tehama Formation consists of fine-grained sands and silts with discontinuous lenses of coarse sand and gravels.

3.2 Site Conceptual Hydrogeologic Model

This section presents a description of the conceptual hydrogeologic model for the Site. Components of the conceptual hydrogeologic model include hydrostratigraphy, groundwater sources, and groundwater sinks. These components govern the flow of groundwater in the vicinity of the Site and are essential to development of the numerical groundwater flow model. Much of the information used to construct the Site conceptual hydrogeologic model is presented in various groundwater investigation reports which include the Phase II Site Characterization Report (Dames & Moore, 1993), the 1994 Annual Water Monitoring Report (PNL, 1995a), the Groundwater Characterization Field Activities for 1995-1996 Report (PNNL, 1996b), the 1995 Annual Water Monitoring Report (PNNL, 1996a), and the 1995 AIP Summary Report (Parfitt, 1996). Information

presented in these reports has been supplemented with results from recent groundwater field investigation activities and additional data gathered to support model development.

3.2.1 Hydrostratigraphy

This section presents a discussion of hydrostratigraphy in the vicinity of the Site. Included are discussions of stratigraphy, groundwater gradients and flow directions, and aquifer parameter estimates.

3.2.1.1 Stratigraphy

The subsurface stratigraphy for the Site has been evaluated from the geologic well logs and CPT logs collected during field investigations. Four hydrogeologic units that involve the groundwater IRA have been identified. These are the vadose zone, HSU-1, HSU-2, and HSU-3 (formerly the "unnamed aquitard"). The vadose zone, HSU-1 and HSU-2 are part of the Putah Creek Fan. The vadose zone is between 42 and 47 feet thick and consists primarily of unsaturated clay and silt with interbedded sand and gravel. HSU-1 has similar stratigraphy as the vadose zone and is between 29 to 40 feet thick. The bottom of HSU-1 varies from 76 to 88 feet bgs across the Site. HSU-2 is between 38 feet and 54 feet thick, consists primarily of sand in the upper portion and gravel in the lower portion, and contacts an unnamed aquitard between 114 feet and 130 feet bgs across the Site. Figure 4 presents a schematic cross section of the site hydrostratigrahpic units.

As reported by Mann (1992), in the vicinity of the Site, the lower sand and gravel unit of the Putah Creek Fan (HSU-2) is directly underlain by the Tehama Formation. HSU-3 represents the top of the Tehama Formation. Based on well drillers logs for nearby irrigation wells, HSU-3 consists primarily of clay and silty clay, is approximately 90 feet thick, and extends to an approximate depth of 250 feet bgs. Underlying HSU-3 are sand and gravel intervals referred to as HSU-4. The thickness of HSU-4 in the vicinity of the Site is not known, but data from drillers' logs support the conclusion that HSU-4 is less permeable than HSU-2.

3.2.1.2 Gradient and Flow Direction

Hydrographs have been maintained for HSU-1 and HSU-2 wells for over six years. Water levels across the Site in HSU-1 and HSU-2 are typically highest in March and April, decline rapidly from April to August, and recover from September through March. Seasonal/annual fluctuations since 1990 range from a maximum of approximately 40 feet between August 1994 and March 1995 to a minimum of 15 feet between August and 1993 and March 1994 (PNNL, 1996a). The seasonal changes in water levels are primarily due to pumping from HSU-2 and deeper intervals to supply local agriculture during the summer months. Water levels in both HSU-1 and HSU-2 also respond to changes in river stage in Putah Creek. HSU-1 wells located near Putah Creek respond directly to

changes in stage level, while HSU-2 wells located near Putah Creek show a dampened response to stage level changes.

On average, horizontal hydraulic gradients of both HSU-1 and HSU-2 range from approximately 0.0004 to 0.0015 and are shallower in the fall and winter and steeper in the spring and summer. The groundwater flow direction is generally northeast in HSU-1 (30 to 60 degrees from east) and to the east with a northerly component groundwater flow direction in HSU-2 (5 to 25 degrees from east). These gradients vary based on recharge, vertical gradients, and local use. Vertical gradients between HSU-1 and HSU-2 are variable in January through March, downward from April through August and generally upward from September through December.

The changes in gradient and flow direction indicate two distinct end member hydrologic conditions. In March water levels are at the highest levels due to rebound from the previous summer season irrigation pumping and recharge from precipitation. During this time the horizontal gradient is at its annual low, and the flow direction in HSU-2 has a larger northerly component. In August, water levels are at their lowest, due to irrigation pumping. Horizontal gradients appear to be at their highest and the flow direction in HSU-2 has less of a northerly component. During the rest of the year the system appears to be in a state of transition between these two end member conditions.

3.2.1.3 Aquifer Parameter Estimates

Aquifer testing methods have been used to estimate aquifer parameters for HSU-1 and HSU-2. Slug tests have been conducted to estimate the hydraulic conductivity (K) of HSU-1 and HSU-2 (PNNL, 1996a). An aquifer pumping test was performed to estimate the transmissivity (T), K, storativity (S) of HSU-2, as well as leakage between HSU-1 and HSU-2. A spinner test was conducted to assess the distribution of producing zones across HSU-2.

Slug Tests

Slug tests were conducted in 13 HSU-1 wells and 7 HSU-2 wells in 1995. Slug tests methods and results are presented in the Groundwater Characterization Field Activities for 1995-1996 Report (PNNL, 1996b). Hydraulic conductivity estimates for the HSU-1 slug tests range from 1.9 to 11 feet per day (ft/day), with an average value of 3.6 ft/day. Hydraulic conductivity estimates for the HSU-2 slug tests range from 121 to 622 ft/day, with an average value of 371 ft/day.

Spinner Test

A spinner test was conducted in EW2-1 to estimate the vertical distribution of water production within HSU-2. During the spinner test a pump was positioned above the top of the well screen and the well was pumped at approximately 150 gpm. A spinner log was run for the entire screen

interval to measure the distribution of flow velocities during pumping. Results of the spinner test indicate three distinct production zones are present. The upper zone occurs between 79 and 98 feet bgs and produces approximately 17 percent of the total flow. The middle zone occurs between 98 and 109 feet bgs, and produces approximately 78 percent of the total flow. The lower zone occurs between 109 and 114 and produces the remaining 5 percent of the total flow.

Aquifer Pumping Tests

Step drawdown and constant-rate aquifer pumping tests were conducted in October 1996 to support the design of the groundwater IRA. The pumping test approach and methodology were previously described in the LEHR Groundwater IRA Pre-Design Activities Technical Memorandum/Work Plan (Dames & Moore, 1996b). Since aquifer pumping test results have not previously been reported, a brief description of the pumping test methodology, data analysis and results is provided below.

To support the pumping test, an extraction well and four observation wells were installed. Well locations are shown in Figure 3. Extraction well EW2-1 was installed in HSU-2 with a 40 foot screen interval penetrating the entire HSU. Observation well UCD1-28 was installed in HSU-1, and observation wells UCD2-29, UCD2-30 and UCD2-31 were installed in HSU-2 to provide water level monitoring locations near the pumping well during testing. Additionally, water levels were monitored in HSU-1 well UCD1-25, and HSU-2 wells UCD2-14, UCD2-15, UCD2-26. Each well was equipped with a pressure transducer and datalogger to electronically monitor water levels during aquifer testing.

A step drawdown test was performed to evaluate sustainable flow rates for the constant-rate pumping test. Extracted groundwater was discharged to a nearby sewer manhole for conveyance to the UC Davis wastewater treatment plant. Results of the step drawdown test indicated EW2-1 is capable of sustaining flow rates in excess of 500 gpm. However, results of the step drawdown test also indicated the sewer lines were capable of sustaining flows up to only 180 gpm.

Prior to conducting the constant-rate test, water levels in selected observation wells were monitored electronically for 2 to 7 days to assess background water level trends. Following the rest period, the constant-rate aquifer pumping test was performed at a flow rate of 270 gpm for a 48-hour period. Effluent was discharged to the sewer system at a rate of 180 gpm. Excess effluent was temporally stored in tanks and discharged to the sewer at the end of the pumping period. Water levels were monitored electronically with periodic manual measurements to verify electronic readings. At the end of the pumping period, recovery-phase water levels were monitored electronically over a 2- to 8-day period. In addition, barometric pressure was monitored electronically prior to and during the pumping period, and during the recovery period of the test.

Constant-rate aquifer pumping test results are summarized in Table 1. Drawdown was observed in all observation wells including UCD2-15 located approximately 1,500 feet from the pumping well. Prior to analysis, drawdown data were corrected for barometric pressure effects and the regional rebound of water levels from summer irrigation pumping. Based on time versus drawdown data for HSU-2 observation wells, the aquifer response displayed typical leaky aquifer conditions. This observation is further supported by the drawdowns observed in HSU-1 wells.

Corrected drawdown data were analyzed using the Cooper-Jacob (1946) method (pumping well) and Hantush- Jacob (1955) leaky aquitard method (observation wells) to estimate T, K, S and a leakage factor. Corrected recovery data were analyzed using the Theis Recovery method. The software package Aqtesolv™ was used to fit type curves to the drawdown data. In most cases, the nonlinear least squares automatic parameter estimation option was used.

Groundwater model parameter estimates are summarized in Table 2. Estimates of transmissivity range from 32,950 to 52,340 ft^2/day, with an average value of 43,420 ft^2/day. Estimates of hydraulic conductivity range from 749 to 1,210 ft/day, with an average value of 1,024 ft/day. Estimates of storativity range from 0.0005 to 0.0067, with an average value of 0.0016. Leakage factor estimates range from 7,168 to 11,448 feet, with an average value of 8,970 feet.

3.2.2 Groundwater Sources and Sinks

Potential sources to the groundwater system are precipitation, agricultural irrigation, and leakage from the river. Known groundwater system sinks in the vicinity of the Site are irrigation supply wells. Each of these systems are discussed further below.

3.2.2.1 Precipitation

The annual precipitation in the Site vicinity is 17 inches on average and generally occurs between the months of October and April (National Climatic Data Centers, 1992). A portion of this water enters the subsurface as recharge, while the balance leaves the Site either as runoff or through evaporation.

3.2.2.2 Agricultural Irrigation

Available information on current irrigation practices indicates that water infiltrating through the subsurface into the aquifer in the Site vicinity is designed to match the crop demand. Therefore, percolation due to agricultural irrigation is not assumed to make up a significant portion of the groundwater budget.

3.2.2.3 Creek Leakage

Site characterization data indicate that water from Putah Creek recharges the groundwater system. The results of previous data analysis (Dames and Moore, 1993) indicated that in 1991, approximately two cubic feet per second entered the groundwater system from the creek over a 12,000-foot segment of the creek in the vicinity of the Site. In recent years, Putah Creek has flowed near the Site throughout the year. Therefore, it is expected that the creek is a groundwater source throughout the year.

3.2.2.4 Groundwater Sinks

As indicated above, known groundwater system sinks in the vicinity of the Site are irrigation supply wells. Drillers logs for wells located within 1 mile of the Site were reviewed to assess what hydrogeologic units supply water to the wells. The wells closest to the Site are the 22N and 22P2 wells. These wells are screened in both HSU-2 and HSU-3. Based on the available well construction and hydrogeologic information, it appears that up to 90 percent of the water pumped from these wells is derived from HSU-2 (Parfitt, 1996). Summer pumping rates for these wells (personal communication, John Currey, 1996) average 789 gpm for well 22P2 and 1,198 gpm for well 22N for the peak pumping month of August 1995.

3.2.3 Summary of Groundwater System Stresses and Responses

The available information indicates that the groundwater system stresses vary seasonally. Furthermore, the sets of stresses acting in the winter and summer, and the resulting responses appear to be distinct. The system is recharged through precipitation and river leakage in the winter when water elevations rise in both HSU-1 and HSU-2. In contrast, there is a net withdrawal of groundwater from the system in the summer when agricultural irrigation wells are operated, resulting in a decline in water levels.

3.3 Numerical Groundwater Flow Model

The following sections summarize groundwater modeling performed in support of the IRA evaluation and design. First, the model construction is presented followed by a discussion on the model calibration and remedial action simulations performed.

3.3.1 Model Construction

As indicated in Section 3.2.3, two distinct sets of stresses act on the groundwater system during the year. The range in groundwater response to these stresses and, therefore, potential effects on the IRA were considered by constructing two steady-state models. One model depicted winter conditions, and the other depicted summer conditions. The three-dimensional flow models were constructed using the software package MODFLOW (MacDonald and Harbaugh, 1988) and information from characterization work for the Site.

The model incorporated the Site and surrounding area into a grid that was 11,500 feet long and 7,000 feet wide (Figure 5). A grid spacing of 50 feet was used for the Site located in the center of the grid, and progressively larger spacings were used away from the center. Four model layers were used in the vertical dimension. Model Layer 1 was used to represent HSU-1. Model Layers 2, 3, and 4 were constructed to represent three different intervals within HSU-2. The three intervals in HSU-2 were selected based on flow conditions observed in the spinner logging described above. This grid spacing resulted in a model mesh with 72 rows, 108 columns, and 4 layers, for a total of 31,104 cells. A west to east orientation of the model grid was selected to coincide with the general direction of groundwater flow across the Site.

Variations in the thicknesses of HSU-1 and HSU-2 were based on the available characterization data (monitoring well logs, CPT logs, irrigation well logs and geophysical data) and depicted variations in the model layer thicknesses. Model layers are specified as unconfined, confined, or variable in MODFLOW. Model Layer 1, the uppermost layer, was represented as unconfined to correspond to the conditions in HSU 1. Layers 2 through 4, representing the three different intervals within HSU-2, were specified as confined, and based on vertical hydraulic conductivity input corresponding to semi-confined conditions in HSU-2.

A separate hydraulic conductivity value was used for each of the model layers. The value for Layer 1 was based on previous slug test data for HSU 1 (see section 3.2.1.3). The values for Layers 2 through 4 were based on the results of the pumping test and spinner logging described earlier in this report. Values for vertical hydraulic conductivities were estimated from aquifer testing results and revised during model calibration as discussed in the following section.

For the winter model, precipitation recharge was represented as a single value uniformly applied over Layer 1 and estimated during calibration. For the summer model, irrigation recharge and evapotranspiration were considered to contribute relatively little to the groundwater budget and, therefore, were not modeled. Recharge from the creek was simulated in the same fashion for both summer and winter models based on an infiltration rate of two cubic feet per second, spread equally across the length of Putah Creek.

For the summer model, groundwater extraction from the two irrigation supply wells closest to the Site (22N and 22P2) was also simulated in Layers 2 through 4. The pumping rates were set based on available information referenced above in Section 3.2.2.4. Portions of the total pumping rate for each well were allocated to each of the model layers based on the horizontal hydraulic conductivity assigned to the layer.

Constant-head conditions were used for the west and east model boundaries. No-flow conditions were used on the north and south boundaries. These boundaries were placed far enough away from potential groundwater pumping locations so that no artificial boundary effects would influence the remedial action modeling results. A no-flow boundary was placed at the base of the model and corresponds to the presence of HSU-3.

3.3.2 Model Calibration

The model was calibrated to both winter and summer conditions for 1995. Values for vertical hydraulic conductivity, precipitation recharge, and the constant-head boundaries were selected as part of the model calibration. The available Site characterization information was used to guide the selection of values for these model parameters in conjunction with the model calibration techniques described in this section. The calibration entailed adjusting values for the above-mentioned parameters in a systematic manner until a reasonable fit was obtained between the groundwater elevation data (for March 24 and August 31, 1995) and the model predictions of groundwater elevation. This process was performed consistent with American Society for Testing and Materials (ASTM) standard D 5447 (ASTM, 1993).

As indicated above, precipitation recharge and vertical hydraulic conductivity were estimated for the winter model, and vertical hydraulic conductivity was estimated for the summer model. The estimation was performed by iteratively running the models to perform parameter estimation using the software package MODFLOWP (Hill, 1992). Values for the constant-head boundaries were also estimated by manual adjustment between estimation runs with MODFLOWP. Because the estimated values for vertical hydraulic conductivity were somewhat different for the winter and summer models, a single average value was ultimately used for both models in the evaluation of IRA pumping scenarios. Table 2 presents the model parameter values ultimately used in the model.

Figures 6 and 7 present a comparison of HSU-2 winter and summer predicted water level elevation contours for the calibrated models, observed water levels, and calibration residuals. Comparison of predicted water elevation contours and observed water level measurements indicates that the winter and summer models generally reproduce the groundwater elevations and flow directions at the Site.

3.3.3 Remedial Action Scenarios

Pumping well locations and rates were selected by running pumping scenarios with the calibrated flow models and delineating the resulting groundwater capture zones using the particle tracking software package MODPATH (Pollock, 1989). Evaluations were performed for both the winter and summer to identify appropriate well locations and pumping rates for injection and extraction. All IRA wells were simulated for model Layers 2 through 4. Portions of the total pumping rate for each

well were allocated to each of the model layers based on the horizontal hydraulic conductivity estimated for each respective model.

First, extraction simulations were performed to assess extraction well locations and associated flow rates needed to provide plume capture (as defined by the 1-part-per-billion contour for chloroform). For the winter simulations, operation of extraction well EW2-1 at approximately 120 gallons per minute (gpm) appears adequate for capturing the groundwater plume in the upgradient direction (Figure 8). For the summer simulations, the IRA requirements depend on whether the Nishi well (irrigation well 22N) is operating. Without irrigation well 22N well operating, extraction from EW2-1 at approximately 190 gpm appears adequate for capturing the groundwater plume in the upgradient direction (Figure 9). With the irrigation well 22N operating, a second extraction well, EW2-2, is required to achieve plume capture upgradient of EW2-1 (Figure 10; EW2-1 at 190 gpm and EW2-2 at 90 gpm). In summary, without well 22N operating, one extraction well, namely EW2-1, should be sufficient to provide plume capture in the upgradient direction year round.

Next, simulations were performed to assess locations for reinjecting treated groundwater effluent. Reinjection simulations were performed for two reasons: to assess the hydraulic effects of reinjection on plume capture; and to assess how much reinjected groundwater will be recaptured by creating a closed loop between the extraction well and injection well. Simulated reinjection well locations were selected to be upgradient of LEHR/SCDS source areas and to maximize eventual recapture by the extraction well. Upgradient locations were selected to minimize the potential for altering local groundwater flow directions near site source areas. Simulation results indicate that an injection well (IW2-1) located across Old Davis Road opposite the southwest corner of the Site is preferable. For both summer (EW2-1 at 190 gpm) and winter (EW2-1 at 120 gpm) extraction conditions, simulations indicate plume capture will be maintained during reinjection of treated groundwater.

For all reinjection scenarios evaluated, the model predicts that some of the treated groundwater that is reinjected will not be recaptured by EW2-1. Model predictions indicate the amount of treated water that is not recaptured may vary from approximately 8 percent in the summer (Figure 11) to approximately 34 percent in the winter (Figure 12). The variability in the amount of treated groundwater contained in a closed loop is caused by the seasonal fluctuation in groundwater flow direction within HSU-2. It should be noted that although 100 percent of the reinjected water is not maintained in a closed loop, this water will have already been treated to meet approved water quality goals.

4.0 SITE GROUNDWATER QUALITY

This chapter presents a summary of groundwater quality data available for the Site and vicinity. Data available is primarily from ongoing quarterly sampling and analysis of Site monitoring wells, and from several phases of hydropunch sampling and analysis conducted on and around the Site boundaries. This chapter summarizes existing groundwater analytical data, discusses the distribution of Site constituents of concern, summarizes background groundwater quality information, and presents an estimate of the concentrations of Site parameters in extracted groundwater.

4.1 Summary of Existing Data

Data from the quarterly monitoring program were collected from 1990 through the present and provide data over time from wells located downgradient of potential source areas. Quarterly groundwater monitoring samples are analyzed for a wide variety of analytical parameters including VOCs, semi-VOCs, pesticides and PCBs, metals, radionuclides, and general chemical parameters. Data from four hydropunch sampling events were collected between 1991 and 1996 and provide data from areas downgradient and beyond the Site and UC Davis property boundaries. Analysis of hydropunch samples typically focussed on key Site parameters including chloroform, hexavalent chromium, tritium, and nitrate.

A summary and analysis of Site groundwater quality data has been presented in several previous Site reports, including the Phase II Site Characterization Report (Dames & Moore 1993), and the 1993, 1994, and 1995 Annual Water Monitoring Reports (PNL, 1994, 1995a; PNNL, 1996a). The review in each of these reports treated data for HSU-1 and HSU-2 separately. Based on the results of statistical analyses presented in the Annual Reports, concentrations of nitrate, total chromium, hexavalent chromium, and barium were concluded to be elevated in most downgradient wells for both HSUs. Arsenic, selenium, chloroform (and several other VOCs), carbon-14, and tritium were found to be elevated in only a few wells in both HSUs and distributed beneath localized portions of the Site. The pesticide dieldrin is consistently reported in one area of the Site within HSU-1 only.

In general, the lateral extent of groundwater impacts from these constituents is greater in HSU-2 than in HSU-1. This is assumed to be due to the low lateral hydraulic conductivity of sediments that limit the lateral migration of impacts in HSU-1. As a result, when chemical and radiologic compounds move from HSU-1 into HSU-2, significantly higher hydraulic conductivities allow them to migrate laterally from the apparent source areas downgradient and east of the Site.

4.2 Site Constituents of Concern

Based on the findings from quarterly monitoring and hydropunch sampling, several Site constituents are consistently reported in groundwater at elevated concentrations and will likely be

the focus of Site remedial activities. These parameters include: chloroform (and associated VOCs), hexavalent chromium and chromium, nitrate and TDS, and tritium. The most notable of these parameters is chloroform, because impacts in HSU-2 extend downgradient beyond the UC Davis property boundary. The distribution of each of these parameters is discussed below.

4.2.1 Chloroform

Chloroform is the most significant VOC that has been observed in Site groundwater. Chloroform is consistently reported at high concentrations (> 10,000 μg/L) in downgradient well UCD1-12, and a plume of chloroform-impacted water extends downgradient off the Site. Several other VOCs (1,2-dichloroethane, 1,1-dichloroethene, and 1,1-dichloroethane) have been reported in Site groundwater, but at much lower concentrations. As a result, chloroform is the VOC of primary concern at the Site.

Chloroform concentrations in Site groundwater decrease with depth near the suspected source areas (north portions of landfill unit #2 and eastern trenches), and increase with depth downgradient of the source areas. Chloroform in HSU-1 occurs at high concentrations (> 10,000 μg/L) in samples from well UCD1-12 and in hydropunch locations in the area immediately east and downgradient of UCD1-12. Further downgradient, however, HSU-1 concentrations decrease rapidly to values near the detection limit at the property boundary.

In HSU-2, data on chloroform are primarily from hydropunch samples and recently installed wells for the RI/FS and IRA. These data show that chloroform impacts are more widely distributed in the HSU-2 and extend over 2,000 feet east of the UC Davis property boundary. Chloroform has also been reported at relatively low concentrations in at least two off-property agricultural wells downgradient of the Site. Within HSU-2, chloroform concentrations are highest in the middle and upper portions of HSU-2. Chloroform in the vicinity of anticipated IRA extraction well is approximately 100 μg/L, as reported for samples collected from extraction EW2-1 and monitoring wells UCD2-29, UCD2-30, and UCD2-31. Figure 13 presents a compilation of hydropunch data and well data for chloroform in HSU-1 and HSU-2.

4.2.2 Hexavalent Chromium and Chromium

Previous reviews of Site groundwater data have concluded that the distribution of hexavalent chromium is similar to the distribution of total chromium. This is believed to be because 80 percent or more of the chromium detected in the groundwater is in hexavalent form. As a result, discussions of chromium and hexavalent chromium in groundwater at the Site typically focus on hexavalent chromium distribution because it is the most mobile and has a higher toxicity than total chromium.

Hexavalent chromium concentrations in Site groundwater decrease with depth. Within HSU-1, two areas of hexavalent chromium-contaminated groundwater are present; one is centered north of Landfill 2, and the other is located northeast of Landfill 1. Both areas contain hexavalent chromium above the total chromium MCL of 50 μg/L with the highest concentration reported for new HSU-1 well UCD1-28 at 550 mg/L, located near the anticipated extraction location. In HSU-2, however, only a few detections of hexavalent chromium have been reported, and impacts are both lower in concentration and less widely distributed. Downgradient data from recently installed wells for the RI/FS and IRA pre-design support these previous findings: relatively high detections of hexavalent chromium were reported from HSU-1 wells (e.g. UCD1-28), but hexavalent chromium was reported below or near detection limits for wells screened in HSU-2. Figure 14 presents a compilation of hydropunch data and well data for hexavalent chromium in HSU-1 and HSU-2.

4.2.3 Nitrate and TDS

Nitrate and TDS are the most widespread of the Site constituents of concern in both HSU-1 and HSU-2. Much of the groundwater within HSU-1 beneath the Site and surrounding property contains nitrate as NO_3 at concentrations above the MCL of 45 mg/L, with the highest HSU-1 concentrations reported downgradient of the dog pens and beneath all three landfill units. The upper portion of HSU-2 also contains nitrate in excess of the MCL. Figure 15 presents a compilation of Hydropunch and well data for nitrate in HSU-1 and HSU-2. Data for the distribution of TDS is available only for monitoring wells. TDS is a measurement of all dissolved material in water and includes salts such as chloride, sulfate, calcium, magnesium, sodium, and total alkalinity. TDS in HSU-2 is consistently reported above 500 mg/L in downgradient wells UCD2-7 and UCD2-14. As with other Site constituents of concern, the highest concentrations of nitrate and TDS in HSU-2 are reported in a similar area (but at lower concentrations) to the areas of highest concentrations reported in HSU-1.

4.2.4 Tritium

The most significant and consistently reported radionuclide in Site groundwater is tritium. Tritium concentrations in groundwater are highest in HSU-1 and decrease with depth into HSU-2. The highest concentrations of tritium are consistently reported in HSU-1 from well UCD1-13, located in the vicinity of the eastern trenches and just downgradient of the waste burial holes, the likely source area. As seen with many other compounds, the lateral distribution of tritium in HSU-1 appears to be limited to a relatively small area downgradient of the probable source areas. The highest tritium concentrations in HSU-2 are consistently reported for well UCD2-14 (which is located next to UCD1-13) and are significantly lower than those in HSU-1. Tritium was not reported in any HSU-2 wells or in Hydropunch samples in the vicinity of the anticipated extraction well EW2-1. Figure 16 presents a compilation of hydropunch data and well data for tritium in HSU-1 and HSU-2. The MCL for tritium is 20,000 pCi/L.

4.3 Background Water Quality

This section presents a review of groundwater data for the Site and vicinity in order to evaluate background water quality in the vicinity of the Site. The purpose of evaluating background conditions is to help in establishing water quality goals for potential discharge to HSU-2 through reinjection. The water quality goals for reinjection are then used to evaluate treatment alternatives that are technologically and economically feasible to protect applicable beneficial uses of the water.

The water quality evaluation was conducted by reviewing data from three sources. Water quality data from municipal, domestic, and irrigation wells in the Davis Area was evaluated to provide information on a regional scale. Regional data were compiled previously for a Draft Technical Memorandum for Background Data Review — Groundwater (Dames & Moore, 1995). Data collected as part of the Site neighbor's well sampling program was reviewed to evaluate concentrations of Site constituents in areas immediately surrounding the Site. The neighbor's well data are collected quarterly as part of the LEHR Environmental Restoration. Data from Site monitoring wells UCD1-18 and UCD2-17 provides water quality information from areas immediately upgradient from the Site. These two wells are located approximately 500 feet west of the Site and are sampled as part of the Site quarterly monitoring program. A summary of data from each of these areas is presented in the following three sections.

4.3.1 Regional Water Quality

Groundwater in the vicinity of the Site and Davis is considered a magnesium bicarbonate type because the dominant cation is magnesium, and the dominant anion is bicarbonate. Groundwater in this area is included in the south alluvial fan facies, one of six hydrochemical facies of shallow groundwater in the Sacramento Valley defined by Hull (1984). This facies is characterized by higher dissolved solids concentrations than other Sacramento Valley groundwater, and elevated boron, fluoride, and chloride concentrations. Dissolved solids and chloride in groundwater in the area typically increase from west to east, with TDS concentrations typically exceeding 500 mg/L in the Davis area (Evenson, 1985). Significant temporal increases in dissolved solids and nitrate concentrations have been documented since the mid-1950s. Dissolved solids concentrations have increased at a rate of 4.75 mg/L per year, and nitrate as NO_3 has increased at a rate of 0.16 mg/L per year (Hull, 1984). The increase over time of TDS and nitrate as NO_3 concentrations is generally attributed to local agricultural practices and to the loading of salts to agricultural land by using groundwater for irrigation.

In addition to general water quality information for the Davis and Site region, information on two Site constituents of concern, nitrate and chromium, was also presented in the Draft Background Data Review (Dames & Moore, 1995). Nitrate as NO_3 concentrations in the shallow groundwater

system in the Davis area range from less than 45 mg/L to greater than 177 mg/L, with the majority of the concentrations falling in the range between 45 and 90 mg/L. Total chromium concentrations in Davis area groundwater range from non-detect to greater than 100 μg/L. The majority of the total chromium concentrations lie in the range between non-detect and 25 μg/L. A summary of regional data is presented in Table 3.

4.3.2 Neighbor's Wells Water Quality

Tables 3, 4a , and 4b present a summary of results from the analysis of neighbor's wells samples for hexavalent chromium and nitrate. The samples were collected as part of quarterly monitoring in 1995 and 1996 of domestic and irrigation wells located near the Site. Data for both nitrate as NO_3 and hexavalent chromium show a great deal of variability. Concentrations of nitrate as NO_3 range from 16.4 mg/L to 221 mg/L, and typically occur between 22 mg/L and 66 mg/L. Concentrations of hexavalent chromium range from <10 μg/L to 140 μg/L and typically occur between 10 μg/L and 30 μg/L. It is important to note when looking at these results that groundwater sampled from these domestic and irrigation wells is derived from multiple hydrostratigraphic units. However, as discussed in the modeling analysis in Chapter 3.0, most of the flow in the neighbor's well (up to 90%) is anticipated to come from HSU-2. These results do show that there is a great deal of variation within the vicinity of the Site in the concentrations of these two Site constituents of concern.

4.3.3 Local Water Quality

Annual Reports produced for the Site water monitoring program have evaluated Site impacts by comparing data from onsite and downgradient monitoring wells to data from upgradient monitoring wells UCD1-18 and UCD2-17 (PNL, 1994, 1995; PNNL, 1996a). The comparisons have been conducted by calculating separate upper tolerance limits (UTL) for the data from UCD1-18 (HSU-1) and UCD2-17 (HSU-2). The UTL values were calculated separately for HSU-1 and HSU-2 and compared to downgradient data from HSU-1 and HSU-2, respectively. Downgradient results that exceed the UTL value for a parameter are considered elevated for the Site at the 95% confidence level. As a result, the UTL values for Site parameters have generally been considered as the statistical upper limit of upgradient concentrations for Site groundwater parameters.

The most recently calculated UTL values for several Site parameters in HSU-2 were calculated for the 1995 Annual Monitoring Report (PNNL, 1996a). The UTLs were calculated using the most recent eight quarters of data collected between the Winter of 1994 and the fall of 1995. Eight quarters of data were used in this calculation to reduce bias toward the most recent results. UTL values for HSU-2 well UCD2-17 are presented in Table 3.

4.4 Anticipated Extraction Well Water Quality

In order to more accurately estimate the quality of water that would be generated during the Site IRA, groundwater samples were collected and analyzed from new extraction well EW2-1 in October 1996. A total of three samples were collected from EW2-1; the first sample was collected after installation of extraction well EW2-1; the second sample was collected at the final step in the step drawdown pumping test; and the third sample was collected after pumping 47 hours during the constant-rate pumping test.

4.4.1 Extraction Well Analytical Results

Results reported from groundwater samples collected and analyzed from EW2-1 are presented below and in Table 5.

- Chloroform concentrations remained relatively constant (87 μg/L to 100 μg/L) in the three samples.
- One other volatile organic constituent (VOC), 1,2-DCA was reported just above the detection limit in samples collected during the step drawdown test and the constant-rate pumping test.
- Tritium was non-detect in all three samples.
- Semi-volatile organic constituents (SVOCs), analyzed in the constant-rate sample only, were all nondetect.
- Nitrate was reported at consistent concentrations in all three samples and ranged from 23.5 to 26.6 mg/L as NO_3, below the maximum contaminant level (MCL) for drinking water of 45 mg/L.
- Total dissolved solids (TDS) ranged from 380 mg/L in the sample collected at rest, to 470 mg/L in the sample collected during the constant-rate pumping test. The drinking water MCL is 500 mg/L.
- Hexavalent chromium was reported as nondetect in the samples collected from EW2-1 after installation, and during the step drawdown test, and was reported as 15 μg/L in the sample collected during the constant-rate pumping test (with a detection limit of 10 μg/L). Although there is no drinking water MCL for hexavalent chromium, the MCL for total chromium is 50 μg/L.

4.4.2 Discussion

Data collected from EW2-1 during aquifer testing represent the anticipated quality of extracted groundwater (Table 6). Because the data used to estimate the extracted groundwater quality were collected within a relatively short time span (one month), and because the samples were collected after minimal pumping (47 hours), these estimates do not take into account potential changes in

water quality that could occur due to year-round, long-term pumping for the IRA, or due to the seasonal variations in vertical hydraulic gradient. As a result, the concentrations of key parameters could change during the course of long-term operation of the IRA extraction system. For example, HSU-1 groundwater in the vicinity of the extraction well has been reported with significantly higher concentrations of hexavalent chromium, nitrate, and TDS than water from HSU-2. It is possible that as HSU-1 groundwater is drawn down into HSU-2 during IRA extraction or during seasonal changes in vertical gradient, the concentrations of hexavalent chromium, nitrate, or TDS could increase.

4.5 Summary

Chloroform (and associated VOCs) is the most significant parameter in impacted groundwater that will be extracted for the IRA. On UC Davis property, chloroform is reported at concentrations exceeding 100 μg/L over 750 feet downgradient of suspected source areas. Off UC Davis property, chloroform appears to decrease in concentration in the downgradient direction to below detection limits approximately 2,000 feet east of the UC Davis property boundary. The anticipated concentration of chloroform in the extracted groundwater is 100 μg/L.

Background water quality in the vicinity of the Site was evaluated using data collected from area irrigation, domestic and municipal wells, and from upgradient monitoring well UCD2-17. A summary of regional and local data is presented in Table 3. The data indicate concentrations in area groundwater of several key Site constituents (nitrate, hexavalent chromium, and TDS) vary significantly. The variations and relatively high concentrations of some of these parameters are believed to be due in large part to land use practices and the use of groundwater for irrigation.

The overall quality of extracted groundwater has been estimated based on samples collected from the anticipated extraction well. In general, this estimate is consistent with Site groundwater monitoring and hydropunch data, and is representative of HSU-2 conditions in the vicinity of anticipated extraction. However, the quality of extracted water could change during the IRA as a result of prolonged extraction or seasonal stresses on HSU-2. Continued monitoring in and around the extraction well will allow changes in water quality to be tracked and will be conducted as part of IRA operation and the routine Site groundwater monitoring program.

The estimated quality of extracted groundwater is generally consistent with the range of background values for groundwater in the vicinity of the Site, with the exception of the presence of chloroform and other VOCs. As a result, chloroform and other VOCs are the likely focus of remediation efforts undertaken as part of the groundwater IRA. Several other Site parameters, nitrate, hexavalent chromium, and TDS (and some other included salts) are anticipated to exceed

local background values as determined by data from upgradient well UCD2-17, but are below MCLs and are within the general range of concentrations observed in groundwater within the Davis area.

5.0 REMOVAL ACTION OBJECTIVES

This Chapter presents the regulatory basis supporting the groundwater IRA at the Site, the corresponding objectives of the IRA, the constituents of concern, anticipated Applicable or Relevant and Appropriate Requirements (ARARs), and other relevant criteria. Together, these sections constitute the Removal Action Objectives for the groundwater IRA.

5.1 Regulatory Framework

The NCP and CERCLA define removal actions to include "the cleanup or removal of released hazardous substances from the environment, such actions as may necessarily be taken in the event of the threat of release of hazardous substances in the environment, such actions as may be necessary to monitor, assess, and evaluate the release or threat of release of hazardous substances, the disposal of removed material, or taking of such other actions as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat from a release."

The planned groundwater IRA described in this document will be implemented to prevent, minimize, or mitigate damage to public health or to the environment, which may otherwise result from a release or threat of release. Further, this IRA has been categorized as a non-time critical removal action, as defined in Section 104 of CERCLA, based on the relative urgency or threat of the situation at the Site and the subsequent timeframe in which the action must be initiated.

The statutory requirements for removal actions are set forth in Section 300.415 of the NCP. Section 300.415(b)(4) stipulates that a planning period for a removal action should generally not exceed six months, and Section 300.415(b)(5) stipulates that removal actions shall be terminated after $2 million has been obligated for the action or 12 months have elapsed from the date that removal activities begin onsite. However, it has been generally determined by all parties involved with the remedial actions at the Site that the IRA, and the related timeline for implementation, is otherwise appropriate and consistent with the continued response action to be taken (Section 300.415(b)(5)(ii) and 300.415(c)).

5.2 Scope and Objectives of the Groundwater IRA

The scope of the IRA as presented in the Assessment of Remedial Options, Groundwater Extraction and Treatment (Dames & Moore, 1996a), and the Technical Memorandum/Work Plan, Pre-Design Activities, LEHR Groundwater IRA (Dames & Moore, 1996b) includes design and installation of a groundwater extraction, treatment and discharge system at the Site. The scope of the Groundwater IRA has been developed to meet the removal action objectives of the IRA, as stipulated in these two documents, as modified and presented below.

- To prevent, minimize, or mitigate potential threat to public health or the environment.
- To eliminate or substantially decrease potential offsite migration of constituents of concern in HSU-2 at the Site through plume containment and without impacting potential site source areas.
- To substantially reduce the overall mass of constituents of concern in groundwater.
- To provide information on aquifer response and effects of long-term pumping.
- To provide information on the quality of extracted groundwater.
- To provide operational data which will aid in assessment of groundwater treatment effectiveness and the need for further groundwater remedial action.
- To provide data on discharge effectiveness.

Groundwater flow modeling, based on a constant-rate pumping test, was used to select locations for extraction well(s), evaluate flow rates needed to achieve capture, and evaluate options for disposal of treated water. Extraction rates are anticipated to be between 190 and 280 gallons per minute from one or two extraction wells located downgradient of primary source areas (Figures 7 through 11). The extraction well(s) will be best located to capture or substantially control the chloroform in groundwater plume to a 0.5-μg/L concentration. In addition, because the extraction well is located downgradient of most LEHR/SCDS source areas, the groundwater IRA will also provide significant capture for other site constituents of concern in HSU-2. Extracted groundwater will be treated to meet discharge criteria established by the RWQCB. This extraction, treatment and discharge system will, in concept, form a closed loop in which most of the reinjected water is eventually captured via the extraction well.

A monitoring plan for the IRA will be presented in the Removal Action Work Plan, and will comply with the Waste Discharge Requirements issued by the RWQCB. Operational maintenance of the IRA system will be as described in an Operation and Maintenance Manual, and as established in the Waste Discharge Requirements for the permit for reinjection issued by the RWQCB. System operation and maintenance monitoring will be conducted to ensure system integrity, minimize down time, and allow adequate assessment of system performance. Evaluation of groundwater recapture, to assess whether removal action objectives are met, and to assess impact of reinjection on groundwater quality, will be largely accomplished through continued monitoring of the well network at the Site. Monitoring of influent and effluent streams will be conducted to assess treatment effectiveness and, to demonstrate compliance with effluent discharge limitations, and assess potential system modifications, if necessary.

The scope of the IRA will supply information in support of and consistent with objectives for an anticipated long-term groundwater remedial action at the Site. The anticipated system will ensure that the Site is stabilized until long-term remedial action begins. Operation of the IRA system could also allow further evaluation or pilot-scale testing of other remedial treatment technologies within the stabilized plume area, as necessary.

5.3 Applicable or Relevant and Appropriate Requirements (ARARs)

The IRA, though not considered a permanent remedy, will be subject to CERCLA requirements for meeting remediation goals. Remediation goals are developed in order to establish acceptable exposure levels that are protective of human health and the environment and must meet ARARs, where technically and economically feasible.

ARARs are generally separated into three categories:

- ***Chemical-Specific Requirements*** that set health- or risk-based concentration limits or ranges for allowable discharge of particular chemicals or presence of chemicals in a particular medium;
- ***Action-Specific Requirements*** that govern the design and performance of systems or performance activities associated with remedial/removal action; and
- ***Location-Specific Requirements*** which restrict concentrations of hazardous substances or otherwise govern cleanup activities based on the location of the Site.

A list of general ARARs is shown on Table 7.

5.3.1 Chemical-Specific ARARs

Chemical-specific standards may be applicable or relevant and appropriate with respect to aquifer clean-up goals, and may also govern the quality of water that may be discharged from the groundwater IRA system. However, because the groundwater IRA is an interim action, cleanup goals will not be established and chemical-specific ARARs will not be agreed upon for this action. As a result, chemical-specific standards will eventually be considered in establishing clean-up goals, but are not described in detail as part of this EE/CA.

5.3.2 Action-Specific ARARs

The proposed groundwater removal action will involve extracting, treating, and discharging treated water. Treated effluent could be discharged to the UC Davis wastewater treatment plant, to Putah Creek, or to the aquifer through reinjection. Discharges to the wastewater treatment plant must meet pre-treatment standards promulgated for the facility. Surface water discharge or reinjection of treated water must meet action-specific ARARs. Action-specific ARARs for the proposed

groundwater IRA are discussed below, and will be further evaluated as the remedial action is better defined and accepted by the regulatory agencies and the public.

5.3.2.1 Reinjection of Treated Effluent into Aquifers

If treated groundwater is reinjected into the subsurface, regulations governing underground injection may be applicable. Specifically, the Federal Safe Drinking Water Act requires an Underground Injection Control (UIC) program. In California, the UIC program is administered by the US EPA. For CERCLA clean-ups, the UIC program regulates the method and location of the injection. These federal injection requirements are ARARs for the Site.

Federal RCRA requirements and the state's Toxic Injection Well Control Act of 1985 (California Health and Safety Code Section 25159.10 et seq.) are also ARARs for reinjection of treated groundwater. The Injection Well Control Act stipulates requirements for reinjection of wastes, including design and operation safeguards, monitoring requirements, and geological assessment of substrata. The waste stream from the IRA treatment system will not be a hazardous waste and, therefore, will not need to be in strict compliance with this regulation. Section 3020(b) of RCRA addresses injection of contaminated groundwater into the aquifer from which it was withdrawn. Section 258.58 of 40 CFR applies to interim measures necessary to ensure the protection of human health.

Chemical concentrations in treated effluent to be reinjected may also be regulated by the Porter-Cologne Water Quality Control Act and the SWRCB Antidegradation Policy (SWRCB Resolution No. 68-16). Establishing aquifer clean-up levels for the final remedy which are consistent with current and future use of the aquifer as a drinking water source should meet the requirements of the state's Antidegradation Policy (SWRCB Resolution 68-16). This policy calls for the protection of all present and anticipated beneficial uses of water, unless demonstrated to the state that any change in water quality will be consistent with the maximum benefit to the people of the state; will not unreasonably affect present or probable future beneficial uses of such water; and will not result in water quality less than prescribed in state policies. Unless these three conditions are met, background groundwater quality is to be maintained. If the state determines that some water quality degradation is in the best interest of the people of California, some incremental increase in pollutant concentration above background concentrations but below water quality objectives may be permitted under this policy.

Water quality objectives for groundwater and surface water at the Site are found in the Water Quality Control Plan for the Sacramento River, and San Joaquin River Basins. The objectives were established by the RWQCB to implement the Porter-Cologne Act. The concentrations of site constituents of concern in treated groundwater shall be at or below background levels for the

aquifer, unless specific findings are made by the RWQCB, in which case the concentrations may be no higher than the water quality objectives.

5.3.2.2 Air Emission Standards

Any new source that emits toxic chemicals to the atmosphere at concentrations determined by Yolo-Solano County Air Quality Management District (YSAQMD) to be appropriate for review must have authorization to construct and a permit to operate issued by that agency.

5.3.3 Location-Specific ARARs

Two location-specific ARARs have been evaluated for applicability to the Site.

5.3.3.1 Fault Zone

40 CFR Section 264.18 (a) requires that portions of new facilities where treatment, storage, or disposal of hazardous waste will be conducted must not be located within 61 meters (200 feet) of a fault which has displacement in Holocene time. The Site is not located within 200 feet of a known fault. Therefore the relevant and appropriate requirement under 40 CFR Section 264.18 (a) is satisfied.

5.3.3.2 Floodplain

40 CFR Section 264.18 (b) requires that hazardous waste treatment, storage, or disposal facilities located within a 100-year floodplain must be designed, constructed, operated, and maintained to prevent washout of any hazardous waste by a 100-year flood, unless the owner or operator can demonstrate that the waste could be: 1) removed to a safer location before flood waters reach the facility, or 2) no adverse effects on human health or the environment would result if washout occurs. Because the Site is not located within a 100-year floodplain, 40 CFR Section 264.18 (b) is satisfied.

5.3.4 To-Be-Considered Criteria (TBCs)

"To-Be-Considered" criteria (TBCs) are meant to complement the use of ARARs. The TBCs are also useful in determining what is protective of a site, and will be considered in refining the proposed removal action. Briefly described below are potential TBC criteria that may be applied in evaluating the applicability of other ARARs.

Section 2550.4 of CCR 23, Division 3, Chapter 15, Article 5, addresses concentration limits that are established for corrective action programs. However, as an interim removal action, concentration limits established under 2550.4 may not necessarily apply to the groundwater IRA at LEHR/SCDS. Instead, final concentration limits will be included in a Record of Decision written following further groundwater investigation. The final concentration limits will most likely be based on background

levels. Only if a discharger demonstrates that it is technologically or economically infeasible to achieve background levels, the RWQCB may adopt concentration limits greater than background, but no higher than water quality goals.

In CERCLA Section 121(d)(4)(A), early or interim actions allow the US EPA to waive ARARs. Waivers described in Section 300.430(f)(ii)(C) of the NCP may be used for removal actions. In determining if compliance with ARARs is practical, the regulatory agencies may consider the urgency of the situation and the scope of the removal action conducted.

5.3.5 Application of ARARs and TBC Criteria

Section 300.415(I) of the NCP requires that removal actions under US EPA Section 104 and removal actions pursuant to CERCLA Section 106, attain ARARs under Federal or State environmental laws, to the extent practicable considering the urgency of the situation and the scope of the removal. The aspect of the IRA most impacted by the ARARs discussed are the discharge limits for treated water, especially for the reinjection alternative. However, because the groundwater IRA is an interim action, cleanup goals will not be established and chemical-specific ARARs will not be agreed upon for this action. ARARs cited that are applicable to developing discharge limits for the reinjection alternative are action-specific State standards for meeting background water quality.

As chemical specific ARARs and action-specific ARARs are evaluated for their applicability to the groundwater IRA, NCP and State policies allow that the technical and economic feasibility of the alternative be considered. If for technical or economic reasons an alternative does not meet a state or federal standard, the alternative may still be selected under NCP Section 300.430(f)(1)(ii)(C)(1) if the alternative is an interim measure and if the alternative will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement.

6.0 IDENTIFICATION OF REMOVAL ACTION ALTERNATIVES

This chapter identifies the removal action alternatives considered for the IRA. An initial screening of the different IRA elements (extraction, treatment, and discharge) based on implementability, effectiveness and associated costs is provided in Section 6.1. This qualitative assessment of each individual extraction, treatment and discharge element determines the viability of a complete IRA alternative. Complete IRA alternatives are identified and further screened in Section 6.2 based on: (1) meeting IRA objectives; and (2) associated costs with implementation. A more detailed pre-design and cost analysis of the preferred IRA alternatives are presented in Chapter 7.0.

Initial consideration of extraction, treatment and discharge options was provided in the Assessment of Remedial Options, Groundwater Extraction and Treatment (Dames & Moore, 1996a). Further assessment into the feasibility of different remedial options required an aquifer pumping test, groundwater flow modeling, and further inquiries into discharge options to address uncertainties related to the following:

1. Required groundwater extraction rates for hydraulic containment;
2. Extracted groundwater quality to identify necessary treatment requirements to meet specific discharge water quality criteria; and
3. Water quality criteria (limits) for various discharge options, including: reinjection to the HSU-2 aquifer; connection to the sanitary sewer for treatment at the UC Davis wastewater treatment plant; discharge to Putah Creek; and land discharge (irrigation) of surrounding agricultural properties.

6.1 Screening of Extraction, Treatment, and Discharge Technologies

Feasibility of extraction, discharge, and treatment technologies required to provide hydraulic containment and treatment of contaminated groundwater under an IRA was evaluated based on the following screening criteria:

- ***Effectiveness:*** Ability to meet removal action objectives;
- ***Implementability:*** Technical and administrative feasibility; and
- ***Cost:*** Relative capital combined with operational and maintenance costs.

Analyses of individual extraction, treatment, and discharge options using these three screening criteria are presented below in Sections 6.1.1, 6.1.2, and 6.1.3, respectively.

6.1.1 Extraction Well Options

The hydrogeologic modeling results (Chapter 3.0) presented two possible groundwater extraction options for providing hydraulic containment of the contaminated groundwater. The two options

address the capture zone effectiveness with and without operation of the irrigation well 22N. The hydrogeologic modeling results show that operating the irrigation well 22N creates a groundwater gradient shift in a northeasterly direction toward the irrigation well 22N which results in a decrease of the capture zone effectiveness created by extracting from EW2-1 (see Figure 11). Two extraction options (Option 1, Single Extraction Well; and Option 2, Two Extraction Wells) are identified and screened below.

6.1.1.1 Option 1: Single Extraction Well (EW2-1)

Option 1 includes extracting groundwater at a flow rate of 190 gpm from Extraction Well EW2-1, and installing a new well to replace the irrigation well 22N.

Effectiveness: Hydraulic containment of the contaminated groundwater plume (as defined by the 1-μg/L chloroform plume) can be achieved in the upgradient direction by pumping at 190-gpm flow rate and not operating the irrigation well 22N. If option 1 is implemented, an alternative irrigation well is planned to replace the irrigation needs provided by the irrigation well 22N, if necessary. Extraction from a single well, in combination with not using the irrigation well 22N, can meet the removal action objective of providing plume containment (Figure 8).

Implementability: Installing a pump and maintaining an extraction rate of 190-gpm from EW2-1 is technically feasible based on the observed maximum flow rate (400 gpm) achieved during the aquifer testing performed using EW2-1. If well 22N is removed from service, an alternative water supply would need to be provided to meet the irrigation needs currently served by well 22N. A well permit will be needed for the construction of a replacement irrigation well for the irrigation well 22N.

Cost: This extraction option requires replacing the irrigation well 22N. The estimated capital cost is $80,000, which includes installation of one irrigation well to a depth of 290 feet, a 50-hp pump, and related electrical connections.

6.1.1.2 Option 2: Two Extraction Wells (EW2-1 and EW2-2)

Option 2 includes extraction of groundwater at a total flow rate of 280 gpm; 190 gpm from Extraction Well EW2-1 (same as Option 1); plus an 90-gpm flow from the new proposed Extraction Well EW2-2. The combined 280-gpm extraction rate provides plume capture while operating the irrigation well 22N.

Effectiveness: Hydraulic containment of the contaminated groundwater plume during the irrigation well 22N operation is technically feasible by pumping EW2-1 at 190 gpm, combined

with additional pumping from proposed EW2-2 at 90 gpm. Figure 9 presents model simulations that indicate that pumping EW2-1 and EW2-2 provides hydraulic capture of contaminated groundwater during periods of operating the irrigation well 22N.

Implementability: Installing a groundwater pump and maintaining a 190-gpm pumping rate from EW2-1 and a 90-gpm flow from proposed EW2-2 is technically feasible as determined from the aquifer testing performed with EW2-1. However, additional water level monitoring and hydraulic controls (valving) will be required to adjust and balance flow from both of the extraction wells while operating irrigation well 22N, simultaneously.

Cost: Capital costs include installation of a new extraction well (EW2-2), which is estimated to be $42,000. This cost includes a 100-gpm pump, piping, valving, and electrical connections. The cost implications of the additional flow contribution from EW2-2 on treatment and discharge requirements are discussed in Section 6.2.

6.1.1.3 Extraction Well Screening Summary

As summarized in the table shown below, both extraction elements are retained for further analysis since each option can be effective in providing hydraulic containment, and are technically feasible without significant differences in relative costs between the one-well and two-well extraction options.

Screening of Extraction Options

Extraction Option	Effectiveness	Implementability	Cost	Retained for Further Evaluation
1. Flowrate 190 gpm*	Yes	Yes	Yes	Yes
2. Flowrate 280 gpm**	Yes	Yes	Yes	Yes

* Includes operation of a single, existing extraction well EW2-1 and installation of a replacement irrigation well.
** Includes operation of EW2-1, and installation and operation of a new extraction well, EW2-2.

6.1.2 Discharge Options

Section 6.1.2 presents four alternatives for discharging the extracted groundwater:

- Reinjection into HSU-2 aquifer;
- Sanitary sewer discharge;
- Putah Creek discharge; and
- Agricultural land discharge (Irrigation)

Each of these four discharge alternatives listed above are evaluated relative to effectiveness, implementability, and costs.

6.1.2.1 Option 1: Reinjection into HSU-2 Aquifer

Option 1 includes reinjection of treated groundwater at a location upgradient of the contaminated source area. The location of the proposed injection well and the hydraulic effects on plume capture is discussed in Chapter 3.0, and shown on Figures 10 and 11.

Water quality criteria for reinjection has been discussed with RWQCB, however no formal limits have been established. It is anticipated that reinjection limits will be established by the RWQCB based on local and regional background water quality data presented in Section 4.3, and based on technical and economic feasibility of implementation. Estimated ranges of local and regional background water quality data were presented in Table 3.

Effectiveness: Properly locating an injection well and providing treatment to meet RWQCB water quality limits ensures that reinjection can be protective of human health and the environment. Model results presented in Chapter 3.0 show that by locating the injection well upgradient of the extraction well, a large portion of the injected water is contained and recaptured by the extraction well(s). The effectiveness of recapturing a large portion of the injected water will be monitored and the data will be used to evaluate the fate of selected chemical constituents not removed by treatment prior to reinjection. In addition, reinjection or return of groundwater to the original HSU-2 from which it was extracted ensures that water will remain an available groundwater resource for future use.

Implementability: Installing and operating an injection well to discharge treated groundwater is technically feasible at either the 190-gpm or 280-gpm flow rate. The hydraulic conductivity was verified through pumping tests described in Chapter 3.0, and the proposed injection flow rates are significantly below recharge assimilative capacity of the proposed HSU-2 injection well.

Water hardness has the ability to limit technical implementability due to potential for scaling and clogging of reinjection well screens. However, this potential problem can be managed through proper injection well design, monitoring and maintenance. An injection well permit that includes reinjection water quality limits, or the substantive criteria for such a permit, will be required.

Costs: The capital cost of installation of an injection well and the associated valving and piping is estimated to be $90,000.

6.1.2.2 Option 2: Sanitary Sewer Discharge

Option 2 includes direct discharge to UC Davis wastewater treatment plant (WWTP) via an existing onsite sanitary sewer system. Discharge water quality limits established by UC Davis Engineering Services are listed in Table 8.

Effectiveness: The option of discharging to the sanitary sewer would be protective of human health and the environment, provided the UC Davis WWTP achieves a level of treatment that meets its discharge permit requirements. No pretreatment of extracted groundwater would be required prior to discharge to the sewer system (Phillips, December 1996).

Implementability: It is not technically feasible to discharge extracted groundwater at either the 190-gpm or 280-gpm flow rate without surpassing the existing 2.33 million-gallon-per-day (mgd) hydraulic design capacity of the UC Davis WWTP (UC Davis, Dave Phillips, December 1996). Although it is anticipated that the new WWTP will be constructed in 1999, waiting for improvements would require delaying the implementation of the interim removal action. In addition, significant improvements may be required to the existing sanitary sewer system, including retrofitting the lift station located at the Site.

Cost: Significant capital costs would be incurred by upgrading the existing sewer system and WWTP capacity for treating extracted groundwater. This cost is based on percentage of the total plant flow rate that the discharge from the IRA would represent, which is approximately 12%. Because the total cost for the proposed UC Davis wastewater treatment plant is $16 million, the estimated capital cost to discharge to the sewer is $1.9 million. Discharge from the IRA is not included in the anticipated flow rates for the new WWTP design. If the IRA were to discharge to the WWTP, it would be using flow capacity planned for other future campus projects. Thus, discharge from the IRA could cause a need to expand the new WWTP, resulting in the estimated capital costs presented above. The estimated capital cost of $1.9 million does not include the additional costs for upgrading the existing sewer system capacity to accommodate the IRA discharge.

6.1.2.3 Option 3: Putah Creek Discharge

Option 3 consists of constructing a pipeline and outfall structure at Putah Creek.

Effectiveness: Discharging approximately 274,000 to 403,000 gallons per day constitutes a significant percentage of total stream flow in Putah Creek. Therefore, a consistent level of treatment of extracted groundwater prior to discharging to Putah Creek would be needed to ensure strict adherence to established discharge limits to be protective of human health and the environment. Because significant increases in the Putah Creek flow would result, further study

of the effect on the environmental quality of Putah Creek ecosystem may be needed. The proposed Putah Creek discharge option could require further evaluation by completion of a CEQA compliance audit.

Implementability: Discharge of treated groundwater directly to Putah Creek would require a National Pollutant Discharge Elimination System (NPDES) permit from the RWQCB or meeting the substantive requirements of an NPDES permit. For purposes of this EE/CA, it assumed that the WDRs for a Site treatment system would resemble the July 1996 WDRs for a proposed Putah Creek discharge of the treated groundwater from a remediation system at the University's Davis Campus Pedrick Road Landfill (WDR Order 96-227).

As discussed below and presented in Table 8, the potential applicable limits for discharge to Putah Creek are based on Order No. 96-227. The Order limits daily maximum discharges of total chromium (Cr) and hexavalent chromium (Cr^{+6}) to 50 μg/L and 15 μg/L, respectively. In addition, the Order limits concentrations of VOCs in the discharge to below detection limits. Based on a comparison of the expected influent groundwater quality to the Putah Creek discharge limits (Table 8), it is anticipated that the discharge to Putah Creek from the Site may require removal of VOCs, and reduction in the levels of hexavalent chromium, nitrate, and TDS.

Cost: Capital costs associated with the Putah Creek discharge option include constructing a pipeline and outfall structure ($50,000) and significant additional treatment costs in excess of $500,000 for removing non-VOCs, such as chromium, to meet Putah Creek water quality discharge criteria. Treatment costs are discussed in Section 6.1.3.

6.1.2.4 Option 4: Discharge Treated Groundwater to Agricultural Land

Option 4 includes constructing a pipeline to a discharge point that is accessible to farmers to use as irrigation water.

Effectiveness: Treating extracted groundwater prior to discharging to agricultural land would protect human health and the environment from the constituents of concern.

Implementability: Discharge of extracted groundwater, either treated or untreated, solely to adjacent agricultural land does not appear feasible because the groundwater extraction system will be operated continuously, even during the wet season when no agricultural demand for water exists. Application of extracted groundwater to land would require WDRs or a Record of Decision that contains equivalent requirements. The WDRs or Record of Decision would specify the water quality, designate an application area, and would specify a monitoring

program for the discharge. The discharge location would probably be onto the private agricultural parcels to the east of the Site, or onto UC Davis agricultural parcels to the west of the Site. Although discharge to agricultural land does not appear to be implementable as a sole means of discharge, application to land could be accomplished with other discharge options and managed in a manner to meet needs of irrigation.

Cost: Capital costs associated with this discharge option include constructing a piping distribution system for irrigation system connections. Capital cost estimates were not calculated because this option is considered technically unfeasible.

6.1.2.5 Discharge Option Screening Summary

As summarized on the table below, only Option 1, reinjection, is retained for further analysis. The costs for options 2 and 3 are potentially higher when compared to Option 1. Option 4 was judged to be not implementable.

Screening of Discharge Options

Discharge Option	Effectiveness	Implementability	Cost	Retained for Further Evaluation
1. Reinjection	Yes	Yes	Yes	Yes
2. UC Davis WWTP	Yes	Yes	No	No
3. Putah Creek	Yes	Yes	No	No
4. Agricultural Land	Yes	No	No	No

6.1.3 Treatment Options

The type of treatment unit process as well as the required level of treatment depends upon the influent flow rate and quality, and the conditions and limits for discharge. Chapters 3.0 and 4.0 discuss the expected flow rate and the quality of the extracted groundwater. Section 6.1.2 presented possible flow and quality limits for several discharge options. This influent flow and quality information, and the effluent (discharge) limits are summarized on Table 8, and were used to evaluate treatment needs. The groundwater flow rate was estimated to be 190 or 280 gpm. Depending upon which discharge is selected, treatment may require removal of VOCs, chromium, nitrate, and TDS.

Several alternative technologies are presented. These include air stripping, ion exchange, bone char adsorption, and reverse osmosis. Each of the technologies is discussed below and summarized on a table presented at the end of this section. The combination of chemical constituents to be

treated in groundwater presents unique treatment challenges. For example, an air stripping unit may be capable of removing VOCs, but ineffective at removing nitrate or inorganic constituents, such as chromium and TDS. Similarly, a reverse osmosis unit may remove TDS, but not organic compounds such as chloroform.

Other treatment options, such as liquid phase activated carbon, were previously evaluated and considered technically infeasible (Dames & Moore, 1996a). In-situ options were also discussed briefly in the previous document; however, in meeting the IRA objectives, only conventional proven technologies were judged to be appropriate. Although the less conventional in-situ and ex-situ technologies were not considered feasible for this IRA, they will be considered for future groundwater treatment and source removal actions at the Site.

6.1.3.1 Option 1: Air Stripping

Air stripping can be effective in reducing VOCs. The air stripper anticipated for the Site would be a manufactured tray-type unit. In the air stripper, the contaminated water is introduced downward into a baffled sieve tray and air is blown upward through hundreds of holes in the tray bottom creating a froth wherein the VOCs are volatilized and eventually vent to the atmosphere.

Effectiveness: Air stripping can remove VOCs from the extracted groundwater to nondetectable levels. However, air stripping will not be effective in removing slightly elevated levels of hexavalent chromium, nitrate, and TDS. If water quality discharge limits require treating hexavalent chromium, nitrate and TDS, then the air stripping treatment system would be combined with another treatment option, such as reverse osmosis. Based on an evaluation of VOC emission rates from the air stripping treatment system, an off-gas permit or treatment system will not be required.

Implementability: Installing and operating an air stripping unit to treat VOCs in groundwater is technically feasible, based on air stripping modeling results conducted using expected influent groundwater quality results presented on Table 3. Based on information provided by the Yolo-Solano Air Quality Management District, an air emissions permit will not be required.

Cost: Capital cost for a low-profile air stripping unit is approximately $70,000 and $100,000 at 190-gpm and 280-gpm flow rates, respectively. Annual costs for air stripping are estimated to be $50,000.

6.1.3.2 Option 2: Ion Exchange

Ion exchange (IX) involves the use of synthetic resins to remove dissolved ions (frequently heavy metals such as hexavalent chromium) from aqueous solution. The extracted groundwater is treated

by passing it through a column filled with beads called ion exchange resins. During the process of removing ions from the aqueous stream, other ions that are found on the resin are released into solution. The resin columns are eventually used up or spent. The columns can then be regenerated on- or offsite. A complete ion exchange system typically consists of an influent tank, pump, filtration (bag and media), quadraplex resin tanks, regeneration storage tank, and controls. The specific unit can be designed with a resin that selectively removes chromium or other target constituents.

Effectiveness and Limitations: Ion exchange can remove chromium, nitrate, and some TDS. Ion exchange is not effective at removing VOCs. The ion exchange column can be affected by the presence of the suspended solids, therefore requiring prefiltration.

A drawback associated with ion exchange is that a concentrated salt solution (reject) may be generated on a continuous basis. The IX unit is estimated to have a reject rate of approximately 5 percent of the incoming flow rate. The TDS would be concentrated in the reject flow and discharged to the sanitary sewer. For hexavalent chromium removal only, it may be possible not to have a reject flow stream. In this case, spent columns could be transported for offsite regeneration.

Implementability: The feasibility of using IX depends on what chemical constituents would be required to be removed. Designing an IX unit for the removal of hexavalent chromium is potentially feasible with offsite regeneration of the spent resin. Removal of nitrate using the IX treatment would likely require use of a selective resin and onsite regeneration. Operation in the onsite regeneration mode would result in a reject stream to the WWTP. Use of IX may not be technically feasible if significant TDS removal is required prior to discharge. Implementation of IX would require detailed analysis of groundwater chemistry and pilot-scale testing prior to design. These pre-design activities, combined with a longer lead time for obtaining the IX equipment, will require extending the timeframe for IRA implementation.

Cost: The cost for an ion exchange unit is dependent upon the flow rates and the amount of hexavalent chromium and nitrate reduction required. Capital costs for ion exchange treatment units may range between $260,000 and $350,000. Annual operating and maintenance costs will be a function of the rate of resin usage and whether the resin columns are generated on- or offsite.

6.1.3.3 Option 3: Bone Char Adsorption

Effectiveness: Bone Char Adsorption, a technology similar to conventional activated granular carbon, would be a potentially effective treatment option for treatment of chromium. Due to

low adsorption rates and possible adsorption interferences with TDS, treatment using bone char would require further treatability testing to determine removal efficiencies.

Implementability: Installing and operating a bone char adsorption unit for the removal of hexavalent chromium is potentially feasible. However, bone char cannot be regenerated and offsite disposal would be required. Use of bone char carbon could be implementable if hexavalent chromium removal only is required. Bone char will not effectively reduce nitrate or TDS levels.

Cost: Capital costs for bone char carbon treatment units are approximately $90,000 and $150,000 at 190-gpm and 280-gpm flow rates, respectively. Annual operating and maintenance costs will be a function of the adsorption rate and cost for offsite disposal.

6.1.3.4 Option 4: Reverse Osmosis

Reverse osmosis (RO) is commonly used to reduce TDS from liquid streams. RO will also remove hexavalent chromium and nitrate. In using RO, the groundwater extracted from the Site would first be prefiltered to remove solids prior to passing through the reverse osmosis module. The RO process involves creating a pressure gradient and flow across an RO membrane, causing the water to permeate through the membrane. The concentrate (high TDS component) must be appropriately treated and discharged at the UC Davis WWTP, while the permeate (clean groundwater) could be discharged.

Effectiveness: Reverse osmosis would be effective in meeting IRA goals if discharge limits are established for hexavalent chromium, nitrate, and TDS. If RO treatment is used, only a portion of extracted groundwater flow would have to be routed through the RO unit to meet discharge limits. For example, treatment for approximately 50% of the total extracted groundwater flow rate could result in an combined effluent stream that meets discharge water quality criteria. Therefore, in the case of the Site, treatment flow rates of approximately 100 gpm and 150 gpm would flow through the reverse osmosis system, based on total groundwater extraction flow rates of 190 gpm and 280 gpm, respectively.

Approximately 25% of the influent stream into the reverse osmosis unit is generated as a concentrated waste stream requiring sewer discharge for treatment at the UC Davis WWTP. At this time, the UC Davis WWTP can accept the concentrated waste stream at approximately 25-gpm to 40-gpm flow rates (Phillips, 1996b).

Implementability: Technical feasibility is obtained by proper system design flow rates to meet water quality discharge criteria. The existing sewer system infrastructure can accommodate the

RO reject concentrate waste stream flow. Additional field testing and detailed chemical analysis of groundwater will be required and a longer lead time for obtaining RO equipment must be considered. Therefore, implementation of RO treatment at the Site could require modifying the IRA schedule presented in Chapter 9.0.

Cost: Capital costs for reverse osmosis treatment system are expected to range between $250,000 and $350,000. Annual operating and maintenance costs are approximately $200,000 to $250,000 due to significant electrical costs for maintaining the required pressurized flow stream through the RO membrane.

6.1.3.5 Treatment Option Screening Summary

The table below shows air stripping and reverse osmosis being retained for further evaluation. Ion exchange and bone char adsorption are not retained, as these two technologies may not be effective in significantly reducing TDS prior to discharge.

Screening of Treatment Options

Treatment Option	Effectiveness	Implementability	Cost	Retained for Further Evaluation
1. Air Stripping for VOCs	Yes	Yes	Yes	Yes
2. Ion Exchange for Cr^{+6} and NO_3	Yes	No	Yes	No
3. Bone Char Carbon for Cr^{+6}	Yes	No	Yes	No
4. Reverse Osmosis for Cr^{+6} NO_3 · TDS	Yes	Yes	Yes	Yes

6.2 Identification of IRA Alternatives

The identification of complete IRA alternatives was conducted following the use of screening criteria for extraction, treatment, and discharge options in Section 6.1. The IRA extraction, treatment, and discharge elements retained by the Section 6.1 screening process are summarized below:

Extraction

- Single extraction well (EW2-1) at 190 gpm and replacement of the irrigation well 22N
- Two extraction wells at 190 gpm (EW2-1) and 90 gpm (EW2-2)

Treatment

- Air stripping (VOC removal)

❖ Reverse osmosis (hexavalent chromium, nitrate, and TDS removal)

Discharge

❖ Reinjection in HSU-2 upgradient from source area

Combining the extraction, treatment, and discharge option results in a total of four complete IRA alternatives produces the following table:

IRA Alternatives

Alternative	Extraction	Treatment	Discharge	Capital Cost	O&M (1 year)	Capital* O&M (5 years)
No. 1	190 gpm	Air Stripping	Reinjection	$536,000	$93,600	$0.91M
No. 2	190 gpm	Air Stripping/ Reverse Osmosis	Reinjection	$1,336,000	$250,000	$2.33M
No. 3	280 gpm	Air Stripping	Reinjection	$531,000	$116,000	$0.99M
No. 4	280 gpm	Air Stripping/ Reverse Osmosis	Reinjection	$1,300,000	$280,000	$2.44M

* Present worth based on 5-year project life and on 8% interest rate.

6.3 Screening of Complete IRA Alternatives

The above table presents four complete IRA alternatives. It also presents the costs for the four options. Because two of the four options differ only with regard to flow rate, a further screening of the four options related to the flow rate is performed and discussed below.

The purpose of providing two alternative extraction rates (190 gpm and 280 gpm) relates to the need to retain and operate the irrigation well 22N. As stated in Chapter 3.0, operating the irrigation well 22N during the summer months will require a two-extraction well system with a combined flow of 280 gpm. If the irrigation well 22N is not operated, a single extraction well pumping at 190 gpm is capable of maintaining an effective capture zone year-round (Chapter 3.0). As shown in Figure 9, the capture zone with two extraction wells is wider to account for the influence of well 22N. However, the two-well scenario would also generate an additional 90 gpm that would widen the distribution of injected water. Although the expected concentrations of site constituents generated during pumping two extraction wells could not be estimated due to a lack of well data, the likely effect of adding 90 gpm of water from a second, downgradient extraction well would be

to dilute the concentration of several site constituents. The dilution, however, would only occur during the pumping season, and the design of the treatment system would still have to accommodate the higher concentrations anticipated from extraction well EW2-1.

As shown in the above table, the incremental cost increase to install and operate a 280-gpm system, instead of a 190-gpm system, over a 5-year period is approximately $80,000 (when comparing Options 1 and 3), and $90,000 (when comparing Options 2 and 4). It should be noted that both 190-gpm options include costs for replacing the irrigation well 22N with a new irrigation well and pump system.

With regard to the two alternative flow rates, all four options are effective and implementable to nearly the same degree, only the cost differential is relevant. Therefore, it is concluded that only the more cost-effective, 190-gpm options be retained for further analysis.

The two 190-gpm options (Alternative 1 and Alternative 2) differ with respect to the level of treatment. Alternative 1 includes air stripping to remove VOCs, and Alternative 2 includes VOC removal using air stripping, plus reverse osmosis to remove hexavalent chromium, nitrate, and TDS. Chapter 7.0 provides a detailed analysis of Alternative 1 and Alternative 2.

7.0 ANALYSIS OF REMOVAL ACTION ALTERNATIVES

This section presents an analysis of the two potential removal action alternatives for consideration as the final recommended Interim Removal Action (IRA). The two alternatives were developed and identified through the screening process presented in Section 6.2.

- ***Alternative 1 — Extraction/VOC Removal/Reinjection:*** Alternative 1 includes groundwater extraction at 190 gpm with replacement of the irrigation well 22N, treatment using air stripping for VOC removal, and discharge to proposed injection well (IW2-1);

- ***Alternative 2 — Extraction/VOC, Nitrate, Hexavalent Chromium, and TDS Removal/ Reinjection:*** Alternative 2 includes groundwater extraction at 190 gpm with replacement of the irrigation well 22N; treatment using air stripping for VOC removal followed by reverse osmosis for reducing hexavalent chromium, nitrate, and TDS concentrations; and discharge to proposed injection well (IW2-1).

Both alternatives are evaluated independently in Sections 7.1 and 7.2. Each evaluation is based on a detailed assessment of long-term effectiveness, issues pertaining to technical and administrative implementability, and the associated capital and operational and maintenance costs. Section 7.3 includes a comparison of advantages and disadvantages for each alternative leading to the selection of one final IRA alternative. Recommendations for the final implementation of the preferred IRA alternative are provided in Section 7.4.

7.1 Alternative 1 - Groundwater Extraction/VOC Removal/Reinjection

7.1.1 Description

Descriptions of the extraction, treatment and discharge elements comprising Alternative 1 are discussed below.

Groundwater Extraction: Hydraulic containment requires an extraction flow rate at 190 gpm from EW2-1 and replacing the irrigation well 22N with a new irrigation well. As discussed in Chapter 3.0, groundwater flow modeling assessed groundwater extraction well field locations with the specific intent of limiting further offsite migration of VOC impacted groundwater. The groundwater modeling simulations indicate that replacing the irrigation well 22N and pumping existing extraction well EW2-1 provides sufficient hydraulic containment. Therefore, a new irrigation well will be located outside of the hydraulic influence of EW2-1, to provide irrigation water previously supplied by irrigation well 22N.

VOC Removal: The treatment of groundwater as part of the response action must substantially reduce the hazardous constituents to the extent technically and economically feasible, and the

response action must be sufficiently protective of human health and the environment. Air stripping can be effective in removing VOCs down to non-detectable levels. The air stripper used at the Site would treat the 190-gpm flow rate using a three-tray, low-profile unit. The air stripper unit considered for the Site is readily available. The Alternative 1 unit including the air stripper will be enclosed within a building. The stripper would operate using a 15-hp blower at approximately 1,800 standard cubic feet per minute to effectively remove VOCs from extracted groundwater to non-detectable levels. Based on the estimated air emission rates from operation of this air stripper unit, the UC Davis/Site groundwater treatment system would be exempt from YSAQMD air permitting and off-gas treatment requirements. Air emission rates from the IRA unit will not result in the modification of the UC Davis campus-wide allowable air discharge levels and permits (Oatman, 1997).

Reinjection: Treated groundwater may be reinjected assuming that treatment levels achieved by air stripping meets the waste discharge requirements for reinjection to be established by RWQCB. Water quality criteria for reinjecting treated groundwater will be determined by the RWQCB based on drinking water standards and local and regional background water quality, as discussed in Chapters 4.0 and 5.0.

7.1.2 Alternative 1 Effectiveness

The evaluation of the effectiveness of attaining IRA objectives with Alternative 1 was performed according to a detailed analysis of long-term viability, compliance with ARARs, and ability to reduce the toxicity, mobility, or volume of contaminants.

Long-term effectiveness and permanence: Adequate capture of the contaminated groundwater plume and VOC removal from the extracted groundwater prior to reinjection will provide permanent removal of VOCs from the Site. Air stripper modeling results demonstrated, and vendor experience indicates, that air stripping can remove 1,1-DCA, 1,1-DCE, 1,2-DCA and chloroform to a concentration less than 0.5 μg/L. However, the air stripping unit will likely be ineffective in removing nitrate, chromium, and TDS from extracted groundwater. These constituents are present at concentrations below the drinking water MCLs. Reducing salt concentrations using reverse osmosis treatment is analyzed as part of Alternative 2, which is discussed in Section 7.2.

Compliance with ARARs: Alternative 1 uses the air stripping treatment option to reduce the concentrations of VOCs to nondetectable levels. Air stripping will not reduce the chromium, nitrate, and TDS concentrations (Table 9). Therefore, the ability to comply with all ARARs will depend on the reinjection discharge limits to be set by the RWQCB. If the RWQCB requires chromium, nitrate, and TDS removal, Alternative 1 may not be viable.

Reduction of toxicity, mobility, or volume through treatment: The migration of VOC contamination offsite is limited through hydraulic containment of the groundwater plume with extraction from EW2-1. Ex-situ treatment of the extracted groundwater with air stripping effectively transfers VOCs from the extracted groundwater into the air media. The need to treat the VOCs present in the resulting air stripper outgas was evaluated by reviewing the YSAQMD New Source Review (NSR) regulations. The regulations address VOCS from two perspectives: Reactive Organic Gases (ROG) emissions which are precursors to ozone formation (criteria pollutant), and health risk (air toxics).

7.1.2.1 Criteria Pollutant

Regulatory requirements under NSR for criteria pollutants require new stationary sources and major modifications to existing stationary sources that may emit Reactive Organic Gases (ROG), to apply for an Authority to Construct/Permit to Operate (ATC/PTO) with the YSAQMD. However, under current regulatory requirements, there is an NSR exemption to obtaining an Authority to Construct (ATC)/Air Permit if the source has an emission rate less than 2 lb/day. NSR regulatory requirements also contain regulatory emission standards for applying Best Available Control Technology (BACT). Any stationary source emitting more than 10 lbs/day of ROG, NOx, PM_{10} , or SOx, or 550 lbs/day of CO, must apply BACT.

Air emissions from the groundwater treatment system were calculated assuming that the air stripper removes 100% of the VOCs from the water. The ROG air emission estimates for the proposed groundwater treatment system is less than 0.3 lb/day, which is below the NSR exemption level (2.0 lb/day), and is therefore exempt from Yolo-Solano NSR regulations for criteria pollutants. This information indicates that the treatment system does not require an ATC/Air Permit. Furthermore, since daily emissions are less then the Yolo-Solano BACT requirements, the system is not required to apply off-gas emissions controls or BACT.

7.1.2.2 Air Toxics

Yolo-Solano Regulatory requirements also contain requirements pertaining to Toxic Air Contaminants (TACs). The regulatory requirements list a de minimus health risk level for requiring Toxic-Best Available Control Technology (T-BACT). The de minimus health risk for requiring T-BACT is 1 excess cancer case per million people ($1x10^{-6}$). The de minimus health risk trigger level after applying T-BACT or off-gas emissions treatment is $1x10^{-5}$.

Air emissions were calculated assuming the air stripper removes 100% of the TACs since they are a component of the VOCs. The groundwater treatment system could potentially emit three TACs: chloroform, 1,2-dichloroethane, and 1,1-DCA. Hexavalent chromium is also present in the groundwater and is considered a TAC. The transfer of hexavalent chromium from groundwater to

air occurs if aerosols (mist) are emitted. Since the proposed air stripper is a shallow-tray system equipped with a mist eliminator, aerosol emissions will be minimized, and hexavalent chromium was not included as a potential TAC.

A screening level health risk assessment was performed by Dames & Moore to estimate potential carcinogenic health affects from maximum downwind air concentrations of chloroform, 1,2-DCA, and 1,1-DCA. Maximum hourly concentrations to the maximum exposed individual from the treatment system were calculated using (US EPA's) air dispersion model SCREEN3. One-hour modeled concentrations were converted to annual concentrations using standard US EPA methodology. Calculated annual concentrations of each TAC were multiplied by their respective unit risk factors to estimate potential excess cancer cases per million people exposed. SCREEN3 model input and output are presented in Table 10. Estimated maximum potential excess cancer cases for all TAPs were below 1×10^{-6}, which is below both the T-BACT de minimus levels. Due to minimal air emissions, the treatment system does not require T-BACT.

7.1.3 Implementability

Technical Feasibility: The TDS concentrations, particularly the levels of calcium and magnesium, are sufficiently high to cause scaling on the trays located within the air stripping unit. If managed through a regular maintenance program, the air stripper manufacturer estimates that the shallow-tray air stripper will require cleaning with a weak acid solution approximately once a month. The effects of scaling on air stripper performance can be addressed during design and by development of an effective maintenance program. The potential for scaling also exists in the reinjection well. Scaling in the reinjection well will be evaluated by monitoring pressure loss over time at the injection well head. Specific methods for addressing fouling of the air stripper and reinjection well will be described in the O&M Plan.

Administrative Feasibility: To discharge groundwater via reinjection will require meeting the substantive requirements of Waste Discharge Requirements (WDRs). The WDRs issued by the RWQCB will include reinjection water quality criteria. In addition, a well permit will be needed for installation of injection Well (IW2-1). As discussed above, an air permit will not be required for the air stripper discharge.

Availability of Services and Materials: No foreseen shortage exists in availability of services and materials associated with implementation of this alternative.

State Acceptance: Implementation of this alternative requires development of WDRs that establish discharge limits for reinjection. If more stringent waste discharge requirements are imposed by the

RWQCB than attainable with air stripping treatment, then additional treatment would be needed or selection of another discharge option requiring less stringent water quality criteria.

Community Acceptance: Preventing the migration of VOCs at the point of extraction, and providing VOC treatment prior to discharge provides protection of human health and the environment. Nitrate, hexavalent chromium, and TDS levels will not be reduced, but these constituents are present in the extracted groundwater at concentrations below drinking water MCLs. Additionally, reinjecting the treated groundwater upgradient from the contaminant source area allows for further management of groundwater impacts by providing long-term containment of most residual chemical constituents onsite. Reinjecting treated groundwater also allows for the future use of the groundwater resource.

7.1.4 Cost

The total estimated capital cost for Alternative 1 is $536,000. This cost includes engineering, administration, compliance monitoring, and contingencies. A summary of capital costs for Alternative 1 is presented on Table 11, and includes an extraction well system, air stripper treatment unit, injection well system, and a sewer connection for disposal of scaling solutions generated by the cleaning of the air stripper unit.

The annual operation and maintenance costs are estimated to be approximately $93,600 (Table 11). The primary operating costs include electrical power for the treatment system, and labor and materials for monitoring and maintaining the air stripper system on a monthly basis.

7.2 Alternative 2 - Extraction/VOC, Nitrate, Hexavalent Chromium, and TDS Removal/ Reinjection

7.2.1 Description

Alternative 2 is identical to Alternative 1 with regard to method of extraction and discharge. Groundwater is extracted at 190 gpm from well EW2-1 and discharge is accomplished through the use of a proposed injection well (IW2-1). Therefore, the following description focuses only on treatment, since Alternative 2 differs from Alternative 1 by the addition of a reverse osmosis treatment unit.

VOC, Nitrate, Hexavalent Chromium, and TDS Removal: Following the air stripping treatment unit previously described as part of Alternative 1, would be a reverse osmosis (RO) treatment unit to specifically reduce hexavalent chromium, nitrate and TDS concentrations. In using RO, the groundwater extracted from the Site would first be prefiltered to remove solids prior to passing through an air stripper, and then the reverse osmosis module. The RO process involves creating a

pressure gradient and flow across an RO membrane, causing the water to permeate through the membrane.

The estimated water quality potentially attainable with using the combination of the air stripping followed by a reverse osmosis treatment unit is shown in Table 9. It should be noted that in order to meet the yet-to-be estimated water quality limits for discharge, it was anticipated that only a portion of the total 190-gpm flow (requiring VOC removal to nondetectable levels with the air stripper) must be passed through the RO unit. For purposes of the EE/CA, the actual flow rate required to pass through the RO unit was estimated using the influent nitrate concentration of approximately 27.0 ug/L, and an assumed potential injection water quality discharge limit of 16.8 ug/L (assumed to be appropriate for purposes of discussion and analysis). Given these parameters, a 100-gpm RO unit should be sufficient, and the remaining 90-gpm effluent stream from the air stripper would bypass the RO unit.

From the 100-gpm flow rate passing through the RO unit, an estimated 25-gpm concentrate waste stream (reject) would be discharged to the UC Davis WWTP. The resulting 75-gpm permeate stream (clean groundwater) would combine and mix with the remaining 100 gpm from the air stripping unit and be reinjected into well IW2-1.

The 100-gpm RO unit would consist of a series of membrane units that would be placed on a skid approximately 9 feet wide and 27 feet long. Due to the relatively large size of the treatment system, housing it would be difficult and costly. Since reverse osmosis systems are weather proofed, it would not have to be enclosed indoors.

7.2.2 Effectiveness

The evaluation of the effectiveness of attaining IRA objectives with Alternative 2 was performed according to a detailed analysis of long-term viability, compliance with ARARs, and ability to reduce the toxicity, mobility, or volume of contaminants.

Long-term effectiveness and permanence: Adequate capture of the contaminated groundwater plume with treatment for VOC and inorganics from the extracted groundwater will provide removal of the constituents of concern from the Site. As previously discussed, the air stripper can remove 1,1-DCA, 1,1-DCE, 1,2-DCA and chloroform to a concentration less than 0.5 μg/L. The addition of RO will provide effective removal of nitrate, hexavalent chromium, and TDS from extracted groundwater.

Compliance with ARARs: Alternative 2 using the air stripper in combination with a reverse osmosis treatment unit will reduce the concentrations of VOCs and inorganics to discharge limits. The level of RO treatment will depend on the eventual reinjection water quality criteria applicable at the Site.

Reduction of toxicity, mobility, or volume through treatment: The migration of the contaminated groundwater plume is limited through hydraulic containment with groundwater extraction from EW2-1 at the 190-gpm flow rate. Treatment of the extracted groundwater with air stripping effectively transfers VOC contamination from the extracted groundwater into the air media, as previously discussed under Alternative 1. Additional treatment for chromium, nitrate and TDS with a reverse osmosis unit will effectively transfer concentrations in the extracted groundwater influent stream into a concentrated effluent stream for discharge to the UC Davis WWTP. Therefore, the combination of air stripping and reverse osmosis treatment is capable of meeting any potential discharge quality limits yet to be determined for reinjection.

In summary, Alternative 2 will effectively reduce the presence of hazardous constituents of concern from the extracted groundwater through controlling the mobility of contaminants offsite with subsequent reductions in toxicity through treatment for the removal of contaminants of concern.

7.2.3 Implementability

Technical Feasibility: Similar to the previous discussion for air stripping treatment units, reverse osmosis treatment units are also sensitive to the presence of solids. Therefore, pretreatment or filtering would need to be provided in front of the RO unit. Although RO is effective in removing nitrate, TDS and hexavalent chromium, RO will not effectively remove VOCs. A drawback associated with RO is that a concentrated salt solution (reject) is generated on a continuous basis. The RO unit may have a reject flow of approximately 25 percent of incoming flow rate (100 gpm); therefore, the reject flow rate estimated for the Site would be approximately 25 gpm. Specifically, the chromium would be concentrated in this 25-gpm flow stream. For example, if the incoming hexavalent chromium concentration is estimated to be 25 μg/L, the concentration of hexavalent chromium in the concentrate will be approximately 100 μg/L. This level of hexavalent chromium could be discharged to the UC Davis WWTP by establishing a waste load allocation (Phillips, 1996b). Therefore, it appears that the inorganics contained in the RO reject stream, such as hexavalent chromium, will not have to be reduced prior to disposal at the WWTP.

Administrative Feasibility: Similar to Alternative 1, discharging treated groundwater via reinjection will require establishing water quality criteria contained in WDRs issued by the RWQCB. As discussed above under Alternative 1, an air permit will not be required for the Site groundwater treatment system. Additionally, it appears that a waste load allocation can be obtained to allow discharge of the reverse osmosis reject stream to the UC Davis WWTP.

Availability of Services and Materials: RO treatment requires trained operators and a service contract with the RO vendor. In terms of material availability, an RO unit anticipated for the Site project is not an off-the-shelf item, and a significant lead time for delivery to the Site is anticipated. The schedule for IRA implementation (Chapter 9.0) will have to be extended if RO treatment is required.

State Acceptance: Critical to implementing this alternative is the establishment of the water quality criteria for reinjection. The WDRs, as developed by the RWQCB, will determine the discharge limits, and thus the level of treatment required for the extracted groundwater prior to injection. If the WDRs require a reduction in hexavalent chromium, nitrate, and TDS, then reverse osmosis treatment will likely be needed. Other discharge options may have to be reconsidered if the injection discharge limits established by the RWQCB are as stringent as other discharge options (e.g., Putah Creek) discussed in Chapter 6.0 and summarized on Table 8.

Community Acceptance: Limiting the migration of chemical constituents of concern through the groundwater extraction and treatment system provides protection of human health and the environment to the satisfaction of the local community. As in Alternative 1, reinjecting the treated groundwater upgradient from the contaminant source area allows for further management of groundwater impacts by providing long-term containment of most residual constituents onsite. Also, reinjecting treated groundwater allows for the future use of the groundwater resource.

If RO treatment is implemented, significant predesign activities will be needed. Specifically, a complete analysis of all anions and cations will be performed on a water sample from the proposed extraction well (EW2-1). An RO simulative program would then be performed to size and design the RO unit. Final design will be governed by the water quality of the extracted groundwater and the discharge limits established for reinjection.

7.2.4 Cost

The cost for an RO unit is dependent upon the flow rate. The cost for a 100-gpm unit is estimated to be $250,000, with an additional UC Davis WWTP capital cost of $230,000 assessed for the RO reject stream. The 25-gpm reject stream is a significant portion of the POTW's total capacity, and thus the capital cost for discharging the reject stream is significant. The University is planning to have a new WWTP in operation by 1999. The new plant will have a dry-weather capacity of 2.7 mgd and is estimated to cost $16,000,000. The reject stream from the reverse osmosis unit will be approximately 1.4% of the WWTP's total capacity. Therefore, the capital cost for discharge of the RO effluent stream to the WWTP would be approximately $230,000. This increases the total capital cost of the 100-gpm reverse osmosis process to an estimated $480,000.

As discharge fees are routinely charged to dischargers to POTWs, the University's cost to treat wastewater generated on the campus is currently $0.87 per 100 cubic feet (CCF). This cost does not include any capital costs for the WWTP. The operation and maintenance costs for the 100-gpm RO unit is approximately $120,000, which includes electric power, membrane replacement, and disposal to the sanitary sewer.

The total capital requirement for Alternative 2 including both the air stripping and reverse osmosis treatment unit is estimated at $1,336,000 (Table 12). The annual operation and maintenance costs for Alternative 2 are approximately $250,000. Annual operation and maintenance costs include compliance monitoring costs , electrical power costs, acid cleaning the air stripping unit, and a cleaning service contract with the vendor for the RO unit.

7.3 Comparison of Alternatives

This section presents a comparison of the two IRA alternatives:

- Alternative 1 — Extraction/VOC Removal/Reinjection.

- Alternative 2 — Extraction/VOC, Nitrate, Hexavalent Chromium, and TDS Removal/ Reinjection.

As discussed in Section 7.2, the alternatives are identical with respect to extraction and discharge. Both alternatives include groundwater extraction by placing a pump in extraction well EW2-1 and pumping at a flow rate of approximately 190 gpm; and both alternatives include constructing a pipeline to a proposed upgradient location where an injection well will be installed and used to discharge the treated water. The two options are only different with respect to the level of treatment and the cost. A comparison of the two alternatives relative to treatment level and cost is presented below.

7.3.1 Level of Treatment

The degree or level of treatment is dependent upon the quality of the extracted groundwater and the discharge limits to be established by the RWQCB at the point of injection. The expected quality of the extracted groundwater is presented on Table 8. As discussed in Chapter 4.0, the water quality presented in the table was obtained from the pumping test performed on EW2-1, the same well proposed for extraction during implementation of the IRA. Chapter 4.0 also indicates that some chemical constituents of concern, such as nitrate, hexavalent chromium, and TDS, are present at higher concentrations in HSU-1 and that some potential exists for these chemicals to migrate from HSU-1 to HSU-2 during seasonal gradient differences or IRA pumping. Since well

EW2-1 is screened within HSU-2, some potential exists for the quality in the extraction well to change over time.

The water quality limits placed at the point of injection will be determined by the RWQCB based on application of the appropriate ARARs and other factors such as the cost of IRA implementation. Information on background water quality was presented in Chapter 4.0 and is summarized on Table 3. A comparison of Table 3 with Table 6 indicates the respective range of background water quality with the expected quality of water removed from the extraction well.

Alternative 1 includes the use of air stripping to remove VOCs. The expected level of treatment of water achieved through air stripping is shown on Table 9. Table 9 indicates that nitrate, hexavalent chromium, and other inorganics are not affected by air stripping treatment. Alternative 2, which includes air stripping to remove VOCs, and reverse osmosis to remove the inorganics, results in an overall water quality that is likely to meet the most stringent limits potentially placed at the point of injection.

7.3.2 Screening Level Risk Evaluation

A screening level risk evaluation was performed to estimate the reduction in risk that would be achieved by groundwater IRA remedial alternatives. The risk evaluation was conducted by calculating the cumulative cancer risk and the non-cancer hazard index for site constituents of concern in groundwater before and after Alternative 1 (VOC removal only) and Alternative 2 (VOC and inorganic removal). The evaluation was conducted using procedures detailed in the US EPA Region IX Preliminary Remediation Goals (US EPA, 1996).

The screening level risk evaluation was conducted for chloroform, 1,2 dichloroethane, hexavalent chromium, and nitrate. These parameters are the primary constituents of concern that are anticipated to be present in extracted groundwater, and for which there are published US EPA preliminary remediation goals (PRGs). TDS was not included in the evaluation because the measurement is not specific to a single chemical and there is no published PRG. Tritium was not included in the evaluation because it has not been reported in groundwater analyzed from extraction well EW2-1. Values for constituents used in the evaluation were:

Parameter	PRG[1]	Influent Concentration	Treated Concentration (Air Stripper Only)	Treated Concentration (Air Stripper + RO)
Hexavalent chromium	0.16 μg/L	15 μg/L	15 μg/L	5 μg/L[2]
1,2-dichloroethane	0.12 μg/L	1.2 μg/L[2]	0.25 μg/L[2]	0.25 μg/L[2]
Chloroform	0.16 μg/L	100 μg/L	0.25 μg/L[2]	0.25 μg/L[2]
Nitrate	58 mg/L	26.7 μg/L	26.7 μg/L	16 μg/L

(1) Derived from US EPA, August 1, 1996.
(2) When the treatment technology is expected to reduce concentrations to below the detection limit, a value of 1/2 the detection limit was used.

To complete the calculation of risk, the anticipated concentrations of carcinogenic parameters (chloroform, 1,2-dichloroethane, and hexavalent chromium) were divided by their respective PRGs, summed, and multiplied by 1×10^{-6}. A hazard index was calculated for nitrate (a non-carcinogen) by dividing the anticipated concentration of nitrate by its PRG. The formulas for calculating the cancer risk and non-cancer hazard index are as follows:

$$Cancer\ Risk = \left[\left(\frac{Conc_{Cr6}}{PRG_{Cr6}} \right) + \left(\frac{Conc_{12DCA}}{PRG_{12DCA}} \right) + \left(\frac{Conc_{Chloroform}}{PRG_{Chloroform}} \right) \right] \times 10^{-6}$$

$$Hazard\ Index = \frac{Conc_{NO_3}}{PRG_{NO_3}}$$

Where:

$conc_x$ = the concentration of a site constituent in the extracted or treated groundwater.

PRG_x = the EPA preliminary remediation goal (PRG) for drinking water for the site constituent.

For untreated water:

$$Cancer\ Risk = \left[\left(\frac{15}{0.16} \right) + \left(\frac{1.2}{0.12} \right) + \left(\frac{100}{0.16} \right) \right] \times 10^{-6} = 7.2 \times 10^{-4}$$

$$Hazard\ Index = \frac{26.7}{58} = 0.46$$

For groundwater treated by air stripping only:

$$Cancer\ Risk = \left[\left(\frac{15}{0.16} \right) + \left(\frac{0.25}{0.12} \right) + \left(\frac{0.25}{0.16} \right) \right] \times 10^{-6} = 9.7 \times 10^{-5}$$

$$Hazard\ Index = \frac{26.7}{58} = 0.46$$

For groundwater treated by air stripping and reverse osmosis:

$$Cancer\ Risk = \left[\left(\frac{5}{0.16} \right) + \left(\frac{0.25}{0.12} \right) + \left(\frac{0.25}{0.16} \right) \right] \times 10^{-6} = 3.5 \times 10^{-5}$$

$$Hazard\ Index = \frac{16}{58} = 0.28$$

As shown above, treatment by airstripping changes the cancer risk from 7.2×10^{-4} to 9.7×10^{-5}, a reduction of 6.3×10^{-4}. The hazard index does not change because the concentration of nitrate is not reduced by airstripping. Treatment by using reverse osmosis and airstripping to remove nitrate and hexavalent chromium reduces the risk from 7.2×10^{-4} to 3.5×10^{-5}, a reduction of 6.9×10^{-4}, and reduces the hazard index from 0.46 to 0.28. Based on these calculations, the greatest reduction in risk is achieved by removing VOCs (specifically chloroform) from the groundwater prior to reinjection. The removal of nitrate and hexavalent chromium from groundwater by RO results in a much smaller additional decrease in risk.

7.3.3 Cost Comparison of Alternatives

The table below presents the cost differences in capital and operation and maintenance costs associated with Alternatives 1 and 2. The cost differences are as follows:

	Alternative 1 VOC Removal	Alternative 2 VOC and Inorganic Removal	Incremental Cost Difference
Capital Cost	$536,000	$1,336,000	$800,000
O&M Cost per Year	$94,000	$250,000	$156,000
5-yr Present Worth*	$910,000	$2,334,000	$1,424,000

* Assuming 8% interest rate, 5-year project life.

The information indicates that the incremental improvement in water quality requires a significant incremental cost for treatment. The information presented on Table 9 shows improvement in water quality and the difference in cost between Alternatives 1 and 2. For example, Table 9 shows that by implementing Alternative 2, hexavalent chromium is reduced from 15 μg/L to below the detection limit, and nitrate is reduced from 26 to 16 μg/L. The incremental cost difference to achieve this incremental improvement in water quality is $1,424,000 over a 5-year project life.

7.4 Selection of IRA Alternative

Alternative 1 and Alternative 2 are identical in terms of the methods of extraction and discharge, but differ in regard to the level of treatment. Alternative 1 includes VOC removal, and Alternative 2 includes VOC and inorganic constituent removal by RO. Alternative 1 is preferred because the discharge water quality following VOC removal, while marginally higher than the local background water quality for some constituents of concern such as nitrate or hexavalent chromium, is below MCLs and within the range of background water quality for the regional aquifer. Alternative 1 is recommended because the incremental cost increase for Alternative 2 ($1,424,000), for the corresponding incremental improvement in water quality, does not appear to be economically justified.

Alternative 1 is also preferred over Alternative 2 when considering the IRA implementation schedule. If RO treatment (Alternative 2) is needed, the implementation schedule for the IRA will have to be extended to allow time for pre-design activities, such as more extensive water chemistry analysis and model simulations to optimize the RO system design. The time schedule will also have to be extended to allow for the equipment lead time and time to secure an RO operator for system start-up and operation.

Implementation of RO treatment (Alternative 2) will result in an RO reject stream that contains the concentrated inorganic constituents that would be discharged to the UC Davis Wastewater

Treatment Plant. A separate, waste load allocation would be required for discharge, as the UC Davis treatment must meet their respective WDRs and discharge limits to Putah Creek.

8.0 CONCLUSIONS

This EE/CA was conducted in order to evaluate and recommend remedial alternatives for the proposed groundwater IRA at the Site. As part of the EE/CA, groundwater chemical, Site hydrogeologic, and regulatory information were reviewed to establish the framework and to identify the objectives of the anticipated groundwater IRA. A variety of remedial alternatives were then evaluated against the IRA objectives through a screening process which resulted in two removal actions as the potential final alternatives. An analysis of the two alternatives was then conducted by assessing the long term effectiveness, the implementability, and the cost of each alternative. The result of the analysis is the selection of one alternative that is recommended for implementation as the Site groundwater IRA.

The above described process has been presented in the previous sections of this EE/CA Report and the recommended alternative consists of: groundwater extraction at 190 gpm with the replacement of the irrigation well 22N; treatment of VOCs using air stripping; and discharge to a proposed reinjection well. The purpose of this section is to summarize the recommended alternative within the context of the IRA objectives. The discussion below is organized according to the components of the selected alternative: extraction; discharge; and treatment.

8.1 Groundwater Extraction

The selected IRA alternative for groundwater extraction includes capture of impacted groundwater from HSU-2 in a area near the UC Davis property boundary from existing well EW2-1. Extraction in HSU-2 addresses the most permeable hydrostratigraphic unit within which Site constituents are most likely to move off-property. Extraction at the EW2-1 location will result in a capture zone that contains the upgradient portion of the existing VOC plume at the 0.5 μg/L level and that significantly reduces the future movement of Site constituents from downgradient areas.

The one condition to implementation of this extraction alternative is the removal of the irrigation well 22N. Groundwater flow models developed for the Site show that upgradient capture during the summer irrigation season can be accomplished by eliminating irrigation well 22N, or by installing a second extraction well that, along with existing extraction well EW2-1, can account for the affects of the irrigation well 22N. Based on a cost evaluation presented as part of the screening analysis, eliminating irrigation well 22N and replacing it with another irrigation well appears to be more cost effective than installing and maintaining an additional extraction well.

8.2 Discharge of Treated Groundwater

The selected discharge option for the groundwater IRA is reinjection of treated groundwater to HSU-2 in an area upgradient of the Site. This option was selected because other potential options that were considered — discharge to Putah Creek, discharge to the UC Davis Wastewater Treatment

Plant, or discharge to agricultural land — are not cost-effective or feasible within the context of the IRA. Reinjection to groundwater will require specific discharge limits that will be based on the overall protection of groundwater quality. The discharge limits will be designated by the regulatory agencies and will ultimately determine if the selected treatment option, as discussed below, is implementable for this IRA.

The reinjection alternative was evaluated using a groundwater flow model to select a location for reinjection, to evaluate the compatibility of reinjection with extraction, and to assess the amount of reinjected water that could be recaptured by the extraction system. Based on this evaluation, reinjection is recommended to occur upgradient (west) of the Site. Simulations suggest that the capture zone will be maintained during reinjection at this location. In addition, depending on the season, 66 to 92 percent of the treated, reinjected groundwater will be recaptured by the extraction system.

8.3 Selected Treatment Alternative

The treatment of extracted groundwater was evaluated in the detailed analysis of the final two alternatives with the understanding that the most likely discharge alternative would be reinjection. Discharge limits designated for reinjection will largely determine the type and level of treatment necessary. An evaluation of extraction water quality and background water quality in the vicinity of the Site indicates that VOCs (namely chloroform) are the most significant constituent of concern present in extracted groundwater. Nitrate, hexavalent chromium, and TDS are also present in extracted groundwater but at concentrations marginally above local background values, below MCLs, and within the general range of concentrations observed in regional groundwater.

The recommended alternative for treatment of extracted groundwater is air stripping in order to remove VOCs. Air stripping is a dependable and proven technology for treating VOCs, but it will not treat other potential constituents such as nitrate, hexavalent chromium, or TDS. The alternative was selected for the following reasons:

- decreasing the concentration of nitrate, hexavalent chromium, and TDS and other salts would require treatment by reverse osmosis (RO) which would result in a significant increase in capital and O&M costs (approximately $1.4 million over five years);
- treatment by RO would result in only an incremental improvement in water quality to meet local background water quality values.;
- treatment by RO results in a concentrated salt solution that must be then disposed of;

- time constraints to perform additional field testing, design, and equipment procurement for treatment of nitrate, hexavalent chromium, and TDS will affect the schedule for implementation of the IRA; and

- groundwater flow modeling predicts that 66 to 92 percent of reinjected water will be captured by the extraction well within a closed loop.

8.4 Conclusions

If implemented, the groundwater IRA including the selected remedial alternative is the initial step in Site groundwater remediation, and is consistent with eventual long-term remedial actions that are likely to address groundwater impacts closer to the source areas. The selected alternative is implementable within a reasonable time frame and is cost effective relative to other potential remedial alternatives. The extraction, treatment, and reinjection of groundwater is protective of the environment and will substantially decrease offsite migration of Site constituents.

9.0 IRA SCHEDULE

The general schedule for the IRA, including the anticipated start and completion time, is shown on Figure 19. It should be noted that this schedule assumes acceptance of the recommendation presented in this EE/CA report. If it is necessary to evaluate other alternatives, this schedule will change, as necessary.

As shown on the schedule, this final EE/CA report will be renoticed for public comment. Comments received on the draft EE/CA (and the corresponding responses) have been attached to this final EE/CA as Appendix A. Comments received on this final EE/CA will be addressed in the Removal Action Work Plan. In order to expedite the IRA process, preparation of design and bid documents began after close of the comment period for the draft EE/CA and will consist of 50% and 100% design documents. This was possible because substantive changes were not required to the IRA scope and design due to comments received. Upon release of this final EE/CA, the US EPA will begin work on the Action Memorandum for the IRA. UC Davis will prepare a Removal Action Work Plan that includes supporting data for IRA aquifer testing and modelling, and a monitoring plan for system startup and operation. Documentation of compliance with the substantive requirements of the groundwater IRA are scheduled to begin upon approval of an Action Memorandum from the US EPA. Procurement and contracting with a subcontractor to construct the IRA based on the bid documents is anticipated to take approximately 45 days from completion of final design documents. Construction of the IRA system should take approximately two months.

Initial groundwater treatment system startup will begin upon completion of construction. A one- to three-month evaluation period will follow, during which the system's ability to meet removal action objectives will be assessed. After the evaluation, a system monitoring report will be prepared that evaluates the needs for and presents, as necessary, modifications to the IRA system. Once the system has been tested and is believed to be operating reliably, normal system operation will commence. Operation of the IRA system will continue with periodic monitoring and re-evaluation of its effectiveness until the objectives of the removal action have been met.

If monitoring data indicate the IRA system has the potential to cost-effectively remediate the plume to applicable standards, the action may be proposed as the final remedy. Alternatively, the system may be modified and/or expanded over time and operation extended until the groundwater remedial objectives are satisfied.

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TABLE 1
CONSTANT-RATE AQUIFER PUMPING TEST RESULTS
EE/CA REPORT GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

Pumping Well and Pumping Parameters	Observation Well	Zone	Distance from Pumping Well (feet)	Zone Thickness (feet)	Response Observed	Maximum Drawdown (feet)	Evaluation of Drawdown (D) or Recovery (R) Data	Method of Analysis	T(S) (ft2/day)	Hydraulic Conductivity (ft/day)	S	Leakage Factor (B) (feet)
Pumping Well: EW2-1 Q = 270 gpm Pump On: 10/11/96 15:30 Pump Off: 10/13/96 15:30 Duration Pumped: 2,880 min	UCD1-25	HSU-1	294	34	Y	0.41	—	—	—	—	—	—
	UCD1-28		60	34	Y	0.69	—	—	—	—	—	—
	EW2-1	HSU-2	0	41	Y	2.45	D	Cooper-Jacob	41,300	1,007	—	—
							R	Theis Recovery	43,250	1,055	—	—
	UCD2- 14		971	44	Y	0.45	D	Huntush Leaky	47,920	1,089	0.000503	11,448
							R	Theis Recovery	52,730	1,198	—	—
	UCD2-15		1,504	44	Y	0.32	D	Hantush Leaky	49,180	1,118	0.000684	8,550
							R	Theis Recovery	53,240	1,210	—	—
	UCD2-26		294	44	Y	0.75	D	Hantush Leaky	39,550	899	0.000594	9,162
							R	Theis Recovery	39,560	899	—	—
	UCD2-29		60	41	Y	1.02	D	Hantush Leaky	41,160	1,004	0.000856	8,551
							R	Theis Recovery	42,570	1,038	—	—
	UCD2-30		80	41	Y	0.98	D	Hantush Leaky	41,070	1,002	0.000689	8,939
							R	Theis Recovery	42,990	1,049	—	—
	UCD2-31		120	41	Y	0.87	D	Hantush Leaky	39,990	975	0.001096	7,168
							R	Theis Recovery	43,850	1,070	—	—
								Dist vs. Draw	32,947	749	0.006700	—
								Average	43,420	1,024	0.001589	8,970

TABLE 2
GROUNDWATER MODEL PARAMETER VALUES
EE/CA REPORT GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

Parameter	Winter	Summer
Horizontal Hydraulic Conductivity (feet/day)		
Layer 1	3.6	3.6
Layer 2	348.0	348.0
Layer 3	2,460.0	2,460.0
Layer 4	348.0	348.0
Vertical Hydraulic Conductivity (feet/day)		
Layer 1	0.1	0.1
Layer 2	22.3	22.3
Layer 3	157.4	157.4
Layer 4	22.3	22.3
Precipitation Recharge (feet/day)		
Layer 1	2.7×10^{-4}	None
Riverbed Hydraulic Conductivity[1] (feet/day)		
Layer 1	0.6×10^{-1}	0.6×10^{-1}
Irrigation Well Pumping Rates (gpm)		
22N	Not in use	717
22P2	Not in use	1,089

Notes: 1) Based on an assumed river bed thickness of 1 foot.

TABLE 3
SUMMARY OF WATER QUALITY DATA —LEHR AND VICINITY
EE/CA REPORT - GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA, DAVIS

Contaminants	Units	Upper Tolerance Limits Upgradient Well UCD2-17	Range of Concentrations from Neighbor's Wells	Range of Concentrations from Regional Data
Chloroform	ug/L	ND	<1.0 - 38	-
Bromodichloromethane	ug/L	ND	<1.0	-
1,1,2 TCA	ug/L	ND	<1.0	-
1,1 DCA	ug/L	ND	<1.0	-
1,1 DCE	ug/L	ND	<1.0	-
1,2 DCA	ug/L	ND	<1.0 - 1.4	-
1,2 Dichloropropane	ug/L	ND	<1.0	-
Chromium VI	ug/L	(1)	<10 - 140	-
Total Chromium	ug/L	24.8	<10 - 140	<10 - 100
Nitrogen as NO_3	mg/L	16.8	16-222	<45 - 177
Tritium	pCi/L	292	<250-1,712	-
TDS	mg/L	438	-	>500
Chloride	mg/L	20.6	-	-
SO4 (Sulfate)	mg/L	41	-	-
Alkalinity as CaCO3	mg/L	361	-	-
Sodium	mg/L	32.2	-	-
Calcium	mg/L	39.5	-	-
Magnesium	mg/L	65	-	-
Potassium	mg/L	(1)	-	-
EC (Specific Conductance)	μmhos/cm	1330	667-1,548	-
pH	std. units	8.07	-	-
Chemical Oxygen Demand	ppm	(1)	-	-

(1) Too few detections to calculate as UTL value.
- = No data available

TABLE 4A
SUMMARY OF NITRATE RESULTS — NEIGHBORS' WELLS
EE/CA REPORT GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

Sample Code	2/27/95	5/30/95	9/12/95	12/12/95	3/20/96	6/20/96	9/03/96
RIW	—	—	—	—	—	42	—
RDW	75	115	22 97	75 75	89	—	—
MIW	75	84	39		45		—
MDW	66	71	89 89	75	80	—	—
NPIW (22P)	—	—	—	—	—	—	21 21
NIW (22N)	—	26	24 24	—	—	—	18
NJIW (22J)	—	—	—	—	—	106	62
NDW	62	62	57	57	57		53
MARIW	—	—	16	—	—	18	21
MARDW	26	—	—	—	—	—	—
IDDW	49	71	80	49	22 22	—	42
OHDW	71	66	80	66 66	75	—	84
RUSDW	17 17	19	17	16	17	—	18
CMDW	45	53	57	49	49	—	—
CWDW	39	42 42	40	36	40	—	—
RDDW	142 142	159	151	106	222	—	—
DDW	36	43	49	40	53	—	—
CAMDW	23	—	93	29	27	—	—
DAIW	—	—	—	—	—	16	—
APIW	—	—	—	—	23	—	—
AJIW	—	—	—	—	93	—	—
Field Blank	<0.5	<0.5	<0.5	<0.5	42	71	199

1. Nitrate as NO_3 in milligrams per liter of water (mg/L).
2. I = Irrigation Well.
3. D = Domestic Well.
4. Where two values are given for the same date, this indicates that duplicate (quality control) samples were taken.

— No sample.

TABLE 4B
SUMMARY OF HEXAVALENT CHROMIUM RESULTS — NEIGHBORS' WELLS
EE/CA REPORT GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

Sample Code	02/27/95	05/30/95	09/12/95	12/12/95	03/20/96	06/20/96	09/03/96
RIW	—	—	—	—	—	0.027	—
RDW	0.038	0.035	0.041	0.038 0.032	0.035	—	—
MIW	0.031	0.047	<0.01		0.019	—	—
MDW	0.036	0.039	0.034 0.043	0.043	0.037	—	—
NPIW (22P)	—	0.025	0.026 0.026	—	—	—	0.019 0.019
NIW (22N)	—	—	—	—	—	—	0.026
NJIW (22J)	—	—	—	—	—	0.055	<0.010
NDW	0.057	0.074	0.065	0.061	0.068	—	0.066
MARIW	—	—	—	—	—	0.025 0.026	<0.010
MARDW	<0.02	—	—	—	—	—	—
IDDW	0.052	0.061	0.045	0.039	0.028 0.029	—	<0.010
OHDW	0.046	0.053	0.046	0.056 0.056	0.061	—	0.052
RUSDW	<0.010 <0.010	<0.01	0.013	<0.01	0.011	—	<0.010
CMDW	0.10	0.064	0.13	0.098	0.094	—	—
CWDW	0.11	0.14 0.14	0.13	0.11	0.045	—	—
RDDW	0.061 0.047	0.066	0.067	0.066	0.074 0.074	—	—
DDW	0.037	0.071	0.081	0.069	0.11	—	—
CAMDW	0.081		0.099	0.083	0.085	—	—
DAIW	—	—	—	—	—	0.028	—
APIW	—	—	—	—	0.034	—	—
AJIW	—	—	—	—	0.064	—	—
Field Blank	<0.02	<0.02	<0.01	<0.01	<0.003	<0.003	<0.003

1. All units are in milligrams per liter of water (mg/L).
2. I = Irrigation Well.
3. D = Domestic Well.
4. Where two values are given for the same date, this indicates that duplicate (quality control) samples were taken.

— No sample.

TABLE 5
SUMMARY OF ANALYTICAL RESULTS — WELL EW2-1
EE/CA REPORT GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

Analyte	Analytical Results			Reporting Limit
	At Rest	Step Drawdown	Constant-Rate	
Chloroform (μg/L)	87	100	91	1.0 μg/L
1,2-DCA (μg/L)	ND	1.2	1.1	1.0 μg/L
Tritium (pCi/L)	ND	ND	ND	120 pCi/L
Nitrate as NO_3 (mg/L)	25.8	26.3	23.6	2.0 mg/L
TDS (mg/L)	380	454	470	20 mg/L
Chromium VI (μg/L)	ND	ND	15	10 μg/L

TABLE 6
ANTICIPATED WATER QUALITY FROM EXTRACTION WELL EW2-1
EE/CA REPORT - GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA, DAVIS

Contaminants	Units	Estimated Influent Concentration
Chloroform	ug/L	100
Bromodichloromethane	ug/L	ND
1,1,2 TCA	ug/L	ND
1,1 DCA	ug/L	0.4
1,1 DCE	ug/L	0.5
1,2 DCA	ug/L	1.2
1,2 Dichloropropane	ug/L	0.3
Chromium VI	ug/L	15
Total Chromium	ug/L	15
Nitrogen (as NO_3)	mg/L	26.7
Tritium	pCi/L	<120
TDS	mg/L	470
Chloride	mg/L	27
SO4 (Sulfate)	mg/L	43
Alkalinity as CaCO3	mg/L	350
Sodium	mg/L	37
Calcium	mg/L	41
Magnesium	mg/L	70
Potassium	mg/L	1.4
EC (Specific Conductance)	μmhos/cm	600
pH	std. units	7.81
Chemical Oxygen Demand	ppm	<10

TABLE 7
SUMMARY OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)
EE/CA REPORT GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

ARAR	Type	Description	Comment
The Safe Drinking Water and Toxic Enforcement Act	Applicable	(22 CCR §12000 et seq; "Prop. 65"). Prohibits the discharge of known carcinogens or reproductive toxins to sources of drinking water.	Action-specific.
CVRWQCB Basin Plan for the Sacramento River Basin	Relevant and Appropriate	Establishes water quality objectives including narrative and numerical standards. Remedial actions must meet the objectives.	Chemical-specific.
SWRCB Resolution 68-16	Applicable	Provides for maintaining the existing water quality of the state.	Location- and chemical-specific.
SWRCB Resolution 88-63	Applicable	Specifies that, with few exceptions, all groundwater and surface water have the beneficial use of municipal and/or domestic supply.	Location- and chemical-specific.
SWRCB Resolution 92-49	Applicable	Requires cleanup of waste and restoration of affected water to background conditions.	Location- and chemical-specific.
22 CCR §64444.5	Relevant and Appropriate	State drinking water regulations. Establishes maximum contaminant levels for specific constituents in water supplied to the public (see Table 2).	Chemical-specific.
10 CFR 20	Applicable	Sets standards for protection against radiation.	Chemical-specific.
40 CFR 122 (NPDES Permit)	Relevant and Appropriate	Wastewater discharges to surface water must have discharge limits and monitoring requirements.	Action- and chemical-specific.

TABLE 7 (CONTINUED)
SUMMARY OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)
EE/CA REPORT GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

ARAR	Type	Description	Comment
40 CFR 141.61	Relevant and Appropriate	National drinking water regulations. Establishes maximum contaminant levels for specific constituents in water supplied to the public (see Table 8).	Chemical-specific.
40 CFR 144.13(c), 144.26-27, 146.51-52	Relevant and Appropriate	(Underground Injection Control-UIC) Prohibits recharge of fluids containing contaminants into or above a drinking water formation.	Action-specific.
40 CFR 258.51	Relevant and Appropriate	A groundwater monitoring system is required to characterize background water quality and water quality at the point of compliance.	Chemical-specific.
Health & Safety Code Section 25159.24(a)	Relevant and Appropriate	(California Toxic Injection Well Act) Regulates use of water injection wells for disposal of waste.	Action-specific.
California Environmental Quality Act (CEQA)	Applicable	Requires analysis of environmental impacts of response actions and implementation of appropriate mitigation measures.	Location-specific.

TABLE 8
SUMMARY OF DISCHARGE WATER QUALITY LIMITS
EE/CA REPORT GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

Contaminants	Units	MCL	Estimated Influent Concentration	UCD Local Sewer Limits[1]	Putah Creek Discharge Limits[2]	Estimated Discharge Limits for Reinjection
Chloroform	ug/L	[3]	100	420	ND	ND
Bromodichloromethane	ug/L	[3]	ND	140	ND	ND
1,1,2 TCA	ug/L	5	ND	-	ND	ND
1,1 DCA	ug/L	5	ND	-	ND	ND
1,1 DCE	ug/L	6	ND	0	ND	ND
1,2 DCA	ug/L	0.5	1.2	-	ND	ND
1,2 Dichloropropane	ug/L	5	ND	-	ND	ND
Chromium VI	ug/L	-	15	59	15	[5]
Total Chromium	ug/L	50	15	200	50	[5]
Nitrate (as NO_3)	mg/L	45	26.7	-	-	[5]
Tritium	pCi/L	20,000	<120	11,024[4]	20,000	[5]
TDS	mg/L	500*	470	-	500	[5]
Chloride	mg/L	250*	27	-	-	[5]
SO4 (Sulfate)	mg/L	400	43	-	-	[5]
Alkalinity as CaCO3	mg/L		350	-	-	[5]
Sodium	mg/L		37	-	-	[5]
Calcium	mg/L		41	-	-	[5]
Magnesium	mg/L		70	-	-	[5]
Potassium	mg/L		1.4	-	-	[5]
EC (Specific Conductance)	micro ohms	900*	600	-	-	[5]
pH	std. units	6.5-8.5*	7.81	5-11	6.5-8.5	[5]
Chemical Oxygen Demand	ppm		<10	-	-	[5]

Notes:
MCL = Maximum Contaminant Level
* = Recommended Secondary Maximum Contaminant Level
ND = Non-Detect
- = No Limit
[1] = UC Davis Sewer Local Limits provided by Dave Phillips, P.E., UC Davis Facilities- Engineering Services
[2] = Waste Discharge Requirements for UC Davis Campus Landfill Ground Water Cleanup System, Yolo County, NPDES No. CA0083712
[3] = The MCL for total trihalomethanes (sum of bromoform, bromodichloromethane, chloroform, and dibromochloromethane) is 100 μg/L, based largely on technology and economics.
[4] = Based on 2 Curies per year (per Steve Kubo, UC Davis EH&S) and a discharge rate of 135 gpm adjusted for discharge flow rate of 200 gpm
[5] = Will be set in Waste Discharge Requirements

TABLE 9
ALTERNATIVE 1 AND 2 COMPARISON:
LEVEL OF TREATMENT VERSUS COST
EE/CA REPORT GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

Parameter	Unit	Detection Limits	Influent Flow Stream	Alternative 1	Alternative 2
Chloroform	μg/L	0.5	100	ND	ND
Bromodichloro methane	μg/L	1.0	ND	ND	ND
1,1,1-TCA	μg/L	1.0	ND	ND	ND
1,1-DCA	μg/L	1.0	ND	ND	ND
1,1-DCE	μg/L	1.0	ND	ND	ND
1,2-DCA	μg/L	1.0	1.2	ND	ND
1,2-Dichloropropane	μg/L	1.0	ND	ND	ND
Hexavalent Chromium	μg/L	10.0	15	15	<10
Total Chromium	μg/L	10	15	15	<10
Nitrate as NO_3	mg/L	0.5	26.7	26.7	16
Tritium	pCi/L	300	<120	<120	<120
TDS	mg/L	20	470	470	279
Chloride	mg/L	1	27	27	16
Sulfate	mg/L	1	43	43	26
Alkalinity	mg/L	10	350	350	*
Sodium	mg/L	2	37	37	22
Calcium	mg/L	2	41	41	24
Magnesium	mg/L	2	70	70	42
Potassium	mg/L	2	1.4	1.4	0.8
Specific Conductance	μmhos/cm	NA	600	600	*
pH	std units	NA	7.81	7.81	*
COD	mg/L	50	<10	<10	*
Estimated Capital Cost				$536,000	$1,336,000
Estimated Annual O&M Cost				$93,600	$250,000
Present Worth Cost**				$910,400	$2,334,000

* Requires testing of effluent stream
** Present worth cost estimate assuming a 5-year life and an interest rate of 8%.

TABLE 10
SCREENING LEVEL HEALTH RISK EVALUATION
SCREEN3 MODEL INPUT AND OUTPUT
EE/CA REPORT GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

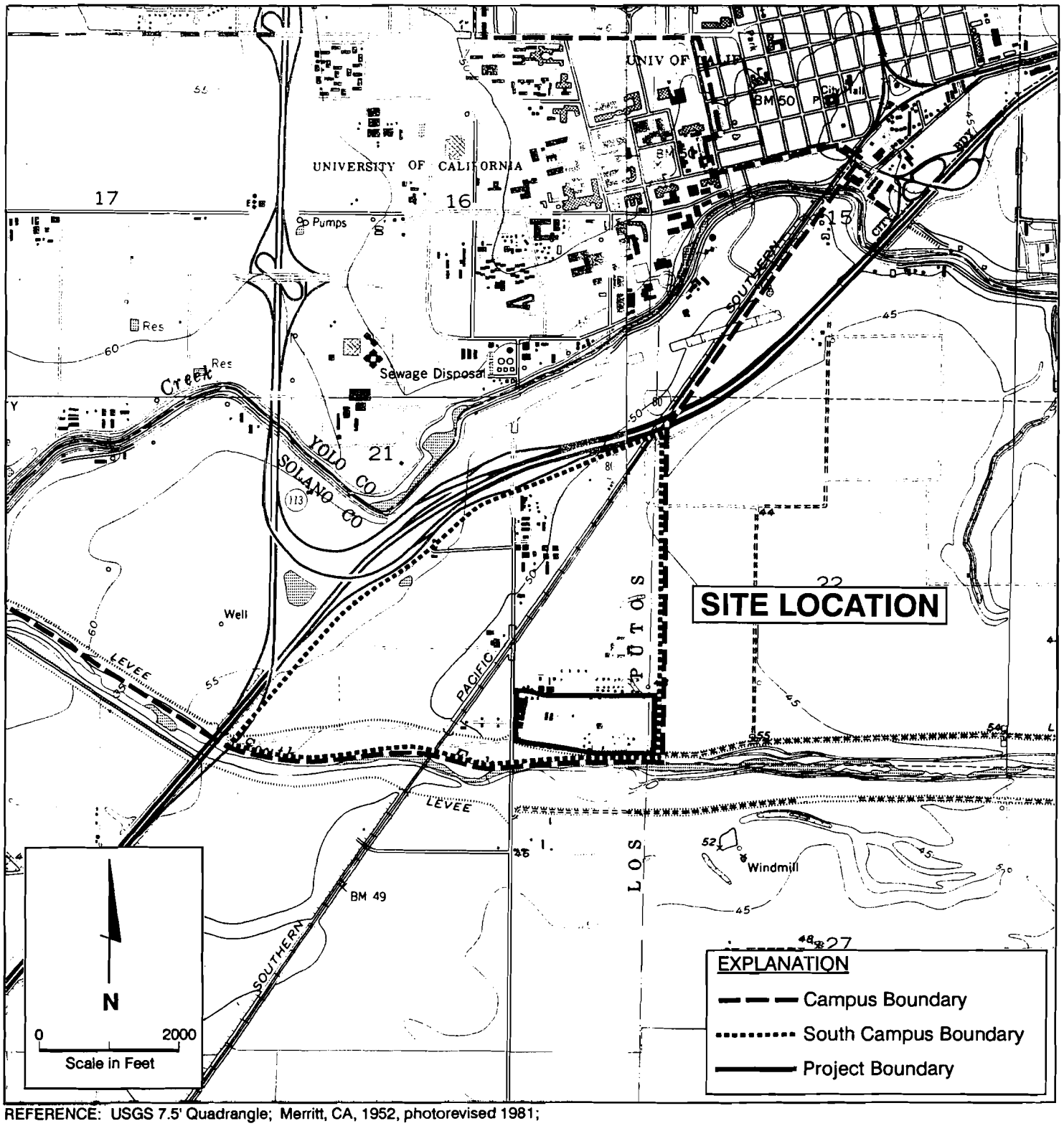
Input Parameter	1,2-DCA	Chloroform
Source Type	Point	Point
Emission Rate (g/s)	1×10^{-5}	1×10^{-5}
Air flow rate (cfm)	1.89×10^{3}	1.89×10^{3}
Stack Height (m)	6.096	6.096
Stack Inside Diameter (m)	0.3048	0.3048
Stack Gas Exit Temperature (k)	288.7	288.7
Ambient Temperature (k)	293	293
Receptor Height (m)	1.8	1.8
Building Height (m)	4.572	4.572
Min. Horizontal Building Dimension	6.096	6.096
Max. Horizontal Building Dimension	9.144	9.144
Meteorology	Full Met.	Full Met.
Terrain	Simple	Simple
Automated Distance Array Minimum (m)	160	160
Automated Distance Array Maximum (m)	1,500	1,500
Output Parameters	**1,2-DCA**	**Chloroform**
Distance to Receptor	525	525
Modeled Concentration ($\mu g/m^3$)	1.2×10^{-2}	1.46
Annual Concentration using 0.1 conversion ($\mu g/m^3$)	1.29×10^{-3}	0.146
Carcinogenic Risk	2.6×10^{-8}	7.7×10^{-7}

TABLE 11
COST ESTIMATE SUMMARY
ALTERNATIVE 1 — EXTRACTION/VOC REMOVAL/REINJECTION
EE/CA REPORT GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

Description	Quantity	Unit	Unit Cost	Total Cost
Direct Capital Costs				
Construction Costs				
Permitting				$1,500
Replace Irrigation Well 22N	1	ea	$80,000	$80,000
Extraction Well(s)				$0
Groundwater Pump(s) & Controls	1	ea	$12,000	$12,000
Injection Well(s) & Controls	1	ea	$30,000	$30,000
Piping Installation				
Extraction Well	200	LF	$25	$5,000
Injection Well	2,400	LF	$25	$60,000
Sewer Connection	1	ea	$1,500	$1,500
Irrigation Pipeline (treated groundwater)	600	LF	$25	$15,000
Treatment Plant Building	1	ea	$15,000	$15,000
Treatment Unit(s) Equipment and Materials (E/M)				
Air Stripping	1	190 gpm	$70,000	$70,000
Field Costs				
Construction Management			$30,000	$30,000
Startup Costs			$15,000	$15,000
			Direct Capital Cost	**$335,000**
Indirect Capital Costs				
Engineering/Design			25% of DCC	$83,750
Administrative/Legal Costs			15% of DCC	$50,250
Contingencies			20% of DCC	$67,000
			Indirect Capital Cost	**$201,000**
			TOTAL CAPITAL REQUIREMENT	**$536,000**
Annual Operating and Maintenance Costs				
Construction Management				$20,000
Compliance Monitoring				$6,000
Treatment System E/M				$2,000
Sewer Discharge Fee				$0
Electrical Costs				$50,000
Contingency			20% of subtotal	$15,600
			Total Annual O&M Costs	**$93,600**
			PW Cost (5 yr life, 8%)	**$374,400**
			TOTAL	**$910,400**

TABLE 12
COST ESTIMATE SUMMARY
ALTERNATIVE 2 — EXTRACTION/VOC, NITRATE, CHROMIUM, TDS REMOVAL/REINJECTION
EE/CA REPORT GROUNDWATER IRA
LEHR/SCDS ENVIRONMENTAL RESTORATION
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

Description	Quantity	Unit	Unit Cost	Total Cost
Direct Capital Costs				
Construction Costs				
Permitting				$1,500
Replace Irrigation Well 22N	1	ea	$80,000	$80,000
Extraction Well(s)				$0
Groundwater Pump(s) & Controls	1	ea	$12,000	$12,000
Injection Well(s) & Controls	1	ea	$30,000	$30,000
Piping Installation				
Extraction Well	200	LF	$25	$5,000
Injection Well	2,400	LF	$25	$60,000
Sewer Connection	1	ea	$1,500	$1,500
Irrigation Pipeline (treated groundwater)	600	LF	$25	$15,000
Treatment Plant Building	1	ea	$15,000	$15,000
Treatment Unit(s) Equipment and Materials (E/M)				
Air Stripping	1	190 gpm	$70,000	$70,000
Reverse Osmosis (RO)	1	100 gpm	$250,000	$250,000
RO Reject: UCD WWTP Capital costs	1	25 gpm	$230,000	$230,000
Field Costs				
Construction Management			$40,000	$40,000
Startup Costs			$25,000	$25,000
			Direct Capital Cost	**$835,000**
Indirect Capital Costs				
Engineering/Design			25% of DCC	$208,750
Administrative/Legal Costs			15% of DCC	$125,250
Contingencies			20% of DCC	$167,000
			Indirect Capital Cost	**$501,000**
			TOTAL CAPITAL REQUIREMENT	**$1,336,000**
Annual Operating and Maintenance Costs				
Construction Management				$30,000
Compliance Monitoring				$10,000
Treatment System E/M				$52,000
Sewer Discharge Fee				$16,000
Electrical Costs				$100,000
Contingency			20% of subtotal	$41,600
			Total Annual O&M Costs	**$250,000**
			PW Cost (5 yr life, 8%)	**$998,000**
			TOTAL	**$2,334,000**



REFERENCE: USGS 7.5' Quadrangle; Merritt, CA, 1952, photorevised 1981; and Davis, CA, 1952, photorevised 1981.

SITE VICINITY MAP

EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

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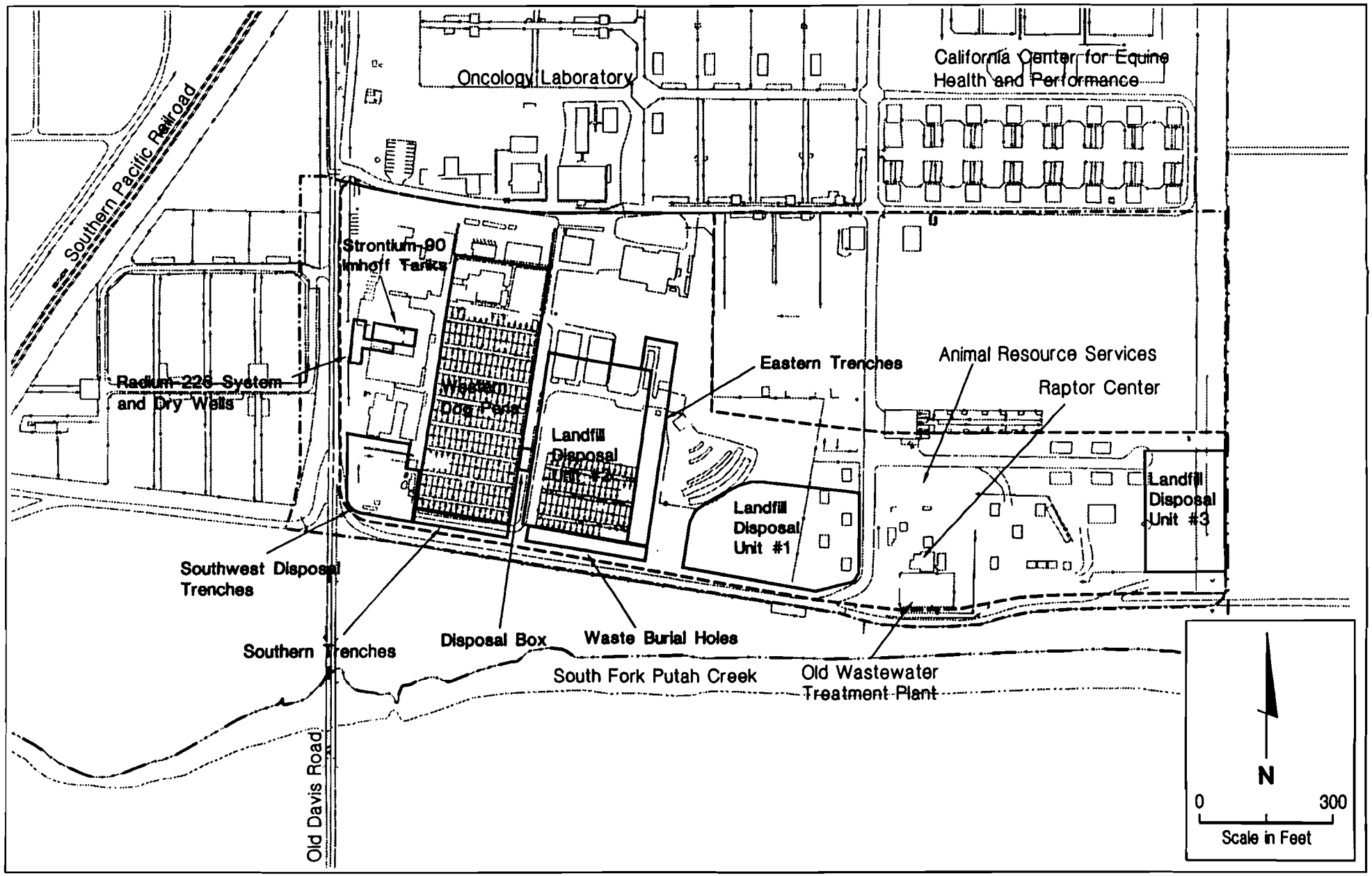
FIGURE 1



EXPLANATION

—·· —·· Campus Boundary

- - - - - - - LEHR/SCDS Boundary

·—·—·—·— Project Boundary

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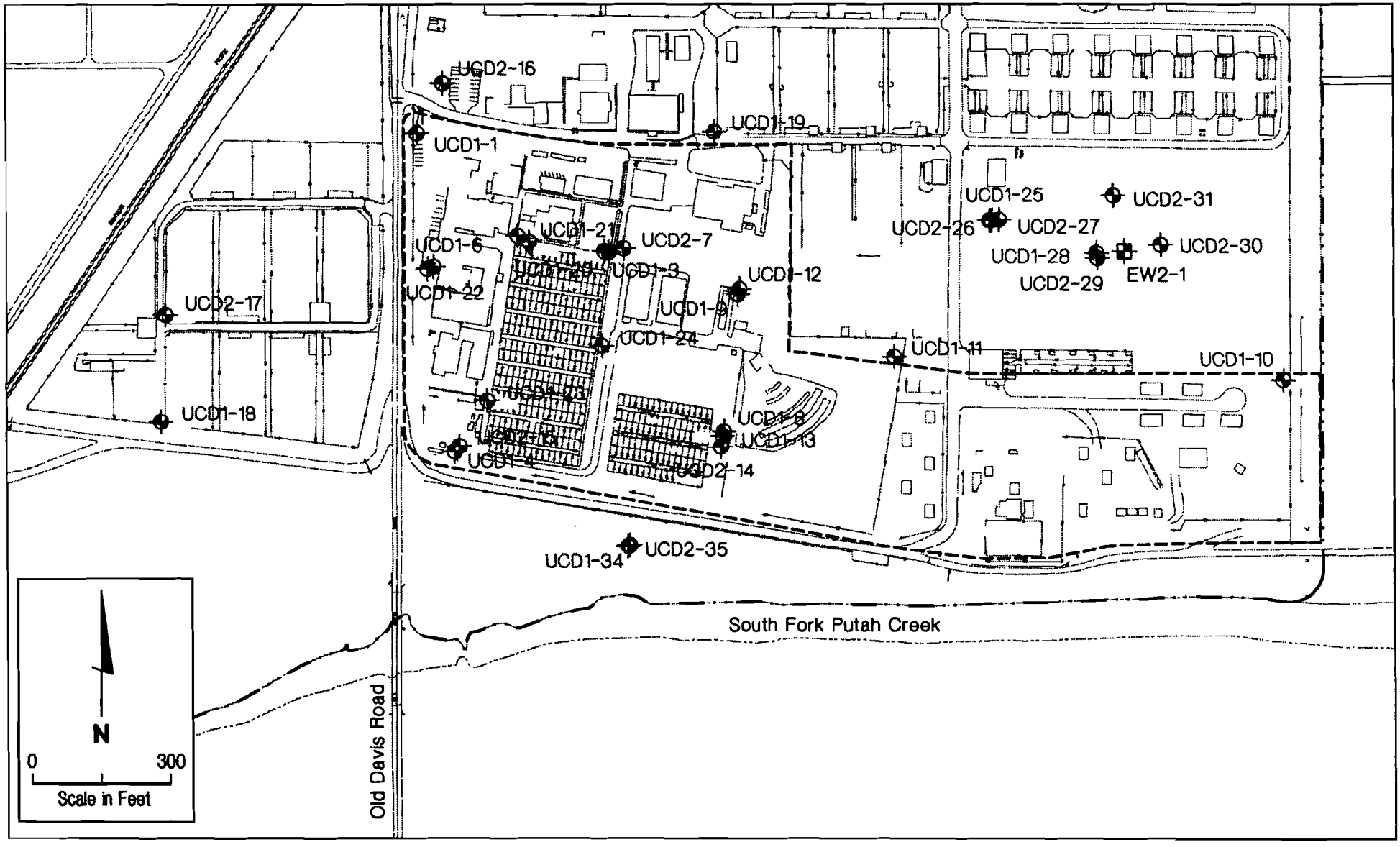
WASTE DISPOSAL AREAS
EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California
FIGURE 2



EXPLANATION

- UCD1-11 HSU-1 Monitoring Well
- UCD2-17 HSU-2 Monitoring Well
- EW2-1 HSU-2 Extraction Well
- LEHR/SCDS Boundary
- Campus Boundary

WELL LOCATION MAP

EE/CA Report - LEHR Groundwater IRA
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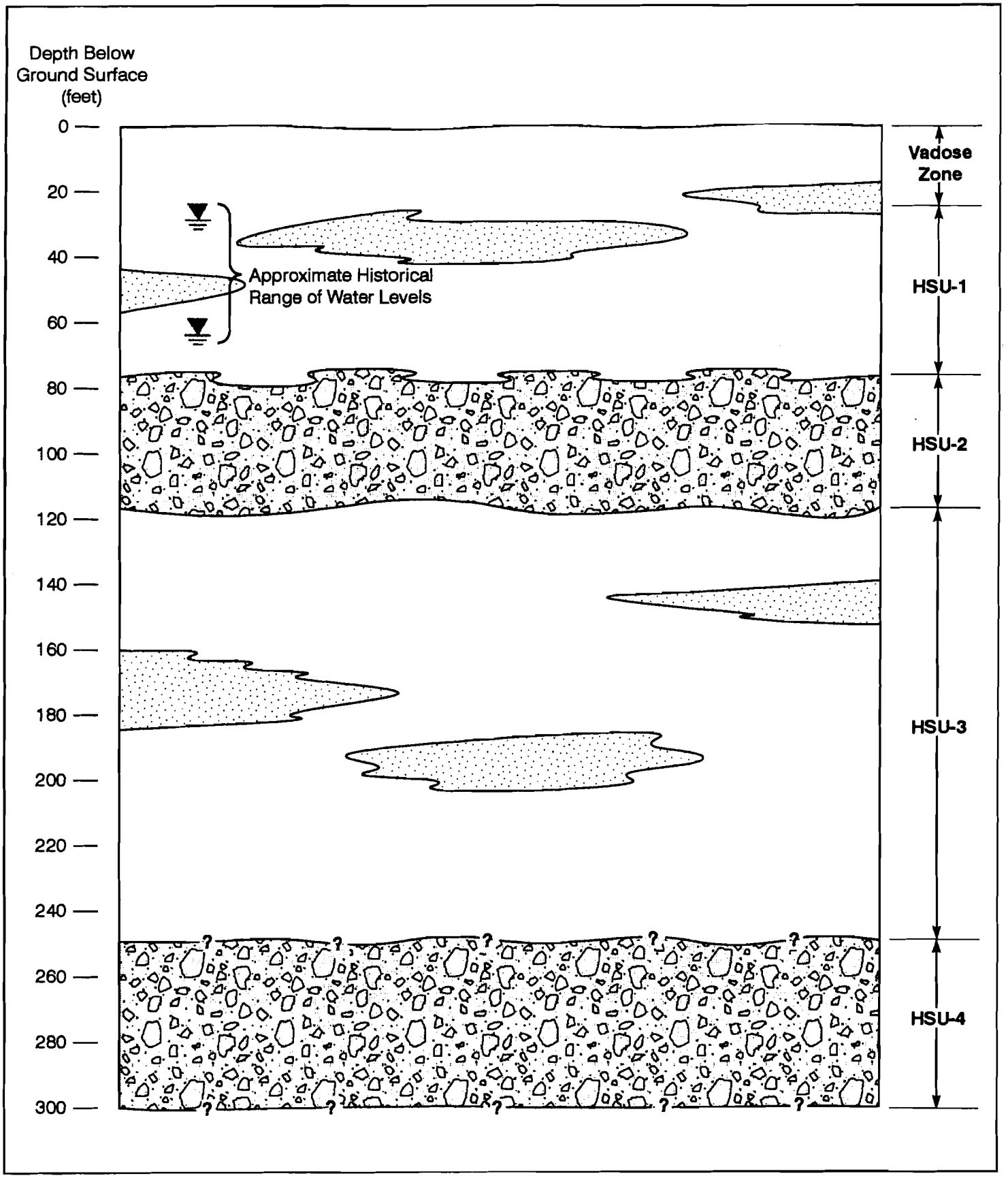
FIGURE 3



SCHEMATIC CROSS SECTION
HYDROSTRATIGRAPHIC UNITS

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Davis, California

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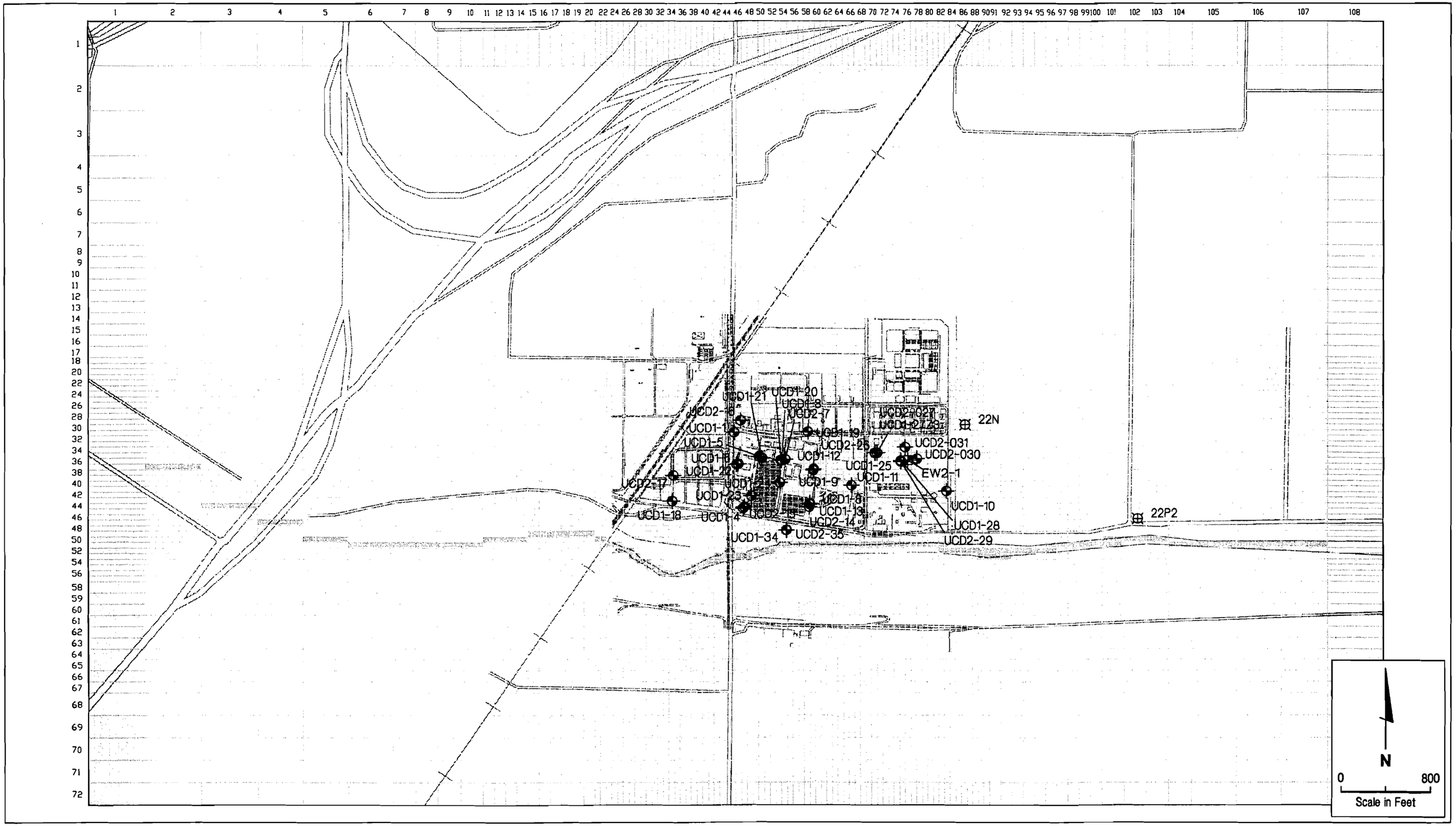
00234-255-A6505-044 ah A6505Q 3/20/97

FIGURE 4



EXPLANATION

- Constant Head Boundary (All Model Layers)
- No Flow Boundary Bordering Outside of Grid Cells (All Model Layers)
- River Cells (Layer 1 Only)
- Monitoring Well Locations
- Agricultural Supply Well Locations (Simulated in Model)
- Extraction Well Location

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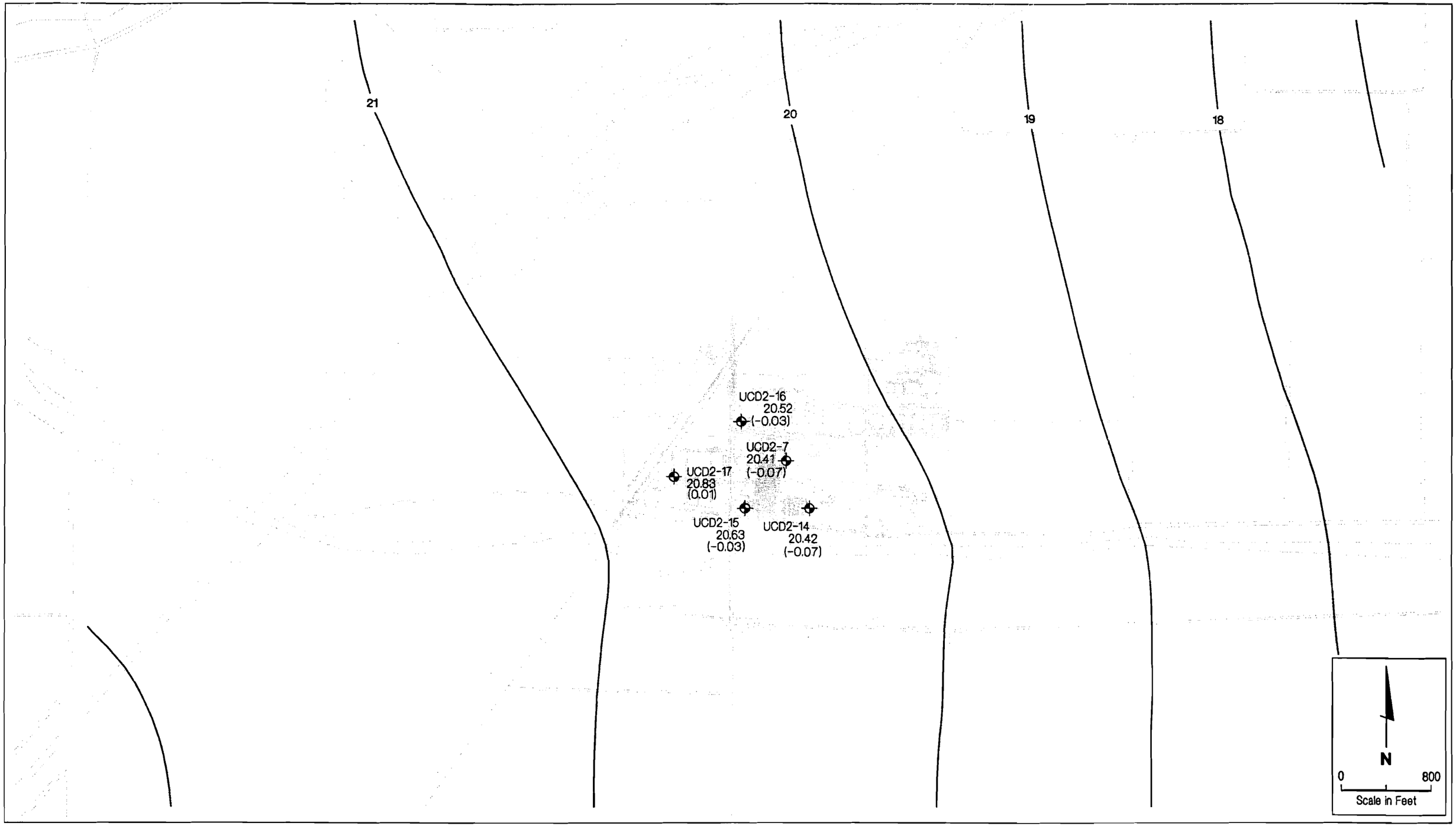
00234-255-6505-044 ah A6505C 3/19/97

MODEL GRID AND BOUNDARY CONDITIONS

EE/CA report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

FIGURE 5



EXPLANATION

UCD2-17	Monitoring Well Location
4.83	March 24, 1995 Measured Water Elevations in Feet MSL
(0.09)	Calibration Residual Water Levels (Predicted-Observed) in Feet

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00234-255-6505-044 AH A6505D 3/19/97

WINTER CALIBRATION WATER LEVELS - HSU-2

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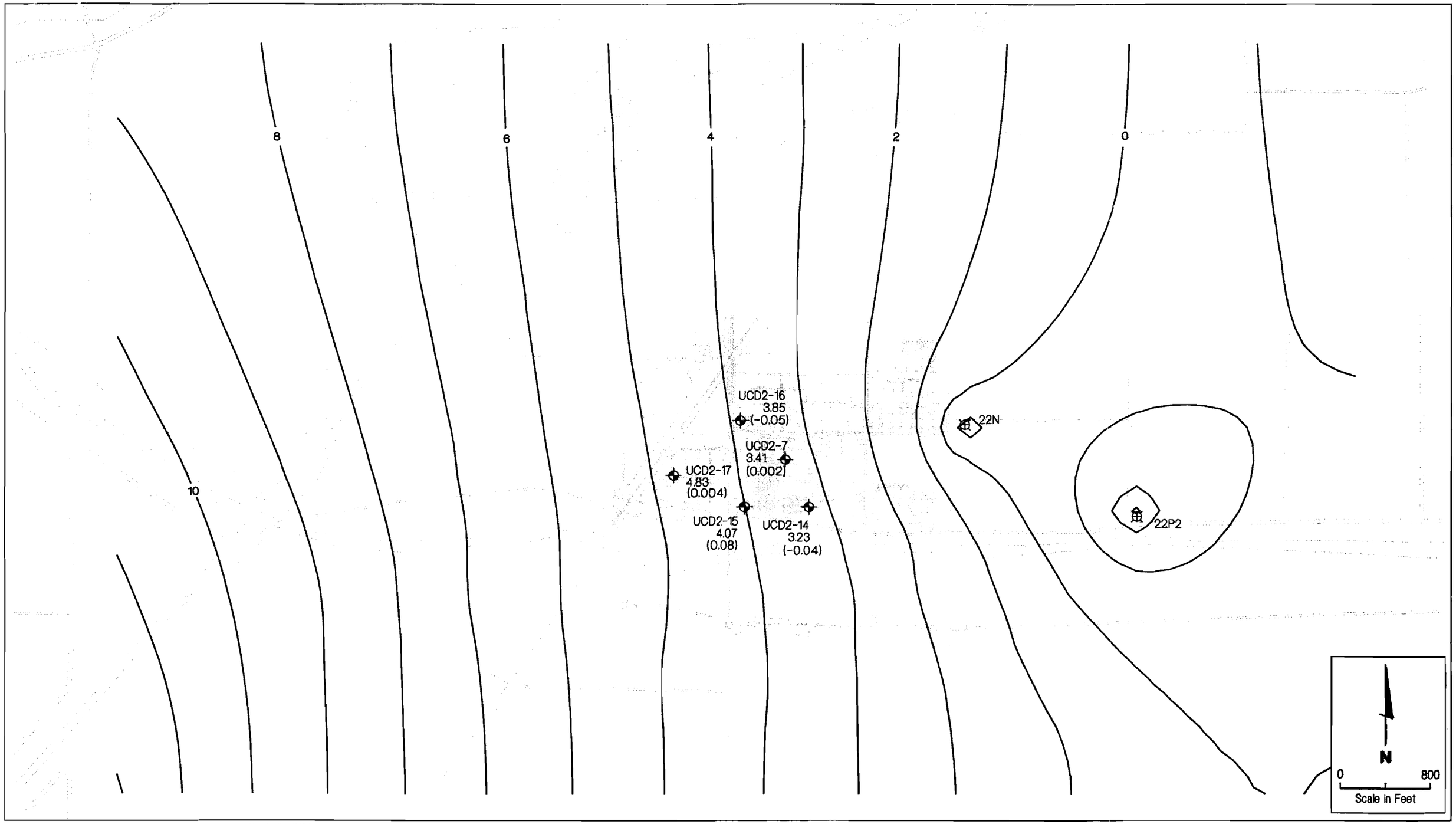
LEHR/SCDS Environmental Restoration
Davis, California

FIGURE 6



EXPLANATION

⊕	UCD2-17	Monitoring Well Location
	4.83	August 31, 1995 Measured Water Elevations in Feet MSL
	(0.09)	Calibration Residual Water Levels (Predicted-Observed) in Feet
⊞	22N	Simulated Irrigation Well Location

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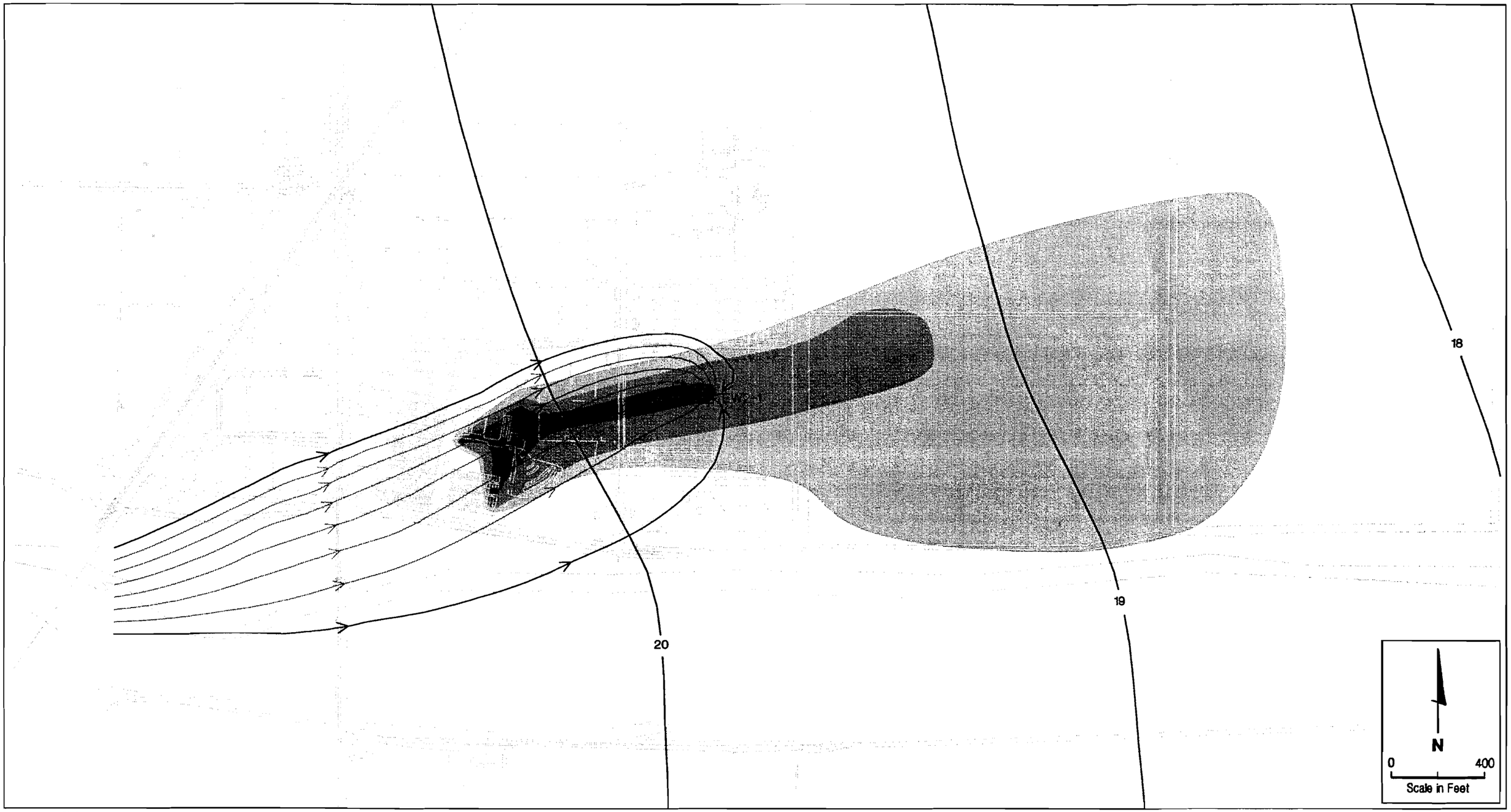
00234-255-6505-044 AH A6505E 3/19/97

SUMMER CALIBRATION WATER LEVELS - HSU-2

EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

FIGURE 7



EXPLANATION

Simulated Extraction Well Location

4 Simulated Groundwater Elevation Contour for Model Layer 3 (HSU-2) in Feet MSL

Simulated Particle Trace

Simulated Particle Trace Showing Predicted Capture Extent

Chloroform Concentrations Above 1 ug/L

Chloroform Concentrations Above 10 ug/L

Chloroform Concentrations Above 100 ug/L

Chloroform Concentrations Above 1,000 ug/L

WINTER PARTICLE TRACKING RESULTS
EW2-1 PUMPING AT 120 gpm

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LEHR/SCDS Environmental Restoration
Davis, California

FIGURE 8

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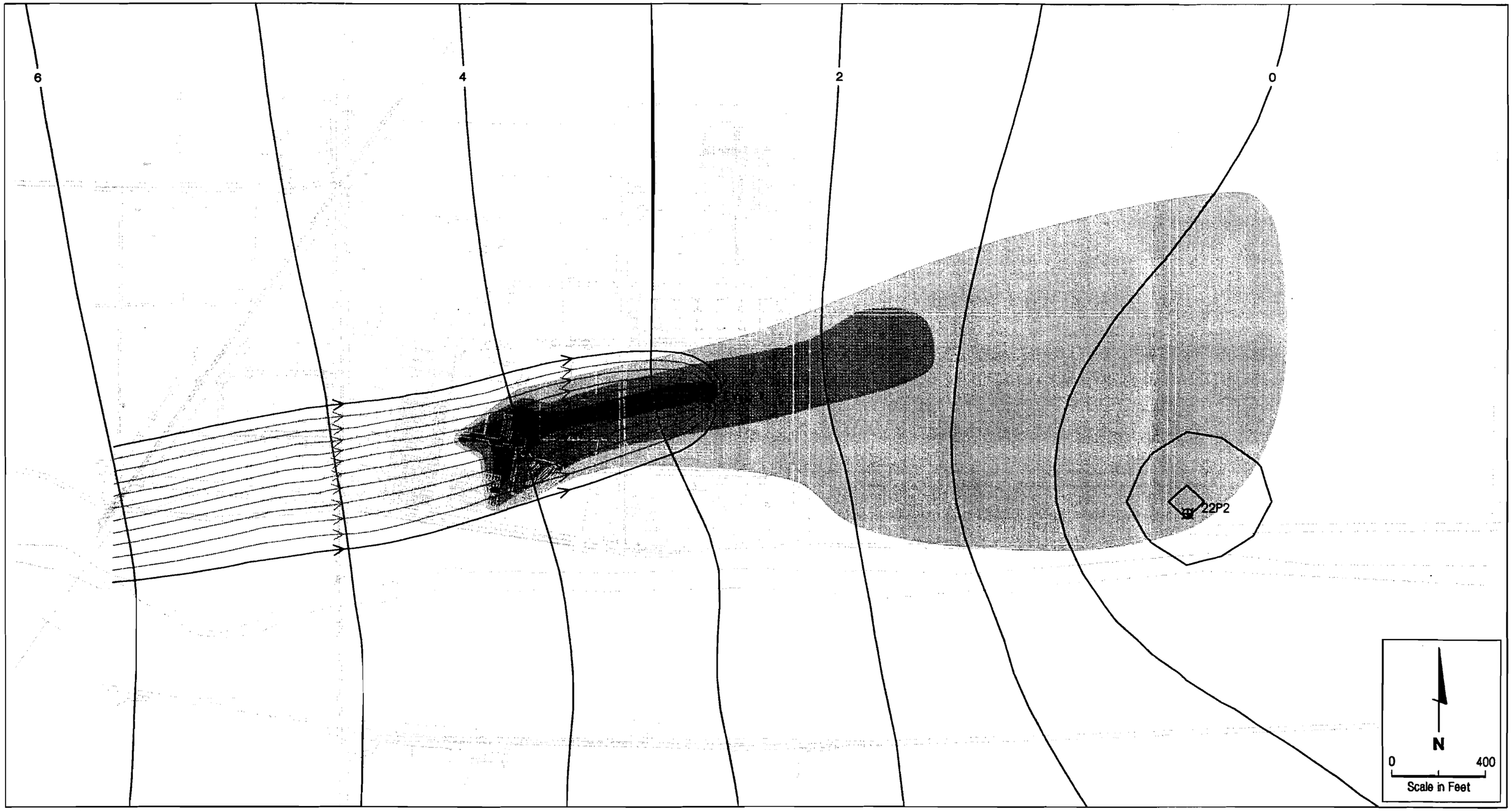
00234-255-6505-044 ah A6505F 3/19/97



EXPLANATION

- Simulated Extraction Well Location
- Simulated Irrigation Well Location
- 4 — Simulated Groundwater Elevation Contour for Model Layer 3 (HSU-2) in Feet MSL
- Simulated Particle Trace
- Simulated Particle Trace Showing Predicted Capture Extent
- Chloroform Concentrations Above 1 ug/L
- Chloroform Concentrations Above 10 ug/L
- Chloroform Concentrations Above 100 ug/L
- Chloroform Concentrations Above 1,000 ug/L

SUMMER PARTICLE TRACKING RESULTS
EW2-1 PUMPING AT 190 gpm

EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

FIGURE 9

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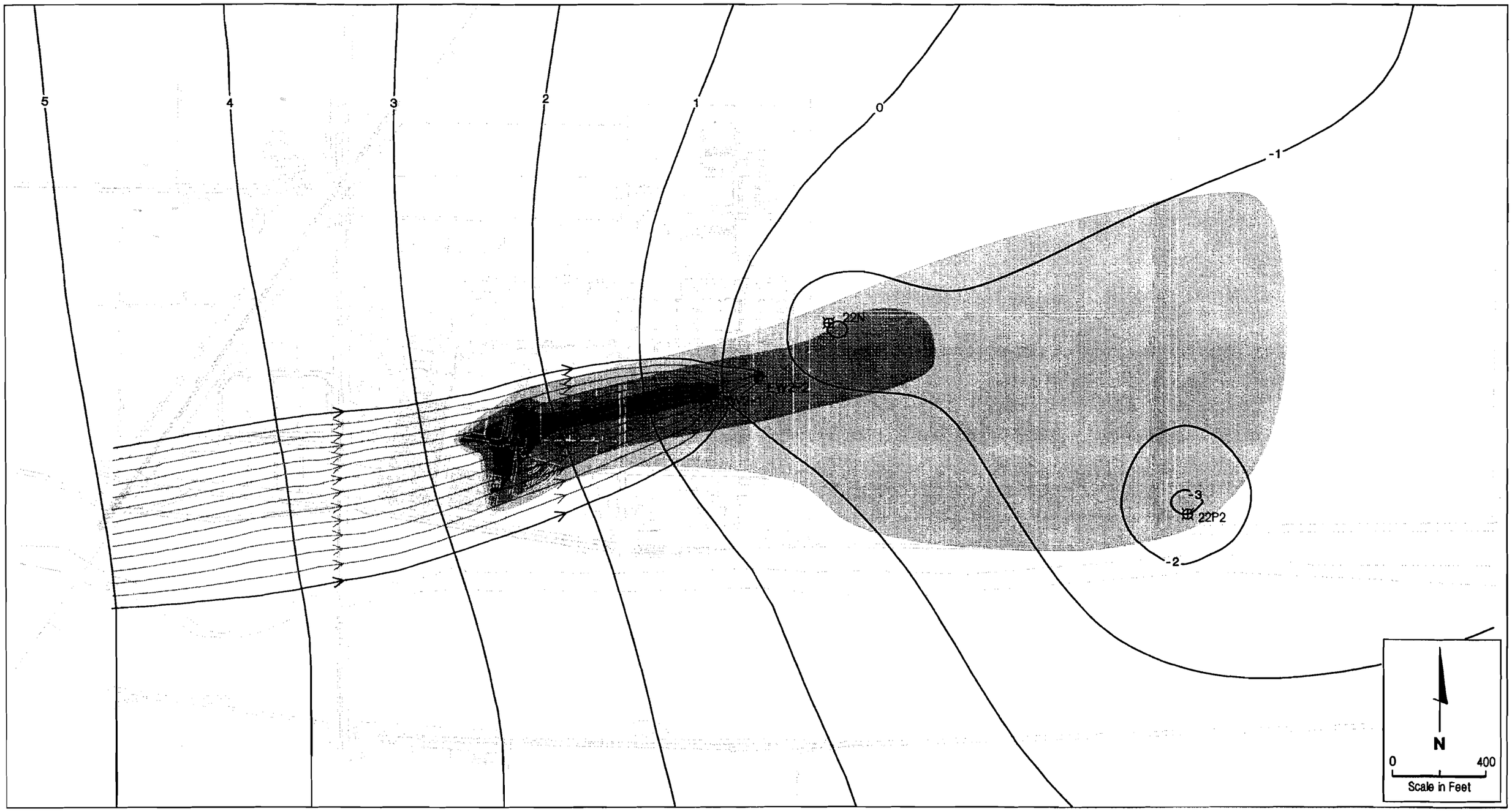
00234-255-6505-044 ah A6505G 3/19/97



EXPLANATION

- Simulated Extraction Well Location
- Simulated Irrigation Well Location
- 4 — Simulated Groundwater Elevation Contour for Model Layer 3 (HSU-2) in Feet MSL
- Simulated Particle Trace
- Simulated Particle Trace Showing Predicted Capture Extent
- Chloroform Concentrations Above 1 ug/L
- Chloroform Concentrations Above 10 ug/L
- Chloroform Concentrations Above 100 ug/L
- Chloroform Concentrations Above 1,000 ug/L

SUMMER PARTICLE TRACKING RESULTS EW2-1 PUMPING AT 190 gpm, EW2-2 PUMPING AT 90 gpm, 22N PUMPING

EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

FIGURE 10

DAMES & MOORE
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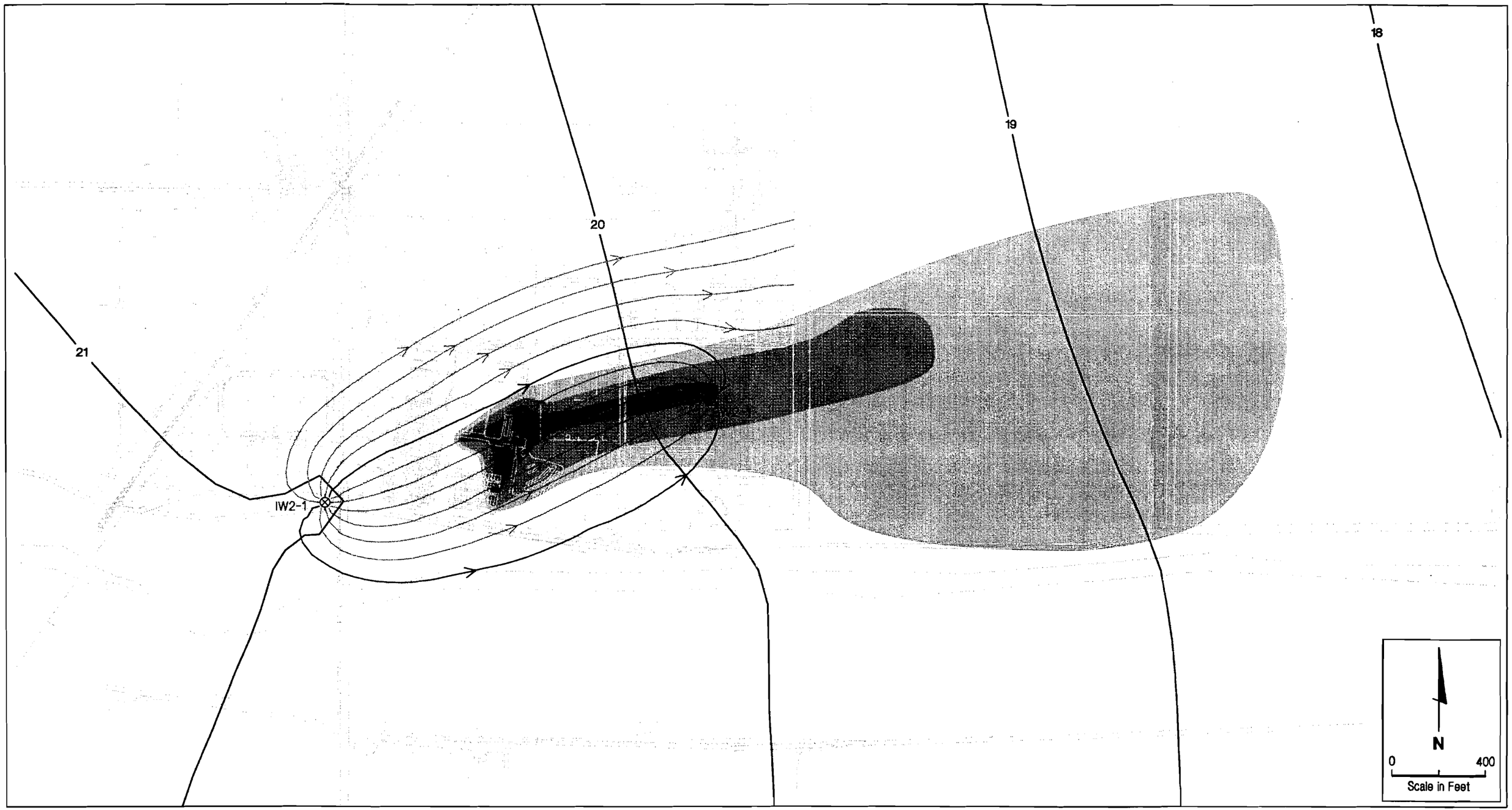
00234-255-6505-044 ah A6505H 3/19/97



EXPLANATION

- Simulated Extraction Well Location
- Simulated Reinjection Well Location
- 4 — Simulated Groundwater Elevation Contour for Model Layer 3 (HSU-2) in Feet MSL
- Simulated Particle Trace of Treated Reinjected Groundwater
- Simulated Particle Trace Showing Predicted Recapture Extent of Reinjected Groundwater
- Chloroform Concentrations Above 1 ug/L
- Chloroform Concentrations Above 10 ug/L
- Chloroform Concentrations Above 100 ug/L
- Chloroform Concentrations Above 1,000 ug/L

WINTER PARTICLE TRACKING RESULTS
EW2-1 PUMPING AT 120 gpm
WITH REINJECTION

EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

FIGURE 11

DAMES & MOORE
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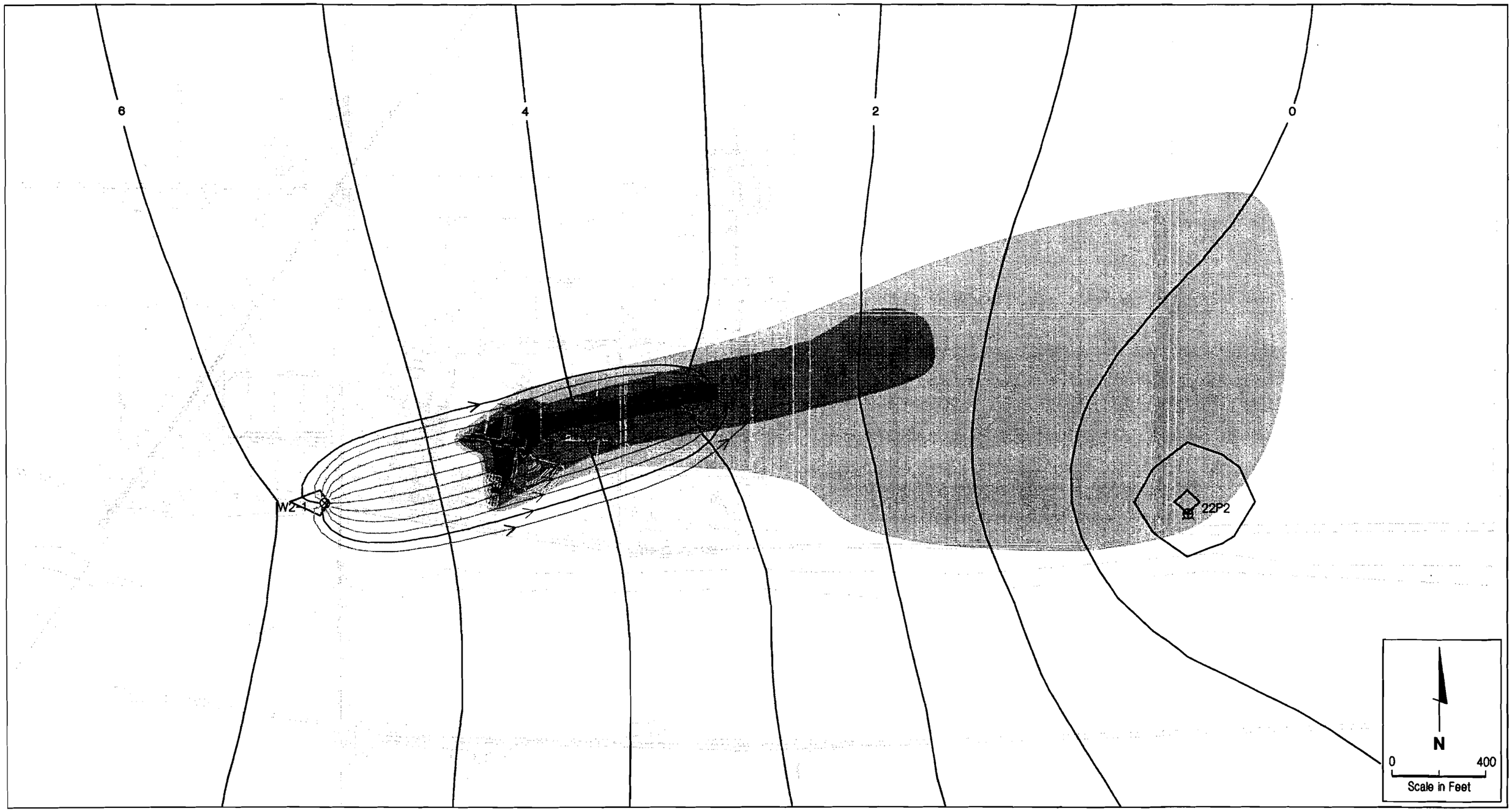
00234-255-6505-044 ah A6505J 3/19/97



EXPLANATION

- Simulated Extraction Well Location
- Simulated Reinjection Well Location
- Simulated Irrigation Well Location
- 4 — Simulated Groundwater Elevation Contour for Model Layer 3 (HSU-2) in Feet MSL
- Simulated Particle Trace of Treated Reinjected Groundwater
- Simulated Particle Trace Showing Predicted Recapture Extent of Reinjected Groundwater
- Chloroform Concentrations Above 1 ug/L
- Chloroform Concentrations Above 10 ug/L
- Chloroform Concentrations Above 100 ug/L
- Chloroform Concentrations Above 1,000 ug/L

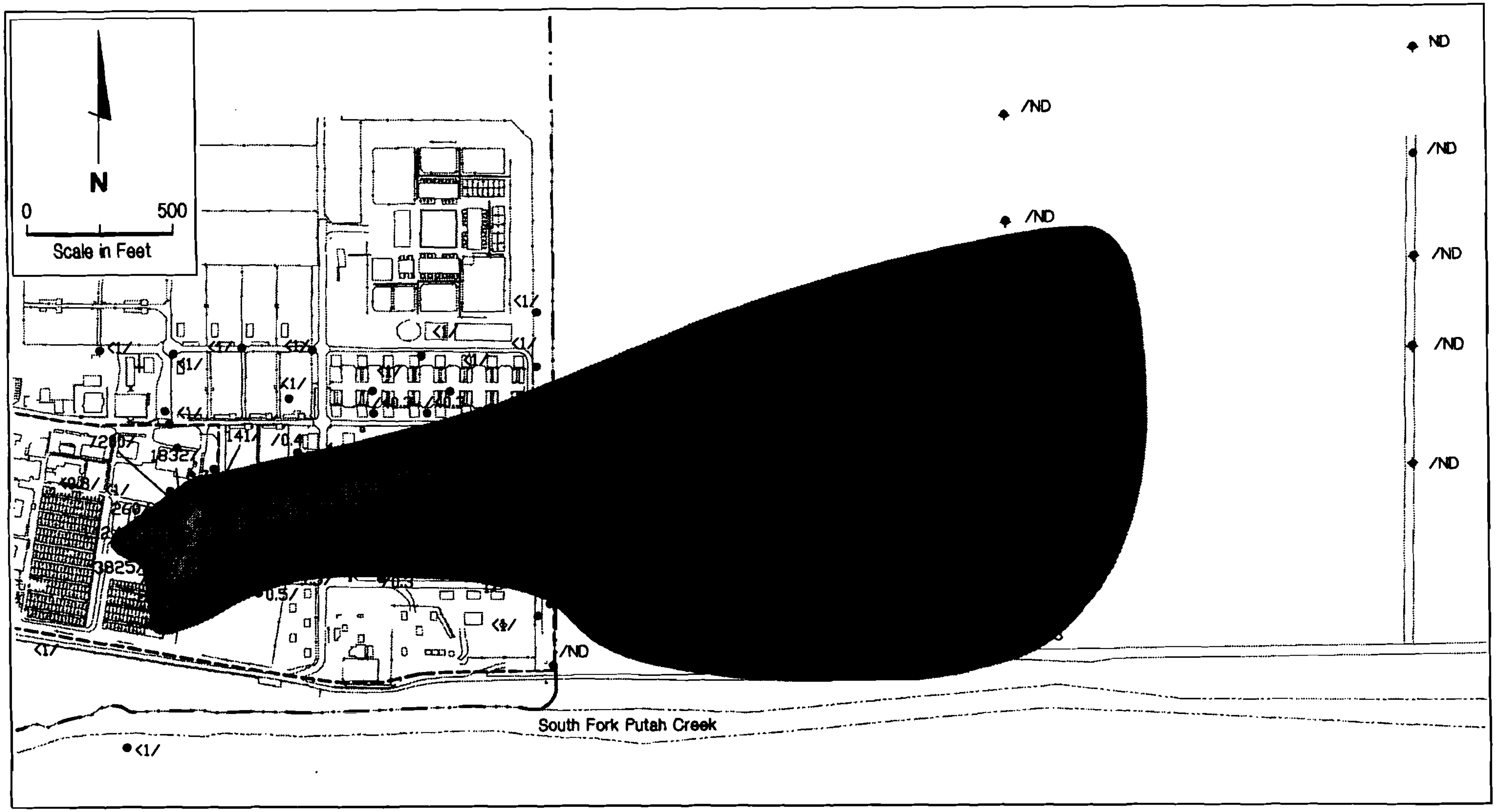
SUMMER PARTICLE TRACKING RESULTS
EW2-1 PUMPING AT 190 gpm WITH REINJECTION

EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

00234-255-6505-044 ah A6505K 3/19/97

FIGURE 12



EXPLANATION

37/140 HSU-1 Concentration/HSU-2 Concentration

HSU-2 Concentration Contour (Middle Zone)

ND Non-detected

All Results Reported in ug/L

Campus Boundary

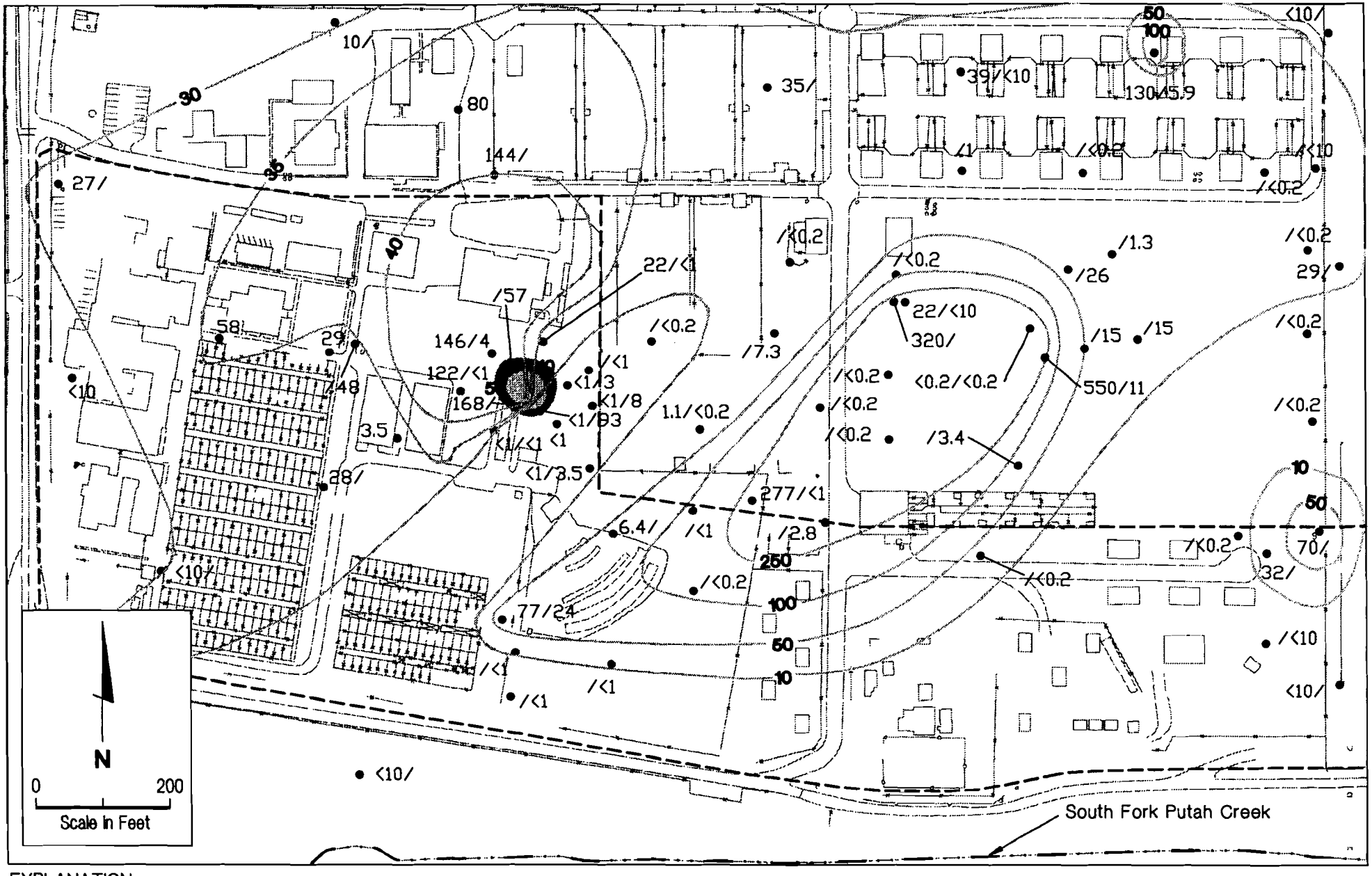
LEHR/SCDS Boundary

CONCENTRATION CONTOUR PLOT
CHLOROFORM IN HSU-2
EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

00234-255-6505-044 ah A6505L 3/19/97

FIGURE 13



EXPLANATION

1.5/4.1 HSU-1 Concentration/HSU-2 Concentration

HSU-1 Concentration Contour

HSU-2 Concentration Contour

Campus Boundary

LEHR/SCDS Facility Boundary

All Results Reported in ug/L

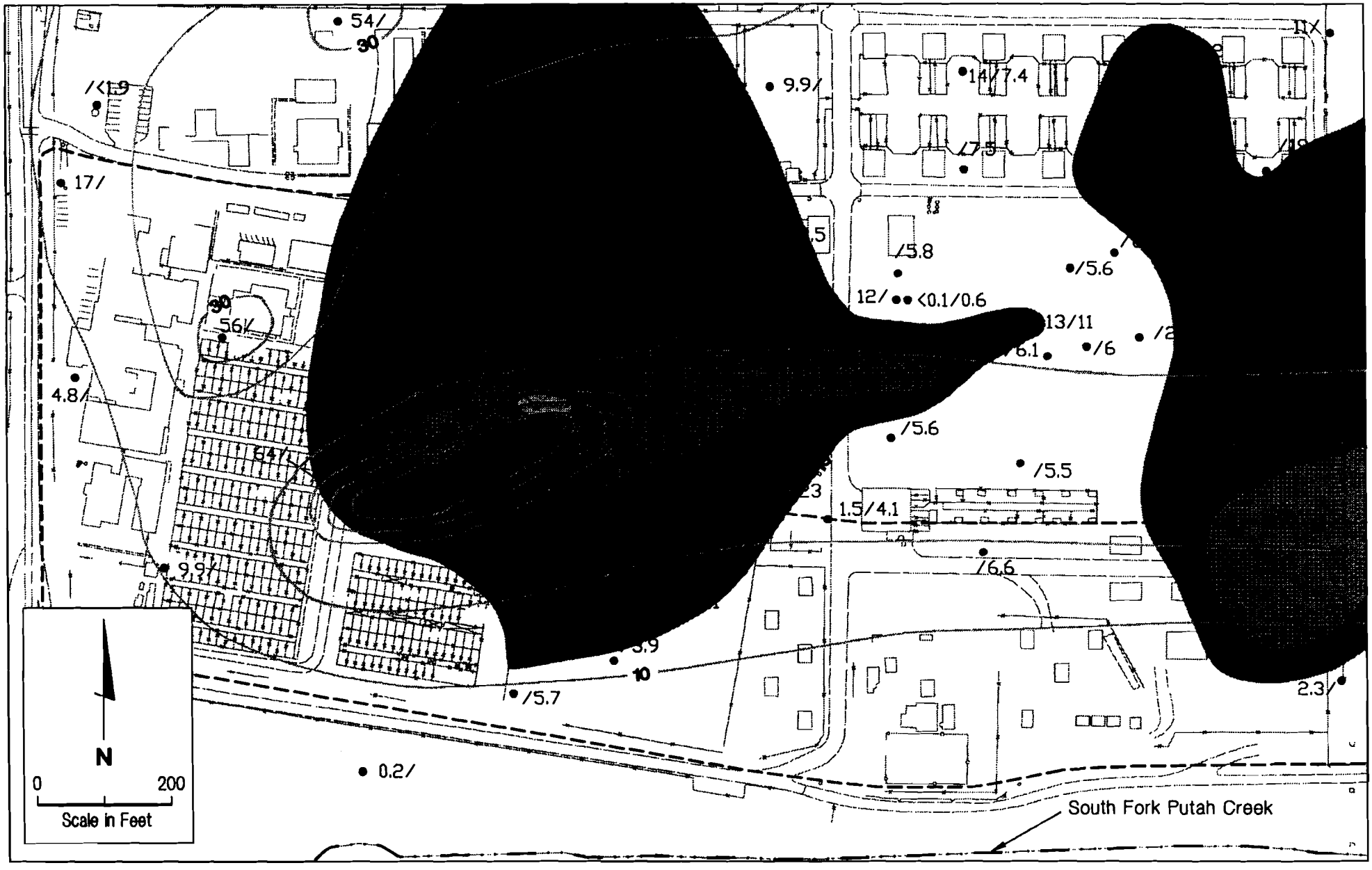
CONCENTRATION CONTOUR PLOT HEXAVALENT CHROMIUM IN HSU-1 AND HSU-2

EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

00234-255-6505-044 ah A6505M 3/19/97

FIGURE 14



EXPLANATION

1.5/4.1 HSU-1 Concentration/HSU-2 Concentration

HSU-1 Concentration Contour

HSU-2 Concentration Contour

Campus Boundary

LEHR/SCDS Boundary

All Results Reported in mg/L

CONCENTRATION CONTOUR PLOT NITRATE IN HSU-1 AND HSU-2

EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

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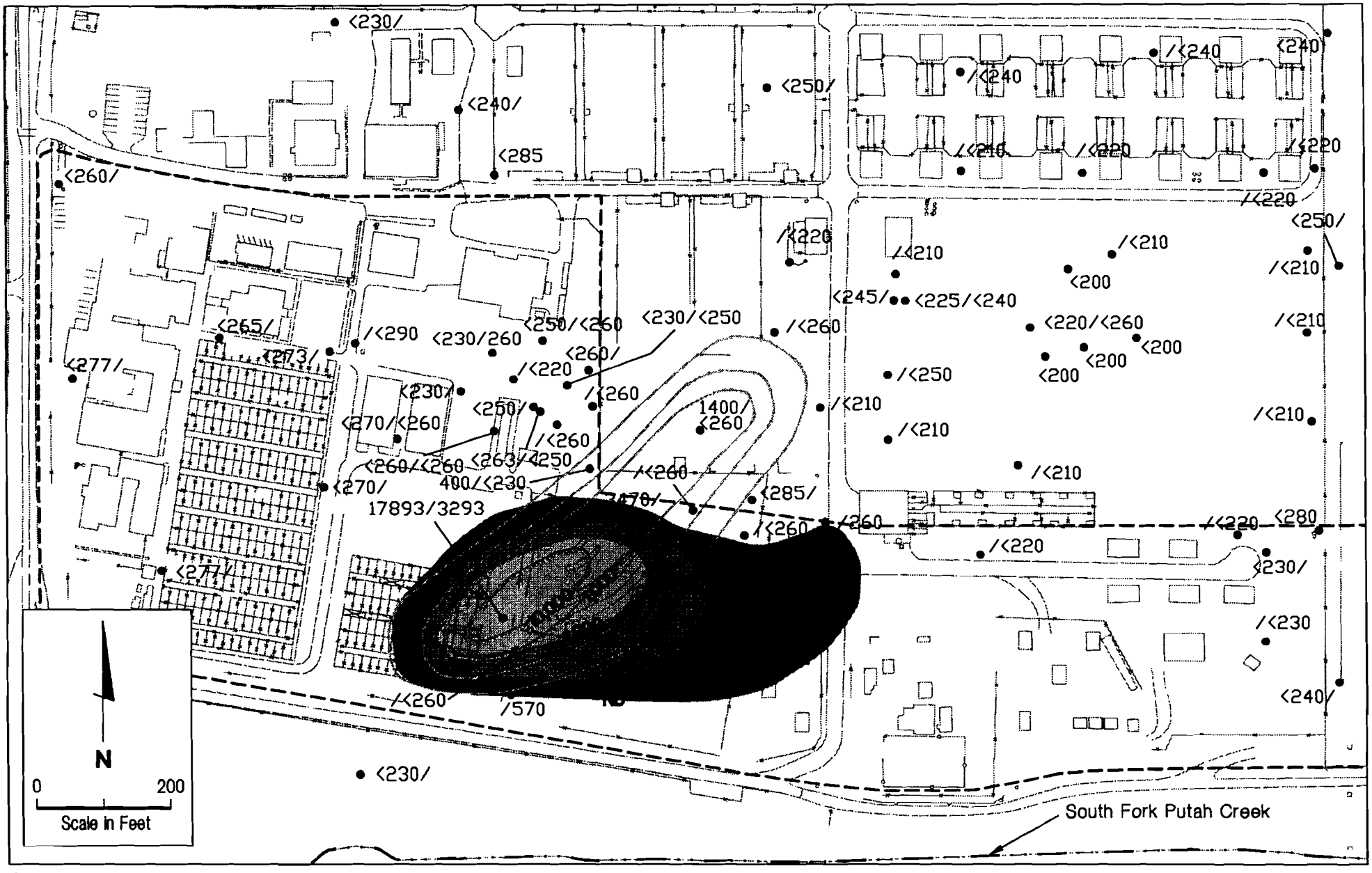
00234-255-6505-044 sh A6505N 3/19/97

FIGURE 15



EXPLANATION

1.5/4.1 HSU-1 Concentration/HSU-2 Concentration

HSU-1 Concentration Contour

HSU-2 Concentration Contour

Campus Boundary

LEHR/SCDS Boundary

All Results Reported in pCi/L

CONCENTRATION CONTOUR PLOT TRITIUM IN HSU-1 AND HSU-2

EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

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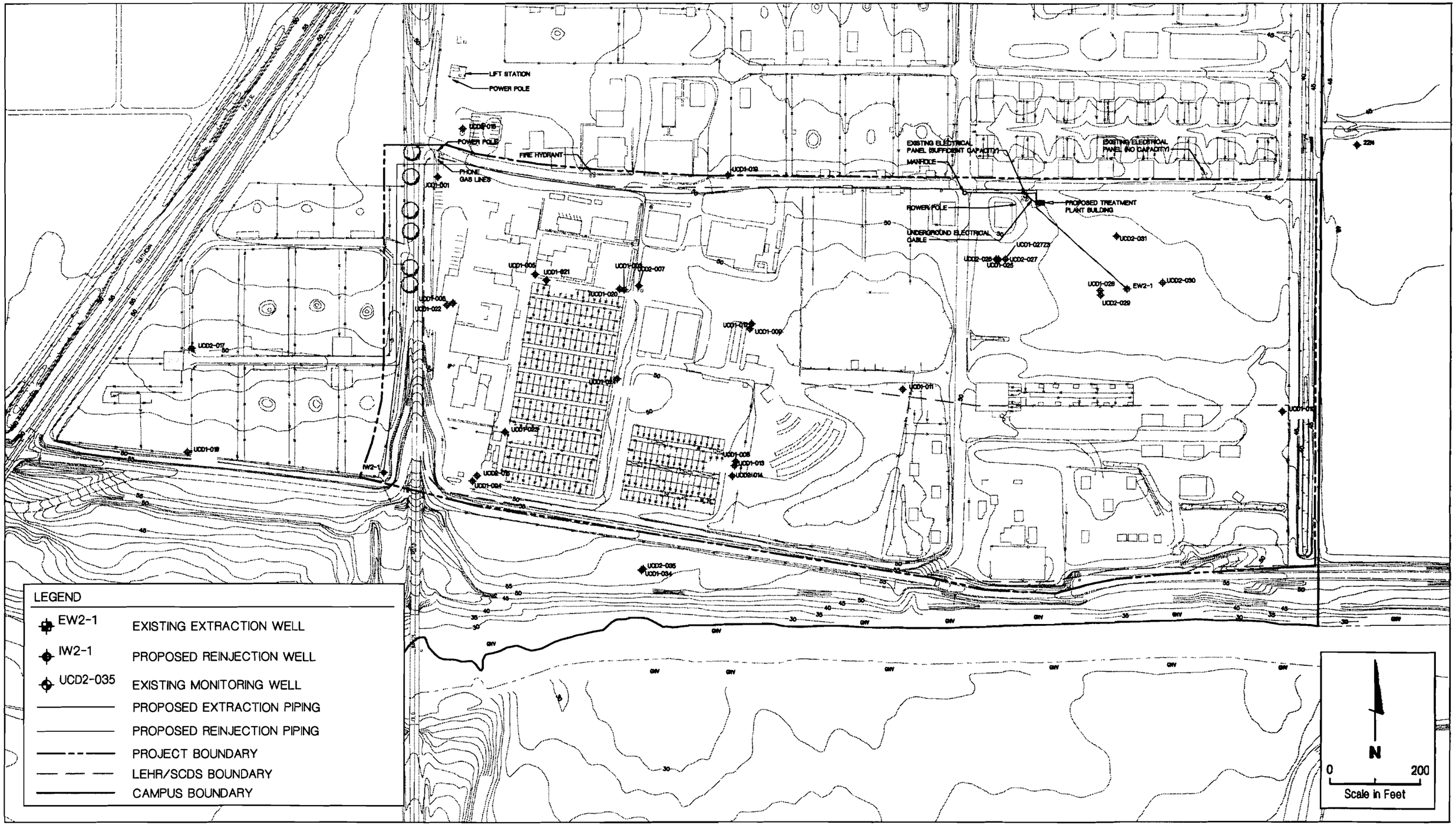
00234-255-6505-044 sh A6505P 3/19/97

FIGURE 16



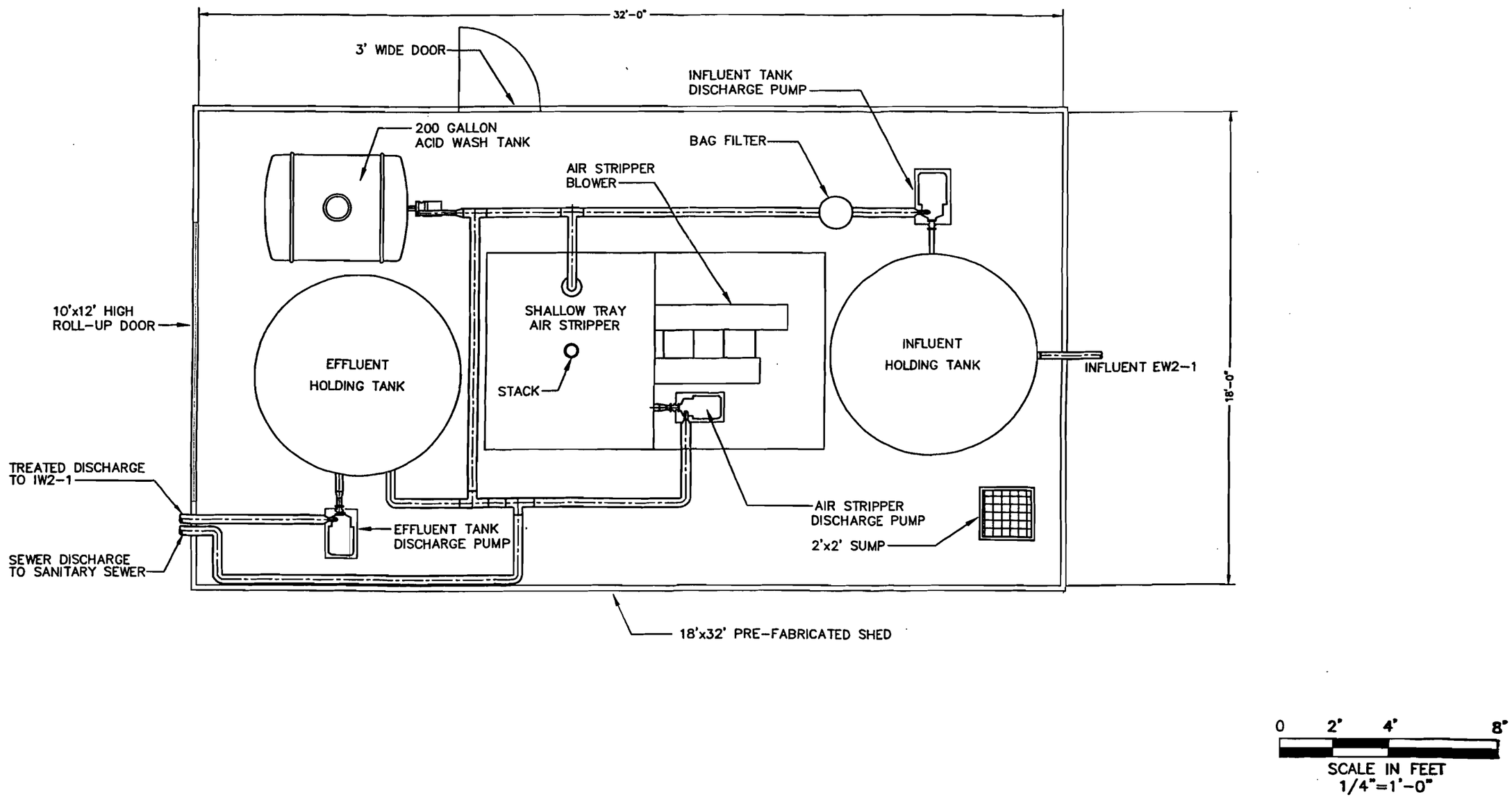
CONCEPTUAL LAYOUT

EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

FIGURE 17

DAMES & MOORE
A DAMES & MOORE GROUP COMPANY

00234-255-6405-130 JBS 6405A 2/27/97



CONCEPTUAL TREATMENT PLANT LAYOUT

EE/CA Report - LEHR Groundwater IRA
LEHR/SCDS Environmental Restoration
Davis, California

FIGURE 18

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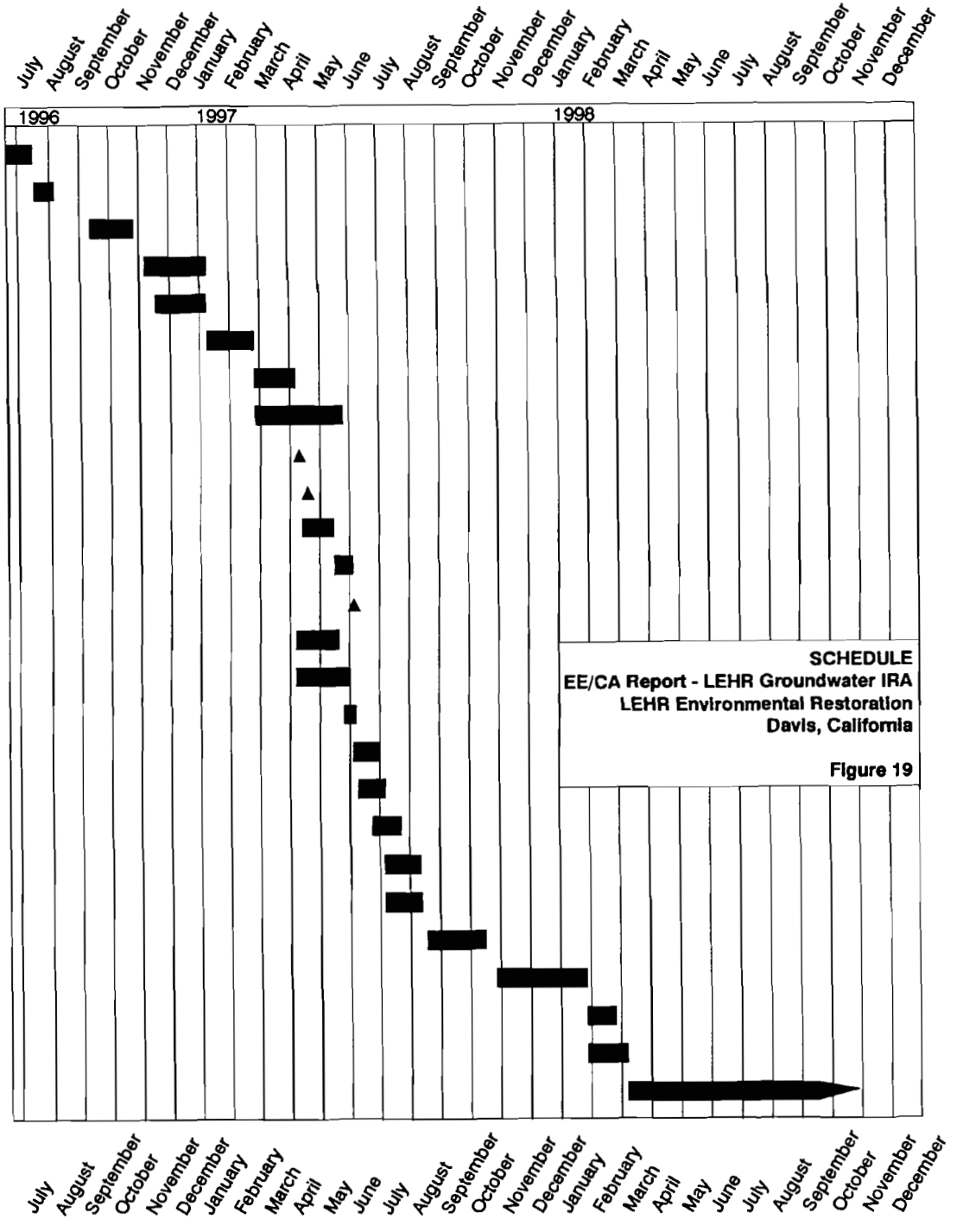
00234-255-6405-044 JBS 64058 2-27-97

Technical Memorandum/Work Plan	35d	06/10/96	07/15/96
Regulatory Review	18d	07/15/96	08/02/96
Well Installation/Hydraulic Testing	46d	09/09/96	10/25/96
Hydrogeologic Modeling	67d	11/04/96	01/10/97
Draft EE/CA Report	56d	11/15/96	01/10/97
EE/CA Comment Period	46d	01/10/97	02/25/97
EE/CA Response to Comments	38d	02/25/97	04/04/97
50% Design Documents	87d	02/25/97	05/23/97
Final EE/CA		04/11/97	
Publish Draft Initial Study		04/18/97	
Initial Study Comment Period	32d	04/18/97	05/19/97
Initial Study Response to Comments	18d	05/19/97	06/06/97
Final Initial Study			06/06/97
Action Memorandum	35d	04/11/97	05/16/97
Draft Removal Action Work Plan	49d	04/04/97	05/30/97
50% Design Document Review	11d	05/26/97	06/06/97
RAWP Regulatory Review	18d	06/02/97	06/20/97
100% Design Documents	25d	06/09/97	07/04/97
Final Removal Action Work Plan	30d	06/20/97	07/20/97
Fact Sheet on Removal Action	35d	07/04/97	08/08/97
Bid Assistance/Procurement	35d	07/04/97	08/08/97
Removal Action Construction	61d	08/18/97	10/18/97
Start-Up Monitoring	92d	10/27/97	01/27/98
System Monitoring Report	28d	01/27/98	02/24/98
O&M Plan	38d	01/27/98	03/06/98
Long-Term Operations		03/06/98	



SCHEDULE
EE/CA Report - LEHR Groundwater IRA
LEHR Environmental Restoration
Davis, California

Figure 19

j:\ucdlehr\eeca com\timeline.cdr

Appendix A
Comments to Draft EE/CA and Corresponding Responses

Response to Comments - Hedy Ficklin - EPA
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
3	Concentrations of COCs in treated groundwater to be reinjected into HSU-2 must be at or below background levels for the receiving aquifer unless UCD shows that it is technically or economically infeasible to treat to background levels. In that case, the levels must not exceed water quality objectives. In Alternative 1, UCD proposes treating VOCs to nondetectable concentrations using air stripping. In Alternative 2, UCD proposes treating VOCs with air stripping and additional COCs, specifically chromium, nitrates and TDS, using reverse osmosis (RO). UCD compares treatment costs for Alternative 1 with costs for Alternative 2. The estimated cost of using RO and air stripping is about two and one-half times more than using only air stripping. The additional cost of using RO for the incremental improvement in water quality at present effluent levels as shown on Table 10 is uneconomical. Also, RO produces a waste stream highly concentrated with TDS which must be discharged. UCD proposes discharging the concentrated waste stream to the waste water treatment plant which discharges to Putah Creek. Given the options as presented, treating only for VOCs during this interim action seems appropriate.	*No response necessary.*

Response to Comments - Hedy Ficklin - EPA
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
6	Section 3.2.1.3, Aquifer Pumping Tests Please submit drawdown curves and an explanation of how corrections for the barometric pressure effects and regional rebound of water levels were made.	*To maintain the aggressive schedule necessary to implement the groundwater IRA before the end of 1997, a more complete package of backup information for the aquifer pumping test, including information on how barometric pressure effects and regional rebound of water levels were made, will be included as part of the Removal Action Work Plan.*
7	Section 3.3.1, Model Construction. The last sentence in paragraph four is unclear. Please explain the reference to vertical hydraulic conductivity input.	*In review of the EE/CA report, it appears that this comment refers to Section 3.3.1 paragraph three rather than paragraph four. The comment refers to the sentence "Layer 2 through 4, representing the three different intervals within HSU-2, were specified as confined, and based on vertical hydraulic conductivity input corresponding to semi-confined conditions in HSU-2"". In MODFLOW three different layer types are used in the model. These model layer types are confined, unconfined and variable. Confined layer types imply the water level will remain above the top of the model layer throughout the simulation, and therefore the layer thickness remains a constant. A model layer specified as confined can simulate a semi-confined layer by allowing vertical leakage between adjacent model layers to occur. The amount of vertical leakage that occurs is a function of the vertical hydraulic conductivity specified in the model input. For this model, vertical hydraulic conductivity values assigned to layers 2 through 4 correspond to sands and gravels and therefore allow for vertical movement of water between these layers. Layer 1 of the model represents the silts and clays of HSU-1 and in our conceptual model represents the semi-confining layer bounding HSU-2. Aquifer testing results indicate that HSU-1 has a lower vertical hydraulic conductivity than HSU-2, but still allows for significant vertical movement of water between HSU-1 and HSU-2. This process is reflected in the vertical hydraulic conductivity input for layer 1 of the model.*

Response to Comments - Hedy Ficklin - EPA
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
8	Section 3.3.2 Model Calibration, page 16. The text states that the model calibration is consistent with ASTM standard D 5447. A sensitivity analysis was not included in the report, though it is highly recommended. The ASTM standard states : "The purpose of a sensitivity analysis is to quantify the uncertainty in the calibrated model caused by uncertainty in the estimates of aquifer parameters, stresses, and boundary conditions". Since a sensitivity analysis was not presented, the uncertainty of the flow model can not be evaluated. Of particular concern is the paucity of data in the model domain. The majority of the data points(which forms the basis of the calibration) have similar water levels without much variability. It would be very helpful if the model were run to replicate the pumping tests. A comparison could then be made between observed and modeled drawdown vs. time.	*ASTM Standard D-5447 addresses three components of evaluating the ability of a groundwater flow model to simulate a groundwater system. These components are model calibration, sensitivity analysis and model verification. As part of this model evaluation a calibration study was performed in accordance with the ASTM standard. For the purposes of supporting the EE/CA Report, a full scale sensitivity analysis was not performed. However, the sensitivity of model calibration to model input parameters was evaluated in part during model calibration using the parameter estimation package MODFLOWP. MODFLOWP provides calibration statistics that are based upon sensitivity to input parameters. These statistics are generated by automatically varying input parameters of interest during the calibration process. Therefore, a form of sensitivity analysis was performed. The results of this sensitivity analysis will be presented in a modeling appendix in the RAWP. Additional sensitivity analysis will be performed and presented in the RAWP, as warranted. In addition, the uncertainty in the extraction well pumping rate required to achieve capture zone objectives will be evaluated. The uncertainty analysis will include varying model input parameters within the degree of anticipated uncertainty and evaluating the change in pumping rate required to achieve capture. Based on the results of the uncertainty analysis, the design capacity of the extraction/treatment system will be finalized.*

Response to Comments - Hedy Ficklin - EPA
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
8 (con't)		*Model verification using pumping test data has not been performed. It should be noted that information resulting from the pumping test is the basis for estimating horizontal hydraulic conductivity (K_h) of HSU-2. This approach was taken so that the least certain input parameters, vertical hydraulic conductivity (K_v) and recharge(R), could be estimated with a higher level of certainty (for this particular groundwater system it is not reasonable to estimate K_h, K_v and R simultaneously). It is our opinion that the modeling performed to date, supplemented with additional sensitivity analysis and uncertainty analysis is sufficient to support design of the groundwater IRM. Eventually, an evaluation of capture zone performance will be performed independent of the model, which will be based on actual water level data during system operations.*
9	Section 5.2: UCD states "The extraction well(s) will be best located to capture or substantially control the chloroform in groundwater plume to a 1-µg/L concentration level, and will also substantially control other constituents of concern in groundwater." This language is unclear. UCD should state clearly that the extraction system will capture the plume so that no detectable chloroform leaves the site. The detection limit for chloroform should be 0.5 µg/L.	*Sentence rewritten as "The extraction well(s) will be best located to capture or substantially control the chloroform in the HSU-2 groundwater plume to a 0.5 µg/L concentration. In addition, because the extraction well is located downgradient of most LEHR/SCDS source areas, the groundwater IRA will also provide significant capture for other site constituents of concern in HSU-2."*
10	Section 5.3: Chemical specific ARARS should not be included since this is an interim action. In theory the timeframe for deciding on the action should be quite limited. That short timeframe would be impossible if all parties including the state regulators and the Regional Water Quality Control Board had to agree on the ultimate chemical specific ARARS. Therefore, after listing the types of ARARS generally, it should state that since this is only an interim action and not the final remedy at the site, there are no chemical specific ARARS. The entire section 5.3.1 should be deleted.	*Section 5.3.1 has been revised to summarize chemical-specific ARARs; detail has been eliminated as requested.*

Response to Comments - Hedy Ficklin - EPA
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
11	Section 5.3.2: The section on reinjection should provide more detail. Instead of making a general statement that a statute applies, it would be more helpful to cite the specific regulations. SWRCB 88-63 and 92-49 both are applicable as chemical specific ARARS to the final remedy but need not be cited here.	*Section 5.3.2 has been revised as requested. The paragraph that references resolutions 88-63 and 92-49 has been removed.*
12	Section 5.3.2, Reinjection of Treated Effluent to Aquifers. Page 31: First Line Insert "and surface water" after "groundwater" and second line: Delete "Sacramento-San Joaquin Delta".	*New page 29, paragraph 4, first line has been changed as requested.*
13	Page 31, Last Sentence of First Incomplete Paragraph Change the sentence which begins "The water quality objectives" to "The concentrations of COCs in treated groundwater shall be at or below background levels for that aquifer, unless specific findings are made by the RWQCB, in which case the concentrations may be no higher than the water quality objectives."	*New page 29, paragraph 4, 3rd sentence has been changed as requested.*
14	Section 5.3.4: What does the phrase "potential alternative TBC criteria" mean? In the second paragraph, the Antidegradation Policy is included as a TBC. It should be an action specific ARAR for reinjection.	*Text changed to read "potential TBC."* *The Antidegradation Policy is included as both an action specific ARAR, and a TBC. Additional language from the Antidegradation Policy has been included as a TBC, because the conditions cited allow for some interpretation of strict application of the policy. These conditions were cited as TBC for the IRA in case this strict application would limit or restrict implementation of the IRA which, because of technical and economic infeasibility, will not meet background groundwater quality.*

Response to Comments - Hedy Ficklin - EPA
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
15	Page 32, Paragraph 2 Make the following changes in the second paragraph on page 32 and then insert the paragraph into the first line on page 31 (after "No. 68-16)." From line 4 of the second paragraph, page 32, delete "probable" and replace "any future" with "anticipated". In the last line of the second paragraph on page 32 insert "but below water quality objectives," after "background concentrations".	*Changed as requested, and inserted into section titled, "Reinjection of Treated Effluent into Aquifers."*
16	Section 2550.4 refers to background levels for the final cleanup so it is not necessary to include for an interim action. Final cleanup standards will be included in a Record of Decision following further groundwater investigation. This should be stated in the EE/CA and the Action Memorandum. It should be noted that section 2550.4 addresses concentration limits to be established for corrective action programs. Under this section, if a discharger has demonstrated that it is technologically or economically infeasible to achieve background levels, the RWQCB may adopt concentration limits greater than background, but no higher than the water quality objectives.	*Section 5.3.4 has been rewritten as: "Section 2550.4 of CCR 23, Division 3, Chapter 15, Article 5, addresses concentration limits that are established for corrective action programs. However, as an interim removal action, concentration limits established under 2550.4 may not necessarily apply to the groundwater IRA at LEHR/SCDS. Instead, final concentration limits will be included in a Record of Decision written following further groundwater investigation. The final concentration limits will most likely be based on background levels. Only if a discharger demonstrates that it is technologically or economically infeasible to achieve background levels, the RWQCB may adopt concentration limits greater than background, but no higher than water quality goals."*
17	Section 5.3.5: The last paragraph should be rephrased to say that NCP Section 300.430(f)(1)(ii)(C)(1) states that "An alternative that does not meet an ARAR under federal environmental or state environmental or facility siting laws may be selected under the following circumstances: The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement." Currently the EE/CA states that the NCP allows waiving of ARARS and that the standards should be "considered". There is also an inference that there may not be any additional RA when it states "additional actions can be implemented". "Can" should be changed to "will".	*The last paragraph of section 5.3.5 has been rewritten as follows: "As chemical specific ARARs and action-specific ARARs are evaluated for their applicability to the groundwater IRA, NCP and State policies allow that the technical and economic feasibility of the alternative be considered. If for technical or economic reasons an alternative does not meet a state or federal standard, the alternative may still be selected under NCP Section 300.430(f)(1)(ii)(C)(1) if the alternative is an interim measure and if the alternative will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement."*

Response to Comments - Hedy Ficklin - EPA
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
18	Section 6.3, Screening of Complete IRA Alternatives UCD gives very little information regarding alternative 3. Alternative 3 proposes operating two extractions wells without destroying irrigation well 22N. UCD justifies discarding this option based on cost alone. UCD should present information regarding zone of capture, effect on injection scenario and the expected concentration of COCs in the effluent if a second extraction well is operated.	*Alternatives 3 (and 4) were eliminated during the screening process due to cost because the effectiveness and implementability of the two-well scenario were not significantly different from the single-well scenarios. Zone of capture information for alternatives 3 and 4 that include 2 extraction wells were presented in Figure 9. The following text has been added to Section 6.3: "As shown in this figure, the capture zone with 2 wells is wider to account for influence of pumping from well 22N. However, the two-well scenario would also generate an additional 90 gpm that would subsequently widen the distribution of injected water. The expected concentrations of COCs in water extracted during the pumping season for alternatives 3 and 4 were not estimated because of a lack of data in the second extraction well location. The likely effect of adding 90 gpm of water from a second downgradient extraction well would be to dilute the concentrations of several site COCs. The dilution, however, would only occur during the pumping season and design of the treatment system would still have to accommodate the higher concentrations anticipated from extraction well EW2-1.*

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Item	Comment	Response
Comments which must be addressed in the removal action work plan:		
19	UCD must monitor the effluent frequently to determine if concentrations of COCs increase over time. Table 6 shows the anticipated water quality from extraction well EW2-1. Several COCs are above background concentrations but below water quality objectives. TDS at 470 ppm in the estimated effluent concentration exceeds background and the agricultural water quality objective of 450 ppm. TDS concentrations beneath the site are as high as 1,500 ppm in HSU-1 and 850 ppm in HSU-2; thus, there is potential for the concentration in extracted groundwater to increase over time. This is true of some other COCs, such as chromium. The CVRWQCB will designate water quality objectives for each COC in waste discharge requirements. Daily maximums above background or water quality objectives for some COCs may be allowed; however, the 30-day median shall be no greater than the water quality objectives. Since TDS is slightly above water quality objectives in the effluent, I will propose that the WDRs allow injection at the present effluent level for a limited time with monitoring to ensure that the groundwater is not being degraded outside of the extraction well capture zone. If TDS levels in the effluent do not decrease during this time or TDS levels increase in groundwater not captured by the extraction well, UCD may have to treat the effluent for TDS or propose another discharge method. UCD will have to decide how to meet permit requirements.	*UC Davis will prepare a monitoring plan that details the location and specifications of additional monitoring wells, as necessary, the monitoring schedule for IRA system start-up and continued operation, an analytical parameter list, and a reporting schedule. The monitoring plan will be included in the draft RAWP and will be based on the EPA guidance document Methods for Monitoring Pump-and-Treat Performance, EPA/600/R-94/123, June 1994.* *The monitoring plan will be designed to collect data so that UC Davis can evaluate the effectiveness of the IRA system including plume capture and the effectiveness of treatment. Monitoring data will also be compared to requirements specified in the Waste Discharge Requirements to evaluate system compliance. In the event that monitoring data indicates that provisions of the WDRs are not being met by the IRA system, the plan will also include a contingency plan for monitoring and system operation that addresses non-compliance issues.*
20	UCD must include a groundwater monitoring plan to monitor plume capture, effect of injection on water quality and effect of extraction on the down gradient (offsite) water quality. A contingency plan needs to be included as well. At a minimum this plan should describe UCD's response to elevated concentrations of COCs in groundwater due to injection and to elevated concentrations of COCs in the effluent.	*See response to EPA comment #19.*

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Item	Comment	Response
21	Section 5.2 Scope and Objectives of the Groundwater IRA, page 26. Please explain the distinction between bullets 3 & 4 on page 27. EPA recommends that an additional bullet be added such as "To provide operational data on assessment of plume capture and the need for additional groundwater remedial action". Performance monitoring must be a component of this document. EPA recommends adding a discussion in this document as to how plume capture will be monitored. This should include identification of monitoring wells, parameters and frequency. Please see EPA guidance document Methods for Monitoring Pump-and-Treat Performance, EPA/600/R-94/123, June 1994 for further guidance.	*The 4th bullet "To, over time, decrease the mass of constituents of concern in HSU-1 at the Site" has been deleted.* *The 7th bullet (now the 6th bullet) already states "To provide operational data which will aid in assessment of groundwater treatment effectiveness and the need for further groundwater remedial action." This bullet has been retained.* *A monitoring plan for the IRA start-up and operation will be presented in the RAWP (see response to EPA comment #19).*

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Item	Comment	Response
Informational comments:		
22	Section 3.0 Site Hydrogeology, page 9. The site conceptual model appears to be well constructed and thought out. In particular the relative flow relationship determined with the spinner logs show the critical impact of site heterogeneities. It would be useful to have a block diagram presented here. This would also be helpful for comparing the numeric model to the conceptual model.	*A schematic cross section has been added as Figure 4.*
23	Section 8.0, Conclusions. UCD has chosen Alternative 1 as the preferred alternative. This alternative requires the removal of irrigation well 22N. UCD will have to show that the owner of the well is in agreement with UCD's plans.	*Prior to the removal of irrigation well 22N from service, UCD will enter into a legal agreement with the property owner that describes the terms and conditions of the removal of well 22N from service.*
24	Table 3, Summary of Water Quality Data. This table presents regional groundwater quality data, groundwater quality data from nearby neighbors' wells and background water quality data from onsite upgradient monitor well UCD2-17. Monitor well UCD2-17 is screened in HSU-2. The other data presented on this table is from wells screened across more than one aquifer or from wells of unknown screen lengths and depths. On page 22, UCD states that "most flow in the neighbor's well is anticipated to come from HSU-2." UCD must support this evaluation with hydrostratigraphic data and well logs if it wants to show that the neighbors, wells represent background for HSU-2. Only data based on HSU-2 background groundwater quality is relevant to setting water quality goals for the treated groundwater.	*UC Davis agrees that data from local and regional irrigation and domestic supply wells are not strictly appropriate for establishing water quality goals for HSU-2. These data were included because they represent the only data other than data from site monitoring wells that are available to evaluate regional groundwater quality in the vicinity of the site. Additional hydrostratigraphic data and wells logs will be presented in the RAWP.*

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Item	Comment	Response
General Editorial Comments		
25	Page v. The acronym "ARARs" stands for "Applicable or Relevant and Appropriate Requirements". Please correct the phrase where inaccurately referenced throughout the document. Also, the acronyms "RWQCB" and "SCDS" should be defined on this page.	*The references to ARARs have been changed throughout the document. An explanation of the acronyms RWQCB and SCDS have been added to page v.*
26	Section 3.2.1.2 Gradient and Flow Direction, second paragraph. UCD refers to "lateral hydraulic gradients" which means side gradients. A better description would be "horizontal hydraulic gradients".	*The reference has been changed to "horizontal hydraulic gradients."*
27	Page 19. Chloroform UCD needs to be consistent in reporting chloroform concentrations from monitoring well UCD2-12.	*The references to the elevated concentrations of chloroform in well UCD1-12 have been changed to ">10,000 µg/L."*
28	Page 23, Last Bulleted Paragraph. Correct the total chromium MCL to 50 µg/L.	*Changed as requested.*
29	Page 31, First Complete Paragraph. Change the second sentence to "The requirements of this resolution are used to derive water quality objectives." In the last sentence change "effected" to "affected".	*Per EPA comment #11, this paragraph has been deleted.*
30	Table 7 In the column labeled "type", change "appropriate" to "applicable" and "relevant" and "applicable" to "relevant and appropriate".	*Changed as requested.*
31	Figures 12-15 UCD needs to include the units on these figures.	*Units have been identified on these figures.*

Response to Comments - Duncan Austin - California Department of Toxic Substances Control
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Item	Comment	Response
General		
	There is a consensus that the proposed removal action should be implemented this year if possible. Clearly, the proposed removal action would produce environmental benefits and the information which would be obtained during monitoring of the removal action is needed. However, the EE/CA contains errors and deficiencies which render it unapprovable at this time. In order to proceed as quickly as possible so that the proposed action could be implemented this year, we are suggesting revisions to the EE/CA which could be quickly accomplished. The revised EE/CA would then be "renoticed" for public comment during the same public comment period as the initial study required by the California Environmental Quality Act. In this way, the EE/CA could be approved and the overall schedule for completing the removal action this year could be maintained.	*The final draft of the EE/CA will be re-noticed for public comment. The comment period for the EE/CA will be slightly behind the comment period for the initial study.*
	On the other hand, there is a substantial amount of additional information which needs to be prepared for submission to the agencies and DSCSOC. The technical work included in the document, which appears to be well done, was presented in summary form without sufficient supporting documentation which would enable a reviewer to reproduce or otherwise verify the accuracy of those results. Additional supporting documentation for pump test analysis, the groundwater model, the statistical analysis of background water quality and the air quality screening health risk assessment needs to be provided. However, that information is not necessarily crucial to the completion of the EE/CA and therefore, in the interest of expediting the completion of the EE/CA, we propose that the information be presented with the removal action work plan or design as appropriate.	*Additional supporting documentation for pump test analysis, and the groundwater model will be provided in the RAWP. Backup information for the air quality screening health risk assessment has been added to section 7.1.2.2 of the EE/CA report. The methods and results of the statistical analysis for background groundwater calculations was presented in the 1995 Annual Water Monitoring Report (PNNL, 1996).*

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Item	Comment	Response
	Thus, the groundwater modeling results presented in the report should be taken to represent a rough estimate of potential capture only. Further analysis and refinement of the model is needed during the design phase of the project in order to develop some confidence in the design flow rates for the groundwater treatment plant. In particular, higher and lower permeability values, changes in the thickness of the model layers, and allowing for the transient and different head levels in each layer would provide an estimate of the sensitivity of the model to those parameters and thus provide a basis for choosing a conservative treatment plant design flow rate.	*See response to EPA comment #8.*
	Likewise, the current estimates of the contaminant plume concentration and configuration cannot be considered definitive or permanent. The groundwater treatment system should be designed to adequately treat water contaminated at higher levels than those currently found in Extraction Well 2-1.	*A conceptual design of the IRA system will be presented in the RAWP. The 50% design documents will also be distributed to the RPMs for comment upon request.*
1	Revision of the ARARs Analysis:	
1a	The term "ARARs" is a common acronym used in the environmental remediation field which means "applicable or relevant and appropriate requirements." The legal and regulatory significance of the term should be well understood by an environmental consultant with the experience of Dames & Moore. Regrettably, the document wrongly defines the term ARARs four times in three differing ways (page v, List of Acronyms and Abbreviations; section 5.0 on page 26; page 28, heading for section 5.3, and Table 7).	*The definition and reference to ARARs has been changed throughout the document.*

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Item	Comment	Response
1b	Fortunately, despite the fact that the term ARARs was misdefined, most of the important ARARs for the remedial alternatives were discussed in the document. There are a few potential action specific ARARs, such as worker health and safety regulations, which were not mentioned but would nonetheless apply to the selected alternative.	*No response necessary.*
1c	The EE/CA indicates that ARARs must be met "where technically and economically feasible" (page 28, second paragraph and see page 32, paragraph 4, which states "early or interim actions allow EPA to waive ARARs"). At this time, we find that these statements are inaccurate in that the LEHR facility is a Federal Superfund Site and DOE is the lead federal agency. In revising the ARARs analysis, it should be kept in mind that UCD is proceeding in this action on a voluntary basis and thus, all applicable or relevant and appropriate requirements must be met.	*UC Davis has negotiated responsibility with the DOE as the other responsible party at the LEHR/SCDS site. As a result of that negotiation, UC Davis and DOE have agreed that there is mutual responsibility for groundwater impact at the LEHR/SCDS site and that UC Davis will take the lead on groundwater issues, including the groundwater IRA. The US EPA, we understand, is the lead regulatory agency on this CERCLA action. The US EPA has, in their comments to the EE/CA, stated that since this is only an interim action and not the final remedy at the site, chemical-specific ARARs are not applicable.*

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Item	Comment	Response
2	Revision of Alternative Analysis:	
2a	The decision as to whether or not to select reverse osmosis (RO) as an additional treatment step will depend on the Regional Water Quality Control Board's consideration and issuance of waste discharge requirements. The decision will be made based upon the additional risk reduction and water quality improvement gained through the use of RO versus the additional costs. Information on health risks posed by reinjected water (if it is not treated with RO) and information on the amount and fate of reinjected water which will not be subject to recapture needs to be developed. In lieu of placing this information in the EE/CA, it could be provided in the CEQA documentation.	*A discussion of risk reduction as a result of the treatment alternatives proposed for the groundwater IRA has been added to section 7 of the EE/CA report. Evaluating health risks posed by reinjected water not treated by RO, and other fate of reinjected water which will not be recaptured, will be developed in the monitoring plan included in the RAWP.*
2b	The EE/CA does address cost issues but several aspects of the cost analysis require additional justification and correction. Almost one-half of the additional capital costs of adding reverse osmosis ($230,000 of $500,000) are attributable to UCD wastewater treatment plant (UCD WWTP) capital costs. A justification for this amount is needed. Indirect capital costs should not be based upon the UCD WWTP costs unless those costs are going to be actually incurred. Likewise, increased operation and maintenance costs for RO should have additional justification. In Table 11, there is an error in the mathematical addition of the capital items and an error in the way capital costs are added to present worth operation and maintenance costs.	*Discharge to the UC Davis WWTP from an air stripping/RO treatment system will generate a flow to the WWTP that constitutes a significant portion of the WWTP capacity. UC Davis is currently designing a new WWTP and capital costs to design and construct the plant will be allocated to dischargers that generate significant flow to the new plant. Although discharge costs for treatment systems are typically included as O&M costs, because of the significant flow and the current status of the UC Davis WWTP, the majority of costs to be incurred by the IRA to discharge to the WWTP have been included as capital costs. The formula for allocating the capital costs is presented in section 7.2.4 of the EE/CA report. O&M costs referenced for RO are primarily for the high energy demands of an RO system, the regular replacement and maintenance of membranes, and the costs of a service contract from the RO vendor.*

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Item	Comment	Response
3	Revision of Table 9:	
3a	Table 9 seems to have been included in the document in draft form. Table 9 contains a column for constituent detection limits which was inadvertently left blank. Footnote 4 has no corresponding reference in the table, the "shading" footnote was not used and the "no limit" category is inappropriately used. Table 9 also lists the maximum contaminant level for chloroform as 100 μg/L. This mistake has been made numerous times by UCD and DOE despite repeated requests from the agencies and the community oversight group and assurances that the mistake will not occur again.	*Table 9 has been revised to address these comments.*
4.	Revision of Reference Section:	
4a	Several references cited in the text are either not in the reference section or are cited incorrectly (page vi, paragraph 2, page vii, paragraph 4, page 2, paragraph 1, references to Dames & Moore 1996 documents should include an "a" or "b"; page 3, paragraph 1, contains references to Rockwell, 1994 and DOE, March 1988 documents which are not included in reference section; page 9, paragraph 4, contains a reference to a Dames & Moore, 1995 and a second PNNL, 1996 document not listed in the reference section; page 11, paragraph 4, contains a reference to a second PNLL, 1996 document not listed in the reference section; and page 21, paragraph 2 and 4, contain a reference to a Dames & Moore, 1995 document not listed in the reference section.	*The reference section has been revised to address these comments.*

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Item	Comment	Response
5	Lastly, we note that the preferred option calls for the removal of a private irrigation well (22N) located east of the extraction well, near the border of UCD property. Prior to selection of this aspect of the preferred alternative, UCD will need to prepare a plan for replacement of the well which is acceptable to the property owner. This effort should begin and witten concurrence with the plan from the property owner should be provided to the regulatory agencies as soon as possible.	*UC Davis has been working with the property owner in recent months resolving issues regarding irrigation wells located downgradient of the LEHR/SCDS site, which has included destruction of irrigation well 22P2 in August 1996. Prior to the removal of irrigation well 22N from service, UC Davis will reach agreement with the property owner concerning the terms and conditions of the well removal.* *See also response to House Agricultural Consultants Comment #1.*

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Item	Comment	Response
1	p. vi., 1st paragraph, second sentence. This sentence should read "The EE/CA evaluates a non-time Critical Removal Action . . ." Additional recommended change in 1st paragraph, 3rd sentence, replace "damage" with "impact."	*P.vi, 1st paragraph second sentence rewritten as: "The groundwater IRA is considered....."* *The word "damage" has been replaced with "impacts."*
2	p. viii, last paragraph. There is no statement that the selection of Alternative 1 is dependent on state acceptance of reinjection of groundwater. Discussion of Alternative 2 focuses on "treatment of some general mineral parameters" with no mention of hexavalent chrome. The last sentence states that ". . . Alternative 2, versus Alternative 1, was not feasible or effective." Based on Section 7.2.2, it appears that Alternative 2 effective but has not been selected due to its relatively high cost.	*The selection of Alternative 1 is not dependent upon the State accepting reinjection of groundwater but is dependent on the limits that the state sets in Waste Discharge Requirements for the IRA.* *It is true that one of the primary reasons Alternative 2 was not chosen was because if its relatively high cost. However, Alternative 2 is also less effective because the option results in only a marginal increase in treated water quality, and because it results in a concentrated waste stream that must then be disposed.*
3	p. ix. Add discussion at end of section on what follows the EE/CA (e.g., Action Memorandum, implementation schedule, etc.).	*A paragraph that summarizes the schedule for the groundwater IRA has been added to the executive summary.*
4	p. ix. The statement in Section 9 that this "action may be proposed as the final remedy," is not contained in the Executive Summary.	*To be more correct, the entire sentence, "If monitoring data indicate the IRA system has the potential to cost-effectively remediate the plume to applicable standards, the action may be proposed as the final remedy," is not contained in the Executive Summary.*
5	p. v. ARAR acronym definition is incorrect. It should be "Applicable or Relevant and Appropriate Requirement."	*The ARAR acronym definition and all references to ARAR have been changed to "Applicable or Relevant and Appropriate Requirements."*
6	p. 3. Reference to the Field Activity Report (PNNL, 1995) and the DOE Areas Characterization Report (Weiss Associates, 1997) should be included in the first paragraph.	*References to these reports have been added.*

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Item	Comment	Response
7	p. 3, third paragraph. This paragraph is unclear. The distinction between the South Campus Disposal Sites and LEHR is not defined in this paragraph or in preceding text. Partial definitions of these areas are not found in the document until p. 6. Additionally, "Site areas and systems" are not defined at all in the context of this paragraph at any point in the document. It is suggested that source areas and responsibility for their investigation and cleanup not be addressed in this portion of the document. A brief statement on why the University is doing the work is probably adequate.	*Page 3 third paragraph has been rewritten as: "The Site consists of a variety of landfills, subsurface disposal areas, and waste treatment systems. The responsibility for the investigation and clean-up of various site areas is currently being divided between the DOE and UC Davis. Although the exact division has not yet been officially agreed upon, it is likely that investigation and clean-up of areas designated as part of the LEHR site will be conducted by the DOE, and that investigation and clean-up of areas designated as SCDS will be conducted by UC Davis. A brief summary of the LEHR/SCDS areas is presented in section 2.2.1 below. This EE/CA report refers to both LEHR and SCDS as "the Site.""*
8	p. 5. Please indicate that the onsite septic systems were not used by LEHR after 1971.	*The following has been added to the last sentence describing the septic systems: "and the onsite septic systems were not used by LEHR thereafter."*
9	p. 6. Regarding the UCD disposal areas: Why aren't the results from the summer 1996 trenching program discussed and/or referenced?	*As of the writing of the EE/CA report, the results of the 1996 UC Davis trenching program have not been reported.*
10	p.6. Southern Disposal Area: Change to: UC Davis and possibly LEHR waste...	*Changed as requested.*
11	p.7. First paragraph, first sentence should be changed to read "The investigation of potential ground water impacts..."	*p.7 first paragraph has been rewritten as: "The investigation of groundwater impacts at the Site began in 1988."*
12	p.8. Descriptions of HSU-1 and HSU-2 are not provided. Screen intervals of EW2-1 are not provided (nor are the proposed reinjection well screen intervals mentioned later in the report).	*Brief descriptions of HSU-1 and HSU-2 are provided on page 7 in Section 2.2.2. A more detailed discussion of Site hydrostratigraphy is provided in section 3.2.1.* *The last sentence of the section titled "Well Installations" has been rewritten as: "Well EW2-1 was installed into HSU-2 as a fully penetrating extraction well for the eventual IRA....."*

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Item	Comment	Response
13	p.10. A generalized HSU stratigraphic column or block diagram for the LEHR area would be very helpful to visualize the subsurface.	*A schematic cross section has been added as Figure 4.*
14	p.17. The proposed location of the injection well may have the potential to adversely impact source areas by elevating water levels and mobilizing contaminants. In general, we believe that more detail in the report is required to address, at a minimum, the following questions: What were the alternative locations modeled? Why was the proposed location determined to be optimal? What impacts will the injection have on water levels in HSU-1? WA estimates that relocating the well about 350ft east-southeast of its present proposed location will enhance the potential for a closed-looped injection/extraction. This option should be modeled and presented in the report.	*Potential locations modeled for IRA reinjection wells included the proposed location, and several locations further west of the proposed location. These locations were selected to avoid altering the local HSU-2 groundwater flow direction in the vicinity of LEHR and SCDS source areas. The following text has been added to the third paragraph of Section 3.3.3:* *"Simulated reinjection well locations were selected to be upgradient of LEHR/SCDS source areas and to maximize eventual recapture by the extraction well. Upgradient locations were selected to minimize the potential for altering local groundwater flow directions near site source areas."* *Data from the pumping test (see Table 1 of EE/CA report) suggest that HSU-1 water levels will rise less than 2 feet in the vicinity of the injection well. The proposed location 350 feet east-southeast of the present location is within or near several LEHR/SCDS source areas, including the southwest trenches, the southern trenches, the western dog pens, and the waste burial holes. The proximity of a reinjection well to these potential source areas does not meet the criteria of minimizing the potential to alter local groundwater flow directions near source areas.*
15	Figure 12. Not clear what the dots with no data posted near them mean on this figure.	*Figure 12 has been revised.*
16	p.20. Unlike other similar sections, the 20,000 pCi/L MCL for tritium is not discussed in the section on tritium. Similarly, the 10 mg/L MCL for NO_3 as N is not discussed or mentioned in the nitrate section.	*The MCLs for tritium and nitrate have been added to the respective discussions for reference.*

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Item	Comment	Response
17	p.23. The Chromium MCL is 50 ug/L not 50 g/L.	*Changed as requested*
18	p.27. DOE would like to have an RAO stating that the IRA will not adversely impact contaminant sources at the site.	*The second bullet has been rewritten as: "To eliminate or substantially decrease potential offsite migration of constituents of concern in HSU-2 through plume containment and without impacting potential Site source areas."*
19	p.33. ARARs: When will the ARARs be finalized? This section gives no indication as to whether the listed potential ARARs have been discussed or approved by the regulatory agencies.	*Water quality goals and other requirements that will govern the operation of the groundwater IRA system will be detailed by the RWQCB in Waste Discharge Requirements.*
20	p.37. How long will the IRA be implemented before the final remedy will be implemented?	*At the time of the EE/CA, there is no set time schedule for the continued operation of the groundwater IRA or the implementation of a final groundwater remedy.*
21	p.37. Given the concern about elevating water levels, more information on the capacity of HSU-2 to accept the reinjected water without raising water levels in HSU-1 is needed. A monitoring plan to ensure that there is no adverse impact on vadose zone sources is also needed.	*Additional backup data regarding the aquifer testing will be provided in the Remedial Action Work Plan.*
22	p.41. It is not clear that liquid phase activated carbon is not a potentially better choice than RO for the case where VOCs and hexavalent chromium require some level of control, especially if the cleanup for reinjection is greater than non-detect while the criteria for hexavalent chromium is non-detect.	*Our research into liquid phase activated carbon indicate that it is ineffective in treating chloroform, questionably effective for treating low concentrations of hexavalent chromium, and ineffective for treating nitrate and TDS.*
23	p.48. When will the water quality criteria for reinjection be established?	*Water quality criteria for reinjection will be established by the RWQCB in the Waste Discharge Requirements for the IRA.*

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Item	Comment	Response
24	p.50. If scaling of the air stripper trays is a problem, then fouling of the reinjection well may also be a problem. No discussion is contained in the report on the viability of long term operation of the reinjection well, methods explored to ensure that fouling of the reinjection well will not occur, chemicals considered for prevention of equipment fouling, local data on pumping this water, and effect of downtime on effectiveness--when dealing with cleaning a well or treatment equipment.	*The following sentences have been added to Section 7.1.3: "The potential for scaling also exists in the reinjection well. Scaling in the reinjection well will be evaluated by monitoring pressure loss over time at the reinjection well head. Methods for addressing fouling of the air stripper and reinjection well will be described in the O&M Plan"*
25	p.51. No figure is supplied for process flow for Alternative 2.	*A conceptual diagram has only been prepared for the Selected Alternative.*
26	Table 9. The Detection Limit column is blank on this table.	*Table 9 has been revised.*
27	Ex. Summary, page vii upper paragraph, there are no UCD2-13. It is UCD1-13.	*Reference has been changed to UCD1-13.*
28	Page 3, 3rd paragraph, it is not clear what is meant by "The DOE is responsible for the investigation and cleanup of the site areas and system". This is a very broad statement. Suggest deleting it. There is no reason to discuss this issue in the EE/CA document.	*See response to DOE comment #7.*
29	Page 5. We are not able to find any indication to suggest that Domestic tank #7 ever received any waste from the Co-60 building. Review of engineering drawings suggests that the building was connected to the campus system and the tank was never used.	*Text changed to read, "Six of seven onsite septic tanks were reported. . . ."*
30	Page 19, 3rd paragraph states chloroform levels as 1000ppb from UCD1-12. It is more likely to be 10,000ppb. May be a typo?	*The chloroform concentration that is referenced has been changed to 10,000 μg/L.*
31	Is UCD planning to request a waiver for compliance with ARARs? Page 33 suggests that, but it is not clear if this is the intent.	*No. Please see response to EPA comment #17 regarding selecting an alternative that does not meet a State or federal standard.*

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Item	Comment	Response
32	Would a Report of Waste Discharge (ROWD) be required to obtain Waste Discharge Requirements?	*Yes.*

Response to Comments - John Hamel, Craig Rust - House Agricultural Consultants
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Item	Comment	Response
1.	We note that the conclusion on page 58 states that "eliminating irrigation well 22N and replacing it with another irrigation well appears to be more cost effective than installing and maintaining an additional extraction well". On page 35 of this report the cost for such a well is estimated at $80,000.	*The plume of VOC impacted groundwater has, to date, not affected the downgradient property owner's ability to irrigate farmland. This ability will not be affected until the IRA system is operational and irrigation well 22N has been removed from service. As discussed in previous RPM meetings, site regulators have agreed that continued use of well 22N is acceptable for the 1997 irrigation season. Therefore, with the use of well 22N, the ability to irrigate Hamel Ranch Partnership (HRP) farmland located east of the LEHR/SCDS should not be affected until the 1998 irrigation season.*
	We concur. A new well would be the fastest way to remedy our inability to irrigate a portion of our land due to UCD's groundwater toxics problems. It also appears to be a more reliable method to avoid future groundwater toxic problems than trying to use well 22N which would be subject to a lower water table due to the UCD extraction wells.	*UC Davis does accept responsibility for replacing irrigation capabilities lost by taking well 22N out of service when that occurs.*
	We wish to point out, however, that simply drilling a new water well will not totally solve our problem, since the new well cannot be drilled in or near the fields that 22N now services. After closing well 22N, irrigating these fields will require some new means of delivering water to them. Our proposed new well site along the west side of field 17 (about mid way north and south) would take care of fields and 16 and 17. Field 10, however, will need a new buried pipeline to get its water.	*The concern for delivering water to fields formerly served by well 22N will be incorporated into an agreement between UC Davis and the HRP. As noted above, this concern would not need to be addressed until the 1998 irrigation season.*

Response to Comments - John Hamel, Craig Rust - House Agricultural Consultants
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
1 (con't)	This pipeline can come from either the new well or our existing well #2 (see map). Rather than have the water come from the new well, we would prefer that field 10 get its water from our existing well #2. This would be a distance of between 3,000 and 4,000 feet and cost an estimated $20,000. We estimate piping the water west from the new well to field 10 would also be about 3,000 feet, so there is no big difference either way; nevertheless, we prefer the pipeline from well #2 to allow better overall usage of the entire irrigation system.	*See response to House Agricultural Consultants Comment #1, above.*
2	We would rather that the responsibility for the installation were placed in the hands of our farm manager, House Agricultural Consultants. We propose that if UCD will pay us the $80,000 directly, we will agree and certify that UCD's responsibility in this matter is needed. We agree to use the money to install the new well and complete the necessary pipelines, etc.	*The price to replace well 22N presented in the EE/CA is an estimate derived for the purpose of evaluating various IRA alternatives and does not constitute an offer to the HRP. The cost for the eventual solution to irrigating farmland located downgradient of LEHR/SCDS will be developed after financial responsibilities have been agreed upon between UC Davis and the HRP.*

Response to Comments - Edgar D. Bailey, Department of Health Services
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
1	Page 24, paragraph 2 states that prolonged extraction could result in the detection of parameters such as tritium within the extracted groundwater. Page 27, paragraph 1 states that this is not anticipated even though there is a possibility that constituents that exceed local background values "may be detected in groundwater removed, treated, and reinjected as part of this IRA". Please provide more discussion on the possibility of elevated constituents (such as tritium) upgradient from the well impacting the extracted groundwater. Also provide a discussion on planning or strategies that will address this issue.	*Results of groundwater modeling completed for the IRA suggest that the IRA will not significantly alter the gradient or flow direction in HSU-2 in upgradient areas or beneath potential source areas. As a result, we do not expect the IRA to directly influence the distribution of site constituents, such as tritium, in upgradient and potential source areas. The modeling suggests that the IRA system will sufficiently affect gradient and flow direction in the vicinity of the extraction well to create capture of the chloroform plume. The IRA system will also affect vertical gradients and flow in HSU-1 in the vicinity of the extraction well. A contingency plan will be included as part of the removal action work plan, and will address the possibility of elevated concentrations of other site constituents detected in the IRA system effluent or monitoring system.*
2	Table 7: Summary of Appropriate or Relevant and Applicable Requirements (ARARs). The correct meaning for the abbreviation ARARs is "Applicable or Relevant and Appropriate Requirements" which appears to have been misnamed throughout the entire document. The table lists 10CFR20 as appropriate, when it should be listed as an applicable requirement. All listings of federal and state laws in Table 7 should be corrected to reflect either "applicable requirements" or relevant and appropriate requirements."	*References to ARARs in the EE/CA report have been corrected. Table 7 has been revised.*

Response to Comments - Mary Rust, Hamel Ranch Partnership
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
General		
1.	"If the reinjection approach is approved, additional monitoring will be necessary to ensure that reinjection does not add to groundwater contamination." The IRA proposes to treat only chloroform and related VOCs through air stripping. Air stripping will not remediate many of the other contaminants, including nitrate, chromium, and TDS. The IRA also proposes to reinject the treated water, and indicates that not all of the injected water will be recaptured by the extraction well. As a result, it is very possible that the injected water, which contains residual contaminants that have not been treated, will become even more contaminated as it passes once again beneath existing contaminant sources. If this process is ultimately approved, we request that monitoring wells be placed in areas where the uncaptured reinjected water will pass. These wells should be tested monthly during operation of the IRA and provisions should be made to stop or modify the IRA if these wells reveal significant contamination migrating to the east.	*See response to EPA comment # 19 regarding the development of a monitoring plan.*
2.	"The IRA does not seek to directly remediate contamination migrating off-site from the LEHR facility, and should address when and how it will be dealt with." The IRA does not propose to remediate groundwater contamination downgradient of the extraction well EW2-1. The chloroform plume shown on Figure 7 extends well beyond the anticipated capture zone of the extraction well, beneath the Hamel Property. A specific plan and time frame should be proposed by UCD to fully evaluate and remediate the contaminated groundwater downgradient of the extraction well.	*It is true that the EE/CA report and proposed groundwater IRA do not directly address impacts to groundwater that are already downgradient of the proposed extraction location. These concerns are beyond the scope of this action. However, data collected during the start-up and operation of the IRA and from off-site irrigation and monitoring will provide valuable data that will be used to design a plan to address impacts downgradient of the proposed IRA.* *Also: see response to EPA comment #2.*

Response to Comments - Mary Rust, Hamel Ranch Partnership
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
3.	"The effect of the IRA on HSU-1 is unclear and should be addressed." The IRA proposes to treat extracted water from EW2-1, which is completed in HSU-2. It is unclear what effect this will have on remediating contamination in HSU-1. A full description of the contamination in HSU-1 and a plan to mitigate it should be included as part of the IRA.	*The proposed groundwater IRA (and therefore the EE/CA report) focusses on addressing impacts in HSU-2 because the potential for (and observed) off-site migration of site constituents of concern is much greater in HSU-2 than HSU-1. Therefore, by design, the proposed IRA system will have little effect on impacts in HSU-1 water except within the immediate vicinity of the extraction well.* *Although, impacts in HSU-1 have not been directly addressed in the proposed IRA, it is likely that they will be one the main focusses of remedial activities that are evaluated for the source areas located upgradient of the IRA.*
4.	"The impacts of contamination on HSU-4, the underlying aquifer, are unknown and should be discussed in the current plan." If the lower aquifer is determined to be contaminated, this will potentially impact the use of wells for irrigation and domestic purposes on the Hamel Ranch Partnership property. Therefore, an adequate characterization of HSU-4 is imperative. The University should include in the IRA a plan and time frame to investigate water quality in HSU-4, including areas downgradient of the proposed extraction well.	*A plan to address impacts in HSU-4 would be premature before we know if HSU-4 has been impacted. When results of sampling the newly installed HSU-4 well have been reported, a plan can be designed to address the results.*

Response to Comments - Mary Rust, Hamel Ranch Partnership
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
5.	"The Partnership should be provided with adequate irrigation capabilities and the impact of irrigation on the spread of contamination should be evaluated and discussed as part of the IRA." As we have previously commented, the Partnership must be able to perform its desired irrigation practices and make other use of groundwater beneath the property with assurances, obtained by the responsible parties, that these practices are entirely appropriate and pose no environmental risk. We appreciate the University's cooperation in working on substitute irrigation facilities to replace irrigation provided by the Nishi irrigation well. The Partnership continues to seek assurances in this process that the University will retain responsibility for ensuring that irrigation facilities will be adequate to replace the Nishi well capabilities and to make any changes needed if the effects of irrigation on contamination are found to pose problems in the future.	*See response to comment #1 from House Agricultural Consultants.*
6.	"The references to 'background' concentrations in the IRA documents are not based on adequate evaluation and should not be the basis for cleanup goals or the final remedial action. Any cleanup goals must preserve all potential uses of groundwater beneath Hamel Ranch Partnership property." Final cleanup goals should consider true background concentrations for the area and address domestic drinking water quality as well as irrigation uses. Background concentrations have not been adequately established. As a result, the 'background' concentrations referred to in the IRA should not be the basis for the IRA cleanup goals or for any final remedial action. UCD should provide a plan to establish true background concentrations based on a more thorough assessment of water quality, and the final cleanup goals should take these values and the full range of potential uses of the land and groundwater into account.	*The references to "background" presented in the EE/CA report were not made in an attempt to propose clean-up goals for the groundwater IRA. Background groundwater data was provided so that the reinjection alternative and various treatment scenarios could be evaluated for effectiveness, implementability, and cost. The limits eventually set for the reinjection of treated water will be determined by the RWQCB and may take into account local upgradient or "background" data that currently exist (see EPA/RWQCB comment #19). The "background" data are also relevant to the IRA because they are derived from well UCD2-17 which is located near the proposed location for the IRA reinjection well. Final clean-up goals or concentration limits that are established for groundwater at LEHR/SCDS will eventually be established in a Record of Decision prepared by the US EPA following further groundwater investigation.*

Response to Comments - Julie Roth, Ex. Dir., Davis South Campus Superfund Oversight Committee
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
1	Dr. G. Fred Lee has provided DSCSOC with his comments regarding UCD's public announcement of their "Groundwater Interim Removal Action" and I am enclosing his report for your review.	
2	Dr. Lee's comments raise many issues of concern to the public about UCD's IRA for the groundwater remediation at LEHR. DSCSOC, as representatives of the public, will not accept this approach as appropriate for the remediation of the polluted groundwaters at the LEHR site. This IRA can only be considered the first, experimental action taken in addressing only a limited portion of UCD's responsibilities for the remediation of the groundwater at LEHR. Addressing the chloroform plume is only a part of the ultimate groundwater remediation that will need to be undertaken by UCD in order to protect the current and future offsite groundwater resources. UCD should not be allowed to pollute groundwaters with a variety of waste-derived constituents that impair the use of the groundwater for domestic and other purposes. UCD must also adequately evaluate the degree of additional pollution arising from implementation of the IRA that will occur.	*See response to EPA comment #2 regarding off-site impacts, and comment #19 regarding the completion and implementation of a monitoring plan.*
3	The investigation of HSU-4 must be addressed and a plan put in place to address the off-site pollution by chloroform and other constituents that are now under adjacent properties as a result of LEHR wastes. The proposed IRA is not the comprehensive approach for the remediation that is necessary to address the pollution of the off-site groundwater by LEHR site wastes, and UCD must submit plans to begin to address these issues.	*See response to M. Rust comment #4 regarding the characterization of HSU-4. The proposed IRA is not intended to be a "comprehensive approach" to remediation at the site.*
4	Any actions by UCD must conform to the Central Valley Regional Water Quality Control Board's Basin Plan and provide protection from the unregulated, potentially hazardous and deleterious chemicals that are present in the groundwater arising from UCD's mismanagement of the wastes at LEHR.	*The Central Valley RWQCB will issue Waste Discharge Requirements for the groundwater IRA that set limits on the treated and discharge water from the IRA.*

Response to Comments - Julie Roth, Ex. Dir., Davis South Campus Superfund Oversight Committee
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
	UCD's approach must be respective of the regulatory requirements, public health, environmental protection and the responsibility of a waste management entity to manage wastes in a technically valid, cost-effective manner that fully complies with current regulatory requirements.	

Response to Comments - G. Fred Lee, PhD, DEE, DSCSOC Technical Advisor
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
1	Basically, as part of this IRA, UCD proposes to pump groundwaters from the chloroform *et al.* plume, remove VOCs (chloroform and other chemicals that are volatile under air-stripping) and re-inject the air-stripped water into the aquifer upgradient - west of Old Davis Road from the LEHR site. One of the principal areas of concern from the public's perspective is the degree of treatment provided to the extracted groundwater before re-injection. UCD in the Dames & Moore report provides background information on the various alternatives considered for treatment of the groundwater before discharge to the environment. I have found, in review of the Dames & Moore report, that Dames & Moore and UCD have continued to make highly significant technical errors on issues of concern and have presented unreliable and out of date information on the significance of chemical constituents as they may impact public health and the environment as well as other topic areas. I will not, at this time, discuss many of these issues since UCD does not propose to discharge the IRA pumped groundwaters to either the campus wastewater treatment plant or directly to Putah Creek. Therefore, the errors and inappropriate information provided by Dames & Moore and UCD on these possible remediation approaches is not of immediate concern. Many of the errors and inappropriate statements made by Dames & Moore and UCD in the Dames & Moore report have been discussed by me in the materials I previously provided DSCSOC and DSCSOC has provided to UCD, DOE, and the RPMs. I will be providing comments to DSCSOC on them at a later date.	*No response necessary.*

Response to Comments - G. Fred Lee, PhD, DEE, DSCSOC Technical Advisor
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
2	While UCD considered a number of treatment options, the one that was selected as an alternative to only VOC stripping was to add reverse osmosis to VOC stripping before re-injecting the pumped groundwater. UCD states on the bottom of the first page, second column, last paragraph, *"Treatment by reverse osmosis was not recommended because the incremental improvement in water quality did not justify the significant additional cost."* UCD also states, *"The groundwater treatment system will be designed so that most of the reinjected water is recapture by the extraction well."* This proposed IRA will, if implemented as proposed, apparently result in removal of chloroform from the re-injected water down to about 1 μg/L which is close to the Central Valley Regional Water Quality Control Board's chloroform clean-up objective of 0.5 μg/L. However, the other constituents in the polluted groundwaters that are pumped from the chloroform *et al.* plume could be increased in concentration from the concentrations currently in the plume at the point of pumping due to the fact that the sources of the constituents that are causing groundwater pollution are not yet being controlled, i.e. additional pollution of groundwaters passing under the LEHR site is occurring today by wastes present at the site as well as the waste components in the re-injected water. The residual components in the re-injected water could receive an additional load of waste constituents as the re-injected water passes under and near the waste sources.	*The eventual groundwater IRA system will be monitored to evaluate its effectiveness and to evaluate if it is meeting RWQCB Waste Discharge Requirements. It is anticipated that the WDRs will require that operation of the IRA does not result in an increase of constituents of concern in groundwater. Please see EPA comment #19 regarding the preparation of a monitoring plan.*

Response to Comments - G. Fred Lee, PhD, DEE, DSCSOC Technical Advisor
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
3	Dames & Moore states that the amount of re-injected water that will not be recaptured as it passes the point of groundwater extraction-pumping will be about 8% during the summer and 34% during the winter, while Dames & Moore states in the last paragraph, last sentence, page 17 of their report, *"It should be noted that although 100 percent of the reinjected water is not maintained in a closed loop, this water will have already been treated to approved water quality limits."* Such a statement is more of the UCD propaganda that attempts to justify failing to clean up the groundwaters at the LEHR site with UCD derived wastes in accord with Central Valley Regional Water Quality Control Board basin plan objectives of no impaired use. This issue is discussed further below. Since only some of the re-injected water will be recaptured and the re-injected water that has only been VOC stripped will not be adequately cleaned up to protect water from impaired use by UCD derived wastes, this means that there is the potential for additional, more concentrated pollution moving off-site as part of this IRA.	*UC Davis will develop a monitoring plan that will evaluate the effectiveness of the IRA and will provide data to assess "the potential for additional, more concentrated pollution moving off-site as part of the IRA." The monitoring plan will be presented as part of the RAWP and will be approved by the appropriate regulatory agencies. See response to EPA comment #19.*
4	A key component of the IRA will be the additional requirement that UCD properly monitor the additional pollution of the groundwaters arising from eight to 34 percent of the partially treated re-injected groundwaters escaping recapture. Based on a review of the Dames & Moore report on this issue, the degree of additional pollution that will occur has not been adequately evaluated. UCD will likely have to install several additional monitoring wells to determine the magnitude of potential off-site pollution arising from this aspect of the IRA. Further, if the monitoring of the re-injected waters shows that significant additional pollution is or could be occurring, then the IRA will have to be shut down until such time as more appropriate treatment of the re-injected groundwaters is practiced. This is an issue that can be discussed at the next RPM meeting.	*See response to EPA comment #19.*

Response to Comments - G. Fred Lee, PhD, DEE, DSCSOC Technical Advisor
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
5	While UCD claims in the flier and in the Dames & Moore report that the treatment of the pumped groundwaters by reverse osmosis *". . . did not justify the significant additional cost,"* UCD, in making this analysis, apparently considered nitrate, TDS and hexavalent chromium. Thus far, UCD has chosen to ignore the highly important issue of unregulated, hazardous, or deleterious constituents as well as regulated constituents in the groundwaters derived from UCD's LEHR are waste management activities that can impair the use of the groundwaters in violation of the Central Valley Regional Water Quality Control Board's Basin Plan requirements of remediation of groundwaters to control all impairment of uses, including the control of tastes and odors, etc. Previously, I have provided DSCSOC, UCD, and the RPMs with a discussion of why it is naive and highly inappropriate to consider that the only pollution of groundwaters impairing their use that has occurred at the LEHR site is due to the few chemicals that have been examined in the groundwater monitoring program that DOE and UCD have conducted at the LEHR site compared to the thousands of chemicals that were present in the wastes UCD deposited at the LEHR site that represent threats to public health, groundwater resources, and the interests of those who now or in the future will own or use properties down groundwater gradient from the LEHR site. For complex waste disposal sites such as the LEHR site, it is essential that attention be given to remediation of potentially hazardous unidentified chemicals that are present in the groundwaters due to UCD's mismanagement of its campus and LEHR site wastes.	*Quarterly groundwater monitoring has been ongoing at the LEHR/SCDS site since 1990. Monitoring has been conducted according to methods and procedures described in the LEHR Phase II Site Characterization Work Plan (Dames & Moore, 1990), and the LEHR Water Monitoring Plans (PNL 1994, PNNL, 1995). These plans were developed in accordance with State and federal regulations and underwent regulatory review and approval for monitoring schedule and analyte list.*

Response to Comments - G. Fred Lee, PhD, DEE, DSCSOC Technical Advisor
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
6	Those familiar with water and wastewater treatment know that certain types of treatment processes, such as activated carbon beds, reverse osmosis, and some others which remove many types of chemicals, can and should be used to treat groundwater polluted by complex mixtures of wastes such as has and continues to occur at the LEHR site. I have discussed these issues in several papers I have written on this topic, including Lee, G.F. and Jones-Lee, A., "Appropriate Degree of Domestic Wastewater Treatment Before Groundwater Recharge and for Shrubbery Irrigation," *AWWA, WEF 1996 Water Reuse Conference Proceedings,* American Water Works Association, Denver, CO, pp. 929-939 February (1996). A copy of this paper is available upon request. While it focuses on domestic wastewater, it has direct applicability to the LEHR site situation. This issue has also been addressed by a National Research Council committee report entitled, *Ground Water Recharge Using Waters of Impaired Quality,"* National Academy Press, Washington, D.C. (1994), as well as an in-press committee report by the American Society of Civil Engineers devoted to developing guidance on groundwater recharge. I am serving as a member of that committee and helped develop the groundwater recharge guidance manual that will soon be published.	*No response necessary.*
7	While UCD and DOE both have attempted to claim that there is no way to address the problems associated with the unregulated chemicals in complex mixtures of wastes that have polluted groundwaters, such claims ignore the fact that for years there have been procedures available for evaluating whether a constituent or mixtures of constituents are potential carcinogens, teratogens, and mutagens. These procedures could readily be used to determine whether groundwaters polluted by LEHR site wastes have the potential to cause cancer, birth defects, and mutations in those who consume waters polluted by these wastes.	*See response to Dr. Lee comment #5.*

Response to Comments - G. Fred Lee, PhD, DEE, DSCSOC Technical Advisor
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
8	UCD, in the Dames & Moore report, attempts to justify the pollution of groundwaters under the LEHR site by LEHR site wastes based on its analysis of the composition of groundwaters in the region and the composition of a single upgradient from the LEHR site groundwater monitoring well. UCD's analysis of this situation is fundamentally flawed and strongly contrary to public health and groundwater resource protection. Basically, UCD's approach with respect to the pollution of the off-site groundwaters by a variety of waste-derived constituents besides chloroform is to propose that UCD should be allowed to use the groundwaters under LEHR and adjacent properties as a recipient for its wastes up to the limit of worst or near-worst conditions that already exist in the region. This obviously is contrary to current regulatory requirements, public health and environmental protection and the responsibility of a waste management entity to manage wastes in a technically valid, cost-effective manner that complies with regulatory requirements. It is basically the approach that is often advocated by recalcitrant polluters who are trying to get by with doing the least possible just to meet minimum regulatory requirements as interpreted by staff who have been looking the other way with respect to requiring UCD to achieve public health and environmental protection in accord with current regulations.	*See EPA comment #2 and the corresponding response.*
9	UCD states in their two-page discussion of the IRA, *"This Interim Removal Action is the first step in cleanup of groundwater impacts at the site. Additional concerns may be addressed in the final remedy for groundwater at a future date. The EE/CA report proposes that UC Davis begin the cleanup of chloroform - the groundwater contaminant that is most widespread and has the greatest potential to impact health or the environment."*	*As cited, "This Interim Removal Action is the first step in cleanup of groundwater impacts at the Site." In addition, one of the objectives of the IRA will be to "provide operational data which will aid in assessment of groundwater treatment effectiveness and the need for further groundwater remedial action."*

Response to Comments - G. Fred Lee, PhD, DEE, DSCSOC Technical Advisor
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
9a	It appears from this statement that UCD may be attempting to lay the groundwork for only addressing the chloroform plume. It is my recommendation that DSCSOC make it clear to the UCD L. Vanderhoef administration that the public will not accept that approach as an appropriate approach for the remediation of the polluted groundwaters at the LEHR site. The IRA should be allowed to proceed, provided that the University of California, Davis L. Vanderhoef administration and the regulatory agencies understand that addressing the chloroform plume is only a small part of the ultimate groundwater remediation that will have to be undertaken by UCD at the LEHR site in order to protect the current and future offsite groundwater resources.	
11	One of the issues of concern is the way in which UCD is attempting to claim there is no need to remove other pollutants in the groundwaters arising from the LEHR site waste disposal practices. UCD states, *"Anticipated concentrations of nitrate, TDS and hexavalent chromium in extracted groundwaters will be within the range of background levels of those parameters found in regional groundwater."*	*UC Davis does not attempt to claim that there is "no need to remove other pollutants in groundwater arising from the LEHR site waste disposal practices." The cited statement refers specifically to the groundwater IRA and to concentrations of site parameters anticipated to be withdrawn from the IRA extraction well which is located downgradient of LEHR/SCDS source areas and downgradient of the highest observed concentrations of site parameters. Please also see EPA comment #2 and the corresponding response.*

Response to Comments - G. Fred Lee, PhD, DEE, DSCSOC Technical Advisor
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
12	UCD's analysis of the situation is inappropriate with respect to establishing groundwater clean-up objectives in accord with the Central Valley Regional Water Quality Control Board's Basin Plan requirements. The issue is not one of whether the concentrations in the re-injected groundwaters are within the *range* of concentrations of these constituents in the region. It is whether UCD's pollution of groundwaters from waste management activities at the LEHR site causes groundwaters at this site and those that will migrate from this site to have elevated concentrations of constituents which impair the uses of the waters for domestic or other purposes. The Dames & Moore report makes reference to a *"Draft Technical Memorandum for Background Data Review — Groundwater (Dames & Moore, 1995)."* A check of the references provided in the Dames & Moore report shows Dames & Moore did not list a reference for its 1995 report. As far as I know, I have not seen that report. Dames & Moore should provide DSCSOC with a copy of that report.	*Cleanup objectives will not be established as part of the groundwater IRA. (See EPA comment #16 and the corresponding response.) The Central Valley RWQCB will issue Waste Discharge Requirements for the IRA that establish water quality objectives for IRA treatment and discharge. A reference for the technical memorandum has been added to the reference section.*
13	It is inappropriate for the UCD L. Vanderhoef administration to claim that it should be allowed to pollute groundwaters with a variety of waste-derived constituents at the LEHR site, thereby impairing their use for domestic or other purposes because groundwaters in the region contain elevated concentrations of constituents. The issue is not the range of concentrations of constituents in the region, but whether groundwater passing under the LEHR site waste management units acquire additional waste-derived constituents that impair the use of the groundwaters for domestic or other purposes. To the extent that this occurs, this represents groundwater pollution that is not allowed under the current Basin Plan requirements.	*See response to EPA comment #24.*

Response to Comments - G. Fred Lee, PhD, DEE, DSCSOC Technical Advisor
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
LEHR Environmental Restoration

Item	Comment	Response
14	I have repeatedly pointed out that there has been and continues to be inadequate groundwater monitoring of LEHR site upgradient groundwaters to enable a reliable analysis of the full extent of groundwater pollution by the LEHR site. UCD and DOE continue to ignore this situation apparently with the mistaken belief that by failing to properly define the true characteristics of the upgradient groundwaters, this would enable UCD to be able to practice less remediation as a result of the variability of the composition of the upgradient groundwaters that arise to a considerable extent out of the inadequate upgradient groundwater monitoring program that UCD and DOE have conducted at the LEHR site. Duncan Austin has already warned UCD and DOE that they should not be using the extreme range of variability of conditions in establishing clean-up objectives. The downgradient LEHR public should, at the LEHR adjacent property line, be entitled to a groundwater that in perpetuity is not impacted for any use by LEHR site derived wastes. Contrary to the assertion made by UCD, the range of variability that occurs in groundwater composition in the region as well as in the single upgradient well has little relevance to establishing clean-up objectives for LEHR site polluted groundwaters. While DSCSOC may wish to support the experimental, short-term IRA as UCD has proposed, with additional groundwater monitoring as discussed above, as part of developing background information needed to ultimately clean up UCD's pollution of groundwaters by LEHR site wastes, UCD should understand that it will be required to fully remediate groundwater pollution by LEHR site wastes so that there is no impairment of the beneficial uses of the groundwaters as they pass under the LEHR site and receive any percolation of water that has penetrated through the soil and geological strata column associated with the site. This remediation will require that treatment processes such as activated carbon beds and reverse osmosis be used to treat the	*Groundwater cleanup objectives will not be set as part of the groundwater IRA. (Please see response to EPA comment #16 regarding the establishment of site concentration limits, and the response to M. Rust comment #6 regarding the use of background groundwater data.)*

Response to Comments - G. Fred Lee, PhD, DEE, DSCSOC Technical Advisor
Engineering Evaluation/Cost Analysis (EE/CA)
Groundwater Interim Removal Action
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Item	Comment	Response
14 (con't)	groundwaters to remove LEHR site derived waste components both under the site and under adjacent properties. Both technologies are readily implementable. This cost is part of the true cost that UCD will not have to pay for conducting research and for practicing inadequate solid waste management at the UCD campus at less than their real cost.	

Response to Comments - G. Fred Lee, PhD, DEE, DSCSOC Technical Advisor
Engineering Evaluation/Cost Analysis (EE/CA)
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LEHR Environmental Restoration

Item	Comment	Response
15	UCD attempts, through the Dames & Moore report, to justify not cleaning up LEHR site chromium polluted groundwaters unless the pollution by chromium exceeds a drinking water MCL. Such an approach is not accord with Basin Plan requirements and strongly contrary to future and current generations' ability to use groundwaters in the future for domestic or other purposes. Basically the UCD L. Vanderhoef administration wishes to usurp from adjacent property owners the groundwaters assimilative capacity for the additional natural chromium that is present in the geological strata of the region that is causing elevated concentrations of chromium in the groundwaters. Since chromium VI is a conservative constituent in groundwater under oxic conditions, any additional chromium added to the groundwater system represents a threat to the use of groundwaters. The naturally occurring chromium in the geological strata in some instances causes the chromium in off-site wells to exceed drinking water MCLs. By UCD's proposed approach of increasing the chromium in the groundwaters passing under the LEHR site with waste-derived chromium up to the drinking water MCL, UCD is depriving off-site downgradient groundwater users of groundwaters that have chromium less than the drinking water MCL. The natural chromium added downgradient of the site in addition to the natural chromium present in the upgradient groundwaters is the background of the region that must be maintained. UCD cannot be allowed to add any additional chromium or, for that matter, other constituents from the LEHR site to these groundwaters since there is a significant potential to represent an impairment of use.	*The selection of a treatment alternative that does not directly address chromium, nitrate, and TDS concentrations in extracted groundwater was made based on the cost* ***and*** *effectiveness of potential treatments, not on MCLs. The eventual treatment implemented for the IRA will be chosen, based on these criteria, and to meet RWQCB Waste Discharge Requirements.*

Response to Comments - G. Fred Lee, PhD, DEE, DSCSOC Technical Advisor
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16	The same situation applies to nitrate. While the elevated nitrate in the groundwaters of the region arises from inappropriate farming practices conducted by UCD and others, where excessive amounts of fertilizers are applied to crops compared to that needed by the crop, such practices are allowed under current regulatory requirements. The disposal of wastes which pollute-impair the use of groundwaters, however, as UCD has been doing, is regulated, and, therefore, UCD can be required to cleanup to no impaired use. Such clean up will require the use of waste treatment practices, such as reverse osmosis and/or activated carbon beds, of any pumped groundwater before re-injection into the aquifer.	*See response to Dr. Lee comment #15, above.*

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20	The bottom-line issue is that the IRA should be allowed to continue with the understanding that this is an experimental approach that can be used to gather some background information that should be useful to help design a more complete and appropriate pump and treat operation that will result in on-site and off-site groundwaters being remediated in accord with the Central Valley Regional Water Quality Control Board's Basin Plan objectives. This remediation will consider all impairment of uses, not just those mentioned in the IRA of only achieving drinking water standards for a few regulated chemicals. In addition to the regulated chemicals, UCD will have to provide for groundwater remediation for the large arena of unregulated, potentially hazardous and deleterious chemicals that are present in groundwaters arising from UCD's mismanagement of its campus and LEHR site wastes.	*No response necessary.*
22	There are a number of areas associated with groundwater clean-up that still have not been addressed by UCD that are of great significance to the public. One of the most important of these is the failure of UCD to begin to effectively address the pollution of HSU-4 by LEHR site wastes. The Dames & Moore report ignores HSU-4 issues. This is part of a pattern that has occurred in UCD Dames & Moore reports on the LEHR site where Dames & Moore will discuss the geology of the region but not mention that the most important aquifer of the region, HSU-4, has been most certainly polluted by LEHR site wastes. It appears now that DSCSOC will have to file a complaint with the regulatory agencies in order to require UCD to start to address, in a meaningful way, the pollution of HSU-4.	*See response to M. Rust comment #4.*

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22	Further, UCD has not yet presented information on how it plans to address the off-site pollution by chloroform and other constituents that has occurred by LEHR site wastes that is now under adjacent properties. While the proposed IRA will, to some extent, reduce the off-site pollution, this is an experimental program that is a first step in the development of an overall approach to managing the polluted groundwaters under the LEHR site as well as under adjacent properties. It will have to be followed by a more comprehensive approach for remediation than is being addressed in the IRA.	*Please see responses to M. Rust comment #2 and EPA comments #2 and #19.*
23	UCD, through Dames & Moore, in the first paragraph of page 28 of their report states, *"The anticipated system will ensure that the Site is stabilized until long-term remedial action begins."* This statement ignores the on-site and off-site groundwater pollution that has and continues to occur near landfill No. 3. UCD must be required to do a more comprehensive evaluation of the pollution of groundwaters by this landfill in order to define the *full* extent of pollution and to begin a remediation program to clean up this pollution.	*Several phases of hydropunch investigation and continued monitoring of well UCD1-10 have shown little impact downgradient of Landfill No. 3. The IRA will address primary sources of VOCs to groundwater. Further evaluation of groundwater downgradient of Landfill Unit #3 will be addressed along with remaining impacts off-site downgradient after implementation of the proposed IRA.*
24	UCD has also caused pollution of groundwaters along Putah Creek by its excessive discharges of VOCs in its campus wastewater treatment plant effluent. UCD should be required to immediately investigate the full extent of this pollution, to initiate a wastewater treatment program that will stop further pollution of groundwaters by the inadequate treatment of its wastewaters that are discharged to Putah Creek and to begin to remediate the VOCs (carcinogen pollution of groundwaters by the discharge of inadequately treated campus wastewaters to Putah Creek).	*The EE/CA report was specifically written for the evaluation of groundwater Interim Removal Action remediation alternatives and does not address surface water concerns.*