E.O. Lawrence Berkeley National Laboratory
University of California
Environmental Restoration Program

United States Department of Energy

RCRA Facility Investigation Report

for the

Lawrence Berkeley National Laboratory

ENVIRONMENTAL RESTORATION PROGRAM

September 2000

Note: The *draft final* RCRA Facility Investigation Report (RFI) Report, for the Lawrence Berkeley National Laboratory Environmental Restoration Program, dated September 2000, was approved by the Department of Toxic Substances Control (DTSC) as final. The *final* RCRA Facility Investigation Report (RFI) Report contained herein consists of the draft final document accompanied by the DTSC approval letter dated July 27, 2001.

Department of Toxic Substances Control

Edwin F. Lowry, Director
700 Heinz Avenue, Suite 200
Berkeley, California 94710-2721

Winston H. Hickox
Agency Secretary
California Environmental
Protection Agency

Gray Davis
Governor

July 27, 2001

Mr. Iraj Javandel
Environmental Restoration Program
Lawrence Berkeley National Laboratory
One Cyclotron Road
Berkeley, California 94720

APPROVAL OF DRAFT FINAL RCRA FACILITY INVESTIGATION REPORT, LAWRENCE BERKELEY NATIONAL LABORATORY (LBNL), BERKELEY, CALIFORNIA, EPA ID No. CA 4890008986

Dear Mr. Javandel:

The Department of Toxic Substances Control (DTSC) has completed its review of the "Draft Final RCRA Facility Investigation (RFI) Report," dated September 29, 2000. DTSC concurs with its findings and recommendations and hereby approves the report.

Enclosed is the document entitled, "Response to Comments" prepared by the DTSC. These comments were received during the public comment period that extended from November 15, 2000 to February 15, 2001. One workshop was held on December 6, 2000 and another public meeting was held on January 24, 2001 during this public comment period.

DTSC requests that LBNL submit a Corrective Measures Study Workplan within four weeks of the date of this letter.

Should you have any questions please call Mr. Waqar Ahmad at (510) 540-3932.

Sincerely,

Mohinder S. Sandhu, P.E., Chief
Standardized Permits and Corrective Action Branch

Enclosure

cc: See next page.

WA.dm
WA01W.071

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E.O. Lawrence Berkeley National Laboratory
University of California
Environmental Restoration Program

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ENVIRONMENTAL RESTORATION PROGRAM

A Joint Effort of
Environment, Health and Safety Division and
Earth Sciences Division
Lawrence Berkeley National Laboratory
University of California
Berkeley, CA 94720

and

Parsons Engineering Science, Inc.
Oakland, California

September 2000

This work was done at the Lawrence Berkeley Laboratory operated by the University of California for the U. S. Department of Energy under contract DE-AC03-76SF00098.

DRAFT FINAL

RCRA Facility Investigation Report

for the

Lawrence Berkeley National Laboratory

ENVIRONMENTAL RESTORATION PROGRAM

September 2000

______________________________ **Date:** 29 Sept 2000

David Baskin, Certified Engineering Geologist
Parsons Engineering Science, Inc.

______________________________ **Date:** 9/29/00

David Diamond, Certified Hydrogeologist
Parsons Engineering Science, Inc.

______________________________ **Date:** 9.29.00

Frederick Stanin, Certified Hydrogeologist
Parsons Engineering Science, Inc.

Approved by:

______________________________ **Date:** 9-29-2000

Iraj Javandel

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LIST OF ABBREVIATIONS

AOC	Area of Concern
ARB	California Air Resources Board
BAAQD	Bay Area Air Quality Management District
bgs	Below ground surface
BEHP	Bis(2-ethylhexyl)phthalate
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CAL-EPA	California Environmental Protection Agency
CAM	California Assessment Manual
CAP	Corrective Action Program
CCR	California Code of Regulations
CFCs	Chlorofluorocarbons
CFR	Code of Federal Regulations
CMS	Corrective Measures Studies
COB	City of Berkeley
COPCs	Chemicals of Potential Concern
DCA	Dichloroethane
DCE	Dichloroethene
DO	Dissolved oxygen
DHS	California Department of Health Services
DOE	U.S. Department of Energy
DTSC	California EPA Department of Toxic Substances Control
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utilities District
EH&S	Environment, Health and Safety Division
ERP	Environmental Restoration Program
EW	Extraction well
FY	Fiscal Year
GAC	Granular activated carbon
gpm	Gallons per minute
HSPP	Health and Safety Program plan
HWHF	Hazardous Waste Handling Facility
ICM	Interim Corrective Measure
ISR	In situ respiration test
K	Hydraulic conductivity
kg	Kilograms
LBNL	Lawrence Berkeley National Laboratory (Berkeley Lab)
MCL	Maximum Contaminant Level
µg/L	Micrograms per liter (10^{-6} grams per liter)
mg/kg	Milligrams per kilogram
msl	mean sea level
MTBE	methyl tertiary butyl ether

NFA	No Further Action
NFI	No Further Investigation
NTLF	National Tritium Labeling Facility
OD	Outside diameter
OR	Oxygen reduction potential
PAHs	Polycyclic aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PCE	Tetrachloroethylene (perchloroethene)
PEL	Permissible Exposure Limit
PG&E	Pacific Gas and Electric Company
ppbv	Parts per billion by volume
PID	Photoionization detector
PRG	Preliminary Remediation Goal
PVC	Polyvinyl chloride
QAPP	Quality Assurance Program Plan
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RWQCB	Regional Water Quality Control Board (State of California)
SOP	Standard Operating Procedure
SVE	Soil vapor extraction
SVOCs	semi-volatile organic compounds
SWMU	Solid Waste Management Unit
TCA	Trichloroethane
TCE	Trichloroethylene
TDS	Total dissolved solids
THC	Total hydrocarbons
TOC	Total organic carbon
TPH	Total Petroleum Hydrocarbons
TPH-CO	Crude oil range hydrocarbons
TPH-D	Diesel-range hydrocarbons
TPH-C/WO	Crude/waste oil range hydrocarbons
TPH-G	Gasoline-range hydrocarbons
TPH-H/MO	Hydraulic/motor oil range hydrocarbons
TPH-K	Kerosene-range hydrocarbons
TPH-MO	Motor oil range hydrocarbons
TSCA	Toxic Substances Control Act
UC	University of California
UCB	University of California, Berkeley
UST	Underground storage tank
USEPA	U. S. Environmental Protection Agency
VOCs	Volatile organic compounds
WSP	Worksite Safety Plan

EXECUTIVE SUMMARY

INTRODUCTION

The Ernest O. Lawrence Berkeley National Laboratory (LBNL) has prepared this Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Final Report in accordance with the provisions outlined in LBNL's Part B Hazardous Waste Facility Permit. This report documents RFI activities conducted from July 1, 1995 through completion of the RFI (September 22, 2000). RFI activities conducted from the start of the RFI in November 1992 through June 30, 1995 are documented in the Draft Final RFI Phase I (LBNL, 1994l) and Phase II (LBNL, 1995k) Progress Reports that were submitted to the regulatory agencies in 1994 and 1995, respectively.

The following activities were conducted during the RFI:

- soil borings were drilled to collect soil samples and evaluate the geologic framework of the site
- soil-gas probes were installed to collect soil-gas samples
- lysimeters were installed to collect soil water samples
- monitoring wells and temporary groundwater sampling points were installed to collect groundwater samples and perform hydrogeological testing
- groundwater samples were collected from hydraugers and slope stability wells
- surface water and sediment samples were collected from site creeks, catch basins, and drain lines.
- indoor and outdoor air samples were collected
- Interim Corrective Measures (ICMs) were implemented to address immediate threats to human health or the environment.

This report contains four introductory sections that describe the status of Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs), the physical and environmental setting of the LBNL site and the purpose, and the methodology of the investigations. The introductory sections are followed by four modules that describe investigation results for specific areas of LBNL. These modules are the Bevalac Area (Module A), the Old Town Area (Module B), the Support Services Area (Module C), and Outlying Areas (Module D).

Information discussed in each module includes:

- the physical characteristics of the module area, including geology and hydrogeology
- a description of the SWMUs and AOCs that were investigated
- results of contamination characterization activities that were completed
- potential and identified sources of contamination
- contaminant migration pathways
- ICMs that were implemented.

Investigations of radionuclide contamination are not included in this report, since radionuclides and radioactive waste are not regulated under RCRA. Radiological contamination at SWMUs and AOCs is being addressed under the oversight of the United States Department of Energy (DOE) as a separate process. However, to keep the RCRA oversight agencies informed on the status of radiological investigations, results of those investigations have been included in the Quarterly Progress Reports that have been submitted to the oversight agencies.

SITE DESCRIPTION AND BACKGROUND

LBNL is a multipurpose research facility managed by the University of California (UC) for the DOE. It is located in the Berkeley/ Oakland hills in Alameda County, California. The western three-quarters of LBNL are in the city of Berkeley and the eastern quarter is in the City of Oakland. In general, the structures at LBNL are owned by DOE, while the land is owned by UC and leased to DOE.

Since an initial emphasis on high-energy and nuclear physics in the 1940s, LBNL has diversified to include materials sciences, chemistry, earth sciences, biosciences, and energy conservation research. Many types of chemicals have been used at LBNL or have been produced as wastes. The primary chemical contaminants detected in soil and groundwater at LBNL have been volatile organic compounds (VOCs) including tetrachloroethene (PCE), trichloroethene (TCE), carbon tetrachloride, 1,1-dichloroethene (1,1-DCE), cis-1,2-dichloroethene (cis-1,2-

DCE), 1,1,1-trichloroethane (1,1,1-TCA), and 1,1-dichloroethane (1,1-DCA). Other contaminants detected in soil and/or groundwater have included petroleum hydrocarbons, polychlorinated biphenyls (PCBs), Freon-113, and metals.

The hydrogeological characteristics of the bedrock units and surficial materials, along with the physiography of the site, are primary factors controlling groundwater flow and contaminant transport. These factors were used to develop the conceptual hydrogeologic and contaminant transport models described in each of the modules.

STATUS OF SOLID WASTE MANAGEMENT UNITS (SWMUs) AND AREAS OF CONCERN (AOCs)

LBNL periodically submitted requests for No Further Action (NFA) or No Further Investigation (NFI) status for selected SWMUs and AOCs to the appropriate oversight agency during the RFI. In accordance with a process approved by DTSC, LBNL requested NFA status for SWMUs and AOCs where sufficient characterization activities had been conducted, and soil contaminant concentrations were within LBNL background levels or below Preliminary Remediation Goals (PRGs) for residential soil. Where soil contaminant concentrations were above both LBNL background levels and PRGs for residential soil, NFI status was requested.

Seventy-five SWMUs and 88 AOCs were identified during the RCRA Facility Assessment (RFA) (LBNL, 1992d) or in subsequent investigations. Except for groundwater AOCs and the National Tritium Labeling Facility (NTLF), all identified SWMUs and AOCs have been approved for either NFA or NFI Status. Of the 163 SWMUs and AOCs that were identified, 30 will be further evaluated in the next phase of the RCRA Corrective Action Process, which is the Corrective Measures Study (CMS). As shown in the following table, these include 23 SWMUs and AOCs that have been approved for NFI status and 7 groundwater plume AOCs. A request for NFI or NFA status for the NTLF will be submitted to the DOE when investigations at that unit have been completed. A copy of the document will then be distributed to the RCRA oversight agencies.

SWMUs and AOCs to be Included in the CMS

LBNL Unit Name	LBNL Unit Number	DTSC Unit Number
Building 7 Former Plating Shop	SWMU 2-1	
Building 52B Abandoned Liquid Waste AST and Sump	SWMU 2-2	SWMU-4
Building 17 Former Scrap Yard and Drum Storage Area	SWMU 2-3	SWMU-11
Building 69A Storage Area Sump	SWMU 3-5	
Building 75 Former Hazardous Waste Handling and Storage Facility	SWMU 3-6	
Building 76 Motor Pool and Collection Trenches and Sump	SWMU 4-3	SWMU-29
Building 76 Present and Former Waste Accumulation Area #3	SWMU 4-6	SWMU-35
Building 51 Vacuum Pump Room Sump and Collection Basins	SWMU 9-4	SWMU-1
Building 51 Motor Generator Room Sump	SWMU 9-6	
Building 16 Former Waste Accumulation Area	SWMU 10-4	SWMU-9
Building 25 Plating Shop Floor Drains	SWMU 10-10	
Building 7E Former UST	AOC 2-1	AOC-4
Building 7 Former Hazardous Materials Storage Area	AOC 2-2	
Building 7 Sump	AOC 2-5	
Building 88 Hydraulic Gate Unit	AOC 6-3	AOC-2
Building 46 Hazardous Materials Storage Area	AOC 7-3	
Building 58 Former Hazardous Materials Storage Area	AOC 7-6	
Building 58/B70 Sanitary Sewer	AOC 8-6	
Building 51 Sanitary Sewer and Drainage System	AOC 9-9	
Building 51/64 Former Temporary Equipment Storage Area	AOC 9-12	
Building 52 Former Hazardous Materials Storage Area	AOC 10-2	
Building 62 Hazardous Materials Storage Area	AOC 13-1	
Building 37 Proposed Electrical Substation	AOC 14-7	
Groundwater AOCs		
Building 71 Groundwater Solvent and Freon Plumes	AOC 1-9	
Old Town Groundwater Solvent Plume	AOC 2-4	
Solvents in Groundwater South of Building 76	AOC 4-5	
Building 51/64 Groundwater Plume	AOC 9-13	
Solvent Contaminated Groundwater in Area 10	AOC 10-5	
Well MWP-7 Groundwater Contamination	AOC 14-5	
Site Wide Contaminated Hydrauger Discharges	AOC-SW1	AOC-8

GROUNDWATER PLUME AOCs

Groundwater plume AOCs were evaluated for compliance with the following requirements, which are noted for the Berkeley Sub-Area Groundwater Management Zone in the RWQCB's East Bay Plain Groundwater Basin Beneficial Evaluation Report (RWQCB, 1999c).

1. sources of groundwater contamination have been located and sources have been removed or will be removed.
2. the magnitude and horizontal and vertical extent of groundwater contamination have been defined.
3. the plumes appear to be stable and a long-term monitoring program has been established to verify plume stability.

Groundwater monitoring will continue at LBNL in accordance with requirements of the RWQCB.

INTERIM CORRECTIVE MEASURES

Throughout the RFI Phase of the RCRA Corrective Action Process, when an immediate threat to human health or the environment was identified, LBNL has conducted an ICM in consultation with the regulatory oversight agencies. These measures are discussed in Modules A through D and include:

- removing sources of groundwater contamination
- removing soil contamination that poses an immediate threat to human health or the environment
- preventing further migration of contaminated groundwater
- stopping discharge of contaminated groundwater to surface waters
- eliminating potential pathways that could contaminate groundwater.

FUTURE ACTIVITIES

LBNL will conduct future corrective actions that include:

- A Corrective Measures Study Workplan will be prepared as part of the RCRA Corrective Action Process. During this study, remedial alternatives will be proposed and evaluated for areas of impacted soil and/or groundwater.
- Based on the Corrective Measures Study, a proposed remedy selection will be made. DTSC will prepare a Statement of Basis for this remedy selection and will seek public input during a 45-day public comment period.
- LBNL will implement corrective action after a remedy is approved.

In addition, groundwater investigations will continue pursuant to the RWQCB's authority under the California Water Code.

SECTION 1

INTRODUCTION

1.1 BACKGROUND

The Ernest O. Lawrence Berkeley National Laboratory (LBNL) has prepared this Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Final Report in accordance with the provisions outlined in LBNL's Part B Hazardous Waste Facility Permit. LBNL's Hazardous Waste Handling Facility operates under a RCRA, Part B Hazardous Waste Facility Permit issued by the California Environmental Protection Agency (CAL-EPA) Department of Toxic Substances Control (DTSC) on May 4, 1993. Section 3004(u) of RCRA, as amended by the Hazardous and Solid Waste Amendments (HSWA) and Title 40 of the Code of Federal Regulations (CFR) §264, requires that permits issued after November 8, 1984 address corrective action of all releases of hazardous wastes including hazardous constituents from any Solid Waste Management Unit (SWMU).

As part of the permitting process, DTSC and LBNL conducted RCRA Facility Assessments (RFAs) to determine whether there was an actual or potential release of hazardous waste or hazardous constituents at the facility. Reports summarizing the findings of the RFA was prepared by the DTSC in November 1991 (DTSC, 1991) and LBNL in September 1992 (LBNL, 1992d). The RFAs indicated that hazardous waste or hazardous constituents had been released to soil and groundwater. Based on the findings of these RFAs, DTSC concluded that corrective action would be necessary to clean up past and present contamination at the site. The DTSC therefore requested that LBNL submit a workplan for conducting a RCRA Facility Investigation (RFI) to further assess the extent of contamination. LBNL submitted the RFI Work Plan to DTSC in November 1992 (LBNL, 1992e).

The RFI was conducted between October 1992 and September 2000 and involved:

- locating the source(s) of release(s) of contaminants
- characterizing the magnitude and extent of contamination and defining the pathways and processes of migration

- identifying potential receptors
- implementing Interim Corrective Measures (ICMs) to control or abate threats to human health or the environment and/or to prevent or minimize the further spread of contamination.

1.2 PURPOSE AND SCOPE OF REPORT

This RFI Report presents the following information necessary to support further corrective action decisions:

- the nature, magnitude, and extent of contamination
- contaminant sources and migration pathways
- actual or potential receptors.

Based on this information, LBNL will conduct a Corrective Measure Study (CMS) to develop and evaluate corrective measures alternatives and to recommend final corrective measures. The first phase of the CMS, the CMS Workplan, will include a human health and ecological risk assessment workplan. The objectives of the risk assessments will be to:

- estimate the potential threat to public health and the environment
- provide a basis for establishing remedial actions and cleanup goals, if required.

In accordance with the RFI Work Plan, results of RFI investigations were to be included in two initial progress reports and a final RFI Report. The draft Final RFI Phase I Progress Report (LBNL, 1994l), which documented RFI activities conducted between October 1, 1993 and June 30, 1994, was submitted to the DTSC in November 1994. The Draft Final Phase II Progress Report (LBNL, 1995k), which documented RFI activities conducted between July 1, 1994 and June 30, 1995, was submitted to the DTSC in November 1995. LBNL submitted a Draft Final RFI Report to the regulatory agencies in February 1997, prior to completion of the RFI (LBNL, 1997b). This RFI Report supersedes (replaces) the 1997 report and documents RFI activities conducted subsequent to those reported in the Draft Final RFI Phase II Progress Report (July 1, 1995) through completion of the RFI (September 22, 2000).

Investigations of radionuclide contamination are not included in this report, since radionuclides and radioactive waste are not regulated under RCRA. Radiological contamination at SWMUs and Areas of Concern (AOCs) is being addressed under the oversight of the United

States Department of Energy (DOE), as a separate process. However, to keep the RCRA oversight agencies informed on the status of radiological investigations, results of those investigations have been included in the Quarterly Progress Reports.

1.3 PROJECT ORGANIZATION

LBNL is a multipurpose research facility managed by the University of California (UC) for the DOE. LBNL's various divisions manage and operate the laboratory facilities. Primary funding and oversight are provided by the DOE. Investigations of areas of potential environmental contamination, including soil, surface water, and groundwater contamination, are conducted at LBNL under the Environmental Restoration Program (ERP). The ERP is part of LBNL's Environmental Protection Group, which is in the Environment, Health and Safety (EH&S) Division. The ERP is part of a nationwide effort by the DOE to identify and clean up contaminated areas at its facilities. The ERP is responsible for conducting RCRA corrective actions in accordance with LBNL's RCRA Part B Permit requirements.

In July 1993, the DTSC specified oversight agency authority and responsibilities at LBNL under the RCRA Corrective Action Program (CAP) at LBNL (DTSC, 1993a). The City of Berkeley was assigned as the lead agency for the technical review of all material pertaining to underground storage tanks (USTs). The San Francisco Bay Region of the California Regional Water Quality Control Board (RWQCB) was assigned as the lead agency for the technical review of all material pertaining to surface water and groundwater contamination. The DTSC assigned review responsibilities for specific SWMUs and AOCs to each of these agencies. In addition DTSC noted that the RWQCB would address any groundwater remediation required from other RCRA or non-RCRA investigations. The DTSC maintained technical review for all material pertaining to all SWMUs and AOCs listed in LBNL's RFI Work Plan (LBNL, 1992e), except for those that would be addressed by the RWQCB or City of Berkeley. The DTSC also maintained the authority to review the evaluations and decisions of the other regulatory agencies, to assure compliance with RCRA requirements.

Additionally, the DOE serves as the lead regulatory oversight agency for investigating and addressing releases of radiological constituents that may have occurred at the facility, under a separate process.

1.4 REPORT ORGANIZATION

This report contains four introductory sections (Sections 1 through 4) that describe overall site characteristics and the purpose and methodology of the investigations. This section (Section 1) provides the background, purpose, and scope of this report and the project organization. The remainder of Section 1 summarizes the history of environmental investigations at LBNL and discusses the status of SWMUs and AOCs. Section 2 describes the history and location of the site and contains the following general information:

- location and description of LBNL
- land use
- ecology and meteorology
- utilities
- contaminants detected.

Section 3 discusses the purpose and methodology of the investigations including groundwater use, potential contaminant migration pathways, and actual and potential receptors. Section 4 contains a general description of the physical characteristics of the site, including the geology and hydrogeology.

The introductory sections are followed by four modules that contain the results of the RFI activities. The site was divided into four area specific modules to present a more comprehensive integration of the soil and groundwater contamination. These modules are the Bevalac Area (Module A), the Old Town Area (Module B), the Support Services Area (Module C), and the Outlying Areas (Module D). Areas were selected for inclusion in each module based on the locations of groundwater plumes, the direction of groundwater flow, and potential contaminant migration pathways. Modules A, B, and C encompass the majority of the soil and groundwater contamination that has been detected at the site.

RFI activities over the remainder of the site are included in the fourth module (Module D). The areal coverage for each module is shown on Figure 1.4-1. Area-specific information is discussed in each module and includes:

- the physical characteristics of the module area, including geology and hydrogeology
- a description of solid waste management units (SWMUs), areas of concern (AOCs), and other areas that were investigated
- results of characterization activities that were completed
- interim corrective measures (ICMs) that were implemented
- potential and identified sources of contamination
- contaminant migration pathways.

1.5 HISTORY OF ENVIRONMENTAL INVESTIGATIONS AT LBNL

In February 1988, DOE's Environmental Survey Team visited LBNL to identify site-wide chemical use, potentially contaminated areas, and chemicals of concern in soil and groundwater (DOE, 1988). DOE informed the RWQCB that groundwater contamination might exist on site. Subsequently, LBNL submitted a funding proposal to DOE for the establishment of a site-wide program of environmental investigation and monitoring. The program included monitoring groundwater at the property boundary and onsite for evidence of contaminants.

The following is a chronology of the major subsequent events in LBNL's Environmental Restoration Program:

1988	Harding Lawson Associates (HLA) performed a fast-track sampling effort at LBNL. Volatile organic compounds were detected in groundwater collected from two slope indicator wells near Building 53. HLA also conducted soil sampling and installed and sampled a groundwater monitoring well west of Building 7 (HLA, 1988a).
October 1988	The RWQCB required LBNL to determine the source of groundwater contamination and characterize its lateral and vertical extent, in order to obtain a National Pollutant Discharge Elimination System (NPDES) Permit to discharge treated groundwater at LBNL.
October 1989	Investigations conducted by LBNL detected three areas of contaminated groundwater (Javandel, 1990). The contaminants detected consisted primarily of chlorinated hydrocarbons in the area between Buildings 51 and

	71 and in the Old Town area (Buildings 7, 52, and 53) and tritium in the Corporation Yard (Buildings 69 and 75). Additional monitoring wells were installed to investigate the extent of contamination.
April 1991	LBNL formally established the Environmental Restoration Program (ERP).
July 1991	LBNL began a program for site-wide quarterly sampling of groundwater monitoring wells.
August 1991	LBNL began its RCRA Facility Assessment (RFA).
November 1991	DTSC issued an independent RFA report based on a Preliminary Review and Visual Site Inspection findings at the site (DTSC, 1991).
October 1992	LBNL completed its RFA Report (LBNL, 1992d).
November 1992	LBNL submitted the draft RFI Workplan (LBNL, 1992e) to the DTSC and other regulatory agencies for review.
May 1993	DTSC issued LBNL's RCRA Part B Hazardous Waste Facility Permit.
July 1993	The DTSC specified oversight agency authority and responsibilities at LBNL (DTSC, 1993a).
August 1993	The LBNL ERP submitted its first Quarterly Progress Report to the DTSC (LBNL, 1993c).
November 1994	The LBNL ERP submitted its Phase I Progress Report to the DTSC for investigations conducted between October 1, 1993 and June 30, 1994 (LBNL, 1994l).
November 1995	The LBNL ERP submitted its Phase II Progress Report to the DTSC for investigations conducted between July 1, 1994 and June 30, 1995 (LBNL, 1995k).
April 27, 2000	LBNL receives No Further Action (NFA) Status or No Further Investigation (NFI) Status approval for the final RCRA SWMU or AOC, excluding groundwater AOCs (DTSC, 2000d).
September 22, 2000	The RWQCB reviewed information submitted by LBNL on groundwater AOCs and informed DTSC that they approved submission of the Final RFI report.

1.5.1 Reporting

As required by LBNL's RCRA Part B Permit, LBNL submits Quarterly Progress Reports to the DTSC. The reports include:

- a description of work completed during the reporting period
- summaries of all findings, including summaries of laboratory data for the reporting period
- summaries of all problems or potential problems encountered during the reporting period and actions taken to rectify problems
- projected work for the next reporting period.

Quarterly Progress Reports have been submitted to the DTSC for the following periods:

Quarterly Progress Reports

Reporting Period	Reference (Quarterly Progress Report)
January 1 to March 31, 1993	LBNL, 1993c
April 1 to June 30, 1993	LBNL, 1993f
July 1 to September 30, 1993	LBNL, 1994a
October 1 to December 31, 1993	LBNL, 1994e
January 1 to March 31, 1994	LBNL, 1994h
April 1 to June 30, 1994	LBNL, 1994n
July 1 to September 30, 1994	LBNL, 1995b
October 1 to December 31, 1994	LBNL, 1995e
January 1 to March 31, 1995	LBNL, 1995j
April 1 to June 30, 1995	LBNL, 1995n
July 1 to September 30, 1995	LBNL, 1996c
October 1 to December 31, 1995	LBNL, 1996f
January 1 to March 31, 1996	LBNL, 1996h
April 1 to June 30, 1996	LBNL, 1996l
July 1 to September 30, 1996	LBNL, 1997c
October 1 to December 31, 1996	LBNL, 1997I
January 1 to March 31, 1997	LBNL, 1997n
April 1 to June 30, 1997	LBNL, 1997o
July 1 to September 30, 1997	LBNL, 1998c
October 1 to December 31, 1997	LBNL, 1998g
January 1 to March 31, 1998	LBNL, 1998l
April 1 to June 30, 1998	LBNL, 1998n
July 1 to September 30, 1998	LBNL, 1999c
October 1 to December 31, 1998	LBNL, 1999g
January 1 to March 31, 1999	LBNL, 1999m
April 1 to June 30, 1999	LBNL, 1999t
July 1 to September 30, 1999	LBNL, 2000c
October 1 to December 31, 1999	LBNL, 2000g

The ERP holds quarterly review meetings with the regulatory agencies to keep them informed of LBNL activities. Participants at these meetings include representatives from the DOE, the RWQCB, the DTSC, the City of Berkeley (COB) Toxics Management Division, the City of Oakland, and UC.

ERP documents are available for public review in the Information Repositories at the University of California Doe Library and at the LBNL library in Building 50.

1.6 STATUS OF SOLID WASTE MANAGEMENT UNITS (SWMUs) AND AREAS OF CONCERN (AOCs)

1.6.1 Identification of Solid Waste Management Units and Areas of Concern

According to LBNL's RCRA Part B Permit, a Solid Waste Management Unit (SWMU) is defined as any unit at a RCRA facility from which hazardous constituents might migrate, irrespective of whether the unit was intended for the management of wastes. "Hazardous constituent" means a constituent identified in Appendix VIII of California Code of Regulations (CCR), Title 22, Division 4.5, Chapter 11 (Identification and Listing of Hazardous Waste); or any element, chemical compound, or mixture of compounds which is a component of a hazardous waste or leacheate and which has a chemical or physical property that causes the waste or leacheate to be identified as a hazardous waste (CCR, Title 22, Section 66260.10). SWMUs identified at LBNL include primarily above-ground and underground waste storage tanks; sumps, scrap yards, plating shops, the former hazardous waste handling facility, waste accumulation areas, hazardous waste storage areas, and waste treatment units. An Area of Concern (AOC) includes other potential source areas of contamination. AOCs identified at LBNL include primarily chemical product storage tanks such as fuel tanks, transformers, and hazardous materials storage areas. In addition, for the purpose of identification and assessment, LBNL also designated groundwater contamination plumes and sanitary sewer lines as AOCs.

SWMUs and AOCs investigated during the RFI were identified and evaluated according to the process described below.

- DTSC prepared an RFA that identified 35 SWMUs and 8 AOCs at LBNL (DTSC, 1991). The DTSC RFA evaluated suspected and potential releases from the identified SWMUs and AOCs.

- LBNL prepared an independent RFA report, which was submitted to DTSC in September 1992 (LBNL, 1992d). The LBNL RFA reported 73 SWMUs and 63 AOCs, including those identified by the DTSC. The potential for release to soil, groundwater, surface water, and air was evaluated for each SWMU and AOC using criteria presented in the "RCRA Facility Assessment Guidance" (USEPA, 1986). The RFA recommended which of the identified SWMUs and AOCs should be included in the RFI, based on their potential to have released contaminants to the environment.
- Other areas investigated during the RFI, such as specific sanitary sewer lines and areas of groundwater contamination, that were not initially designated as AOCs or SWMUs in the RFA were subsequently designated as AOCs.
- Additional SWMUs and AOCs were identified during the RFI. These units were discovered during LBNL construction activities or as a result of ongoing records searches.

A list of SWMUs and AOCs is provided in Table 1.6-1a (LBNL SWMUs and AOCs included in the RFI) and Table 1.6-1b (Other SWMUs and AOCs identified in the RFA). Table 1.6-1a also notes those SWMUs and AOCs that are discussed in this report. A total of 75 SWMUs and 88 AOCs were identified. Of those, 28 SWMUs and 56 AOCs were included in the RFI. The potential contaminants associated with each unit investigated during the RFI are listed in Table 1.6-2. The module in which the unit is discussed (Bevalac, Old Town, Support Services, or Outlying Areas) and the study area number for each of those units are also indicated in the table. For reporting purposes, the RFA subdivided LBNL into 15 separate study areas (Figure 1.6-1). SWMUs and AOCs were numbered based on their location within a study area.

1.6.2 Screening Process for SWMUs and AOCs

To evaluate which soil sample data might represent environmental contamination, analytical results were compared to background levels. For compounds that are not naturally occurring, such as many organic compounds, any detection of that compound was assumed contamination, unless other sources such as laboratory contamination of the sample could be identified. For naturally-occurring constituents such as metals, analytical results were compared to the statistically-estimated background levels at LBNL to identify, with a certain degree of confidence, which constituents were present at concentrations that represent contamination. These statistically-estimated background levels were developed for LBNL by applying the upper tolerance limit method (USEPA, 1989) to 498 soil samples collected at LBNL from 1991 through 1994 (LBNL, 1995i). Outliers and data from areas of known metals contamination were excluded from the data set. Background levels were estimated both for the overall site and for the individual geologic units.

As approved by the DTSC, LBNL used United States Environmental Protection Agency (USEPA) Region IX Preliminary Remediation Goals (PRGs) (USEPA, 1999) and LBNL background levels as action levels to help assess whether further action was required at a site (i.e., whether the unit will be included in the site-wide risk assessment). DTSC PRGs (Cal-Modified PRGs) were used where Region IX PRGs either had not been established, or were greater than the DTSC values. As a conservative measure, PRGs for soil *at residential sites* were used rather than the less-stringent PRGs for soil *at industrial sites*. PRGs for residential soil for metals and organic chemicals (USEPA, 1999) detected in the soil at LBNL and LBNL background levels for metals are listed in Table 1.6-3a and Table 1.6-3b. The PRGs used in the screening process may have differed from those shown in the table, since the USEPA PRG table is modified periodically.

1.6.3 Approval of No Further Action or No Further Investigation Status

LBNL periodically submitted requests for No Further Action (NFA) or No Further Investigation (NFI) status for selected SWMUs and AOCs to the appropriate oversight agency during the RFI, in accordance with the DTSC approved screening process described above. The oversight agency for each LBNL SWMU and AOC is listed in Table 1.6-1a and 1.6-1b. LBNL collected soil samples to assess whether a release had occurred and to evaluate the magnitude and extent of contamination. Where soil contaminant concentrations were within LBNL background levels or below PRGs for residential soil LBNL requested NFA status for the SWMU or AOC. If, however, soil contaminant concentrations were above both LBNL background levels and PRGs for residential soil, LBNL requested NFI status for the unit.

No further site characterization is required for SWMUs and AOCs approved for either NFA or NFI status, and units that have been approved for NFA status will not be included in the CMS phase of the RCRA CAP. However, SWMUs and AOCs approved for NFI status will be included in the next phase of the RCRA Corrective Action process, the CMS. SWMUs and

AOCs that have been approved for NFA or NFI status by the regulatory oversight agencies include:

- those for which LBNL recommended no additional investigations in the LBNL RFI Work Plan (LBNL, 1992e), which was approved by the DTSC.
- those included in the RFI and formally granted NFA or NFI status by the DTSC or City of Berkeley (LBNL's NFA or NFI status requests and the NFA or NFI approval letters are referenced in Table 1.6-1a and 1.6-1b for each SWMU and AOC).

A request for NFI status for the groundwater AOCs was submitted to the RWQCB in February 1999 (LBNL, 1999e). The RWQCB responded that due to the complexity of the site and potential of multiple unknown sources, they could not approve the request for No Further Investigation Status (NFI) (RWQCB, 1999b). They also provided comments in their letter to "facilitate completion of the draft final RCRA Facility Investigation and initiation of the Corrective Measure Study.…" The RWQCB reviewed LBNL's responses to their comments and informed DTSC on September 22, 2000 that they approved submission of the Final RFI report.

Although not included in the RFI, LBNL followed a similar process for investigating radiological units and requesting NFA approval. LBNL submitted requests for approval of NFA status for radiological units to the DOE for review and approval. The following approval letters were issued by DOE:

- DOE (DOE, 1998) approved NFA status for SWMU 11-2 and 11-3 based on a request report from LBNL dated June 25, 1998 (LBNL, 1998i). NFA was approved "with the understanding that it did not release the structure, equipment, or area from any existing controls."
- DOE (DOE, 1999) approved NFA status for AOC 1-7, SWMU 10-2, and SWMU 10-3 based on a request report from LBNL dated September 1999 (LBNL, 1999r). NFA was approved with the condition the "approval does not authorize release to the general public, and is only intended for LBNL's reuse of the subject areas."

Two additional radiological units SWMU 3-8 and SWMU 10-1 were recommended for no additional work in the RFA (LBNL, 1992).

Except for groundwater AOCs and the National Tritium Labeling Facility (NTLF) (SWMU 3-7), all identified SWMUs and AOCs have been approved for NFA or NFI status. Additional investigations of groundwater contamination at LBNL may continue, pursuant to

RWQCB's authority under the California Water Code. In addition, LBNL will submit a report to the DOE requesting NFI or NFA status for the NTLF when investigations at that unit have been completed. The report will be distributed to the RCRA oversight agencies for their review.

The following table summarizes the status of SWMUs and AOCs:

Status of SWMUs and AOCs

	SWMUs and AOCs Approved for NFA Status	SWMUs and AOCs Approved for NFI Status	RWQCB Groundwater AOCs	DOE SWMUs and AOCs (non RCRA)	Total
AOCs	68	12	7	1	88
SWMUs	57	11		7	75
Totals	**125**	**23**	**7**	**8**	**163**

The SWMUs and AOCs that will be included in the CMS are listed in Table 1.6-4. These SMUS and AOCs include those that have been approved for NFI status and groundwater AOCs over which the RWQCB has oversight authority.

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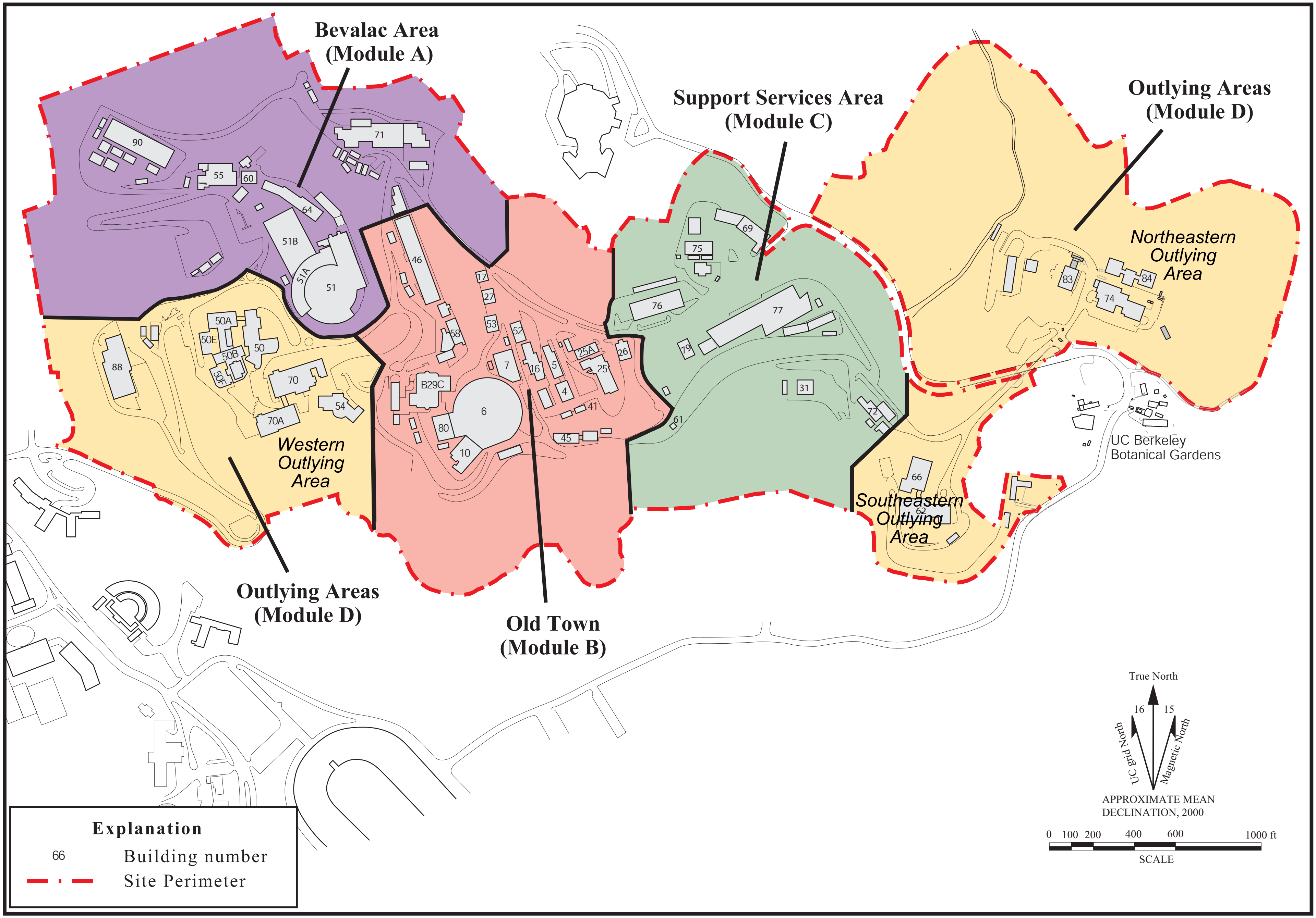

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Figure 1.4-1. Areas of the Four Modules, Lawrence Berkeley National Laboratory.

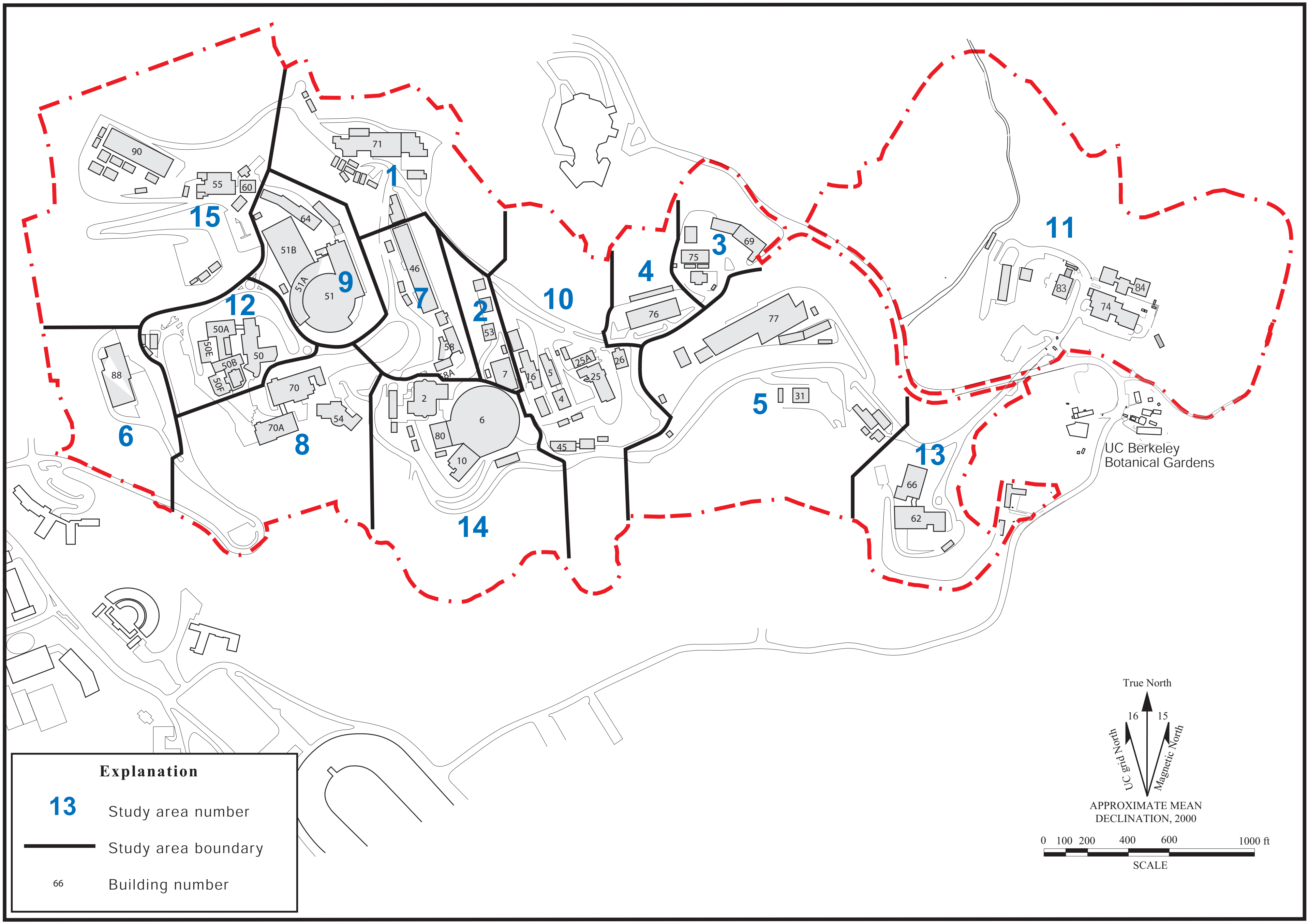

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Figure 1.6-1. Locations of the Fifteen Study Areas, Lawrence Berkeley National Laboratory.

LIST OF TABLES

Table 1.6-1a
LISTING OF SWMUs AND AOCs INCLUDED IN THE RCRA FACILITY INVESTIGATION

LBNL Unit Name	LBNL Unit Number	DTSC Unit Number	Oversight Agency	NFA or NFI Request		NFA or NFI Approval		Regulatory Approved Status
				Date	Reference	Date	Reference	
B7 Former Plating Shop	**SWMU 2-1**		DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFI
B52B Abandoned Liquid Waste AST and Sump	**SWMU 2-2**	**SWMU-4**	DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFI
B17 Former Scrap Yard and Drum Storage Area	**SWMU 2-3**	**SWMU-11**	DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFI
B69 Former (Present) Waste Oil UST	SWMU 3-3	SWMU-8	COB	1/9/1996	LBNL, 1996a	7/29/1996	COB, 1996a	NFA
B69/75A Former Scrap Yard and Drum Storage Area	SWMU 3-4	SWMU-14	DTSC	7/22/1998	LBNL, 1998j	9/3/1998	DTSC, 1998	NFA
B69A Storage Area Sump	SWMU 3-5		DTSC	1/9/1996	LBNL, 1996a	8/25/1997	DTSC, 1997	NFI
B75 Former Haz Waste Handling and Storage Facility	**SWMU 3-6**		DTSC	2/29/2000	LBNL, 2000d	4/21/2000	DTSC, 2000b	NFI
B76 Oil/Water Separator, Basin, and Sumps	SWMU 4-2	SWMU-24	DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B76 Motor Pool and Collection Trenches (and sump)	**SWMU 4-3**	**SWMU-29**	DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFI
B76 Present and Former Waste Accumulation Area #3	SWMU 4-6	SWMU-35	DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFI
B42 Scrap Yard	SWMU 5-1	SWMU-12	DTSC	11/29/1994	LBNL, 1994l	5/18/1995	DTSC, 1995	NFA
B77 Plating Shop Floor and Sump	**SWMU 5-4**	**SWMU-30**	DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B77 Waste Accumulation Area	SWMU 5-6		DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B77G Waste Accumulation Area	SWMU 5-7	SWMU-34	DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B77 Sand Blasting Room	SWMU 5-9	SWMU-37	DTSC	11/29/1994	LBNL, 1994l	5/18/1995	DTSC, 1995	NFA
B77 Present and Former Yard Decontamination Areas	SWMU 5-10	SWMU-32	DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B88 Waste Accumulation Area	SWMU 6-2	SWMU-36	DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B58 Inactive Underground Rinseate Tank	SWMU 7-1	SWMU-6	COB	1/9/1996	LBNL, 1996a	7/29/1996	COB, 1996a	NFA
B58 Sumps	**SWMU 7-5**		DTSC	2/28/1997	LBNL, 1997d	8/25/1997	DTSC, 1997	NFA
B70A Former Waste Water Holding Tanks	SWMU 8-1	SWMU-2	DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B51 Vacuum Pump Room Waste Oil Tank	**SWMU 9-1**	**SWMU-1**	DTSC	2/28/1997	LBNL, 1997d	8/25/1997	DTSC, 1997	NFA
B51 Vacuum Pump Room Sump and Collection Basins	**SWMU 9-4**	**SWMU-1**	DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFI
B51 Motor Generator Room Sump	**SWMU 9-6**		DTSC	9/8/1999	LBNL, 1999o	9/21/1999	DTSC, 1999a	NFI
B16 Former Waste Accumulation Area	**SWMU 10-4**	**SWMU-9**	DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFI
B16 Present Waste Accumulation Area	SWMU 10-5		DTSC	2/28/1997	LBNL, 1997d	8/25/1997	DTSC, 1997	NFA
B25 Plating Shop Floor Drains	**SWMU 10-10**		DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFI
B50 Former Residual Photographic Solution UST	SWMU 12-1	SWMU-5	COB	1/9/1996	LBNL, 1996a	7/29/1996	COB, 1996a	NFA
B62 Waste Accumulation Area	**SWMU 13-2**		DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA

Table 1.6-1a
LISTING OF SWMUs AND AOCs INCLUDED IN THE RCRA FACILITY INVESTIGATION

LBNL Unit Name	LBNL Unit Number	DTSC Unit Number	Oversight Agency	NFA or NFI Request		NFA or NFI Approval		Regulatory Approved Status
				Date	Reference	Date	Reference	
B46A Former Motor Pool Gasoline UST	**AOC 1-1**		COB	2/28/1997	LBNL, 1997d	5/9/1997	COB, 1997a	NFA
B71 Linear Accelerator Cooling Unit	**AOC 1-3**		DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B71 Former Hazardous Materials Storage Area	AOC 1-5		DTSC	11/29/1994	LBNL, 1994l	5/18/1995	DTSC, 1995	NFA
B71 Transformers	**AOC 1-6**		DTSC	2/28/1997	LBNL, 1997d	8/25/1997	DTSC, 1997	NFA
B71 Mercury Contamination	**AOC 1-10**		DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B7E Former UST	**AOC 2-1**	**AOC-4**	COB	1/7/1999	LBNL, 1999a	4/9/1999	COB, 1999	NFI
B7 Former Hazardous Materials Storage Area	AOC 2-2		DTSC	2/28/1997	LBNL, 1997d	8/25/1997	DTSC, 1997	NFI
B7 Sump	**AOC 2-5**		DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFI
B69/B75 Fire Drill Area	AOC 3-2		DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B76 Former Gasoline UST	**AOC 4-1**		COB	7/1/1997	LBNL, 1997l	7/15/1997	COB, 1997b	NFA
B76 Former Diesel UST	**AOC 4-2**		COB	7/1/1997	LBNL, 1997l	7/15/1997	COB, 1997b	NFA
B79 Hazardous Materials Storage Area #2	AOC 5-3		DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B77 Sanitary Sewer System	**AOC 5-4**	**AOC-7**	DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFA
B77 Generator Pad	AOC 5-5		DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B88 Abandoned Diesel UST	AOC 6-1		COB	1/9/1996	LBNL, 1996a	7/29/1996	COB, 1996a	NFA
B88 Transformers	AOC 6-2		DTSC	11/29/1994	LBNL, 1994l	5/18/1995	DTSC, 1995	NFA
B88 Hydraulic Gate Unit	AOC 6-3	AOC-2	DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFI
B88 Hazardous Materials Storage Area	AOC 6-4		DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA
B46 Former Scrap Yard	**AOC 7-1**	**SWMU-13**	DTSC	11/29/1994	LBNL, 1994l	5/18/1995	DTSC, 1995	NFA
B46 Hazardous Materials Storage Area	AOC 7-3		DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFI
B58 Former Hazardous Materials Storage Area	**AOC 7-6**		DTSC	1/9/1996	LBNL, 1996a	8/25/1997	DTSC, 1997	NFI
B70A Diesel UST	**AOC 8-1**		COB		Closure Report	5/4/1998	COB, 1998	NFA
B70 Diesel UST	**AOC 8-2**		COB		Closure Report	12/3/1996	COB, 1996b	NFA
B70A Transformer	AOC 8-3		DTSC	11/29/1994	LBNL, 1994l	5/18/1995	DTSC, 1995	NFA
B70 Transformer	AOC 8-4		DTSC	11/29/1994	LBNL, 1994l	5/18/1995	DTSC, 1995	NFA
B70 Hazardous Materials Storage Area	AOC 8-5		DTSC	2/28/1997	LBNL, 1997d	8/25/1997	DTSC, 1997	NFA
B58/B70 Sanitary Sewer	AOC 8-6		DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFI
B70A Sanitary Sewer	AOC 8-7	AOC-6	DTSC	9/24/1999	LBNL, 1999p	9/28/1999	DTSC, 1999b	NFA
B51 Diesel UST	AOC 9-2		COB	7/1/1997	LBNL, 1997l	7/15/1997	COB, 1997b	NFA
B51 Former Hazardous Materials Storage Area	**AOC 9-7**		DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFA
Sanitary Sewer Lines West of Buildings 51 and 51B	**AOC 9-8**		DTSC	1/14/2000	LBNL, 2000a	2/15/2000	DTSC, 2000a	NFA
B51 Sanitary Sewer and Drainage System	**AOC 9-9**		DTSC	4/24/2000	LBNL, 2000f	4/27/2000	DTSC, 2000d	NFI
B64 Catch Basin	AOC 9-10		DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFA

Table 1.6-1a
LISTING OF LBNL SWMUs AND AOCs INCLUDED IN THE RCRA FACILITY INVESTIGATION

LBNL Unit Name	LBNL Unit Number	DTSC Unit Number	Oversight Agency	NFA or NFI Request		NFA or NFI Approval		Regulatory Approved Status
				Date	Reference	Date	Reference	
Former Cooling Towers Southeast of Building 51	**AOC 9-11**		DTSC	3/29/2000	LBNL, 2000e	4/27/2000	DTSC, 2000c	NFA
B51/64 Former Temporary Equipment Storage Area	**AOC 9-12**		DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFI
B52 Former Hazardous Materials Storage Area	**AOC 10-2**		DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFI
B25A Sanitary Sewer	**AOC 10-3**		DTSC	1/14/2000	LBNL, 2000a	2/15/2000	DTSC, 2000a	NFA
B25 Sanitary Sewer	AOC 10-4	AOC-5	DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFA
B74 (Former) Diesel UST	**AOC 11-1**		COB	1/7/1999	LBNL, 1999a	4/9/1999	COB, 1999	NFA
B83 Diesel AST	AOC 11-2		DTSC	2/28/1997	LBNL, 1997d	8/25/1997	DTSC, 1997	NFA
B83/83A Sanitary Sewers	**AOC 11-3**		DTSC	2/28/1997	LBNL, 1997d	8/25/1997	DTSC, 1997	NFA
B50 Sanitary Sewer Dislocations	**AOC 12-4**		DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFA
B62 Hazardous Materials Storage Area	**AOC 13-1**		DTSC	1/9/1996	LBNL, 1996a	7/5/1996	DTSC, 1996b	NFI
B62 Former Diesel UST	**AOC 13-2**	**AOC-3**	COB	7/1/1997	LBNL, 1997l	7/15/1997	COB, 1997b	NFA
B62 Possible Solvent Spills East of B62	**AOC 13-4**		DTSC	2/28/1997	LBNL, 1997d	8/25/1997	DTSC, 1997	NFA
B62 Acid Sewer Lines West of B62	AOC 13-8		DTSC	2/28/1997	LBNL, 1997d	8/25/1997	DTSC, 1997	NFA
B62 Sanitary Sewers South of B62	AOC 13-9		DTSC	2/28/1997	LBNL, 1997d	8/25/1997	DTSC, 1997	NFA
B10 and B80 Sanitary Sewers	**AOC 14-6**		DTSC	7/22/1998	LBNL, 1998j	9/30/1998	DTSC, 1998	NFA
B37 Proposed Electrical Substation	AOC 14-7		DTSC	4/21/1994		6/16/1994	DTSC, 1994b	NFI

Groundwater AOCs Included In the RCRA Facility Investigation

B71 Groundwater Solvent and Freon Plumes	**AOC 1-9**		RWQCB					
Old Town Groundwater Solvent Plume	**AOC 2-4**		RWQCB					
Solvents in Groundwater South of Building 76	**AOC 4-5**		RWQCB					
Building 51/64 Groundwater Plume	**AOC 9-13**		RWQCB					
Solvent Contaminated Groundwater in Area 10	**AOC 10-5**		RWQCB					
Well MWP-7 Groundwater Contamination	**AOC 14-5**		RWQCB					
Site Wide Contaminated Hydrauger Discharges	**AOC-SW1**	**AOC-8**	RWQCB					

NOTES:

NFA : No Further Action Status. Unit is removed from any additional RCRA Corrective Action Process requirements.

NFI : No Further Investigation status. Unit will be included in the site-wide risk assessment.

Slightly different terminology was used up to 7/15/96 approvals. "NFI with risk assessment" and "NFI" were used instead of NFI and NFA.

"NFI with risk assessment" was equivalent to NFI (defined above) and "NFI" was equivalent to NFA (defined above).

COB : City of Berkeley Planning and Development Department, Toxic Management Division.

DTSC : California Environmental Protection Agency, Department of Toxic Substances Control.

RWQCB: San Francisco Bay Region Regional Water Quality Control Board

Note: SWMUs and AOCs discussed in this report are indicated in bold type.

Table 1.6-1b
LISTING OF Other SWMUs AND AOCs Identified in the RFA

LBNL Unit Name	LBNL Unit Number	DTSC Unit Number	Oversight Agency	NFA Request		NFA Approval		Regulatory Approved Status
				Date	Reference	Date	Reference	
B71 Laboratory Sumps and Holding Tanks	SWMU 1-1		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B71 Former Ion Exchange Column	SWMU 1-2		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B53 Present and Former Waste Accumulation Area #1	SWMU 2-4	SWMU-10	DTSC	12/13/1993	LBNL, 1993h	4/6/1994	DTSC, 1994a	NFA
B53 Waste Accumulation Area #2	SWMU 2-5		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B69A Hazardous Waste Handling Facility	SWMU 3-1	SWMU-15	DTSC	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B69 Former Waste Oil UST	SWMU 3-2	SWMU-7	COB	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B75D UCB Hazardous Waste Handling Facility	SWMU 3-8	SWMU-28	DTSC	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B76 Former Waste Oil AST	SWMU 4-1	SWMU-3	DTSC	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B76 Present and Former Waste Accumulation Area #1	SWMU 4-4	SWMU-35	DTSC	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B76 Waste Accumulation Area #2	SWMU 4-5	SWMU-35	DTSC	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B76 Paint Shop Waste Recovery Unit	SWMU 4-7		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B76 Paint Shop Sink	SWMU 4-8		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B77 Present Waste Water Pre-Treatment Unit	SWMU 5-2	SWMU-19	DTSC	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B77 Future Waste Water Pre-Treatment Unit	SWMU 5-3	SWMU-20	DTSC	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B77 Plating Shop Annex	SWMU 5-5	SWMU-31	DTSC	12/13/1993	LBNL, 1993h	4/6/1994	DTSC, 1994a	NFA
B77 Former Yard Solution Bath Area	SWMU 5-11	SWMU-33	DTSC	12/13/1993	LBNL, 1993h	4/6/1994	DTSC, 1994a	NFA
B77 Coolant Recycling Unit	SWMU 5-8		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B88 Acid Dip Sink	SWMU 6-1		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B58 Acid Dip Sink	SWMU 7-2		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B58 Collection Trench	SWMU 7-3		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B58 Waste Accumulation Area	SWMU 7-4		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B70 New and Inactive Waste Neutralization Units	SWMU 8-2	SWMU-18	DTSC	12/13/1993	LBNL, 1993h	4/6/1994	DTSC, 1994a	NFA
B70 Temporary Waste Accumulation Area	SWMU 8-3		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B51 Former Mercury Sink Trap #1	SWMU 9-2	SWMU-26	DTSC	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B51 Former Mercury Sink Trap #2	SWMU 9-3	SWMU-26	DTSC	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B51 Waste Accumulation Area	SWMU 9-5		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B51 Acid Dip Sink	SWMU 9-7		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B64 Former Waste Accumulation Area	SWMU 9-8		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B25 Waste Water Treatment Facility	SWMU 10-6	SWMU-17	DTSC	12/13/1993	LBNL, 1993h	4/6/1994	DTSC, 1994a	NFA

Table 1.6-1b
LISTING OF Other SWMUs AND AOCs Identified in the RFA

LBNL Unit Name	LBNL Unit Number	DTSC Unit Number	Oversight Agency	NFA Request		NFA Approval		Regulatory Approved Status
				Date	Reference	Date	Reference	
B25 Copper Purification Chamber	SWMU 10-7	SWMU-23	DTSC	12/13/1993	LBNL, 1993h	4/6/1994	DTSC, 1994a	NFA
B25 Waste Accumulation Area	SWMU 10-8		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B25 Plating Shop Floor and Sump	SWMU 10-9		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B74 Temporary Waste Accumulation Area	SWMU 11-1		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B62 Machine Shop Acid Dip Sink	SWMU 13-1		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B62 Former Ion Exchange Column	SWMU 13-3		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B2 Acid Waste Neutralization Unit	SWMU 14-1	SWMU-16	DTSC	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B2 Temporary Waste Accumulation Unit	SWMU 14-2		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B10 Silver Recovery Unit #1	SWMU 14-3	SWMU-21	DTSC	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B10 Silver Recovery Unit #2	SWMU 14-4	SWMU-22	DTSC	RFI WP	LBNL, 1992e	9/14/1993	DTSC, 1993b	NFA
B90 (Former) Silver Recovery Unit	SWMU 15-1	SWMU-25	DTSC	12/13/1993	LBNL, 1993h	4/6/1994	DTSC, 1994a	NFA
B71 Freon-113 Storage Tank	AOC 1-2		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B71H Former Hazardous Materials Storage Area	AOC 1-4		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B82 Diesel AST	AOC 1-8		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B53 Present and Former Hazardous Materials Storage Area	AOC 2-3		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B69A Hazardous Materials Storage and Delivery Area	AOC 3-1		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B76 Present Gasoline UST	AOC 4-3		COB	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B76 Present Diesel UST	AOC 4-4		COB	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B31 Storage Area	AOC 5-1		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B77 Hazardous Materials Storage Area #1	AOC 5-2		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B46 Transformer	AOC 7-2		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B47 Former Photographic Lab	AOC 7-4		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B58 Transformer Oil UST	AOC 7-5		COB	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B58 Transformers	AOC 7-7		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B51 Mercury Storage Room	AOC 9-1		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B51 Transformers	AOC 9-3		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B51 Diesel AST	AOC 9-4		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B64 Possible Solvent Spills	AOC 9-5		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA

Table 1.6-1b
LISTING OF Other SWMUs AND AOCs Identified in the RFA

LBNL Unit Name	LBNL Unit Number	DTSC Unit Number	Oversight Agency	NFA Request		NFA Approval		Regulatory Approved Status
				Date	Reference	Date	Reference	
B64 Lead Storage Area	AOC 9-6		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B16 Transformers	AOC 10-1		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B50 Transformer	AOC 12-1		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B50A Transformer	AOC 12-2		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B50B Transformer	AOC 12-3		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B62 Transformer	AOC 13-3		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B66 Diesel UST #1	AOC 13-5		COB	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B66 Aboveground Diesel Day Tank	AOC 13-6		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B66 Diesel UST #2	AOC 13-7		COB	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B2 Two Diesel USTs	AOC 14-1		COB	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B6 Present and Former Transformers	AOC 14-2		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B10 Photographic Laboratories	AOC 14-3		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B80 Photographic Laboratory	AOC 14-4		DTSC	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA
B55 Diesel UST	AOC 15-1		COB	RFI WP	LBNL, 1992e	4/6/1994	DTSC, 1994a	NFA

Radiological Units								
B71 Radiation Release	AOC 1-7		DOE					NFA
B75A Radioactive Waste Storage Area	SWMU 3-9	SWMU-27	DOE					NFA
B74 Abandoned Aboveground Rad Waste Holding Tanks	SWMU 11-2		DOE					NFA
B74 Six Inactive Aboveground Rad Waste Holding Tanks	SWMU 11-3		DOE					NFA
B5 Former Decontamination Area	SWMU 10-2		DOE					NFA
B5 Former Outdoor Radioactive Waste Storage Area	SWMU 10-3		DOE					NFA
B4 Former Radioactive Waste Storage and Staging Area	SWMU 10-1		DOE					NFA
B75 National Tritium Labeling Facility	SWMU 3-7		DOE					

NOTES:

NFA : No Further Action Status. Unit is removed from any additional
RCRA Corrective Action Process requirements.

RFI WP : No additional work was recommended for this unit in the RFI Workplan (October 30, 1992).

COB : City of Berkeley Planning and Development Department, Toxic Management Division.

DOE : United States Department of Energy.

DTSC : California Environmental Protection Agency, Department of Toxic Substances Control.

Table 1.6-2
POTENTIAL CONTAMINANTS ASSOCIATED WITH SWMUs AND AOCs INCLUDED IN RFI

Module Area	RFA Study Area	Unit Number	SWMU or AOC Name	Potential Contaminants
Module A Bevalac Area	1	**AOC 1-1**	**B46A Former Motor-Pool Underground Gasoline Storage Tank**	**Gasoline**
		AOC 1-3	**B71 Linear Accelerator Cooling Unit**	**Freon-113**
		AOC 1-5	B71 Former Hazardous Materials Storage Area	Kerosene, alcohol, lubricants, organic solvents
		AOC 1-6	**Building 71 Transformers**	**Dielectric oil with PCBs**
		AOC 1-9	**Building 71 Groundwater Solvent and Freon Plumes**	**Organic solvents, Freon 113**
		AOC 1-10	**B71 Mercury Contamination**	**Mercury**
	9	**SWMU 9-1**	**Building 51 Vacuum Pump Room Waste Oil Tank**	**Waste oil, PCBs, and metals**
		SWMU 9-4	**B51 Vacuum Pump Room Sump and Collection Basins**	**Waste oil, PCBs, metals, and organic solvents**
		SWMU 9-6	**B51 Motor Generator Room Filter Sump**	**Waste oil, PCBs, mercury, and organic solvents**
		AOC 9-2	**B51 Underground Diesel Storage Tank**	**Diesel fuel**
		AOC 9-7	**B51 Former Hazardous Materials Storage Area**	**Waste oil, PCBs, metals, and organic solvents**
		AOC 9-8	**Sanitary Sewer Lines West of B51 and 51B**	**Waste oil, PCBs, mercury, and organic solvents**
		AOC 9-9	**B51 Sanitary Sewer and Drainage System**	**Waste oil, PCBs, mercury, and organic solvents**
		AOC 9-10	B64 Catch Basin	Mercury
		AOC 9-11	**Former Cooling Tower Southeast of B51**	**Metals, waste caustics, acids, and possibly solvents**
		AOC 9-12	**B51/64 Former Temporary Equipment Storage Area**	**Metals (especially mercury) and organic solvents**
		AOC 9-13	**B51/64 Groundwater Plume**	**Organic solvents**
Module B Old Town Area	2	**SWMU 2-1**	**B7 Former Plating Shop**	**Acids, caustics, cyanide, metals, solvents**
		SWMU 2-2	**B52B Abandoned above ground liquid waste storage tank (TK-01-07)**	**PCB oil, gasoline, acetone, alcohol, organic solvents, kerosene, metals**
		SWMU 2-3	**B17 Former Scrap Yard and drum storage area**	**Waste oil with PCBs, mercury, waste solvents**
		AOC 2-1	**B7E Former UST**	**Kerosene, BTEX**
		AOC 2-2	B7 Former Hazardous Materials Storage Area	Organic solvents
		AOC 2-4	**Old Town Groundwater Solvent Plume**	**Organic solvents**
		AOC 2-5	**B7 Sump**	**Organic solvents**
	7	SWMU 7-1	B58 Inactive Underground Rinsate Tank	Non-PCB Diala Shell oil and rinseate
		SWMU 7-5	**B58 Sumps**	**Organic solvents**
		AOC 7-1	**B46 Former Scrap Yard Area**	**Metals**
		AOC 7-3	B46 Hazardous Materials Storage Area	Organic solvents, sodium hydroxide, ethylene glycol, and phenyl acetate
		AOC 7-6	**B58 Former Hazardous Materials Storage Area**	**Kerosene, solvents, and oils**
	10	**SWMU 10-4**	**B16 Former Waste Accumulation Area**	**Waste oil**
		SWMU 10-5	B16 Present Waste Accumulation Area	Waste oil, flammable solvents
		SWMU 10-10	**B25 Plating Shop Floor Subdrains**	**Metals**
		AOC 10-2	**B52 Former Hazardous Materials Storage Area**	**Transformer oil, oils, and organic solvents**
		AOC 10-3	**B25A Sanitary Sewer**	**Halogenated organic compounds and metals**
		AOC 10-4	B25 Sanitary Sewer	Halogenated organic compounds, fuels, and metals
		AOC 10-5	**Solvent Contaminated Groundwater in Area 10**	**Organic solvents**
	14	**AOC 14-5**	**B37 Groundwater Contamination**	**TCE, PCE**
		AOC 14-6	**B10 and B80 Sanitary Sewers**	**Organic compounds and acids**
		AOC 14-7	Building 37 Electrical Substation Site	Diesel

Table 1.6-2
POTENTIAL CONTAMINANTS ASSOCIATED WITH SWMUs AND AOCs INCLUDED IN RFI

Module Area	RFA Study Area	Unit Number	SWMU or AOC Name	Potential Contaminants
Module C Support Sevices	3	SWMU 3-3	B69 (Former) Present Waste Oil UST	Non-PCB waste oils
		SWMU 3-4	B69 Former Scrapyard and Drum Storage Area	(Waste oil, waste solvents?)
		SWMU 3-5	B69A Storage Area Sump	Organic solvents and oils, including PCBs
		SWMU 3-6	**B75 Hazardous waste Handling and Storage Facility**	**PCB oil, waste oil, asbestos, acids, chlorides, nitrites, organic and inorganic solvents**
		AOC 3-2	B69/75 Fire Drill Area	Fire extinguishing foam, hydrocarbons
	4	SWMU 4-2	B76 Oil/water Separator, Basin and Sumps	Oil/grease, solvents, antifreeze, detergents
		SWMU 4-3,	**B76 Motor Pool Collection Trenches,**	**Oil/grease, solvents, antifreeze, detergents**
		SWMU 4-6	B76 Former and Present Waste Accumulation Area #3	Paint thinner, waste lacquer, waste oil, organic solvents
		AOC 4-1,4-2	**B76 Former Gasoline and Diesel USTs**	**gasoline, diesel**
		AOC 4-5	**Solvents in Groundwater South of Building 76**	**Organic solvents**
	5	SWMU 5-1	B42 Scrap Yard Area	PCB-containing oils, lead, waste oil, mercury vacuum pumps
		SWMU 5-4	**B77 Plating Shop Floor and Sump**	**Chromium, acids with cyanide, caustics, PCE, TCA, metals**
		SWMU 5-6	B77 Waste Accumulation Area	Waste oils, coolant, lubricating solvents, halogenated solvents, abrasives, and lead.
		SWMU 5-7	B77G Waste Accumulation Area	Waste oils, spent coolant, halogenated solvents, lead, used carbon canisters
		SWMU 5-9	B77 Sand Blasting Room	Garnet sand possibly with aluminum, steel, and plastics
		SWMU 5-10	B77 Present and Former Yard Decontamination and Solution Bath Area	Rinse water with machine oils/lubricants; acids, caustics, cyanide,
		AOC 5-3	B79 Hazardous Materials Storage Area #2	Organic solvents and oils
		AOC 5-4	**B77 Sanitary Sewer System**	**Organic solvents, metals, acids, oil & grease, cyanide, phenolic compounds**
		AOC 5-5	B77 Generator Pad	Diesel

Table 1.6-2
POTENTIAL CONTAMINANTS ASSOCIATED WITH SWMUs AND AOCs INCLUDED IN RFI

Module Area	RFA Study Area	Unit Number	SWMU or AOC Name	Potential Contaminants
Module D Outlying Areas	6	SWMU 6-2	B88 Waste Accumulation Area	Waste oil and solvents
		AOC 6-1	B88 Abandoned Diesel UST	Diesel fuel
		AOC 6-2	B88 Transformers	Dielectric oils with PCBs
		AOC 6-3	B88 Hydraulic Gate Unit	Oils with PCBs
		AOC 6-4	B88 Hazardous Materials Storage Area	Isopropyl alcohol, TCE, FRYQUEL, and flammable gases
	8	SWMU 8-1	B70A Former Waste Water Holding Tanks	hydrofluoric, and hydrochloric acid
		AOC 8-1	**B70A Underground Diesel Storage Tank (TK-10-70A)**	**Diesel fuel**
		AOC 8-2	**B70 Underground Diesel Storage Tank (TK-10-70)**	**Diesel fuel**
		AOC 8-3	B70A Transformer	Dielectric oils with PCBs
		AOC 8-4	B70 Transformer	Dielectric oils with PCBs
		AOC 8-5	B70 Hazardous Materials Storage Area	Isopropyl alcohol, MEK, vacuum pump oil, 1,1-TCA, and flammables
		AOC 8-6	B58/70 Sanitary Sewer	Various chemicals including organic solvents
		AOC 8-7	**B70A Sanitary Sewer**	**Various chemicals including organic solvents**
	11	**AOC 11-1**	**B74 Underground Diesel Storage Tank (TK-11-74) Perimeter Wells**	**Diesel**
		AOC 11-2	B83 Diesel UST	Diesel
		AOC 11-3	**B83/83A Sanitary Sewer**	**Various chemicals**
	12	SWMU 12-1	B50 Inactive Underground Residual Photo Solution Storage Tank	Photo Wastes and recovered silver
		AOC 12-4	**B50 Sanitary Sewer Dislocations**	**Halogenated organic compounds, fuels, and metals**
	13	**SWMU 13-2**	**B62 Waste Accumulation and Chemical Storage Area**	**TCE, Freon, kerosene, MEK, waste solvents**
		AOC 13-1	**B62 Hazardous Materials Storage Area**	**Hydraulic, vacuum, and cutting oils and heptane**
		AOC 13-2	**B62 Former Underground Diesel Storage Tank (TK-02-62)**	**Diesel fuel**
		AOC 13-4	**Possible Solvent Spills East of B62**	**Organic solvents**
		AOC 13-8	Acid Sewer Lines West of B62	Organic solvents, metals, and acids
		AOC 13-9	Sanitary Sewer South of B62	Organic solvents and metals
Site Wide		**AOC SW1**	**Site-wide Contaminated Hydrauger Discharges**	**Organic solvents**

Note: SWMUs and AOCs included in this report are indicated in bold type.

Table 1.6-3a

Preliminary Remediation Goals and Background Levels for Metals

Metals	Chemical Symbol	PRG for Residential Soil (mg/kg)		LBNL Maximum Background (mg/kg)
Antimony and compounds		3.1E+01	nc	5.5
Arsenic (noncancer endpoint)	As	2.2E+01	nc	19.1
Arsenic (cancer endpoint)	As	3.9E-01	ca*	19.1
Barium and compounds	Ba	5.4E+03	nc	323.6
Beryllium and compounds	Be	1.5E+02	nc	1
Cadmium and compounds	Cd	3.7E+01	nc	2.7
"CAL-Modified PRG" (PEA, 1994)		9.0E+00		2.7
Total Chromium (1:6 ratio Cr VI:Cr III)	Cr	2.1E+02	ca	99.6
Chromium III		1.0E+05	max	
Chromium VI		3.0E+01	ca**	
"CAL-Modified PRG" (PEA, 1994)		2.0E-01		
Cobalt	Co	4.7E+03	nc	22.2
Copper and compounds	Cu	2.9E+03	nc	69.4
Lead	Pb	4.0E+02	nc	16.1
Mercury and compounds	Hg	2.3E+01	nc	0.4
Molybdenum	Mo	3.9E+02	nc	7.4
Nickel (soluble salts)	Ni	1.6E+03	nc	119.8
"CAL-Modified PRG" (PEA, 1994)		1.5E+02		
Selenium	Se	3.9E+02	nc	5.6
Silver and compounds	Ag	3.9E+02	nc	1.8
Thallium compounds (minimum PRG)	Tl	6.3E+00	nc	7.6
Vanadium	V	5.5E+02	nc	74.3
Zinc		2.3E+04	nc	106.1

Key : ca=CANCER PRG nc=NONCANCER PRG sat=SOIL SATURATION

MAX=ceiling limit NS=no PRG specified

*(where: nc < 100X ca) **(where: nc < 10X ca)

PRGs listed are current as of December 1999.

Different values of PRGs may have been used for site screening.

Table 1.6-3b
Preliminary Remediation Goals and Background Levels for Detected Organic Contaminants and Cyanide

Contaminant	Common Abbreviation	PRG for Residential Soil (mg/kg)	
Aldrin		2.9E-02	ca*
Acetone		1.6E+03	nc
Benzene		6.7E-01	ca*
Benzyl alcohol		1.8E+04	nc
Bis(2-ethylhexyl)phthalate	DEHP	3.5E+01	ca*
sec-Butylbenzene		1.1E+02	nc
tert-Butylbenzene		1.3E+02	nc
Butyl benzyl phthalate		1.2E+04	nc
Carbon disulfide		3.6E+02	nc
Carbon tetrachloride		2.4E-01	ca**
Chlorobenzene		1.5E+02	nc
Chloroform		2.4E-01	ca**
Chloromethane		1.2E+00	ca
Cyanide compounds		1.1E+01 to 1.2E+04	nc
DDE		1.7E+00	ca
DDT		1.7E+00	ca*
Dibutyl phthalate (Di-n-butylphthalate)		6.1E+03	nc
1,3-Dichlorobenzene		1.3E+01	nc
1,4-Dichlorobenzene		3.4E+00	ca
Dichlorodifluoromethane	Freon-12	9.4E+01	nc
1,1-Dichloroethane	1,1-DCA	5.9E+02	nc
1,2-Dichloroethane	1,2-DCA	3.5E-01	ca*
1,1-Dichloroethylene	1,1-DCE	5.4E-02	ca
1,2-Dichloroethylene (cis)	cis-1,2-DCE	4.3E+01	nc
1,2-Dichloroethylene (trans)	trans-1,2-DCE	6.3E+01	nc
Dieldrin		3.0E-02	ca
Diethyl phthalate		4.9E+04	nc
Dimethyl phthalate		1.0E+05	max
Ethylbenzene		2.3E+02	sat
Hexachlorobutadiene		6.2E+00	ca**
Methylene chloride		8.9E+00	ca
Methyl ethyl ketone	MEK	7.3E+03	nc
Methyl(methylethyl)benzene		NS	
Methyl tert-butyl ether	MTBE	NS	
n-butylbenzene		NS	
p-isopropyltoluene		NS	
Polychlorinated biphenyls	PCBs	2.2E-01	ca
Aroclor 1232		2.2E-01	ca
Aroclor 1242		2.2E-01	ca
Aroclor 1248		2.2E-01	ca
Aroclor 1254		2.2E-01	ca**
Aroclor 1260		2.2E-01	ca

Table 1.6-3b
Preliminary Remediation Goals and Background Levels for Detected Organic Contaminants and Cyanide

Contaminant	Common Abbreviation	PRG for Residential Soil (mg/kg)	
Polynuclear aromatic hydrocarbons	PAHs		
Anthracene		2.2E+04	nc
Benz[a]anthracene		6.2E-01	ca
Benzo[a]pyrene		6.2E-01	ca
Benzo[b]fluoranthene		6.2E-01	ca
Benzo[k]fluoranthene		6.2E+00	ca
Chrysene		6.2E+01	ca
"CAL-Modified PRG" (PEA, 1994)		6.1E+00	
Dibenz[ah]anthracene		6.2E-02	ca
Fluoranthene		2.3E+03	nc
Fluorene		2.6E+03	nc
Indeno[1,2,3-cd]pyrene		6.2E-01	ca
Naphthalene		5.6E+01	nc
Phenanthrene		NS	
Pyrene		2.3E+03	nc
Isopropylbenzene	cumene	1.6E+02	nc
n-Propylbenzene		1.4E+02	nc
Styrene		1.7E+03	sat
1,1,1,2-Tetrachloroethane	1,1,1,2-PCA	3.0E+00	ca
1,1,2,2-Tetrachloroethane	1,1,2,2-PCA	3.8E-01	ca
Tetrachloroethylene	PCE	5.7E+00	ca*
Toluene		5.2E+02	sat
1,2,3-Trichlorobenzene		NS	
1,2,4-Trichlorobenzene		6.5E+02	nc
1,1,1-Trichloroethane	1,1,1-TCA	7.7E+02	nc
Trichloroethylene	TCE	2.8E+00	ca**
Trichlorofluoromethane	Freon-11	3.9E+02	nc
1,2,3-Trichloropropene		1.2E+01	nc
1,1,2-Trichloro-1,2,2-trifluoroethane	Freon-113	5.6E+03	sat
1,2,4-Trimethylbenzene		5.7E+00	sat
1,3,5-Trimethylbenzene		2.1E+01	nc
Vinyl chloride		2.2E-02	ca
Xylenes		2.1E+02	sat

Key : ca=CANCER PRG nc=NONCANCER PRG sat=SOIL SATURATION

MAX=ceiling limit NS=no PRG specified

*(where: nc < 100X ca) **(where: nc < 10X ca)

PRGs listed are current as of December 1999.

Different values of PRGs may have been used for site screening.

Table 1.6-4

SWMUs AND AOCs TO BE INCLUDED IN CORRECTIVE MEASURES STUDIES

LBNL Unit Name	LBNL Unit Number	DTSC Unit Number
DTSC Oversight Agency		
B7 Former Plating Shop	SWMU 2-1	
B52B Abandoned Liquid Waste AST and Sump	SWMU 2-2	SWMU-4
B17 Former Scrap Yard and Drum Storage Area	SWMU 2-3	SWMU-11
B69A Storage Area Sump	SWMU 3-5	
B75 Former Haz Waste Handling and Storage Facility	SWMU 3-6	
B76 Motor Pool and Collection Trenches (and sump)	SWMU 4-3	SWMU-29
B76 Present and Former Waste Accumulation Area #3	SWMU 4-6	SWMU-35
B51 Vacuum Pump Room Sump and Collection Basins	SWMU 9-4	SWMU-1
B51 Motor Generator Room Sump	SWMU 9-6	
B16 Former Waste Accumulation Area	SWMU 10-4	SWMU-9
B25 Plating Shop Floor Drains	SWMU 10-10	
B7 Former Hazardous Materials Storage Area	AOC 2-2	
B7 Sump	AOC 2-5	
B88 Hydraulic Gate Unit	AOC 6-3	AOC-2
B46 Hazardous Materials Storage Area	AOC 7-3	
B58 Former Hazardous Materials Storage Area	AOC 7-6	
B58/B70 Sanitary Sewer	AOC 8-6	
B51 Sanitary Sewer and Drainage System	AOC 9-9	
B51/64 Former Temporary Equipment Storage Area	AOC 9-12	
B52 Former Hazardous Materials Storage Area	AOC 10-2	
B62 Hazardous Materials Storage Area	AOC 13-1	
B37 Proposed Electrical Substation	AOC 14-7	
City of Berkeley Oversight Agency		
B7E Former UST	AOC 2-1	AOC-4
RWQCB Oversight Agency		
B71 Groundwater Solvent and Freon Plumes	AOC 1-9	
Old Town Groundwater Solvent Plume	AOC 2-4	
Solvents in Groundwater South of Building 76	AOC 4-5	
Building 51/64 Groundwater Plume	AOC 9-13	
Solvent Contaminated Groundwater in Area 10	AOC 10-5	
Well MWP-7 Groundwater Contamination	AOC 14-5	
Site Wide Contaminated Hydrauger Discharges	AOC-SW1	AOC-8

COB : City of Berkeley Planning and Development Department, Toxic Management Division.

DTSC : California Environmental Protection Agency, Department of Toxic Substances Control.

RWQCB: San Francisco Bay Region Regional Water Quality Control Board

SECTION 2

DESCRIPTION OF THE SITE

2.1 LOCATION AND DESCRIPTION OF THE FACILITY

2.1.1 Location

LBNL is located in the Berkeley/Oakland hills in Alameda County, California on approximately 200 acres of land above the UC Berkeley (UCB) campus (Figure 2.1-1). The site is on the ridges and draws of Blackberry Canyon, which forms the central part of the Laboratory, and Strawberry Canyon, which forms the southern boundary. The western three-quarters of the LBNL site is located in the City of Berkeley and the eastern quarter is in the City of Oakland.

2.1.2 Regional Setting

LBNL is located 5 miles east of San Francisco Bay (Figure 2.1-2). The San Francisco Bay Area consists of a total land area of 4.6 million acres and a population of approximately 6 million. Alameda County, with an area of 469,400 acres, has major educational, research, industrial, and agricultural resources. The estimated population of Alameda County is approximately 1,408,000.

The western portion of LBNL is in the City of Berkeley, which encompasses 6,720 acres (Figure 2.1-3). The city is best known for the presence of the University of California at Berkeley. Industries include major biotechnology companies, chemical and pharmaceutical companies, and service industries. The population of Berkeley is approximately 108,000.

To the south and east of Berkeley is Oakland, with a population of approximately 387,000. Its industrial and professional base includes major corporate headquarters in the food, health care, household, and building materials fields. Recreational opportunities include 60,000 acres of community park land.

2.2 LAND USE

2.2.1 Site History and Operations

LBNL began as an accelerator laboratory in 1931, when Ernest O. Lawrence established the Radiation Laboratory with the construction of the 27-Inch Cyclotron on the UCB campus. The laboratory was moved to its present location in 1940, when the 184-Inch Cyclotron was built on a hill overlooking the campus and the City of Berkeley. During a period of rapid growth between 1940 and 1946, the original hillside laboratory (Old Town area) became crowded with temporary wooden buildings hastily erected in response to national defense needs. Further development during the 1950's was more carefully planned, with the construction of permanent concrete and steel-frame structures east and west of the earlier buildings. From 1948 until 1972, LBNL was known as the Lawrence Radiation Laboratory and was funded by the U.S. Atomic Energy Commission and its successor agencies. The name was changed to the Lawrence Berkeley Laboratory in 1972 and changed again in 1995 to the Ernest Orlando Lawrence Berkeley National Laboratory. In general, the structures of LBNL are DOE-owned, while the land is owned by UC and leased to DOE.

From an initial emphasis on high-energy and nuclear physics, LBNL has diversified to include materials sciences, chemistry, earth sciences, biosciences, and energy conservation research. A wide range of energy-related research activities have been conducted at LBNL, including research in nuclear and high-energy physics; accelerator research and development; materials research; and research in chemistry, geology, molecular biology and biomedical research. LBNL has developed and operated a number of experimental facilities, including four large subatomic particle accelerators (the 184-inch Cyclotron, the Bevatron, the Super Heavy Ion Linear Accelerator, and the 88-inch Cyclotron), several small accelerators, and radiochemical laboratories. Of the four large accelerators, only the 88-inch Cyclotron is currently operational.

2.2.2 Laboratory Population and Space

About 3,000 scientists and support personnel work at LBNL. In addition, LBNL hosts approximately 1,900 guests annually, with 700 of them on site at any one time. There are 80 permanent buildings and 107 trailers and temporary buildings on site.

2.2.3 Adjacent Land Use

LBNL is bordered on the north by single-family homes and on the west by multi-unit dwellings, student residence halls, and private homes. The area to the west of LBNL is urbanized (Figure 2.2-1). To the northeast of LBNL are Tilden and Wildcat Parks, which are operated by the East Bay Regional Park District. Approximately one quarter of the parkland is developed with recreation facilities and a Botanical Garden.

2.3 ECOLOGY

Since the arrival of European settlers, the native plant communities at LBNL have been greatly disturbed by human activities. Grasslands became more extensive as grazing by livestock reduced scrub and brushland. Annual grass species largely supplanted native perennial species. The major plant communities at LBNL can be categorized as grassland, coyote brushland, north coastal scrub, oak-bay redwood, conifer and eucalyptus plantations, and landscaped plantings near buildings. The largest vegetated areas at LBNL are located around the perimeter of the site, away from the central developed area. The most common and widespread plant communities are eucalyptus and conifer plantations and grasslands, which contain many non-native species. Native redwood, oak, laurel, willows, and brush populate the Blackberry and Strawberry Canyon areas. A vegetation map of the site is shown on Figure 2.3-1. No protected plant or animal species are known to be present on the site.

2.4 METEOROLOGY

Characterized as Mediterranean, the climate at the site is influenced by the moderating effects of nearby San Francisco Bay and the Pacific Ocean to the west and the sheltering effects of the hills to the east of the site. These factors contribute to the cool, dry summers and relatively warm, wet winters. Comfortable outdoor conditions generally prevail throughout the year, although occasional hard freezes can occur in mid-winter and heat waves in summer. The mean annual temperature at LBNL during 1998 was about 11.8°C (53.2°F). The yearly extremes ranged from a high of 33.4°C (92°F) on August 3 to a low of –2.6°C (27°F) on December 21. Annual average relative humidity values range from 85–90% in the early morning, when ocean fog often blankets the site, to between 55–65% in the afternoon.

Predominant wind patterns have winds blowing from the southeast during the night and from the west during the day. These patterns are consistent with those from previous years. A graphical summary of the annual wind pattern (windrose) for 1998 is displayed on Figure 2.4-1. The average wind speed for the year was 4.7 miles per hour and the maximum 55 miles per hour.

Yearly Precipitation is totaled over a water year (October 1 to September 30). The winter storms (October through April) produce nearly all the precipitation the laboratory receives during the water year. The average annual precipitation at the site since the 1974-1975 water year is about 28 inches. The annual average precipitation from 1993 to 1998 was 38 inches, which includes 1997 when nearly 60 inches of precipitation fell. Drought periods of several years duration are not uncommon, and neither are abnormally wet winters. Monthly rainfall for 1998 and average monthly rainfall since 1974 are shown on Figure 2.4-2.

2.5 UTILITIES

2.5.1 Water Supply

The Laboratory's water is supplied by the East Bay Municipal Utility District (EBMUD) and originates in the Sierra Nevada watershed. Water is brought to the Bay Area and ultimately to LBNL through a system of lakes, aqueducts, and treatment stations. The piping system that distributes the EBMUD water within the site consists of an extensive layout providing domestic water and fire-protection water to all installations. The system also supplies makeup water for cooling towers, irrigation water, and water for other miscellaneous uses. The system includes fire hydrants and fire department connections and sprinkler services to almost all buildings.

2.5.2 Sanitary Sewer System

The sanitary sewer system consists of cast iron or ductile iron pipe, manholes, and two monitoring stations (Figure 2.5-1). The system is gravity flow and discharges through either a monitoring station at Hearst Avenue directly to the City of Berkeley sewer main or a monitoring station located adjacent to Centennial Drive in Strawberry Canyon to University-owned piping and then to the City of Berkeley system. Those buildings that lie within the eastern and southern Strawberry Canyon watershed discharge to the Strawberry monitoring station, along with effluent from several UCB campus facilities, mainly the Lawrence Hall of Science, the Space Sciences Laboratory, the Mathematical Sciences Research Institute, and the Botanical Gardens.

2.5.3 Storm Drain System

LBNL lies within the 874 acre Strawberry Creek watershed. There are two main creeks in the watershed, Strawberry Creek and the North Fork of Strawberry Creek. This watershed also includes other University of California property, public streets of both the cities of Oakland and Berkeley, and private property. In the vicinity of LBNL, the Strawberry Creek watershed is subdivided into the Blackberry Canyon and Strawberry Canyon watersheds (Figure 2.5-2).

Because of its hillside location and moderate annual rainfall, surface runoff at LBNL is a prevalent feature. A storm drain system, designed and installed in the 1960s, discharges into the North Fork of Strawberry Creek in the Blackberry Canyon watershed on the north side of LBNL and Strawberry Creek in the Strawberry Canyon watershed on the south side (Figure 2.5-2). This system provides for runoff intensities expected in a 25-year maximum-intensity storm.

Stormwater runoff from the Laboratory and from the upper parts of the Blackberry Canyon watershed discharges into a 60-inch concrete culvert at the head of LeConte Avenue in Berkeley.

2.6 DETECTED CONTAMINANTS

Many types of chemicals have been used at LBNL or have been produced as wastes. These include solvents, gasoline, diesel fuel, waste oils, polychlorinated biphenyls (PCBs), Freon, metals, acids, etchants, and lead and chromate based paints.

The primary contaminants detected in soil and groundwater at LBNL have been volatile organic compounds (VOCs) including tetrachloroethene (also known as tetrachloroethylene or perchloroethene [PCE]), trichloroethene (also known as trichloroethylene [TCE]), carbon tetrachloride, 1,1-dichloroethene (1,1-DCE), cis-1,2-dichloroethene (cis-1,2-DCE), 1,1,1-trichloroethane (1,1,1-TCA), and 1,1-dichloroethane (1,1-DCA). Some of these are common solvents and degreasers that have been used at LBNL for equipment cleaning. Smaller concentrations of other VOCs (e.g., benzene, toluene, ethylbenzene, and xylenes [BTEX]; chloroform; and vinyl chloride) have also been detected.

Other contaminants detected in soil and/or groundwater have included petroleum hydrocarbons, PCBs, Freon-113, and metals. Contamination of soil and groundwater by petroleum hydrocarbons is associated with former underground storage tank (UST) sites. PCB contamination is primarily associated with spilled transformer oils and waste oil tanks. Freon-113, a coolant for experimental apparatus, has been detected in groundwater south of Building 71.

LIST OF FIGURES

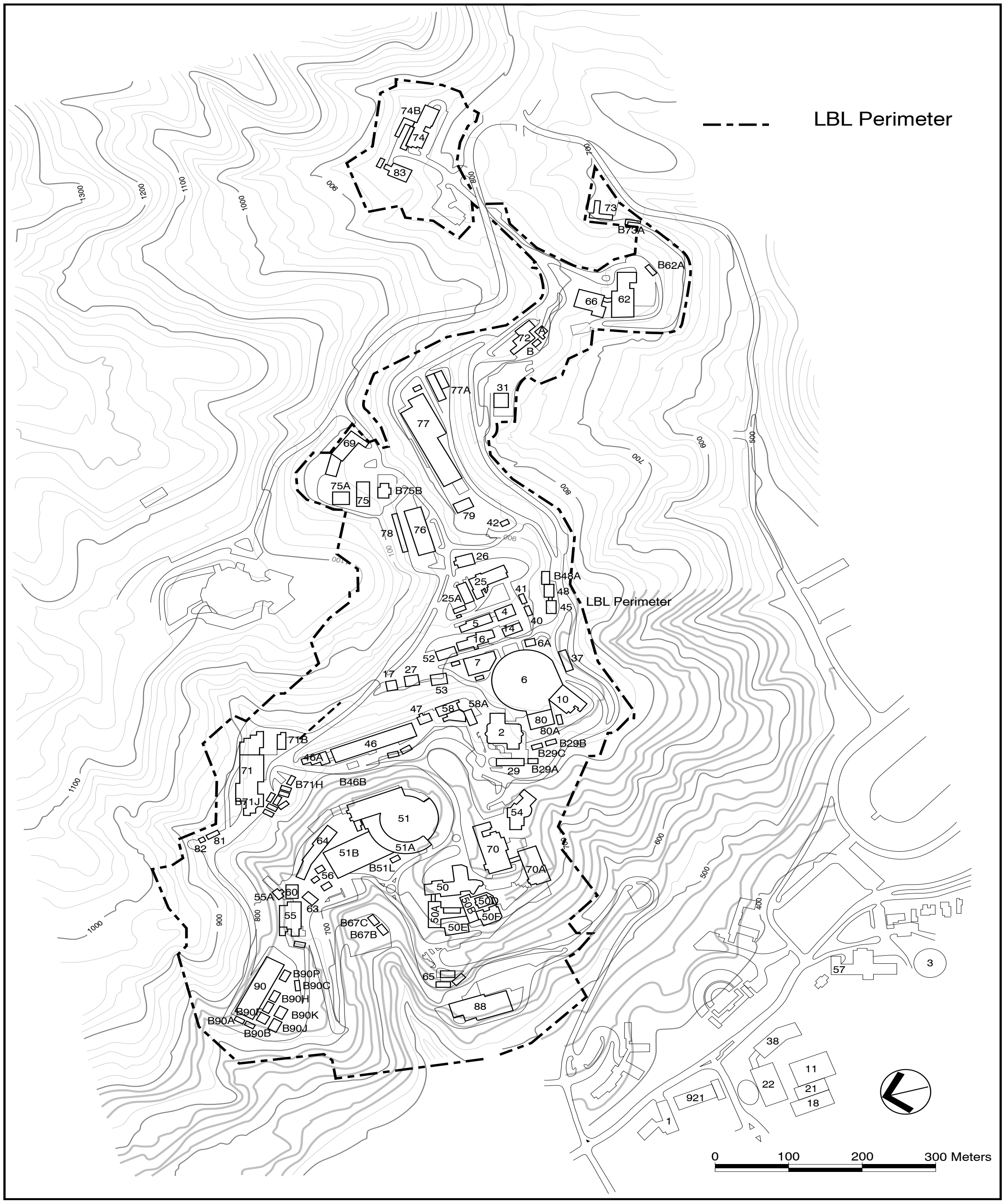

Figure 2.1-1. LBNL On-Site Buildings

2	Advanced Materials Laboratory (AML)
2a	Materials Storage
4	ALS Support Facility
4A	Safety Equipment Storage
5	Accelerator and Fusion Research
5A	Mechanical Storage
5B	Electrical Storage
6	Advanced Light Source (ALS)
7	ALS Support Facility
7A	Radio Shop
7C	Office
10	ALS Support Facility
10A	Utility Storage
13A-C	Environmental Monitoring
13E,F	Sewer Monitoring Station
13G	Waste Monitoring Station
13H	Radiation Monitoring Station
14	Earth Sciences Laboratory
16	Accelerator and Fusion Research Laboratory
17	EH&S
25	Engineering Shop
25A	Engineering Shop
25B	Waste Treatment Facility
26	Health Services, EH&S
27	ALS Support Facility
29	Engineering, Life Sciences
29A,B	Engineering
29C	Environmental Energy Technologies
31	Chicken Creek Maintenance Bldg., Earth Sciences
31A	Earth Sciences
34	ALS Chiller Building
36	Grizzly Substation
37	Utilities Service
40	Engineering Electronics Lab
41	Engineering Communications Lab
42A	Emergency Generator House
43	Compressor Bldg.
44	Indoor Air Pollution Studies
44B	Environmental Energy Technologies
45	Fire Apparatus
46	Accelerator and Fusion Research, Engineering, Environmental Energy Technologies, Photography Services, Printing
46A	Engineering Div. Office
46B	Engineering
46C, D	Accelerator and Fusion research
47	Accelerator and Fusion research
48	Fire Station
50	Accelerator & Fusion Research, Physics, Library
50A	Director’s Office, Nuclear Science, physics
50B	Physics, Computing Sciences
50C	Computing Sciences, NERSC
50D	Center for Computational Sciences and Engineering
50E	Computing Sciences, Offices
50F	Computing Services
51	Technical and Electronics Information
51A	Bevatron
51B	External Particle Beam (EPB) Hall
51F, G	Nuclear Science
51L	Computer Training Center
51N, Q	Earth Sciences
52	Cable Winding Facility
52A	Utility Storage
52B	ALS Support
53	Environmental energy technologies
53A	Gardner’s Storage
53B	Accelerator and Fusion Research
54	Cafeteria
55	Life Sciences
55A	Life Sciences
55B	Emergency Generator
55C	Life Sciences
56	Biomedical Isotope Facility
58	Heavy Ion Fusion
58A	Accelerator Research & Development
58B	Lubricant and Solvent Storage
60	High Bay Laboratory
61	Standby Propane Plant
62	Materials & Chemical Sciences
62A	Environmental Energy Technologies, Materials Sciences
62B	Utility Storage
63	Environmental Energy Technologies
64	B-factory, Life Sciences
64B	Riggers
65	Site Access Office
66	Surface Science Catalysis Lab, Materials Sciences, Center for Advanced Materials
67B,C	Environmental Energy Technologies
67D	Mobile Infiltration Test Unit
67E	Environmental Energy Technologies Field Lab
68	Upper Pump House
69	Archives and Records, Shipping
70	Nuclear Science, Environmental Energy Technologies
70A	Chemical Sciences, Earth Sciences, Engineering, Life Sciences, Nuclear Science
70B	Utility
70E	Storage
70G	Liquid Nitrogen Storage
71	Center for Beam Physics, Ion Beam Technology
71A	Ion Beam Technology, Low Beta Lab
71B	Center for Beam Physics
71C,D,F,H,J,P	B-factory
71K	Accelerator and Fusion Research, B-factory, Chemical Sciences
72	National Center for Electron Microscopy (NCEM)
72A	High Voltage Electron Microscope (HVEM)
72B	Atomic Resolution Microscope (ARM)
72C	ARM Support Laboratory
73	Atmospheric Aerosol Research
74	Life Sciences Laboratory
74C	Emergency Generator
75	Radioisotope Service & National Tritium Labeling Facility (NTLF)
75A,B,C	Environment, Health & safety
76	Facilities Shops, Motor Pool/Garage
77	Engineering Shops
77A	Ultra High Vacuum Assembly Facility (UHV)
77C	Welding Storage
77D	Drum Liquid Storage
77H	Auxiliary Plating
77J-N	Chemical Storage
78	Craft Stores
79	Metal Stores
80	ALS Support Facility
80A	ALS Support Facility
81	Liquid Gas Storage
82	Lower Pump House
83	Life Sciences Laboratory
84	Human Genome Laboratory
85	Hazardous Waste Handling Facility
88	88-Inch Cyclotron, Nuclear Science
88B	Compressor Shelter and Storage
88C	Flammable Gas/Liquid Storage
88D	Emergency Generator
90	Copy Center, DOE Site Office, Earth Sciences, Environmental Energy Technologies
90B,F,G,H,J,K	Facilities
90C, P	Earth Sciences
90R	Utility Storage

Figure 2.1-1 (cont’d.). Key to LBNL Buildings Shown on the Previous Page

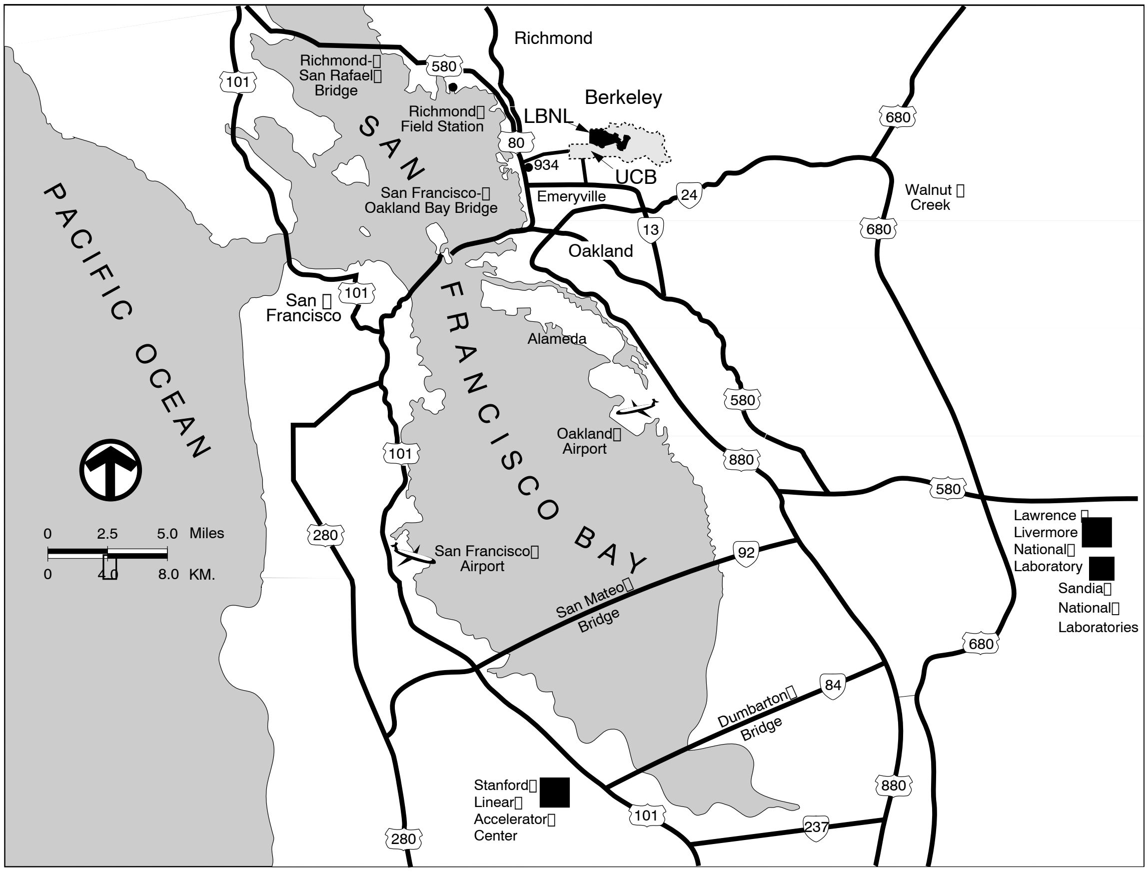

Figure 2.1-2. San Francisco Bay Area Map

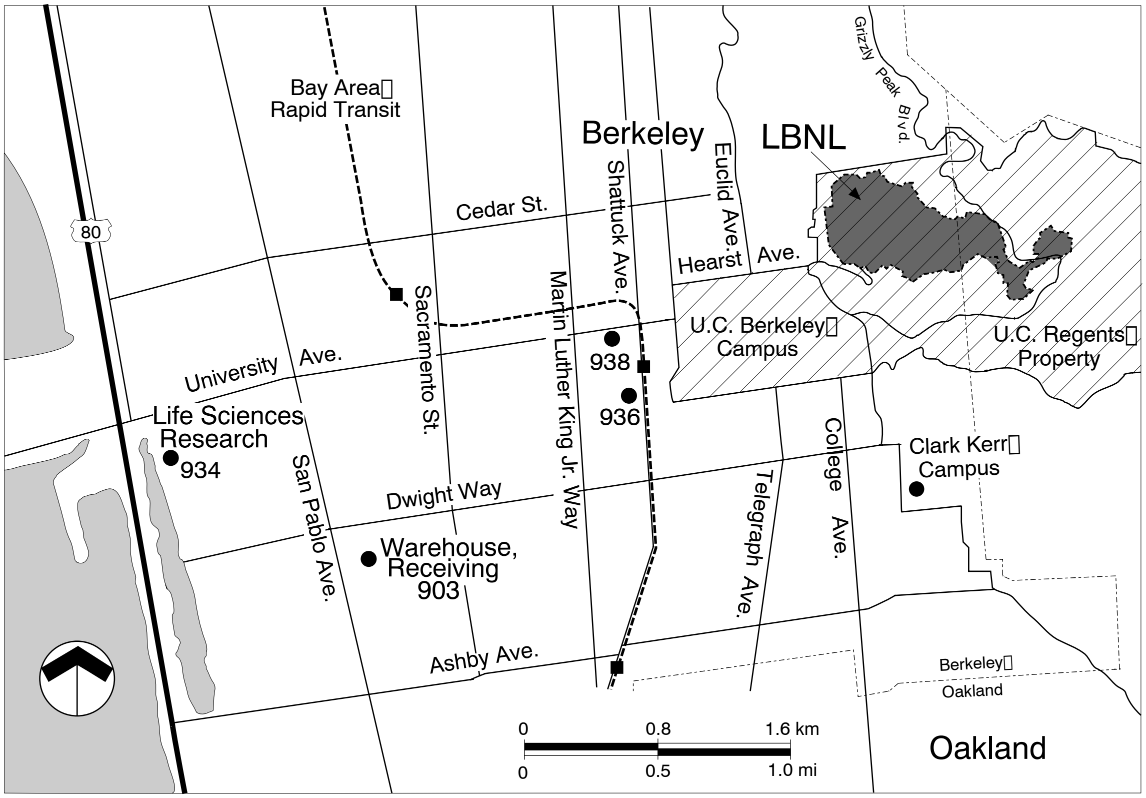

Figure 2.1-3. Vicinity Map

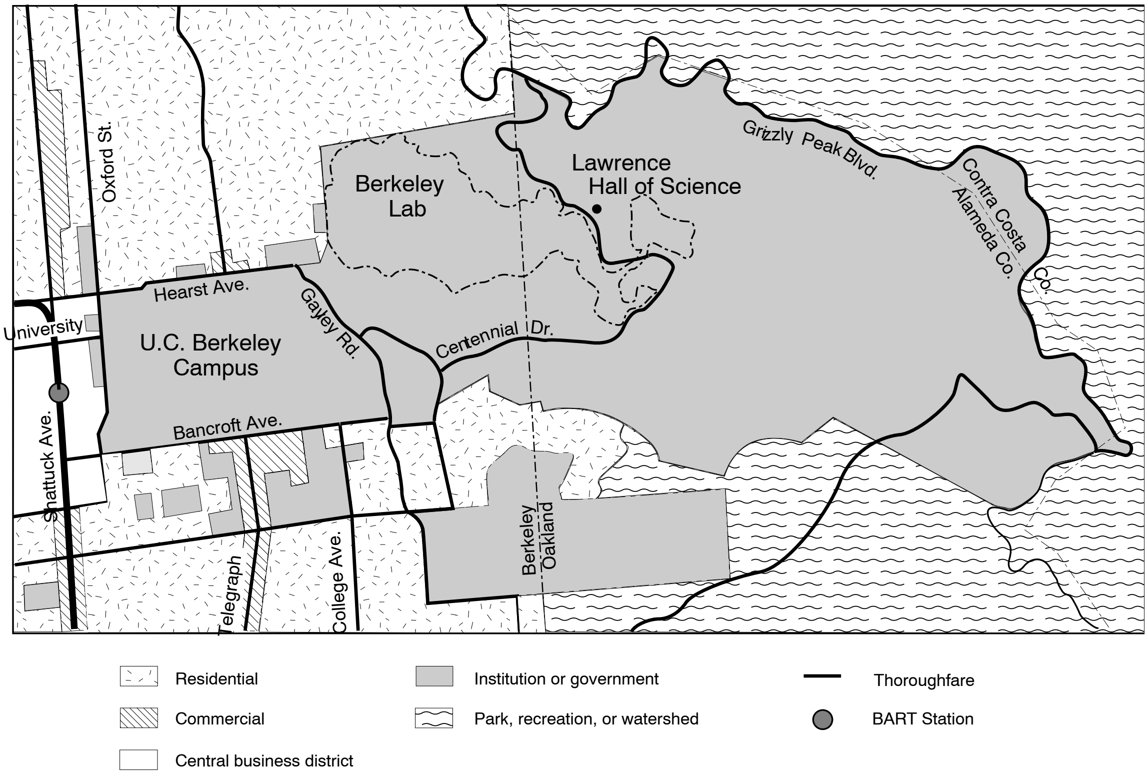

Figure 2.2-1. Adjacent Land Use

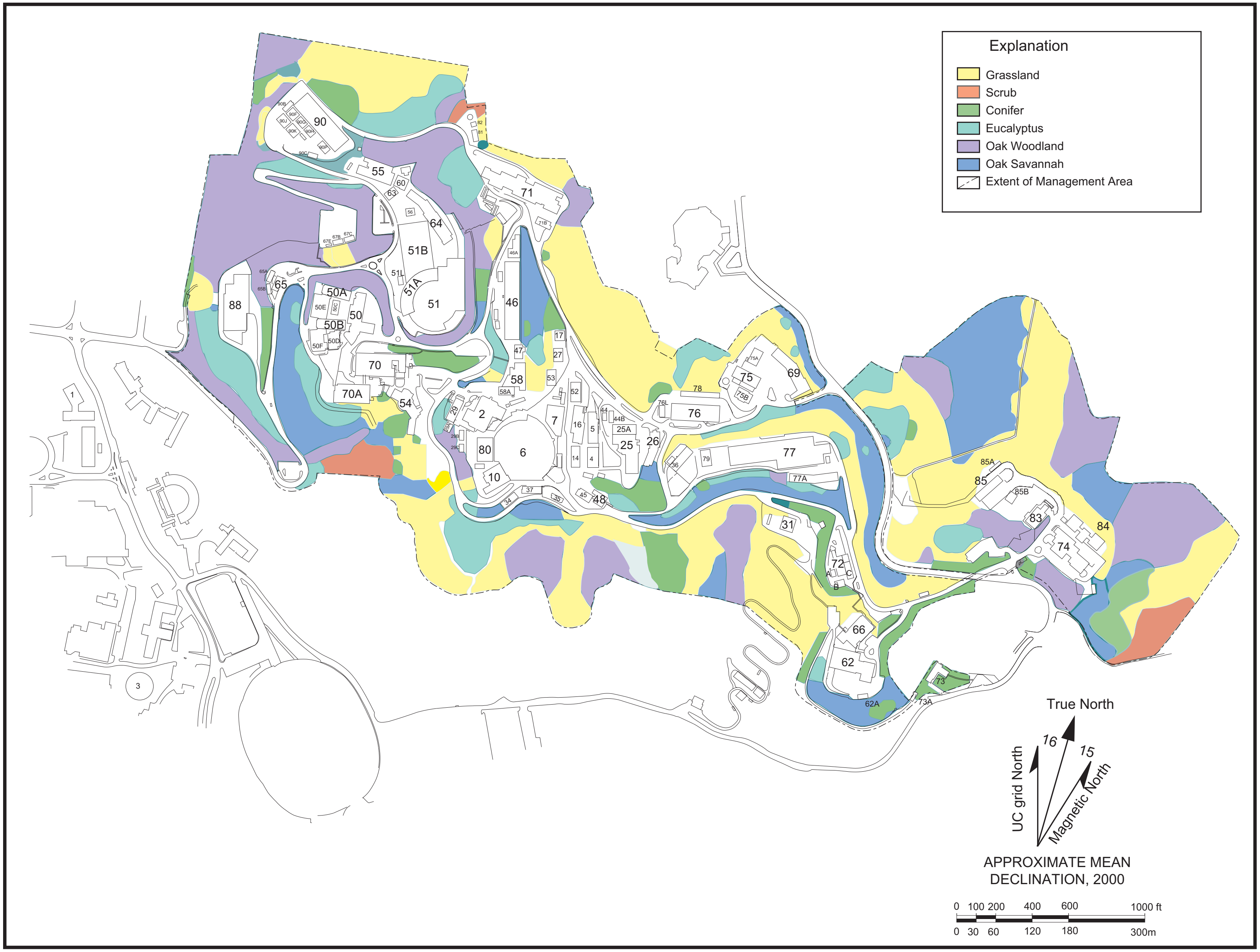

Figure 2.2-2. Major Plant Communities at Lawrence Berkeley National Laboratory.

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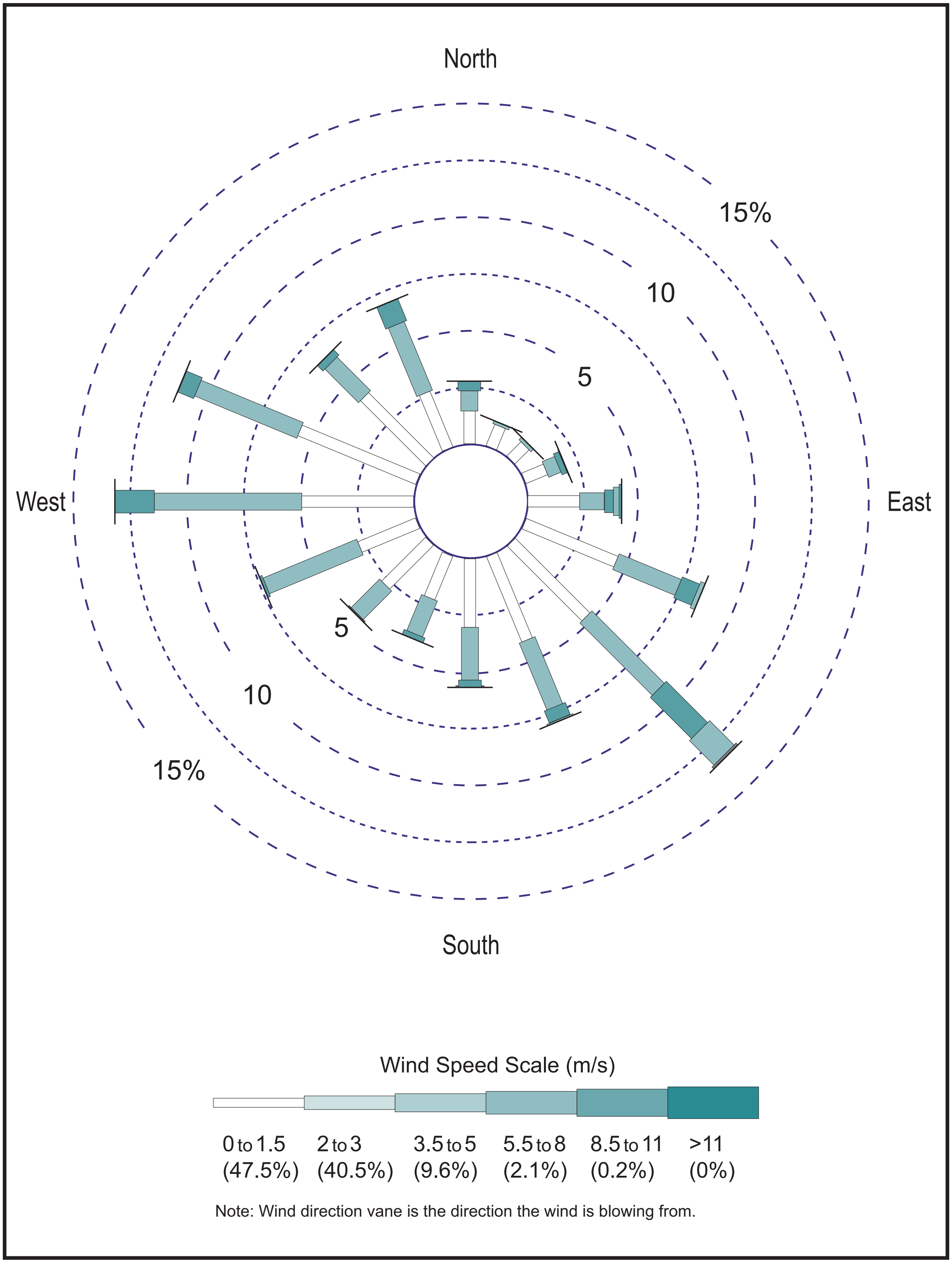

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Figure 2.4-1. Windrose Diagram for Lawrence Berkeley National Laboratory, 1998.

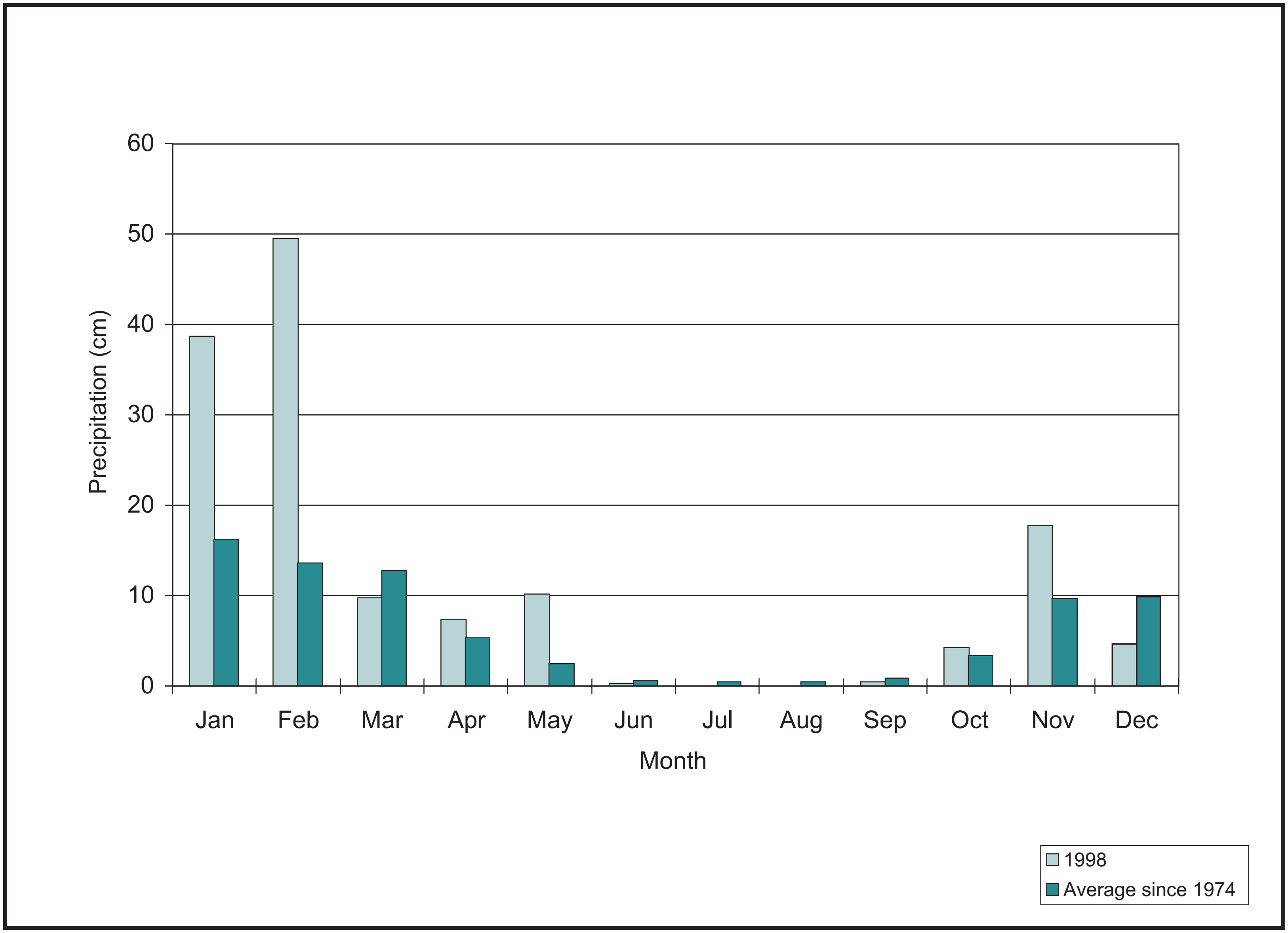

Figure 2.4-2. Precipitation Summary By Month, Lawrence Berkeley National Laboratory.

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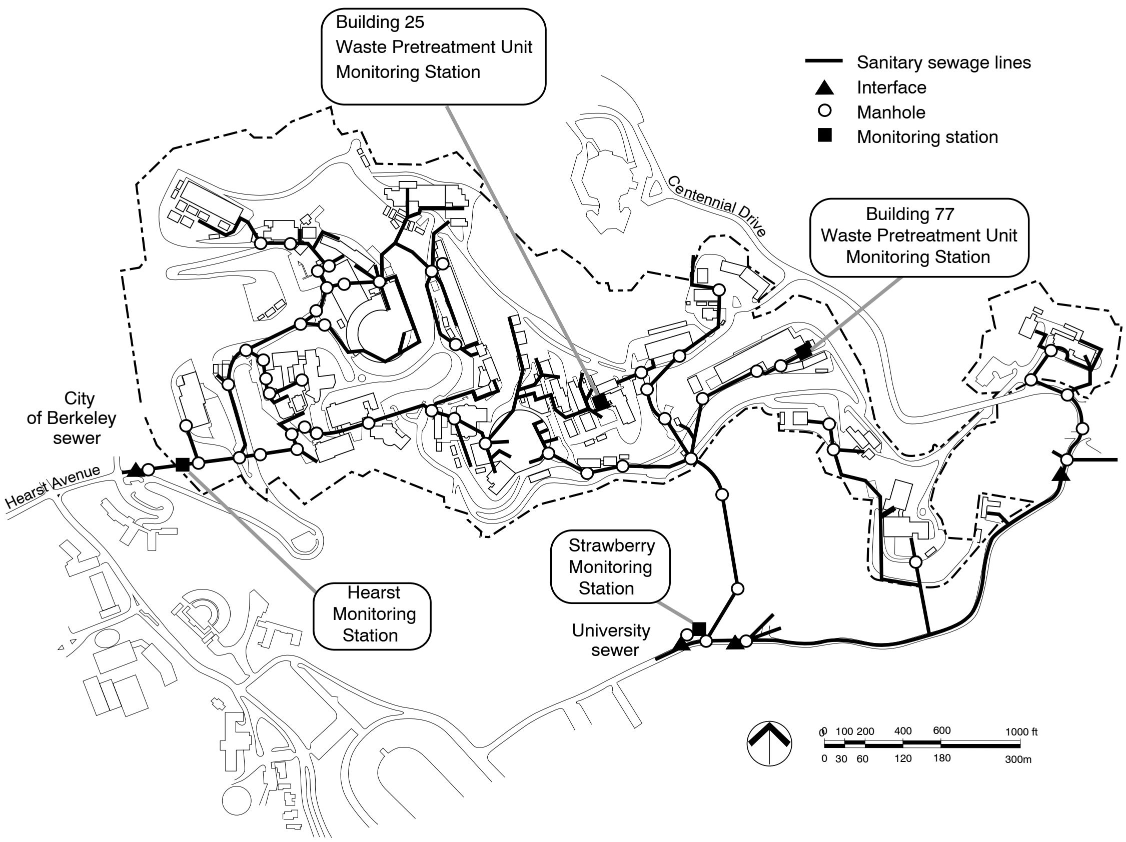

Figure 2.5-1. Sanitary Sewer System

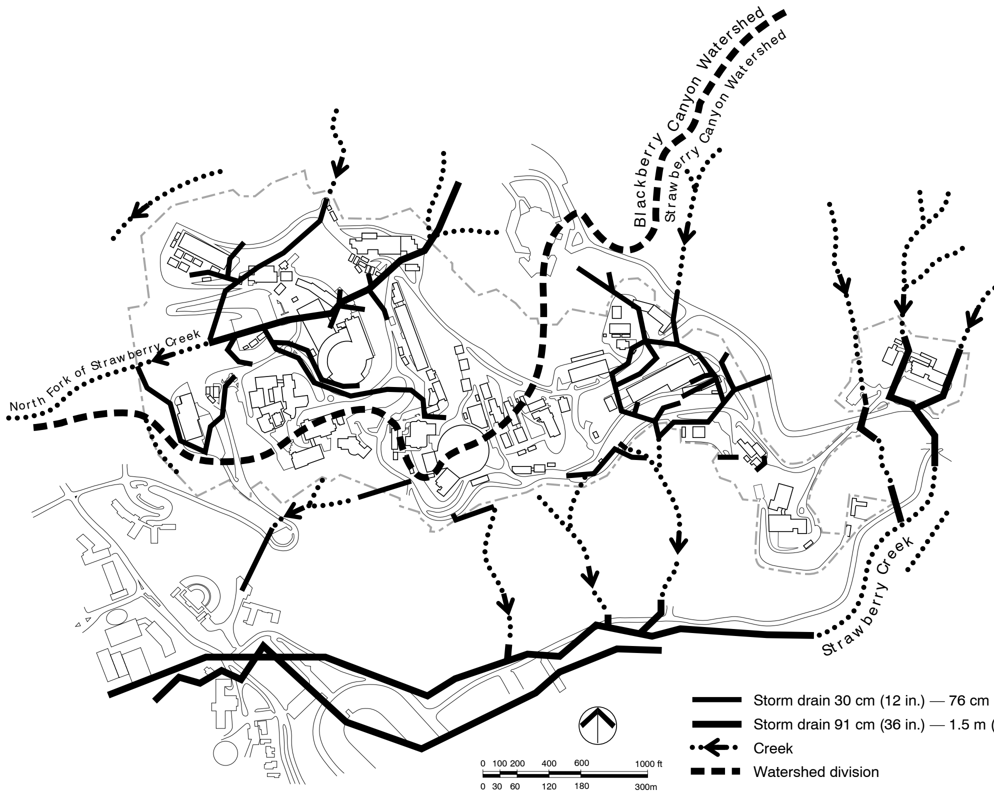

Figure 2.5-2. Stormwater Drainage in the Strawberry Creek Watershed

SECTION 3

PURPOSE AND METHODOLOGY OF INVESTIGATIONS

3.1 GUIDANCE DOCUMENTS AND PROCEDURES

3.1.1 Guidance Documents

ERP RFI activities were carried out in accordance with the following regulatory guidelines:

- California Department of Water Resources Well Standards (DWR, 1991)
- California Environmental Protection Agency Guidance Manual for Groundwater Investigations (CAL EPA, 1994a)
- California Environmental Protection Agency Guidelines for Hydrogeologic Characterization of Hazardous Substance Release Sites (CAL EPA, 1994b).

3.1.2 Program Procedures

ERP field personnel are safety trained and certified in accordance with the Code of Federal Regulations (CFR), 29 CFR 1910.120 and are part of a medical monitoring program. Required personnel protection equipment and monitoring requirements are specified in Worksite Safety Plans (WSP) prepared prior to intrusive activities at each work location.

ERP RFI activities are carried out in accordance with requirements specified in the following documents:

- Quality Assurance Program Plan (QAPP) (LBNL, 1994g)
- Health and Safety Program Plan (HSPP) (LBNL, 1993e)
- Groundwater Sampling and Analysis Plan (LBNL, 1992a)
- Specifications for Site Restoration Program Environmental Monitoring Wells and Piezometers, Supplement B of the Well Management Plan (LBNL, 1992c)
- Vadose Zone Monitoring Plan (LBNL, 1991).

Soil, surface-water, sediment, and groundwater samples were collected in accordance with LBNL ERP Standard Operating Procedures (SOPs) (LBNL, 1994j). Specific procedures utilized during RFI activities included:

SOP No.	SOP Title
1.1	Borehole Drilling
1.2	Borehole Logging
1.3	Soil Sampling
1.4	Monitoring Well Installation
1.5	Monitoring Well Development
1.6	Well Closures
1.7	Drum Sampling
2.1	Presample Well Purging
2.2	Water Sampling
2.3	Field Measurements on Surface and Groundwaters
3.1	Water Level Measurements
3.2	Aquifer (Slug) Testing
3.3	Aquifer Pumping Test
3.4	Calibration of Pressure Transducers Used in Measuring Water Levels in Wells
4.1	Sample Control and Documentation
4.2	Sample Containers, Preservation and Holding Times
4.3	Handling, Packaging, and Shipping of Samples
4.4	Equipment Decontamination
4.5	General Instructions for Field Personnel
4.6	Water Treatment Systems
4.7	Containerization and Disposal of Investigation-Derived Wastes
4.8	Data Validation.

3.1.3 Program Workplans

RFI investigation activities were specified in the RCRA Facility Investigation (RFI) Workplan (LBNL, 1992e) and subsequent workplan addenda. Requirements of the RFI Workplan were based on the findings described in the RCRA Facility Assessments (RFAs) (LBNL, 1992d; DTSC, 1991).

The RFI Work Plan (LBNL, 1992e) was submitted to DTSC and other regulatory agencies for review in November 1992. The Work Plan was an overview of all work planned for the RFI. Subsequently, more detailed workplans were completed for work planned in fiscal year 1995 (FY95) [RCRA Facility Investigation Workplan (Phase II) (LBNL, 1994k) submitted to DTSC and other regulatory agencies in October 1994] and FY96 [RCRA Facility Investigation

Workplan (Phase III) (LBNL, 1995l) submitted to DTSC and other regulatory agencies in October 1995]. In addition, the LBNL ERP submitted workplan addenda for regulatory agency review prior to the start of specific activities. The addenda contained detailed specifications of boring or monitoring well locations, sampling intervals, analytical requirements, work schedule, etc.

As part of the process, LBNL obtained well permits from the City of Berkeley for groundwater monitoring well and temporary groundwater sampling point installations or well destruction. The following addenda to the RFI Work Plan were submitted to the City of Berkeley (COB) and/or DTSC for monitoring well construction, or slope stability well abandonment or upgrading.

June 1993	Construction of monitoring wells series 93-1 to 93-12 (LBNL, 1993a)
September 1993	Abandonment and upgrading of slope stability wells, and construction of groundwater monitoring wells series 93-13 to 93-20 (LBNL, 1993d)
November 1993	Abandonment of slope stability wells SSW9-130 and SSW13-130 (LBNL, 1993g)
March 1994	Construction of monitoring wells series 94-1 to series 94-9 (LBNL, 1994b)
August 1994	Construction of monitoring wells series 94-10 to 94-16, abandoning and upgrading of slope stability wells, and soil sampling at the former Building 50 UST (LBNL, 1994f)
February 1995	Construction of monitoring wells series 95-1 to 95-10 and abandonment of slope stability well SSW-6.37 (LBNL, 1995a)
August 1995	Construction of monitoring wells series 95-14 to 95-22 (LBNL, 1995h)
November 1995	Construction of monitoring wells series 95-23 to 95-27 (LBNL, 1995m)
March 1996	Construction of monitoring wells series 96-1 to 96-9 (LBNL, 1996d)
September 1996	Construction of monitoring wells series 96-10 to 96-20 (LBNL, 1996i)
April 1997	Construction of monitoring wells series 97-1 to 97-11 and destruction of slope stability wells (LBNL, 1997f)
August 1997	Construction of monitoring wells series 97-12 to 97-23 (LBNL, 1997m)
March 1998	Construction of monitoring wells series 98-1 to 98-5 (LBNL, 1998d)
August 1998	Construction of monitoring wells series 98-6 to 98-22 (LBNL, 1998k)
February 1999	Construction of monitoring wells series 99-1 and 99-2 (LBNL, 1999f)
May 1999	Installation of temporary groundwater sampling points SB64-99-4 to SB64-99-7 (LBNL, 1999h)

June 1999	Construction of monitoring well series 99-3 to 99-5 (LBNL, 1999j)
September 1999	Installation of temporary monitoring wells (SB51L-99-1 and SB69A-99-1) and reconstruction of damaged monitoring wells (LBNL, 1999q)
November 1999	Construction of monitoring well series 99-6 to 99-8 (LBNL, 1999u)

The following addenda to the RFI Work Plans were submitted to the DTSC and other regulatory agencies for soil investigations at SWMUs and AOCs:

March 1994	Addendum to the RFI Workplan for soil investigations (LBNL, 1994c)
April 1995	Workplan for additional investigations in the Building 74-83 area (Human Genome construction site) (LBNL, 1995d)
April 1995	Addendum to the RCRA Facility Investigation Workplan (Phase II) for soil investigations at SWMUs and AOCs (LBNL, 1995c)
June 1995	Investigations at the Building 7 sump site (LBNL, 1995f)
July 1995	Second Addendum to the RFI Workplan (Phase II) (LBNL, 1995g)
March 1996	Addendum to the RFI Workplan (Phase III) Building 51 (Bevatron) Complex (LBNL, 1996e)
June 1996	Addendum to the RFI Workplan (Phase III) (LBNL, 1996g)
September 1996	Addendum to the RFI Workplan (Phase III) (LBNL, 1996j)
January 1997	Addendum to the RFI Workplan Phase (III) (LBNL, 1997a)
April 1997	Investigations for closure of the Hazardous Waste Handling Facility (LBNL, 1997h)
March 1998	Addendum to the RFI Workplan Phase (III) (LBNL, 1998d)
June 1999	Investigations at the Building 51 Motor Generator Room sump (LBNL, 1999k)
August 1999	Investigations at the Building 75 Former Hazardous Waste Handling and Storage Facility (LBNL, 1999n)
December 1999	Investigations at the Building 51 Sanitary Sewer and Drainage System in the Motor Generator Room Basement (LBNL, 1999v)
January 2000	Investigations at the Former Cooling towers Southeast of Building 51 (LBNL, 2000b)

In addition to the addenda to the RFI Work Plans submitted to the regulatory agencies for soil investigations at SWMUs and AOC and for construction of monitoring wells or abandonment or upgrading of slope stability wells, LBNL submitted the following workplans for the implementation of Interim Corrective Measures (ICMs) and pilot tests to the DTSC and other regulatory agencies:

January 1996	Interim Corrective Measures Workplan for the Old Town Groundwater Plume (LBNL, 1996b)
September 1996	Interim Corrective Measures/Pilot Test Workplan for the Former Building 7E UST (LBNL, 1996m)
July 1997	Interim Corrective Measures Workplan for the Building 7 Former Plating Shop (LBNL, 1997j)
July 1997	Interim Corrective Measures Workplan for the Building 52B Abandoned Liquid Waste Above-Ground Storage Tank (LBNL, 1997k)
January 1998	Interim Corrective Measures Workplan for the Building 51 Motor Generator Room (LBNL, 1998a)
February 1998	Interim Corrective Measures Workplan for the Building 7E Former Diesel UST (LBNL, 1998b)
March 1998	Interim Corrective Measures Workplan for the Old Town Groundwater Contamination Plume (LBNL, 1998e)
September 1998	Interim Corrective Measures Workplan for PCB removals at the Building 17 Former Scrapyard and Drum Storage Area (SWMU 2-3) and Building 75 Former Hazardous Waste Handling and Storage Facility (SWMU 3-6) (LBNL, 1998m)
August 1999	Interim Corrective Measures Workplan for the Building 51 Vacuum Pump Room (LBNL, 1999l)
October 1999	Interim Corrective Measures Workplan for the Building 51/64 Groundwater Plume (LBNL, 1999s)

LBNL prepared reports detailing the results and status of ICMs in 1996 (LBNL, 1996k) and 1998 (LBNL, 1998h).

3.1.4 Laboratory Procedures

Analytical laboratories used by the ERP are required to be certified by the California Department of Health Services (DHS) under the California Environmental Laboratory Accreditation Program (ELAP). Laboratory quality control procedures are specified in the LBNL Quality Assurance Program Plan (LBNL, 1994g) and include the analysis of method blanks and spike samples according to protocols established for specific USEPA Methods.

Soil and groundwater analyses primarily included the following USEPA methods:

Constituent	EPA Method
Volatile organic compounds (VOCs)	8260
Metals	7000 series
Semi-volatile organic compounds (SVOCs)	8270
Polychlorinated biphenyls (PCBs)	8080 or 8082
Polynuclear aromatic hydrocarbons (PAHs)	8310
Total Petroleum Hydrocarbons (TPH)	8015M

Samples were analyzed for metal concentrations in accordance with the California Code of Regulations (CCR) Title 22 California Assessment Manual (CAM). Analytes include antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc (Title 22 metals or CAM 17 metals).

3.2 GENERAL DESCRIPTION OF RFI FIELD ACTIVITIES

3.2.1 Soil Investigations at SWMUs and AOCs

The objectives of soil investigations were to:

- assess whether chemical releases had occurred at SWMUs or AOCs
- identify released chemicals, their concentration, and extent of contamination in the soil
- identify immediate threats to human health and the environment
- provide and document data in support of the CMS.

The primary method used to achieve these objectives was to collect soil samples for chemical analysis. Shallow soil samples (less than 5 feet) were generally collected using a decontaminated soil drive-sampler loaded with a 6-inch long brass liner. Samples deeper than 5 feet were obtained from boreholes which were generally drilled using a truck mounted drilling rig, using hollow-stem augers. Where the borehole location was not accessible to a truck mounted drilling rig, alternative drilling methods such as portable hydraulic drilling equipment was used. Soil samples were generally obtained from borings for chemical analysis at 5- or 10-foot intervals using a Modified California split-spoon sampler, lined with three 6-inch long, 2-inch outside diameter (OD) brass liners.

Soil samples were also collected from borings drilled for geological investigations and construction of monitoring wells. Where the monitoring well was located near a SWMU or AOC, samples were analyzed in accordance with potential contaminants from that unit. In addition, soil samples were collected at construction sites to assist the LBNL Facilities Department in determining requirements for disposal or reuse of excavated soil, potential health and safety requirements, and other restrictions that might be imposed on construction because of potential contaminants. Analytical results from these subsidiary investigations provided supplemental information on the extent and magnitude of soil contamination.

The physical characteristics and composition of the soil and rock, drilling details, sampling information, and well construction details were recorded on Exploratory Boring Log forms. Descriptions were recorded in a format similar to that described in ASTM Method D2488-90, "Standard Practice for Description and Identification of Soils (Visual -Manual Procedure)" and described in the ERP SOP 1.2 (Borehole Logging).

Soil samples were also collected in conjunction with UST removals under the supervision of the LBNL Environmental Protection Group, with oversight from the City of Berkeley Emergency and Toxics Management Program. UST removals and initial soil sampling and excavation were conducted by LBNL subcontractors. The subcontractors submitted closure reports containing sample analytical results to the City of Berkeley. UST sites that did not receive closure approval based on the data in the tank removal reports were maintained as active AOCs. Additional site characterization and soil excavation, where required at these sites, was conducted under the supervision of the LBNL ERP and are reported in this document.

3.2.2 Hydrogeological Investigations

The objectives of the hydrogeological investigations were to:

- locate the source and characterize the extent of groundwater contamination
- determine the hydrogeologic properties that affect the movement of groundwater and groundwater contaminants
- identify preferential flow pathways
- evaluate if intrinsic degradation is occurring

- identify potential beneficial uses of groundwater
- evaluate potential Interim Corrective Measures for groundwater remediation.

Information required for the hydrogeolgic investigations was primarily obtained from the installation and sampling of groundwater monitoring wells. Shallow soil gas samples and grab water samples from geological borings were also utilized to help characterize the extent of groundwater contamination and determine the need and location for the installation of new monitoring wells. In addition, hydrogeologic testing, measurements of groundwater elevations, and measurements of the physical and chemical characteristics of the groundwater were utilized to help achieve the above listed objectives.

Installation and Sampling of Groundwater Monitoring Wells

Groundwater monitoring well construction details are provided in Table 3.2-1a and Table 3.2-1b (by Module). Groundwater monitoring wells were installed to:

- evaluate the source and characterize the magnitude and extent of groundwater contamination
- monitor groundwater quality downgradient from the developed areas of the site and downgradient from areas of known contamination
- monitor groundwater quality at, and downgradient from, SWMUs and AOCs to assess if releases had occurred
- provide data for evaluating the potential for future contaminant migration.

Monitoring wells were generally installed using a truck mounted drilling rig and 8.5-inch OD hollow-stem augers. Where the proposed well location was not accessible to a truck-mounted drilling rig, portable hydraulic drilling equipment was used.

Groundwater samples were collected in accordance with SOP 2.1 “Presample Well Purging” and SOP 2.2 “Water Sampling.” Duplicate groundwater samples were collected from all new monitoring wells and analyzed for VOCs, Title 22 metals, and other potential contaminants as indicated in the RFI Work Plan (LBNL, 1992e) or identified during the RFI.

The groundwater monitoring program at LBNL originally consisted of quarterly sampling for VOCs by EPA Method 8260 and annual sampling for Title 22 metals in all monitoring wells.

LBNL requested approval for a modified sampling schedule in 1994 based on the location and historical results from the well (LBNL, 1994m and 1994d). The revised schedule consisted of reducing the frequency of sampling for VOCs to semiannually in selected site wells, and eliminating the requirement for annual sampling for metals in all wells except perimeter and offsite wells, and wells where elevated concentrations of metals had been detected in groundwater or soil. The RWQCB approved the revised schedule (RWQCB, 1995a).

LBNL requested approval from the RWQCB for modifying the sampling schedule again in March 1997 (LBNL, 1997e) and in June 1999 (LBNL, 1999i). The revised sampling schedules were approved by the RWQCB (RWQCB, 1997 and 1999a). The rationale for the schedule was as follows:

Sampling for VOCs

- Perimeter wells will remain on a quarterly schedule.
- Groundwater monitoring wells downgradient from VOC plumes and monitoring wells located in the interior of plumes will be sampled quarterly.
- Groundwater monitoring wells located along the upgradient and transgradient edges of VOC plumes will be sampled semi-annually.
- Some wells will remain on a quarterly schedule to document variations in specific chemical concentrations.
- Wells that duplicate the function of adjacent wells will be monitored annually.
- Wells outside plume areas where contaminants have either not been detected or detected only sporadically will be monitored annually.

Sampling for Metals

- Wells where metals are confirmed at concentrations at, or above, Maximum Contaminant Levels (MCLs) for drinking water will be monitored annually.
- Wells where metals are confirmed at concentrations greater than 50% of MCLs, or confirmed at relatively high values where no MCL has been specified (e.g. molybdenum > 100 μg/L), will be monitored annually.
- Wells where metal contamination has been detected in soil near the well will be monitored annually.

Results of groundwater sampling are discussed in detail in Modules A through D.

Hydrogeological Testing

Hydrogeological testing was performed to help evaluate the rate and direction of contaminant migration in the groundwater and the potential effectiveness of alternatives for groundwater remediation. Parameters required for hydrogeologic characterization include the hydraulic conductivity, which indicates the capacity of the medium to transmit water; transmissivity, which is the rate at which water is transmitted; hydraulic gradient, which controls the direction and velocity of groundwater flow; and storativity, which is the volume of water that can be stored or released. Single well hydraulic tests (slug tests), multi-well pumping tests, and tracer tests were conducted at LBNL to attempt to estimate values of these parameters. In addition, groundwater elevations were measured to determine groundwater gradients.

Details of the hydrogeological testing are provided in Section 4.3. Results of the hydrogeolgical testing are included in the discussions on hydrogeology in Modules A through D, where the information is presented for specific areas of the site.

Hydraulic Conductivity and Storativity

Transmissivity and storativity were estimated using single-well hydraulic tests (slug or bail test) and, to a limited extent, multi-well (interference) pumping tests. Hydraulic conductivity was calculated by dividing the transmissivity by the saturated thickness of the aquifer. For slug tests, the saturated well screen length was used as an approximation of the saturated thickness, since the thickness of the aquifer is generally not known. For pumping tests, the distance between the water table and the Moraga/Orinda Formation contact (bottom of hydrogeologic unit) was used to approximate the saturated thickness.

Single-well hydraulic tests (slug tests) were performed to estimate the hydraulic conductivity in the immediate vicinity of site monitoring wells. After an "instantaneous" known volume of clean water was added to the well, changes in the water level were measured continuously using a pressure transducer and recorded automatically on a data-logger. A computer code, AQUITEST, was used to calculate the hydraulic conductivity of the geologic materials exposed to the sand pack around the well screen based on the slug test data. The code uses an analytical solution to calculate the variation of the water level through time assuming initial values of the hydraulic conductivity and specific storage. The program then compares the calculated results with the observed slug test data, alters the values of the hydraulic conductivity and specific storage, and recalculates the water level variation until a "best-fit" to the data is found. The solutions assume radial flow in a confined aquifer away from a fully penetrating well (Cooper *et al.,* 1967).

Pumping tests are generally not practical at LBNL since most site wells cannot produce enough water to generate a detectable drawdown within a reasonable period of time in nearby observation wells. This limited radius-of-influence of pumping is due to the low permeability of Orinda Formation rocks that underlie wide areas of the site. However, pumping tests have been successfully performed in wells screened in the more permeable Moraga Formation. Pumping tests were conducted by pumping groundwater from a well at a constant rate and recording the water-level drop (drawdown) in the pumping well and in nearby observation wells using pressure transducers and a data logging computer. The recovery of water levels in the wells was monitored after the tests were completed. The hydraulic conductivity and storativity of the aquifer were calculated using a numerical code, AQTESOLV, which is based on a modified Theis solution that may account for either vertical leakage (Neuman, 1975) or well bore storage (Papadopulos, 1967).

Hydraulic Gradient and Groundwater Flow

Depth to water from the top of the casing is measured monthly in all site monitoring wells using water-level meters. The top of casing elevations of all site wells have been surveyed in order to accurately determine water level elevations. The water levels are used to produce piezometric maps of the site, which show contours of equal hydraulic potential. In a homogeneous isotropic medium, groundwater flow is perpendicular to the equal hydraulic potential contour lines. The hydraulic gradient, which is the change in the hydraulic potential for a given flowpath distance, can be used to calculate groundwater flow velocities.

Tracer tests were conducted to help evaluate contaminant migration pathways and rates of migration. As discussed in the following section, the applicability of tests results was limited since breakthrough of the tracer was generally not observed. Tracer tests were conducted by injecting water with a distinguishing signature (tracer) into a well and monitoring downgradient wells for its arrival. Several different tracers were used, including fluorescent dye, lithium bromide, and oxygen-18 and chloroform (signatures of drinking water).

Measurement of temperature, electrical conductivity, and concentrations of inorganic constituents (minerals) were used to help characterize groundwater flow fields, areas of recharge, and areas of discharge. The temperature and electrical conductivity of groundwater were measured monthly in all site monitoring wells until September 1994. After September 1994, temperature and electrical conductivity were only measured in new monitoring wells for the first three months after installation. Mineral concentrations were measured in samples collected from all monitoring wells. Analytes included: calcium, magnesium, sodium, potassium, hydroxide, carbonate, bicarbonate, chloride, sulfate, nitrate (nitrite as NO_3), pH, electrical conductivity (EC), total dissolved solids (TDS), calculated hardness (as $CaCO_3$), and alkalinity (as $CaCO_3$).

Groundwater can be classified according to anion and cation type and anion and cation facies as determined by the position of the mineral constituents on the quadrilateral field of a Piper diagram (Piper, 1944). Classifying groundwater samples on a Piper diagram can help differentiate groundwaters with different mineral constituents and thereby identify areas of recharge, mixing, or discrete groundwater bodies.

3.2.3 Surface Water and Sediment Investigations

Surface water and sediment samples were collected to provide information on the migration of contaminants. Surface water and sediment samples were collected from North Fork Strawberry Creek and several subsidiary creeks that drain into the main fork of Strawberry Creek: Botanical Garden Creek, Cafeteria Creek, Chicken Creek, No Name Creek, Ten-Inch Creek, and Ravine Creek. These creeks transport runoff from the LBNL site. The locations of these creeks are shown on Figure 3.2-1. Water samples were also collected from LBNL hydraugers (subhorizontal drains installed in unstable hillsides to prevent landsliding). In addition, a limited number of sediment samples were collected from storm drain catch basins, primarily in areas of known contamination. Surface water samples were periodically analyzed for VOCs and metals. Sediment samples were generally analyzed for SVOCs and metals. Selected samples were analyzed for specific contaminants of concern associated with SWMUs and AOCs upflow of the drainages. Results of surface water sampling are discussed in detail in Modules A through D.

3.2.4 Geological Investigations

The purpose of the geological investigations was to characterize the geometry and hydrogeological properties of the geological formations underlying LBNL, in order to evaluate potential migration pathways for groundwater contamination and to provide input for modeling contaminant fate and transport, if required. The migration and fate of contaminants are largely influenced by the physical characteristics (e.g. porosity, permeability, fracture spacing and connectivity, fracture aperture, sorption properties, etc.) and structural geometry of subsurface materials. In this regard, the primary controls on the migration and fate of contaminants at LBNL are the high contrast in physical properties between rocks of the Moraga and Orinda Formations and the geometry of the contact between the two formations.

The geologic investigations at LBNL focused on areas with known or potential importance to contaminant investigations. Sources of data used in the geological investigations included:

- available LBNL geotechnical data and historical records
- borehole logs
- geologic maps
- published literature
- aerial photographs.

Details of the geological investigations are provided in Section 4.2 on a site wide basis. Information on the geology is also included on an area specific basis in Modules A through D.

Records Search

Regional geologic studies of the area presently occupied by LBNL date back to at least 1900 (Lawson and Palache, 1900). These studies were reviewed for information pertaining to stratigraphic nomenclature and the geometry of regional geologic structures such as faults.

Maps of the topography and facility layout of LBNL for the last 70 years are available from the Facilities Department at LBNL. Preconstruction maps were examined to assess potential contaminant migration pathways such as the locations of former creek beds. Aerial photographs from a variety of sources, including LBNL's Facilities Department, the National Archives, and private aerial photography vendors were also reviewed to aid in structural interpretations.

LBNL Photographic Services maintains an archive of all photographs since the inception of the lab in 1944. A portion of the construction progress photographs from this archive were reviewed to obtain geologic information from historical excavations.

The Civil Engineering section of the Facilities Department at LBNL maintains a file system containing over 300 geotechnical reports that contain borehole logs, trench logs, geologic maps, and written descriptions of the geology and hydrogeology. These reports have been prepared for design of foundations of new facilities, to establish criteria for site grading, and to address slope stability and seismic concerns.

RFI Drilling

Several hundred borings for monitoring well installation, soil investigations at SWMUs and AOCs, and geological studies were drilled and logged during the RFI. These data, together with the geologic information in previous geotechnical reports, were used to prepare the geologic cross sections and structure contour maps presented in this report.

Geologic Mapping

Bedrock and surficial geologic maps were prepared for the site, although it should be noted that about 90% of the ground surface at LBNL is covered by soil. ERP geologists mapped most outcrops at LBNL, focusing particularly on areas where contamination was a concern. This information was supplemented by logs of recent construction excavations.

Petrographic and Mineralogic Analyses

Soil and rock samples were collected at LBNL during drilling, excavation logging, and geologic mapping. Rock samples were also collected from outcrops adjacent to LBNL. Selected samples that were not required for chemical analysis have been archived as representative of the lithologies at LBNL.

Selected archive samples were examined in thin section to refine general lithologic descriptions and to help resolve uncertainties in stratigraphic identification that arose during borehole logging. Petrographic analysis focused on mineralogical composition, clast size distribution and sorting, and textural features such as fracturing and brecciation. The petrographic descriptions have been tabulated and archived, along with the thin sections and rock samples.

3.2.5 Vadose Zone Investigations

Vadose Zone Monitoring Systems

A vadose zone monitoring system was installed in the source area for Old Town Plume groundwater contamination adjacent to the former location of the Building 7 sump (AOC 2-5) (OT Site). The purpose of the system was to provide information on the following parameters, which relate to contaminant fate and transport, and how they changed over time:

- the distribution of moisture content, the vertical direction of water flow, and the location of perched water zone(s)
- types and concentrations of contaminants in the liquid (soil water) phase, the vapor (soil gas) phase, and the adsorbed state
- vertical extent to which contaminants have migrated in each of these phases; and pathways for contaminant migration.

Two 12-inch boreholes (OT1 and OT2) were installed with vacuum lysimeters (soil-water samplers), soil-gas samplers (OT2 only), and tensiometers (to measure water pressure).

The instrumentation was nested at several depths inside boreholes and the instrumented intervals were isolated with bentonite seals. Monitoring equipment was installed at one depth in OT1 (below the groundwater table), and seven depths in OT2. Instrumentation depths were selected based on the stratigraphy encountered during drilling and the results of psychrometer (water-potential measurements). An attempt was made to instrument each major lithological unit. Neutron access tubes were also installed at each site to monitor changes in soil-moisture content.

Soil Gas Sampling

Soil gas samplers were installed to help locate the sources of groundwater contamination, assess the extent of groundwater contamination, and/or provide data for locating groundwater monitoring wells. Soil gas samplers consisted of shallow probes constructed of either 3/4 inch inside-diameter (ID) steel pipes that were driven into the ground (soil-gas monitoring points) or 1/2 inch slotted polyvinyl chloride (PVC) pipes placed in boreholes (soil-gas monitoring wells). The monitoring points were generally driven approximately 5.5 feet below ground surface (bgs) and then the drive tips were advanced below the bottom of the pipe to allow soil gas to enter the probe. The slotted sections of the monitoring wells were backfilled with permeable sand sections and the remainder of the hole backfilled with bentonite grout. Monitoring wells were placed at various depths, and in four cases in multi-level arrays, depending on the sampling objective. Prior to sampling, probes were purged using a photoionization detector (PID) equipped with a sampling pump. PID readings were monitored during purging, and at selected locations, samples were collected for laboratory analysis. Laboratory samples were generally collected immediately after stabilization of PID readings.

3.2.6 Air Sampling

Outdoor and indoor air samples were collected to provide data that will be required for the human health risk assessment. Samples were collected in six-liter stainless-steel canisters (summa canisters). The canisters were cleaned and certified to the 0.1 parts per billion by volume (ppbv) level. Canisters were equipped with a particulate filter and flow controller calibrated to a 24-hour sampling period. Samples were analyzed for specific VOCs using EPA

Modified Method TO-14. Results of the outdoor and indoor air sampling are discussed on an area specific basis in Modules A through D.

Outdoor Air Sampling

Outdoor air samples were collected at ten locations, including upwind and downwind of the principal areas of groundwater contamination. Site selection was based on historical wind patterns. Samples were collected approximately 5 feet above the ground surface (in the approximate breathing zone). Outdoor air samples were analyzed for the following six compounds:

- tetrachloroethene (PCE)
- trichloroethene (TCE)
- carbon tetrachloride
- chloroform
- Freon-113
- vinyl chloride.

These compounds were selected for monitoring since they are the most prevalent and/or the most toxic of the VOCs detected in groundwater and soil at the site. They are also representative of the range of relative vapor densities and Henry's Law Constants of the VOCs detected at the site. The monitoring was completed over a weekend, when laboratory activity is at a minimum, in order to reduce potential impact from on-site activities.

Indoor Air Sampling

Indoor air samples were collected in 21 LBNL buildings, including one background location. The summa canisters were placed at a height between 3 and 7 feet above the floor on the lowest level of each building, at locations where the least amount of chemical handling might occur. The sampling duration for most of the sites was extended past 24 hours to achieve the laboratory-recommended < 5 inches of mercury (" Hg) vacuum pressure, requisite for the requested low detection limits.

Indoor air samples were analyzed for the following seven compounds:

- tetrachloroethene (PCE)
- trichloroethene (TCE)
- benzene
- 1,1-dichloroethene (1,1-DCE)
- carbon tetrachloride
- chloroform
- vinyl chloride.

These chemicals are among the most commonly detected in soil gas and potentially most toxic should their vapors infiltrate into buildings. Two other chemicals (1,1,1-trichloroethane [1,1,1-TCA] and 1,1-dichloroethane [1,1-DCA]) were monitored at Building 64 because high concentrations of these chemicals had been detected in the groundwater and soil in that area.

3.2.7 Natural Biodegradation of Contaminants in Groundwater

A preliminary assessment of the natural biodegradation of halogenated hydrocarbons in groundwater was completed. The purpose of the evaluation was to provide information on the transport and fate of contaminants in the groundwater. Results of the assessment are included in discussions of specific groundwater plumes, where applicable, in Modules A through D. The natural biodegradation of organic chemicals can occur when indigenous (naturally occurring) microorganisms capable of degrading the chemicals are present and sufficient concentrations of nutrients, electron acceptors, and electron donors are available to the microorganisms. Under favorable conditions, highly chlorinated hydrocarbons such as PCE, TCE, and 1,1,1-TCA will biodegrade to less chlorinated compounds (i.e., DCE, DCA and vinyl chloride) (Figure 3.2-2).

Microorganisms obtain energy for growth and activity from oxidation and reduction reactions (redox reactions). Redox reactions involve the transfer of electrons to produce chemical energy. Oxidation is a reaction where electrons are lost (from an electron donor) and reduction is the reaction where electrons are gained (by an electron acceptor). During natural biodegradation, a carbon source typically serves as the primary growth substrate (food) for the microorganisms, and is the electron donor that is oxidized. The carbon source can include natural organic carbon or anthropogenic (man-made) carbon such as fuel hydrocarbons. Electron acceptors can be elements or compounds occurring in relatively oxidized states such as oxygen, nitrate, sulfate, ferric iron, and carbon dioxide.

Natural biodegradation of organic compounds causes measurable changes in groundwater geochemistry. The indicator parameters of the redox reactions, including metabolic byproducts can be measured. The following factors indicate conditions favorable for biodegradation:

- Dissolved oxygen (DO) less than 0.5 mg/L
- Nitrate less than 1.0 mg/L
- Sulfate less than 20 mg/L
- Divalent manganese and ferrous iron greater than 1 mg/L
- Low values of the Oxidation-Reduction Potential (ORP).

Groundwater samples were collected from selected areas of LBNL and analyzed for specific indicator parameters (i.e., electron acceptors and metabolic byproducts) to assess whether biodegradation could have occurred in the past or might occur in the future. Results of the sampling are discussed in Module A (Bevalac Area).

3.3 GROUNDWATER USE

3.3.1 Beneficial Uses

The East Bay Plain Groundwater Basin (East Bay Plain) is located along the eastern shore of San Francisco Bay. The basin is 2 to 7 miles wide and includes portions of several East Bay cities including Berkeley and Oakland. The Hayward Fault, which traverses the extreme western portion of the LBNL site, forms the eastern boundary of the basin. The ultimate points of discharge of groundwater in the East Bay Plain are surface water bodies including streams, lakes, and San Francisco Bay.

Some groundwater at the western edge of LBNL in Great Valley Group rocks may be a source of recharge for the East Bay Plain Groundwater Basin. This is outside the area of groundwater AOCs. The San Francisco Bay Basin Water Quality Control Plan (RWQCB, 1995b) identifies existing beneficial uses of East Bay Plain groundwater as municipal and domestic water supply, industrial process water supply, industrial service water supply, agricultural water supply, and possibly freshwater replenishment supply.

Currently, groundwater is not used for drinking water at LBNL or UCB. Except for the City of Hayward, water service to cities in the East Bay Plain is provided by the East Bay Municipal Utility District (EBMUD). According to the RWQCB's review of General Plans for several East Bay cities, including Oakland and Berkeley, there were no plans to develop local groundwater resources for drinking water purposes, because of existing or potential salt water intrusion, contamination, or poor or limited quantity (RWQCB, 1999c). Future potential uses include the use of the Basin's deep aquifers for storage of surface water imported by EBMUD for use during drought or earthquake.

Within the East Bay Plain, the RWQCB identified the Berkeley Sub-Area Groundwater Management Zone as Zone B (RWQCB, 1999a). The RWQCB report noted that groundwater extraction for municipal drinking water supply is unlikely in the Berkeley Sub-Area due to the relatively thin aquifer. "Accordingly, remedial strategies should be focussed on actively protecting existing domestic irrigation and industrial uses and potential aquatic receptors rather than as a municipal drinking water supply".

3.3.2 Well Survey

LBNL completed an off-site well survey in 1993 to locate off-site wells and to assess uses of groundwater in the vicinity of LBNL (LBNL, 1993i). The primary data source for well information was the Alameda County East Bay Plain Well Inventory Report. This source was updated with a listing of wells obtained in January 1993 from the State of California Department of Water Resources (DWR) for wells constructed within approximately 1 mile of LBNL since 1980. The locations of the wells identified during the survey are shown on Figure 3.3-1. The current status of the listed wells (whether they are still in use) has not been confirmed.

According to the survey, only two wells listed as installed for domestic purposes are located within approximately 1 mile of LBNL (1S/3W 6N2 and 1S/3W 6N3). These wells are located approximately 0.8 miles south of LBNL near the Oakland/Berkeley border. Three irrigation wells (1S/3W 7E2 & 1S/3W 7E3 and 1S/4W 12H2) and one well listed as "household (domestic) including residential agriculture" (1S/4W 12H1) are located approximately 1.4 miles south of LBNL. Eight other wells used for domestic purposes are located approximately 2 to 3 miles south or southeast of LBNL. No wells for domestic use were listed in the City of Berkeley downgradient of LBNL. Several wells listed for irrigation use are located downgradient of LBNL.

EBMUD has a database of well owners in its area for their Backflow Prevention Program. Backflow devices are installed at houses with a well, regardless of whether the well is in use or tied to the customer's water system. A map of locations of well owners with well backflow prevention devices was provided in the 1999 RWQCB report (RWQCB, 1999b). The nearest well with a backflow prevention device is approximately ½ mile west of LBNL. There are also eight wells with backflow prevention devices approximately 1 mile from LBNL.

3.4 EVALUATION OF POTENTIAL MIGRATION PATHWAYS AND RECEPTORS

A conceptual model of potential contaminant migration pathways and receptors is presented on Figure 3.4-1. The potential migration pathways are listed in the following table, together with the methodology that was utilized for their evaluation.

Evaluation of Potential Contaminant Migration Pathways

Potential Migration Pathway	RFI Evaluation Methodology
Contaminants originating from a surface spill or subsurface leak would move vertically (downward) and laterally through the vadose zone either as product or dissolved in soil moisture. Contaminants in groundwater could partition to soil in the saturated zone. Contaminants in soil gas could partition to soil in the vadose zone	Soil samples were collected to characterize the horizontal and vertical extent of soil contamination.

Contaminants in the vadose zone could volatilize to soil gas and be released to the air. Contaminants in groundwater could volatilize to soil gas and be released to the air.	Air samples were collected to assess concentrations of contaminants in indoor and outdoor air.
Contaminants could be transported to surface water either as the direct result of sheetflow or flow into the storm drain system.	Surface water and sediment samples were collected to assess the magnitude and extent of contamination in sediment and surface water downflow from areas of contamination.
Contaminants in hydrauger effluent and springs could be transported to surface water.	Water samples were collected from the Building 71 spring and hydrauger effluent. Contaminated hydrauger discharges are treated. Surface water and sediment samples were collected from downflow areas
Percolation of soil water could transport contaminants to groundwater. Groundwater could be transported to surface water.	Water samples were collected from groundwater monitoring wells and temporary groundwater sampling points to assess the magnitude and extent of contamination. Monitoring wells were also installed downgradient from areas of groundwater contamination to assess plume migration.
Soil contamination could be transported as dust.	Soil samples were collected to characterize the horizontal and vertical extent of soil contamination.

Current potential human receptors are indoor (office and laboratory) workers and outdoor construction and maintenance workers. Future hypothetical human receptors are on-site and nearby residents, recreators, indoor workers and construction workers. There are currently no residents on-site; however, future land use could potentially include residential development, although this scenario is unlikely. Potentially complete exposure pathways and associated human receptors will be developed more fully in the Human Health and Ecological Risk Assessment and Assumptions Document that will be completed as part of the CMS workplan. Potentially complete exposure pathways for ecological receptors and the associated ecological receptor will also be developed in that document.

LIST OF FIGURES

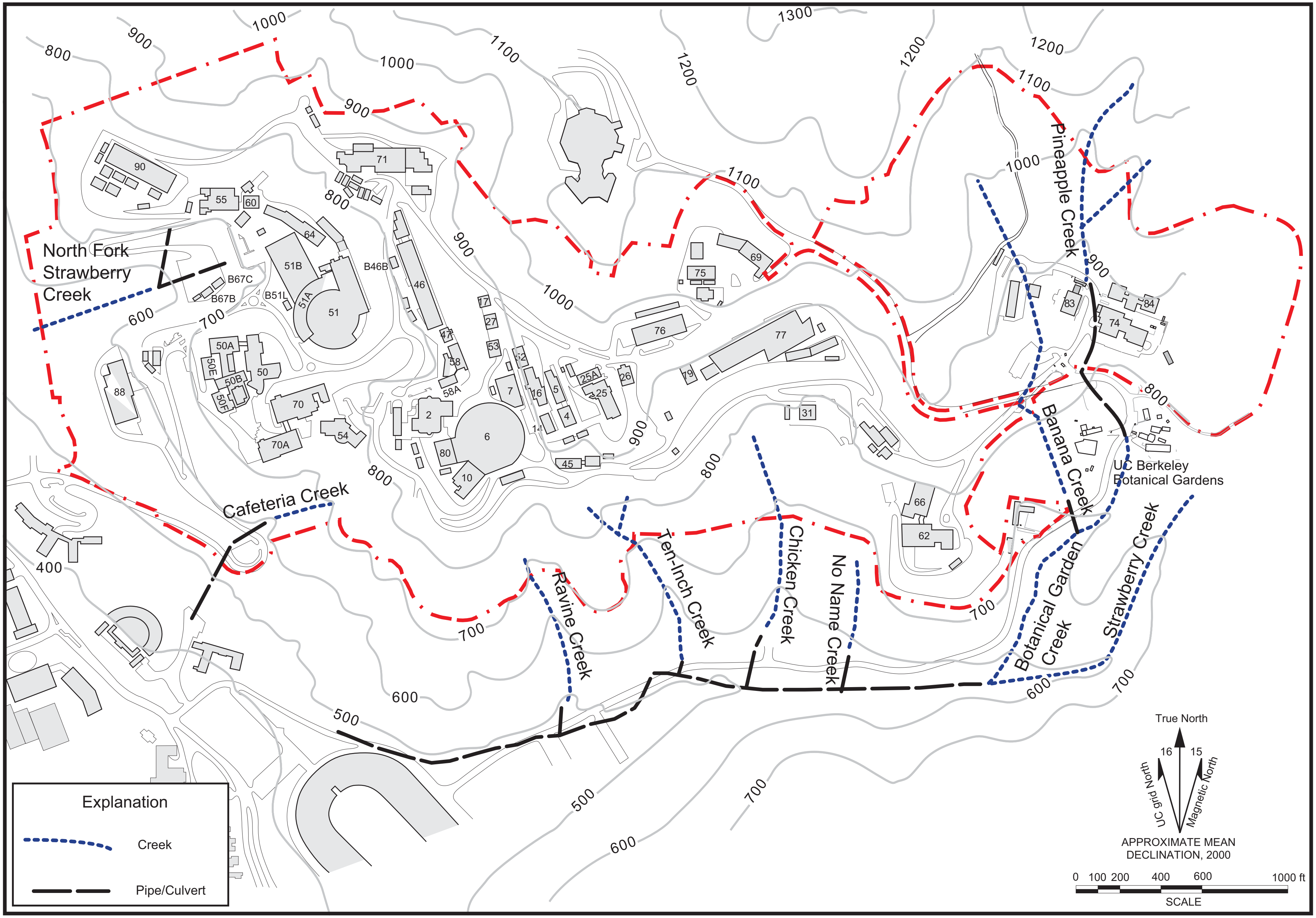

Figure 3.2-1. Location of Creeks, Lawrence Berkeley National Laboratory.

3..2-1 Creek&Surf.ai
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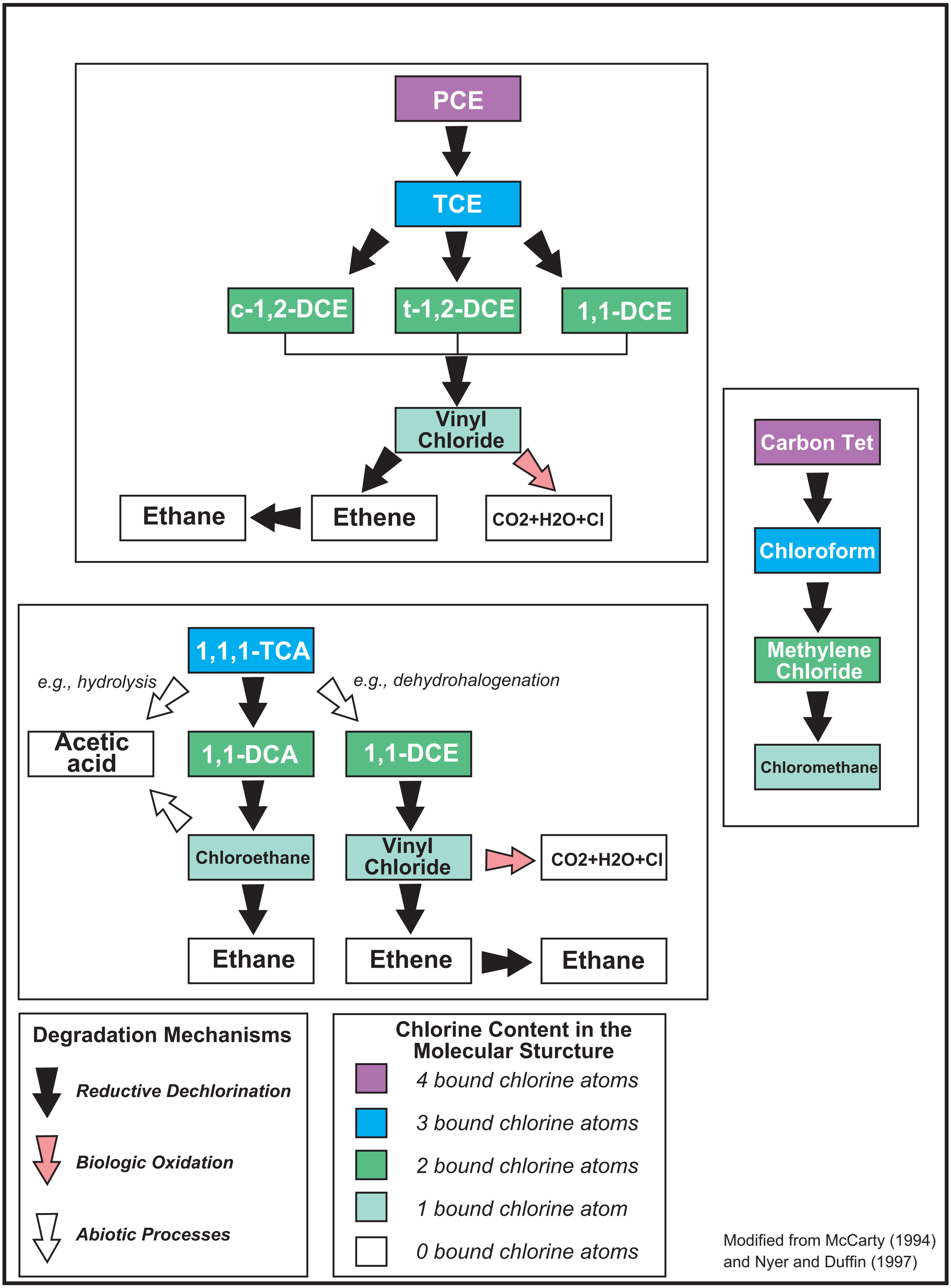

Figure 3.2-2. Generalized Degradation Pathways of Chlorinated Hydrocarbons.

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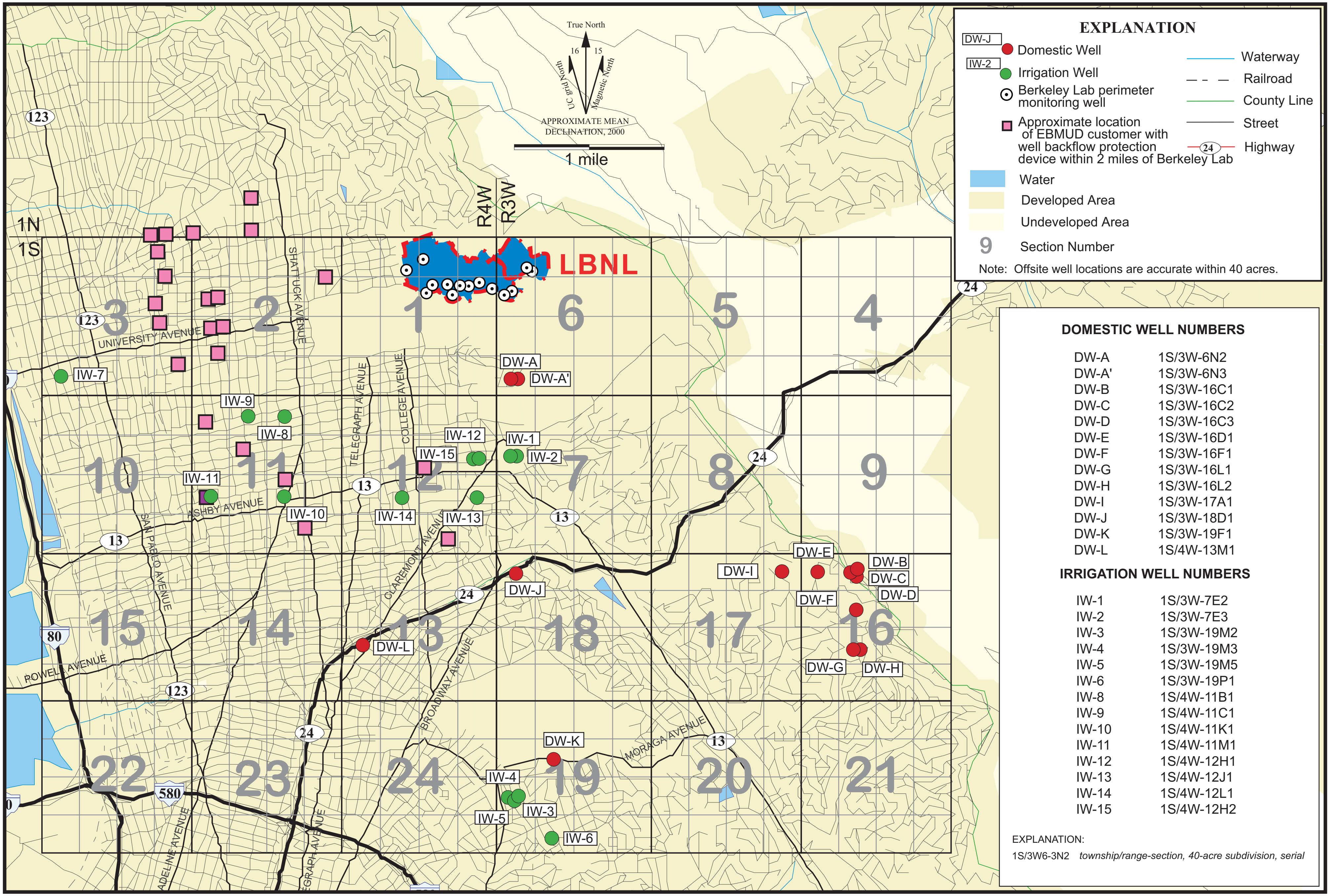

Figure 3.3-1. Locations of Wells in the Areas Surrounding Lawrence Berkeley National Laboratory.

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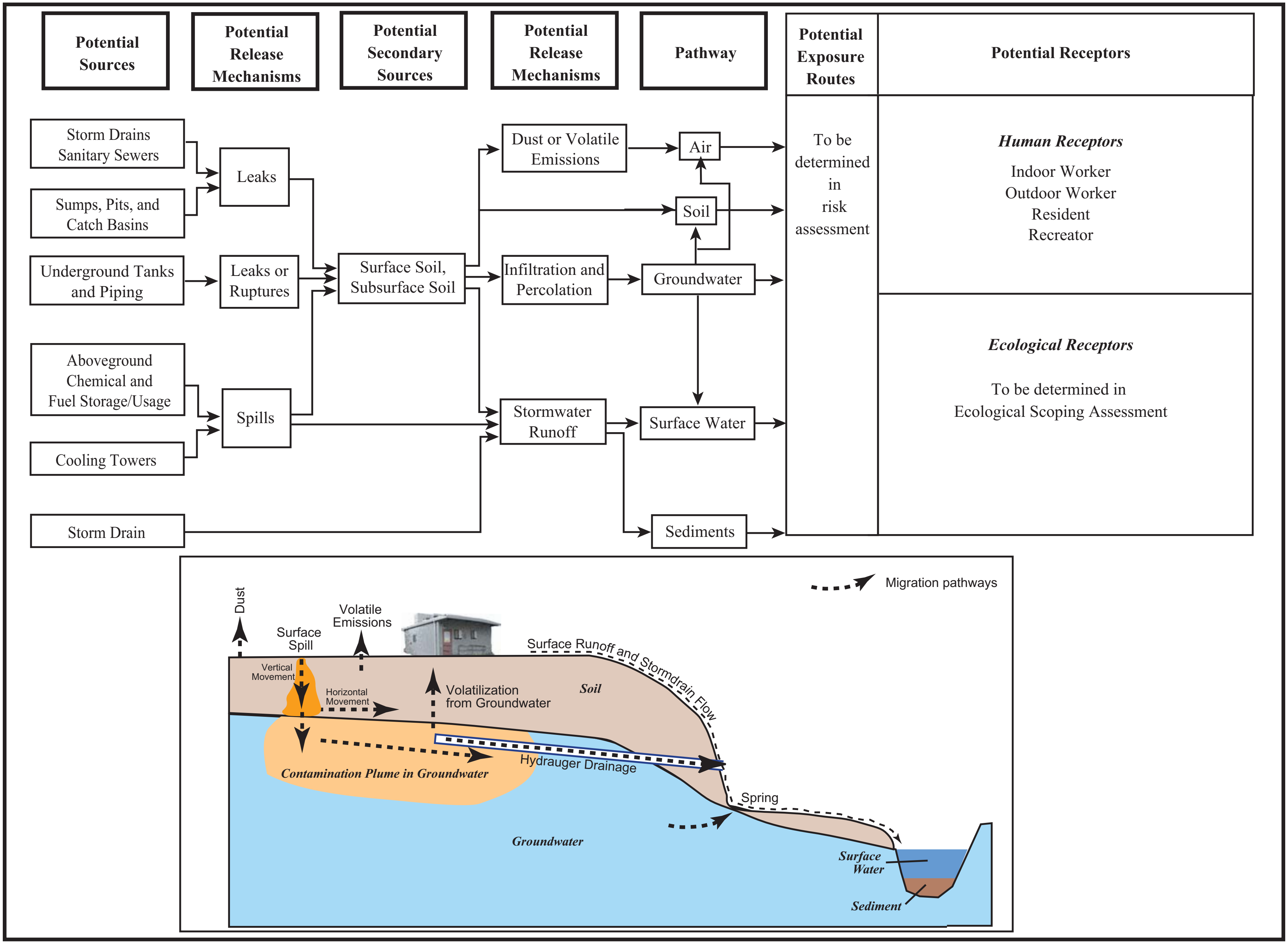

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Figure 3.4-1. Conceptual Model of Potential Migration Pathways and Receptors.

LIST OF TABLES

Table 3.2-1a
LBNL Monitoring Well Construction Details

Well ID	Module	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
MW90-2	Old Town Area	2	7/19/90	253.21	2637.82	60.0	880.78	2	25-35	**Moraga/Orinda**
MW90-3	Bevalac Area	1	7/23/90	1134.60	2460.40	60.0	820.50	2	48-58	Colluvium
MW90-4	Bevalac Area	1	12/1/90	1103.90	2289.30	25.5	746.15	2	15-25	Colluvium
MW90-5	Bevalac Area	1	12/1/90	1067.30	2293.70	25.0	745.75	4	15-25	Colluvium
MW90-6	Bevalac Area	1	12/1/90	1046.70	2291.60	25.5	746.00	2	15-25	Colluvium/Orinda
MW91-1	Support Services Area	5	5/30/91	-69.08	4050.61	55.0	877.98	2	44-54	Orinda
MW91-2	Support Services Area	5	5/31/91	-65.83	3666.47	51.0	877.43	2	40-50	Fill/Orinda
MW91-3	Support Services Area	3	6/4/91	566.47	3807.95	63.5	981.69	2	53-63	Orinda
MW91-4	Support Services Area	3	12/2/91	476.81	3756.52	146.0	978.21	2	115-145	Orinda
MW91-5	Support Services Area	3	6/3/91	490.76	3815.48	40.5	978.28	2	30-40	Colluvium/Orinda
MW91-6	Support Services Area	3	11/17/91	382.38	3879.71	45.0	975.22	4	34-44	Orinda
MW91-7	Bevalac Area		1/1/04							Moraga
MW91-8	Old Town Area	2	1/9/92	465.11	2662.97	76.5	887.02	2	65.5-75.5	Moraga
MW91-9	Old Town Area	10	12/9/91	246.20	2896.17	39.5	915.67	2	28.5-38.5	Orinda
MWP-1	Bevalac Area	15	6/6/91	1177.15	1674.81	49.5	630.65	2	39-49	Fill/Colluvium/Great Valley
MWP-10	Support Services Area	5	6/8/91	-246.37	3862.41	67.0	809.74	2	57-67	Orinda
MWP-2	Outlying Areas	8	12/6/91	219.37	1693.34	76.0	710.33	2	66-76	Great Valley
MWP-4	Old Town Area	14	6/19/91	-36.08	2169.41	53.5	831.56	2	43-53	Great Valley
MWP-5	Old Town Area	14	6/25/91	-262.06	2213.41	109.0	852.37	2	98-108	Great Valley
MWP-6	Old Town Area	14	6/9/91	-256.79	2476.38	38.0	845.47	2	27-37	Great Valley
MWP-7	Old Town Area	14	6/10/91	-206.48	2638.97	35.5	854.01	2	25-35	Orinda/Great Valley
MWP-8	Old Town Area	10	6/14/91	-292.68	2876.29	35.0	872.34	2	25-35	Orinda
MWP-9	Support Services Area	5	6/18/91	-196.07	3674.77	62.0	818.83	2	51-61	Orinda
MW1-220	Old Town Area	2	9/24/88	578.73	2751.09	93.0	901.64	4	83-93	Moraga
MW7-1	Old Town Area	2	8/12/88	295.97	2681.13	18.0	884.13	4	8-18	Fill/Colluvium/Moraga
MW76-1	Support Services Area	4	8/9/88	137.13	3366.07	30.0	923.70	4	20-30	Orinda
MW62-B1A	Outlying Areas	13	9/26/87	-987.16	4129.20	38.0	757.70	2	23-33	
MW62-B2	Outlying Areas	13	9/1/86	-984.02	4127.06	34.15	756.60	2	24-34	
51-92-2	Bevalac Area	9	3/19/92	660.30	2174.22	16.5	724.69	2	6.5-16.5	Fill/Orinda
88-92-4	Outlying Areas	6	3/18/92	931.05	1029.80	59.0	590.82	2	49-59	Great Valley
37-92-5	Old Town Area	14	3/28/92	-125.20	2668.23	105.0	881.56	2	85-105	Great Valley

Table 3.2-1a (Continued)
LBNL Monitoring Well Construction Details

Well ID	Module	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
37-92-6	Old Town Area	14	2/23/92	-245.60	2649.39	39.0	854.15	2	29-39	Colluvium/Great Valley
70-92-7	Outlying Areas	8	3/8/92	403.84	1708.83	26.0	762.93	2	20.8-25.8	Great Valley
46-92-9	Old Town Area	7	3/1/92	612.25	2423.20	79.0	805.30	2	68.5-78.5	Orinda
77-92-10	Support Services Area	5	3/3/92	19.05	4092.31	68.5	879.11	2	48-68	Orinda
26-92-11	Old Town Area	10	3/9/92	165.02	3175.74	31.0	936.19	2	20.5-30.5	Orinda
61-92-12	Support Services Area	5	2/28/92	-356.90	3347.90	99.5	843.90	2	89-99	Orinda
74-92-13	Outlying Areas	11	4/15/92	-355.80	5301.10	48.2	834.90	2	38.2-48.2	San Pablo (?)
83-92-14	Outlying Areas	11	2/22/92	-354.70	5254.65	59.0	830.09	2	48-58	San Pablo (?)
46A-92-15	Bevalac Area	1	9/12/92	1187.20	2539.10	40.0	830.10	2	29-39	Fill/Colluvium/Orinda
7-92-16	Old Town Area	2	8/28/92	181.20	2635.90	60.0	882.40	2	39-59	Moraga
6-92-17	Old Town Area	14	8/27/92	40.50	2729.10	40.0	891.20	2	24-39	Mixed/Orinda
37-92-18	Old Town Area	14	8/31/92	-237.40	2723.80	30.0	860.30	2	19-29	Orinda
37-92-18A	Old Town Area	14	9/14/92	-240.60	2730.30	70.0	861.20	2	49-69	Great Valley
7-92-19	Old Town Area	2	8/29/92	299.60	2684.50	41.0	884.80	2	24-39	Moraga/Mixed
27-92-20	Old Town Area	2	10/14/92	544.10	2661.00	85.0	881.10	2	63.5-83.5	Moraga/Orinda
53-92-21-130'	Old Town Area	2	10/1/92	358.33	2657.18	130.0	886.97	2	125-130	Orinda
53-92-21-147'	Old Town Area	2	10/1/92	357.94	2657.11	147.0	886.99	2	142-147	Orinda
53-92-21-167'	Old Town Area	2	10/1/92	358.07	2656.90	167.0	886.97	2	162-167	Orinda
53-92-21-193'	Old Town Area	2	10/1/92	358.35	2656.90	193.0	886.98	2	188-193	Orinda
69A-92-22	Support Services Area	3	1/22/93	320.97	3951.1	65.0	977.06	2	44-64	Orinda
75-92-23	Support Services Area	3	9/2/92	362.50	3797.00	50.0	972.10	6	29-49	Fill/Colluvium/Orinda
75B-92-24	Support Services Area	3	9/1/92	218.40	3692.30	57.5	956.90	2	37-57	Orinda
76-92-25	Support Services Area	4	9/13/92	181.90	3293.20	39.0	928.70	2	23.5-38	Orinda
62-92-26	Outlying Areas	13	9/3/92	-1157.60	4402.30	58.0	773.70	2	47-57	Great Valley
62-92-27	Outlying Areas	13	9/4/92	-1112.00	4157.10	67.0	769.90	2	56-66	Great Valley
CD-92-28	Offsite	off site	10/26/92	-1240.92	2435.51	55.0	486.29	2	45-55	Great Valley
71-93-1	Bevalac Area	1	9/9/93	1458.58	2562.60	64.0	872.39	2	43-63	Moraga/Mixed/Orinda
71-93-2	Bevalac Area	1	9/8/93	1352.87	2441.60	60.0	844.39	2	39-59	Moraga
58-93-3	Old Town Area	7	5/17/94	331.23	2515.06	24.0	830.18	2	14-24	Colluvium/Moraga
6-93-4	Old Town Area	2	9/10/93	229.92	2599.52	50.5	881.60	2	35-50	Fill/Moraga
37-93-5	Old Town Area	14	8/26/93	-231.11	2573.04	49.5	850.62	2	39-49	Great Valley

Table 3.2-1a (Continued)
LBNL Monitoring Well Construction Details

Well ID	Module	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
76-93-6	Support Services Area	4	8/25/93	252.62	3600.80	44.5	948.61	2	34-44	Orinda
76-93-7	Support Services Area	4	8/28/93	141.90	3299.84	40.0	924.85	2	24-39	Orinda
77-93-8	Support Services Area	5	8/23/93	-44.32	3554.55	26.5	879.01	2	16-26	Fill/Colluvium/Orinda
53-93-9	Old Town Area	2	9/9/93	427.92	2732.45	89.0	900.68	2	68-88	Moraga/Mixed/Orinda
5-93-10	Old Town Area	10	9/10/93	179.51	2873.28	37.5	914.90	2	22-37	Moraga/Orinda
88-93-11A	Outlying Areas	6	3/2/94	956.00	864.20	65.85	537.35	2	55-65	Great Valley
46-93-12	Old Town Area	7	9/7/93	673.46	2530.88	14.0	807.57	2	8.5-13.5	Moraga/Mixed/Orinda
88-93-13	Outlying Areas	6	11/1/93	671.81	980.85	139.0	581.50	2	118.5-138.5	Great Valley
52-93-14	Old Town Area	10	12/9/93	276.79	2842.59	40.0	900.03	2	24.5-39.5	Moraga/Mixed/Orinda
25-93-15	Old Town Area	10	11/8/93	-46.77	3057.62	75.5	935.44	2	55-75	Moraga/Mixed/Orinda
53-93-16-42'	Old Town Area	2	1/29/94	356.87	2674.05	42.3	887.45	2	31.5-41.5	Moraga
53-93-16-69'	Old Town Area	2	1/29/94	356.74	2673.78	69.3	887.40	4	58.5-68.5	Moraga
53-93-17	Old Town Area	2	11/2/93	458.40	2707.41	76.0	902.62	2	60.5-75.5	Moraga
51B-93-18A	Bevalac Area	9	5/19/94	1070.65	2174.99	43.9	709.95	2	23.5-43.5	Orinda
46A-93-19	Bevalac Area	1	1/15/94	1024.48	2439.82	65.0	809.77	2	44-64	Orinda
71-94-1	Bevalac Area	1	5/21/94	1381.17	2358.57	48.9	845.84	2	38.5-48.5	Moraga
7-94-3	Old Town Area	2	5/13/94	267	2705.26	43.0	882.88	2	22.5-42.5	Mixed/Orinda
77-94-5	Support Services Area	5	5/9/94	-53.24	3604.82	63.3	878.96	2	43.5-63.5	Orinda
77-94-6	Support Services Area	5	5/5/94	-67.94	3722.2	61.4	876.76	2	40.5-60.5	Fill/Colluvium/Orinda
74-94-7	Outlying Areas	11	4/28/94	-508.66	5233.24	44.2	819.82	2	33.5-43.5	San Pablo (?)
74-94-8	Outlying Areas	11	5/10/94	-594.5	5343.25	30.4	815.74	2	20-30	Colluvium/San Pablo (?)
37-94-9	Old Town Area	14	5/12/94	-228.55	2682.42	44.8	856.51	2	24-44	Orinda/Great Valley
52-94-10	Old Town Area	10	10/17/94	465.38	2859.99	68.5	906.04	2	47-67	Moraga/Orinda
51-94-11	Bevalac Area	1	10/18/94	1194.70	2263.64	29.0	756.83	4	8-18	Colluvium/Moraga/Orinda
25-94-12	Old Town Area	10	10/14/94	24.60	3021.73	46.0	937.59	2	26-46	Moraga/Orinda
16-94-13	Old Town Area	10	10/11/94	253.46	2762.79	43.0	892.50	2	22-42	Mixed/Orinda
58A-94-14	Old Town Area	7	10/4/94	424.85	2457.65	40.7	821.73	2	21-41	Colluvium/Moraga
51-94-15	Old Town Area	7	11/7/94	625.97	2264.47	45.2	771.17	4	30-40	Orinda
46-94-16	Old Town Area	7	11/7/94	906.27	2300.02	37.5	756.16	2		Orinda
71-95-1	Bevalac Area	1	4/11/95	1479.30	2335.13	48.3	846.94	2		Moraga
52-95-2A	Old Town Area	10	8/29/95	372.05	2864.37	45.0	910.27	2	34.5-44.5	Moraga

Table 3.2-1a (Continued)
LBNL Monitoring Well Construction Details

Well ID	Module	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
52-95-2B	Old Town Area	10	8/29/95	372.19	2864.56	110.0	910.23	2	65-110	Moraga/Mixed
16-95-3	Old Town Area	10	4/18/95	45.73	2787.74	38.3	901.52	2	23-38	Mixed/Orinda
25A-95-4	Old Town Area	10	4/20/95	219.82	3033.97	49.5	938.35	2	28-48	Orinda
25-95-5	Old Town Area	10	8/22/95	-154.47	3091.60	94.8	932.88	2	69-94	Moraga/Mixed/Orinda
74-95-6	Outlying Areas	11	7/14/95	-354.67	5334.83	49.5	838.16	4	35-50	San Pablo (?)
83-95-7	Outlying Areas	11	7/14/95	-285.14	5246.70	47.0	840.75	4	36-46	San Pablo (?)
71-95-8	Bevalac Area	1	4/13/95	1298.86	2549.05	49.0	839.09	2	29-49	Orinda
71-95-9	Bevalac Area	1	4/14/95	1249.27	2662.35	38.4	854.18	2	23.5-38.5	Fill/Colluvium
58-95-11	Old Town Area	7	5/15/95	296.22	2512.06	28.9	831.62	4	8.5-28.5	**Moraga/Mixed/Orinda**
53-95-12	Old Town Area	2	7/19/95	360.87	2616.60	51.2	867.45	1	33-48	**Moraga/Mixed/Orinda**
52B-95-13	Old Town Area	10	7/21/95	282.76	2732.91	27.9	887.40	1	16-31	Moraga/Orinda
6-95-14	Old Town Area	2	8/15/95	184.75	2631.08	67.8	881.43	4	22-67	**Moraga/Mixed/Orinda**
25A-95-15	Old Town Area	10	8/3/95	148.22	2960.59	47.5	931.68	2	22-47	Orinda
62-95-16	Outlying Areas	13	8/4/95	-972.38	4088.45	34.1	741.06	4	18.5-33.5	Great Valley
51-95-17	Bevalac Area	9	2/12/96	913.86	2272.51	40.2	744.67	2	22-37	Orinda
58-95-18	Old Town Area	7	8/9/95	471.88	2401.55	17.8	788.61	4	7.5-17.5	Colluvium/Moraga/Orinda
58-95-19	Old Town Area	7	9/13/95	395.42	2562.55	33.5	834.33	1	20.5-29.5	Orinda
58-95-20	Old Town Area	7	8/8/95	494.26	2517.86	34.4	818.81	2	14.5-34.5	Moraga/Orinda
7B-95-21	Old Town Area	2	8/11/95	283.95	2679.19	37.6	883.63	4	13.5-38.5	Moraga/Mixed
7-95-22	Old Town Area	2	8/10/95	278.23	2659.08	37.6	882.16	4	13.5-38.5	Fill/Moraga/Mixed
7-95-23	Old Town Area	2	12/22/95	285.15	2659.67	53.1	882.37	4	43-53	Mixed/Orinda
7B-95-24	Old Town Area	2	12/18/95	318.75	2655.51	72.8	883.88	4	53-73	Moraga/Mixed/Orinda
7B-95-25	Old Town Area	2	12/13/95	274.27	2634.08	44.3	882.03	2	24-44	Colluvium/Mixed/Moraga/Orinda
25-95-26	Old Town Area	10	4/29/96	-54.01	3139.20	57.6	935.81	2	38-58	Moraga/Mixed/Orinda
25-95-27	Old Town Area	10	12/20/95	-327.09	3045.68	34.7	859.83	2	19.5-34.5	Orinda
53-96-1 (MW91-7)	Old Town Area	2	4/19/96	344.37	2682.54	81.4	887.64	4	67-82	Moraga/Mixed/Orinda
4-96-2	Old Town Area	10	4/17/96	-84.00	2889.05	64.3	912.64	2	45-65	Orinda
51-96-3	Bevalac Area	9	4/23/96	546.48	2240.66	27.5	766.44	4		Orinda
88-96-4	Outlying Areas	6	4/26/96	968.53	1105.35	66.0	594.25	2	46.5-66.5	Great Valley
70A-96-5	Outlying Areas	8	4/15/96	370.50	1757.93	29.2	762.68	4	15-30	Fill/Great Valley
70A-96-6	Outlying Areas	8	4/16/96	334.24	1764.19	39.6	762.67	4	20-40	Great Valley

Table 3.2-1a (Continued)
LBNL Monitoring Well Construction Details

Well ID	Module	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
46-96-10	Old Town Area	7	11/4/96	886.68	2397.81	36.8	790.35	2	22-37	Moraga/Mixed
58-96-11	Old Town Area	2	6/11/96	350.19	2588.64	42.5	848.23	2	14.5-39.5	Mixed/Orinda
58-96-12	Old Town Area	7	12/4/96	295.46	2508.67	7.0	831.84	4	2-7	Fill/Moraga
70A-96-13	Outlying Areas	8	9/24/96	292.97	1511.04	145.1	711.87	2	111-141	Great Valley
70A-96-14	Outlying Areas	8	9/24/96	392.41	1498.87	145.1	716.64	2	112-142	Great Valley
51-96-15	Bevalac Area	9	9/26/96	1004.38	2109.8	40.0	709.83	2	20-40	**Fill/Orinda/Great Valley**
51-96-16	Bevalac Area	9	9/25/96	1054.3	2095.66	29.6	709.72	2	10-30	Fill
51-96-17	Bevalac Area	9	9/25/96	1054.56	2093.45	54.3	709.64	2	35-55	Orinda/Great Valley
51-96-18	Bevalac Area	9	9/27/96	1126.37	2170.13	15.3	710.76	2	6-16	Orinda
51-96-19	Bevalac Area	9	9/27/96	1066.52	2184.14	13.5	709.40	2	5-15	Fill/Orinda
75-96-20	Support Services Area	3	2/13/97	487.72	3762.28	50.0	979.07	2	24.5-49.5	Orinda ?
64-97-1	Bevalac Area	9	5/20/97	1194.82	2167.79	25.0	709.94	2	4.5-24.5	Orinda
64-97-2	Bevalac Area	9	5/20/97	1142.40	2085.16	30.0	709.65	2	9-29	Orinda
51-97-3	Bevalac Area	9	6/3/97	1102.96	1902.48	75.0	709.81	2	54.5-74.5	Fill
51-97-4	Bevalac Area	9	6/25/97	1101.16	1902.01	105.0	709.66	2	89-104	Great Valley
75-97-5	Support Services Area	3	7/19/97	232.73	3768.01	70.0	963.73	2	39-69	Colluvium/Orinda
75-97-6	Support Services Area	3	5/22/97	262.75	3819.22	74.0	967.89	4	53.5-73.5	Colluvium/Orinda
75-97-7	Support Services Area	3	6/9/97	253.44	3870.26	79.0	970.70	2	58.5-78.5	Orinda
69-97-8	Support Services Area	3	9/13/97	256.51	3937.09	70.0	979.52	2.25	50-70	Colluvium/Orinda
77-97-9	Support Services Area	5	6/4/97	76.53	3753.30	49.5	888.69	2	19-49	Fill/Colluvium/Orinda
77-97-10	Support Services Area	5	5/21/97	-91.93	3871.35	52.5	877.73	2	32-52	Fill/Orinda
77-97-11	Support Services Area	5	6/24/97	-205.88	3749.71	43.0	814.67	2	22.5-42.5	Fill/Colluvium/Orinda
51-97-12	Bevalac Area	9	9/2/97	1109.18	1904.55	49.6	709.37	2	29.5-49.5	Fill
51-97-13	Bevalac Area	9	9/11/97	1196.36	1901.98	68.5	709.48	2	48-68	Fill/Colluvium/Orinda
51-97-14	Bevalac Area	9	9/10/97	1020.26	1883.14	64.3	708.89	2	44-64	Fill
51-97-15	Bevalac Area	9	9/12/97	1155.18	1803.16	109.0	706.11	2	88-108	Fill/Great Valley
51-97-16	Bevalac Area	9	9/9/97	875.26	1917.64	35.1	709.58	2	14.5-34.5	Fill/Colluvium/Great Valley
31-97-17	Support Services Area	5	9/5/97	-459.67	3738.68	31.8	746.15	2	21.5-31.5	Colluvium
31-97-18	Support Services Area	5	9/4/97	-480.52	3779.68	59.9	747.80	2	39.5-59.5	Colluvium/Great Valley
78-97-20	Support Services Area	4	10/10/97	298.21	3429.47	34.0	949.54	2	14-34	Orinda
69-97-21	Support Services Area	3	9/23/97	471.24	3985.45	42.0	1003.4	2	18.5-38.5	Orinda

Table 3.2-1a (Continued)
LBNL Monitoring Well Construction Details

Well ID	Module	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
76-97-22	Support Services Area	4	10/17/97	165.14	3545.94	45.0	937.91	2	25-45	Colluvium/Orinda
71-97-23	Bevalac Area	1	9/8/97	1221.62	2469.83	60.0	844.45	2	39.5-59.5	Fill/Orinda
25A-98-1	Old Town Area	10	4/23/98	99.79	2986.86	50.0	936.88	2	30-50	Orinda
56-98-2	Bevalac Area	9	4/24/98	1264.86	1887.99	55.0	709.76	2	35-55	Fill/Colluvium/Orinda
25A-98-3	Old Town Area	10	4/21/98	175.76	3027.87	45.0	940.14	2	25-45	Orinda
64-98-4	Bevalac Area	9	4/20/98	1133.05	2172.54	15.0	711.12	2	5-15	Fill/Orinda
51-98-5	Bevalac Area	9	5/8/98	951.70	1922.10	50.0	709.63	2	30-50	Colluvium
25A-98-6	Old Town Area	10	10/2/98	134.29	3091.47	40.0	939.90	2	20.5-40.5	Moraga/Orinda
25A-98-7	Old Town Area	10	9/1/98	140.51	3001.67	35.0	942.71	2	19-34	Orinda
52A-98-8A	Old Town Area	10	9/16/98	339.79	2883.49	33.5	913.56	2	23-33	Colluvium
52A-98-8B	Old Town Area	10	9/17/98	339.86	2883.73	80.0	913.51	2	60-80	Moraga
52-98-9	Old Town Area	10	9/11/98	377.44	2864.09	80.0	910.86	2	60-80	Moraga
25-98-10	Old Town Area	10	9/12/98	-105.23	3087.97	90.0	934.42	2	70-90	Moraga/Orinda
46A-98-11	Bevalac Area	1	11/3/98	1049.68	2422.42	74.0	813.66	2	54-74	Orinda
71B-98-13	Bevalac Area	1	9/23/98	1202.90	2583.97	30.0	832.33	2	15-30	Fill/Orinda
75-98-14	Support Services Area	3	9/17/98	436.14	3711.28	35.0	977.94	2	20-35	Orinda
75-98-15	Support Services Area	3	9/21/98	479.95	3640.78	35.0	977.97	2	20-35	Orinda
75-98-16	Support Services Area	3	10/12/98	603.26	3451.27	90.0	1074.19	2	69-89	Orinda
31-98-17	Support Services Area	5	9/14/98	-719.39	3709.06	65.0	693.47	2	50-60	Colluvium
63-98-18	Bevalac Area	9	9/15/98	1352.18	1819.94	35.0	709.99	2	20-35	Fill
64-98-19	Bevalac Area	9	2/1/99	1130.56	2178.51	26.0	711.11	2	21-26	Orinda
64-98-20	Bevalac Area	9	4/30/99	1133.29	2180.09	14.5	710.98	2	9.5-14.5	Orinda
76-98-21	Support Services Area	4	9/25/98	137.79	3352.42	35.0	923.20	2	15-35	Orinda
76-98-22	Support Services Area	4	12/18/98	72.85	3375.83	40.0	904.57	2	19-39	Orinda
51-99-1	Bevalac Area	9	5/1/99	679.33	1978.83	35.0	724.44	2	25-35	Great Valley
25A-99-2	Old Town Area	10	5/1/99	137.70	3037.07	30.0	940.45	2	20-30	Moraga/Orinda
71B-99-3	Bevalac Area	1	7/6/99	1179.35	2637.78	30.0	843.21	2	20-30	Orinda
75-99-4	Support Services Area	3	7/20/99	462.42	3665.77	38.0	977.90	2	19.5-34.5	Orinda
25A-99-5	Old Town Area	10	7/19/99	166.42	3062.06	47.5	940.16	2	24-44	Moraga/Orinda
75-99-6	Support Services Area	3	11/19/99	519.69	3687.82	27.0	979.94	2	15.5-25.5	Orinda
75-99-7	Support Services Area	3	11/19/99	463.30	3749.60	26.0	977.92	2	14-24	Colluvium/Orinda

Table 3.2-1a (Continued)
LBNL Monitoring Well Construction Details

Well ID	Module	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
75-99-8	Support Services Area	3	12/6/99	502.05	3669.34	32.0	979.34	2	20-30	Orinda
51-00-1	Bevalac Area	9	2/5/00	690.86	2162.65	25.0	725.48	2	20-25	Orinda
71B-00-2	Bevalac Area	1	3/20/00			60.0	Not surveyed	2	45-60	Orinda
58A-00-3	Old Town Area	7					Not surveyed		69-84	Orinda
7-00-4	Old Town Area	2					Not surveyed		84-99	Orinda
25A-00-5	Old Town Area	10					Not surveyed		68-83	Orinda
52A-00-6	Old Town Area	10					Not surveyed		105-120	Orinda
	Soil Gas Wells									
Outlying Areas	74-95-6	11	7/14/95			49.5		1	15-20	San Pablo (?)
	83-95-7	11	7/14/95			47.0		1	25-30	San Pablo (?)
Bevalac Area	71-95-10	1	4/17/95					3/4"	9.9-10.4	Artificial Fill
								3/4"	20.1-20.6	Artificial Fill
								3/4"	32.7-33.2	Artificial Fill

Artificial Fill: soils placed during grading activities
Colluvium: Quaternary soil/colluvium
San Pablo (?): shallow marine sandstones tentatively assigned to the San Pablo Group

Orinda: Orinda Formation sediments
Great Valley: Upper Cretaceous sedimentary rocks
Moraga: Moraga Formation volcanics

Table 3.2-1b
LBNL Monitoring Well Construction Details (Listed by Module)

Module	Well ID	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
Bevalac Area	MWP-1	15	6/6/91	1177.15	1674.81	49.5	630.65	2	39-49	Fill/Colluvium/Great Valley
	MW90-3	1	7/23/90	1134.60	2460.40	60.0	820.50	2	48-58	Colluvium
	MW90-4	1	12/1/90	1103.90	2289.30	25.5	746.15	2	15-25	Colluvium
	MW90-5	1	12/1/90	1067.30	2293.70	25.0	745.75	4	15-25	Colluvium
	MW90-6	1	12/1/90	1046.70	2291.60	25.5	746.00	2	15-25	Colluvium/Orinda
	51-92-2	9	3/19/92	660.30	2174.22	16.5	724.69	2	6.5-16.5	Fill/Orinda
	46A-92-15	1	9/12/92	1187.20	2539.10	40.0	830.10	2	29-39	Fill/Colluvium/Orinda
	71-93-1	1	9/9/93	1458.58	2562.60	64.0	872.39	2	43-63	Moraga/Mixed/Orinda
	71-93-2	1	9/8/93	1352.87	2441.60	60.0	844.39	2	39-59	Moraga
	51B-93-18A	9	5/19/94	1070.65	2174.99	43.9	709.95	2	23.5-43.5	Orinda
	46A-93-19	1	1/15/94	1024.48	2439.82	65.0	809.77	2	44-64	Orinda
	71-94-1	1	5/21/94	1381.17	2358.57	48.9	845.84	2	38.5-48.5	Moraga
	51-94-11	1	10/18/94	1194.70	2263.64	29.0	756.83	4	8-18	Colluvium/Moraga/Orinda
	71-95-1	1	4/11/95	1479.30	2335.13	48.3	846.94	2		Moraga
	71-95-8	1	4/13/95	1298.86	2549.05	49.0	839.09	2	29-49	Orinda
	71-95-9	1	4/14/95	1249.27	2662.35	38.4	854.18	2	23.5-38.5	Fill/Colluvium
	51-95-17	9	2/12/96	913.86	2272.51	40.2	744.67	2	22-37	Orinda
	51-96-3	9	4/23/96	546.48	2240.66	27.5	766.44	4		Orinda
	51-96-15	9	9/26/96	1004.38	2109.8	40.0	709.83	2	20-40	Fill/Orinda
	51-96-16	9	9/25/96	1054.3	2095.66	29.6	709.72	2	10-30	Fill
	51-96-17	9	9/25/96	1054.56	2093.45	54.3	709.64	2	35-55	Orinda/Great Valley
	51-96-18	9	9/27/96	1126.37	2170.13	15.3	710.76	2	6-16	Orinda
	51-96-19	9	9/27/96	1066.52	2184.14	13.5	709.40	2	5-15	Fill/Orinda
	64-97-1	9	5/20/97	1194.82	2167.79	25.0	709.94	2	4.5-24.5	Orinda
	64-97-2	9	5/20/97	1142.40	2085.16	30.0	709.65	2	9-29	Orinda
	51-97-3	9	6/3/97	1102.96	1902.48	75.0	709.81	2	54.5-74.5	Fill
	51-97-4	9	6/25/97	1101.16	1902.01	105.0	709.66	2	89-104	Great Valley
	51-97-12	9	9/2/97	1109.18	1904.55	49.6	709.37	2	29.5-49.5	Fill
	51-97-13	9	9/11/97	1196.36	1901.98	68.5	709.48	2	48-68	Fill/Colluvium/Orinda
	51-97-14	9	9/10/97	1020.26	1883.14	64.3	708.89	2	44-64	Fill
	51-97-15	9	9/12/97	1155.18	1803.16	109.0	706.11	2	88-108	Fill/Great Valley
	51-97-16	9	9/9/97	875.26	1917.64	35.1	709.58	2	14.5-34.5	Fill/Colluvium/Great Valley

Table 3.2-1b (Continued)
LBNL Monitoring Well Construction Details (Listed by Module)

Module	Well ID	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
Bevalac Area	71-97-23	1	9/8/97	1221.62	2469.83	60.0	844.45	2	39.5-59.5	Fill/Orinda
	56-98-2	9	4/24/98	1264.86	1887.99	55.0	709.76	2	35-55	Fill/Colluvium/Orinda
	64-98-4	9	4/20/98	1133.05	2172.54	15.0	711.12	2	5-15	Fill/Orinda
	51-98-5	9	5/8/98	951.70	1922.10	50.0	709.63	2	30-50	Colluvium
	46A-98-11	1	11/3/98	1049.68	2422.42	74.0	813.66	2	54-74	Orinda
	71B-98-13	1	9/23/98	1202.90	2583.97	30.0	832.33	2	15-30	Fill/Orinda
	63-98-18	9	9/15/98	1352.18	1819.94	35.0	709.99	2	20-35	Fill
	64-98-19	9	2/1/99	1130.56	2178.51	26.0	711.11	2	21-26	Orinda
	64-98-20	9	4/30/99	1133.29	2180.09	14.5	710.98	2	9.5-14.5	Orinda
	51-99-1	9	5/1/99	679.33	1978.83	35.0	724.44	2	25-35	Great Valley
	71B-99-3	1	7/6/99	1179.35	2637.78	30.0	843.21	2	20-30	Orinda
	51-00-1	9	2/5/00	690.86	2162.65	25.0	725.48	2	20-25	Orinda
	71B-00-2	1	3/20/00			60.0	Not surveyed	2	45-60	Orinda
Old Town Area	MWP-4	14	6/19/91	-36.08	2169.41	53.5	831.56	2	43-53	Great Valley
	MWP-5	14	6/25/91	-262.06	2213.41	109.0	852.37	2	98-108	Great Valley
	MWP-6	14	6/9/91	-256.79	2476.38	38.0	845.47	2	27-37	Great Valley
	MWP-7	14	6/10/91	-206.48	2638.97	35.5	854.01	2	25-35	Orinda/Great Valley
	MWP-8	10	6/14/91	-292.68	2876.29	35.0	872.34	2	25-35	Orinda
	MW7-1	2	8/12/88	295.97	2681.13	18.0	884.13	4	8-18	Fill/Colluvium/Moraga
	MW1-220	2	9/24/88	578.73	2751.09	93.0	901.64	4	83-93	Moraga
	MW90-2	2	7/19/90	253.21	2637.82	60.0	880.78	2	25-35	Orinda
	MW91-8	2	1/9/92	465.11	2662.97	76.5	887.02	2	65.5-75.5	Moraga
	MW91-9	10	12/9/91	246.20	2896.17	39.5	915.67	2	28.5-38.5	Orinda
	37-92-5	14	3/28/92	-125.20	2668.23	105.0	881.56	2	85-105	Great Valley
	37-92-6	14	2/23/92	-245.60	2649.39	39.0	854.15	2	29-39	Colluvium/Great Valley
	46-92-9	7	3/1/92	612.25	2423.20	79.0	805.30	2	68.5-78.5	Orinda
	26-92-11	10	3/9/92	165.02	3175.74	31.0	936.19	2	20.5-30.5	Orinda
	7-92-16	2	8/28/92	181.20	2635.90	60.0	882.40	2	39-59	Moraga
	6-92-17	14	8/27/92	40.50	2729.10	40.0	891.20	2	24-39	Mixed/Orinda
	37-92-18	14	8/31/92	-237.40	2723.80	30.0	860.30	2	19-29	Orinda
	37-92-18A	14	9/14/92	-240.60	2730.30	70.0	861.20	2	49-69	Great Valley
	7-92-19	2	8/29/92	299.60	2684.50	41.0	884.80	2	24-39	Moraga/Mixed

Table 3.2-1b (Continued)
LBNL Monitoring Well Construction Details (Listed by Module)

Module	Well ID	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
Old Town Area	27-92-20	2	10/14/92	544.10	2661.00	85.0	881.10	2	63.5-83.5	Moraga/Orinda
	53-92-21-130'	2	10/1/92	358.33	2657.18	130.0	886.97	2	125-130	Orinda
	53-92-21-147'	2	10/1/92	357.94	2657.11	147.0	886.99	2	142-147	Orinda
	53-92-21-167'	2	10/1/92	358.07	2656.90	167.0	886.97	2	162-167	Orinda
	53-92-21-193'	2	10/1/92	358.35	2656.90	193.0	886.98	2	188-193	Orinda
	58-93-3	7	5/17/94	331.23	2515.06	24.0	830.18	2	14-24	Colluvium/Moraga
	6-93-4	2	9/10/93	229.92	2599.52	50.5	881.60	2	35-50	Fill/Moraga
	37-93-5	14	8/26/93	-231.11	2573.04	49.5	850.62	2	39-49	Great Valley
	53-93-9	2	9/9/93	427.92	2732.45	89.0	900.68	2	68-88	Moraga/Mixed/Orinda
	5-93-10	10	9/10/93	179.51	2873.28	37.5	914.90	2	22-37	Moraga/Orinda
	46-93-12	7	9/7/93	673.46	2530.88	14.0	807.57	2	8.5-13.5	Moraga/Mixed/Orinda
	52-93-14	10	12/9/93	276.79	2842.59	40.0	900.03	2	24.5-39.5	Moraga/Mixed/Orinda
	25-93-15	10	11/8/93	-46.77	3057.62	75.5	935.44	2	55-75	Moraga/Mixed/Orinda
	53-93-16-42'	2	1/29/94	356.87	2674.05	42.3	887.45	2	31.5-41.5	Moraga
	53-93-16-69'	2	1/29/94	356.74	2673.78	69.3	887.40	4	58.5-68.5	Moraga
	53-93-17	2	11/2/93	458.40	2707.41	76.0	902.62	2	60.5-75.5	Moraga
	7-94-3	2	5/13/94	267	2705.26	43.0	882.88	2	22.5-42.5	Mixed/Orinda
	37-94-9	14	5/12/94	-228.55	2682.42	44.8	856.51	2	24-44	Orinda/Great Valley
	52-94-10	10	10/17/94	465.38	2859.99	68.5	906.04	2	47-67	Moraga/Orinda
	25-94-12	10	10/14/94	24.60	3021.73	46.0	937.59	2	26-46	Moraga/Orinda
	16-94-13	10	10/11/94	253.46	2762.79	43.0	892.50	2	22-42	Mixed/Orinda
	58A-94-14	7	10/4/94	424.85	2457.65	40.7	821.73	2	21-41	Colluvium/Moraga
	51-94-15	7	11/7/94	625.97	2264.47	45.2	771.17	4	30-40	Orinda
	46-94-16	7	11/7/94	906.27	2300.02	37.5	756.16	2		Orinda
	52-95-2A	10	8/29/95	372.05	2864.37	45.0	910.27	2	34.5-44.5	Moraga
	52-95-2B	10	8/29/95	372.19	2864.56	110.0	910.23	2	65-110	Moraga/Mixed
	16-95-3	10	4/18/95	45.73	2787.74	38.3	901.52	2	23-38	Mixed/Orinda
	25A-95-4	10	4/20/95	219.82	3033.97	49.5	938.35	2	28-48	Orinda
	25-95-5	10	8/22/95	-154.47	3091.60	94.8	932.88	2	69-94	Moraga/Mixed/Orinda
	58-95-11	7	5/15/95	296.22	2512.06	28.9	831.62	4	8.5-28.5	Moraga/Orinda
	53-95-12	2	7/19/95	360.87	2616.60	51.2	867.45	1	33-48	Moraga/Mixed
	52B-95-13	10	7/21/95	282.76	2732.91	27.9	887.40	1	16-31	Moraga/Orinda

Table 3.2-1b (Continued)
LBNL Monitoring Well Construction Details (Listed by Module)

Module	Well ID	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
	6-95-14	2	8/15/95	184.75	2631.08	67.8	881.43	4	22-67	Moraga/Mixed
	25A-95-15	10	8/3/95	148.22	2960.59	47.5	931.68	2	22-47	Orinda
	58-95-18	7	8/9/95	471.88	2401.55	17.8	788.61	4	7.5-17.5	Colluvium/Moraga/Orinda
	58-95-19	7	9/13/95	395.42	2562.55	33.5	834.33	1	20.5-29.5	Orinda
	58-95-20	7	8/8/95	494.26	2517.86	34.4	818.81	2	14.5-34.5	Moraga/Orinda
	7B-95-21	2	8/11/95	283.95	2679.19	37.6	883.63	4	13.5-38.5	Moraga/Mixed
	7-95-22	2	8/10/95	278.23	2659.08	37.6	882.16	4	13.5-38.5	Fill/Moraga/Mixed
	7-95-23	2	12/22/95	285.15	2659.67	53.1	882.37	4	43-53	Mixed/Orinda
	7B-95-24	2	12/18/95	318.75	2655.51	72.8	883.88	4	53-73	Moraga/Mixed/Orinda
	7B-95-25	2	12/13/95	274.27	2634.08	44.3	882.03	2	24-44	Colluvium/Mixed/Moraga/Orinda
	25-95-26	10	4/29/96	-54.01	3139.20	57.6	935.81	2	38-58	Moraga/Mixed/Orinda
	25-95-27	10	12/20/95	-327.09	3045.68	34.7	859.83	2	19.5-34.5	Orinda
	53-96-1 (MW91-7)	2	4/19/96	344.37	2682.54	81.4	887.64	4	67-82	Moraga/Mixed/Orinda
	4-96-2	10	4/17/96	-84.00	2889.05	64.3	912.64	2	45-65	Orinda
	46-96-10	7	11/4/96	886.68	2397.81	36.8	790.35	2	22-37	Moraga/Mixed
	58-96-11	2	6/11/96	350.19	2588.64	42.5	848.23	2	14.5-39.5	Mixed/Orinda
	58-96-12	7	12/4/96	295.46	2508.67	7.0	831.84	4	2-7	Fill/Moraga
	25A-98-1	10	4/23/98	99.79	2986.86	50.0	936.88	2	30-50	Orinda
	25A-98-3	10	4/21/98	175.76	3027.87	45.0	940.14	2	25-45	Orinda
	25A-98-6	10	10/2/98	134.29	3091.47	40.0	939.90	2	20.5-40.5	Moraga/Orinda
	25A-98-7	10	9/1/98	140.51	3001.67	35.0	942.71	2	19-34	Orinda
	52A-98-8A	10	9/16/98	339.79	2883.49	33.5	913.56	2	23-33	Colluvium
	52A-98-8B	10	9/17/98	339.86	2883.73	80.0	913.51	2	60-80	Moraga
	52-98-9	10	9/11/98	377.44	2864.09	80.0	910.86	2	60-80	Moraga
	25-98-10	10	9/12/98	-105.23	3087.97	90.0	934.42	2	70-90	Moraga/Orinda
	25A-99-2	10	5/1/99	137.70	3037.07	30.0	940.45	2	20-30	Moraga/Orinda
	25A-99-5	10	7/19/99	166.42	3062.06	47.5	940.16	2	24-44	Moraga/Orinda
	58A-00-3	7					Not surveyed		69-84	Orinda
	7-00-4	2					Not surveyed		84-99	Orinda
	25A-00-5	10					Not surveyed		68-83	Orinda
	52A-00-6	10					Not surveyed		105-120	Orinda

Table 3.2-1b (Continued)
LBNL Monitoring Well Construction Details (Listed by Module)

Module	Well ID	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
Support Services Area	MWP-9	5	6/18/91	-196.07	3674.77	62.0	818.83	2	51-61	Orinda
	MWP-10	5	6/8/91	-246.37	3862.41	67.0	809.74	2	57-67	Orinda
	MW76-1	4	8/9/88	137.13	3366.07	30.0	923.70	4	20-30	Orinda
	MW91-1	5	5/30/91	-69.08	4050.61	55.0	877.98	2	44-54	Orinda
	MW91-2	5	5/31/91	-65.83	3666.47	51.0	877.43	2	40-50	Fill/Orinda
	MW91-3	3	6/4/91	566.47	3807.95	63.5	981.69	2	53-63	Orinda
	MW91-4	3	12/2/91	476.81	3756.52	146.0	978.21	2	115-145	Orinda
	MW91-5	3	6/3/91	490.76	3815.48	40.5	978.28	2	30-40	Colluvium/Orinda
	MW91-6	3	11/17/91	382.38	3879.71	45.0	975.22	4	34-44	Orinda
	77-92-10	5	3/3/92	19.05	4092.31	68.5	879.11	2	48-68	Orinda
	61-92-12	5	2/28/92	-356.90	3347.90	99.5	843.90	2	89-99	Orinda
	69A-92-22	3	1/22/93	320.97	3951.1	65.0	977.06	2	44-64	Orinda
	75-92-23	3	9/2/92	362.50	3797.00	50.0	972.10	6	29-49	Fill/Colluvium/Orinda
	75B-92-24	3	9/1/92	218.40	3692.30	57.5	956.90	2	37-57	Orinda
	76-92-25	4	9/13/92	181.90	3293.20	39.0	928.70	2	23.5-38	Orinda
	76-93-6	4	8/25/93	252.62	3600.80	44.5	948.61	2	34-44	Orinda
	76-93-7	4	8/28/93	141.90	3299.84	40.0	924.85	2	24-39	Orinda
	77-93-8	5	8/23/93	-44.32	3554.55	26.5	879.01	2	16-26	Fill/Colluvium/Orinda
	77-94-5	5	5/9/94	-53.24	3604.82	63.3	878.96	2	43.5-63.5	Orinda
	77-94-6	5	5/5/94	-67.94	3722.2	61.4	876.76	2	40.5-60.5	Fill/Colluvium/Orinda
	75-96-20	3	2/13/97	487.72	3762.28	50.0	979.07	2	24.5-49.5	Orinda ?
	75-97-5	3	7/19/97	232.73	3768.01	70.0	963.73	2	39-69	Colluvium/Orinda
	75-97-6	3	5/22/97	262.75	3819.22	74.0	967.89	4	53.5-73.5	Colluvium/Orinda
	75-97-7	3	6/9/97	253.44	3870.26	79.0	970.70	2	58.5-78.5	Orinda
	69-97-8	3	9/13/97	256.51	3937.09	70.0	979.52	2.25	50-70	Colluvium/Orinda
	77-97-9	5	6/4/97	76.53	3753.30	49.5	888.69	2	19-49	Fill/Colluvium/Orinda
	77-97-10	5	5/21/97	-91.93	3871.35	52.5	877.73	2	32-52	Fill/Orinda
	77-97-11	5	6/24/97	-205.88	3749.71	43.0	814.67	2	22.5-42.5	Fill/Colluvium/Orinda
	31-97-17	5	9/5/97	-459.67	3738.68	31.8	746.15	2	21.5-31.5	Colluvium
	31-97-18	5	9/4/97	-480.52	3779.68	59.9	747.80	2	39.5-59.5	Colluvium/Great Valley
	78-97-20	4	10/10/97	298.21	3429.47	34.0	949.54	2	14-34	Orinda
	69-97-21	3	9/23/97	471.24	3985.45	42.0	1003.4	2	18.5-38.5	Orinda

Table 3.2-1b (Continued)
LBNL Monitoring Well Construction Details (Listed by Module)

Module	Well ID	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
Support Services Areas	76-97-22	4	10/17/97	165.14	3545.94	45.0	937.91	2	25-45	Colluvium/Orinda
	75-98-14	3	9/17/98	436.14	3711.28	35.0	977.94	2	20-35	Orinda
	75-98-15	3	9/21/98	479.95	3640.78	35.0	977.97	2	20-35	Orinda
	75-98-16	3	10/12/98	603.26	3451.27	90.0	1074.19	2	69-89	Orinda
	31-98-17	5	9/14/98	-719.39	3709.06	65.0	693.47	2	50-60	Colluvium
	76-98-21	4	9/25/98	137.79	3352.42	35.0	923.20	2	15-35	Orinda
	76-98-22	4	12/18/98	72.85	3375.83	40.0	904.57	2	19-39	Orinda
	75-99-4	3	7/20/99	462.42	3665.77	38.0	977.90	2	19.5-34.5	Orinda
	75-99-6	3	11/19/99	519.69	3687.82	27.0	979.94	2	15.5-25.5	Orinda
	75-99-7	3	11/19/99	463.30	3749.60	26.0	977.92	2	14-24	Colluvium/Orinda
	75-99-8	3	12/6/99	502.05	3669.34	32.0	979.34	2	20-30	Orinda
Outlying Areas	MWP-2	8	12/6/91	219.37	1693.34	76.0	710.33	2	66-76	Great Valley
	MW62-B1A	13	9/26/87	-987.16	4129.20	38.0	757.70	2	23-33	
	MW62-B2	13	9/1/86	-984.02	4127.06	34.15	756.60	2	24-34	
	88-92-4	6	3/18/92	931.05	1029.80	59.0	590.82	2	49-59	Great Valley
	70-92-7	8	3/8/92	403.84	1708.83	26.0	762.93	2	20.8-25.8	Great Valley
	74-92-13	11	4/15/92	-355.80	5301.10	48.2	834.90	2	38.2-48.2	San Pablo (?)
	83-92-14	11	2/22/92	-354.70	5254.65	59.0	830.09	2	48-58	San Pablo (?)
	62-92-26	13	9/3/92	-1157.60	4402.30	58.0	773.70	2	47-57	Great Valley
	62-92-27	13	9/4/92	-1112.00	4157.10	67.0	769.90	2	56-66	Great Valley
	88-93-11A	6	3/2/94	956.00	864.20	65.85	537.35	2	55-65	Great Valley
	88-93-13	6	11/1/93	671.81	980.85	139.0	581.50	2	118.5-138.5	Great Valley
	74-94-7	11	4/28/94	-508.66	5233.24	44.2	819.82	2	33.5-43.5	San Pablo (?)
	74-94-8	11	5/10/94	-594.5	5343.25	30.4	815.74	2	20-30	Colluvium/San Pablo (?)
	74-95-6	11	7/14/95	-354.67	5334.83	49.5	838.16	4	35-50	San Pablo (?)
	83-95-7	11	7/14/95	-285.14	5246.70	47.0	840.75	4	36-46	San Pablo (?)
	62-95-16	13	8/4/95	-972.38	4088.45	34.1	741.06	4	18.5-33.5	Great Valley
	88-96-4	6	4/26/96	968.53	1105.35	66.0	594.25	2	46.5-66.5	Great Valley
	70A-96-5	8	4/15/96	370.50	1757.93	29.2	762.68	4	15-30	Fill/Great Valley
	70A-96-6	8	4/16/96	334.24	1764.19	39.6	762.67	4	20-40	Great Valley
	70A-96-13	8	9/24/96	292.97	1511.04	145.1	711.87	2	111-141	Great Valley
	70A-96-14	8	9/24/96	392.41	1498.87	145.1	716.64	2	112-142	Great Valley
Offsite	CD-92-28	off site	10/26/92	-1240.92	2435.51	55.0	486.29	2	45-55	Great Valley

Table 3.2-1b (Continued)
LBNL Monitoring Well Construction Details (Listed by Module)

Module	Well ID	Area	Completion Date	UC Grid North Coordinate	UC Grid East Coordinate	Total Depth (ft)	Top of Casing Elevation (ft above MSL)	Casing Diameter (inches)	Screened Interval (ft below TOC)	Geologic Unit(s) Exposed to Sand Pack
	Soil Gas Wells									
Outlying Areas	74-95-6	11	7/14/95			49.5		1	15-20	San Pablo (?)
	83-95-7	11	7/14/95			47.0		1	25-30	San Pablo (?)
Bevalac Areas	71-95-10	1	4/17/95					3/4"	9.9-10.4	Artificial Fill
								3/4"	20.1-20.6	Artificial Fill
								3/4"	32.7-33.2	Artificial Fill

Artificial Fill: soils placed during grading activities
Colluvium: Quaternary soil/colluvium
San Pablo (?): shallow marine sandstones tentatively assigned to the San Pablo Group
Orinda: Orinda Formation sediments
Great Valley: Upper Cretaceous sedimentary rocks
Moraga: Moraga Formation volcanics

SECTION 4

PHYSICAL CHARACTERISTICS OF THE SITE

The following sections contain a detailed description of the physiography, geology, and hydrogeology of the LBNL site. The hydrogeological characteristics of the bedrock units and surficial materials, along with the physiography of the site, are primary factors controlling groundwater flow and contaminant transport. These factors were used to develop the hydrogeologic models and conceptual models for contaminant transport developed in Modules A through D. The physiography, geology, and hydrogeology of LBNL are discussed on an areas specific basis in each of the modules.

4.1 PHYSIOGRAPHY

LBNL is located on the west- and south-facing slopes of the Berkeley Hills immediately east of the UCB campus. The topography of the site consists of moderate to locally steep relief, with surface elevations ranging from 500 feet above mean sea level (msl) at the western boundary of the site to approximately 1,000 feet above msl on the northeast side (Figure 3.2-1). The physiography at LBNL is dominated by a steep southwest-facing slope that has been modified by erosion of several steep stream canyons, by mobilization of landslides, and by cut and fill operations associated with construction of LBNL facilities. Two main creeks and related tributaries drain the LBNL site (Figure 3.2-1). The west-trending Strawberry Creek is south of the site and receives water from several north-south trending tributaries which head within or above LBNL. North Fork Strawberry Creek (in Blackberry Canyon) is west-trending and drains the western portion of the site. Growth of LBNL since the 1940s has been accommodated through local modification of the topography by extensive surface grading and fill placement. As a result, the tributaries feeding North Fork Strawberry Creek have been disrupted, and surface water from these tributaries is collected and conveyed through reinforced concrete pipes. Both Strawberry Creek and North Fork Strawberry Creek are perennial and are fed by springs during the summer.

4.2 GEOLOGY

The overall distribution of geologic units at LBNL is shown on the bedrock geologic map (Figure 4.2-1), and on geologic cross-sections A-A' through C-C' (Figures 4.2-2 through 4.2-4). Bedrock at LBNL consists primarily of Cretaceous and Miocene sedimentary and volcanic units. These units form a northeast-dipping, faulted homocline, which underlies most of LBNL. Cretaceous marine sedimentary rocks of the Great Valley Group form the structurally lowest portion of the homocline and underlie the southern and western slopes of LBNL. Miocene nonmarine sedimentary rocks of the Orinda Formation lie structurally above the Great Valley Group along a fault contact that dips at a shallow angle to the northeast. The Orinda Formation is conformably overlain by Miocene volcanic rocks of the Moraga Formation.

Numerous isolated masses of Moraga formation volcanic rock underlie the developed portions of LBNL. These masses lie structurally below the main Moraga Formation outcrop belt and are interpreted to be paleolandslide (ancient landslide) deposits.

In the easternmost portion of LBNL, the homocline is disrupted by the north-striking Wildcat and East Canyon faults. The area east of these faults is underlain by marine sedimentary rocks of both the Miocene Claremont Formation and the Miocene San Pablo (?) Group.

At the western LBNL property boundary, the homocline is truncated by the north to northwest striking Hayward Fault, a regionally extensive, active, right-lateral strike-slip fault. Rocks west of the Hayward fault consist of the Jurassic to Cretaceous Franciscan Complex.

4.2.1 Bedrock Stratigraphy

A stratigraphic column showing correlations between the rock units underlying the LBNL area is shown on Figure 4.2-5. A brief description of the lithology, petrology, and stratigraphic relationships of each unit is given below.

Contra Costa Group (Orinda and Moraga Formations)

The Orinda and Moraga Formations are the only units of the Contra Costa Group exposed at LBNL, and constitute the bedrock underlying most site buildings. The Moraga Formation is a resistant ridge-forming unit that underlies the uppermost slopes of LBNL, whereas the less-resistant Orinda Formation generally underlies the slopes below the Moraga Formation.

Orinda Formation

Regionally, the Orinda Formation consists of a sequence of nonmarine sandstones, mudstones, and conglomerates that attain a maximum thickness of about 2600 feet and lie in apparently conformable contact on marine sedimentary rocks of the Claremont Formation. The lower several hundred feet of the formation consists predominantly of fine-grained sandstone and siltstone with thin interbeds of conglomerate, whereas the upper part is characterized by a coarsening-upward sequence of massive conglomerates alternating with sandy mudstone intervals (Curtis, 1989). The unit is interpreted to have been deposited in alluvial and fluvial environments. Clast composition and paleoflow data suggest that the clastic detritus within the unit was derived from erosion of Great Valley Group and/or Franciscan Complex rocks that formerly existed to the west (Graham *et al.*, 1984). The age of the Orinda Formation is approximately 13 to 10.5 million years (Ma) (Jones and Curtis, 1991).

The section of Orinda Formation exposed at LBNL typically consists of nonmarine mudstone sand fine- to medium-grained sandstones, which range in color from blue- or greenish-gray-to reddish-brown, and are intensely to little fractured, friable, and little to moderately weathered. In addition to these lithologies, the unit also contains interbedded, commonly lenticular bodies composed of coarse sandstone, pebbly sandstone, and conglomerate. Borehole and outcrop data at LBNL indicate that the Orinda Formation coarsens stratigraphically upwards away from its basal fault contact with the Great Valley Group. Conglomerate and sandstone clast compositions commonly include rock fragments consisting of graywacke, arkose, glaucophane schist, quartzite, vein quartz, greenstone, shale, and chert.

Moraga Formation

The Moraga Formation consists of a thick section composed primarily of andesitic volcanic rocks that conformably overlie the Orinda Formation. These rocks are typically highly fractured, jointed, brecciated, and commonly vesicular. The contact with the underlying Orinda Formation is in places gradational, as shown by local intercalation of volcanic rocks typical of the Moraga Formation with sedimentary rocks typical of the Orinda Formation.

The Moraga Formation attains a maximum thickness of approximately 2300 feet about 6 km southeast of LBNL near Round Top Hill, which has been interpreted as the eruptive center for at least the lower part of the formation. However, it is significantly thinner elsewhere and is about 1100 feet thick on Grizzly Peak Boulevard directly east of LBNL. Jones and Curtis (1991) recognized about ten distinct basalt and basaltic andesite units in the Moraga Formation east of the Wildcat Fault (Figure 4.2-1), which includes lahars, tuffs, and volcaniclastic sandstone interbeds that range in age from 10.2 to 9.0 Ma.

While the Moraga Formation subunits to the east of the Wildcat Fault are distinctive and may be mapped as continuous units, individual units are difficult to distinguish and somewhat chaotic west of the fault in the vicinity of LBNL. The western section seems to constitute a distinct facies which has been interpreted to have been deposited in close proximity to an eruptive volcanic center (Curtis, 1989). The basal portion of this western section underlies the slopes above and immediately northeast of LBNL, and consists predominantly of andesite and andesitic breccia with minor interbedded volcaniclastic sandstone and conglomerate. The rocks are typically gray where fresh, brown where weathered, closely fractured, moderately strong to strong, and coarsely brecciated in places. Reddish to purplish oxidized zones are typically present at the tops and bottoms of flow units.

Extensive outcrops composed of rocks derived from the Moraga Formation have been mapped as paleolandslide deposits along much of the northern LBNL boundary (Figure 4.2-1). The blocks within these deposits are composed of lithologies typical of the western, chaotic facies described above, and are probably derived from the rocks found immediately west of the East Canyon Fault. Due to the fact that these deposits apparently represent a distinct hydrogeologic unit at LBNL, and because their age of displacement is poorly known, they are mapped as a bedrock unit distinct from surficial historic landslide units and are denoted as Moraga Formation in the remainder of this report.

San Pablo Group (?)

Fossiliferous marine sandstones were discovered in the eastern portion of LBNL during grading for the new Hazardous Waste Handling Facility (Building 85). These sandstones are typically silty with minor interbeds of pebbly conglomerate, and contain numerous bivalve and plant fossils. The rocks are light gray where fresh and light brown where weathered, and are little-fractured to massive, weak to moderately strong, and little to moderately weathered. Jones suggested that these rocks might be part of the San Pablo Group; Buising concurred with this hypothesis (D.L. Jones, personal communication, A. Buising, personal communication). However, given the uncertainty of assigning them to the San Pablo Group, references to these rocks at LBNL are queried (i.e. San Pablo Group [?]).

Claremont Formation

The Claremont Formation is part of the regionally extensive Monterey Group, (Curtis, 1989), and consists primarily of siliceous rocks interpreted to be largely of deep-water, biogenic origin that range in age from approximately 16 to 13 million years (Ma). East of LBNL, these deep marine deposits grade eastward into shales and sandstones deposited in a shallower marine environment (Graham *et al.*, 1984).

The easternmost portion of LBNL is underlain by outcrops of the Claremont Formation, composed primarily of light brown to gray, thinly bedded to laminated chert. The chert is interbedded with gray to brown shale laminae and minor amounts of light brown to white sandstone that occurs as dikes, beds, and boudins. Both the chert and sandstone are weak to strong while the shale is friable. All of these lithologies are intensely to closely fractured, and typically little to moderately weathered, although locally the chert is deeply weathered to a highly porous residual deposit consisting primarily of limonite. Outcrops of the formation form steep slopes due to the resistance of the chert to erosion.

Great Valley Group

Marine mudstones, sandstones, and shales, with lesser amounts of conglomerate, typically underlie the elevations below approximately 750 feet above msl at LBNL, and form benches and promontories where weathering along the contact has eroded the overlying, less resistant Orinda Formation. These rocks are typically gray where fresh and brown where weathered; weak to moderately strong; and are closely to little fractured, except adjacent to the fault contact with the overlying Orinda Formation, where they are generally intensely fractured. Radbruch (1969) mapped these strata as the Upper Cretaceous Joaquin Miller, Shepherd Creek and Redwood Canyon Formations and possibly unrecognized Eocene Rocks. Dibblee (1980a, b) mapped these rocks as the Upper Cretaceous Panoche Formation. In this report, they are denoted as Great Valley Group, since all of the formations mentioned belong to this group.

Neither the top nor the bottom of the Great Valley Group is exposed at LBNL, although at least 6,000 feet of Cretaceous strata are exposed elsewhere in the East Bay Hills (Case, 1968). Regionally, these strata are unconformably overlain by the Claremont Formation, although this relationship is not observed at LBNL.

Franciscan Complex

The Franciscan Complex consists of structurally disrupted Jurassic and Cretaceous sedimentary and metamorphic rocks and underlies the entire region west of the Hayward Fault. The large displacement known to have occurred along the Hayward Fault and regional information on the genesis of the Franciscan Complex indicate that it is not stratigraphically contiguous with other rock units at LBNL. This unit is not described in detail here because it is only present along the western property boundary of LBNL west of the Hayward Fault, and does not influence contaminant migration at LBNL.

4.2.2 Structural Geometry of Bedrock Units

The geologic structure of LBNL is dominated primarily by a moderately northeast dipping homocline consisting of tilted strata of the Moraga Formation, Orinda Formation, and

Great Valley Group that has been deeply dissected by headward erosion of stream canyons. Superposed on this relatively simple structure are several large masses of the Moraga Formation, interpreted to be paleolandslide blocks, that have been displaced downward on to structurally lower units, and several major faults which show substantial stratigraphic offset. These features are described in detail below.

Paleolandslide Blocks

Several masses composed primarily of volcanic rock typical of the Moraga Formation underlie the developed areas of LBNL. These masses consist primarily of andesitic breccia up to 100 feet thick and generally occupy depressions in the undulatory surface of the underlying Orinda Formation. The masses are generally lenticular in cross section, and several are elongated in plan view. Since these masses lie structurally below the main outcrop belt of the Moraga Formation (Figures 4.2-1 and 4.2-3), several previous investigators had mapped them as fault-bounded blocks of Moraga Formation, although Harding-Lawson Associates (1984 and 1988b) interpreted them to be paleolandslide (ancient landslide) blocks.

Moraga Formation Blocks

The volcanic masses are typically composed of brecciated andesite. Where exposed in the road cut south of Building 25, a historic landslide scarp between Buildings 64 and 71, and in construction excavations southeast of Building 58 and between Buildings 84 and 85, the breccia is uncemented. The volcanic mass between the Lawrence Hall of Science (LHS) and the Old Town area of LBNL is the only mass composed of unbrecciated andesite. This mass has well-defined bedding, as exhibited in the road cut above the Old Town area. These beds dip moderately to the northwest, as opposed to the north to northeast attitudes of in-place outcrops of the Moraga and Orinda Formations measured throughout the rest of LBNL.

"Mixed Unit"

At the base of several of the masses of Moraga Formation, volcanic rocks are interlayered with siltstones, tuffs, and sandstones immediately above the underlying contact with the Orinda Formation. The siltstones and sandstones are generally volcaniclastic or sedimentaclastic, and resemble sedimentary rocks common to both the Moraga and Orinda Formations. In some cases contacts between volcanic and sedimentary rocks appear to be depositional, with contact-parallel bedding exhibited. In other cases, particularly close to the basal contact with the Orinda Formation, the contacts are slickensided shear surfaces, so the volcanic and sedimentary rocks appear to be tectonically interleaved. Bedding within the unit ranges from subvertical to subhorizontal, and is locally folded on the scale of a core sample. Bedding was observed to be parallel to the margins of the volcanic mass in construction excavations in the eastern portion of LBNL. Due to the difficulty of discriminating between depositionally and structurally interleaved strata, the entire section that contains both volcanic and sedimentary strata has been informally denoted as the "Mixed Unit" in this report. The thickest sections of the Mixed Unit (up to 40-feet thick) occur along the western margins of the volcanic masses in the central portion of LBNL.

Internal Structure

Wherever the contact between the volcanic masses and the underlying Orinda Formation has been exposed by construction activities or historic landsliding, slickensides parallel or subparallel to the contact have been observed. Slickensides are also observed in core samples that transect the contact, most notably at the toe of the slope west of Building 58. The orientation of the contact and the slickensides is typically steepest at the margins of the volcanic masses and shallowest beneath their centers. Even where a thick section of the Mixed Unit is not present, rocks at the contact between the volcanic masses and the underlying Orinda Formation are usually interleaved at the contact. In addition, colluvial soils containing chert fragments are interleaved beneath volcanic rocks at the east edge of the large volcanic mass present in the East Canyon (Figure 4.2-1).

Interpretation of Field Relations

Although the volcanic rock masses are interpreted here to be paleolandslide blocks, field exposures at LBNL are generally poor, so alternative interpretations may be valid. Two alternative interpretations are that the blocks may consist of volcanic material deposited in depressions in an original, deeply-eroded surface, or that they may be fault-bounded blocks that have been downdropped relative to the main Moraga Formation outcrop belt. Combinations of these three interpretations are also possible. The following discusses the rationale for selection of the preferred paleolandslide interpretation.

The masses composed of Moraga Formation blocks and the Mixed Unit lie structurally below the main Moraga Formation outcrop belt (Figure 4.2-1) and typically fill depressions in the underlying Orinda Formation. The Orinda Formation surface is undulatory (Figures 4.2-2 through 4.2-4), with a morphology suggestive of dissected stream channels. The contact between the Moraga and Orinda Formation outside LBNL is not known to exhibit this morphology.

The presence of slickensides and the structural interleaving of lithologies at the contact of the volcanic rock masses and the underlying Orinda Formation is consistent with creation of the masses through either landsliding or faulting rather than through deposition in depressions present in the original depositional surface. The lack of cementation of the brecciated andesites suggests that brecciation occurred post-depositionally, rather than through auto-brecciation that is common in volcanic flow processes, which further supports creation of the masses through either landsliding or faulting.

The wide range of slickenside orientations, particularly the subhorizontal attitudes observed beneath the center of the volcanic mass between Buildings 84 and 85, as well as the lensoidal shape of the masses, is more consistent with landsliding than faulting. The pervasive brecciation of the volcanic masses is also more consistent with landsliding than faulting. Development of the masses through faulting alone would require a complex network of faults trending in numerous directions to downdrop and separate the volcanic masses observed. The observations and reasoning described above concur with Harding-Lawson Associates (1984 and 1988b) interpretation that the volcanic rock masses underlying LBNL are landslide deposits. This interpretation will be followed for the remainder of this report and was utilized to construct the bedrock geologic maps and cross sections.

Age

The Moraga and Orinda Formations appear to have been exposed only at the time of deposition (i.e. 9 to 10 Ma), and after uplift and development of the present day topography, which has been occurring since about 5 Ma (Graham *et al.*, 1984). Therefore, displacement of the Moraga Formation paleolandslide blocks would have occurred during one or both of these periods. Several historic landslides composed of these rocks have moved since development of LBNL, and appear to have resulted from reactivation of segments of the paleolandslides. The historic landslides are discussed further in Section 4.2.4 below. The present existence of slopes sufficiently unstable to allow reactivation of the paleolandslide blocks suggests that original displacement of the paleolandslides may have occurred on relatively late during the development of the present day topography (i.e. later than 5 Ma). However, most of the paleolandslide blocks do not exhibit evidence of recent movement, and currently underlie promontories, ridgelines, or benches, suggesting that they are at least old enough for the surrounding, more erodible Orinda Formation rocks to waste away. Therefore, displacement probably took place primarily prior to the Holocene.

Orinda Formation Paleolandslides

Samples from the Orinda Formation throughout LBNL are frequently found to be brecciated and slickensided, particularly in core samples in the main canyon of the Support Services area and in a broad outcrop exposed during grading for Building 77 (Dames and Moore, 1982). This observation suggests that this canyon may contain a paleolandslide deposit.

Summary

The interpreted paleolandslide blocks composed of volcanic rocks are designated as Q Tls(m) on the geologic maps and cross sections in this report to reflect their derivation from the Moraga Formation and the uncertainty in their age. The blocks will be referred to simply as the Moraga Formation throughout most sections of this report. Although this designation may not be stratigraphically correct, this nomenclature is used due to the difficulty in distinguishing in-place Moraga Formation from paleolandslide blocks, and the historic use of the term at LBNL.

Likewise, the interpreted paleolandslide blocks composed of mixed lithologies are designated as QTls(mo) and referred to as “The Mixed Unit”.

Faults

Four main faults, with several subsidiary branches, have been mapped at LBNL (Figure 4.2-6). The general characteristics of these faults are discussed below.

The Hayward Fault is a major, active, right-lateral, strike-slip fault that traverses the LBNL western property boundary just west of the Hearst Avenue Gate (Williams and Hosokawa, 1992). In the vicinity of LBNL, the fault splits into two branches: the westernmost branch separates rocks of the Franciscan Complex to the southwest from the northeastward-dipping, faulted homocline of Cretaceous and Miocene sedimentary and volcanic rocks underlying LBNL to the northeast; the easternmost branch lies completely within strata of the Great Valley Group and does not show any mappable stratigraphic offset. The Hayward Fault is part of the regionally extensive San Andreas fault system. Based on the known history of the San Andreas fault system, and offset of geologic markers, movement on the Hayward Fault is thought to have begun as early as 10 Ma, and has resulted in a total offset on the fault of between 4 and 25 miles (Graham *et al.*, 1984).

The Wildcat Fault passes along the eastern margin of LBNL, and has also been identified as a part of the San Andreas Fault System. However, its character and history are not well understood. Regionally, it is difficult to map throughout its length and appears to be discontinuous (Gilpin, 1994), although it clearly truncates and offsets strata at many locations. At LBNL, it generally juxtaposes the San Pablo Group (?) and Claremont Formation (Figure 4.2-1) and strata adjacent to the fault have been severely disrupted by steep, east-to-northeast-dipping, subsidiary shear zones. Local fault investigations as well as evidence observed in pre-construction excavations at Building 85 indicate that the fault is inactive in this area (Harding-Lawson Associates, 1980; Gilpin, 1994; Geo/Resources Consultants Inc., 1994). Curtis (G. H. Curtis, personal communication) suggested that the Moraga Formation in the vicinity of LBNL has been displaced approximately 6 km northwest from a position adjacent to the volcanic center at Round Top by movement along the Wildcat Fault. Jones (D.L. Jones, personal communication) stated that strata assigned to the San Pablo Group (?) that are exposed adjacent to the fault at LBNL may have been displaced from similar San Pablo Group rocks on the opposite side of the Wildcat Fault system that lie near Lake Chabot 14 km to the south.

The existence of the East Canyon Fault, which lies subparallel and a short distance west of the Wildcat Fault, was originally suggested by Borg (1991), based on historic spring locations, air photo analysis, and mapping. Additional evidence for the existence of the fault includes the apparent offset of a sliver of Orinda Formation rocks north of the main outcrop belt near the eastern edge of LBNL (Figure 4.2.1). In addition, slickensided surfaces consistent with the orientation of the East Canyon Fault were observed in trenches along the apparent fault trace (Geo/Resources Consultants Inc., 1992). However, poor exposures along the hypothesized trace of the fault make verification of the existence of the fault difficult.

Radbruch (1969) mapped the Orinda Formation/Great Valley Group contact at LBNL as a fault. The dips of Great Valley Group strata vary from northward to northeastward, while dips of Orinda Formation strata are consistently northeastward, indicating there is some disparity between the dips of the strata in the two rock units. The excavation for Building 2 revealed a thin clay seam at the contact, and the Great Valley Group immediately below the contact contained shear surfaces (Harding-Lawson Associates, 1987). Core samples taken at the contact south and east of Building 6 (the Advanced Light Source), south of Building 31, and south of Building 51 also exhibit pervasive slickensided surfaces. Borehole logs in the vicinity of Building 6 as well as mapping of the Building 2 excavation indicate that the contact dips moderately (20° to 30°) to the north and east. Moderate dips to the south and southwest were observed in strata of the Orinda Formation in the excavation for the Building 48 (Firehouse) Addition and in boreholes drilled at Building 35. Projection of these dips indicates that the Orinda Formation strata are truncated by the contact. In addition, the Claremont Formation, which depositionally underlies the Orinda Formation throughout most of the Berkeley Hills area, is missing from the section along the contact. All of these observations support the low-angle fault interpretation of Radbruch (1969). This fault is apparently truncated by the East Canyon Fault and/or the inactive Wildcat Fault at its eastern extent, and is therefore assumed to be inactive.

4.2.3 Seismic Hazards

Three major faults in the broad region surrounding LBNL are known to be active and have been zoned as active faults by the California State Geologist. These faults are all part of the San Andreas Fault System, which forms the boundary between the North American and Pacific tectonic plates.

The northern portion of the Hayward fault passes immediately adjacent to LBNL's western property boundary and currently creeps aseismically at a rate of 5±1 mm/yr, with a total slip rate of 9±1 mm/yr (Lienkaemper *et al.*, 1991, Schulz *et al.*, 1982). It has the potential to produce an earthquake of approximately Richter magnitude 7.5. The Alquist-Priolo Earthquake Fault Zone for this fault is shown on Figure 4.2-6, and denotes an area within approximately 1/8 mile of the surface trace of an active fault where surface rupture during an earthquake might be expected to occur.

The San Andreas Fault zone, which has potential for a magnitude 8.3 earthquake, lies about 32 kilometers (20 miles) west of LBNL, offshore beyond the Golden Gate. The Calaveras Fault, another branch of the San Andreas, lies about 24 kilometers (15 miles) east of the site.

For an earthquake of any given magnitude, the Hayward Fault would produce the most intense ground shaking at LBNL because of its proximity.

None of the other faults described in the preceding section are believed to be active, or have been zoned as active faults by the California State Geologist.

4.2.4 Surficial Geology

Surficial geologic units at LBNL consist primarily of artificial fill, colluvium, and landslide deposits. A map of the surficial geology is shown on Figure 4.2-7.

Artificial Fill

Grading has significantly altered the original topography at LBNL, with cuts up to 40 feet deep and fills up to 110 feet thick. The characteristics of the fill masses vary considerably, based upon the material and compaction methods used. Engineered fill generally consists of stiff, dense non-expansive material whereas non-engineered fill consists of medium stiff or loose, expansive and non-expansive material mixed with a significant proportion of organic, construction, and other debris.

Materials used in the artificial fills appear to have been derived locally from the Great Valley Group, San Pablo Group, Orinda Formation, and Moraga Formation rocks and from residual soils and colluvium overlying these rocks. Some of the fill masses appear to have been derived exclusively from one of these parent materials, while other masses contain material from several of these parents. Several bodies of fill were observed to exhibit stratification in which each layer was composed of a single parent material, but the parent materials for successive layers were different.

Residual Soils and Colluvium

The soil profile developed on the bedrock at LBNL is typically a moderately to highly expansive silty clay less than 2 feet thick. In addition, colluvial deposits, generally less than 20 feet thick, have developed along the bases of slopes and in hillside concavities.

Historic Landslide Deposits

Numerous landslides have occurred at LBNL during its operation. These landslides have involved every substrate material present at LBNL and a variety of failure modes, including rotational/translational, debris flow, and rock fall. Figure 4.2-7 includes the geotechnically important landslide deposits mapped by Harding-Lawson Associates (1982). The paleolandslide deposits discussed in section 4.2.2 are not considered to be historically active and are therefore not shown on Figure 4.2-7. The LBNL facilities division has classified and mapped areas of LBNL that are considered to have a risk of landslide movement (Figure 4.2-8). These areas include both known historical landslide deposits (generally classified as high risk) and areas where landslides have not occurred, but that are known or suspected to be susceptible to landsliding. Figure 4.2-8 also shows the position of groundwater plume AOCs in relation to these landslide risk areas.

4.3 SATURATED ZONE HYDROGEOLOGY

The major mappable geologic units in which LBNL monitoring wells are screened are artificial fill, colluvium, Moraga Formation, Orinda Formation, Mixed Unit, San Pablo Group (?), and Great Valley Group. As described in Sections 4.2.1 and 4.2.4, each of these units consists of a distinct assemblage of soil and rock types. For this reason, the units are assumed to have characteristic hydrogeologic properties and therefore are also treated as hydrogeologic units, although it is recognized that these properties both vary within, and overlap between, each unit.

Among the bedrock units, volcanic rocks of the Moraga Formation and sedimentary rocks of both the Orinda Formation and the Great Valley Group underlie the major portion of the site. The Mixed Unit, a locally occurring unit composed of structurally interleaved volcanic and sedimentary rocks is an important unit only within the central (Old Town) area of the site. The Claremont Formation and the San Pablo Group (?) are present only in the easternmost part of LBNL. Surficial sediments, consisting primarily of colluvium and artificial fill, overlie these bedrock units to a depth of several tens of feet in a number of locations. The structural geometry and the physical characteristics of these bedrock units and surficial sediments, along with the physiography of the site, are the principal hydrogeologic factors controlling groundwater flow and contaminant transport.

Of the 193 groundwater monitoring wells at LBNL as of the end of August, 2000, 113 are screened in only one of these units. The remaining 80 wells are screened across more than one of the units. A summary of the geologic units in which each well is screened is shown in Tables 3.2-1a and 3.2-1b.

4.3.1 Hydrologic Parameters

The two primary hydrologic parameters are hydraulic conductivity and specific storage. These parameters are the principal factors controlling the groundwater flow and contaminant transport through the unit. Hydraulic conductivity varies over many orders of magnitude, and is typically the key parameter in hydrogeologic investigations. Hydraulic conductivity values were used to help develop the conceptual hydrogeologic models included in Modules A through D.

Three methods were utilized at LBNL to attempt to determine values of hydraulic conductivity and/or specific storage: slug tests, pumping tests, and tracer tests. The methodologies for these tests are described in Section 3.2.

Slug Tests

Slug tests have been conducted in 105 wells at LBNL to obtain representative values of hydraulic conductivity for the geologic formations at LBNL and to obtain values of hydraulic conductivity specifically in the areas of groundwater contamination. Test data were analyzed using a computer curve-matching program based on the method of Cooper and others (1967) and assuming radial flow away from a fully penetrating well in a confined aquifer. As an example, Figure 4.3-1 shows the observed slug test data and the "best-fit" curve generated by the curve-matching program for well MW71-93-1. The computed curve matches the observed data for this well, suggesting that the assumptions of the method match the well conditions. The estimated hydraulic conductivity for each tested well is shown in Table 4.3-1. Slug tests were repeated at selected wells to confirm the initial test results. Generally, there was good agreement between the initial and repeat test results. The observed slug test data and "best-fit" curves generated by AQUITEST for all tested wells are contained in Appendix A. The calculated hydraulic conductivities based on these tests range from approximately 10^{-10} to 10^{-4} meters/second (m/s) for all tested formations at LBNL (Table 4.3-1).

In addition to these slug tests, slug test calculations were made on water level data collected from three levels of a four-level well cluster (MW53-92-21) screened in deep horizons (130 feet, 147 feet, and 193 feet) of the Orinda Formation. This is the deepest well at the site. Water levels in three of the four levels are still recovering to static since well installation in 1992. The recovery curves for these wells were used to calculate hydraulic conductivities based on the method of Bouwer and Rice (1976) and Bouwer (1989). These calculations indicated extremely low hydraulic conductivities, on the order of 10^{-12} to 10^{-13} m/sec, and indicate that the more deeply buried horizons of the Orinda Formation may be significantly less permeable than horizons tested in shallower wells.

Pumping Tests

As discussed in section 3 Pumping tests are generally not practical at LBNL since most site wells cannot produce enough water to generate a detectable drawdown within a reasonable period of time in nearby observation wells. Pumping tests were therefore conducted in only a limited number of wells, primarily in the area of the Old Town Groundwater Plume, where a sufficient drawdown could be generated.

Hydraulic conductivity and storativity were computed using the computer program AQTESOLV, employing a modified Theis solution that may account for either vertical leakage (Neuman, 1975) or well bore storage (Papadopulos, 1967). As an example, Figure 4.3-2 shows the best-fit curve for Well 27-92-20, where the calculated drawdown curve fits the pump test data relatively well. The following table summarizes both the pumping tests conducted and describes modifications to the Theis solution that yielded the best fit to the drawdown data for computing hydrologic parameters. Semi-log analysis was used to calculate the hydraulic conductivity from the recovery data. The locations of the pumping test wells in the Old Town Area are shown in Figure 4.3-3. The locations of the pumping test wells in the Building 74/83 area are shown on Figure 4.3-4. Pumping test data and best-fit curves are given in Appendix A.

Summary of Pumping Tests

Test No.	Location	Pumping Well / Observation Wells	Pumping Rate/ Pumping Duration	Comments
1	Old Town VOC Plume	MW91-8 (pumping) MW27-92-20 MW91-7 MW7-92-19 OW7-102 MW53-92-21-130' MW53-92-21-147'	5 gpm for 12.8 hours	No drawdown observed in MW7-92-19, MW53-92-21-130' or MW53-92-21-147'. OW7-102 was reconstructed as multi-level monitoring well MW53-93-16. Theis solution modified for leakage from the unsaturated zone, with an image well to simulate boundary effects used.
2	Old Town VOC Plume	MW91-8 (pumping) MW27-92-20 MW91-7 MW7-92-19 MW53-93-16-42' MW53-93-16-69' MW53-93-9 MW53-93-17 MW53-92-21-130' MW53-92-21-147' MW53-92-21-167' MW53-92-21-193'	3 gpm for 12 days	No drawdown observed in MW7-92-19, MW53-92-21 or MW53-93-16-42'. Poorly defined drawdown curve in MW53-93-17 and MW53-93-9. Theis solution modified for leakage from the unsaturated zone, with an image well to simulate boundary effects used.
3	Old Town Diesel Plume	MW7-92-16 (pumping) MW90-2 MW6-92-17 MW6-93-4	1.6 gpm for 36 hours	No drawdown observed in MW90-2 or MW6-92-17. Free product (kerosene) noted in pumping well after test. Theis solution with an image well to simulate boundary effects.
4	Building 74/83 Diesel Plume	MW74-92-13 (pumping) MW83-92-14 MW74-94-7 MW74-94-8	1.2 gpm for 6 hours	No drawdown observed in observation wells. Theis solution modified to account for well bore storage used.
5	Old Town Diesel Plume	MW7-92-16 (pumping) MW90-2 MW6-92-17 MW6-93-4	1.9 gpm for 8 hours	No drawdown observed in MW90-2 or MW6-92-17. 3" layer of free product noted in pumping well after test. Theis solution with an image well to simulate boundary effects.

6	Old Town VOC Plume	MW53-93-16-69’ MW53-93-16-42’ MW91-7 MW91-8 MW27-92-20 MW53-93-9 MW53-93-17 MW7-92-19	0.6 to 1.0 gpm for 43 days	No drawdown observed in MW53-93-16-42’ or MW7-92-19. VOC concentration increased from 600 ug/L to 1,600 ug/L during test. Theis solution modified for leakage from the unsaturated zone, with an image well to simulate boundary effects used.
7	Building 58 - Downgradient of Old Town VOC Plume	MW58-95-11 MW58-93-3 SB58-95-1 SB58-95-2	0.14 gpm max sustained	Theis solution modified to account for well bore storage used.
8	Building 58 - Downgradient of Old Town VOC Plume	MW58-93-3 SB58-95-1 SB58-95-2 MW58-95-11	0.35 max sustained	Theis solution modified to account for well bore storage used.
9	Building 58 Downgradient of Old Town VOC Plume	SB58-95-1 SB58-95-2 MW58-93-3 MW58-95-11	0.3 gpm max sustained	Theis solution modified to account for well bore storage used.
10	Building 58 Downgradient of Old Town VOC Plume	SB58-95-2 SB58-95-1 MW58-93-3 MW58-95-11	0.45 gpm max sustained	Theis solution modified to account for well bore storage used.

Results of most of the pumping test analyses are given in the following table. An exception is MW7-92-16 (test 3 and test 5) due to a non-unique solution that resulted from the inability to determine hydraulic conductivity and storativity from the drawdown data for this well because of overlap of the well bore storage and boundary effects.

Results of Pumping Test Analyses

Pump Test Results					Slug Test Results
Well Name	Geologic Unit	Hydraulic Conductivity (m/s)		Storage Coefficient	Hydraulic Conductivity (m/s)
		Drawdown	Recovery	Drawdown	
OW7-102 (test 1)	Moraga	8.7×10^{-6}	2.5×10^{-5}	3.4×10^{-4}	NA
53-93-16-69’ (test 2)	Moraga	1.1×10^{-5}	7.6×10^{-6}	8.6×10^{-4}	
MW91-7 (test 1)	Moraga	2.0×10^{-5}	3.8×10^{-5}	6.1×10^{-4}	8.8×10^{-7}
MW91-7 (test 2)	Moraga	1.1×10^{-5}	9.5×10^{-6}	1.8×10^{-3}	
MW91-7 (test 6)	Moraga	2.7×10^{-5}	not recorded	1.2×10^{-3}	
MW91-8 (test 1)	Moraga	8.0×10^{-6}	6.3×10^{-6}	5.3×10^{-2}	3.3×10^{-5}
MW91-8 (test 2)		1.2×10^{-5}	6.1×10^{-6}	8.9×10^{-2}	

MW91-8 (test 6)		4.0×10^{-5}	not recorded	1.7×10^{-3}	
MW74-92-13 (test 4)	San Pablo (?)	4.3×10^{-6}	7.4×10^{-6}	4.3×10^{-5}	8.0×10^{-6}
MW7-92-16	Moraga	no fit	1.0×10^{-6}	no fit	5.4×10^{-6}
MW27-92-20 (test 1)	Moraga/ Orinda	1.5×10^{-5}	1.7×10^{-5}	4.0×10^{-5}	2.5×10^{-5}
MW27-92-20 (test 2)	Moraga/ Orinda	2.2×10^{-5}	5.1×10^{-6}	1.1×10^{-5}	
MW27-92-20 (test 6)	Moraga/ Orinda	1.8×10^{-5}	5.1×10^{-6}	2.4×10^{-3}	
MW58-93-3 (tests 8 & 9)	Colluvium/ Moraga	8.7×10^{-7}	2.2×10^{-7}		NA
MW6-93-4	Fill/Moraga	2.0×10^{-6}	2.2×10^{-6}	3.8×10^{-4}	7.0×10^{-6}
MW53-93-9 (test 6)	Moraga/ Mixed/Orinda	6.3×10^{-5}	not recorded	2.1×10^{-3}	1.7×10^{-5}
MW53-93-16-69' (test 6)	Moraga	2.9×10^{-5}	not recorded	6.6×10^{-6}	6.8×10^{-7}
MW53-93-17 (test 6)	Moraga	4.4×10^{-5}	not recorded	1.0×10^{-3}	1.5×10^{-9}
MW58-95-11 (test 9)	Moraga/ Orinda	3.8×10^{-7}	3.5×10^{-8}		NA
SB58-95-1	Moraga/ Orinda	3.4×10^{-7}	2.0×10^{-7}		NA
SB58-95-2	Moraga/ Orinda	7.5×10^{-7}	3.1×10^{-7}		NA

The hydraulic conductivity values calculated from the pumping test results for each well were generally within an order of magnitude of the hydraulic conductivity value that was derived from the slug test at each well. However, larger deviations between these test methods were observed at wells MW91-7, MW53-93-16-69', and MW53-93-17, where the slug test results were from 1.5 to 4 orders of magnitude lower than the pumping test results. These discrepancies are probably due to the intrusion of grout into the formation as a result of abandonment procedures (i.e. pressure-grouting) conducted at nearby wells. The deviation between pumping test and slug test results for well MW53-93-17 is more pronounced than at the other wells because it was installed by drilling out a slope indicator well, which had been grouted over the entire depth of the subsequently installed well screen.

Tracer Tests

Four tracer tests were conducted at LBNL. The tests were conducted to assess the hydraulic conductivity and potential migration pathways for the Old Town Groundwater Plume. The results of the tests are described in the following table. For two of the tests (Tests 1 and 4), breakthrough of the tracer was not observed at the monitoring points. For the two tracer tests (Tests 2 & 3 conducted in the Building 7 Sump Area (Figure 4.3-5) breakthrough of the tracer was observed in only one extremely close monitoring point.

Summary of Tracer Tests

	Test 1	Test 2	Test 3	Test 4
Injection Point	53-93-16-69’	Backfilled Excavation/ Injection Area 1	B7 Sump Backfill/ Injection Area 2	90-3
Extraction Well	91-8	90-2, 7-92-19, VZM-OT-1, & VZM-OT-2	90-2, 7-92-19, 7-94-3, 7B-95-21, 7-95-22,VZM-OT-1,& VZM-OT-2	Hydraugers: 51-01-03, 51-01-03A, & 51-01-04
Tracer	Fluoroscein dye	Lithium bromide	Oxygen 18 (EBMUD water)	Choroform (EBMUD water)
Test Purpose	To estimate hydraulic conductivity	To find out transport pathways	To find out transport pathways	To test flow rate
Test Date	April 1994	December 8, 1994	October 30, 1995	June 13, 1996
Test Duration	10 days	77 days	39 days	43 days
Test Results	Not detected	Breakthrough at 2.5 m bgs installation in VZM-OT2. Not detected in monitoring wells	Breakthrough at 9 m bgs installation in VZM-OT1. Not detected in monitoring wells	Flow rate is very low

4.3.2 Hydrogeologic Units

The characteristics of the hydrogeologic units at LBNL are discussed in the following subsections. The range of hydraulic conductivity magnitudes measured for each of these units is summarized in the table below and on Figures 4.3-6 and 4.3-7. These ranges were derived primarily from slug tests. As shown on Figure 4.3-6, hydraulic conductivity values for the rocks underlying LBNL span the range from 10^{-12} to 10^{-4} m/s, although the values for individual hydrogeologic units have more restricted ranges.

Typical Hydraulic Conductivity Ranges for Geologic Units at LBNL

Geologic Unit	Hydraulic Conductivity
Artificial Fill	10^{-6} to 10^{-8} m/s
Colluvium (includes Alluvium)	10^{-6} to 10^{-10} m/s
Moraga Formation	10^{-4} to 10^{-6} m/s
Mixed Unit	10^{-5} to 10^{-9} m/s
Orinda Formation	10^{-5} to 10^{-13} m/s
Orinda Formation – fine-grained sandstone or finer	10^{-7} to 10^{-12} m/s
Orinda Formation – medium-grained sandstone or coarser	10^{-5} to 10^{-7} m/s
San Pablo Group	10^{-6} to 10^{-8} m/s
Great Valley Group	10^{-5} to 10^{-8} m/s

Artificial Fill

Measured hydraulic conductivity values for the artificial fill at LBNL have a narrow range compared to other geologic units at LBNL (Figure 4.3-6). However, few measurements were taken in this unit, and almost all of the measurements were made in wells screened in the artificial fill beneath the Building 51/64 complex. This fill is engineered, and typically consists of materials derived from colluvium, the Moraga and Orinda Formations, and the Great Valley Group. There is no aquifer testing data for the non-engineered fills at the site, such as the base of the fill beneath the Corporation Yard. The hydraulic conductivity of these fills is probably greater than that of the engineered fills due to their lack of compaction, inclusion of large amounts of organic debris in some locations, and possible inclusion of coarse-grained layers.

Colluvium

The distribution of hydraulic conductivity values for colluvium at LBNL is not well defined due to the low number of measurements made in this unit (Figure 4.3-6). The range of values measured covers many orders of magnitude, presumably due to the variety of grain sizes and sorting of the colluvium. Additionally, units mapped as colluvium may also contain alluvial deposits due to the difficulty of definitively differentiating the two, further increasing this uncertainty.

Moraga Formation

Rocks of the Moraga Formation have the highest overall hydraulic conductivities measured at LBNL (Figure 4.3-6). As described in Section 4.3.2 and in Table 4.3-1, the three lowest values of hydraulic conductivity shown on Figure 4.3-6 for this unit are suspected to be non-representative of typical values for the Moraga Formation, due to local conditions at the test locations. Therefore, the hydraulic conductivity values for the Moraga Formation may be even higher than depicted on the figure. In addition to the well testing results shown, several historic springs were located along the downslope contact between Moraga Formation volcanic rocks and the underlying Orinda Formation. This observation provides additional evidence that the Moraga Formation has a high hydraulic conductivity relative to the relatively less permeable Orinda Formation. The presence of low permeability interbeds of clay and other sediments as well as less fractured zones within this formation is suspected to result in perched water conditions at some locations within the formation, as suggested by the lack of drawdown observed in well MW53-93-16-42' during pumping tests 2 and 6.

Groundwater flow is presumed to be predominantly though fractures in this formation. However, based upon examination of excavations, outcrops and core samples, the spacing of the fractures is sufficiently close throughout most of the site that groundwater flow can be assumed to approximate pore flow at the scale measured in monitoring wells.

Mixed Unit

No hydraulic conductivity tests were conducted on wells screened solely in the Mixed Unit. However, based on tests that were conducted on wells screened in both this and adjacent units (Table 4.3-1), hydraulic conductivity is relatively low in this unit. However, examination of core samples and excavations in the Mixed Unit indicate that the permeability of the strata in the Mixed Unit is probably highly variable. At one location within an excavation in the eastern portion of LBNL, groundwater was observed flowing from a relatively permeable bed within the Mixed Unit. This saturated section was observed to lie adjacent to unsaturated Moraga Formation andesites and San Pablo Group (?) sandstones, suggesting that local zones within the Mixed Unit may have higher hydraulic conductivities than either of these units.

Orinda Formation

The Orinda Formation has a broad range of hydraulic conductivities as shown in Figure 4.3-6. The highest hydraulic conductivity values measured in the Orinda Formation occur in wells screened in relatively coarse-grained sections of the unit (Figure 4.3-8). Although Orinda Formation rocks are typically intensely fractured, examination of core samples suggests the fractures are generally closed, suggesting that groundwater flow may be primarily through intergranular pores. It is sometimes observed during well installation that groundwater is recovered more readily from coarser-grained horizons within the Orinda Formation than from overlying or underlying fine-grained strata. This suggests that coarse-grained strata may form confined aquifers in some locations.

Wells screened at least partially in coarser-grained strata constitute approximately a quarter of the wells screened in the Orinda Formation. The coarser portion of the Orinda Formation at LBNL is structurally and topographically higher than the finer-grained portion of the formation. This indicates that the Orinda Formation rocks at higher elevations at LBNL are likely to have higher hydraulic conductivities than those at lower elevations. The thick section of Orinda Formation siltstones and claystones immediately overlying the Great Valley Group along the middle slopes of LBNL are expected to have very low hydraulic conductivities. This relationship is illustrated by the slug test calculations made on the long-term recovery data for deep horizons of well MW53-92-21, which indicated hydraulic conductivities as low as 10^{-12} m/s.

Coarse-grained strata within the Orinda Formation are in many cases intercalated with finer-grained beds on the scale of feet to tens-of-feet. As the coarser strata generally have substantially higher hydraulic conductivities than the finer strata, hydraulic conductivity within in the Orinda Formation as a whole may be somewhat anisotropic.

San Pablo Group (?)

The hydraulic conductivity of the San Pablo Group (?) is poorly defined due to the small number of wells screened within it, as shown on Figure 4.3-6. As this unit consists primarily of fine-grained sandstone that is little fractured to massive, groundwater flow is probably through the intergranular porosity.

Claremont Formation

No aquifer testing data are available for this unit.

Great Valley Group

Rocks of the Great Valley Group have the relatively high hydraulic conductivities, similar to those measured in the Moraga Formation (Figure 4.3-6). Based upon examination of outcrops, excavations and core samples, groundwater flow in this unit is believed to be primarily through fractures. The intensity of fracturing generally increases close to the fault contact with the Orinda Formation. However, the two lowest hydraulic conductivity values shown on Figure 4.3-6 were calculated for wells very close to the fault, indicating that flow through fractures may not be significant near the contact.

4.3.3 Water Table Properties

Seasonal fluctuations observed in groundwater elevation data show a good correlation with rainfall data, as illustrated on Figure 4.3-9. The magnitudes of groundwater elevation fluctuations in wells screened in the Moraga Formation were generally more consistent than for wells screened in other units. This result may be due to the high permeability of the Moraga Formation. In addition, the Moraga Formation is generally the uppermost bedrock unit at LBNL, so that infiltration of groundwater into the Moraga formation is not generally impacted by the hydraulic properties of overlying units. Seasonal water level and rainfall data for all LBNL groundwater monitoring wells are summarized in Appendix B.

In some areas, groundwater elevation data can be used to make inferences regarding the local hydrogeology, as follows:

- Several wells near Building 71 that are screened in shallow, highly permeable fractured andesite of the Moraga Formation show nearly identical seasonal water level variations (Figure 4.3-9), probably because they are screened in the same aquifer. A similar relationship is observed in wells MW53-93-16, MW91-7, MW91-8, MW53-93-9, MW53-93-17 and MW27-92-20 in the Old Town area, also indicating that they are screened in the same aquifer. The Old Town results confirm the observations made during pumping tests described above.
- Wells screened in low permeability rocks of the Orinda Formation, or in areas that are separated from recharge zones by low permeability zones (e.g. wells MWP-1 and MW46-92-16), show poor correlation between water levels and rainfall.
- At well MW52-94-10 (Figure 4.3-10), which is screened across the Moraga Formation/Orinda Formation contact, the groundwater level drops rapidly during the summer months to slightly below the elevation of the Moraga/Orinda contact, but then does not decline further. This observation confirms the low hydraulic conductivity of the Orinda Formation indicated by aquifer testing.

Water levels in several wells at LBNL show anomalous responses to rainfall. However, these responses are generally due to extraneous factors unrelated to hydrogeology, as follows:

- Water levels in MW7-92-19 (Figure 4.3-11), MW90-2, MW7-94-3, MW7B-95-21 and MW7-95-22 all respond to rainfall at an anomalously rapid rate compared to most other LBNL wells. This is interpreted to be due to infiltration of high volumes of rainwater from a storm drain near the wells.
- The water levels in MW46-93-12 (Figure 4.3-12), MW51-97-16, and MW51-92-2 fluctuate very little because they are located adjacent to subdrains or storm drains, which maintain a relatively constant local groundwater level.
- In the Building 71 area, the groundwater elevation began increasing before the rainfall in 1994 (Figure 4.3-9). This increase correlated with an increase in chloroform (a constituent of EBMUD drinking water) in samples collected from these wells, and was subsequently found to be caused by the break in an EBMUD water supply pipe.

- Well MW77-92-10 shows both variable water level fluctuations and high nitrate concentrations. These observations suggest a nearby sanitary sewer near the well may be leaking.

Piezometric Gradient

A groundwater elevation map for September 1999 (end of the dry season) is presented on Figures 4.3-13 for wells screened close to the water table. This map is assumed to approximate the piezometric surface as measured at the water table, and the groundwater flow direction is assumed to approximately follow the piezometric gradient. Although seasonal water level changes of 12 to 15 feet have been observed in many wells, the contour pattern of the groundwater piezometric surface does not change significantly from season to season. The groundwater piezometric surface generally mirrors the surface topography at LBNL both in direction and magnitude. In the western portion of the site, the piezometric gradient is generally directed to the west; over the rest of LBNL, the gradient is generally directed toward the south.

The direction and magnitude of the piezometric gradient deviates locally from the general trends suggested by the surface topography due to the subsurface geometry of the hydrogeologic units. For example, in the northern portion of the Old Town area (north of Building 7) the piezometric gradient is directed northward, approximately 90° to the westward slope of the surface topography. The anomalous gradient direction in this area is thought to be a result of the presence of a northward trending body of Moraga Formation at the water table in this area. Since the Moraga Formation has a high hydraulic conductivity relative to the underlying units, it constitutes a preferential flow pathway in this area. Further details of this example are given in Module B of this report (the Old Town Area).

4.3.4 Groundwater Chemistry

The electrical conductivity of the groundwater from 183 of the 193 groundwater monitoring wells was measured, and groundwater samples from these wells were analyzed for inorganic constituents (minerals). The inorganic analytes included total dissolved solids (TDS) content, calcium, magnesium, sodium, potassium, hydroxide, carbonate, bicarbonate, chloride, sulfate, nitrate (nitrite as NO_3), pH, calculated hardness (as $CaCO_3$), and alkalinity (as $CaCO_3$). These results are presented in Table 4.3-2.

Electrical Conductivity and Total Dissolved Solids

For water with relatively low TDS content, electrical conductivity varies almost directly with TDS content. Electrical conductivity of groundwater at LBNL varies from 193 to more than 5800 micro-mhos per centimeter. This corresponds to a TDS content between approximately 105 and 4460 mg/L. Average TDS contents of wells screened in each geologic unit are shown in the table below. For wells with multiple TDS measurements, the average value was calculated using only the first result measured at each of those wells.

Average Total Dissolved Solids Concentrations for Units at LBNL

Geologic Unit	Average TDS (mg/L)
Artificial Fill	862
Colluvium	647
Moraga Formation	519
Orinda Formation	813
San Pablo Formation	1232
Great Valley Group	723

Major Cations and Anions

The relative abundance of groundwater mineral species for each well assigned to a geological unit is shown on the Piper diagrams in Figures 4.3-14 to 4.3-20. These diagrams can be used to classify groundwater for each unit by anion and cation facies as shown on Figure 4.3-21. The groundwater classification for each unit is shown on the following table (Piper, 1944):

Groundwater Classification for Geologic Units at LBNL

Formation	Cation Facies	Cation Type	Anion Facies	Anion Type
Artificial Fill	calcium-sodium	no dominant	bicarbonate	bicarbonate
Colluvium	calcium-sodium	no dominant	bicarbonate to bicarbonate-chloride-sulfate	bicarbonate
Moraga Formation	calcium-sodium	no dominant	bicarbonate to bicarbonate-chloride-sulfate	bicarbonate
Orinda Formation	sodium-potassium and calcium-sodium	no dominant to sodium or potassium	bicarbonate-chloride-sulfate	bicarbonate
San Pablo (?) Formation	sodium-potassium	sodium or potassium	bicarbonate-chloride-sulfate	bicarbonate
Great Valley Group	calcium-sodium	no dominant	bicarbonate-chloride-sulfate	bicarbonate

Figures 4.3-15 to 4.3-20 show graphical representation of these geochemical facies, and indicate that the facies associated with each hydrogeologic unit is relatively distinctive. In addition, with the exception of the artificial fill, this observation also holds true for wells screened in multiple units, which generally have approximately the same relative abundance of mineral species as that from wells screened in the single unit which occupies the greatest portion of the screened interval of the multiple unit well (as shown on Table 4.3-1. This is particularly relevant for the wells assigned to the Moraga Formation, of which approximately half are screened in multiple units. The only outlying results for the Moraga Formation wells shown on Figure 4.3-17 are those from MW1-220. This well is screened from approximately 83 to 93 feet bgs in a thick section of Moraga Formation.

All of the near 100% sodium/potassium groundwater results from the Great Valley Group shown on Figure 4.3-20 come from wells installed just below the Orinda Formation/Great Valley

Group contact. As the majority of the groundwater results from the Orinda Formation are >90% sodium/potassium, this suggests some penetration of Orinda Formation groundwater into the top of the Great Valley Group.

Groundwater mineral concentrations (in milliequivalents per liter) are depicted on Stiff diagrams included in Modules A to D.

LIST OF FIGURES

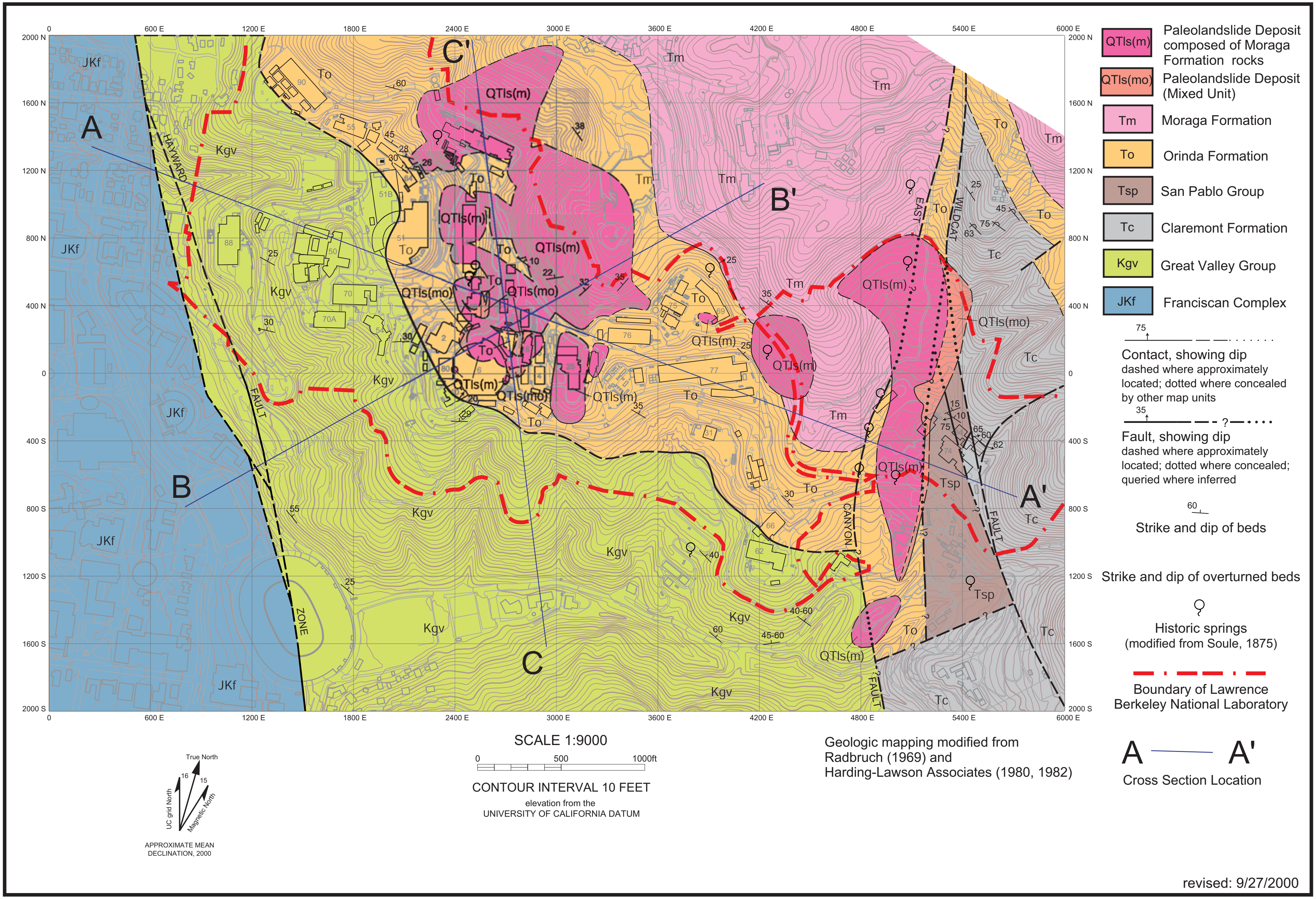

Figure 4.2-1. Bedrock Geologic Map, Lawrence Berkeley National Laboratory.

4.2-1 site br map.ai
09/00

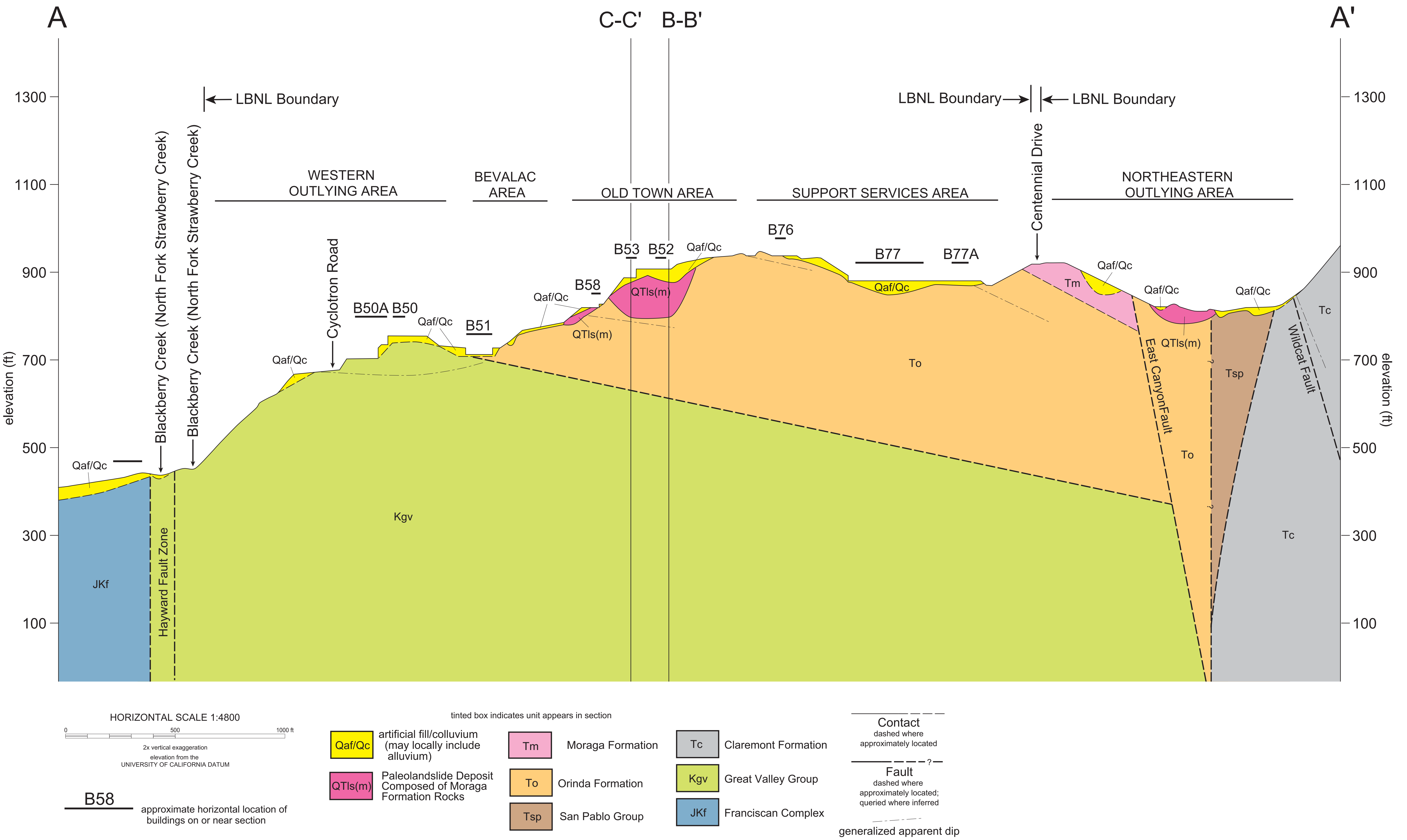

Figure 4.2-2. LBNL Site Cross Section A-A'.

4.2-2 A-A'.ai
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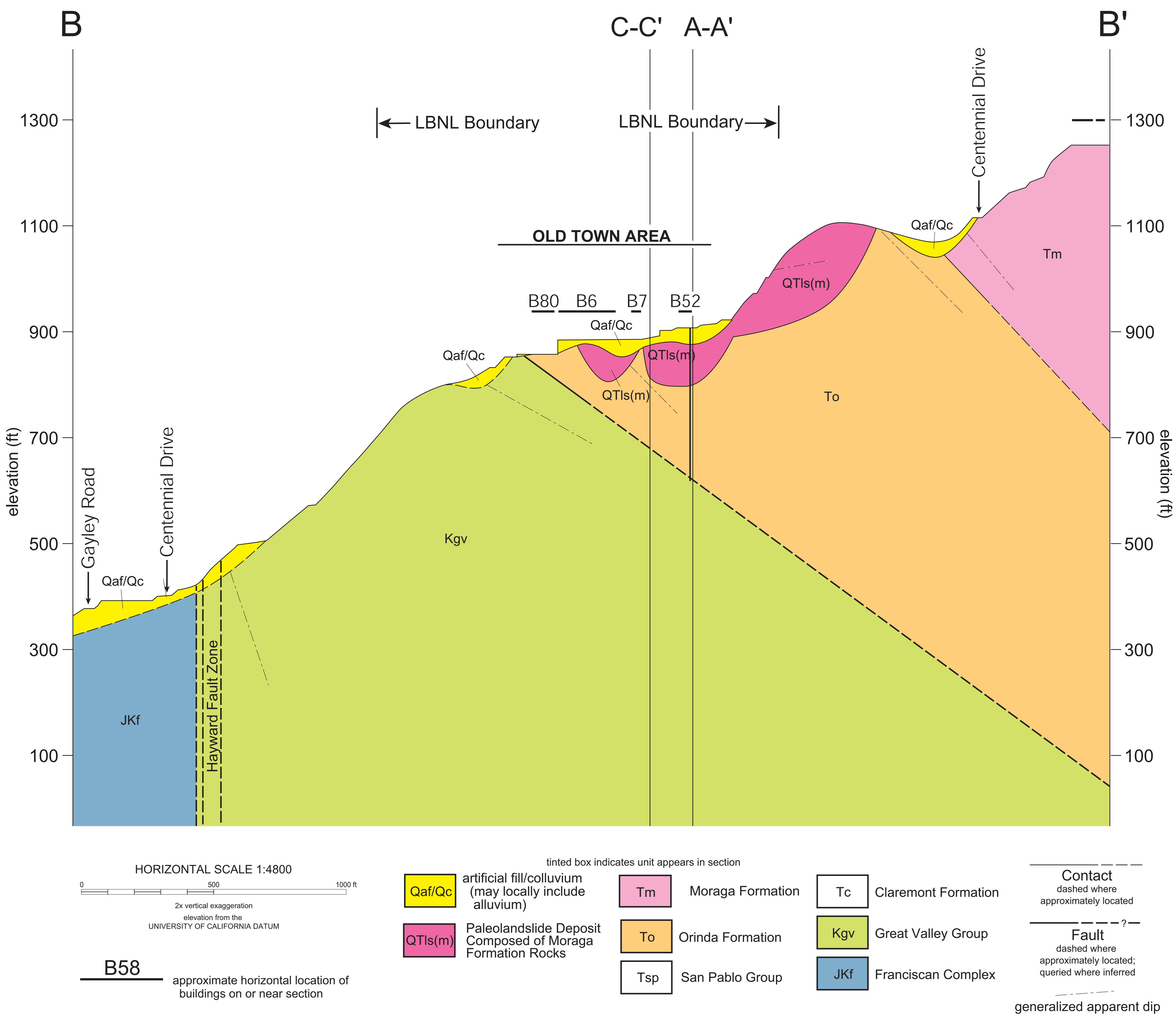

revision: 9/26/2000

Figure 4.2-3. LBNL Site Cross Section B-B'.

4.2-3 B-B'.ai
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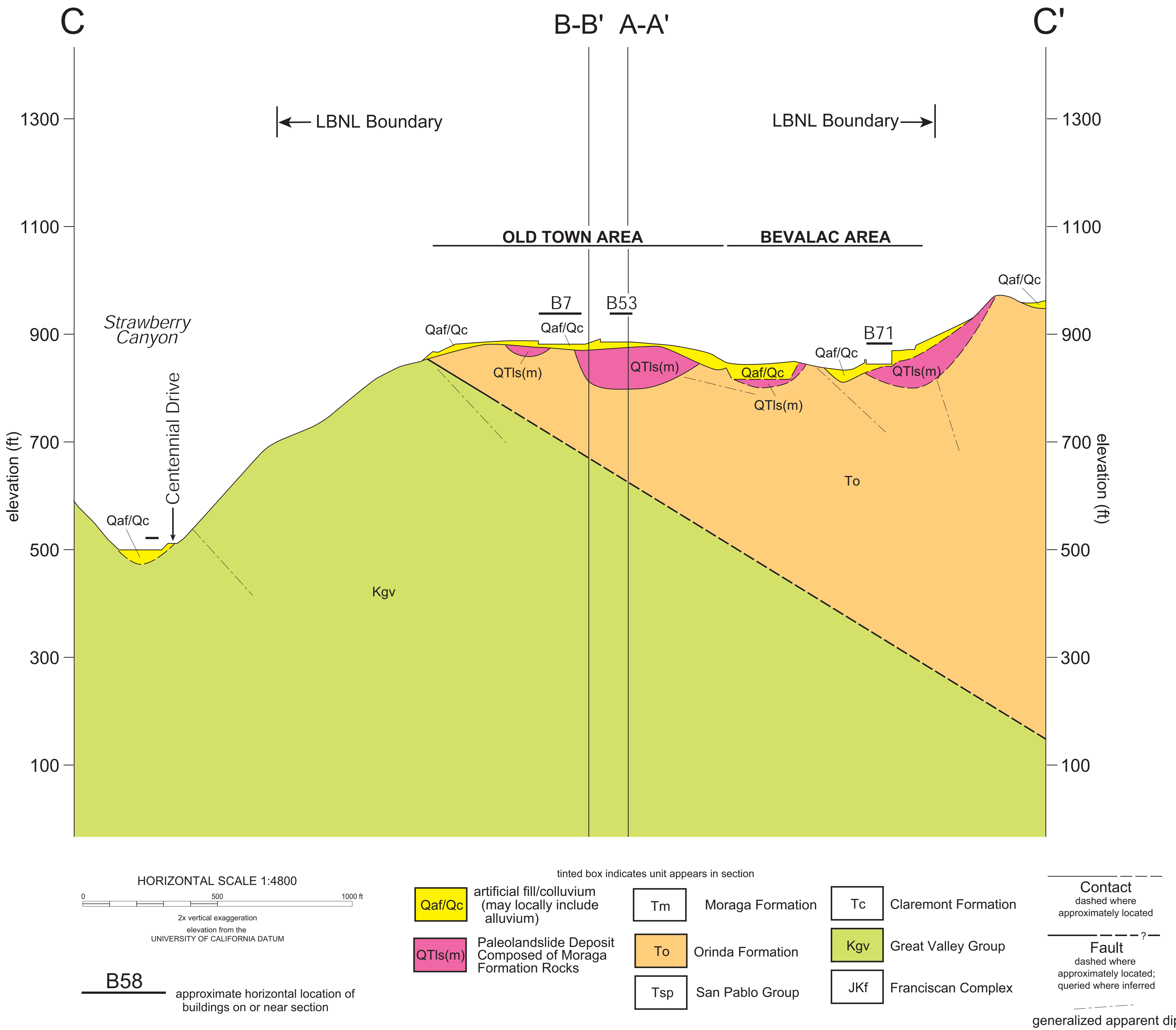

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Figure 4.2-4. LBNL Site Cross Section C-C'.

4.2-4 C-C'.ai
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Age	Formation	Description
Quaternary	Artificial fill	Generally engineered fill consisting of fine-grained material. Older fills include vegetative and other debris.
	Colluvium	Predominantly clayey silt.
	Debris flows	Boulders and gravels of basalt, chert, and porcelenite in a silty clay matrix.
	Landslides	Translational/rotational slide masses incorporating bedrock. Occur at the Moraga/Orinda Formation contact.

	WEST OF HAYWARD FAULT	EAST OF HAYWARD FAULT					
		West of Life Sciences Area Main Canyon Landslide Deposit			*East of Life Sciences Area Main Canyon Landslide Deposit*		
Age		**Group**	**Formation**	**Description**	**Group**	**Formation**	**Description**
Tertiary		Contra Costa	Moraga	Andesitic flows, breccias, and agglomerates with minor amounts of basaltic flows and interbedded volcaniclastic sandstone and conglomerate.	San Pablo (?)	Neroly	Fossiliferous, shallow marine, fine grained sandstones with minor amounts of siltstone.
			Orinda	Alluvial sedimentary deposits consisting primarily of claystone and siltstone with lenticular to linear beds of sandstone and conglomerate.		Briones	Fossiliferous, shallow marine, fine grained sandstones with minor amounts of siltstone.
					Monterey	Claremont	Chert and shale with minor amounts of sandstone.
Cretaceous		Great Valley		Marine mudstones, shales, and sandstones.			
Jurassic	Franciscan Complex						

Figure 4.2-5. Stratigraphic Correlation Chart, Lawrence Berkeley National Laboratory.

4.2-5 StratChart.xls
09/00

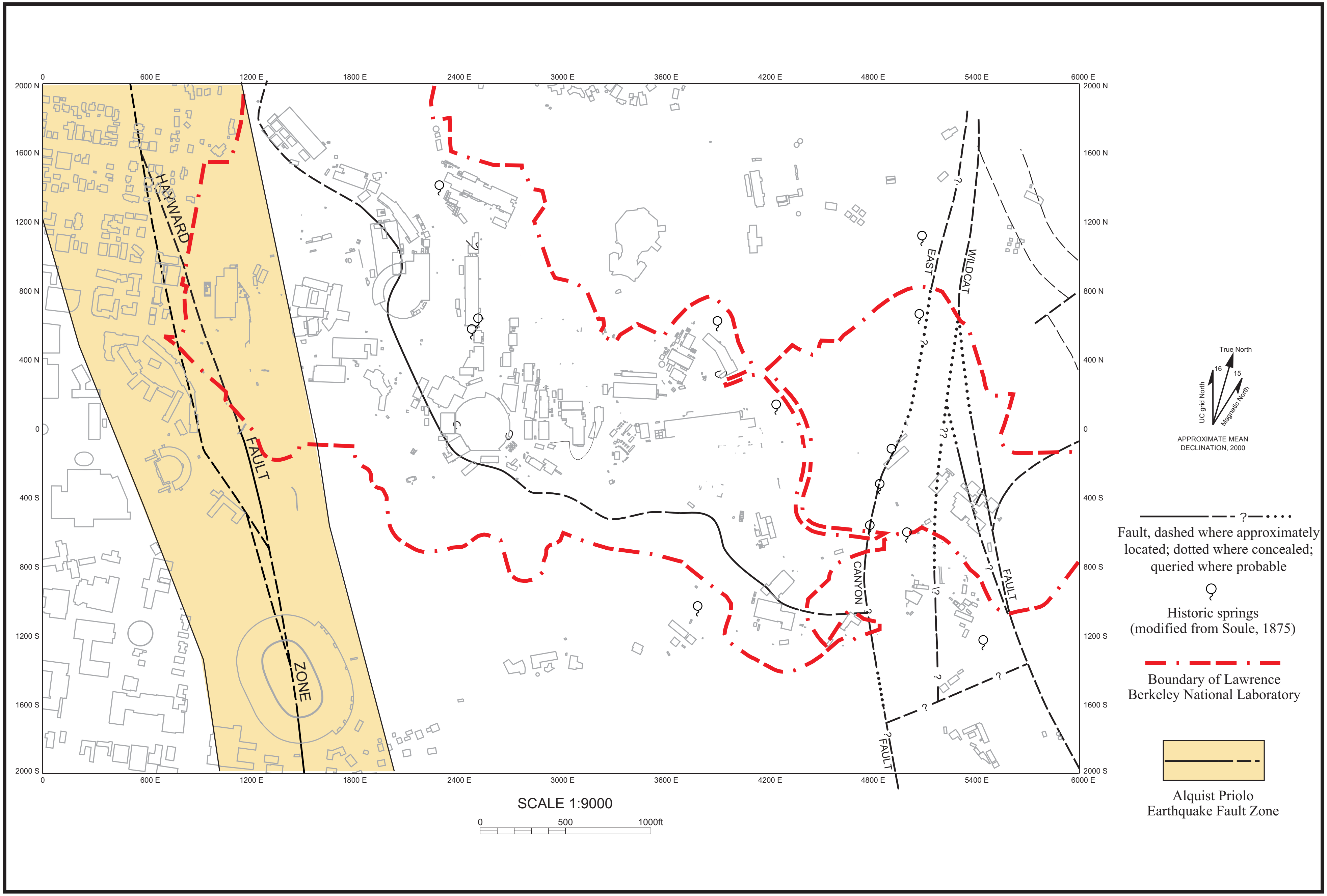

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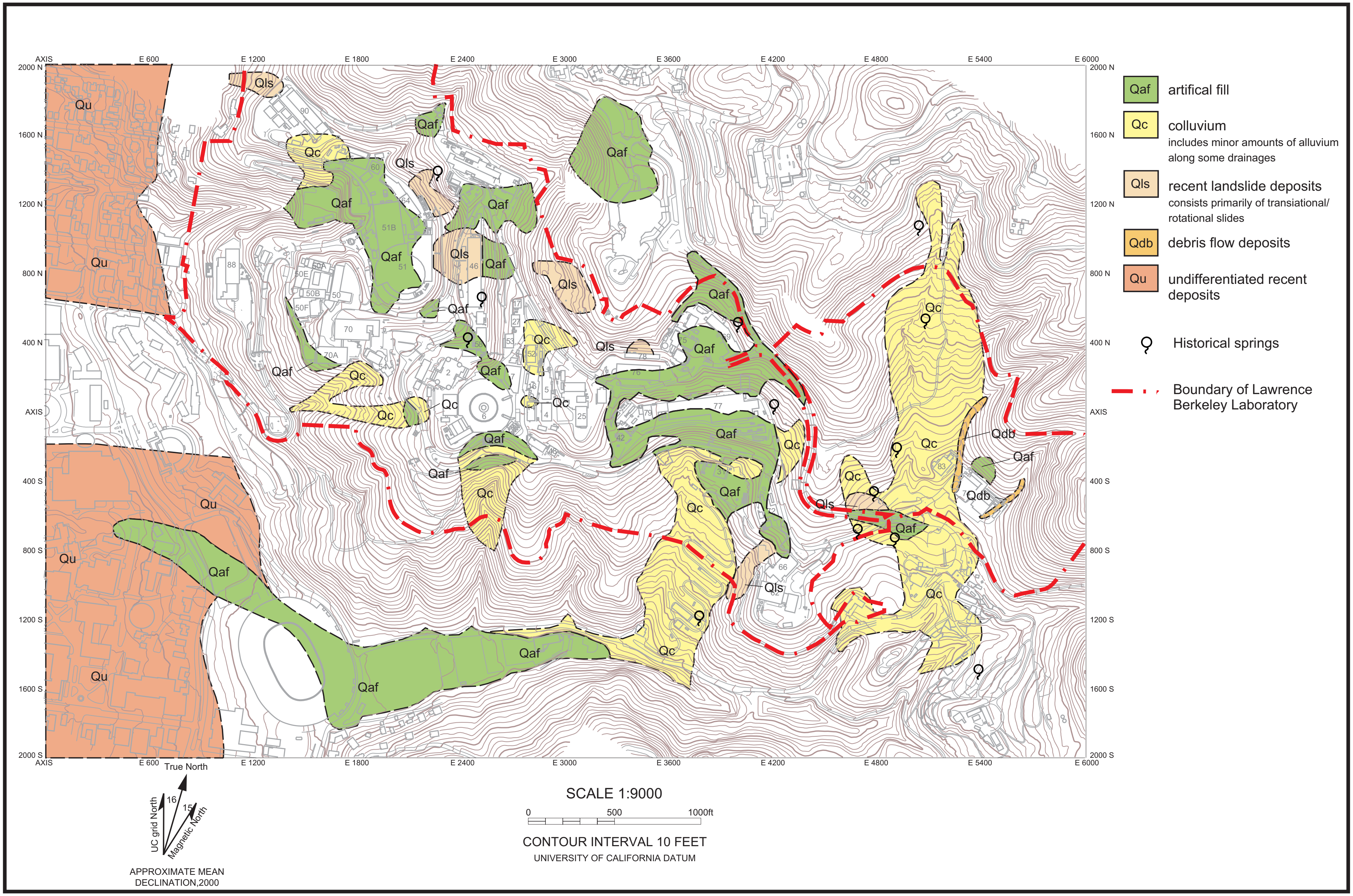
Figure 4.2-6. Fault Map of LBNL Showing Location of Alquist Priolo Earthquake Fault Zone.



4.2-7 site surf map.ai
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Figure 4.2-7. Surficial Geologic Map, Lawrence Berkeley National Laboratory (modified from Harding-Lawson Associates, 1982).

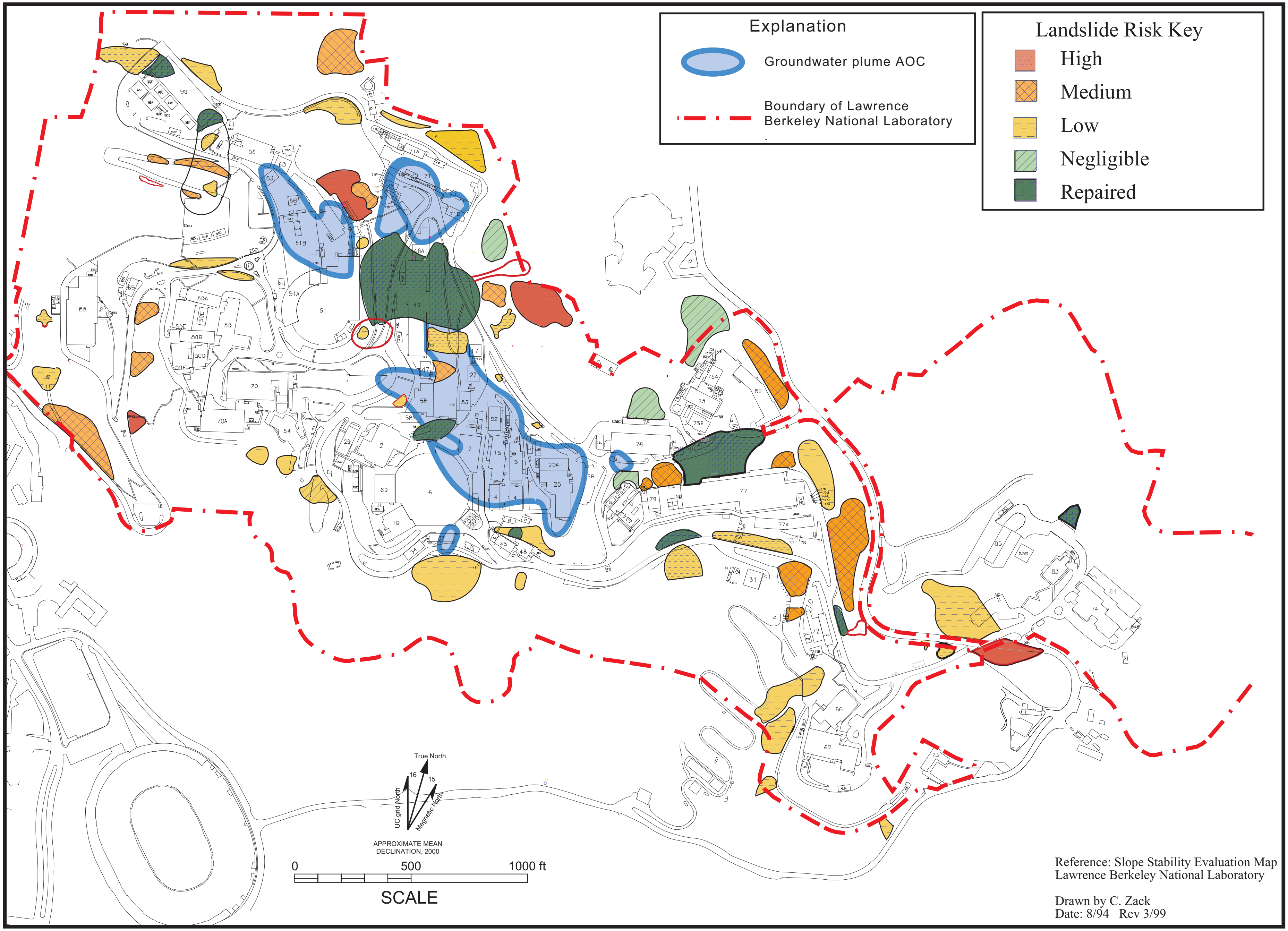

Figure 4.2-8. Locations of Groundwater AOCs and Landslide Risk.

4.2-8 SlidePlumes.ai
09/00

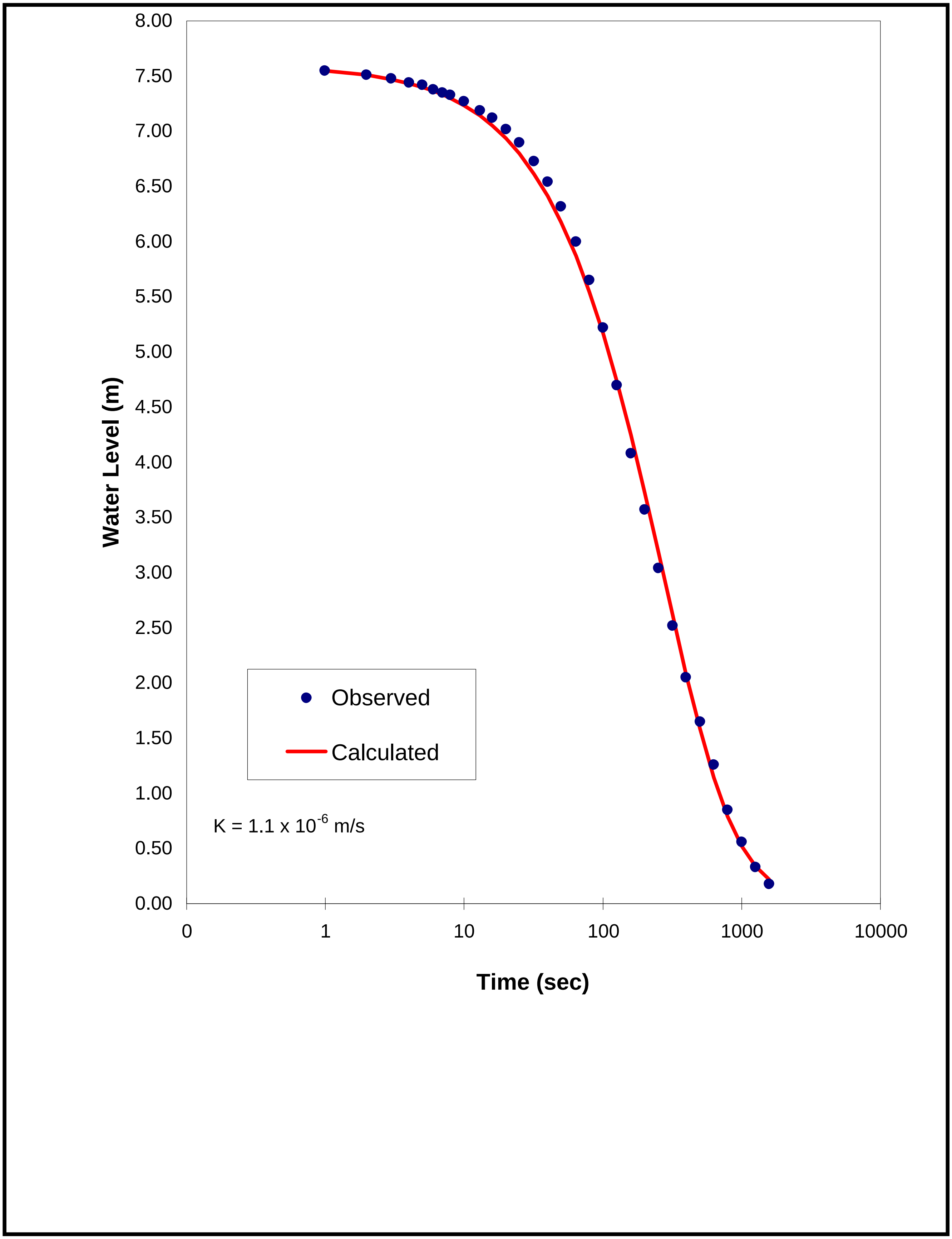

Figure 4.3-1. Slug Test at LBNL, MW71-93-1.

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09/00

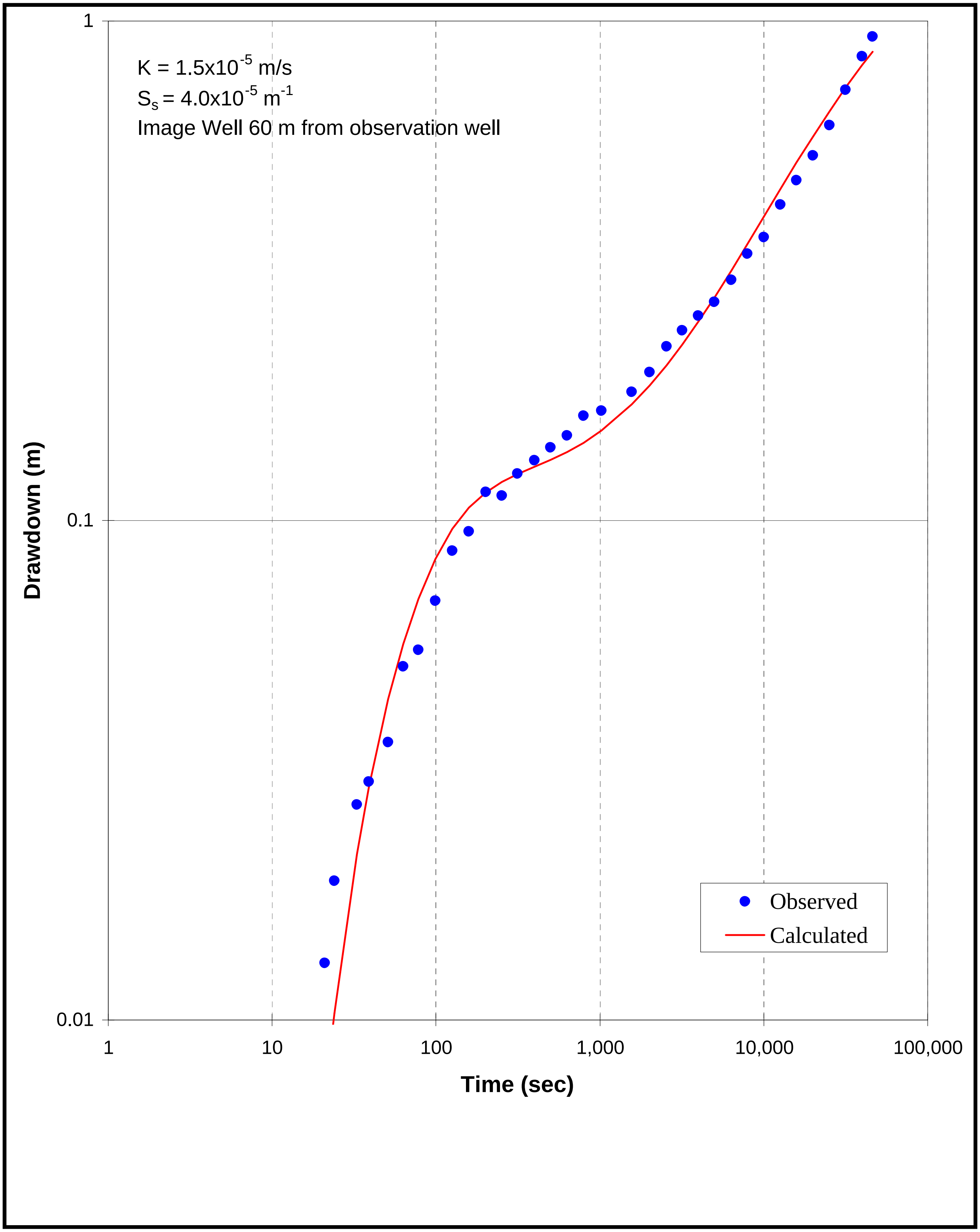

Figure 4.3-2. Drawdown in MW27-92-20 During 5 gpm Pumping Test at MW91-8.

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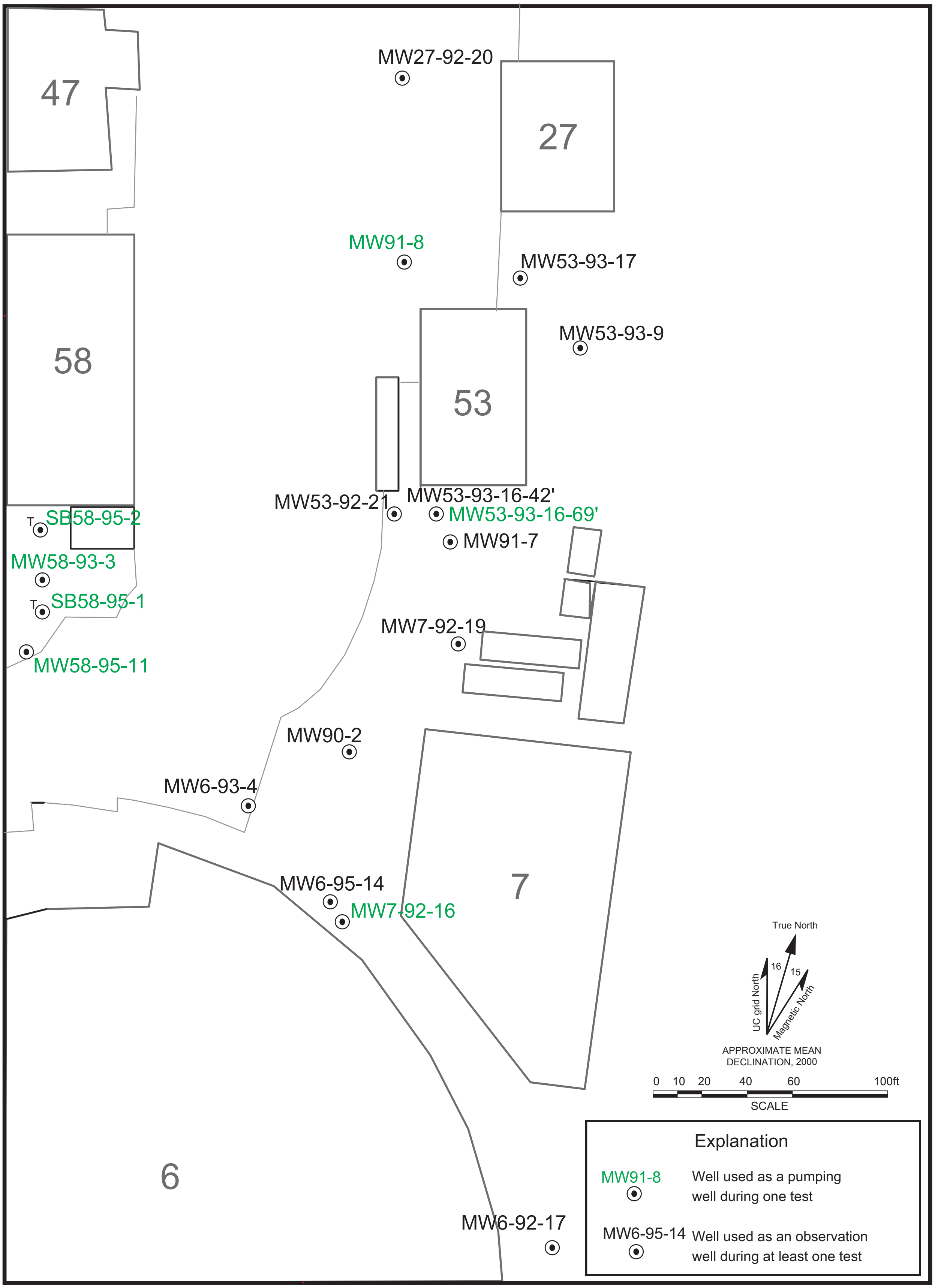

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Figure 4.3-3. Locations of Old Town Pumping Test Wells.

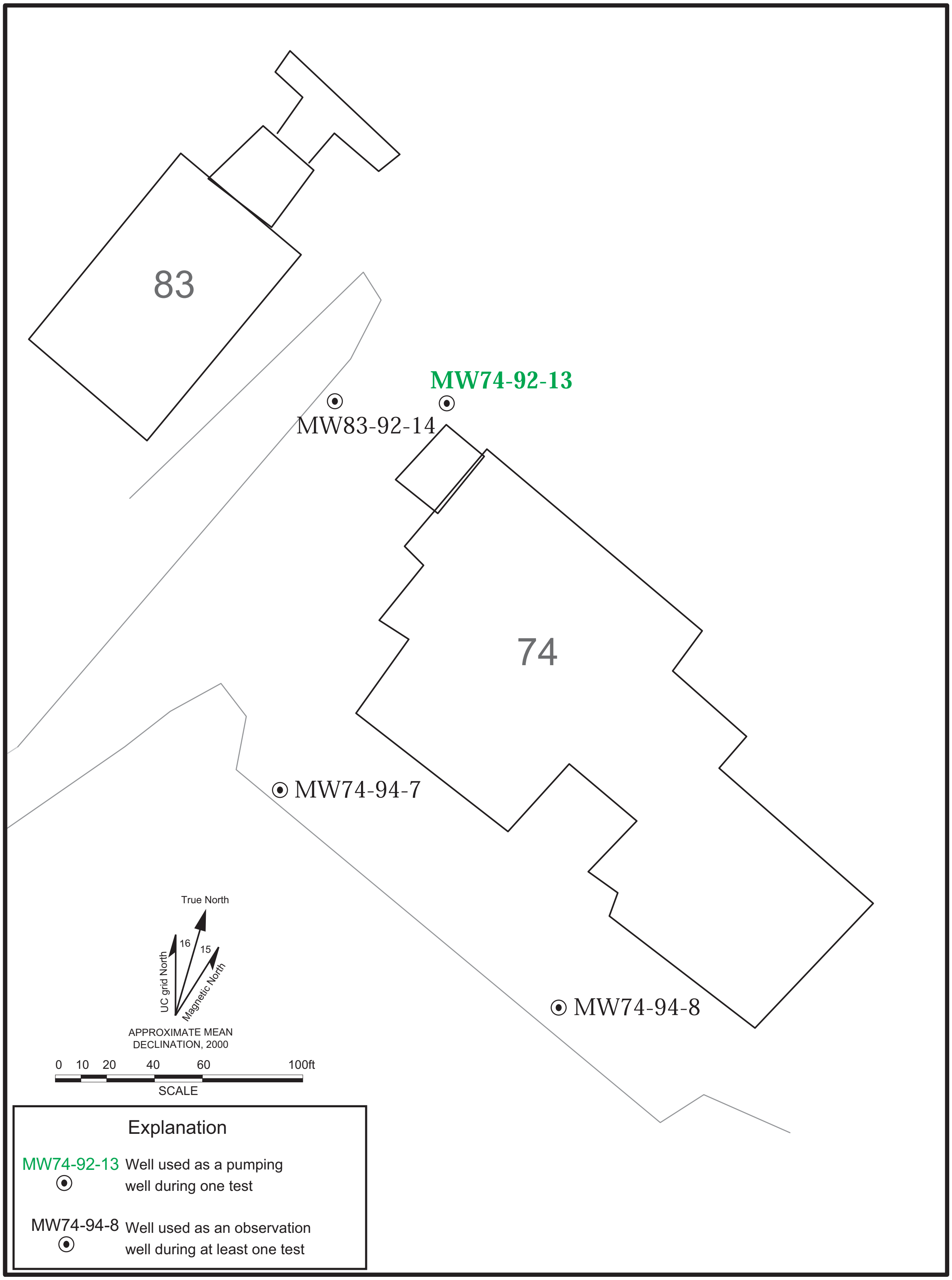

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Figure 4.3-4. Locations of Building 74/83 Pumping Test Wells.

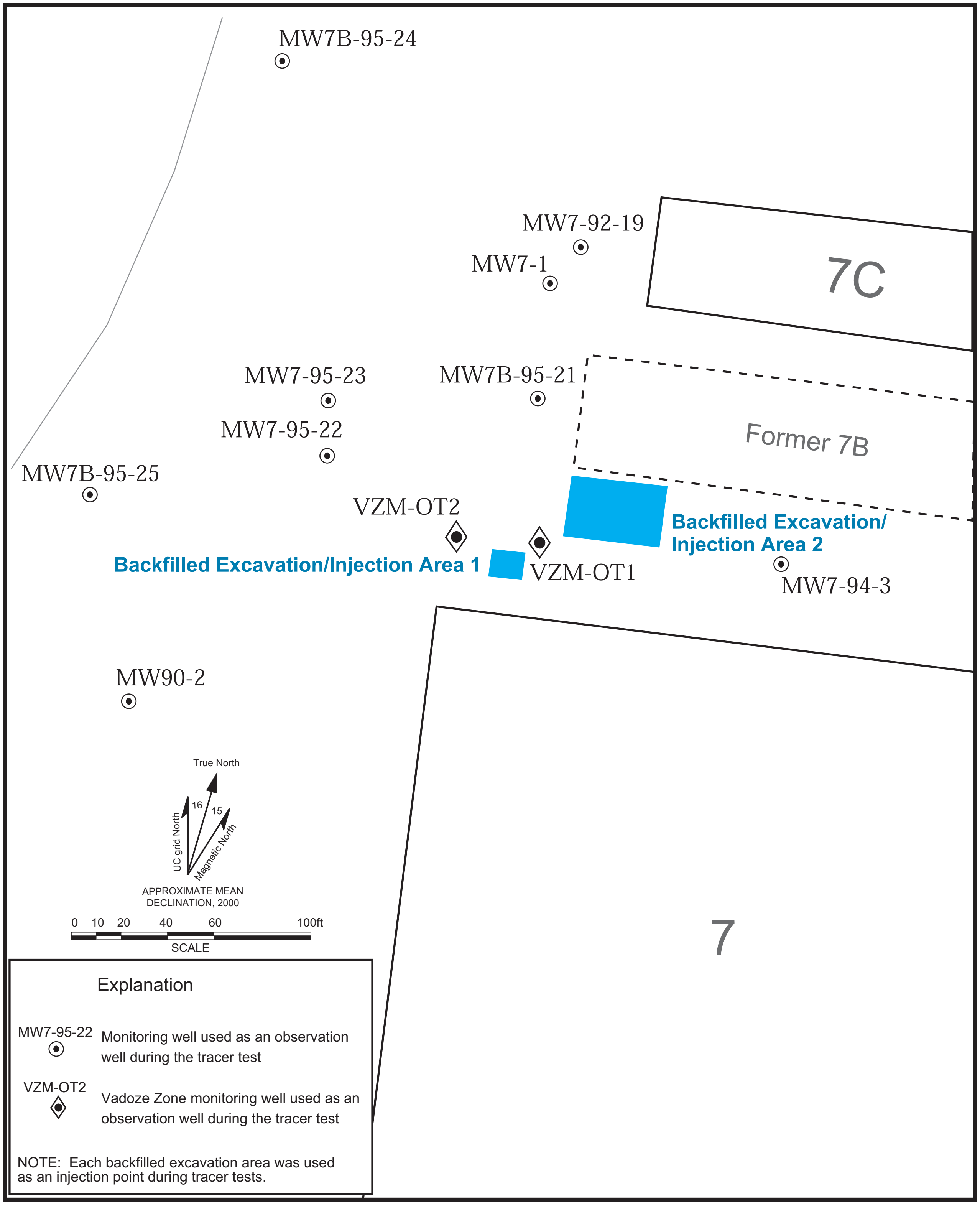

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Figure 4.3-5. Building 7 Sump Tracer Test Locations.

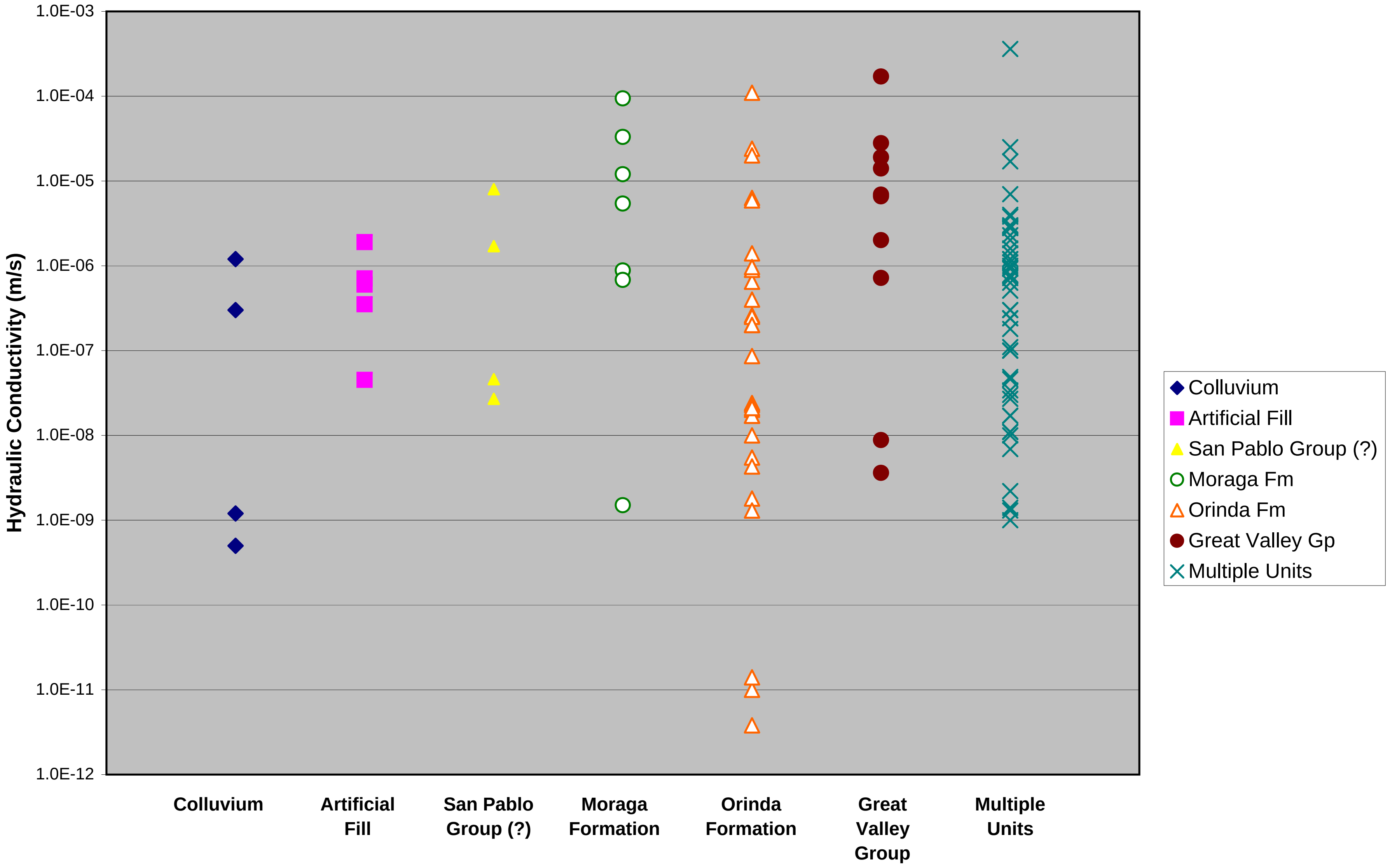

Figure 4.3-6. Hydraulic Conductivity Measurements Sorted by Geologic Unit at LBNL.

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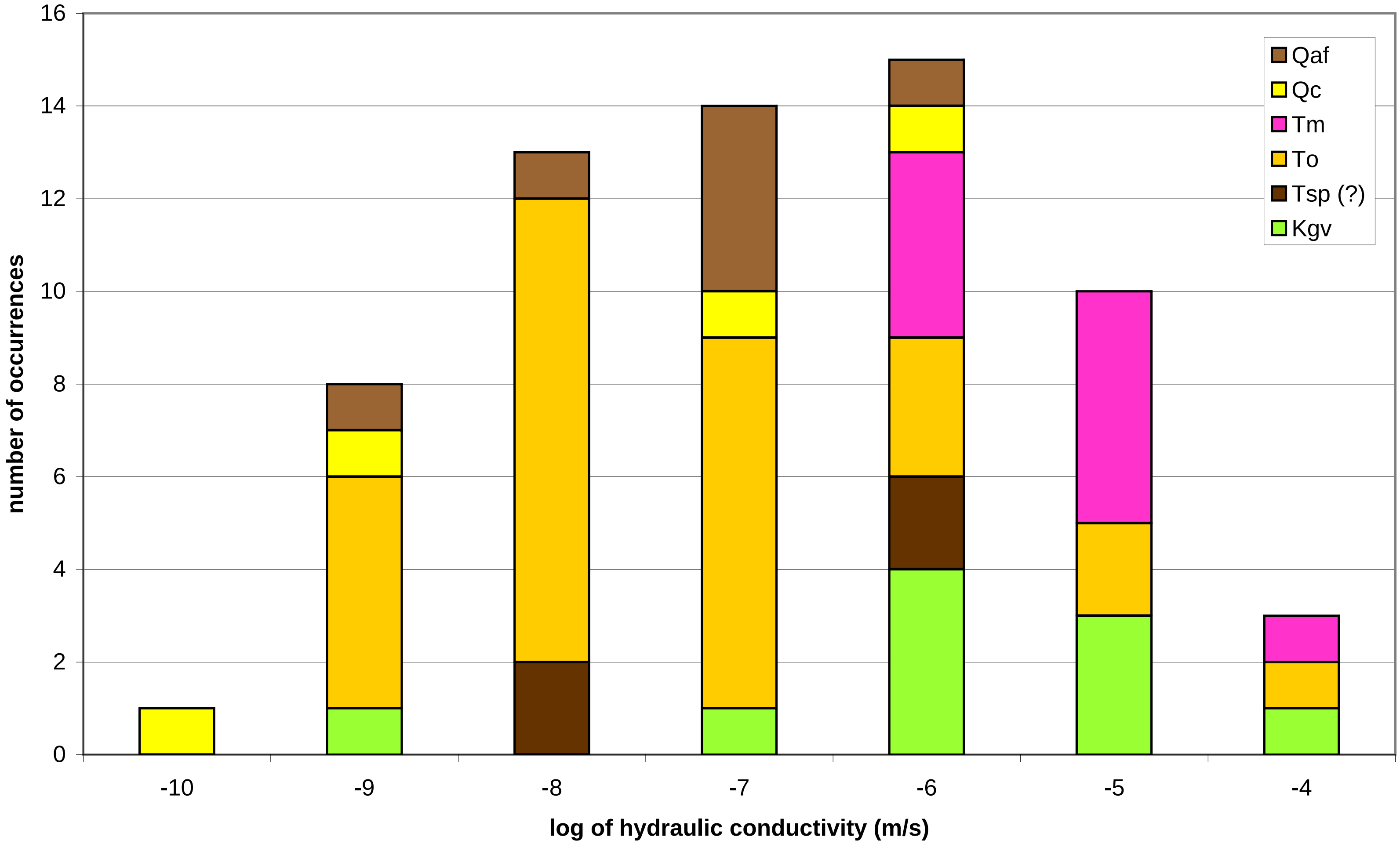

Figure 4.3-7. Distribution of Hydraulic Conductivities by Geologic Unit at LBNL.

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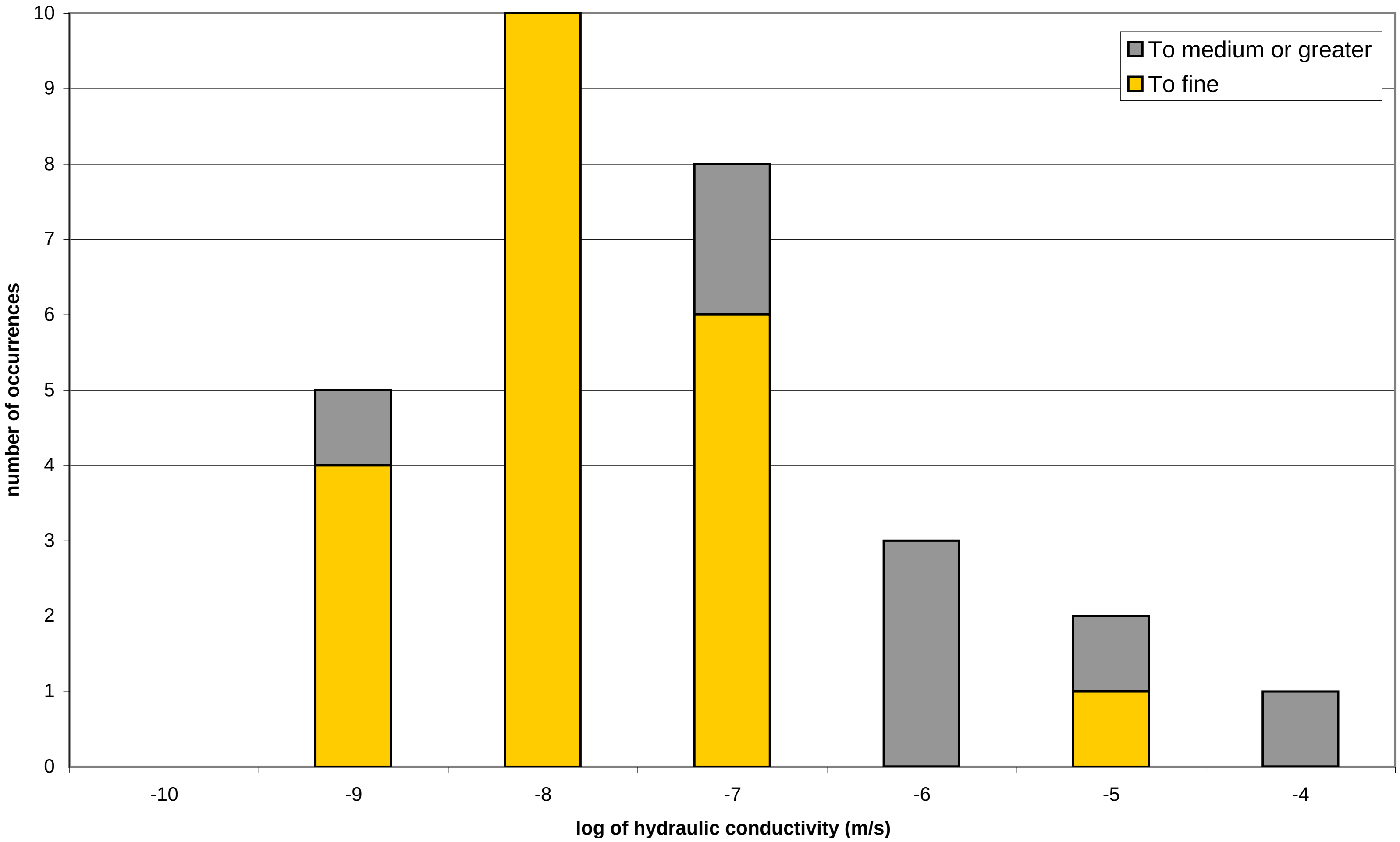

Note: Medium or greater includes any well whose sand pack is exposed to any medium-grained sandstone or coarser. Fine includes the remaining wells.

Figure 4.3-8. Distribution of Hydraulic Conductivities in the Orinda Formation by Grain Size Categories.

4.3-8.xls
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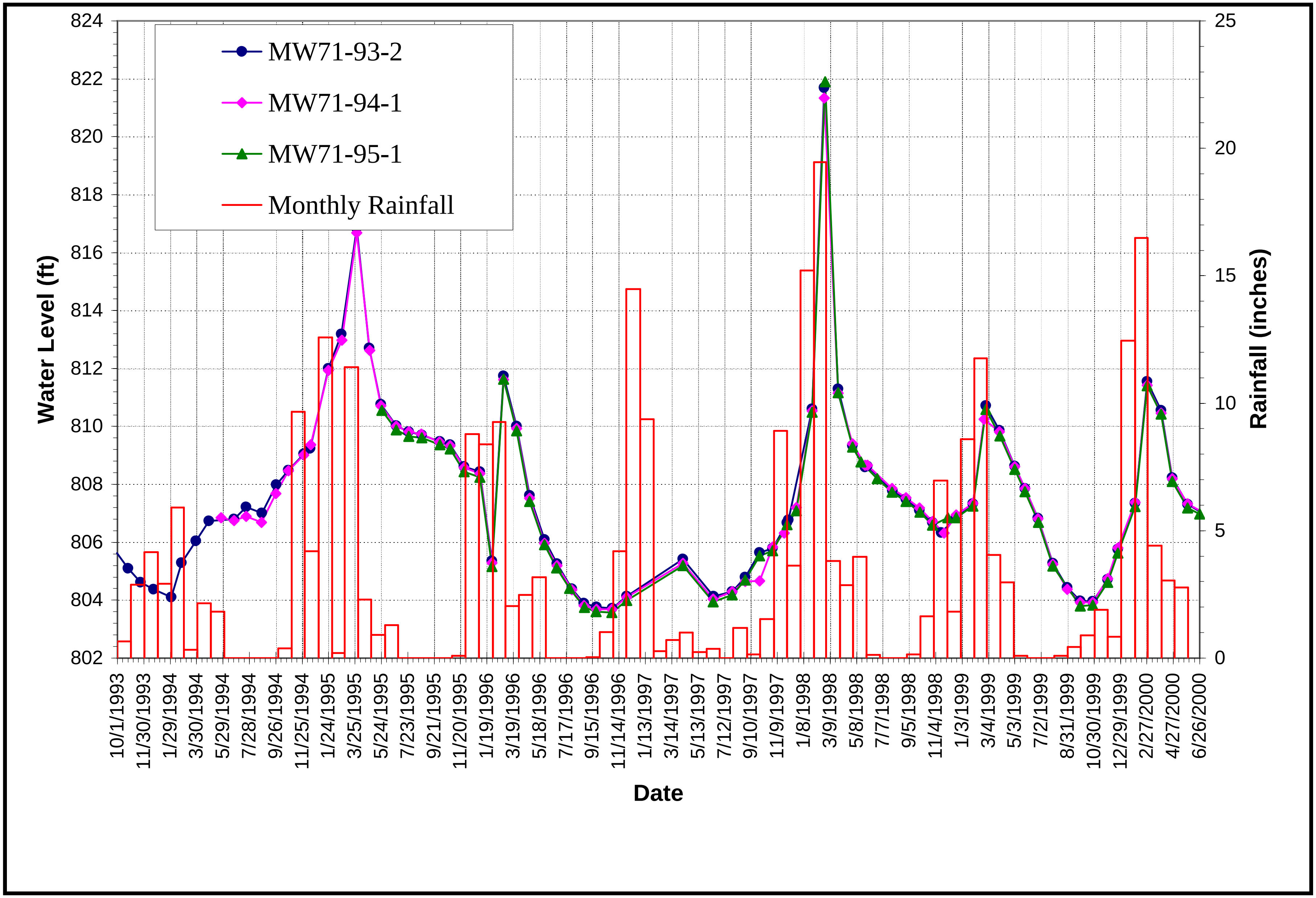

Figure 4.3-9. Water Table Fluctuations Near Building 71.

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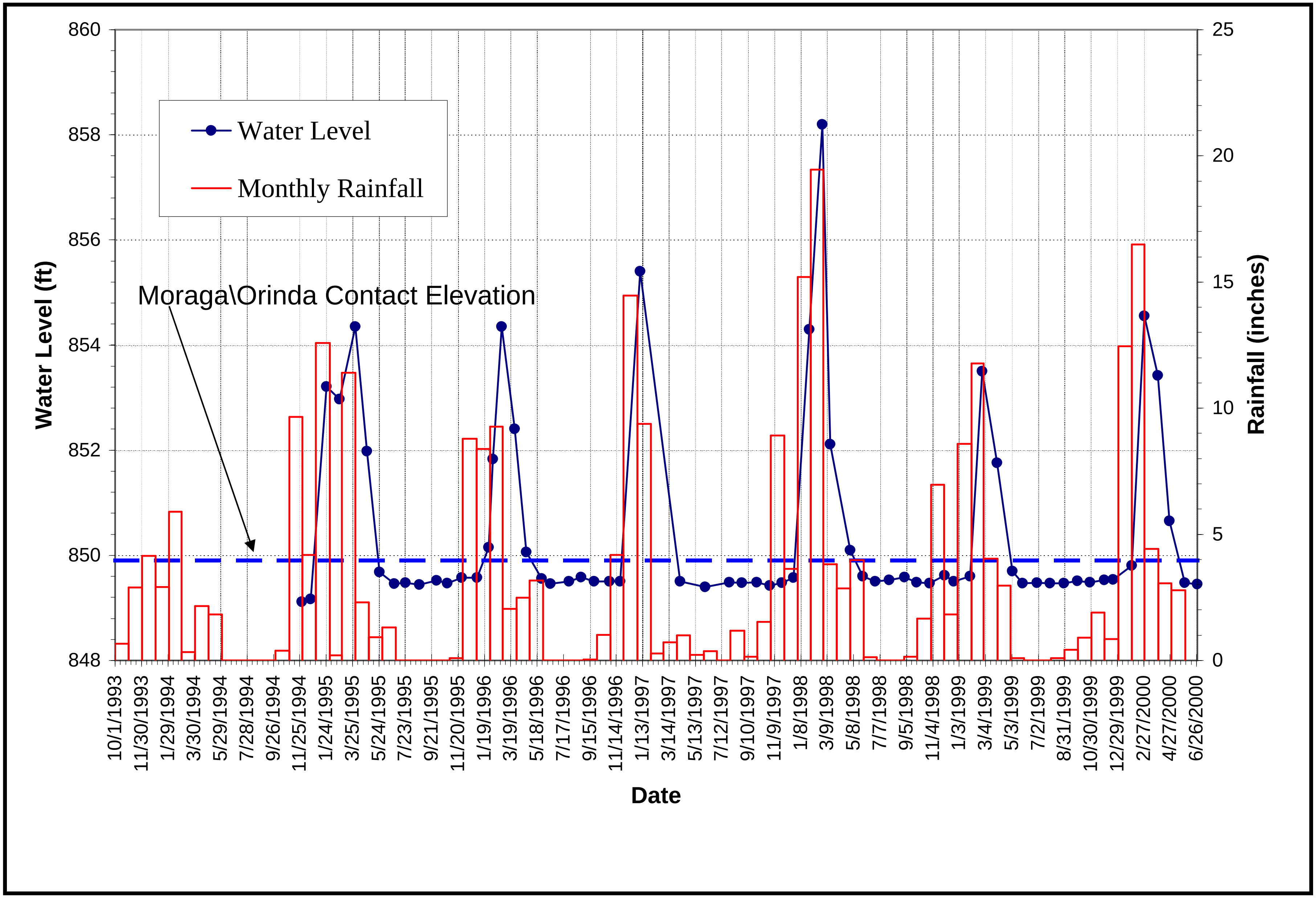

Figure 4.3-10. Water Table Fluctuations in MW52-94-10.

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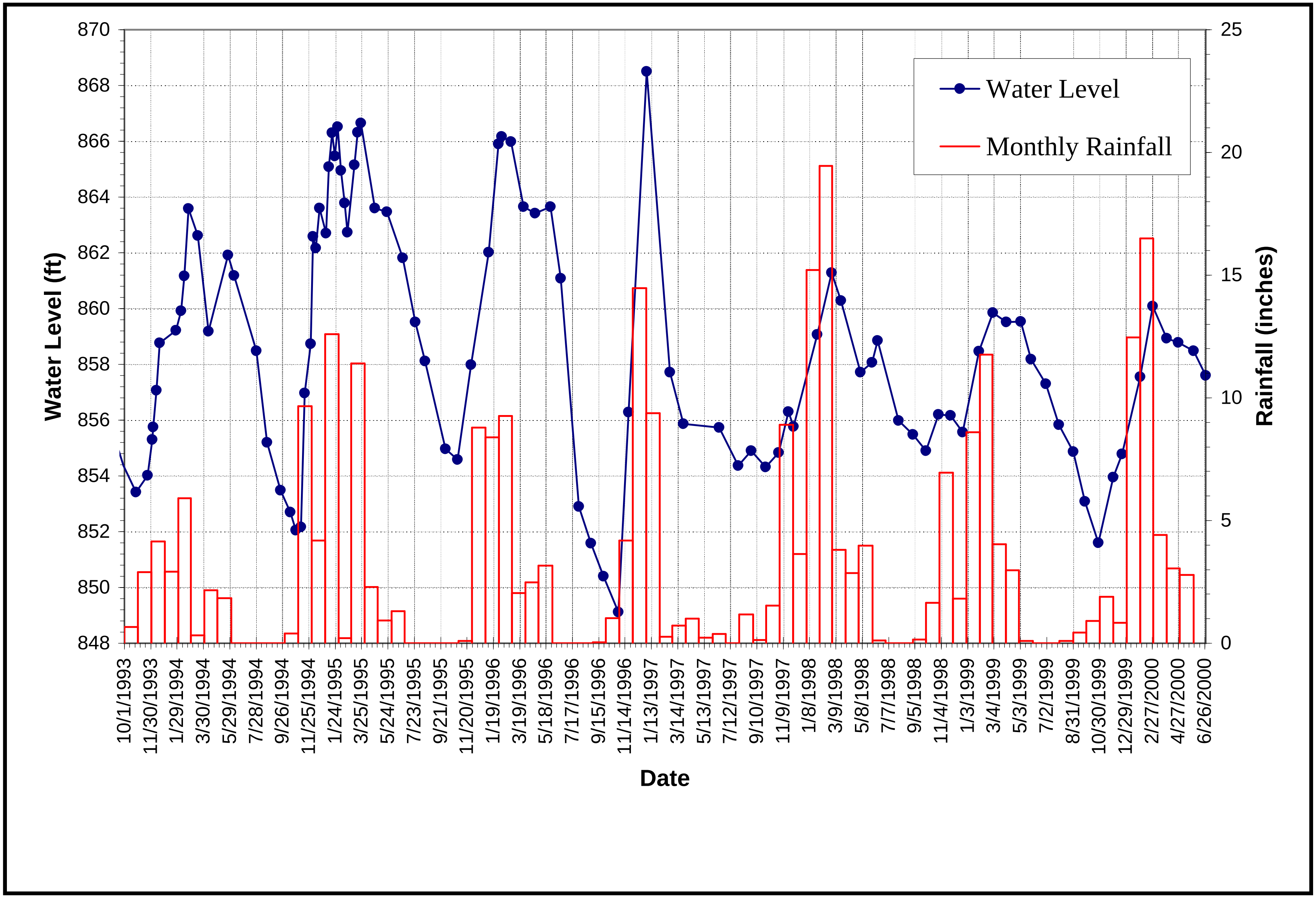

Figure 4.3-11. Water Table Fluctuations in MW7-92-19.

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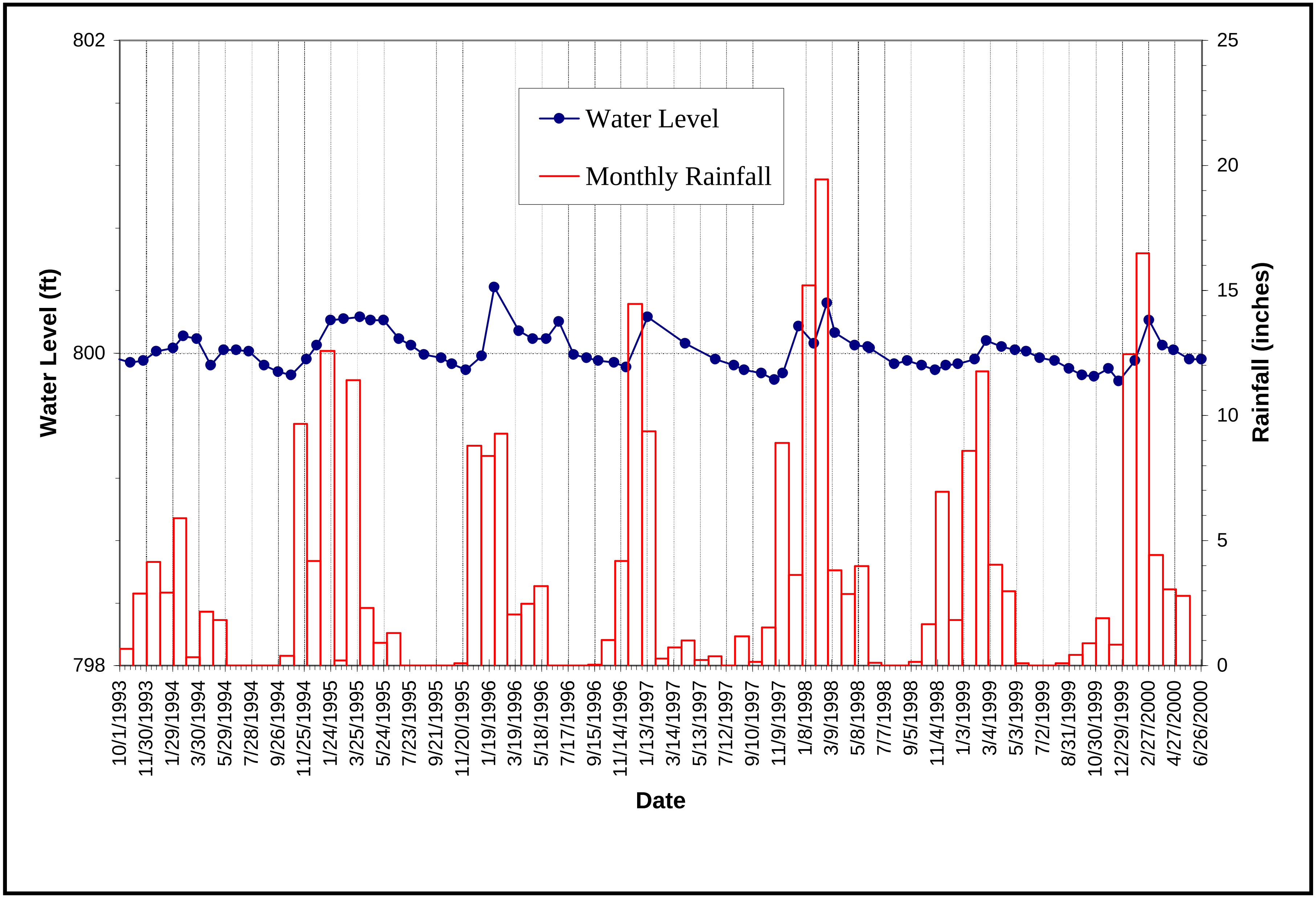

Figure 4.3-12. Water Table Fluctuations in MW46-93-12.

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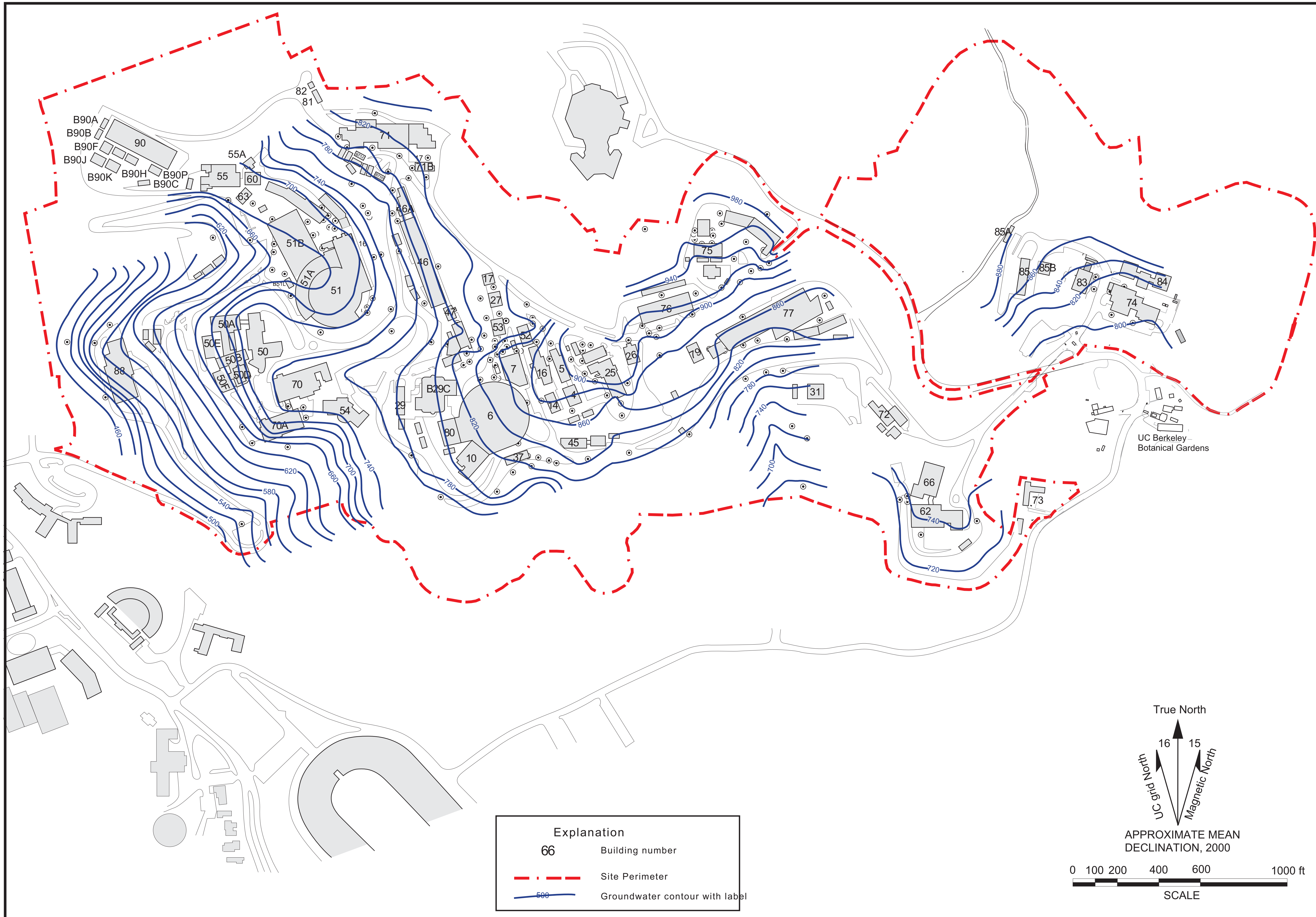

Figure 4.3-13. Water Level Elevation Contour Map (feet above MSL) of LBNL, Fourth Quarter FY 1999.

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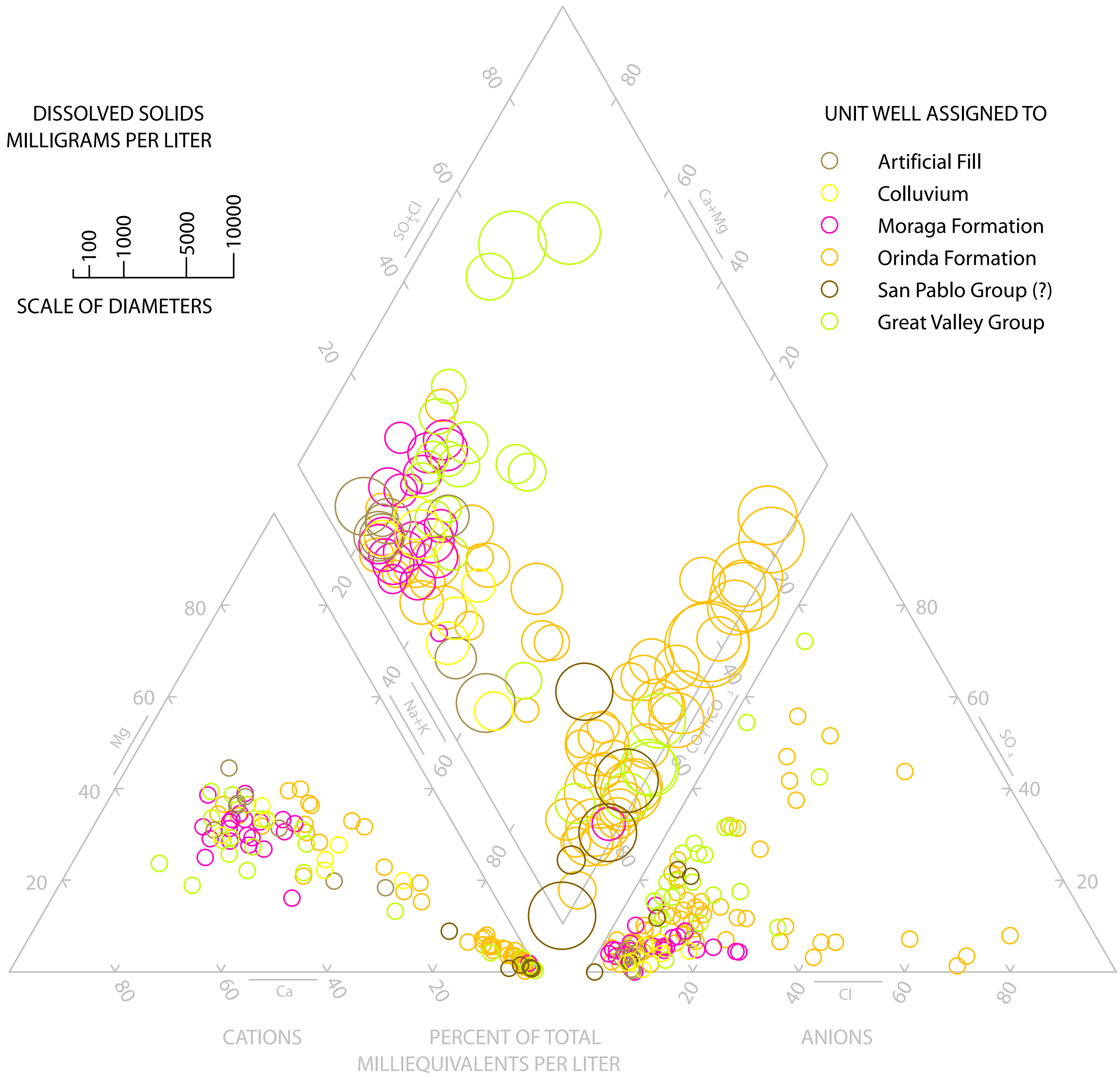

Figure 4.3-14. Piper Diagram of Mineral Results for Wells Assigned to a Geological Unit.

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4.3-14.dwg

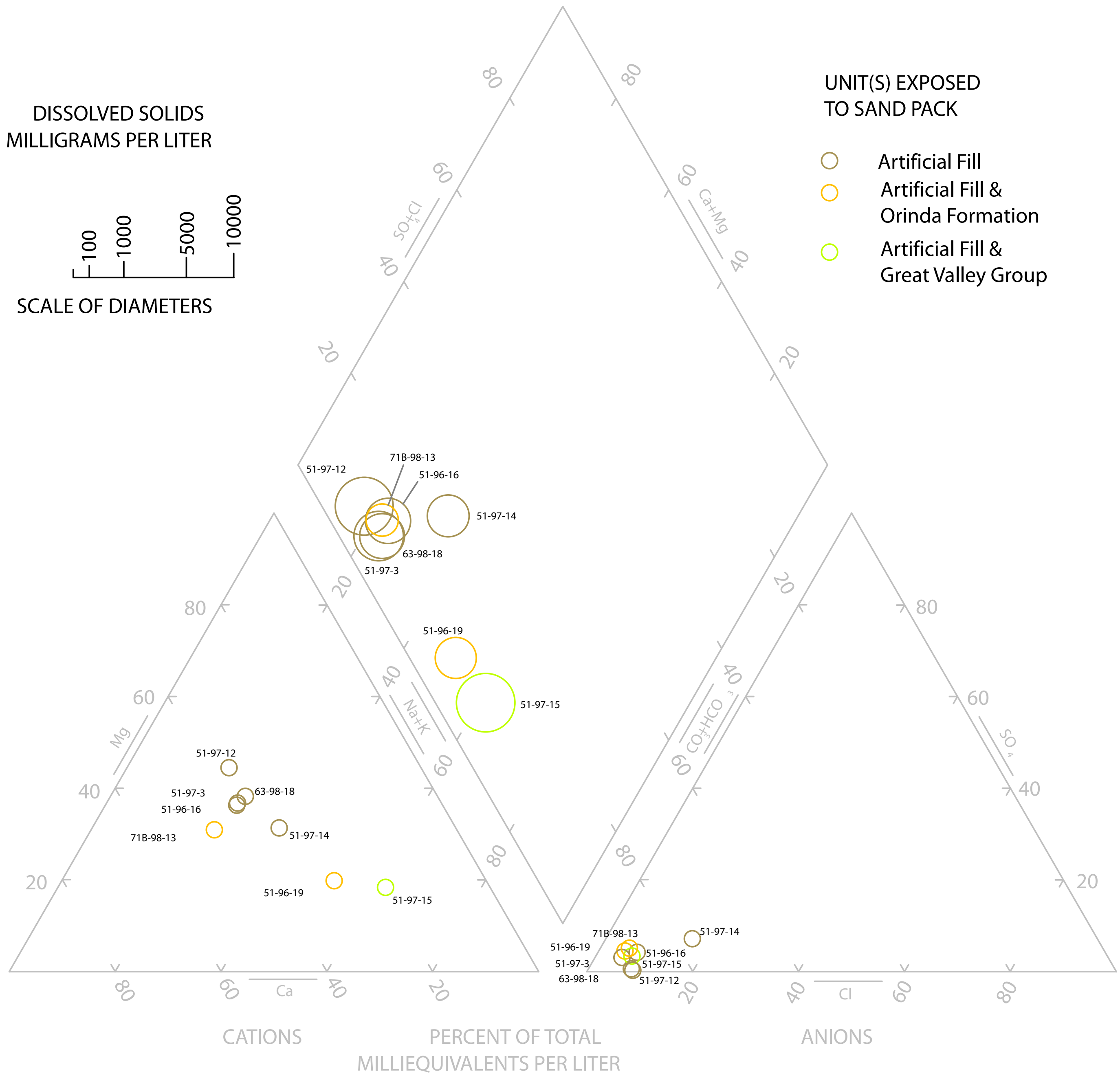

Figure 4.3-15. Piper Diagram For All Wells Assigned To Artificial Fill.

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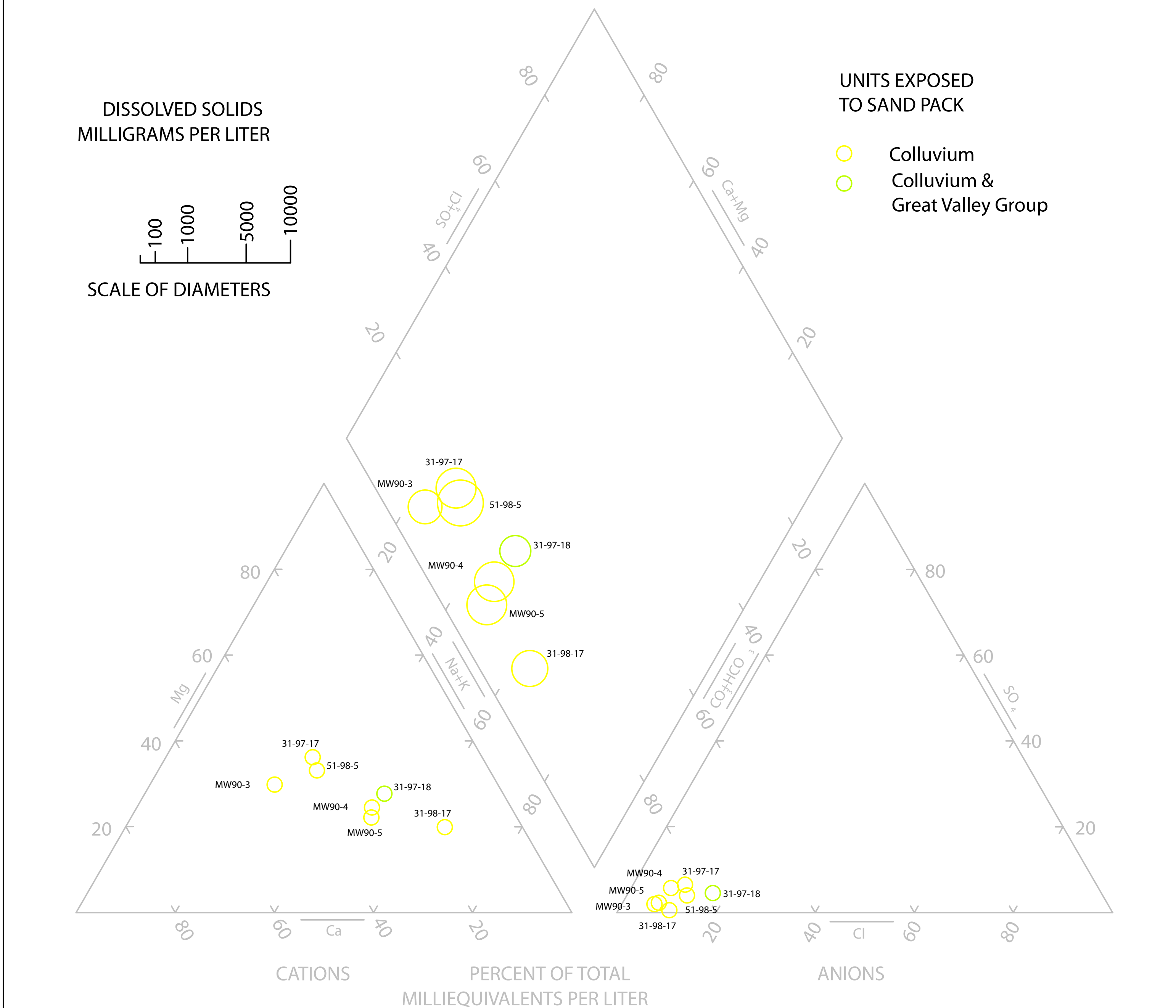

Figure 4.3-16. Piper Diagram For All Wells Assigned to Colluvium.

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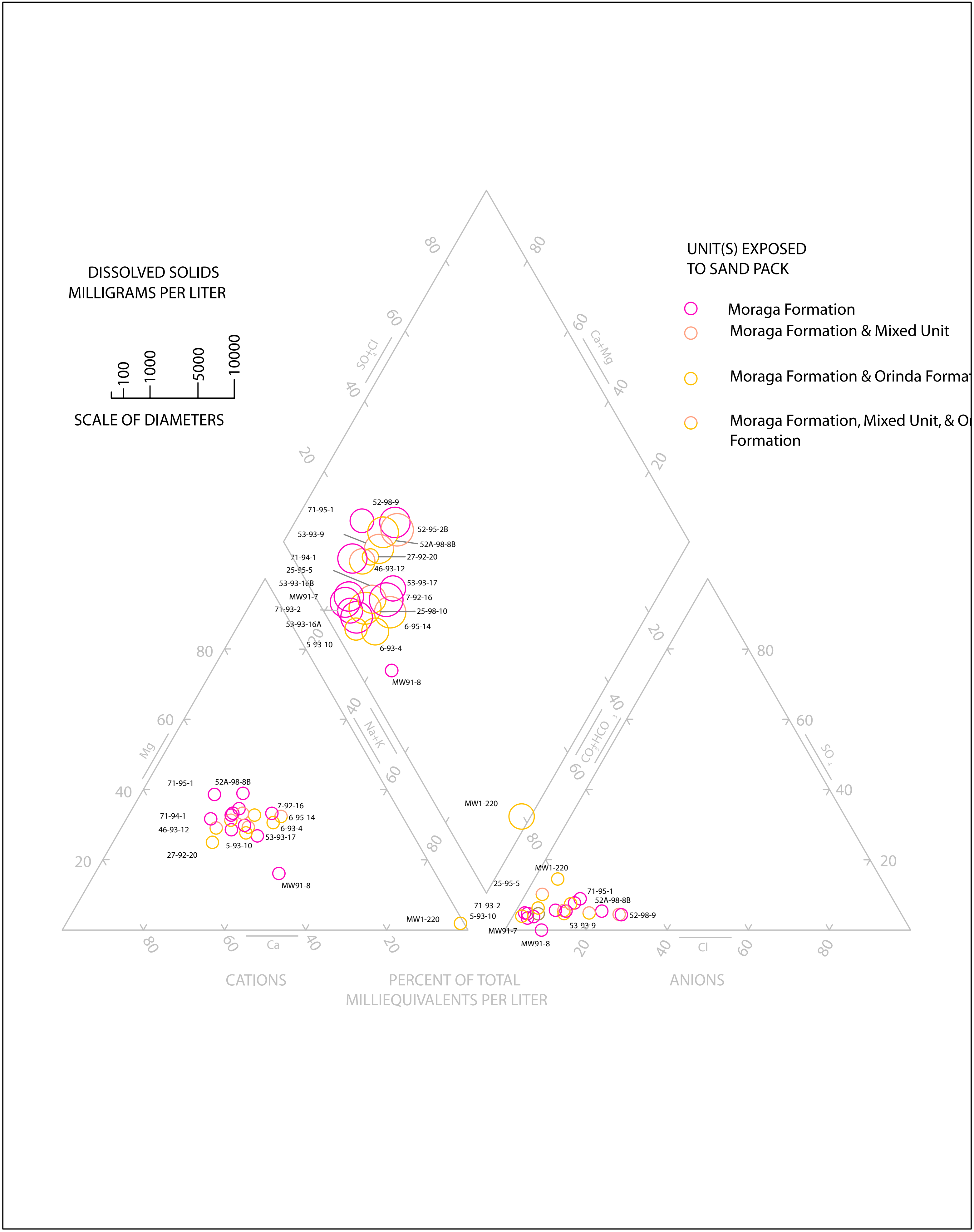

Figure 4.3-17. Piper Diagram For Wells Assigned to the Moraga Formation.

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4.3-17.dwg

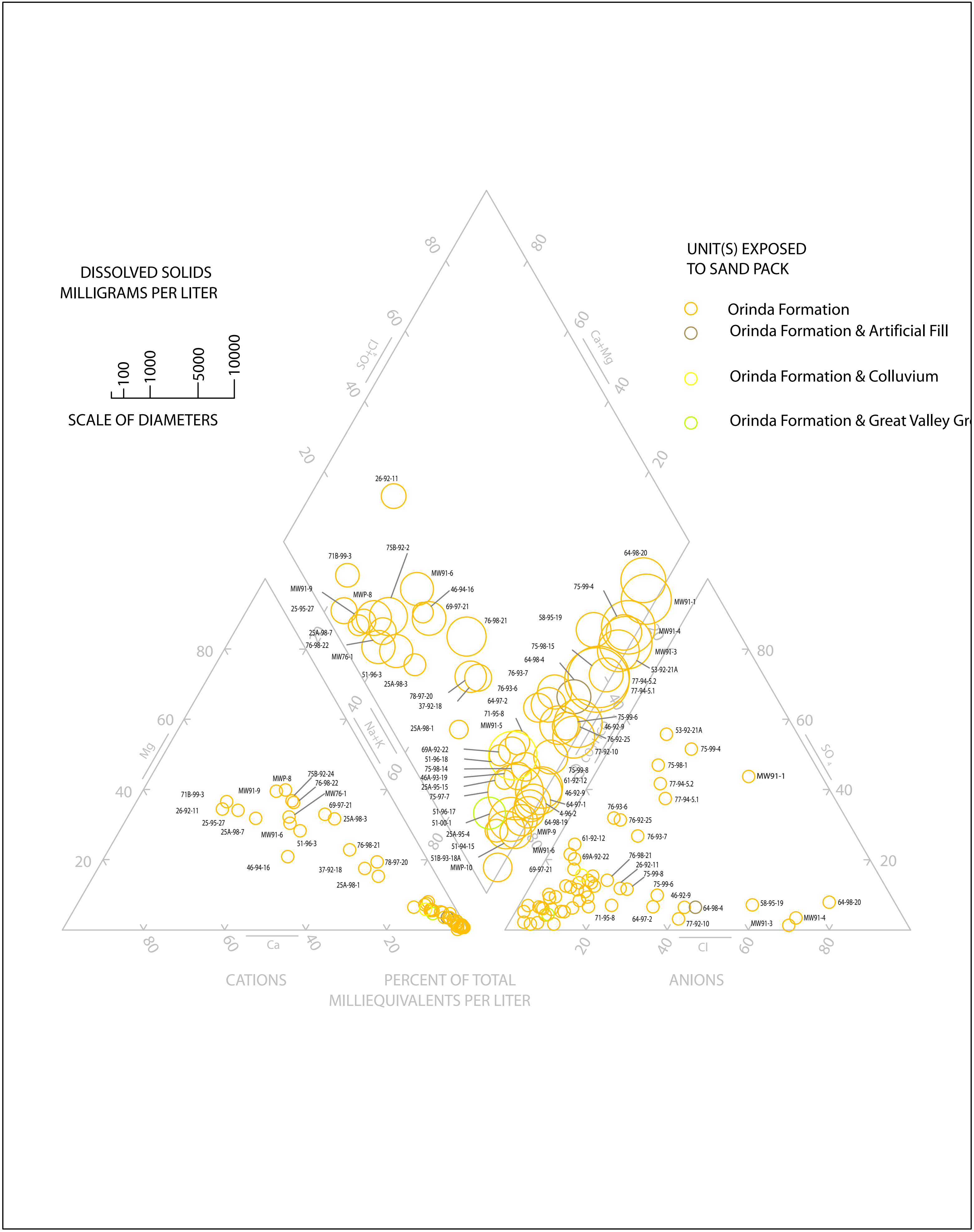

Figure 4.3-18. Piper Diagram For Wells Assigned to the Orinda Formation.

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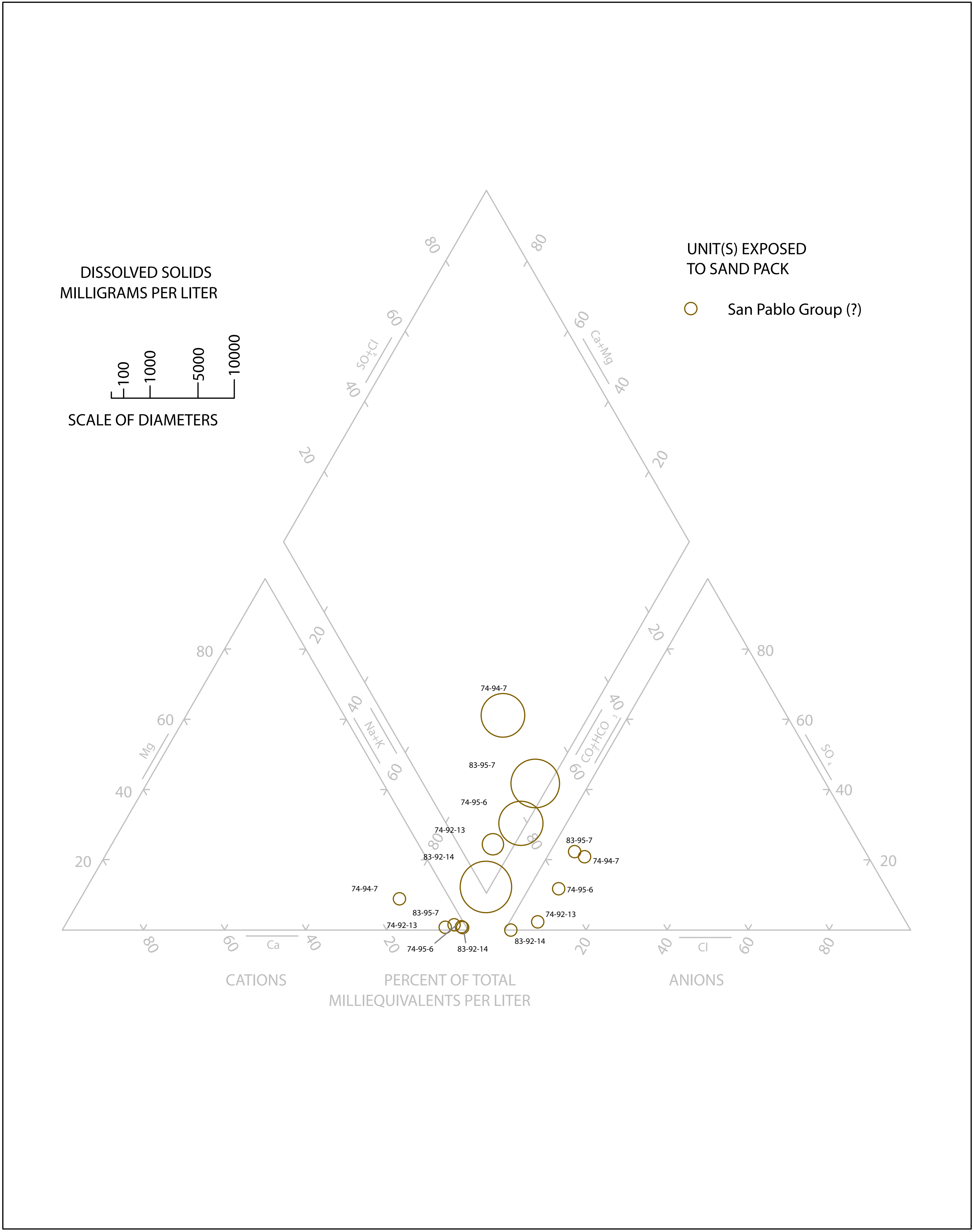


Figure 4.3-19. Piper Diagram for Wells Assigned to the San Pablo Group (?).

PDJ 8/29/2000
4.3-19.dwg

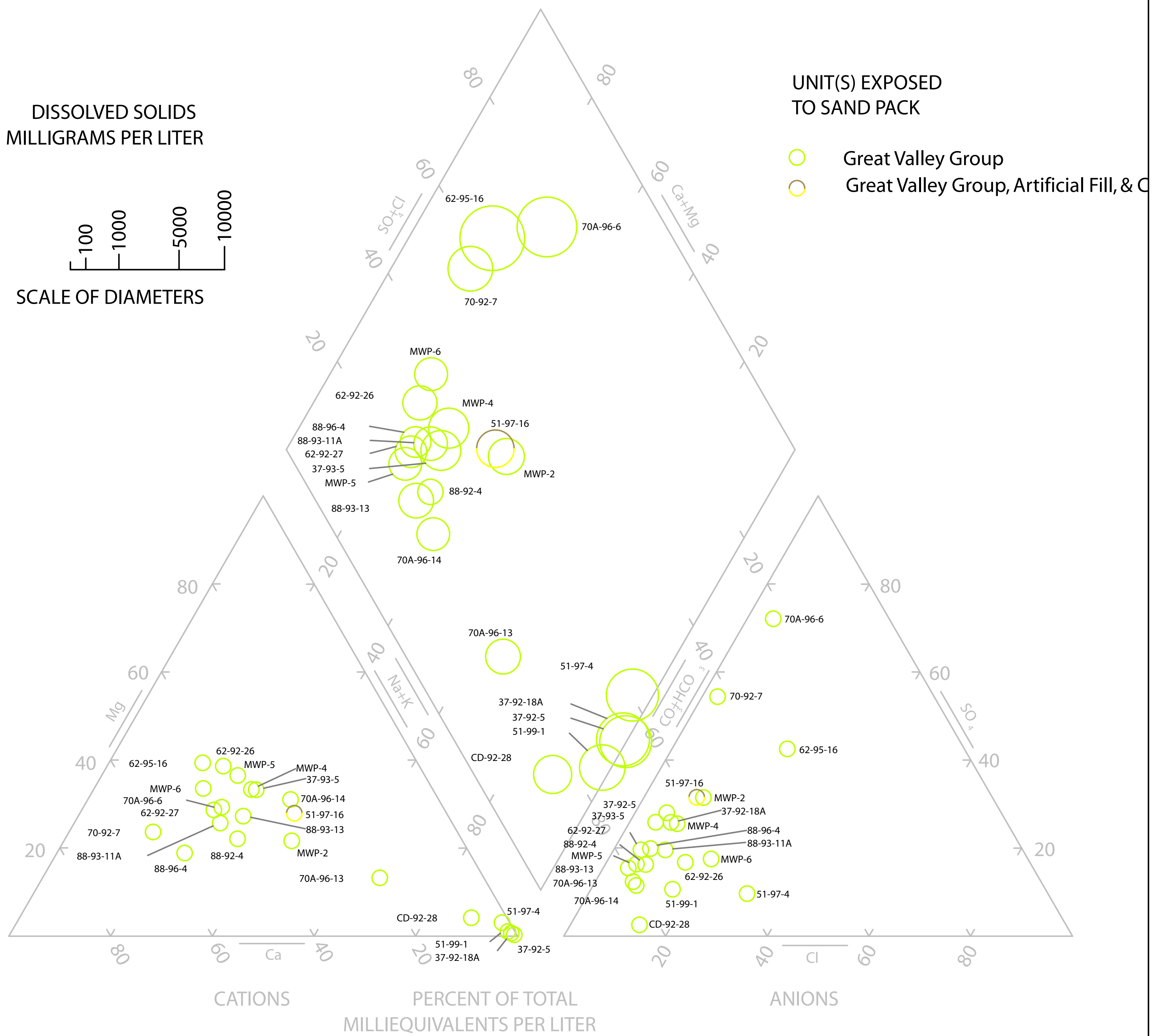
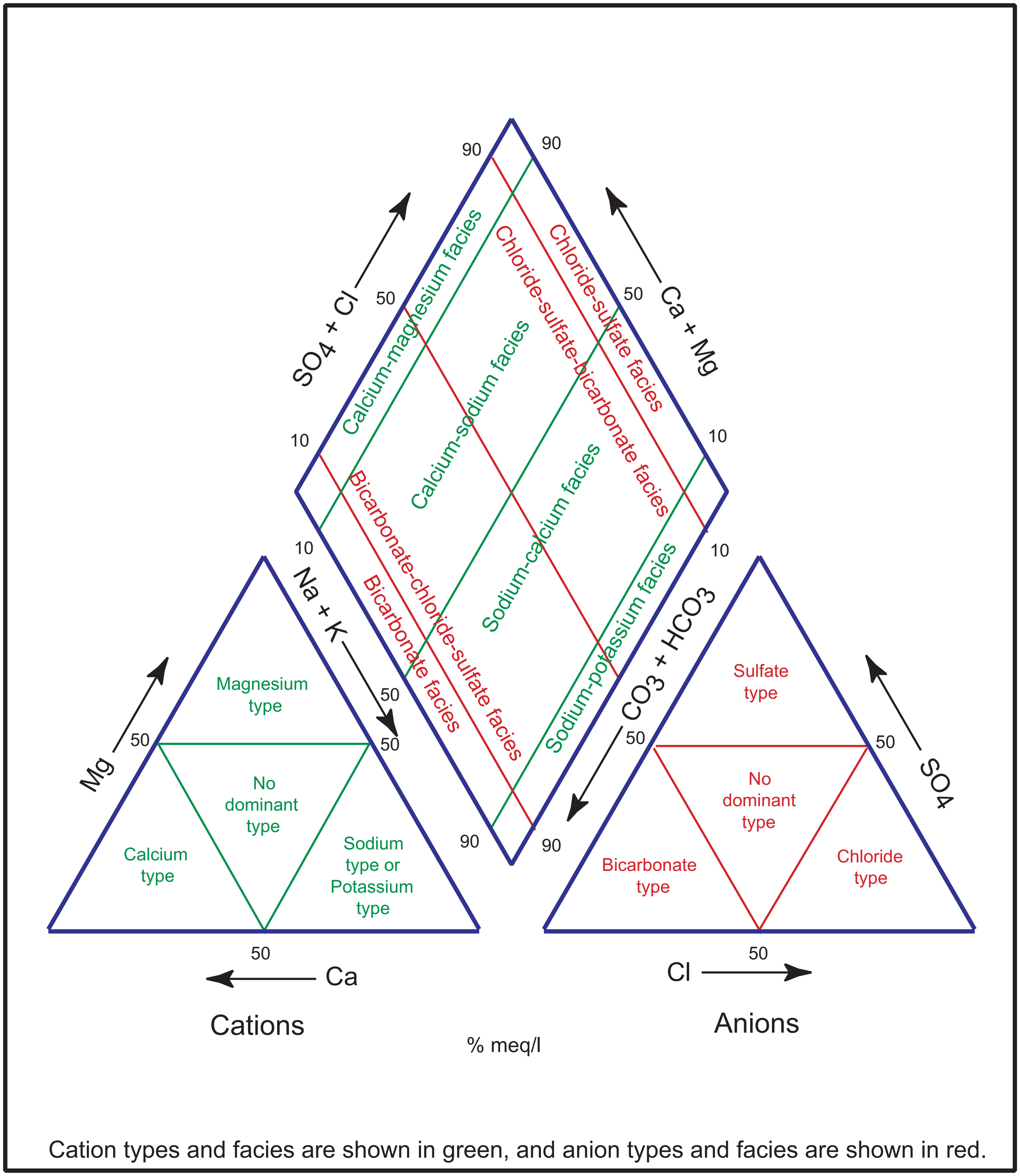


Figure 4.3-20. Piper Diagram For Wells Assigned to the Great Valley Group.

PDJ 8/29/2000 4.3-20.dwg



4.3-21.ai
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Figure 4.3-21. Classification Diagram for Anion and Cation Types and Facies in Terms of Major Ion Percentages (Morgan and Winner, 1962; and Back, 1966).

LIST OF TABLES

Table 4.3-1
Slug Test Results

Hydrogeological Unit Exposed in Sand Pack	Monitoring Well Number	Hydraulic Conductivity (m/sec)	Hydrogeological Unit Intervals (depth bgs)
Artificial Fill	51-96-16	4.5E-08	Qaf:9-31
	51-97-3	1.9E-06	Qaf:53-75
	51-97-12	7.1E-07	Qaf:27-50
	51-97-14	3.5E-07	Qaf:40-65
	63-98-18	6.E-07	Qaf:17-35
Colluvium	MW90-3	1.2E-06	Qc:46-58
	MW90-4	1.2E-09	Qc:14-26
	MW90-5	3.0E-07	Qc:15-26
	31-98-17	5.E-10	Qc:48-61
Moraga	MW91-7	8.8E-07	Tm:52-64
	MW91-8	3.3E-05	Tm:64-77
	7-92-16	5.4E-06	Tm:39-60
	71-93-2	1.2E-05	Tm:36-60
	53-93-16-69'	6.8E-07	Tm:57-69
	53-93-17	1.5E-09	Tm:60-76
	71-94-1	9.4E-05	Tm:36-49
Orinda Formation	MW91-1	2.0E-08	To:43-55
	MW91-3	1.4E-06	To:52-65
	MW91-6	6.3E-06	To:33-45
	MW91-9	1.1E-04	To:27-40
	MWP-9	6.5E-07	To:51-63
	MWP-10	9.0E-07	To:56-68
	76-1	2.8E-08	
	26-92-11	2.4E-05	To:21-31
	53-92-21-130'	1.0E-11 to 1.5E-12	To:80-194
	53-92-21-147'	1.4E-11 to 2.1E-12	To:80-194
	53-92-21-130'	3.8E-11 to 5.4E-13	To:80-194
	69A-92-22	2.6E-07	To:41-65
	76-92-25	1.7E-08	To:22-39
	76-93-6	9.7E-07	To:32-46
	51B-93-18A	5.5E-09	To:22-44
	77-94-5	4.3E-09	
	25A-95-4	8.6E-08	To:25-48
	71-95-8	5.9E-06	To:27-50
	25A-95-15	1.7E-08	To:21-47
	51-96-3	2.4E-08	
	51-96-18	2.5E-07	To:5-16
	64-97-1	2.3E-08	To:3-25
	64-97-2	1.8E-09	To:8-30
	75-97-7	1.3E-09	To:57-79
	25A-98-1	2.E-07	To:28-50

Table 4.3-1 (Continued)
Slug Test Results

Hydrogeological Unit Exposed in Sand Pack	Monitoring Well Number	Hydraulic Conductivity (m/sec)	Hydrogeological Unit Intervals (depth bgs)
Orinda Formation	25A-98-3	2.E-05	To:23-47
	25A-98-7	2.E-07	To:17-36
	75-98-15	4.E-07	To:18-36
	76-98-22	1.E-08	To:17-40
San Pablo (?)	74-92-13	8.0E-06	Tsp(?):36-49
	83-92-14	2.7E-08	Tsp(?):47-59
	74-94-7	4.6E-08	Tsp(?):26-45
	83-95-7	1.7E-06	Tsp(?):35-47
Great Valley Group	MWP-2	8.8E-09	Kgv:64-76
	MWP-6	6.9E-06	Kgv:26-40
	88-92-4	1.4E-05	Kgv:47-59
	37-92-5	3.6E-09	Kgv:83-105
	70-92-7	1.7E-04	Kgv:21-26
	62-92-26	2.0E-06	Kgv:45-58
	62-92-27	6.6E-06	Kgv:54-67
	37-93-5	7.2E-07	Kgv:37-51
	88-93-13	2.8E-05	
	88-96-4	1.9E-05	Kgv:44-67
Multiple Units	MW90-2	1.4E-06	Tm:23-24, To:24-35
	MW90-6	3.0E-07	Qc:14-20, To:20-26
	MW91-2	2.2E-09	Qaf:39-46, To:46-52
	MW91-5	1.0E-09	Qc:29-29, To:29-41
	MW62-B1A	1.2E-06	
	MW62-B2	1.0E-06	
	46A-92-15	4.0E-06	Qaf:28-32, Qc:32-35, To:35-40
	6-92-17	3.0E-06	Tmo:22-29, To:29-40
	7-92-19	1.1E-08	Tm:23-31, Tmo:31-41
	27-92-20	2.5E-05	Tm:59-79, To:79-85
	75-92-23	5.1E-07	Qaf:28-31, Qc:31-49, To:49-50
	71-93-1	1.1E-06	Tm:42-46, Tmo:46-62, To:62-65
	6-93-4	7.0E-06	Qaf:33-36, Tm:36-51
	77-93-8	4.9E-08	Qaf:14-15, Qc:15-23, To:23-31
	53-93-9	1.7E-05	Tm:67-83, Tmo:83-87, To:87-90
	5-93-10	2.9E-06	Tm:20-33, To:33-38
	46-93-12	3.6E-04	Tm:7-11, Tmo:11-12, To:12-14
	25-93-15	2.7E-08	Tm:53-65, Tmo:65-67, To:67-75
	7-94-3	1.1E-07	Tmo:20-29, To:29-44
	77-94-6	3.4E-08	Qaf:38-44, Qc:44-54, To:54-63
	74-94-8	6.3E-07	Qc:19-28, Tsp(?):28-32
	37-94-9	7.7E-07	To:23-32, Kgv:32-45
	52-94-10	2.0E-06	Tm:45-56, To:56-69
	51-94-11	1.8E-07	Qc:5-12, Tm:12-14, To:14-19

Table 4.3-1 (Continued)
Slug Test Results

Hydrogeological Unit Exposed in Sand Pack	Monitoring Well Number	Hydraulic Conductivity (m/sec)	Hydrogeological Unit Intervals (depth bgs)
Multiple Units	16-94-13	2.4E-07	Tmo:19-32, To:32-46
	58A-94-14	4.6E-08	Qc:20-22, Tm:22-30, Qc:30-42
	52-95-2B	1.6E-06	Tm:63-106, Tmo:106-110
	16-95-3	7.2E-07	Tmo:20-28, To:28-39
	71-95-9	2.8E-06	Qaf:21-28, Qc:28-40
	53-95-12	9.2E-07	Tm:31-37, Tmo:37-49, To:49-50
	52B-95-13	1.2E-06	Tm:14-28, To:28-35
	6-95-14	2.8E-06	
	58-95-20	1.7E-08	Tm:13-24, To:24-35
	7B-95-21	1.4E-09	Tm:12-23, Tmo:23-40
	7-95-22	1.7E-08	Qaf:12-15, Tm:15-19, Tmo:19-40
	7-95-23	1.3E-09	Tmo:40-51, To:51-58
	7B-95-24	2.4E-07	Tm:50-64, Tmo:64-72, To:72-79
	7B-95-25	3.8E-06	Qc:22-23, Tm:23-28, Tmo:28-43, To:43-44
	58-96-11	1.1E-08	Tmo:12-38, To:38-40
	51-96-15	2.8E-06	Qaf:18-22, To:22-37, Kgv:37-40
	51-96-17	1.0E-08	To:33-53, Kgv:53-55
	51-96-19	7.8E-07	Qaf:2-14, To:14-15
	75-97-6	1.0E-07	Qc:52-57, To:57-74
	51-97-13	9.5E-07	Qaf:45-53, Qc:53-67, To:67-70
	51-97-15	6.9E-09	Qaf:84-108, Kgv:108-109
	51-97-16	2.3E-06	Qaf:13-15, Qc:15-21, Kgv:21-35
	56-98-2	1.E-07	Qaf:33-47, Qc:47-54, To:54-55
	64-98-4	3.E-08	Qaf:3-5, To:5-15
	71B-98-13	3.E-07	Qaf:13-26, To:26-30

Qaf: artificial fill
Qc: colluvium
Tm: Moraga
Tmo: Mixed Unit
To: Orinda Formation
Tsp(?): San Pablo Group (?)
Kgv: Great Valley Group

Table 4.3-2
Groundwater Monitoring Results
Minerals
(Concentrations in mg/L)

Area	Well No.	Lab	Date	Calcium	Magnesium	Sodium	Potassium	Carbonate	Bicarbonate	Sulfate	Chloride	Nitrate/ Nitrite as NO3	pH	Electrical Conductivity (µmhos/cm)	T Diss S
			MCL:							250 (a)	210 (a)	10 as N	6.5-8.5		50
1	MW90-3	BC	Aug-94	91	35	51	0.6	<2.6	526	11	26.8	<0.4	7.2	857	5
	MW90-4	BC	Aug-94	78	39	136	3.3	<2.6	658	42	43.6	0.9	7.4	1180	6
	MW90-5	BC	Sep-94	78	34	135	2.3	<2.6	695	17	39.8	<0.4	7.2	1130	7
	MW90-6	BC	Aug-94	13.6	7.2	170	2.4	<2.6	426	44	30.4	2.7	8.1	821	5
	46A-92-15	BC	Aug-94	91	34	35	1.5	<2.6	514	<5	17.7	<0.4	7.0	795	4
	71-93-1	BC	Aug-94	37	15.8	42	0.5	<2.6	248	16	14.4	5.3	7.7	470	2
	71-93-2	BC	Aug-94	69	26	42	3.3	<2.6	396	20	7.4	13.3	7.4	673	4
	46A-93-19	BC	Aug-94	7.6	5.3	171	5.8	8.6	340	42	51.7	4.9	8.4	816	4
	71-94-1	BC	Aug-94	101	39	43	0.8	<2.6	500	32	40.3	11.1	7.7	918	5
	51-94-11	BC	Mar-95	33	18.2	171	5.3	<2.6	427	57	91.1	8.8	8.1	1000	6
		AEN	Mar-95	37	24	160	6.2	<2	370	65	100		8.0	1000	5
		AEN	Mar-95	35	23	150	5.9	<2	370	67	98		8.0	1100	5
	71-95-1	AEN	May-95	88	45	33	2.5	<2	270	30	35		7.7	660	3
		BC	May-95	66	26	32	0.7	<2.6	319	31	32.7	6.2	7.5	645	3
	71-95-8	AEN	May-95	10	6.6	140	2.3	<2	270	26	62		7.8	740	3
		BC	May-95	10.2	7.1	150	2.5	<2.6	348	25	49.9	<0.4	8.5	724	4
	71-95-9	AEN	May-95	64	25	28	0.6	<2	120	54	66		6.5	640	3
		BC	May-95	58	23	30	0.6	<2.6	276	53	19.2	3.1	7.0	574	3
	71-97-23	BC	Oct-97	89	54	39	<1.0	<2.6	570	24	24	<0.4	7.08	912	5
	71B-98-13	BC	Jun-99	74.0	29	36	2.7	<5.0	346	19	15	<0.44	7.10	651	4
	71B-99-3	BC	Dec-99	65	33	33	1.3	<5.0	294	12	21	2	7.45	592	3
	71B-00-2	BC	Jun-00	4.1	2.8	230	47	88.0	281	108	43	19	9.08	1110	7
2	MW90-2	BC	Aug-94	123	42	66	3.0	<2.6	603	64	28.3	18.2	7.0	1130	6
	MW91-7	BC	Aug-94	98	44	58	1.3	<2.6	622	22	18.3	6.2	7.2	980	5
	MW91-8	BC	Aug-94	15	3.7	19.1	0.2	<2.6	93.9	<5	6.6	2.2	7.4	193	1
	MW7-1†	BC	Aug-94	86	36	30	2.2	<2.6	503	14	9.1	<0.4	6.8	784	4
	MW1-220	BC	Aug-94	1.5	1.7	161	3.0	34.2	263	52	15.2	20.4	9.2	680	4
	7-92-16	BC	Aug-94	91	54	100	1.6	<2.6	651	41	69.3	<0.4	6.8	1190	7
	7-92-19	BC	Aug-94	54	22	29	1.6	<2.6	314	14	12.3	1.3	7.2	545	3
	27-92-20	BC	Aug-94	31	9.0	14.4	2.0	<2.6	134	12	14.8	3.1	7.1	298	1

Table 4.3-2
Groundwater Monitoring Results
Minerals
(Concentrations in mg/L)

Area	Well No.	Lab	Date	Calcium	Magnesium	Sodium	Potassium	Carbonate	Bicarbonate	Sulfate	Chloride	Nitrate/ Nitrite as NO3	pH	Electrical Conductivity (µmhos/cm)	T Diss S
			MCL:							250 (a)	210 (a)	10 as N	6.5-8.5		50
2	53-92-21-130'	BC	Sep-94	8.2	0.41	364	3.5	72.7	187	430	68	17.7	9.2	1720	1
	6-93-4	BC	Aug-94	60	32	68	1.0	<2.6	463	23	21.6	3.5	7.4	797	4
	53-93-9	BC	Aug-94	90	38	54	1.3	<2.6	443	27	74.9	16.8	7.2	964	5
	53-93-16-42'	BC	Sep-94	98	42	71	6.4	<2.6	650	32	16.2	7.5	7.1	1040	6
	53-93-16-69'	BC	Aug-94	95	44	57	1.7	<2.6	570	23	23	8.4	7.2	940	5
		BC	Aug-94	94	44	57	1.7	<2.6	570	22	22.6	8.8	7.2	940	5
	53-93-17	BC	Aug-94	62	25	56	3.5	<2.6	341	32	40.7	9.7	7.6	710	4
	7-94-3	BC	Aug-94	41	22	55	2.9	<2.6	309	31	10.8	12	7.7	583	3
	53-95-12	BC	Sep-96	100	59	38	0.7	<2.6	603	31.6	22	48.7	7.43	1070	6
	52B-95-13	BC	Sep-96	68	23	49	0.7	<2.6	400	15.9	6.4	12.8	7.54	701	4
	6-95-14	BC	Sep-95	72	44	90	2.8	<2.6	552	30	57.6	2.2	7.2	1030	6
	7B-95-21	BC	Sep-95	56	27	35	3.7	<2.6	354	18	12.8	3.5	7.6	600	3
	7-95-22	BC	Sep-96	86	37	36	2.2	<2.6	399	49	13.1	53.1	7.57	837	5
	7-95-23	BC	Sep-96	9.3	8.0	124	13.3	<2.6	281	37	40.8	1.3	8.56	698	3
	7B-95-24	BC	Jan-96	68	36	49	2.8	<2.6	447	22	27.7	5.3	7.4	772	5
		AEN	Jan-96	63	33	68	3.4	<2	320	24	27		7.2	790	4
	7B-95-25	BC	Jan-96	41	25	24	0.2	<2.6	215	27	8.1	53.1	6.8	494	3
		AEN	Jan-96	43	26	26	0.2	<2	160	30	8.2		6.6	520	3
	53-96-1	BC	Jul-96	62	33	90	4.7	<2.6	538	21.8	19.6	8	7.6	833	5
	58-96-11	BC	Jan-97	81	40	48	1.1	<2.6	463	30.4	30.2	6.2	7.30	839	5
		BC	Mar-97	89	40	62	1.2	<2.6	496	36.0	34.8	5.8	7.37	911	5
	7-00-4	BC	Jun-00	7.7	2.5	200	4.3	80.0	237	55	79	3.5	9.28	974	5
3	MW91-3	BC	Aug-94	8.8	2.6	724	2.3	8.6	491	22	835	<0.4	8.2	3410	1
	MW91-4	BC	Aug-94	14.2	5.5	709	2.7	<2.6	439	55	820	<0.4	7.5	3400	1
		LBNL	May-96									<5			
	MW91-5	BC	Aug-94	40	18.2	497	4.5	<2.6	1050	215	113	66.4	7.5	2370	1
	MW91-6	BC	Aug-94	80	48	115	1.8	<2.6	548	155	28.1	<0.4	7.4	1150	7
		BC	Aug-94	77	48	122	2.3	<2.6	552	163	27.8	<0.4	7.5	1160	7
	69A-92-22	BC	Aug-94	12.6	7.3	162	2.4	4.3	332	90	23	<0.4	8.2	785	4
	75-92-23	BC	Sep-94	342	176	140	1.9	<2.6	1250	575	221	<0.4	6.8	3040	2

Table 4.3-2
Groundwater Monitoring Results
Minerals
(Concentrations in mg/L)

Area	Well No.	Lab	Date	Calcium	Magnesium	Sodium	Potassium	Carbonate	Bicarbonate	Sulfate	Chloride	Nitrate/ Nitrite as NO3	pH	Electrical Conductivity (µmhos/cm)	T Diss S
			MCL:							250 (a)	210 (a)	10 as N	6.5-8.5		50
3	75B-92-24	BC	Aug-94	96	78	142	2.3	<2.6	862	100	41.6	<0.4	7.2	1470	9
	75-96-20	BC	Mar-97	32	19.6	692	7.7	<2.6	665	108	750	<0.4	7.87	3490	1
	75-97-5	BC	Aug-98	99	73	171	8.6	<2.6	1080	19	34	2.6	6.95	1660	9
	75-97-6	BC	Aug-97	136	89	1280	12.2	<2.6	1480	1960	139	4.4	7.54	5820	4
	75-97-7	BC	Jul-97	31	15.8	754	8.9	<2.6	1670	252	153	0.4	7.89	3130	2
	69-97-8	BC	Jul-98	140	86	226	5.9	<5.0	1120	20	45	<0.4	6.79	1950	1
	69-97-21	BC	Mar-98	61	58	150	5.6	<2.6	591	132	47	<0.4	7.54	1180	7
	75-98-14	BC	Jul-99	7.5	5.5	188	3.7	18	316	56	52	4.7	8.35	883	5
	75-98-15	BC	Mar-99	3.0	1.3	253	1.4	<5	214	249	56	7.1	7.23	1170	7
	75-99-4	BC	Oct-99	5.2	2.9	279	2.4	16	166	92	318	<0.4	8.83	1310	8
	75-99-6	BC	Feb-00	10	6.7	330	6.3	42	399	73	177	53	8.44	1560	9
	75-99-7	BC	Dec-99	120	100	340	15.0	<5.0	828	385	97	<0.4	7.37	2640	1
	75-99-8	BC	Feb-00	4.1	3.7	260	6.1	60	324	67	103	28	8.75	1200	7
4	MW76-1	BC	Sep-94	85	55	119	4.3	<2.6	765	17	41.6	<0.4	7.0	1230	7
		AEN	Sep-94	94	62	150	5.2			19	52	<0.1	6.8	1500	7
	76-92-25	BC	Aug-94	4.1	2.4	181	2.3	6.0	241	133	40	7.1	8.5	822	5
	76-93-6	BC	Aug-94	17.5	9.3	268	4.0	6.0	407	221	55.7	<0.4	8.4	1250	7
	76-93-7	BC	Aug-94	16	8.6	239	3.8	<2.6	348	166	88.5	20.8	7.9	1200	7
	78-97-20	BC	Oct-97	25	21	134	3.9	<2.6	336	70.0	47	2.2	8.08	800	4
	76-98-21	BC	Jul-99	71	51	240	7.3	<5.0	622	125	118	8.1	7.27	1640	1
	76-98-22	BC	Jan-99	52	42	77	4.6	<2.6	491	33	25	<0.4	7.41	844	4
5	MW91-1	BC	Aug-94	11.4	3.4	598	2.3	4.3	252	595	384	4.9	8.2	2820	1
		BC	Dec-96									<0.5			
	MW91-2	BC	Sep-94	105	71	135	4.0	<2.6	847	82	68	0.9	7.2	1500	9
	MWP-9	BC	Aug-94	3.3	1.2	243	1.2	18.8	485	38	60	<0.4	8.4	1060	6
	MWP-10	BC	Aug-94	1.6	0.93	219	1.3	50.5	456	9	20.9	<0.4	9.0	1090	5
	77-92-10	BC	Aug-94	2.7	1.7	435	2.9	23.1	522	30	286	53.1	8.6	1910	1
		BC	Aug-94	2.7	1.9	424	3.0	23.1	513	30	293	53.1	8.6	1920	1
	61-92-12	BC	Sep-94	3.4	2.5	403	4.2	16.2	692	235	35.5	4.9	8.5	1720	1
	77-93-8	BC	Aug-94	77	46	82	2.0	<2.6	571	56	37.3	<0.4	7.2	1020	5

Table 4.3-2
Groundwater Monitoring Results
Minerals
(Concentrations in mg/L)

Area	Well No.	Lab	Date	Calcium	Magnesium	Sodium	Potassium	Carbonate	Bicarbonate	Sulfate	Chloride	Nitrate/ Nitrite as NO3	pH	Electrical Conductivity (µmhos/cm)	T Diss S
			MCL:							250 (a)	210 (a)	10 as N	6.5-8.5		50
	77-94-5	BC	Sep-94	15.8	9	878	7.0	18.0	673	595	244	487	8.2	3910	2
		BC	Aug-99	15	8.7	845	4.7	14	657	657	203	316	8.30	3630	2
	77-94-6	BC	Sep-94	155	78	114	2.3	<2.6	948	90	79	<0.4	7.0	1740	1
	77-97-9	BC	Aug-97	76	50	280	6.8	<2.6	1090	29.2	73.9	1.3	7.60	1730	1
	77-97-11	BC	Jul-97	134	88	140	9.5	<2.6	918	123	114	<0.4	7.78	1750	1
	31-97-17	BC	Oct-97	100	60	84	2.1	<2.6	637	48	57	0.9	7.34	1230	7
	31-97-18	BC	Oct-97	43	28	86	4.8	<2.6	376	21	58	3.1	8.08	766	4
	31-98-17	BC	Jul-99	38	27	160	3.0	<5.0	489	3.0	40	9.4	7.84	977	5
6	88-92-4	BC	Sep-94	40	11.8	32	1.2	<2.6	194	40	14.4	0.9	7.2	432	2
	88-93-11A	BC	Sep-94	79	26	49	4.5	<2.6	340	91	34.8	<0.4	7.4	803	4
	88-93-13	BC	Aug-94	79	31	64	3.1	<2.6	423	79	18.6	<0.4	7.3	860	5
	88-96-4	BC	Jul-96	76	15.2	35	2.2	<2.6	284	74.3	19.5	<0.4	7.6	605	3
7	46-92-9	BC	Aug-94	4.3	4.3	549	10.6	24.8	567	70	327	212	8.6	2470	1
		BC	Aug-99	3.9	3.3	446	5.3	<5.0	662	119	95	241	8.18	2090	1
	58-93-3	BC	Sep-94	64	32	72	1.2	<2.6	448	30	39.5	4.0	7.3	835	4
	46-93-12	BC	Aug-94	73	26	36	0.6	<2.6	356	23	35.8	3.1	7.4	680	4
		BC	Aug-94	73	26	36	0.6	<2.6	357	23	35.8	3.1	7.2	685	4
	58A-94-14	BC	Feb-95	58	30	175	3.3	<2.6	524	57	107	0.9	7.7	1210	7
	51-94-15	BC	Feb-95	8.4	4.7	356	4.4	49.6	745	53	56.3	<0.4	8.4	1470	9
	46-94-16	BC	Mar-95	36	12.9	50	1.7	<2.6	209	36	22.7	11.1	7.5	490	2
	58-95-11	AEN	Jun-95	44	28	99	4.6	<2	360	85	53		7.7	820	4
		BC	Jun-95	40	26	110	5.5	<2.6	418	34	48.8	1.8	7.9	831	4
	58-95-18	BC	Sep-96	83	47	135	0.9	64.1	459	81.9	114	11.5	8.69	1380	8
	58-95-19	BC	Sep-96	16.1	8.7	260	2.4	10.3	239	48.4	286	9.7	9.2	1460	7
	58-95-20	BC	Aug-96	9.9	5.1	154	3.5	19.7	303	31.6	34.7	23.9	8.4	748	4
	46-96-10	BC	Aug-97	41	17.6	67	0.8	<2.6	310	27.6	23.3	7.5	7.72	610	4
	58-96-12	BC	Jan-97	105	55	69	1.6	<2.6	511	112.0	46.6	44.3	7.28	1150	7
	58A-00-3	BC	Jun-00	7.8	2.8	320	6.0	57.0	279	68	245	4.0	9.03	1540	9
8	MWP-2	BC	Sep-94	64	24	89	3.1	<2.6	297	158	43.3	0.9	7.6	880	5
	70-92-7	BC	Aug-94	154	36	41	3.3	<2.6	296	363	14.9	<0.4	7.2	1120	8

Table 4.3-2
Groundwater Monitoring Results
Minerals
(Concentrations in mg/L)

Area	Well No.	Lab	Date	Calcium	Magnesium	Sodium	Potassium	Carbonate	Bicarbonate	Sulfate	Chloride	Nitrate/ Nitrite as NO3	pH	Electrical Conductivity (µmhos/cm)	T Diss S
			MCL:							250 (a)	210 (a)	10 as N	6.5-8.5		50
	70A-96-5	CLS	Jan-96	120	37	31	3.1	<1	270	170	34	<5	6.8	860	5
	70A-96-6	BC	Jan-96	204	81	121	5.7	<2.6	323	825	25	<0.4	7.3	1870	1
		CLS	Jan-96	210	82	130	6.2	<1	270	820	43			1500	1
	70A-96-13	BC	Jan-97	38	14.3	130	5.9	<2.6	429	63.6	28.1	<0.4	7.86	858	5
	70A-96-14	BC	Jan-97	53	32	71	4.5	<2.6	395	54.6	29.6	<0.4	7.69	784	4
	OW3-225	BC	Aug-94	77	32	56	2.1	<2.6	295	180	14.9	<0.4	7.2	830	5
9	51-92-2	BC	Aug-94	6.8	4.3	354	2.6	<2.6	704	135	61	<0.4	8.1	1490	9
	51B-93-18A	BC	Sep-94	2.3	1.7	265	3.0	84.7	424	31	48.3	1.8	9.0	1080	6
	51-95-17	BC	Jul-96	4.5	4.2	288	4.2	43.6	438	26.5	110	36.7	8.5	1260	7
	51-96-3	BC	Jul-96	80	47	128	10.1	<2.6	735	14	66.8	<0.4	7.4	1180	7
	51-96-15	BC	Jan-97	18.8	8.4	29	2.8	<2.6	130	16.1	6.6	15.1	8.14	296	1
	51-96-16	BC	Jan-97	122	65	74	3.1	<2.6	818	37.4	48.4	<0.4	7.22	1320	7
	51-96-17	BC	Jan-97	15.2	6.5	230	3.4	16.2	560	28.3	39.2	<0.4	8.20	1050	6
	51-96-18	BC	Jan-97	11.2	4.2	99	3.4	16.2	200	31.2	24.2	<0.4	8.65	515	2
	51-96-19	BC	Jan-97	70	28	132	3.3	<2.6	653	31.1	25.3	1.8	7.92	1060	6
	64-97-1	BC	Jul-97	2.6	2.1	300	4.2	41.9	496	75.7	72.8	8.9	8.99	1280	8
	64-97-2	BC	Jul-97	12.1	9.3	183	7.3	11.1	299	32.8	121	7.5	8.42	946	5
	51-97-3	BC	Aug-97	147	80	91	1.2	<2.6	1040	33.6	40.8	<0.4	7.17	1550	9
	51-97-4	BC	Aug-97	6.5	7	404	10.9	72.7	500	89.9	214	<0.4	9.10	1780	1
	51-97-12	BC	Oct-97	208	143	97	3.5	<2.6	1480	9.4	93	<0.4	6.77	2200	1
	51-97-13	BC	Oct-97	96	48	70	1.7	<2.6	629	20	26	<0.4	7.11	1030	5
	51-97-14	BC	Oct-97	97	52	102	3.8	<2.6	603	54.3	91.2	<0.4	6.98	1220	6
	51-97-15	BC	Oct-97	96	51	316	4.2	<2.6	1320	48	71	<0.4	7.04	2100	1
	51-97-16	BC	Oct-97	77	41	110	3.2	<2.6	380	198	48	<0.4	7.40	1030	5
	56-98-2	BC	Jul-98	122	58	48	1.5	<2.6	705	12	30		6.72	1050	6
	64-98-4	BC	Jul-98	9.2	5.5	272	3.6	20	308	41	204	<0.4	8.50	1290	7
	51-98-5	BC	Oct-99	131	71	119	3.1	<5.0	741	76	34	2.2	7.19	1520	9
	64-98-19	BC	Jul-99	2.1	1.4	262	2.3	45	396	46	57	1.7	8.81	1070	6
	64-98-20	BC	Jul-99	14	10	490	9.7	11	171	86	608	<0.4	8.41	2450	1
	51-99-1	BC	Dec-99	4.0	1.8	310	1.5	50	466	80	72	1	8.67	1330	8
	51-00-1	BC	Feb-00	10	7.1	450	6.8	38	869	55	93	0.44	8.21	1930	1

Table 4.3-2
Groundwater Monitoring Results
Minerals
(Concentrations in mg/L)

Area	Well No.	Lab	Date	Calcium	Magnesium	Sodium	Potassium	Carbonate	Bicarbonate	Sulfate	Chloride	Nitrate/ Nitrite as NO3	pH	Electrical Conductivity (µmhos/cm)	T Diss S
			MCL:							250 (a)	210 (a)	10 as N	6.5-8.5		50
10	MW91-9	BC	Aug-94	39	31	44	1.7	<2.6	352	26	6	9.7	7.7	608	3
	MWP-8	BC	Aug-94	86	75	112	5.5	<2.6	768	53	35.8	48.7	7.4	1340	8
	26-92-11	BC	Aug-94	59	27	29	0.9	<2.6	248	43	60.1	4.0	7.6	641	4
	5-93-10	BC	Aug-94	51	20	39	2.5	<2.6	321	13	5.3	8.0	7.5	540	3
	52-93-14	BC	Mar-95	54	29	100	1.4	<2.6	457	28	30.6	16.8	7.6	840	4
	25-93-15	BC	Aug-94	13.1	5.6	115	2.6	<2.6	277	20	36.8	1.8	8.1	586	3
	52-94-10	BC	Mar-95	36	13.5	38	3.2	<2.6	233	15	13.1	7.5	7.2	440	2
	25-94-12	BC	Mar-95	44	22	172	7.1	<2.6	560	34	56.2	12.4	7.6	1050	6
	16-94-13	BC	Feb-95	28	11.9	109	4.0	<2.6	369	26	13.1	6.6	8.0	650	4
	52-95-2B	BC	Oct-95	98	48	69	1.5	<2.6	470	29	124	29.7	7.7	1170	6
	16-95-3	BC	Jun-95	49	24	42	1.5	21.4	293	16	9.2	16.4	7.8	555	3
	25A-95-4	BC	Jun-95	2.7	3.1	114	4.1	<2.6	278	13	17.4	6.2	8.8	510	3
	25-95-5	BC	Sep-95	70	30	56	1.1	<2.6	430	49	14.7	13.3	7.0	790	5
	25A-95-15	BC	Sep-96	5.6	2.7	80	1.8	11.1	158	25.9	13.3	7.5	9.2	418	2
	25-95-26	BC	Jul-96	27	24	47	2.0	<2.6	251	28.3	7.5	23.9	8.0	515	2
	25-95-27	BC	Jul-96	69	34	42	5.5	<2.6	435	9.9	11.6	46.5	7.9	777	4
	4-96-2	BC	Aug-96	2.3	1.9	257	3.4	55.6	384	37.0	70.6	27.4	8.7	1120	6
	25A-98-1	BC	Jul-98	14	8.4	70	3	16	166	20	12	<0.4	8.28	424	2
	25A-98-3	BC	Jun-98	22	22	63	2.7	<5	241	25	13	5.6	7.99	526	3
	25A-98-7	BC	Dec-99	44	22	38	1.3	<5.0	238	3.7	13	10	7.97	465	2
	52A-98-8B	BC	Jul-99	90	55	59	1.9	<5.0	411	29	84	40	7.26	1080	6
	52-98-9	BC	Jul-99	93	47	61	1.2	<5.0	379	23	103	19	7.31	1020	6
	25-98-10	BC	Oct-99	93	48	79	1.7	<2.6	471	19	32	74	7.68	1040	6
	25A-99-2	BC	Jul-99	41	24	45	1.2	<5.0	214	42	14	18	7.91	537	3
	25A-99-5	BC	Sep-99	9.3	5.1	102	1.7	<5.0	219	22	13	0.65	7.98	478	2
	25A-00-5	BC	Jun-00	20	11	180	6.3	37.0	289	58	84	3.7	8.47	1000	6
	52A-00-6	BC	Jun-00	3.7	2.1	290	2.2	53.0	574	2.7	17	0.44	8.72	1180	7
11	74-92-13	BC	Aug-94	5.4	0.5	110	1.0	<2.6	283	7	15.3	1.3	7.8	505	3
	83-92-14	BC	Aug-94	6.4	2.7	710	4.3	<2.6	1900	<5	20	<0.4	8.1	2690	1
	74-94-7	BC	Aug-94	58	24	395	5.6	<2.6	890	255	83	10.2	7.5	1990	1

Table 4.3-2
Groundwater Monitoring Results
Minerals
(Concentrations in mg/L)

Area	Well No.	Lab	Date	Calcium	Magnesium	Sodium	Potassium	Carbonate	Bicarbonate	Sulfate	Chloride	Nitrate/ Nitrite as NO3	pH	Electrical Conductivity (µmhos/cm)	T Diss S
			MCL:							250 (a)	210 (a)	10 as N	6.5-8.5		50
11	74-94-8	BC	Aug-94	57	23	719	5.4	<2.6	982	875	30.5	1.8	7.5	3190	2
		BC	Sep-94	37	18	671	4.9	<2.6	1020	755	29	6.6	7.6	3010	2
	74-95-6	BC	Aug-95	5.2	2.5	485	3.9	<2.6	1060	148	68.5	<0.4	8.2	1950	1
	83-95-7	BC	Aug-95	14	4.6	551	4.0	<2.6	1050	314	62.5	<0.4	7.8	2310	1
13	MW62-B1A	BC	Aug-94	21	5	107	10.1	10.3	26.1	188	64.4	0.9	9.9	735	4
	MW62-B2	BC	Sep-94	27	8.1	110	3.6	6.0	60	184	69.3	0.9	8.6	748	4
	62-92-26	BC	Aug-94	72	41	37	6.2	<2.6	345	82	55.9	<0.4	7.4	836	4
	62-92-27	BC	Aug-94	68	25	37	4.5	<2.6	319	80	16.1	<0.4	7.5	679	4
	62-95-16	BC	Jul-96	233	124	88	10.2	<2.6	503	590	232	0.9	7.4	2280	1
14	MWP-4	BC	Sep-94	90	48	76	4.1	<2.6	445	168	46.2	<0.4	7.3	1080	6
	MWP-5	BC	Aug-94	62	35	42	3.5	<2.6	365	74	20.3	0.4	7.8	730	4
	MWP-6	BC	Aug-94	72	31	32	2.6	<2.6	270	73	62	1.3	7.3	738	4
	MWP-7	BC	Sep-94	115	46	93	1.8	<2.6	585	94	56.1	21.2	7.0	1200	7
	37-92-5	BC	Aug-94	2	0.79	446	8.5	21.4	724	305	50	3.5	8.8	1910	1
	37-92-6	BC	Sep-94	139	79	88	1.8	<2.6	743	105	112	16.8	7.0	1600	9
	6-92-17	BC	Aug-94	38	24	61	0.8	<2.6	347	21	11.3	12.0	7.7	614	3
	37-92-18	BC	Sep-94	42	25	171	5.3	<2.6	500	94	65.7	<0.4	7.8	1100	6
	37-92-18A	BC	Sep-94	3.3	1.5	400	2.9	17.1	648	250	58	12.8	8.5	1770	1
	37-93-5	BC	Aug-94	88	48	77	7.2	<2.6	478	172	25.1	5.8	7.4	1080	6
	37-94-9	BC	Mar-95	108	56	137	4.3	<2.6	696	96	82	8.4	7.1	1390	8
		BC	Aug-94	80	46	230	5.0	<2.6	810	118	72.7	4.9	7.4	685	9
15	MWP-1	BC	Aug-94	138	57	160	3.8	<2.6	895	121	55.5	<0.4	7.2	1600	9
	63-98-18	BC	Mar-99	114	68	76	1.9	<5	694	2.1	46	<0.4	6.80	1290	7
OS	CD-92-28	BC	Aug-94	14.3	5	192	12.9	<2.6	474	14	54.4	<0.4	8.1	905	6

< = Constituent not detected above reporting limit
[ ] = Compound not included in analysis
AEN = Analysis by American Environmental Network

BC = Analysis by BC Laboratories
MCL = Maximum contaminant level for drinking water
(a) = Secondary MCL

* = /
† =

SECTION 5

REFERENCES

Boggs Environmental, 1995. Summary of Underground Storage Tank Removal Activities (Draft), Lawrence Berkeley Laboratory Underground Storage Tank #8, Facilities ID TK-11-74. Boggs Environmental, Oakland, California, January 11, 1995.

Boggs Environmental, 1995b, Summary of Underground Storage Tank Removal Activities (Tank TK-10-70A). February 1998.

Boggs Environmental, 1996, Summary of Underground Storage Tank Removal Activities (Tank TK-10-70).

Borg, S.G., 1991. Geology of Lawrence Berkeley Laboratory. Report prepared for the LBL Environmental Restoration Project.

Bouwer, H., 1989. The Bouwer and Rice Slug Test an Update, Ground Water, Vol. 27, No. 3, May-June 1989.

Bouwer, H. and R.C. Rice, 1976, A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells, Water Resources Research, pp. 423 to 428, June.

California EPA, 1994a. Guidance Manual For Groundwater Investigations, Interim Final, August 1994.

California EPA, 1994b. Guidelines for Hydrogeologic Characterization of Hazardous Substance Release Sites, Interim Final, August 1994.

Case, J.E., 1968. Upper Cretaceous and lower Tertiary rocks, Berkeley and San Leandro Hills, California. U.S. Geological Survey Bulletin 1251-J, p. J1-J29.

Curtis, G.H., 1989. Berkeley Hills. In Wahrhaftig, C. and Sloan, D., eds., Geology of San Francisco and Vicinity. Field Trip Guidebook T105, 28th International Geological Congress, Amer. Geoph. Union, p. 34, 47-52.

COB, 1996a. Request for No Further Investigation Status for SWMU 12-1, SWMU 7-1, SWMU 3-3, AOC 6-1, letter from Shirley Marshall (Toxics Management Division) to Iraj Javandel (LBNL), July 29, 1996.

COB, 1996b. No Further Action for Building 70 Underground Storage Tank, letter from Shirley Marshall (Toxics Management Division) to Charles Smith (LBNL), December 3, 1996.

COB, 1997a. Building 46A-Former Motor Pool Gasoline UST, letter from Shirley Marshall (Toxics Management Division) to Iraj Javandel (LBNL), May 9, 1997.

COB, 1997b. Request for No Further Action Status for Selected Fuel Storage Tanks, letter from Shirley Marshall (Toxics Management Division) to Iraj Javandel (LBNL), July 15, 1997.

COB, 1998. Approval of No Further Action for the Former Building 70A Diesel UST (AOC 8-1). Letter from Michael C. McMillan (Toxics Management Division) to Ron Pauer (LBNL), dated May 4, 1998.

COB, 1999. Response to City of Berkeley Comments on Request for NFI for Building 7E and NFA for Building 74, letter from Geoffrey Fiedler (Toxics Management Division) to Iraj Javandel (LBNL), April 9, 1999.

Cooper, H.. J. Bredehoeft and I. Papadapulos, 1967. Response of a Finite-Diameter Well to an Instantaneous Charge of Water. Water Resources Research, Vol. 3, No. 1 (first quarter 1967), p.263-269.

Curtis, G.H., 1989. Berkeley hills. In Wahrhaftig, C. and Sloan, D. eds. Geology of san Francisco and Vicinity, field Trip Guidebook T105, 28th International Geological Congress, Amer. Geoph. Union.

Dames and Moore, 1961. Foundation investigation, proposed Cyclotron Building 6, increment II, Lawrence Radiation Laboratory, Berkeley, California. LBNL Geotechnical File Number 66.

Dames and Moore, 1986. Subsurface Investigation Report, Tank TK-02-88, Building 88, Lawrence Berkeley Laboratory. Dames and Moore, San Francisco, California, November 6, 1986.

Dames and Moore, 1987a. Underground Tank Removal and Soil Excavation Report, Tank TK-02-62, Building 62, Lawrence Berkeley Laboratories. Dames and Moore, San Francisco, California, Job Number 234-187-03, November 10, 1987.Dibblee, T.W., Jr., 1980. Preliminary Geologic Map of the Briones Valley Quadrangle, Alameda and Contra Costa Counties, California. U.S. Geological Survey, Open File Report 80-539, scale 1:24000.

Dibblee, T.W., Jr., 1980a. Preliminary Geologic Map of the Richmond Quadrangle, Alameda and Contra Costa Counties, California. U.S. Geological Survey, Open File Report 80-1100, scale 1:24000.

Dibblee, T.W., Jr., 1980b. Preliminary Geologic Map of the Briones Valley Quadrangle, Alameda and Contra Costa Counties, California. U.S. Geological Survey, Open File Report 80-539, scale 1:24,000.

DOE, 1988. Environmental Survey Preliminary Report of Lawrence Berkeley Laboratory, Berkeley, California. United States Department of Energy, July 1988.

DOE, 1998. Approval of the request for No Further Action (NFA) Status for SWMUs 11-2 and 11-3, dated June 1998, letter from Roger Liddle (DOE) to Iraj Javandel (LBNL), July 13, 1998.

DOE, 1999. Request for No Further Action (NFA) Status for Solid Waste Management Units 10-2 and 10-3 and Area of Concern 1-7, dated September 1999, letter from Joe Cullen (DOE) to Iraj Javandel (LBNL), September 30, 1999.

DTSC, 1991. RCRA Facility Assessment for Lawrence Berkeley Laboratory, Berkeley, California. California Environmental Protection Agency Department of Toxic Substances Control, Region 2, November 1991.

DTSC, 1993a. Responsibilities and Coordination Among Regulatory and Governmental Agencies With Oversight Responsibilities and/or Jurisdiction Over RCRA Facility investigation (RFI) / Corrective Action at Lawrence Berkeley Laboratory EPA ID. No. CA4 890 008 986, letter from Sal Ciriello (DTSC) to David McGraw (LBNL). July 29, 1993.

DTSC, 1993b. Notice of Deficiency for LBNL's RCRA Facility Investigation Work Plan, LBNL, Berkeley, California. Letter from Bernie Edrada (DTSC, Region 2) to Jackie Thomas (LBNL), September 14, 1993.

DTSC, 1994a. Approval of RCRA Facility Investigation (RFI) for LBNL. Letter from Charlene F. Williams (DTSC) to Iraj Javandel (LBNL), April 6, 1994.

DTSC, 1995. Approval of the RCRA Facility Investigation Report (Phase I) for Lawrence Berkeley Laboratory (LBNL) CA4890008986, letter from Lester Kaufman (DTSC) to Iraj Javandel (LBNL), May 18, 1995.

DTSC, 1996a. Approval of the RCRA Facility Investigation Report (Phase II) for Lawrence Berkeley Laboratory (LBNL) CA4890008986, letter from Lester Kaufman (Sal Ciriello) (DTSC) to Iraj Javandel (LBNL), January 18, 1996.

DTSC, 1996b. Corrections to Table 1 in the Approval Letter for RCRA Facility Investigation Report (Phase III) for Lawrence Berkeley National Laboratory (LBNL) EPA ID No. CA4 890 008 986, letter from Bernie Edrada (DTSC) to Iraj Javandel (LBNL), July 5, 1996.

DTSC, 1996c. Approval of RCRA Facility Investigation Report (Phase III) for Lawrence Berkeley National Laboratory (LBNL) EPA ID No. CA4 890 008 986, letter from Lester Kaufman (DTSC) to Iraj Javandel (LBNL), May 3, 1996.

DTSC, 1997. Approval for No Further Action and No Further Investigation Status for SWMUs and AOCs, Lawrence Berkeley National Laboratory, Berkeley, California, EPA ID No. CA4 890 008 986, letter from Bernie Edrada (DTSC) to Iraj Javandel (LBNL), August 25, 1997.

DTSC, 1998. Approval for No Further Action and No Further Investigation Status for SWMUs and AOCs, Lawrence Berkeley National Laboratory, Berkeley, California, EPA ID No. CA4 890 008 986, letter from Bernie Edrada (DTSC) to Iraj Javandel (LBNL), September 30, 1998.

DTSC, 1999a. Approval for No Further Investigation Status for SWMU 9-6, Building 51 Motor generator Room Sump, Lawrence Berkeley National Laboratory, Berkeley, California, EPA ID No. CA4 890 008 986, letter from Tony Natera (DTSC) to Iraj Javandel (LBNL), September 21, 1999.

DTSC, 1999b. Approval for "No Further Action Required" Status (NFA) for Area of Concern 8-7 (AOC 8-7), Building 70A sanitary Sewer, Lawrence Berkeley National Laboratory, Berkeley, California, EPA ID No. CA4 890 008 986, letter from Tony Natera (DTSC) to Iraj Javandel (LBNL), September 28, 1999.

DTSC, 2000a. Approval of "No Further Action Required" Status for Area of Concern 9-8 (Sanitary Sewer Lines North and West of Building 51 and 51B) and Area of Concern 10-3 (Building 25A Sanitary Sewer, Lawrence Berkeley National Laboratory, U.S. EPA ID Number CA 489 000 8986, letter from Salvatore Ciriello (DTSC) to Iraj Javandel (LBNL), February 15, 2000.

DTSC, 2000b. Approval of No Further Investigation Status (NFI) for Solid Waste Management Unit 3-6, Building 75 Former Hazardous Waste Handling Facility, Lawrence Berkeley National Laboratory, U.S. EPA ID Number CA 489 000 8986, letter from Salvatore Ciriello (DTSC) to Iraj Javandel (LBNL), April 21, 2000.

DTSC, 2000c. Approval of No Further Action (NFA) Status for Area of Concern 9-11, Former Cooling Towers Southeast of Building 51, Lawrence Berkeley National Laboratory, U.S. EPA ID Number CA 489 000 8986, letter from Salvatore Ciriello (DTSC) to Iraj Javandel (LBNL), April 27, 2000.

DTSC, 2000d. Approval of No Further Investigation (NFI) Status for Area of Concern 9-9, Building 51 Basement sanitary Sewer and Drainage System, Lawrence Berkeley National Laboratory, U.S. EPA ID Number CA 489 000 8986, letter from Salvatore Ciriello (DTSC) to Iraj Javandel (LBNL), April 27, 2000.

DWR, 1991. California Well Standards, Bulletin 74-90. California Department of Water Resources, June 1991.

Environmental Solutions. 1994. Summary of Underground Storage Tank Removal Activities, Underground Storage Tank #4, Facilities ID TK-35-51, Lawrence Berkeley Laboratory, Berkeley, California. Environmental Solutions Inc., Petaluma, California, September 8, 1994.

Geo/Resources Consultants Inc., 1991. Tank Replacement Report, Underground Storage Tanks 2 and 3 at Building 76, Lawrence Berkeley Laboratory, Berkeley, California., Geo/Resources Consultants, Inc., San Francisco, California, November 1991.

Geo/Resources Consultants Inc., 1994. Fault Investigation - Building 85 - Hazardous Waste Handling Facility, Lawrence Berkeley Laboratory, Berkeley, California.

Gilpin, L.M., 1994. Geologic evaluation, Wildcat Fault, Human Genome Laboratory, Lawrence Berkeley Laboratory, Berkeley, California. Subsurface Consultants.

Graham, S.A., McCloy, C., Hitzman, M., Ward, R., and Turner, R., 1984. Basin evolution during change from convergent to transform continental margin in central California. Amer. Assoc. Petroleum Geol. Bull., v. 68, p. 233-249.

Hammon, Jensen & Wallen, 1956. Topographic Map - Plot 'O' of 'M' Peralta Grant, LBL Drawing Number B21G0336, scale 1:2400.

Harding Lawson Associates, 1982. Geology of Lawrence Berkeley Laboratory, HLA Job No. 2000,135,01. LBNL Geotechnical File Number 41.

Harding-Lawson Associates, 1980. Wildcat Fault Study, Biomedical II Laboratory project, Lawrence Berkeley Laboratory, Berkeley, California, Job No. 2000.145. LBNL Geotechnical File Number 35.

Harding-Lawson Associates, 1984. Geotechnical investigation, Building 17 to 25A road realignment, Lawrence Berkeley Laboratory, Berkeley, California, Job No. 2000.169. LBNL Geotechnical File Number 53.

Harding-Lawson Associates, 1987. Building 2 services during construction, Lawrence Berkeley Laboratory, Berkeley, California, Job No. 2000.201. LBNL Geotechnical File Number 264.

Harding Lawson Associates, 1988a. Fast Track Sampling Effort, Report No. HLA 2000, 200.02, Harding Lawson Associates, Novato, California.

Harding-Lawson Associates, 1988b. Settlement investigation - Building 58A, Lawrence Berkeley Laboratory, Berkeley, California, Job No. 2000.210. LBNL Geotechnical File Number 117.

Harding Lawson Associates, 1988c, Closure Work Plan, Tank Closure TK-01-07, Lawrence Berkeley Laboratory, California, Job No. 2000,214.01, March 25

Holland, P.J. and Wollenberg, H.A., 1992. Initial Appraisal of the Geologic Controls of Groundwater Occurrence and Movement in the "Grizzly" Area of Lawrence Berkeley Laboratory. LBID-1852.

Javandel, 1990. Preliminary Environmental Investigations at the Lawrence Berkeley Laboratory, prepared for the U.S. Department of Energy, Oakland, California.

Jones, D.L. and Curtis, G.H., 1991. Guide to the geology of the Berkeley Hills, central Coast Ranges, California. In Sloan, D. and Wagner, D.L., eds., Geologic Excursions in Northern California: San Francisco to the Sierra Nevada. Calif. Div. Mines and Geology Spec. Pub. 109, p. 63-73.

Kaldveer Associates, 1991. Workplan for Phase II PCB Investigation, Bevatron Building 51, Lawrence Berkeley Laboratory, Berkeley, California, March 18, 1991

Lawson, A.C. and Palache, C., 1900. The Berkeley Hills: A detail of Coast Range geology. Univ. of California, Department of Geology Bulletin, v. 2, p. 349-450.

LBNL, 1989, Underground Tank Release Report. Letter from Ralph H. Thomas (LBNL) to Britt Johnson (City of Berkeley), with report form, April 25.

LBNL, 1991. Vadose Zone Monitoring Plan for the Site Restoration Program, Earth Sciences Division, Lawrence Berkeley Laboratory, Berkeley, California, December 23, 1991.

LBNL, 1992a. Groundwater Sampling and Analysis Plan, Lawrence Berkeley Laboratory, Berkeley, California, May 4, 1992.

LBNL, 1992b. Soil Disposal Plan for the Lawrence Berkeley Laboratory, Lawrence Berkeley Laboratory, Berkeley, California, August 14, 1992.

LBNL, 1992c. Well Management Plan, Lawrence Berkeley Laboratory, Berkeley, California, August 1992.

LBNL, 1992d. RCRA Facility Assessment at the Lawrence Berkeley Laboratory, Environmental Restoration Program, September 30, 1992.

LBNL, 1992e. RCRA Facility Investigation Work Plan for the Lawrence Berkeley Laboratory, Environmental Restoration Program, October 30, 1992.

LBNL, 1993a. Addendum to the RCRA Facility Investigation Work Plan for the Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, June 1993.

LBNL, 1993b. Community Relations Plan for the Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, July 1993.

LBNL, 1993c. Quarterly Progress Report, Second Quarter Fiscal Year 1993 (January 1 to March 31, 1993) for the Lawrence Berkeley Laboratory Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, August 1993.

LBNL, 1993d. Addendum to the LBNL RCRA Facility Investigation Workplan, Specifications for Well Abandonment, Upgrading of Slope Stability Wells, and Construction of Groundwater Monitoring Wells, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, September 1993.

LBNL, 1993e. Health and Safety Program Plan for the Environmental Restoration Program, Revision 4, Lawrence Berkeley Laboratory, Berkeley, California, September 1993.

LBNL, 1993f. Quarterly Progress Report, Third Quarter Fiscal Year 1993 (April 1 to June 30, 1993) for the Lawrence Berkeley Laboratory Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, November 1993.

LBNL, 1993g. Workplan for Abandoning Slope Stability Wells SSW9-130 and SSW13-130, Revision 2, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, November 1993.

LBNL, 1993h. Letter from Iraj Javandel (LBNL) to Bernie Edrada (DTSC), chron. no. 1565, December 13, 1993.

LBNL, 1993i. Investigation of Potential Offsite Contaminant Migration and Offsite well Survey , Lawrence Berkeley Laboratory, Berkeley, California, November 1993.

LBNL, 1994a. Quarterly Progress Report, Fourth Quarter Fiscal Year 1993 (July 1 to September 30, 1993) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, February 1994.

LBNL, 1994b. Addendum to the LBNL RCRA Facility Investigation Work Plan for Construction of Monitoring Wells MW77-94-1, MW77-94-2, MW71-94-3, MW53-94-4, MW7-94-5, MW52-94-6, MW37-94-7, MW74-94-8, and MW74-94-9, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, March 1994.

LBNL, 1994c. Addendum to the LBNL RCRA Facility Investigation Work Plan for Soil Investigations at SWMUs 2-2, 2-3, 4-2, 4-3, 5-1, 5-4, 5-10 & 10-4 and AOCs 4-1, 4-2, 6-3, &7-1, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, March 1994.

LBNL, 1994d. Proposed Changes in Monitoring Well Schedule. Letter from Iraj Javandel (LBNL) to Jack Gregg (RWQCB), Chron Number 1647, May 19, 1994.

LBNL, 1994e. Quarterly Progress Report, First Quarter Fiscal Year 1994 (October 1 to December 31,1993) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, May 1994.

LBNL, 1994f. Addendum to the LBNL RCRA Facility Investigation Workplan, Specifications for Well Abandonment (SSW-1.151, SSW3.151, SI-27.63, and B69A?), Upgrading of Slope Stability Well (SSW-14.63), Construction of Groundwater Monitoring Wells (52-94-10, 51-

94-11, 25-94-12, 16-94-13, 58A-94-14, 51-94-15, and 46-94-16), and Soil Sampling (SWMU 12-1), Lawrence Berkeley Laboratory Environmental Restoration Program, August, 1994.

LBNL, 1994g. Lawrence Berkeley Laboratory Environmental Restoration Program Quality Assurance Program Plan, Lawrence Berkeley Laboratory, Berkeley, California, August 1994.

LBNL, 1994h. Quarterly Progress Report, Second Quarter Fiscal Year 1994 (January 1 to March 31, 1994) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, August 1994.

LBNL, 1994j. Lawrence Berkeley Laboratory Environmental Restoration Program Standard Operating Procedures, Lawrence Berkeley Laboratory, Berkeley, California, September, 1994.

LBNL, 1994k. Lawrence Berkeley Laboratory Environmental Restoration Program, RCRA Facility Investigation Workplan (Phase II) for the Lawrence Berkeley Laboratory Environmental Restoration Program, Berkeley California, October 1994.

LBNL, 1994l. Draft Final RFI Phase I Progress Report, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, November 1994.

LBNL, 1994m. Proposed Changes in Monitoring Well Schedule. Letter from Iraj Javandel (LBNL) to Jack Gregg (RWQCB), Chron Number 1756, November 10, 1994.

LBNL, 1994n. Quarterly Progress Report, Third Quarter Fiscal Year 1994 (April 1 to June 30, 1994) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, November 1994.

LBNL, 1995a. Addendum to the LBNL RCRA Facility Investigation Workplan (Phase II) for Construction of Monitoring Wells MW71-95-1, MW52-95-2, MW16-95-3, MW25A-95-4, MW25-95-5, MW74-95-6, MW83-95-7, MW71-95-8, MW71-95-9, and MW71-95-10 and Abandonment of Slope Stability Well SSW-6.37, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, February 1995.

LBNL, 1995b. Quarterly Progress Report, Fourth Quarter Fiscal Year 1994 (July 1 to September 30, 1994) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, February 1995.

LBNL, 1995c. Addendum to the RCRA Facility Investigation Workplan (Phase II), Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, April 1995.

LBNL, 1995d. Workplan for Additional Investigations in the Building 74-83 Area (Human Genome Construction Site), Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, April 1995.

LBNL, 1995e. Quarterly Progress Report, First Quarter Fiscal Year 1995 (October 1 to December 31, 1994) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, May 1995.

LBNL, 1995f. Supplement to the Addendum to the RCRA Facility Investigation Workplan (Phase II) (dated April 1995), Environmental Restoration Program, Lawrence Berkeley Laboratory, Berkeley, California, June 1995.

LBNL, 1995g. Second Addendum to the RCRA Facility Investigation (RFI) Workplan (Phase II), Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, July 1995.

LBNL, 1995h. Addendum to the LBNL RCRA Facility Investigation Workplan (Phase II) for Construction of Monitoring Wells MW6-95-14, MW25-95-15, MW62-95-16, MW51-95-17, MW58-95-18, MW58-95-19, MW58-95-20, MW7B-95-21, and MW7-95-22, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, August 1995.

LBNL, 1995i. Protocol for determining background concentrations of metals in soil at Lawrence Berkeley National Laboratory (LBNL), August 1995.

LBNL, 1995j. Quarterly Progress Report, Second Quarter Fiscal Year 1995 (January 1 to March 31, 1995) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, August 1995.

LBNL, 1995k. Draft RFI Phase II Progress Report, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, September 1995.

LBNL, 1995l. Draft final RCRA Facility Investigation Work Plan (Phase III) for the Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, October 1995.

LBNL, 1995m. Addendum to the LBNL RCRA Facility Investigation Workplan (Phase II) for Construction of Monitoring Wells MW7-95-23, MW7B-95-24, MW58-95-25, MW25-95-26, and MW25-95-27, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, November 1995.

LBNL, 1995n. Quarterly Progress Report, Third Quarter Fiscal Year 1995 (April 1 to June 30, 1995) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley national Laboratory, Berkeley, California, November 1995.

LBNL, 1996a. Request for No Further Investigation (NFI) Status for Selected Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs) at the E.O. Lawrence Berkeley National Laboratory, January 9, 1996.

LBNL, 1996b. Interim Corrective Measures Workplan for the Old Town Groundwater Plume, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, January 1996.

LBNL, 1996c. Quarterly Progress Report, Fourth Quarter Fiscal Year 1995 (July 1 to September 30, 1995) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, February 1996.

LBNL, 1996d. Addendum to the LBNL RCRA Facility Investigation Phase III Workplan for Construction of Monitoring Wells MW53-96-1, MW4-96-2, MW51-96-3, MW88-96-4, MW70A-96-5, MW70A-96-6, MW25-96-7, MW52B-96-8, and MW7C-96-9, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, March 1996.

LBNL, 1996e. Addendum to the LBNL RCRA Facility Investigation Workplan (Phase III), Building 51 (Bevatron) Complex, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, March 1996.

LBNL, 1996f. Quarterly Progress Report, First Quarter Fiscal Year 1996 (October 1 to December 31, 1995) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, May 1996.

LBNL, 1996g. Addendum to the LBNL RCRA Facility Investigation Workplan (Phase III) Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, June 1996.

LBNL, 1996h. Quarterly Progress Report, Second Quarter Fiscal Year 1996 (January 1 to March 31, 1996) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, August 1996.

LBNL, 1996i. Addendum to the LBNL RCRA Facility Investigation Workplan (Phase III) for Construction of Groundwater Monitoring Wells (MW46-96-10, MW58-96-11, MW58-96-12, MW70A-96-13, MW70A-96-14, MW51-96-15, MW51-96-16, MW51-96-17, MW51-96-18, MW51-96-19, and MW75-96-20), Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, September 1996.

LBNL, 1996j. Addendum to the LBNL RCRA Facility Investigation Workplan (Phase III) Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, September 1996.

LBNL, 1996k. Status Report on Interim Corrective Measures (ICMs). Lawrence Berkeley National Laboratory, Berkeley, California, October 1996.

LBNL, 1996l. Quarterly Progress Report, Third Quarter Fiscal Year 1996 (April 1 to June 30, 1996) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, November 1996.

LBNL, 1996m. Interim corrective Measures/Pilot Test Workplan for the Former Building 7E Diesel Underground Storage Tank (UST) Site, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, September 1996.

LBNL, 1997a. Addendum to the LBNL RCRA Facility Investigation Workplan (Phase III) Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, January 1997.

LBNL, 1997b. Draft Final RCRA Facility Investigation Report, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, February 1997.

LBNL, 1997c. Quarterly Progress Report, Fourth Quarter Fiscal Year 1996 (July 1 to September 30, 1996) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, February 1997.

LBNL, 1997d. Request for No Further Action (NFA) or No Further Investigation (NFI) Status for 5 Solid Waste management units (SWMUs) and 9 Areas of Concern (AOCs) at Lawrence Berkeley National Laboratory, February 28, 1997.

LBNL, 1997e. Proposal for Revising Well Sampling Schedule, Environmental Restoration Program, E.O. Lawrence Berkeley National Laboratory, Letter from Iraj Javandel (LBNL) to Jack Gregg RWQCB, March 14, 1997.

LBNL, 1997f. Addendum to the LBNL RCRA Facility Investigation Workplan (Phase III) for Construction of Groundwater Monitoring Wells and Destruction of Slope Stability Wells, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, April 1997.

LBNL, 1997g. Environmental Health-Risk Assessment for Tritium Releases at the National Tritium Labeling Facility at Lawrence Berkeley National Laboratory, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, April 1997.

LBNL, 1997h. Workplan for Soil Investigations for Closure of the Hazardous Waste Handling Facility (EPA ID NO. CA4890008986), for the Lawrence Berkeley National Laboratory Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, April 1997.

LBNL, 1997i. Quarterly Progress Report, First Quarter Fiscal Year 1997 (October 1 to December 31, 1996) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, May 1997.

LBNL, 1997j. Interim Corrective Measures Workplan for the Building 7 Former Plating Shop, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, July 1997.

LBNL, 1997k. Interim Corrective Measures Workplan for the Building 52B Abandoned Liquid Waste Above-Ground Storage Tank, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, July 1997.

LBNL, 1997l. Request for No Further Action (NFA) Status for Selected Fuel Storage Tanks for the Lawrence Berkeley National Laboratory Environmental Restoration Program , July 1, 1997.

LBNL, 1997m. Addendum to the LBNL RCRA Facility Investigation Workplan (Phase III) for Construction of Groundwater Monitoring Wells, MW51-97-12, MW51-97-13, MW51-97-14, MW51-97-15, MW51-97-16, MW31-97-17, MW31-97-18, MW75-97-19, MW78-97-20, MW69-97-21, MW76-97-22, and MW71-97-23, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, August 1997.

LBNL, 1997n. Quarterly Progress Report, Second Quarter Fiscal Year 1997 (January 1 to March 31, 1997) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, August 1997.

LBNL, 1997o. Quarterly Progress Report, Third Quarter Fiscal Year 1997 (April 1 to June 30, 1997) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, November 1997.

LBNL, 1997p. Clarification of Status for LBNL SWMU 3-5 and LBNL AOC 7-6, letter from Iraj Javandel (LBNL) to Bernie Edrada (DTSC, August 22, 1997.

LBNL, 1998a. Investigation/Interim Corrective Measures (ICM) Workplan for the Building 51 Motor Generator Room, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, January 1998.

LBNL, 1998b. Interim Corrective Measures (ICM) Workplan, Building 7E Former Diesel UST Site, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, February 1998.

LBNL, 1998c. Quarterly Progress Report, Fourth Quarter Fiscal Year 1997 (July 1 to September 30, 1997) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, February 1998.

LBNL, 1998d. Addendum to the RCRA Facility Investigation (Phase III) for Investigation of Soil Contamination and Construction of Groundwater Monitoring Wells, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, March 1998.

LBNL, 1998e. Interim Corrective Measures (ICM) Workplan for the Old Town Groundwater Contamination Plume, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, March 1998.

LBNL, 1998g. Quarterly Progress Report, First Quarter Fiscal Year 1998 (October 1 to December 31, 1997) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, May 1998.

LBNL, 1998h. Status Report on Interim Corrective Measures (ICMs). Lawrence Berkeley National Laboratory, Berkeley, California, June 1998.

LBNL, 1998i. Request for No Further Action (NFA) Status for SWMU 11-2 and SWMU 11-3 for the Lawrence Berkeley National Laboratory Environmental Restoration Program, June 1998.

LBNL, 1998j. Request for No Further Action (NFA) or No Further Investigation (NFI) Status for Selected Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs) for the Lawrence Berkeley National Laboratory Environmental Restoration Program, July 1998.

LBNL, 1998k. Addendum to the RCRA Facility Investigation (Phase III) for Construction of Groundwater Monitoring Wells MW25A-98-6, MW25A-98-7, MW52A-98-8, MW52-98-9, MW25-98-10, MW46A-98-11, MW46A-98-12, MW71B-98-13, MW75-98-14, MW75-98-15, MW75-98-16, MW31-98-17, MW63-98-18, MW64-98-19, MW64-98-20, MW76-98-21, and MW76-98-22, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, August 1998.

LBNL, 1998l. Quarterly Progress Report, Second Quarter Fiscal Year 1998 (January 1 to March 31, 1998) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, August 1998.

LBNL, 1998m. Interim Corrective Measures (ICM) Workplan for PCB Removals at the Building 17 Former Scrapyard and Drum Storage Area (SWMU 2-3) and Building 75 Former Hazardous Waste Handling and Storage Facility (SWMU 3-6), Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, September 1998.

LBNL, 1998n. Quarterly Progress Report, Third Quarter Fiscal Year 1998 (April 1 to June 30, 1998) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, November 1998.

LBNL, 1998p, Closure Report for the Hazardous Waste Handling Facility (Buildings 75, 75A, and 69), Ernest Orlando Lawrence Berkeley National Laboratory, April 21.

LBNL, 1999a. Request for No Further Action (NFA) and No Further Investigation (NFI) Status for Selected Fuel Storage Tanks. Lawrence Berkeley National Laboratory Environmental Restoration Program, December 1998 (Cover letter dated January 7, 1999).

LBNL, 1999c. Quarterly Progress Report, Fourth Quarter Fiscal Year 1998 (July 1 to September 30, 1998) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, February 1999.

LBNL, 1999e. Request for No Further Investigation (NFI) Status for Areas of Groundwater Contamination Designated as Areas of Concern (AOCs). Lawrence Berkeley National Laboratory Environmental Restoration Program, February 1999.

LBNL, 1999f. Workplan for Investigation of Groundwater Contamination Source Areas, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, February 1999.

LBNL, 1999g. Quarterly Progress Report, First Quarter Fiscal Year 1999 October 1 to December 31, 1998) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, May 1999.

LBNL, 1999h. Workplan for Investigation of Source Area in Building 51/64 Groundwater Contamination Plume, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, May 1999.

LBNL, 1999i. Proposal for Revised Groundwater Monitoring Schedule, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, June 1999.

LBNL, 1999j. Workplan for Installation of Groundwater Monitoring Wells MW71B-99-3, MW75-99-4, and MW25A-99-5, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, June 1999.

LBNL, 1999k. Workplan for Soil Investigations at the Building 51 Motor Generator Room Filter Sump (SWMU 9-6), Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, June 1999.

LBNL, 1999l, Interim Corrective Measures (ICMs) Workplan for the Building 51 vacuum pump Room, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, August 1999.

LBNL, 1999m. Quarterly Progress Report, Second Quarter Fiscal Year 1999 (January 1 to March 31, 1999) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, August 1999.

LBNL, 1999n. Workplan for Investigation of Soil Contamination at the Building 75 Former Hazardous Waste Handling and Storage Facility (SWMU 3-6), Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, August 1999.

LBNL, 1999o. Request for No Further Investigation (NFI) Status for the Building 51 Motor Generator Room Sump (Solid Waste Management Unit 9-6) for the Lawrence Berkeley National Laboratory Environmental Restoration Program, September 1999.

LBNL, 1999p. Request for No Further Action (NFA) Status for the Building 70A Sanitary Sewer (Area of Concern 8-7) for the Lawrence Berkeley National Laboratory Environmental Restoration Program, September 1999.

LBNL, 1999q. Workplan for Installation of Temporary Monitoring Wells SB51L-99-1 and SB69A-99-1, and Reconstruction of Monitoring Wells MWP-8 and MW37-93-5, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, September 1999.

LBNL, 1999r. Request for No Further Action (NFA) Status for Building 71 Radiation Release, Building 5 Former Decontamination Area, Building 5 Former Outdoor Radioactive Waste Storage Area for the Lawrence Berkeley National Laboratory Environmental Restoration Program, October 1999.

LBNL, 1999s. Interim Corrective Measures (ICMs) Workplan for the Building 51/64 groundwater Plume, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, October 1999.

LBNL, 1999t. Quarterly Progress Report, third Quarter Fiscal Year 1999 (April 1 to June 30, 1999) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, November 1999.

LBNL, 1999u. Workplan Addendum for Further Investigation at Building 75 Former Hazardous Waste Handling Facility (SWMU 3-6), Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, November 1999.

LBNL, 1999v. Workplan for Further Investigation at Building 51 Sanitary Sewer and Drainage System in Motor Generator Room Basement (AOC 9-9), Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, December 1999.

LBNL, 2000a. Request for No Further Action (NFA) Status for Sanitary Sewer Lines North and west of Building 51 and 51B (Area of Concern 9-8) and Building 25A Sanitary Sewer (Area of Concern 10-3) for the Lawrence Berkeley National Laboratory Environmental Restoration Program, January 14, 2000.

LBNL, 2000b. Workplan for Further Investigation at former Cooling Towers Southeast of Building 51 (AOC 9-11, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, January 2000.

LBNL, 2000c. Quarterly Progress Report, Fourth Quarter Fiscal Year 1999 (July 1 to September 30, 1999) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, February 2000.

LBNL, 2000d. Request for No Further Investigation (NFI) Status for Building 75 Former Hazardous Waste Handling and Storage Facility Solid Waste Management Unit 3-6 for the

Lawrence Berkeley National Laboratory Environmental Restoration Program, February 29, 2000.

LBNL, 2000e. Request for No Further Action (NFA) Status for Former Cooling Towers Southeast of Building 51 (AOC 9-11) for the Lawrence Berkeley National Laboratory Environmental Restoration Program, March 29, 2000.

LBNL, 2000f. Request for No Further Investigation (NFI) Status for Building 51 Sanitary Sewer and Drainage System (AOC 9-9) for the Lawrence Berkeley National Laboratory Environmental Restoration Program, April 24, 2000.

LBNL, 2000g. Quarterly Progress Report, First Quarter Fiscal Year 2000 (October 1 to December 31, 1999) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, May 2000.

LBNL, 2000h. Quarterly Progress Report, Second Quarter Fiscal Year 2000 (January 1 to March 31, 2000) for the LBNL Hazardous Waste Facility Permit, Environmental Restoration Program, Lawrence Berkeley National Laboratory, Berkeley, California, August 2000.

Lienkaemper, J.J., Borchardt, G., and, Lisowski, M., 1991. Holocene creep rate and potential for seismic slip along the Hayward Fault, California. Journal of Geophysical Research, v. 96, no. B11, p. 18,261-18, 283.

Neuman, S., 1975. Analysis of Pumping Test Data from Anisotropic Unconfined Aquifers Considering Delayed Yield. Water Resources Research, Vol. 11, No. 2 (1975), p.329-342.

Pacific Gas and Electricity (PG&E), 1994, Grizzly Substation Site Background and Sampling Results, August.

Papadopulos, I. S., and H. H. Cooper, 1967. Drawdown in a well of large diameter, Water Resouces Research, v. 3, no. 1, pp. 241-244.

Piper, A. M., 1944. A Graphic Procedure in the Geochemical Interpretation of Water Analyses: American Geophysical Union transactions, v. 25, pp. 914-923.

Radbruch-Hall, D. H., 1969. Areal and Engineering Geology of the Oakland East Quadrangle, California. *U.S. Geological Survey*, *Geologic Quadrangle* GQ-769, Scale 1:24,000.

RWQCB, 1995a. Proposed Changes in Monitoring Well Sampling Schedule, Letter from Steven Ritchie (RWQCB) to Iraj Javandel (LBNL), File No. 2199.9026A(JHG), April 13, 1995.

RWQCB, 1999b. San Francisco Bay Basin (Region 2) Water Quality Control Plan, California Regional Water Quality Control Board San Francisco Bay Region, June, 21, 1995.

RWQCB, 1997. Proposed Changes in Monitoring Well Sampling Schedule, Letter from Loretta K. Barsamian (RWQCB) to Iraj Javandel (LBNL), File No. 2199.9026A(JHG), June 19, 1997.

RWQCB, 1999a. Proposal for Revised Groundwater Monitoring Schedule dated June 1999, Letter from Michael Rochette (RWQCB) to Iraj Javandel (LBNL), July 27, 1999.

RWQCB, 1999b. Request for No Further Investigation Status for Areas of groundwater Contamination Designated as Areas of Concern (AOCs), Letter from Michael Rochette (RWQCB) to Iraj Javandel (LBNL), September 27, 1999.

RWQCB, 1999c. East Bay Plain Groundwater basin Beneficial Use Evaluation Report Alameda and Contra Costa Counties, CA, California Regional Water Quality Control Board San Francisco Bay Region Groundwater Committee, June, 1999.

Schulz, S.S., Mavko, G.M., Burford, R.O., and Stuart, W.D, 1982. Long-term fault creep observations in central California. Journal of Geophysical Research, v. 87, pg. 6, 977-6,982.

Soule, Frank, Jr., Map of Strawberry Valley and Vicinity, showing the natural sources of the Water Supply of the University of California, with proposed System of Reservoirs, distributing Pipes etc.: Scale 1:3,600, Lithography by Britton Rey & Co., San Francisco, 1875.

University of California, Berkeley, 1948. Access road to Wilson Tract - location map - Berkeley campus, sheet 1 of 8, Drawing Number 4221, scale 1:1200.

USEPA, 1986. RCRA Facility Assessment Guidance. United States Environmental Protection Agency, Office of Solid Waste Management.

USEPA, 1989. Statistical Analysis of Ground-Water Monitoring data at RCRA Facilities, Interim Final Guidance, PB89-151047, Office of Solid Waste, February, 1989.

USEPA, 1999. Preliminary Remediation Goals (PRGs), United States Environmental Protection Agency, Region IX,.

USEPA, 1998. Disposal of Polychlorinated Biphenyls (PCBs), Final Rule. Federal register: June 29, 1998, Vol.63. No. 124, pages 35383 to 35474..

Williams, P.L., and Hosokawa, A.M., 1992. Geomorphic features related to the Hayward fault at the University of California, Berkeley. In Taylor, C.L., ed., Field Trip Guidebook: Second Conference on Earthquake Hazards in the Eastern San Francisco Bay Area, March 25-29, 1992, California State University, Hayward, California.