Attachment A

To Notice of Lodging

Consent Decree Pertaining to Defendants
Lyons and Tondas

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TONDA AND DIANE M. TONDA

UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF CALIFORNIA
FRESNO DIVISION

UNITED STATES OF AMERICA, Plaintiff, vs. STEPHEN C. LYON, et al, Defendants.	Case No. 1:07-CV-00491-LJO-MJS **CONSENT DECREE PERTAINING TO DEFENDANTS LYONS AND TONDAS**

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I. BACKGROUND

A. On March 28, 2007, the United States of America ("United States"), on behalf of the Administrator of the United States Environmental Protection Agency ("EPA"), filed a complaint in this matter pursuant to Section 107 of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. § 9607, as amended ("CERCLA")("the Complaint"), seeking reimbursement of response costs incurred or to be incurred for response actions taken at or in connection with the release or threatened release of hazardous substances at the Modesto Groundwater Superfund Site in Modesto, California ("the Site"). The Complaint also seeks penalties for alleged violations of Section 104(e) of CERCLA, 42 U.S.C. § 9604(e), by defendants Stephen C. Lyon, Suzanne S. Lyon, Russell R. Tonda and Diane M. Tonda (collectively "Settling Defendants").

B. The Complaint alleges that a dry cleaning facility operated on a portion of the Site, 941 McHenry Avenue, Modesto, California, commencing in 1948, and that hazardous substances from that facility were released into the environment. The Complaint alleges that Settling Defendants have owned the 939 and 941 McHenry Avenue property since 1974.

C. On March 31, 1989, the Site was placed on the National Priorities List, 54 Fed. Reg. 13296, 13305. On September 26, 1997, EPA issued a Record of Decision for the Site, which selected groundwater and soil vapor extraction and treatment as the interim remedy for the Site.

D. By entering into this Consent Decree Settling Defendants do not admit any liability to the United States arising out of the transactions or occurrences alleged in the Complaint.

E. The United States and Settling Defendants agree, and this Court by entering this Consent Decree finds, that this Consent Decree has been negotiated by the Settling Defendants and the United States (collectively "the Parties") in good faith, that settlement of this matter will avoid prolonged and complicated litigation between the Parties, and that this Consent Decree is fair, reasonable, and in the public interest.

THEREFORE, with the consent of the Parties to this Decree, it is ORDERED,

ADJUDGED, AND DECREED:

II. JURISDICTION

1. This Court has jurisdiction over the subject matter of this action pursuant to 28 U.S.C. §§ 1331 and 1345 and 42 U.S.C. §§ 9607 and 9613(b) and also has personal jurisdiction over Settling Defendants. Solely for the purposes of this Consent Decree and the underlying complaint, Settling Defendants waive all objections and defenses that they may have to jurisdiction of the Court or to venue in this District. Settling Defendants shall not challenge the terms of this Consent Decree or this Court's jurisdiction to enter and enforce this Consent Decree.

III. PARTIES BOUND

2. This Consent Decree is binding upon, and shall inure to the benefit of, the United States, and upon Settling Defendants and their heirs, successors, and assigns. Any change in ownership or corporate or other legal status, including but not limited to, any transfer of assets or real or personal property, shall in no way alter the status or responsibilities of Settling Defendants under this Consent Decree.

IV. DEFINITIONS

3. Unless otherwise expressly provided herein, terms used in this Consent Decree that are defined in CERCLA or in regulations promulgated under CERCLA shall have the meanings assigned to them in CERCLA or in such regulations. Whenever terms listed below are used in this Consent Decree or in any appendix attached hereto, the following definitions shall apply:

a. “Affiliates” shall mean those individuals listed in Appendix A, but only to the extent that the potential liability of such individuals derives from their relationship to or affiliation with a Settling Defendant and not from an independent basis of liability under CERCLA Section 107(a), 42 U.S.C. § 9607(a) at the time of the entry of this Consent Decree.

b. “CERCLA” shall mean the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, 42 U.S.C. § 9601, et seq.

c. “Consent Decree” shall mean this Consent Decree and all appendices attached hereto. In the event of conflict between this Consent Decree and any appendix, the Consent Decree shall control.

d. "Day" shall mean a calendar day. In computing any period of time under this Consent Decree, where the last day would fall on a Saturday, Sunday, or federal holiday, the period shall run until the close of business of the next working day.

e. "DOJ" shall mean the United States Department of Justice and any successor departments, agencies, or instrumentalities of the United States.

f. "Effective Date" shall mean the date upon which this Decree is entered by the Court or a motion to enter the Consent Decree is granted, whichever occurs first, as recorded on the Court's docket.

g. "EPA" shall mean the United States Environmental Protection Agency and any successor departments, agencies, or instrumentalities of the United States.

h. "EPA Hazardous Substance Superfund" shall mean the Hazardous Substance Superfund established by the Internal Revenue Code, 26 U.S.C. § 9507.

i. "Interest" shall mean interest at the rate specified for interest on investments of the EPA Hazardous Substance Superfund established by 26 U.S.C. § 9507, compounded annually on October 1 of each year, in accordance with 42 U.S.C. § 9607(a). The applicable rate of interest shall be the rate in effect at the time the interest accrues. The rate of interest is subject to change on October 1 of each year.

j. "Paragraph" shall mean a portion of this Consent Decree identified by an Arabic numeral or an upper or lower case letter.

k. "Parties" shall mean the United States and Settling Defendants.

l. "Plaintiff" shall mean the United States.

m. "Property" shall mean that portion of the Site owned by Settling Defendants as of the Effective Date of this Consent Decree. The Property is located at 939 and 941 McHenry Avenue, City of Modesto, Stanislaus County, California, more particularly described in Appendix B.

n. "RCRA" shall mean the Solid Waste Disposal Act, 42 U.S.C. §

6901, *et seq*. (also known as the Resource Conservation and Recovery Act).

o. “Section” shall mean a portion of this Consent Decree identified by a Roman numeral.

p. “Settling Defendants” shall mean Stephen C. Lyon, Suzanne S. Lyon, Russell R. Tonda, and Diane M. Tonda.

q. “Site” shall mean the Modesto Groundwater Superfund site, consisting of the hazardous substance release located at 941 McHenry Avenue, located in the City of Modesto, Stanislaus County, California and other areas where those hazardous substances have come to be located.

r. “United States” shall mean the United States of America, including all of its departments, agencies, and instrumentalities, which includes without limitation EPA and DOJ.

V. PAYMENT OF RESPONSE COSTS

4. Payment of Response Costs to EPA. Within ninety (90) days of entry of this Consent Decree, Settling Defendants shall collectively pay to EPA one million, five hundred twenty-five thousand dollars ($1,525,000).

5. Payment shall be made by FedWire Electronic Funds Transfer (“EFT”) to the U.S. Department of Justice account in accordance with EFT instructions provided to Settling Defendants by the Financial Litigation Unit of the U.S. Attorney’s Office in the Eastern District of California following lodging of this Consent Decree.

6. At the time of payment, Settling Defendants shall also send notice that payment has been made to EPA and DOJ in accordance with Section XIII (Notices and Submissions). Such notice shall reference the EPA Region and Site/Spill Identification Number 09J4, DOJ Case Number 90-11-3-08737, and the Civil Action Number 1:07-CV-00491-LJO-MJS.

7. The total amount to be paid pursuant to Paragraph 4 shall be deposited in the Modesto Groundwater Superfund Site Special Account within the EPA Hazardous Substance Superfund to be retained and used to conduct or finance response actions at or in connection with

the Site, or to be transferred by EPA to the EPA Hazardous Substance Superfund.

VI. ACCESS AND INSTITUTIONAL CONTROLS

8. Settling Defendants and Affiliates shall, provided that they own the Property:

a. Commencing on the date of lodging of this Consent Decree, provide the United States and its representatives, including EPA and its contractors, with access to the Property at all reasonable times for the purpose of conducting any response activity related to the Site, including, but not limited to, the following activities:

(1) Monitoring, investigation, removal, remedial, or other activities at the Site;

(2) Verifying any data or information submitted to the United States;

(3) Conducting investigations relating to contamination at or near the Site;

(4) Obtaining samples;

(5) Assessing the need for, planning, or implementing additional response actions at or near the Site;

(6) Assessing Settling Defendants' compliance with this Consent Decree; and

(7) Determining whether the Property is being used in a manner that is prohibited or restricted, or that may need to be prohibited or restricted, by or pursuant to this Consent Decree;

b. Commencing on the date of lodging of this Consent Decree, refrain from using the Property in any manner that would interfere with or adversely affect the implementation, integrity, or protectiveness of the investigation and remedial and other response measures to be performed at the Site; and

c. Execute and record in the Recorder's Office or Registry of Deeds or other appropriate land records office of Stanislaus County, State of California, a Land Use

Covenant ("LUC") in the form attached hereto as Appendix C, within twenty (20) business days of receipt by the Settling Defendants and their counsel of written approval by both EPA and California Department of Toxic Substances Control ("DTSC") of the LUC, running with the land, that (i) grants a right of access to the Property for the purpose of conducting response activities at the Site, and (ii) grants the right to enforce the land/water use restrictions listed in Paragraph 8(a) of this Consent Decree, or other restrictions that EPA determines are necessary to implement, ensure non-interference with, or ensure the protectiveness of the removal or remedial measures to be performed at the Site. Settling Defendants and Affiliates shall grant the access rights and the rights to enforce the land/water use restrictions to one or more of the following persons as determined by EPA (i) the United States, on behalf of EPA, and its representatives, (ii) the State and its representatives, (iii) and/or other appropriate grantees. Settling Defendants and Affiliates shall, within forty-five (45) days of entry of this Consent Decree, submit to EPA and DTSC for review and approval with respect to such property:

(1) A draft Land Use Covenant, in substantially the form attached hereto as Appendix C, that is enforceable under the laws of the State of California, free and clear of all prior liens and encumbrances (except as approved by EPA), and acceptable under the Attorney General's Title Regulations promulgated pursuant to 40 U.S.C. § 255; and

(2) Current title commitment or report prepared in accordance with the U.S. Department of Justice Title Standards 2001 – A guide for the preparation of title evidence in land acquisitions by the United States of America (the "Standards").

9. Within fifteen (15) days of EPA's and DTSC's approval and acceptance of the Land Use Covenant, Settling Defendants shall update the title search and, if it is determined that nothing has occurred since the effective date of the commitment or report to affect the title adversely, record the Land Use Covenant with the Recorder's Office or Registry of Deeds or other appropriate office of Stanislaus County. Within thirty (30) days of recording the Land Use Covenant, Settling Defendants shall provide EPA and DTSC with final title evidence acceptable under the Standards and a certified copy of the original recorded Land Use Covenant showing the clerk's recording stamps.

10. If EPA determines that land/water use restrictions in the form of state or local laws, regulations, ordinances, or other governmental controls are needed to implement response activities at the Site, ensure the integrity and protectiveness thereof, or ensure non-interference therewith, Settling Defendants shall cooperate with EPA's efforts to secure such governmental controls.

11. Notwithstanding any provision of this Consent Decree, the United States retains all of its access authorities and rights, as well as all of its rights to require land/water use restrictions, including enforcement authorities related thereto, under CERCLA, RCRA, and any other applicable statute or regulation.

VII. FAILURE TO COMPLY WITH CONSENT DECREE

12. Interest on Late Payments. If Settling Defendants fail to make any payment under Paragraph 4 (Payment of Response Costs) by the required due date, Interest shall continue to accrue on the unpaid balance through the date of payment.

13. Stipulated Penalties.

a. If any amounts due under Paragraph 4 are not paid by the required date or Settling Defendants fail to comply with the Consent Decree, Settling Defendants shall be in violation of this Consent Decree and shall pay to EPA, as a stipulated penalty, in addition to the Interest required by this Consent Decree, $500 per violation per day that such payment is late.

b. Stipulated penalties are due and payable within thirty (30) days of the date of the demand for payment of the penalties by EPA. All payments to EPA under this Paragraph shall be identified as "stipulated penalties" and shall be made by certified or cashier's check made payable to "EPA Hazardous Substance Superfund." The check, or a letter accompanying the check, shall reference the name and address of the party(ies) making payment, the Site name, the EPA Region and Site Spill ID Number 09J4, DOJ Case Number 90-11-3-08737, and the Civil Action Number 1:07-CV-00491-LJO-GSA. Settling Defendants shall send the check (and any accompanying letter) to:

U.S. Environmental Protection Agency
Superfund Payments
Cincinnati Finance Center
PO Box 979076

St. Louis, MO 63197-9000

c. At the time of each payment, Settling Defendants shall also send notice that payment has been made to EPA and DOJ in accordance with Section XIII (Notices and Submissions). Such notice shall reference the EPA Region and Site/Spill ID Number 09J4, DOJ Case Number 90-11-3-08737, and the Civil Action Number 1:07-CV-00491-LJO-MJS.

d. Penalties shall accrue as provided in this Paragraph regardless of whether EPA has notified Settling Defendants of the violation or made a demand for payment, but need only be paid upon demand. All penalties shall begin to accrue on the day after payment is due or the day a violation occurs, and shall continue to accrue through the date of payment or the final day of correction of the noncompliance or completion of the activity. Nothing herein shall prevent the simultaneous accrual of separate penalties for separate violations of this Consent Decree.

14. If the United States brings an action to enforce this Consent Decree and substantially prevails, Settling Defendants shall reimburse the United States for all costs of such action, including but not limited to costs of attorney time.

15. Payments made under this Section shall be in addition to any other remedies or sanctions available to Plaintiff by virtue of Settling Defendants' failure to comply with the requirements of this Consent Decree.

16. The obligations of Settling Defendants to pay amounts owed the United States under this Consent Decree are joint and several. In the event of the failure of any one or more Settling Defendants to make the payments required under this Consent Decree, the remaining Settling Defendants shall be responsible for such payments.

17. Notwithstanding any other provision of this Section, the United States may, in its unreviewable discretion, waive payment of any portion of the stipulated penalties that have accrued pursuant to this Consent Decree. Payment of stipulated penalties shall not excuse Settling Defendants from payment as required by Section V or from performance of any other requirements of this Consent Decree.

VIII. COVENANT NOT TO SUE BY UNITED STATES

18. Covenant Not to Sue by United States. Except as specifically provided in Section IX (Reservation of Rights by United States), the United States covenants not to sue or to take administrative action against Settling Defendants and their Affiliates: (a) pursuant to Sections 106 and 107(a) of CERCLA, 42 U.S.C. §§ 9606 and 9607(a), and Section 7003 of RCRA, 42 U.S.C. § 6973, with regard to the Site; and (b) for penalties for violations of Section 104 of CERCLA, 42 U.S.C. § 9604, arising prior to the Effective Date. This covenant not to sue shall take effect upon receipt by EPA of all payments required by Section V, Paragraph 4 (Payment of Response Costs) and any amount due under Section VII (Failure to Comply with Consent Decree). This covenant not to sue is conditioned upon the satisfactory performance by Settling Defendants of their obligations under this Consent Decree. This covenant not to sue extends only to Settling Defendants and their Affiliates and does not extend to any other person.

IX. RESERVATIONS OF RIGHTS BY UNITED STATES

19. The United States reserves, and this Consent Decree is without prejudice to, all rights against Settling Defendants and Affiliates with respect to all matters not expressly included within the Covenant Not to Sue by United States in Paragraph 18. Notwithstanding any other provision of this Consent Decree, the United States reserves all rights against Settling Defendants and Affiliates with respect to:

a. liability for failure of Settling Defendants to meet a requirement of this Consent Decree;

b. criminal liability;

c. liability for damages for injury to, destruction of, or loss of natural resources, and for the costs of any natural resource damage assessments;

d. liability arising from, disposal, release or threat of release of a hazardous substance, pollutant, or contaminant at the Site after signature of this Consent Decree by Settling Defendants; and

e. liability arising from the past, present, or future disposal, release or threat of release of a hazardous substance, pollutant, or contaminant outside of the Site.

X. COVENANT NOT TO SUE BY SETTLING DEFENDANTS

20. Settling Defendants covenant not to sue and agree not to assert any claims or causes of action against the United States, or its contractors or employees, with respect to Response Costs or this Consent Decree, including but not limited to:

a. any direct or indirect claim for reimbursement from the Hazardous Substance Superfund based on Sections 106(b)(2), 107, 111, 112, or 113 of CERCLA, 42 U.S.C. §§ 9606(b)(2), 9607, 9611, 9612, or 9613, or any other provision of law;

b. any claim arising out of the response actions at the Site, including any claim under the United States Constitution, the Constitution of the State of California, the Tucker Act, 28 U.S.C. § 1491, the Equal Access to Justice Act, 28 U.S.C. § 2412, as amended, or at common law; or

c. any claim against the United States pursuant to Sections 107 and 113 of CERCLA, 42 U.S.C. §§ 9607 and 9613.

21. Nothing in this Consent Decree shall be deemed to constitute approval or preauthorization of a claim within the meaning of Section 111 of CERCLA, 42 U.S.C. § 9611, or 40 C.F.R. 300.700(d).

XI. EFFECT OF SETTLEMENT/CONTRIBUTION PROTECTION

22. Nothing in this Consent Decree shall be construed to create any rights in, or grant any cause of action to, any person not a Party to this Consent Decree.

23. Contribution Protection. The Parties agree, and by entering this Consent Decree this Court finds, that Settling Defendants and Affiliates are entitled, as of the date of entry of this Consent Decree, to protection from contribution actions or claims as provided by Section 113(f)(2) of CERCLA, 42 U.S.C. § 9613(f)(2), for “matters addressed” in this Consent Decree. The “matters addressed” in this Consent Decree are all response actions taken or to be taken and all response costs incurred or to be incurred, at or in connection with the Site, by the United States or any other person, except the State of California. The “matters addressed” in this Consent Decree do not include those response costs or response actions as to which the United States has reserved its rights under this Consent Decree (except for claims for failure to comply

with this Consent Decree), in the event that the United States asserts rights against the Settling Defendants or Affiliates coming within the scope of such reservations.

24. Each Settling Defendant agrees that, with respect to any suit or claim for contribution brought by it for matters related to this Consent Decree, it will notify EPA and DOJ in writing no later than sixty (60) days prior to the initiation of such suit or claim. Each Settling Defendant also agrees that, with respect to any suit or claim for contribution brought against it for matters related to this Consent Decree, it will notify EPA and DOJ in writing within ten (10) days of service of the complaint or claim upon it. In addition, each Settling Defendant shall notify EPA and DOJ within ten (10) days of service or receipt of any Motion for Summary Judgment, and within ten (10) days of receipt of any order from a court setting a case for trial, for matters related to this Consent Decree.

25. In any subsequent administrative or judicial proceeding initiated by the United States for injunctive relief, recovery of response costs, or other relief relating to the Site, Settling Defendants shall not assert, and may not maintain, any defense or claim based upon the principles of waiver, res judicata, collateral estoppel, issue preclusion, claim-splitting, or other defenses based upon any contention that the claims raised by the United States in the subsequent proceeding were or should have been brought in the instant case; provided, however, that nothing in this Paragraph affects the enforceability of the Covenant Not to Sue by the United States set forth in Section X.

XII. <u>RETENTION OF RECORDS</u>

26. Until three (3) years after the entry of this Consent Decree, each Settling Defendant shall preserve and retain all records now in its possession or control, or which come into its possession or control, that relate in any manner to response actions taken at the Site or the liability of any person under CERCLA with respect to the Site, regardless of any corporate retention policy to the contrary.

27. After the conclusion of the three (3)-year document retention period in the preceding Paragraph, Settling Defendants shall notify EPA and DOJ at least ninety (90) days prior to the destruction of any such records, and, upon request by EPA or DOJ, Settling

Defendants shall deliver any such records to EPA. Settling Defendants may assert that certain records are privileged under the attorney-client privilege or any other privilege recognized by federal law. If Settling Defendants assert such a privilege, they shall provide Plaintiff with the following: 1) the title of the record; 2) the date of the record; 3) the name, title, affiliation (e.g., company or firm), and address of the author of the record; 4) the name and title of each addressee and recipient; 5) a description of the subject of the record; and 6) the privilege asserted. If a claim of privilege applies only to a portion of a record, the record shall be provided to Plaintiff in redacted form to mask the privileged information only. Settling Defendants shall retain all records that they claim to be privileged until the United States has had a reasonable opportunity to dispute the privilege claim and any such dispute has been resolved in the Settling Defendants' favor. However, no records created or generated pursuant to the requirements of this or any other settlement with the EPA pertaining to the Site shall be withheld on the grounds that they are privileged.

28. Each Settling Defendant hereby certifies individually that, to the best of its knowledge and belief, after thorough inquiry, it has not altered, mutilated, discarded, destroyed or otherwise disposed of any records, reports, or information relating to its potential liability regarding the Site since notification of potential liability by the United States, or the State, or the filing of suit against it regarding the Site and that it has fully complied with any and all EPA requests for information pursuant to Sections 104(e) and 122(e) of CERCLA, 42 U.S.C. §§ 9604(e) and 9622(e), and Section 3007 of RCRA, 42 U.S.C. § 6972.

XIII. NOTICES AND SUBMISSIONS

29. Whenever, under the terms of this Consent Decree, notice is required to be given or a document is required to be sent by one party to another, it shall be directed to the individuals at the addresses specified below, unless those individuals or their successors give notice of a change to the other Defendants in writing. Written notice as specified herein shall constitute complete satisfaction of any written notice requirement of the Consent Decree with respect to the United States, EPA, DOJ, and Settling Defendants, respectively.

<u>As to the United States</u>:

As to DOJ:

Chief, Environmental Enforcement Section
Environment and Natural Resources Division
U.S. Department of Justice (DJ # 90-11-3-08737)
P.O. Box 7611
Washington, DC 20044-7611

As to EPA:

Laurie Williams (ORC-3)
Assistant Regional Counsel
U.S. Environmental Protection Agency Region IX
75 Hawthorne Street
San Francisco, CA 94105

Marie Lacey (SFD-7-2)
Remedial Project Manager
U.S. Environmental Protection Agency Region IX
75 Hawthorne Street
San Francisco, CA 94105

David Wood (MTS-4-2)
Superfund Accounting
U.S. Environmental Protection Agency Region IX
75 Hawthorne Street
San Francisco, CA 94105

As to Settling Defendants:

Stephen and Suzanne Lyon
424 Liberty Street
San Francisco, CA 94114-2949

Russell and Diane Tonda
9760 Rimrock Circle
Loomis, CA 95650-7117

XIV. RETENTION OF JURISDICTION

30. This Court shall retain jurisdiction over this matter for the purpose of interpreting and enforcing the terms of this Consent Decree.

XV. INTEGRATION

31. This Consent Decree constitutes the final, complete, and exclusive agreement and understanding among the Settling Defendants with respect to the settlement embodied in this Consent Decree. The Parties acknowledge that there are no representations, agreements, or understandings relating to the settlement other than those expressly contained in

this Consent Decree.

XVI. LODGING AND OPPORTUNITY FOR PUBLIC COMMENT

32. This Consent Decree shall be lodged with the Court for a period of not less than thirty (30) days for public notice and comment. The United States reserves the right to withdraw or withhold its consent if the comments regarding the Consent Decree disclose facts or considerations which indicate that this Consent Decree is inappropriate, improper, or inadequate. Settling Defendants consent to the entry of this Consent Decree without further notice.

33. If for any reason this Court should decline to approve this Consent Decree in the form presented, this agreement is voidable at the sole discretion of any party and the terms of the agreement may not be used as evidence in any litigation between the Parties.

XVII. SIGNATORIES/SERVICE

34. Each undersigned representative of a Settling Defendant to this Consent Decree and the Assistant Attorney General for the Environment and Natural Resources Division of the United States Department of Justice certifies that he or she is authorized to enter into the terms and conditions of this Consent Decree and to execute and bind legally such Party to this document.

35. Each Settling Defendant hereby agrees not to oppose entry of this Consent Decree by this Court or to challenge any provision of this Consent Decree, unless the United States has notified Settling Defendants in writing that it no longer supports entry of the Consent Decree.

36. Each Settling Defendant shall identify, on the attached signature page, the name and address of an agent who is authorized to accept service of process by mail on behalf of that Party with respect to all matters arising under or relating to this Consent Decree. Settling Defendants hereby agree to accept service in that manner and to waive the formal service requirements set forth in Rule 4 of the Federal Rules of Civil Procedure and any applicable local rules of this Court, including but not limited to, service of a summons.

XVIII. FINAL JUDGMENT

37. Upon approval and entry of this Consent Decree by the Court, this Consent

Decree shall constitute the final judgment between and among the United States and the Settling Defendants. The Court finds that there is no just reason for delay and therefore enters this judgment as a final judgment under Fed. R. Civ. P. 54 and 58.

SO ORDERED THIS __ DAY OF _______, 2010.

____
United States District Judge

THE UNDERSIGNED PARTIES enter into this Consent Decree in the matter of *United States v. Lyon, et al.*, 07-CV-00491-LJO-MJS, relating to the Modesto Groundwater Superfund Site.

FOR THE UNITED STATES OF AMERICA

Dated: 1/21/11

IGNACIA S. MORENO
Assistant Attorney General
Environmental and Natural Resources Division
U.S. Department of Justice
Washington, DC 20530

Dated: 1/27/11

ELISE FELDMAN
MATTHEW D. THURLOW
Attorneys
Environmental Enforcement Section
Environmental and Natural Resources Division
U.S. Department of Justice
301 Howard Street, Suite 1050
San Francisco, CA 94105

THE UNDERSIGNED PARTIES enter into this Consent Decree in the matter of *United States v. Lyon, et al.*, 07-CV-00491-LJO-MJS, relating to the Modesto Groundwater Superfund Site.

FOR THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Dated: 1/27/2011

JANE DIAMOND
Director, Superfund Division
U.S. Environmental Protection Agency
Region IX
75 Hawthorne Street
San Francisco, CA 94105

Dated: 1/25/11

LAURIE WILLIAMS
Assistant Regional Counsel
U.S. Environmental Protection Agency
Region IX
75 Hawthorne Street
San Francisco, CA 94105

THE UNDERSIGNED PARTIES enter into this Consent Decree in the matter of *United States v. Lyon, et al.*, 07-CV-00491-LJO-MJS, relating to the Modesto Groundwater Superfund Site.

FOR DEFENDANT STEPHEN C. LYON
AND SUZANNE S. LYON

Dated: 12/10/10

Stephen and Suzanne Lyon
424 Liberty Street
San Francisco, CA 94114-2949

Agent Authorized to Accept Service on Behalf of Above-Signed Party:

Name: ____________________

Title: ____________________

Address: ____________________

THE UNDERSIGNED PARTIES enter into this Consent Decree in the matter of *United States v. Lyon, et al.*, 07-CV-00491-LJO-MJS, relating to the Modesto Groundwater Superfund Site.

FOR DEFENDANT RUSSELL R. TONDA AND
DIANE M. TONDA

Dated: 12/23/2010

Russell and Diane Tonda
9760 Rimrock Circle
Loomis, CA 95650-7117

Agent Authorized to Accept Service on Behalf of Above-Signed Party:

Name: ______________________

Title: ______________________

Address: ______________________

Appendix A
(List of Affiliates)

to

Consent Decree Pertaining to Defendants
Lyons and Tondas

APPENDIX A

Collette Fearneyhough

Dave Fearneyhough

Luc Fearneyhough

Sophie Fearneyhough.

Avery Lyon

Adam W. Lyon

Chad H. Lyon

Cody Lyon

Grant Lyon

Kaisa Lyon

Quincy Lyon

Shelly Lyon

Drew Tonda

Kellie Tonda

Regan Tonda

Scott Tonda

Taylor Tonda

Appendix B
(Property Description)

to

Consent Decree Pertaining to Defendants Lyons and Tondas

RECORDING REQUESTED BY

SAFECO TITLE INSURANCE CO.
Escrow No. 206-323-C

AND WHEN RECORDED MAIL TO

NAME Russell Tonda, et al
ADDRESS 28 Chilton Avenue
CITY & STATE San Carlos, CA 94270

SAFECO TITLE
OFF'L RECORDS STANISLAUS CO. CALIF.
STEVE R. NELSON, RECORDER
BY
ASST. RECORDER

BOOK 2647 PAGE 631

3⁰⁰

TAX PAID 55

SPACE ABOVE THIS LINE FOR RECORDER'S USE

MAIL TAX STATEMENTS TO

NAME Same as above
ADDRESS
CITY & STATE

Documentary transfer tax $ 55.00
☒ Computed on full value of property conveyed, or
☐ Computed on full value less liens & encumbrances remaining thereon at time of sale.

Shirley Cruse **SAFECO TITLE INS. CO.**
Signature of declarant or agent determining tax - firm name

☐ Unincorporated area ☒ City of Modesto

FAX PAID
6347 AUG 14 74

6347 AUG 14 74

SAFECO

Grant Deed

L-1

FOR A VALUABLE CONSIDERATION, receipt of which is hereby acknowledged,

DAWNINE D. HALFORD, a widow,

hereby GRANT(S) to RUSSELL TONDA and DIANE M. TONDA, husband and wife, as Joint Tenants, as to an undivided one-half interest; and STEVEN LYON and SUE LYON, husband and wife, as Joint Tenants, as to an undivided one-half interest,

the following described real property in the City of Modesto, county of Stanislaus, state of California:

Lot 2 of the FALK TRACT, as per Map filed July 5, 1939, in Vol. 11 of Maps, page 62, Stanislaus County Records. EXCEPTING THEREFROM the East 18 feet thereof.

Dated July 17, 1974

Dawnine D. Halford

STATE OF CALIFORNIA
COUNTY OF STANISLAUS } SS.

On July 17, 1974 before me, the undersigned, a Notary Public in and for said County and State, personally appeared DAWNINE D. HALFORD, known to me to be the person whose name is subscribed to the within instrument and acknowledged that she executed the same.

Signature of Notary

FOR NOTARY SEAL OR STAMP

OFFICIAL SEAL
DOUGLAS M. SUTTER
NOTARY PUBLIC - CALIFORNIA
COUNTY OF STANISLAUS
My Comm. Expires Dec. 30, 1977

Title Order No. Escrow No. 206-323-C

L-1 (G.S.) (Rev. 5-67) 8 pt.

MAIL TAX STATEMENTS AS DIRECTED ABOVE

undersigned, owners of the land shown on this map, do hereby consent to the
and filing of same and we hereby dedicate to public use the streets and
as shown on this map

f California
of Stanislaus ss
day of June 1939, before me, J. H. King a Notary Public in and
County of Stanislaus, State of California, personally appeared
, known to me to be the persons whose names are subscribed
within instrument, and they acknowledged to me that they executed the same.

J. H. King
Notary Public, Stanislaus County, Calif.

to certify that there are no liens for any unpaid state, county, municipal, irrig-
taxes, or special assessments except taxes or special assessments not yet
s, against the land shown on this map

County, School, or State Taxes Dated 1939
County Auditor

rrigation District Taxes Dated June 22 1939
Tax Collector

to certify that this map is approved in accordance with the requirements of the
Subdivision Act of 1937 and Stanislaus County Ordinance Number 148, and
such matters, it is correct
5-8, 1939
County Surveyor

undersigned, County Surveyor and County Assessor of the County of Stanislaus,
eby certify that we have examined each and every lot shown on this map, and
d same suitable for residential purposes, and we make no further recomendations.
5-31 1939 Dated May 9, 1939
nty Surveyor County Assessor

y that the land shown on the attached map is not subject to any special assess-
that have been paid off in full, other than special assessments collected as taxes,
s certificate does not include any assessment district, the bonds of which have
t become a lien.
5-8, 1939
County Surveyor

o certify that the land shown on this map, in the County of Stanislaus, State of California,
knowledged and certified, as required by law, having been presented to the Board of
sors of said County, which Board is the governing body having control of roads, avenues,
ys, alleys, lanes, ways, places, in the territory shown on this map, and it is ordered
roads, avenues, highways, alleys, lanes, ways, places, be rejected, except those heretofore
d to be public highways. Otherwise, this map is approved
June 26th 1939
Chairman Board of Supervisors
Attest
By Deputy

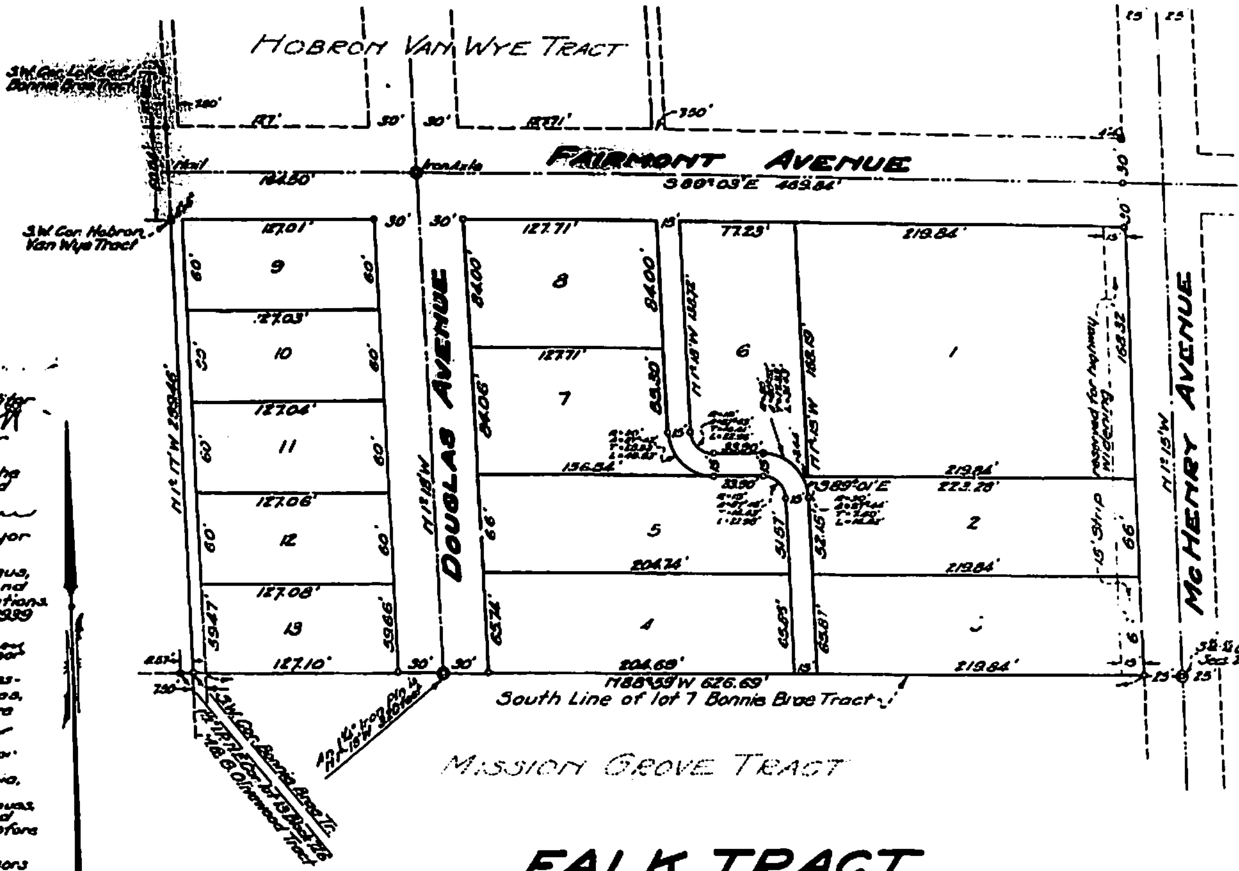
o certify that the owners of the land shown on this map, have filed a bond with
rd of Supervisors for the faithful payment of all taxes, which are, at the time
of this map, a lien against such tract, or any part thereof.
June 26th 1939
By Deputy

d by the Stanislaus County Planning Commission in accordance with the requirements
n duly authorized meeting held 5-8, 1939
Chairman

by the City of Modesto Planning Commission in accordance with the requirements
in duly authorized meeting held June 6, 1939.
Chairman

d in accordance with the requirements of law on May 8 1939.
City Engineer

ndy, a duly licensed land surveyor for the State of California, do hereby certify that I
rveyed the land shown on this map, and that said map shows correctly the physical
ons portrayed.



FALK TRACT

BEING A RESUBDIVISION OF LOTS 6-7 & A PORTION OF LOT 5 BONNIE BRAE TRACT IN S.E. 1/4 OF SECTION 20 T.3S. R.9E. M.D.B.&M.

SCALE 1"=60' MAY 1939

Basis of Bearings: Line common to Sections 20 & 21. See Map of Bonnie Brae Tract, Vol. 9 of Maps, Page 1.

All lot corners marked with Iron Pipe

Note: Structures facing McHenry Avenue must be set back a minimum of 60 feet from ℄ of street.

7734

Accepted for record and recorded in Vol. 11 of Maps at Page 62 in the Office of the County Recorder of Stanislaus County, California, this 5th day of July 1939 at 3:00 P.M.
R. G. Waring
Recorder of the County of Stanislaus
Fee $5.00 Paid

RECORDING REQUESTED BY
SAFECO TITLE INSURANCE COMPANY

AND WHEN RECORDED MAIL TO

NAME Mrs. Dawnine D. Halford
ADDRESS C/o Douglas M. Sutter
1939 G Street
CITY & STATE ZIP Modesto, California 95354

Title Order No.________ Escrow No. 206-323-C

RECORDED AT REQUEST OF
SAFECO TITLE INSURANCE CO.
OFF'L RECORDS STANISLAUS CO. CALIF.
STEVE R. NELSON, RECORDER
BY
ASST. RECORDER

BOOK 2647 PAGE 632

300

6348 AUG 14 74

SPACE ABOVE THIS LINE FOR RECORDER'S USE

DEED OF TRUST AND ASSIGNMENT OF RENTS

BY THIS DEED OF TRUST, made this 17th day of July, 19 74, between RUSSELL TONDA and DIANE M. TONDA, husband and wife, and STEVEN LYON and SUE LYON, husband and wife, herein called Trustor, whose address is

28 Chilton Avenue, San Carlos, CA 94270
(number and street) (city) (state zip)

and SAFECO TITLE INSURANCE COMPANY, a California corporation, herein called Trustee, and DAWNINE D. HALFORD, a widow, herein called Beneficiary, Trustor grants, transfers, and assigns to trustee, in trust, with power of sale, that property in Stanislaus County, California, described as:

Lot 2 of the FALK TRACT, as per Map filed July 5, 1939, in Vol. 11 of Maps, page 62, Stanislaus County Records. EXCEPTING THEREFROM the East 18 feet thereof.

re

6348 AUG 14 74

SAFECO

Trustor also assigns to Beneficiary all rents, issues and profits of said realty reserving the right to collect and use the same except during continuance of default hereunder and during continuance of such default authorizing Beneficiary to collect and enforce the same by any lawful means in the name of any party hereto.

For the purpose of securing:
(1) Payment of the indebtedness by one promissory note in the principal sum of $ 40,000.00 of even date herewith, payable to Beneficiary, and any extensions or renewals thereof; (2) the payment of any money that may be advanced by the Beneficiary to Trustor, or his successors, with interest thereon, evidenced by additional notes (indicating they are so secured) or by endorsement on the original note, executed by Trustor or his successor; (3) performance of each agreement of Trustor incorporated by reference or contained herein.

On October 25, 1973, identical fictitious Deeds of Trust were recorded in the offices of the County Recorders of the Counties of the State of California, the first page thereof appearing in the book and at the page of the records of the respective County Recorder as follows:

COUNTY	Book	Page	COUNTY	Book	Page	COUNTY	Book	Page	COUNTY	Book	Page
Alameda	3540	69	Kings	1018	394	Placer	1528	440	Siskiyou	697	407
Alpine	18	753	Lake	743	552	Plumas	227	443	Solano	1860	581
Amador	250	243	Lassen	271	367	Riverside	1973	139405	Sonoma	2810	975
Butte	1870	678	Los Angeles	T8512	751	Sacramento	731025	59	Stanislaus	2587	332
Calaveras	368	92	Madera	1176	234	San Benito	386	94	Sutter	817	182
Colusa	409	347	Marin	2736	463	San Bernardino	8294	877	Tehama	630	522
Contra Costa	7077	178	Mariposa	143	717	San Francisco	B820	585	Trinity	161	393
Del Norte	174	526	Mendocino	942	242	San Joaquin	3813	6	Tulare	3137	567
El Dorado	1229	594	Merced	1940	361	San Luis Obispo	1750	491	Tuolumne	396	309
Fresno	6227	411	Modoc	225	668	San Mateo	6491	600	Ventura	4182	662
Glenn	565	290	Mono	160	215	Santa Barbara	2486	1244	Yolo	1081	335
Humboldt	1213	31	Monterey	877	243	Santa Clara	0623	713	Yuba	564	163
Imperial	1355	801	Napa	922	96	Santa Cruz	2358	744			File No.
Inyo	205	660	Nevada	665	303	Shasta	1195	293	San Diego		73-299568
Kern	4809	2351	Orange	10961	398	Sierra	59	439			

The provisions contained in Section A, including paragraphs 1 through 5, and the provisions contained in Section B, including paragraphs 1 through 9 of said fictitious Deeds of Trust are incorporated herein as fully as though set forth at length and in full herein.

The undersigned Trustor requests that a copy of any notice of default and any notice of sale hereunder be mailed to Trustor at the address hereinabove set forth, being the address designated for the purpose of receiving such notice.

STATE OF CALIFORNIA,
COUNTY OF San Francisco } SS

On July 29 1974, before me, the undersigned, a Notary Public in and for said County and State, personally appeared Russell Tonda, Diane M. Tonda and Sue Lyon and Steven Lyon known to me to be the person(s) whose name(s) is (are) subscribed to the within instrument and acknowledged that executed the same.

Hildegard K. Pratt

Russell Tonda

Diane M. Tonda

Steven Lyon

Sue Lyon

FOR NOTARY SEAL OR STAMP

HILDEGARD K. PRATT
NOTARY PUBLIC - CALIFORNIA
CITY & COUNTY OF SAN FRANCISCO
My Commission Expires March 9, 1978

RECORDED AT 9 BY
city of Modesto

OFFICIAL RECORDS
STANISLAUS CO., CALIF.

DAVID A. WURM,
RECORDER

Record and return to
City Clerk, City Hall
Modesto, California

00799 JUL 683

NO FEE

NOTICE OF LIEN

Pursuant to the authority vested in me by the Improvement Act of 1911, I did, on the 19th day of April, 19 76, cause the sidewalk ______ to be constructed, and the legislative body of said city did, on the 24th day of May, 1983, by Resolution No. 83-329, assess the cost of such construction upon the real property hereinafter described and the same has not been paid nor any part thereof, and the said city does hereby claim a lien on said real property in the sum of $1,005.00, and the same shall be a lien upon said real property until the said sum, with interest at the rate of seven (7%) per cent per annum, from the 24th day of June, 19 83, has been paid in full and discharged of record.

The real property hereinbefore mentioned and upon which a lien is claimed, is that certain piece or parcel of land lying and being in the City of Modesto, County of Stanislaus, State of California, and more particularly described as follows;

Lot 2 of Bl. 727 of the Falk Tract as per map filed July 5, 1939 in Vol. 11 of Maps, Pg. 62, Stan. Cty. Records.

(Stan. Cty. Assessor's Parcel No. 002-03 113-0636-400)

00799 JUL 683

SEAL IMPRESSED

Standing in the name of: Russell E. & Diane M. Tonda and Steven and Sue Lyon

DATE: June 1, 1983

Superintendent of Streets
CITY OF MODESTO

STATE OF CALIFORNIA }
COUNTY OF STANISLAUS } ss

On this 1st day of June, 19 83 before me, the undersigned, the City Clerk of the City of Modesto, a city within the said County and State, personally appeared Ed Walker, known to me to be the Superintendent of Streets of the municipal corporation described in and that executed the within instrument, and also known to me to be the person who executed the within instrument on behalf of the municipal corporation therein named, and acknowledged to me that such municipal corporation executed the same.

Norrine Coyle
City Clerk of the City of Modesto

By: ______

Ack. Corporation

City Clerk of the City of Modesto

028852 APR 21 89

RECORDED AT 1:40 BY
Attorney
OFFICIAL RECORDS
STANISLAUS CO., CALIF.
DAVID A. WURM,
RECORDER

41

RECORDING REQUESTED BY
Bernard M. King, Esq.

WHEN RECORDED RETURN TO:
Allan E. and Josephine E. Walton
196 Mill Creek Road
Fremont, CA 94539

ASSIGNMENT OF NOTE AND DEED OF TRUST

For value received, the undersigned hereby grants, assigns and transfers to ALLAN E. WALTON and JOSEPHINE E. WALTON, Co-Trustees of the WALTON FAMILY TRUST, all of her beneficial interest under that certain deed of trust dated July 17, 1974, executed by Russell Tonda, Diane M. Tonda, Steven Lyon and Sue Lyon, Trustors, to Safeco Title Insurance Company, a California, corporation, Trustee, recorded August 14, 1974, under Recorder's Series No. 6348, Book 2647, Page 632, of Official Records in the County Recorder's Office of Stanislaus County, California.

This assignment also covers the undersigned's interest in the promissory note for which said deed of trust is security.

Dated: April 5, 1989

JOSEPHINE E. WALTON

028852 APR 21 89

STATE OF CALIFORNIA)
COUNTY OF ALAMEDA) ss

On this 5th day of April, 1989, before me, the undersigned, personally appeared JOSEPHINE E. WALTON, personally known to me (or proved to me on the basis of satisfactory evidence) to be the person whose name is subscribed to this instrument, and acknowledged to me that she executed it.

NOTARY PUBLIC

BERNARD M. KING
My Comm. Exp. April 14, 1989

8

RECORDING REQUESTED BY
CHICAGO TITLE COMPANY
AND WHEN RECORDED MAIL TO

DIANE M. TONDA & RUSSELL R. TONDA
6195 WILHOFF LANE
GRANITE BAY, CA 95746

Stanislaus, Co Recorder's Office
Karen Mathews, County Recorder
DOC - 95-0050911-00
Acct 501-Chicago Title
Friday, JUN 30, 1995 08:00:00
REC $3.00 | MOD $3.00 | MIC $1.00
STF $0.00 |
Ttl Pd $7.00
Nbr-0000070440
NGG/R1/0

Escrow No. 7170 -
Order No. 000007170 -

SPACE ABOVE THIS LINE FOR RECORDER'S USE

RECONVEYANCE NO. -

FULL RECONVEYANCE

SECURITY UNION TITLE INSURANCE COMPANY, a corporation, formerly SAFECO TITLE INSURANCE COMPANY,

as Trustee, or Successor Trustee, or Substituted Trustee, under Deed of Trust dated July 17, 1974 executed by

RUSSELL TONDA AND DIANE M. TONDA, HUSBAND AND WIFE, AND
STEVEN LYON AND SUE LYON, HUSBAND AND WIFE

CHICAGO TITLE

Trustor, and recorded as Instrument/Series No. 6348 on August 14, 1974 in Book/Reel 2647 Page/Image 632, of Official Records in the office of the Recorder of STANISLAUS County, California, describing land therein as:

MORE FULLY DESCRIBED IN SAID DEED OF TRUST

having received from holder of the obligations thereunder a written request to reconvey, reciting that all sums secured by said Deed of Trust have been fully paid, and said Deed of Trust and the note or notes secured thereby having been surrendered to said Trustee for cancellation, does hereby RECONVEY, without warranty, to the person or persons legally entitled thereto, the estate now held by it thereunder.

050911 JUN 30 95

Date June 29, 1995

SECURITY UNION TITLE INSURANCE COMPANY, a corporation, formerly SAFECO TITLE INSURANCE COMPANY, Trustee

By: ____________________
MARY ANN GARNER

Authorized Signature

STATE OF CALIFORNIA
COUNTY OF STANISLAUS } S.S.

On JUNE 29, 1995 before me, EVELYN BRIDGES
a Notary Public in and for said County and State, personally appeared
MARY ANN GARNER
personally known to me (or proved to me on the basis of satisfactory evidence) to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

WITNESS my hand and official seal.

MPC2
EVELYN BRIDGES
COMM. #1057758
NOTARY PUBLIC-CALIFORNIA
STANISLAUS COUNTY
My Comm. Expires May 3, 1999
MPC2

____
NOTARY'S SIGNATURE

(THIS AREA FOR OFFICIAL NOTARIAL SEAL OR STAMP)

FRSAFE2-10/04/94bk

Appendix C
(Land Use Covenant)

to

Consent Decree Pertaining to Defendants
Lyons and Tondas

RECORDING REQUESTED BY:
Stephen C. Lyon, Suzanne S. Lyon,
Russell R. Tonda and Diane M. Tonda
939 & 941 McHenry Street
Modesto, California 95350-5416

WHEN RECORDED, MAIL TO:

ADDRESS ABOVE, and,

State of California
Department of Toxic Substances Control
8800 Cal Center Drive
Sacramento California 95826
Attention: James L. Tjosvold, Chief
Northern California – Central Cleanup
Operations Branch

SPACE ABOVE THIS LINE RESERVED FOR RECORDER'S USE

COVENANT TO RESTRICT USE OF PROPERTY
ENVIRONMENTAL RESTRICTION

(Re: Parcel Number 113-006-036**)**

DTSC Site Code 100111

This Covenant and Agreement ("Covenant") is made by and between Stephen C. Lyons, Suzanne S. Lyon, Russell R. Tonda and Diane M. Tonda ("Covenantors"), the current owners of property situated in Modesto, County of Stanislaus, State of California, described in Exhibit "A" and depicted in Exhibit "B," attached, (the "Property"), and the Department of Toxic Substances Control (the "Department"). Pursuant to Civil Code section 1471, the Department has determined that this Covenant is reasonably necessary to protect present or future human health or safety or the environment as a result of the presence on the land of hazardous materials as defined in Health and Safety Code section 25260. The Covenantors and the Department, collectively referred to as the "Parties," hereby agree, pursuant to Civil Code section 1471, and Health and Safety Code section 25355.5, that the use of the Property be restricted as set forth in this Covenant; and the Parties further agree that the Covenant shall conform with the requirements of California Code of Regulations, title 22, section 67391.1. The provisions of this Covenant shall be for the benefit of, and shall be enforceable by, the United States Environmental Protection Agency ("U.S. EPA"), as a third party beneficiary pursuant to general contract law, including, but not limited to, Civil Code Section 1559.

ARTICLE I

STATEMENT OF FACTS

1.01. The Property. The Property, totaling approximately **.**31 acres, is more particularly described and depicted in the attached Exhibits "A" and “B”. The Property is located in the area now generally bounded by McHenry Avenue to the East, and located in the city block that is bounded by West Fairmont Avenue to the North, Douglas Street to the West and Griswold Avenue to the South. The Property is also generally described as Stanislaus County Assessor's Parcel No: 113-006-036**.**

1.02. Hazardous Substances. As defined in section 25316 of the California Health and Safety Code (“H&SC”), (within Chapter 6.8, Division 20 of the H&SC), and in section 101(14) of the Comprehensive Environmental Response, Compensation and Liability Act of 1980, as amended (“CERCLA”) (42 USC §9601 (14)); and also Title 40 Code of Federal Regulations (“CFR”) parts 261.3 and 302.4, hazardous substances remain on portions of the Property. These substances are also hazardous materials as defined in Health and Safety Code section 25260(d). These contaminant(s) include tetrachloroethylene (PCE) in the soil and groundwater.

1.03. Remediation of the Property. The Property is being remediated pursuant to an Interim Record of Decision ("ROD") for the Modesto Groundwater Superfund Site (the “Site”) issued by the U.S. EPA, dated September 26, 1997. Under the ROD, as modified, the U.S. EPA Region IX Superfund Division Director selected interim remedial actions for the Property pursuant to CERCLA. The Department concurred with this remedy. Pursuant to the ROD, EPA Region 9 has implemented soil vapor extraction and treatment, and groundwater extraction and treatment. Pursuant to a five-year review, EPA Region 9 has addressed contamination of indoor air with PCE. EPA anticipates issuance of a final ROD that may select additional or different measures or goals. If necessary, an updated Covenant may need to be recorded at that time. The Risk Assessments that document the risk posed by the PCE in soil and groundwater at the Property and the Site are provided as Exhibits C and D. Response actions on the Property may include, but not be limited to, monitoring, maintenance of remediation systems, removal or modification of structures, and installation of additional treatment works.

1.04. Land Use Covenant. A land use covenant is necessary to preclude residential use of the Property given that hazardous substances will remain at the Property following completion of the remediation and to preclude disruption of the selected constructed remedy. As noted above, the Interim ROD provides for a land use covenant to limit future uses of the Property. U.S. EPA, with the concurrence of the Department, has concluded that the Property, when remedied to the interim goals presented in the Interim ROD, and when used in compliance with the terms of this Covenant, does not present an unacceptable threat to human safety or the environment.

ARTICLE II

DEFINITIONS

2.01. Department. "Department" means the California Department of Toxic Substances Control and includes its successor agencies, if any.

2.02. U.S. EPA. "U.S. EPA" means the United States Environmental Protection Agency and includes its successor agencies, if any.

2.03. Owners. "Owners" means the Covenantors and their successors in interest, including heirs and assigns, which at any time hold title or an ownership interest to all or any portion of the Property.

2.04. Occupant. "Occupant" means Owners and any person or entity entitled by ownership, leasehold, or other legal relationship to the right to occupy any portion of the Property.

2.05. CERCLA Lead Agency. "CERCLA Lead Agency" means the governmental entity having the designated lead responsibility to implement response action under the National Contingency Plan ("NCP"), 40 C.F.R. Part 300. U.S. EPA or a state agency acting pursuant to a contract or cooperative agreement executed under CERCLA section 104(d)(1), 42 U.S.C. 9604(d)(1), or designated pursuant to a CERCLA Memorandum of Agreement entered into under subpart F of the NCP (40 C.F.R. 300.505) may be designated CERCLA Lead Agency.

2.06 Environmental Restrictions. "Environmental Restrictions" means all protective provisions, covenants, restrictions, prohibitions, and terms and conditions as set forth in any section of this Covenant.

2.07 Improvements. "Improvements" include, but are not limited to: buildings, structures, roads, driveways, improved parking areas, wells, pipelines, or other utilities.

2.08 Lease. "Lease" means lease, rental agreement, or any other document that creates a right to use or occupy any portion of the Property.

2.09 Remedial Systems. "Remedial Systems" shall mean the remedial equipment and systems located on the Property, including the soil vapor extraction and treatment, and groundwater extraction and treatment systems located at the Property and shown in Exhibit E.

ARTICLE III
GENERAL PROVISIONS

3.01. Restrictions to Run with the Land. This Covenant sets forth Environmental Restrictions, that apply to and encumber the Property and every portion thereof no matter how it is improved, held, used, occupied, leased, sold, hypothecated, encumbered, and/or conveyed. This Covenant: (a) Runs with the land pursuant to Health and Safety Code section 25355.5(a) and Civil Code section 1471; (b) Inures to the benefit of and passes with each and every portion of the Property; (c) Is for the benefit of, and is enforceable by the Department; and (d) Is imposed upon the entire Property unless expressly stated as applicable only to a specific portion thereof.

3.02. Binding upon Owners/Occupants. Pursuant to the Health and Safety Code, this Covenant binds all Owners and Occupants of the Property. Pursuant to Civil Code section 1471, all successive owners of the Property are expressly bound hereby for the benefit of the Department.

3.03. Incorporation into Deeds and Leases. The Covenant and its Environmental Restrictions shall be incorporated by reference in each and every deed and lease for any portion of the Property.

3.05. Conveyance of Property. The Owner shall provide notice to the Department not later than thirty (30) days after any conveyance of any ownership interest in the Property (excluding mortgages, liens, and other non-possessory encumbrances). The written notice shall include the name and mailing address of the new owner of the Property and shall reference DTSC site code 100111. The notice shall also include the Assessor's Parcel Number ("APN") listed in Section 1.01. If the new owner's property has been assigned a different APN, each such APN that covers the Property must be provided. The Department shall not, by reason of this Covenant, have authority to approve, disapprove, or otherwise affect proposed conveyance, except as otherwise provided by law or by administrative order.

ARTICLE IV

RESTRICTIONS

4.01. Prohibited Uses. The Property shall not be used for any of the following purposes:

(a) A residence, including any mobile home or factory built housing, constructed or installed for use as residential human habitation.

(b) A hospital for humans.

(c) A public or private school for persons under 21 years of age.

(d) A day care center for children.

(e) A long-term care facility for the elderly, handicapped, or infirm.

(f) Any other purpose involving residential occupancy on a 24-hour basis.

4.02. Soil Management. Any contaminated soils or contaminated materials brought to the surface by grading, excavation, trenching or backfilling shall be managed in accordance with all applicable provisions of State and federal law. Such soils and materials shall not be removed from the Property without a Soil Management Plan approved by the Department.

4.03. Prohibited Activities. Unless a change is authorized pursuant to Article VI of this Covenant, the following activities are specifically prohibited without prior written approval from the CERCLA Lead Agency:

(a) Drilling for drinking water, oil, or gas.

(b) Extraction of groundwater for purposes or uses other than site remediation.

(c) Alteration of existing drainage patterns as anticipated or constructed as part of the Remedial System.

(d) Creation of significant topographic low areas where water may pond, including accessory structures, swimming pools and spas.

4.04. Non-Interference with Remedial Systems.

(a) The Owner and Occupant shall not participate in or allow any activity that would interfere with the operation of the Remedial Systems or other Site-wide response activities at the Property without prior written approval from the CERCLA Lead Agency, such approval not to be unreasonably withheld.

(b) All uses and development of the Property shall preserve the integrity of the Remedial Systems or other Site-wide response activities.

(c) Owner shall provide a copy of this Covenant to all easement holders for all or any portion of the Property.

4.05. Access for the Department and U.S. EPA. The Department shall have reasonable right of entry and access to the Property for inspection, monitoring, and other activities for the Remedial Systems on the Property consistent with the purposes of this Covenant as deemed necessary by the Department in order to protect the public health or safety, or the environment. Nothing in this instrument shall limit or otherwise affect U.S. EPA’s right of entry and access, or U.S. EPA's authority to take response actions, under CERCLA; the National Contingency Plan, 40 Code of Federal Regulations Part 300 (1997) and its successor provisions; or federal law. Nothing in this instrument shall limit or otherwise effect the Department's right of entry and access, or authority to take response actions, under CERCLA; the National Contingency Plan, 40 Code of Federal Regulations Part 300 (1997) and its successor provisions; Chapter 6.8, Division 20 of the California Health and Safety Code; California Civil Code, or other applicable State Law.

4.06 Access for Implementing Operation and Maintenance. The entity, person or persons responsible for implementing the operation and maintenance activities related to the Remedial Systems shall have reasonable right of entry and access to the Property for the purpose of implementing these operation and maintenance activities. Such right of entry and access shall continue until such time as the CERCLA Lead Agency determines that such activities are no longer required.

4.07 Inspection and Reporting Requirements. The Owner shall conduct an annual inspection and submit an Annual Inspection Report to the Department for its approval by January 15th of each year. The annual report shall describe how all requirements outlined in this Covenant have been met. The annual report, filed under penalty of perjury, shall certify that the Property is being used in a manner consistent with this Covenant. The annual report must include the dates, times, and names of those who conducted and reviewed the annual inspection report. It also shall describe how the observations were performed that were the basis for the statements and conclusions in the annual report (e.g., drive by, fly over, walk in, etc.) If violations are noted, the annual report must detail the steps taken to return to compliance. If the Owner identifies any violations of this Covenant during the annual inspections or at any other time, the Owner must, within ten (10) days of identifying the violation: determine the identity of the party in violation; send a letter advising the party of the violation of the Covenant; and demand that the violation cease immediately. Additionally, copies of any correspondence related to the enforcement of this covenant shall be sent to the Department and U.S. EPA within ten (10) days of its original transmission.

ARTICLE V

ENFORCEMENT

5.01. Enforcement. Failure of the Covenantor, Owner or Occupant to comply with this Covenant shall be grounds for the Department to require modification or removal of any Improvements constructed or placed upon any portion of the Property in violation of this Covenant. Violation of this Covenant, including but not limited to, failure to submit, or the submission of any false statement, record or report to the Department shall be grounds for the Department to pursue administrative, civil or criminal actions.

5.02 Enforcement Rights of U.S. EPA as a Third Party Beneficiary. U.S. EPA, as a third party beneficiary, has the right to enforce the Environmental Restrictions contained herein.

ARTICLE VI

VARIANCE, TERMINATION, AND TERM

6.01. Variance. Owner, or any other aggrieved person, may apply to the Department for a written variance from the provisions of this Covenant. Such application shall be made in accordance with Health and Safety Code section 25233 and a copy of the application shall be submitted to U.S. EPA simultaneously with the application submitted to the Department. No variance may be granted under this paragraph without prior notice to and an opportunity to comment by U.S. EPA.

6.02 Termination. Owner, or any other aggrieved person, may apply to the Department for a termination or modification of one or more terms of this Covenant as they apply to all or any portion of the Property. Such application shall be made in accordance with Health and Safety Code section 25234 and a copy of the application shall be submitted to U.S. EPA simultaneously with the application submitted to the Department. No termination may be granted under this paragraph without prior notice to and opportunity to comment by U.S. EPA.

6.03 Term. Unless ended in accordance with paragraph 6.02, by law, or by the Department in the exercise of its discretion, after providing notice to and an opportunity to comment by U.S. EPA, this Covenant shall continue in effect in perpetuity.

ARTICLE VII

MISCELLANEOUS

7.01. No Dedication or Taking Intended. Nothing set forth in this Covenant shall be construed to be a gift or dedication, or offer of a gift or dedication, of the Property, or any portion thereof to the general public or anyone else for any purpose whatsoever. Further, nothing in this Covenant shall be construed to effect a taking under State or federal law.

7.02. Notices. Whenever any person gives or serves any Notice ("Notice" as used herein includes any demand or other communication with respect to this Covenant), each such Notice shall be in writing and shall be deemed effective: (1) when delivered, if personally delivered to the person being served or to an officer of a corporate party being served, or (2) three (3) business days after deposit in the mail, if mailed by United States mail, postage paid, certified, return receipt requested:

To Owners:
Stephen C. Lyon, Suzanne S. Lyon,
Russell R. Tonda and Diane M. Tonda
939 & 941 McHenry Street
Modesto, California 95350-5416

and

Stephen and Suzanne Lyon
424 Liberty Street
San Francisco CA 94114-2949

and

Russell and Diane Tonda
9760 Rimrock Circle
Loomis, CA 95650-7117

To Department:
__________________, Chief
Northern California-Central Cleanup Operations Branch
Site Mitigation and Brownfield Reuse Program
California Department of Toxic Substances Control
8800 Cal Center Drive
Sacramento CA 95826-3200

To the U.S. EPA:
U.S. Environmental Protection Agency
Region IX
Attention: Marie Lacey
75 Hawthorne Street
San Francisco, CA 94105-3901

Any party may change its address or the individual to whose attention a Notice is to be sent by giving written Notice in compliance with this paragraph.

7.03. Partial Invalidity. If this Covenant or any of its terms are determined by a court of competent jurisdiction to be invalid for any reason, the surviving portions of this Covenant, or the application of it to any person or circumstance, shall remain in full force and effect as if such portion found invalid had not been included herein.

7.04. Statutory and Regulatory References. All statutory and regulatory references include successor provisions.

7.05. Incorporation of Attachments. All attachments and exhibits to this Covenant are incorporated herein by reference.

7.06. California Law. This Covenant shall be governed, performed and interpreted under the laws of the State of California.

7.07. No Delegation. Nothing set forth in this Covenant shall be construed to be a delegation of any authorities of DTSC under any statute or regulation.

IN WITNESS WHEREOF, the Parties execute this Covenant.

Covenantors, Stephen C. Lyon, Suzanne S. Lyon, Russell R. Tonda and Diane M. Tonda :

By: ______________________________________Date:_____________________
Stephen C. Lyon

By: ______________________________________Date:_____________________
Suzanne S. Lyon

By: ______________________________________Date:_____________________
Russell R. Tonda

By: ______________________________________Date:_____________________
Diane M. Tonda

Department of Toxic Substances Control

By: ______________________________________Date:_____________________

_______________________, Chief
Department of Toxic Substances Control

State of California

County of _________

On ________________________ before me,

____

(Here insert name and title of the officer/notary),

Personally appeared____

____

____, personally known to me (or proved to me on the basis of satisfactory evidence) to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

WITNESS my hand and official seal.

Signature __________________________________ (Seal)

State of California

County of _________

On ________________________ before me,

____

(here insert name and title of the officer/notary),

Personally appeared____

____

____, personally known to me (or proved to me on the basis of satisfactory evidence) to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

WITNESS my hand and official seal.

Signature __________________________________ (Seal)

EXHIBITS

A – Legal Property Description

B – Assessor's Map

C – Baseline Human Health Risk Assessment, Modesto Groundwater Contamination Site, Modesto, California, May 1994, prepared for EPA by Ecology & Environment, Inc.

D – Baseline Human Health Risk Assessment (Revision 1), Modesto Groundwater Contamination Site, Modesto, California, July 1997, prepared for EPA by Ecology & Environment, Inc.

E – Diagram of SVE and Groundwater Treatment Systems at the Property

Exhibit A

Legal Property Description
Property Subject to Environmental Restriction

Lot 2 of the FALK TRACT, as per Map filed July 5, 1939, in Vol. 11 of Maps, page 62, Stanislaus County Records, EXCEPTING THEREFROM the East 18 feet thereof.

(Stanislaus County Assessor Parcel 113-006-036)

Exhibit B

Assessor's Parcel Map of
Property Subject to Environmental Restriction

Note: The dimensions found in the current County Assessor Map reflect the correct legal description of the parcel, including the exception of the eastern 18 feet of the parcel in the 1939 FALK TRACT map.

Exhibit C

(Baseline Human Health Risk Assessment,
Modesto Groundwater Contamination Site,
Modesto, California, May 1994)

to

Appendix C
(Land Use Covenant)

to

Consent Decree Pertaining to Defendants
Lyons and Tondas

BASELINE HUMAN HEALTH RISK ASSESSMENT MODESTO GROUNDWATER CONTAMINATION SITE MODESTO, CALIFORNIA

ecology and environment, inc.
International Specialists in the Environment

ecology and environment, inc.
160 SPEAR STREET, SAN FRANCISCO, CALIFORNIA 94105, TEL. 415/777-2811
International Specialists in the Environment

BASELINE HUMAN HEALTH RISK ASSESSMENT MODESTO GROUNDWATER CONTAMINATION SITE MODESTO, CALIFORNIA

May 1994

Prepared for:

U.S. ENVIRONMENTAL PROTECTION AGENCY

ARCS Regions IX and X
Contract 68-W9-0020
Work Assignment 20-15-9LJ4

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EXECUTIVE SUMMARY

Ecology and Environment, Inc. (E & E), and the U.S. Environmental Protection Agency (EPA) conducted a Remedial Investigation/Feasibility Study (RI/FS) at the Modesto Groundwater Contamination Site, a Superfund site in Modesto, California. As an attachment to the FS report, this report describes the risk assessment that evaluated the human health risks from volatile organic compounds (VOCs), primarily per- or tetrachloroethylene (PCE), in site groundwater and soil gas. The residential groundwater ingestion and inhalation of indoor air exposure pathways were evaluated for current and future land use scenarios using soil gas and groundwater data collected during the RI. The inhalation exposure to ambient indoor air was estimated from the soil gas data using an EPA-approved model (1992b). The inhalation of volatile chemicals released during routine household water use (e.g., showering and dish washing) was also evaluated. For the current land use scenarios, risks were estimated for exposure to treated and untreated Municipal Well 11 drinking water. The future land use scenario assumed ingestion of untreated site groundwater from a "hot spot" near Halford's Cleaners. Average and reasonable maximum exposures (RMEs) were calculated to assess carcinogenic and noncarcinogenic risks.

In conducting the risk assessment, conservative upper-bound exposure values developed by EPA were used to calculate the "theoretical excess cancer risk." The theoretical excess cancer risk is an estimation of the probability of developing cancer over and above the normal background incidence of cancer. A number of assumptions were made in the risk assessment that were designed to err on the side of health protection in order to avoid underestimating the risk to the public. Moreover, the chemical concentrations used to estimate the increased individual carcinogenic risk assumed that continuous exposure occurs over a 30-year period; therefore, the actual probability of cancer is likely to be much lower than the estimates and may even be as low as zero (EPA 1989a).

As shown in the table below, current carcinogenic risks range from 1 x 10^{-6} to 4 x 10^{-5} while hazard indices range from 0.5 to 1; under future land use conditions, carcinogenic risks range from 4 x 10^{-2} to 5 x 10^{-1} while hazard indices range from 4 to 46. The groundwater ingestion and inhalation pathways contribute the greatest risk.

SUMMARY OF ESTIMATED RISK VALUES:
RISK BY PATHWAY AND EXPOSURE SCENARIO

Pathway	Hazard Index RME	Hazard Index Average	Cancer Risk RME	Cancer Risk Average
Current Scenario: Assumes treated Well 11 groundwater use[a]				
Indoor Air: Inhalation of Soil Gas	1	0.5	1 x 10^{-5}	1 x 10^{-6}
Drinking Water: Ingestion and Inhalation	9 x 10^{-7}	4 x 10^{-7}	1 x 10^{-8}	5 x 10^{-9}
Total Risk	**1**	**0.5**	**1 x 10^{-5}**	**1 x 10^{-6}**
Current Scenario: Assumes untreated Well 11 groundwater use[b]				
Indoor Air: Inhalation of Soil Gas	1	0.5	1 x 10^{-5}	1 x 10^{-6}
Drinking Water: Ingestion and Inhalation	2 x 10^{-3}	2 x 10^{-4}	3 x 10^{-5}	3 x 10^{-6}
Total Risk	**1**	**0.5**	**4 x 10^{-5}**	**4 x 10^{-6}**
Future Scenario: Assumes onsite groundwater use at a hot spot near Halford's[c]				
Indoor Air: Inhalation of Soil Gas	1	0.5	1 x 10^{-5}	1 x 10^{-6}
Drinking Water: Ingestion and Inhalation	45	3	5 x 10^{-1}	4 x 10^{-2}
Total Risk	**46**	**4**	**5 x 10^{-1}**	**4 x 10^{-2}**

RME = Reasonable Maximum Exposure
Average = Average of typical exposure parameters

[a] Risk values derived from PCE concentrations of 0.60 and 0.47 µg/L for RME and average, respectively.

[b] Risk values derived from PCE concentrations of 30.4 and 10.3 µg/L for RME and average, respectively.

[c] Risk values derived from PCE concentrations of 4,200 and 1,239 µg/L for RME and average, respectively.

EPA has adopted the policy that acceptable exposures to known or suspected carcinogens fall within an excess upper-bound lifetime cancer risk of between one in 10,000 (10^{-4}) and one in a million (10^{-6}) (EPA 1991a). In this risk assessment, the inhalation and drinking water risks associated with current land use scenarios were within acceptable risk levels; however, the risks associated with a future exposure scenario, which assumed consumption of untreated site groundwater at the hot spot, were above the currently acceptable standards (EPA 1991a).

In summary, this risk assessment found that current risk levels are within EPA's acceptable levels; however, for the hypothetical future scenario in which an individual ingests untreated groundwater directly from the hot spot, the risks were found to be outside EPA's acceptable levels. To safeguard against such a scenario, EPA will be implementing institutional controls that will prohibit groundwater usage at this site.

1. INTRODUCTION

Ecology and Environment, Inc. (E & E), was tasked by the U.S. Environmental Protection Agency (EPA) to assess public health risks from volatile organic compounds (VOCs) in groundwater at the Modesto Groundwater Contamination Site, a Superfund site in Modesto, California. E & E and EPA conducted the remedial investigation (RI) and feasibility study (FS); this risk assessment report is an attachment to the FS report. This baseline risk assessment was conducted by E & E under Work Assignment 20-15-9LJ4 issued under EPA Region IX/X Superfund Alternative Remedial Contracts Strategy (ARCS) Contract 68-W9-0020.

The Modesto Groundwater Contamination Site was placed on the National Priorities List on March 31, 1989. The site includes Municipal Well 11 (Well 11), which has been found to contain per- or tetrachloroethylene (PCE) above the federal and state maximum contaminant level (MCL) of 5.0 parts per billion (ppb). This introduction describes the physical setting of the site and summarizes the investigations and groundwater treatment to date. Additional background information can be found in the RI and FS reports (E & E 1993a,b; 1994).

1.1 BACKGROUND

1.1.1 Site Description

Modesto is in Stanislaus County in the San Joaquin Valley approximately four miles south of the Stanislaus River and five miles west of the Tuolumne River. The city encompasses approximately 12 square miles and has a population of approximately 170,000. Major industries include canneries, wineries, and dairy, meat, poultry, and frozen food processing plants.

The climate is characterized by hot, dry summers and mild winters. The mean annual precipitation is 12 inches with 87 percent occurring between October and May. Groundwater is the primary source of water for municipal, industrial, and agricultural use in Modesto. Water supplies include 49 wells owned by the City of Modesto, 62 wells owned by the Del Este Water Company, and numerous private domestic wells.

Figure 1-1 shows the site location and facilities. The RI study area was at an approximate elevation of 90 feet above mean sea level (MSL). The site and vicinity are nearly flat with a gentle slope to the west at a gradient of approximately 0.001.

1.1.2 Site Investigations

The City of Modesto regularly tests the water from Well 11 for PCE and other contaminants of concern to ensure that drinking water standards are met. PCE was initially detected in Well 11 in September 1984 at 16.7 ppb, which is above the federal and state MCL of 5 ppb. Well 11 was one of 12 wells initially sampled in Modesto under provisions of California Assembly Bill (AB) 1803. Within a few weeks after contamination was detected in Well 11, local regulatory agency representatives raised the possibility that Halford's Cleaners at 941 McHenry Avenue was the source of PCE contamination. Halford's was suspected because of its proximity to Well 11 (approximately 1,000 feet southeast) and the likely use of PCE at a drycleaning facility. A timeline of various activities at Well 11 is shown in Figure 1-2.

In April 1985, the Stanislaus County Department of Environmental Resources conducted a groundwater investigation in the immediate vicinity of Halford's. An inactive air conditioning well at the Elks Lodge, approximately 100 feet northwest of Halford's, contained PCE at 84.6 ppb. Following the groundwater investigation, the county collected soil samples at Halford's near a drycleaning machine. The results revealed a maximum PCE soil concentration of 176,000 ppb.

After being deactivated in 1984 when PCE contamination was initially detected, Well 11 was reactivated in April 1987, six months after monitoring indicated no detectable levels of PCE or other chlorinated solvents. In February 1989, Well 11 was again taken out of service after PCE was detected at 8.28 ppb in December 1989. The well remained out of service until a wellhead granular activated carbon (GAC) treatment system was installed by the City of Modesto in May 1991. Well 11 was returned to service in June 1991 and is currently operating.

In August 1985, the City of Modesto collected sludge and sediment samples from sewer lines north and south of Halford's. A maximum PCE concentration in sludge of 1,360 ppb was found in the main sewer line immediately downgradient from Halford's service connection.

In 1987, Radian Corporation, under contract to the California Department of Health Services (DHS), conducted an investigation of potential groundwater contaminant sources in Modesto. The objectives of the Radian investigation were to:

- Identify the businesses that potentially use PCE and could be associated with contamination found in 10 Modesto domestic water supply wells.
- Evaluate potential health risks associated with the drinking water ingestion.
- Develop a list of remedial alternatives.

The results indicated that 106 businesses warranted further investigation as potential contaminant sources. A followup evaluation eliminated 73 businesses from the list, leaving 34 businesses considered for soil gas sampling.

In December 1989, as EPA's Technical Assistance Team (TAT) contractor, E & E collected soil and soil gas samples in the vicinity of Halford's. The results showed PCE at a maximum of 6,050 parts per million (ppm) in the soil near the northwest corner of the Halford's building and an elevated PCE concentration of 1,965 ppm in soil gas adjacent to the automobile dealership immediately south of Halford's. Both the soil and soil gas data suggested decreasing PCE concentrations at increasing distances from Halford's.

A second TAT investigation was conducted in July 1990 and consisted of:

- Drilling and sampling of six boreholes in the vicinity of Halford's.
- Video monitoring of the nearby Elks Lodge well to determine whether it could be acting as a conduit for the downward migration of contaminants.
- Sampling of the Elks Lodge well.

The highest PCE concentration in soil (21,000 ppb) was detected within 5 feet of the surface of the borehole closest to Halford's, approximately 1,000 feet southeast of Well 11 (Figure 1-1). Water sample results from the Elks Lodge well indicated PCE at 73 ppb although information from the video monitoring was inconclusive.

In March and April of 1990, the Regional Water Quality Control Board (RWQCB) conducted a second soil gas investigation to delineate potential contaminant plumes associated with the City of Modesto's Wells 11, 14, and 21 (Well 21 is not on Figure 1). The results indicated that the "Halford's Plume" just west of McHenry Avenue and south of Roseburg Avenue is most likely affecting Well 11. The southern portion of this plume coincides with the city sewer line, indicating that PCE discharges to the sewer line may be a source of the contamination. Halford's is also a likely source of this plume. Another plume, the "Village Plume," may also be impacting Well 11 according to the RWQCB results although the source is likely to be another drycleaner upgradient from Well 11. The Village Plume reportedly originates at McHenry Village Mall, extends west along Grange Avenue, and migrates southwest near the Doctors' Hospital Medical Complex.

On September 25, 1990, the EPA Emergency Response Section issued a Removal Order to the potential responsible parties (PRPs) for soil remediation at Halford's. Halford's installed a soil vapor extraction system in compliance with the Removal Order. E & E conducted Phase I and II RIs at the site to determine the chemicals of concern and locate PCE hot spots. The Phase I investigation consisted of conducting a soil gas survey, installing four monitoring wells, sampling and analyzing subsurface soils, testing groundwater from the monitoring wells and Well 11, and conducting an aquifer pump test. The Phase II investigation was designed to support this risk assessment by defining the horizontal and vertical extent of the PCE soil gas contamination identified in the Phase I RI. Both biased and random sampling methods to characterize the PCE contamination, and additional groundwater samples were collected and analyzed (E & E 1993a,b).

1.1.3 Groundwater Treatment System at Municipal Well 11

Well 11 is located at the corner of Magnolia and Mensinger avenues and is owned and operated by the City of Modesto. This well is part of the system that supplies potable water to over 150,000 residents. As reported in AB 1803, Well 11 (State Number 3S/9E-20J1) was installed in 1936 and has a capacity of 1,150 gallons per minute (gpm) and a well casing depth of 116 feet.

As discussed in Section 1.1.2, Well 11 has a history of off-line use since 1984. Since the installation of the GAC treatment system, Well 11 has not gone off line. Both treated (effluent) and untreated (influent) groundwater are regularly analyzed for VOCs.

1.2 SCOPE OF THE RISK ASSESSMENT

This baseline risk assessment evaluated the potential human health risk from VOCs identified in groundwater at the Modesto Groundwater Contamination Site. The preliminary residential exposure pathways investigated included the inhalation of soil gas vapors as well as the inhalation and ingestion of groundwater by residents. This report was prepared in accordance with the following federal and regional risk assessment guidance as well as other references mentioned throughout:

- *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part A)*, EPA/540/1-89/002, December 1989.
- *Risk Assessment Guidance for Superfund Human Health Risk Assessment, U.S. EPA Region IX Recommendations* (Interim Final), December 15, 1989.
- *EPA Region IX Preliminary Remediation Goals (PRGs)*, Third Quarter, 1993.

The risk assessment was conducted according to standard risk assessment procedures for the following (EPA 1989b, 1988):

- Identification of contaminants of potential concern
- Exposure assessment
- Toxicity assessment
- Risk characterization
- Uncertainty analysis.

Current (treated and untreated) drinking water and future land use exposure scenarios were evaluated in this assessment.

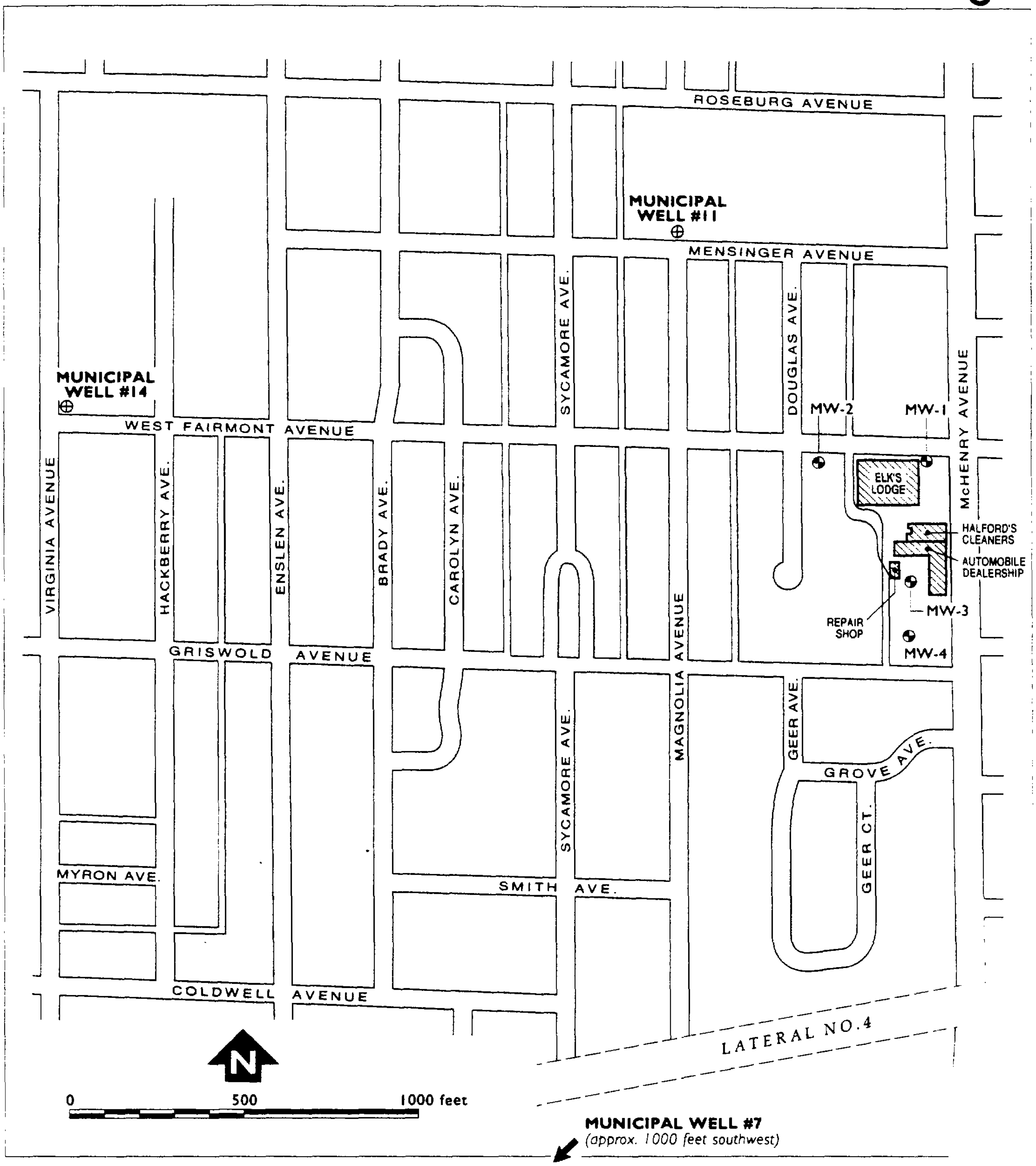

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Figure 1-1

LOCATION OF ONSITE MONITORING WELLS

Modesto Groundwater

Modesto, California

WELL 11 INACTIVE

1984
- ◄ PCE first detected; 16.7 ppb; Well 11 deactivated

1985
- ◄ County groundwater investigation; 85 ppb at Elks Club well; soil max = 176,000 ppb PCE
- ◄ Sludge/sediment sampling by City of Modesto; 1,360 ppb PCE in sludge from sewer line

1986

ACTIVE

1987
- ◄ Well 11 turned on

1988
- ▶ RADIAN INVESTIGATION

1989
- ◄ First TAT soil & gas survey; 6,050 ppm PCE (soil); 1,965 ppm PCE (soil gas)

INACTIVE

1990
- ◄ 8.3 ppb PCE detected; Well 11 turned off
- ▶ RWQCB conducts soil gas survey, "Halford's Plume" identified
- ◄ 2nd TAT study; Elk's Club well = 73 ppb, PCE; video monitoring; six boreholes installed
- ◄ EPA issues Corrective Order to Halford's Cleaners

1991
- ◄ Removal action starts; soil vapor extraction system installed
- ◄ Granular activated carbon (GAC) system installed

ACTIVE

1992
- ◄ Well 11 turned back on

1993
- ◄ **PHASE I RI**
- ◄ **PHASE II RI**

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Figure 1-2

TIMELINE OF ACTIVITIES AT WELL 11

Modesto Groundwater

Modesto, California

2. DATA COLLECTION AND EVALUATION

This section summarizes the results of E & E's Phase I and II RIs (E & E 1993a,b). The RI data and data obtained from the City of Modesto (1993) were used exclusively in this risk assessment. The sampled media were soil, groundwater, and soil gas.

Selected samples were analyzed and validated by EPA contract laboratories using EPA functional guidelines (EPA 1983, 1989c, 1990). Data review and validation is a two-step process. First, laboratory personnel qualitatively review the data for overall precision, accuracy, comparability, and completeness using standard quality assurance/quality control (QA/QC) procedures. Second, an independent validation specialist evaluates the data and assigns validation qualifiers that account for any variability encountered in the chemical analyses. For example, a "J" qualifier indicates that a laboratory instrument identified the chemical, but the concentration was too low to be accurately quantified (i.e., the chemical was present but at a concentration below the quantitation limit). If the chemical was analyzed for but not detected, the result is qualified with a "U." In accordance with EPA guidance (1989a), if there is no reason to believe a chemical was present in a sample, a U-qualified result is regarded as zero. If, however, there is reason to believe a chemical is present because, for example, it was detected in other samples collected nearby, one-half the method detection limit is used in the exposure assessment.

The following sections list the types of chemical compounds that were analyzed for and summarize the analytical laboratory results.

2.1 REMEDIAL INVESTIGATION ANALYTICAL RESULTS

2.1.1 Groundwater Results

Groundwater samples were collected from four monitoring wells (Wells MW-1 through MW-4), Well 11, and the Elks Club well in February and March 1992 (Phase I) and again in November 1993 (Phase II). Effluent (treated) and influent (untreated) samples were collected from Well 11. Duplicate samples were collected for QA/QC purposes, and average concentrations were used in exposure calculations. All samples were analyzed by an EPA Contract Laboratory Program (CLP) laboratory using Routine Analytical Service (RAS) and Special Analytical Services (SAS) methods. All data underwent validation according to EPA guidelines (EPA 1990). Groundwater samples collected from monitoring wells during the Phase I RI were analyzed for Target Compound List (TCL) VOCs, TCL semivolatile organic compounds (SOCs), TCL pesticides, polychlorinated biphenyls (PCBs), Target Analyte List (TAL) metals, herbicides, and radionuclides including alpha, beta, radium-226/228, and radon-222.

No detectable levels of pesticides, PCBs, SOCs, or herbicides were found. In the Phase I RI, several tentatively identified compounds (TICs) were identified in samples from the Elks Club well and qualified with a "J" meaning "estimated." The TICs were butane, pentane, methyl pentane, hexane, and methyl hexane. The quantitation limit for these compounds was 2 micrograms per liter (μg/L). One equipment blank and two field duplicates were analyzed. The field duplicates had comparable PCE concentrations; the equipment blank had analyte concentrations below the quantitation limits. PCE was detected in all samples except Well 11 effluent. Trace quantities of several other VOCs were detected, but the number of exceedances did not warrant further analysis. None of the TICs were suspect at the site so they were eliminated from further consideration per EPA guidance (1989a).

Since many of the compounds tested for in the Phase I RI such as PCBs and pesticides were not present at significant quantities, only VOCs were analyzed for in the Phase II RI. The Phase II VOC data were similar to the Phase I data (i.e., same chemical identification at similar concentrations).

About 12 TICs of unknown identity were observed in samples from Well MW-3. Methyl pyrrolidinone was identified (probability of identification assigned "B" or "moderate") at concentrations of 20 to 100 μg/L (J-qualified) in five of the samples. None of the 64 possible SOCs were detected above the quantitation limits. Two field duplicates and one equipment blank were collected and analyzed for SOCs.

Herbicides were analyzed for using EPA Test Method 8150. Again, two field duplicates and one equipment blank were analyzed for QA/QC purposes. No herbicides were detected above the quantitation limits.

Water samples were also analyzed for SAS metals and molybdenum. The data were reviewed in accordance with the SAS requirements for molybdenum and EPA guidance (EPA 1983, 1989c). During Phase I, one well (Well MW-3) contained the following compounds above the MCLs: aluminum (12,000 μg/L), chromium (65 μg/L), iron (11,800 μg/L), and manganese (282 μg/L). Secondary values were used for aluminum, iron, and manganese because primary standards were not available; secondary standards provide information on aesthetics and palatability (EPA 1994a). The field crew noted that the Well MW-3 sample was unusually turbid and that the well is near a storm drain where dumping may have occurred. The metal concentrations were below the primary MCLs in all other monitoring well samples. Phase II sampling found that the metals concentrations in Well MW-3 had decreased substantially to 177 μg/L for aluminum, 92.4 μg/L for iron, and 34 μg/L for manganese; chromium was below the detection limit. Because these concentrations were below the MCLs and EPA Region IX Preliminary Remediation Goals* (PRGs) and because the analyte concentrations had decreased from Phase I to Phase II, these metals were not considered chemicals of potential concern (COPCs). The results are discussed in more detail in Section 2.3.

None of the 11 water samples analyzed contained RAS pesticides or PCBs above the 0.05 to 1 μg/L quantitation limits.

Gross alpha and beta radioactivity, radium-226 and -228, and uranium analyses were also performed on water samples collected March 6 through 26, 1992. Several different methods were used to analyze the various types of radioactivity. The data were reviewed for completeness and compliance with the methods only; no judgment was made on data quality. The results did not indicate a need for further study.

2.1.2 Soil Gas Results

The objective of the Phase I soil gas survey was to identify potential sources of PCE contamination impacting Well 11 groundwater. On the basis of a conservative estimate of the radius of influence of Well 11, a one-mile radius was initially selected as the study area for the soil gas survey. A Field Analytical Screening Procedure (FASP) was used to screen samples for PCE, 1,1,1-trichloroethane (TCE), *cis*-1,2 dichloroethene (*cis*-1,2-DCE), *trans*-1,2-dichloroethene (*trans*-1,2-DCE), 1,2-dichloroethane (1,2-DCA), and 1,1-dichloroethane (1,1-DCA) (E & E 1990). PCE was detected in most samples, and several samples contained TCE and *cis*-1,2-DCE. Soil gas samples were collected from 10 to 20 feet below ground surface (bgs).

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* PRGs are developed from EPA toxicity values combined with health-protective exposure assumptions to estimate "safe" contaminant levels in environmental media (e.g., soil, air, and water). In general, chemical concentrations above the PRGs need closer examination by a toxicologist and/or site-specific review and evaluation.

Preliminary soil gas samples were collected during the Phase I RI survey at 17 businesses within one-mile radius of Well 11. Three samples collected around Halford's had relatively high PCE concentrations (21 to 96 μg/L), suggesting that this area might be a hot spot (E & E, 1993a). A second soil gas survey was therefore conducted in November 1993 to further define the soil gas concentrations around Halford's. The Phase II survey focused on a smaller area than the Phase I soil gas survey to further characterize soil gas concentrations (Figure 2-1).

In the Phase II soil gas survey, 57 samples were collected 3 to 15 feet bgs and screened by a mobile laboratory for PCE, TCE, and vinyl chloride; 28 samples were random, and 29 were biased as shown in Figure 2-1. When a high PCE concentration (> 10 μg/L) was observed, a duplicate sample was collected in a Summa canister (6-liter, stainless steel); 14 canisters were submitted to a laboratory and analyzed for PCE, TCE, and vinyl chloride by EPA Test Method TO-14. As shown in Table 2-1, PCE was found in nearly all the samples, and *cis*-1,2-DCE and TCE were found in several samples, but vinyl chloride was not detected. The highest PCE concentration (78 μg/L) was found in a sample collected behind Halford's near the sewer line, which was consistent with the Phase I data (96 μg/L at 20 feet bgs). The data showed a common trend in that the PCE concentrations were highest near the sewer line and decreased away from the sewer line. As noted in other studies, the sewer line appears to be the primary PCE source (E & E 1993a).

2.1.3 Soil Results

Soil samples were collected from the four soil borings during monitoring well installation and analyzed for VOCs by RAS and SAS methods. The highest PCE concentrations ranged from 180 to 230 micrograms per kilogram (μg/kg) of soil and were found in samples collected at or below the groundwater surface (70 to 90 feet bgs) in the boring for Well MW-4 near the sewer line (Figure 2-1). In six subsurface soil samples collected less than 15 feet bgs, PCE concentrations ranged from nondetect in five samples to 5 μg/kg in one sample. The maximum detected PCE concentration was 230 μg/kg in a sample collected 90 feet bgs in the boring for Well MW-4.

2.2 CITY OF MODESTO QUARTERLY GROUNDWATER SAMPLING DATA

Quarterly groundwater monitoring data received from the City of Modesto (1993) were used to augment the Phase I and II Well 11 data. The City of Modesto samples collected from May 7, 1985, to August 3, 1993, were analyzed using EPA Test Methods 602 and 502.2. Data from August 1, 1991, to August 3, 1993, were used in the exposure assessment. Tables 2-2, 2-3, and 2-4 list Phase I and II RI PCE concentrations in untreated Well 11 water, treated Well 11 water, and water from Monitoring Wells 1 through 4, respectively. According to DHS (1993), the PCE detection limit (reportable or "DLR") for the City of Modesto data was 0.5 μg/L.

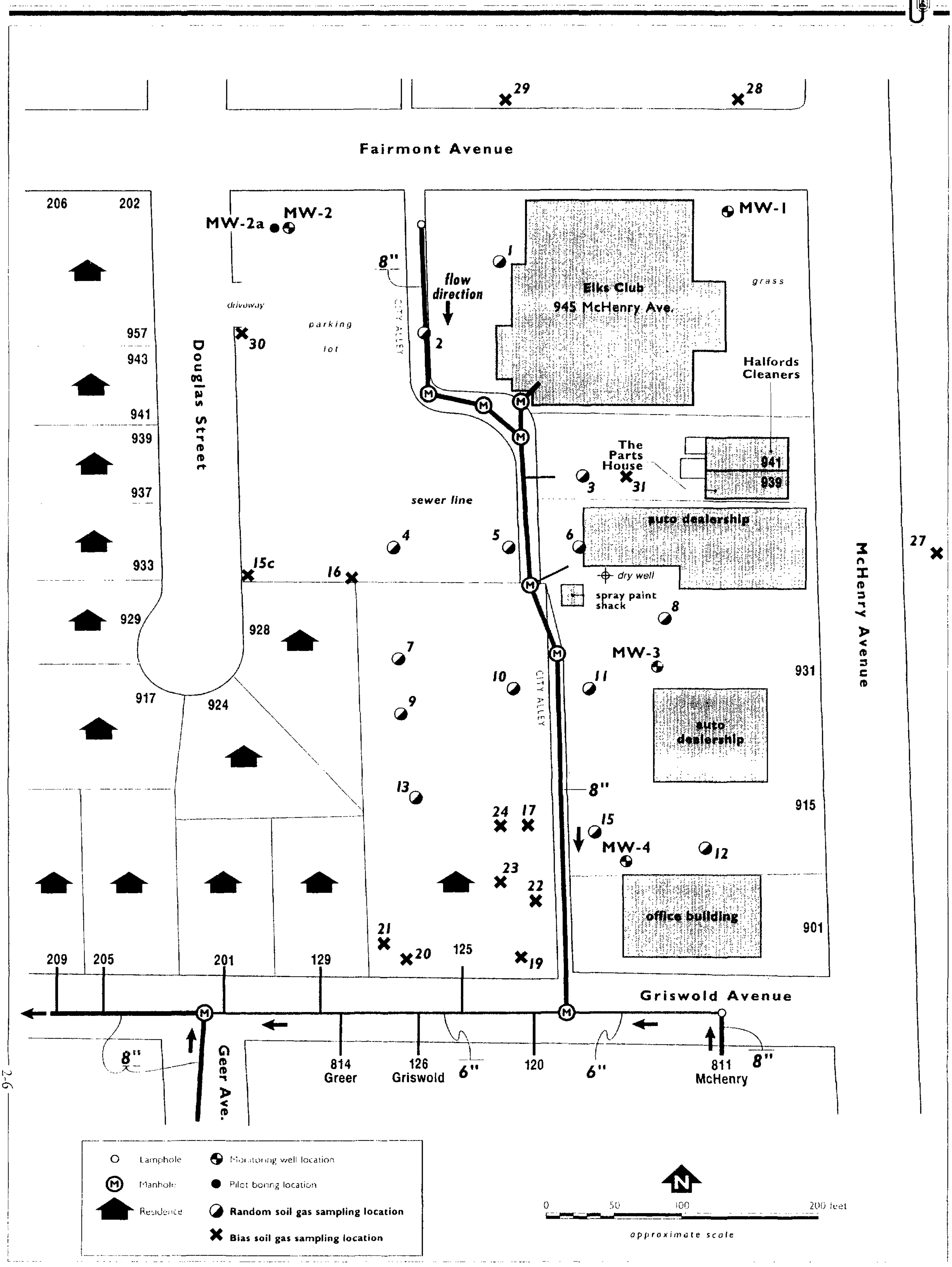
2.3 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

Because PCE was detected in nearly all soil gas and groundwater samples, it was considered the leading COPC. In both the Phase I and II soil gas surveys, *cis*-1,2-DCE and TCE were also detected at a frequency of detection that exceeded the EPA criteria for identifying COPCs and so were also considered COPCs for the inhalation exposure pathway (EPA 1989a).

As discussed in Section 2.1.1, the Phase I chemical analyses indicated that Well MW-3 contained aluminum, chromium, iron, and manganese at concentrations above the MCLs. The metals concentrations in all other monitoring well samples were below the primary MCLs, and Phase II sampling indicated that the metals concentrations in Well MW-3 had decreased substantially to below the MCLs and EPA Region IX PRGs. These metals were, therefore, not considered COPCs.

Groundwater samples from the four monitoring wells showed trace quantities of *cis*-1,2-DCE, 1,1,1-TCA, TCE, chloroform, benzene, toluene, ethylbenzene, and xylenes in addition to PCE. All maximum concentrations found were below EPA's PRGs except for the concentrations of TCE (34 μg/L) and chloroform (0.5 μg/L) in samples from Well MW-3 during the Phase II RI (EPA 1993). It should be noted that none of these chemicals were found at any time in Well 11. Because the detection frequency of 5% was exceeded for TCE and chloroform, both of these chemicals are eligible for selection as COPCs in the groundwater ingestion and inhalation pathways. Chloroform was, however, present at a concentration (0.2 μg/L, J-qualified) very close to the screening level (0.21 μg/L), and the groundwater inhalation and ingestion cancer risks calculated using the maximum detected chloroform concentration were negligible, about 10^{-8} (see Section 3.3.5 and Table 3-3) . Chloroform was, therefore, not considered to be a COPC.

In summary, PCE and *cis*-1,2-DCE were considered COPCs for the residential groundwater ingestion and inhalation pathways. PCE, TCE, and *cis*-1,2-DCE were considered COPCs for the soil gas inhalation pathway.



ZS6073 a(c38) 05/13/94

Figure 1

SOIL GAS SAMPLING LOCATIONS
Modesto Groundwater
Modesto, California

Table 2-1

SOIL GAS RESULTS

Sample	PCE ppb (v/v)	PCE (ug/L)(a)	TCE ppb (v/v)	TCE (ug/L)(a)	cis-1,2-DCE ppb (v/v)	cis-1,2-DCE (ug/L)(a)
SG1-3	3,300	22.8	nd	nd	nd	nd
SG1-15	5,600	38.6	nd	nd	nd	nd
SG4-3	1,800	12.4	nd	nd	nd	nd
SG3-3	7,100	49.0	nd	nd	nd	nd
SG3-15	21,000 (b)	144.9	nd	nd	nd	nd
SG6-3	15,000	103.5	1200	6.6	740	3.0
SG6-15	15,000	103.5	1400	7.7	380	1.5
SG11-15	25,000	172.5	nd	nd	nd	nd
SG13-15	2,500	17.2	nd	nd	nd	nd
SG17-15	12,000	82.8	350	1.9	nd	nd
SG24-15	14,000	96.6	nd	nd	nd	nd
SG30-15	20 (c)	0.14	nd	nd	nd	nd
Average		70.3		1.3		0.4
Maximum		172		7.7		3.0

Calculate the 95% UCL using formula in Section 3.3:

Given: x = 3.98, sd= 0.92

H(df=9, sd=0.9, 0.95) = 3.074 (Land, 1975)

Then: 95% UCL = 212 ug/L

Notes:

(a) Convert ppb (v/v) to ug/L by (MW/24.04)(1/1000); assumes temp = 20C

(b) Average of duplicate samples 30,000 and 12,000 ppb

(c) One-half the detection limit of 40 ppb

PCE : Tetrachloroethylene

TCE: trichloroethylene

1,2-DCE: cis-1,2-dichloroethylene

Table 2-2

PCE IN UNTREATED WELL 11 GROUNDWATER (8/1/91 to 8/3/93)

Date	Concentration (ug/L)	ln(conc.) (ug/L)
4/28/92	0.6	-0.511
5/5/92	0.6	-0.51
11/3/92	1.2	0.18
3/3/92	1.3	0.26
8/1/91	1.4	0.34
1/7/92	1.7	0.53
4/1/93	1.8	0.59
10/1/91	3	1.10
2/28/92	4.2	1.44
12/3/91	5.3	1.67
2/4/92	7.3	1.99
2/25/92 *	7	1.95
11/1/91	10	2.30
6/2/92	12.2	2.50
7/1/92	16	2.77
8/4/92	17	2.83
1/5/93	18	2.89
9/1/92	21	3.04
10/1/92	27	3.30
7/1/93	27	3.30
11/24/93 *	32	3.47
Average	10.3	1.69
Stand. dev.	10.0	1.30

Calculate 95% UCL using formula in Section 3.3:

Given: x= 1.69, sd=1.30
H(df=20, sd=1.3, 0.95) = 2.923 (Land 1975)

Then: 95% UCL = 30.4 ug/L

Notes

(*) E&E RI data; all other data from City of Modesto
Detection Limit : 0.5 ug/L

Table 2-3

PCE IN TREATED WELL 11 GROUNDWATER (8/1/91 to 8/3/93)

Date	Concentration (ug/L)
8/1/91	ND
10/1/91	ND
11/1/91	ND
12/3/91	ND
1/7/92	ND
2/4/92	ND
2/28/92	<0.500
3/3/92	ND
2/25/92 *	<2
4/28/92	ND
5/5/92	ND
6/2/92	<0.500
7/1/92	ND
8/4/92	ND
9/1/92	ND
10/1/92	ND
11/3/92	ND
12/1/92	ND
1/5/93	ND
2/3/93	0.600
3/2/93	ND
4/1/93	ND
5/4/93	ND
6/2/93	ND
7/1/93	ND
8/3/93	ND
11/24/93 *	<1

Notes
(*) E&E RI data

ND: non detected
Detection Level: 0.5 ug/L

pcl 5/13/94
[RISK_AST.XLW]PCE_EFF.XLS

Table 2-4

Phase I and II RI PCE Monitoring Well Concentrations

Monitoring Well	Phase I (3/92) PCE Concentration (ug/L)	Phase II (11/93) PCE Concentration (ug/L)
1	71	340
2	47	51
3	900	4,200
4	2,800	1,500

3. EXPOSURE ASSESSMENT

The objective of the exposure assessment was to estimate the magnitude, frequency, duration, and routes of human exposure to site-related chemicals. Accomplishing this objective involved the following tasks:

- Characterizing the exposure setting including the physical environment and potentially exposed populations.
- Identifying the exposure pathways including contaminant sources and releases, exposure points, and exposure routes.
- Quantifying the exposure including exposure concentrations and intake variables.

The results are expressed as the daily dose of each COPC (per body weight) calculated independently for each of the exposure pathways investigated.

3.1 EXPOSURE SETTING

3.1.1 Physical Setting

The basic physical features of the site were discussed in Section 1.1. The site and surrounding area are both residential and commercial (Figure 1-1). They are zoned for both low- and medium-density residential (R-1 and R-2) and heavy and light business (C-1 and C-2) (City of Modesto Planning Office 1993). To a large extent, the area around the site is R-1 and C-2. The primary businesses on Griswold and West Fairmont avenues are the Elk's Club, Halford's Cleaners, several automobile dealerships, and the Stanislaus Integrated Service Agency (SISA) Community Center. Most of the surface of the site is paved with asphalt or concrete except for the yards of residences.

3.1.2 Characteristics of PCE Contamination

PCE is the primary COPC and was detected in groundwater at levels above the state and federal maximum contaminant levels (MCLs). Known sources of PCE contamination in the study area include current and former drycleaning operations that discharge to sewer lines. PCE is denser than and moderately soluble in water (up to 150 mg/l at 25°C). It has a moderate to high soil mobility and exhibits little soil affinity, i.e., the chemical does not readily sorb onto soil particles (PHS 1987). PCE, therefore, tends to leach into groundwater and migrate vertically through the saturated zone until a low-permeability layer such as a clay bed is encountered. Depending on the rate of PCE migration and the mineralogy and lithology of the low-permeability layer, a fraction of the undissolved PCE (i.e., pure product) can remain adsorbed in the upper portion of the low-permeability layer, or the PCE can continue to migrate vertically along the low-permeability layer.

PCE is a relatively volatile chemical, evaporating readily. The Henry's Law constant for PCE, which relates to its volatilization from water, is 2.3×10^{-2} atmosphere cubic meters per mole (atm-m^3/mol). This value is similar to that of other volatile gasoline-type hydrocarbons such as benzene as well as the other two COPCs, *cis*-1,2-DCE and TCE. Thus, soil VOC concentrations were expected to be low as was observed (Section 2.1.3). In addition, surface soil concentrations are expected to remain low as the plume migrates, assuming steady-state conditions. The paving over much of the surface area at the site also limits volatilization.

Although direct discharges of PCE to the environment are generally not well documented, recent studies support the concept of contamination from sewer lines. According to the Central Valley RWQCB (1992), there are five possible mechanisms by which PCE can be released from sewer lines:

- Through breaks or cracks in pipes.
- Through pipe joints and other connections.
- By leaching in liquid form directly through pipes into the vadose zone.
- By saturation of the bottoms of pipes with a liquid containing a high concentration of PCE and then volatilization of PCE from the outer surfaces of the pipes into the soil.
- By penetrating pipes as a gas.

The report stated that all sewer lines leak to some extent and that the last three mechanisms listed probably occur in all pipes.

Whether PCE is discharged directly to the environment or leaks from sewer lines, it subsequently migrates through the vadose zone to the saturated zone. PCE separates into three phases upon entering the subsurface environment: a vapor phase that migrates through the vadose zone, a dissolved (miscible) phase entrained in groundwater that migrates according to groundwater flow patterns, and an undissolved (immiscible) phase that sinks through the unsaturated and saturated zones.

3.1.3 Potentially Exposed Populations

The people living on site or in the immediate vicinity are considered primary receptors. Long-time residents are considered to have the greatest risk since potential carcinogenic risk is based on a cumulative exposure. To a lesser extent, employees of nearby businesses are also potentially exposed to the COPCs at the site. Such employees likely work eight-hour shifts five to six days per week. The Elks Club patrons who use the asphalt parking lot likely have minimal exposure to PCE. When the estimated risk to the long-time residents who have greater potential exposure is insignificant, the risk to other receptors with less potential exposure is also insignificant.

3.2 IDENTIFICATION OF EXPOSURE PATHWAYS

An exposure pathway is the means by which an individual or population is exposed to a chemical originating from a given source. Each pathway represents a different mechanism of exposure. Pathways include incidental dermal contact with soil, inhalation of soil dust or vapors, and ingestion of groundwater or surface water. The route of exposure is the method of entry of a chemical into the body such as inhalation, ingestion, or dermal contact. As described in EPA guidance on exposure assessments, four elements comprise an exposure pathway (EPA 1989b, 1988):

- Source and mechanism of chemical release
- Retention or transport medium (air, soil, or water)
- Point of potential human contact with the contaminated medium
- Route of entry into the body at the point of contact.

Potential exposure pathways are evaluated for these four elements, and pathways found to be complete, i.e., that have all four elements, are then evaluated for potential risk. The sections below discuss the rationale for eliminating or retaining exposure pathways for further risk evaluation.

3.2.1 Incomplete Pathways

During the Phase I RI, soil samples were collected at 10-foot intervals during the installation of four monitoring wells to about 100 feet bgs. The samples were analyzed for PCE, but those collected below 15 feet bgs were not quantitatively evaluated since resident contact with such deep soils is unlikely. Overall, the maximum detected PCE concentration was 0.230 mg/kg at 90 feet bgs the boring for Well MW-4. Both of these values are below the residential PRG for soils of 22 mg/kg (EPA 1994b). As discussed in Section 3.1.2, low PCE soil concentrations are characteristic of high-volatility, low-soil-affinity VOCs. The pathways associated with soils (i.e., dermal contact, inhalation of soil dust, ingestion of vegetables, and incidental soil ingestion) were, therefore, considered negligible and not evaluated further.

The inhalation of soil gas vapors outdoors is not expected to significantly impact human health for several reasons:

- Unlike in buildings where soil gases might accumulate, soil gases released to ambient outside air will largely disperse into the atmosphere.
- The inhalation rate for an individual outdoors (5 m^3/day) is only one-third of the inhalation rate indoors (15 m^3/day), reducing exposure and hence the risk proportionally.
- Most of the site is paved with asphalt or concrete, which will limit the mobilization of soil gases.
- Indoor air inhalation risk values (see Section 5.3), based on more conservative exposure parameters than outdoor inhalation exposure scenarios, are not significantly large.

Dermal contact with contaminated soil was not evaluated in this risk assessment because of the high degree of uncertainty associated with this pathway. These uncertainties are discussed in detail in Section 5.2.4.

3.2.2 Complete Pathways

The potentially complete pathways under current site conditions were, therefore, considered to be:

- Indoor inhalation of vapors emanating from contaminated soil.
- Inhalation of vapors emanating from contaminated groundwater used during household activities (e.g., showering and dish washing).
- Ingestion of contaminated groundwater.

These potential pathways are depicted schematically in Figure 3-1. Because this baseline risk assessment was designed to be a representative characterization of the site, pathways were selected to reflect the range of exposures. Those considered were exposure pathways for adult residents. Industrial exposure pathways were not evaluated since residential scenarios are more conservative and therefore yield higher risk values.

Current zoning suggests that land use is unlikely to change significantly in the future; however, additional drinking water wells could be installed on site if future residential development occurs. A future residential scenario was, therefore, evaluated using the VOC concentrations in the monitoring wells; it is discussed in greater detail in the next section.

3.3 QUANTITATIVE ASSESSMENT OF EXPOSURE

This section describes how the quantitative exposure values were derived from the site data presented in Section 3.3.1 and how the average daily intakes were calculated for each pathway.

Average and RME residential exposure pathways were evaluated for three different scenarios:

- **Current, treated:** Inhalation risks were calculated using Phase II RI soil gas data. For the groundwater pathway, PCE exposure-point concentrations were calculated using the latest two years of treated (effluent) groundwater data.
- **Current, untreated:** Again, inhalation risks were calculated using Phase II RI soil gas data. PCE exposure-point concentrations were calculated using the latest two years of untreated (influent) groundwater data.

- **Future:** Analytical data for the four monitoring wells were used to evaluate potential risks from residential usage of groundwater assuming the installation of drinking water wells on site. Groundwater ingestion and inhalation risks were determined. The inhalation of soil gas under current scenarios was used to estimate future inhalation risks.

According to EPA (1989b, 1992a), both the RME and average (central tendency) exposure calculations should be used in Superfund risk assessments. The RME is defined as the highest exposure that could reasonably be expected to occur by a given exposure pathway at a site; it is intended to account for both uncertainty in the contaminant concentration and variability in exposure parameters such as exposure frequency or averaging time. The RME, sometimes called the "high-end" risk, characterizes the risk to an individual "at the upper end of the risk distribution at approximately the 90th percentile of the population distribution" (EPA 1992c). The goal of the RME approach is to combine upper-bound and mid-range exposure factors to estimate exposures that are both protective and reasonable but not worst-case (EPA 1991b).

The central tendency (CT), on the other hand, incorporates the arithmetic mean source term concentration and default exposure factors approximating the average or 50th percentile value. The arithmetic mean is simply the sum of the concentrations divided by the total number of concentration values.

Because of the uncertainty associated with estimating the true average concentration at a site, the 95% upper confidence limit (UCL) of the arithmetic mean is used for the concentration term in the RME calculations. The 95% UCL provides reasonable confidence that the true site average will not be underestimated (EPA 1989b, 1992a). This estimate of the average concentration is also used because carcinogenic and chronic noncarcinogenic toxicity criteria are based on lifetime average exposures and because average concentrations are most representative of the concentration that would be contacted at a site over an extended period of time.

The W-test was used to determine whether medium-specific data sets were consistent with a normal or log normal distribution (Gilbert 1987). A normal distribution is typically described as a bell-shaped curve whereas a log normal distribution peaks closer to zero and is skewed toward the x-axis. This test was performed using a computerized statistical software package, Statistica™ (StatSoft 1993).

In general, both groundwater and soil gas data were log normally distributed; therefore, the UCL was calculated as:

$$UCL = \exp[x + 0.5s + \frac{sH_{\alpha-1}}{\sqrt{n-1}}]$$

where x is the mean concentration, s is the standard deviation, n is the number of samples, and $H_{\alpha-1}$ is the one-sided upper 95% UCL (Gilbert 1987).

3.3.1 Exposure Concentrations

3.3.1.1 Groundwater Ingestion and Inhalation Concentrations

Exposure-point concentrations for the combined groundwater ingestion and inhalation pathway assessment were derived from the City of Modesto quarterly groundwater and Phase I and II RI data sets. The City of Modesto data for PCE was collected from May 1985 to July 1, 1993. For the current, treated drinking water exposure scenario, the data were from the last two years of monthly sampling (August 1, 1991, to July 1, 1993) plus data collected during the Phase I and II RI. For the current, untreated drinking water scenario, PCE concentrations were obtained from the treated water data, which consisted mostly of non-detected values and where one-half the detection limit was used to estimate the average concentration. The 95% UCL could not be generated since the data did not fit log normal or normal distributions. Finally, for the future scenario, monitoring well data from the Phase I and II RI were used to develop exposure point concentrations. Again, 95% UCL concentrations could not be generated from these data because of the limited number of data points (eight) and the highly variable concentrations (1 to 4,200 μg/L). In these cases, the maximum concentration was used to estimate the RME exposure concentration (EPA 1989b). A single equation (see Section 3.3.5) was used to estimate exposure from groundwater through the inhalation and ingestion pathways. The resulting exposure point concentrations are given in Table 3.3.

3.3.1.2 Indoor Air Concentrations

The results for the Phase II RI Summa canister soil gas samples were used to calculate exposure-point concentrations for the indoor inhalation route of exposure. Since the calculated 95% UCL for PCE was greater than the maximum concentration, the maximum concentration was used instead for the RME scenario per EPA guidance (EPA 1989b).

Soil gas sampling data were input to the Farmers Model, a predictive model used to estimate the indoor air concentration (EPA 1992b). The Farmers Model was originally developed to estimate emission rates from covered landfills experiencing internal gas generation as described in the EPA (1986) *Superfund Exposure Assessment Manual* (SEAM). The SEAM's model differs from the Farmer's Model in assuming completely dry soil and containing an explicit surface area term for estimating soil gas concentration from waste decomposition. The Farmers Model can be used to calculate emissions from chemicals dissolved in groundwater or in contaminated soil. It assumes that the chemical concentration in the soil does not decrease as the contaminant migrates upward (i.e., no microbiological degradation) and that the depth to the top of the pollutant source remains constant.

In this risk assessment, EPA (1989a) screening parameter values were used as model inputs. For example, the fraction of the floor that is accessible to intrusion was assigned a value of 50%, and the building exchange rate was assigned a value of 0.25 change per hour. The building volume was assumed to be $\approx$35,000 ft^3, and the building area was assumed to be $\approx$2,100 ft^2, which are typical of California home dimensions. Additional details and results are in Appendix A.

3.3.2 Intake Rates

All exposure parameter values used in this risk assessment were obtained from EPA sources or guidance documents. The average and RME ingestion rates used were 1.4 and 2 L/day (EPA 1989d, 1991b). Typically, 20 m^3/day is used as the inhalation rate, which assumes 15 m^3/day indoors and 5 m^3/day outdoors (EPA 1991b). Since this assessment was based on indoor exposure, 15 m^3/day was used in the inhalation exposure calculations for both average and RME exposures. The exposure parameters are given in Table 3-1 and discussed in more detail below.

3.3.3 Duration and Frequency of Exposure

The exposure duration over which chemical intake may occur is based on assumptions about the exposure period and the averaging time. The frequency of exposure is the proportion of time that residents might be exposed to soil gas vapors or groundwater (e.g., 350 days per year), whereas the exposure duration is the total amount of time that residents might be exposed (e.g., 30 years). For both the inhalation of soil vapors and ingestion and inhalation of groundwater, 350 days/year was used as the exposure frequency for the average and RME scenarios except 275 days/year was used for the average inhalation frequency of exposure scenario (EPA 1989d, 1991b).

The dose for evaluating carcinogenic effects is calculated differently from the dose for noncarcinogenic effects (EPA 1989b). In calculating the lifetime dose for assessing carcinogenic effects, the period of exposure is prorated over the life span (e.g., 30 years divided by 70 years). For noncarcinogenic effects, however, the dose is calculated as the daily dose averaged over the period of exposure and not prorated over the life span.

The RME and average exposure scenarios assume continuous 30-year exposure for all pathways of exposure from childhood to age 30, which was determined to be a conservative estimate of the RME on the basis of population statistics (EPA 1991b). For the average exposure scenario, nine years was assumed on the basis of the average residence time reported by EPA (1989d).

3.3.4 Body Weight

For all exposure scenarios, a standard lifetime body weight of 70 kg was assumed for all ages (EPA 1991b). This value is commonly used as the average adult body weight.

3.3.5 Calculation of Dose and Risk

Health risk is determined from the amount of chemical taken up by the body at the exposure-point concentration. Intake rates are expressed in milligrams per kilogram of body weight per day (mg/kg-day). For the inhalation pathway, exposure is calculated as (EPA 1989b):

$$Intake = \frac{CW \ x \ IR \ x \ ET \ x \ EF \ x \ ED}{BW \ x \ AT}$$

where

CW = chemical concentration in air ($\mu g/m^3$)
IR = inhalation rate (m^3/hour)
ET = exposure time (hours/day)
EF = exposure frequency (day/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = period over which exposure is averaged (day).

For carcinogens, risk is estimated by multiplying the intake by the slope factor (SF), which accounts for a chemical's toxicity. The SF has units of $(\text{mg/kg-day})^{-1}$, which corresponds to an inverse dose (mg) per unit body weight (kg) per unit time (day). SFs are derived from animal studies and are discussed in more detail in Section 4.0. In general, carcinogenic risk is the probability of an incremental increase in the likelihood of cancer over a lifetime exposure. Somewhat analogous to the SF used to calculate carcinogenic risk, the reference dose (RfD) represents the toxicity of noncarcinogenic compounds. The SF and RfD terms are introduced in this section since they are incorporated into the groundwater risk equations presented below. The equations, exposure parameters, and dose/risk calculations for the inhalation pathways are shown in Table 3-2.

Under residential land use, the risk from contaminated groundwater is primarily due to direct ingestion and inhalation of volatile chemicals released from the water during household activities such as showering and dishwashing. According to EPA guidance (1991c), the inhalation and ingestion of volatile chemicals can be evaluated simultaneously when the COPC has a Henry's Law constant greater than 10 atm-m^3/mole and a molecular weight less than 200 g/mole. PCE meets these criteria so the following equations were used. The equation to calculate carcinogenic risk incorporates two terms to account for the groundwater ingestion and inhalation pathways (EPA 1991c):

$$Risk = \frac{EF \ x \ ED \ x \ C \ x \ [(SF_o \ x \ IR_w) + (SF_i \ x \ K \ x \ IR_a)]}{BW \ x \ AT \ x \ 365 days/yr}$$

where

C = chemical concentration in water (mg/L)

IR_a = indoor inhalation rate (m^3/day)

IR_w = water ingestion rate (L/day)

SF_i = inhalation slope factor (kg-day/mg)

SF_o = oral slope factor (kg-day/mg)

EF = exposure frequency (days/year)

ED = exposure duration (years)

K = volatilization factor (unitless)

BW = body weight (kg)

AT = period over which exposure is averaged (day).

Primarily on the basis of experimental data for the volatilization of radon from household uses of water, Andelman (1990) derived an equation that defines the relationship between the concentration of a contaminant in household water and the average concentration of the volatilized contaminant in air. In the derivation, all uses of household water were considered including showering, laundering, and dishwashing. The equation uses a default volatilization constant (K) upper-bound value of 0.0005 x 1,000 L/m^3. The 1,000 L/m^3 factor converts the air concentration to a water concentration.

In cases where the chemical intakes produced risks greater than 10^{-2}, the one-hit equation was used to calculate carcinogenic risks (EPA 1989b). This equation, risk = 1 - exp(-CDI x SF), is consistent with the linear low-dose model.

CDI is the chronic daily intake averaged over 70 years. For noncarcinogens, an analogous equation was used:

$$Hazard\ Index = \frac{EF\ x\ ED\ x\ C\ [(1/RfD_o\ x\ IR_w) + (1/RfD_i\ x\ IR_a)]}{BW\ x\ AT\ x\ 365 days/yr}$$

where

RfD_o = oral chronic reference dose (mg/kg-day)

RfD_i = inhalation chronic reference dose (mg/kg-day).

These equations, exposure parameters, and dose/risk calculations are shown in Table 3-3.

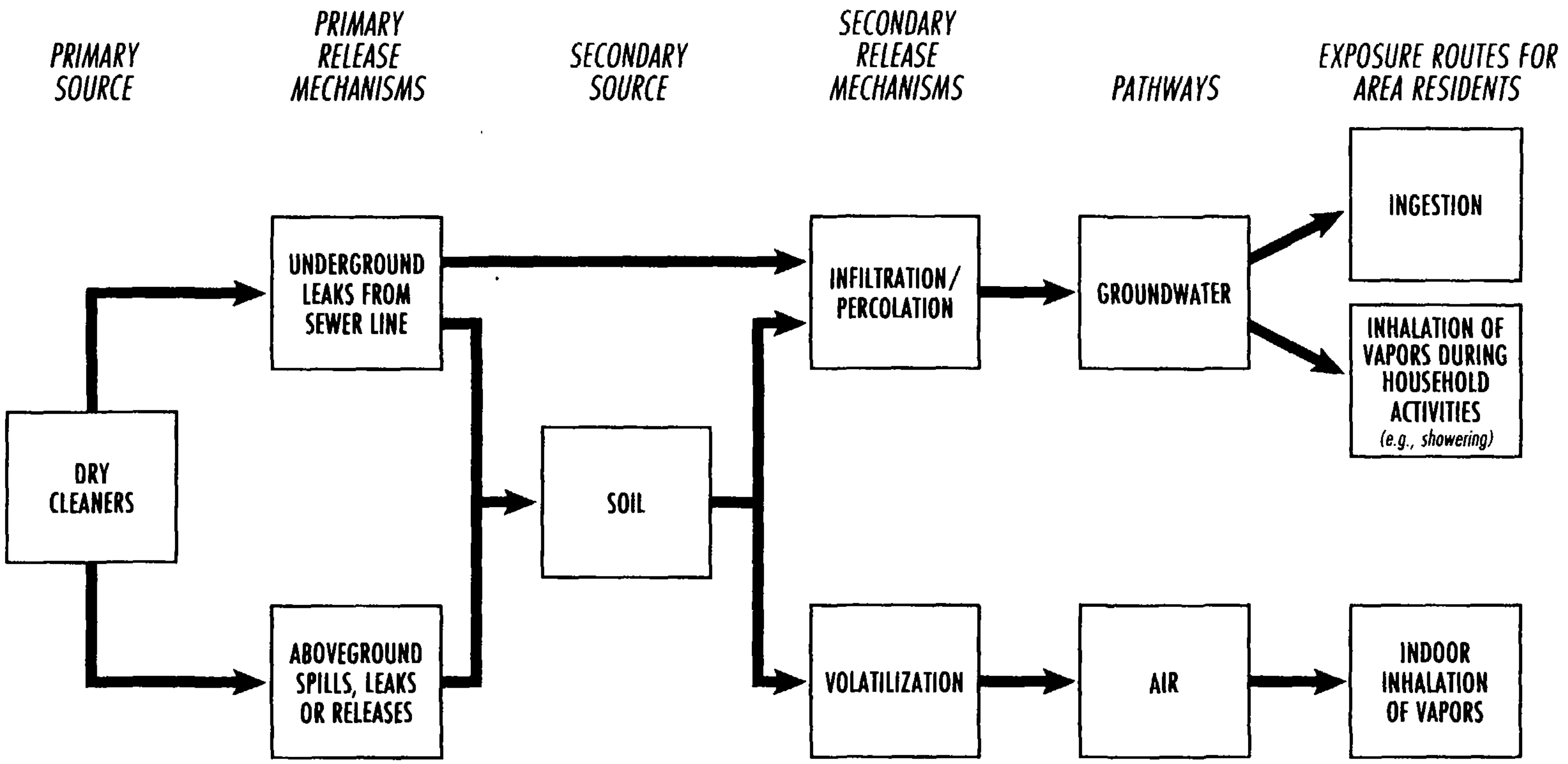


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Figure 3-1

CONCEPTUAL EXPOSURE MODEL

Modesto Groundwater

Modesto, California

Table 3-1

Exposure Parameters

Groundwater Ingestion Pathway

Variable	Describtion	Value	Units	Reference
CW	Chemical Concentration in Water	--	ug/L	--
IR	Ingestion Rate (average, RME)	1.4, 2	L/day	EPA 1989d, 1991a
EF	Exposure Frequency	350	days/year	EPA 1991a
ED	Exposure Duration (average, RME)	9, 30	years	EPA 1989d, 1991a
BW	Body Weight	70	kg	EPA 1991a
AT	Averaging Time - Carcinogens	25,550	days	EPA 1991a
AT	Averaging Time - Nonarcinogens	10,950	days	EPA 1991a

Inhalation Pathways

Variable	Describtion	Value	Units	Reference
CA	Chemical Concentration in Air	-	ug/m3	--
IR	Inhalation Rate: (15 m3/day) / (24 hrs/day)	0.63	m3/hour	EPA 1991a
ET	Exposure Time	24	hrs/day	EPA 1991a
EF	Exposure Frequency (average, RME)	275, 350	days/year	EPA 1989d, 1991a
ED	Exposure Duration (average, RME)	9, 30	years	EPA 1989d, 1991a
CF	Conversion Factor	1E-03	mg/ug	--
BW	Body Weight	70	kg	EPA 1991a
AT	Averaging Time - Carcinogens	25,550	days	EPA 1991a
AT	Averaging Time - Nonarcinogens	10,950	days	EPA 1991a

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Table 3-2
Inhalation Exposure/Risk Using Farmers Model Results

Equation

Intake (mg/kg-day) = (CA)(IR)(ET)(EF)(ED)(CF) / (BW)(AT)

Parameters

CA = Chemical Concentration in Air Estimated by Farmer Model (ug/m3)
IR = Inhalation Rate (m3/hour)
ET = Exposure Time (hours/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
CF = Conversion Factor (1E-3 mg/ug)
BW = Body Weight (kg)
AT = Averaging Time (Period over which exposure is averaged - days)

Carcinogens

Chemical	CA ug/m3	IR m3/hour	ET hours/day	EF day/yr	ED years	CF mg/ug	BW kg	AT days	Intake mg/kg-day	Slope Factor (mg/kg-day)^-1	Risk
PCE - ave	20.7	0.63	24	275	9	1E-03	70	25,550	4.3E-4	2.0E-3 (1)	8.7E-7
TCE - ave	0.4	0.63	24	275	9	1E-03	70	25,550	8.3E-6	6.0E-3 (1)	5.0E-8
1,2-DCE - ave	0.1	0.63	24	275	9	1E-03	70	25,550	2.3E-6	--	--
PCE - max	57.1	0.63	24	350	30	1E-03	70	25,550	5.1E-3	2.0E-3 (1)	1.0E-5
TCE - UCL	2.5	0.63	24	350	30	1E-03	70	25,550	2.3E-4	6.0E-3 (1)	1.4E-6
1,2-DCE - UCL	1.0	0.63	24	350	30	1E-03	70	25,550	8.8E-5	--	--

Subtotals *Average* *9.2E-7*
RME *1.1E-5*

Noncarcinogens

Chemical	CA ug/m3	IR m3/hour	ET hours/day	EF day/yr	ED years	CF mg/ug	BW kg	AT days	Intake mg/kg-day	Inhal RfD (mg/kg-day)	Hazard Index
PCE - ave	20.7	0.63	24	275	9	1E-03	70	3,285	3.4E-3	1.0E-2 (2)	0.3
TCE - ave	0.40	0.63	24	275	9	1E-03	70	3,285	6.4E-5	6.0E-3 (1)	0.01
1,2-DCE - ave	0.1	0.63	24	275	9	1E-03	70	3,285	1.8E-5	9.0E-3 (3)	0.002
PCE - max	57.1	0.63	24	350	30	1E-03	70	10,950	1.2E-2	1.0E-2 (2)	1.2
TCE - UCL	2.5	0.63	24	350	30	1E-03	70	10,950	5.3E-4	6.0E-3 (1)	0.09
1,2-DCE - UCL	1.0	0.63	24	350	30	1E-03	70	10,950	2.0E-4	9.0E-3 (3)	0.02

Subtotals *Average* *0.35*
RME *1.29*

Footnotes

(1) From EPA - ECAO
(2) Route-to-route extraplolation
(3) HEAST

Abbreviations

PCE : Tetrachloroethylene
TCE: trichloroethylene
1,2-DCE: cis-1,2-dichloroethylene

Table 3-3

Ingestion and Inhalation of Volatiles in Groundwater

From Risk Assessment Guidance for Superfund: Volume I (Part B, Development of Risk-Based Preliminary Remediation Goals)
Publication 9285.7-01B, December 1991.

$$\text{Risk} = \text{SFo} \times (\text{Intake from ingestion of water}) + \text{SFi} \times (\text{Intake from inhalation of volatiles in water})$$

$$= \frac{\text{SFo} \times \text{C} \times \text{IRw} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT} \times 365\ \text{days/yr}} + \frac{\text{SFi} \times \text{C} \times \text{K} \times \text{IRa} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT} \times 365\ \text{days/yr}}$$

$$= \frac{\text{EF} \times \text{ED} \times \text{C} \times [(\text{SFo} \times \text{IRw}) + (\text{SFi} \times \text{K} \times \text{IRa})]}{\text{BW} \times \text{AT} \times 365\ \text{days/yr}}$$

where,

C: chemical concentration in water (mg/L)
SFi: inhalation slope factor (mg/kg-day)^-1
SFo: oral cancer slope factor (mg/kg-day)^-1
BW: adult body weight (kg)
AT: averaging time (yr)

EF: exposure frequency (days/year)
ED: exposure duration (yr)
IRa: indoor inhalation rate (m3/day)
IRw: daily water ingestion rate (L/day)
K: volatiozation factor (unitless)

Chemical	C ug/L	C- mg/L	EF days/yr	ED yr	IRa m3/day	IRw L/day	SFo (mg/kg-day)^-1	SFi (mg/kg-day)^-1	K --	BW kg	AT yr	Risk
PCE - (Untrtd, UCL)	30.4	3.0E-2	350	30	0.63	2	5.5E-2 (e)	2.0E-3 (e)	0.5	70	70	3.2E-5
PCE - (Untrtd ave)	10.3	1.0E-2	350	9	0.63	1.4	5.5E-2 (e)	2.0E-3 (e)	0.5	70	70	2.5E-6
PCE - (Trtd, ave)	0.47	4.7E-4	350	9	0.63	1.4	5.5E-2 (e)	2.0E-3 (e)	0.5	70	70	5.3E-9
PCE - (Trtd, max)	0.60	6.0E-4	350	30	0.63	2	5.5E-2 (e)	2.0E-3 (e)	0.5	70	70	1.2E-8
PCE - (MW,ave)	1,239	1.2	350	9	0.63	1.4	5.5E-2 (e)	2.0E-3 (e)	0.5	70	70	3.6E-2
chlorfm - (MW, ave)	0.56	5.6E-4	350	9	0.63	1.4	6.1E-3 (i)	8.05E-2 (i)	0.5	70	70	7.6E-9
TCE (MW,ave)	5.4	5.4E-3	350	9	0.63	1.4	1.1E-2 (e)	6.0E-3 (e)	0.5	70	70	7.1E-7
PCE - (MW,max)	4,200	4.2	350	30	0.63	2	5.5E-2 (e)	2.0E-3 (e)	0.5	70	70	4.6E-1
chlorfm - (MW, max)	1	1.0E-3	350	30	0.63	2	6.1E-3 (i)	8.05E-2 (i)	0.5	70	70	3.5E-8
TCE (MW,max)	34	3.4E-2	350	30	0.63	2	1.1E-2 (e)	6.0E-3 (e)	0.5	70	70	4.0E-5

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Table 3-3 (cont)

Noncarcinogens

$$\text{Risk} = \frac{EF \times ED \times C \times [(1/RfDo \times IRw) + (1/RfDi \times K \times IRa)]}{BW \times AT \times 365 \text{ days/yr}}$$

Chemical	C ug/L	C_ mg/L	EF days/yr	ED yr	IRa m3/day	IRw L/day	RfDo (mg/kg-day)	RfDi (mg/kg-day)	K --	BW kg	AT yr	Hazard Index
PCE - (Untrtd, UCL)	30.4	3.0E-2	350	30	0.63	2	1.0E-2 (i)	1.0E-2 (r)	0.5	70	70	2.4E-3
PCE - (Untrtd ave)	10.3	1.0E-2	350	9	0.63	1.4	1.0E-2 (i)	1.0E-2 (r)	0.5	70	70	2.1E-4
PCE - (Trtd, ave)	0.47	4.7E-4	350	9	0.63	1.4	1.0E-2 (i)	1.0E-2 (r)	0.5	70	70	4.4E-7
PCE - (Trtd, max)	0.60	6.0E-4	350	30	0.63	2	1.0E-2 (i)	1.0E-2 (r)	0.5	70	70	9.2E-7
PCE - (MW,ave)	1239	1.2	350	9	0.63	1.4	1.0E-2 (i)	1.0E-2 (r)	0.5	70	70	3.0E+0
chlorfm - (MW, ave)	0.6	5.6E-4	350	9	0.63	1.4	1.0E-2 (i)	---	0.5	70	70	5.4E-7
TCE (MW,ave)	5.4	5.4E-3	350	9	0.63	1.4	6.0E-3 (e)	6.0E-3 (r)	0.5	70	70	9.1E-5
PCE - (MW,max)	4200	4.2	350	30	0.63	2	1.0E-2 (i)	1.0E-2 (r)	0.5	70	70	4.5E+1
chlorfm - (MW, max)	1	1.0E-3	350	30	0.63	2	1.0E-2 (i)	---	0.5	70	70	1.7E-6
TCE (MW,max)	34	3.4E-2	350	30	0.63	2	6.0E-3 (e)	6.0E-3 (r)	0.5	70	70	4.3E-3

Footnotes

i: IRIS
h: HEAST
e: ECAO
r: route-to-route
NA: Not available

PCE : Tetrachloroethylene
cis 1,2-DCE : cis 1,2-dichloroethylene
1,1,1-TCA : 1,1,1-trichloroethane
TCE: trichloroethylene

untrtd: untreated groundwater
trtd: treated groundwater
MW: monitoring well

4. TOXICITY ASSESSMENT

The purpose of the toxicity assessment was to develop toxicity and carcinogenicity data for the COPCs and to estimate the relationship between the extent of exposure and the likelihood and severity of adverse effects. The toxicity assessment was accomplished in two steps, a hazard identification and a dose-response assessment, which are discussed in detail in the following subsections. The dose-response assessment process results in a risk probability that indicates the potential to cause adverse effects on human health as a result of exposure on site.

The COPCs evaluated in this risk assessment can be classified in one of two groups, noncarcinogens and probable human carcinogens, on the basis of guidance contained in an online database system called the Integrated Risk Information System (IRIS 1994). This section presents a brief toxicity profile for each of the COPCs. Health risk assessment information on a chemical is included in IRIS only after a comprehensive review of chronic toxicity data by work groups composed of EPA scientists from several program offices. Of the COPCs, only PCE and chloroform have IRIS-approved values; all other toxicity values used in this assessment are from EPA Region IX guidance (1993), which cites the Health Effects Assessment Summary Tables (HEAST) and the EPA Environmental Criteria and Assessment Office (ECAO) references or uses route-to-route extrapolation.

4.1 PCE TOXICITY

PCE is a synthetic VOC widely used in drycleaning, metal-degreasing, and the manufacture of chemicals. It can be found in many household products including suede protectors, water repellents, spot removers, and wood cleaners. Most PCE released surface soil or surface water will rapidly evaporate. PCE is moderately soluble in water, biodegrades slowly in groundwater, and has medium to high mobility in soil (USDHHS 1987). Under anaerobic conditions (i.e., without oxygen), PCE has been reported to break down to DCE, TCE, and vinyl chloride (Vogel and McCarty 1985). Others have reported that PCE does not undergo significant biodegradation under aerobic conditions (Bouwer *et al. 1982*). Detectable background levels of PCE frequently occur in air and less frequently in drinking water. Exposure to PCE may occur by breathing contaminated air or ingesting contaminated food or water. For the general public, inhalation is the most likely route of exposure.

4.1.1 Noncarcinogenic Effects of PCE

Exposure to high concentrations of PCE in air, particularly in confined areas, can cause acute effects on the central nervous system such as dizziness, headache, sleepiness, confusion, nausea, and possibly unconsciousness and death. Animal studies conducted with concentrations much higher than those usually encountered in the environment suggest that PCE can cause liver and kidney damage, developmental effects on fetuses, and toxicity to pregnant animals (IRIS, 1993). Liver toxicity is the most critical effect and serves as the basis for the RfD used in the risk assessment.

The RfD is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate, with uncertainty spanning perhaps an order of magnitude, of the daily exposure to the human population including sensitive subgroups that is likely to be encountered without an appreciable risk of deleterious effects during a lifetime (IRIS 1993). RfDs can also be derived for the noncarcinogenic health effects of compounds that are also carcinogens.

An uncertainty factor of 1,000 was used in calculating the RfD to account for intra- and interspecies variability and extrapolate a subchronic effect level to its chronic equivalent. A medium confidence level was assigned by EPA to the RfD because no one study combines the features desired for deriving an RfD. These features include oral exposure, a large number of animals, multiple dose groups, testing in both sexes, and chronic exposure (IRIS 1993). The toxicity values used in this risk assessment are given in Table 4-1.

4.1.2 Carcinogenic Effects of PCE

PCE causes liver and kidney cancer in mice and rats. There are conflicting results from studies of human PCE exposure in relationship to increased cancer risk. EPA classified PCE as a Group B2 carcinogen, meaning that sufficient evidence exists in animals but inadequate evidence in humans. This classification is currently under review, and a final decision on whether this substance should be classified in Group B2 or C has not been made

(IRIS 1993). PCE is currently being reviewed by an interoffice EPA work group, and a risk assessment summary will be included in IRIS when the review has been completed (IRIS 1993). For this risk assessment, the toxicity values in Table 4-1 were used to estimate risk.

4.2 TCE TOXICITY

TCE is a synthetic widely used as a cleaning agent and solvent in degreasing operations. TCE may also occur in drinking water supplies and consumer products including metal cleaners, spot removers, rug cleaning fluids, paints, and paint removers. Most TCE released into surface water or surface soil will evaporate rapidly. In the subsurface, TCE is moderately to highly mobile and can migrate to groundwater. TCE biodegrades very slowly in subsurface soils and groundwater, and microbial degradation products may include dichloroethylene and vinyl chloride. Humans are most likely to be exposed to TCE in air.

4.2.1 Noncarcinogenic Effects of TCE

TCE may cause adverse health effects following exposure via inhalation, ingestion, or skin or eye contact. Exposure to high levels of TCE can cause central nervous system disorders including drowsiness, dizziness, headache, blurred vision, tremors, lack of coordination, and mental confusion. Other effects include flushed skin, nausea, vomiting, fatigue, irregular heartbeat, and, in some cases, death. In the past, TCE was used as an anesthetic, but this use was discontinued when TCE was found to cause irregular heartbeats. Chronic exposure to TCE can cause liver damage and skin reactions as well as central nervous system effects.

4.2.2 Carcinogenic Effects of TCE

The exposure of laboratory animals to TCE has been associated with an increased incidence of a variety of tumors including kidney, liver, and lung cancers; however, it is uncertain whether people exposed to TCE have a higher risk of cancer. TCE is classified in Group B2, meaning sufficient evidence exists in animals but inadequate evidence in humans. This designation is currently undergoing review. The toxicity values used in this risk assessment are shown in Table 4-1.

4.3 *Cis*-1,2-DCE TOXICITY

Cis-1,2-DCE is a flammable liquid with a sharp, harsh odor. It is used primarily in the production of solvents and as an additive to dyes, lacquer solutions, perfumes, and thermoplastics. There are two forms of 1,2-DCE — *cis*-1,2-DCE and *trans*-1,2-DCE — which may occur separately or as a mixture. In the environment, both forms of 1,2-DCE evaporate rapidly. When *cis*-1,2-DCE occurs underground in landfills or chemical waste sites, it can dissolve in water and migrate into groundwater where it can degrade to vinyl chloride. *Cis*-1,2-DCE can enter the body by drinking water, eating food, or breathing air that contains the compound. Because it evaporates readily, inhalation is the most likely route of human exposure.

4.3.1 Noncarcinogenic Effects of *cis*-1,2-DCE

The inhalation of high levels of *cis*-1,2-DCE can cause nausea, drowsiness, dizziness, and even death. Liver, heart, and lung damage were observed in laboratory animals after short- and long-term exposures to *cis*-1,2-DCE in air. Liver and lung damage was also reported in animals fed *cis*-1,2-DCE, and death can occur in animals fed large amounts of *cis*-1,2-DCE. Changes in blood chemistry are the most critical effects and the basis of the RfD used in this risk assessment.

4.3.2 Carcinogenic Effects of *cis*-1,2-DCE

The long-term health effects resulting from exposure to *cis*-1,2-DCE are unknown. It is classified in Group D, meaning not classifiable as to human carcinogenicity. An increased risk of cancer has not been reported in humans or animals exposed to *cis*-1,2-DCE.

4.4 TOXICITY ASSESSMENT SUMMARY

The toxicity values used in this risk assessment are shown in Table 4-1. The "o" and "i" denote ingestion (oral) and inhalation, and the I, E, and H signify the source, IRIS, ECAO, and HEAST, respectively.

Table 4-1

TOXICITY SUMMARY OF COPCs

COPC	oRfD	iRfD	oSF	iSF
PCE	1.0E-2 (I)	1.0E-2 (R)	5.5E-2 (E)	2.0E-3 (E)
TCE	6.0e-3 (E)	6.0E-3 (E)	1.1E-2 (E)	6.0E-3 (E)
cis-1,2-DCE	9.0E-3 (H)	9.0E-3 (H)	___	___

5. RISK CHARACTERIZATION

This section presents the estimates of the magnitude of potential adverse health effects under the various conditions defined in the exposure assessment. The risk characterization integrated all of the information developed during the exposure and toxicity assessments to characterize the overall potential health effects by the different exposure pathways.

5.1 HEALTH IMPACT RISK CALCULATIONS

5.1.1 Carcinogenic Risk

According to EPA (1989b) guidance, carcinogenic risk is the chance of developing cancer due to exposure to a carcinogen; it does not imply death due to cancer. An example of a 1 x 10^{-6} incidental cancer risk is illustrated below. On average, one in every four Americans will develop some form of cancer such as skin cancer from ultraviolet light or lung cancer from smoking at some time during his or her lifetime. This is equivalent to 250,000 cases of cancer for every 1,000,000 people. Thus, a one in 1,000,000 (or 1 x 10^{-6}) incremental cancer risk corresponds to 250,001 cases of cancer for 1,000,000 people. The one theoretical extra case results from the calculated chemical exposure.

The potential risks associated with the various exposure pathways are estimated as the probabilities of excess cancer using the equation:

$$Risk_i = SF \times D_i$$

where

$risk_i$ = the risk associated with pathway *i*

SF = cancer slope factor $(kg\text{-}day/mg)^{-1}$

D_i = dose from pathways *i*, (kg-day/mg).

The potential cumulative health risk associated with exposure via multiple exposure pathways is determined by summing the risks across all exposure pathways:

$$Cancer\ risk = \sum_i risk_i$$

The cumulative risk for all pathways (i) indicates the lifetime probability of excess cancer that may occur through exposure to the COPCs. Equations, exposure parameters, and dose/risk calculations for calculating carcinogenic risk are given in Tables 3-1 through 3-3.

5.1.2 Noncarcinogenic Health Impacts

Noncarcinogenic health impacts are evaluated separately from carcinogenic risks. Unlike carcinogenic effects, noncarcinogenic effects are assumed to have a threshold dose below which no adverse effect is observed. Health risks are therefore evaluated by comparing the calculated daily dose to an EPA RFD. The RFD is calculated from the no adverse effect dose, which considers sensitive populations, after taking into account uncertainties and species differences.

The noncarcinogenic health risk is expressed as the hazard quotient (HQ) calculated as:

$$HQ_i = \frac{D_i}{RfD}$$

where

HQ_i = hazard quotient associated with pathway *i*
D_i = chronic dose from pathway *i* (mg/kg-day)
RfD = reference dose (mg/kg-day).

An HQ greater than 1.0 suggests that exposure to a substance exceeds a generalized level of concern.

Cumulative noncarcinogenic impacts for all relevant pathways of exposure (i) are calculated as:

$$Hazard\ index = \sum_i HQ_i$$

The cumulative hazard index should only be calculated for exposures that affect similar target organs or similar mechanisms. Since the COPCs evaluated in this risk assessment affect kidney and liver systems, it is appropriate to assess their hazard index. A hazard index of 1 or less is generally recognized as the level at which no adverse health effects are expected. Equations, exposure parameters, and risk calculations for noncarcinogens are given in Tables 3-1 through 3-3.

5.2 UNCERTAINTIES

In most risk assessments, numerous assumptions must be made in estimating exposure and chemical toxicity because of a lack of actual data. While such assumptions may not be universally agreed upon, they should be based on sound scientific information and site-specific conditions, and their rationale should be explicitly stated. Uncertainties in the risk assessment process may cause the exposure levels to differ from the exposures that the populations might actually experience. This section identifies these factors, discusses their potential effects on exposure estimates, and presents an estimate of the degree of confidence in the risk assessment results.

5.2.1 Estimated Exposure Media Concentrations

Samples collected during the RI were analyzed to characterize the nature and extent of VOC contamination at the site. Accordingly, sampling locations were selected in a biased or directed manner. As a result, most samples were collected where the highest VOC concentrations were likely to be found. Such sampling provides considerable information about the site, but the results are not statistically representative of the entire study area and tend to overestimate average and RME concentrations. In some cases, because of data limitations, the maximum COPC concentration detected was used to estimate the source concentration (see Section 3.3.1), which results in overestimating risk.

In order to estimate vapor transport, air transport modeling uses many conservative assumptions as discussed in Appendix A. The Farmers Model, for example, ignores attenuation factors, and, therefore, it is "likely that this model overpredicts the contaminate flux," which results in a larger source concentration value and hence a greater degree of potential risk (EPA 1992b).

Chemical degradation, partitioning between groundwater, soil, and air, absorption rates in humans from various routes of exposure, and other physical chemical properties are not taken into account, nor are they well understand for the COPCs. By ignoring such factors, potential risk tends to be overestimated.

5.2.2 Analytical Data Limitations

Two factors associated with analytical data can marginally reduce the level of confidence in the COPC concentrations. First, J-qualified data will not have the same level of accuracy or precision as data meeting all of the standard quality assurance criteria. Second, high analytical detection limits can allow some chemicals to go undetected, which reduces the level of confidence in the calculated upper limit of the potential risk associated with each environmental medium.

As noted in Section 2.1.2, the Phase II RI soil gas survey produced data in both mobile and standard laboratories. The standard laboratory data were used in the exposure estimates because they were higher and therefore more conservative concentrations and because standard laboratory data are generally regarded as higher in quality.

5.2.3 Exposure Estimate Calculations

The exposure parameters used in calculating the exposure estimates were obtained primarily from EPA guidance. These values are intentionally conservative and designed to err on the side of overestimating exposure; therefore, there is considerable uncertainty regarding the actual exposure that a receptor would experience. A major source of uncertainty in the quantitative aspect of risk assessments is the propagation of error. The calculation of risk is a sequential process with assumptions in one calculation carried foreword as assumptions in the next calculation. As a result, the errors are compounded at each step in the assessment.

The RME ingestion of groundwater assumes that residents of all ages drink 2 liters of groundwater almost every day, which may be an overestimate considering the increase in the consumption of bottled water as well as other beverages over the last several years. Furthermore, the future scenario assumes this same quantity of groundwater will be ingested at the site and will come from new drinking water wells installed at the hot spot identified on site.

The amount of uncertainty in risk assessment cannot be easily quantified. In order to accomplish a standard statistical analysis of uncertainty, it is necessary to have a quantitative estimate of the range of uncertainty in each variable and each source as well as information on the underlying statistical distribution of each parameter. At that point, a *Monte Carlo uncertainty analysis* can be performed.

5.2.4 Uncertainties Related to Toxicity Assessment

For carcinogens, the conservative assumption is made that some finite risk is associated with exposure to a single molecule of a compound ("no dose threshold"). EPA slope factors are generally based on linear high-to-low dose extrapolations, and detoxification mechanisms, which significantly reduce the risk of cancer at low doses, are not considered. Moreover, the EPA criteria used for the toxicity assessment and risk characterization steps are inherently conservative. Because of the numerous data gaps involved at all levels, conservative assumptions are multiplied at various stages of these calculations. In addition, chemicals from the site may have synergistic or antagonistic interactions, which can increase or decrease their toxicity. Finally, when the response from high-dose animal toxicity or epidemiological studies are extrapolated to low doses in humans, an uncertainty factor of 10 or more is applied to the no-observed-adverse-effect level (NOAEL) to estimate an acceptable dose for humans.

Uncertainties in the assessment of dermal exposure via soil and water were noted in Section 3.2.1. Uncertainties that limit the evaluation of dermal assessment are (EPA 1992d):

- Oral reference doses and slope factors are used to evaluate potential toxicity from the dermal route of exposure.
- Information to quantitatively evaluate potential toxicity at the skin surface is unavailable.

- For dermal exposure to soil, exposure factors such as exposed skin surface area and frequency of exposure are not well defined.
- For most chemicals, there are no data to quantify the percentage absorbed through the skin.
- Permeability coefficients for water are based on estimated model predictions.

5.3 SUMMARY OF HUMAN HEALTH RISKS

This risk assessment evaluated the human health risks associated with the VOCs — PCE, TCE, and *cis*-1,2 DCE — in groundwater and soil gas at the Modesto Groundwater Contamination Site. Two residential exposure pathways, groundwater ingestion and indoor air inhalation, were evaluated under current and future land use scenarios using soil gas and groundwater data collected during the RI. The inhalation of the COPCs released during routine household water use such as showering and dishwashing was also evaluated. For the current land use scenarios, the risks were estimated for ingesting treated and untreated Well 11 drinking water. For the future land use scenario, risks were estimated for ingesting untreated site groundwater from a hot spot near Halford's. Both average and RME exposures were calculated to assess the carcinogenic and noncarcinogenic risks.

In conducting this risk assessment, conservative upper-bound exposure values developed by EPA were used to calculate the "theoretical excess cancer risk," which is an estimation of the probability of developing cancer over and above the normal background incidence of cancer. A number of assumptions were made in the risk assessment that were intended to err on the side of health protection in order to avoid underestimating the risk to the public. Moreover, the chemical concentrations used to estimate the increased individual carcinogenic risk were based on continuous exposure over a 30-year period. *The actual probability of cancer is, therefore, likely to be much lower than these estimates and may even be as low as zero.*

As shown in Table 5-1, the current carcinogenic risk estimates range from 1×10^{-6} to 4×10^{-5} while the hazard indices range from 0.5 to 1. Under future land use conditions, the carcinogenic risk estimates range from 4×10^{-2} to 5×10^{-1} while the hazard indices range from 4 to 46. The groundwater ingestion and inhalation pathways contribute the greatest risks.

EPA has adopted a policy that acceptable exposures to known or suspected carcinogens fall within an excess upper-bound lifetime cancer risk range of one in 10,000 (10^{-4}) to one in a million (10^{-6}) (EPA 1991a). The inhalation and drinking water risks associated with current land use scenarios calculated in this assessment are within acceptable risk levels. The risks calculated for a future exposure scenario in which on-site, untreated groundwater at the hot spot is ingested are higher than the currently acceptable standards (EPA 1991a).

In summary, in this risk assessment, it was found that the current risk levels are within acceptable EPA parameters. Unacceptable risks were, however, predicted in a hypothetical, future scenario in which an individual ingests untreated groundwater from the hot spot on site. To safeguard against such an occurrence, EPA will be implementing institutional controls to prohibit groundwater use at this site.

Table 5-1

SUMMARY OF ESTIMATED RISK VALUES: RISK BY PATHWAY AND EXPOSURE SCENARIO

Pathway	Hazard Index RME	Hazard Index Average	Cancer Risk RME	Cancer Risk Average
Current Scenario: Assumes treated Well 11 groundwater use[a]				
Indoor Air: Inhalation of Soil Gas	1	0.5	1×10^{-5}	1×10^{-6}
Drinking Water: Ingestion and Inhalation	9×10^{-7}	4×10^{-7}	1×10^{-8}	5×10^{-9}
Total Risk	**1**	**0.5**	**1×10^{-5}**	**1×10^{-6}**
Current Scenario: Assumes untreated Well 11 groundwater use[b]				
Indoor Air: Inhalation of Soil Gas	1	0.5	1×10^{-5}	1×10^{-6}
Drinking Water: Ingestion and Inhalation	2×10^{-3}	2×10^{-4}	3×10^{-5}	3×10^{-6}
Total Risk	**1**	**0.5**	**4×10^{-5}**	**4×10^{-6}**
Future Scenario: Assumes use of onsite groundwater from at a hot spot near Halford's[c]				
Indoor Air: Inhalation of Soil Gas	1	0.5	1×10^{-5}	1×10^{-6}
Drinking Water: Ingestion and Inhalation	45	3	5×10^{-1}	4×10^{-2}
Total Risk	**46**	**4**	**5×10^{-1}**	**4×10^{-2}**

RME = Reasonable Maximum Exposure
Average = Average of typical exposure parameters

a. Risk values derived from PCE concentrations of 0.60 and 0.47 µg/L for RME and average, respectively.
b. Risk values derived from PCE concentrations of 30.4 and 10.3 µg/L for RME and average, respectively.
c. Risk values derived from PCE concentrations of 4,200 and 1,239 µg/L for RME and average, respectively.

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Appendix A

FARMERS MODEL

The Farmers Model can be used for calculating emissions from chemicals dissolved in groundwater or in contaminated soil (EPA 1992b). It assumes that the chemical concentration in the soil does not decrease as the contaminant migrates upward (i.e., no microbiological degradation) and that the depth to the top of the pollutant source remains constant.

The vapor phase contaminant diffuses through the soil at a rate dependent on the soil porosity, pore space geometry, the chemical's air diffusion coefficient, and the concentration gradient between the source and point of exit form the soil. The *effective diffusion coefficient* (D_s) *is calculated as:*

$$D_s = \frac{D_A\, P_a^{3.33}}{P_T^2}$$

where

D_A = vapor phase diffusion coefficient in air (cm^2/sec)

P_a = air filled soil porosity (unitless)

P_T = total soil porosity (unitless).

The flux is the quantity of the chemical that passes through a fixed unit of space in a certain amount of time. The steady-state flux, J (mg/cm^2-sec), is calculated as:

$$J = \frac{D_s\,(C_g - C_2)}{L}$$

where

C_g = chemical concentration in the vapor phase (mg/cm^3)
C_2 = vapor phase concentration at the surface, assumed to be zero to maximize flux value (mg/cm^3)
L = the distance from the source to the surface (cm).

Because the model ignores all attenuating factors, it is likely to overestimate the contaminant flux (EPA 1992b). Because of the model's simplicity however, it provides a simple method to estimate the likely maximum rate at which chemicals could be transported to a building. After calculating chemical flux, the indoor air concentration is estimated as:

$$C_{indoor} = \frac{E}{Q}$$

where

C_{indoor} = indoor air concentration (mg/cm^3)
E = contaminant infiltration rate (mg/sec)
Q = building ventilation rate (cm^3/sec).

The contaminant infiltration rate, E, is approximated by:

$$E = J \times A \times F$$

where

J = steady-state flux (mg/cm^2-sec)
A = area of the building floor (cm^2)
F = fraction of floor though which soil gas can enter (unitless).

The building ventilation rate (Q) is estimated as:

$$Q = \frac{ACH \times V}{3600}$$

where ACH is the number of air changes per hour (hr^{-1}), V is the volume of the building (cm^3), and 3,600 converts hours to seconds.

The values for the ACH and F, 0.25 and 0.50, respectively, were taken from EPA Region IX PRGs (1993), and the area and volume were consistent with a 2,000-square-foot home. For comparison, Mueller *et al.* reported that typical ACHs for single-family residences range from 0.5 to 1.5 with the ACHs for new or weatherized structures generally 0.5 to 0.8 but possibly as low as 0.2 (EPA 1992b). Fractional floor space values range from 0.001 for slab floors to 0.01 to 0.1 for the floors of average California houses (Grummund *et al.*, cited in EPA 1992b).

Appendix B

ACRONYM LIST

AB	Assembly Bill
ARCS	Alternative Remedial Contracts Strategy
bgs	below ground surface
cis-1,2-DCE	*cis*-1,2-dichloroethene
COPC	chemical of potential concern
1,2-DCA	1,2-dichloroethane
1,1-DCA	1,1-dichloroethane
DHS	Department of Health Services (California)
DLR	detection limit reported
E & E	Ecology and Environment, Inc.
ECAO	EPA Environmental Criteria and Assessment Office
EPA	U.S. Environmental Protection Agency
FS	feasibility study
g/mole	grams per mole
GAC	granular activated carbon
gpm	gallons per minute
HEAST	Health Effects Assessment Summary Tables
HQ	hazard quotient
IRIS	Integrated Risk Information System
MCL	maximum contaminant level
MSL	mean sea level
MW	monitoring well

NOAEL	no-observed-adverse-effect level
PCB	polychlorinated biphenyls
PCE	tetrachloroethylene
ppm	parts per million
PRG	preliminary remediation goal
PRP	potentially responsible party
QA/QC	quality assurance/quality control
PCE	tetrachloroethylene
ppb	parts per billion
RAS	Routine Analytical Services
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
RWQCB	Regional Water Quality Control Board (California)
SAS	Special Analytical Service
SISA	Stanislaus Integrated Service Agency
SEAM	Superfund Exposure Assessment Manual
SF	slope factor
SOC	semivolatile organic chemical
SAS	Special Analytical Services
TAT	Technical Assistance Team
TCE	1,1,1-trichloroethane
TCL	Target Compound List
TIC	tentatively identified compound
trans-1,2-DCE	*trans*-1,2-dichloroethene
UCL	upper confidence limit
v/v	volume/volume
VOC	volatile organic compound

Exhibit D

(Baseline Human Health Risk Assessment (Revision 1),
Modesto Groundwater Contamination Site,
Modesto, California, July 1997)

to

Appendix C
(Land Use Covenant)

to

Consent Decree Pertaining to Defendants
Lyons and Tondas

SFUND RECORDS CTR
2464-00177

SFUND RECORDS CTR
88162568

AR0331

BASELINE HUMAN HEALTH RISK ASSESSMENT
MODESTO GROUNDWATER CONTAMINATION SITI
MODESTO, CALIFORNIA

July 1997

ecology and environment, inc.
International Specialists in the Environment

ZS6073

BASELINE HUMAN HEALTH RISK ASSESSMENT
MODESTO GROUNDWATER CONTAMINATION SITE
MODESTO, CALIFORNIA

July 1997

Prepared for:

U.S. ENVIRONMENTAL PROTECTION AGENCY

ARCS Regions IX and X
Contract 68-W9-0020
Work Assignment 20-15-9LJ4

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LIST OF ACRONYMS

ARCS	Alternative Remedial Contracts Strategy
bgs	below ground surface
cis-1,2-DCE	*cis*-1,2-dichloroethene
COPC	chemical of potential concern
1,2-DCA	1,2-dichloroethane
1,1-DCA	1,1-dichloroethane
DHS	Department of Health Services (California)
E & E	Ecology and Environment, Inc.
EPCs	Exposure Point concentrations
EPA	U.S. Environmental Protection Agency
FASP	Field Analytical Support Project
FS	feasibility study
GAC	granular activated carbon
gpm	gallons per minute
HEAST	Health Effects Assessment Summary Table
HQ	hazard quotient
IRIS	Integrated Risk Information System
LOAEL	lowest-observed-adverse-effect level
MCL	maximum contaminant level
MF	modifying factor
MSL	mean sea level
MW	monitoring well

List of Acronyms (cont.)

NCEA	EPA National Center for Environmental Assessment
NOAEL	no-observed-adverse-effect level
PCE	tetrachloroethene
ppb	parts per billion
PRP	potentially responsible party
QA/QC	quality assurance/quality control
RAS	Routine Analytical Services
RfC	reference concentration
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
RWQCB	Regional Water Quality Control Board (California)
SISA	Stanislaus Integrated Service Agency
SEAM	Superfund Exposure Assessment Manual
SF	slope factor
SOCs	semivolatile organic chemicals
SAS	Special Analytical Services
TAT	Technical Assistance Team
TCE	1,1,1-trichloroethane
TCL	Target compound List
TIC	tentatively identified compound
trans-1,2-DCE	*trans*-1,2-dichloroethene
UCL	upper confidence limit
UF	uncertainty factor
v/v	volume/volume
VOC	volatile organic compound

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) conducted a Remedial Investigation/Feasibility (RI/FS) at the Modesto Groundwater Contamination Site, a Superfund site in Modesto, California. As an attachment to the RI report, this report describes the risk assessment that evaluated the human health risks from volatile organic compounds (VOCs), primarily tetrachloroethene (PCE), in site groundwater and soil gas. This report updates the original EPA risk assessment report, prepared in May 1994. The results of the original risk assessment concluded that current risks are within EPA's acceptable levels; however, for the hypothetical future scenarios in which an individual ingests untreated groundwater directly from the "hot spot", the risks were greater than EPA acceptable levels. The original risk assessment was conducted using data collected during EPA's Phase 1 (1991) and Phase 2 (1993) RIs. This update was prepared to incorporate Phase 3 RI data (1995).

The residential groundwater ingestion and inhalation of indoor air exposure pathways were evaluated for current and future land use scenarios using soil gas and groundwater data collected during the RI. The inhalation exposure to ambient indoor air was estimated from the soil gas data using the Farmers Model (1992b) (see Appendix A). The inhalation of volatile chemicals released during routine household water use (e.g., showering and dish washing) also was evaluated. For the current land use scenarios, risks were estimated for exposure to indoor vapors based on modeling of soil gas concentrations. The future land use scenario assumed ingestion of untreated site groundwater from a "hot spot" near Halford's Cleaners. Average and reasonable maximum exposure (RMEs) were calculated to assess carcinogenic and noncarcinogenic risks.

In conducting the risk assessment, conservative upper-bound exposure values developed by EPA were used to calculate the "theoretical excess cancer risk." The theoretical excess cancer risk is an estimation of the probability of developing cancer over and above the normal background incidence of cancer. A number of assumptions were made in the risk assessment that were designed to err on the side of health protection in order to avoid underestimating the risk to the public. Moreover, the chemical concentrations used to estimate the increased individual carcinogenic risk assumed that continuous exposure occurs over a 30-year period; therefore, the actual probability of cancer is likely to be much lower than the estimates and may even be as low as zero (EPA 1989a).

As shown in Table ES-1, current carcinogenic risks range from 9 x 10^{-7} to 9 x 10^{-6} while hazard indices range from 0.1 to 0.5 under future land use conditions, carcinogenic risks range from 1 x 10^{-2} to 5 x 10^{-2} while hazard indices range from 100 to 400 The ingestion of untreated groundwater at the hot spot and inhalation pathways contribute the greatest risk.

EPA has adopted the policy that acceptable exposures to known or suspected carcinogens fall within an excess upper-bound lifetime cancer risk of between one in 10,000 (10^{-4}) and one in a million (10^{-6}) (EPA 1991a). For noncarcinogens, a hazard index of 1 or less is recognized as the level at which no adverse health effects would be expected. In this risk assessment, the inhalation risks associated with current land use scenarios were generally within acceptable risk levels; however, the risks associated with a future exposure scenario, which assumed consumption of untreated site groundwater at the hot spot (i.e., MW-8), were above the currently acceptable standards (EPA 1991a).

In summary, this risk assessment found the current risk levels are within EPA's acceptable levels; however, for the hypothetical future scenario in which an individual ingests untreated groundwater directly from the hot spot, the risks were found to be outside EPA's acceptable levels.

Table ES-1

SUMMARY OF ESTIMATED RISK VALUES
BASELINE HUMAN HEALTH RISK ASSESSMENT
MODESTO GROUNDWATER CONTAMINATION SITE
MODESTO, CALIFORNIA

Pathway	Hazard Index RME	Hazard Index Average	Cancer Risk RME	Cancer Risk Average
Current Scenario:				
Indoor Air. Inhalation of Soil Gas	0.5	0.1	9×10^{-6}	9×10^{-7}
Total Risk[a]	**0.5**	**0.1**	$\mathbf{9 \times 10^{-6}}$	$\mathbf{9 \times 10^{-7}}$
Future Scenario: Assumes residential use of groundwater from MW-8				
Indoor Air: Inhalation of Soil Gas	0 5	0.1	9×10^{-6}	9×10^{-7}
Drinking Water· Ingestion and Inhalation	400	100	5×10^{-2}	1×10^{-2}
Total Risk[b]	**400**	**100**	$\mathbf{5 \times 10^{-2}}$	$\mathbf{1 \times 10^{-2}}$

RME = Reasonable Maximum Exposure
Average = Average of typical exposure parameters

[a] See Table 3-2.
[b] See Tables 3-3 and 3-4

1. INTRODUCTION

The Modesto Groundwater Contamination Site was placed on the National Priorities List on March 31, 1989. The site initially included Municipal Well 11 (Well 11), which has been found to contain tetrachloroethene (PCE) above the federal and state maximum contaminant level (MCL) of 5.0 parts per billion (ppb), the site is currently defined to include contaminant sources This introductory section describes the physical setting of the site and summarizes the investigations and groundwater treatment to date.

1.1 BACKGROUND

1.1.1 Site Description

Modesto is in Stanislaus County approximately four miles south of the Stanislaus River and five miles west of the Tuolumne River in the San Joaquin Valley. The city encompasses approximately 12 square miles and has a population of approximately 170,000. Major industries include canneries, wineries, and dairy, meat, poultry, and frozen food processing plants.

The climate is characterized by hot, dry summers and mild winters. The mean annual precipitation is 12 inches, 87 percent occurring between October and May Groundwater is the primary source of water for municipal, industrial, and agricultural use in Modesto Water supplies include 49 wells owned by the City of Modesto, 62 wells owned by the Del Este Water Company, and numerous private domestic wells.

A site location map and a site plan are shown in Figures 1-1a and 1-1b. The RI study area lies at an appropriate elevation of 90 feet above mean sea level (MSL). The site and vicinity are nearly flat with a gentle slope to the west at a gradient of approximately 0 001

Well 11 is outside the RI study area at the corner of Magnolia and Mensinger avenues and is owned by the City of Modesto. Although Well 11 is no longer in operation (see Section 1 1.2), it was formerly operated by the City as part of a system that supplies potable water to over 150,000 residents. As reported in California Assembly Bill (AB) 1803, Well 11 (State Number

Base map source USGS 1:24000 Riverbank (PR 1957) and Salida (PR 1987) 7.5' quadrangles

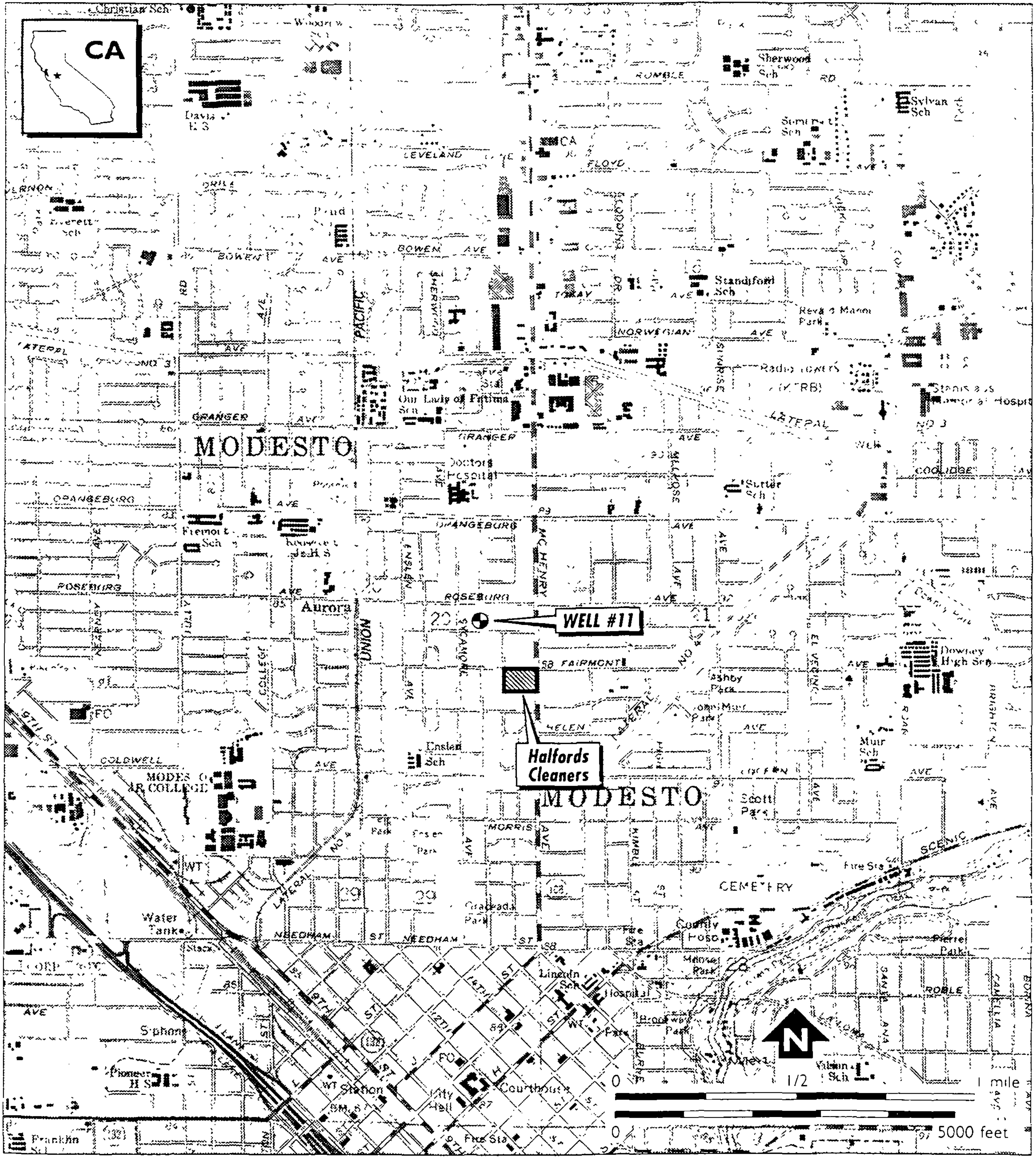

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Figure 1-1a

SITE LOCATION MAP

Modesto Groundwater Contamination Site

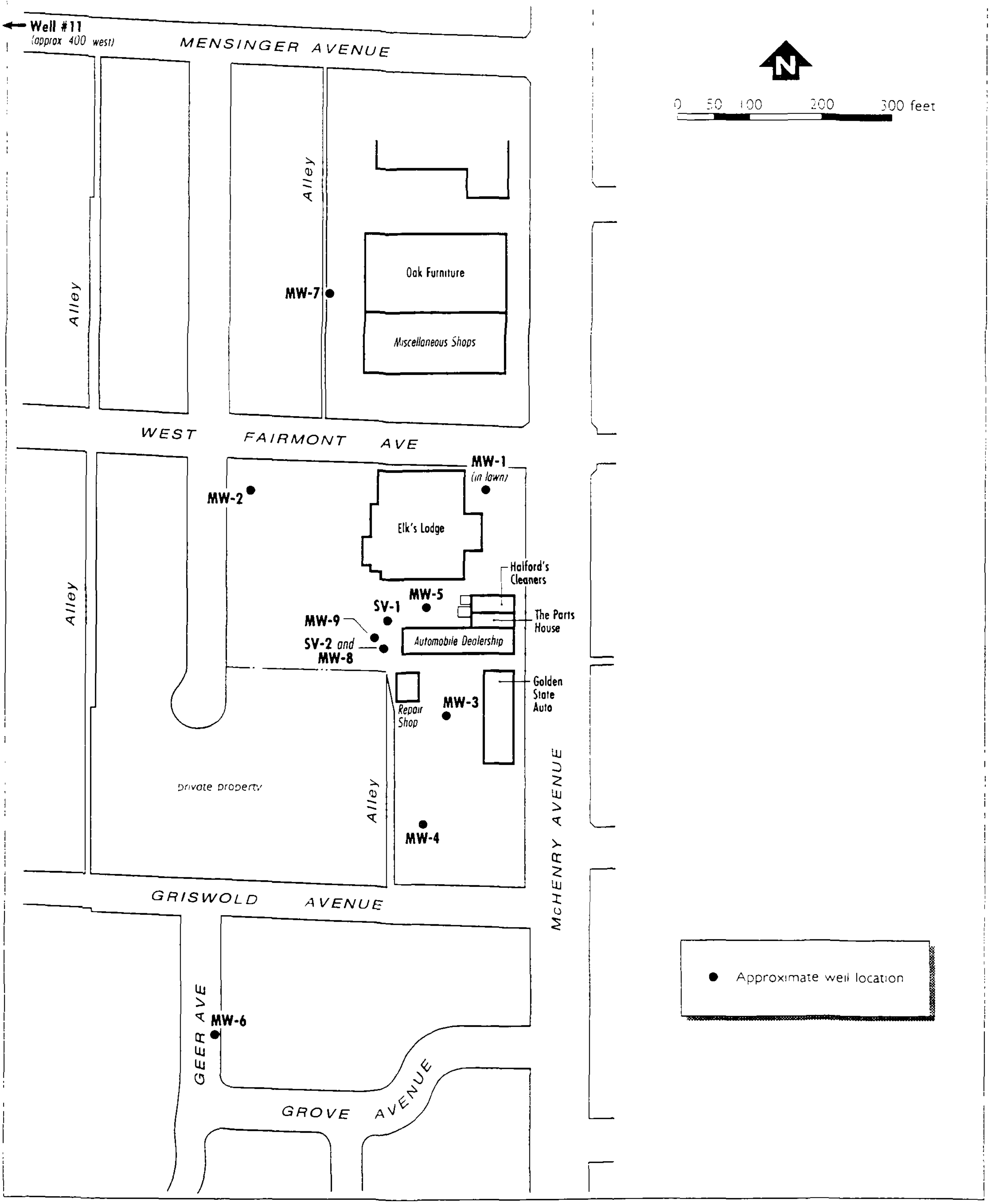

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Figure 1-1b

SITE PLAN

Modesto, California

3S/9E-20J1) was installed in 1936 and has a 1.150 gallons-per-minute (gpm) capacity and a well casing depth of 116 feet.

Dry Creek, a naturally occurring stream approximately one mile to the southeast, is the closest drainage to the site. Dry Creek flows west to the Tuolomne River, a tributary of the San Joaquin River. Water delivery laterals extend from the Modesto Main Canal and run east-west 0.8 mile north and 0 3 mile south of the site.

1.1.2 Site Investigations

PCE was initially detected in Well 11 in September 1984 at 16 7 ppb, which is above the federal and state MCL of 5 ppb. Well 11 was one of 12 wells initially sampled in Modesto under provisions of AB 1803. Within a few weeks after contamination was detected in Well 11, local regulatory agency representatives raised the possibility that Halford's Cleaners, 941 McHenry Avenue, was the source of PCE contamination. Halford's was suspected because of its proximity to Well 11 (approximately 1,000 feet southeast) and the likely use of PCE at the drycleaning facility A timeline of various activities at Well 11 is shown in Figure 1-2.

In April 1985, the Stanislaus County Department of Environmental Resources conducted a groundwater investigation in the immediate vicinity of Halford's. An inactive air conditioning well at the Elks Lodge, approximately 100 feet northwest of Halford's, contained PCE at 84 6 ppb Following the groundwater investigation, the county collected soil samples at Halford's near a drycleaning machine. The results revealed a maximum PCE soil concentration of 176,000 ppb

After being deactivated in 1984 when PCE contamination was initially detected, Well 11 was reactivated in April 1987, after continued monitoring indicated to detectable levels of PCE or other chlorinated solvents. In February 1989, Well 11 was again taken out of service after PCE at 8.28 ppb was detected in December 1989. The well remained out of service until a wellhead granular activated carbon (GAC) treatment system was installed by the City of Modesto in May 1991 Well 11 was returned to service in June 1991 but again taken off line in 1995 when naturally occurring uranium was detected above MCLs. Well 11 is currently still inactive.

In August 1985, the City of Modesto collected sludge and sediment samples from sewer lines north and south of Halford's. A maximum PCE concentration in sludge of 1,360 ppb was found in the main sewer line immediately downgradient from Halford's service connection.

Well 11	Year	Activities
WELL 11 INACTIVE	1984	◄ PCE first detected; 16.7 ppb; Well 11 deactivated
	1985	◄ County groundwater investigation; 85 ppb at Elks Club well; soil max = 176,000 ppb PCE ◄ Sludge/sediment sampling by City of Modesto; 1,360 ppb PCE in sludge from sewer line
	1986	
ACTIVE	1987	◄ Well 11 turned on
	1988	► RADIAN INVESTIGATION
	1989	◄ First EPA soil & gas survey; 6,050 ppm PCE (soil); 1,965 ppm PCE (soil gas)
INACTIVE	1990	◄ 8.3 ppb PCE detected; Well 11 turned off ► RWQCB conducts soil gas survey, "Halford's Plume" identified ◄ 2nd EPA study; Elk's Club well = 73 ppb, PCE; video monitoring; six boreholes installed ◄ EPA issues Removal Order to Halford's Cleaners
	1991	◄ Removal action starts; soil vapor extraction system installed ◄ Granular activated carbon (GAC) system installed at Well 11
ACTIVE	1992	◄ Well 11 turned back on
	1993	◄ **PHASE I RI** ◄ **PHASE II RI**
	1995	◄ **PHASE III RI**; Well 11 taken off-line again

Figure 1-2

TIMELINE OF ACTIVITIES AT WELL 11

Modesto Groundwater

Modesto, California

In 1987, Radian Corporation, under contract to the California Department of Health Services (DHS), conducted an investigation of potential groundwater contaminant sources in Modesto The objectives of the Radian investigation were to:

- Identify the businesses that potentially use PCE and could be associated with contamination found in 10 Modesto domestic water supply wells.
- Evaluate potential health risks associated with the drinking water ingestion
- Develop a list of remedial alternatives

The results indicated that 106 businesses warranted further investigation as potential contaminant sources. A followup evaluation eliminated 73 businesses from the list, leaving 34 business considered for soil gas sampling.

In December 1989, as EPA collected soil and soil gas samples in the vicinity of Halford's Cleaners. The results showed PCE at a maximum of 6,050 ppm in the soil near the northwest corner of the Halford's building and an elevated PCE concentration of 1,965 ppm in soil gas adjacent to the automobile dealership immediately south of Halford's Both the soil and soil gas data suggested decreasing PCE concentrations at increasing distances from Halford's A second EPA investigation was conducted in July 1990 and consisted of.

- Drilling and sampling six boreholes in the vicinity of Halford's
- Video monitoring of the nearby Elks Lodge well to determine whether it could be acting as a conduit for downward migration of contaminants
- Sampling the Elks Lodge well.

The highest PCE concentrations in soil (21,000 ppb) were detected within 5 feet of the surface of the borehole closest to Halford's, approximately 1,000 feet southeast of Well 11 (Figure 1-1b). Water sample results from the Elks Lodge well indicated PCE at 73 ppb although information from the video monitoring of the Elks Lodge well was inconclusive.

In March and April of 1990, the Regional Water Quality Control Board (RWQCB) conducted a soil gas investigation to delineate potential contaminant plumes associated with City of Modesto Wells 11, 14, and 21. Although the results do not necessarily correlate with groundwater contamination the southern portion of this plume coincides with the city sewer line, indicating that PCE discharges to the sewer line may be a source of the contamination. Halford's Cleaners is also a likely source of this plume.

On September 25, 1990, the EPA Emergency Response Section issued a Removal Order to the potential responsible parties (PRPs) for soil remediation at Halford's Cleaners. Halford's has installed a soil vapor extraction system in compliance with the Removal Order. EPA conducted Phase 1 and 2 RIs at the site to determine the chemicals of concern and locate PCE hot spots (E & E 1993a, b). The Phase I investigation consisted of a soil gas survey, installing four monitoring wells, sampling and analyzing subsurface soils, groundwater testing at the monitoring wells and Well 11, and an aquifer pump test. The pump test confirmed that Halford's Cleaners is the only dry cleaner within the capture zone of Well 11. The Phase 2 investigation was designed to support this risk assessment by defining the horizontal and vertical extent of the PCE soil gas contamination identified in the Phase I RI and collecting additional groundwater samples. The Phase 2 RI used both biased and random sampling methods to characterize the PCE contamination

The Phase 3 RI, conducted in 1995, included more comprehensive sampling of soil, groundwater and soil gas in the vicinity of Halford's Cleaners. five new groundwater monitoring wells and two soil vapor monitoring wells were installed and sampled. Monitoring well borings were also sampled to better establish vertical contaminant profiles.

1.2 SCOPE OF THE RISK ASSESSMENT

This baseline risk assessment evaluated potential human health risk from VOCs identified in groundwater at the Modesto Groundwater Contamination Site The results of the original risk assessment concluded that current risks are within EPA's acceptable levels; however, for the hypothetical future scenarios in which an individual ingests untreated groundwater directly from the "hot spot", the risks were greater than EPA acceptable levels.

This report updates the original human health risk assessment conducted by EPA in 1994 The update is necessary to incorporate data collected in 1995 (Phase 3 RI). The preliminary residential exposure pathways investigated included inhalation of soil gas vapors as well as inhalation and ingestion of groundwater by residents. This report was prepared in accordance with the following federal as well as regional risk assessment guidance:

- *Risk Assessment Guidance for Superfund. Volume 1 - Human Health Evaluation Manual (Part A)*, EPA/540/1-89/002. December 1989
- *Risk Assessment Guidance for Superfund Human Health Risk Assessment*, U.S. EPA Region IX Recommendations (Interim Final). December 15, 1989.
- *EPA Region IX Preliminary Remediation Goals (PRGs)*. 1996.

The risk assessment was conducted according to standard risk assessment procedures (EPA 1989a) that include the following processes.

- Identification of contaminants of potential concern
- Exposure assessment
- Toxicity assessment
- Risk characterization
- Uncertainty analysis

Current (treated and untreated) drinking water and future land use exposure scenarios were evaluated in this assessment.

2. DATA COLLECTION AND EVALUATION

This section summarizes the results of EPA's Phase 1, 2, and 3 remedial investigations (E & E 1996, 1994b, 1993). The RI data and data obtained from the City of Modesto (1993) were used exclusively in this risk assessment. The sampled media were soil, groundwater,and soil gas.

All laboratory data were reviewed and validated by EPA contract laboratories using EPA functional guidelines (EPA 1983, 1985, 1989c, 1990). Only validated data were used in the quantitative risk assessment. Data review and validation is a two-step process. First, laboratory personnel review the data qualitatively for overall precision, accuracy, comparability, and completeness using standard quality assurance/quality control (QA/QC) procedures. Second, an independent validation specialist evaluates the data and assigns validation qualifiers ("flags"). The qualifiers account for variability encountered in the chemical analyses: for example, a "J" qualifier indicates that a laboratory instrument identified the chemical, but the concentration was too low to be accurately quantified (i.e., the chemical was present but at a concentration below the quantitation limit). If the chemical was analyzed for but not detected, the result is qualified with a "U" In accordance with EPA guidance (1989a), if there was no reason to believe a chemical was present in a sample, a U-qualified result is regarded as zero.

The following sections list the types of chemical compounds that were analyzed for and summarize the analytical laboratory results.

2.1 REMEDIAL INVESTIGATION ANALYTICAL RESULTS

2.1.1 Groundwater Results

Phase 1 and 2 RI

Groundwater samples were collected from four monitoring wells (Wells MW-1 through MW-4), Well 11, and the Elks Club well in February 1992 (Phase 1) and again in November 1993 (Phase 2). At Well 11, effluent (treated) and influent (untreated) samples were collected. For

QA/QC purposes, duplicate samples were collected, and average concentrations were used in exposure calculations. All samples were analyzed by an EPA Contract Laboratory Program (CLP) laboratory using a Routine Analytical Service (RAS) volatiles method. Special Analytical Services (SAS) methods were also used to analyze groundwater samples for VOCs. All data underwent validation according to EPA guidelines (EPA 1990). Groundwater samples collected from monitoring wells during the Phase I RI were analyzed for Target Compound List (TCL) VOCs, TCL semivolatile organic compounds (SOCs), TCL pesticides, polychlorinated biphenyls (PCBs), TCL metals, radionuclides including alpha, beta, radium-226/228, and radon-222, and herbicides

No detectable levels of pesticides, PCBs, SOCs, or herbicides were found. In the Phase 1 RI, several tentatively identified compounds (TICs) were identified in samples from the Elks Club well. All TIC results were qualified with a "J" meaning estimated. The TICs were butane, pentane, methyl pentane, hexane, and methyl hexane. The quantitation limit for these compounds was 2 micrograms per liter (μg/L). One equipment blank and two field duplicates were analyzed. The field duplicates had comparable PCE concentrations: the equipment blank had analyte concentrations below the quantitation limits. PCE was detected in all samples except Well 11 effluent. Trace quantities of several other VOCs were detected, but none exceeded MCLs. None of the TICs are suspect at the site so they were eliminated from further consideration per EPA guidance (1989a).

Since many of the compounds tested for in the Phase I RI were not detected (e.g., PCB, pesticides, semivolatiles), and others were below MCLs and/or tentatively identified as discussed above, only VOCs analyses were conducted for the Phase 2 RI The Phase 2 VOC data were similar to the Phase I data (same chemical identification at similar concentrations).

Approximately a dozen TICs of unknown identity were observed in samples from MW-3, and methyl pyrrolidinone was identified (probability of identification equal to "B" or "moderate") at concentrations of 20 to 100 μg/L (J-qualified) in five of the samples. None of the 64 possible SOCs were detected above the quantitation limits. Two field duplicates and one equipment blank were collected and analyzed for SOCs.

Herbicides were analyzed for using EPA Test Method 8150. Again, two field duplicates and one equipment blank were analyzed for QA/QC. No herbicides were detected above the quantitation limits.

Water samples were also analyzed for SAS metals and molybdenum. The data were reviewed in accordance with the SAS requirements for molybdenum and EPA guidance (EPA 1983, 1989c). Samples from MW-3 were found to contain the following compounds above the MCLs. aluminum (12,000 μg/L), chromium (65 μg/L), iron (11,800 μg/L), and manganese (282 μg/L).

Validation of RAS Pesticides/PCBs were performed using EPA guidance (EPA 1985). None of the 11 water samples analyzed contained pesticides or PCBs above the quantitation limits

Gross alpha and beta radioactivity, radium-226 and -228, and uranium analyses were also performed on the water samples collected March 6 through 26, 1992. Several different methods were used to analyze the various types of radioactivity. The data were reviewed for completeness and compliance with the methods only; no judgment was made on data quality.

Phase 3 RI

As part of the Phase 3 RI, additional monitoring wells were installed at "hot spots," upgradient, and downgradient from the site. Phase 3 groundwater samples were analyzed for total and dissolved metals, volatile organic compounds, general chemistry, and radionuclides, except the sample from MW-8, which was analyzed for volatile organic compounds only. Volatile organic analyses were performed in the onsite FASP laboratory using EPA Method 8010/8020 Metals analyses were conducted through the Contract Laboratory Program (CLP), and analyses for groundwater quality parameters (e.g., alkalinity, hardness, sulfides, etc.) were conducted at the EPA Richmond Laboratory.

The PCE concentration in groundwater is highest in wells near Halford's Cleaners (wells MW-3, MW-4, MW-5, and MW-8). The federal and state MCLs for PCE in drinking water is 5.0 μg/L. The MCL was exceeded in all wells except MW-7, and the highest concentration of PCE was 74,000 μg/L in MW-8 near Halford's Cleaners sewer connection to the main line. The other shallow groundwater sample near Halford's Cleaners (MW-5) indicated 17,300 μg/L PCE. MW-7, which was placed upgradient of Halford's Cleaners, indicated the lowest PCE concentration of 4.2 μg/L, based on this low relative concentration, an upgradient source of contamination appears unlikely. MW-6, which was placed downgradient of Halford's Cleaners to help define the lateral extent of contamination, indicated 44 0 μg/L of PCE.

Toluene was found at MW-8 at 13,200 μg/L. the state MCL for toluene is 150 μg/L. Since toluene is not a breakdown product of PCE and is not typically associated with the PCE manufacturing process, the presence of toluene may indicate a separate source of contamination. Toluene was not detected at other wells near Halford's Cleaners. Low levels were detected at MW-6 (8.2 μg/L) and MW-7 (4.0 μg/L). Other volatile organic analytes were acetone, chloroform, and chloromethane.

2.1.2 Soil Gas Results

Phase 1 and 2 RI

The objective of the Phase 1 soil gas survey was to identify potential sources of PCE contamination impacting Well 11 groundwater. On the basis of a conservative estimate of the radius of influence of Well 11, a one-mile radius was initially selected as the study area for the soil gas survey. One sample was collected 20 feet below ground surface (bgs); others were collected 10 feet bgs.

The EPA "Region IX ASP Volatile Organic Compounds in Soil Gas" method was used to analyze the samples for PCE, 1,1,1-trichloroethane (TCE), *cis*-1,2dichloroethene (*cis*-1,2-DCE), *trans*-1,2-dichloroethene (*trans*-1,2-DCE), 1,2-dichloroethane (1,2-DCA), and 1,1-dichloroethane (1,1-DCA). PCE was detected in all five samples collected, and one sample contained TCE and *cis*-1,2-DCE.

Since only five samples were collected during the Phase 1 RI, a second soil gas survey was conducted in November 1993. The Phase 2 soil gas survey focused on a smaller study area (Figure 2-1), and the objective was to further define hot spots detected in the Phase 1 survey. Samples from 3 and 15 feet bgs were collected and analyzed in a mobile van for PCE, TCE, and vinyl chloride. A total of 57 samples were collected: 28 were random, and 29 were biased as shown in Figure 2-1 Then 14 additional samples were collected in Summa canisters (6-liter, stainless steel) where high PCE concentrations (> 10 μg/L) were found by the mobile laboratory The Summa canister samples were submitted to a laboratory and analyzed for PCE, TCE, and vinyl chloride by EPA Test Method TO-14 PCE was found in nearly all samples and *cis*-1,2-DCE and TCE were found in several samples. No vinyl chloride was found. The highest PCE concentration

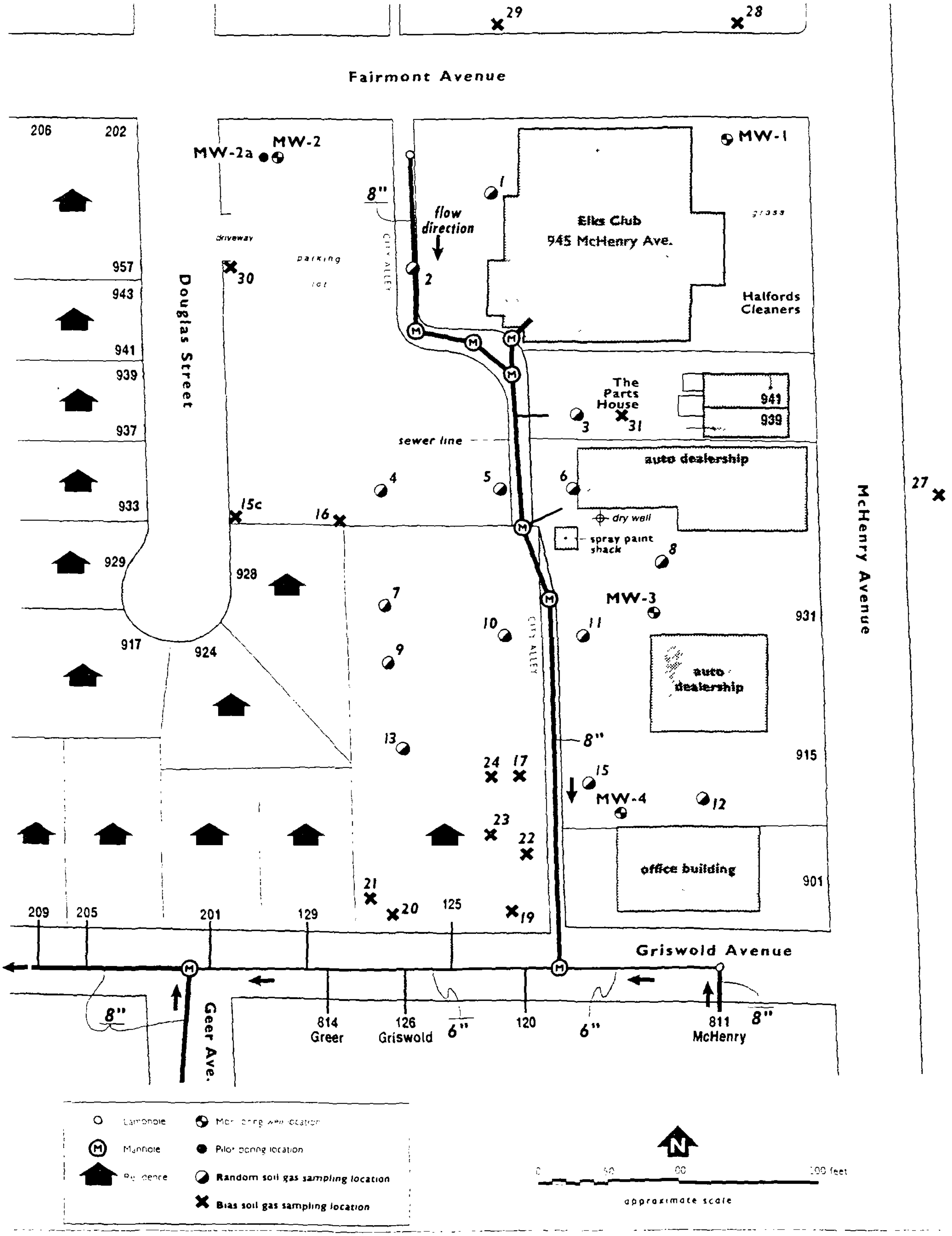

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Figure 2-1

SOIL GAS SAMPLING LOCATIONS

Modesto Groundwater

Modesto, California

(78 µg/L) was found in a sample collected behind Halford's Cleaners near the sewer line, which was consistent with the Phase 1 data (96 µg/L at 20 feet bgs).

A comparison of PCE concentrations analyzed by the mobile and analytical laboratories is shown in Table 2-1. In general, the two data sets correspond reasonably well; both share similar minima and maxima; however, analytical laboratory concentrations were greater than mobile laboratory concentrations, and the mobile laboratory found vinyl chloride in several samples whereas the analytical laboratory did not.

A large home adjacent to the site is of special concern since it is currently occupied by a family with small children. Eight samples were collected close to the house (Figure 2-1). All samples from 3 feet bgs contained PCE at less than 1 µg/L, and the maximum concentration in samples from 15 feet bgs was 15 µg/L (Sample SG17-15) A corresponding Summa canister sample contained 83 µg/L. A common trend among the data is that PCE concentrations are highest near the sewer lines and decrease significantly at increasing distance from the sewer line.

Phase 3 RI

As part of the Phase 3 RI, two additional soil gas monitoring wells were installed Soil gas samples were analyzed in the onsite FASP laboratory using EPA Method 8010/1020 Soil vapor data were collected to determine the occurrence of PCE in the vicinity of Halford's Cleaner private sewer connection to the main line. PCE was present in each soil gas sample and concentrations ranged from 200.0 µg/L in SV2-C (32 to 34 feet bgs) to 1591.7 µg/L in SV1-A (50-55 feet bgs).

2.1.3 Soil Results

Phase 1

Soil samples were collected from the four soil borings during Phase 1 monitoring well installation and analyzed for VOCs by RAS and SAS methods. The highest PCE concentrations, approximately 80 to 230 micrograms per kilogram of soil (µg/kg) were found in samples collected at or below the groundwater surface (approximately 70 to 90 feet bgs) in MW-4, which is near the sewer line (Figure 2-1). In six subsurface soil samples collected less than 15 feet bgs, the PCE concentrations ranged from nondetect in five samples to 5 µg/kg in one sample. Overall,

Table 2-1

CHEMICALS OF POTENTIAL CONCERN
MODESTO GROUNDWATER CONTAMINATION SITE
MODESTO, CALIFORNIA

Groundwater	Soil Gas
Benzene	cis-1,2-Dichloroethene
Chloroform	Tetrachloroethene
1,2-Dibromoethane	Trichloroethene
1,2-Dichloroethane	
1,2-Dichloropropane	
Tetrachloroethene	
Toluene	
Trichloroethene	

the maximum detected PCE concentration was 230 μg/kg (0 230 mg/kg) in a sample collected 90 feet bgs in Well MW-4

Phase 3

No soil samples were collected during the Phase 2 RI. For the Phase 3 RI, boring samples were submitted for volatile organic analysis for each 5-foot depth interval. In addition, selected soil samples were submitted to offsite laboratories for Total Organic Carbon (TOC) analysis using SW-846 Method 9060 A, bulk density using ASTM Method D 2937, grain size using ASTM method D-422, moisture content using ASTM method 2216-90, and pH using SW-846 Method 9045. Volatile organic data were collected to identify discrete areas of PCE and related organic contamination. The TOC and physical property data will be used for future design of a soil vapor extraction system.

Elevated concentrations of PCE in the unsaturated soils were only found in samples from MW-5 and MW-9 The highest PCE concentration in unsaturated soil was 248.4 μg/kg at 31.5 feet bgs in boring MW-5, near the former location of the leaking dry cleaning machine. Samples from other borings in the immediate vicinity of Halford's Cleaners (MW-8, MW-9, and SV-1) also indicated detectable levels of PCE in the unsaturated zone Samples from outlying borings (MW-6 and MW-7) indicated no detectable levels of PCE in the unsaturated zone.

Elevated PCE concentrations in saturated soils were found in samples from MW-3, MW-4, MW-5 and MW-9. The highest PCE concentration found in saturated soil was 555 μg/kg at 67.5 feet bgs in boring MW-8, near Halford's Cleaners sewer connection to the main line. Detectable levels of PCE were found in saturated soil samples from all other borings, although the outlying borings again indicated the lowest levels. Maximum PCE levels in saturated soil were 32.7 μg/kg at MW-6 (90 feet bgs) and 4.8 μg/kg at MW-7 (90 feet bgs).

2.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN (COPCs)

For this assessment, COPCs were determined by comparing detected concentrations of groundwater contaminants to Preliminary Remediation Goals (PRGs, EPA 1996). This approach is consistent with EPA, Region IX, guidance. In addition, inorganic contaminants were compared to MCLs. Arsenic, lead, and thallium were detected in groundwater at concentrations exceeding

PRGs; however, these contaminants are not site-related and did not show any apparent correlation with the organic contamination. As a result, no inorganics were retained as COPCs for this risk assessment. PCE concentrations in groundwater exceeded PRGs in all three phases of sampling. In addition, this compound also was detected in nearly all soil gas samples. Consequently, PCE is the leading COPC. Cis-1,2-Dichloroethane and TCE also were detected frequently in soil gas; therefore, these compounds were considered for the inhalation of indoor vapors exposure pathway. Results of the COPC screening are presented in Table 2-1.

The analytical results for Phase 1, Phase 2, and Phase 3 are provided in E & E (1993), E & E (1994b), and E & E (1996), respectively.

3. EXPOSURE ASSESSMENT

The objective of the exposure assessment was to estimate the magnitude, frequency, duration, and routes of human exposure to site-related chemicals. Accomplishing this objective involved the following tasks:

- Characterizing the exposure setting including the physical environment and potentially exposed populations.
- Identifying the exposure pathways including contaminant sources and releases, exposure points, and exposure routes.
- Quantifying the exposure concentrations and intake variables.

The results are expressed as the daily doses of each COPC (per body weight) calculated independently for each of the exposure pathways investigated.

3.1 EXPOSURE SETTING

3.1.1 Physical Setting

The basic physical features of the site were discussed in Section 1.1 The site and surrounding area are both residential and commercial (Figure 1-1). They are zoned for both low- and medium-density residential (R-1 and R-2) and heavy and light business (C-1 and C-2) (City of Modesto Planning Office 1993). To a large extent, the area around the site is R-1 and C-2. The primary businesses on Griswold and West Fairmont avenues are the Elk's Club, Halford's Cleaners, several automobile dealerships, and the Stanislaus Integrated Service Agency (SISA) Community Center. Most of the surface of the site is paved with asphalt or concrete except for the yards of residences.

3.1.2 Characteristics of PCE Contamination

PCE is the primary COPC and was detected in groundwater at levels above the state and federal maximum contaminant levels (MCLs). Known sources of PCE contamination in the study area include current and former drycleaning operations that discharge to sewer lines. PCE is denser than water and moderately soluble in water (up to 150 mg/l at 25°C). It has a moderate to high soil mobility and exhibits little soil affinity. i.e.. the chemical does not readily sorb onto soil particles (PHS 1987). PCE, therefore. tends to leach into groundwater and migrate vertically through the saturated zone until a low-permeability layer such as a clay bed is encountered. Depending on the rate of PCE migration and the mineralogy and lithology of the low-permeability layer, a fraction of the undissolved PCE (i.e., pure product) can remain adsorbed in the upper portion of the low- permeability layer, or the PCE can continue to migrate vertically along the low-permeability layer.

PCE is a relatively volatile chemical. evaporating readily. The Henry's Law constant for PCE, which relates to the volatilization of PCE from water. is 2.3×10^{-2} atmosphere cubic meters per mole (atm-m^3/mol). This value is similar to that of other volatile gasoline-type hydrocarbons such as benzene. Thus. soil VOC concentrations were expected to be low. as was observed (Section 2.1.3). In addition. surface soil concentrations are expected to remain low as the plume migrates. assuming steady-state conditions. The paving over much of the surface area at the site also limits volatilization.

Although direct discharges of PCE to the environment are generally not well documented. recent studies support the concept of contamination from sewer lines. According to the Central Valley RWQCB (1992). there are five possible mechanisms by which PCE can be released from sewer lines:

- Through breaks or cracks in pipes.
- Through pipe joints and other connections
- By leaching in liquid form directly through pipes into the vadose zone.

- By saturation of the bottoms of pipes with liquid containing a high concentration of PCE and then volatilization of PCE from the outer surfaces of the pipes into the soil

- By penetrating pipes as a gas.

The report stated that all sewer lines leak to some extent and that last three mechanisms listed probably occur in all pipes.

Whether PCE is discharged directly to the environment or leaks from sewer lines, it subsequently migrates through the vadose zone to the saturated zone. PCE separates into three phases upon entering the subsurface environment: a vapor phase that migrates through the vadose zone, a dissolved (miscible) phase entrained in groundwater that migrates according to groundwater flow patterns, and an undissolved (immiscible) phase that sinks through the unsaturated and saturated zones.

3.1.3 Potentially Exposed Populations

The people living on site or in the immediate vicinity are considered primary receptors. Long-time residents are considered to have the greatest risk since potential carcinogenic risk is based on a cumulative exposure. To a lesser extent, employees of nearby businesses are also potentially exposed to the COPCs at the site. Such employees likely work eight-hour shifts five to six days per week. The Elks Club patrons who the use the asphalt parking lot likely have minimal exposure to PCE. When estimated risk to the long-time residents who have greater potential exposure is insignificant, the risk to other receptors with less potential exposure is also insignificant.

3.2 IDENTIFICATION OF EXPOSURE PATHWAYS

An exposure pathway is the means by which an individual or population is exposed to a chemical originating from a source. Each pathway represents a different mechanism of exposure. Pathways include incidental dermal contact with soil, inhalation of soil dust or vapors, and ingestion of groundwater or surface water. The route of exposure is the method of entry of a chemical into the body such as inhalation, ingestion, or dermal contact. A complete exposure pathway must exist for a contaminant to pose a potential human health risk and must consist of the following four elements:

- A mechanism for contaminant release to the environment (e.g.. dispersion of contaminants in soil);
- An environmental transport medium (e g., groundwater) for the released contaminant:
- A point of potential human contact with the contaminated medium (e.g., breathing zone), and
- A route of entry into the body at the point of contact.

If an exposure pathway is incomplete, then it can be concluded that there is no current human exposure. Consequently, adverse effects to human health would not be expected under current conditions. However, future changes in land use may result on completion of some potential exposure pathways. The sections below discuss the rationale for eliminating or retaining exposure pathways for further risk evaluation.

3.2.1 Incomplete Pathways

During the Phase I RI. soil samples were collected at 10-foot intervals during the installation of four monitoring wells to about 100 feet bgs. The samples were analyzed for PCE; however, those collected below 15 feet bgs were not quantitatively evaluated since resident contact with such deep soils is unlikely. The maximum detected PCE concentration was 0.230 mg/kg at 90 feet bgs in the boring for Well MW-4 Soil samples were collected and submitted for volatile organic analysis during the installation of additional monitoring wells in the Phase 3 RI. In general, boring samples were submitted for each 5-foot interval. The highest PCE concentration in unsaturated soil was 2.5 mg/kg at 31.5 feet bgs in the boring for MW-5. Both of these values are below the residential PRG for soils of 5 4 mg/kg (EPA 1996). In addition, the site area is paved. For these reasons, the exposure pathways associated with soils (i.e., dermal contact, inhalation of soil dust, ingestion of vegetables, and incidental soil ingestion) were, considered negligible and not evaluated further.

The inhalation of soil gas vapors outdoors is not expected to significantly impact human health for several reasons:

- Unlike in buildings, where soil gases might accumulate, soil gases released to ambient outside air will largely disperse into the atmosphere.
- The inhalation rate for an individual outdoors (5 m^3/day) is only one-third of the inhalation rate indoors (15 m^3/day), reducing exposure and hence the risk proportionally.
- Most of the site is paved with asphalt or concrete, which will limit the mobilization of soil gases.

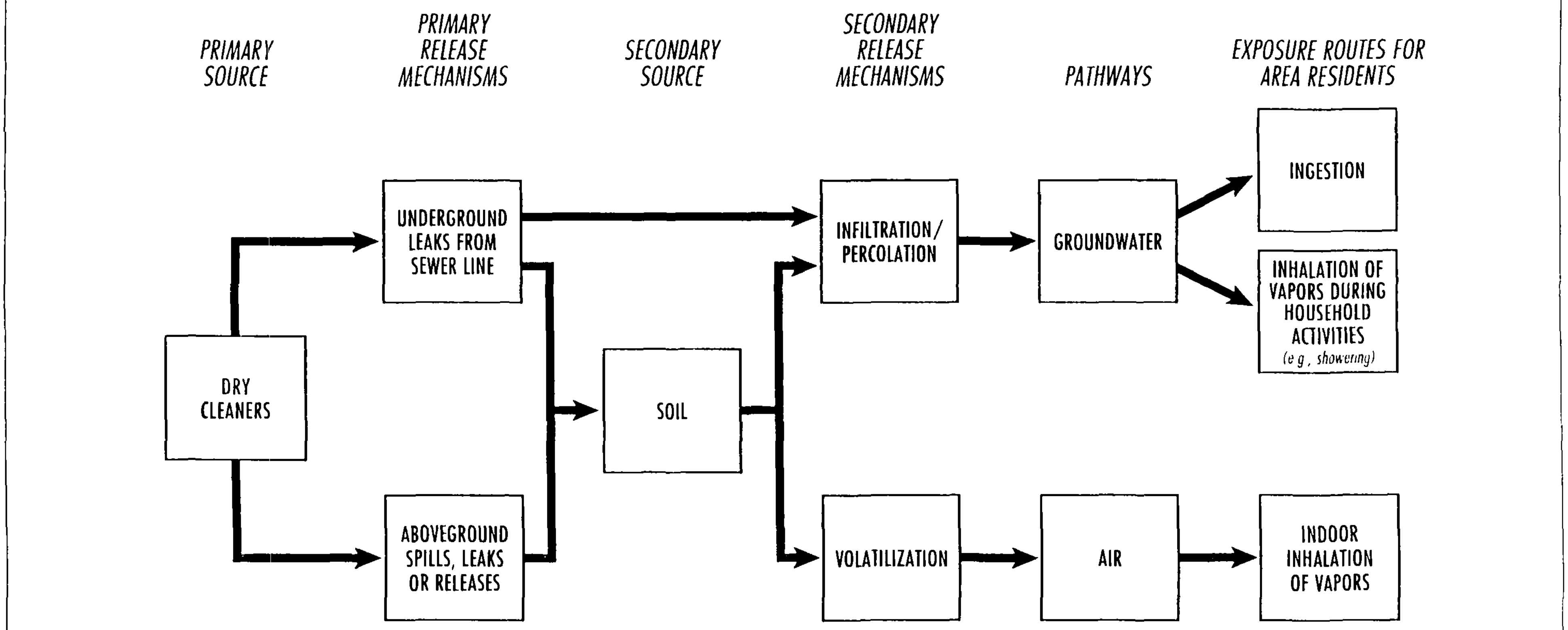
Dermal contact with contaminated soil was not evaluated in this risk assessment because the highest PCE concentrations were found at depth and the site is paved.

3.2.2. Complete Pathways

The potentially complete pathways under current or future site conditions were, therefore, considered to be:

- Indoor inhalation of vapors emanating from contaminated soil.
- Inhalation of vapors emanating from contaminated groundwater used during household activities (e.g., showering and dish washing).
- Ingestion of contaminated groundwater.

A conceptual exposure model indicating sources, release mechanism, exposure pathways, and receptors is presented in Figure 3-1. Because this baseline risk assessment was designed to be a representative characterization of the site, pathways were selected to reflect the range of potential exposures. Those considered were exposure pathways for adult residents; although children were not explicitly considered, no additional pathways unique to children are anticipated. Industrial exposure pathways were not evaluated since residential scenarios are more conservative and would therefore yield higher risk values.



ZS6073 b(c39) 04/26/94

Figure 3-1

CONCEPTUAL EXPOSURE MODEL

Modesto Groundwater

Modesto, California

Current zoning suggests that land use is unlikely to change significantly in the future; however, additional drinking water wells could be installed on site if future residential development occurs. A future residential scenario was, therefore, evaluated using the VOC concentrations in the monitoring wells; it is discussed in greater detail in the next section.

3.3 QUANTITATIVE ASSESSMENT OF EXPOSURE

This section describes how the quantitative exposure values were derived from the site data presented in Section 3.3.1 and how the average daily intakes were calculated for each pathway.

Average and RME residential exposure pathways were evaluated for two different scenarios:

- **Current:** Inhalation risks were calculated using Phase 2 and Phase 3 RI soil gas data.
- **Future:** Analytical data for the nine monitoring wells were used to evaluate potential risks from residential usage of groundwater assuming the installation of drinking water wells on site. Groundwater ingestion and inhalation risks were determined separately for each of the nine wells. The inhalation of soil gas under current scenarios was used to estimate future inhalation risks. Because MW-11 is no longer used as a source of domestic water, risks for this well were not determined.

According to EPA (1989b, 1992a), both the RME and average (central tendency) exposure calculations should be used in Superfund risk assessments. The RME is defined as the highest exposure that could reasonably be expected to occur by a given exposure pathway at a site; it is intended to account for both uncertainty in the contaminant concentration and variability in exposure parameters such as exposure frequency or averaging time. The RME, sometimes called the "high-end" risk, characterizes the risk to an individual "at the upper end of the risk distribution at approximately the 90th percentile of the population distribution" (EPA 1992c). The goal of the RME approach is to combine upper-bound and mid-range exposure factors to estimate exposures that are both protective and reasonable but not work-case (EPA 1991b).

The central tendency (CT), on the other hand, incorporates the arithmetic mean source term concentration and default exposure factors approximating the average of 50th percentile value. The arithmetic mean is simply the sum of the concentrations divided by the total number of concentration values.

Because of the uncertainty associated with estimating the true average concentration at a site, the 95-percent upper confidence limit (UCL) of the arithmetic mean is used for the concentration term in the RME calculations. The 95% UCL provides reasonable confidence that the true site average will not be underestimated (EPA 1989b, 1992a). This estimate of the average concentration also is used because carcinogenic and chronic noncarcinogenic toxicity criteria are based on lifetime average exposures and because average concentrations are most representative of the concentration that would be contacted at a site over an extended period of time.

The W-test was used to determine whether medium-specific data sets were consistent with a normal or lognormal distribution (Gilbert 1987) A normal distribution is typically described as a bell- shaped curve whereas a log normal distribution peaks closer to zero and is skewed toward the x-axis. This test was performed using a computerized statistical software package, Statistical™ (StatSoft 1993).

In general, both groundwater and soil gas data were lognormally distributed; therefore, the UCL was calculated as:

$$UCL = \exp[x + 0.5s + \frac{sH_{i}}{\sqrt{n}-1}]$$

where, x is the mean concentration, s is the standard deviation, n is the number of samples, and H_{x-1} is the one-sided upper 95% UCL (Gilbert 1987)

3.3.1 Exposure Concentrations

3.3.1.1 Groundwater Ingestion and Inhalation Concentrations

EPCs for groundwater were developed for each monitoring well in which at least one COPC was positively detected. This well-by-well approach was used because it is possible that an individual monitoring well could represent the sole source of exposure to groundwater. Groundwater monitoring well data from the Phase 1, 2, 3 RI were used to develop exposure point concentrations for the future scenario. COPCs were identified separately in each monitoring well. The maximum detected concentration of each COPC in each well was used as the RME and average concentration. A single equation (see Section 3 3.5) was used to estimate exposure from groundwater through the inhalation and ingestion pathways. The resulting exposure point concentrations for each COPC in each monitoring well are given in Table 3.3.

3.3.1.2 Indoor Air Concentrations

The results for the Phase 2 and Phase 3 RI soil gas samples were used to calculate exposure-point concentrations for the indoor inhalation route of exposure. Because limited soil gas data were available at each sampling location, the maximum concentration value for each sampling location was used in the RME scenario per EPA guidance (EPA 1989b)

Soil gas sampling data were input to Farmers Model, a predictive model used to estimate the indoor air concentrations (EPA 1992b). The Farmers Model was originally developed to estimate emission rates from covered landfills experiencing internal gas generation as described in the EPA (1988) *Superfund Exposure Assessment Manual* (SEAM) The SEAM's model differs from the Farmer's Model in assuming completely dry soil and containing an explicit surface area term for estimating soil gas concentration from waste decomposition. The Farmers Model can be used to calculate emissions from chemicals dissolved in groundwater or in contaminated soil. It assumes that the chemical concentration in the soil does not decrease as the contaminant migrates upward (i.e., no microbiological degradation) and that the depth to the top of the pollutant source remains constant

In this risk assessment, EPA (1989a) screening parameter values were used as model inputs For example, the fraction of the floor that is accessible to intrusion was assigned a value of 50%, and the building exchange rate was assigned a value of 0.25 change per hour. The building volume was assumed to be ≈35,000 ft^3, and the building area was assumed to be ≈2,100 ft^2, which are typical California home dimensions. Additional details and results are provided in Appendix A.

3.3.2 Intake Rates

All exposure parameter values used in this risk assessment were obtained from EPA sources or guidance documents. The average and RME ingestion rates used in this risk assessment were 1.4 and 2 L/day, respectively (EPA 1988, 1991c). Typically, 20 m^3/day is used as the inhalation rate, which assumes 15 m^3/day indoors and 5 m^3/day outdoors (EPA 1991b). Since this assessment was based on indoor exposure, the 15 m^3/day rate was used in the inhalation exposure calculations for both average and RME exposures. The exposure parameters are given in Table 3-1 and discussed in more detail below.

3.3.3 Duration and Frequency of Exposure

The exposure duration over which chemical intake may occur is based on assumptions about the exposure period and the averaging time. The frequency of exposure is the proportion of time that residents might be exposed to soil gas vapors or groundwater (e g., 350 days per year), whereas the exposure duration is the total amount of time that residents might be exposed (e.g., 30 years). Three hundred fifty days per year was used as the exposure frequency for the average and RME groundwater ingestion scenario The exposure frequency was 275 days/year for the average exposure scenario, and 350 days/year for the RME inhalation exposure scenario (EPA 1989d, 1991b).

The dose for evaluating carcinogenic effects is calculated differently from the dose for noncarcinogenic effects (EPA 1989b). In calculating the lifetime dose for assessing carcinogenic effects, the period of exposure is prorated over the life span (e g., 30 years divided by 70 years). For noncarcinogenic effects, however, the dose is calculated as the daily dose averaged over the period of exposure and not prorated over the life span.

The RME and average exposure scenarios assume continuous 30-year exposure for all pathways, which was determined to be a conservative estimate of the RME on the basis of population statistics (EPA 1991b). For the average exposure scenario, nine years was assumed on the basis of the average residence time reported by EPA (1989d).

3.3.4 Body Weight

For all exposure scenarios, a standard lifetime body weight of 70 kg was assumed for all ages (EPA 1991b). This value is commonly used as the average adult body weight.

3.3.5 Calculation of Dose and Risk

Health risk is determined from the amount of chemical taken up by the body at the exposure-point concentration. Intake rates are expressed in milligrams per kilogram of body weight per day (mg/kg/day). For the inhalation pathway, exposure is calculated as (EPA 1989b):

$$Intake = \frac{CA \ x \ IR \ x \ EF \ x \ ED \ x \ CF}{BW \ x \ AT \ x \ 365 \ d/y}$$

where:

CA = chemical concentration in air ($\mu g/m^3$)
IR = inhalation rate (m^3/day)
EF = exposure frequency (day/year)
ED = exposure duration (years)
CF = conversion factor (1×10^{-3} mg/μg)
BW = body weight (kg)
AT = period over which exposure is averaged (years)

For carcinogens, risk is estimated by multiplying the intake by the slope factor (SF), which account for a chemical's toxicity The SF has units of $(mg/kg/day)^{-1}$, which corresponds to an inverse dose (mg) per unit body weight (kg) per unit time (day). In general, carcinogenic risk is the probability of an incremental increase in the likelihood of cancer over a lifetime exposure. Somewhat analogous to the SF used to calculate carcinogenic risk, the reference dose (RfD) represents the toxicity of noncarcinogenic compounds. SFs and RfDs are discussed in detail in the Toxicity Assessment (Section 4). The equations, exposure parameters, and dose/risk calculations for the indoor air inhalation pathway are shown in Table 3-2.

Under residential land use, the risk from contaminated groundwater is primarily due to direct ingestion and inhalation of volatile chemicals released from the water during household activities such as dishwashing and showering. According to EPA guidance (1991c), inhalation and ingestion of volatile chemicals can be evaluated simultaneously when the COPC has a Henry's Law constant greater than 10^{-5} atm-m^3/mole and a molecular weight less than 200 g/mole. All groundwater COPCs meet these criteria so the following equations were used. The equation to calculate carcinogenic risk incorporates two terms to account for the groundwater ingestion and inhalation pathways (EPA 1991c).

$$Risk = \frac{EF \ x \ ED \ x \ C \ x \ [(SF_o \ x \ IR_w) + (SF_i \ x \ K \ x \ IR_a)]}{BW \ x \ AT \ x \ 365 \ days/yr}$$

where:

C = chemical concentration in water (mg/L)
IR_a = indoor inhalation rate (m^3/day)
IR_w = water ingestion rate (L/day)
SF_i = inhalation slope factor (kg-day/mg)
SF_o = oral slope factor (kg-day/mg)
EF = exposure frequency (days/year)
ED = exposure duration (years)
K = volatilization factor (unitless, see text)
BW = body weight (kg)
AT = period over which exposure is averaged (day).

Primarily on the basis of experimental data for the volatilization of radon from household uses of water, Andelman (1990) derived an equation that defines the relationship between the concentration of a contaminant in household water and the average concentration of the volatilized contaminant in air. In the derivation, all uses of household water were considered including showering, laundering, and dishwashing. The equation uses a default volatilization constant (K) upper-bound value of 0.0005 x 1.000 L/m^3. The 1.000 L/m^3 conversion factor converts the air concentration to a water concentration.

In cases where the chemical intakes produced risks greater than 10^{-2}. the one-hit equation was used to calculate carcinogenic risks (EPA 1989b). This equation. risk = 1-exp(-CDI x SF). is consistent with the linear low-dose model.

CDI is the chronic daily intake averaged over 70 years. For noncarcinogens. an analogous equation was used:

$$Hazard\ Index = \frac{EF\ x\ ED\ x\ C\ x\ [(1/RfD_o\ x\ IR_w)\ -\ (1/RfD_i\ x\ IR_a)]}{BW\ x\ AT\ x\ 365\ days/yr}$$

where

RfD_o = oral chronic reference dose (mg/kg-day)
RfD_i = inhalation chronic reference dose (mg/kg-day)

These equations. exposure parameters. and dose/risk calculations are shown in Tables 3-3 and 3-4.

Table 3-1

Exposure Parameters

Groundwater Ingestion Pathway

Variable	Description	Value		Units	Reference
		Average	RME		
CW	Chemical Concentration in Water	Well Specific	Well Specific	ug/L	See Tables 3-3,3-4
IR	Ingestion Rate	1.4	2	L/day	EPA 1989d, 1991a
EF	Exposure Frequency	350	350	days/year	EPA 1991a
ED	Exposure Duration	9	30	years	EPA 1989d, 1991a
BW	Body Weight	70	70	kg	EPA 1991a
AT_{carc}	Averaging Time - Carcinogens	25,550	25,550	days	EPA 1991a
AT_{non}	Averaging Time - Noncarcinogens	10,950	10,950	days	EAP 1991a

Groundwater and Indoor Air Inhalation Pathways

Variable	Description	Average	RME	Units	Reference
CA	Chemical Concentration in Air	Chem. Specific	Chem. Specific	ug/m^3	See Tables 3-2-3-4
IR	Inhalation Rate	15	15	m^3/day	EPA 1991a
ET	Exposure Time	24	24	hours/day	EPA 1991a
EF	Exposure Frequency	275	350	days/year	EPA 1989d, 1991a
ED	Exposure Duration	9	30	years	EPA 1989d, 1991a
CF	Conversion Factor	0.001	0.001	mg/ug	--
BW	Body Weight	70	70	kg	EPA 1991a
AT	Averaging Time - Carcinogens	25,550	25,550	days	EPA 1991a
AT	Averaging Time - Noncarcinogens	10,950	10,950	days	EPA 1991a

Table 3-2

Inhalation Exposure/Risk Using Farmers Model Results

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CA \times IR \times EF \times ED \times CF}{BW \times AT}$$

Parameters:

CA = Chemical Concentration in Air Estimated by Farmer Model (ug/m^3)
IR = Inhalation Rate (m^3/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
CF = Conversion Factor (1 x 10^{-3} mg/ug)
BW = Body Weight (kg)
AT = Averaging Time (days)

Carcinogens:

Chemical	CA ug/m^3	IR m^3/hr	EF days/yr	ED yrs	CF mg/ug	BW kg	AT days	Intake mg/kg-day	Slope Factor (mg/kg-day) [1]	Risk
PCE - ave	6.6	15	275	9	0.001	70	25550	1.4E-4	0.00203	2.8E-7
TCE - ave	0.48	15	275	9	0.001	70	25550	1.0E-5	0.006	6.0E-8
1,2-DCE - ave	0.36	15	275	9	0.001	70	25550	7.5E-6	0.0805	6.0E-7
PCE - max	19	15	350	30	0.001	70	25550	1.7E-3	0.00203	3.4E-6
TCE - max	1.5	15	350	30	0.001	70	25550	1.3E-4	0.006	7.9E-7
1,2-DCE - max	0.65	15	350	30	0.001	70	25550	5.7E-5	0.0805	4.6E-6

Subtotals		
	Average	9.4E-7
	RME	8.8E-6

Noncarcinogens:

Chemical	CA ug/m^3	IR m^3/hr	EF days/yr	ED yrs	CF mg/ug	BW kg	AT days	Intake mg/kg-day	Inhal. RfD mg/kg-day	Risk
PCE - ave	6.6	15	275	9	0.001	70	3285	1.1E-3	0.01	0.11
TCE - ave	0.48	15	275	9	0.001	70	3285	7.7E-5	0.006	0.01
1,2-DCE - ave	0.36	15	275	9	0.001	70	3285	5.8E-5	0.00286	0.02
PCE - max	19	15	350	30	0.001	70	10950	3.9E-3	0.01	0.39
TCE - max	1.5	15	350	30	0.001	70	10950	3.1E-4	0.006	0.05
1,2-DCE - max	0.65	15	350	30	0.001	70	10950	1.3E-4	0.00286	0.05

Subtotals		
	Average	0.14
	RME	0.49

PCE - Tetrachloroethylene
TCE - Trichloroethylene
1,2-DCE - cis-1,2-dichloroethylene

Table 3-3
Ingestion and Inhalation of Carcinogenic Volatiles in Groundwater

Risk $= SF_o \times (\text{Intake from ingestion of water}) + SF_i \times (\text{Intake from inhalation of volatiles in water})$

$$= \frac{SF_o \times C \times IR_w \times EF \times ED}{BW \times AT \times 365 \text{ days/yr}} + \frac{SF_i \times C \times K \times IR_a \times EF \times ED}{BW \times AT \times 365 \text{ days/yr}}$$

$$= \frac{EF \times ED \times C \times [(SF_o \times IR_w) + (SF_i \times K \times IR_a)]}{BW \times AT \times 365 \text{ days/yr}}$$

Where

SF_o = Oral cancer slope factor $(\text{mg/kg-day})^{-1}$	ED = Exposure duration (years)
SF_i = Inhalation cancer slope factor $(\text{mg/kg-day})^{-1}$	BW = Adult body weight (kg)
C = Chemical concentration in water (mg/L)	AT = Averaging time (years)
IR_w = Daily water ingestion rate (L/day)	K = Volatilization factor (unitless)
EF = Exposure frequency (days/year)	IR_a = Indoor inhalation rate (m^3/day)

RME Scenario

Well	COPC	C ug/L	C mg/L	EF days/yr	ED yrs	IR_a m3/day	IR_w L/day	SF_o (mg/kg-day)-1	SF_i (mg/kg-day)-1	K	BW kg	AT yr	Risk	Total Risk by Well
Elk	1,2-Dichloroethane	0.3	3E-04	350	30	15	2	0.091	0.0805	0.5	70	70	1.4E-6	
Elk	Benzene	0.4	4E-04	350	30	15	2	0.029	0.029	0.5	70	70	6.5E-7	
Elk	Tetrachloroethene	32	0.032	350	30	15	2	0.052	0.00203	0.5	70	70	2.2E-5	2.4E-5
MW-1	1,2-Dibromoethane	0.2	2E-04	350	30	15	2	85	0.77	0.5	70	70	2.1E-4	
MW-1	1,2-Dichloropropane	0.2	2E-04	350	30	15	2	0.068	0.068	0.5	70	70	7.6E-7	
MW-1	Benzene	0.4	4E-04	350	30	15	2	0.029	0.029	0.5	70	70	6.5E-7	
MW-1	Tetrachloroethene	340	0.34	350	30	15	2	0.052	0.00203	0.5	70	70	2.4E-4	4.5E-4
MW-2	1,2-Dibromoethane	0.2	2E-04	350	30	15	2	85	0.77	0.5	70	70	2.1E-4	
MW-2	Chloroform	0.1	1E-04	350	30	15	2	0.0061	0.0805	0.5	70	70	3.6E-7	
MW-2	Tetrachloroethene	171.8	0.172	350	30	15	2	0.052	0.00203	0.5	70	70	1.2E-4	3.3E-4
MW-3	1,2-Dibromoethane	8	0.008	350	30	15	2	85	0.77	0.5	70	70	8.3E-3	
MW-3	1,2-Dichloropropane	6	0.006	350	30	15	2	0.068	0.068	0.5	70	70	2.3E-5	
MW-3	Chloroform	0.5	5E-04	350	30	15	2	0.0061	0.0805	0.5	70	70	1.8E-6	
MW-3	Tetrachloroethene	4200	4.2	350	30	15	2	0.052	0.00203	0.5	70	70	2.9E-3	
MW-3	Trichloroethene	34	0.034	350	30	15	2	0.011	0.006	0.5	70	70	1.3E-5	1.1E-2
MW-4	1,2-Dibromoethane	0.4	4E-04	350	30	15	2	85	0.77	0.5	70	70	4.1E-4	

Table 3-3
Ingestion and Inhalation of Carcinogenic Volatiles in Groundwater

RME Scenario (Cont.)

Well	COPC	C ug/L	C mg/L	EF days/yr	ED yrs	IR$_a$ m3/day	IR$_w$ L/day	SF$_o$ (mg/kg-day)-1	SF$_i$ (mg/kg-day)-1	K	BW kg	AT yr	Risk	Total Risk by Well
MW-4	1,2-Dichloropropane	0.2	2E-04	350	30	15	2	0.068	0.068	0.5	70	70	7.6E-7	
MW-4	Chloroform	1	0.001	350	30	15	2	0.0061	0.0805	0.5	70	70	3.6E-6	
MW-4	Tetrachloroethene	2800	2.8	350	30	15	2	0.052	0.00203	0.5	70	70	2.0E-3	
MW-4	Trichloroethene	3	0.003	350	30	15	2	0.011	0.006	0.5	70	70	1.2E-6	2.4E-3
MW-5	1,2-Dibromoethane	0.4	4E-04	350	30	15	2	85	0.77	0.5	70	70	4.1E-4	
MW-5	1,2-Dichloropropane	0.2	2E-04	350	30	15	2	0.068	0.068	0.5	70	70	7.6E-7	
MW-5	Chloroform	0.3	3E-04	350	30	15	2	0.0061	0.0805	0.5	70	70	1.1E-6	
MW-5	Tetrachloroethene	17300	17.3	350	30	15	2	0.052	0.00203	0.5	70	70	1.2E-2	
MW-5	Trichloroethene	3	0.003	350	30	15	2	0.011	0.006	0.5	70	70	1.2E-6	1.3E-2
MW-6	Tetrachloroethene	44	0.044	350	30	15	2	0.052	0.00203	0.5	70	70	3.1E-5	3.1E-5
MW-7	Chloroform	1.6	0.002	350	30	15	2	0.0061	0.0805	0.5	70	70	5.8E-6	
MW-7	Tetrachloroethene	4.2	0.004	350	30	15	2	0.052	0.00203	0.5	70	70	2.9E-6	8.7E-6
MW-8	Tetrachloroethene	74000	74	350	30	15	2	0.052	0.00203	0.5	70	70	5.2E-2	
MW-8	Toluene	13200	13.2	350	30	15	2	NA	NA	0.5	70	70	--	**0.1**
MW-9	Tetrachloroethene	40	0.04	350	30	15	2	0.052	0.00203	0.5	70	70	2.8E-5	2.8E-5

Average Scenario

Well	COPC	C ug/l	C mg/L	EF days/yr	ED yrs	IR$_a$ m3/day	IR$_w$ L/day	SF$_o$ (mg/kg-day)-1	SF$_i$ (mg/kg-day)-1	K	BW kg	AT yr	Risk	Total Risk by Well
Elk	1,2-Dichloroethane	0.3	3E-04	350	9	15	1.4	0.091	0.0805	0.5	70	70	3.9E-7	
Elk	Benzene	0.4	4E-04	350	9	15	1.4	0.029	0.029	0.5	70	70	1.8E-7	
Elk	Tetrachloroethene	32	0.032	350	9	15	1.4	0.052	0.00203	0.5	70	70	5.0E-6	5.5E-6
MW-1	1,2-Dibromoethane	0.2	2E-04	350	9	15	1.4	85	0.77	0.5	70	70	4.4E-5	
MW-1	1,2-Dichloropropane	0.2	2E-04	350	9	15	1.4	0.068	0.068	0.5	70	70	2.1E-7	
MW-1	Benzene	0.4	4E-04	350	9	15	1.4	0.029	0.029	0.5	70	70	1.8E-7	
MW-1	Tetrachloroethene	340	0.34	350	9	15	1.4	0.052	0.00203	0.5	70	70	5.3E-5	9.7E-5
MW-2	1,2-Dibromoethane	0.2	2E-04	350	9	15	1.4	85	0.77	0.5	70	70	4.4E-5	
MW-2	Chloroform	0.1	1E-04	350	9	15	1.4	0.0061	0.0805	0.5	70	70	1.1E-7	
MW-2	Tetrachloroethene	171.8	0.172	350	9	15	1.4	0.052	0.00203	0.5	70	70	2.7E-5	7.1E-5
MW-3	1,2-Dibromoethane	8	0.008	350	9	15	1.4	85	0.77	0.5	70	70	1.8E-3	
MW-3	1,2-Dichloropropane	6	0.006	350	9	15	1.4	0.068	0.068	0.5	70	70	6.4E-6	

Table 3-3
Ingestion and Inhalation of Carcinogenic Volatiles in Groundwater

Average Scenario (Cont.)

Well	COPC	C ug/L	C mg/L	EF days/yr	ED yrs	IR$_a$ m3/day	IR$_w$ l/day	SF$_o$ (mg/kg-day)-1	SF$_i$ (mg/kg-day)-1	K	BW kg	AT yr	Risk	Total Risk by Well
MW-3	Chloroform	0.5	5E-04	350	9	15	1.4	0.0061	0.0805	0.5	70	70	5.4E-7	
MW-3	Tetrachloroethene	4200	4.2	350	9	15	1.4	0.052	0.00203	0.5	70	70	6.5E-4	
MW-3	Trichloroethene	34	0.034	350	9	15	1.4	0.011	0.006	0.5	70	70	3.6E-6	2.4E-3
MW-4	1,2-Dibromoethane	0.4	4E-04	350	9	15	1.4	85	0.77	0.5	70	70	8.8E-5	
MW-4	1,2-Dichloropropane	0.2	2E-04	350	9	15	1.4	0.068	0.068	0.5	70	70	2.1E-7	
MW-4	Chloroform	1	0.001	350	9	15	1.4	0.0061	0.0805	0.5	70	70	1.1E-6	
MW-4	Tetrachloroethene	2800	2.8	350	9	15	1.4	0.052	0.00203	0.5	70	70	4.3E-4	
MW-4	Trichloroethene	3	0.003	350	9	15	1.4	0.011	0.006	0.5	70	70	3.2E-7	4.4E-4
MW-5	1,2-Dibromoethane	0.4	4E-04	350	9	15	1.4	85	0.77	0.5	70	70	8.8E-5	
MW-5	1,2-Dichloropropane	0.2	2E-04	350	9	15	1.4	0.068	0.068	0.5	70	70	2.1E-7	
MW-5	Chloroform	0.3	3E-04	350	9	15	1.4	0.0061	0.0805	0.5	70	70	3.2E-7	
MW-5	Tetrachloroethene	17300	17.3	350	9	15	1.4	0.052	0.00203	0.5	70	70	2.7E-3	
MW-5	Trichloroethene	3	0.003	350	9	15	1.4	0.011	0.006	0.5	70	70	3.2E-7	2.8E-3
MW-6	Tetrachloroethene	44	0.044	350	9	15	1.4	0.052	0.00203	0.5	70	70	6.8E-6	3.1E-5
MW-7	Chloroform	1.6	0.002	350	9	15	1.4	0.0061	0.0805	0.5	70	70	1.7E-6	
MW-7	Tetrachloroethene	4.2	0.004	350	9	15	1.4	0.052	0.00203	0.5	70	70	6.5E-7	2.4E-6
MW-8	Tetrachloroethene	74000	74	350	9	15	1.4	0.052	0.00203	0.5	70	70	1.1E-2	
MW-8	Toluene	13200	13.2	350	9	15	1.4	NA	NA	0.5	70	70	--	**1.1E-2**
MW-9	Tetrachloroethene	40	0.04	350	9	15	1.4	0.052	0.00203	0.5	70	70	6.2E-6	6.2E-6

Bold - Monitoring well containing the greatest RME or average scenario risk

Table 3-4
Ingestion and Inhalation of Noncarcinogenic Volatiles in Groundwater

$$\text{Risk} = \frac{EF \times ED \times C \times [(1/RfD_o \times IR_w) + (1/RfD_i \times K \times IR_i)]}{BW \times AT \times 365\ \text{days/yr}}$$

Where:

RfD_o = Oral reference dose (mg/kg-day)
RfD_i = Inhalation reference dose mg/kg-day
C = Chemical concentration in water (mg/L)
IR_w = Daily water ingestion rate (L/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Adult body weight (kg)
AT = Averaging time (years)
K = Volatilization factor (unitless)
IR_i = Indoor inhalation rate (m^3/day)

RME Scenario

Well	COPC	C ug/L	C mg/l	EF days/yr	ED yrs	IR_a m3/day	IR_w L/day	RfD_o mg/kg-day	RfD_i mg/kg-day	K	BW kg	AT yr	Hazard Quotient	Hazard Index
Elk	1,2-Dichloroethane	0.3	3E-04	350	30	15	2	0.00286	0.00286	0.5	70	70	5.9E-3	
Elk	Benzene	0.4	4E-04	350	30	15	2	0.00171	0.00171	0.5	70	70	1.3E-2	
Elk	Tetrachloroethene	32	0.032	350	30	15	2	0.01	0.01	0.5	70	70	1.8E-1	2.0E-1
MW-1	1,2-Dibromoethane	0.2	2E-04	350	30	15	2	0.000052	0.000052	0.5	70	70	2.1E-1	
MW-1	1,2-Dichloropropane	0.2	2E-04	350	30	15	2	0.000114	0.000114	0.5	70	70	9.8E-2	
MW-1	Benzene	0.4	4E-04	350	30	15	2	0.00171	0.00171	0.5	70	70	1.3E-2	
MW-1	Tetrachloroethene	340	0.34	350	30	15	2	0.01	0.01	0.5	70	70	1.9E+0	2.2E+0
MW-2	1,2-Dibromoethane	0.2	2E-04	350	30	15	2	0.000052	0.000052	0.5	70	70	2.1E-1	
MW-2	Chloroform	0.1	1E-04	350	30	15	2	0.01	0.01	0.5	70	70	5.6E-4	
MW-2	Tetrachloroethene	171.8	0.172	350	30	15	2	0.01	0.01	0.5	70	70	9.6E-1	1.2E+0
MW-3	1,2-Dibromoethane	8	0.008	350	30	15	2	0.000052	0.000052	0.5	70	70	8.6E+0	
MW-3	1,2-Dichloropropane	6	0.006	350	30	15	2	0.000114	0.000114	0.5	70	70	2.9E+0	
MW-3	Chloroform	0.5	5E-04	350	30	15	2	0.01	0.01	0.5	70	70	2.8E-3	
MW-3	Tetrachloroethene	4200	4.2	350	30	15	2	0.01	0.01	0.5	70	70	2.3E+1	
MW-3	Trichloroethene	34	0.034	350	30	15	2	0.006	0.006	0.5	70	70	3.2E-1	3.5E+1
MW-4	1,2-Dibromoethane	0.4	4E-04	350	30	15	2	0.000052	0.000052	0.5	70	70	4.3E-1	

Table 3-4
Ingestion and Inhalation of Noncarcinogenic Volatiles in Groundwater

RME Scenario (Cont.)

Well	COPC	C ug/L	C mg/L	EF days/yr	ED yrs	IR_a m3/day	IR_w l/day	RfD_o mg/kg-day	RfD_i mg/kg-day	K	BW kg	AT yr	Hazard Quotient	Hazard Index
MW-4	1,2-Dichloropropane	0.2	2E-04	350	30	15	2	0.000114	0.000114	0.5	70	70	9.8E-2	
MW-4	Chloroform	1	0.001	350	30	15	2	0.01	0.01	0.5	70	70	5.6E-3	
MW-4	Tetrachloroethene	2800	2.8	350	30	15	2	0.01	0.01	0.5	70	70	1.6E+1	
MW-4	Trichloroethene	3	0.003	350	30	15	2	0.006	0.006	0.5	70	70	2.8E-2	1.6E+1
MW-5	1,2-Dibromoethane	0.4	4E-04	350	30	15	2	0.000052	0.000052	0.5	70	70	4.3E-1	
MW-5	1,2-Dichloropropane	0.2	2E-04	350	30	15	2	0.000114	0.000114	0.5	70	70	9.8E-2	
MW-5	Chloroform	0.3	3E-04	350	30	15	2	0.01	0.01	0.5	70	70	1.7E-3	
MW-5	Tetrachloroethene	17300	17.3	350	30	15	2	0.01	0.01	0.5	70	70	9.6E+1	
MW-5	Trichloroethene	3	0.003	350	30	15	2	0.006	0.006	0.5	70	70	2.8E-2	9.7E+1
MW-6	Tetrachloroethene	44	0.044	350	30	15	2	0.01	0.01	0.5	70	70	2.5E-1	2.5E-1
MW-7	Chloroform	1.6	0.002	350	30	15	2	0.01	0.01	0.5	70	70	8.9E-3	
MW-7	Tetrachloroethene	4.2	0.004	350	30	15	2	0.01	0.01	0.5	70	70	2.3E-2	3.2E-2
MW-8	Tetrachloroethene	74000	74	350	30	15	2	0.01	0.01	0.5	70	70	4.1E+2	
MW-8	Toluene	13200	13.2	350	30	15	2	0.2	0.114	0.5	70	70	5.9E+0	4.2E+2
MW-9	Tetrachloroethene	40	0.04	350	30	15	2	0.01	0.01	0.5	70	70	2.2E-1	2.2E-1

Average Scenario

Well	COPC	C ug/L	C mg/L	EF days/yr	ED yrs	IR_a m3/day	IR_w l/day	RfD_o mg/kg-day	RfD_i mg/kg-day	K	BW kg	AT yr	Hazard Quotient	Hazard Index
Elk	1,2-Dichloroethane	0.3	3E-04	350	9	15	1.4	0.00286	0.00286	0.5	70	70	1.6E-3	
Elk	Benzene	0.4	4E-04	350	9	15	1.4	0.00171	0.00171	0.5	70	70	3.7E-3	
Elk	Tetrachloroethene	32	0.032	350	9	15	1.4	0.01	0.01	0.5	70	70	5.0E-2	5.5E-2
MW-1	1,2-Dibromoethane	0.2	2E-04	350	9	15	1.4	0.000052	0.000052	0.5	70	70	6.0E-2	
MW-1	1,2-Dichloropropane	0.2	2E-04	350	9	15	1.4	0.000114	0.000114	0.5	70	70	2.8E-2	
MW-1	Benzene	0.4	4E-04	350	9	15	1.4	0.00171	0.00171	0.5	70	70	3.7E-3	
MW-1	Tetrachloroethene	340	0.34	350	9	15	1.4	0.01	0.01	0.5	70	70	5.3E-1	6.2E-1
MW-2	1,2-Dibromoethane	0.2	2E-04	350	9	15	1.4	0.000052	0.000052	0.5	70	70	6.0E-2	
MW-2	Chloroform	0.1	1E-04	350	9	15	1.4	0.01	0.01	0.5	70	70	1.6E-4	
MW-2	Tetrachloroethene	171.8	0.172	350	9	15	1.4	0.01	0.01	0.5	70	70	2.7E-1	3.3E-1
MW-3	1,2-Dibromoethane	8	0.008	350	9	15	1.4	0.000052	0.000052	0.5	70	70	2.4E+0	
MW-3	1,2-Dichloropropane	6	0.006	350	9	15	1.4	0.000114	0.000114	0.5	70	70	8.3E-1	

Table 3-4
Ingestion and Inhalation of Noncarcinogenic Volatiles in Groundwater

Average Scenario (Cont.)

Well	**COPC**	**C** **ug/L**	**C** **mg/L**	**EF** **days/yr**	**ED** **yrs**	**IR$_a$** **m3/day**	**IR$_w$** **l/day**	**RfD$_o$** **mg/kg-day**	**RfD$_i$** **mg/kg-day**	**K**	**BW** **kg**	**AT** **yr**	**Hazard Index**	**Hazard Index**
MW-3	Chloroform	0.5	5E-04	350	9	15	1.4	0.01	0.01	0.5	70	70	7.8E-4	
MW-3	Tetrachloroethene	4200	4.2	350	9	15	1.4	0.01	0.01	0.5	70	70	6.6E+0	
MW-3	Trichloroethene	34	0.034	350	9	15	1.4	0.006	0.006	0.5	70	70	8.9E-2	9.9E+0
MW-4	1,2-Dibromoethane	0.4	4E-04	350	9	15	1.4	0.000052	0.000052	0.5	70	70	1.2E-1	
MW-4	1,2-Dichloropropane	0.2	2E-04	350	9	15	1.4	0.000114	0.000114	0.5	70	70	2.8E-2	
MW-4	Chloroform	1	0.001	350	9	15	1.4	0.01	0.01	0.5	70	70	1.6E-3	
MW-4	Tetrachloroethene	2800	2.8	350	9	15	1.4	0.01	0.01	0.5	70	70	4.4E+0	
MW-4	Trichloroethene	3	0.003	350	9	15	1.4	0.006	0.006	0.5	70	70	7.8E-3	4.5E+0
MW-5	1,2-Dibromoethane	0.4	4E-04	350	9	15	1.4	0.000052	0.000052	0.5	70	70	1.2E-1	
MW-5	1,2-Dichloropropane	0.2	2E-04	350	9	15	1.4	0.000114	0.000114	0.5	70	70	2.8E-2	
MW-5	Chloroform	0.3	3E-04	350	9	15	1.4	0.01	0.01	0.5	70	70	4.7E-4	
MW-5	Tetrachloroethene	17300	17.3	350	9	15	1.4	0.01	0.01	0.5	70	70	2.7E+1	
MW-5	Trichloroethene	3	0.003	350	9	15	1.4	0.006	0.006	0.5	70	70	7.8E-3	2.7E+1
MW-6	Tetrachloroethene	44	0.044	350	9	15	1.4	0.01	0.01	0.5	70	70	6.9E-2	6.9E-2
MW-7	Chloroform	1.6	0.002	350	9	15	1.4	0.01	0.01	0.5	70	70	2.5E-3	
MW-7	Tetrachloroethene	4.2	0.004	350	9	15	1.4	0.01	0.01	0.5	70	70	6.6E-3	9.1E-3
MW-8	Tetrachloroethene	74000	74	350	9	15	1.4	0.01	0.01	0.5	70	70	1.2E+2	
MW-8	Toluene	13200	13.2	350	9	15	1.4	0.2	0.114	0.5	70	70	1.7E+0	**1.2E+2**
MW-9	Tetrachloroethene	40	0.04	350	9	15	1.4	0.01	0.01	0.5	70	70	6.3E-2	6.3E-2

Bold - Well containing the highest RME and average scenario hazard index.

4. TOXICITY ASSESSMENT

The purpose of this toxicity assessment is to compile toxicity data for the Modesto site COPCs and estimate the relationship between the extent of exposure to a contaminant (i e., the dose level) and the likelihood or severity of adverse effects. This dose-response relationship provides the basis for deriving the toxicity values (i e., SFs and RfDs) used in the baseline risk assessment. Toxicity values for each COPC are presented in Section 4 1, and uncertainties in the toxicity assessment process are discussed in Section 4.2.

4.1 TOXICITY VALUES

Toxicity values were compiled to estimate the relationship between the extent of exposure to a contaminant and the potential increased likelihood or severity of adverse effects. The methods for deriving toxicity criteria and estimating potential adverse effects are presented below. The toxicity values for the COPCs evaluated in this baseline risk assessment are presented at the end of this section.

The following EPA sources were used to obtain toxicity values:

- Integrated Risk Information System (IRIS) computer database (EPA 1997) IRIS is the preferred source of information because this database contains the most recent toxicity values that have been reviewed extensively by EPA, and
- Health Effects Assessment Summary Table (HEAST, EPA 1995) This table was consulted if a toxicity value was unavailable on IRIS (EPA 1997). EPA's National Center for Environmental Assessment (NCEA) compiled these values for use in risk assessments Toxicity values presented in HEAST are not reviewed as rigorously as those presented in IRIS.

4.1.1 Categorization of Chemicals as Carcinogens or Noncarcinogens

Carcinogenic and noncarcinogenic health effects were evaluated quantitatively in this baseline risk assessment. The endpoints for these two types of effects are assessed differently because the mechanisms by which chemicals cause cancer are assumed to be fundamentally different from the processes by which noncarcinogenic effects are caused. The principal difference reflects the assumption that noncarcinogenic effects are assumed to exhibit a threshold dose below which no adverse effects occur, whereas no such threshold has been proven to exist for carcinogenic effects.

As used here the term *carcinogen* refers to any chemical for which there is sufficient evidence that exposure may result in continuing uncontrolled cell division (i.e., cancer) in humans or animals. Conversely, the term *noncarcinogen* refers to any chemical for which the carcinogenic evidence is negative or insufficient. These definitions are under constant review by EPA and are subject to change as new information becomes available and the weight-of-evidence is modified. Because exposure to some chemicals may result in carcinogenic and noncarcinogenic effects, both endpoints associated with a COPC were evaluated quantitatively in the baseline risk assessment.

The likelihood that an agent is a human carcinogen is evaluated using EPA's weight-of-evidence classification (EPA 1986) Data derived from human and animal studies are reviewed and characterized as 1) sufficient, 2) limited, 3) inadequate, 4) no data, or 5) evidence of no effect. The weight-of-evidence classifications are presented in Table 4-1

4.1.2 Assessment of Carcinogens

In contrast to noncarcinogenic effects (for which thresholds are thought to exist), thresholds have not been demonstrated for carcinogenic effects. Consequently, federal regulatory agencies (i.e., EPA, the Food and Drug Administration, and the Occupational Safety and Health Administration) assume that any exposure to a carcinogen entails some finite risk of cancer. However, depending on the potency of a specific carcinogen and the level of exposure, such a risk could be extremely small.

Several mathematical models have been developed to estimate low-dose carcinogenic risks from high-dose cancer bioassays. Consistent with current theories of carcinogenesis, EPA selected the linearized multistage model to estimate toxicity values (EPA 1989b) In this model, EPA uses the 95% UCL of the slope of the dose-response curve to estimate cancer SFs. Using these procedures, the regulatory agencies are unlikely to underestimate the actual SFs (also known as *carcinogenic potency factors*) for humans. SFs are expressed as risks per mg/kg-day^{-1}. However, toxicity values for carcinogenic effects sometimes are expressed in terms of risk per unit concentration of the substance in the medium where human contact occurs. Inhalation SFs may be derived from inhalation unit risks (expressed as micrograms per cubic meter [$\mu g/m^3]^{-1}$) by assuming a body weight of 70 kg and an inhalation rate of 20 cubic meters per day (m^3/day) Oral SFs may be derived from drinking water unit risks by assuming a 70-kg body weight and a water ingestion rate of 2 liters per day (L/day) Where an absorption fraction of less than 1 0 was applied in deriving the unit risk, an additional conversion factor is necessary so that the SF will be based on an administered dose. The standard duration assumption for SFs is continuous lifetime exposure. Hence, when no absorption adjustment is required:

$$\underset{(\text{mg/kg-day})^{-1}}{\text{Inhalation Slope Factor}} = \frac{\text{Air Unit Risk } (\mu\text{g/m}^3)^{-1} \times 70 \text{ kg} \times 10^3\ \mu\text{g/mg}}{20 \text{ m}^3/\text{day}}$$

$$\underset{(\text{mg/kg-day})^{-1}}{\text{Oral Slope Factor}} = \frac{\text{Water Unit Risk } (\mu\text{g/L})^{-1} \times 70 \text{ kg} \times 10^3\ \mu\text{g/mg}}{2 \text{ L/day}}$$

Oral and inhalation SFs for the COPCs identified at the Modesto site are presented in Table 4-2. EPA's weight-of-evidence classification for the chemical and the type of cancer that may be associated with exposure to the chemical also are included in Table 4-2.

4.1.3 Assessment of Noncarcinogens

The potential for adverse health effects associated with noncarcinogens (e g., organ damage, immunological effects, birth defects, and skin irritation) usually is assessed by comparing the estimated average daily intake (i.e., exposure dose) to an RfD. EPA develops the RfD by identifying the no-observed-adverse-effect level (NOAEL) or lowest-observed-adverse-effect level (LOAEL) in the scientific literature. NOAELs and LOAELs may be derived from either human epidemiological studies or animal studies; however, because human data often are lacking, they usually are derived from laboratory animal studies in which relatively high doses are administered. Uncertainty factors (UFs) then are applied to the NOAELs and LOAELs to compensate for the data limitations inherent in the experiments, in addition to uncertainties associated with extrapolating high-dose animal data to the relatively low-dose environmental exposure situation in humans. UFs are applied to NOAELs and LOAELs as follows (EPA 1989b):

- A UF of 10 is used to account for variation in the general population. This factor is intended to protect sensitive subpopulations (i.e., the elderly and children);
- A UF of 10 is used when extrapolating from animals to humans. This factor is intended to account for the interspecies variability between humans and other mammals;
- A UF of 10 is used when a NOAEL is derived from a subchronic, rather than a chronic, study; and
- A UF of 10 is used when a LOAEL is used instead of a NOAEL. This factor is intended to account for the uncertainty associated with extrapolating from LOAELs to NOAELs.

In addition to the UFs listed above, a modifying factor (MF) is applied:

- An MF ranging from 0 to 10 is included to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire database. The default value for the MF is 1.

To calculate the RfD, the appropriate NOAEL (or the LOAEL if a suitable NOAEL unavailable) is divided by the product of all of the applicable UFs and the MF:

$$\text{RfD} = \text{NOAEL or LOAEL}/(\text{UF}_1 \times \text{UF}_2 \ldots \times \text{MF})$$

Oral RfDs typically are expressed in mg/kg-day. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily intake to humans (including sensitive subgroups) that should not result in an appreciable risk of deleterious effects. EPA assigns a qualitative level of confidence (i e., low, medium, or high) to the study used to derive the toxicity value, database, and RfD. The relative degree of uncertainty associated with the RfDs and the level of confidence that EPA assigns to the data and the toxicity value are considered when evaluating the quantitative results of the risk assessment.

RfDs are developed for specific exposure routes (i e., oral, dermal, and inhalation). EPA frequently provides noncancer toxicity criteria for inhalation exposure as reference concentrations (RfCs) rather than RfDs. RfCs are derived using the same principles as those for oral RfDs. However, the analysis of inhalation exposures is more complex because of the dynamics of the respiratory system and its diversity across species and because of differences in the physicochemical properties of contaminants (EPA 1989b) RfCs are expressed as a concentration in air (in milligrams per cubic meter [mg/m^3]) for continuous, 24-hour-per-day exposure. However, for risk assessment purposes, the RfC must be converted to a corresponding inhalation RfD (RfD$_i$). A human adult body weight of 70 kg and an inhalation rate of 20 m^3/day are used to convert an RfC to an RfD$_i$:

$$\text{RfD}_i \text{ (mg/kg-day)} = \text{RfC (mg/m}^3\text{)} \times 20 \text{ (m}^3\text{/day)} \times 1/(70 \text{ [kg]})$$

RfDs and RfCs may be derived for chronic and subchronic exposures: EPA defines *chronic* as 7 years or longer and *subchronic* as 2 weeks to 7 years (EPA 1989b). In this baseline risk assessment, chronic RfDs were employed to evaluate all potential noncancer health effects.

RfDs are used as reference points for assessing the likelihood that potential adverse health effects would be associated with site-related exposures Usually, adverse health effects are unlikely to be associated with exposures that are less than the RfD: the likelihood of adverse health effects in a human population increases as the predicted exposures exceed the RfD. However, it is impossible to state definitively that all exposures below the RfD are acceptable (risk-free) and that all exposures above the RfD are unacceptable (causing adverse effects).

RfDs for the COPCs identified at the Modesto site are presented in Table 4-3 Other entries in the table include.

- Confidence level—The degree of confidence that should be placed in the RfD value;
- Critical effect—The effect or target organ affected by the smallest dose of the chemical that produces any adverse effect and serves as the basis for the RfD.
- RfD source—The reference for the RfD; and
- RfD basis—The route through which the chemical was administered, or the medium of exposure in the study(ies) that served as the basis for the RfD.

4.2 ROUTE-TO-ROUTE EXTRAPOLATION OF REFERENCE DOSES AND SLOPE FACTORS ORAL-TO-INHALATION EXTRAPOLATION

Oral RfDs and SFs also may be used to derive inhalation toxicity values if inhalation route RfDs and SFs are unavailable for organic COPCs. However, it is inappropriate to perform oral-to-inhalation extrapolation of toxicity values if the critical effects for either route are at the point of contact (as is the case for most metals). For this baseline risk assessment, oral RfDs and SFs were used as inhalation RfDs and SFs, respectively for organic COPCs.

Table 4-1

WEIGHT-OF-EVIDENCE CLASSIFICATIONS FOR CHEMICAL CARCINOGENICITY MODESTO GROUNDWATER CONTAMINATION SITE MODESTO, CALIFORNIA

Group	Descrption
A	Human Carcinogen
B	Probable Human Carcinogen B1 Limited human data are available B2 Sufficient evidence in animals or no evidence in humans
C	Possible Human Carcinogen
D	Not Classifiable
E	Evidence of Noncarcinogenicity for Humans

Source United States Environmental Protection Agency (1986)

Table 4-2

TOXICITY VALUES FOR POTENTIAL CARCINOGENIC EFFECTS
BASELINE HUMAN HEALTH RISK ASSESSMENT
MODESTO GROUNDWATER CONTAMINATION SITE
MODESTO, CALIFORNIA

Chemical	Carcinogenicity Classification	Route	Slope Factor $(\text{mg/kg-day})^{-1}$	Target Organ	Tumor Type	Species	Exposure Route	Source
Benzene	A	Oral	0.029	Blood	Leukemia	Human	Inhalation	IRIS
		Inhalation	0.029	Blood	Leukemia	Human	Inhalation	IRIS
Chloroform	B2	Oral	0.0061	Kidney	All	Rat/Osborne-Mendel, male	Drinking water	IRIS
		Inhalation	0.0805[a]	Liver	Hepatocellular carcinoma	Mouse/B6C3F1, female	Oral, gavage	IRIS
1,2-Dibromoethane	B2	Oral	85	Forestomach	Squamous cell carcinoma	Rat/Osborne-Mendel, male	Gavage	IRIS
		Inhalation	0.77[b]	Nasal Cavity	Adenoma, adenocarcinoma, papillary adenoma, squamous cell carcinoma and/or papilloma	Rat/Fisher 344, male	Inhalation	IRIS
1,2-Dichloroethane	B2	Oral	0.091	--	Hemangiosarcoma	Rat/Osborne-Mendel, male	Gavage	IRIS
		Inhalation	0.0805[c]	--	Hemangiosarcoma	Rat/Osborne-Mendel, male	Gavage	IRIS
1,2-Dichloropropane		Oral	0.068	--	--	--	--	HEAST
		Inhalation	0.068	--	--	--	--	Oral SF
Tetrachloroethene		Oral	0.052	--	--	--	--	NCEA
		Inhalation	0.00203	--	--	--	--	NCEA

Key at end of table

Table 4-2

TOXICITY VALUES FOR POTENTIAL CARCINOGENIC EFFECTS
BASELINE HUMAN HEALTH RISK ASSESSMENT
MODESTO GROUNDWATER CONTAMINATION SITE
MODESTO, CALIFORNIA

Chemical	Carcinogenicity Classification	Route	Slope Factor $(mg/kg\text{-}day)^{-1}$	Target Organ	Tumor Type	Species	Exposure Route	Source
Trichloroethene		Oral	0.011	--	--	--	--	--
		Inhalation	0.006	--	--	--	--	NCEA

a - Inhalation slope factor based on the unit risk of 2.3E-05 ug/m3
b - Inhalation slope factor based on the unit risk of 2.2E-04 ug/m3
c - Inhalation slope factor based on the unit risk of 2.5E-05 ug/m3

Key

EPA = United States Environmental Protection Agency
HEAST = Health Effects Assessment Summary Table
IRIS = Integrated Risk Information System
mg/kg = Milligrams per kilogram
NCEA = National Center for Environmental Assessment
-- = Not determined
Oral SF = Derived from oral slope factor

Table 4-3

TOXICITY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS
BASELINE HUMAN HEALTH RISK ASSESSMENT
MODESTO GROUNDWATER CONTAMINATION SITE
MODESTO, CALIFORNIA

Chemical	Route	RfD (mg/kg-day)	Uncertainty Factor	Modifying Factor	Confidence Level	Target Organ	Critical Effect	Source
Benzene	Oral	--	--	--	--	--	--	--
	Inhalation	0.00171	--	--	--	--	--	NCEA
Chloroform	Oral	0.01	1,000	1	Medium	Liver	Fatty cyst formation	IRIS
	Inhalation	--	--	--	--	--	--	--
1,2-Dibromoethane	Oral	--	--	--	--	--	--	--
	Inhalation	0.000052[a]	1,000	1	--	--	Sperm effects in humans	HEAST
1,2-Dichloroethane	Oral	--	--	--	--	--	--	--
	Inhalation	0.00286	--	--	--	--	--	NCEA
cis-1,2-Dichloroethene	Oral	0.01	3,000	1	--	Blood	Decreased hematocrit	HEAST
	Inhalation	--	--	--	--	--	--	--
1,2-Dichloropropane	Oral	--	--	--	--	--	--	--
	Inhalation	0.000114[b]	300	1	Medium	Nasal mucosa	Hyperplasia	IRIS
Tetrachloroethene	Oral	0.01	1,000	1	Medium	--	Hepatotoxicity, weight gain	IRIS
	Inhalation	--	--	--	--	--	--	--
Toluene	Oral	0.2	1,000	1	Medium	Kidney, liver	Alternations in organ weight	IRIS
	Inhalation	0.114[c]	3000	1	Medium	Central nervous system	Neurological effects	IRIS
Trichloroethene	Oral	0.006	--	--	--	--	--	NCEA
	Inhalation	0.006	--	--	--	--	--	Oral RfD

a - Derived from the reference concentration of 2E-04 mg/m3
b - Derived from the reference concentration of 4E-03 mg/m3
c - Derived from the reference concentration of 0 4 mg/m3

Key

-- = Not available
ECAO = Environmental Criteria and Assessment Office
EPA = United States Environmental Protection Agency
HEAST = Health Effects Assessment Summay Table
IRIS = Integrated Risk Information System
mg/kg = Milligrams per kilogram
ND = Not determined
NCEA = National Center for Environmental Assessment
Oral RfD = Derived from chronic oral reference dose
RfD = Reference dose

5. RISK CHARACTERIZATION

This section presents the estimates of the magnitude of potential adverse health effects under various conditions defined in the exposure assessment. The risk characterization integrates all of the information developed during the exposure and toxicity assessments to characterize the potential health effects by the different exposure pathways.

5.1 HEALTH IMPACT RISK CALCULATIONS

5.1.1 Carcinogenic Risk

According to EPA (1989b) guidance, carcinogenic risk is the chance of developing cancer due to exposure to a carcinogen; it does not imply death due to cancer. An example of a 1×10^{-6} incidental cancer risk is illustrated below On average, one in every four Americans will develop some form of cancer such as skin cancer from ultraviolet light or lung cancer from smoking at some time during his or her lifetime. This is equivalent to 250,000 cases of cancer for every 1,000,000 people. Thus, a one in 1,000,000 (or 1×10^{-6}) incremental cancer risk corresponds to 250,001 cases of cancer for 1,000,000 people The one theoretical extra case results from the calculated chemical exposure.

The potential risks associated with the various exposure pathways are estimated as the probability of excess cancer using the equation:

$$Risk_i = SF \times D_i$$

where:

$risk_i$ = the risk associated with pathway i

SF = cancer slope factor (kg-day/mg)

D_i = dose from pathways i, (mg/kg-d)

The potential cumulative health risks associated with exposure via multiple exposure pathways is determined by summing the risks across all exposure pathways:

$$Cancer\ Risk = \sum_{i} risk_i$$

The cumulative risk for all pathways (i) indicates the excess lifetime probability of cancer that may occur through exposure to the COPCs. Equations, exposure parameters, and dose/risk calculations for calculating carcinogenic risk are given in Tables 3-1 through 3-4.

5.1.2 Noncarcinogenic Health Impacts

Noncarcinogenic health impacts are evaluated separately from carcinogenic risks. Unlike carcinogenic effects, noncarcinogenic effects are assumed to have a threshold dose below which no adverse effect is observed. Health risks are therefore evaluated by comparing the calculated daily dose to an EPA RfD. The RfD is calculated from the no adverse effect does, which considers sensitive populations, after taking into account uncertainties and species differences.

The noncarcinogenic health risk is expressed as the hazard quotient (HQ) which is calculated as:

$$HQ_i = \frac{D_i}{RfD}$$

where

HQ_i = hazard quotient associated with pathway i
D_i = chronic dose from pathway i (mg/kg-day)
RfD = reference dose (mg/kg-day)

An HQ greater than 1 0 suggests that exposure to a substance exceeds a generalized level of concern.

Cumulative noncarcinogenic impacts for all relevant pathways of exposure (i) are calculated as:

$$Hazard\ Index = \sum_i HQ_i$$

A hazard index of 1 or less is generally recognized as the level where no adverse health effects would be expected. Equations, exposure parameters, and risk calculations for noncarcinogens are given in Tables 3-1 through 3-4.

5.2 UNCERTAINTIES

In most risk assessments, many assumptions must be made in estimating exposure and chemical toxicity because of a lack of actual data. While such assumptions may not be universally agreed upon, they should be based on sound scientific information and site-specific conditions, and their rationale should be explicitly stated. Uncertainties in the risk assessment process may cause the exposure levels to differ from the exposures that the populations might actually experience. This section identifies these factors, discusses their potential effects on exposure estimates, and presents an estimate of the degree of confidence in the risk assessment results.

5.2.1 Estimated Exposure Media Concentrations

Samples collected during the RI were analyzed to characterize the nature and extent of VOC contamination at the site. Accordingly, sampling locations were selected in a biased or directed manner. As a result, most samples were collected where the highest VOC concentrations were likely to be found. Such sampling provides considerable information about the site, but the results are not statistically representative of the entire study area and tend to overestimate average and RME concentrations. In some cases, because of data limitations, the maximum COPC concentration detected was used to estimate the source concentration (Section 3.3.1), which results in overestimating risk.

In order to estimate vapor transport, air transport modeling uses many conservative assumptions as discussed in Appendix A The Farmers Model, for example, ignores attenuation factors, and, therefore, it is "likely that this model overpredicts the contaminate flux" which results in a larger source concentration value and hence a greater degree of potential risk (EPA 1992b).

Chemical degradation, partitioning between groundwater, soil, and air, absorption rates in humans from various routes of exposure, and other physical chemical properties are not taken into account, nor are they well understood for the COPCs. By ignoring such factors, potential risk tends to be overestimated.

5.2.2 Analytical Data Limitations

Two factors can be associated with the analytical data that marginally reduce the level of confidence in the COPC concentrations First, J-qualified data will not have the same level of accuracy or precision as data meeting all of the standard quality assurance criteria. Second, high analytical detection limits could allow some chemicals to go undetected, which reduces the level of confidence placed in the calculated upper limit of the potential risk associated with each environmental medium.

5.2.3 Exposure Estimate Calculations

The exposure parameters used in calculating the exposure estimates were obtained primarily from EPA guidance. These values are intentionally conservative and designed to err on the side of overestimating exposure; therefore, there is considerable uncertainty regarding the actual exposure that a receptor would experience. A major source of uncertainty in the quantitative aspect of risk assessments is the propagation of error The calculation of risk is a sequential process with assumptions in one calculation carried forward as assumptions in the next calculation. As a result, the errors are compounded at each step in the assessment.

The RME ingestion of groundwater assumes that residents of all ages drink 2 liters of groundwater almost every day, which may be an overestimate considering the increase in the consumption of bottled water as well as other beverages over the last several years. Furthermore, the future scenario assumes this same quantity of groundwater will be ingested at the site and will come from new drinking water wells installed at the hot spot identified on site.

The amount of uncertainty in risk assessment cannot be easily quantified. In order to accomplish a standard statistical analysis of uncertainty, it is necessary to have a quantitative estimate of the range of uncertainty in each variable and each source as well as information on the underlying statistical distribution of each parameter. At that point, a Monte Carlo uncertainty analysis can be performed.

5.2.4 Uncertainties Related to Toxicity Assessment

For carcinogens, the conservative assumption is made that some finite risk is associated with exposure to a single molecule of a compound ("no dose threshold"). EPA slope factors are generally based on linear high-to-low dose extrapolations, and detoxification mechanisms, which significantly reduce the risk of cancer at low doses, are not considered. Moreover, the EPA criteria used for the toxicity assessment and risk characterization steps are inherently conservative. Because of the numerous data gaps involved at all levels, conservative assumptions are multiplied at various stages of these calculations. In addition, chemicals from the site may have synergistic or antagonistic interactions, which can increase of decrease their toxicity. Finally, when the response from high-dose animal toxicity or epidemiological studies are extrapolated to low doses in humans, an uncertainty factor of 10 or more is applied to the no-observed-adverse-effect level (NOAEL) to estimate an acceptable dose for humans.

Uncertainties in the assessment of dermal exposure were noted in Section 3 2.1 As a result of these uncertainties, dermal contact with groundwater was not considered in this risk assessment. These include (EPA 1992d):

- Oral reference doses and slope factors are used to evaluate potential toxicity from the dermal route of exposure.
- Information to quantitatively evaluate potential toxicity at the skin surface is unavailable.
- For most chemicals, there are not data to quantify the percentage absorbed through the skin.

- Permeability coefficients for water are based on estimated model predictions.

5.3. SUMMARY OF HUMAN HEALTH RISKS

This risk assessment evaluated the human health risks associated with the VOCs in groundwater and soil gas at the Modesto Groundwater Contamination Site. Two residential exposure pathways, residential groundwater use and indoor air inhalation, were evaluated under a future land use scenario using soil gas and groundwater data collected during the RI. Currently, groundwater is not being used at the site, therefore, the current land use scenario incorporates only the indoor air inhalation pathway. Both average and RME exposures were calculated to assess carcinogenic and noncarcinogenic risks. In conducting this risk assessment, conservative upper-bound exposure values developed by EPA were used to calculate the "theoretical excess cancer risk," which is an estimation of the probability of developing cancer over and above the normal background incidence of cancer. A number of assumptions were made in the risk assessment that were intended to err on the side of health protection in order to avoid underestimating the risk to the public. Moreover, the chemical concentrations used to estimate the increased individual carcinogenic risk were based on continuous exposure over a 30-year period. *The actual probability of cancer is, therefore, likely to be much lower than these estimates and may even be zero*

As shown in Table 5-1, the current carcinogenic risk estimates range from 9×10^{-7} to 9×10^{-6} while hazard indices range from 0.1 to 0 5. Under future land use conditions, carcinogenic risk estimates range from 1×10^{-2} to 5×10^{-1} while hazard indices range from 100 to 400. The groundwater ingestion and inhalation pathways contribute the largest risks.

EPA has adopted a policy that acceptable exposures to known or suspected carcinogens fall within an excess upper-bound lifetime cancer risk range of one on 10,000 (10^{-4}) to one in a million (10^{-6}) (EPA 1991a). The indoor air inhalation risks associated with the current land use scenario calculated in this assessment are within acceptable risk levels. The risks calculated for a future exposure scenario in which on-site, untreated groundwater at the location of the most contaminated monitoring well (MW-8) is ingested are higher than the currently acceptable standards (EPA 1991a).

For noncarcinogens, a hazard index of 1 or less is generally recognized as the level at which no adverse health effects would be expected. For the current scenario, the RME and average hazard indices are less than the benchmark of 1; however, under future scenarios, both the average and RME hazard indices exceed the benchmark by 2 orders of magnitude.

In summary, in this risk assessment, it was found that the current risk levels are within acceptable EPA parameters. However, unacceptable risks were, predicted in a hypothetical, future scenario in which an individual ingests untreated groundwater from the hot spot on site.

Table 5-1

SUMMARY OF ESTIMATED RISK VALUES
BASELINE HUMAN HEALTH RISK ASSESSMENT
MODESTO GROUNDWATER CONTAMINATION SITE
MODESTO, CALIFORNIA

Pathway	Hazard Index RME	Hazard Index Average	Cancer Risk RME	Cancer Risk Average
Current Scenario:				
Indoor Air: Inhalation of Soil Gas	0.5	0 1	9 x 10^{-6}	9 x 10^{-7}
Total Risk[a]	**0.5**	**0.1**	**9 x 10^{-6}**	**9 x 10^{-7}**
Future Scenario: Assumes residential use of groundwater from MW-8				
Indoor Air. Inhalation of Soil Gas	0 5	0 1	9 x 10^{-6}	9 x 10^{-7}
Drinking Water· Ingestion and Inhalation	400	100	5 x 10^{-2}	1 x 10^{-2}
Total Risk[b]	**400**	**100**	**5 x 10^{-2}**	**1 x 10^{-2}**

RME = Reasonable Maximum Exposure
Average = Average of typical exposure parameters

[a] See Table 3-2.
[b] See Tables 3-3 and 3-4

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Appendix A
FARMERS MODEL

The Farmers Model can be used for calculating emissions from chemicals dissolved in groundwater or in contaminated soil (EPA 1992b). It assumes that the chemical concentration in the soil does not decrease as the contaminant migrates upward (i.e., no microbiological degradation) and that the depth to the top of the pollutant source remains constant.

The vapor phase contaminant diffuses through the soil at a rate dependent on the soil porosity, pore space geometry, the chemical's air diffusion coefficient, and the concentration gradient between the source and point of exit from the soil. The effective diffusion coefficient (D_s) is calculated as:

$$D_S = \frac{D_A P_a^{3.33}}{P_T^2}$$

where:

D_A = vapor phase diffusion coefficient in air (cm^2/sec)
P_a = air filled soil porosity (unitless)
P_T = total soil porosity (unitless).

The flux is the quantity of the chemical that passes through a fixed unit of space in a certain amount of time. The steady-state flux, J (mg/cm^2-sec), is calculated as:

$$J = \frac{D_s (C_g - C_s)}{L}$$

where:

C_g = chemical concentration in the vapor phase (mg/cm^3)

C_s = vapor phase concentration at the surface, assumed to be zero to maximize flux value (mg/cm^3)

L = the distance from the source to the surface (cm)

Because the model ignores all attenuating factors, it is likely to overestimate the contaminant flux (EPA 1992b). Because of the model's simplicity however, it provides a simple method to estimate the likely maximum rate at which chemicals could be transporting to a building. After calculating chemical flux, the indoor air concentration is estimated as.

$$C_{indoor} = \frac{E}{Q}$$

where

C_{indoor} = indoor air concentration (mg/cm^3)

E = contaminant infiltration rate (mg/sec)

Q = building ventilation rate (cm^3/sec)

The contaminant infiltration rate, E, is approximated as.

$$E = J \times A \times F$$

where

J = steady-state flux (mg/cm^2-sec)

A = area of the building floor (cm^2)

F = fraction of floor though which soil gas can enter (unitless)

The building ventilation rate (Q) is estimated as.

$$Q = \frac{ACH\ x\ V}{3600}$$

where ACH is the number of air changes per hour (hr^{-1}). V is the volume of the building (cm^3), and 3600 converts hours to seconds.

The value for the ACH (0.25) is consistent with the value used in the PRG table (EPA 1996) and the area and volume were consistent with the dimension of a 2.000 ft^2 home. For comparison, Mueller *et al.* reports that typical ACHs for single-family residences range from 0 5 to 1.5 with the ACHs for new or weatherized structures generally ranging from 0 5 to 0.8, but possibly as low as 0.2 (EPA 1992b). Fractional floor space values range from 0.001 for slab floors to 0.01 to 0.1 for the floors of average California houses (Grumund *et al.*, cited in EPA 1992b). Consequently, the most conservative of these values, 0.1, was used in the model.

Table A-1

Flux Calculations

$$J = \frac{C_{sg} \times D_A \times P_a^{(10/3)} \times CF1 \times CF2}{L \times CF3 \times P_T^{2}}$$

Where:

J = Contaminant flux (g/cm2-s)
C_{sg} = Concentration in soil gas (ug/L)
D_A = Diffusivity in air (cm2/s)
P_a = Air-filled soil porosity (unitless)
CF1 = Conversion factor (10^{-6} g/ug)
CF2 = Conversion factor (10^{-3} L/cm^{3})
L = Depth from ground surface to sampling point (ft)
CF3 = Conversion factor (30.48 cm/ft)
P_T = Total soil porosity (unitless)

Phase RI	Sample	Analyte	C_{sg}	D_A	P_a	L	P_T	J
2	SG1-3	Tetrachloroethene	22.76	7.2E-2	0.3	3	0.45	1.6E-12
2	SG1-15	Tetrachloroethene	38.63	7.2E-2	0.3	15	0.45	5.4E-13
2	SG6-3	cis-1,2-Dichloroethene	2.99	7.9E-2	0.3	3	0.45	2.3E-13
2	SG6-3	Trichloroethene	6.54	8.1E-2	0.3	3	0.45	5.2E-13
2	SG6-3	Tetrachloroethene	10.35	7.2E-2	0.3	3	0.45	7.3E-13
2	SG6-15	cis-1,2-Dichloroethene	1.53	7.9E-2	0.3	15	0.45	2.4E-14
2	SG6-15	Trichloroethene	7.63	8.1E-2	0.3	15	0.45	1.2E-13
2	SG6-15	Tetrachloroethene	103.47	7.2E-2	0.3	15	0.45	1.5E-12
2	SG11-15	Tetrachloroethene	172.45	7.2E-2	0.3	15	0.45	2.4E-12
2	SG3-3	Tetrachloroethene	48.98	7.2E-2	0.3	3	0.45	3.4E-12
2	SG3-15	Tetrachloroethene	206.94	7.2E-2	0.3	15	0.45	2.9E-12
2	SG3-15A	Tetrachloroethene	82.78	7.2E-2	0.3	15	0.45	1.2E-12
2	SG13-15	Tetrachloroethene	17.25	7.2E-2	0.3	15	0.45	2.4E-13
2	SG24-15	Tetrachloroethene	96.57	7.2E-2	0.3	15	0.45	1.4E-12
2	SG17-15	Trichloroethene	1.91	8.1E-2	0.3	15	0.45	3.0E-14
2	SG17-15	Tetrachloroethene	82.78	7.2E-2	0.3	15	0.45	1.2E-12
2	SG4-3	Tetrachloroethene	12.42	7.2E-2	0.3	3	0.45	8.7E-13
3	SV2-B	Tetrachloroethene	1017.2	7.2E-2	0.3	50	0.45	4.3E-12
3	SV2-C	Tetrachloroethene	200	7.2E-2	0.3	32	0.45	1.3E-12
3	SV-1 A	Tetrachloroethene	1591.7	7.2E-2	0.3	50	0.45	6.7E-12
3	SV-1 B	Tetrachloroethene	237.2	7.2E-2	0.3	30	0.45	1.7E-12
3	SV-1 C	Tetrachloroethene	611.2	7.2E-2	0.3	23	0.45	5.6E-12
3	SV2-B	Trichloroethene	2.4	8.1E-2	0.3	50	0.45	1.1E-14

Table A-2

Indoor Air Concentrations

$$\boxed{CA = \frac{J \times A \times F \times CF3}{CF4 \times ACH \times V \times CF5}}$$

CA = Target concentration in air (mg/m3)
A = Area of building floor (cm2)
F = Fraction of building floor through which soil gas can enter
CF4 = Conversion factor (3,600 s/hour)
CF5 = Conversion factor (0.001g/mg)
CF6 = Conversion factor (0.000001 m3/cm3)
ACH = Building air changes per hour
V = Volume of building (cm3)

Phase RI	Sample	Analyte	J	A	F	ACH	V	CA
2	SG1-3	Tetrachloroethene	1.6E-12	1,950,963	0.1	0.25	991.089,631	4.54E-03
2	SG1-15	Tetrachloroethene	5.43E-13	1,950,963	0.1	0.25	991,089,631	1.54E-03
2	SG6-3	cis-1,2-Dichloroethene	2.303E-13	1,950,963	0.1	0.25	991,089,631	**6.53E-04**
2	SG6-3	Trichloroethene	5.17E-13	1,950,963	0.1	0.25	991.089.631	**1.47E-03**
2	SG6-3	Tetrachloroethene	7.272E-13	1,950,963	0.1	0.25	991,089,631	2.06E-03
2	SG6-15	cis-1.2-Dichloroethene	2.365E-14	1,950,963	0.1	0.25	991,089,631	6.70E-05
2	SG6-15	Trichloroethene	1.206E-13	1,950,963	0.1	0.25	991,089,631	3.42E-04
2	SG6-15	Tetrachloroethene	1.454E-12	1.950,963	0.1	0.25	991,089,631	4.12E-03
2	SG11-15	Tetrachloroethene	2.424E-12	1.950,963	0.1	0.25	991,089,631	6.87E-03
2	SG3-3	Tetrachloroethene	3.442E-12	1.950.963	0.1	0.25	991.089.631	9.76E-03
2	SG3-15	Tetrachloroethene	2.909E-12	1.950,963	0.1	0.25	991.089.631	8.25E-03
2	SG3-15A	Tetrachloroethene	1.164E-12	1,950,963	0.1	0.25	991,089,631	3.30E-03
2	SG13-15	Tetrachloroethene	2.424E-13	1,950,963	0.1	0.25	991.089.631	6.87E-04
2	SG24-15	Tetrachloroethene	1.357E-12	1.950,963	0.1	0.25	991.089.631	3.85E-03
2	SG17-15	Trichloroethene	3.016E-14	1.950,963	0.1	0.25	991.089,631	8.55E-05
2	SG17-15	Tetrachloroethene	1.164E-12	1.950.963	0.1	0.25	991.089.631	3.30E-03
2	SG4-3	Tetrachloroethene	8.727E-13	1,950,963	0.1	0.25	991,089,631	2.47E-03
3	SV2-B	Tetrachloroethene	4.289E-12	1,950,963	0.1	0.25	991.089,631	1.22E-02
3	SV2-C	Tetrachloroethene	1.318E-12	1,950,963	0.1	0.25	991,089.631	3.74E-03
3	SV-1 A	Tetrachloroethene	6.712E-12	1,950,963	0.1	0.25	991,089,631	**1.90E-02**
3	SV-1 B	Tetrachloroethene	1.667E-12	1.950.963	0.1	0.25	991,089,631	4.73E-03
3	SV-1 C	Tetrachloroethene	5.603E-12	1,950,963	0.1	0.25	991.089.631	1.59E-02
3	SV2-B	Trichloroethene	1.139E-14	1.950.963	0.1	0.25	991.089,631	3.23E-05

Bold - Maximum indoor air concentration for COPC.

Exhibit E

(Diagram of SVE and Groundwater Treatment Systems)

to

Appendix C

(Land Use Covenant)

to

Consent Decree Pertaining to Defendants
Lyons and Tondas

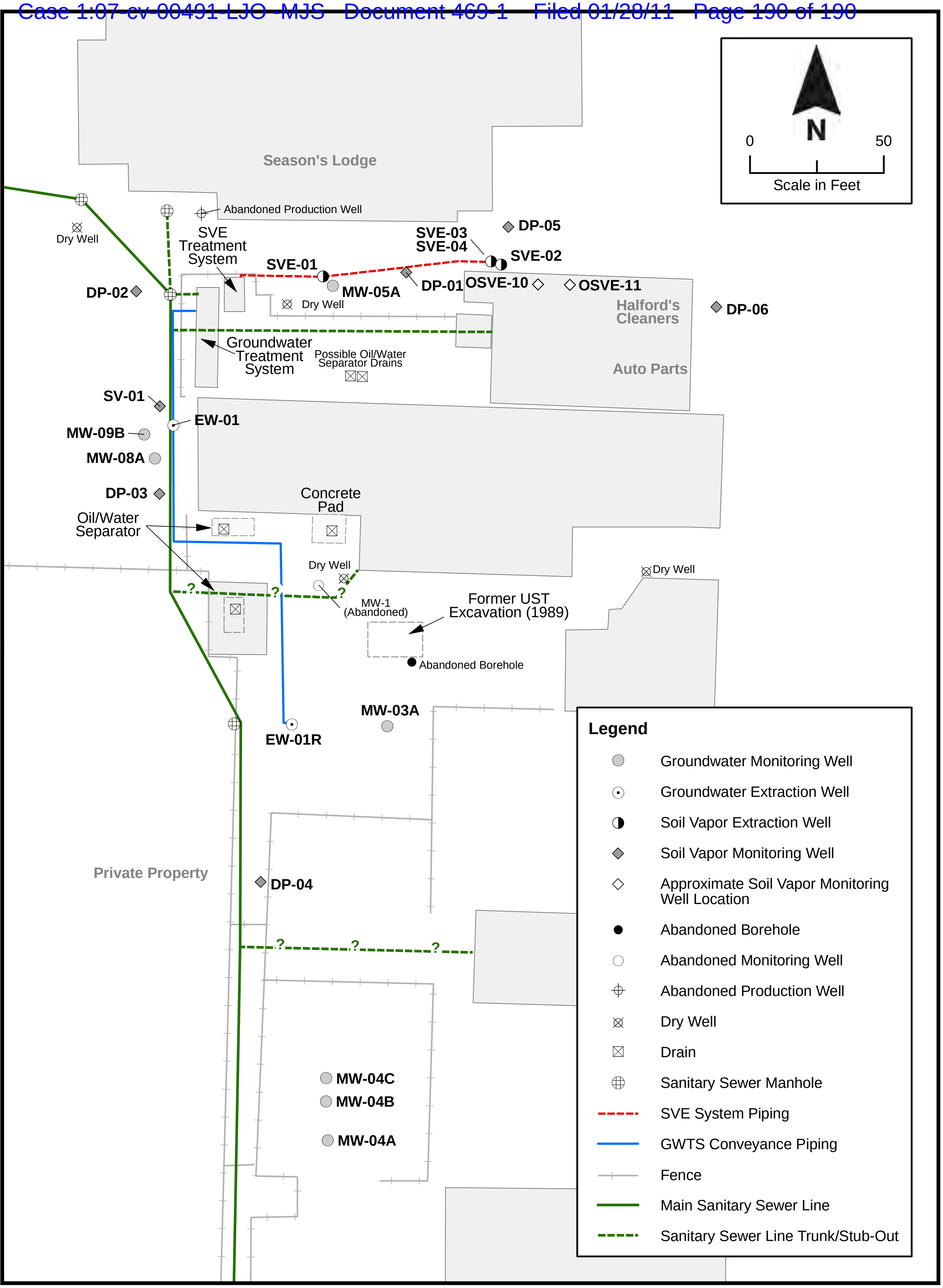

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Figure 2-1. Site Layout
Modesto Groundwater Superfund Site