CDM Camp Dresser & McKee

Report

City of Fresno

Technical Memorandum Comparative Analysis of Alternatives

November 2, 1995

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Comparative Analysis of Alternatives

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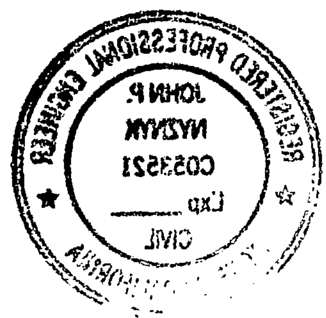

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Introduction

1.1 Purpose of the Technical Memorandum

This purpose of this technical memorandum is to document the evaluations of the remedial alternatives that have been developed to address groundwater remediation at the Fresno Sanitary Landfill (FSL- see Figure 1-1). This technical memorandum also presents the results of a comparative analysis of the alternatives. This technical memorandum is a required submittal based on the U.S. Environmental Protection Agency (EPA) approval (letter dated March 6, 1995) of the proposed deliverables as defined in the memorandum from Camp Dresser & McKee Inc. (CDM) to EPA entitled *Fresno Sanitary Landfill, Focused Feasibility Study* (CDM, 1994).

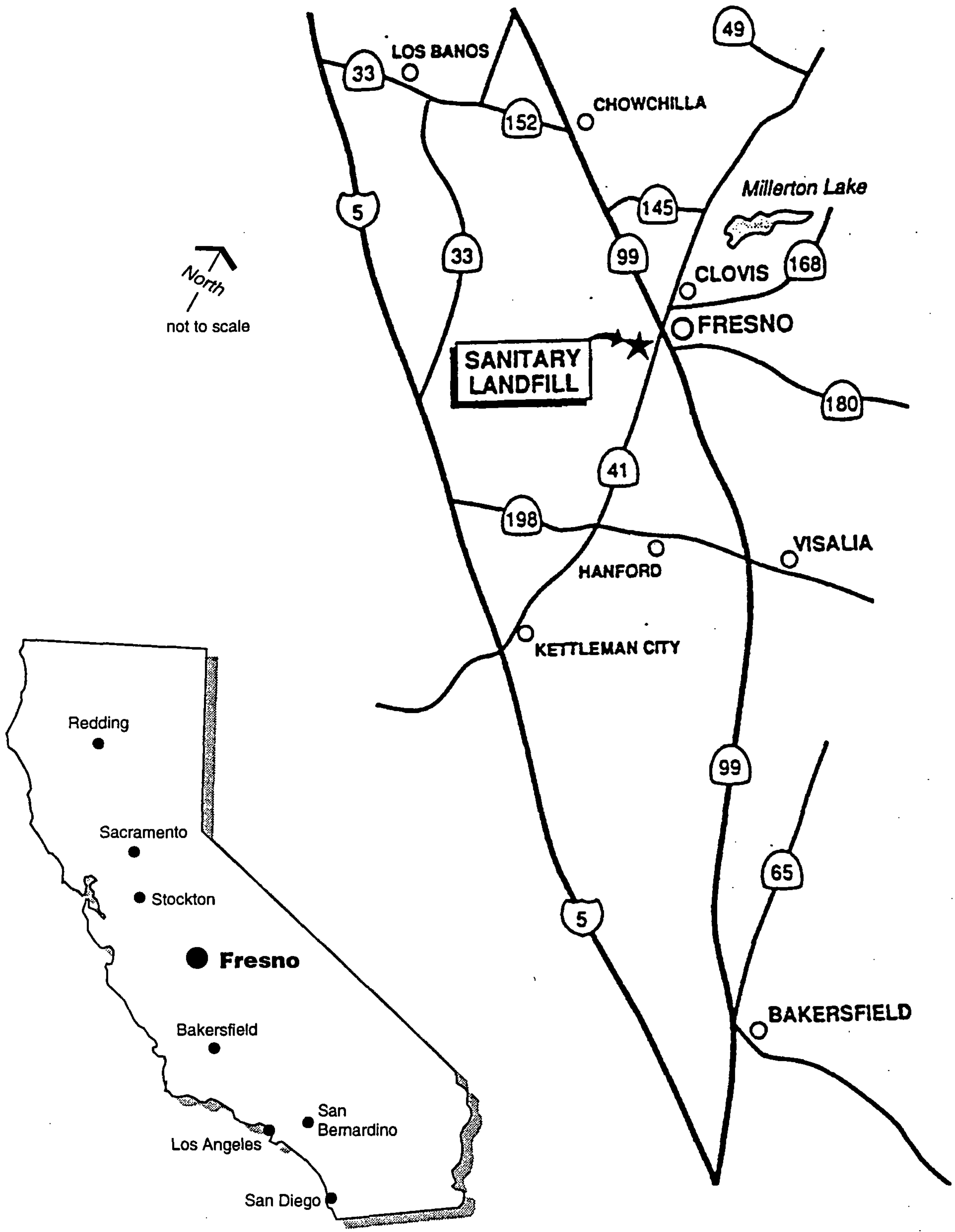
This memorandum provides a mechanism for regulatory review of the remedial alternatives evaluations. The goal is to establish consensus between the City of Fresno (City) and EPA on the direction of the Feasibility Study (FS) alternatives evaluations at an early stage. Based on input from the EPA and state regulators, the evaluations may be modified or refined prior to preparation of the Draft FS Report.

1.2 Memorandum Organization

This Technical Memorandum consists of four sections including this *Introduction*, which provides background information on the FSL and the groundwater modeling used as a tool for developing and comparing the remedial alternatives. Section 2, *Identification of Remedial Alternatives and Evaluation Criteria*, identifies the remedial alternatives to be examined, discusses assumptions that have been made as part of the alternatives evaluations, provides a brief discussion regarding phased implementation of remedial action at the FSL, and defines the CERCLA evaluation criteria applied for the analysis of the remedial alternatives. In Section 3, *Detailed Analysis of Alternatives*, each of the six alternatives are described in detail, followed by a presentation of the comprehensive analysis. This memorandum concludes with Section 4, *Comparative Analysis of Alternatives*, which summarizes the results of the alternatives evaluations with the objective of comparing and contrasting the alternatives.

1.3 Background Information

This section presents a brief overview of the nature and extent of contamination at the FSL, discusses clean-up goals considered as part of the alternatives evaluation, and presents a summary of the groundwater modeling performed.



Site Location Map
Fresno Sanitary Landfill FS
Fresno, CA

Figure 1-1

CDM
Camp Dresser & McKee

1.3.1 Overview of the Nature and Extent of Contamination

The contamination to be addressed in the FS for the FSL consists of a groundwater plume extending approximately 1,300 feet (CDM, 1994) downgradient of the landfill, west of the site. The plume consists of volatile organic compound (VOC) contamination, with tetrachloroethylene (PCE), trichloroethylene (TCE), and vinyl chloride identified as contaminants of concern. Most of the VOC contamination is in the shallow A aquifer. Concentrations of VOCs detected in monitoring wells screened in the B aquifer are at least an order of magnitude lower than in the A aquifer. Analysis of site data suggest that contamination in the B aquifer can be attributed to the operation of water supply wells in the vicinity of the landfill that are screened in both the A and B horizons. It is anticipated that the decommissioning of these wells will eliminate the source of VOC contamination in zones beneath the A horizon. The *Final Remedial Investigation Report* (CDM, 1994) documents the activities undertaken and analyses performed in formulating this characterization of the nature and extent of the groundwater contamination.

1.3.2 Clean-up Goal

For sites undergoing remediation under CERCLA, establishment of clean-up goals is the responsibility of the EPA with input from other regulatory agencies, including the State of California for this site. Clean-up goals are ultimately established for a site based on a number of factors.

Because the aquifer is used as a drinking water supply in the vicinity of the FSL, the main applicable, relevant, and appropriate regulations (ARARs) of concern for the purposes of this document are groundwater cleanup standards. Federal ARARs specify that Maximum Contaminant Levels (MCLs) should be applied as the clean-up levels. The other factor typically considered, risk-based levels, ~~will not be applied since~~ the EPA's health risk assessment determined that minimal risk to human health exists from the contaminated groundwater in the vicinity of the FSL (EPA, 1994). The State policy governing groundwater clean-up is that contaminant levels may not exceed background levels (non-detect for the VOCs), unless it can be shown that it is technologically or economically infeasible to reduce the contaminant levels to background. At the current time, a definitive clean-up goal has not been established for the FSL by the EPA.

For the purposes of this Technical Memorandum and for the FS, two clean-up goals have been addressed — background concentrations and MCLs. Alternatives 3 and 4 have been subdivided to allow analysis of the two clean-up goals.

Background and MCL concentrations for TCE, PCE, and vinyl chloride (contaminants of concern at the FSL) are summarized below in Table 1-1. For the purposes of this Technical Memorandum, background is defined as less than the analytical detection limit (0.5 μg/l) for the site contaminants of concern.

Table 1-1
Alternative Clean-up Goals for
Contaminants of Concern

Constituent	Background Concentration	MCL Concentration
Trichloroethylene	Nondetect (<0.5 μg/l)	5.0 μg/l
Tetrachloroethylene	Nondetect (<0.5 μg/l)	5.0 μg/l
Vinyl chloride	Nondetect (<0.5 μg/l)	2.0 μg/l 0.5μg/l

Notes:
1) "μg/l" = micrograms per liter.
2) "Nondetect" = below the detection limit for the method of analysis.
3) "MCL" = maximum contaminant level.

In the Draft FS Report, discussion will be provided in an appendix which addresses the practicability of achieving the potential clean-up goals that have been included in the alternatives evaluations. The presentation will take into consideration data from laboratory testing (literature review) and ongoing groundwater pump-and-treat operations relative to effectiveness in achieving established clean-up goals. The Record of Decision (ROD) developed for the FSL will specify the clean-up goal which must be achieved by the remedial action.

1.3.3 Groundwater Modeling

Groundwater modeling was performed as an important element in the analysis of the remedial alternatives. These modeling activities included the estimation of the current extent and volume of groundwater contamination, analytical and numerical modeling of extraction well pumping scenarios, estimation of the number of aquifer pore volumes to be flushed in order to achieve clean-up goals, and estimation of the time required to achieve clean-up goals under an aquifer restoration alternative.

1.3.3.1 Estimate of Current Extent and Volume of Contamination

As part of the groundwater modeling efforts, it was necessary to define the current downgradient extent of contamination. Of the contaminants of concern at the FSL, PCE is generally present in the highest concentration and constitutes the contaminant with the greatest downgradient extent. Shown on Figure 1-2 is the current estimate of the extent of PCE contamination. The PCE contamination is shown in terms of areas above background and MCL concentrations. The PCE contamination areas are based on the most recent groundwater monitoring data (CDM, 1995c) and groundwater sampling data from the recently installed monitoring wells (CDM-8A and CDM-8B). PCE is an appropriate compound on which to base groundwater cleanup activities for several reasons. In addition to its larger extent and generally higher concentrations detected among the VOCs, PCE has a higher soil-water partitioning coefficient than the other contaminants of concern and thus will require larger volumes of water to be flushed through the aquifer to reach clean-up goals.

Given the areas of contamination shown in Figure 1-2 and using aquifer thickness and porosity data for the A and B aquifers obtained during the site remedial investigation, estimates of the total volume of contaminated groundwater were made. These data are summarized below in Table 1-2.

Table 1-2
Estimated Volumes of Contaminated Groundwater
A and B Aquifers

	A Aquifer	B Aquifer
Thickness of aquifer	40 feet	80 feet
Porosity	0.30	0.40
Volume of contaminated groundwater:		
• At concentrations greater than background	1.32×10^8 ft^3 (990 million gallons)	3.53×10^8 ft^3 (2,639 million gallons)
• At concentrations greater than MCLs	9.16×10^7 ft^3 (685 million gallons)	2.44×10^8 ft^3 (1,828 million gallons)

Notes:
1) Average thickness based on modeled aquifer unit thickness plus one-half the thickness of the B aquitard (10 feet).
2) Average porosities estimated from Fetter (1988) for Fine Sand (A aquifer) and for Silty sand with some clay (B aquifer).
3) The calculated areas of contamination reflect the areas shown on Figure 1-2.
   - Area with concentration above background - 1.10×10^7 ft^2
   - Area with concentration above MCLs - 7.64×10^6 ft^2

1.3.3.2 Modeling of Extraction Well Pumping Scenarios

Modeling of extraction well pumping scenarios was conducted in order to determine the appropriate number of wells, spacing of wells, and pumping rates needed to achieve the remedial alternative goals. The minimum number of wells pumping at the minimum collective discharge rate was targeted. A series of steps were applied toward the design of each extraction well scenario presented in Section 3.

The first step was determining the maximum discharge that the extraction wells could sustain. A theis analytical model (General Aquifer Analysis, Theis2 - Version 3, 1986) was used to estimate the amount of discharge from each well that would result in drawdown of the aquifer to two thirds of the initial saturated thickness. This discharge rate was considered the maximum sustainable well yield.

The next step involved an iterative approach using the General Particle Tracking (GPTRAC) module of the EPA Model for Delineation of Wellhead Protection Areas (WHPA Version 2.0, EPA 1991) in order to reach remedial alternative goals with the minimum number of wells pumped at the minimum necessary rate. The capture zones of the extraction wells were delineated in GPTRAC with pumping scenarios varied over time in order to most effectively achieve the remedial alternative goals. The locations for the extraction wells utilized the May 1995 distribution of PCE as presented in Figure 1-2.

The optimal extraction well number, spacing, and discharge rates over a 30-year remediation period were estimated using the above analytical models and verified using the 3-dimensional numerical model developed for the site (Dynflow and Dyntrack).

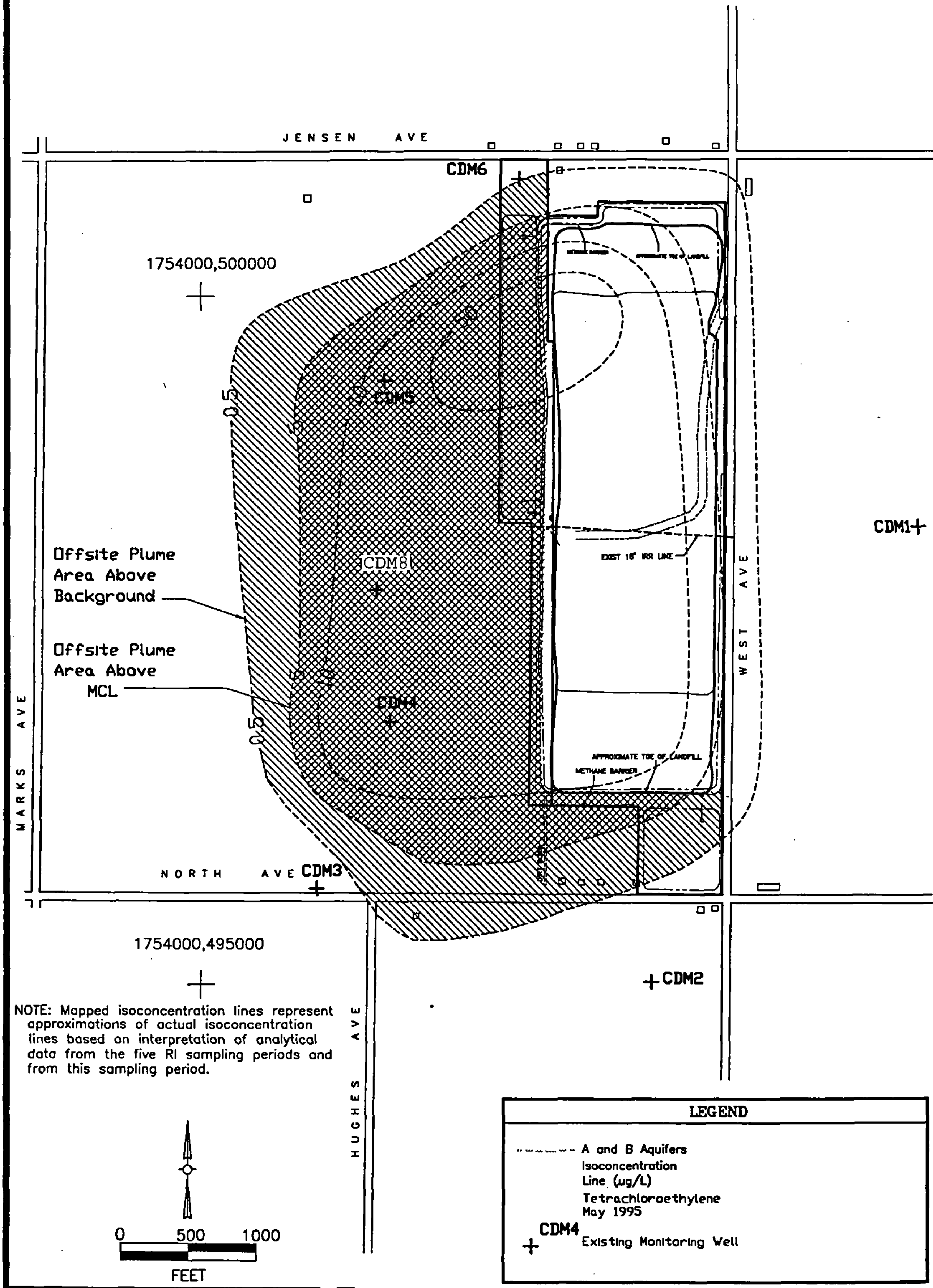
1.3.3.3 Estimation of Aquifer Pore Volumes

Non-equilibria desorption modeling was conducted in order to estimate the number of pore volume flushes required to remediate the aquifer. This value is needed to estimate the amount of time necessary under a pumping scenario for contaminant concentrations in an aquifer to be below clean-up goals. Site contaminants of concern are sorbed onto solid particles in the aquifer. As the groundwater is pumped, additional contamination will be released into the aqueous phase from this sorbed phase. The rate of desorption into an aquifer is extremely difficult to determine, and at numerous sites across the country has resulted in pump-and-treat systems that have failed to reach remedial action goals within the time periods estimated using equilibrium desorption assumptions.

Desorption is most effectively measured using on-site measurements or by conducting laboratory column desorption studies using site soils. Since neither of these data are available, site desorption rates were estimated using analytical modeling and inputs from literature. The soil-water partitioning coefficients (Kd) for PCE and TCE were estimated based on site organic carbon and grain size data. The estimates for the Kd for PCE and TCE in the A and B aquifers are shown below:

	A Aquifer Kd	B Aquifer Kd
TCE	1.04	1.23
PCE	1.12	1.38

These Kd values were the most important inputs into the non-equilibrium desorption analytical model, CXTFIT. The estimated number of pore volumes required to reach remedial clean-up goals (MCL and background) based on this model are as follows:



CDM environmental engineers, scientists, planners, & management consultants

FRESNO LANDFILL FS

EXTENT OF GROUNDWATER CONTAMINATION AND OFFSITE PLUME REMEDIATION AREAS

Figure 1-2

PCE595.DWG

	Aquifer	Pore Volumes to Background	Pore Volumes to MCL
TCE	A B	22 20	15 11
PCE	A B	26 25	17 13

These pore volumes reflect a very high uncertainty; the model assumes a homogenous aquifer and the site aquifers are very heterogeneous. It is possible that actual pore volumes could be significantly higher. The calculations performed and modeling inputs and results for the nonequilibrium desorption analysis will be provided in an appendix as part of the Draft FS Report.

1.3.3.4 Estimate of Time Required to Reach Cleanup Goals

Based on the above estimated pore volumes, the volume of PCE contaminated groundwater, and the results of the modeling of extraction well pumping scenarios, the time required to reach cleanup goals was estimated. The modeling estimated the rate of extraction of contaminated groundwater. The estimated time to reach remedial action goals was calculated as follows:

$$\text{Time to reach clean-up goal (years)} = \frac{\text{Volume of Contaminated Groundwater (million gallons)} * \text{Number of Pore Volumes}}{\text{Rate of Extraction (million gal/y)}}$$

The results of the estimates for the time require to reach remedial action goals are presented in Section 3.

Section 2
Identification of Remedial Alternatives and Evaluation Criteria

2.1 Introduction

This section discusses the development of the remedial alternatives, including the range of alternatives considered, assumptions that apply to the alternatives evaluations for the purposes of this technical memorandum, and identification of the six remedial alternatives evaluated in this document. EPA encourages a phased approach to the implementation of the remedial action process (Superfund Report, 1995). This section includes a discussion regarding the proposed phasing of implementation of groundwater remediation at the FSL. Additionally, definitions for the evaluation criteria applied in this Technical Memorandum are provided.

2.1.1 Range of Alternatives Considered

The feasibility study process consists of the development and evaluation of a range of remedial alternatives which achieve varying degrees of environmental clean-up. The alternatives identified for the groundwater remediation at the FSL site range from No Action to complete aquifer restoration. Providing a range of alternatives achieves two objectives:

1) Allows the decisionmakers to balance the extent of clean-up desired with the resources required to achieve this clean-up; and

2) Provides a framework for phasing the remedial action. Specifically for groundwater clean-ups, recent EPA guidance stresses the need for a phased approach to implementation of remedial action rather than implementation of the most comprehensive remedy initially.

The alternatives undergo extensive evaluation as part of the FS with analysis performed from several perspectives including technical effectiveness, ability to implement the remedial system, and cost. Therefore, they must be developed in sufficient detail to provide the information necessary for performing the evaluation. This requires the preparation of a conceptual level design for each alternative.

+50% -30% level of effort

Each groundwater remedial alternative at the FSL, except No Action, consists of four primary components:

1) Groundwater extraction well system and conveyance system.

2) Groundwater monitoring well system.

3) Groundwater treatment system.

4) Treated groundwater management system.

For each alternative, the number of extraction wells, well depths, and casing diameters are specified in Section 3. Conveyance piping alignments and sizes are determined to provide a basis for developing cost estimates. In addition, establishing the extraction well configuration defines the extent of the contaminated plume to be controlled under each alternative which is important information in evaluating the extent of an alternative's protectiveness. The FS, to be prepared at a later date, will identify all of the significant capital cost items for the selected treatment system, including necessary tankage and process units. In a similar manner, the pumps, piping, and storage required to manage the treated groundwater will be documented in the FS. Preliminary costs developed for this technical memorandum are discussed in Section 3.

Estimating operations and maintenance costs requires establishing time periods for which each alternative must be operated. The remedial action duration is a function of the clean-up goal established. As described above in Section 1, two clean-up goals will be evaluated, background and MCLs. Estimates were developed for the time required to reach these goals for Alternative 4. This in turn helps establish operational costs for the systems over the time period.

2.1.2 Assumptions for the Alternatives Evaluations

Preparation of this Technical Memorandum is an interim step in the on-going preparation of the FS Report. As described in the *Technical Memorandum -- Documenting Development of Remedial Alternatives* (CDM, 1995b), the individual components of the "active" remedial alternatives (No-Action being the exception) fall into two general categories:

1) Those elements which are common to all four alternatives; and
2) Those elements which vary among the individual alternatives.

This Technical Memorandum serves to compare those elements which vary among the individual alternatives. A detailed evaluation of the common elements — institutional controls, well decommissioning, groundwater treatment, and management of treated effluent — will be documented in the FS Report and will include specific recommendations for selection and implementation. For the purpose of developing and comparing remedial alternatives in this Technical Memorandum, the following assumptions have been made relative to the common remedial alternative elements.

- Irrigation supply wells which currently influence hydraulic flow conditions within the A and B aquifer horizons will be decommissioned (i.e., boreholes will be plugged and abandoned in accordance with regulatory requirements). Costs for well decommissioning, considered to be equivalent under each of the alternatives, have not been determined and are not included in this analysis.

- Groundwater treatment will entail a 2-step process. The first step will consist of an air-stripping unit for removal of VOCs from the groundwater. This will be followed by a granular activated carbon (GAC) unit for adsorption of VOCs from the off-gas stream.

- Extracted groundwater will be conveyed to a groundwater treatment plant located on City-owned property adjacent to the landfill.

- Treated groundwater will be managed by conveying it to a nearby irrigation district or some other infiltration ponding system. Costs for management of treated groundwater are not included in this analysis.

- Institutional controls will be implemented in the vicinity of the FSL to minimize exposure to groundwater-related contamination. This may include land use controls, well drilling prohibitions, and site access restrictions.

2.2 Identification of Alternatives

Four groups of alternatives have been identified for detailed analysis in the FS. These alternatives, listed below, were developed to reflect the two stated clean-up goals, background and MCLs.

- *Alternative 1* — No Action. Off-site groundwater plume and monitoring.

- *Alternative 2* — Landfill perimeter groundwater containment with landfill perimeter groundwater monitoring and off-site groundwater plume monitoring. For the purposes of siting off-site plume monitoring wells, the clean-up goal is background.

- *Alternative 3a and 3b* — Landfill perimeter groundwater containment and off-site groundwater plume containment. Includes landfill perimeter groundwater monitoring and off-site groundwater plume monitoring. For the purposes of siting capture wells, the clean-up goals are background and MCLs for Alternatives 3a and 3b, respectively.

- *Alternative 4a and 4b* — Landfill perimeter groundwater containment, off-site groundwater plume containment, and aquifer restoration. Includes landfill perimeter and off-site plume groundwater monitoring. Clean-up goals are background and MCLs for Alternatives 4a and 4b, respectively.

The primary components of each of the alternatives are summarized in the Table 2-1:

Table 2-1
Remedial Alternative Components

	Groundwater Monitoring	Landfill Perimeter Containment	Off-Site Plume Containment	Off-Site Plume Restoration
Alternative 1	✔			
Alternative 2	✔	✔		
Alternatives 3a and 3b	✔	✔	✔	
Alternatives 4a and 4b	✔	✔	✔	✔

2.3 Phased Implementation of the Remedial Action

Recent EPA guidance (Superfund Report, 1995) emphasizes the need for phasing of remedial action at a site rather than implementing the most comprehensive remedy during the initial stages of remediation. An important benefit of this approach is that data generated during early phases can be used to refine and enhance later phases of the remedial action. Discussions among the City, EPA, and State regulatory representatives regarding the groundwater remediation at the FSL have supported this concept of phased implementation. In response to these discussions, the remedial alternatives identified and evaluated in this technical memorandum were designed to facilitate this concept of phased implementation.

The remedial actions are configured in such a way that the components of any particular alternative are consistent with the previous alternative. Higher-numbered alternatives utilize the same number of wells at the same locations as previous alternatives and are supplemented by a remedial action component which affords an additional level of protectiveness or accomplishes a greater extent of clean-up.

Regardless of the remedial alternative selected by the EPA for the FSL site, as part of the phased implementation approach it is anticipated that the remedial activities in the lower-numbered alternatives will be implemented first, before components of the next remedial alternative are implemented. For example, if Alternative 3 is the selected alternative, the City will begin implementation of remedial action by installing extraction wells along the perimeter of the FSL and operating them in order to contain the groundwater VOC source. Groundwater monitoring beyond the landfill perimeter and beyond the off-site plume will also be undertaken. These actions embody the components of Alternative 2. This final decision will be made in R.D.

remediation system would then be operated for a length of time sufficient to provide data on aquifer cleanup and off-site plume migration to determine whether to proceed to active off-site plume containment (Alternative 3).

The length of time that the components of a given alternative will operate before upgrading to the next set of remedial actions, and the explicit criteria for upgrading, cannot be provided until site-specific operational data become available. It is anticipated, however, that the following types of information will be used to make those decisions.

1. Upgrade from Alternative 2 (landfill perimeter containment wells) to Alternative 3 (off-site plume containment wells).
    - Water level data to assess whether the perimeter containment wells are capturing all of the contamination migrating beneath the FSL.
    - Water quality data from the monitoring well and extraction well systems to assess migration of the downgradient extent of the off-site plume.
2. Upgrade from Alternative 3 (off-site plume containment wells) to Alternative 4 (off-site plume restoration).
    - Water level data to assess whether the off-site plume is being contained by the Alternative 3 containment wells.
    - Water quality data from the monitoring well and extraction well systems to assess whether the lateral edges of the contaminated portion of the aquifer near the FSL appear to be cleaning up due to flushing of clean groundwater through those areas.

As indicated above, these would be the general types of information collected to assess the need to implement the next higher level of remedial activity. Any decisions regarding an upgrade from one level of remedial activity to the next would be made based on explicit criteria, to be determined during the initial operations phases, and after discussions among the City, EPA, and appropriate State regulatory officials. In this regard, a phased remediation approach can make best use of site-specific hydrogeologic and geochemical data collected during early phases of the site remediation program to implement later actions in the most efficient and effective manner possible.

2.4 Definition of Evaluation Criteria

The evaluation criteria applied in this technical memorandum are those outlined in the National Contingency Plan (NCP) for CERCLA sites. The nine criteria address both technical and policy considerations that have been determined to be important in selecting remedial alternatives. Each alternative will be evaluated against the nine criteria. Criteria definitions are included below.

Overall Protection of Human Health and the Environment — This criterion provides a final check to assess whether the alternative is protective of human health and the environment. The overall assessment of protection is based on a composite of factors assessed under the evaluation criteria, especially long-term effectiveness, short-term effectiveness, and compliance with Applicable or Relevant and Appropriate Requirements (ARARs).

The Human Health Risk Assessment conducted by EPA for the FSL site indicated that contaminated groundwater is at the low end of the EPA's range of allowable human health carcinogenic risk. The large depth to groundwater and the lack of nearby springs, seeps or other groundwater discharge points means that the contaminated groundwater also poses essentially no risk to environmental receptors in the area. Based on the minimal risk posed by contaminated groundwater at the FSL site, the institutional controls such as well drilling prohibitions and land use/site access restrictions that will be implemented under all alternatives should be sufficient to protect human health and the environment using the risk assessment criteria evaluated by the EPA. To provide a comparative analysis among the alternatives described in this Technical Memoranda, however, the relative benefits to protecting human health and the environment provided by each alternative will be discussed.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) — This evaluation criteria, compliance with ARARs, is used to determine to what extent the remedial alternatives satisfy laws and regulations. Several sources of both State and Federal laws and regulations exist which govern many aspects of a groundwater treatment program. For the purposes of the FSL alternatives evaluation, the laws which govern the extent to which the groundwater is remediated are the most significant.

The Federal standards impacting groundwater remediation are found in the National Primary Drinking Water Standards, 40CFR, Part 141. This regulatory framework establishes MCLs for both inorganic and organic contaminants which can be applied to groundwater clean-ups.

The primary State law associated with groundwater clean-up at landfills is the Porter Cologne Water Quality Control Act. This Act established the authority of the Regional Water Quality Control Boards to protect water quality by regulating solid waste disposal. Under this authority, Title 23, Chapter 15 of the California Code of Regulations establishes water quality standards for groundwater impacted by landfills.

If it can be shown that it is technically or economically infeasible to reduce contaminant levels to those levels defined by State or Federal regulations, there are provisions in both Federal and State regulations for establishing alternative clean-up goals. For the purposes of this Technical Memorandum, the ARARs for groundwater cleanup are defined as background or MCLs.

Long-Term Effectiveness and Permanence — This criterion addresses the results of the remedial action in terms of the risk remaining at the site after the response objectives have been met. The primary focus of this evaluation is to determine the scope and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes. The factors to be evaluated include the magnitude of remaining risk (measured by numerical standards such as cancer risk levels), and the adequacy, suitability, and long-term reliability of management controls for providing continued protection from untreated wastes.

Reduction of Toxicity, Mobility, or Volume Through Treatment — This criterion addresses the preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the contaminants. Extracted groundwater from all five active remedial alternatives, Alternatives 2, 3a, 3b, 4a, and 4b will be treated in a similar manner. Therefore, an equivalent reduction of the toxicity, mobility, and volume of the contaminants in the extracted groundwater will be achieved for all alternatives. However, the volume and mobility of contaminants remaining in the aquifer varies among alternatives. This issue will be assessed for each alternative under the evaluation criteria.

Short-Term Effectiveness — This criterion addresses the effects of the alternative during the construction and implementation phase until the remedial actions have been completed and the selected level of protection has been achieved. Each alternative is evaluated with respect to its effects on the community and site workers during the remedial actions, environmental impacts resulting from implementation, and the amount of time until protection is achieved.

Implementability — Alternatives are evaluated to determine the ability to implement the alternative. The three major issues considered in the evaluation under this criterion are: administrative implementability, technical implementability, and availability of goods and services.

Administrative implementability concerns coordination with other government bodies, including regulatory agencies, and the ability to obtain permits and access agreements. Technical implementability refers to the ability to construct and operate the technology, the reliability of the technology, and the ability to monitor effectiveness of the remedy. Availability of goods and services considers the accessibility of materials and the number of contractors capable of performing the work required to install and operate the control systems.

Cost — Each alternative is formulated in sufficient detail to develop capital and operating costs within a range of accuracy of +50 to -30 percent. Capital costs include both construction and overhead costs associated with construction. Annual operation and maintenance (O&M) costs address all aspects of operating the remedial action including labor costs, administrative costs, and charges associated with utilities and management of residuals from the system operation. A present worth analysis is used to evaluate the annual O&M costs. A discount rate of 5.25 percent has been applied for this analysis (Wall Street Journal, October 16, 1995). This represents the current cost of money, as adjusted for inflation. The approach used in developing cost estimates and cost estimating calculations are provided in Appendix A.

State Acceptance — Alternatives are evaluated to determine whether they meet the technical and administrative issues and concerns of the State of California. For this project, State ARARs addressing groundwater protection standards administered by the Central Valley RWQCB will establish the degree of acceptance by the State. As stated in EPA guidance, this criterion will be addressed in the ROD once comments on the FS Report and Proposed Plan have been received.

Community Acceptance — This criterion incorporates public concerns into the evaluation of the remedial alternatives. Public input is obtained after the Proposed Plan has been published by the EPA. A public hearing is held to receive public comment on the Proposed Plan. This criterion will be applied after the community has had an opportunity to review the remedial alternatives considered.

Section 3
Detailed Analysis of Alternatives

The objectives of this section are to provide a detailed description of the remedial alternatives and then to evaluate the alternatives against the evaluation criteria defined in Section 2.4. Each remedial alternative is characterized in terms of the clean-up goal, the groundwater extraction system, and the groundwater monitoring system. These elements of the alternative descriptions are defined below:

- *Clean-up Goal* — The clean-up goal defines the level of contamination that is allowed to remain in the aquifer system after remedial efforts have been completed. Where the clean-up goal is applied, groundwater extraction will be required until it is demonstrated that the contaminant level in the aquifer is below the established clean-up goal. Both background concentrations and MCLs have been evaluated as part of this technical memoranda. Background and MCL concentrations for TCE, PCE, and vinyl chloride (contaminants of concern at the FSL) are summarized in Table 1-1.

- *Groundwater Extraction System* — Depending on the alternative selected, the groundwater extraction system for the remedial alternatives may consist of three distinct components:

  (1) *Landfill Perimeter Extraction System*. The objective of this system is to contain groundwater flow along the landfill perimeter such that contaminated groundwater present beneath the FSL will not migrate off-site. This system constitutes the presumptive remedy element of the remedial action.

  (2) *Off-site Plume Extraction System*. The objective of this system is to contain the off-site plume such that currently uncontaminated groundwater remains unaffected by the off-site plume. This system is a non-presumptive remedy component of the remedial action.

  (3) *Off-Site Plume Restoration System*. The objective of this system is to achieve restoration of the aquifer downgradient of the FSL to the established cleanup goals. This system is a non-presumptive remedy component of the remedial action.

- *Groundwater Monitoring System* — The groundwater monitoring system consists of two distinct components:

  (1) Monitoring wells to assess the effectiveness of the landfill perimeter extraction wells in containing the source of contamination.

(2) Monitoring wells to assess contaminant migration beyond the existing limits of the off-site plume.

3.1 Alternative 1 — No Action

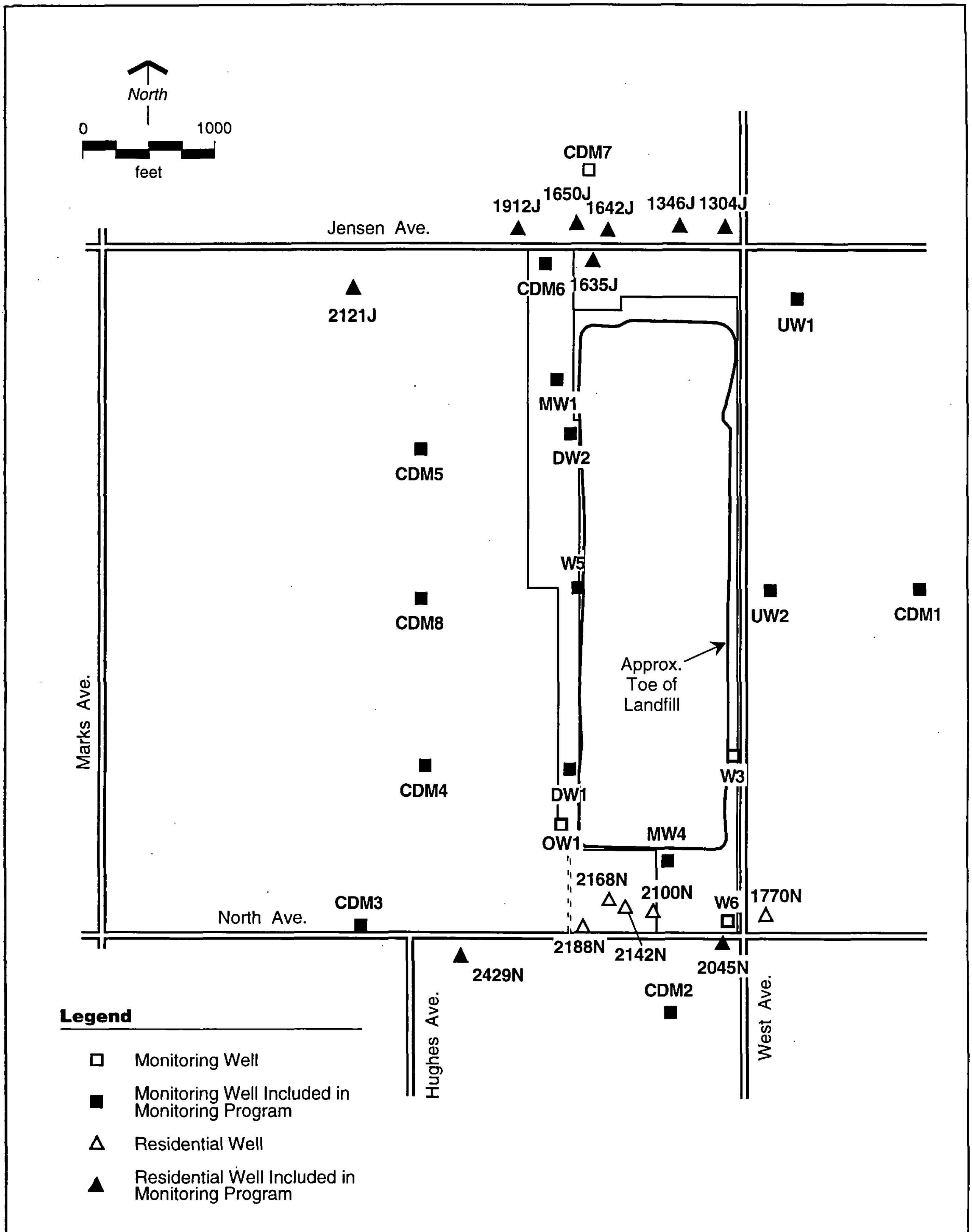
3.1.1 Narrative Description

As part of Alternative 1, no remedial actions will be taken to control groundwater flow either beyond the landfill perimeter or beyond the current off-site contaminant plume. Groundwater modeling has indicated that there is a continuing migration of the leading edge of the contaminant plume in the direction of groundwater flow on the order of one to ten feet per year. Continuing migration would not be minimized in any way as a result of actions undertaken as part of this alternative.

The groundwater monitoring program currently underway will be continued as a way of quantifying the impacts associated with no remedial response action. The monitoring program is described in detail in the submittal from CDM to EPA entitled *Semi-Annual Groundwater Monitoring Program* (CDM, 1995a), as modified by EPA comments dated May 2, 1995. The groundwater monitoring program under Alternative 1 consists of the following elements:

- *Semi-annual groundwater monitoring* — Periodic sampling of the groundwater will be conducted. No new wells will be drilled under this alternative.
- *Quarterly water level measurements* — Water level measurements will be made on a quarterly basis.
- *Reporting* — Reports will be prepared on a semi-annual basis and will summarize the analytical laboratory results of the semi-annual groundwater monitoring event and the two previous water level measurement events.
- *Periodic evaluation of the monitoring program* — The groundwater monitoring program will be evaluated after 5 years of operation. Modifications to the program may be proposed based on the monitoring record.

The groundwater monitoring system includes 32 groundwater monitoring wells, 9 residential wells, and 4 water supply wells. Quarterly water level measurements are carried out on all of the groundwater monitoring wells. Table 3-1 provides a summary of the groundwater monitoring program to be implemented under Alternative 1. The table includes a listing of the wells and the frequency of sampling and water level measurements. Figure 3-1 shows the monitoring well locations to be implemented as part of Alternative 1.



Groundwater Monitoring Program Well Locations
Fresno Sanitary Landfill RI/FS
Fresno, CA

Figure 3-1

CDM
Camp Dresser & McKee

Table 3-1
Alternative 1
Groundwater Monitoring Program Summary

Monitoring Well	Sampling		Water Level Measurements
	May	November	Quarterly
CDM-1A, B, C		X	X
CDM-2A, B, C	X	X	X
CDM-3A, B	X	X	X
CDM-4A, B, C	X	X	X
CDM-5A, B, C	X	X	X
CDM-6A	X	X	X
CDM-11A, B	X	X	X
MW-1	X	X	X
DW-1B	X	X	X
W5	X	X	X
MW-4	X	X	X
DW1 A, C		X	X
DW2 A, B, C			X
UW1 A, B, C		X	X
UW2 A, B, C			X
2429 North Avenue	X	X	
2045 North Avenue	X	X	
1650 Jensen Avenue		X	
1635 Jensen Avenue		X	
1304 Jensen Avenue		X	
1346 Jensen Avenue		X	
1642 Jensen Avenue		X	
1912 Jensen Avenue		X	
2121 Jensen Avenue		X	

3.1.2 Alternative 1 Assessment

3.1.2.1 Overall Protection of Human Health and the Environment

The No Action alternative provides the least additional protection to human and environmental receptors in the long or short term compared to the other alternatives. EPA's risk assessment for the site indicates that the greatest human health risk posed by contaminated groundwater is through ingestion (EPA, 1994). The institutional controls and the groundwater monitoring program that will be implemented under this alternative will reduce the potential for exposure to groundwater-related contamination, and will provide information on whether the groundwater plume is spreading, potentially affecting human receptors in the future.

3.1.2.2 Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

The No Action alternative is not likely to meet the clean-up standards for contaminated groundwater established under either Federal or State law based on existing contaminant concentrations in the A and B aquifers.

3.1.2.3 Long-Term Effectiveness and Permanence

The No Action alternative does not provide any controls for the contaminated groundwater which will remain at the FSL after the alternative is implemented. The contamination will remain until the contaminant source at the landfill has been limited through source control measures and the downgradient aquifer is restored through natural attenuation.

3.1.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Natural processes which attenuate the VOC compounds, including volatilization, sorption, biodegradation, and dispersion will reduce contaminant concentrations to some extent. However, there is no treatment of hazardous materials at the site under the No Action alternative. Therefore, the criterion is not achieved.

3.1.2.5 Short-Term Effectiveness

Alternative 1 does not provide increased protection of public health and the environment over the short-term. Implementation of this alternative, which consists solely of ongoing monitoring of the existing monitoring well network, does not pose an additional threat of exposure to site workers and the community.

3.1.2.6 Implementability

Alternative 1 is readily implementable from both an administrative and technical perspective.

3.1.2.7 Cost

The costs associated with the No Action alternative are only those required to perform the monitoring of and periodic review of data from the existing groundwater monitoring well network. Annual O&M costs are estimated to be $68,000 which result in a total present worth value of $1,018,000 over a 30-year postclosure period.

3.1.2.8 State Acceptance

This criterion will be addressed in the ROD once comments on the FS Report and Proposed Plan have been received.

3.1.2.9 Community Acceptance

This criterion will be applied after the community has had an opportunity to review the remedial alternatives considered in the Proposed Plan.

3.2 Alternative 2 — Landfill Perimeter Containment and Offsite Plume Monitoring; Background Water Quality

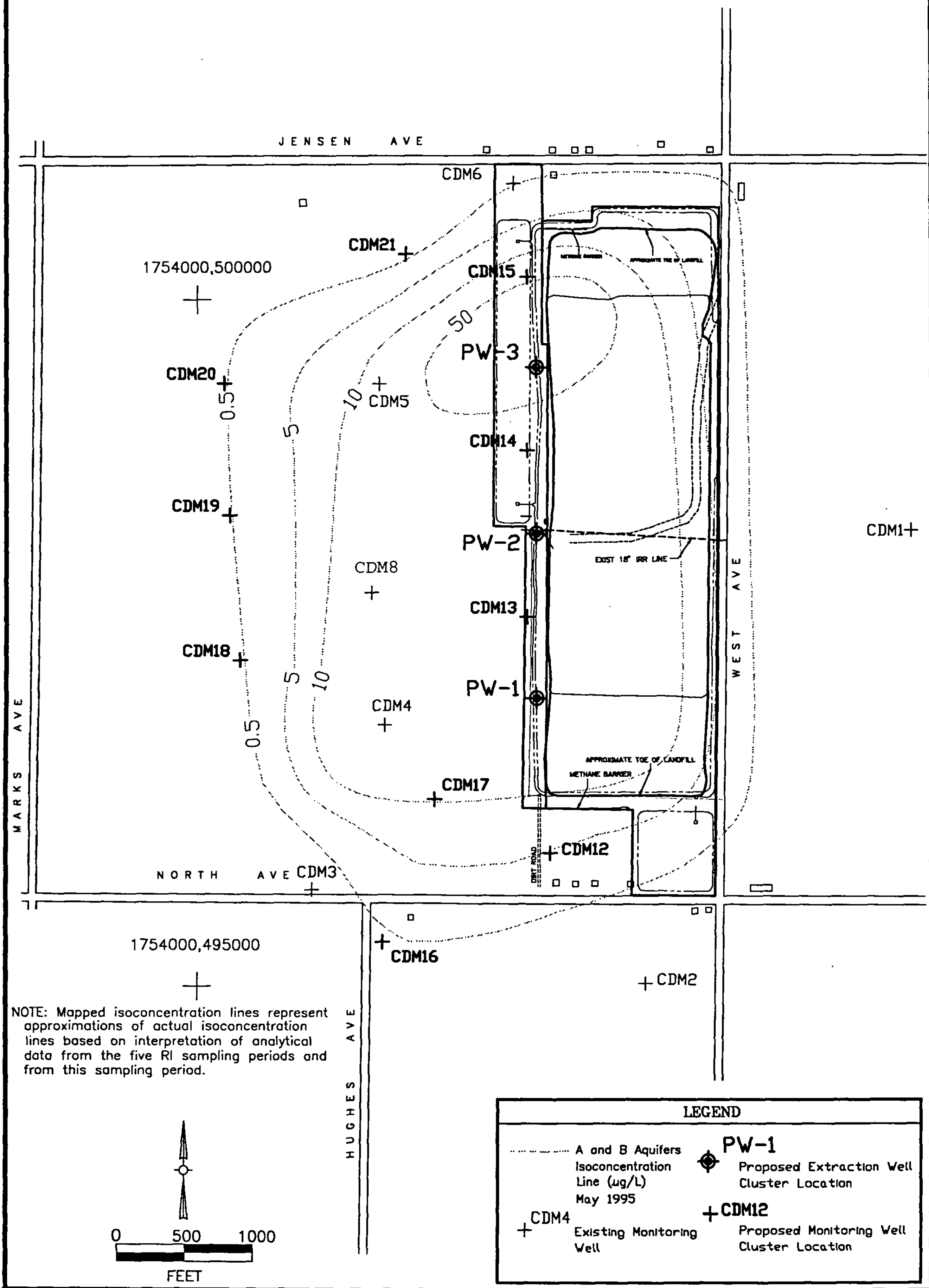
3.2.1 Narrative Description

Toxic organic compounds are introduced into the groundwater as the water flows underneath the waste fill at the FSL. The primary objective of Alternative 2 is to isolate this source of groundwater contamination from impacting downgradient waters. This is accomplished by creating a hydraulic barrier along the downgradient, western perimeter of the landfill. Such a barrier system effectively prevents the impacted groundwater from mixing with downgradient waters. Alternative 2 constitutes the presumptive remedy component of the groundwater remedial action.

Once the landfill perimeter extraction wells are installed and operating in each aquifer unit, pumping in a given aquifer layer will draw down the aquifer in that layer and will create cones of depression centered around each well. These cones of depression will cause water to flow towards the extraction wells, from locations both upgradient and downgradient of the wells. Water downgradient of a perimeter extraction well can flow towards the well because the hydraulic gradient has been reversed due to the cones of depression created during pumping. Some of the contaminated groundwater within the off-site plume will therefore be captured by the perimeter extraction wells as an outcome of providing hydraulic containment at the landfill perimeter.

Groundwater flow and contaminant transport modeling was used to determine the size and shapes of the cones of depression and the zones of groundwater within each aquifer that would flow to a given well over time. These capture zones get larger over time as the wells continue to pump and the cones of depression grow. Sufficient overlap of the capture zones allows the extraction well pumping rates to be reduced while continuing to contain the groundwater plume via well capture.

Larger portions of the off-site plume not captured directly by the perimeter extraction wells also will be affected by the pumping. The cones of depression extending in the downgradient direction will flatten the hydraulic gradient, thus causing portions of the off-site plume to migrate at much slower rates. Current plume migration rates, based on data presented in the *Final Remedial Investigation Report* (CDM, 1994), are approximately 1 to 10 feet/year. Reducing



NOTE: Mapped isoconcentration lines represent approximations of actual isoconcentration lines based on interpretation of analytical data from the five RI sampling periods and from this sampling period.

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FSL Alternative 2

Landfill Perimeter Plume Containment

Figure 3-2

WELL-A2.DWG

plume migration rates below this gives naturally-occurring processes such as volatilization, sorption and biodegradation more time to act on and attenuate the existing plume. Once the perimeter extraction wells have been operating and the cones of depression have expanded in the downgradient direction, off-site plume monitoring data will be used to evaluate whether the rates of plume attenuation are keeping pace with the rates of plume migration.

Groundwater monitoring will be performed downgradient of the perimeter extraction well system and at the downgradient edge of the off-site contaminant plume. The effectiveness of Alternative 2 will be evaluated based upon the extent to which movement of the off-site plume is controlled due to source containment and the extent to which the off-site plume is attenuated by natural processes after the landfill perimeter extraction well system is in place.

The off-site plume will not be actively remediated under this alternative. Natural contaminant attenuation of the off-site waters will occur with time as no additional contaminant mass will be introduced to the plume.

This alternative will also include a system of piping to convey extracted groundwater from the wells to the on-site treatment plant and piping to convey the treated groundwater away from the treatment plant.

3.2.1.1 Clean-up Goal

There is no clean-up goal associated with the perimeter groundwater extraction system. The system will be designed to intercept all groundwater flowing beneath the landfill within the A and B aquifer horizons. Groundwater extraction along the landfill perimeter is expected to continue for a minimum of a 30-year operating period.

Although Alternative 2 does not include any active remediation for the off-site contaminant plume, the clean-up goal influences the placement of the off-site plume monitoring well system. Under Alternative 2, monitoring wells will be placed between the extraction wells, and beyond the background concentration contour for PCE (described in Section 1 as having the greatest concentration and the greatest downgradient extent of the site's contaminants of concern).

Phased Implementation of the Remedial Action — If monitoring of the off-site plume identifies above background concentrations of the contaminants of concern, active pumping to contain the off-site contaminant plume will be implemented. Implementation of active groundwater containment at the edge of the off-site plume effectively progresses the remedial action into Alternative 3.

3.2.1.2 Groundwater Extraction System

As discussed in Section 1, groundwater flow and particle tracking modeling was used as a tool to assist in the layout of the extraction well system. The criteria for the design of the groundwater extraction systems was to determine the minimum number of wells and minimum wellfield pumping rate to meet the objective of the alternative. Figure 3-2 depicts the configuration of the groundwater extraction system under Alternative 2, including groundwater extraction wells and monitoring wells. The groundwater extraction system consists of 3 wells for extraction of groundwater from the A aquifer and 3 wells for extraction of groundwater from the B aquifer. These will be co-located, single completion wells. The extraction well system is designed to effectively intercept all groundwater flowing underneath the landfill in the A and B aquifer horizons, within approximately three months after the system starts operating. In addition, these wells will capture some of the off-site contamination plume. Modeling suggests that the downgradient extent of capture is 600 to 800 feet.

Modeling has shown that the rate of well pumping can be scaled back over the 30-year period of operation while still maintaining the necessary hydraulic controls. Modeling has indicated that an optimal pumping scenario for Alternative 2 would include starting at a high pumping rate, then decreasing the number of wells pumping and the discharge rates over the 30-year operational period. Final pumping rates will be determined during the FS. Preliminary pumping rates for Alternative 2 consist of initially pumping the A aquifer continuously at 450 gallons per minute (gpm) and decreasing to approximately 220 gpm during the 30-year operational period. The B aquifer will be initially pumped continuously at 500 gpm, decreasing to approximately 250 gpm during the 30-year operational period.

The A aquifer extraction wells will be installed to a depth of approximately 100 feet below ground surface (bgs). The 40-foot screened zone for these wells will extend from 60 feet to 100 feet bgs. The B aquifer extraction wells will be installed to a depth of approximately 150 feet bgs. The 30-foot screened zone for these wells will extend from 120 feet to 150 feet bgs. All wells will be eight inches in diameter and installed in boreholes drilled using air rotary methods.

Each well will consist of stainless steel well screen and end cap, and PVC blank casing, with a surface well head with sampling ports and a backflow prevention device. In order to accommodate anticipated end use of the facility as a City park, the well head will be protected at the surface with a locking service box assembly set at grade over the top of the well head.

The groundwater extraction system for Alternative 2 includes conveyance piping to transport extracted groundwater to and from the on-site groundwater treatment plant. Lateral and header conveyance pipes can either be placed above grade or below grade. Advantages to above grade installation of piping include reduced installation costs and accessibility for maintenance and repair. However, piping placed above ground is constantly exposed to sunlight contributing to ultraviolet degradation and potentially resulting in brittleness and cracking. In

Need C monitoring wells. ROD will not decide # monitoring wells / comment

addition, above grade placement exposes header piping to physical damage from maintenance activities and/or vandalism.

Advantages of below grade installation include protection from ultraviolet degradation and physical damage. However, material and labor costs associated with installation are slightly higher than for above grade piping.

Taking into consideration anticipated end-uses, a below grade conceptual design was developed for this system. The 4-inch diameter lateral piping will convey groundwater from the individual extraction wells to a main header. The 8-inch diameter main header will connect to the on-site groundwater treatment facility.

3.2.1.3 Groundwater Monitoring System

The groundwater monitoring system under Alternative 2 will consist of groundwater monitoring wells located downgradient of the perimeter extraction well system and groundwater monitoring wells located at the downgradient edge of the off-site plume. Six A aquifer monitoring wells and 6 B aquifer monitoring wells will be used for assessing the effectiveness of the landfill perimeter extraction system. These monitoring wells will be located approximately at the midpoint between adjacent extraction wells, and will include existing monitoring well nest CDM-3.

Five A aquifer monitoring wells and 5 B aquifer monitoring wells will be used to monitor groundwater quality conditions along the downgradient boundary of the off-site contaminant plume. The monitoring wells will be placed beyond the background concentration contour of the site contaminants of concern. Figure 3-2 depicts the locations of the Alternative 2 groundwater monitoring wells. All monitoring wells will consist of 4-inch diameter PVC well screen and casing, completed similar to those installed under the remedial investigation. The monitoring wells will be equipped with dedicated bladder pumps and will be placed in a service box assembly at grade.

3.2.2 Alternative 2 Assessment

3.2.2.1 Overall Protection of Human Health and the Environment

Alternative 2 provides additional protection of human health the environment compared to Alternative 1 by limiting additional contaminant mass from impacting groundwater downgradient of the disposal facility. This is accomplished with the operation of the perimeter extraction system which intercepts contaminated groundwater originating underneath the landfill prior to being conveyed downgradient. Only partial environmental protection is achieved because contamination beyond the influence and downgradient of the perimeter extraction system remains and may impact uncontaminated groundwater as it moves downgradient.

ARARs addressing the clean-up of groundwater by establishing the concentration levels of specific toxic compounds may not be met with this alternative. Groundwater with levels of VOCs remain after the alternative has been implemented. Plume attenuation will occur over time as clean groundwater flows through the aquifer system flushing out contaminant mass.

Protection of human health is achieved to the extent that extracted groundwater is treated sufficiently prior to reuse such that exposure through ingestion or dermal contact does not pose a risk to human health. The alternative provides no reduction of the minimal risk currently present to human receptors from the groundwater downgradient of the influence of the perimeter extraction system.

3.2.2.2 Compliance With Applicable or Relevant and Appropriate Requirements (ARARs)

Federal or State ARARs as defined in Section 2.4 governing groundwater clean-up levels may not be achieved within a reasonable timeframe under Alternative 2. VOC contaminants above regulatory allowable limits will remain in the plume downgradient of the perimeter extraction system for some time prior to being attenuated below the regulatory limits. In addition, ARARs requiring corrective action measures which prevent further spread of the contaminant plume may not be achieved with this alternative.

Alternative 2 is the presumptive remedy established in EPA guidance on landfill CERCLA sites. The non-presumptive component of the remedial action addresses the off-site plume.

3.2.2.3 Long-Term Effectiveness and Permanence

Potential for exposure to toxic constituents in the groundwater remains in the untreated contaminant plume after the perimeter extraction wells are in operation. The magnitude of the risk which remains is initially the same as under existing site conditions until attenuation of the downgradient plume is accomplished through natural mechanisms. As discussed in Section 1.3.2, EPA's risk assessment determined minimal overall human health risk associated with the off-site plume (ICF International, 1994). Increased risk of exposure may occur after remedial action implementation if the contaminant plume travels along the groundwater gradient in a westerly and southerly direction.

The groundwater treatment process, air stripping with vapor phase carbon adsorption, will produce a treatment residual containing elevated levels of VOCs. The risk to human health and the environment associated with the management of the spent carbon is minimal if handled properly. Proper management includes the use of the appropriate facility to regenerate or dispose of the spent carbon.

The mechanical components of the extraction and treatment systems used under Alternative 2 are generally reliable. It is anticipated that pumping rates from the extraction wells can be maintained over the life of the system. The system will effectively intercept contaminated groundwater originating under the landfill thereby limiting the impact of the contaminant source on downgradient waters. The air stripping process has a good track record of meeting treatment objectives, VOC removal to non-detect concentrations, under a wide range of operating conditions. Both systems have routine long-term operations and maintenance requirements which must be performed to assure that remedial action objectives are met.

3.2.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2 is primarily a source control remedial action in that active clean-up of the off-site contaminant plume is not the primary objective. The perimeter extraction wells serve to intercept contaminated groundwater originating underneath the landfill from providing additional contaminant mass to the groundwater downgradient of the site. Some clean-up of the offsite plume is achieved as the perimeter extraction wells pull back in an easterly direction a portion of the off-site plume. In this regard the mobility and the toxicity of the offsite contaminant plume are both reduced.

The treatment process proposed for Alternative 2 and all the alternatives, is air stripping with vapor phase carbon adsorption. This treatment process removes significant amounts of the VOCs from the groundwater, resulting in a significant reduction in the toxicity and mobility of contaminants in the groundwater. The mass of contaminants is not destroyed, but transferred to another media in a more manageable form.

The treatment residual produced, the spent activated carbon, must be handled appropriately either through regeneration or disposal. The spent carbon is not anticipated to pose a risk to public health and the environment.

3.2.2.5 Short-Term Effectiveness

The major construction activity associated with Alternative 2 is the installation of a series of groundwater extraction wells along the western perimeter of the landfill. Well locations are at a substantial distance from residences, with the possible exception being the home located adjacent to the northwest boundary of the landfill. Minimal impact to the community is anticipated during the construction and ongoing operation of the Alternative 2 remedial action.

The potential exists for workers implementing the remedial action to be exposed to contaminated groundwater. This could occur during the well drilling operation or the operation of the groundwater treatment system. However, standard health and safety practices should minimize the potential for exposure and the risk from incidental exposure to the contaminated groundwater is minimal. Air monitoring during installation of the perimeter well extraction system will be performed to determine if landfill gas is present in the borehole.

Multiple aquifer units will be targeted for the perimeter extraction wells. The potential exists that waters from different aquifer units may mix for a short time during drilling operations, potentially resulting in an adverse impact to the groundwater. However, vertical hydraulic gradients are minimal when the irrigation wells are not operating, and extraction wells will terminate in the lower part of the B aquifer, so the risk associated with providing a conduit for contaminants to be conveyed between the A and B aquifers, or to unimpacted groundwaters in the C aquifer, is limited.

The objective of the perimeter extraction system is to intercept contaminated groundwater as it flows underneath the disposal site. The intercepted water is extracted and treated to remove VOCs, thereby assuring that additional contaminant mass does not move downgradient. It is estimated that Alternative 2 will effectively isolate the contaminant source from downgradient waters within approximately 3 months of well system operation.

3.2.2.6 Implementability

Alternative 2 is considered to be readily implementable from an administrative standpoint. The State regulatory agencies which govern a groundwater clean-up, the Central Valley RWQCB and DTSC, have been integrally involved throughout the process of remedial alternative identification and development. Concurrence and approval from these agencies would be received prior to the initiation of the remedial design and remedial action. The Fresno Air Pollution Control District, which has not been involved in the project to date, regulates emissions allowed from the groundwater treatment process. Coordination with this agency will be required during the remedial design phase of the project.

Standard well drilling operations and water treatment process will be used to implement Alternative 2. The remedial action is clearly feasible from a technical perspective. Both the well pumping and water treatment technologies proposed are reliable with a long track record indicating that the systems are mechanically sound. Contractors capable of providing services to construct the extraction wells, monitoring wells, groundwater conveyance and treatment systems are plentiful locally. A significant amount of similar types of construction work occurs throughout Fresno and the Central Valley.

Monitoring the effectiveness of the Alternative 2 perimeter extraction system in intercepting contaminated groundwater prior to being conveyed downgradient of the site will require 6 monitoring wells completed in the A and B aquifer units. These wells, placed between the extraction wells and located west of the landfill, can be used to determine the effectiveness of the perimeter extraction well system in two ways:

1) Provide a sampling location to determine groundwater quality, and

2) Provide an observation point to determine the hydraulic influence from the extraction system.

These wells are the same as those proposed under Alternative 1, shown on Figure 3-2. Existing downgradient wells, CDM-3, 4, 5, and 8 will be used to supplement the proposed monitoring system.

3.2.2.7 Cost

The capital cost for constructing the perimeter extraction system is $3,714,000. Annual O&M costs are estimated to be $453,000 which results in a present worth value of $6,774,000 over the 30-year remediation period. The total 30-year present worth value of the Alternative 2 extraction and monitoring systems is $10,488,000.

3.2.2.8 State Acceptance

This criterion will be addressed in the ROD once comments on the FS Report and Proposed Plan have been received.

3.2.2.9 Community Acceptance

This criterion will be addressed in the ROD once comments on the FS Report and Proposed Plan have been received.

3.3 Alternative 3 — Landfill Perimeter Plume Containment and Offsite Plume Containment

3.3.1 Narrative Description

The primary objective of the Alternative 3 remedial action is to prevent contamination of currently uncontaminated portions of the aquifer system. This is accomplished by preventing the VOC groundwater plume from expanding in both a lateral and vertical direction. Plume containment is achieved by installing two systems of groundwater extraction wells. The extraction well systems, designed to act as hydraulic barriers to groundwater flow, will be constructed adjacent to the western boundary of the landfill (as in Alternative 2) and along the downgradient edge of the off-site contaminant plume.

The landfill perimeter extraction system is to intercept groundwater passing underneath the landfill in the A and B aquifer horizons and is identical to that described for Alternative 2. This system will limit additional contaminant mass from impacting groundwater downgradient of the FSL. The purpose of the off-site extraction system is to limit the movement of the groundwater plume in a downgradient (southerly and westerly) direction in the A and B horizons. The lateral and vertical extent of the plume is contained such that downgradient water quality is not jeopardized.

A secondary goal of Alternative 3 is to isolate the existing off-site VOC plume as a means to achieve aquifer clean-up. Attenuation of the off-site plume will occur as the source of contaminants is cut off by the perimeter extraction system and clean groundwater flows through the contaminated aquifer soils, flushing it and causing desorption of contaminants from the aquifer media.

Alternative 3 is further divided into 2 subalternatives -- Alternative 3a and Alternative 3b. The division is made based solely on the clean-up goal. Differences between the subalternatives are highlighted in the discussions presented below.

3.3.1.1 Clean-up Goal

There is no cleanup goal for this alternative, since the remedial action objective is plume containment. For Alternative 3a, the basis for placing off-site containment wells is background concentrations for PCE, TCE, and vinyl chloride. For Alternative 3b, the basis for off-site well placement is MCL concentrations for these compounds.

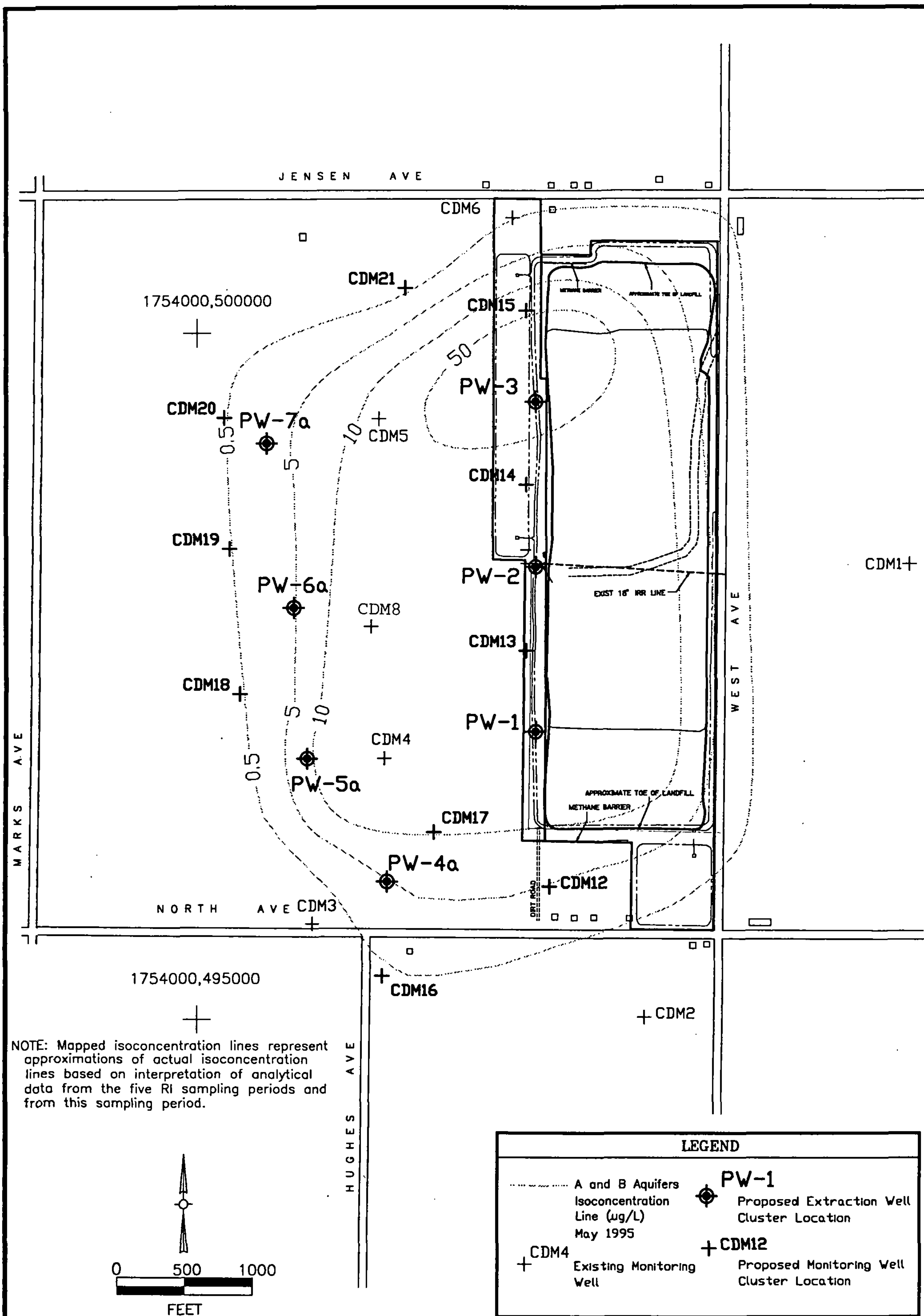
3.3.1.2 Groundwater Extraction System

The groundwater extraction well system located along the western boundary of the landfill, as described in Alternative 2, will be included in Alternative 3 (3 wells intercepting A aquifer flows and 3 wells intercepting B aquifer flows).

In addition to the landfill perimeter extraction wells, 4 groundwater extraction wells will be located along the boundary of the off-site plume for extraction of groundwater from the A aquifer and 4 wells for extraction of groundwater from the B aquifer. These will be co-located, single completion wells drilled, installed and completed as described for the landfill perimeter extraction wells.

The number of groundwater extraction wells located along the edge of the off-site plume will be the same for Alternative 3a and Alternative 3b. However, as a result of the different clean-up goals between Alternatives 3a and 3b, there will be a change in the location of these wells. The Alterative 3a off-site plume extraction wells will be located slightly downgradient of the Alternative 3b off-site plume extraction wells in order to capture contamination present in the aquifer above background levels. Figures 3-3 and 3-4 depict the configuration of the groundwater extraction system under Alternative 3a and Alternative 3b, respectively. The figures include the locations of the groundwater extraction wells and monitoring wells.

Modeling has indicated that an optimal pumping scenario for Alternative 3 would include starting at a high pumping rate, then decreasing the number of



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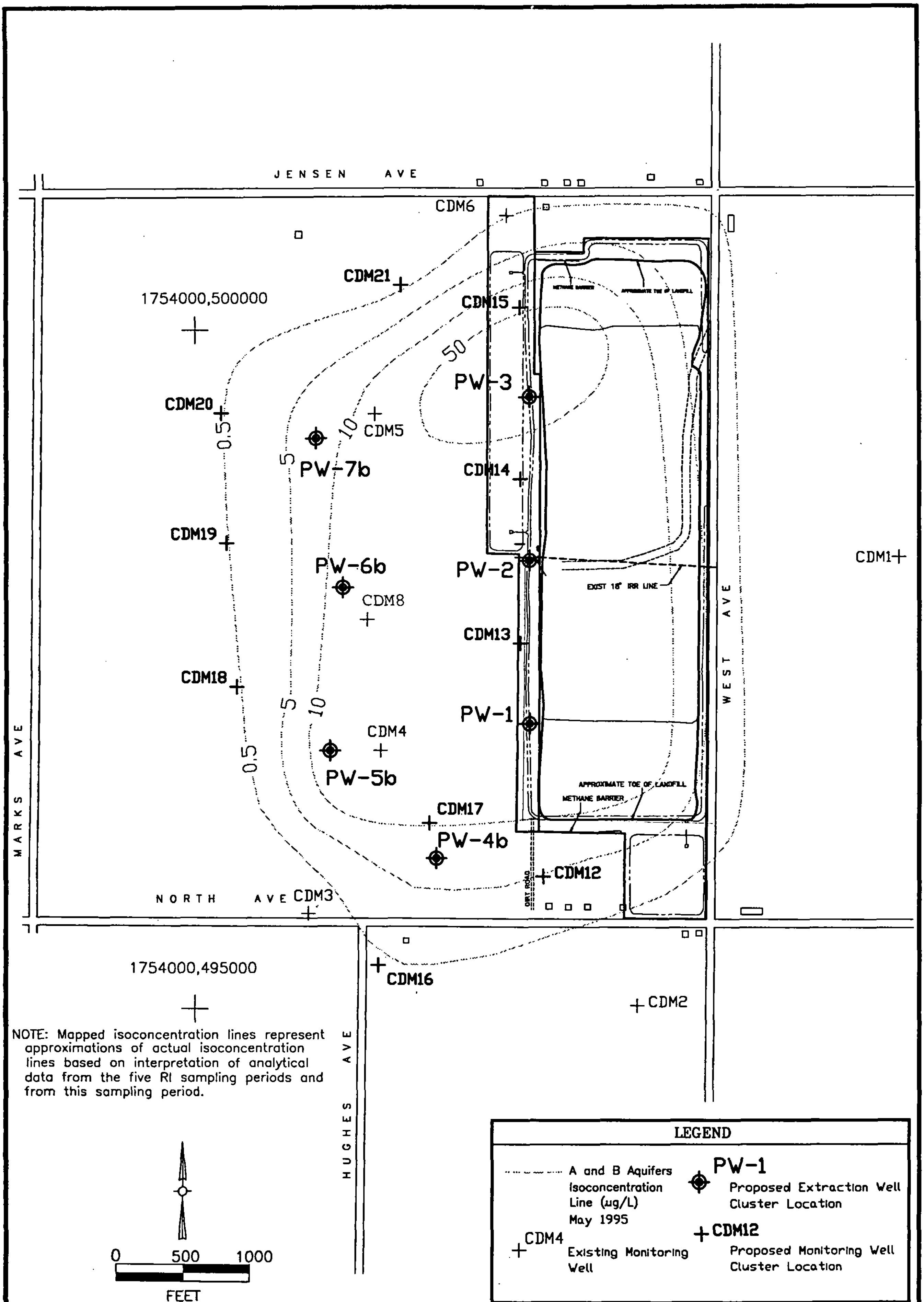
FSL Alternative 3A
Landfill Perimeter Plume Containment and Offsite Plume Containment – to Background

Figure 3-3

WELL-A2.DWG



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FSL Alternative 3B
Landfill Perimeter Plume Containment and Offsite Plume Containment – to MCL

Figure 3-4

WELL-A2.DWG

wells pumping and the discharge rates over the 30-year operational period. Final pumping rates will be determined during the FS. Preliminary pumping rates for Alternative 3 consist of initially pumping the A aquifer at 1,050 gpm and decreasing to approximately 320 gpm during the 30-year operational period. The B aquifer will be initially pumped at 1,150 gpm, decreasing to approximately 440 gpm during the 30-year operational period. The relatively high initial rates allow for plume containment approximately 3 months after system start-up.

Construction details for the off-site plume extraction wells and the conveyance system are similar to the description for Alternative 2. Note that there will be additional piping needed for transport of groundwater pumped from the off-site plume containment wells to the groundwater treatment plant.

3.3.1.3 Groundwater Monitoring System

The groundwater monitoring system for Alternatives 3a and 3b will be identical to the system described under Alternative 2.

There will be 6 monitoring well nests for assessing the effectiveness of the landfill perimeter extraction system and 6 monitoring nests for assessing migration beyond the off-site plume extraction system. Figure 3-3 depicts the locations of the Alternative 3a groundwater monitoring wells. Figure 3-4 depicts the locations of the Alternative 3b groundwater monitoring wells.

3.3.2 Alternative 3 Assessment

Three criteria have been identified for which the distinction between Alternative 3a (clean-up to background levels) and Alternative 3b (clean-up to MCLs) is relevant. The four criteria that are different between these alternatives are overall protection of human health and the environment, compliance with ARARs and State acceptance.

3.3.2.1 Overall Protection of Human Health and the Environment

Groundwater extraction at the landfill perimeter and the downgradient edge of the plume provides protection of human health and the environment by preventing additional contaminant mass from impacting downgradient groundwater. Both the currently contaminated plume and the groundwater downgradient of the present plume boundary will not be exposed to further contamination. This is accomplished through the perimeter extraction wells and the off-site containment wells isolating the existing plume hydraulically from other waters.

ARARs relating to clean-up of contaminated groundwater are partially satisfied in that no further degradation of groundwater resources occurs once Alternative 3 is in place. However, groundwater above regulatory allowable limits still remain within the plume for some time after the primary Alternative 3 response objective of containing the plume has been achieved. Therefore, ARARs are determined to be only partially met. Alternative 3a (clean-up to background levels) fulfills both State and Federal ARARs. Alternative 3b (clean-up to MCLs) does not fully achieve State ARARs. This is based upon the State's non-degradation policy of not allowing constituent levels of regulated components to remain above those levels which are naturally occurring.

Protection of human health is achieved to the extent that extracted groundwater is treated sufficiently such that exposure through ingestion or dermal contact does not pose a risk to human health. In addition, by containing the plume to its current dimensions, human receptors downgradient of the existing plume are protected.

3.3.2.2 Compliance With ARARs

The plume containment achieved through the combination of the perimeter extraction wells and the plume boundary extraction wells satisfies the State's policy of eliminating degradation of non-impacted waters. Complete ARARs compliance with respect to aquifer cleanup will not be achieved within a reasonable time period because groundwater with contaminants at concentrations above allowable regulatory limits will remain downgradient of the landfill and upgradient of the off-site containment wells.

3.3.2.3 Long-Term Effectiveness and Permanence

Alternative 3 greatly reduces the risk remaining from the untreated contaminant plume by isolating the plume from contact with existing unimpacted groundwater resources. Attenuation of the plume will be enhanced through dispersion and flushing of the off-site plume once the perimeter extraction wells and plume boundary containment wells are in operation and clean groundwater enters the off-site plume area. The magnitude of the contamination which remains after pumping has been initiated diminishes at a rate established by these natural attenuation mechanisms.

The groundwater treatment process, air stripping with vapor phase carbon adsorption, will produce a treatment residual containing elevated levels of VOCs. The risk to human health and the environment associated with the management of the spent carbon is minimal if handled properly.

The two extraction systems and the groundwater treatment system proposed for Alternative 3 are mechanically reliable. It is anticipated that the pumping rates from the extraction wells at both the landfill perimeter and plume boundary can be maintained dependably over the life of the remediation. This results in the effective containment of the plume; additional contaminant mass from the landfill will be intercepted prior to moving downgradient of the landfill edge with the plume boundary controls preventing the plume size from expanding. The air stripping process has a good track record of meeting treatment objectives under a wide range of operating conditions. The extraction and treatment systems have routine long-term operations and maintenance requirements which must be performed to assure that remedial action objectives are met.

3.3.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 3 is a containment remedial action with the primary objective to prevent the contaminant levels from increasing in the plume through landfill perimeter extraction and to limit the plume size from expanding through plume boundary extraction. Remediation of the off-site plume will eventually occur as the perimeter extraction system draws offsite groundwater in an easterly direction and the boundary extraction wells intercepts the contaminated groundwater to the west for ultimate extraction. This will reduce contaminant mass, and thus toxicity to a much greater extent than under Alternative 2. In addition, this alternative reduces contaminant volume and completely eliminates contaminant mobility.

The treatment process proposed for Alternative 3 and all the alternatives, is air stripping with vapor phase carbon adsorption. This treatment process removes significant amounts of the VOCs from the groundwater, resulting in a significant reduction in the toxicity, and mobility of contaminants in the groundwater. The mass of contaminants is not destroyed, but transferred to another media in a more manageable form.

The treatment residual produced, the spent activated carbon, must be handled appropriately either through regeneration or disposal. The spent carbon is not anticipated to pose a risk to public health and the environment.

3.3.2.5 Short-Term Effectiveness

Installation of the perimeter extraction well system, and the plume boundary containment system are the major construction activities specified under Alternative 3. As indicated above for Alternative 2, the work will be conducted at substantial distances from existing residences. However, Alternative 3 requires that the plume boundary containment system, the conveyance piping to bring the extracted groundwater to the treatment plant location, and the monitoring well network be placed on private property. Implementation of the remedial action will impact the agricultural practices which typically occur on this property.

The potential exists for workers implementing the remedial action to be exposed to contaminated groundwater. This could occur during the well drilling operation or the operation of the groundwater treatment system. However, standard health and safety practices should minimize the potential for exposure and the risk from incidental exposure to the contaminated groundwater is minimal. Air monitoring during installation of the perimeter well extraction system will be performed to determine if landfill gas is present in the borehole.

Multiple aquifer units will be targeted for the perimeter extraction wells. The potential exists that waters from different aquifer units may mix for a short time during drilling operations, potentially resulting in an adverse impact to the groundwater. However, vertical hydraulic gradients are minimal when the irrigation wells are not operating, and extraction wells will terminate in the lower part of the B aquifer, so the risk associated with providing a conduit for contaminants to be conveyed between the A and B aquifers, or to unimpacted groundwaters in the C aquifer, is limited.

The primary objective of the extraction systems specified under Alternative 3 is to isolate the contaminant plume from the local groundwater. This is accomplished by intercepting the contaminated groundwater at the landfill before it moves downgradient and by extracting at the plume boundary to limit its spread. These hydraulic objectives will be achieved within approximately 3 months of putting the extraction systems on line.

3.3.2.6 *Implementability*

Alternative 3 has the same considerations associated with its administrative feasibility as described above for Alternative 2. The primary State regulatory agencies governing the pump and treat clean-up, Central Valley RWQCB and DTSC, are currently participating in the development of the alternatives. Concurrence and approval from these agencies will be received prior to initiation of the remedial design.

The plume boundary containment system, and its associated monitoring well network, will be constructed on private property. Access agreements and long-term easements with the property owner will be necessary prior to the system installation. Although demonstrated to be feasible in the past, negotiating with the property owner will require time and resources from the City.

Standard well drilling operations are required to install the two extraction systems specified in Alternative 3. As stated above, both the treatment technologies and extraction systems to be used are mechanically reliable. A monitoring well network will be installed downgradient of the current plume boundary, identical to the monitoring well system described in Alternative 2.

3.3.2.7 *Cost*

The capital cost for constructing the perimeter extraction and monitoring systems and plume boundary containment and monitoring systems is $6,375,000. Annual O&M costs for these extraction and monitoring systems are estimated to be $598,000 which result in a present worth value of $8,940,000. The total 30-year present worth value for the Alternative 3 extraction and monitoring system is $15,315,000.

3.3.2.8 State Acceptance

This criterion will be addressed in the ROD once comments on the FS Report and proposed plan have been received.

3.3.2.9 Community Acceptance

This criterion will be addressed in the ROD once comments on the FS Report and proposed plan have been received.

3.4 Alternative 4 — Landfill Perimeter Plume Containment and Offsite Plume Restoration; Background Water Quality/MCL Water Quality

3.4.1 Narrative Description

The primary goal of Alternative 4 is to restore the contaminated aquifer downgradient of the FSL to levels below regulatory standards. This is accomplished by extracting the contaminated groundwater in the region west of the FSL within the existing off-site plume, in conjunction with source control measures. This action will allow the aquifer to be flushed with clean upgradient waters. Isolating the groundwater flowing underneath the site with the perimeter extraction system will result in no additional contaminant mass being added to the off-site plume, thus facilitating restoration of the aquifer within the off-site plume.

The extraction well system for this alternative is more extensive than the system developed under Alternative 3. Additional extraction wells are placed within the plume for the aquifer restoration remedial action.

A groundwater monitoring system is used to assess the groundwater quality downgradient of the landfill perimeter extraction system as well as the off-site plume remediation system.

Alternative 4 is further divided into 2 subalternatives. The division is made based on the clean-up goal. Differences between the subalternatives are highlighted in the discussions presented below.

3.4.1.1 Clean-up Goal

For Alternative 4a, the clean-up goal is background concentration of PCE. For Alternative 4b, the clean-up goal is MCL for PCE. Consistent with the previous alternatives, there is no clean-up goal associated with the perimeter groundwater extraction system. The clean-up goal applies to the remedial action at the off-site contaminant plume and influences the placement of extraction wells intended for off-site plume restoration. The off-site plume groundwater extraction system will be designed to reduce the concentrations of the contaminants of concern in the aquifer downgradient of the landfill (A and B horizons) to less than background (Alternative 4a) or to less than MCL (Alternative 4b).

3.4.1.2 Groundwater Extraction System

The groundwater extraction well system located along the western boundary of the landfill, as described in Alternative 2, will be included in Alternative 4 (3 wells intercepting A aquifer flows and 3 wells intercepting B aquifer flows).

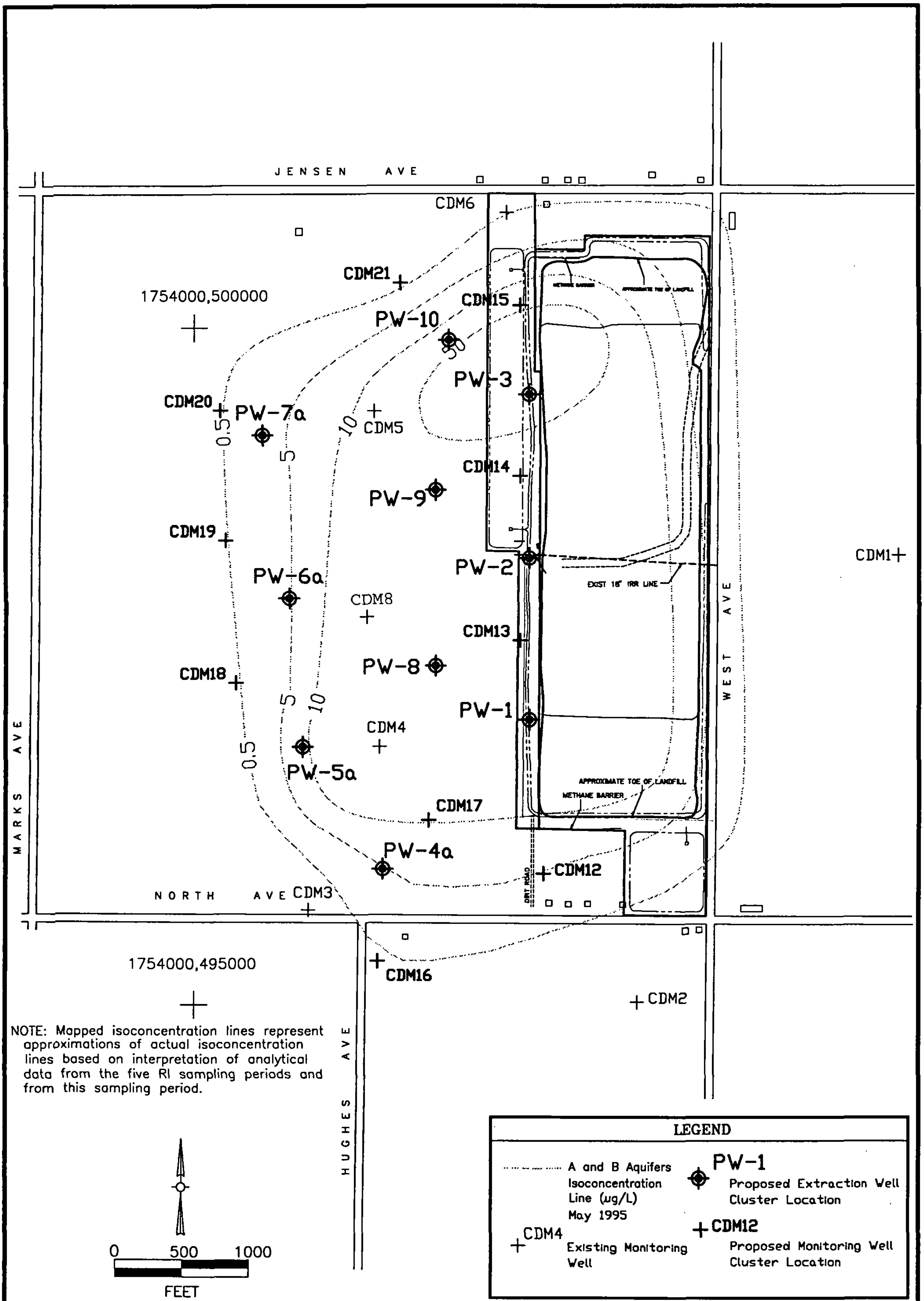
In addition to the landfill perimeter extraction wells, 7 groundwater extraction wells will be located within the off-site plume for extraction of groundwater from the A aquifer and 7 wells for extraction of groundwater from the B aquifer. These will be co-located, individual completions, similar in construction to the landfill perimeter extraction wells. The objectives of these wells are to contain the off-site contaminant plume and to restore the aquifer.

The number of groundwater extraction wells located within the off-site plume will be the same for Alternative 4a and Alternative 4b. However, as a result of the different clean-up goals between Alternatives 4a and 4b, there are differences in the location of these wells. The Alternative 4a off-site plume extraction wells will be located further west than the Alternative 4b off-site plume extraction wells. Figures 3-5 and 3-6 depict the configuration of the groundwater extraction system under Alternative 4a and Alternative 4b, respectively. The figures include groundwater extraction wells and monitoring wells.

An extensive conveyance system will be required to transport extracted groundwater from the well field to the on-site location of the groundwater treatment plant.

Modeling has indicated that an optimal pumping scenario for Alternative 4 would include starting at a high pumping rate, then decreasing the number of wells pumping and the discharge rates over the 30-year operational period. Final pumping rates will be determined during the FS. Preliminary pumping rates for Alternative 4 consist of initially pumping the A aquifer at 1,500 gpm and decreasing to approximately 320 gpm during the 30-year operational period. The B aquifer will be initially pumped at 1,650 gpm, decreasing to approximately 400 gpm during the 30-year operational period.

The time period of pumping required to restore the aquifer was estimated as discussed in Section 1.3.3. Based on the pore volumes required for restoration and volume of PCE contaminated groundwater presented in Section 1.3.3, and assuming that all groundwater pumped was contaminated, the following time periods would be required to reach the remedial alternative goals of aquifer restoration below background and MCL:



CDM
environmental engineers, scientists, planners, & management consultants

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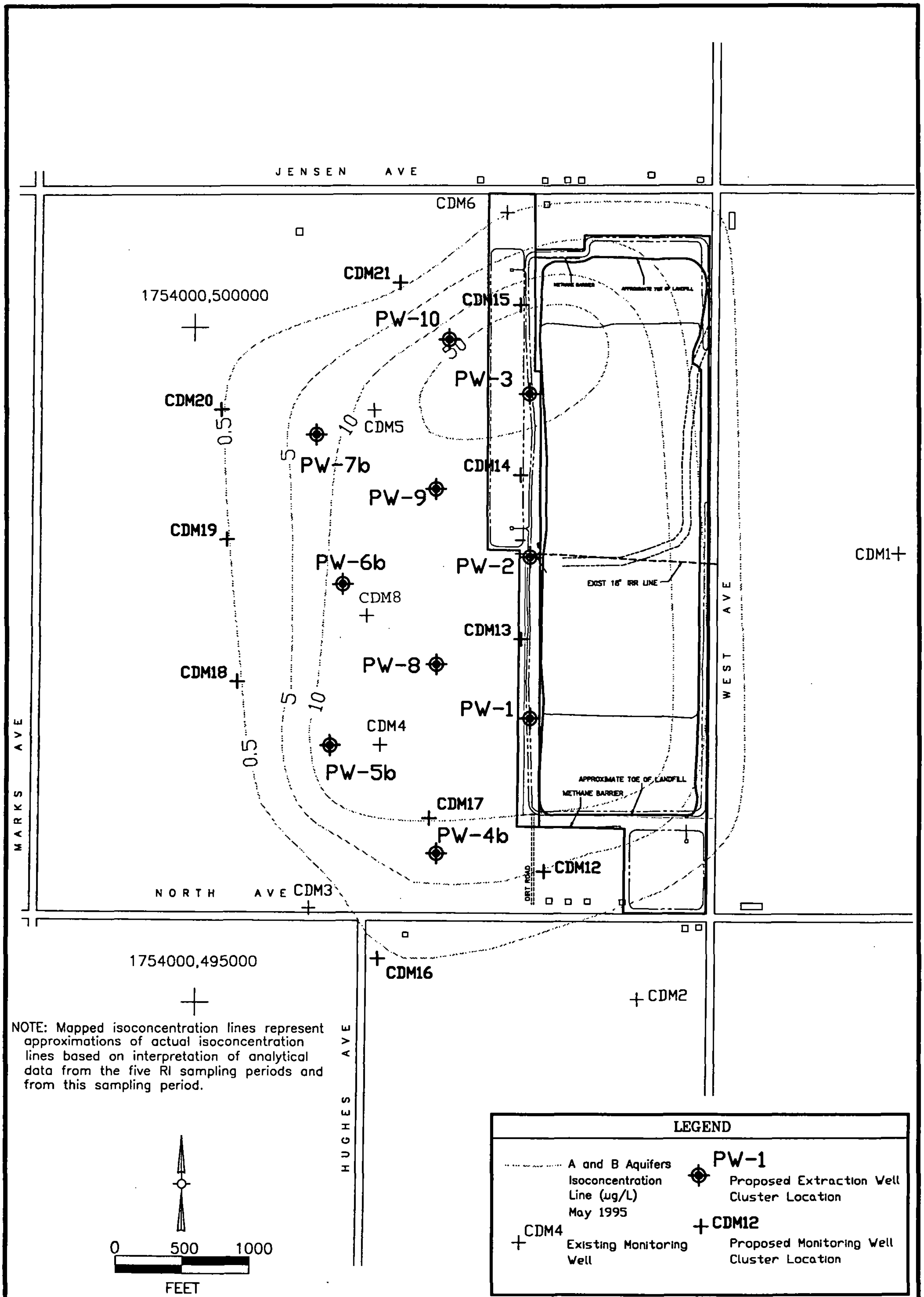
FSL Alternative 4A
Landfill Perimeter Plume Containment and Offsite Plume Restoration – to Background

Figure 3-5

WELL-A2.DWG



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FSL Alternative 4B
Landfill Perimeter Plume Containment and Offsite Plume Restoration – to MCL

Figure 3-6

WELL-A2.DWG

	Restoration to Background (years)	Restoration to MCL (years)
Aquifer A	148	63
Aquifer B	310	108

In actuality, the pumping system will recover uncontaminated groundwater as well as the contaminated groundwater, so the clean-up times will be longer than given above.. As previously discussed, there is a very high uncertainty associated with the number of pore volumes required to reach remediation goals, and thus these clean-up timeframes should be viewed as general estimates. These timeframes do indicate, however, the very long duration that this system would need to operate to achieve either clean-up goal. In order to refine these pore volume estimates, bench-scale laboratory or field analyses would need to be performed.

3.4.1.3 Groundwater Monitoring System

The groundwater monitoring system is identical to the system described for Alternatives 2 and 3. Figure 3-5 and Figure 3-6 depict the locations of the monitoring wells for Alternative 4a and Alternative 4b, respectively.

3.4.2 Alternative 4 Assessment

Three criteria have been identified for which the distinction between Alternative 4a (clean-up to background levels) and Alternative 4b (clean-up to MCLs) is relevant. The three criteria identified include overall protection of human health and the environment, compliance with ARARs and State acceptance.

3.4.2.1 Overall Protection of Human Health and the Environment

Alternative 4 provides protection of the environment by containing the contaminant plume and reducing plume concentrations, thereby eliminating the plume's impact on downgradient groundwater resources. Active restoration of the plume through the operation of the interior extraction system results in accelerated clean-up of the groundwater contamination compared to plume clean-up achieved under Alternative 3.

Alternative 4a satisfies both State and Federal ARARs by implementing a clean-up goal of background for the contaminant plume. The MCL clean-up goal of Alternative 4b does not achieve State ARARs as reflected in the State's non-degradation policy. Allowing VOC levels to remain above what would be considered naturally occurring, or non-detect, is not in full compliance with State laws governing groundwater remediation.

Protection of human health is achieved to the extent that extracted groundwater is treated sufficiently such that exposure through ingestion or dermal contact does not pose a risk to human health. In addition, by containing the plume to its current dimensions and by actively remediating the entire plume, the potential for exposure to human receptors is minimized.

3.4.2.2 Compliance With ARARs

Alternative 4a, which consists of restoring the aquifer to background levels of VOCs, is in compliance with both State and Federal ARARs. Only Federal ARARs are achieved completely with Alternative 4b which establishes the aquifer restoration clean-up goals of MCLs. The State's non-degradation policy requires that contaminant levels must be cleaned up to those concentrations which naturally occur. This is non-detect for the VOC chemicals of concern at the FSL. In either case, however, clean-up goals would be achieved after an excessively lengthy period of system operation.

3.4.2.3 Long-Term Effectiveness and Permanence

Alternative 4 completely eliminates any groundwater contamination associated with the FSL groundwater plume if a given remedial action objective can be met. This is true for both Alternative 4a (clean-up to background) and Alternative 4b (clean-up to MCLs). If clean-up goals are achieved, the aquifer is restored to a condition which reflects the same risk to public health and the environment associated with the groundwater occurring under natural conditions.

The groundwater treatment process, air stripping with vapor phase carbon adsorption, will produce a treatment residual containing elevated levels of VOCs. The risk to human health and the environment associated with the management of the spent carbon is minimal if handled properly.

The three extraction systems (landfill perimeter, off-site plume boundary and plume interior wells) and the groundwater treatment system proposed under Alternative 4 are mechanically reliable. It is anticipated that the perimeter containment system and the plume boundary containment system can be effectively operated over the life of the system. This results in no additional contaminant mass being added to the impacted plume and the plume size being contained at its current configuration.

Although mechanically reliable, it is anticipated that the aquifer restoration extraction system will not achieve the clean-up goals of either background or MCLs. Past experience from other pump and treat remedial actions indicate a consistent pattern of the inability to reduce VOC levels in the aquifer down to the 5 $\mu g/l$ range, the MCL for PCE and TCE. It is not likely that Alternative 4a or 4b will meet the performance goals specified.

The air stripping treatment process has a good track record of meeting treatment objectives, VOC removal to non-detect concentrations, under a wide range of operating conditions. Both the extraction and treatment systems have routine long-range operations and maintenance requirements.

3.4.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 4 is a restoration remedial action designed to treat all the contaminated groundwater occurring in the plume downgradient of the landfill. It satisfies the statutory preference for selecting a remedial action that permanently and substantially reduces toxicity, mobility, and volume of the toxic constituents through treatment.

The treatment process proposed for Alternative 2 and all the alternatives, is air stripping with vapor phase carbon adsorption. This treatment process removes significant amounts of the VOCs from the groundwater, resulting in a significant reduction in the toxicity, and mobility of contaminants in the groundwater. The mass of contaminants is not destroyed, but transferred to another media in a more manageable form.

The treatment residual produced, the spent activated carbon, must be handled appropriately either through regeneration or disposal. The spent carbon is not anticipated to pose a risk to public health and the environment.

3.4.2.5 Short-Term Effectiveness

The impacts on the community from implementation of Alternative 4 are similar to those described above under Alternative 3. Most of the activities will occur at a substantial distance from existing residences. However, the plume boundary containment wells and the aquifer restoration extraction system, including the associated conveyance piping required, will be located on private property to the west of the site. The construction and operation of the Alternative 4 remedial action will impact the agricultural practices occurring on these private properties.

The potential exists for workers implementing the remedial action to be exposed to contaminated groundwater. This could occur during the well drilling operation or the operation of the groundwater treatment system. However, standard health and safety practices should minimize the potential for exposure and the risk from incidental exposure to the contaminated groundwater is minimal. Air monitoring during installation of the perimeter well extraction system will be performed to determine if landfill gas is present in the borehole.

Well drilling operations for all three extraction systems have the potential for mixing contaminated groundwater among different waterbearing units. However, all extraction wells are targeted to terminate above the C aquifer. The potential for creating a conduit for contaminants to be conveyed to currently unimpacted groundwater resources is low.

The ultimate remedial action objective for Alternative 4 is to restore the contaminated aquifer such that VOC levels are either at background or MCLs (Alternatives 4a and 4b, respectively). It is difficult to estimate the time required to achieve this objective. Many aquifer restoration remediations historically have never been able to achieve these low clean-up goals (see Appendix ___ of the Draft FS Report). As discussed in Section 3.4.1.2, an extensive time period is estimated to be required to achieve aquifer restoration to both MCLs and background. Operation of the system for a relatively short period of time should provide an indication of whether achieving background or MCL levels in the aquifer is feasible.

3.4.2.6 Implementability

Alternative 4 consists of an aquifer restoration extraction system resulting in a well field throughout the off-site plume. Installation of the well field, including the monitoring network required to determine system effectiveness, will occur on private property. Access arrangements and long-term easement to allow the system operations and maintenance will require extensive negotiations with the property owner. Alternative 4 is readily implementable in terms of coordinating with the regulatory agencies governing the groundwater clean-up action.

The same technologies used in Alternatives 2 and 3 are applied with Alternative 4. There is simply a greater number of extraction wells, more conveyance piping, and possibly a treatment system with greater capacity. Accordingly, system operations and maintenance will be somewhat more complex. However, the alternative is still technically feasible as the pump and treat system technologies have been demonstrated to be mechanically sound. Contractors with the capabilities necessary to install and even operate the system are readily available locally.

Alternative 4 does not require any greater degree of monitoring than Alternatives 2 and 3. The same number of monitoring wells will be installed in slightly modified locations.

3.4.2.7 Cost

The capital cost for constructing the landfill perimeter extraction, plume boundary containment, and aquifer restoration systems is $7,948,000. Annual O&M costs for the extraction and monitoring systems are estimated to be $624,000 which results in a present worth value of $9,329,000. The total 30-year present worth value of the Alternative 4 extraction and monitoring systems is $17,277,000.

3.4.2.8 State Acceptance

This criterion will be addressed in the ROD once comments on the FS Report and proposed plan have been received.

3.4.2.9 Community Acceptance

This criterion will be addressed in the ROD once comments on the FS Report and proposed plan have been received.

Section 4
Comparative Analysis of Alternatives

4.1 Introduction

The purpose of this section is to present a comparative analysis of how each of the six alternatives developed to remediate the groundwater at the FSL were evaluated against seven criteria. (The remaining two criteria, State Acceptance and Community Acceptance will be evaluated after the Proposed Plan has been developed and review comments received.)

This section is organized by evaluation criteria. The extent to which each alternative satisfies the criteria will be compared and contrasted among the four alternatives.

4.2 Overall Protection of Human Health and the Environment

Minimal risk to human health is posed by the current conditions, based upon the analysis performed by the EPA and documented in the Final Human Health Risk Assessment for the Fresno Sanitary Landfill Superfund Site (EPA, 1994). The contribution of the contaminated groundwater to the total human health carcinogenic risk is within the upper end of the EPA's range of allowable risk (10^{-6} excess deaths due to cancer).

Alternatives 2 through 4 are relatively more protective of human health and the environment than the No Action alternative, because contaminants are removed from the aquifer under each of these letter alternatives which reduces the plume toxicity and volume. It should be emphasized, however, that with implementation of Institutional Controls (site access restrictions, well drilling limitations, well plugging and abandonment) and other measures to prevent exposure that will be implemented under Alternatives 1 through 4, all alternatives are expected to achieve an acceptable level of protection of human health and the environment. The landfill capping and landfill gas remediation actions to be undertaken at the site will reduce the contaminant contributions to the aquifer. Combined with natural attenuation processes within the aquifer and the institutional controls listed above, the No Action alternative should be sufficiently protective of human health from a human health risk perspective.

Alternative 2 adds a further level of protection as compared with Alternative 1, however, by providing source control and containment of the off-site plume through monitoring. Alterative 3 will provide a higher level of protection, via active containment of the off-site plume. This will prevent the off-site plume from migrating into clean portions of the aquifer and will not lead to exposure of currently unexposed populations. Alternative 4 provides the highest level of protection, but only when its plume restoration goal is satisfied. Given the unreasonably long timeframes anticipated to reach aquifer restoration, Alternative 4 must be viewed as offering no greater protection of human health and the environment than Alternative 3.

4.3 Compliance with ARARs

Due to the very lengthy timeframes estimated for aquifer cleanup (ranging from 150 to greater than 300 years), none of the alternatives satisfy aquifer restoration to a clean-up level of background. Alternative 4b, aquifer restoration to MCLs, violates the State's non-degradation policy. The extended time period before cleanup goals can be reached, and the question of whether the clean-up goals can physically be attained, makes differences among alternatives for this criteria relatively less important.

The plume containment achieved under Alternative 3 satisfies the remedial action objective of preventing the VOC plume from moving downgradient and impacting previously uncontaminated groundwater resources. Although the contaminant plume is not remediated directly, Alternative 3 establishes the conditions where additional groundwater resources will not be impacted and plume attenuation through natural mechanisms will occur. Plume containment is not achieved to as complete a degree with the perimeter extraction system specified by Alternative 2; however, the flow conditions created under Alternative 2 are such that westward movement of the plume is minimal. The proposed phasing of the project described above will allow Alternative 2 to be evaluated over time in terms of eliminating plume movement downgradient.

The No Action Alternative is not in compliance with groundwater cleanup-based ARARs as defined in Section 2.4.

4.4 Long-Term Effectiveness and Permanence

The controls instituted in all three active remedial alternatives are reliable over the long term. The technologies associated with groundwater extraction and treatment are dependable when properly operated and maintained. Alternatives 2, 3, and 4 will require long term operation of the extraction and treatment systems.

The perimeter extraction system specified in Alternatives 2 through 4, and the plume boundary containment system specified in Alternatives 3 and 4, will likely meet performance objectives. These systems will effectively isolate the off site plume from the contaminant source, which is the disposal site, and will limit the plume from expanding in a westerly direction.

It is anticipated that the clean-up goals established for the aquifer restoration remedial action, Alternative 4, will not be achieved within a reasonable timeframe estimates of aquifer cleanup are on the order of 60 to 300 years. This is based upon groundwater modeling and past performance of pump and treat systems where clean-up to low levels of VOCs, background and MCLs, has not been achieved consistently.

No long-term effectiveness is accomplished with Alternative 1, because no controls are implemented under the no action scenario. The perimeter extraction system prevents additional contaminant mass from being added to the groundwater downgradient from the site. However, the VOCs may be spread over a greater area under Alternative 2 as the plume limits are not actively contained. No untreated waste remains after the Alternative 4 remedial action objectives are achieved.

4.5 Reduction of Toxicity, Mobility, and Volume Through Treatment

This criteria will be achieved to some degree within the contaminated portions of the aquifer under each of the Alternatives, due to natural attenuation (including compound dispersion, adsorption, and biodegradation) which reduces contaminant mass, and therefore contaminant toxicity and volume. Alternatives 2 through 4 reduce contaminant toxicity and volume to successively higher degrees since they remove increasing amounts of contaminated water from the aquifer. Alternatives 2 through 4 also reduce the toxicity and volume of contaminated groundwater to successively higher degrees through treatment of extracted water. Alternatives 3 and 4 will reduce off-site plume contaminant volumes more so than Alternative 2 due to the greater number of wells located in the off-site plume and higher initial pumping rates under Alternative 4.

Alternative 2 reduces contaminant mobility to a moderate degree since the perimeter containment wells capture some of the off-site plume. The hydraulic gradient in the off-site plume area is also reduced by operation of the perimeter containment wells; this will decrease groundwater flow rates and therefore also reduce the migration rate of the off-site plume. It is possible that the reduced migration rate of the off-site plume in Alternative 2 may be balanced by plume attenuation rates. If this occurs, then the plume will, in effect, stop migrating. In this regard, Alternative 2 may be equally effective in reducing contaminant mobility as Alternatives 3 and 4. Alternatives 3 and 4 reduce contaminant mobility to about the same degree in the off-site plume.

4.6 Short-Term Effectiveness

The perimeter extraction and plume boundary containment system specified in the active alternatives will effectively isolate the contaminant plume within approximately 3 months of operation. However, reaching the clean-up goals established under Alternatives 4a and 4b for complete aquifer restoration may never be achieved. This is based upon performance records of other pump and treatment systems where low clean-up goals for VOCs were never met. Thus, Alternatives 2 and 3 are more effective in the short-term at achieving their remedial action objectives. Alternative 4 achieves the plume containment objective about as quickly as Alternative 3.

Implementation of all four alternatives will have minimal impacts on the residential community. The systems proposed are at a substantial distance from the local residences. Portions of Alternatives 2, 3 and 4 will be constructed on private property which is currently under cultivation. Implementation of these three alternatives will interfere with the agricultural operations occurring on the private property.

The well drilling operations and the operation of the groundwater treatment facility provides a potential exposure to contaminated groundwater by workers. The risk to human health associated with the low levels of VOCs in the groundwater is minimal. Potential environmental impacts during implementation include well installation resulting in the mixing of waters among different water bearing units. Proper well design and installation practices should limit the potential for this to occur.

4.7 Implementability

The No Action alternative is readily implemented, requiring the least number of permits, access easements, or controls to institute. The existing monitoring well network will be sampled on a periodic basis in a similar manner as being performed currently.

Alternatives 2, 3, and 4 require the same relative amount of coordination with the regulatory community. The State agencies governing groundwater clean-ups, the Central Valley RWQCB and DTSC, are presently involved in the identification and development of remedial actions at FSL. Extensive post-ROD coordination with these entities is not anticipated.

Alternatives 2, 3, and 4 will be progressively more difficult to implement, due to the increased number of wells, higher production rates, more extensive piping and treatment systems required and larger operations and maintenance efforts involved. Implementation of the three active alternatives require access to private property located west of the landfill in which to install and operate plume extraction and monitoring wells. Plume boundary monitoring wells will be installed approximately 1,500 feet west of the site. For Alternatives 3 and 4, an extraction well system will be constructed on the private property in addition to the downgradient monitoring well network, while the extraction wells for

Alternative 2 will be located on City property. Negotiating construction access agreements and long-term easements, while feasible, will require extensive effort.

The extraction and treatment technologies specified for Alternatives 2, 3, and 4 use standard well drilling techniques and treatment processes. Air strippers are commonly used for water treatment applications similar to the FSL project. Multiple contractors are available locally with the capability of providing the services necessary to construct and operate the three active alternatives.

The monitoring well networks proposed for Alternatives 2, 3, and 4 will be similar for all three alternatives, with well points located immediately downgradient of both the landfill perimeter extraction system and the downgradient plume boundary. They are therefore equally implementable.

4.8 Cost

The EPA has defined a 30-year time period on which to calculate costs for the remedial systems. While costs have been estimated for this time period, it should be emphasized that Alternative 4 does not achieve its goal of aquifer restoration within 100 years, and the containment systems in Alternatives 2 and 3 will also need to operate for periods for longer than 30 years. The total present worth life cycle costs for the No Action alternative are minimal compared to the three active alternatives. The $1,018,000 reflects no capital costs. Semi-annual groundwater monitoring is conducted using the existing well network. Table 4-1 presents a summary of the cost estimates.

Table 4-1
Fresno Sanitary Landfill Feasibility Study
Alternatives Cost Summary

	Description	Capital Costs	Annual O&M Costs	Present Worth
Alternative 1	No Action	$0	$68,000	$1,018,000
Alternative 2	Source Control	$3,714,000	$453,000	$10,488,000
Alternative 3	Source Control & Offsite Plume Containment	$6,375,000	$598,000	$15,315,000
Alternative 4	Source Control & Offsite Aquifer Restoration	$7,948,000	$624,000	$17,277,000

Note: Costs shown in the table are based on a 30-year period of operation. Clean-up goals are not achieved within this time period.

Capital costs for the Alternatives, 2, 3, and 4, range from $3,714,000 for Alternative 2 to $7,949,000 for Alternative 4. Annual costs for the active alternatives range from $453,000 for Alternative 2 to $624,000 for Alternative 4.

Annual costs (in terms of present worth) represent approximately 55 to 65 percent of the total present worth value of the three active alternatives.

4.9 State Acceptance

This criterion will be addressed in the ROD after comments on the FS Report and proposed plan have been received.

4.10 Community Acceptance

This criterion will be addressed in the ROD after comments on the FS Report and proposed plan have been received.

Section 5
References

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Appendix A

Preliminary Feasibility Study Cost Estimates

Appendix A
Preliminary Feasibility Study Cost Estimates

This appendix describes the approach used in preparing the preliminary cost estimates for each of the Fresno Sanitary Landfill (FSL) remedial alternatives. Cost estimate spreadsheets are provided at the end of this section.

Cost Estimating Approach

The cost estimating approach used for determining costs for the FS follows the guidelines established by EPA and described in the publication *Remedial Action Costing Procedures Manual* (EPA, 1987). The cost estimates were calculated using standard cost data obtained from the *Environmental Restoration: Assemblies Cost Book* (ECHOS, 1995), *Compendium of Costs of Remedial Technologies at Hazardous Waste Sites* (EPA, 1984), data obtained from various suppliers and contractors, and estimating calculations performed by Camp Dresser & McKee Inc. Costing at this stage in the FS is in the -30 percent to +50 percent range of accuracy.

A detailed cost analysis was performed and includes direct and indirect capital costs, direct and indirect operations and maintenance (O&M) costs, and present worth costs. Direct capital costs are the estimated costs for performing a remedial action and for construction of treatment facilities. For this Technical Memorandum FS, this specifically includes installation and construction of:

- extraction wells and pumping systems
- groundwater treatment plant
- conveyance structures to carry extracted groundwater to the plant
- monitoring wells

Indirect capital costs include items that are incidental to the direct capital costs and are related as a percentage of the direct costs:

- 20% for engineering and design
- 5% for legal fees
- 5% for substantive permitting requirements
- 25% for EPA review and oversight
- 25% for contingencies

O&M costs are annual post-construction costs necessary to the remedial action. O&M costs include labor, materials, laboratory analysis, and energy charges for:

- operation of groundwater extraction system
- operation of groundwater treatment plant

- equipment maintenance
- equipment replacement
- redrilling and redevelopment of wells
- monitoring and sampling
- pumping
- chemical analysis and reporting
- periodic review of remedial action, monitoring program, and Public Health Evaluation to assess performance

Indirect O&M costs represent the estimated costs for administrating the direct O&M work (at 10 percent) and a reserve and contingency allowance for possible unexpected O&M costs (at 20 percent of the direct O&M costs).

The present worth analysis is conducted to evaluate the effects of O&M and periodic capital costs over the life of the project. The present worth of periodic costs was calculated assuming a 30-year life for the project and using the current discount rate of 5.25 percent, as published by the *Wall Street Journal* on October 17, 1995.

Cost estimates for each alternative are provided in terms of total capital costs, annual costs, and total present worth for comparison between alternatives. Components of each alternative and assumptions made in generating the attached cost estimates are listed described below.

General Costing Assumptions

- Well installation costs (extraction and monitoring wells)
  - derived largely from *Environmental Restoration: Assemblies Cost Book* (ECHOS, 1995), with the following exceptions:
    - drilling - CDM RI/FS experience
    - waste control - CDM RI/FS experience
    - well vaults - remediation project in Sparks, NV
    - power drop - CDM RI/FS experience
    - decommissioning - CDM RI/FS experience

- Operation and routine maintenance of wells
  - CDM RI/FS experience
  - Unit pumping cost is 10¢/kwh. Annual pumping power cost is proportional to the various pumping drawdown rates for each stage, aquifer and alternative, which are shown in the cost estimates.

- Well rehabilitation costs
  - extraction wells - *Draft Phase III Feasibility Study* for the Lowry Landfill OUs 1/6 (shallow groundwater, subsurface liquids, and deep groundwater), HLA (1992)
  - monitoring wells - extrapolated from extraction well cost data

- Well replacement
  - extrapolated from installation costs based on CDM experience

- Pump replacement
  - extrapolated from installation costs using CDM experience

- Conveyance system from extraction wells to groundwater treatment plant
  - 4" PVC pipe will be used to carry water from wells to an 8" PVC header pipe which will convey water to the treatment plant
  - for costing purposes, unit cost of 6" diameter PVC pipe used for all piping at $5.00/ft/inch diameter of pipe, which equals $30/ft.

- Groundwater treatment
  - on-site, adjacent to FSL
  - air stripping system with GAC for off-gasses
  - capital cost (C_2) estimated using unit costs derived from similar treatment system evaluated by CDM, adjusted using formula based on maximum treatment rate Q_2 of alternative:
    - $C_2 = C_1 (Q_2/Q_1)^{0.6}$ where C_1 = $3.32 million and Q_1 = 5,000 gpm
  - O&M costs derived from similar system assuming same labor costs and prorated GAC material costs per size of system

- Management of treated effluent
  - treated groundwater conveyed to an irrigation district in the vicinity of Fresno or percolation pond system
  - pump station and hookup costs not estimated at this time, but will be developed for the FS

Common Components of All Alternatives

- Institutional controls will be implemented by local government
  - restrict installation of water supply wells in affected area
  - no costs assigned to this item

- Well decommissioning
  - 4 residential supply wells
  - 3 water supply wells
  - 2 groundwater monitoring wells
  - costs not estimated at this time, but will be developed for the FS

- Continued monitoring with existing wells
  - 9 groundwater monitoring wells

- 9 residential wells
- 4 water supply wells
- monitoring frequency
  - semi-annual monitoring/sampling to assess groundwater quality
  - quarterly water level measurements (13 wells only)
- semi-annual reporting
- re-evaluate monitoring program every 5 years and adjust as necessary

Alternative 1 – No Action

- Includes only those items listed above under *Common Components of All Alternatives*

Alternative 2 – Landfill Perimeter Containment and Offsite Contaminant Plume Monitoring

- Landfill extraction wells along western perimeter of landfill
  - separate wells will be constructed for extraction from Aquifers A and B
  - well head service boxes set at grade
  - submersible pumps will be installed in each well
  - extraction schedules based on modeling results, with pumping rates adjusted to reflect time-weighted sequences over 2 operating periods
    - all wells will be operated in years 1 through 5 at rates shown in cost estimates
    - number of wells in operation and extraction rates reduced in years 6 through 30 as shown in cost estimates
  - extracted water will be conveyed to groundwater treatment plant via below grade lateral (4" diameter) and header pipes (8" diameter)

- Monitoring wells
  - separate wells will be constructed in Aquifers A and B downgradient of perimeter extraction wells
  - multi-depth wells (completed in both A and B aquifers) will be constructed downgradient of plume
  - well head service boxes set at grade
  - all wells equipped with dedicated bladder pumps

Alternative 3 – Landfill Perimeter Plume Containment and Offsite Contaminant Plume Containment

- Landfill extraction wells along western perimeter of landfill (same as Alternative 2)

- Off-site extraction wells on western perimeter of plume
  - construction details of wells and conveyance systems will be similar to landfill extraction wells

- extraction schedules based on modeling results, with pumping rates adjusted to reflect time-weighted sequences over 2 operating periods
  - all wells will be operated in years 1 through 5 at rates shown in cost estimates
  - number of wells in operation and extraction rates reduced in years 6 through 30 as shown in cost estimates
- extracted water will be conveyed to groundwater treatment plant via below grade lateral (4" diameter) and header pipes (8" diameter)

■ Monitoring wells will be essentially identical to Alternative 2

■ Alternative 3 will be evaluated as two separate alternatives, defined by cleanup goal
- Alternative 3a treats to background water quality
- Alternative 3b treats to MCL water quality
- the difference between Alternatives 3a and 3b is in the location of the plume extraction wells; for costing purposes, this results in no difference in costs and only one cost estimate is provided

Alternative 4 – Landfill Perimeter Plume Containment and Offsite Contaminant Plume Restoration

■ Landfill extraction wells along western perimeter of landfill (same as Alternative 2)

■ Off-site extraction wells within the plume west of the landfill
- construction details of wells and conveyance systems will be similar to landfill extraction wells
- extraction schedules based on modeling results, with pumping rates adjusted to reflect time-weighted sequences over 2 operating periods
  - all wells will be operated in years 1 through 5 at rates shown in cost estimates
  - number of wells in operation and extraction rates reduced in years 6 through 30 as shown in cost estimates
- extracted water will be conveyed to groundwater treatment plant via below grade lateral (4" diameter) and header pipes (8" diameter)

■ Monitoring wells will be essentially identical to Alternative 2

■ Alternative 4 will be evaluated as two separate alternatives, defined by cleanup goal
- Alternative 4a treats to background water quality
- Alternative 4b treats to MCL water quality
- the difference between Alternatives 4a and 4b is in the location of the plume extraction wells; for costing purposes, this results in no difference in costs and only one cost estimate is provided

Cost Estimating Tables

Alternative 1

SCREENING OF ALTERNATIVES
COST ESTIMATING WORKSHEET DATE: 31-Oct-95 09:12 AM
BY: JEClark

PROJECT: FRESNO SANITARY LANDFILL DRAFT FS COST ESTIMATES

ITEM: ALTERNATIVE 1 (NO ACTION)

DESCRIPTION: Decommissioning of existing wells potentially causing cross-aquifer contamination and continuation of current monitoring program.

DIRECT CAPITAL COSTS :
(Includes Labor, Equipment & Materials, Unless Otherwise Noted)

COST COMPONENT	UNIT	QUANTITY	UNIT COST	TOTAL CAPITAL COST
1. Well Decommisioning	EA	9	$ -	$ -
2a. Landfill extraction wells Aquifer A	EA	-	$ 48,400	$ -
2b. Landfill extraction wells Aquifer B	EA	-	$ 50,600	$ -
3a. Plume extraction wells Aquifer A	EA	-	$ 48,400	$ -
3b. Plume extraction wells Auifer B	EA	-	$ 50,600	$ -
4a. Pipe Conveyance	FT	-	$ 30	$ -
4b. Mobilization	LS	-	$ 75,000	$ -
4c. Command Post	MO	-	$ 7,000	$ -
5a. Landfill monitoring wells Aquifer A	EA	-	$ 14,800	$ -
5b. Landfill monitoring wells Aquifer B	EA	-	$ 18,100	$ -
6a. Plume monitoring wells Aquifer A	EA	-	$ 14,800	$ -
6b. Plume monitoring wells Aquifer B	EA	-	$ 18,100	$ -
7. Groundwater treatment plant	LS	-	$ -	$ -
8. Treated Effluent Pump station & hook up	LS	-	$ -	$ -

TOTAL DIRECT COSTS : $ -

INDIRECT CAPITAL COSTS : (% of Direct Capital Costs)

1. Engineering & Design	20%	$ -
2. Other Indirect Costs		
A. Legal Fees	5.0%	$ -
B. Regulatory License/Permit Costs	5.0%	$ -
C. EPA review and oversight	25%	$ -
3. Contingency	25%	$ -

TOTAL INDIRECT CAPITAL COSTS : $ -

TOTAL CAPITAL COSTS	$ -
PRESENT WORTH ANNUAL COSTS	$ 1,018,000
TOTAL PRESENT WORTH COSTS	**$ 1,018,000**

SCREENING OF ALTERNATIVES
COST ESTIMATING WORKSHEET — DATE: 31-Oct-95 — 09:12 AM
BY: JEClark

PROJECT: FRESNO SANITARY LANDFILL DRAFT FS COST ESTIMATES

Discount rate 5.25%

ITEM: ALTERNATIVE 1 (NO ACTION)

DESCRIPTION: Decommissioning of existing wells potentially causing cross-aquifer contamination and continuation of current monitoring program.

ANNUAL/STAGED OPERATION & MAINTENANCE COSTS

STAGED DIRECT OPERATIONAL COSTS	Units	QTY	(gpm) pump	hp pump	UNIT COST	KWH/hp-hr	days/yr	hrs/day	KWH	KWH annual COST	unit cost Operation 4% of capital	annual Operation	Total Annual operation + Annual KWH	Present worth year zero
1. Current Monitoring	30												$50,000	$ 747,195
2a. Landfill extraction wells Aquifer A	years													
- years 1 to 5	5	0	0	-	$ 0.10	0.7457	365	24	-	$0	$1,936	$0	$0	$ -
-years 6 to 30	25	0	0	-	$ 0.10	0.7457	365	24	-	$0	$1,936	$0	$0	$ -
2b. Landfill extraction wells Aquifer B														
- years 1 to 5	5	0	0	-	$ 0.10	0.7457	365	24	-	$0	$2,024	$0	$0	$ -
- years 6 to 30	25	0	0	-	$ 0.10	0.7457	365	24	-	$0	$2,024	$0	$0	$ -
3a. Plume extraction wells Aquifer A														
- years 1 to 5	5	0	0	-	$ 0.10	0.7457	365	24	-	$0	$1,936	$0	$0	$ -
- years 6 to 30	25	0	0	-	$ 0.10	0.7457	365	24	-	$0	$1,936	$0	$0	$ -
3b. Plume extraction wells Aquifer B														
- years 1 to 5	5	0	0	-	$ 0.10	0.7457	365	24	-	$0	$2,024	$0	$0	$ -
- years 6 to 30	25	0	0	-	$ 0.10	0.7457	365	24	-	$0	$2,024	$0	$0	$ -

	Units	1000 gal	unit cost	Annual Cost	Present worth year zero
4. Groundwater treatment O/M					
- years 1 to 5	5	-	$0.56	$0	$ -
- years 6 to 30	25	-	$0.61	$0	$ -

	Units	Volume per 100ft^3	$/100ft^3	Annual effluent surcharge	Present worth year zero
5a.Treated Effluent POTW charge					
- years 1 to 5	5	-	$0.281	$0	$ -
- years 6 to 30	25	-	$0.281	$0	$ -
5b. effluent pump station O/M					
- years 1 to 5	5	-	$0.00	$0	$ -
- years 6 to 30	25	-	$0.00	$0	$ -
					$ 747,195

STAGED DIRECT MAINTENANCE COSTS	Qty pumps	year	unit cost
6. Extraction Well Maintenance			
6a. Replace pumps			

Item	Unit	Qty	Times	Unit Cost Maint	Unit cost	times/year	annual sampling	annual maint. / total	total annual	Present worth
- after first 10 years		0	10		$ 9,660					$ -
- after 20 years		0	20		$ 9,660					$ -
6b. Redrill Extraction Wells		Qty wells								
- Aquifer A wells		0	15		$ 35,000					$ -
- Aquifer B wells		0	15		$ 35,000					$ -
6c. Redevelop Extraction wells										
- once every 5 years (except if redrilled)		0	4		$ 4,000					$ -
Total Present Worth of the Staged Direct Operational & Maintenance Costs										$ 747,195
ANNUAL DIRECT OPERATIONAL & MAINTENANCE COSTS					unit cost	times/year			total annual	
7a. Pipe Conveyance	EA	0			$1,000	2			$ -	
7b. Instrumentation/Electrical	EA	0			$2,000	2			$ -	
				Unit Cost Maint	Unit cost sampling	sampling/yr	annual sampling	annual maint.		
8a. Landfill monitoring wells Aquifer A	EA	0		$ 100	$ 1,335	2	$0	$ -	$ -	
8b. Landfill monitoring wells Aquifer B	EA	0		$ 100	$ 1,335	2	$0	$ -	$ -	
9a. Plume monitoring wells Aquifer A	EA	0		$ 100	$ 1,335	2	$0	$ -	$ -	
9b. Plume monitoring wells Aquifer B	EA	0		$ 100	$ 1,335	2	$0	$ -	$ -	
10a. Replace Monitoring Wells		Qty wells	times					total		
once every ten years										
- Aquifer A & B monitoring wells		0	2		$ 14,800			$0	$ -	
10b. Redevelop monitoring wells										
- once every 5 years		0	5		$ 1,000			$0	$ -	
11a. Public Health Evaluation (every 5 yrs)	EA		0		$50,000			$0	$ -	
11b. Remedy as necessary	EA		0		$ 5,000			$0	$ -	
12a. Monitoring Program Review (every 5 yrs)	EA		6		$10,000			$60,000	$ 2,000	
12b. Remedy as necessary	EA		5		$ 2,500			$12,500	$ 417	
TOTAL DIRECT COSTS:									$ 2,417	$ 747,195
INDIRECT COSTS (% of Direct Costs):										
Administration	LS	ANNUAL				10%			$ 242	$74,720
Contingency Costs	LS	ANNUAL				20%			$ 483	$149,439
TOTAL INDIRECT COSTS									$ 725	$224,159
TOTAL COSTS									$ 3,142	$ 971,354

PW of Annual costs	$ 3,142	30 yrs	5.25%	=		$ 46,949
PW of Staged costs						$ 971,354
PW of All O&M Costs						**$ 1,018,000**
Annualized O&M Costs						**$ 68,000**

Cost Estimating Tables

Alternative 2

SCREENING OF ALTERNATIVES
COST ESTIMATING WORKSHEET DATE: 31-Oct-95 09:12 AM
BY: JEClark

PROJECT: FRESNO SANITARY LANDFILL DRAFT FS COST ESTIMATES

ITEM: ALTERNATIVE 2 (SOURCE CONTROL)

DESCRIPTION: Decommissioning of existing wells potentially causing cross-aquifer contamination and continuation of current monitoring program. Extraction wells along western perimeter of landfill. Conveyance by pipe to WTP. Monitoring wells downgradient of landfill and plume.

DIRECT CAPITAL COSTS :
(Includes Labor, Equipment & Materials, Unless Otherwise Noted)

COST COMPONENT	UNIT	QUANTITY	UNIT COST	TOTAL CAPITAL COST
1. Well Decommisioning	EA	9	$ -	$ -
2a. Landfill extraction wells Aquifer A	EA	3	$ 48,400	$ 145,200
2b. Landfill extraction wells Aquifer B	EA	3	$ 50,600	$ 151,800
3a. Plume extraction wells Aquifer A	EA	-	$ 48,400	$ -
3b. Plume extraction wells Auifer B	EA	-	$ 50,600	$ -
4a. Pipe Conveyance	FT	3,750	$ 30	$ 112,500
4b. Mobilization	LS	1	$ 75,000	$ 75,000
4c. Command Post	MO	4	$ 7,000	$ 28,000
5a. Landfill monitoring wells Aquifer A	EA	4	$ 14,800	$ 59,200
5b. Landfill monitoring wells Aquifer B	EA	4	$ 18,100	$ 72,400
6a. Plume monitoring wells Aquifer A	EA	6	$ 14,800	$ 88,800
6b. Plume monitoring wells Aquifer B	EA	6	$ 18,100	$ 108,600
7. Groundwater treatment plant	LS	1	$ 1,222,000	$ 1,222,000
8. Treated Effluent Pump station & hook up	LS	1	$ -	$ -

TOTAL DIRECT COSTS :		$ 2,063,500
INDIRECT CAPITAL COSTS : (% of Direct Capital Costs)		
1. Engineering & Design	20%	$ 412,700
2. Other Indirect Costs		
A. Legal Fees	5.0%	$ 103,175
B. Regulatory License/Permit Costs	5.0%	$ 103,175
C. EPA review and oversight	25%	$ 515,875
3. Contingency	25%	$ 515,875
TOTAL INDIRECT CAPITAL COSTS :		$ 1,650,800
TOTAL CAPITAL COSTS		$ 3,714,000
PRESENT WORTH ANNUAL COSTS		$ 6,774,000
TOTAL PRESENT WORTH COSTS		$ 10,488,000

SCREENING OF ALTERNATIVES
COST ESTIMATING WORKSHEET

DATE: 31-Oct-95 09:12 AM
BY: JEClark

PROJECT: FRESNO SANITARY LANDFILL DRAFT FS COST ESTIMATES

Discount rate 5.25%

ITEM: ALTERNATIVE 2 (SOURCE CONTROL)

DESCRIPTION: Decommissioning of existing wells potentially causing cross-aquifer contamination and continuation of current monitoring program. Extraction wells along western perimeter of landfill. Conveyance by pipe to WTP. Monitoring wells downgradient of landfill and plume.

ANNUAL/STAGED OPERATION & MAINTENANCE COSTS

STAGED DIRECT OPERATIONAL COSTS	Units	QTY	(gpm) pump	hp pump	UNIT COST	KWH/hp-hr	days/yr	hrs/day	KWH	KWH annual COST	unit cost Operation 4% of capital	annual Operation	Total Annual operation + Annual KWH	Present worth year zero
1. Current Monitoring	30												$50,000	$ 747,195
2a. Landfill extraction wells Aquifer A	years													
- years 1 to 5	5	3	114	3.22	$ 0.10	0.7457	365	24	63,169	$6,317	$1,936	$5,808	$12,125	$ 52,134
-years 6 to 30	25	2	110	3.08	$ 0.10	0.7457	365	24	40,248	$4,025	$1,936	$3,872	$7,897	$ 84,055
2b. Landfill extraction wells Aquifer B														
- years 1 to 5	5	3	129	3.22	$ 0.10	0.7457	365	24	63,169	$6,317	$2,024	$6,072	$12,389	$ 53,269
- years 6 to 30	25	2	125	3.08	$ 0.10	0.7457	365	24	40,248	$4,025	$2,024	$4,048	$8,073	$ 85,928
3a. Plume extraction wells Aquifer A														
- years 1 to 5	5	0	114	3.22	$ 0.10	0.7457	365	24	-	$0	$1,936	$0	$0	$ -
- years 6 to 30	25	0	110	3.08	$ 0.10	0.7457	365	24	-	$0	$1,936	$0	$0	$ -
3b. Plume extraction wells Aquifer B														
- years 1 to 5	5	0	129	3.22	$ 0.10	0.7457	365	24	-	$0	$2,024	$0	$0	$ -
- years 6 to 30	25	0	125	3.08	$ 0.10	0.7457	365	24	-	$0	$2,024	$0	$0	$ -

	Units	1000 gal	unit cost	Annual Cost	Present worth year zero
4. Groundwater treatment O/M					
- years 1 to 5	5	383,162	$0.56	$214,571	$ 922,595
- years 6 to 30	25	247,032	$0.61	$150,690	$ 1,603,967

	Units	Volume per 100ft^3	$/100ft^3	Annual effluent surcharge	Present worth year zero
5a.Treated Effluent POTW charge					
- years 1 to 5	5	512,600	$0.000	$0	$ -
- years 6 to 30	25	330,483	$0.000	$0	$ -
5b. effluent pump station O/M					
- years 1 to 5	5	512,600	$ -	$0	$ -
- years 6 to 30	25	330,483	$ -	$0	$ -
					$ 3,549,142

STAGED DIRECT MAINTENANCE COSTS	Qty pumps	year	unit cost
6. Extraction Well Maintenance			
6a. Replace pumps			

- after first 10 years	6	10	$ 9,660	$ 34,746
- after 20 years	6	20	$ 9,660	$ 20,830
6b. Redrill Extraction Wells	Qty wells			
- Aquifer A wells	3	15	$ 35,000	$ 48,737
- Aquifer B wells	3	15	$ 35,000	$ 48,737
6c. Redevelop Extraction wells				
- once every 5 years (except if redrilled)	6	4	$ 4,000	$ 48,273
Total Present Worth of the Staged Direct Operational & Maintenance Costs				$ 3,750,465

ANNUAL DIRECT OPERATIONAL & MAINTENANCE COSTS					unit cost	times/year			total annual	
7a. Pipe Conveyance	EA	1			$1,000	2			$ 2,000	
7b. Instrumentation/Electrical	EA	1			$2,000	2			$ 4,000	
				Unit Cost Maint	Unit cost sampling	sampling/yr	annual sampling	annual maint.		
8a. Landfill monitoring wells Aquifer A	EA	4		$ 100	$ 1,335	2	$10,680	$ 400	$ 11,080	
8b. Landfill monitoring wells Aquifer B	EA	4		$ 100	$ 1,335	2	$10,680	$ 400	$ 11,080	
9a. Plume monitoring wells Aquifer A	EA	6		$ 100	$ 1,335	2	$16,020	$ 600	$ 16,620	
9b. Plume monitoring wells Aquifer B	EA	6		$ 100	$ 1,335	2	$16,020	$ 600	$ 16,620	
10a. Replace Monitoring Wells		Qty wells	times					total		
once every ten years										
- Aquifer A & B monitoring wells		20	2		$ 14,800			$592,000	$ 19,733	
10b. Redevelop monitoring wells										
- once every 5 years		20	5		$ 1,000			$100,000	$ 3,333	
11a. Public Health Evaluation (every 5 yrs)	EA		6		$50,000			$300,000	$ 10,000	
11b. Remedy as necessary	EA		5		$ 5,000			$25,000	$ 833	
12a. Monitoring Program Review (every 5 yrs)	EA		6		$10,000			$60,000	$ 2,000	
12b. Remedy as necessary	EA		5		$ 2,500			$12,500	$ 417	
TOTAL DIRECT COSTS:									$ 97,717	$ 3,750,465
INDIRECT COSTS (% of Direct Costs):										
Administration	LS	ANNUAL				10%			$ 9,772	$375,047
Contingency Costs	LS	ANNUAL				20%			$ 19,543	$750,093
TOTAL INDIRECT COSTS									$ 29,315	$1,125,140
TOTAL COSTS									$ 127,032	$ 4,875,605

PW of Annual costs	$ 127,032	30 yrs	5.25%	=	$ 1,898,349
PW of Staged costs					$ 4,875,605
PW of All O&M Costs					$ 6,774,000
Annualized O&M Costs					$ 453,000

Cost Estimating Tables

Alternative 3

SCREENING OF ALTERNATIVES
COST ESTIMATING WORKSHEET DATE: 31-Oct-95 09:12 AM
BY: JEClark

PROJECT: FRESNO SANITARY LANDFILL DRAFT FS COST ESTIMATES

ITEM: ALTERNATIVE 3 (SOURCE CONTROL & OFFSITE PLUME CONTAINMENT)

DESCRIPTION: Decommissioning of existing wells potentially causing cross-aquifer contamination and continuation of current monitoring program. Extraction wells along western perimeter of landfill.
Extraction wells along western perimeter of off-site plume.
Conveyance by pipe to WTP. Monitoring wells downgradient of landfill and plume.

DIRECT CAPITAL COSTS :
(Includes Labor, Equipment & Materials, Unless Otherwise Noted)

COST COMPONENT	UNIT	QUANTITY	UNIT COST	TOTAL CAPITAL COST
1. Well Decommisioning	EA	9	$ -	$ -
2a. Landfill extraction wells Aquifer A	EA	3	$ 48,400	$ 145,200
2b. Landfill extraction wells Aquifer B	EA	3	$ 50,600	$ 151,800
3a. Plume extraction wells Aquifer A	EA	4	$ 48,400	$ 193,600
3b. Plume extraction wells Auifer B	EA	4	$ 50,600	$ 202,400
4a. Pipe Conveyance	FT	12,380	$ 30	$ 371,400
4b. Mobilization	LS	1	$ 75,000	$ 75,000
4c. Command Post	MO	6	$ 7,000	$ 42,000
5a. Landfill monitoring wells Aquifer A	EA	4	$ 14,800	$ 59,200
5b. Landfill monitoring wells Aquifer B	EA	4	$ 18,100	$ 72,400
6a. Plume monitoring wells Aquifer A	EA	6	$ 14,800	$ 88,800
6b. Plume monitoring wells Aquifer B	EA	6	$ 18,100	$ 108,600
7. Groundwater treatment plant	LS	1	$ 2,031,000	$ 2,031,000
8. Treated Effluent Pump station & hook up	LS	1	$ -	$ -

TOTAL DIRECT COSTS : $ 3,541,400

INDIRECT CAPITAL COSTS : (% of Direct Capital Costs)

1. Engineering & Design	20%	$ 708,280
2. Other Indirect Costs		
A. Legal Fees	5.0%	$ 177,070
B. Regulatory License/Permit Costs	5.0%	$ 177,070
C. EPA review and oversight	25%	$ 885,350
3. Contingency	25%	$ 885,350

TOTAL INDIRECT CAPITAL COSTS : $ 2,833,120

TOTAL CAPITAL COSTS	$ 6,375,000
PRESENT WORTH ANNUAL COSTS	$ 8,940,000
TOTAL PRESENT WORTH COSTS	$ 15,315,000

SCREENING OF ALTERNATIVES
COST ESTIMATING WORKSHEET — DATE: 31-Oct-95 — 09:12 AM
BY: JEClark

PROJECT: FRESNO SANITARY LANDFILL DRAFT FS COST ESTIMATES

Discount rate 5.25%

ITEM: ALTERNATIVE 3 (SOURCE CONTROL & OFFSITE PLUME CONTAINMENT)

DESCRIPTION: Decommissioning of existing wells potentially causing cross-aquifer contamination and continuation of current monitoring program. Extraction wells along western perimeter of landfill. Extraction wells along western perimeter of off-site plume. Conveyance by pipe to WTP. Monitoring wells downgradient of landfill and plume.

ANNUAL/STAGED OPERATION & MAINTENANCE COSTS

STAGED DIRECT OPERATIONAL COSTS	Units	QTY	(gpm) pump	hp pump	UNIT COST	KWH/hp-hr	days/ yr	hrs/ day	KWH	KWH annual COST	unit cost Operation 4% of capital	annual Operation	Total Annual operation + Annual KWH	Present worth year zero
1. Current Monitoring	30												$50,000	$ 747,195
2a. Landfill extraction wells Aquifer A	years													
- years 1 to 5	5	3	97.13	3.11	$ 0.10	0.7457	365	24	60,976	$6,098	$1,936	$5,808	$11,906	$ 51,191
-years 6 to 30	25	2	82	2.41	$ 0.10	0.7457	365	24	31,478	$3,148	$1,936	$3,872	$7,020	$ 74,720
2b. Landfill extraction wells Aquifer B														
- years 1 to 5	5	3	112.4	3.11	$ 0.10	0.7457	365	24	60,976	$6,098	$2,024	$6,072	$12,170	$ 52,326
- years 6 to 30	25	2	102	2.41	$ 0.10	0.7457	365	24	31,478	$3,148	$2,024	$4,048	$7,196	$ 76,593
3a. Plume extraction wells Aquifer A														
- years 1 to 5	5	2	97.13	3.11	$ 0.10	0.7457	365	24	40,651	$4,065	$1,936	$3,872	$7,937	$ 34,127
- years 6 to 30	25	2	82	2.41	$ 0.10	0.7457	365	24	31,478	$3,148	$1,936	$3,872	$7,020	$ 74,720
3b. Plume extraction wells Aquifer B														
- years 1 to 5	5	2	112.4	3.11	$ 0.10	0.7457	365	24	40,651	$4,065	$2,024	$4,048	$8,113	$ 34,884
- years 6 to 30	25	2	102	2.41	$ 0.10	0.7457	365	24	31,478	$3,148	$2,024	$4,048	$7,196	$ 76,593

	Units	1000 gal	unit cost	Annual Cost	Present worth year zero
4. Groundwater treatment O/M					
- years 1 to 5	5	587,227	$0.56	$328,847	$ 1,413,949
- years 6 to 30	25	386,842	$0.61	$235,973	$ 2,511,743

	Units	Volume per 100ft^3	$/100ft^3	Annual effluent surcharge	Present worth year zero
5a.Treated Effluent POTW charge					
- years 1 to 5	5	785,600	$0.000	$0	$ -
- years 6 to 30	25	517,522	$0.000	$0	$ -
5b. effluent pump station O/M					
- years 1 to 5	5	785,600	$ -	$0	$ -
- years 6 to 30	25	517,522	$ -	$0	$ -
					$ 5,148,041

STAGED DIRECT MAINTENANCE COSTS	Qty pumps	year	unit cost
6. Extraction Well Maintenance			
6a. Replace pumps			

	Qty	Times	Unit cost		Present worth
- after first 10 years	8	10	$ 9,660		$ 46,328
- after 20 years	8	20	$ 9,660		$ 27,773
6b. Redrill Extraction Wells	Qty wells				
- Aquifer A wells	4	15	$ 35,000		$ 64,983
- Aquifer B wells	4	15	$ 35,000		$ 64,983
6c. Redevelop Extraction wells					
- once every 5 years (except if redrilled)	8	4	$ 4,000		$ 64,365
				Total Present Worth of the Staged Direct Operational & Maintenance Costs	$ 5,416,472

ANNUAL DIRECT OPERATIONAL & MAINTENANCE COSTS				Unit Cost Maint	unit cost / Unit cost sampling	times/year / sampling/yr	annual sampling	annual maint. / total	total annual	
7a. Pipe Conveyance	EA	1			$1,000	2			$ 2,000	
7b. Instrumentation/Electrical	EA	1			$2,000	2			$ 4,000	
8a. Landfill monitoring wells Aquifer A	EA	4		$ 100	$ 1,335	2	$10,680	$ 400	$ 11,080	
8b. Landfill monitoring wells Aquifer B	EA	4		$ 100	$ 1,335	2	$10,680	$ 400	$ 11,080	
9a. Plume monitoring wells Aquifer A	EA	6		$ 100	$ 1,335	2	$16,020	$ 600	$ 16,620	
9b. Plume monitoring wells Aquifer B	EA	6		$ 100	$ 1,335	2	$16,020	$ 600	$ 16,620	
10a. Replace Monitoring Wells		Qty wells	times					total		
once every ten years										
- Aquifer A & B monitoring wells		20	2		$ 14,800			$592,000	$ 19,733	
10b. Redevelop monitoring wells										
- once every 5 years		20	5		$ 1,000			$100,000	$ 3,333	
11a. Public Health Evaluation (every 5 yrs)	EA		6		$50,000			$300,000	$ 10,000	
11b. Remedy as necessary	EA		5		$ 5,000			$25,000	$ 833	
12a. Monitoring Program Review (every 5 yrs)	EA		6		$10,000			$60,000	$ 2,000	
12b. Remedy as necessary	EA		5		$ 2,500			$12,500	$ 417	
TOTAL DIRECT COSTS:									$ 97,717	$ 5,416,472
INDIRECT COSTS (% of Direct Costs):										
Administration	LS	ANNUAL				10%			$ 9,772	$541,647
Contingency Costs	LS	ANNUAL				20%			$ 19,543	$1,083,294
TOTAL INDIRECT COSTS									$ 29,315	$1,624,942
TOTAL COSTS									$ 127,032	$ 7,041,414

PW of Annual costs	$ 127,032	30 yrs	5.25%	=	$ 1,898,349
PW of Staged costs					$ 7,041,414
PW of All O&M Costs					$ 8,940,000
Annualized O&M Costs					$ 598,000

Cost Estimating Tables

Alternative 4

SCREENING OF ALTERNATIVES
COST ESTIMATING WORKSHEET DATE: 31-Oct-95 09:48 AM
BY: JEClark

PROJECT: FRESNO SANITARY LANDFILL DRAFT FS COST ESTIMATES

ITEM: ALTERNATIVE 4 (SOURCE CONTROL & OFFSITE AQUIFER RESTORATION)

DESCRIPTION: Decommissioning of existing wells potentially causing cross-aquifer contamination and continuation of current monitoring program. Extraction wells along western perimeter of landfill. Extraction wells within western perimeter of off-site plume.
Conveyance by pipe to WTP. Monitoring wells downgradient of landfill and plume.

DIRECT CAPITAL COSTS :
(Includes Labor, Equipment & Materials, Unless Otherwise Noted)

COST COMPONENT	UNIT	QUANTITY	UNIT COST	TOTAL CAPITAL COST
1. Well Decommisioning	EA	9	$ -	$ -
2a. Landfill extraction wells Aquifer A	EA	3	$ 48,400	$ 145,200
2b. Landfill extraction wells Aquifer B	EA	3	$ 50,600	$ 151,800
3a. Plume extraction wells Aquifer A	EA	7	$ 48,400	$ 338,800
3b. Plume extraction wells Auifer B	EA	7	$ 50,600	$ 354,200
4a. Pipe Conveyance	FT	15,450	$ 30	$ 463,500
4b. Mobilization	LS	1	$ 75,000	$ 75,000
4c. Command Post	MO	6	$ 7,000	$ 42,000
5a. Landfill monitoring wells Aquifer A	EA	4	$ 14,800	$ 59,200
5b. Landfill monitoring wells Aquifer B	EA	4	$ 18,100	$ 72,400
6a. Plume monitoring wells Aquifer A	EA	6	$ 14,800	$ 88,800
6b. Plume monitoring wells Aquifer B	EA	6	$ 18,100	$ 108,600
7. Groundwater treatment plant	LS	1	$ 2,516,000	$ 2,516,000
8. Treated Effluent Pump station & hook up	LS	1	$ -	$ -

TOTAL DIRECT COSTS : $ 4,415,500

INDIRECT CAPITAL COSTS : (% of Direct Capital Costs)

1. Engineering & Design	20%	$ 883,100
2. Other Indirect Costs		
A. Legal Fees	5.0%	$ 220,775
B. Regulatory License/Permit Costs	5.0%	$ 220,775
C. EPA review and oversight	25%	$ 1,103,875
3. Contingency	25%	$ 1,103,875

TOTAL INDIRECT CAPITAL COSTS : $ 3,532,400

TOTAL CAPITAL COSTS	$ 7,948,000
PRESENT WORTH ANNUAL COSTS	$ 9,329,000
TOTAL PRESENT WORTH COSTS	$ 17,277,000

SCREENING OF ALTERNATIVES
COST ESTIMATING WORKSHEET — DATE: 31-Oct-95 — 09:48 AM
BY: JEClark

PROJECT: FRESNO SANITARY LANDFILL DRAFT FS COST ESTIMATES

Discount rate 5.25%

ITEM: ALTERNATIVE 4 (SOURCE CONTROL & OFFSITE AQUIFER RESTORATION)

DESCRIPTION: Decommissioning of existing wells potentially causing cross-aquifer contamination and continuation of current monitoring program. Extraction wells along western perimeter of landfill. Extraction wells within western perimeter of off-site plume. Conveyance by pipe to WTP. Monitoring wells downgradient of landfill and plume.

ANNUAL/STAGED OPERATION & MAINTENANCE COSTS

STAGED DIRECT OPERATIONAL COSTS	Units	- QTY	(gpm) pump	hp pump	UNIT COST	KWH/hp-hr	days/yr	hrs/day	KWH	KWH annual COST	unit cost Operation 4% of capital	annual Operation	Total Annual operation + Annual KWH	Present worth year zero
1. Current Monitoring	30												$50,000	$ 747,195
2a. Landfill extraction wells Aquifer A	years													
- years 1 to 5	5	3	54.88	2.01	$ 0.10	0.7457	365	24	39,390	$3,939	$1,936	$5,808	$9,747	$ 41,909
-years 6 to 30	25	3	47.2	1.44	$ 0.10	0.7457	365	24	28,220	$2,822	$1,936	$5,808	$8,630	$ 91,859
2b. Landfill extraction wells Aquifer B														
- years 1 to 5	5	3	69.97	2.01	$ 0.10	0.7457	365	24	39,390	$3,939	$2,024	$6,072	$10,011	$ 43,044
- years 6 to 30	25	3	51	1.44	$ 0.10	0.7457	365	24	28,220	$2,822	$2,024	$6,072	$8,894	$ 94,669
3a. Plume extraction wells Aquifer A														
- years 1 to 5	5	6	54.88	2.01	$ 0.10	0.7457	365	24	78,780	$7,878	$1,936	$11,616	$19,494	$ 83,819
- years 6 to 30	25	5	47.2	1.44	$ 0.10	0.7457	365	24	47,033	$4,703	$1,936	$9,680	$14,383	$ 153,098
3b. Plume extraction wells Aquifer B														
- years 1 to 5	5	6	69.97	2.01	$ 0.10	0.7457	365	24	78,780	$7,878	$2,024	$12,144	$20,022	$ 86,089
- years 6 to 30	25	5	51	1.44	$ 0.10	0.7457	365	24	47,033	$4,703	$2,024	$10,120	$14,823	$ 157,782

		1000 gal	unit cost	Annual Cost	Present worth year zero
4. Groundwater treatment O/M					
- years 1 to 5	5	590,590	$0.56	$330,731	$ 1,422,049
- years 6 to 30	25	361,297	$0.61	$220,391	$ 2,345,886

		Volume per 100ft^3	$/100ft^3	Annual effluent surcharge	Present worth year zero
5a.Treated Effluent POTW charge					
- years 1 to 5	5	790,100	$0.000	$0	$ -
- years 6 to 30	25	483,349	$0.000	$0	$ -
5b. effluent pump station O/M					
- years 1 to 5	5	790,100	$ -	$0	$ -
- years 6 to 30	25	483,349	$ -	$0	$ -
					$ 5,267,400

STAGED DIRECT MAINTENANCE COSTS	Qty pumps	year	unit cost
6. Extraction Well Maintenance			
6a. Replace pumps			

- after first 10 years	9	10	$ 9,660	$ 52,119
- after 20 years	9	20	$ 9,660	$ 31,245
6b. Redrill Extraction Wells	Qty wells			
- Aquifer A wells	9	15	$ 35,000	$ 146,211
- Aquifer B wells	9	15	$ 35,000	$ 146,211
6c. Redevelop Extraction wells				
- once every 5 years (except if redrilled)	9	4	$ 4,000	$ 72,410
Total Present Worth of the Staged Direct Operational & Maintenance Costs				$ 5,715,595

ANNUAL DIRECT OPERATIONAL & MAINTENANCE COSTS					unit cost	times/year			total annual	
7a. Pipe Conveyance	EA	1			$1,000	2			$ 2,000	
7b. Instrumentation/Electrical	EA	1			$2,000	2			$ 4,000	
				Unit Cost Maint	Unit cost sampling	sampling/yr	annual sampling	annual maint.		
8a. Landfill monitoring wells Aquifer A	EA	4		$ 100	$ 1,335	2	$10,680	$ 400	$ 11,080	
8b. Landfill monitoring wells Aquifer B	EA	4		$ 100	$ 1,335	2	$10,680	$ 400	$ 11,080	
9a. Plume monitoring wells Aquifer A	EA	6		$ 100	$ 1,335	2	$16,020	$ 600	$ 16,620	
9b. Plume monitoring wells Aquifer B	EA	6		$ 100	$ 1,335	2	$16,020	$ 600	$ 16,620	
10a. Replace Monitoring Wells		Qty wells	times					total		
once every ten years										
- Aquifer A & B monitoring wells		20	2		$ 14,800			$592,000	$ 19,733	
10b. Redevelop monitoring wells										
- once every 5 years		20	5		$ 1,000			$100,000	$ 3,333	
11a. Public Health Evaluation (every 5 yrs)	EA		6		$50,000			$300,000	$ 10,000	
11b. Remedy as necessary	EA		5		$ 5,000			$25,000	$ 833	
12a. Monitoring Program Review (every 5 yrs)	EA		6		$10,000			$60,000	$ 2,000	
12b. Remedy as necessary	EA		5		$ 2,500			$12,500	$ 417	
TOTAL DIRECT COSTS:									$ 97,717	$ 5,715,595
INDIRECT COSTS (% of Direct Costs):										
Administration	LS	ANNUAL				10%			$ 9,772	$571,560
Contingency Costs	LS	ANNUAL				20%			$ 19,543	$1,143,119
TOTAL INDIRECT COSTS									$ 29,315	$1,714,679
TOTAL COSTS									$ 127,032	$ 7,430,274

PW of Annual costs	$ 127,032	30 yrs	5.25%	=	$ 1,898,349
PW of Staged costs					$ 7,430,274
PW of All O&M Costs					$ 9,329,000
Annualized O&M Costs					$ 624,000