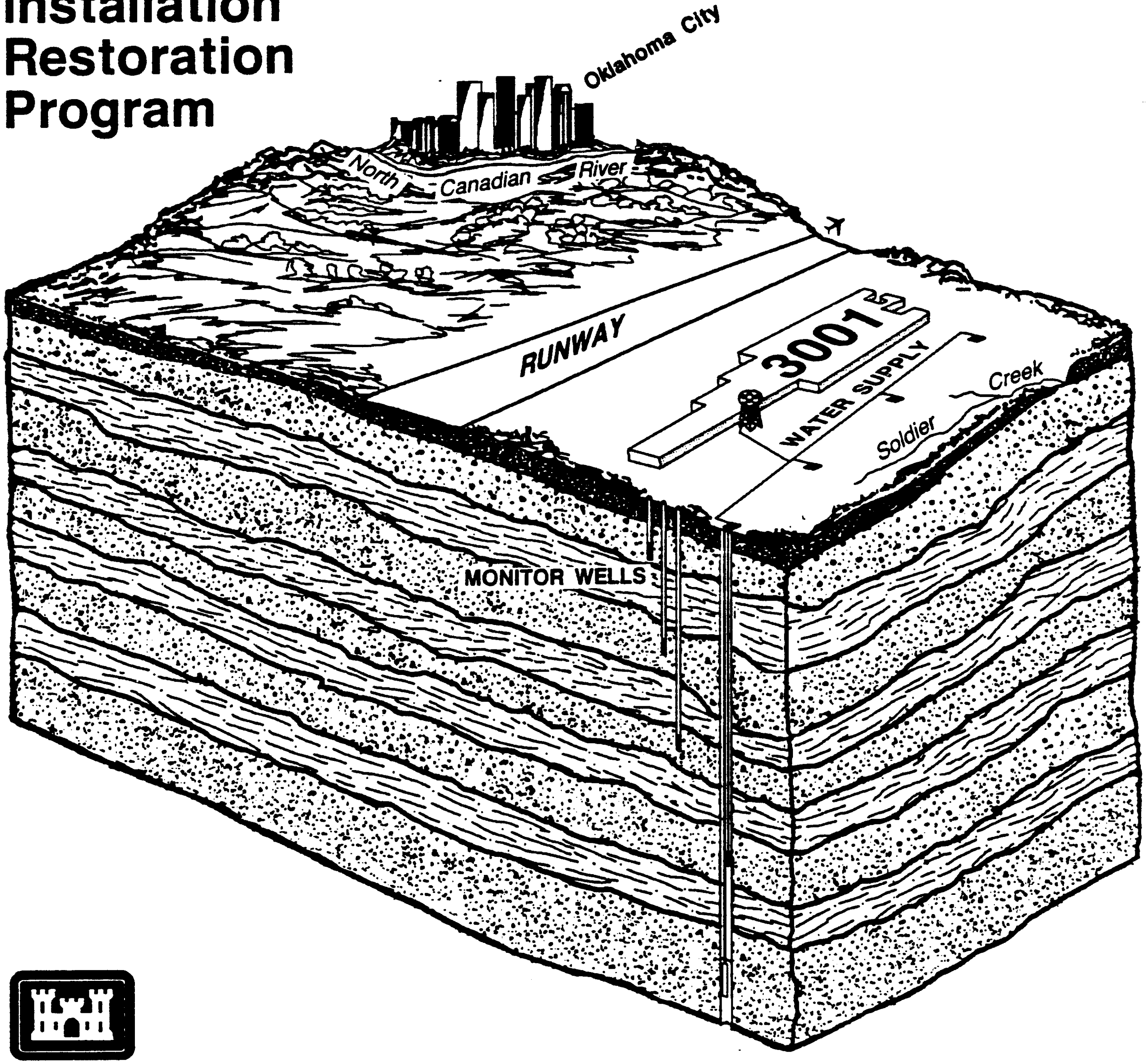
Building 3001
Feasibility Study
Volume 1 - Report

TINKER AIR FORCE BASE
Installation Restoration Program



338

US Army Corps of Engineers
Tulsa District

August 1989

FEASIBILITY STUDY REPORT

BUILDING 3001 SITE
TINKER AIR FORCE BASE, OKLAHOMA

Prepared For:
TULSA DISTRICT CORPS OF ENGINEERS
Contract No. DACA56-88-C-0004
Project No. WWYK86-311
Site I.D. No. Tinker-OT01

Prepared By:
TULSA DISTRICT CORPS OF ENGINEERS
and
BLACK & VEATCH ENGINEERS-ARCHITECTS
Project No. 14186.080
August 16, 1989

PRELIMINARY DRAFT
FEASIBILITY STUDY REPORT
BUILDING 3001 SITE

	Page
EXECUTIVE SUMMARY	1
1.0 INTRODUCTION	1-1
1.1 PURPOSE, SCOPE, AND OVERVIEW OF THIS REPORT	1-2
1.2 SITE BACKGROUND INFORMATION	1-3
1.2.1 Location	1-3
1.2.2 Site Description	1-3
1.2.2.1 Building 3001	1-3
1.2.2.2 North and Southwest Tank Areas	1-6
1.3 PREVIOUS INVESTIGATIONS AND REPORTS	1-7
1.4 NATURE AND EXTENT OF THE PROBLEM	1-15
1.4.1 Contamination Sources	1-16
1.4.2 Soil Contamination	1-17
1.4.3 Perched Aquifer	1-17
1.4.4 Regional Aquifer	1-21
1.4.4.1 Top of the Regional Zone	1-21
1.4.4.2 Regional Zone	1-24
1.4.4.3 Producing Zone	1-24
1.4.5 Soldier Creek	1-25
1.5 OBJECTIVES OF REMEDIAL ACTION	1-25
2.0 SCREENING OF ALTERNATIVES	2-1
3.0 ALTERNATIVES EVALUATION PROCESS	3-1
3.1 ENGINEERING FEASIBILITY	3-2
3.1.1 Performance	3-3
3.1.2 Reliability	3-4
3.1.3 Implementability	3-5
3.1.4 Safety	3-6
3.2 PUBLIC HEALTH IMPACTS	3-6
3.3 ENVIRONMENTAL IMPACTS	3-7
3.4 INSTITUTIONAL REQUIREMENTS	3-8
3.4.1 Conformance with Applicable or Relevant and Appropriate Requirements (ARARs)	3-9
3.4.2 Permitting Requirements	3-10
3.5 COST ANALYSIS	3-11
3.5.1 Cost Estimates	3-11
3.5.2 Contingencies, Allowances, and Assumptions	3-13
3.5.3 Cost Sensitivity Analysis	3-15

	Page
4.0 GROUNDWATER REMOVAL AND COLLECTION	4-1
4.1 DEVELOPMENT AND SELECTION OF ALTERNATIVES	4-1
4.1.1 Preliminary Groundwater Pumping Options	4-1
4.1.2 Selection and Description of Alternatives for Final Evaluation	4-4
4.1.2.1 Alternative 1-1 - No Action	4-4
4.1.2.2 Alternative 1-2 - Groundwater Removal from Exterior Wells Only	4-6
4.1.2.3 Alternative 1-3 - Exterior and Interior Groundwater Removal	4-9
4.2 EVALUATION OF GROUNDWATER PUMPING ALTERNATIVES	4-11
4.2.1 Alternative 1-1 - No Action	4-12
4.2.1.1 Engineering Feasibility	4-12
4.2.1.2 Public Health Impacts	4-22
4.2.1.3 Environmental Impacts	4-23
4.2.1.4 Institutional Requirements	4-23
4.2.1.5 Cost Analysis	4-24
4.2.2 Alternative 1-2 - Exterior Groundwater Removal Only	4-24
4.2.2.1 Engineering Feasibility	4-24
4.2.2.2 Public Health Impacts	4-41
4.2.2.3 Environmental Impacts	4-42
4.2.2.4 Institutional Requirements	4-42
4.2.2.5 Cost Analysis	4-43
4.2.3 Alternative 1-3 - Exterior and Interior Removal	4-43
4.2.3.1 Engineering Feasibility	4-43
4.2.3.2 Public Health Impacts	4-61
4.2.3.3 Environmental Impacts	4-62
4.2.3.4 Institutional Requirements	4-62
4.2.3.5 Cost Analysis	4-63
4.3 SUMMARY OF GROUNDWATER PUMPING ALTERNATIVES	4-63
4.4 RECOMMENDED GROUNDWATER PUMPING PLAN	4-64
5.0 GROUNDWATER TREATMENT AND DISPOSAL	5-1
5.1 DEVELOPMENT AND SELECTION OF ALTERNATIVES	5-1
5.1.1 Alternative 2-1 - Modified IWTP/Industrial Reuse	5-3
5.1.2 Alternative 2-2 - Modified IWTP/Surface Water Discharge	5-13
5.1.3 Alternative 2-3 - Treatment/Industrial Reuse	5-13
5.1.4 Alternative 2-4 - Treatment/Surface Water Discharge	5-16

		Page
5.2	DETAILED EVALUATION OF ALTERNATIVES	5-16
5.2.1	Alternative 2-1 - Modified IWTP/Industrial Reuse	5-16
5.2.1.1	Engineering Feasibility	5-17
5.2.1.2	Public Health Impacts	5-20
5.2.1.3	Environmental Impacts	5-21
5.2.1.4	Institutional Requirements	5-21
5.2.1.5	Cost Analysis	5-29
5.2.2	Alternative 2-2 - Modified IWTP/Surface Water Discharge	5-29
5.2.2.1	Engineering Feasibility	5-29
5.2.2.2	Public Health Impacts	5-31
5.2.2.3	Environmental Impacts	5-32
5.2.2.4	Institutional Requirements	5-32
5.2.2.5	Cost Analysis	5-33
5.2.3	Alternative 2-3 - Treatment/Industrial Reuse	5-33
5.2.3.1	Engineering Feasibility	5-33
5.2.3.2	Public Health Impacts	5-35
5.2.3.3	Environmental Impacts	5-35
5.2.3.4	Institutional Requirements	5-36
5.2.3.5	Cost Analysis	5-36
5.2.4	Alternative 2-4 - Treatment/Surface Water Discharge	5-37
5.2.4.1	Engineering Feasibility	5-37
5.2.4.2	Public Health Impacts	5-39
5.2.4.3	Environmental Impacts	5-39
5.2.4.4	Institutional Requirements	5-39
5.2.4.5	Cost Analysis	5-40
5.2.5	Cost Sensitivity Analysis for Groundwater Treatment and Disposal Alternatives	5-40
5.3	SUMMARY OF ALTERNATIVES	5-49
5.4	RECOMMENDED ALTERNATIVE	5-50
6.0	MANAGEMENT CONTROLS	6-1
6.1	DEVELOPMENT AND SELECTION OF ALTERNATIVES	6-1
6.1.1	Alternative 3-1 - Land Use Control	6-1
6.1.2	Alternative 3-2 - Alternative Water Supplies	6-1
6.1.3	Alternative 3-3 - Relocation	6-1
6.1.4	Alternative 3-4 - Personnel Supervision and Training	6-1
6.1.5	Alternative 3-5 - Coordination with Regulatory Agencies	6-2

		Page
6.2	DETAILED EVALUATION OF ALTERNATIVES	6-2
6.2.1	Alternative 3-1 - Land Use Control	6-2
6.2.1.1	Engineering Feasibility	6-2
6.2.2	Alternative 3-2 - Alternative Water Supplies	6-2
6.2.2.1	Engineering Feasibility	6-2
6.2.2.2	Public Health Impacts	6-3
6.2.2.3	Environmental Impacts	6-3
6.2.2.4	Institutional Requirements	6-3
6.2.2.5	Cost Analysis	6-4
6.2.3	Alternative 3-3 - Relocation	6-4
6.2.3.1	Engineering Feasibility	6-4
6.2.3.2	Public Health Impacts	6-4
6.2.3.3	Environmental Impacts	6-4
6.2.3.4	Institutional Requirements	6-5
6.2.3.5	Cost Analysis	6-5
6.2.4	Alternative 3-4 - Personnel Supervision and Training	6-5
6.2.4.1	Engineering Feasibility	6-5
6.2.4.2	Public Health Impacts	6-5
6.2.4.3	Environmental Impacts	6-5
6.2.4.4	Institutional Requirements	6-5
6.2.4.5	Cost Analysis	6-6
6.2.5	Alternative 3-5 - Coordination with Regulatory Agencies	6-6
6.2.5.1	Engineering Feasibility	6-6
6.2.5.2	Public Health Impacts	6-6
6.2.5.3	Environmental Impacts	6-6
6.2.5.4	Institutional Requirements	6-6
6.2.5.5	Cost Analysis	6-6
6.3	SUMMARY OF ALTERNATIVES	6-6
6.4	RECOMMENDED ALTERNATIVES	6-7
7.0	SUMMARY OF RECOMMENDED ALTERNATIVES	7-1

REFERENCES

LIST OF ABBREVIATIONS

APPENDIX A - DETAILS OF THE GROUNDWATER PUMPING PLAN ALTERNATIVES

APPENDIX B - DETAILED COST SUMMARY FOR THE GROUNDWATER PUMPING PLAN ALTERNATIVES

APPENDIX C - DETAILED COST SUMMARY FOR THE GROUNDWATER TREATMENT AND DISPOSAL ALTERNATIVES

APPENDIX D - TECHNICAL MEMORANDUM FOR AIR STRIPPER EMMISSIONS DISPERSION MODELING

APPENDIX E - DETAILED CHRONIC CARCINOGENIC RISK CALCULATIONS DUE TO AIR STRIPPER EXPOSURE

LIST OF FIGURES

Figure		Page
1-1	LOCATION AND VICINITY MAP	1-4
1-2	SITE PLAN	1-5
1-5	TCE PLUME IN PERCHED AQUIFER	1-18
1-6	Cr PLUME IN PERCHED AQUIFER	1-20
1-7	TCE PLUME IN TOP OF REGIONAL ZONE	1-22
1-8	Cr PLUME IN TOP OF REGIONAL ZONE	1-23
4-1	BUILDING 3001 MONITORING WELL CLUSTER ALTERNATIVE 1-1	4-5
4-2	GROUNDWATER CONTROL/COLLECTION PLAN ALTERNATIVE 1-1	4-7
4-3	GROUNDWATER CONTROL/COLLECTION PLAN ALTERNATIVE 1-2	4-8
4-4	GROUNDWATER CONTROL/COLLECTION PLAN ALTERNATIVE 1-3	4-10
4-5	TCE PLUMES IN THE PERCHED AQUIFER AT 3001 ALTERNATIVE 1-1	4-13
4-6	TCE PLUMES IN THE TOP OF REGIONAL ZONE ALTERNATIVE 1-1	4-14
4-7	TCE PLUMES IN THE REGIONAL ZONE ALTERNATIVE 1-1	4-15
4-8	CHROMIUM PLUMES IN PERCHED AQUIFER AT 3001 ALTERNATIVE 1-1	4-16
4-9	Cr PLUMES IN THE TOP OF REGIONAL ZONE ALTERNATIVE 1-1	4-17
4-10	CHROMIUM PLUMES IN THE REGIONAL ZONE ALTERNATIVE 1-1	4-18
4-11	TCE PLUMES IN THE PERCHED AQUIFER AT 3001 ALTERNATIVE 1-2	4-27
4-12	TCE PLUMES IN THE TOP OF REGIONAL ZONE ALTERNATIVE 1-2	4-28
4-13	TCE PLUMES IN THE REGIONAL ZONE ALTERNATIVE 1-2	4-29
4-14	CHROMIUM PLUMES IN PERCHED AQUIFER AT 3001 ALTERNATIVE 1-2	4-30
4-15	Cr PLUMES IN THE TOP OF REGIONAL ZONE ALTERNATIVE 1-2	4-31
4-16	CHROMIUM PLUMES IN THE REGIONAL ZONE ALTERNATIVE 1-2	4-32
4-17	A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT & WITH PUMPING ALTERNATIVES 1-1 & 1-2	4-33
4-18	A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT & WITH PUMPING ALTERNATIVES 1-1 & 1-2	4-34

LIST OF FIGURES (Continued)

Figure		Page
4-19	A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT & WITH PUMPING ALTERNATIVES 1-1 & 1-2	4-35
4-20	A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT & WITH PUMPING ALTERNATIVES 1-1 & 1-2	4-36
4-21	A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT & WITH PUMPING ALTERNATIVES 1-1 & 1-2	4-37
4-22	A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT & WITH PUMPING ALTERNATIVES 1-1 & 1-2	4-38
4-23	TCE PLUMES IN THE PERCHED AQUIFER AT 3001 ALTERNATIVE 1-3	4-45
4-24	TCE PLUMES IN THE TOP OF REGIONAL ZONE ALTERNATIVE 1-3	4-46
4-25	TCE PLUMES IN THE REGIONAL ZONE ALTERNATIVE 1-3	4-47
4-26	CHROMIUM PLUMES IN PERCHED AQUIFER AT 3001 ALTERNATIVE 1-3	4-48
4-27	CR PLUMES IN THE TOP OF REGIONAL ZONE ALTERNATIVE 1-3	4-49
4-28	CHROMIUM PLUMES IN THE REGIONAL ZONE ALTERNATIVE 1-3	4-50
4-29	A COMPARISON OF GROUNDWATER ELEVATION WITHOUT & WITH PUMPING ALTERNATIVES 1-1 & 1-3	4-52
4-30	A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT & WITH PUMPING ALTERNATIVES 1-1 & 1-3	4-53
4-31	A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT & WITH PUMPING ALTERNATIVES 1-1 & 1-3	4-54
4-32	A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT & WITH PUMPING ALTERNATIVES 1-1 & 1-3	4-55
4-33	A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT & WITH PUMPING ALTERNATIVES 1-1 & 1-3	4-56
4-34	A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT & WITH PUMPING ALTERNATIVES 1-1 & 1-3	4-57
5-1	FLOW SCHEMATIC ALTERNATIVES 2-1 & 2-2	5-4
5-2	GROUNDWATER TREATMENT AND DISPOSAL SITE PLAN ALTERNATIVES 2-1, 2-2, 2-3, AND 2-4	5-5
5-3	FLOW SCHEMATICS ALTERNATIVES 2-3 AND 2-4	5-14

LIST OF TABLES

Table		Page
1-1	ACTIVITIES WITHIN BUILDING 3001	1-6
1-2	SOUTHWEST TANK AREA ABANDONED TANKS	1-8
1-3	PREVIOUS INVESTIGATIONS AND REPORTS	1-9
1-4	PRIMARY DRINKING WATER STANDARDS	1-19
2-1	SCREENED TECHNOLOGIES	2-2
4-1	ALTERNATIVE 1-2 - PERCENTAGE OF TCE AND Cr REMOVAL VS TIME	4-25
4-2	ALTERNATIVE 1-3 - PERCENTAGE OF TCE AND Cr REMOVAL VS TIME	4-44
4-3	SUMMARY OF ALTERNATIVE PUMPING PLAN ANALYSIS	4-65
5-1	PRELIMINARY REMEDIAL ALTERNATIVES	5-2
5-2	VOLATILE ORGANIC COMPOUND INFLUENT AND EFFLUENT CONCENTRATIONS	5-7
5-3	AIR STRIPPER STACK GAS VOLATILE ORGANIC CONCENTRATION AND AIR STANDARDS	5-8
5-4	HEAVY METAL CONCENTRATION IN GROUNDWATER AND TREATMENT REQUIREMENTS	5-11
5-5	INDUSTRIAL WATER REUSE	5-11
5-6	INDUSTRIAL REUSE WATER REQUIREMENTS VS CONTAMINATED GROUNDWATER CHARACTERISTICS	5-12
5-7	FEDERAL ARARs	5-22
5-8	STATE ARARs	5-25
5-9	SUMMARY OF COST SENSITIVITY ANALYSIS WITH VARYING INTEREST RATES	5-42
5-10	SUMMARY OF COST SENSITIVITY ANALYSIS WITH VARYING YEARS OF USEFUL LIFE	5-43
5-11	SUMMARY OF COST SENSITIVITY ANALYSIS OF WATER SOFTENER SLUDGE DISPOSAL	5-44
5-12	SUMMARY OF COST SENSITIVITY ANALYSIS WITH VARYING CARBON LIFE	5-45
5-13	SUMMARY OF GROUNDWATER TREATMENT AND DISPOSAL ALTERNATIVES	5-46
7-1	SUMMARY OF RECOMMENDED ALTERNATIVES	7-2

EXECUTIVE SUMMARY

INTRODUCTION

Building 3001, located in the northeast portion of Tinker Air Force Base (AFB), Oklahoma, houses a large industrial complex where aircraft and jet engines are serviced, repaired, and/or upgraded. The United States Environmental Protection Agency (EPA) has placed the Building 3001 site on the National Priorities List of hazardous waste sites. Remedial investigations [1] have been conducted at the site by the Tulsa District Corps of Engineers (COE) to define and characterize the sources, extent, and magnitude of the contamination. The investigations are part of the U.S. Air Force Installation Restoration program (IRP). The investigations indicate that past activities within and in the vicinity of Building 3001 have resulted in contamination of the upper groundwater zones with industrial solvents, metals, and fuel products. The primary groundwater contaminants are trichloroethylene (TCE) and chromium (Cr) (predominantly hexavalent chromium (Cr^{+6}).

The EPA, the Oklahoma State Department of Health (OSDH), and the U.S. Air Force (USAF) signed a Federal Facility Agreement (FFA) under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) in December 1988. The FFA addresses investigation, remediation, and documentation procedures for hazardous waste contamination at Building 3001 and Soldier Creek. It also specifies procedures for the separate operable units that have been identified at the sites.

Groundwater contamination beneath the Building 3001 site is primarily a result of past industrial operations and storage practices at the facility which have now been essentially corrected. These corrections included replacing leaking subsurface concrete pits and trenches with above grade pits, eliminating improper tie-ins between industrial waste lines and storm drains, eliminating the release of industrial wastes and solvents into storm drains, and plugging of poorly sealed wells. Contamination probably entered the perched aquifer by vertical migration from solvent pits inside the building, West Soldier Creek, and underground storage tanks, or by releases from storm drains. Because of their concentrations and the size of their plumes, the primary groundwater contaminants of concern are TCE and Cr. Other organic compounds and trace metals are present. In addition, TCE and Cr^{+6} are health hazards as identified in the Risk Assessment(6). The contaminated groundwater covers 220 acres beneath the site and extends to a depth of approximately 175 feet. The highest contaminant concentrations exist beneath the building in the perched aquifer, where 330,000 ug/l of TCE and 80,000 ug/l of Cr were detected.

The regional aquifer (Garber-Wellington aquifer) is contaminated in the upper two more permeable zones, referred to as the top of regional and regional zones. The geologic formations are characterized by very low vertical permeabilities and therefore limited vertical migration has occurred compared to horizontal migration. The horizontal spread of contaminated groundwater has extended beyond water supply well locations within Tinker AFB and has allowed artificial vertical migration of contaminants down the sides of poorly sealed wells. Two wells within Building 3001 have been plugged and three wells east of the building (toward East Soldier Creek) currently contain trace levels of organic compounds.

This report presents the results of the feasibility study (FS) for groundwater remediation at the Building 3001 site. The FS was conducted in accordance with the provisions of the National Oil and Hazardous Substances Contingency Plan (NCP) and CERCLA.

PURPOSE OF THE FS

The purpose of this FS is to identify, evaluate, and compare alternatives designed to mitigate or minimize threats to public health and the environment from the Building 3001 site. According to the NCP, the remedial action alternative(s) selected for the site should be the "cost effective remedial alternative that effectively mitigates and minimizes threats to and provides adequate protection of public health and the environment."

The specific goals of remedial action at the Tinker AFB Building 3001 site are as follows:

- Protect the public and AFB personnel from exposure to hazardous levels of contamination in water supplies.
- Prevent the deterioration of groundwater quality in the perched aquifer and the Garber-Wellington Aquifer.
- Protect Soldier Creek from additional contamination. Soldier Creek is being handled as a separate site and a separate RI/FS is planned for this site.
- Improve the quality of groundwater already contaminated in the perched aquifer and the Garber-Wellington Aquifer.
- Satisfy Sections 120 and 121 of CERCLA as amended.

SITE DESCRIPTION AND BACKGROUND

The Building 3001 site includes the building (covering 80 acres) and the surrounding areas corresponding to the lateral extent of the contaminant plume. The site is located near the northeast boundary of the Base and covers an area of approximately 220 acres. Two fuel storage tank areas are located adjacent to Building 3001. One tank area is located immediately north of Building 3001 (north tank area) and the other tank area is located to the southwest (southwest tank area).

Building 3001 houses an aircraft overhaul and modification facility to support the mission of the Oklahoma City Air Logistics Center. Some processes conducted in Building 3001 used or generated solutions containing solvents and metals similar to contaminants found in the underlying groundwater. Organic solvents were used for cleaning and degreasing metal engine parts. Cleaning operations may have included paint stripping in which the stripper and the wastewaters produced contained high concentrations of metals (particularly Cr). Waste materials generated from plating, painting, and heat treating activities contained both solvents and metals.

TCE was the predominant solvent used from the 1940's until the 1970's. The degreasing operations were conducted in tanks set below the floor level in concrete pits. In the early 1970's tetrachloroethylene (PCE) began to replace TCE as the primary solvent used in degreasing operations. About the same time, the subsurface pits were replaced with above grade degreasing stations, where the entire system (tank, piping, pumps, etc.) is aboveground.

The north and southwest tank areas have contributed to groundwater contamination at the 3001 site, through leakage and spills. The north tank area has been identified as an operable unit for which a separate focused record of decision (ROD) will be prepared and sent out for public comment to allow more rapid implementation of remedial actions. The focused ROD will also be attached to the ROD for the main Building 3001 site when it is submitted for public comment. The southwest tank area will be remediated in accordance with the Underground Storage Tank (UST) Regulations. Remedial actions planned or partially completed for the tank areas include tank abandonment, contaminated soil treatment, and recovery of floating fuel product from the groundwater. Other groundwater contamination originating from the tank areas (benzene, toluene, and xylene) will be included as part of the overall groundwater remediation for the Building 3001 Site.

FS ORGANIZATION

Contaminated groundwater remediation alternatives for the Building 3001 site involve removal, collection, treatment, and disposal of contaminated groundwater removed from the various regions of the aquifer beneath the site. Responsibility for the remedial action alternative development and evaluation has been shared between Black & Veatch and the COE. The remedial alternatives for the Building 3001 site were divided into the following three distinct alternative groups.

- Groundwater Removal and Collection
- Groundwater Treatment and Disposal
- Management Controls

Black & Veatch, under contract to the COE, was responsible for development and evaluation of alternatives for groundwater treatment and disposal. The COE developed and evaluated alternatives for the two remaining alternative groups. A no action alternative was also developed for each alternative group and used as a baseline for comparing alternatives. The objective of development and evaluation by alternative groups is to combine the best alternatives from each group, and thus minimize the number of alternatives to be evaluated in detail. The remedial action alternative to be implemented will be done in accordance with Section XI.B.3(c) of the Federal Facility Agreement. All alternatives were developed based on the remedial technologies identified in the PELA report[1]. These alternatives were evaluated based on engineering feasibility, public health and environmental impacts, institutional factors, and implementation costs.

SUMMARY OF ALTERNATIVES

Two alternatives for groundwater removal and collection were developed and evaluated. One of the alternatives involved groundwater extraction from 111 wells, all located outside Building 3001. The recommended alternative, groundwater removal and collection consists of extracting groundwater from 129 wells, 18 of which would be located within Building 3001.

A total of four groundwater treatment and disposal alternatives were developed and evaluated based on the results of the "Preliminary Development and Evaluation of Groundwater Treatment and Disposal Alternatives" report[5]. These alternatives consisted of two basic treatment schemes, each having alternate discharge options for treated groundwater. One treatment plan entails construction of a new plant dedicated for treatment of extracted groundwater flows and the other consists of modifying the existing IWTP. The alternate discharge options for treated groundwater are (1) discharge to East Soldier Creek; and (2) discharge to the existing Tinker AFB industrial reuse system. Other studies currently underway at the Industrial Waste Treatment Facility (IWTP) and uncertainties dealing with future load conditions and discharge compliance considerations at the IWTP preclude the recommendation of a groundwater treatment and disposal alternative at this time.

Five management control alternatives were considered. The alternatives consisted of land use controls, alternate water supplies, facility relocation, personnel supervision and training, and coordination with regulatory agencies. Alternate water supplies, personnel supervision and training, and coordination with regulatory agencies are the recommended alternatives.

1.0 INTRODUCTION

Building 3001, located in the northeast portion of Tinker Air Force Base (AFB), houses a large industrial complex where aircraft and jet engines are serviced, repaired, and upgraded. The United States Environmental Protection Agency (EPA) has placed the site on the National Priorities List (NPL) of hazardous waste sites. Remedial investigations[1] have been conducted at the site by the Tulsa District Corps of Engineers (COE) to define and characterize the sources, extent, and magnitude of the contamination. The investigations are part of the U.S. Air Force Installation Restoration Program (IRP). Investigations have indicated that past activities within and in the vicinity of Building 3001 have resulted in contamination of the upper groundwater zones with industrial solvents, metals, and fuel products. The primary contaminants are trichloroethylene (TCE) and chromium (Cr), predominantly hexavalent chromium (Cr^{+6}).

The EPA, the Oklahoma State Department of Health (OSDH), and the U.S. Air Force (USAF) signed a Federal Facility Agreement (FFA) also known as an Interagency Agreement (IAG) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 120 on December 9, 1988. The intent of this agreement is to ensure that the past and present activities at Building 3001 and Soldier Creek, NPL sites, are thoroughly investigated and appropriately remediated to protect the public, health, welfare, and environment. The FFA establishes procedures and schedules for developing, implementing, monitoring, documenting, and approving response actions at the site, in accordance with CERCLA and NCP, Superfund guidance and policy, RCRA, and RCRA guidance and policy. The FFA establishes requirements for the performance of the Remedial Investigations (RI) and the Feasibility Study (FS) at the site in accordance with CERCLA. The agreement identifies current Operable Units at the site. It establishes procedures for remedial actions and conducting a separate Focused RI/FS for each Operable Unit. It also establishes procedures for proposing a new Operable Unit at the Sites. This process allows for remedial actions to be implemented as Operable Units that have been (or will be) identified prior to the final remedial action for the site. The FFA specifies that Tinker

AFB will establish and maintain an administrative record that will include all documents that form the basis for the selection of a response action at the sites. This FS will be used as a basis for the Proposed Plan, which will be incorporated into the Record of Decision (ROD) for Building 3001. Each of these documents will be part of the Administrative Record for the site.

1.1 PURPOSE, SCOPE, AND OVERVIEW OF THIS REPORT

The purpose of this feasibility study (FS) report is to provide a detailed description and evaluation of remedial action alternatives for the Building 3001 site. The FS was conducted in accordance with the provisions of the National Oil and Hazardous Substances Contingency Plan (NCP), and the CERCLA. The objective of the FS is to develop and evaluate remedial action alternatives to mitigate or minimize potential impacts to public health and the environment from contaminants at or migrating from the Building 3001 site. According to the NCP, the remedial action alternative(s) selected for the site should be the "cost effective remedial alternative that effectively mitigates and minimizes threats to and provides adequate protection of public health and the environment."

This report, the result of a joint effort by the COE and Black & Veatch, supplements the technology screening report prepared by P.E. LaMoreaux & Associates (PELA)[2]. Alternatives were divided into three groups and each group was evaluated separately. The COE developed and evaluated alternatives pertaining to groundwater removal and collection, and management controls. Black & Veatch, under contract to the COE, was responsible for development and evaluation of alternatives for groundwater treatment and disposal. Selection of the remedial action alternatives to be implemented will be the responsibility of the Technical Review Committee (TRC).

All alternatives were developed based on the remedial technologies identified in the PELA[2] report. These alternatives were evaluated based on engineering feasibility, public health and environmental impacts, institutional factors, and implementation costs. A no action alternative was also developed for each alternative group and used as a baseline for comparing alternatives.

Section 1 of this report presents the site background information, the nature and extent of the problem, the objectives of remedial action for the site, and a summary of previous investigations or reports. Presented in Section 2 is a summary of the screened technologies used to develop the remedial alternatives in this report. The evaluation process for the FS is described in Section 3. Presented in Sections 4 through 6 are individual feasibility studies for groundwater removal and collection, groundwater treatment and disposal, and management controls. Included in Sections 4 through 6 are subsections covering the development and selection of alternatives, alternatives evaluation, alternatives evaluation summary, and the recommended alternative. A summary of the recommended alternatives is included in Section 7.

1.2 SITE BACKGROUND INFORMATION

1.2.1 Location

Tinker AFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan complex, in Oklahoma County. The Base is bounded by Sooner Road to the west, Douglas Boulevard to the east, Interstate 40 to the north, and Southeast 74th Street to the south. Building 3001 is located in the northeast portion of the Base, east of the north-south runway. Figure 1-1 shows the location of the Base.

1.2.2 Site Description

The Building 3001 site (as referred to in this report) includes the building (covering 80 acres) and the surrounding areas corresponding to the lateral extent of the contaminant plume. The site is located near the northeast boundary of the Base and covers an area of approximately 220 acres. A site map is shown in Figure 1-2.

1.2.2.1 Building 3001. The building houses an aircraft overhaul and modification facility to support the mission of the Oklahoma City Air

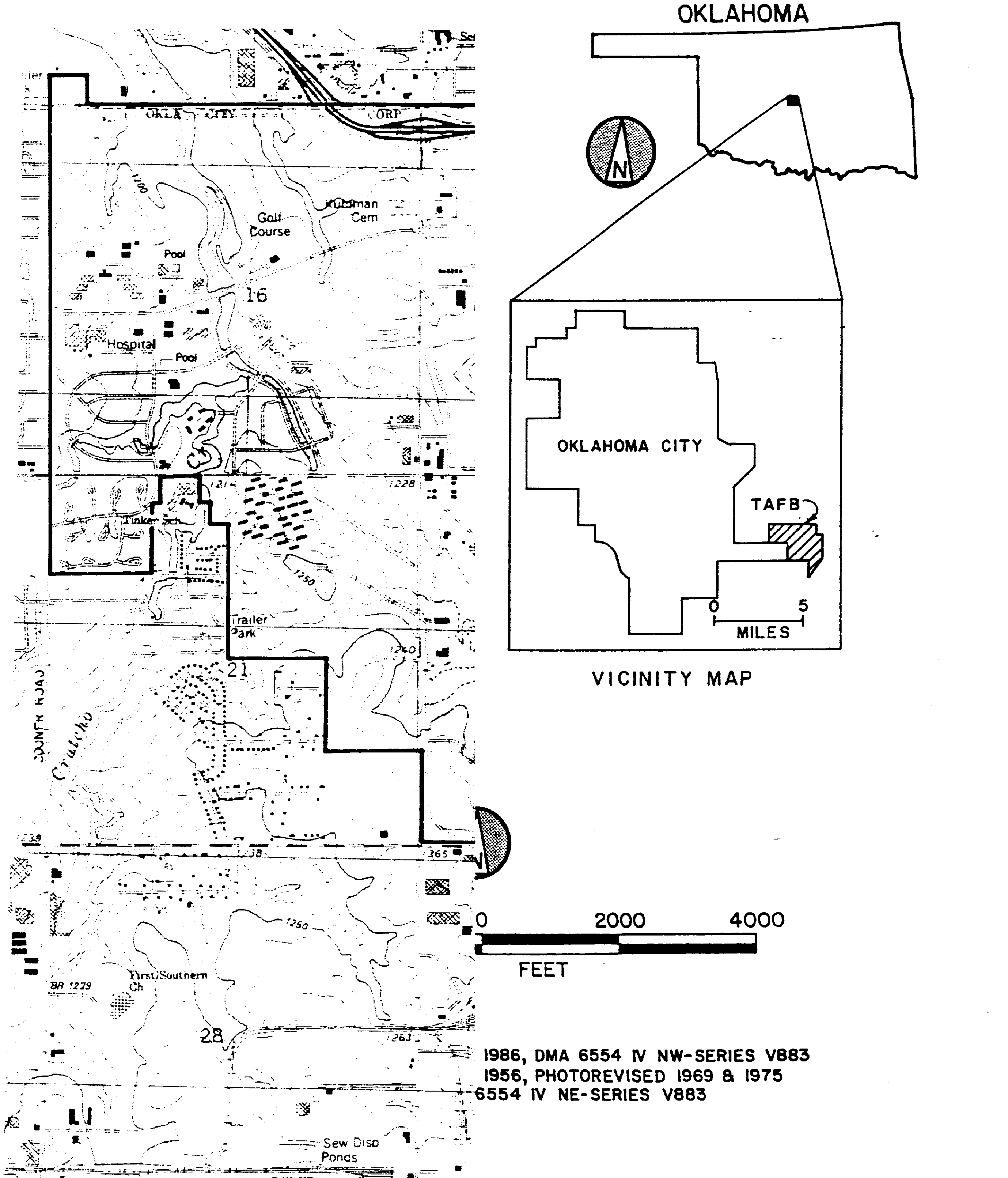


FIGURE 1-1
LOCATION AND VICINITY MAP
TINKER AIR FORCE BASE
BUILDING 3001 SITE

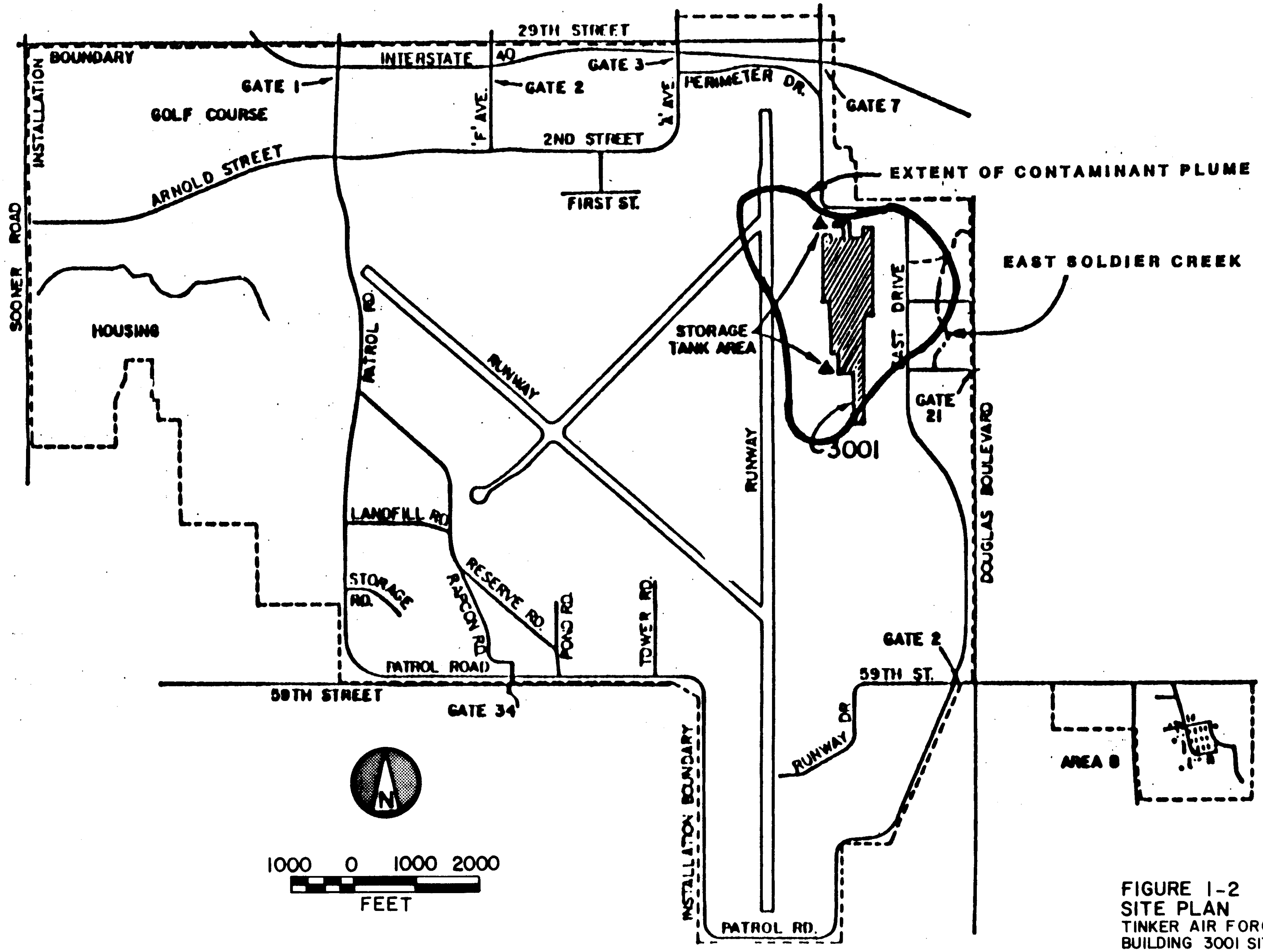


FIGURE 1-2
SITE PLAN
TINKER AIR FORCE BASE
BUILDING 3001 SITE

Logistics Center. Summarized in Table 1-1 are the primary activities conducted in the building since operations began in the early to mid 1940's. Some processes conducted in Building 3001 used or generated solutions containing solvents and metals similar to contaminants found in the underlying groundwater. Organic solvents were used for cleaning and degreasing metal engine parts. Cleaning operations may have included paint stripping in which the stripper and the waste waters produced contained high concentrations of metals (particularly Cr). Waste materials generated from plating, painting, and heat treating activities contained both solvents and metals. TCE was the predominant solvent used from the 1940's until the 1970's. The degreasing operations were conducted in tanks set below the floor level in concrete pits. In the early 1970's, tetrachloroethylene (PCE) began to replace TCE as the primary solvent used in degreasing operations. During the same time frame, the subsurface pits were replaced with above grade degreasing stations, where the entire system (tank, piping, pumps, etc.) is located aboveground. The subsurface pits were abandoned typically by backfilling with sand and capping with concrete. Subsurface contamination below the building complex occurred by leakage from trenches and pits, inadvertent discharging of solvents or waste waters into storm drains, accidental spills, and improper connections between wastewater and storm drains.

TABLE 1-1
ACTIVITIES WITHIN BUILDING 3001

1. Disassembly, degreasing, cleaning, and inspection of aircraft and engine parts and components.

2. Plating, painting, heat treating, and testing of metal parts and components.

3. Assembly and repair shops for accessories including electrical, valve and governor, gear box, tubing and cable, fuel controls, nozzles, pumps, and bearings.

4. Assembly, testing, and packaging of aircraft components.

1.2.2.2 <u>North and Southwest Tank Areas.</u> Although remediation of the north and southwest tank areas are not within the scope of this FS, brief site descriptions are provided because of their contribution to groundwater contamination at the 3001 site. As discussed previously, the north tank area will be remediated as a separate operable unit, and the southwest tank area will be remediated in accordance with the UST regulations.

The north tank area contains an inactive 500 gallon waste oil tank, an inactive underground fuel oil tank (235,000 gallon capacity), and an active underground diesel tank (approximately 20,000 gallon capacity). An abandoned gasoline tank (approximately 13,000 gallon capacity) was removed from the area in 1985. The north tank area is grass covered and encompasses approximately 16,400 square feet. The soil and groundwater beneath the north tank area have become contaminated with fuel product, benzene, toluene, and xylene due to leaking tanks and/or possible fuel spills. Some metals and organic solvents are also present in the groundwater, which may be attributed to leaking pipes in the area or dispersion of contaminants from more distant sources.

The southwest tank area contains both abandoned fuel tanks and abandoned solvent tanks. The tanks and their history of use are listed in Table 1-2. Also, two active 12,000 gallon solvent tanks, containing PD680 Solvent, are located south of Building 3108. The tank area covers approximately 2.5 acres. The groundwater in this area is contaminated with toluene, benzene, and xylene, which likely occurred from past leaking of tanks or possible spills. Some metals and solvents, probably originating from inside Building 3001, are also present in the groundwater.

1.3 PREVIOUS INVESTIGATIONS AND REPORTS

Previous investigations and reports related to the Building 3001 site are summarized in this subsection. Presented in Table 1-3 is a chronological listing of each, beginning with the earliest investigation/report along with pertinent summary information, including who prepared the report, for whom it was prepared, the scope, and the content/summary.

TABLE 1-2

SOUTHWEST TANK AREA ABANDONED TANKS

Size (gal)	Contents	Remarks
20,000	Gasoline	Abandoned in 1972
20,000	Gasoline	"
20,000	Gasoline	"
20,000	Gasoline	"
20,000	Gasoline	"
10,000	Lubricating Oil	
	(Solvent from 1960's to 1972)	Abandoned in 1972
9,000	Gasoline Dump	Abandoned in 1972
9,000	Oil Dump	"
3,800	Naptha	"
3,800	Solvent Stoddard	"
1,000	JP-1	"
1,000	JP-1	"
1,000	Naphtha	"
1,000	Naphtha	"

TABLE 1-3

SUMMARY OF PREVIOUS INVESTIGATIONS
AND REPORTS

INVESTIGATION/REPORT	PREPARED BY AND FOR	SCOPE	CONTENT/SUMMARY
Installation Restoration Program Phase I - Records Search Tinker AFB, Oklahoma April 1982	Engineering Science for U.S.A.F.	Initial Assessment & Records Search	Identified and described potential sites at Tinker AFB. Assessed sites using the HARM scoring method to rank the sites. Made recommendations for additional investigations at each site
Basewide Sampling Program Summer 1983	Tinker AFB	Drinking water supply wells were sampled as part of the Drinking Water Surveillance Program	TCE was detected in the groundwater around Building 3001.
Installation Restoration Program, Phase II-Confirmation/ Quantification Stage 1 Final Report for Tinker AFB, Oklahoma, Volumes 1 and 2, September 1985	Radian Corporation for United States Air Force Occupational and Environmental Health Laboratory (OEHL), Brooks Air Force Base, Texas	Investigation to determine if contamination of the environment resulted from waste disposal practices at Tinker AFB.	Included an estimate of the magnitude and extent of contamination, the identification of environmental consequences of migrating pollutants, and the recommendation of additional investigations necessary to identify the magnitude, extent, and direction of discovered contaminants. Field work included installation and sampling of eleven groundwater monitoring wells, electromagnetic surveys, soil sampling, sampling of on-base water wells, and investigation of TCE contamination in on-base water supply wells 18 and 19. The Building 3001 site, including wells 18 and 19, was identified as investigation Zone 6.

TABLE 1-3 (Continued)

SUMMARY OF PREVIOUS INVESTIGATIONS AND REPORTS

INVESTIGATION/REPORT	PREPARED BY AND FOR	SCOPE	CONTENT/SUMMARY
Installation Restoration Program, Phase II-Confirmation/ Quantification, Stage 2 Final Report, for Tinker AFB, Oklahoma, Volumes 1 and 2, October 1985	Radian Corporation for United States Air Force Occupational and Environmental Health Laboratory (OEHL), Brooks Air Force Base, Texas	Investigation to determine if contamination of the environment resulted from solvent storage and waste disposal practices at Tinker AFB.	Continued documentation, similar to the Stage 1 Final Report, of the magnitude, direction, and environmental consequences of migrating contamination at Tinker AFB. Field work included installation and sampling of groundwater monitoring wells, analysis of sediments from base streams and drainage channels, and a survey of buried waste pits and tanks in the vicinity of Building 3001.
Tinker AFB IRP Safety Plan for COE Personnel, March 1986	Tulsa District COE	A safety plan for expected field work to be performed as part of TAFB IRP.	A comprehensive safety plan for foreseeable field work at TAFB. Provided site descriptions, procedures, and types of safety equipment to be used at sites to be investigated. This includes subsurface investigations at Building 3001, Landfills 1-6, radiological waste disposal sites, and fuel contaminated sites.
Sampling and Analysis Quality Assurance/Quality Control Plan for Corps of Engineers site Investigations, March 1986	Tulsa District COE	A Quality Assurance Project plan for TAFB IRP.	Presented a methodology for collection, preparation, shipment, testing, and quality control for groundwater and soil samples taken at Tinker AFB by Tulsa District sampling personnel.

TABLE 1-3 (Continued)

SUMMARY OF PREVIOUS INVESTIGATIONS
AND REPORTS

INVESTIGATION/REPORT	PREPARED BY AND FOR	SCOPE	CONTENT/SUMMARY
Building 3001 Remedial Investigations, Volumes 1 and 2, Final Report, January, 1988	Tulsa District COE	Remedial investigation as part of the U.S. Air Force Installation Restoration Program (IRP) to define and characterize the sources, extent, and magnitude of contamination at the Building 3001 site	Presented data, conclusions, and recommendations from the remedial investigations. Field and laboratory work included investigating pits within Building 3001, investigating geologic site conditions, installing a groundwater monitoring network, sampling water supply and monitoring wells, and conducting aquifer tests. Appendices to the report included "Report of Plugging Procedures, Water Wells 18 and 19," prepared by Dansby and Associates; "Building 3001 Fire Damaged Area Summary Report," prepared by Tulsa District COE; and "Summary of Existing Data, Building 3001 Site Evaluation, IRP Tinker AFB, OK, Phase IV Remedial Actions," prepared by PELA, March 1987.
Selection of Feasibility Study Alternatives Final Report, Building 3001 Site and Adjacent Fuel Contaminated Areas, Tinker AFB, OK, February 1988	Black & Veatch Engineers-Architects for Tulsa District COE	Feasibility study to select groundwater treatment and disposal alternatives.	Five remedial alternatives, including no action, recommended for further study as follows: o No Action o Offsite Treatment/Disposal o No Treatment/Reuse (Industrial Only) o Modified IWTP/Disposal o Treatment/Reuse o Treatment/Discharge
Development of Water Quality Criteria for the Dischage of Treated groundwater from Tinker AFB into Soldier Creek, Oklahoma and the Impact of the Treatment Processes on Ambient Air Quality draft report, February 1988	Tulsa District COE for Tinker AFB	To determine water and air quality-based permit limits for treated groundwater discharge.	Discusses and shows calculation methodology for water quality after assumed treatment of collected groundwater to determine what concentrations would be permissible for discharge into Soldier Creek.

TABLE 1-3 (Continued)

SUMMARY OF PREVIOUS INVESTIGATIONS AND REPORTS

INVESTIGATION/REPORT	PREPARED BY AND FOR	SCOPE	CONTENT/SUMMARY
Screening of Remedial Control Measures and Technologies, Installation Restoration Program, Building 3001, Tinker Air Force Base, Oklahoma, 1988	P.E. LaMoreaux & Associates, Inc. Consulting Hydrologists, Geologists and Environmental Scientists for U.S. Army Corps of Engineers, Tulsa District	Identification and screening of potential control measures and technologies for remediation of contaminated groundwater and fuel contaminated areas at the areas at the Building 3001 site.	Screened ninety control measure technologies for the Building 3001 site based on feasibility, cost, and public health/environment protection. Recommended a preliminary groundwater remediation plan consisting of groundwater control (pumping), treatment of collected groundwater, disposal of treated water, and management controls. Also recommended a series of potential control measures for the two fuel contaminated areas adjacent to Building 3001.
Draft Identification and Selection of Bench/Pilot Studies, March 1988	Black & Veatch Engineers-Architects for U.S. Army Corps of Engineers, Tulsa District	Identification and recommendation of any bench and pilot scale treatability studies required for evaluation of groundwater remediation technologies and alternatives presented in the "Selection of Feasibility Study Alternatives" report prepared by Black & Veatch	Concluded that only one technology, reduction/precipitation by sulfide precipitation, required pilot scale treatability studies. The recommended emphasis was on evaluating the ability of sulfide precipitation to remove barium.

TABLE 1-3 (Continued)

SUMMARY OF PREVIOUS INVESTIGATIONS AND REPORTS

INVESTIGATION/REPORT	PREPARED BY AND FOR	SCOPE	CONTENT/SUMMARY
U.S. Army Corps of Engineers, Tulsa District, Tinker AFB, Oklahoma City, OK. Sampling and analysis plan, Revision - March 1988	Tulsa District COE	To provide a QAPP for Tinker AFB based on new data acquired from IRP investigations.	Presents a methodology for collection, preparation, shipment, testing, and quality control for groundwater and soil samples taken at Tinker AFB by Tulsa District Sampling personnel.
Risk Assessment of the Building 3001 Site, Tinker Air Force Base, Oklahoma, Final Report, August 1988	U.S. Army Corps of Engineers, Tulsa District for Tinker Air Force Base, Oklahoma	Baseline assessment of the public health threat posed by chemical releases from the Building 3001 site to the regional groundwater aquifer if no action is taken to abate pollution at the site.	Characterized health risks for both carcinogens and non-carcinogens using methodology recommended in USEPA's Superfund Public Health Evaluation Manual. Detailed health evaluation provided for benzene, TCE, PCE, barium, chronium, lead, and nickel from a list of 32 chemicals identified at the Building 3001 site. Identified current and potential pathways of exposure and exposure points. Indicated that subchronic (short term) health effects were unlikely from consumption of Tinker AFB drinking water, but that potential exists for chronic (long term) effects from both Tinker AFB drinking water and long-term consumption of fish from Soldier Creek.

TABLE 1-3 (Continued)

SUMMARY OF PREVIOUS INVESTIGATIONS AND REPORTS

INVESTIGATION/REPORT	PREPARED BY AND FOR	SCOPE	CONTENT/SUMMARY
Preliminary Development and Evaluation of Groundwater Treatment and Disposal Alternatives, Final Report, Building 3001 Site and Adjacent Fuel Contaminated Areas, Tinker AFB, OK September, 1988.	Black & Veatch Engineers-Architects for U.S. Army Corps of Engineers, Tulsa District	Preliminary development and evaluation of groundwater remediation alternatives presented in the "Selection of Feasibility Study Alternatives" report.	Screened groundwater remediation alternatives included in the previous FS report with respect to engineering feasibility, public health and environmental implications, and cost factors. Alternatives which passed screening are: o Alternative 1 - No Action o Alternative 4B - Modified IWTP/ Industrial Reuse o Alternative 4C - Modified IWTP/ Surface Water Discharge o Alternative 5B - Treatment/Industrial Reuse o Alternative 6A - Treatment/Surface Water Discharge

A separate document was prepared concurrently with this report by the COE and Black & Veatch, which provides a description of the environmental impacts of the remedial alternatives recommended in this FS report. The report is entitled "Environmental Assessment of Detailed Alternatives."

1.4 NATURE AND EXTENT OF THE PROBLEM

This subsection presents a brief summary of the nature and extent of contamination at the Building 3001 site. A more detailed account is provided in the Remedial Investigation Report(1).

The past activities within Building 3001 have resulted in contamination of the groundwater, with chlorinated solvents and heavy metals being detected to a maximum depth of approximately 175 feet. The primary contaminants are TCE and Cr whose composite plume encompasses an area of approximately 220 acres. The extent of the composite plume for TCE and Cr is contained horizontally within 1800 feet of Building 3001 and within the boundaries of Tinker AFB. Chemical tests of the valency states of the Cr detected indicate that most of it is hexavalent chromium (Cr^{+6}). Other contaminants that exist at the site include additional organic and metal contaminants, fuel products at the north storage tank area, and benzene, toluene, and xylene at both the southwest and north storage tank areas. The Remedial Investigation report(1) provides detailed information on all contaminants detected in the groundwater at the Building 3001 site.

To date, contamination has been detected in the perched aquifer, upper portions of the regional aquifer (Garber-Wellington aquifer), and in near surface soils. The contamination has been identified through an extensive monitoring well network and soil boring program. The monitoring wells typically monitor: (1) the perched water table from 15 to 30 feet; (2) the top of the regional aquifer, which is the first major water bearing unit of the Garber-Wellington Formation, at depths of 50 to 80 feet; and (3) the regional zone, the deeper portion of the nonproducing zone Garber-Wellington aquifer, at depths of 110 to 175 feet. Production wells for Tinker AFB which pump water from the more productive units of the Garber-

Wellington aquifer found contamination at depths between 250 and 700 feet. This was due to contamination going down the well shaft itself. These wells have since been plugged with a pressure grout to prevent any further contamination from the production wells.

1.4.1 Contamination Sources

During the period from the 1940's to the 1970's, industrial solvents and waste waters inside Building 3001 were contained in subsurface pits and trenches of steel-lined or concrete-lined construction. Leakage from some of the pits percolated into soils and groundwater beneath Building 3001. Also, some solvents and waste waters were released to the storm drain system in the building. The storm drains discharge to the east and west sides of the building into tributaries of Soldier Creek, commonly referred to as East and West Soldier Creek. As a result, contaminants were carried into the creeks[1] and leakage along the storm drain pipes probably occurred, allowing vertical migration into the perched aquifer. Some of the discharge to storm drains occurred from improper tie-in connections between industrial waste lines and storm drains. In the early 1970's, solvent pits began to be replaced with aboveground tanks. Most of the subsurface pits were backfilled with sand and covered with a concrete cap. Based on subsequent investigations of these abandoned pits conducted in 1985 in the north and south portions of Building 3001, only seven were found to contain any significant contamination. Removal of the contents of three pits located in the north portion of the Building 3001 at column-rows E-105, V-85, and LM-107 has been completed as referenced in the RI report. Cleaning, backfilling, and sealing of the pits U-51 and Q-51 are being performed by Tinker AFB personnel. Pits U-51 and Q-51 are separate operable units. Separate Records of Decision for these pits will be prepared and incorporated into the Administrative Record for the Building 3001 site. Three of the four pits on the building's south side were found to contain low concentrations of solvents (TCE, 1,1,1-trichloroethane, and xylenes) with the other pit containing high concentrations of metals (cadmium and lead). Tinker AFB personnel have evaluated and are correcting the handling of industrial waste to ensure that industrial waste is no longer discharged into storm drains[1].

Fuel product detected in the soil and groundwater in the north tank area was identified as a mixture of fuel oil, which was contained in tank number 3404 and gasoline from the tank which has been removed. The presence of fuel product in the soils and groundwater is the result of leakage from the tanks and piping, although some contamination may have resulted from spills.

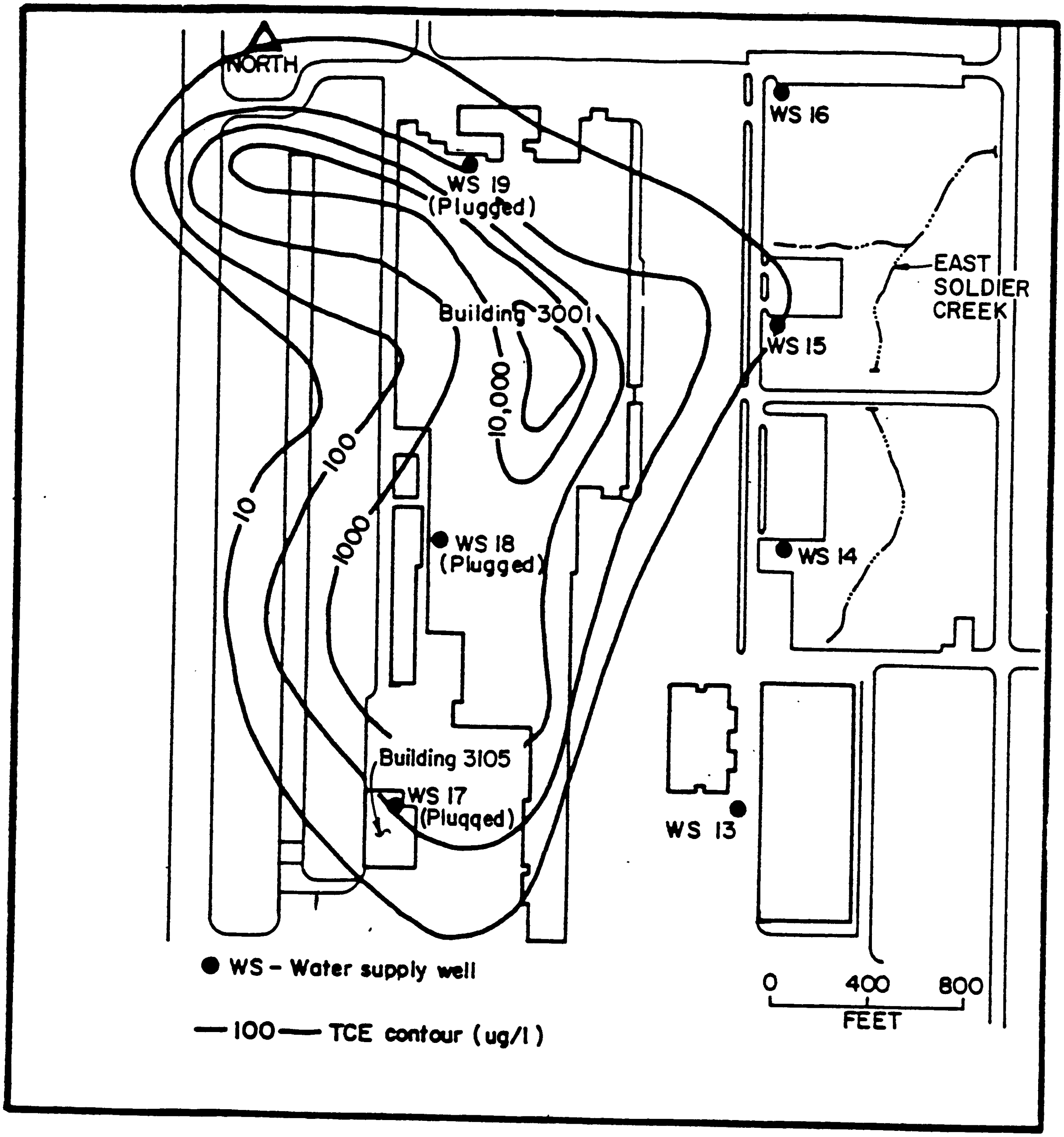
1.4.2 Soil Contamination

Contaminated soil exists in localized areas beneath Building 3001. The soils above the perched water table became contaminated in areas beneath the building due to contaminants migrating from the building sources described earlier. Concentrations of TCE, 1,2-dichloroethylene (1,2-DCE), PCE, methylene chloride, benzene, 1,1,1-trichloroethane (TCA), chlorobenzene, and methylethyl ketone were all detected in localized areas beneath the building. Contaminant concentrations were relatively low, except in two locations where TCE concentrations of 120 and 11 mg/kg were detected. Other contaminants detected in the soils include: Cr, lead (Pb), barium (Ba), and cadmium (Cd). Although most contamination sources have been eliminated, it has been estimated that the soils beneath Building 3001 may continue to leach contaminants into the perched aquifer for more than 50 years[1].

Contaminated soils in the North Tank area will be treated as part of a separate remedial action for that operable unit.

1.4.3 Perched Aquifer

Perched groundwater exists beneath the Building 3001 site, above the regional aquifer. The highest concentrations of contaminants at 3001 site have been detected in this zone. Contamination occurred from percolation of liquids laden with solvents, metals, and fuel products. TCE is present beneath the site with concentrations ranging from 330,000 ug/l beneath the building to less than 5 ug/l at the limits of the plume. The TCE plume, which covers approximately 140 acres, is shown in Figure 1-5. A similar



TCE PLUME IN PERCHED AQUIFER

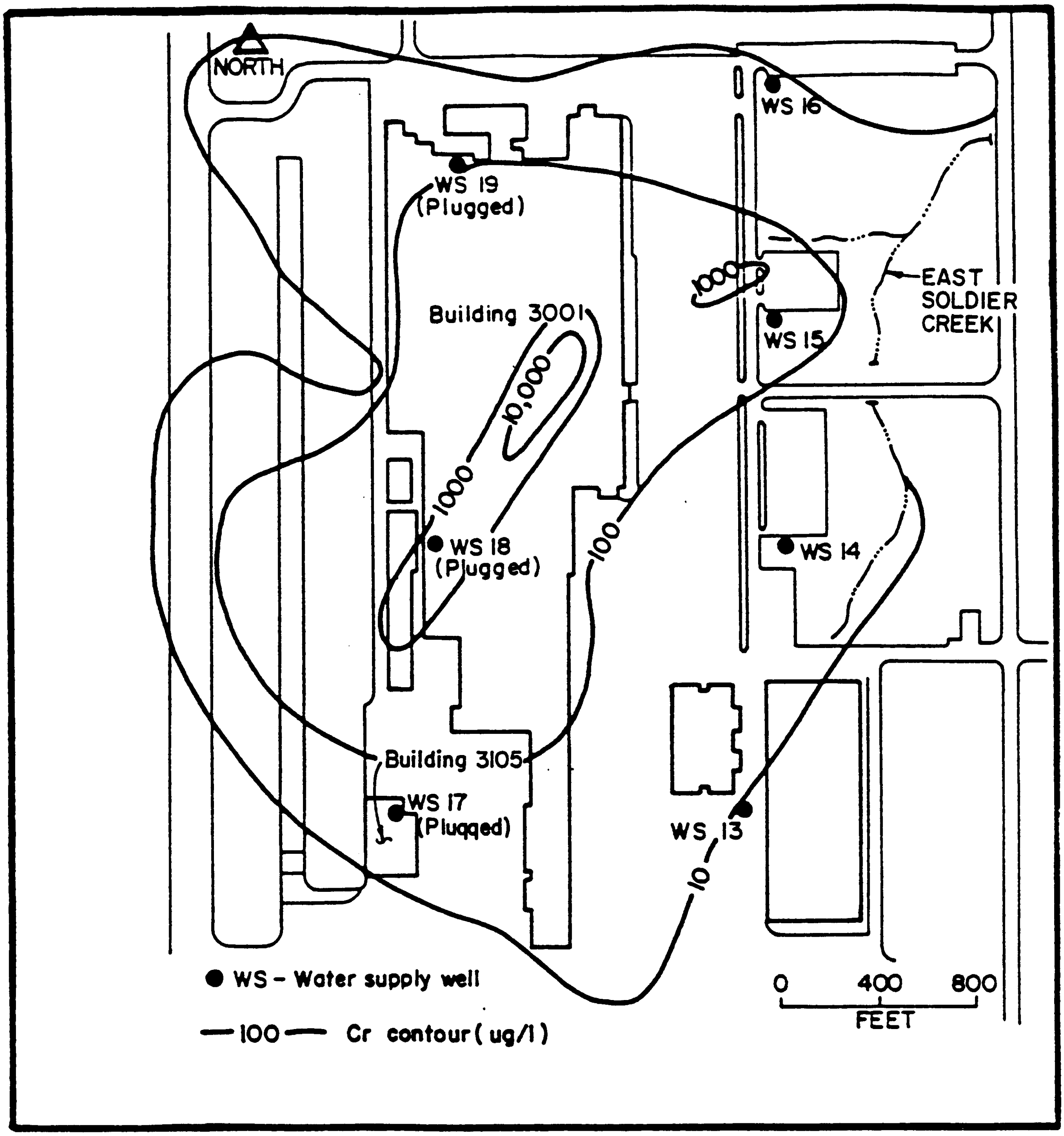
FIGURE 1-5

shaped plume for 1,2-DCE is present with the highest detected concentrations (4,600 ug/l) located west of the building. PCE has been detected at a maximum concentration of 260 ug/l beneath Building 3001. Plumes of 1,2-DCE and PCE cover approximately 78 and 17 acres, respectively. Toluene, benzene, and xylene are found at the North and Southwest Tank Areas and fuel product (estimated at 6,000 to 12,000 gallons) was found floating above the groundwater at the north tank area. The floating fuel product, along with the contaminated soil at the north tank area are a separate Operable Unit. The tanks and contaminated soil at the southwest tank area are to be handled as an UST site. The maximum concentrations of toluene, benzene, and xylene were 47,000, 1,535, and 780 ug/l, respectively. Concentrations of Cr, lead, and barium, in excess of primary drinking water standards, were also detected in the perched zone. Cr is present in the perched aquifer with concentrations ranging from 80,000 ug/l beneath the building to less than 10 ug/l outside the building perimeter at the limits of the plume. The Cr plume, which covers approximately 220 acres, is shown in Figure 1-6. The plumes for Pb and Ba are similarly shaped with maximum concentrations of 570 and 28,000 ug/l, respectively. Primary drinking water standards for the contaminants of concern are presented below in Table 1-4.

TABLE 1-4

PRIMARY DRINKING WATER STANDARDS

Contaminant	Maximum Contaminant Level (ug/l)
Barium (Ba)	1000
Chromium (Cr)	50
Lead (Pb)	50
Trichoroethylene (TCE)	5
Benzene	5



CR PLUME IN PERCHED AQUIFER

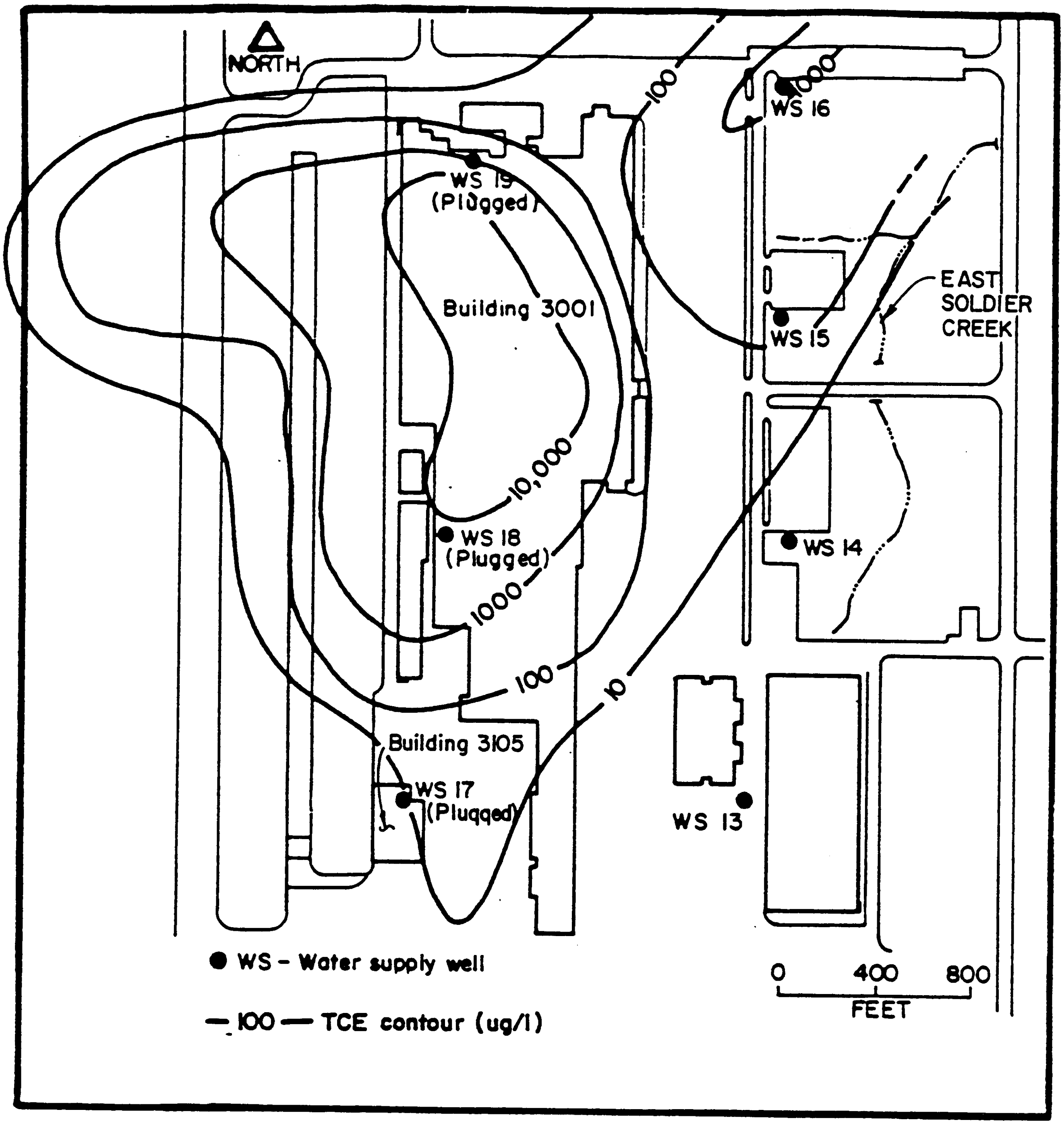
FIGURE 1-6

The perched water is not used for water supply either on-Base or off-Base. Yields within this zone are very low and the quality is generally poor, with high background concentrations of chlorides and sulfates. Background concentrations average 297 mg/l for chlorides and 83 mg/l for sulfates. Discontinuities in underlying shales which support the perched water allow migration of contaminants from the perched aquifer to the regional aquifer.

1.4.4 Regional Aquifer

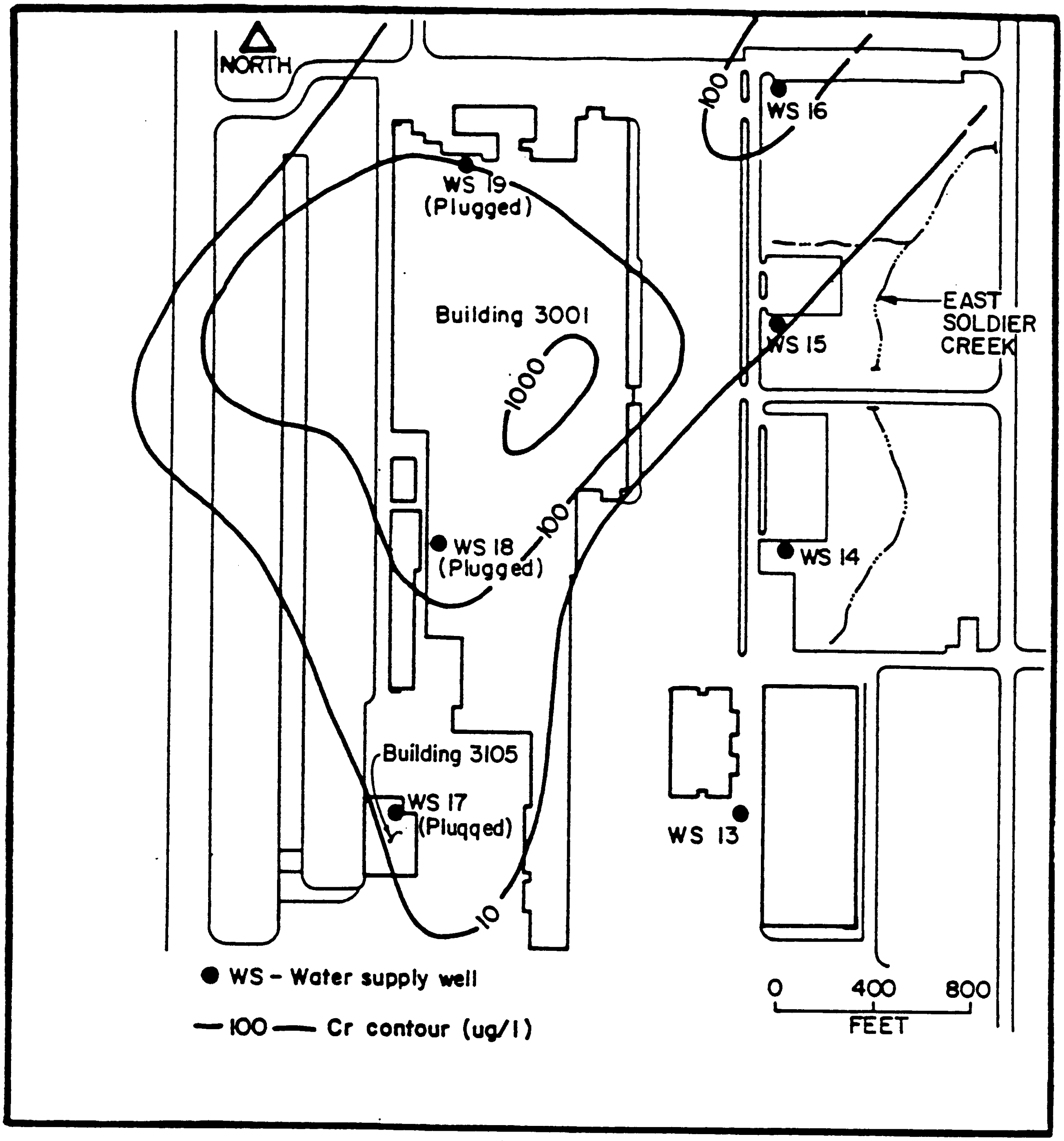
Regional groundwater exists in the Garber-Wellington formation under both confined and unconfined conditions, depending on the presence and condition of overlying shale beds. The upper, nonproducing portion of the aquifer has been conceptually divided into two zones: (1) the top of the regional zone and (2) the regional zone. Below these zones, at depths of 250 to 700 feet, groundwater is pumped by Tinker AFB and is referred to as the producing zone. Detailed discussion of contamination in these zones is presented below.

1.4.4.1 Top of the Regional Zone. TCE, 1,2-DCE, Cr, Pb, and Ba are present in the aquifer in concentrations generally lower than in the perched zone. Concentrations of PCE are slightly higher in the top of regional zone than in the perched zone. The primary contaminants, TCE and Cr, were detected beneath the building with maximum concentrations of 30,000 ug/l and 1,700 ug/l, respectively. The contaminant plume for TCE covers approximately 181 acres, as shown on Figure 1-7. The Cr contaminant plume forms an area of about 153 acres, as shown on Figure 1-8. The highest concentration of 1,2-DCE was 1,400 ug/l in an area northeast of the building. The plume shape for 1,2-DCE is similar to the TCE plume. PCE is present primarily beneath the building with the highest concentration detected at 1,200 ug/l. Plumes for Ba and Pb exist with shapes similar to that of Cr. The maximum detected concentration of Ba is 24,000 ug/l and the maximum concentration of Pb is 410 ug/l.



TCE PLUME IN TOP OF REGIONAL ZONE

FIGURE 1-7



CR PLUME IN TOP OF REGIONAL ZONE

FIGURE 1-8

One area northeast of the building contains elevated concentrations of TCE, 1,2-DCE, PCE, and Cr. Also detected in this area were concentrations of chlorobenzene and vinyl chloride, which were not detected in significant concentrations throughout the rest of the site. The area is upgradient from the Building 3001 site and the contamination source has been identified as the Industrial Wastewater Treatment Plant. The area will be addressed as a different IRP site requiring a separate Installation Restoration Program Response Action. Since this is a separate site that will require a separate remedial action, the effects of any <u>sources</u> of contamination from this site were ignored during evaluation of the alternatives. But, the groundwater contamination itself as it is currently defined was included for the northeast area in the evaluation. If this site is not remediated prior to design of the final plan, any effects of this site on the 3001 remedial action, will be incorporated at that time.

1.4.4.2 <u>Regional Zone</u>. The significant organic compounds found in this zone are TCE and 1,2-DCE, with concentrations much lower than in the top of the regional zone. The maximum concentrations of TCE and 1,2-DCE were 1,000 and 46 ug/l, respectively. The extent to which contaminants have migrated in the regional zone is significantly less than in the top of the regional zone. Contaminants are concentrated primarily beneath the building. The TCE plume in the zone covers approximately 78 acres. Cr is also present with a maximum concentration of 1,200 ug/l beneath the building. The Cr plume has an area of approximately 145 acres. The regional zone is not used by the Base for water supply. The producing zone begins at approximately 100 feet below the bottom of this layer.

1.4.4.3 <u>Producing Zone</u>. There are 25 existing water supply wells on base that pump groundwater from this zone. Seven water supply wells were located in the vicinity of Building 3001, as shown on Figures 1-5 through 1-8 (well numbers 13-19). Wells 18 and 19 which were found to contain TCE and PCE were taken out of operation in 1983 and were plugged in 1987. These wells were within the horizontal limits of the TCE and PCE plumes in the overlying aquifer. The poor condition of the well seals allowed vertical migration of the contaminants from the upper zones to the producing zones. Wells 14, 15, and 16 are active wells and contain trace levels of TCE. Well 16 also contains trace levels of 1,2-DCE and PCE. Well 17, which is near the southwest corner of Building 3001, inside Building 3105, was sampled and plugged in November 1988.

1.4.5 Soldier Creek

Past discharges into East and West Soldier Creeks have resulted in contamination of water and sediments within the creeks. Storm water sewers draining into the creeks have carried discharges of wastes due to improper connections between industrial wastewater lines and storm drains, and the washing down or possible dumping of waste liquids or solvents into drains. Hydrogeologic investigations have shown that East Soldier Creek is a discharge point for some perched groundwater beneath the east portion of Building 3001. Although contaminant concentrations are relatively low in the perched groundwater near the creek, the potential for contaminant migration into the creek exists (Figures 1-5 and 1-6). East and West Soldier Creeks are separate operable units to the NPL site and are being investigated and remediated separately from the Building 3001 site, as directed in the FFA.

Past sampling of sediments in East Soldier Creek have shown the presence of heavy metals and volatile organic compounds[1]. A cleanup operation was conducted in early 1986 to remove heavily contaminated sediments from a portion of East Soldier Creek. Sampling of water and sediments within the creeks is ongoing.

1.5 OBJECTIVES OF REMEDIAL ACTION

The purpose of conducting the FS is to identify, analyze, and compare alternatives designed to reduce, eliminate, or control the threats to public health and the environment. The overall objective of the FS process is to select, from applicable technologies, those remedial solutions consistent with the NCP and EPA policy. Recent changes to CERCLA enacted by the Superfund Amendments and Reauthorization Act (SARA) have been incorporated into the FS, including placing emphasis on permanent solutions and discouraging offsite disposal. Alternatives developed during the FS must also be responsive to other federal, state, and local regulations which make up the applicable or relevant and appropriate requirements (ARARs).

The specific goals of remedial action at the Tinker AFB Building 3001 site are as follows:

- Protect the public and AFB personnel from exposure to hazardous levels of contamination in water supplies.
- Prevent the deterioration of groundwater quality in the perched aquifer and the Garber-Wellington Aquifer.
- Protect Soldier Creek from additional contamination. (A separate RI/FS is currently planned for Soldier Creek.)
- Improve the quality of groundwater already contaminated in the perched aquifer and the Garber-Wellington Aquifer.
- Satisfy Sections 120 and 121 of CERCLA as amended.

2.0 SCREENING OF ALTERNATIVES

Screening of technologies and process options was performed so that the technologies remaining could be combined into alternatives which meet remedial action objectives. Screening was conducted to eliminate those technologies and process options which have not been proven effective in treating or disposing of contaminants and/or media of concern, or are not considered feasible based on site conditions. Technologies and process options which were considered potentially viable were then assembled into remedial action alternatives which have been evaluated further based on engineering feasibility, public health protection, environmental impacts, regulatory compliance and institutional factors, and relative cost.

In the "Screening of Remedial Control Measures and Technologies" report prepared by P.E. LaMoreaux & Associates, Inc. (PELA)[2], for the Tulsa District U.S. Army Corps of Engineers, potential technologies and process options applicable to the site were identified and screened. In this feasibility study, all technologies recommended in the PELA report were given consideration in the development of alternatives. In Table 2-1 the screened technologies from the PELA report are assembled under general response actions to which each remedial technology and process option applies. This table lists the full scope of screened technologies available for remediation of contaminated groundwater at the Building 3001 site.

The screened technologies and process options for groundwater treatment and disposal response actions were used to develop screened remedial action alternatives in the "Preliminary Development and Evaluation of Groundwater Treatment and Disposal Alternatives" report.[5] The groundwater treatment and disposal alternatives which survived the screening of that report, will undergo detailed evaluation in this FS. Screened remedial technologies for groundwater controls and management controls will be used in this report to develop remedial alternatives for contaminated groundwater removal and management controls.

TABLE 2-1

SCREENED TECHNOLOGIES

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS
GROUNDWATER CONTROL		
Pumping	Extraction Wells	Well locations Flow rate Aquifer zone Number of wells Pump locations
MANAGEMENT CONTROL		
Management Control	Land Use Controls	Paving Fencing
	Alternative Water Supplies	Municipal Hook-ups Additional Supply Wells
	Right-of-Way Acquisition	Used as Needed
	Personnel Supervision and Training	Dependent on Selected Alternative
	Permanent Relocation	Not Applicable
GROUNDWATER TREATMENT		
	Pretreatment	Filtration Flow Equalization Oil/Water Phase Separation
	Organics Treatment	Air Stripping Biological Carbon Adsorption Oxidation UV-Oxidation
	Inorganics Treatment	Ion Exchange Precipitation Reduction Filtration
	Treatment Onsite	Existing Industrial Waste Water Treatment Plant (IWTP)

TABLE 2-1 (Continued)

SCREENED TECHNOLOGIES

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS
GROUNDWATER DISPOSAL		
	Reuse	Industrial Reuse Irrigation
	Discharge	Storm Sewer/Surface Water Sanitary Sewer

3.0 ALTERNATIVES EVALUATION PROCESS

This section presents a description of the process used to evaluate the alternatives. In accordance with Section 300.68(h) of the NCP, the alternatives have been evaluated in terms of the following five criteria, which are discussed beginning with Section 3.1.

- o Engineering Feasibility
- o Public Health Impacts
- o Environmental Impacts
- o Institutional Requirements
- o Cost Analysis

The NCP also identifies five categories under which at least one alternative should be developed, to the extent that it is possible and appropriate.

1. No action alternative.
2. Alternatives that attain applicable or relevant and appropriate federal public health and environmental requirements.
3. Alternatives that exceed applicable or relevant and appropriate federal public health and environmental requirements.
4. Alternatives that do not attain applicable or relevant and appropriate federal public health and environmental requirements but will reduce the likelihood of present or future threat from the hazardous substances and that provide significant protection to public health and welfare and the environment. This should include an alternative that closely approaches the level of protection provided by the applicable or relevant and appropriate requirements.
5. Alternatives for treatment or disposal at an offsite facility.

Section 121 of the Superfund Amendments and Reauthorization Act (SARA) states that emphasis should be placed on employing technologies which reduce toxicity, mobility, or volume of contaminants, and on remedial actions that utilize permanent solutions. Alternatives developed under SARA should cover the following categories:

1. No action alternative.
2. A containment alternative involving little or no treatment.

3. Treatment alternatives that reduce toxicity, mobility, or volume of the contaminants.

4. Alternatives that eliminate the need for long-term management, including monitoring.

The detailed evaluation is not intended to be all inclusive, but is intended to present sufficient information on each alternative to facilitate a comparative evaluation of the alternatives. Additional information will be required during the design of the selected alternative.

Detailed evaluations for three alternative groups are included in Sections 4 through 6 for the Building 3001 site. These three groups consist of alternatives for groundwater pumping, groundwater treatment and disposal, and management controls.

The no action alternative is included in the groundwater pumping alternative group, and will apply to each of the other alternative groups. In some cases, alternatives are not evaluated with regard to all five of the evaluation criteria due to nonapplicability. Discussion is provided where this occurs.

Evaluation criteria are presented in the following subsections for the noncost categories (engineering feasibility, public health impacts, environmental impacts, and institutional requirements). The cost analysis includes capital costs to implement each alternative and operation and maintenance costs for a 30-year period. Summaries of the evaluation process are provided at the end of each section for each alternative.

A numerical system with a scale of 1 to 5 has been used to rate individual alternatives with regard to engineering, institutional, and public health and environmental criteria. The ratings range from 1 for the best rating to 5 for the worst. Alternatives were eliminated if they received a rating of 5 for any of the evaluation criteria or subcriteria.

3.1 ENGINEERING FEASIBILITY

This section presents the evaluation process used to determine the engineering feasibility of each alternative. The engineering evaluation considers the performance, reliability, implementability, and safety factors of the remedial actions. These evaluation criteria are specified in the following sections.

3.1.1 Performance

The performance of each alternative is based on the alternative's expected effectiveness and its useful life. The effectiveness evaluation addresses the suitability of the measure to meet the remedial action objectives stated in Section 1.5. It also addresses the degree to which an action will prevent or minimize substantial danger to public health, welfare, or the environment. The effectiveness of an alternative also is a function of how well components of the alternative can be integrated to provide an overall solution. Effectiveness is evaluated on the following scale:

1 - Prevents further migration of all hazardous materials; provides maximum protection of human health and environment.

2 - Minimizes further migration of hazardous materials; adequately protects human health and environment.

3 - Controls release of hazardous materials; adequately protects public health and environment.

4 - Reduces release of most hazardous materials; provides limited protection of public health and environment.

5 - Allows release of hazardous materials; does not protect public health and the environment.

The useful life of a remedial measure is the length of time this level of effectiveness can be maintained with appropriate operation and maintenance procedures without consideration for replacement. Useful life is evaluated on the following scale:

1 - All technologies and remedial actions are permanent and require no maintenance.

2 - Major components of the remedial action are permanent with other components easily repairable through routine maintenance.

3 - Overall long-term solution requiring only routine maintenance.

4 - Short-term solution requiring significant and unpredictable maintenance; difficult to replace or repair.

5 - Short-term solution requiring frequent extensive maintenance; repair impractical upon failure.

3.1.2 Reliability

Key considerations for this criterion include operation and maintenance (O&M) requirements and the demonstrated performance of the technologies at similar sites. O&M requirements include the availability of labor and materials, as well as the frequency and complexity of the tasks necessary to keep the alternative effective after the construction and initial startup have been completed. When assessing reliability, field tested methods are given preference over technologies that have not been applied to actual site cleanup operations. O&M requirements are evaluated on the following scale:

1 - Never requires operation or maintenance attention after implementation.

2 - Requires infrequent attention; capable of functioning unattended with periodic maintenance.

3 - Capable of functioning unattended but requires more frequent attention.

4 - Requires dedicated personnel to maintain functions and regular O&M attention by trained personnel.

5 - Requires very frequent or constant attention by full-time trained personnel.

Demonstrated performance is evaluated on the following scale:

1 - All remedial technologies proven reliable in the field under similar conditions on similar waste materials and mixtures.

2 - All remedial technologies proven reliable in the field under similar conditions but on different waste materials.

3 - Proven reliable but under different conditions and materials.

4 - Demonstrated only in laboratory- or pilot-scale studies on similar materials; reliability is not demonstrated on full scale.

5 - Demonstrated only in laboratory-scale on pure substances or simple mixtures; reliability not demonstrated for practical field conditions.

3.1.3 Implementability

Implementability addresses both the constructability or ease of installation, and the time required to achieve a given level of response. Constructability considers whether the alternative can be constructed on the site and the impact of external conditions on the construction of an alternative, such as the ease of acquiring access, zoning clearances, and local permits. The time it takes to implement an alternative and the time to achieve beneficial results that attain or exceed relevant or applicable standards are also considered. The time to implement an alternative includes allowances for special studies, design, advertising, bid award, and construction. Time to achieve beneficial effects spans from the end of construction to the time when the level of contamination has been reduced to meet applicable or relevant and appropriate requirements.

Constructability is evaluated on the following scale:

1 - Routine construction effort.

2 - Construction effort required is not excessive, few site restrictions, easements are readily obtainable, no public opposition.

3 - Difficult to construct due to site restrictions, difficulty in obtaining easements and lack of public acceptance.

4 - Construction possible but major construction effort is required, many site restrictions and a great deal of public opposition.

5 - Magnitude of construction effort is excessive, difficult to acquire easements, etc., will not be acceptable to public.

Time to implement the remedial alternative is evaluated on the following scale:

1 - Alternative can be implemented in less than 6 months.

2 - Alternative can be implemented within 1 year.

3 - Alternative can be implemented in 1 to 2 years.

4 - Alternative can be implemented in 2 to 3 years.

5 - Alternative requires more than 3 years to implement.

Time to achieve beneficial results is evaluated on the following scale:

1 - Immediate overall results (within implementation period).

2 - Rapid overall results (within 1 year after implementation period).

3 - Timely overall results but requires between 1 and 10 years.

4 - Obtaining overall results requires between 10 and 30 years.

5 - Obtaining overall results requires greater than 30 years.

3.1.4 Safety

This evaluation considers short-term and long-term threats to the safety of nearby residents as well as to persons working on the site. Major risks to consider are exposure to hazardous substances, fire, and explosion due to activities conducted during implementation of the remedial action. Short-term and long-term safety aspects of the remedial action as they pertain to both workers onsite and to the surrounding populace are evaluated on the following scale:

1 - All remedial actions are very safe; requires no more than normal safety procedures required for workers at hazardous waste sites; no threat to surroundings.

2 - Remedial actions are relatively safe; requires few safety procedures other than those normally required at a hazardous waste site; little or no threat to surroundings.

3 - Requires constant monitoring and stringent safety procedures; potential threat to workers and surroundings.

4 - Hazardous; requires stringent safety procedures to ensure worker safety; may possibly require emergency evacuation of homes near the site.

5 - Very hazardous, requires remote operation and evacuation of area homes.

3.2 PUBLIC HEALTH IMPACTS

The public health evaluation of alternatives assesses the extent to which each alternative mitigates long-term exposure to any residual contamination and protects public health during and after completion of the remedial action. SARA emphasizes that remedies must be protective of human health by meeting or exceeding ARARs or health-based threshold concentration limits established through a site-specific endangerment assessment.

In evaluating both long- and short-term public health impacts, two primary areas must be considered. First, there must be an exposure or a potential exposure to the contaminant for the recipient's health to be affected adversely. If there is no exposure, there will be no adverse health effects. The second area requiring consideration in the evaluation of alternatives is the relationship of the actual concentration of the contaminant to published exposure limits or threshold limits established during an endangerment assessment. Both areas must be considered to properly evaluate the impact an alternative might have on public health.

Evaluation of short-term impacts will consider health effects on workers during construction of the remedial action and on the public for the interim periods prior to remedial action implementation. Long-term impacts will be judged based on the chronic intake of the contaminant over the lifetime of the remedial action.

Alternatives for both the short-term and long-term are evaluated on the following scale:

1 - Alternative prevents intake and incidental contact with contaminant concentrations exceeding limits established by ARARs.

2 - Alternative prevents intake but allows potential incidental contact with contaminant concentrations exceeding limits established by ARARs.

3 - Alternative allows for intake of contaminant concentrations approaching limits established by ARARs.

4 - Alternative allows for intake of contaminants at concentrations above limits established by ARARs but below threshold limits.

5 - Alternative allows for intake of contaminants at concentrations above limits established by ARARs and threshold limits.

3.3 ENVIRONMENTAL IMPACTS

Each remedial alternative will be evaluated for beneficial and adverse environmental impacts for both the long- and short-term. Criteria for evaluating beneficial effects are final environmental conditions, improvements in the biological environment, and improvements in resources people use. Criteria for evaluating adverse effects are the expected effect of the remedial action and the measures taken in the event inevitable or irreversible effects are realized.

For each alternative, the environmental impacts are rated in accordance with the following scale:

1 - Alternative mitigates damages to the environment.

2 - Alternative minimizes damages to the environment.

3 - Adverse environmental impacts are generally limited, controllable, and within acceptable limits.

4 - Alternative causes limited uncontrollable or unacceptable effects.

5 - Alternative causes significant uncontrollable or unacceptable effects.

3.4 INSTITUTIONAL REQUIREMENTS

This section describes the institutional requirements evaluation criteria to be used in evaluating the alternatives. These criteria are divided into two categories: conformance with ARARs and permitting requirements. Because public input has not been to this point part of the evaluation and recommendation process, it was not included as an evaluation criterion for institutional requirements. However, a proposed plan describing the FS process for the recommended alternative will be published for public comment, as required by the FFA. Each alternative must comply with the ARARs of the Oklahoma Controlled Industrial Waste Disposal Act. Each alternative that requires a construction permit for either building a new facility or making modifications to an existing facility may require a public hearing. Details of the hearing process are mandated in Section 1-2006 - Definitions - Permits - Hearing - Notice - Review, of the Oklahoma Controlled Industrial Waste Disposal Act. Notice of such hearing will be made public by newspapers and radio stations local to the controlled industrial waste facility proposed for a permit. The hearing may be requested by any person residing or doing business in Oklahoma to oppose the granting of such permit.

To achieve conformance with this statute, Tinker AFB will be responsible for providing proper notice of their intentions of either building a new treatment facility or making modifications to the existing IWTP. Community opposition to any of the alternatives, except the no action alternative, is not anticipated. Therefore, concern by the community should not be a detriment to the process of obtaining the necessary construction permits. Descriptions of each criterion are provided in the following subsections.

3.4.1 Conformance with Applicable or Relevant and Appropriate Requirements (ARARs)

The remedial action alternatives developed in the FS should address all legally applicable or relevant and appropriate standards, requirements, criteria, or limitations. These legally applicable or relevant and appropriate requirements may be any standard, requirement, criteria, or limitation under federal environmental law, or any state environmental or facility siting law that is more stringent than the corresponding federal standard, requirement, criteria, or limitation.

Applicable laws and standards are those that would be specifically triggered when the law or regulation is clearly and indisputably the controlling authority for the planned action for the proposed Superfund remedy, except that the proposed action would be undertaken pursuant to the CERCLA Section 104 or 106; e.g., applicable laws and standards are those which would legally apply if the action was not being taken under the authority of CERCLA.

Relevant and appropriate laws or standards are those in which the intent of the law or standard is to apply to circumstances sufficiently similar to those encountered at CERCLA sites. The term "relevant and appropriate" means that the law or regulation need not be truly applicable or legally required to the proposed action or existing circumstances, but that the intent of the law was to control similar situations.

Conformance With ARARs is evaluated on the following scale:

1 - Alternative will exceed existing ARARs.

2 - Alternative will meet existing ARARs.

3 - Alternative does not attain ARARs but will reduce the likelihood of present or future threats to public health or environment from hazardous substances.

4 - Alternative violates ARARs.

5 - Alternative strongly violates ARARs.

3.4.2 Permitting Requirements

No federal, state, or local permit is required for any remedial action conducted entirely onsite, where such remedial action is selected and carried out in compliance with SARA. However, federal, state, or local permits which are required for offsite activities, including discharges that go offsite, must be obtained. Remedial actions that involve storage, treatment, or disposal of hazardous substances at offsite facilities will involve only such offsite facilities that are operating under appropriate federal and state permits and other legal requirements.

Even though actual permits are not required for on-site work, the requirements of the permits must still be followed or observed. Following are brief discussions of the intent of several permits which, if the action were not taken under SARA, would have to be obtained.

- National Pollution Discharge Elimination System (NPDES) Permit for discharges to surface waters.
- A state waste disposal permit, similar to the NPDES, is issued by the State of Oklahoma.
- Water rights permits for any extraction system, in this case for the use of extraction wells.
- Building permits as needed by county codes.
- Review and approval by the Oklahoma State Health Department of construction reports, plans, and specifications, for any treatment facility.
- Air Emissions Permit may be required by the Clean Air Act (CAA), for a facility which may emit air pollutants, in this case an air stripper.

- State issued construction permits for new facilities or for modifications made to existing facilities.
- Transportation of hazardous waste to an offsite treatment, storage, or disposal facility (TSDF) requires RCRA TSDF permits.
- Transporters of RCRA wastes must be registered with the State of Oklahoma.

Alternatives are evaluated according to the following scale on the amount of effort required to conform to permitting standards as though all pertinent permits were required:

1 - Permits would not be required.
2 - Permits would be easily obtained.
3 - Permits would be obtained with reasonable effort.
4 - Permits would be very difficult to obtain.
5 - Permits would not be obtainable.

3.5 COST ANALYSIS

The detailed cost analysis of alternatives involves estimating the expenditures required to complete each measure in terms of both capital costs and annual O&M costs. Once these values have been identified and a present worth calculated for each alternative, a comparative evaluation can be made.

3.5.1 Cost Estimates

The cost estimates presented in this section are based on the conceptual designs prepared for the alternatives. An estimate of this type, according to EPA guidance documents, is usually expected to be accurate between +50 percent and -30 percent. The cost estimates are presented in 1988 dollars and are prepared from information available at the time of this study for guidance in project evaluation and implementation. The actual cost of the project will depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables. Most of these factors are not expected to affect the relative cost differences between alternatives. Because of potential variations, funding requirements must be carefully reviewed before making specific financial decisions or establishing final budgets.

The development of cost estimates for the assembled alternatives involved the following steps:

- Estimation of the capital cost, including construction, engineering and design, equipment, and site development costs.
- Estimation of annual O&M costs over the life of the cleanup program following initial installation.
- Present worth analysis utilizes the estimated capital costs and annual O&M cost. The present worth for each alternative was based on an 8.875 percent discount rate. A 30-year economic life was assumed, with no salvage value credited after 30 years unless noted otherwise. Inflation was not considered.

Construction costs include cost of materials, labor, and equipment necessary to construct and implement the alternative. Such items as site preparation, treatment plant construction, and installation of monitoring and extraction wells were also included in this category, but the cost of land on which to construct facilities was not included. Indirect capital costs were included for engineering and design, financial services, construction supervision, and licenses and permits. These costs were estimated as a percentage of the total construction cost. Operating costs were calculated for activities that continue after completion of construction, such as continued monitoring of groundwater and surface water quality, and routine operation and maintenance of onsite treatment equipment.

Unit costs were obtained from EPA documents(3) and construction costs guides(4), estimates from similar hazardous waste projects, and estimates provided by equipment vendors, hazardous waste transporters, and treatment facility operators.

For estimating purposes, productivity of the work force was estimated for performing hazardous waste work under Level D protection. It is estimated that the majority of the work would be performed under Level D protection. Present worth analysis was used to facilitate comparison of the total overall cost of each alternative. The present worth of an alternative is the amount of capital required to be deposited at the present time at a given interest rate to yield the total amount necessary to pay for initial construction costs and future expenditures. Present worth analysis provides a method of evaluating and comparing costs that occur over different time periods by discounting all future expenditures to the present year. The influence of the discount rate on the relative cost ranking of the alternatives is evaluated in a cost sensitivity analysis included in the cost analysis subsection for selected alternative groups.

Initial capital costs were considered to occur in year zero (1988). Operation and maintenance costs were considered as annual costs for the lifetime of the remedial action (assumed to be 30 years), or in some cases the estimated duration of the required treatment.

Estimated capital costs, annual operation and maintenance costs, and present worth for each final remedial alternative, except the no action alternative, are summarized following the discussion of each alternative. Detailed cost breakdowns are provided in Appendices B and C.

3.5.2 Contingencies, Allowances, and Assumptions

Because this FS is conceptual and based on data available at this time, contingencies and allowances were estimated to account for unknown costs as discussed below:

- Bid Contingency - A bid contingency of 10 percent of the construction cost was used to cover unknown costs associated with a given project scope, such as adverse weather conditions and geotechnical unknowns.

- Scope Contingency - A scope contingency of 10 percent was used.

- Permitting and Legal - Five percent of the construction cost was assumed to address permitting requirements and legal fees.

- Services During Construction - 10 percent of the construction cost was assumed for supervision and administration, which includes construction management, onsite observation, change order negotiations, submittal review and office services, and engineering and design during construction.

- Engineering Design Cost - An engineering design cost of 6 to 30 percent of the construction cost was used, depending on the complexity of the alternative.

General assumptions common to all alternatives include:

- Modified Level D personal protective equipment will be required for workers directly exposed to contaminated material. Modified Level D equipment includes the following:

  a. Chemical resistant suit.
  b. Gloves - outer, chemical-protective.
  c. Gloves - inner, chemical-resistant.
  d. Boots - inner, chemical-protective, steel toe and shank.
  e. Boot covers - outer, chemical-protective, disposable.
  f. Escape mask.
  g. Safety glasses or safety goggles.
  h. Hard hat with face shield (to be used when overhead hazards exist).

  Upgrades or modification of personal protective equipment may be required as determined by the onsite Health & Safety personnel during construction.

  During construction, decontamination will be required for all vehicles and equipment having direct contact with contaminated groundwater and soils. During final demobilization of equipment, vehicles and other large equipment will be washed and steam-cleaned. Decontamination materials will be contained, sampled, analyzed and disposed as appropriate.

- Workers who will be exposed to contaminated material will receive physical examinations before and after implementing the remedial actions. Health and safety training will be required of all workers.

- A site health and safety officer will be on the property during all phases of activity involving direct worker exposure to contaminated materials.

- A Modified Level D (as is described in Section 4, Page 4-21, paragraph 4.2.1.1.4) is required for recovery and monitoring well installation.

- Monitoring well sampling requires chemically impervious gloves and boots.

3.5.3 Cost Sensitivity Analysis

Factors that may substantially affect the cost differences between alternatives are discussed for selected alternative groups. The cost sensitivity analysis assesses the effect of varying specific components or assumptions associated with each alternative. The cost sensitivity analysis identifies those cost elements or parameters that could bring about a significant change in the overall costs with only a small change in the value of the cost element or parameter.

4.0 GROUNDWATER REMOVAL AND COLLECTION

This section identifies and develops alternative control/collection pumping plans for the contaminated groundwater present in the 3 aquifer zones discussed in Section 1. One of the alternatives is the no action plan for the site as required by the NCP and SARA.

4.1 DEVELOPMENT AND SELECTION OF ALTERNATIVES

Groundwater pumping was the only control technology that passed the PELA screening (Section 2). Three groundwater pumping options were developed for evaluation purposes. A description of the development process and pumping options are given in this subsection.

4.1.1 Preliminary Groundwater Pumping Options.

The objective of groundwater pumping is to:

- Prevent the contamination in the perched aquifer from discharging into East Soldier Creek.
- Control the spread of contaminant plumes in all zones.
- Improve the water quality in all zones by removing as much contaminated water as possible and lowering the overall concentrations.
- Control the vertical migration of contaminants into lower zones.
- Protect the producing zone and therefore the drinking water supply wells.

Groundwater pumping options were developed based on the criteria described below.

- Contaminant Plume Locations. Contaminant plumes were defined during the RI by sampling and testing of the monitoring well network at the site. The concentration and spread of the TCE and Cr contaminant plumes totally encompass the plumes of all other contaminants present in the groundwater at Building 3001. Therefore, it is assumed that the control and removal of the TCE and Cr will ensure recovery of other contaminants to acceptable levels. Extraction wells were located within the TCE and Cr plume boundaries where concentrations exceed 100 ug/l.

- Groundwater Flow Parameters. The groundwater flow parameters were established from field and laboratory data obtained during the RI. Drawdown test, recovery tests, and slug tests were performed in selected monitoring wells at the site (see Appendix N of the RI Report, Reference 1). Estimates of hydraulic conductivity, transmissivity, and storage coefficient were made from these tests. Groundwater elevations were periodically recorded to establish hydraulic gradients and estimate seepage velocities. Laboratory testing was used for establishing aquifer properties such as porosity, vertical hydraulic conductivity, grain size distribution, and percent saturation. The groundwater flow parameters place limiting factors on the numbers of wells and flow rates from these wells, as discussed in Section 4.1.2.

- Physical Surface Constraints. Wells were located with respect to the physical constraints at the site to minimize the impact to normal Base operations. These physical constraints included buildings, runways, taxiways, and roads. A 200-foot clearance from the North-South runway was observed. Wells inside the building were located in high bay areas, aisleways, or areas that are easier to access, but still conducive to efficient groundwater removal. There may be some disturbance to operations in the building. The disturbance can be minimized by installing interior collection wells and piping in the evening, at night, and on weekends when industrial operations are minimal.

- Groundwater Flow and Contaminant Transport Model. The groundwater pumping plan alternatives were evaluated using a 2-dimensional groundwater contaminant transport model developed in the RI phase. The model used for the evaluations is the "Discreet Random Walk Mass Transport Model," by T.A. Prickett. Both the TCE and the Cr groundwater contamination were modeled for each aquifer zone. The model is a useful tool in making predictions of contaminant plume migrations and groundwater response to the different removal plans. The model incorporated the effects of the collection wells, with specific withdrawal rates, and aquifer characteristics in the simulation of the groundwater flow and contaminant transport over a period of continuous pumping. The location and initial flow rate of each well was input to the model, which assumed the well to be screened the full thickness of the aquifer zone. The model adjusted the rate of the pumps during the simulations to prevent complete dewatering of a well location.

  The model combines the currently available data with assumptions based on engineering judgement, knowledge of area geohydrology, and experience. The assumptions that were necessary to model the groundwater contaminant transport through the development of the no action plan are discussed in detail in Appendix K of the RI Report(1). The model assumes an average pumping rate during withdrawal, although, the actual well may be in recovery phase for a percentage of the time (i.e. pumping for seven days then recovery for three days then pumping for seven days...). Using an average pumping rate should not effect the accuracy of the model in simulating aquifer drawdowns or predicting the removal of the contaminants by the pumps. The behavior of organic compounds, other than TCE, in the groundwater were assumed to respond to the groundwater movement and pumping in the same proportion as the TCE. Similarly, inorganic compounds, other than Cr, were assumed to respond in direct proportion to the Cr. The amount of contamination, due to effects of the downward migration of contaminants from the upper zones, was included in the model as a continuous source term. This term represents the contamination that is leached from the contaminated soil above the perched aquifer and the contamination from an upper aquifer zone migrating into a lower aquifer zone. To model this site without taking into account the effects of continuous source contamination would be a gross misrepresentation. If the location of the migration pathways, volume, and concentration of the contamination coming into the aquifers were known, an exact amount of continuous source contamination could be calculated. Although this data is impossible to obtain for this site, it is known that some contamination is migrating from the soil beneath the building and from the upper aquifer zones. Therefore, assumptions based on field and laboratory data, knowledge of how the model uses each parameter, and engineering judgement were used to determine where and how much continuous source contamination to input. Calculations of the continuous source contamination were based on worst case conditions. To account for the decrease in the concentration of the continuous source, as the contamination either migrates downward or is removed by pumping, the amount of continuous source contamination being added was decreased by 10 percent each decade of simulated movement. This is also a conservative, worst case estimation. In reality, decrease is more likely to be 30 percent - 50 percent per decade. The assumptions made in the model give a good indication of the worst case reactions of the contaminant plumes to time and the effects of pumping in each aquifer zone. An objective of the modeling was to see how effective the pumping plans would be even under the most adverse conditions. It should be remembered that the model indicates trends only, and should not be expected to predict concentrations more accurately than an order of magnitude. Due to the lack of historical geohydrologic data and the extreme heterogeneous characteristics of these aquifer zones, an uncertainty of as much as 10 percent to 15 percent is introduced in the model; therefore a recovery of 85 to 90 percent of the contamination should be considered to be within the technological and/or economical limits of the remediation.

This percentage of recovery indicates a remediation of the contamination currently present in the groundwater as well as the majority of the continuous source contamination that is introduced over time.

After pumping is begun at the site, the wells should be monitored and data collected to refine the pumping plan for maximum efficiency. Also, the model should be updated with the additional geohydrologic and chemical data to improve the accuracy of predicting the groundwater reactions.

4.1.2 Selection and Description of Alternatives for Final Evaluation. Groundwater pumping plans were assembled based on several parameters, including the number of wells within each aquifer (as many as 100 wells to as few as one or two per aquifer), which of the aquifer zones to pump from, and the pumping rate from each well. As a result of preliminary evaluations of these parameters, it was determined that when a large number of wells are pumped from an aquifer, the flow rate for individual wells will have to be low to prevent the wells from pumping dry shortly after pumping begins. A minimum initial flow rate of 100 gallons per day (gpd) was used. If the computer model predicted that a collection well at a specific location could not produce this quantity of flow without going dry within the first year of pumping, this well location was deleted from the plan. Also, pumping a low number of wells at a high rate is ineffective since the aquifer zone immediately adjacent to the well is quickly dewatered without affecting the contamination outside of a small area of influence. Therefore, an optimum range for the number of wells - that steadily pump low volumes of groundwater over a long period of time proved to be the most efficient strategy for effective removal of the contaminated water. Optimum well locations, number of wells, and pump flow rates for each well were determined during this process. Based on this preliminary analysis, three groundwater pumping plan alternatives were selected to be completely developed using the groundwater and contaminant transport model and to be evaluated with respect to the feasibility study - process. These alternatives are listed and described below:

4.1.2.1 Alternative 1-1 - No Action. This alternative, required by the NCP and SARA, was used to compare the effectiveness of the other alternatives. The no action alternative does not involve any pumping from the contaminated aquifers but does include monitoring of the groundwater contaminant plumes and surface water monitoring at East Soldier Creek. The monitoring well network would consist of 18 new stainless steel wells

BUILDING 3001 MONITORING WELL CLUSTER

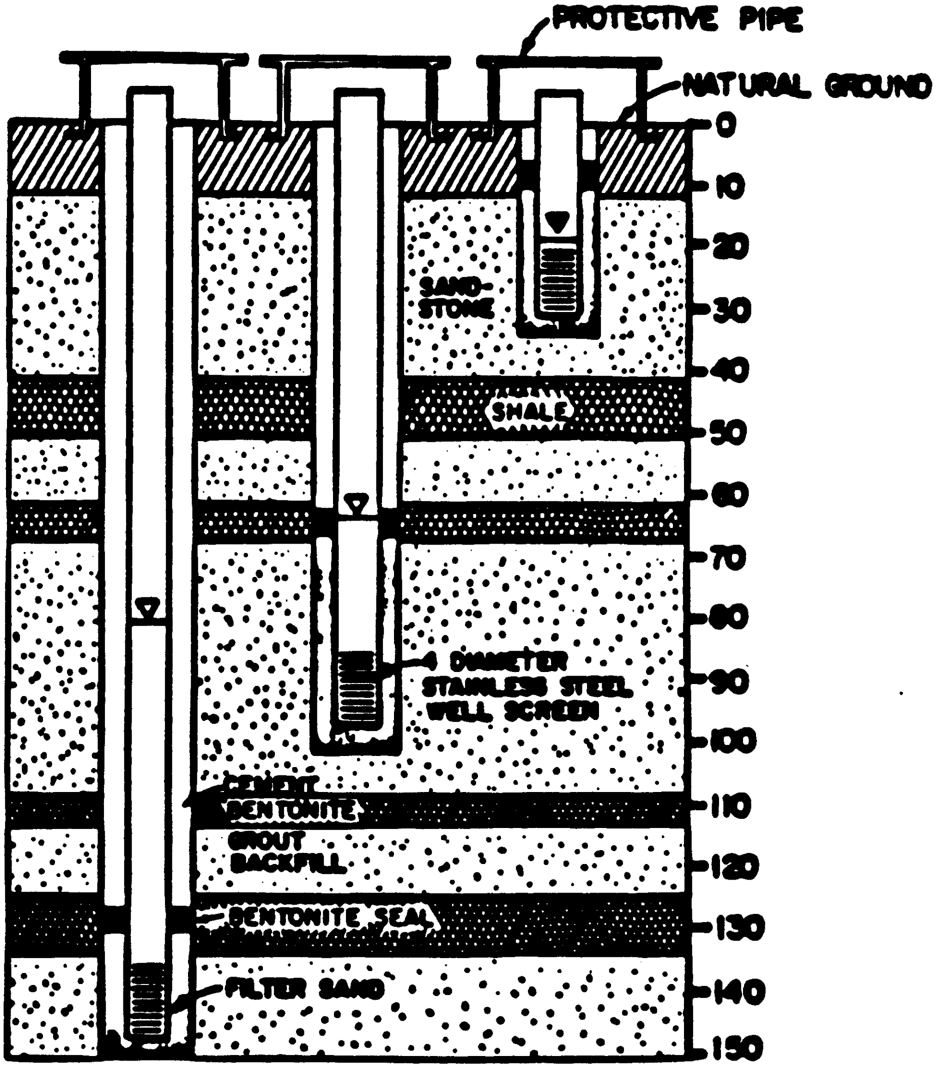


FIGURE 4-1

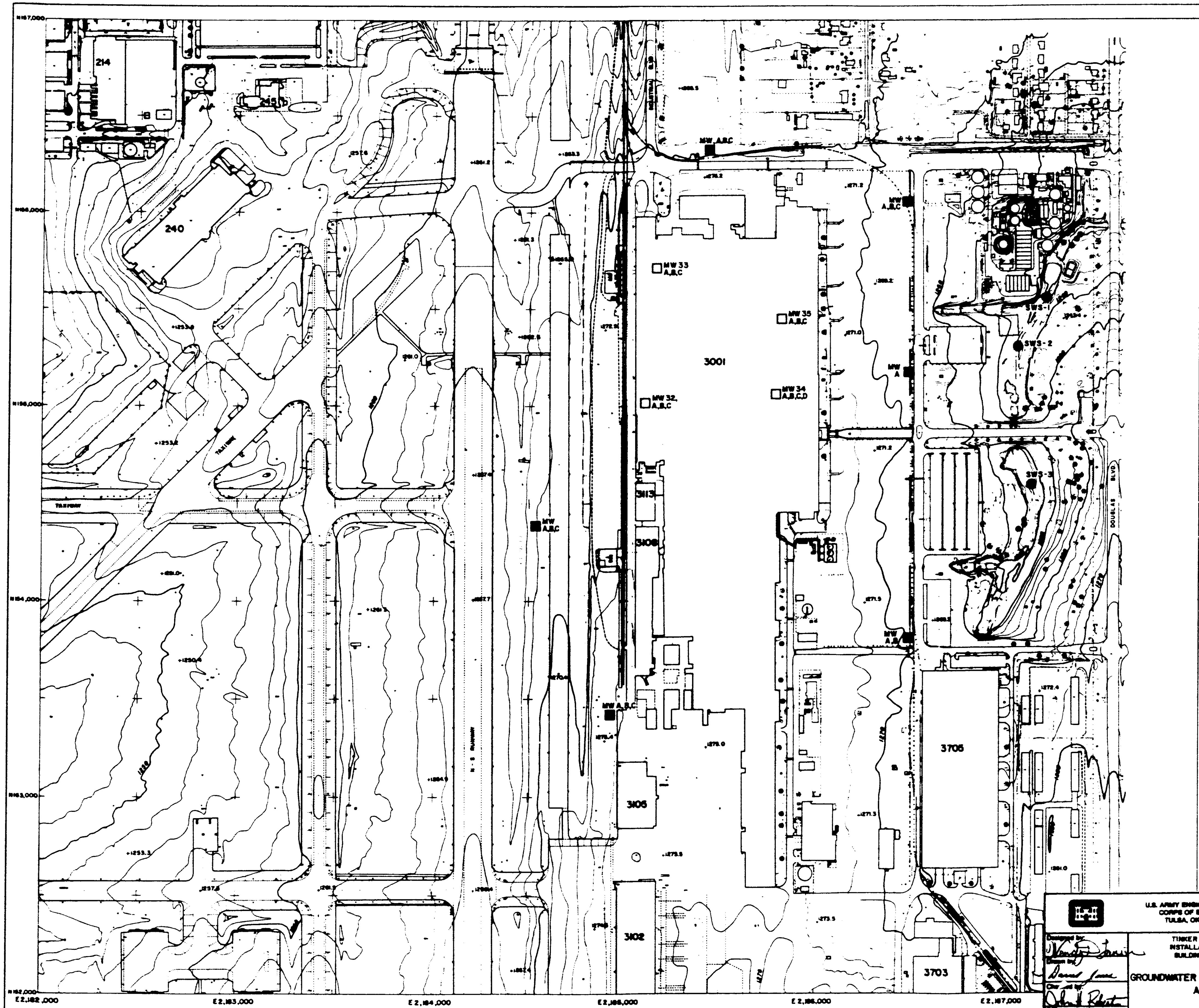
combined with 13 existing stainless steel wells. Dedicated stainless steel and teflon purge and sample pumps would be installed in each well. A typical three aquifer zone well cluster is shown in Figure 4-1. Groundwater monitoring would enable the plume migration to be observed so that any increase in risk to the public or environment could be evaluated. The existing contaminant concentration plumes are shown in the RI Report(1) drawings 10 through 36.

- <u>Perched Aquifer.</u> The monitoring well network for the perched aquifer would consist of four existing stainless steel monitoring wells located inside Building 3001 and seven new monitoring wells outside the building. The three surface water sampling points would be in the area of groundwater discharge and upstream and downstream of the area of discharge. The surface water sampling of East Soldier Creek would be necessary for Alternative 1-1 since the perched aquifer is discharging into the creek in north east portion of the site. Locations of the perched aquifer monitoring well network and the surface water sampling points are shown on Figure 4-2.

- <u>Top-of-Regional Zone.</u> The monitoring well network for this zone would also consist of four existing interior stainless steel monitoring wells and six new exterior monitoring wells. Locations for the top of regional zone monitoring well network are shown on Figure 4-2.

- <u>Regional Zone.</u> There are five interior stainless steel monitoring wells for the regional zone. Two of the wells are at the same location but are screened at different depths (34C and 34D). Also included in this monitoring well network are five new exterior wells. Locations of the existing monitoring wells and the new wells are shown on Figure 4-2.

4.1.2.2 <u>Alternative 1-2 - Groundwater Removal from Exterior Wells Only.</u> This alternative includes pumping groundwater from 111 extraction wells located around the exterior of Building 3001 at a combined flow rate of 71,820 gpd or 50 gallons per minute (gpm), as well as the groundwater monitoring described for Alternative 1-1 (with the exception of the surface water sampling. Surface water sampling would not be necessary with Alternative 1-2 since the pumping in the perched aquifer would prevent the contaminant plumes from reaching East Soldier Creek. Figure 4-3 shows locations for Alternative 1-2 extraction wells and the monitoring wells. The areas of highest contaminant concentrations, directly under the Building 3001, would not be directly pumped by this alternative.



LEGEND

PERCHED AQUIFER WELL (A-WELL)

TOP OF REGIONAL ZONE WELL (B-WELL)

REGIONAL ZONE WELL (C-WELL)

□ EXISTING MONITORING WELL CLUSTER TO BE USED

■ NEW MONITORING WELL CLUSTER

● SURFACE WATER SAMPLING PO

NOTE: WELL CLUSTERS CONTAIN AN INDIVIDUAL WELL LOCATED IN EAC RESPECTIVE AQUIFER ZONE. INDIVIDUA WELLS IN CLUSTER ARE HORIZONTALL SPACED 5 FEET APART.

NOTE: Topographic mapping performed by Westport Consultants for Tinker Air Force Base (Aug. 85) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE
AIRFIELD ELEVATION 1292 FEET

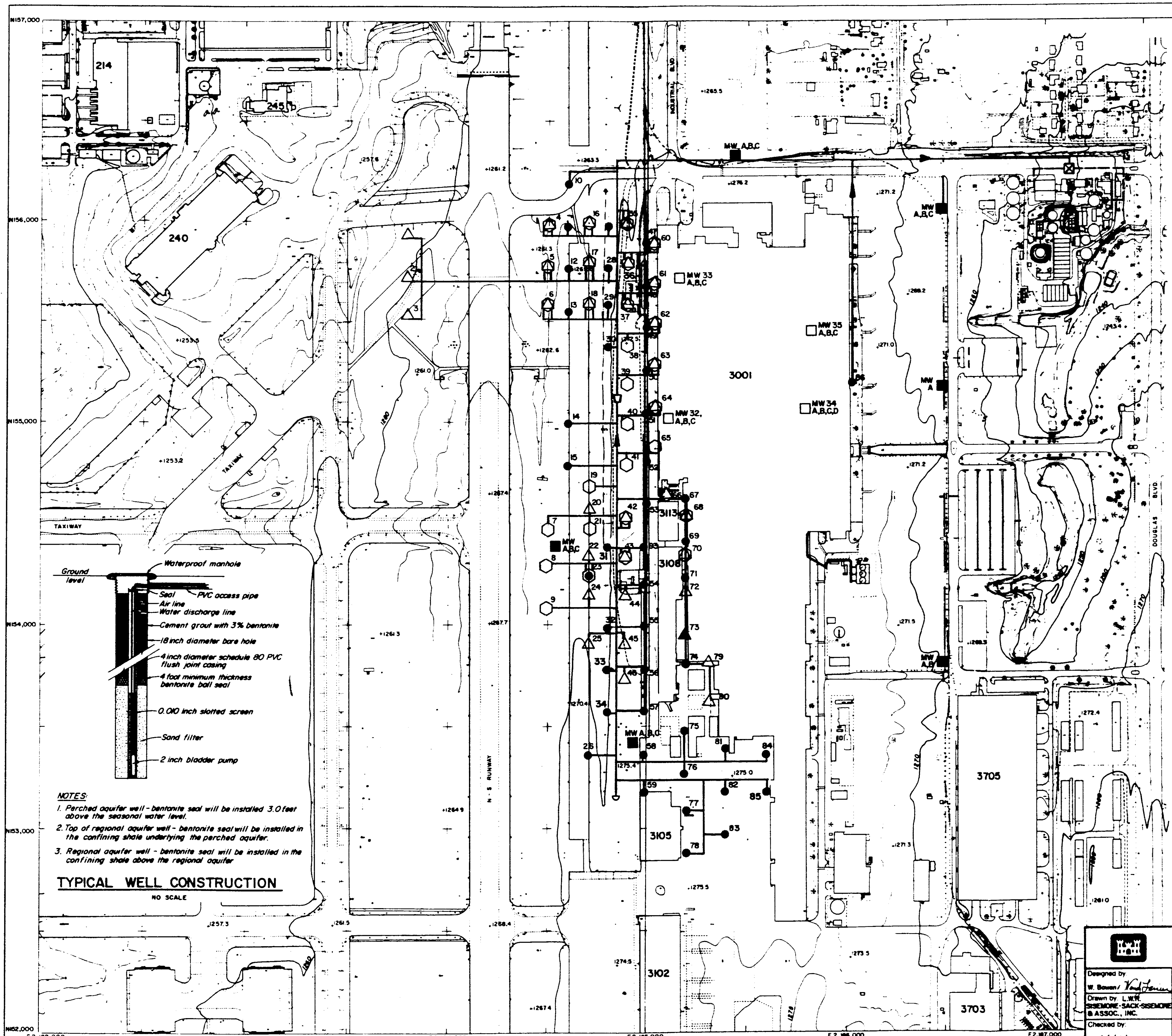
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001/FEASIBILITY STUDIES

Designed by:
Drawn by:
Chr. ... by:
Submitted by:
Geotechnical Branch

GROUNDWATER CONTROL/ COLLECTION PLA
ALTERNATIVE 1-1

FIGURE 4-2



LEGEND

- ● PERCHED AQUIFER COLLECTIO[N] WELL (A-WELL)
- △ TOP OF REGIONAL ZONE COLL[ECTION] WELL (B-WELL)
- ⬡ REGIONAL ZONE COLLECTION [WELL] (C-WELL)
- ▲ A and B WELL CLUSTER
- A and C WELL CLUSTER
- B and C WELL CLUSTER
- A, B and C WELL CLUSTER
- □ EXISTING MONITORING WELL CLUSTER TO BE USED
- ■ NEW MONITORING WELL CLUST[ER]
- —— GROUNDWATER COLLECTION PIPING
- ☒ NEW IWTP MODIFICATION OR NEW GROUNDWATER TREATMENT PLANT
- - - - NEW FACILITIES OUTLET LINE

NOTE: WELL CLUSTERS CONTAIN AN I[NDI]VIDUAL WELL LOCATED IN EACH RESPECTIVE AQUIFER ZONE. INDIVID[UAL] WELLS IN CLUSTER ARE HORIZONTAL[LY] SPACED 5 FEET APART.

NOTE: Topographic mapping performed by Wassport Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4

100 0 100 200 300
SCALE

NOT FOR CONSTRUCTION

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

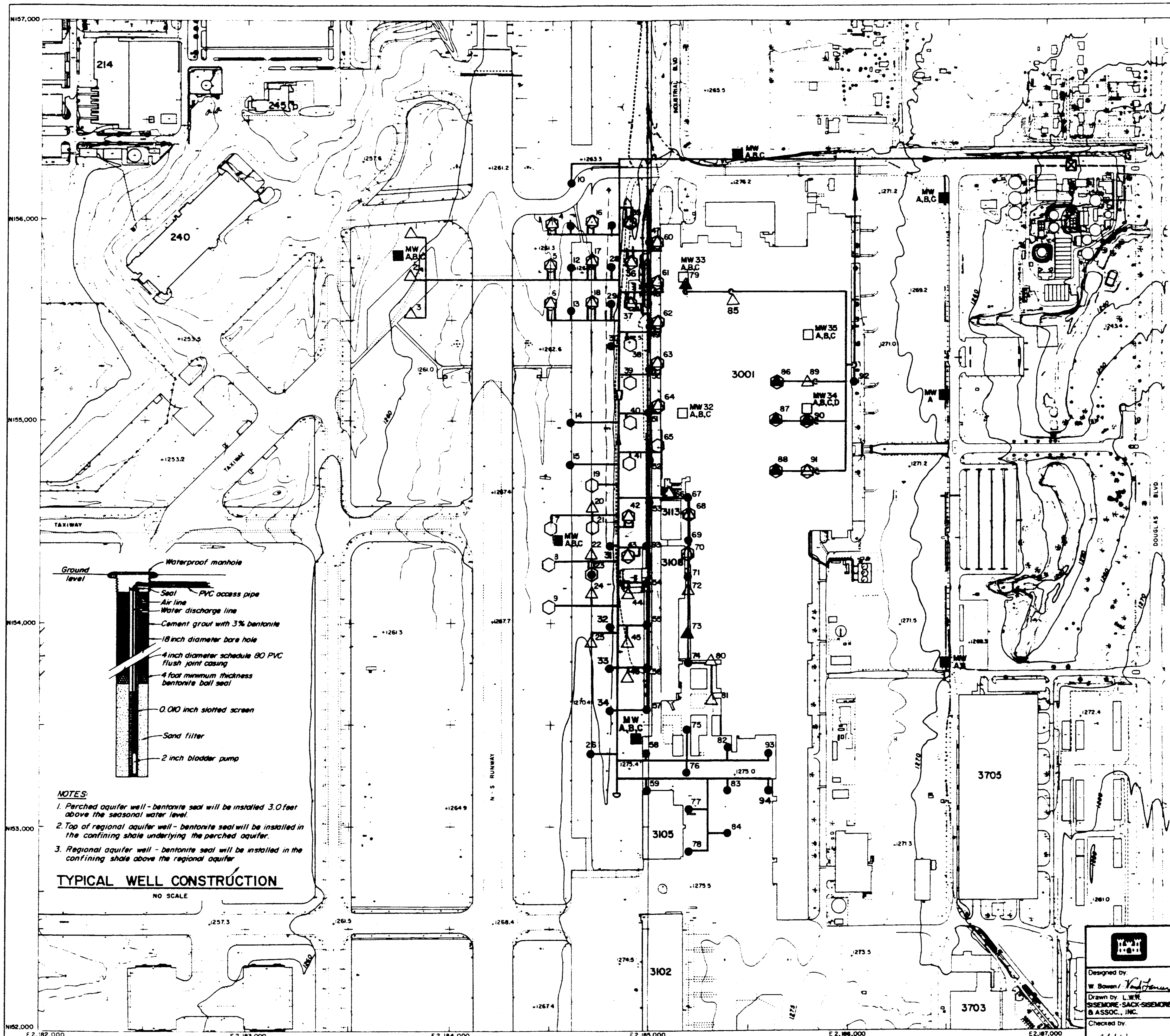
Designed by W. Bowen/	TINKER AIR FORCE BASE, OKLAHOMA INSTALLATION RESTORATION PROGRAM BUILDING 3001/FEASIBILITY STUDIES
Drawn by L.W.W. SISEMORE-SACK-SISEMORE & ASSOC., INC.	
Checked by	GROUNDWATER CONTROL/COLLECTION P[LAN] ALTERNATIVE I-2
Submitted by Chief, Geotechnical Branch	FIGURE 4-3
Date: NOVEMBER 1988	Dw[g]

- Perched Aquifer. Forty-five wells would be installed and pumped in the perched aquifer. Although the perched aquifer has groundwater movement to the east toward Soldier Creek, only one well would be installed east of the building. This is due to the extreme thinness of the aquifer toward the creek. (It can have seasonal decreases in thickness to less then one foot.) When collection wells were placed on this side they invariably would go dry in less then one year with the flow rates of 100 gpd. This criteria was used as a lower efficiency limit to select well locations. The individual wells would operate at flow rates between 150 and 500 gpd. The combined flow rate would be 19,520 gpd. Appendix A, Table A-1 gives locations in state plane coordinates, pump rates, screen depths and other pertinent information for the wells in this aquifer.

- Top of regional zone. Thirty four wells would be installed and pumped in the top-of-regional zone. Groundwater flow in this zone is in the southwest direction. Therefore, collection wells will be installed in this zone to the south and to the west of Building 3001. Individual wells would operate at flow rates of 100 to 500 gpd. The combined flow rate would be 12,700 gpd. Appendix A, Table A-2 gives locations in state plane coordinates, pump rates, screen depths and other pertinent information for the wells in this aquifer.

- Regional zone. Thirty two wells would be installed and pumped in the regional zone. Individual wells would operate at flow rates of 720 to 1,440 gpd. The combined flow rate would be 39,600 gpd. The groundwater flow in this zone is to the southwest. Therefore, collection wells will be installed in the building where concentrations are the highest, south of the building and west of the building. Appendix A, Table A-3 gives locations in state plane coordinates, pump rates, screen depths and other pertinent information for the wells in this aquifer.

4.1.2.3 Alternative 1-3 - Exterior and Interior Groundwater Removal. Alternative 1-3 has the same well layout as Alternative 1-2 with the addition of wells located in the building interior. The 111 exterior wells would be combined with 18 interior wells and pumped at a total flow rate of 88,180 gpd or 62 gpm. The groundwater monitoring described for Alternative 1-1 (with the exception of the surface water sampling) would also be performed under this alternative. Surface water sampling would not be necessary with Alternative 1-3 since the pumping in the perched aquifer would prevent the contaminant plumes from reaching East Soldier Creek. Extraction well and monitoring well locations for this alternative are shown on Figure 4-4. Although this alternative would be more disruptive to the operations in the building, it would include groundwater collection



LEGEND

- ● PERCHED AQUIFER COLLECTION WELL (A-WELL)
- △ TOP OF REGIONAL ZONE COLLECTION WELL (B-WELL)
- ⬡ REGIONAL ZONE COLLECTION WELL (C-WELL)
- ▲ A and B WELL CLUSTER
- A and C WELL CLUSTER
- B and C WELL CLUSTER
- A, B and C WELL CLUSTER
- □ EXISTING MONITORING WELL CLUSTER
- ■ NEW MONITORING WELL CLUSTER
- —— GROUNDWATER COLLECTION PIPING
- ⊠ NEW IWTP MODIFICATION OR NEW GROUNDWATER TREATMENT PLANT
- - - - NEW FACILITIES OUTLET LINE

NOTE: WELL CLUSTERS CONTAIN AN INDIVIDUAL WELL LOCATED IN EACH RESPECTIVE AQUIFER ZONE. INDIVIDUAL WELLS IN CLUSTER ARE HORIZONTALLY SPACED 5 FEET APART.

NOTE: Topographic mapping performed by Woolpert Consultants for Tinker Air Force Base (Aug. 86) as part of Base Comprehensive Planning Directive AFR 86-4.

100 0 100 200 300
SCALE
NOT FOR CONSTRUCTION

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

Designed by: W. Bowen/
Drawn by: L.W.H. SISEMORE-SACK-SISEMORE & ASSOC., INC.
Checked by:
Submitted by:
Chief, Geotechnical Branch

TINKER AIR FORCE BASE, OKLAHOMA
INSTALLATION RESTORATION PROGRAM
BUILDING 3001/FEASIBILITY STUDIES

GROUNDWATER CONTROL/COLLECTION PLAN
ALTERNATIVE I-3

FIGURE 4-4

Dwg. No.

Date: NOVEMBER, 1988

from the areas of the plume with the highest contaminant concentrations. The interior collection wells would be located in either high bay areas or near aisleways to facilitate construction and minimize disturbance of normal operations.

- o <u>Perched Aquifer.</u> Fifty wells would be installed and pumped in the perched aquifer. Although the perched aquifer has groundwater movement to the east toward Soldier Creek, only one well would be installed east of the building. This is due to the extreme thinness of the aquifer toward the creek. (It can have seasonal decreases in thickness to less then one foot.) When collection wells were placed on this side they invariably would go dry in less then one year with flow rates of 100 gpd. This criteria was used as a lower efficiency limit to select well locations. The individual wells would operate at flow rates between 150 and 520 gpd. The combined flow rate is 20,830 gpd. Appendix A table A-4 gives locations in state plane coordinates, pump rates, screen depths and other pertinent information for each individual well.

- o <u>Top of Regional Zone.</u> Forty two wells are pumped from the top of regional zone. Groundwater flow in this zone is in the southwest direction. Therefore, collection wells will be installed in the building where concentrations are highest, south of the building and west of the building. Individual wells would operate at flow rates of 100 to 500 gpd. The combined flow rate is 13,350 gpd. Appendix A, table A-5 gives locations in state plane coordinates, pump rates, screen depths and other pertinent information for each individual well in this aquifer.

- o <u>Regional Zone.</u> Thirty seven wells are pumped from the regional aquifer. Individual wells would operate at flow rates of 720 to 2,880 gpd. The combined flow rate would be 54,000 gpd. The groundwater flow in this zone is to the southwest. Therefore, collection wells will be installed in the building where concentrations are highest, south of the building and west of the building. Appendix A, Table A-6 gives locations in state plane coordinates, pump rates, screen depths and other pertinent information for each individual well in this aquifer.

4.2 EVALUATION OF GROUNDWATER PUMPING ALTERNATIVES.

The three groundwater pumping alternatives described above are evaluated in this section with regard to engineering feasibility, public health impacts, environmental impacts, institutional requirements and cost. The rating system is based on a 1 (best) to 5 (worst) scale. The rating system is described in detail in Section 3.

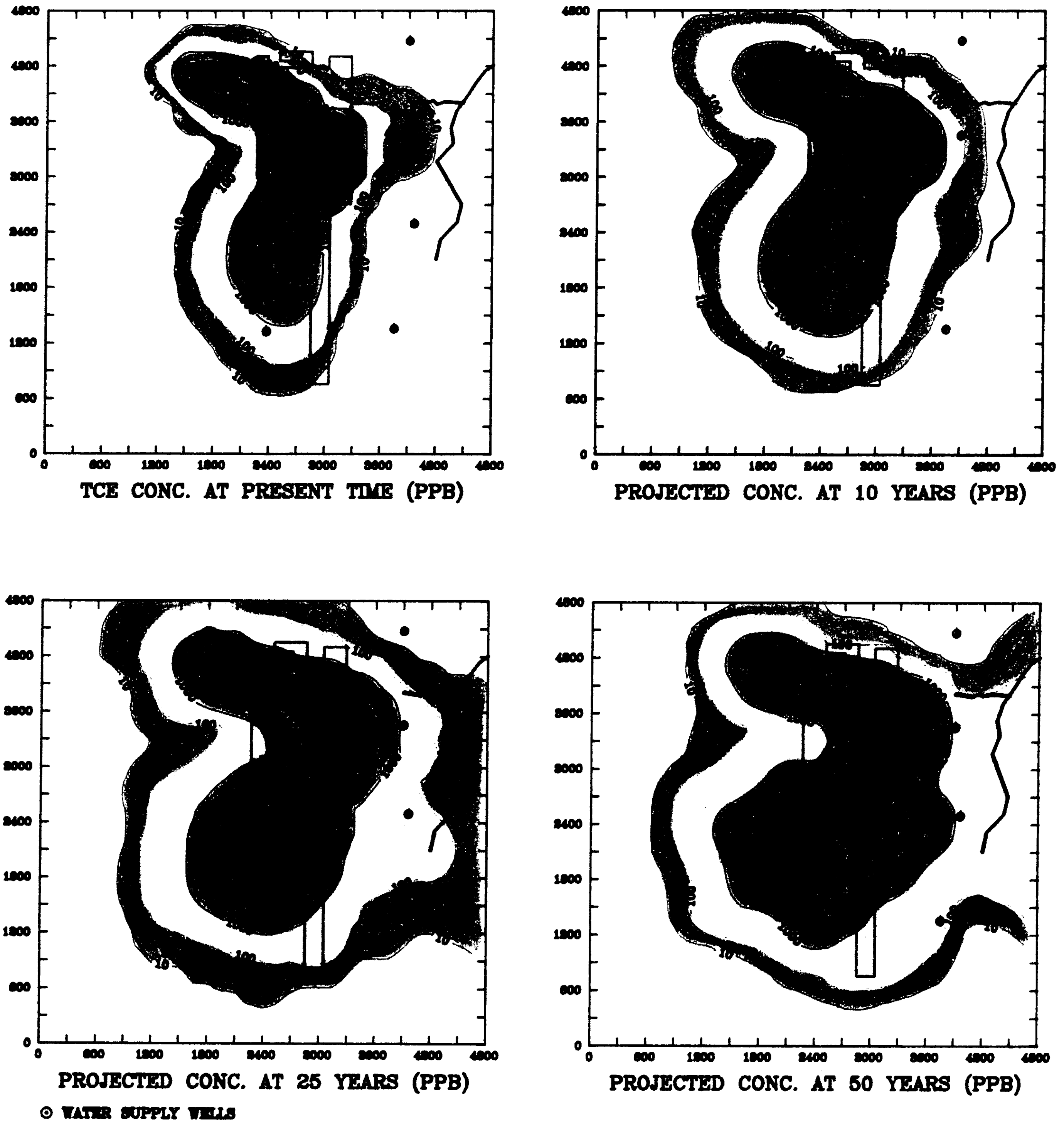
The conformance with ARARs portion of the institutional screening is based on the standards applicable to groundwater used for drinking water supplies as set forth in the Oklahoma Water Quality Standards Section 8, and the Safe Drinking Water Act. The maximum contaminant levels (MCLs) listed in these standards apply only to portions of aquifers that are current or future sources of drinking water. The MCL's do not apply to the contaminant plumes in the upper unused aquifer zones beneath the Building 3001 site since they are not current or future sources of drinking water. Two performance based standards listed in the standards are applicable to the Building 3001 site. These standards require that remedial actions (1) mitigate or prevent the threat of contamination of major groundwater basins such as the producing zone of the Garber-Wellington Aquifer, and (2) mitigate or reduce the likelihood of present or future threat to public health and the environment. Therefore, the selected remedial action must prevent the migration of the existing contamination in the upper zones into the producing zones.

4.2.1 Alternative 1-1 - No Action.

4.2.1.1 Engineering Feasibility. The Alternative 1-1 rating for engineering feasibility criteria are listed below:

Criteria	Rating
Performance	
o effectiveness	5
o effectiveness	5
o useful life	2
Reliability	
o operation & maintenance	2
o demonstrated performance	1
Implementability	
o constructability	1
o time to implement	1
o time for results	5
Safety	1
Normalized Rating	2.25

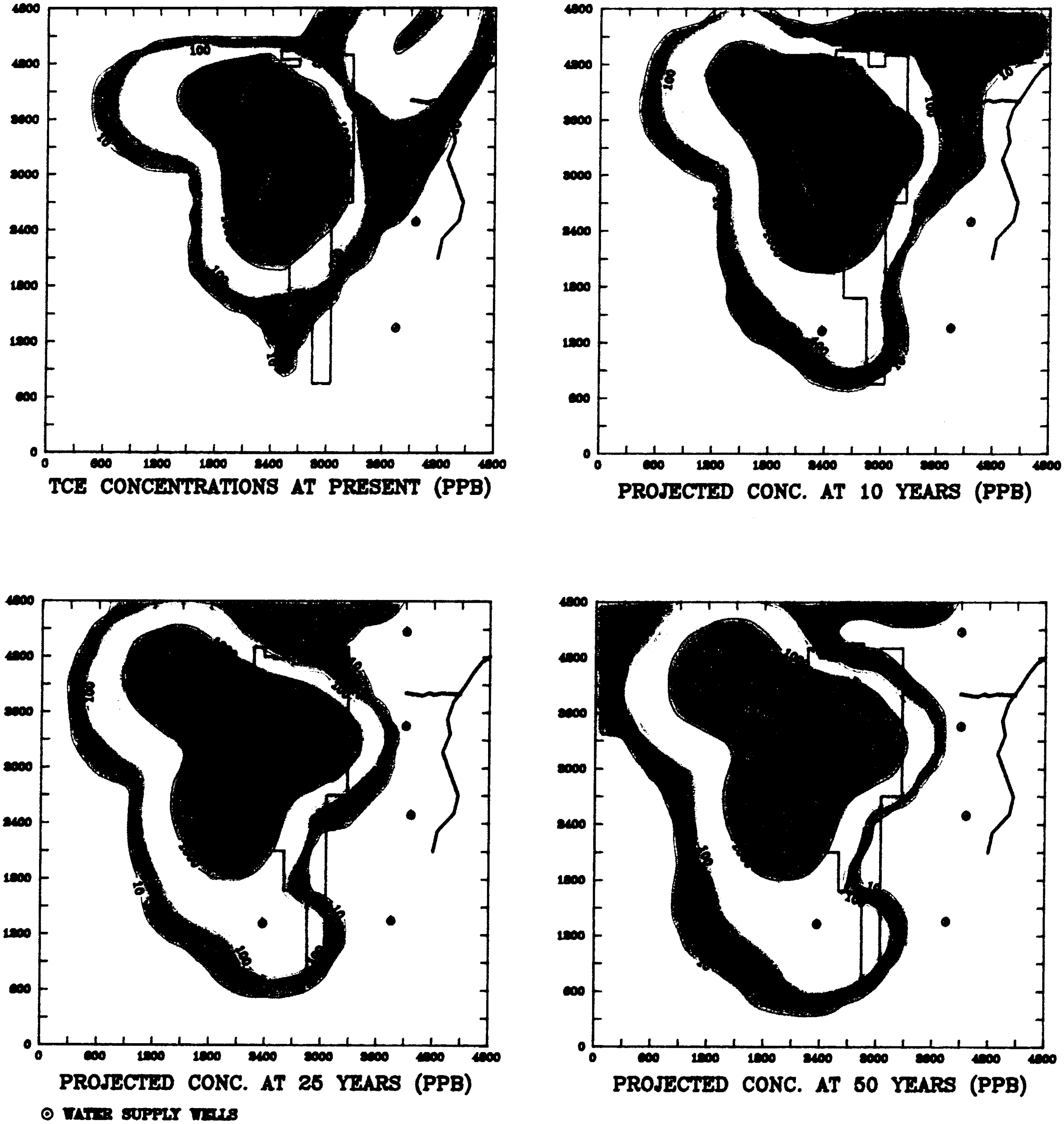
The following subsections present the analysis of the criteria that resulted in these ratings.



ALTERNATIVE 1-1

TCE PLUMES IN THE PERCHED AQUIFER AT 3001

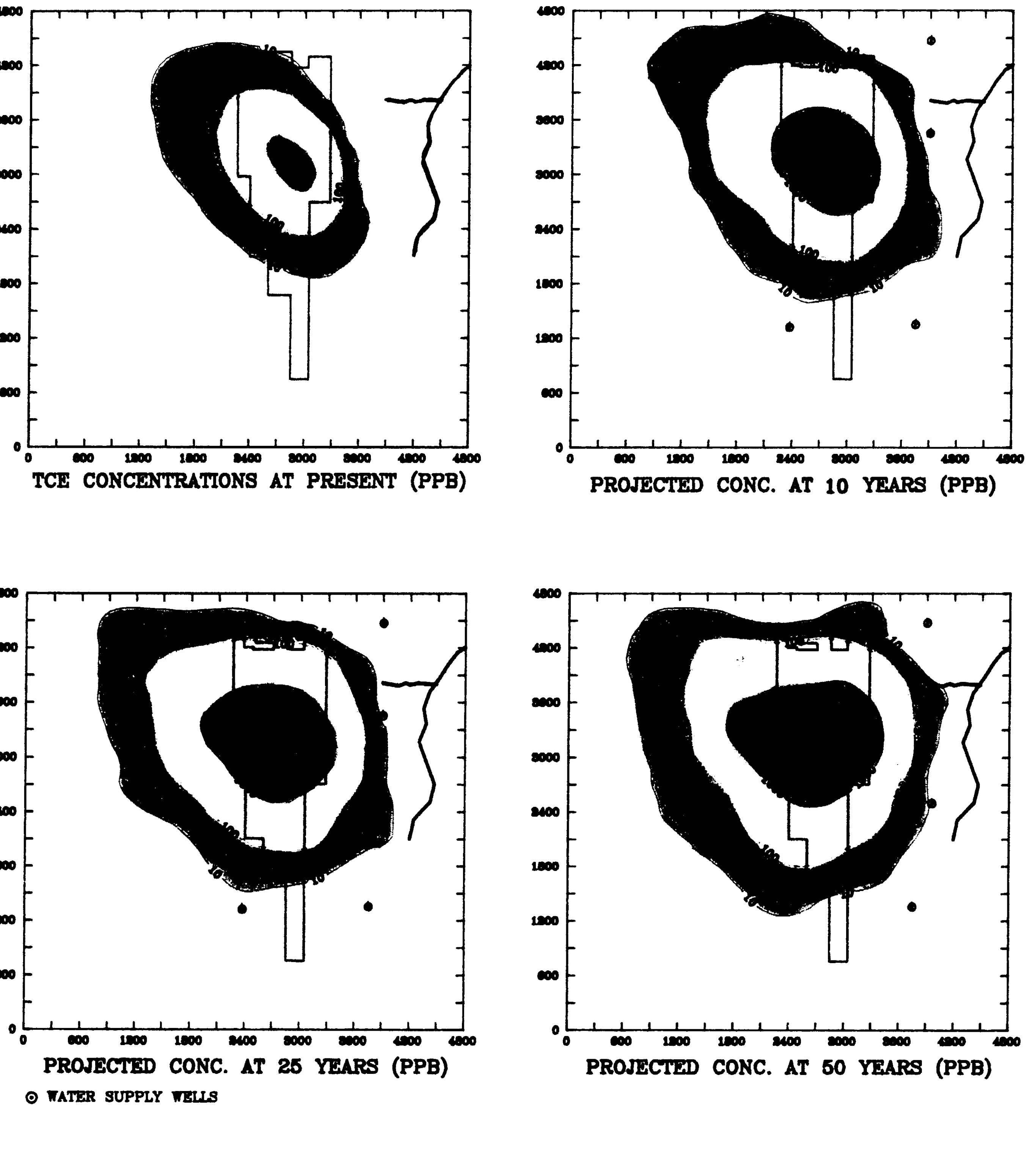
FIGURE 4-5



ALTERNATIVE 1–1

TCE PLUMES IN THE TOP OF REGIONAL ZONE

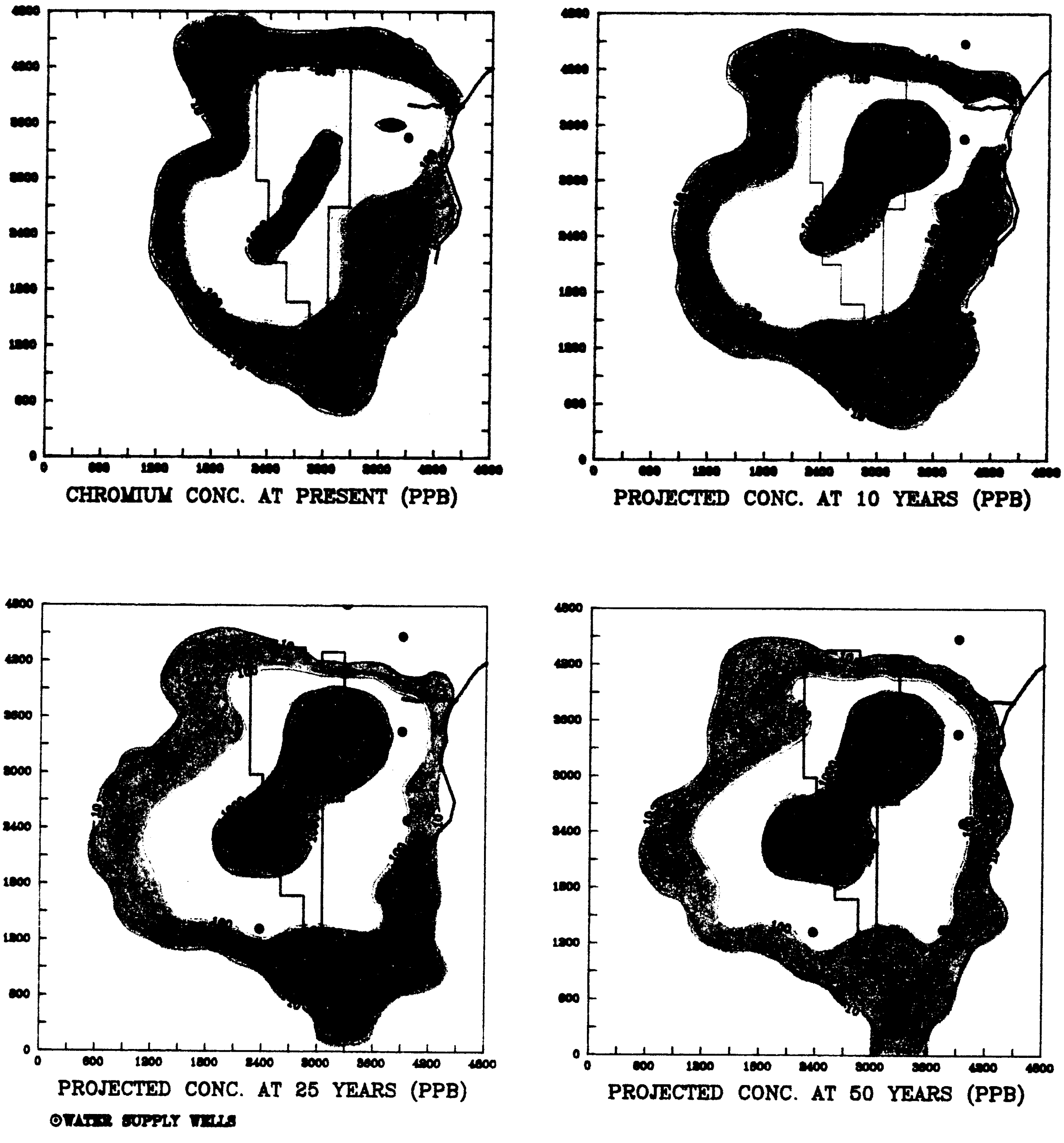
FIGURE 4–6



ALTERNATIVE 1-1

TCE PLUMES IN THE REGIONAL ZONE

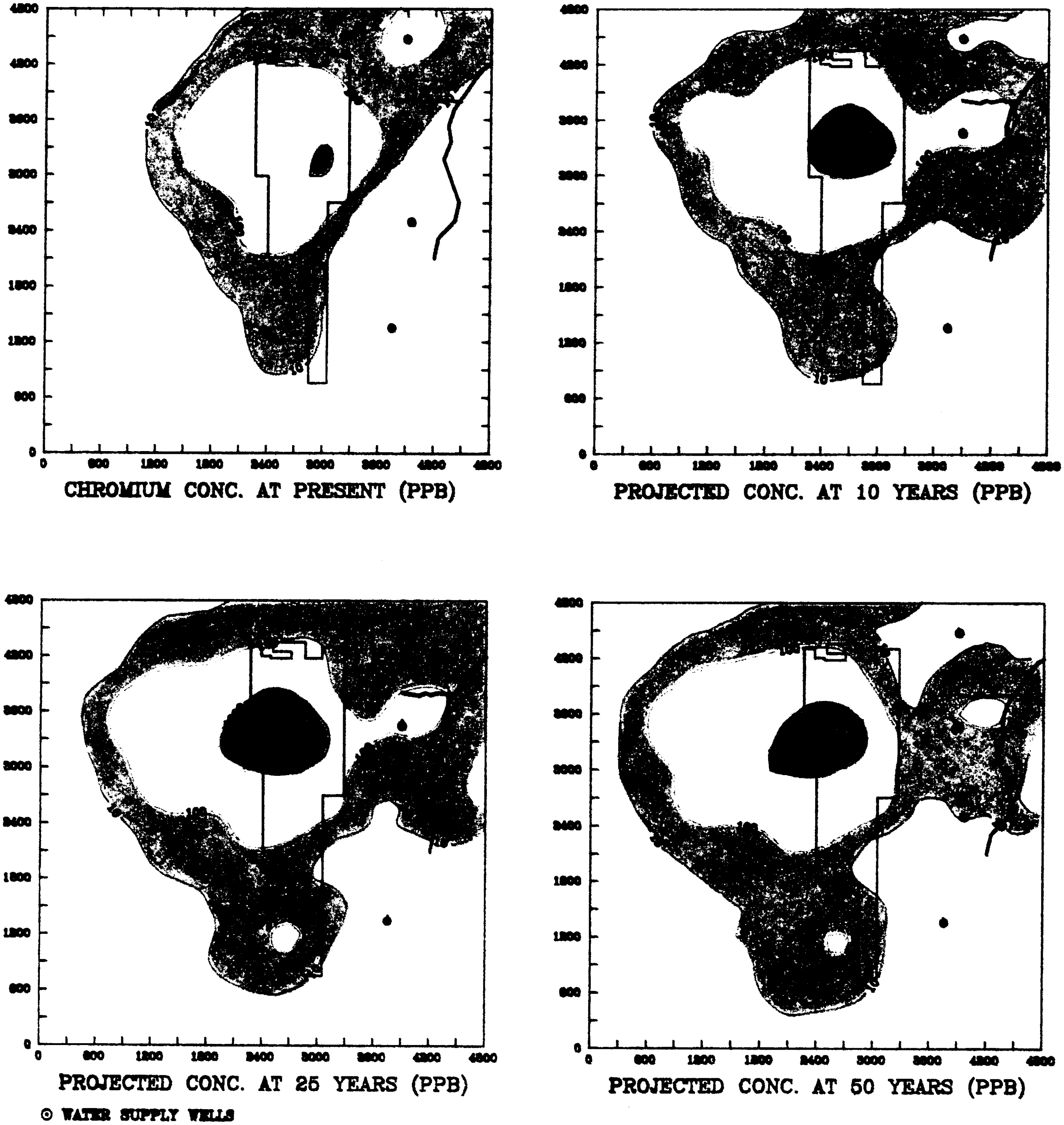
FIGURE 4-7



ALTERNATIVE 1−1

CHROMIUM PLUMES IN PERCHED AQUIFER AT 3001

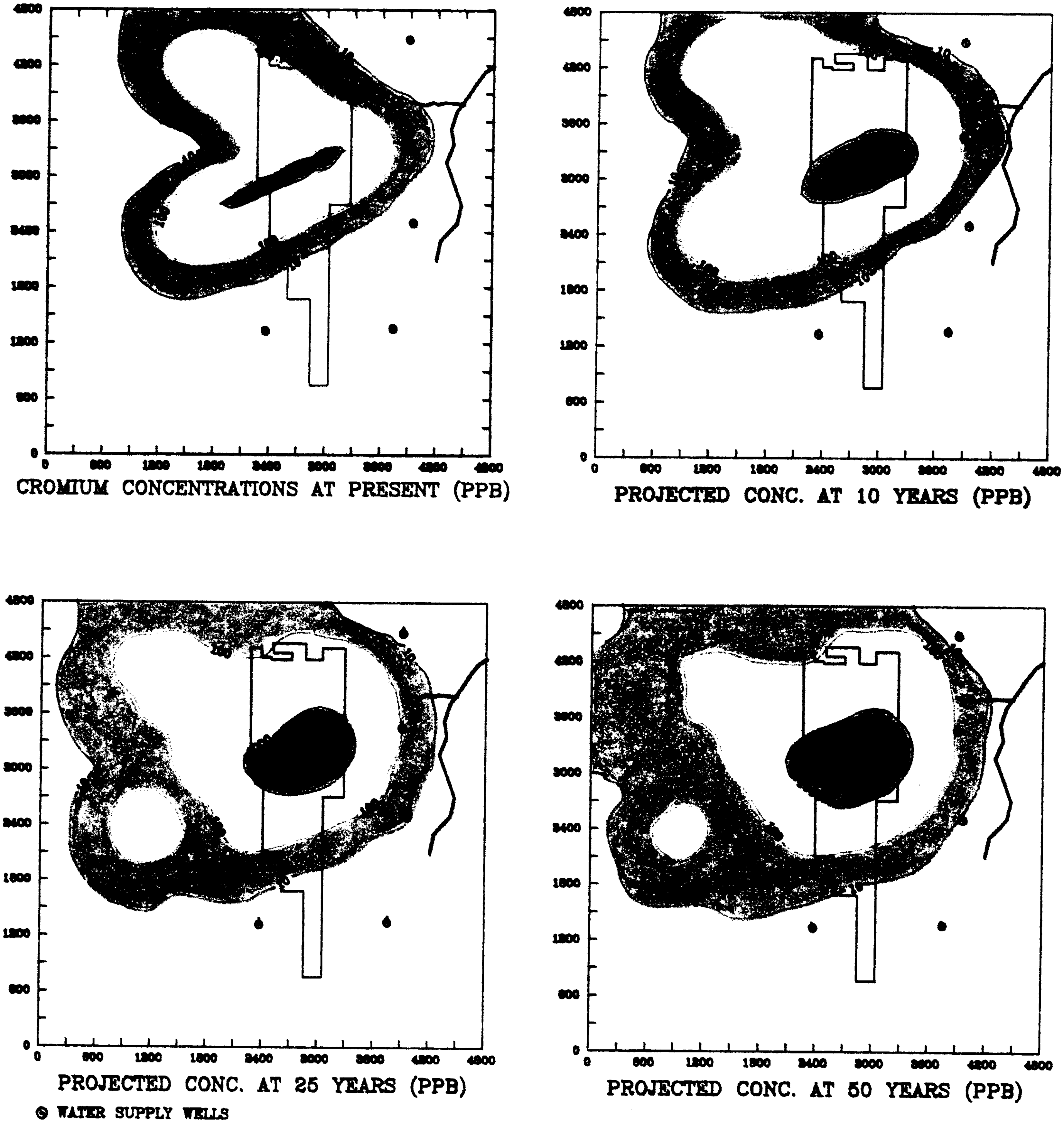
FIGURE 4−8



ALTERNATIVE 1-1

CR PLUMES IN THE TOP OF REGIONAL ZONE

FIGURE 4-9



ALTERNATIVE 1-1

CHROMIUM PLUMES IN THE REGIONAL ZONE

FIGURE 4-10

4.2.1.1.1 Performance. Alternative 1-1 would provide an indication of the migration of the contaminants and warning of the completion of an exposure pathway. Monitoring would not, however, be effective in remediating the contamination. Figures 4-5 through 4-10 show the current TCE and Cr plumes in the perched, top of regional, and regional zones and predicted plumes after 10, 25, and 50 years of simulated migration under the no action plan. As is discussed in Chapter 8 of the RI report(1), rain water percolating through the contaminated soils above the perched aquifer will contribute contaminants to the aquifer. This process will continue for several years into the future but should decline as the soils are cleansed of contamination. Downward vertical migration of contaminated water from the perched aquifer is predicted to continue and will increase the amount of contamination in the top of regional zone. Likewise, the vertical migration of contaminated water from the top of regional zone will continue to be a source of contamination to the regional zone. If left undisturbed, this vertical migration will result in the perched aquifer becoming less contaminated with time but the top of regional and regional zones becoming considerably more contaminated. The vertical migration from the regional zone would eventually increase the contaminant concentrations in the producing zone of the Garber-Wellington Aquifer to levels above current MCLs. Since only the upper three aquifer zones were modeled with the two-dimensional Random Walk Model, the predictions for the concentrations in the Producing Zone were calculated using a one-dimensional Vertical-Horizontal spread model developed by the EPA. The input data for the model was obtained by using current concentration ratios between the Perched, Top-of-Regional, and Regional zones and the Producing aquifer zon-e to convert future predicted upper zone concentrations (from the 2-dimensional modeling results) to predicted lower zone concentrations.

The horizontal migration of the contaminant plumes, to the east, in the perched aquifer is predicted to result in discharge of contaminated water into Soldier Creek in approximately 5 years. Although the vertical migration will decrease the amount of contaminants in the perched aquifer, the horizontal movement of the perched groundwater to the west, southwest, and east will result in an increase in the volume of contaminated water in the perched zone. Likewise, the horizontal migration to the southwest of the contaminant plumes in the top of regional and regional zones will increase the volume of contaminated water in each of these aquifers. The effectiveness rating of this alternative in meeting the objective of the site remediation is 5.

The monitoring well network described for Alternative 1-1 would be effective to observe the groundwater contamination until such time as the horizontal spread of the plumes went beyond the monitoring wells. As the leading edge of contaminant plume moves, new wells may be required to accurately monitor the contamination in the groundwater. The useful life rating for this alternative is 2.

4.2.1.1.2 Reliability. The monitoring well networks for each zone are a proven and reliable technology to monitor the threat to public health or the environment. The rating for demonstrated performance for Alternative 1-1 is 1.

The monitoring wells will require very little maintenance. Occasionally wells may have to cleaned out as sediments enter the screens and fill up the bottom of the well and prevent a sample from being collected. The wells will have to be protected from contamination from the surface, construction accidents, and damage to the wells resulting from normal site operations. The operation of the monitoring well network will require sampling on a semiannual basis and coordination and analysis of testing results. Sampling must be done by trained personnel and all procedures for sampling dedicated monitoring wells listed in Appendix H of the RI Report(1) will be followed. Sampling of the surface water will be done on a quarterly basis by trained personnel using an alpha sampler at one half the stream depth and on the stream surface to collect a composite sample. The rating for operation and maintenance is 2.

4.2.1.1.3 <u>Implementability.</u> Over a third of the required monitoring wells are already installed. These are the 13 interior wells which could be the most difficult to install. Construction of the 18 new wells will require drilling equipment with the capability of drilling at least an eight inch diameter hole to at least a depth of 150 feet. Installation of the monitoring wells should follow the same procedures as is described in the RI Report[1] Section 8.1.b. The surface water sampling points in East S-oldier Creek should have a permanent concrete marker installed at each location. The constructability rating for Alternative 1-1 is 1.

The new monitoring wells can probably be constructed in six weeks, once a qualified driller has been contracted. Sampling of the monitoring well network and the surface water will require approximately 2 weeks. Testing results of the water samples will take an additional six to eight weeks. The rating for time to implement is 1.

Monitoring of the groundwater at the site will continue for an indefinite time period if no action is taken to remediate the site. The only justification to end the monitoring would be if and when the aquifer zones clean themselves by dilution or attenuation of the contaminants. The rating for time for results is 5.

4.2.1.1.4. <u>Safety.</u> Installation of the monitoring wells will require modified level D worker protection. This will include chemically impervious steel toed boots and chemically impervious gloves (under cotton gloves), hard hat, protective disposable coveralls. Eye protection will be worn during drilling and installation of the monitoring wells. Air monitoring in the breathing zone will be done with a photoionizaton meter and a combustible gas meter. All personnel involved with the well installation will be required to have air purifying respirators with organic vapor cartridges should the air monitoring indicate a need. The requirement for respirators or self contained breathing apparatuses will be determined by a certified industrial hygienist. Sampling of the monitoring wells will require chemically impervious gloves and boots. Surface water sampling will require chemically impervious gloves and waders. The Tinker

Air Force Base, Installation Restoration Program, Safety and Occupational Health Plan For Corps of Engineers Personnel will be followed as a minimum. The rating for safety is 1.

4.2.1.2 Public Health Impacts. The public health impacts of the no action alternative were assessed in the baseline risk assessment of the groundwater contamination of Building 3001 site. As a result of the predicted contamination of several water supply wells, a complete pathway of exposure exists. The no action alternative would continue to allow that groundwater pathway to be complete. Although short-term risk analysis from that pathway failed to show potential public health impacts from present levels of contamination in drinking water wells, future migration from the perched aquifer would increase contaminant concentrations to levels greater than Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs) and create potential long-term health risks. Continued migration of the contaminant plume will complete an additional exposure pathway, surface water, under no action. Completion of the surface water pathway into Soldier Creek exposes offsite populations around Tinker AFB and downstream to contaminants through inhalation and ingestion routes. Hazards posed by noncarcinogens and risks by carcinogens from groundwater and surface water pathways were quantified in the baseline risk assessment. Public health risks were indicated from long-term exposure (70 years) to noncarcinogens through ingestion of groundwater and through ingestion of fish in Soldier Creek. The no action alternative will result in noncarcinogenic risks to the populations exposed to long-term consumption of groundwater on TAFB and those consuming fish over the 70 year exposure period. The risk of adverse health effects are generated by heavy metal contaminants in the groundwater and indicated by a hazard index (HI) value $\geq$ 1.0. Consumption of groundwater during the long-term exposure period would result in an HI value of 1.18. Additive effects of consuming the inorganic contaminants could result in adverse health effects. The potential for adverse health effect on local population are greater as groundwater contaminants seep into Soldier Creek and bioconcentrate in fish tissue. Long-term consumption of fish from the stream could result in an HI value of 2.12. The adverse effects result from ingestion of chromium through the fish tissue. Risk characterization of carcinogens indicated acceptable risks (10^{-5} to 10^{-7}) from consumption of groundwater at Tinker AFB (10^{-5}) and consumption of fish from Soldier Creek (10^{-6}). Specific carcinogenic risks from groundwater consumption are 1.2×10^{-5} or 1 additional cancer per 83,000 individuals in the area. Carcinogenic risks from consuming fish once contaminated groundwater reaches Soldier Creek have been estimated at 6.96×10^{-6} or 1 additional cancer case per 144,000 individuals. Although carcinogenic risks lie within acceptable limits, adverse health effects could result from long-term exposure to noncarcinogens. The Alternative 1-1 rating for public health impacts is 5.

4.2.1.3 Environmental Impacts. This alternative does not create any physical disturbance or disruption of the environment but introduces contaminants to the environment that may create toxic or physiological impacts once the surface pathway is complete. The effects of no action have no short-term impacts, but once the perched aquifer reaches Soldier Creek, the contaminants may result in acute or chronic impacts on aquatic organisms. Aquatic organisms will bioconcentrate contaminants from the water column of Soldier Creek potentially resulting in reproductive effects, carcinogenic effects, or physiologic stress resulting in secondary impacts from disease. Terrestrial organisms ingesting water or aquatic organisms from Soldier Creek may experience similar impacts. This alternative could potentially result in adverse impacts on the environment of Soldier Creek. The Alternative 1-1 rating for environmental impacts is 5.

4.2.1.4 Institutional Requirements. The "no action plan ", Alternative 1-1, does not meet all applicable or relevant environmental and public health standards. It does not mitigate or prevent the threat of contamination to the Garber-Wellington aquifer or reduce the likelihood of present or future threat to public health and the environment by preventing or reducing the migration of contaminants to Soldier Creek. No permits would be required for this alternative. The Alternative 1-1 ratings for institutional requirements criteria are listed below.

Criteria	Rating
Conformance with ARAR's	5
Permitting requirements	1
Normalized Rating	3.00

4.2.1.5 Cost Analysis. Costs include the installation of 18 stainless steel monitoring wells (to be incorporated with the 13 existing stainless wells) installation of surface water sampling point permanent monument, and scheduled sampling and analysis of the groundwater and the surface water. The costs are listed below.

Capital Costs	Annual O&M Costs	Present Worth
$ 103,000	$ 41,600	$ 535,200

4.2.2 Alternative 1-2 - Exterior Groundwater Removal Only.

4.2.2.1 Engineering Feasibility. Pumping from exterior wells located around Building 3001 to remove contaminated groundwater is a technically feasible alternative because it is both implementable and effective. The Alternative 1-2 ratings for engineering feasibility criteria are listed below:

Criteria	Rating
Performance	
o effectiveness	3
o useful life	3
Reliability	
o operation & maintenance	3
o demonstrated performance	1
Implementability	
o constructability	2
o time to implement	2
o time for results	4
Safety	1
Normalized Rating	2.38

4.2.2.1.1 Performance. Alternative 1-2 significantly impacts the movement of the contamination plumes in all three zones. The percentages of total TCE removed from the aquifers at various times based on results from modeling of Alternative 1-2 are shown in Table 4-1. The total TCE is the TCE currently in the aquifer plus the continuous source particles that have entered the aquifer zone up to the simulation time indicated. The continuous source contamination that will be migrating into the aquifer after this time is not included in the total upon which the percentage is based. After 30 years the amount of continuous source entering the aquifer is insignificant.

TABLE 4-1

ALTERNATIVE 1-2 - PERCENTAGE OF TCE REMOVAL VS TIME

Time (Years)	Perched Aquifer	Top of regional Zone	Regional Zone
1*	17%		
2*	36%		
3*	46%		
4*	64%		
5	72%	71%	43%
10	88%	91%	56%
20	95%	95%	69%
30	97%	96%	75%

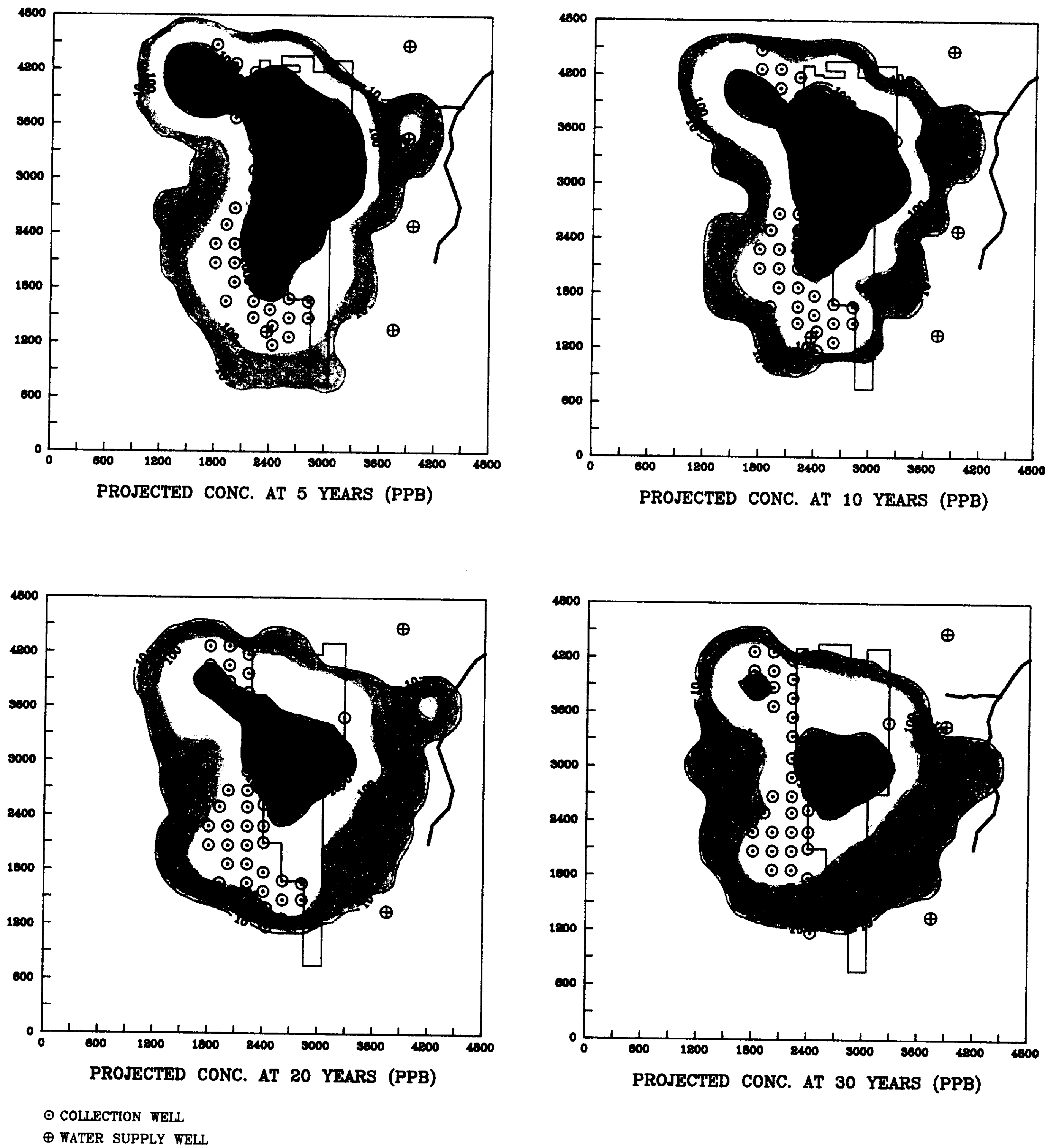
ALTERNATIVE 1-2 - PERCENTAGE OF Cr REMOVAL VS TIME

Time (Years)	Perched Aquifer	Top of regional Zone	Regional Zone
1*	19%		
2*	40%		
3*	53%		
4*	69%		
5	82%	83%	50%
10	89%	87%	60%
20	94%	94%	70%
30	96%	96%	76%

*The first four years of removal are included for the perched aquifer to show the impact of the pumping of the heaviest contaminated zone.

Figures 4-11 through 4-16 show predicted TCE and Cr plumes from the perched, top of regional, and regional zones simulated over time periods of 5, 10, 20, and 30 years. The locations of the Alternative 1-2 collection wells and existing water supply wells are shown on these figures. When comparing these plumes with the no action plumes, it can be seen that the plumes are much smaller and have lower concentrations than the predicted plumes from Alternative 1-1. In the perched aquifer under the no action plan contaminated water with concentrations of TCE greater than 100 parts per billion (ppb) reaches the creek in less than 25 years. The Cr with concentrations greater than 100 ppb reach the creek within 10 years. But, with Alternative 1-2, neither the TCE or Cr greater than 100 ppb ever reaches the creek. In the top of regional zone, concentrations over 10,000 ppb TCE are removed in less than 5 years of pumping. Also in top of regional zone, the plume concentrations over 1000 ppb TCE is less than one fifth the size in twenty years with pumping than it is in 25 years with no pumping. The Cr concentrations over 1000 ppb in the top of regional are removed in less than 5 years and concentrations of Cr over 100 ppb are practically gone in 10 years. In the regional zone, the concentrations of TCE over 1000 ppb are gone in less than 5 years as opp-osed to a significant increase in Alternative 1-1 predictions. The Cr con-centrations over 1000 ppb are gone in less than 10 years with Alternative 1-2 but significantly increase under the no action plan.

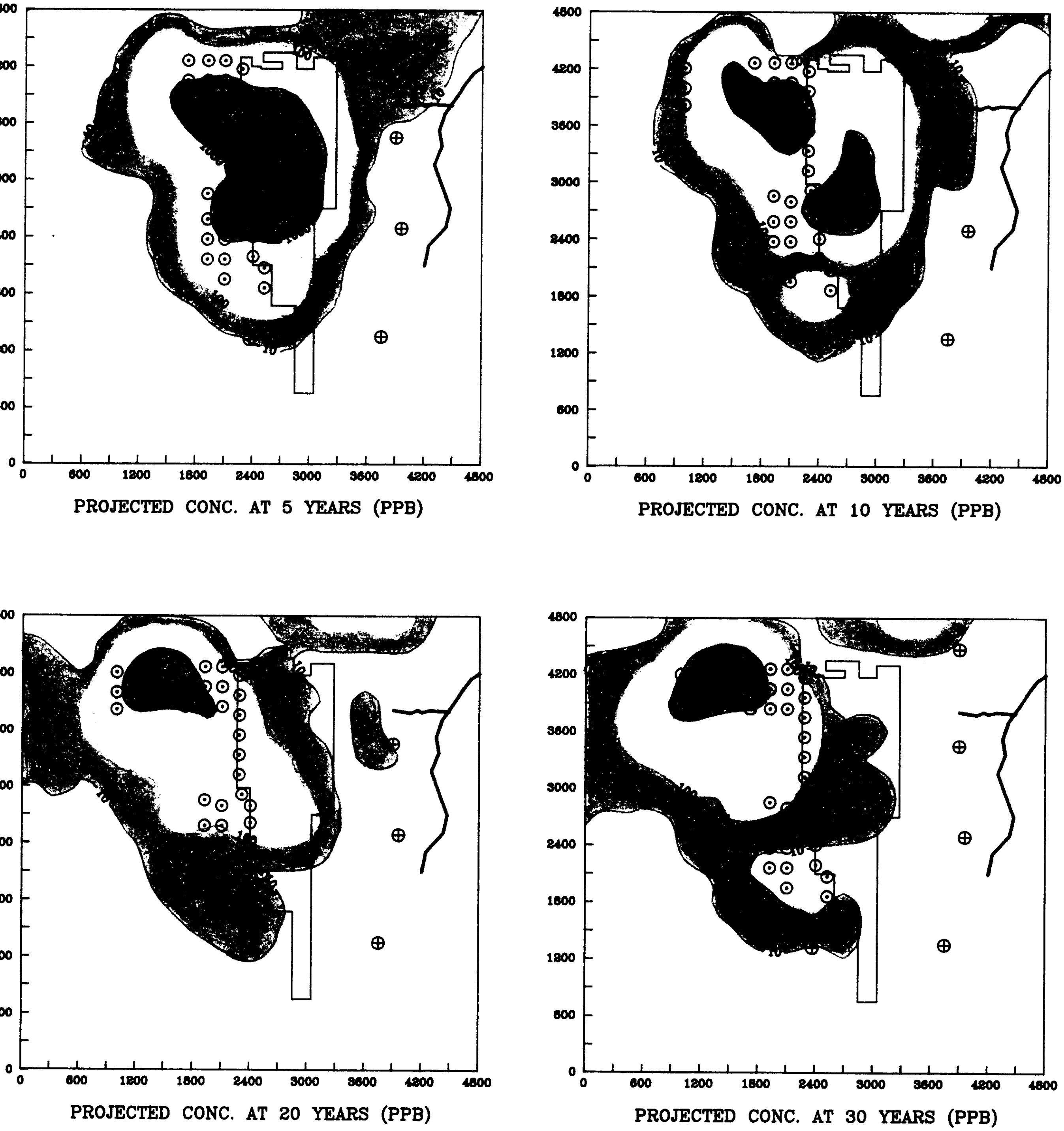
Groundwater elevations in the vicinity of pumping wells are lowered in each aquifer zone, causing a hydraulic gradient reversal which helps control migration. The Alternative 1-2 wells surrounding the building will pump over 71,800 gallons of contaminated water per day. Figures 4-17 through 4-22 compare the effects of Alternative 1-2 pumping with no action after 10 years of operation on the groundwater elevation contours in plane view and surface plots in the perched aquifer, top of regional zone, and the regional zone. The groundwater elevation under the building is lowered by the pumping in each zone. The change in the shape of the groundwater piezometric heads, that results from the pumping, causes a change in the directions of flow within the aquifer zones at the site. The local flow is



ALTERNATIVE 1–2

TCE PLUMES IN THE PERCHED AQUIFER AT 3001

FIGURE 4–11

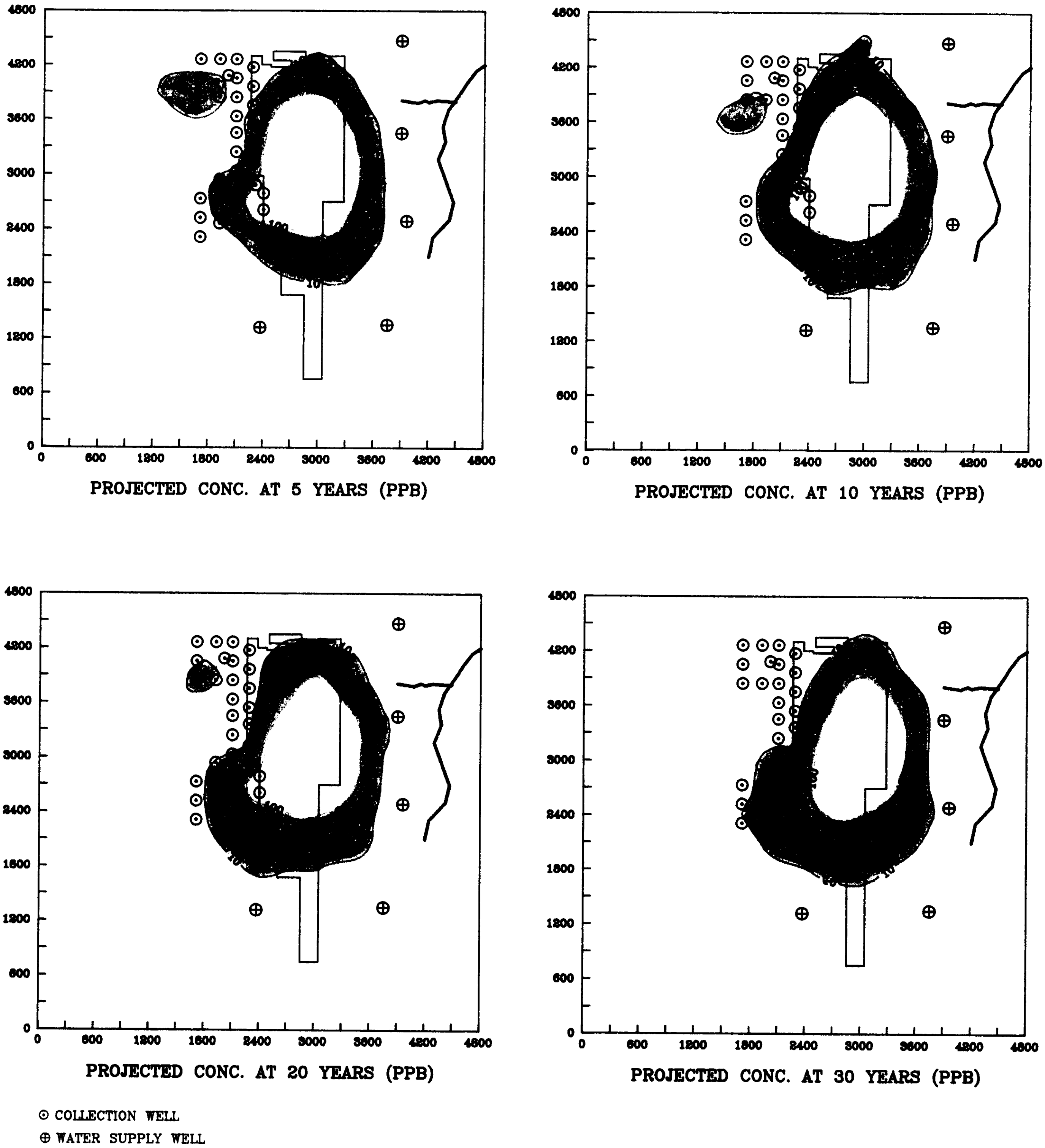


⊙ COLLECTION WELL
⊕ WATER SUPPLY WELL

ALTERNATIVE 1-2

TCE PLUMES IN THE TOP OF REGIONAL ZONE

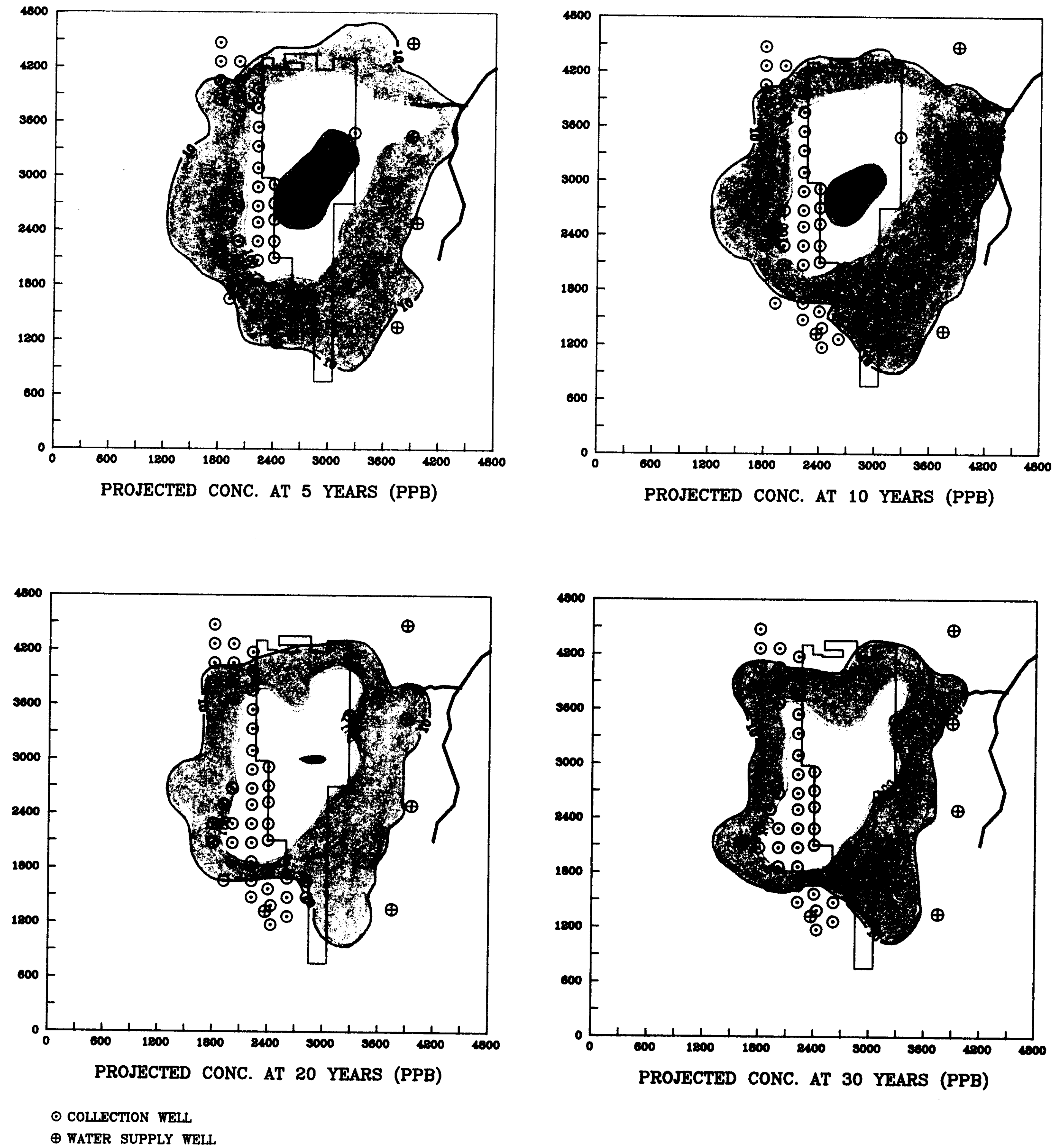
FIGURE 4-12



ALTERNATIVE 1-2

TCE PLUMES IN THE REGIONAL ZONE

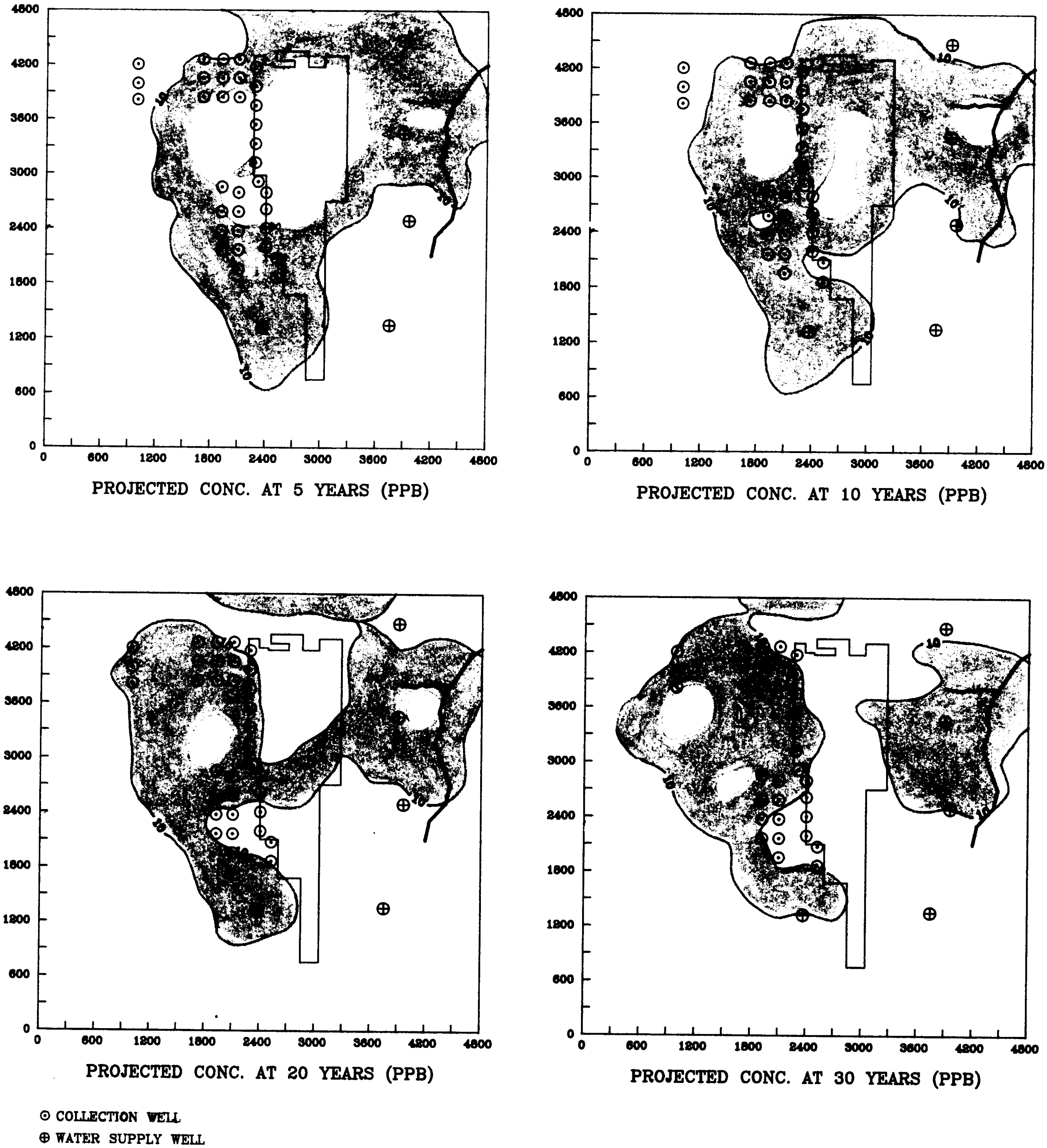
FIGURE 4-13



ALTERNATIVE 1–2

CHROMIUM PLUMES IN PERCHED AQUIFER AT 3001

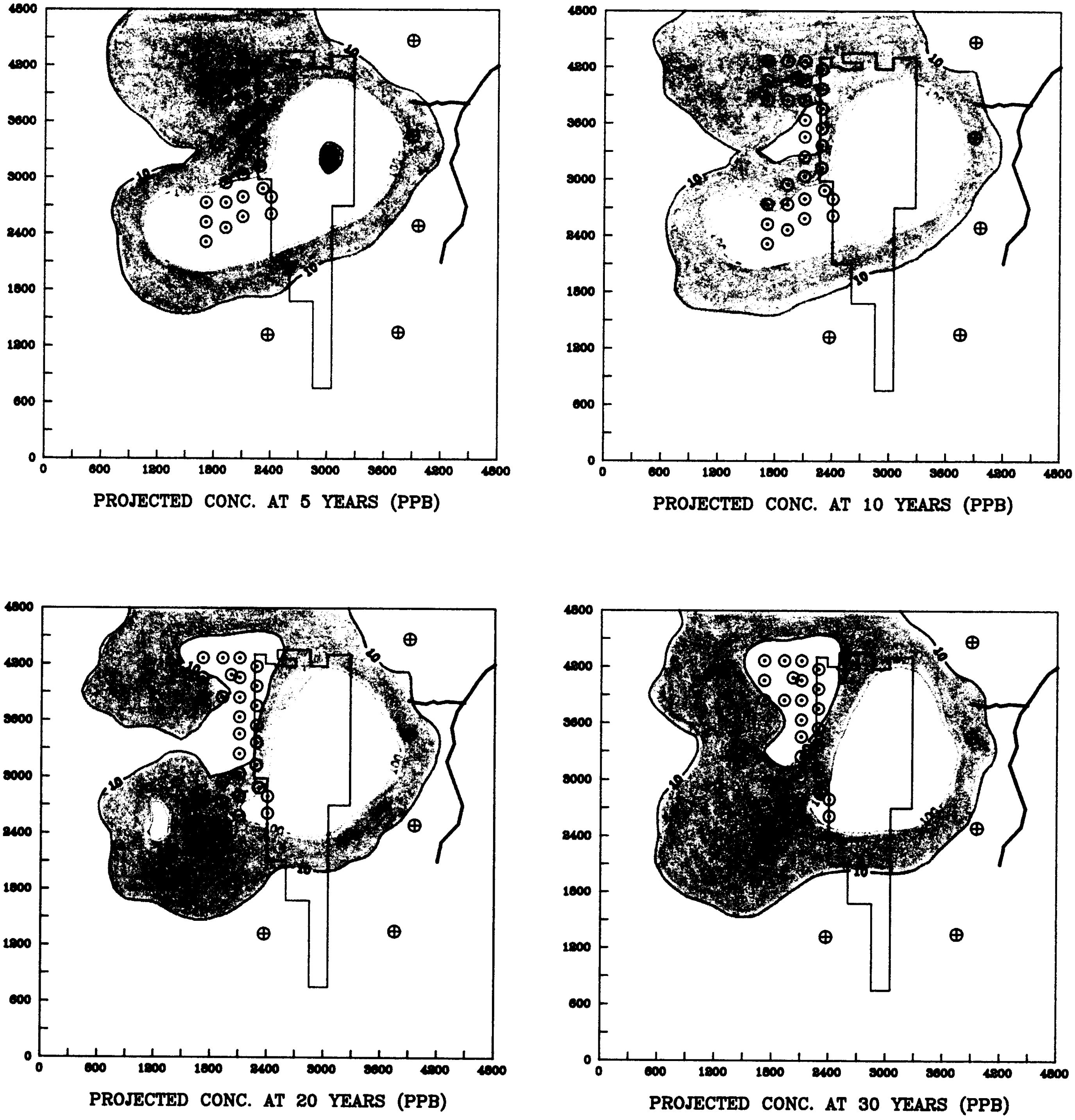
FIGURE 4–14



ALTERNATIVE 1-2

CR PLUMES IN THE TOP OF REGIONAL ZONE

FIGURE 4-15



⊙ COLLECTION WELL
⊕ WATER SUPPLY WELL

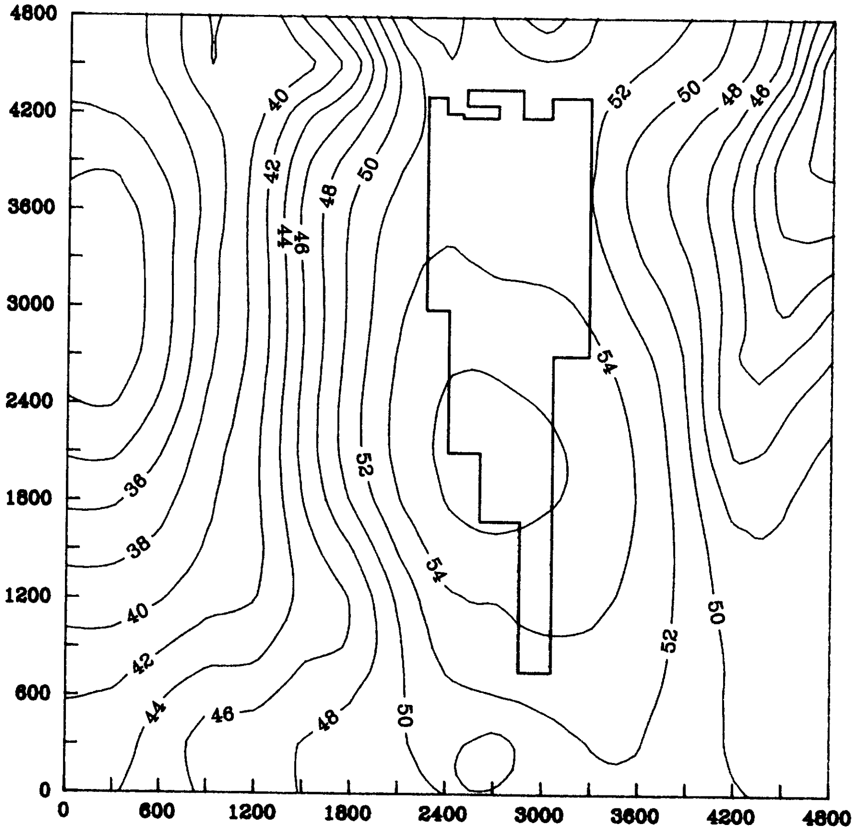
ALTERNATIVE 1-2

CHROMIUM PLUMES IN THE REGIONAL ZONE

FIGURE 4-16

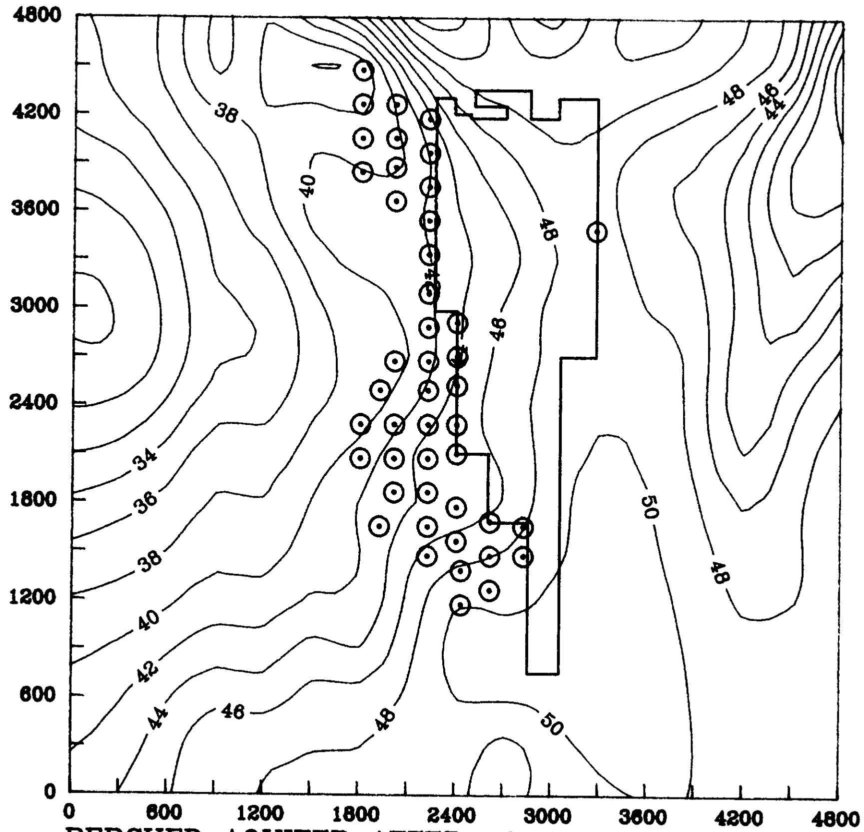
A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT AND WITH PUMPING

ALTERNATIVE 1-1



PERCHED AQUIFER AFTER 10 YEARS WITH NO PUMPING

ALTERNATIVE 1-2



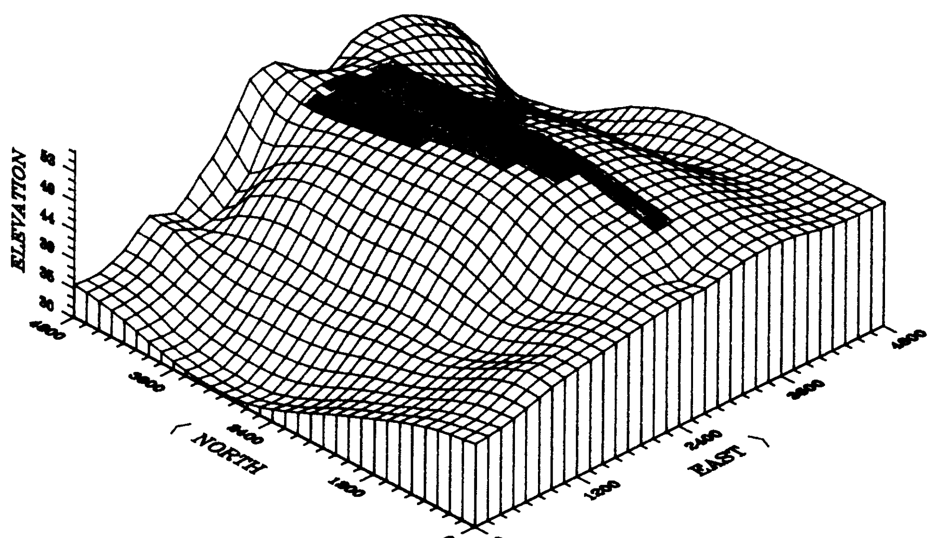
PERCHED AQUIFER AFTER 10 YEARS OF PUMPING

(GROUNDWATER CONTOURS OF 50 = ELEVATION 1250)

EXTRACTION WELL - ⊙

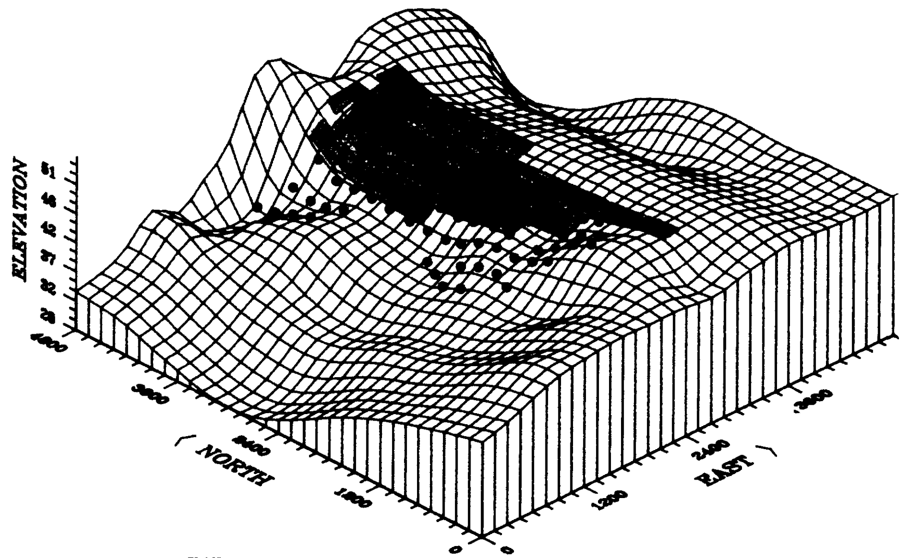
FIGURE 4-17

A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT AND WITH PUMPING



PERCHED AQUIFER AFTER 10 YEARS WITH NO PUMPING

ALTERNATIVE 1−1

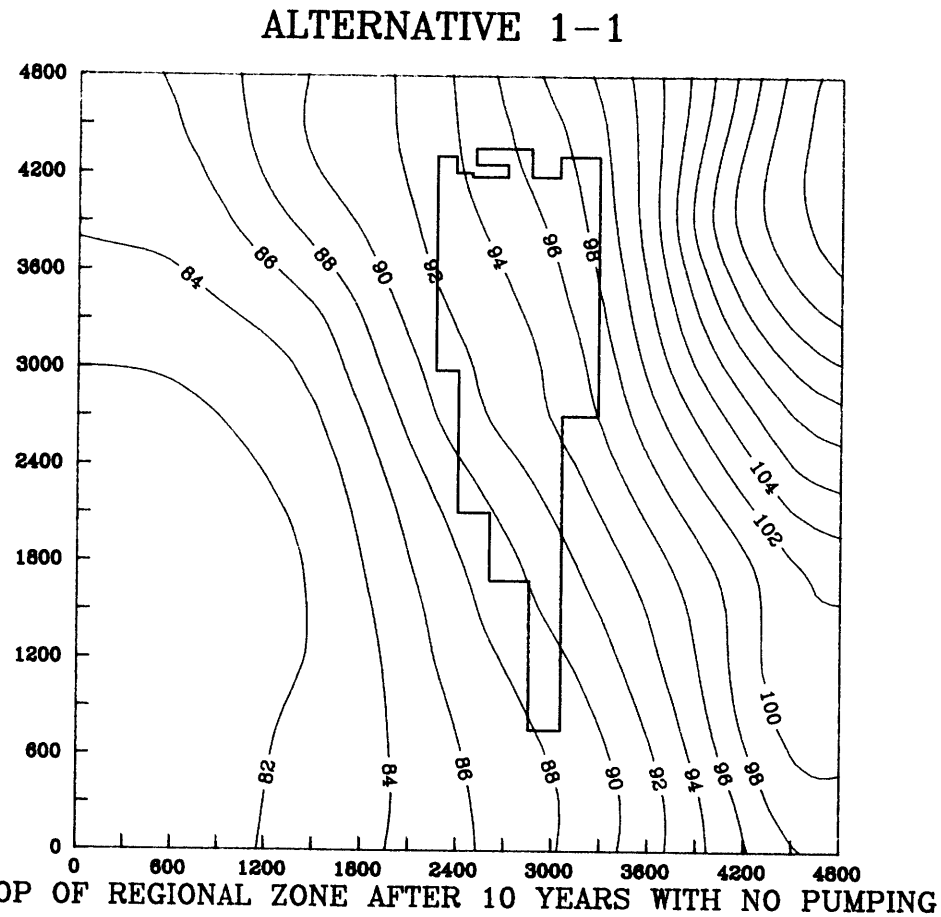


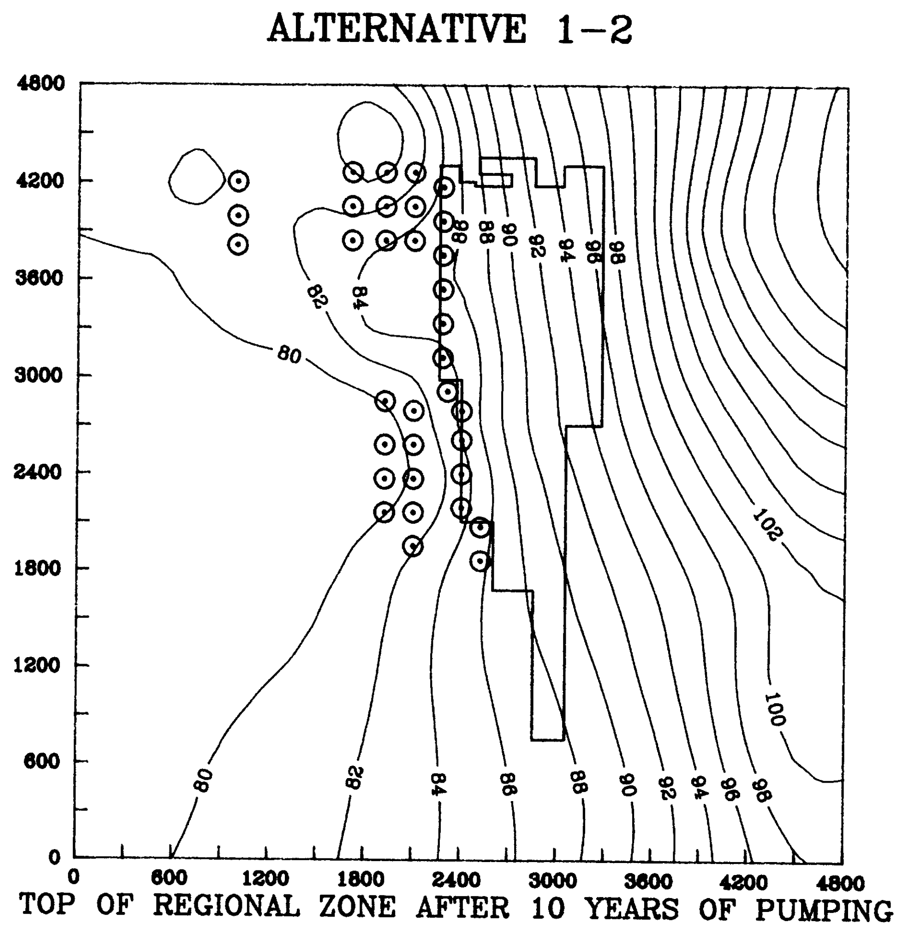
PERCHED AQUIFER AFTER 10 YEARS OF PUMPING

ALTERNATIVE 1−2

FIGURE 4−18

A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT AND WITH PUMPING



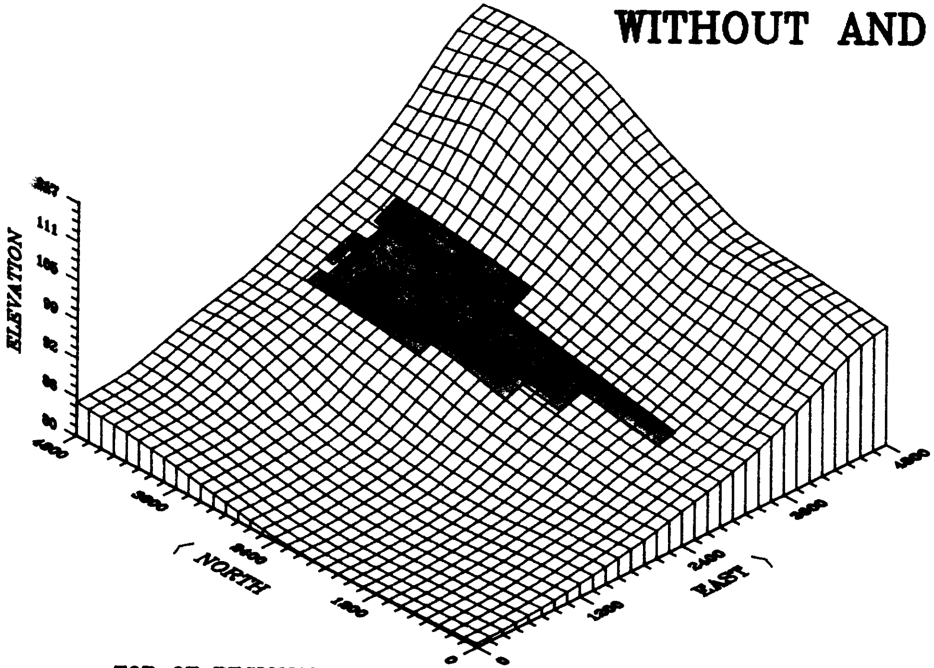


(GROUNDWATER CONTOURS OF 80 = ELEVATION 1180)

EXTRACTION WELL - ⊙

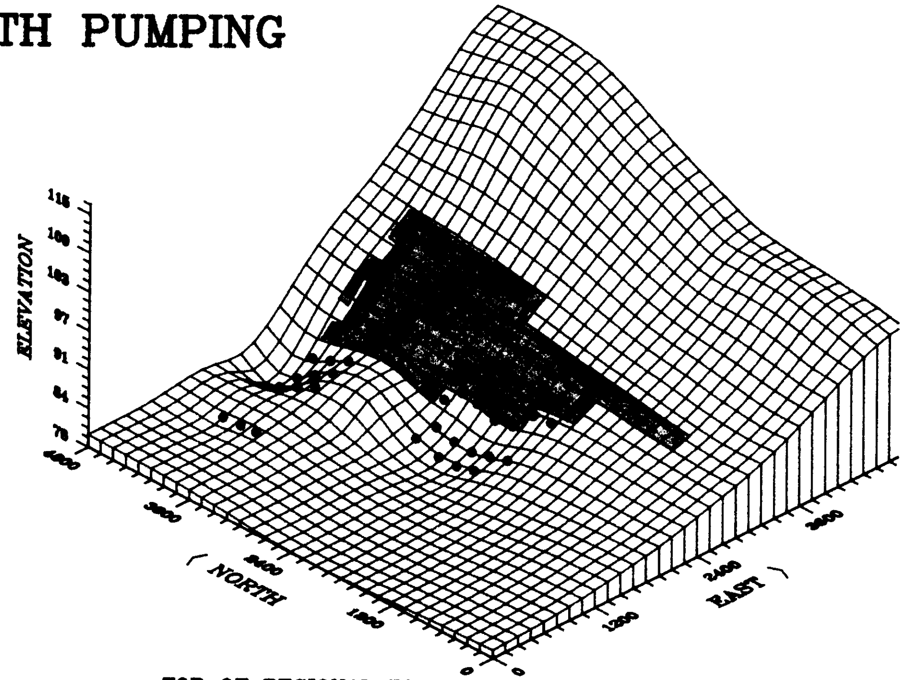
FIGURE 4-19

A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT AND WITH PUMPING



TOP OF REGIONAL ZONE AFTER 10 YEARS WITH NO PUMPING

ALTERNATIVE 1-1



TOP OF REGIONAL ZONE AFTER 10 YEARS OF PUMPING

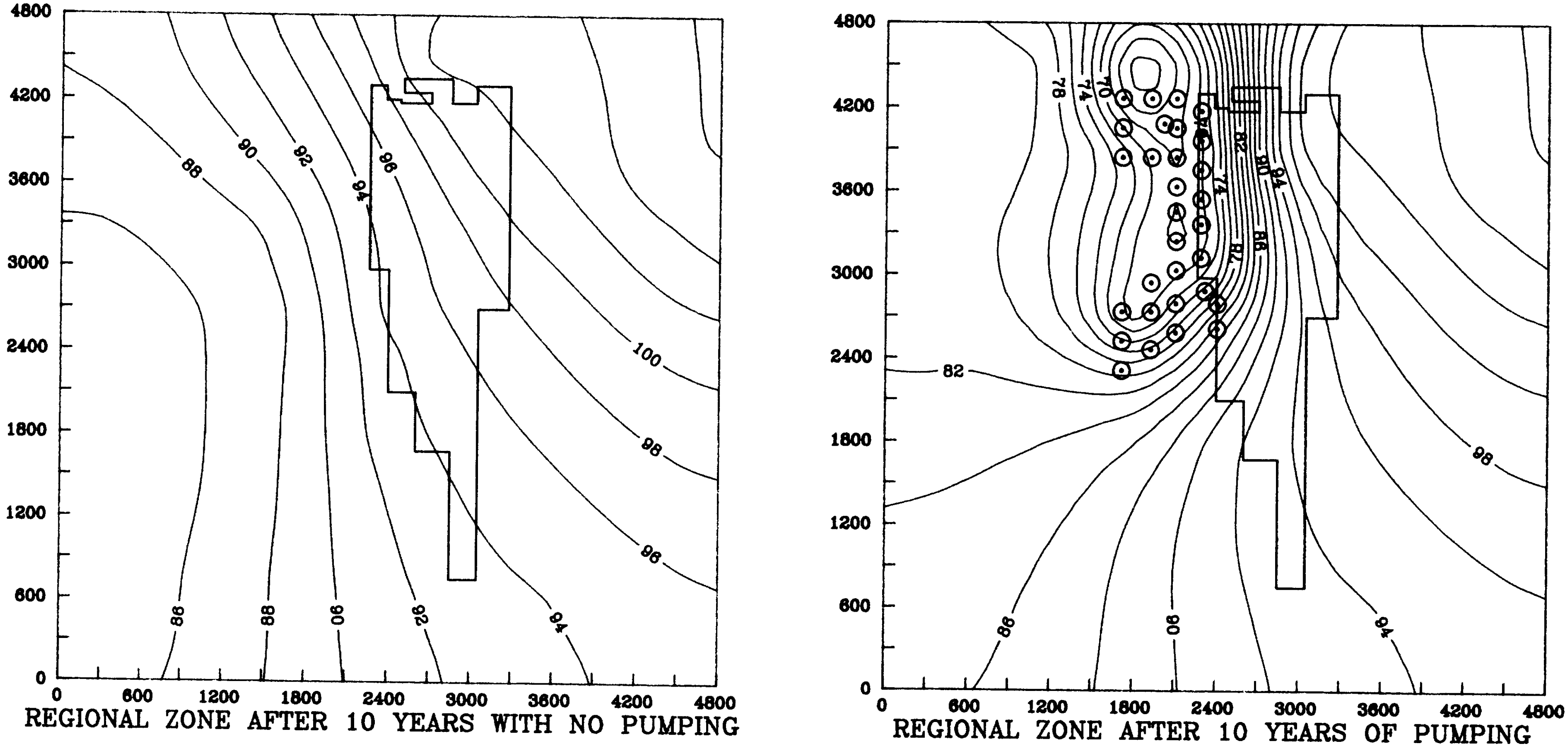
ALTERNATIVE 1-2

FIGURE 4-20

A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT AND WITH PUMPING

ALTERNATIVE 1-1

ALTERNATIVE 1-2

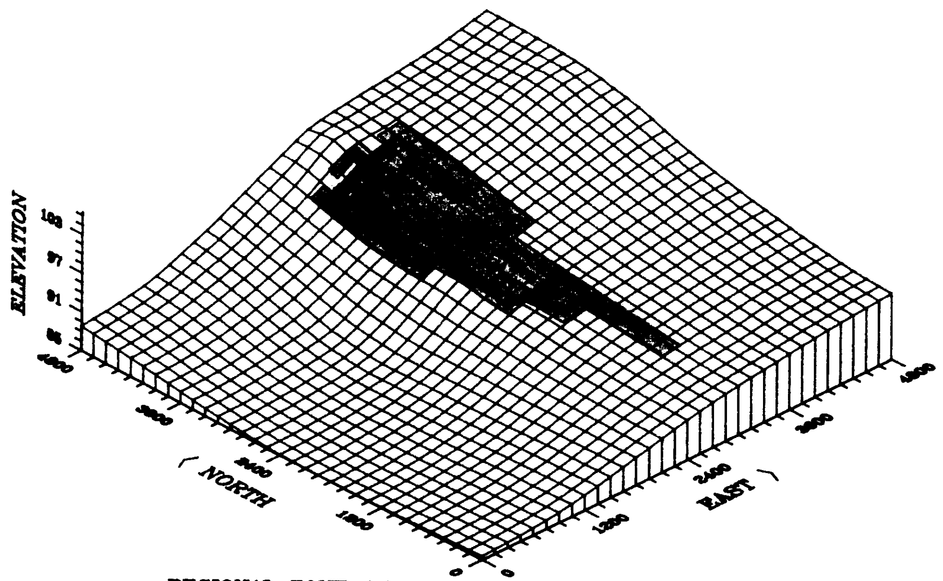


(GROUNDWATER CONTOURS OF 80 = ELEVATION 1180)

EXTRACTION WELL – ⊙

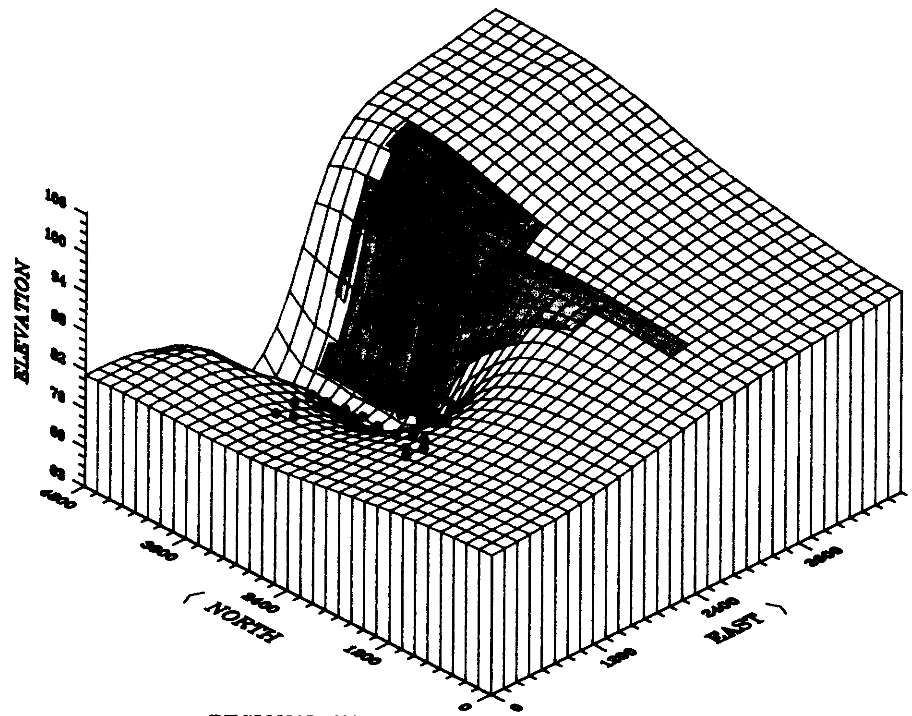
FIGURE 4–21

A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT AND WITH PUMPING



REGIONAL ZONE AFTER 10 YEARS WITH NO PUMPING

ALTERNATIVE 1−1



REGIONAL ZONE AFTER 10 YEARS OF PUMPING

ALTERNATIVE 1−2

FIGURE 4−22

now toward the wells and prevents the contamination from moving off site therefore, controlling the contamination. The rating for effectiveness of Alternative 1-2 is 3.

Alternative 1-2 is expected to take thirty plus years to recover 85 percent of the groundwater contamination at the site. The rating for useful life is 3.

4.2.2.1.2 Reliability. Operation and maintenance will be required to keep the removal wells operating efficiently. The wells will require periodic cleaning to remove silt, algae, mineral deposits, or bacteria that are likely to accumulate on the well screens. The pumps are expected to cycle on and off as the water level fluctuates. As the water level is drawn down close to the bottom of the well, the pumps turn off, allows the aquifer to recharge, and then begins pumping again. This persistent cycling will undoubtedly cause wear on the pumps, resulting in maintenance, repair, and perhaps replacement of some of the pumps. The rating for operation and maintenance is 3.

Removal of contaminated groundwater through pumping is a common technology and has been used successfully at other sites. The rating for demonstrated performance is 1.

4.2.2.1.3 Implementability. The installation of extraction wells and the associated piping outside of the building will cause few disruptions to the production operations within the building. The wells must be located and constructed so that access for routine maintenance is maintained. An eighteen inch diameter bore hole will be drilled to the top of the shale beneath the sandstone layer of the aquifer zone to be pumped. The holes must be drilled with either air or water only. After the hole is drilled, geophysical logs must be run. The location and the length of the screen will be determined from the geophysical log to insure that the full thickness of the aquifer zone will be screened. A sand filter with a hydraulic conductivity of at least 10^{-3} cm/s will be placed around the screen. A five foot sump will be constructed at the bottom of the well. A minimum four foot thick bentonite seal will be set in the shale layer above the aquifer zone. Above the seal, the void around the casing will be grouted with a 3 percent bentonite cement grout to the top of the casing. The well casing will be four inch diameter schedule 80 PVC flush joint casing with 0.010 inch slotted screen. The wells will be constructed in a subgrade waterproof manhole. A typical schematic of an extraction well is shown on Figure 4-3. The constructability rating for this alternative is 2.

After the Record of Decision is finalized, physical, on site construction must begin in fifteen months. The actual time for construction of the wells will depend on the number of drilling rigs that the contractor operates. If two rigs are used, construction of the well field will take approximately four months. The water treatment system must be in operation before groundwater removal can begin. If the water treatment system can be completed in the same time frame, this alternative can be in operation approximately two years after the Record of Decision. The rating for time to implement is 2.

This alternative will begin to provide control of the groundwater contamination within the first year. It will prevent the plumes from moving further off the site. The two upper zones are predicted to be almost 90 percent clean in 10 years but, it will take over 20 years for the regional zone to reach a cleanup of 70 percent. The rating for the time for results is 4.

4.2.2.1.4 <u>Safety.</u> Installation of the monitoring wells and extraction wells included in Alternative 1-2 will require a modified level D. That will include chemically impervious boots and chemically impervious gloves (under cotton gloves), hard hat, protective disposable coveralls, eye protection will be worn during drilling and installation of the monitoring wells. Air monitoring in the breathing zone will be done with a photoionizaton meter and a combustible gas meter. All personnel involved with the well installation will be required to have air purifying respirators with organic vapor cartridges should the air monitoring indicate a need. The requirement for respirators or self contained breathing apparatus will be determined by a certified industrial hygienist based on the TWA-STEL. Sampling of the monitoring wells will require chemically impervious gloves and boots. Operation and maintenance safety will depend on the type of procedure being done. Simple pump or line repair will have the same safety requirements as sampling. Cleaning or repair of the well itself will require the same safety procedures as drilling. The Tinker Air Force Base, Installation Restoration Program, Safety and Occupational Health Plan For Corps of Engineers Personnel will be followed as a minimum. The safety rating for this alternative is 1.

4.2.2.2 Public Health Impacts. Placement and operation of the recovery well field would provide remediation over a 30 year time period. Concentrations of indicator contaminants migrating from highly contaminated overlying aquifers to water supply wells would decline over the remediation period. Contaminant concentrations at these water supply wells (which were predicted to exceed SDWA MCLs between exposure years 50 and 70 under no action) would return to prerelease levels, resulting in a reduction in health threats over the no action alternative. Half of the contaminated monitoring wells are expected to achieve zero concentrations of indicator organics within the first 10 years of remediation. Specifically, contamination of the surface water of Soldier Creek will be prevented under Alternative 1-2. Elimination of the exposure pathway would reduce the potential for noncarcinogenic health effects. Under the no action alternative, noncarcinogenic risk evaluation by the ingestion route of exposure indicated a potential for impact (hazard index of 2.12). Elimination of this pathway and exposure route results in only groundwater ingestion as a source of exposure. The reduction of contaminant concentration by 75 percent at the regional aquifer and overlying aquifers by 97 percent within the first 30 years of the exposure period (70 years) would reduce both the noncarcinogenic and carcinogenic risks to values well within acceptable ranges. Concentrations driving the conservation based risk assessment were based on average concentrations from the three aquifers. Reductions of contaminant concentrations between 75 and 97 percent would reduce the chronic daily intakes to levels that should provide a considerable reduction in contaminant and route specific risk.

Reductions in inorganic concentrations in the groundwater, particularly lead, by 76 to 96 percent, as indicated for chromium, would reduce the hazard index value from 1.18 to a value below 1.0. Carcinogenic risks already at acceptable values of 1.2×10^{-5} would be further reduced in the 10^{-5} to 10^{-7} range. Therefore, no adverse public health impacts would result from this alternative. The Alternative 1-2 rating for public health impacts is 2.

4.2.2.3 Environmental Impacts. The placement and operation of the ground water removal system would result in no adverse impacts on the environment. The alternative would not physically affect the surface environment of Tinker AFB or the surrounding environment. The removal system would stop future migration to uncontaminated waters of the aquifer and over the 30 year remediation period return the groundwater in the producing zone to prerelease quality. Control of the migration of the perched aquifer into Soldier Creek would prevent seepage into the surface water and impacts on the aquatic populations. The remediation alternative would result in beneficial impacts on the human and wildlife environment of Tinker AFB and surrounding community. The Alternative 1-2 rating for environmental impacts is 2.

4.2.2.4 Institutional Requirements. Alternative 1-2 does meet all applicable or relevant environmental and public health standards. It will mitigate or lessen the threat of contamination to the Garber-Wellington aquifer, which is a major groundwater basin in the state of Oklahoma. It will reduce the likelihood of present or future threat to public health and the environment by reducing the migration of contaminants to Soldier Creek. The Alternative 1-2 ratings for institutional requirements are listed below:

Criteria	Rating
Conformance with ARAR's	2
Permitting requirements	3
Normalized Score	2.5

4.2.2.5 Cost Analysis. Costs include the installation of 111 recovery wells, pumps, collection piping, bonding, insurance, maintenance, 18 additional monitoring wells, scheduled sampling, and analysis of the groundwater, and are listed below:

Capital Costs	Annual O & M Costs	Present Worth
$2,707,150	$127,900	$4,036,030

4.2.3 Alternative 1-3 - Exterior and Interior Removal

4.2.3.1 Engineering Feasibility. Remediating the aquifers by pumping around the building perimeter and inside of Building 3001 is a technically feasible alternative because it is both implementable and effective. The Alternative 1-3 ratings for engineering feasibility criteria are listed below:

Criteria	Rating
Performance	
o effectiveness	1
o useful life	3
Reliability	
o operation & maintenance	3
o demonstrated performance	1
Implementability	
o constructability	3
o time to implement	2
o time for results	3
Safety	1
Normalized Rating	2.13

The following subsections present the analysis of the criteria that resulted in these ratings.

4.2.3.1.1 Performance. Alternative 1-3 pumping is predicted to noticeably reduce the movement and amount of contamination in all three of the zones modeled. The percentages of total TCE removed from the aquifers at various times based on results from modeling of Alternative 1-3 are shown in Table 4-2. The total TCE is the TCE currently in the aquifer plus the continuous source particles that will enter the aquifer zone up to the simulation time indicated. The continuous source contamination that will migrate into the aquifer after this time is not included in the total upon which the percentage is based. The continuous source term becomes insignificant after 30 years.

TABLE 4-2

ALTERNATIVE 1-3 - PERCENTAGE OF TCE REMOVAL VS TIME

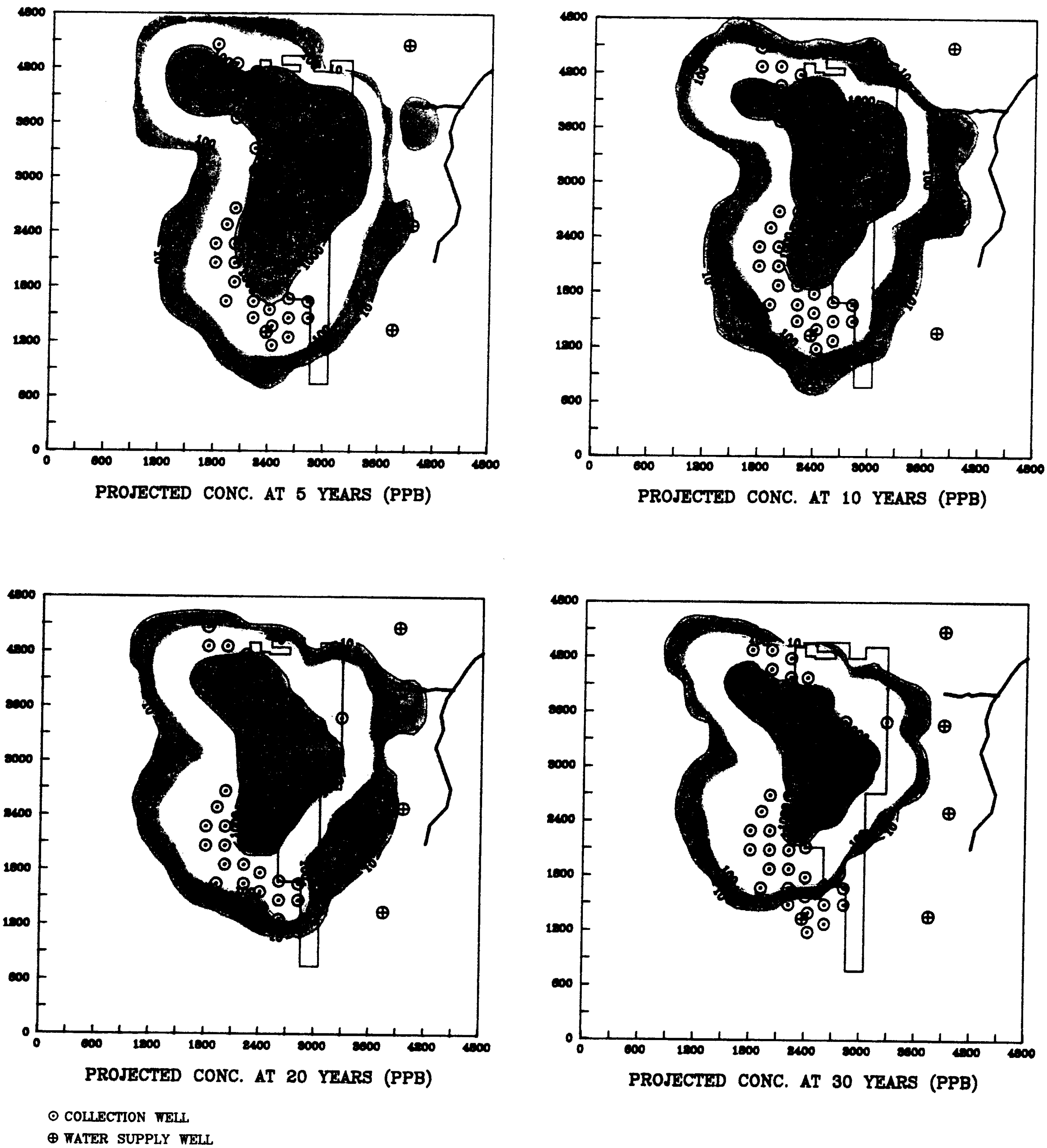
Time (years)	Perched Aquifer	Top of Regional Zone	Regional Zone
1*	20%		
2*	45%		
3*	56%		
4*	71%		
5	72%	66%	63%
10	88%	89%	64%
20	92%	94%	85%
30	94%	95%	93%

ALTERNATIVE 1-3 - PERCENTAGE OF Cr REMOVAL VS TIME

Time (years)	Perched Aquifer	Top of Regional Zone	Regional Zone
1*	24%		
2*	49%		
3*	61%		
4*	69%		
5	77%	76%	61%
10	90%	89%	78%
20	92%	94%	91%
30	96%	97%	94%

*The first four years of removal are included for the perched aquifer to show the impact of the pumping of the heaviest contaminated zone.

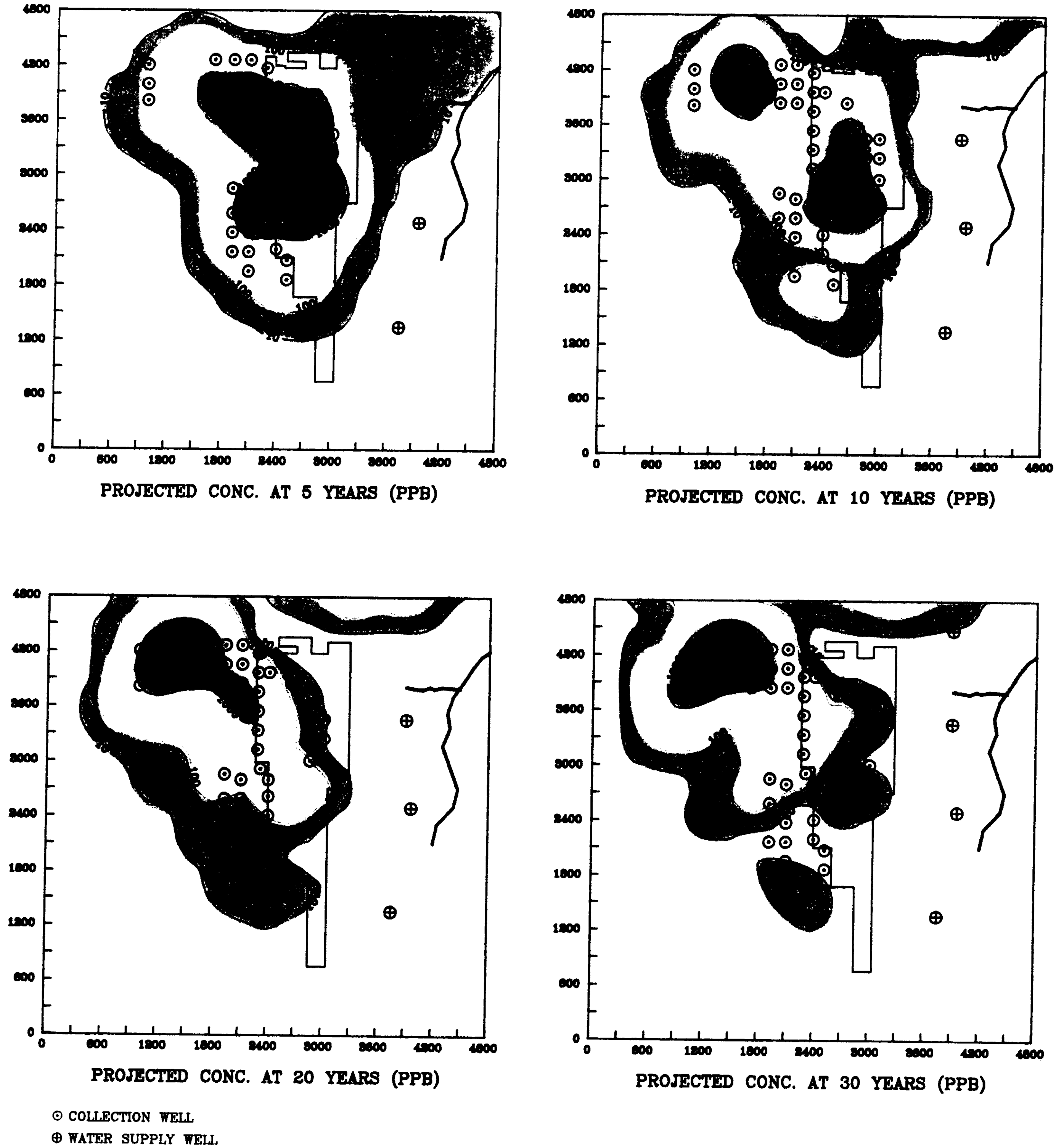
Figures 4-23 through 4-28 show TCE and Cr plumes from the perched, top of regional, and regional zones simulated over time periods of 5, 10, 20, and 30 years. The locations for the Alternative 1-3 collection wells and existing water supply wells are shown on these figures as well. When comparing these plumes with the no action plumes, it can be seen that the plumes are much smaller and have lower concentrations than the predicted plumes from Alternative 1-1. In the perched aquifer under the no action



ALTERNATIVE 1–3

TCE PLUMES IN THE PERCHED AQUIFER AT 3001

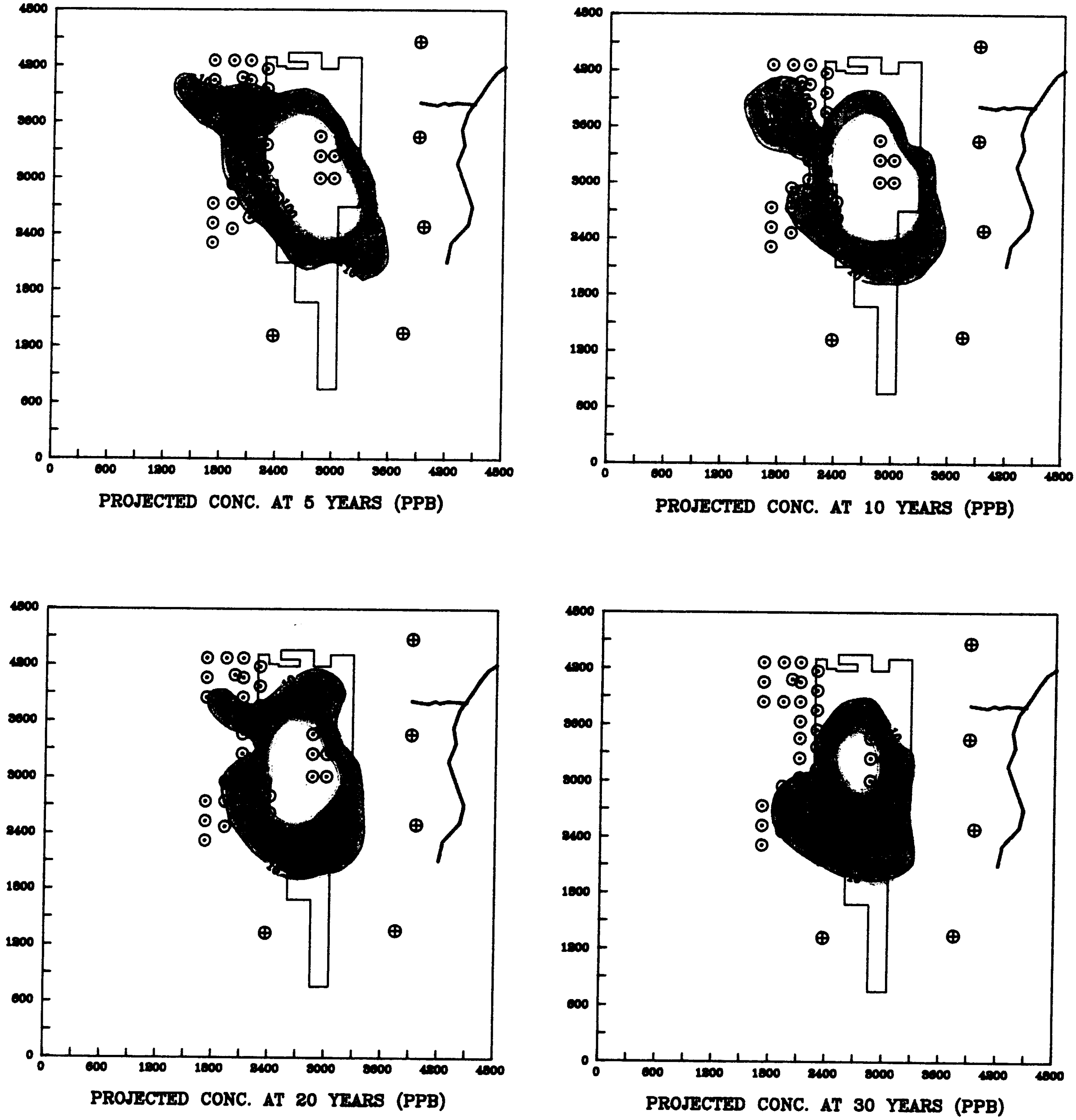
FIGURE 4–23



ALTERNATIVE 1–3

TCE PLUMES IN THE TOP OF REGIONAL ZONE

FIGURE 4–24

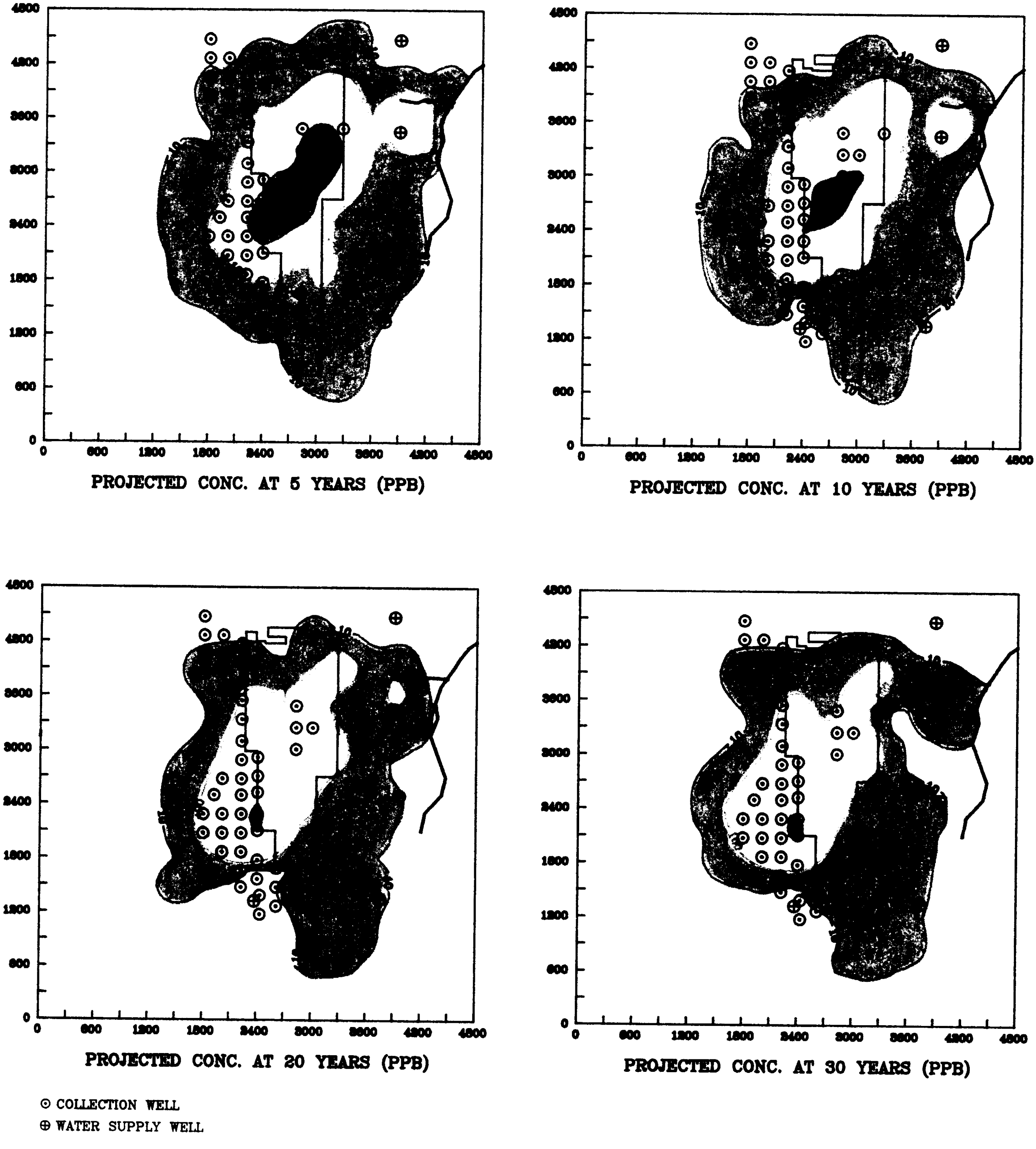


⊙ COLLECTION WELL
⊕ WATER SUPPLY WELL

ALTERNATIVE 1–3

TCE PLUMES IN THE REGIONAL ZONE

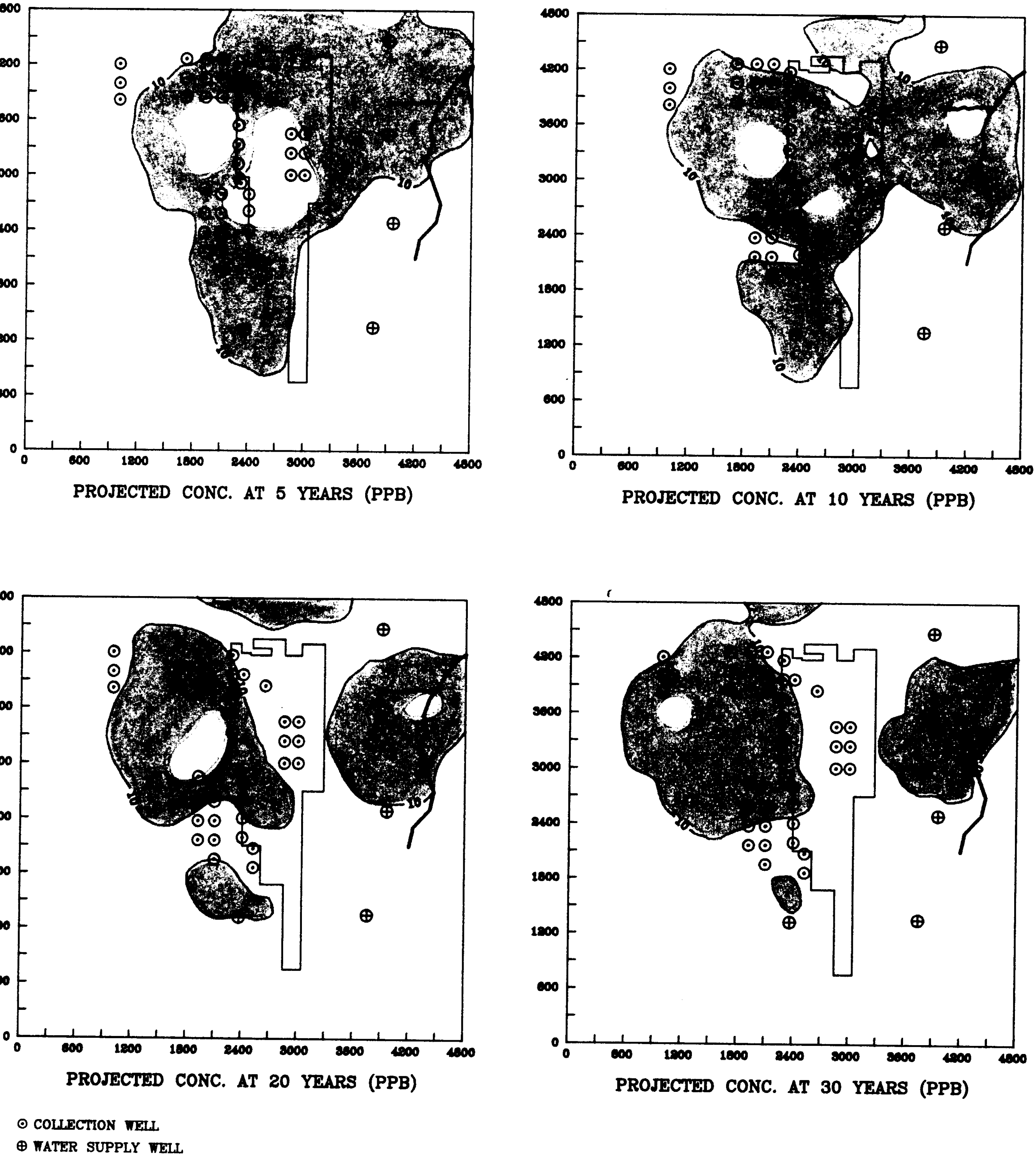
FIGURE 4–25



ALTERNATIVE 1–3

CHROMIUM PLUMES IN PERCHED AQUIFER AT 3001

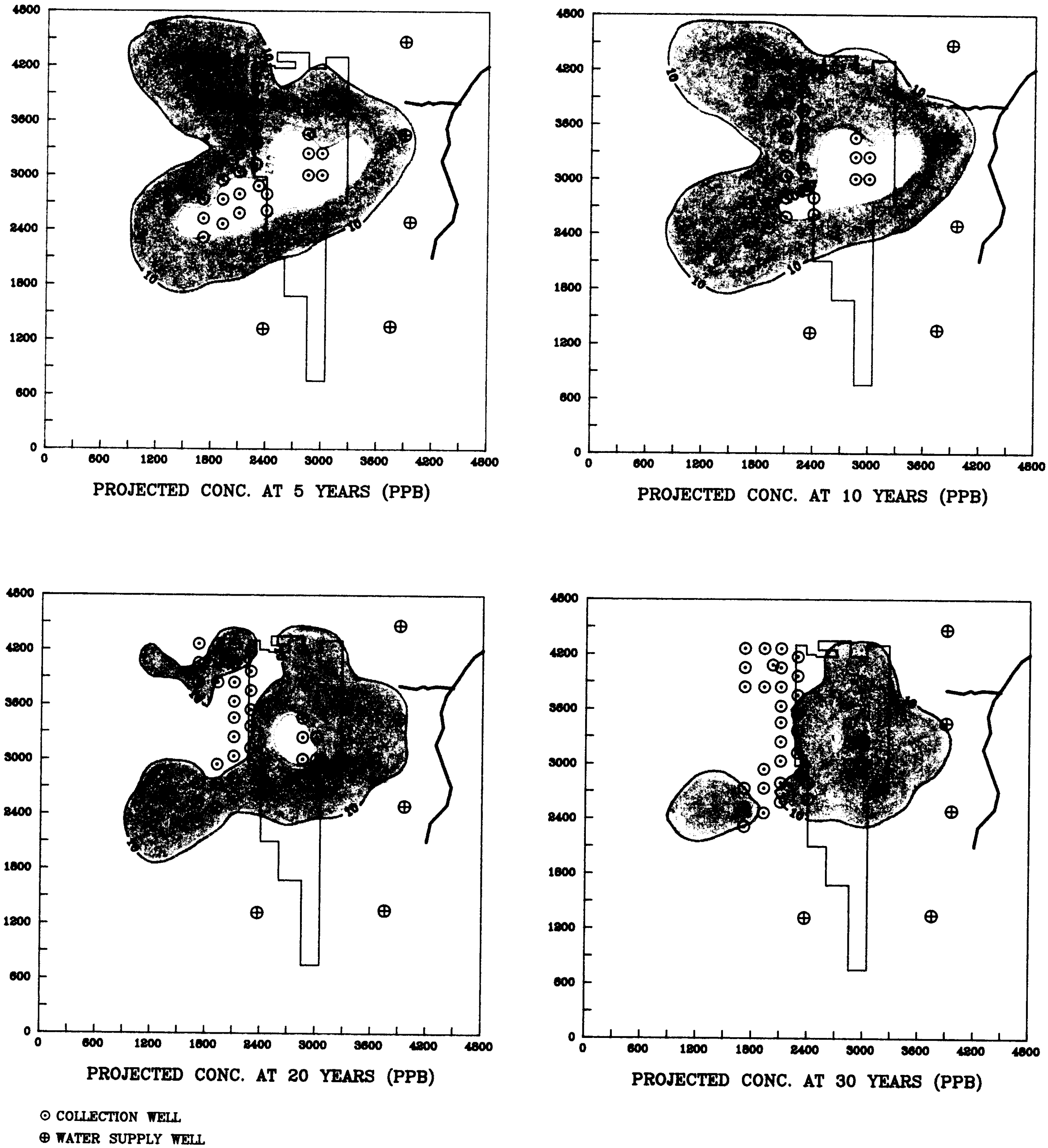
FIGURE 4–26



ALTERNATIVE 1–3

CR PLUMES IN THE TOP OF REGIONAL ZONE

FIGURE 4–27



ALTERNATIVE 1-3

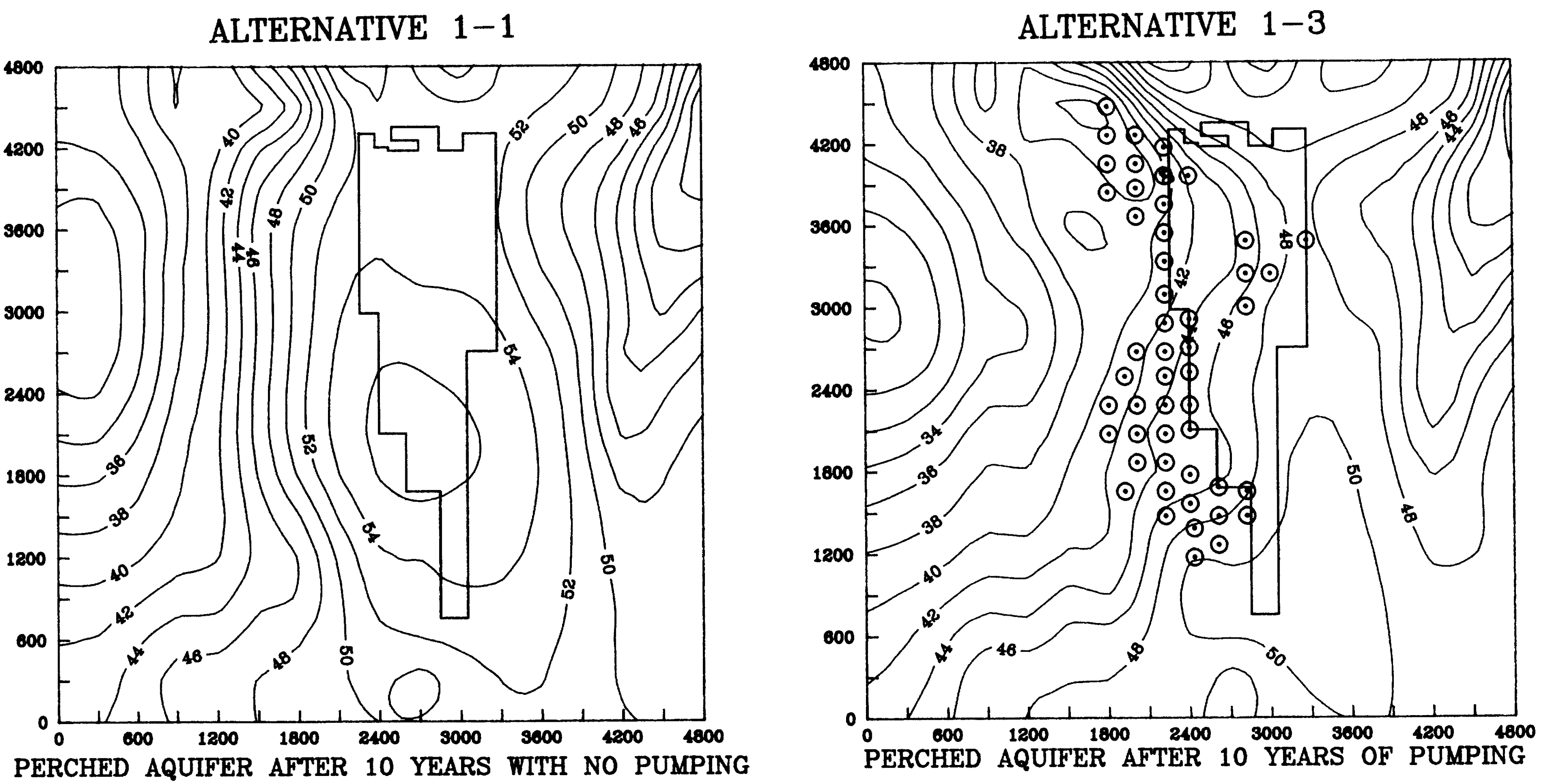
CHROMIUM PLUMES IN THE REGIONAL ZONE

FIGURE 4-28

plan, contaminated water with concentrations of TCE greater than 100 ppb reaches the creek in less than 25 years and concentrations of Cr greater than 100 ppb reach the creek within 10 years. With Alternative 1-3, TCE (in the perched aquifer) greater than 100 ppb never reaches the creek. Within 5 years, concentrations over 10,000 ppb cover a much smaller area of the plume and concentrations over 100,000 ppb TCE are gone. Cr at concentrations greater than 100 ppb stops going into the creek in 10 years. In the top of regional zone, concentrations over 10,000 ppb TCE are removed in less than 5 years of pumping. Also in top of regional, the plume concentrations over 1000 ppb TCE are less than one fifth the size in twenty years with pumping than it is in 25 years with no pumping. The Cr concentrations over 1000 ppb in the top of regional are removed in less than 5 years and concentrations of Cr over 100 ppb are practically gone in 10 years. In the regional zone, the concentrations of TCE over 1000 ppb are gone in less than 5 years as opposed to a significant increase predicted for Alternative 1-1 predictions. The Cr concentrations over 1000 ppb are gone in less than 5 years with Alternative 1-3, but are significantly increasing with the no action plan. Predicted concentrations contours over 100 ppb Cr are virtually gone in 30 years and the area where the TCE concentrations are over 100 ppb is less than half of what it is for the Alternative 1-2 predictions in the regional zone. The concentration contours of Alternative 1-3 are noticeably smaller with lower concentrations than Alternative 1-1 and Alternative 1-2 in the regional zone. The regional zone is the most important zone modeled since it is directly above the producing zone of the Garber-Wellington Aquifer.

Groundwater elevations in the vicinity of pumping wells are lowered in each aquifer zone, causing a hydraulic gradient reversal which helps control migration. The Alternative 1-3 wells will pump over 88,000 gallons of contaminated water per day. Figures 4-29 through 4-34 compare the effects of Alternative 1-3 pumping plan with no action plan after 10 years of operation on the groundwater elevation contours in plane view and surface plots in the perched aquifer, top of regional zone, and the regional zone. The groundwater elevation under the building is lowered by the pumping in each zone. The change in the shape of the groundwater piezometric heads,

A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT AND WITH PUMPING

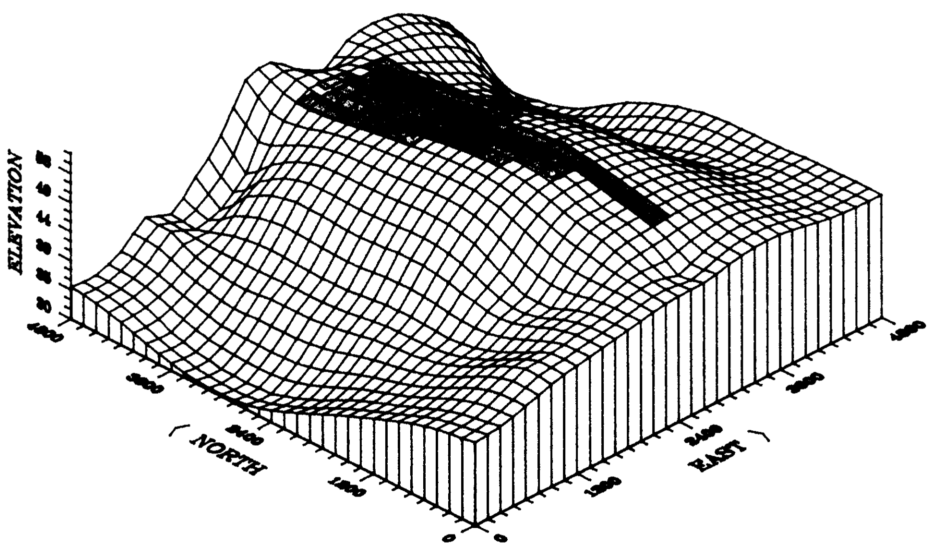


(GROUNDWATER CONTOURS OF 50 = ELEVATION 1250)

EXTRACTION WELL - ⊙

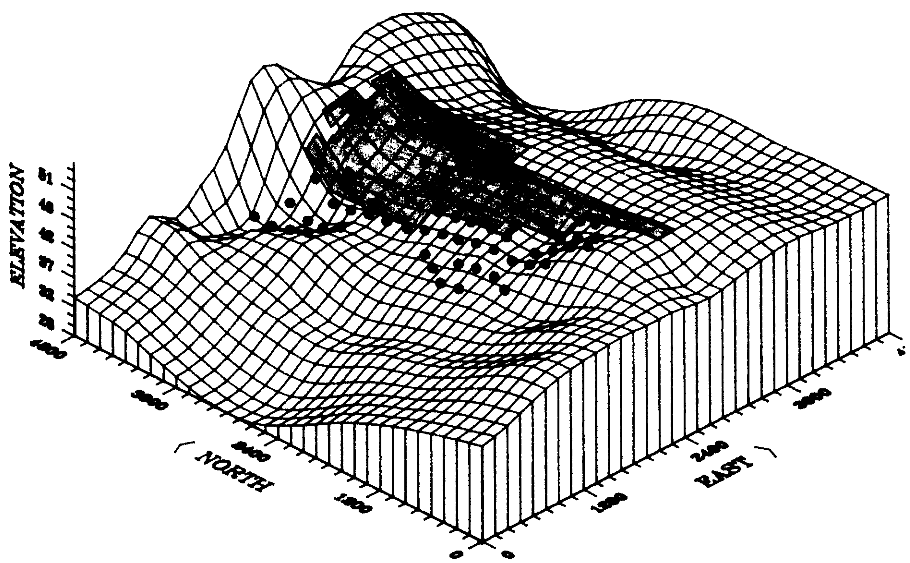
FIGURE 4-29

A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT AND WITH PUMPING



PERCHED AQUIFER AFTER 10 YEARS WITH NO PUMPING

ALTERNATIVE 1−1



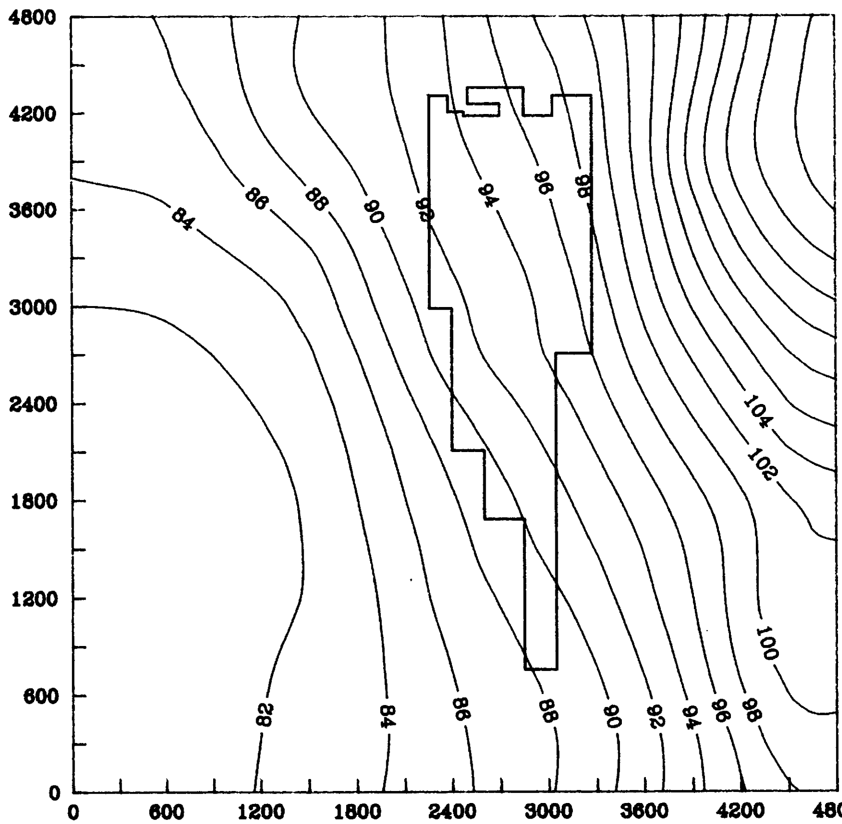
PERCHED AQUIFER AFTER 10 YEARS OF PUMPING

ALTERNATIVE 1−3

FIGURE 4−30

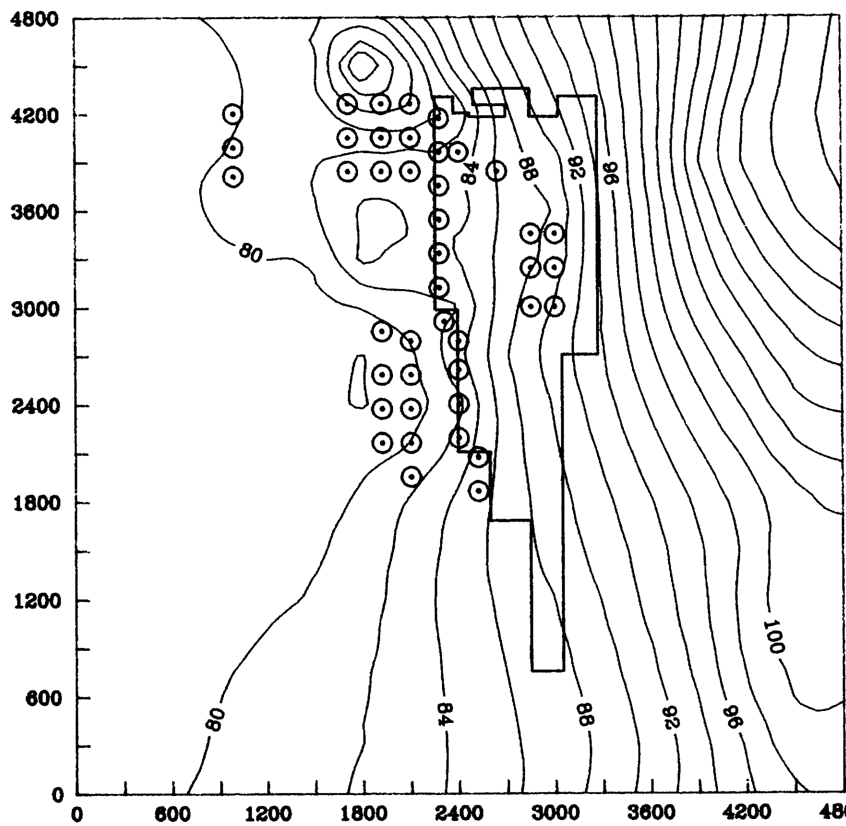
A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT AND WITH PUMPING

ALTERNATIVE 1-1



TOP OF REGIONAL ZONE AFTER 10 YEARS WITH NO PUMPING

ALTERNATIVE 1-3



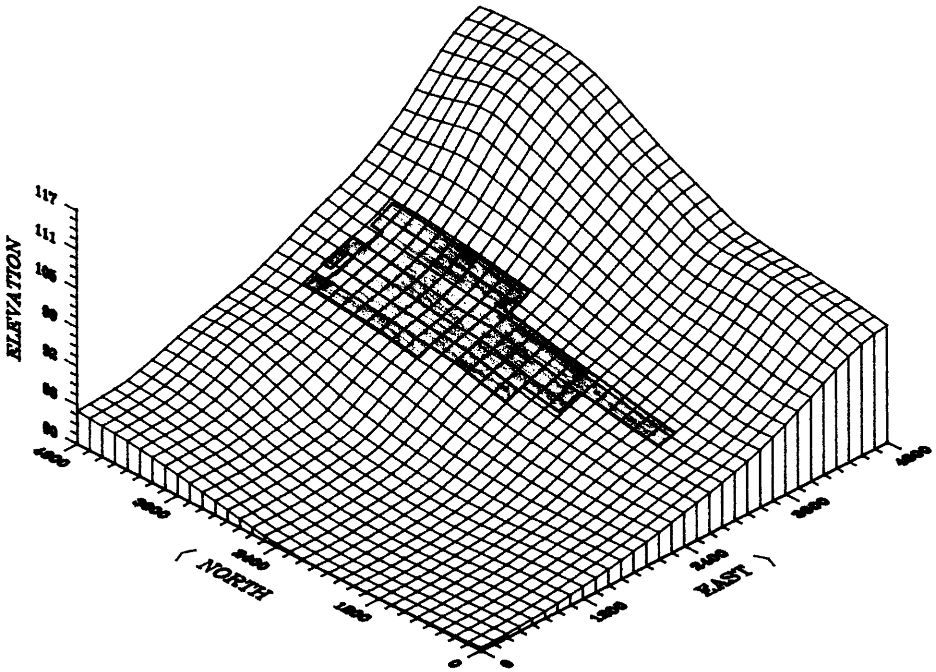
TOP OF REGIONAL ZONE AFTER 10 YEARS OF PUMPING

(GROUNDWATER CONTOURS OF 80 = ELEVATION 1180)

EXTRACTION WELL – ⊙

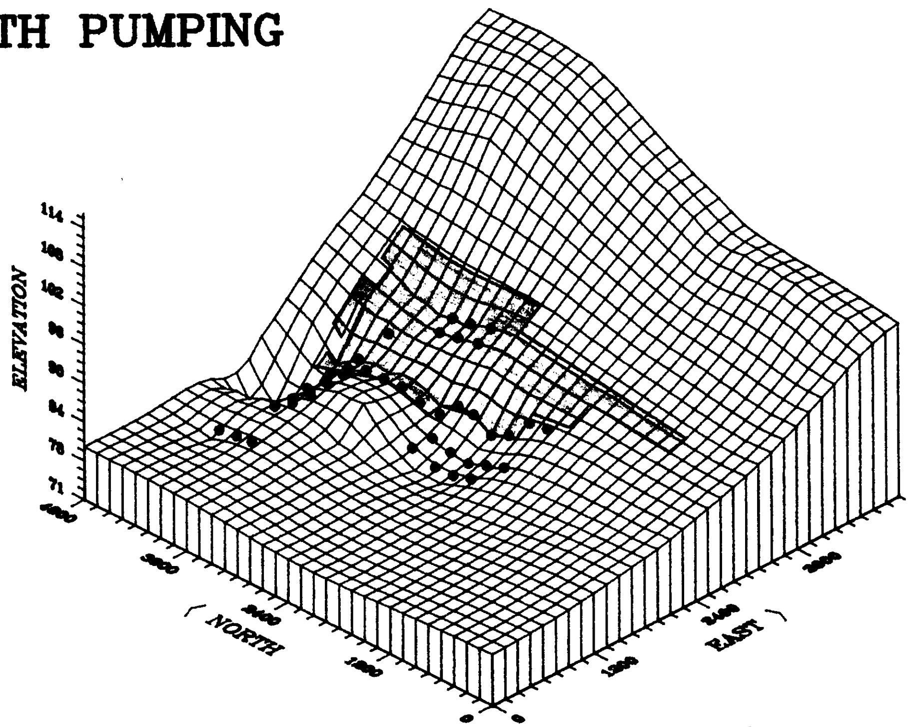
FIGURE 4-31

A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT AND WITH PUMPING



TOP OF REGIONAL ZONE AFTER 10 YEARS WITH NO PUMPING

ALTERNATIVE 1-1

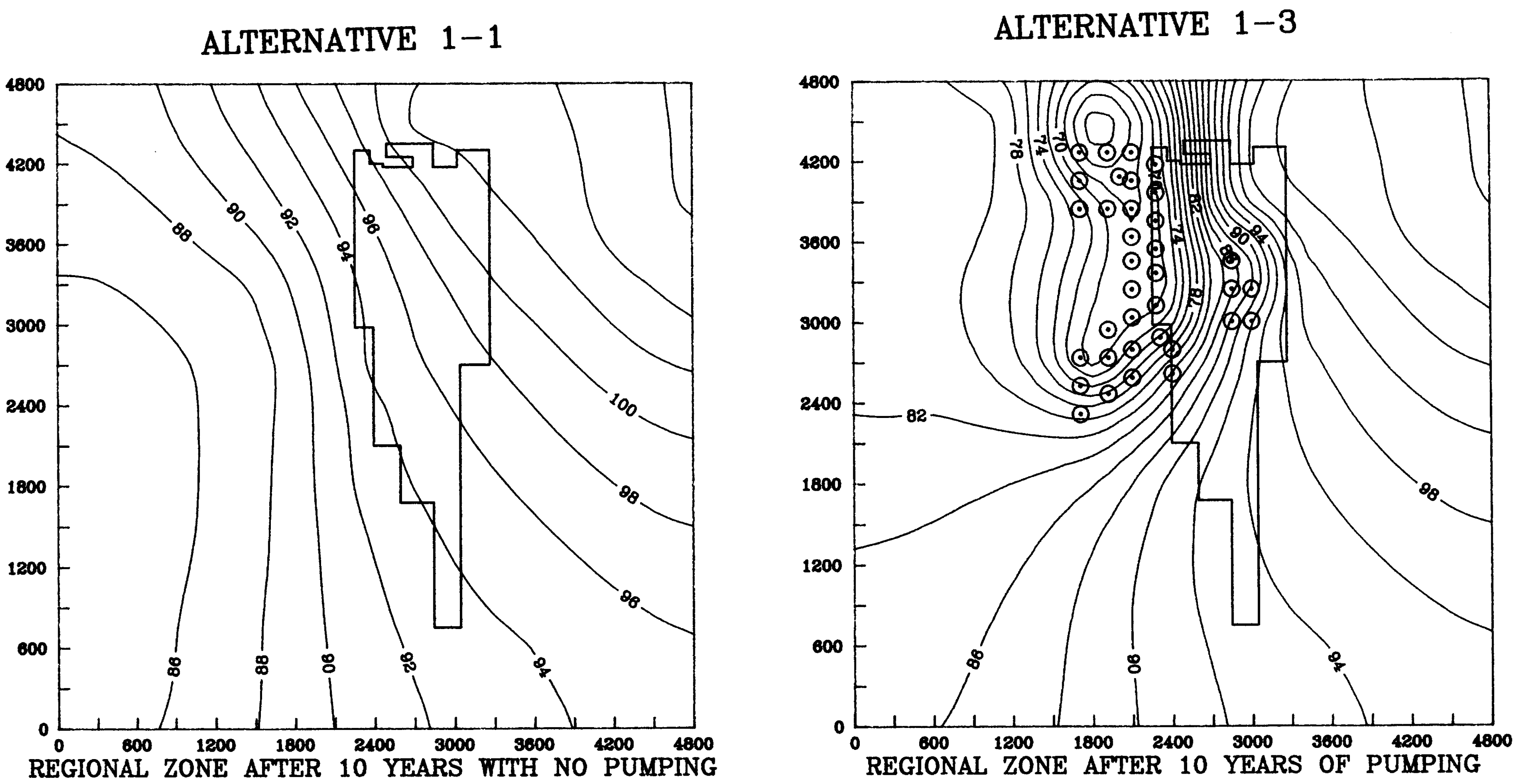


TOP OF REGIONAL ZONE AFTER 10 YEARS OF PUMPING

ALTERNATIVE 1-3

FIGURE 4-32

A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT AND WITH PUMPING

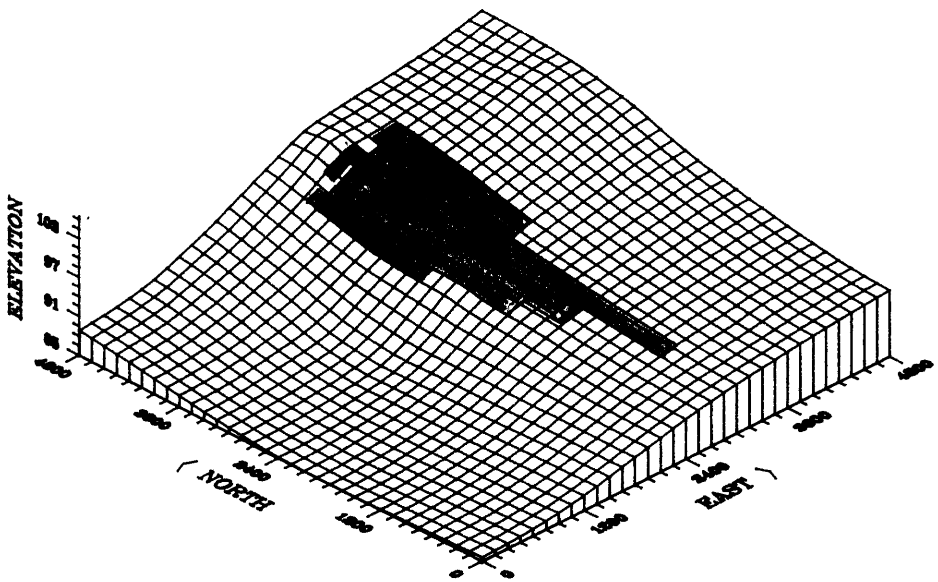


(GROUNDWATER CONTOURS OF 80 = ELEVATION 1180)

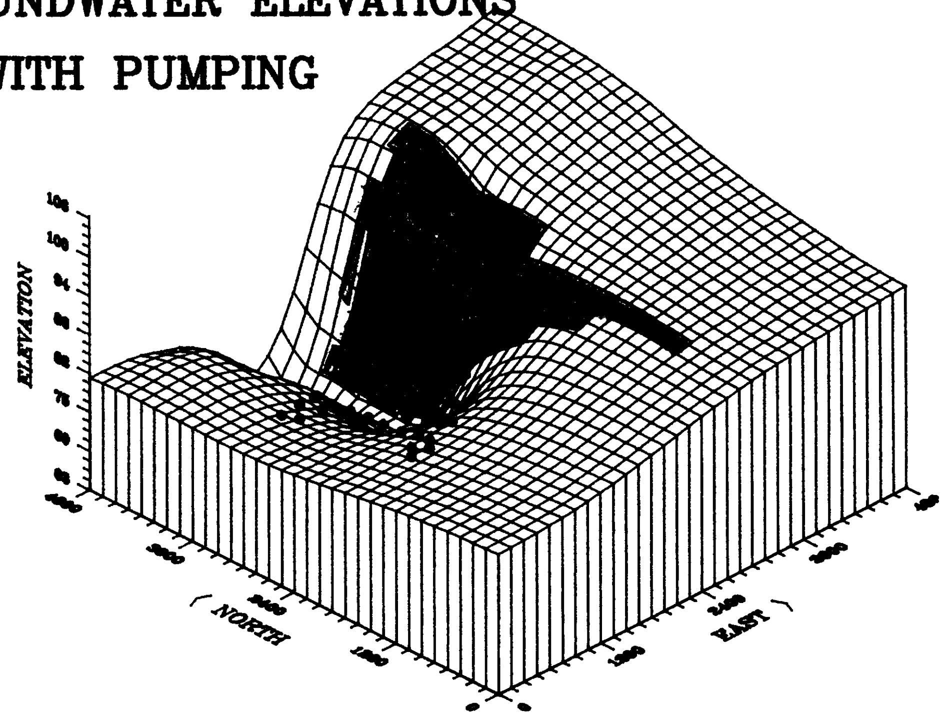
EXTRACTION WELL – ⊙

FIGURE 4–33

A COMPARISON OF GROUNDWATER ELEVATIONS WITHOUT AND WITH PUMPING



ALTERNATIVE 1−1



ALTERNATIVE 1−3

FIGURE 4−34

that results from the pumping, causes a change in the directions of flow within the aquifer at the site. The change in shape is the most noticeable in the regional zone which can be seen on the surface plot (figure 4-25). The regional zone is the thickest of the three zones and the highest individual flow rate for a well is in this zone. The local flow is now toward the wells and prevents the contamination from moving off site, therefore, controlling the horizontal migration. The effectiveness rating for Alternative 1-3 is 1.

Alternative 1-3 is expected to recover over 85 percent of the groundwater contamination in all three zones within twenty years. The rating for useful life is 3.

4.2.3.1.2 <u>Reliability.</u> Operation and maintenance will be required to keep the removal wells operating efficiently. The wells will require periodic cleaning to remove silt, algae, mineral deposits, or bacteria that are likely to accumulate on the well screens. The pumps are expected to cycle on and off as the water level fluctuates due to drawn down and recharge of the aquifer zone. This persistent cycling undoubtedly will cause additional wear on the pumps, resulting in maintenance, repair, and perhaps replacement of some of the pumps. The rating for operation and maintenance of Alternative 1-3 is 3.

Removal of contaminated groundwater through pumping is a common technology and has been used successfully at other sites. The rating for demonstrated performance is 1.

4.2.3.1.3 <u>Implementability.</u> The installation of Alternative 1-3 extraction wells and associated piping inside of the building may cause disruptions to the production operations within the building. The wells must be located and constructed so that access for routine maintenance is maintained. The locations for the wells were selected so that installation with a drill rig would be possible. All interior wells are located in aisleways or high bay areas within 11 feet of the column line to minimize potential shop rearrangement. Special care must be taken when drilling in the building to prevent cracking or spalling of the concrete floor. The collection system piping in the building will run overhead or through the existing industrial waste lines to minimize disruption. An eighteen inch diameter bore hole will be drilled to the top of the shale beneath the sandstone layer of the aquifer zone to be pumped. The holes must be drilled with air or water only. Drilling and installation of the wells in the building must be done during the evening or on weekends and coordinated with the production activities in the building to minimize disruption of industrial operations. After the hole is drilled, geophysical logs must be run. The location and the length of the screen will be determined from the geophysical log to insure the full thickness of the aquifer zone will be screened. A sand filter with a hydraulic conductivity of at least 10^{-3} cm/s will be placed around the screen. A five foot sump will be constructed at the bottom of the well. A minimum of a four foot thick bentonite seal will be set in the shale layer above the aquifer zone. Above the seal, the void around the casing will be grouted with a 3 percent bentonite cement grout to the top of the casing. The well casing will be four inch diameter schedule 80 PVC flush joint casing with 0.010 inch slotted screen. The wells will be constructed in a subgrade waterproof manhole. A typical schematic of an extraction well is shown on Figure 4-4. The constructability for Alternative 1-3 is rated 3.

After the Record of Decision is finalized, physical, on site construction must begin in fifteen months. The actual time for construction of the wells will depend on the number of drilling rigs that the contractor operates. If two rigs are used, construction of the well field will take approximately six months. The water treatment system must be in operation before the groundwater removal can begin. If the water treatment system can be completed in the same time frame, this alternative can be in operation approximately two years after the Record of Decision. The rating for time to implement is 2.

This alternative will begin to provide control of the groundwater contamination within the first year. It will prevent the plumes from moving further off the site. The perched zone is predicted to be almost 60 percent clean in 3 years. In five years all three zones will be close to 70 percent clean and in twenty years they will be over 85% clean. The rating for the time for results of Alternative 1-3 is 3.

4.2.3.1.4 Safety. Installation of the monitoring wells and extraction wells included in Alternative 1-3 will require modified level C protection. This will include chemically impervious boots and chemically impervious gloves (under cotton gloves), hard hat, and protective disposable coveralls. Eye and hearing protection will be worn during drilling and installation of the monitoring wells. Air monitoring in the breathing zone will be done with photoionization meter and a combustible gas meter. All personnel involved with the well installation will be required to have air purifying respirators (with organic vapor cartridges) with them should the air monitoring indicate a need. The requirement for respirators or self contained breathing apparatus will be determined by a certified industrial hygienist based on the TWA-STEL. Sampling of the monitoring wells will require chemically impervious gloves and boots. Special precautions relating to the interior wells in the highly contaminated portions of the plumes may be necessary. The safety procedures required for these wells will be determined by a certified industrial hygienist. All safety procedures required due to industrial operations within the building will be observed. Operation and maintenance safety will depend on the type of procedure being done and will be directed by a certified industrial hygienist. Simple pump or line repair will have the same safety requirements as sampling. Cleaning or repair of the well itself will require the same safety procedures as drilling. The Tinker Air Force Base, Installation Restoration Program, Safety and Occupational Health Plan For Corps of Engineers Personnel will be followed as a minimum. The safety rating for Alternative 1-3 is 1.

4.2.3.2 Public Health Impacts. Public health effects from placement and operation of the groundwater removal system under this alternative would be essentially the same as those of Alternative 1-2. The predicted results in the decline of contaminant concentrations in water supply wells from groundwater removal would have the same beneficial health effects. Placement and operation of the recovery well field would provide remediation over a 30 year time period. Concentrations of indicator contaminants migrating from highly contaminated overlying aquifers to water supply wells would decline over the remediation period. Contaminant concentrations at these water supply wells (which were predicted to exceed SDWA MCLs between exposure years 50 and 70 under no action) would return to prerelease levels, resulting in a reduction in health threats over the no action alternative. Half of the contaminated monitoring wells are expected to achieve zero concentrations of indicator organics within the first 10 years of remediation. Contamination of the surface water of Soldier Creek will be prevented under Alternative 1-3 as pumping operations capture the contaminant plume. Elimination of the exposure pathway would reduce the potential for noncarcinogenic health effects. Under the no action alternative, noncarcinogenic risk evaluation from the ingestion route of exposure indicated a potential for impact (hazard index of 2.12). Elimination of this pathway and route of exposure results in only groundwater ingestion as a source of exposure. The reduction of contaminant concentration by 93 percent at the regional aquifer and overlying aquifers by 97 percent within the first 30 years of the exposure period (70 years) would reduce both the noncarcinogenic and carcinogenic risks to values well within acceptable ranges. Concentrations driving the conservative based risk assessment were based on average concentrations from the three aquifers. Reductions of contaminant concentrations between 93 and 97 percent would reduce the chronic daily intakes to levels that should provide a considerable reduction in contaminant and route specific risk. Reductions in inorganic concentrations in the groundwater, particularly lead, by 94 to 97 percent, as indicated for chromim, would reduce the hazard index value from 1.18 to a value below 1.0. Carcinogenic risks already at acceptable values of 1.2×10^{-5} would be further reduced in the 10^{-5} to 10^{-7} range. Therefore, no adverse public health impacts would result from this alternative. The Alternative 1-3 rating for public health impacts is 2.

4.2.3.3 Environmental Impacts. The placement and operation of the groundwater removal system would result in no adverse impacts on the environment. The alternative would not physically affect the surface environment of Tinker AFB or the surrounding environment. The removal system would stop future migration to uncontaminated waters of the aquifer and over the 30 year remediation period, returning the producing zone groundwater to prerelease quality. Control over migration of the perched aquifer into Soldier Creek would prevent seepage into the surface water and impacts on the aquatic populations. The remediation alternative would result in beneficial impacts on the human and wildlife environment of Tinker AFB and surrounding community. The Alternative 1-3 rating for environmental impacts is 1.

4.2.3.4 Institutional Requirements. Alternative 1-3 does meet all applicable or relevant environmental and public health standards. Relative to Alternative 1-2, it provides quicker remediation of the perched aquifer, and removes a greater amount of contamination from the regional zone. Therefore, Alternative 1-3 is even more effective than Alternative 1-2 in mitigating or preventing the threat of contamination to the Garber-Wellington aquifer. It will reduce the likelihood of present or future threat to public health and the environment by preventing or reducing the migration of contaminants to Soldier Creek. The Alternative 1-3 rating for institutional requirements criteria are listed below:

Criteria	Rating
Conformance with ARAR's	2
Permitting requirements	3
Normalized Rating	2.5

4.2.3.5 Cost Analysis. Costs include the installation of 128 recovery wells, pumps, collection piping, bonding, insurance, maintenance, 18 additional monitoring wells, scheduled sampling, and analysis of the groundwater, and are listed below:

Capital Costs	Annual O & M Costs	Present Worth
$3,408,900	$142,160	$4,885,950

4.3 SUMMARY OF GROUNDWATER PUMPING ALTERNATIVES

Alternative 1-1 will not meet the goals of the groundwater remediation and will allow the contamination at the site to become more of a threat. If left alone the volume of contaminated water at the site will increase significantly, the contamination will discharge into the perched aquifer, and the contamination will steadily move into the producing zone.

Both Alternative 1-2 and Alternative 1-3 will control the spread of contamination into East Soldier Creek and prevent the plumes from moving off site. When comparing the concentration contours of the regional zone (Figures 4-13, 4-16, 4-19, and 4-22) the greater effectiveness of Alternative 1-3 in the removal of contaminated groundwater from the regional zone is obvious. Tables 4-1 and 4-2 present this difference as 93 percent TCE removal in the regional zone after 30 years for Alternative 1-3, compared to 75 percent for Alternative 1-2. Another advantage of Alternative 1-3 is that it removes a greater amount of TCE and Cr from the perched aquifer in years 1 through 4. This early removal is significant in reducing the amount of degradation within the aquifer. The advantages of Alternative 1-3 over Alternative 1-2 are not as readily apparent when comparing the TCE and CR plumes predicted in the perched and top of regional zones, (Figures 4-12, 4-13, 4-15, 4-16, 4-18, 4-19, 4-21, and 4-22) because the plumes appear similar. This apparent similarity between alternatives is also reflected in Tables 4-1 and 4-2 by the percentages of TCE and Cr removed in the perched and top of regional zones from years 5 through 30. The reason the plumes and the percentages are similar is related to the leakage of those two aquifers into the underlying aquifers. Two mechanisms exist for contamination to leave an aquifer, removal by pumping and leakage into a lower aquifer zone. To account for the changes due to the pumping, the model was adjusted to calculate the volume leaking from the aquifer as well as the recharge into the aquifer based on the difference in hydraulic head. Therefore, as the aquifer heads are lowered from pumping, the difference in heads between the source recharging into the aquifer and aquifer being modeled will increase as will the volume recharging into the aquifer. Also, the head difference between the aquifer being modeled and the lower aquifer will decrease as will the volume of leakage out of the aquifer. Since each of the alternative pumping plans induces unique heads within an aquifer, the volume of contaminated water leaking into and out of an aquifer is different for each alternative. Because of this, the amount of continuous source contamination input was different for each of the alternatives. Both types of removal are considered equally in the computations of "percentages removed" in Tables 4-1 and 4-2. The leakage in Alternative 1-2 is therefore as effective in removing contaminants as the pumping in Alternative 1-3. Therefore, even though the plumes appear similar and the percentages removed in Tables 4-1 and 4-2 appear similar, Alternative 1-3 is still more effective because the contaminants are being removed for treatment rather than being allowed to enter the next lower aquifer. Table 4-3 contains a summary of the ratings involved in the comparison of the groundwater removal alternatives.

4.4 RECOMMENDED GROUNDWATER PUMPING PLAN

The groundwater removal alternative that is recommended is Alternative 1-3, which received a ranking score of 1.78. This groundwater collection plan, which is shown in Figure 4-3, consists of 111 collection wells surrounding Building 3001, and 18 collection wells in the interior of the building. The collection wells include 50 wells in the perched aquifer, 79 wells in the upper portions of the Garber-Wellington aquifer. The wells will have a combined flow rate of 88,180 gallons per day.

TABLE 4-3

SUMMARY OF ALTERNATIVE PUMPING PLAN ANALYSIS

Evaluation Criteria	Alternative 1-1 No Action	Alternative 1-2 Exterior Wells	Alternative 1-3 Interior and Exterior Wells
Engineering Feasibility			
short term-effectiveness	None	Fair-Will reduce 36% of TCE and 46% of Cr within first 2 years	Good-Will remove 45% of TCE and 49% of Cr in Perched Aquifer within 2 years
long term-effectiveness	Poor-Degradation of the aquifers continue	Fair-Will remove 75% of TCE and 76% of Cr in the regional zone in 30 years	Good-Will remove 93% of TCE and 94% of Cr in the regional zone in 30 years
reliability	Good	Fair	Fair
implement-ability	Good-construction of monitoring wells is a proven and reliable technology that is currently in operation at the site	Very good-the same comments as Alt 1-1 and pumping to remove contamination requires no special requirements on base	Good-same as Alt. 1-2 although will be more difficult to install interior wells
Normalized Score	2.25	2.25	2.13
Public Health Impacts	Does not protect public health. Allows migration into creek and producing zone	Protects public health. Prevents migration into creek and reduces it to producing zone	Same as Alt. 1-2, but reduces the threat to the producing zone faster
Normalized Score	5	2	2

TABLE 4-3 (Continued)

SUMMARY OF ALTERNATIVE PUMPING PLAN ANALYSIS

Evaluation Criteria	Alternative 1-1 No Action	Alternative 1-2 Exterior Wells	Alternative 1-3 Interior and Exterior Wells
Environmental Impacts	Mobility and volume of contamination will increase	Mobility and volume of contamination will decrease	Mobility and volume of contaminants will decrease more than Alt 1-2 since less will be going into lower aquifers
Normalized Score	5	1.5	1
Institutional Requirements	Does not mitigate or prevent threat of further contamination	Does comply with ARARs	Same as Alternative 1-2
Normalized Score	3.67	2.67	2
TOTAL SCORE	3.98	2.14	1.78
Cost			
-Capital	$103,000	$2,707,149	$3,408,903
-O&M	$41,600	$127,900	$142,160
-Present Worth	$535,200	$4,036,030	$4,885,945

Although Alternative 1-3 is more costly and will involve some disruption to activities in Building 3001, it received the lowest total ranking score indicating that it will provide the best site remediation. Disruption could possibly be minimized by installing the interior wells during the evenings or weekends when activities are slowed down. The benefits of pumping directly out of the most highly contaminated portion of the plume will be significant in the protection of Soldier Creek and the producing zone. The accuracy of the modeling predictions is greatest in the near future and it is in the earliest time intervals that the greatest benefit to pumping from the interior wells is seen. The recommended alternative is the one that will produce the fastest remedial results and provide the greatest protection to the producing zone of the Garber-Wellington aquifer. Alternative 1-3 does this by providing the fastest cleanup of the regional zone and preventing the highly contaminated water from the top of regional zone from migrating into the regional zone.

The computer modeling data shows that the efficiency of the recovery (volume of TCE or Cr/volume of water) of TCE and Cr will be greatest in the first five years and will fall off sharply with time. The overall remediation of Alternative 1-3 will be over 80 percent complete after 10 years with an additional 20 years of pumping retrieving only an additional 15 percent. The literature reports that many groundwater pumping projects are operated more efficiently using what is referred to as "pulsed recovery". This occurs when the recovery wells are shutoff and the contaminant concentrations rebound to levels significantly higher than those that are observed while the pumps are running. After a recovery period, the pumps are turned back on and an exponential recovery curve is again observed, this time leveling off at a lower concentration. This process continues in "pulses", until it is determined that adequate remediation has been achieved. What concentrations are to be considered adequate remediation will be determined by coordination with the OSDH, EPA, the Air Force and the Public in accordance with all applicable sections of the Federal Facility Agreement to protect the public health, welfare, and the environment. It is thus recommended that the recovery system at Building 3001 proceed until concentration values level off at some value, and then be shut off and monitored. If concentrations rebound to unacceptable levels, subsequent pumping periods can be initiated. After concentrations remain constant for a reasonable period, the recovery project can be declared complete. This observation period will be determined based on consideration of aquifer recovery times during the final design phase.

The results from the modeling of the recommended alternative pumping plan (Alternative 1-3) were used to predict the concentrations of the contaminated groundwater at various times over the life of the remedial action. The predicted flow rates and concentrations were used in the development, evaluation, and selection of alternatives for groundwater treatment and disposal which is contained in Section 5 of this report. Tables A-7, A-8, and A-9 in Appendix A provide concentrations that were predicted for each well at various time intervals.

The development, evaluation, and selection of alternatives for management control are contained in Section 6 of this report.

5.0 GROUNDWATER TREATMENT AND DISPOSAL

This section identifies and develops alternatives for the remedial action alternative group consisting of groundwater treatment and disposal at the 3001 site. The no action alternative is evaluated within each alternative group. The technologies surviving the screening process presented in the PELA Report for groundwater treatment and disposal were used to develop remedial action alternatives in this section.

5.1 DEVELOPMENT AND SELECTION OF ALTERNATIVES

Four alternatives for groundwater treatment and disposal, are identified and developed in this subsection. The no action alternative was previously described and evaluated in Section 4. The groundwater treatment and disposal alternatives address everything downstream of the groundwater collection manifold system, previously described in Section 4. Screening of Groundwater Treatment and Disposal Alternatives for the 3001 site was provided in the "Preliminary Development and Evaluation of Groundwater Treatment and Disposal Alternatives" report(5). A total of six preliminary treatment and disposal alternatives were developed in the report to address remedial action objectives and to satisfy the criteria for alternative categories. The six alternatives were further subdivided into 13 treatment and disposal options. The treatment and disposal options are identified in Table 5-1 (from that report). The preliminary alternatives described in Table 5-1 were screened in the previous report according to engineering feasibility, environmental and public health implications, and order-of-magnitude costs. The alternatives that passed the initial screening are as follows:

- o Alternative 2-1 - Modified IWTP/Industrial Reuse
- o Alternative 2-2 - Modified IWTP/Surface Water Discharge
- o Alternative 2-3 - Treatment/Industrial Reuse
- o Alternative 2-4 - Treatment/Surface Water Discharge

TABLE 5-1
PRELIMINARY REMEDIAL ALTERNATIVES

ALTERNATIVE NUMBER	ALTERNATIVE DESCRIPTION	OPTION IDENTIFICATION	OPTION DESCRIPTION
1	No Action	NA	NA
2	Offsite Treatment/Disposal	2A	Offsite Treatment at RCRA-Permitted Facility
		2B	Deep Well Injection
3	No Treatment/Reuse	3A	No Treatment/Irrigation
		3B	No Treatment/Industrial Reuse
4	Modified IWTP/Disposal	4A	Modified IWTP/Irrigation
		4B	Modified IWTP/Industrial Reuse
		4C	Modified IWTP/Surface Water Discharge
		4D	Modified IWTP/Discharge to STP
5	Treatment/Reuse	5A	Treatment/Irrigation
		5B	Treatment/Industrial Reuse
6	Treatment/Discharge	6A	Treatment/Surface Water Discharge
		6B	Treatment/Discharge to STP

NA - Not Applicable

A detailed description of each of these screened alternatives is presented in the following subsections.

5.1.1 Alternative 2-1 - Modified IWTP/Industrial Reuse

Alternative 2-1 consists of routing contaminated groundwater collected from the extraction wells to an air stripper, using the air stripper to remove volatile organic compounds, pumping the air stripper effluent to a storage tank, treating for inorganics and nonvolatile organics at the existing IWTP, and reusing the treated groundwater. Existing treatment processes at the IWTP include oil/water separation, flow equalization, metals reduction/precipitation by sulfide precipitation, biological treatment by activated sludge, oxidation/disinfection by chlorination, and pressure filtration. Sludge is thickened and dewatered onsite and disposed of at an offsite RCRA permitted facility. A flow schematic for Alternative 2-1 is presented in Figure 5-1 and the site plan is presented in Figure 5-2.

Water from the extraction wells will be pumped through a 2 1/2-inch diameter, double walled pipe (for leakage containment) to a covered wet well. The pipe header system will be as described in Section 4 for the selected groundwater removal and collection network. The influent wet well will be six feet in diameter and nine feet deep and constructed of reinforced concrete or reinforced concrete pipe. The purpose of the wet well is threefold:

1. Combining the contaminated groundwater in the wet well provides continuous mixing which produces a wastewater stream with relatively uniform contaminant characteristics.
2. Pumps in the wet well will provide a constant flowrate to the air stripper.
3. Pumps in the wet well which service the air stripper will reduce the horsepower requirements of the pumps in the groundwater extraction wells.

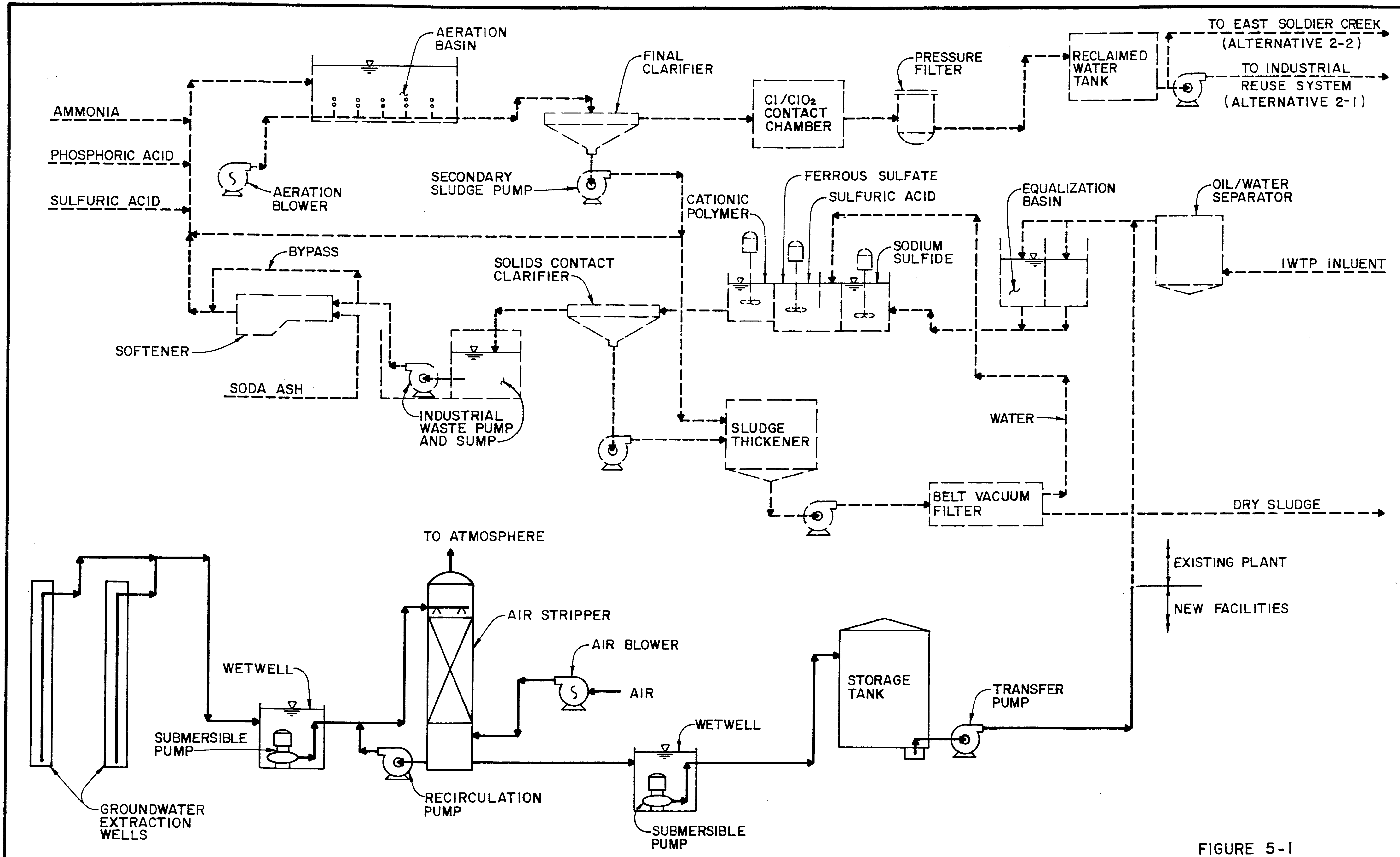


FIGURE 5-1
FLOW SCHEMATIC
ALTERNATIVES 2-1 AND 2-2

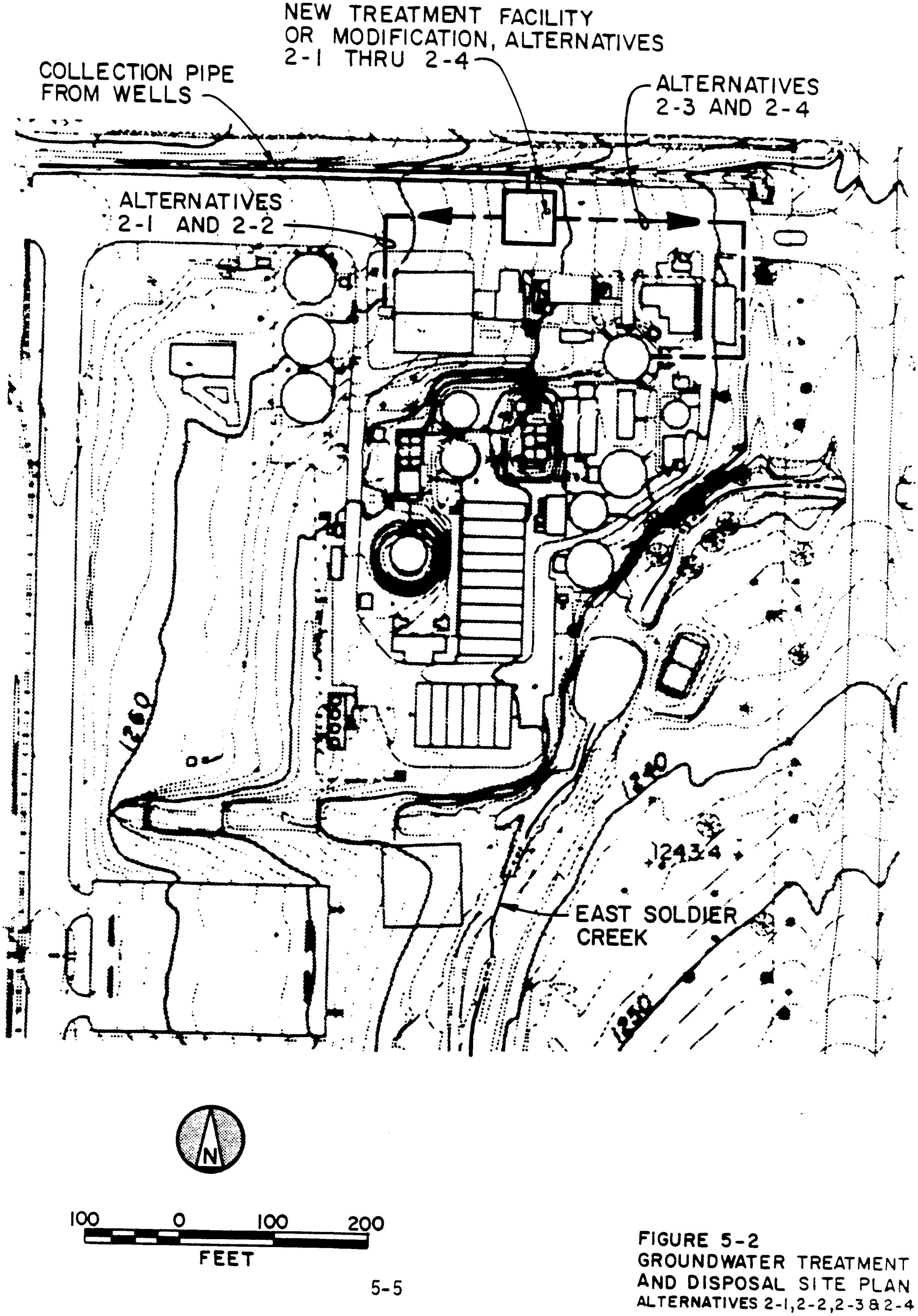


FIGURE 5-2
GROUNDWATER TREATMENT
AND DISPOSAL SITE PLAN
ALTERNATIVES 2-1, 2-2, 2-3 & 2-4

The wet well will contain one 5 horsepower (Hp) submersible pump which will pump the contaminated groundwater through 2 1/2-inch PVC piping to the top of the air stripper. The underground portion of the piping will be constructed in the same manner as the extraction well header (Section 4). Aboveground portions of the air stripper will be insulated and heat traced for freeze protection.

Air stripping is a widely used treatment method for removing volatile organic contaminants from groundwater. Air stripping provides intimate contact between air and water in a counter-current packed column to promote mass transfer of volatile organics at the air/water interface. The packing provides high liquid interfacial area for efficient mass transfer. Operation at high air-to-water volume ratios is possible because of the low pressure drops associated with most packing. High volatile constituent removal efficiency can normally be achieved.

The air stripper design is based on a flow rate of 62 gpm and influent concentrations as presented in Table 5-2. Because NPDES discharge limits have not been established, limits based on toxic pollutant effluent limitations for end of pipe biological treatment for the organic chemistry industry (40 CFR 414.91) are also presented in Table 5-2 for comparison. Proposed discharge permit limits for effluent water at the final design stage will be determined by Tinker AFB, the Environmental Protection Agency, Region VI, and the State of Oklahoma to satisfy Oklahoma Water Quality Standards in conjunction with Best Available Technology Economically Achievable (BAT) using Best Professional Judgement (BPJ) of the permit writer.

Design of the air stripper is based on compliance with the requirements of the Oklahoma Air Pollution Rules, Regulation 3.8 - Control of Emission of Hazardous and Toxic Air Contaminants (Controlling ARAR). The following two provisions of Regulation 3.8 are pertinent in the case of volatile air emissions generated from the air stripper:

- Section 3.84(b)(1) - "No person shall cause or permit the emission of any toxic air contaminant in such concentration as to cause or contribute to a violation of the Maximum Acceptance Ambient Concentration (MAAC)."

- Section 3.84(c) New Sources - "New sources emitting any Category "A" pollutant shall be required, as a minimum, to install Best Available Control Technology (BACT)."

TABLE 5-2

VOLATILE ORGANIC COMPOUND INFLUENT AND EFFLUENT CONCENTRATIONS

VOLATILE ORGANIC	Influent Concentration, ug/l	Effluent Concentration,ug/l	Discharge Limit, ug/l
Trichloroethylene	3,139	.95	21
1,2-Dichloroethylene	122	<1	21
Tetrachloroethylene	27	.003	22
Toluene	6	.001	26
Benzene	4	.0004	37
Xylene	1	NA	--
Acetone	58	NA	--

* Toxic pollutant effluent limitations for end of pipe biological treatment for the organic chemical industry.

The MAAC is defined as the maximum allowable twenty-four hour average concentration, in ambient air (ground level, off property) of a toxic air contaminant. Included in Table 5-3 are the estimated discharge concentrations of volatile organic compounds which would be emitted from the air stripper tower along with the corresponding MAAC values for each compound. In accordance with the Oklahoma Air Pollution Rules - Section 3.8.4(F), all of the volatile organic compounds listed were categorized as highly toxic substances, for which MAAC values are calculated as one-hundredth of the substances Occupation Exposure Limit (OEL/100).

As shown in Table 5-3, TCE is the only contaminant which exceeds the MAAC at the stack. However the MAAC should be compared to the maximum ground level air concentration for TCE; therefore, screening level dispersion modeling was performed. The Industrial Source Complex Short-Term (ISCST) dispersion model, which is EPA approved, was used for the screening level analysis. The results of the dispersion model indicate that a maximum TCE

TABLE 5-3

AIR STRIPPER STACK GAS
VOLATILE ORGANIC CONCENTRATION
AND AIR STANDARDS

Contaminant	Discharge Concentration		Air * Standard, ppm
	ppm	pounds/year	
Trichloroethylene	5.63	855	0.5
1-2 Dichloroethylene	.289	32.4	1.0
Tetrachloroethylene	.038	7.3	0.5
Toluene	.015	1.4	10.0
Benzene	.012	1.1	0.1
Xylene	.002	<1.0	10.0
Acetone	.002	<1.0	1.0

* Maximum Allowable Ambient Concentration

ground level concentration of 0.002 ppm would occur off-property at a distance of 70 meters from the stack. Because .002 ppm is less than the MAAC of 0.5 ppm, the requirements of Section 3.84(b)(1) are achieved. A memorandum, included as Appendix D, further explains the dispersion model and assumptions used.

An applicable exemption from the use of BACT for new sources emitting toxic air contaminants as required in Section 3.84(c) is provided in Section 3.8.4(i)(1)(E)(iii). The exemption states that this regulation (3.8) does not apply to sources with de minimis emissions of less than 1,200 pounds per year and 0.57 pounds per hour assuming 100 percent removal efficiency, the maximum emissions rate for TCE would be 855 lbs per year.

Based on a 24 hr, 7 days per week operation the maximum hourly production of TCE will be approximately 0.10 pounds per hour. Both stack emissions estimates meet the de minimis standards and, therefore exempt the air stripper stack from BACT requirements. Because this is a CERCLA site, no air emissions permits are required.

The air stripping tower will be located in the space dedicated for modifications as shown on Figure 5-2. The nearest resident to the stack is approximately 150 feet away to the north-northeast. However, as discussed earlier the maximum ground level TCE concentration occurs approximately 70 meters (230 feet) from the stack. To obtain a "worst case" carcinogenic risk estimate for residents, the TCE concentration at the 70 meter point was used. Detailed chronic carcinogenic risk calculations for residential exposure at this point, including assumptions used, are provided in Appendix E. The exposure and risk estimates were calculated in accordance with the EPA Superfund Exposure Assessment Manual, April 1988(8). The resulting estimate of increased cancer risk due to TCE exposure at a distance of 70 meters from the stack is 1.3×10^{-5}. According to EPA policy increased carcinogenic risk levels for target compounds may range from 1×10^{-4} to 1×10^{-7}(9).

The air stripping tower will be 30 inches in diameter by 43 feet tall and will be made of corrosion resistant material to reduce cleaning and maintenance. The tower will be shipped to the site complete with packing, packing supports, liquid distribution piping, mist eliminator, access doors, lifting lugs, air inlet and outlet, and other appurtenances. The tower will be fabricated from a composite of PVC overlain with fiberglass reinforced plastic (FRP), which will be mounted on an epoxy-coated steel base. The tower will be flanged near the top of the packed bed in order to facilitate access to the packed section. Packing will be high mass transfer type plastic.

A two (2) horsepower HP centrifugal blower will be used to supply air to the air stripper. Air-to-water ratio on a volumetric basis is expected to be approximately 100:1. The fan will be connected to the stripping tower with a flexible coupling to reduce vibration.

Maintenance of the air stripper treatment unit will consist primarily of lubrication of equipment and rinsing the tower. The tower should be rinsed on a periodic basis with a dilute solution of calcium hypochlorite or other biocide. It may also be necessary to rinse the packing with an acid solution to remove scale formed by inorganic metal salts which come out of solution. To aid in rinsing the tower and packing, a recirculation pump will be installed.

Effluent water from the air stripper will be discharged to a second wet well that will be six feet in diameter by nine feet deep and will be constructed of reinforced concrete or reinforced concrete pipe. The wet well will contain one 2 HP horsepower submersible pump, which will transfer the treated groundwater through a new 2 1/2-inch PVC underground piping system with leak detection to a new storage tank.

The new storage tank will have approximate dimensions of 62 feet in diameter by 23 feet tall (500,000 gallons nominal capacity) and will be designed to AWWA standards.

It was assumed that the existing plant will be operating at full capacity during the weekdays, which means approximately 0.1 MGD of excess water, resulting from groundwater flows, will be stored in the new tank until it can be treated on the weekends.

New centrifugal pumps, 1-1/2 HP, will pump approximately 220 gpm of groundwater to the IWTP and discharge into the system at a point downstream of the oil/water separator.

Control for the new treatment facilities will include an interlock system which will require the stripper air blower to be in operation before the extraction well pumps or the submersible pumps feeding the air stripper can be started. If the air blower or either set of submersible pumps do not function, pumping from the extraction wells and submersible pumps will be stopped.

Groundwater will be treated for heavy metal and nonvolatile organics by using the existing metals reduction/precipitation and activated sludge units of the IWTP as indicated in Figure 5-1. Anticipated concentrations of metals in the groundwater and discharge requirements are shown in Table 5-4.

TABLE 5-4

HEAVY METAL CONCENTRATION IN GROUNDWATER
AND TREATMENT REQUIREMENTS

METAL	GROUNDWATER CONCENTRATION, ug/l	DISCHARGE LIMIT, ug/l
Barium	4138.1	--
Chromium	605.6	100
Lead	153.2	100
Nickel	156.1	500

Note: Discharge limits based on values from the NPDES permit for the IWTP. No limits have been set for barium.

Under this alternative, treated groundwater will be reused in on-Base operations associated with servicing, repairing, or upgrading aircraft and jet engines. Major industrial water reusers identified at Tinker AFB are included in Table 5-5. The existing industrial reuse system consisting of a one million gallon holding tank and associated piping to three of the four areas of industrial reuse is in place at Tinker AFB. Piping to the engine test cells is nearly complete. The water quality requirements for industrial reuse in chemical cleaning and the calculated concentration of contaminants found in the pumped groundwater are given in Table 5-6. In addition, the water quality requirements for chemical cleaning are more stringent than for the other three areas of industrial reuse; therefore, the limits established for chemical cleaning will apply to the industrial reuse system. The industrial reuse system, which is not currently in use, was designed to use effluent from the IWTP.

TABLE 5-5
INDUSTRIAL WATER REUSE

INDUSTRIAL REUSE	BUILDING NUMBER	WATER REQUIREMENTS (gpd)
Chemical Cleaning	3001	200,000
Plating	3001	70,000
Engine Test Cells	3234	131,250
	3703	8,730
Cooling Tower	3306	182,880
	3108	74,880
TOTAL		667,740

TABLE 5-6

INDUSTRIAL REUSE WATER REQUIREMENTS VS. CONTAMINATED GROUNDWATER CHARACTERISTICS

	Instantaneous Limits for Industrial Water Reuse[(1)]	Calculated Concentration of Contaminants in Pumped Groundwater[(2)] (mg/l)
pH	6.0 to 9.5	-
Specific Conductance	2000 umhos/cm	-
Turbidity	50 units	-
Total Hardness as ($CaCO_3$)	200 mg/l	-
Chemical Oxygen Demand	150 mg/l	-
Total Suspended Solids	30 mg/l	-
Cadmium, Total	0.05 mg/l	-
Chromium, Total	1.0 mg/l	0.606
Chromium, Hexavalent	0.1 mg/l	-
Cyanide, Total	0.025 mg/l	-
Copper, Total	0.1 mg/l	-
Lead, Total	0.1 mg/l	0.153
Nickel, Total	1.0 mg/l	0.156
Zinc, Total	1.0 mg/l	-
Phenols	1.0 mg/l	-
Oil and Grease	10.0 mg/l	-
TCE	-	3.149
1,2-DCE	-	0.122
PCE	-	0.027
Toluene	-	0.006
Benzene	-	0.004
Xylene	-	0.001
Acetone	-	0.058
Barium	-	4.138

(1) Tolerance Levels for Treated Effluent Use in Chemical Cleaning

(2) Letter from Black & Veatch to COE, Tulsa District, dated May 11, 1988.

5.1.2 Alternative 2-2 - Modified IWTP/Surface Water Discharge

Alternative 2-2 differs from Alternative 2-1 only by the effluent discharge destination. Instead of industrial reuse of the Modified IWTP effluent, as in Alternative 2-1, the effluent will be discharged to East Soldier Creek via the existing IWTP outfall.

5.1.3 Alternative 2-3 - Treatment/Industrial Reuse

The primary features of Alternative 2-3 consist of treating the air-stripped groundwater using a new sodium sulfide/ferrous sulfate (SS/FS) treatment unit for metals removal and a new granular activated carbon unit for nonvolatile organics removal. This alternative also includes an air stripper, wet wells, and associated piping, as discussed in Alternatives 2-1 and 2-2. A site plan is presented on Figure 5-2 and a flow schematic for this alternative is presented on Figure 5-3.

The air-stripped groundwater will be pumped to a new metal removal process, currently being used at the existing IWTP, and offered exclusively by Environmental Research and Development, Inc. (ERAD). This process uses SS/FS to chemically reduce and precipitate heavy metals. The SS/FS process includes pH adjustment and addition of ferrous sulfate and sodium sulfide to reduce metals. The resulting sludge will be dewatered by a filter press. The solids will then be transported to a RCRA approved landfill. The SS/FS process has been successfully demonstrated in full-scale operation at Tinker AFB in the existing IWTP. The treatment system would be located on a 30' x 50' reinforced concrete pad with a two-foot high confinement berm installed around the perimeter of the pad. Utility requirements will include electrical power for rotating equipment and instrumentation and water for preparation of chemical solutions. Water from the new SS/FS unit will flow to a six-foot diameter by nine-foot deep new wet-well constructed of reinforced concrete or reinforced concrete pipe. The wet-well will contain two 5 HP submersible pumps which will transfer the treated water through a new 2 1/2-inch PVC line to two granular activated carbon units for removal of soluble organics.

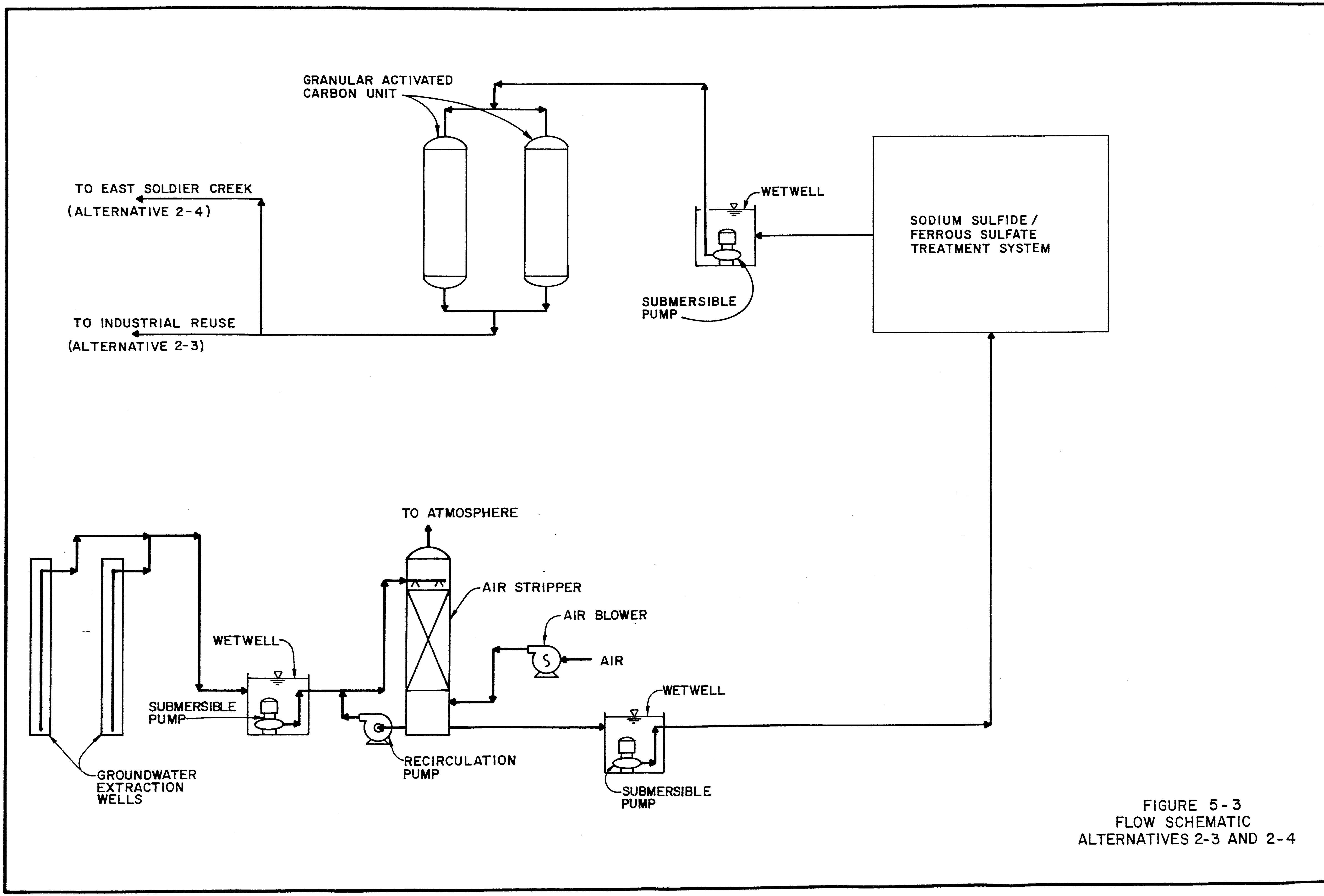


FIGURE 5-3
FLOW SCHEMATIC
ALTERNATIVES 2-3 AND 2-4

The granular activated carbon unit will remove non-volatile organics which may be present from sources such as fuel tank leakage, but would not be removed by the air stripper. Activated carbon is a well developed technology which is widely used in the treatment of hazardous waste streams. It is especially suited for the removal of insoluble organics such as the organic compounds which are present in the fuels that leaked from the storage tanks.

Two carbon adsorption columns will be used. All piping and valves will be installed to allow operation in series, parallel, or with either bed isolated or off-line. Approximate dimensions of the activated carbon columns will be 6.5 feet in diameter by 10 feet tangent to tangent. A six foot deep carbon bed will contain approximately 8,225 pounds of carbon. The carbon adsorption columns will be constructed of mild carbon steel, internally lined with a thermosetting epoxy-phenolic coating which will provide resistance to corrosion and erosion from the wet carbon granules. Each column will be designed for a maximum pressure of 100 psig at 150^{o}F. Each vessel will be provided with inlet and outlet distributors and an air release trap located at the high point of the system.

To develop costs and provide permanent treatment, it has been assumed that the spent carbon will be classified as a hazardous waste and regenerated at an offsite RCRA permitted facility. Spent carbon from the adsorption units will be regenerated at an offsite RCRA permitted facility. It is assumed that the spent carbon will be classified as a hazardous waste and will be regenerated once per year.

Spent carbon will be transferred directly from the adsorber vessels into 55-gallon drums for offsite regeneration. To have complete removal of contaminated carbon with a minimum of associated water, the vessels will be constructed with hopper bottoms and elevated from ground level to allow drums to be placed below discharge valves. Hoses and connectors for discharging spent carbon will be included.

Water from the granular activated carbon unit will then flow through underground 2 1/2-inch PVC pipe to the industrial reuse system described in Alternative 2-1.

5.1.4 Alternative 2-4 - Treatment/Surface Water Discharge

Alternative 2-4 differs from Alternative 2-3 only by the effluent discharge destination. Instead of industrial reuse of the new treatment plant effluent, as in Alternative 2-3, the effluent will be discharged to East Soldier Creek via a new outfall structure. Separate NPDES requirements will have to be met for discharges to this outfall.

5.2 DETAILED EVALUATION OF ALTERNATIVES

Detailed evaluations of remedial alternatives for groundwater treatment and disposal, are presented in this subsection. The alternatives to be evaluated are as follows:

- o Alternative 2-1 - Modified IWTP/Industrial Reuse
- o Alternative 2-2 - Modified IWTP/Surface Water Discharge
- o Alternative 2-3 - Treatment/Industrial Reuse
- o Alternative 2-4 - Treatment/Surface Water Discharge

As discussed in Section 3.1, each alternative is evaluated in terms of engineering feasibility, public health impacts, environmental impacts, institutional requirements, and costs. With the exception of the no action alternative which was evaluated in Section 4, evaluation of all environmental and public health impacts for the groundwater treatment and disposal alternatives are limited to everything downstream of the groundwater collection manifold system (also discussed in Chapter 4).

5.2.1 Alternative 2-1 - Modified IWTP/Industrial Reuse.

Under this alternative the pumped groundwater will be air stripped to remove volatile organics, and then routed to the existing IWTP equalization basins. Excess flows layered by groundwater loading will be held in the new storage tank until industrial wastewater flow to the IWTP is sufficiently low to permit processing of the excess water. At that time, the stored excess water will be pumped back to the existing IWTP for treatment. Effluent from the modified IWTP (including treated groundwater) will be discharged to the existing industrial reuse system.

5.2.1.1 Engineering Feasibility.

The Alternative 2-1 ratings for engineering feasibility are summarized below:

Criteria	Rating
Performance	
o effectiveness	2
o useful life	3
Reliability	
o operation & maintenance	2
o demonstrated performance	2
Implementability	
o constructability	2
o time to implement	5
o time for results	4
Safety	2
Normalized Rating	2.75

The following sections present the analysis of the criteria that resulted in these ratings.

5.2.1.1.1 Performance. The first process in treating the contaminated groundwater after extraction will be an air stripper. The stripping process will effectively reduce the concentration of volatile organic compounds (VOCs) to acceptable levels for subsequent treatment in the existing industrial waste treatment plant. The VOCs found in the groundwater which can be removed by air stripping include trichloroethylene (TCE), 1,2-dichloroethylene (1,2-DCE), perchloroethylene (PCE), toluene, benzene, and xylenes. With the exception of TCE, concentrations of VOCs in the off-gas released to the atmosphere from the air stripper do not exceed ambient air quality standards at the point of release. As previously discussed in Section 5.1, dispersion model results show that TCE concentrations would be significantly lower than ambient air quality standards when the effects of time and distance are taken into account. Minimum concentrations of the VOCs remaining in the water after stripping and low concentrations of other organics, such as acetone, will not adversely impact the biological treatment process used in the existing IWTP.

The existing IWTP is effective in treating an industrial waste that is more heavily contaminated than the effluent stream from the air stripper. The effluent from the IWTP currently meets water quality requirements for industrial reuse; therefore, it is anticipated that the addition of the effluent from the air stripper will not jeopardize the industrial reuse plan, but rather will improve the overall water quality for the industrial reuse program.

The major components of this remedial action will provide a long-term solution to the present groundwater condition while requiring a minimal amount of maintenance beyond the requirements for the existing IWTP. The effectiveness rating for this alternative is 2 and the useful life rating is 3.

5.2.1.1.2 Reliability. Air stripping is a proven and reliable technology in removing VOCs from contaminated groundwater. The air stripping process is capable of functioning unattended with only periodic maintenance. Instrumentation and alarms will provide an indication of any system malfunctions.

The existing IWTP has efficiently removed, from industrial waste streams, compounds similar to those expected to persist in the groundwater stream after air stripping. The existing IWTP is equipped with a metals precipitation process for effective metals removal and a biological treatment process that will effectively remove those organic compounds not removed by the air stripping.

Considering the reliability of Alternative 2-1, the operations and maintenance rating is 2 and the demonstrated performance rating is 2.

5.2.1.1.3 Implementability. There are no site conditions which should adversely affect constructability of the air stripper, wet well, storage tank, and appurtenances for Alternative 2-1. Coordination with other planned facilities may be necessary. The time to implement this alternative is questionable because it is dependent on the amount of time that it will take Tinker AFB to acquire a need for water from its reuse system. Presently, about one MGD of water is available to the industrial reuse program. A total of 0.67 MGD would be required by potential reuse sources that have been identified at Tinker AFB. Although the industrial reuse system is functional, all potentially reusable water is currently being discharged to Soldier Creek. Until a demand is created for reuse water at Tinker AFB, this alternative will not be implementable.

The air stripping tower, storage tank, wet well, and appurtenances could be operational in a short time (less than 12 months). The air stripping tower thoroughly volatilizes organics if the residence time of the groundwater in the tower is 5 to 10 minutes. However, the time to extract the quantity of water from the aquifer that is necessary to cleanup the aquifer to below threshold concentrations is 25 to 40 years, based on the conservative estimates of contaminant transport[1].

Beneficial results are provided as soon as the extraction system is placed in operation; however, due to the inability to predict when the industrial reuse program will become operational, the time to implement the alternative and to achieve the desired cleanup levels is longer than normally desired. Therefore, evaluation of the implementability of Alternative 2-1 leads to a constructability rating of 2, a time to implement rating of 5, and a rating for time to achieve beneficial results of 4.

5.2.1.1.4 Safety. During construction of the wet well and the air stripping facility, neither workers nor the surrounding community will be exposed to hazardous materials. Off-gases from the air stripping tower will have low contaminant concentrations; therefore, neither Tinker AFB personnel nor the surrounding community will be adversely affected by contaminants from air emissions.

Standards for water quality for the reuse program currently exist and workers are trained to handle the treated water in a safe manner. Therefore, additional safety concerns should not be a factor since the treated groundwater will meet the same water quality criteria of the current industrial reuse program. Ratings for both short and long-term safety are 2.

5.2.1.2 Public Health Impacts. A potential exists for short-term health impacts during operation and maintenance of the treatment facilities, particularly contact with contaminated groundwater or inhalation of vapors.

Treatment plant personnel should be aware of the nature of the waste stream being treated and should use the appropriate personnel protection equipment and take the necessary monitoring precautions. Section 5.1 concludes that emissions from the air stripping operation will not affect the health of Tinker AFB personnel or the surrounding populace.

Treated groundwater will have low levels of contaminants when it is directed to the facility reuse system. These levels are expected to be below hazardous exposure levels for groundwater and industrial water. However, the reuse system still may expose (dermal contact and inhalation) Tinker AFB personnel to low levels of hazardous contaminants. Therefore this alternative was given a public health impact rating of 3.

5.2.1.3 Environmental Impacts. The treatment of groundwater in the modified IWTP will reduce the potential for adverse environmental impacts. Under this alternative, contaminants removed from the groundwater will either be released to the air from an air stripper (volatile organic compounds) or sent to a RCRA approved facility for final disposal in the form of sludge (metals). These releases, discussed further in Section 5.1, are not expected to result in any adverse environmental impacts. Organic contaminants will be released to the atmosphere. However, air releases are predicted to be below existing air quality standards after dispersion (Section 5.1). Construction activities associated with IWTP modifications will impose short-term impacts on low quality habitat (not supportive of native wildlife) at the site. Wildlife in this area will experience no long-term impacts as a result of this activity.

This alternative will minimize the release of contaminants to East Soldier Creek and will reduce the extent of groundwater contamination. Therefore, this alternative was given an environmental impact rating of 2.

5.2.1.4 Institutional Requirements.
The Alternative 2-1 ratings for institutional requirements are summarized below:

Criteria	Rating
Conformance with ARARs	2
Permitting requirements	2
Normalized Rating	2.0

The following two sections present the analysis of the criteria that resulted in these ratings.

5.2.1.4.1 Conformance with ARARs. The regulations identified to date which may be applicable or relevant and appropriate to Alternative 2-1 are identified in Tables 5-7 and 5-8. Further information on selected ARARs is provided below:

- RCRA and Oklahoma DOH
  Treating the contaminated groundwater under Alternative 2-2 will provide protection of human health and the environment.

TABLE 5-7
FEDERAL ARARS

Criteria, or Limitation	Citation	Description
Safe Drinking Water Act	40 U.S.C. Section 300	
National Primary Drinking Water Standards	40 CFR Part 141	Establishes health-based standards for public water systems (maximum contaminant levels).
National Secondary Drinking Water Standards	40 CFR Part 143	Establishes welfare-based standards for public water systems (secondary maximum contaminant levels).
Maximum Contaminant Level Goals	Pub. L. No. 99-339, 100 Stat. 642 (1986)	Establishes drinking water quality goals set at levels of no known or anticipated adverse health effects, with an adequate margin of safety.
Clean Water Act	33 U.S.C. Sections 1251-1376	
Water Quality Criteria	40 CFR Part 131 Quality Criteria for water, 1976, 1980, 1986	Sets criteria for water quality based on toxicity to aquatic organisms and human health.
National Pollutant Discharge Elimination System (NPDES)	40 CFR Parts 122 and 125	Requires permits for the discharge of pollutants from any point source into waters of the United States.
Clean Air Act	42 U.S.C. Sections 7401-7642	
National Primary and Secondary Ambient Air Quality Standards	40 CFR Part 50	Established standards for ambient air quality to protect public health and welfare (including standards for particulate matter and lead).
Solid Waste Disposal Act ("SWDA")	42 U.S.C. Sections 6901-6987	
Identification and Listing of Hazardous Wastes	40 CFR Part 261	Defines those solid wastes which are subject to regulation as hazardous wastes under 40 CFR Parts 262-265 and Parts 124, 270, and 271.
Standards Applicable to Generators of Hazardous Waste	40 CFR Part 262	Establishes standards for generators of hazardous waste.
Standards Applicable to Transporters of Hazardous Waste	40 CFR Part 263	Establishes standards which apply to persons transporting hazardous waste within the U.S. if the transportation requires a manifest under 40 CFR Part 262.

TABLE 5-7 (continued)
FEDERAL ARARS

Criteria, or Limitation	Citation	Description
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	40 CFR Part 264	Establishes minimum national standards which define the acceptable management of hazardous waste for owners and operators of facilities which treat, store, or dispose of hazardous waste.
Production of Hazardous Waste Byproducts	40 CFR Part 262	Establishes standards for generation of hazardous wastes.
	Subpart B	General Facility Standards
	Subpart C	Preparedness and Prevention
	Subpart D	Contingency Plan and Emergency Procedures
	Subpart E	Manifest System, Record Keeping, and Reporting
	Subpart F	Release from Solid Waste Management Units
	Subpart G	Closure and Post-Closure
	Subpart H	Financial Requirements
	Subpart J	Tanks
Land Disposal	40 CFR Part 268	Establishes a timetable for restriction of burial of wastes and other hazardous materials.
Hazardous Waste Permit Program	40 CFR Part 270	Establishes provisions covering basic EPA permitting requirements.
Land Disposal Restrictions	42 U.S.C. Section 0924(d)	Prohibits land disposal of specified untreated hazardous wastes.
Occupational Safety and Health Act	29 U.S.C. Sections 651-678	Regulates worker health and safety.
Hazardous Materials Transportation Act	49 U.S.C. Sections 1801-1813	

TABLE 5-7 (continued)
FEDERAL ARARS

Criteria, or Limitation	Citation	Description
Hazardous Materials Transportation Regulations	49 CFR Parts 107, 171-177	Regulates transportation of hazardous materials.
Fish and Wildlife Coordination Act	16 U.S.C. Sections 661-666	Requires consultation when federal department or agency proposes or authorizes any modification of any stream or other water body and adequate provision for protection of fish and wildlife resources.

TABLE 5-8
STATE ARARS

Standard, Requirement, Criteria, or Limitation	Citation	Description
Oklahoma Controlled Industrial Waste Disposal Act	63 OS 1981	
Rules, Regulations, and Minimum Standards	63 OS 1981 Section 1-2005	Establishes rules, regulations, and minimum standards for the listing and characterization of controlled industrial waste, for the treatment, disposal, transportation, storage, and recycling of controlled industrial waste and recyclable materials in Oklahoma.
Construction permit application-Review of county road classification plans - Requirements for issuance of permit - Notice of proposed site and review - Court review	63 OS 1981 Section 1-2005.3	Establishes guidelines for the Board of County Commissions review of the county road classi fication plan in order to ensure that county roads and bridges to be used from industrial waste facilities, may be used without any substantial detriment.
Definitions - Permits - Hearings - Notice - Review	63 OS 1981 Section 1-2006	Establishes requirements for issuance of a construction permit. The permit shall be issued only upon proper application, hearing, if requested, and determination by the Department of Health that the proposed site and facility are physically and technically suitable. Also requires applicant to give notice, by newspapers and radio stations, of opportunity to oppose the granting of such permit by requesting an informal public meeting.
Criteria for controlled industrial waste facility	63 OS 1981 Section 1-2007	Provides criteria, including testing methods and minimum or maximum standards, before construction of a controlled industrial waste facility shall proceed.

TABLE 5-8 (continued)
STATE ARARS

Standard, Requirement, Criteria, or Limitation	Citation	Description
Permits - Application - Liability Insurance - Bond - Financial Responsibility - Operation of Facility - Insolvency - Liability of Guarantors	63 OS 1981 Section 1-2008	Establishes the standards and requirements for applicants seeking permits for the operation of controlled industrial waste facilities from the State Department of Health.
Manifest provided to driver	63 OS 1981 Section 1-2010	Persons generating controlled industrial waste materials shall provide the operator of any mode of any offsite transportation carrying controlled industrial waste a manifest indicating waste characteristics and destination of the waste.
Prohibited disposal - Controlled industrial facility for onsite or offsite treatment, storage, or disposal	63 OS 1981 Section 1-2014	Establishes guidelines for site-selection of a controlled industrial facility.
Oklahoma Water Resources Board - Rules, Regulations, and Modes of Procedure 1985	Authority granted by Title 82 0.5, 1981 Section 1085.2	
Water Quality Certification	Section 1015.1 (a)	Permits issued by EPA under the NPDES program will not violate current Oklahoma Water Quality Standards.
Direct Discharges of Industrial Effluents	Section 1025.10	Lists the requirements of applicants who wish to receive a permit for discharge of treated and non-treated wastewater to surface water.
Plans to be submitted prior to beginning construction	Section 1025.14	Requires plans to be submitted prior to initiating onsite construction of any new wastewater disposal system or addition to any existing wastewater disposal system.
Treatment of Industrial Wastewater	Section 1045.3	Due to the diverse nature of industrial wastewater, each proposed installation must be considered on its own merit. Conferences with the Board's staff are highly desirable during the planning and design phases of waste disposal systems.

TABLE 5-8 (continued)
STATE ARARS

Standard, Requirement, Criteria, or Limitation	Citation	Description
Effluent Limitation Guidelines	Section 1070.1	Effluent limitation guidelines promulgated pursuant to the Federal Water Pollution Control Act (P.L. 92-500) as amended by the Clean Water Act of 1977 (P.L. 95-217) for point sources are hereby adapted.
Guidelines for Wastewater Discharges into Intermittent Streams and Storm Sewers	Section 1070.2	Provides a partial list of maximum effluent concentrations for various constituents. Treatment technology data, wasteload allocation studies, the Oklahoma Water Quality Standards, and other pertinent information will also be utilized in determining constituent limitations for waste disposal permits.
Water Quality Criteria	Section 1070.3	Provisions of "Quality Criteria for Water, 1986" US EPA, EPA 440/5-86-001, as amended, are incorporated herein by reference and will be utilized where appropriate to establish waste disposal permit limitations to protect the waters of the state.
Oklahoma Air Pollution Control Regulations	Air Pollution Control Regulations and Guidelines; Oklahoma State Dept. of Health, Air Quality Service; Dec. 28, 1968; as amended	
Permits	Regulation 1.4	Lists the requirements for sources which emit or may emit a toxic air contaminant.
Control of Emission of Hazardous and Toxic Air Contaminants	Regulation 3.8	Establishes standards to control the routine emission of hazardous and toxic air contaminants from stationary sources.

The treated groundwater will be incorporated into an industrial reuse process. This reuse plan eliminates concern over proper discharge of the treated effluent from the IWTP; however, extra precautions for worker safety will have to be carried out under OSHA regulations which would cover such a reuse plan. The area influenced by operation of the extraction wells will receive a benefit of lower contaminant concentrations in the contaminant plume. Therefore, groundwater protection requirements of RCRA and Oklahoma DOH will be achieved.

- <u>SDWA, EPA Groundwater Protection Strategy, and OWRB</u>
  Groundwater will meet current MCLs as contaminated water is removed and treated. Wells used for water supply in the vicinity of the plume will be monitored to ensure the adequate quality. This alternative will therefore meet the requirements of these regulations.

- <u>Water Pollution Control</u>
  The groundwater extraction/treatment plan should control the spread of the contaminant plume, thus reducing additional contamination of the fresh water aquifers. Because there is no additional discharge of either treated or untreated groundwater to Soldier Creek under this alternative, surface water pollution should not be a factor. Therefore, the requirements of this regulation will be attained.

Based on the preceding discussion, the conformance with ARARs rating for Alternative 2-1 is 2.

5.2.1.4.2 <u>Permitting</u>. Although permits are not required for onsite work performed under CERCLA, the requirements of the permits must be followed. Following is a list of permits or other authorizations which would have to be obtained for this alternative if the remedial action were not initiated under CERCLA.

- Air emissions permit for the air stripper.
- Construction permits for modifying the existing IWTP.
- Review and approval by the State Department of Health of construction plans.

The permitting rating for Alternative 2-1 is 2.

5.2.1.5 Cost Analysis. The costs for Alternative 2-1 include an influent wet well, an air stripper with appurtenances, a pre-IWTP storage tank, process piping, reuse piping, and treatment at the IWTP. Costs for construction contingencies and legal/permitting activities are also included. A credit for the reduction in fresh water usage due to water reuse has not been included in the costs. The capital costs, annual operation and maintenance costs, and total present worth are summarized below:

Capital Costs	Annual Operation and Maintenance Costs	Present Worth
$811,400	$27,000	$1,092,100

5.2.2 Alternative 2-2 - Modified IWTP/Surface Water Discharge.
The only difference between Alternative 2-2 and Alternative 2-1, discussed in the previous sections, is the method by which the treated water is discharged. Each alternative utilizes a modified IWTP, which consists of the addition of an air stripper at the front of the treatment process. While plans for Alternative 2-1 consist of the eventual incorporation of the treated groundwater into the industrial reuse process, the method of discharge in Alternative 2-2 is discharge to Soldier Creek.

5.2.2.1 Engineering Feasibility. The Alternative 2-2 ratings for engineering feasibility are summarized below:

Criteria	Rating
Performance	
o effectiveness	2
o useful life	3
Reliability	
o operation & maintenance	2
o demonstrated performance	2
Implementability	
o constructability	2
o time to implement	2
o time for results	4
Safety	2
Normalized Rating	2.38

The following sections present the analysis of the criteria that resulted in these ratings.

5.2.2.1.1 Performance. The description of the performance of the air stripping process presented in the analysis of Alternative 2-1 is also applicable to the performance rating of Alternative 2-2. The treatment process is the same for each alternative with the method of discharge representing the only difference between the two options.

The primary performance objective of Alternative 2-1 is to reduce the contaminant concentrations to a level that would permit incorporating the treated groundwater into the industrial reuse program. The performance requirements for Alternative 2-2 will be similar. The groundwater must instead be treated to such a degree that disposal will be an environmentally safe practice. If discharge occurs to waters of the State of Oklahoma specific performance objectives will be detailed in the national Pollutant Discharge Elimination System (NPDES) permit and Oklahoma waste disposal permits. Other diposal procedures must address all ARARS. The treatment process of Alternative 2-2 will be capable of producing a high quality effluent which meets remedial action objectives and provides a long-term solution requiring only routine maintenance. The effectiveness rating is 2 and the useful life rating is 3.

5.2.2.1.2 Reliability. The air stripping tower is capable of functioning unattended with only periodic maintenance. Instrumentation and alarms will provide an indication of any system malfunctions. Routine maintenance is required to clean the air filter, pumps, and air blowers. Air stripping is a proven technology that is currently being used at similar sites with similar contaminants. The existing IWTP has been effective in proven treatment of similar contaminants that will be exiting the air stripper.

In evaluating the reliability of Alternative 2-2, the operations and maintenance rating is 2 and the demonstrated performance rating is 2.

5.2.2.1.3 Implementability. There are no site conditions which should adversely affect constructability of the air stripper, wet well, storage tank, and appurtenances for this alternative.

The existing IWTP is designed to use surface water discharge to Soldier Creek as a means to release the treated water that would exceed demands from the industrial reuse program. At present, all treated water (1.0 MGD) is being discharged to Soldier Creek. The additional water from the groundwater treatment process will increase this surface discharge rate to 1.09 MGD. Since the mechanism for discharge to Soldier Creek currently exists under Alternative 2-2, the time to implement is limited only by the time required to construct the IWTP modifications.

The air stripping tower, storage tank, wet well, and appurtenances could be operational in a short time (less than 12 months). The air stripper thoroughly volatilizes organics if the residence time of the groundwater in the tower is 5 to 10 minutes. However, the time to extract the quantity of water from the aquifer that is necessary to cleanup the aquifer to below threshold concentrations is 25 to 40 years, based on the conservative estimates of contaminant transport[1].

In evaluating the implementability of Alternative 2-2, the constructability rating is 2, the time to implement rating is 2, and the time to achieve overall beneficial results rating is 4.

5.2.2.1.4 Safety. All aspects of the safety evaluation, as described for Alternative 2-1 in Section 5.2.1.1.4, also apply to this alternative, except for those references made about the industrial reuse program. Both the short and long-term safety ratings are 2.

5.2.2.2 Public Health Impacts. Under this alternative a potential exists for treatment facility exposures similar to those described for Alternative 2-1. However, there would be no predictable exposures during wastewater reuse since there will be surface water discharge under this alternative. Therefore, this alternative is given a public health impact rating of 2.

5.2.2.3 Environmental Impacts. This alternative will have similar environmental impacts as discussed for Alternative 2-1. With surface water discharges of treated groundwater, increased flows to Soldier Creek can be expected. Provided that treatment of this water reduces contaminants to permitted levels (Section 5.1), these discharges should not adversely affect the aquatic environment. This alternative is given an environmental impact rating of 2.

5.2.2.4 Institutional Requirements. The Alternative 2-2 ratings for institutional requirements are summarized below:

Criteria	Rating
Conformance with ARARs	2
Permitting requirements	3
Normalized Rating	2.5

The following two sections present the analysis of the criteria that resulted in these ratings.

5.2.2.4.1 Conformance with ARARs. All regulations which are applicable or relevant and appropriate to Alternative 2-1 are also applicable or relevant and appropriate to Alternative 2-2. In addition to the ARARs of Alternative 2-1 are applicable regulations governing discharge to surface waters. The conformance with ARARs rating for Alternative 2-2 is 2.

5.2.2.4.2 Permitting. Alternative 2-2 would include the need to acquire all the permits applicable to Alternative 2-1, and, in addition, existing NPDES permits would have to be modified and their state equivalent discharge permits would have to be obtained. Due to the current poor water quality of East Soldier Creek, there may be additional complications in obtaining the necessary discharge permits for release of the IWTP effluent into the creek. Standards of effluent quality not easily obtained by the proposed treatment methods identified in Alternative 2-2 may be required. This potential difficulty in obtaining permits results in a permitting rating for Alternative 2-2 of 3.

5.2.2.5 Cost Analysis. The costs for Alternative 2-2 include an influent wet well, an air stripper with appurtenances, a pre-IWTP storage tank, process piping, and treatment at the IWTP. Costs for construction contingencies and legal/permitting activities are also included. A summary of capital costs, annual O&M costs, and total present worth is presented below:

Capital Costs	Annual Operation and Maintenance Costs	Present Worth
$811,400	$27,000	$1,092,100

5.2.3 Alternative 2-3 Treatment/Industrial Reuse.
This alternative consists of onsite treatment of contaminated groundwater in a new groundwater facility, followed by industrial reuse. The new treatment facility will consist of flow equalization, air stripping, reduction/precipitation, filtration, and carbon adsorption. Sludge will be dewatered onsite and disposed of in a RCRA authorized disposal facility.

5.2.3.1 Engineering Feasibility. The Alternative 2-3 ratings for engineering feasibility are summarized below:

Criteria	Rating
Performance	
o effectiveness	2
o useful life	3
Reliability	
o operation & maintenance	2
o demonstrated performance	2
Implementability	
o constructability	2
o time to implement	5
o time for results	4
Safety	2
Normalized Rating	2.75

The following sections present the analysis of the criteria that resulted in these ratings.

5.2.3.1.1 Performance. A new groundwater treatment plant is an effective alternative in meeting the remedial objectives of groundwater treatment and disposal. The treatment plant can be designed and operated to meet or exceed the water quality criteria required for industrial reuse.
Air stripping is a proven and effective technology for removing VOCs. The effluent from the packed tower air stripper will flow by gravity to metals reduction/precipitation units. The metals reduction/precipitation process used for this treatment scheme will involve treatment by sulfide and sulfate precipitation. This process has been implemented at the IWTP and has been effective in reducing metal concentrations to acceptable levels for either the industrial reuse program or for discharge to Soldier Creek. Subsequent processes, including flocculation, clarification, and filtration, will produce a relatively high quality effluent. To ensure that water quality standards for industrial reuse are met, carbon adsorption is used as a final treatment step to remove residual contaminants not removed in preceding plant operations.

The major components of this remedial action will provide a long-term solution to the present groundwater condition while requiring a similar amount of maintenance as that of the existing IWTP. The effectiveness rating for this alternative is 2 and the useful life rating is 3.

5.2.3.1.2 Reliability. The treatment plant is capable of being operated by personnel with similar training as those personnel at the existing IWTP. Operation and maintenance requirements are not expected to be significant. Instrumentation and alarms located strategically throughout the treatment facility will provide an indication of any system malfunctions. The treatment technologies used have been proven reliable in removing similar contaminants under similar situations. In evaluating the reliability of Alternative 2-3, the operation and maintenance rating is 2 and the demonstrated performance rating is 2.

5.2.3.1.3 Implementability. There are no site conditions which should adversely affect constructability of the onsite treatment plant for this alternative.

As discussed in Section 5.1.1.6, the time to implement such an industrial reuse program cannot be accurately predicted. Presently, a demand for water from the industrial reuse system has not been exhibited and it is not known when and if a demand will be created.

It is possible that the new treatment plant could be operational within three years; however, the time to achieve the overall beneficial results will be related to factors other than construction time. For instance, as previously discussed, the benefit of reusing the treated groundwater is dependent on establishing a need for the extra water. The time to extract the quantity of water from the aquifer that is necessary to cleanup the aquifer to below threshold concentrations is 25 to 40 years, based on the conservative estimates of contaminant transport[1].

In evaluating the implementability of Alternative 2-3, the constructability rating is 2, the time to implement rating is 5, and the time to achieve beneficial results rating is 4.

5.2.3.1.4 Safety. All aspects of the safety evaluation, as described for Alternative 2-1 (Section 5.1.1.6), also apply to this alternative. Both the short and long-term safety ratings are 2.

5.2.3.2 Public Health Impacts. The public health impacts for this alternative will be the same as Alternative 2-1. Therefore, this alternative was given a public health impact rating of 3.

5.2.3.3 Environmental Impacts. This alternative will have similar environmental impacts as Alternative 2-1. Therefore, this alternative was given an environmental impact ratings of 2.

5.2.3.4 Institutional Requirements. The Alternative 2-3 ratings for institutional requirements are summarized below:

Criteria	Rating
Conformance with ARARs	2
Permitting requirements	2
Normalized Rating	2.0

The following two sections present the analysis of the criteria that resulted in these ratings.

5.2.3.4.1 Conformance with ARARs. All regulations which are applicable or relevant and appropriate to Alternative 2-1 are also applicable or relevant and appropriate to Alternative 2-3. The conformance with ARARs rating for Alternative 2-3 is a 2.

5.2.3.4.2 Permitting. Alternative 2-3 would include the same permitting requirements as Alternative 2-1 and would also include the permits required (federal and state) for the transport of hazardous waste. The permits for constructing a new treatment facility may be more difficult to obtain than the permits required in Alternative 2-1, which include permits for modifications to an existing facility. The permitting rating for Alternative 2-3 is a 2.

5.2.3.5 Cost Analysis. The major costs for implementing Alternative 2-3 include an influent wetwell, an air stripper with appurtenances, a metals precipitation unit, a carbon adsorption system, process piping, reuse piping, and treatment. Costs associated with construction contingencies and legal/permitting activities are also included. No credit is included in the costs for the reduction in fresh water usage due to water reuse. The capital costs, annual O&M costs, and total present worth are summarized below:

Capital Costs	Annual Operation and Maintenance Costs	Present Worth
$1,530,700	$104,300	$2,651,100

5.2.4 Alternative 2-4 - Treatment/Surface Water Discharge

The only difference between this alternative and Alternative 2-3, discussed in the previous sections, is the method by which the treated water is discharged. The treatment plant will consist of identical processes. Alternative 2-3 incorporates the effluent from the treatment process into an industrial reuse program, while the effluent of Alternative 2-4 will be discharged to Soldier Creek.

5.2.4.1 Engineering Feasibility. The Alternative 2-4 ratings for engineering feasibility are summarized below:

Criteria	Rating
Performance	
o effectiveness	2
o useful life	3
Reliability	
o operation & maintenance	2
o demonstrated performance	2
Implementability	
o constructability	2
o time to implement	4
o time for results	4
Safety	2
Normalized Rating	2.62

The following sections present the analysis of the criteria that resulted in these ratings.

5.2.4.1.1 Performance. The proposed treatment facility can effectively remove contaminants in the groundwater to meet ARAR discharge criteria. Similar overall performance results are expected for this alternative as for Alternative 2-3 (Section 5.2.3.1) since they differ only by the discharge destination.

This alternative meets the remedial action objectives for groundwater treatment and disposal and provides a long-term solution. The alternative will require similar operating and maintenance expenditures as the existing IWTP. The effectiveness rating is 2 and the useful life rating is 3 for Alternative 2-4.

5.2.4.1.2 Reliability. All aspects of the reliability evaluation previously discussed for Alternative 2-3 (Section 5.2.3.1) also apply to this alternative. Accordingly, the operations and maintenance rating is 2 and the demonstrated performance rating is 2.

5.2.4.1.3 Implementability. There are no site conditions that should adversely affect constructability of the onsite treatment plant for this alternative. The time to implement this alternative will take approximately three years, depending on weather conditions and availability of contractors, equipment, and materials. Activities required prior to implementation would consist of design, report preparation and review, pilot plant testing to determine the air stripping and carbon adsorption design parameters, preparation of drawings and specifications, and construction and start-up.

Beneficial impacts are provided as soon as the extraction system is placed in operation; however, due to the travel times associated with the contaminated groundwater, the time to achieve desired cleanup levels is longer than would be normally desired.

In evaluating the implementability of Alternative 2-4, the constructability rating is 2, the time to implement rating is 4, and the time to achieve beneficial results rating is 4.

5.2.4.1.4 Safety. All aspects of the safety evaluation as described for Alternative 2-1 (Section 5.2.1.1) also apply to this alternative except those references made about the industrial reuse program. In addition, due to the magnitude of the construction project, building a new treatment facility as opposed to modifying the existing IWTP, an added risk could be expected solely because of the longer construction time. Both the short and long-term safety ratings are 2.

5.2.4.2 Public Health Impacts. The public health impacts for this alternative will be the same as Alternative 2-2. Therefore, this alternative is given a public health impact ranking of 2.

5.2.4.3 Environmental Impacts. This alternative will have similar environmental impacts as Alternative 2-2. Therefore, this alternative is given an environmental impact rating of 2.

5.2.4.4 Institutional Requirements. The Alternative 2-5 ratings for institutional requirements are summarized below:

Criteria	Rating
Conformance with ARARs	2
Permitting requirements	3
Normalized Rating	2.5

The following two sections present the analysis of the criteria that resulted in these ratings.

5.2.4.4.1 Conformance with ARARs. Alternative 2-4 will be required to comply with all regulations which are applicable or relevant and appropriate to each of the previously discussed alternatives. The conformance with ARARs rating for Alternative 2-4 is a 2.

5.2.4.4.2 Permitting. Alternative 2-4 has all of the permitting requirements associated with Alternative 2-3. In addition, permits for discharge of the treatment facility effluent to East Soldier Creek must be acquired. As discussed in the permitting section for Alternative 2-2, permits for discharge into East Soldier Creek could be difficult to obtain or the requirements imposed by such a permit may make conformance difficult. Therefore, the permitting rating for Alternative 2-4 is a 3.

5.2.4.5. Cost Analysis. The costs for Alternative 2-4 include an influent wet well, an air stripper with appurtenances, a metals precipitation unit, a carbon adsorption system, process piping, surface water discharge piping, and treatment. Costs for construction contingencies and legal/permitting activities are also included. The capital costs, annual O&M costs, and total present worth are summarized below:

Capital Costs	Annual Operation and Maintenance Costs	Present Worth
$1,530,700	$104,300	$2,651,100

5.2.5 Cost Sensitivity Analysis for Groundwater Treatment and Disposal Alternatives

The major factors that affect the cost differential between alternatives for groundwater treatment and disposal are the interest rate and the useful life of the alternatives. Summarized in Table 5-9 is the effect of variance of the interest rate from the baseline rate of 8.75 percent to rates of 10 and 12 percent. A useful life of 30 years is the baseline assumption for all groundwater treatment and disposal alternatives. The possibility of longer or shorter treatment periods required to bring groundwater quality within the acceptable limits exists. The effect of a varied useful life is summarized in Table 5-10.

As shown in Tables 5-9 and 5-10, the relative rating for the alternatives in terms of total present worth does not change with variance of the interest rate or the useful life.

Consideration must also be given to the cost of disposing of sludge associated with the water softening process of the existing IWTP. Alternatives 2-1 and 2-2, which call for treating the groundwater in a modified existing IWTP, will be subject to changes in operation and maintenance costs as the amount of softener sludge varies. This sludge will have to be disposed of as a hazardous waste; therefore, volumes of sludge produced could significantly affect the cost of Alternative 2-1 and 2-2. Since the hardness of the influent to the IWTP is not known, prediction of the amount of sludge produced is a rough estimate. Table 5-11 shows the effect on costs of Alternatives 2-1 and 2-2 for a sludge production rate of 113 tons/year. This rate would result if hardness were reduced from 300 ppm as $CaCO_3$ to 150 ppm.

It is apparent that producing this amount of sludge does not change the relative rating of the alternatives in terms of total present worth; however, the present worth of Alternatives 2-1 and 2-2 is significantly impacted by the sludge production rate. The sensitivity of Alternatives 2-3 and 2-4 is evaluated with respect to changes in the times required for the regeneration of carbon in the adsorption process. Due to the lack of data on the influent concentration of constituents to be adsorbed by the activated carbon, it is difficult to predict the frequency with which carbon will require regeneration. The effects of changes in carbon life on alternative costs are presented in Table 5-12.

The relative ranking of the alternatives in terms of total present worth does not change in response to possible changes in carbon regeneration time. In addition to considering cost sensitive issues that may impact one alternative more than another, is the need to be aware of those costs which may impact each alternative equally. For instance, costs associated with the disposal of sludge from the metals precipitation unit will affect each alternative equally as the amount of sludge increases or decreases. This is due to the fact that each alternative utilizes the same process for metals precipitation and sludge disposal. The impact of changes in sludge production rates is to either raise or lower operation and maintenance costs at a rate of $200.00/ton of sludge disposed.

Another process that could affect each alternative in a similar manner is the addition of a carbon adsorption unit to treat the off-gas from the air stripper. Although presently the air stripper meets air quality criteria requirements based on dispersion modeling results, it is possible that by such actions as more stringent standards or community concern, carbon treatment of the off-gas may eventually be required. If such a case

TABLE 5-9
SUMMARY OF COST SENSITIVITY ANALYSIS
WITH VARYING INTEREST RATES

	Interest Rate (percent)											
	8.875				10.0				12.0			
Remedial Alternative	Total Capital Cost (dollars)	Total Annual O&M Cost (dollars)	Total Present Worth O&M Cost (dollars)	Total Present Worth (dollars)	Total Capital Cost (dollars)	Total Annual O&M Cost (dollars)	Total Present Worth O&M Cost (dollars)	Total Present Worth (dollars)	Total Capital Cost (dollars)	Total Annual O&M Cost (dollars)	Total Present Worth O&M Cost (dollars)	Total Present Worth (dollars)
2-1 Modified IWTP/ Industrial Reuse	811,400	27,000	280,700	1,092,100	811,400	27,000	254,500	1,065,900	811,400	27,000	217,500	1,028,900
2-2 Modified IWTP/ Surface Water Discharge	811,400	27,000	280,700	1,092,100	811,400	27,000	254,500	1,065,900	811,400	27,000	217,500	1,028,900
2-3 Treatment/ Industrial Reuse	1,530,700	104,300	1,084,400	2,615,100	1,530,700	104,300	983,200	2,513,900	1,530,700	104,300	840,200	2,370,900
2-4 Treatment/ Surface Water Discharge	1,524,800	104,300	1,084,400	2,609,200	1,524,800	104,300	983,200	2,508,000	1,524,800	104,300	840,200	2,365,000

TABLE 5-10
SUMMARY OF COST SENSITIVITY ANALYSIS
WITH VARYING YEARS OF USEFUL LIFE

Alternative	Useful Life (years) 25: Total Present Worth O&M Cost (dollars)	25: Total Present Worth (dollars)	30: Total Present Worth O&M Cost (dollars)	30: Total Present Worth (dollars)	35: Total Present Worth O&M Cost (dollars)	35: Total Present Worth (dollars)	40: Total Present Worth O&M Cost (dollars)	40: Total Present Worth (dollars)
2-1 Modified IWTP/ Industrial Reuse	267,900	1,079,300	280,700	1,092,100	288,700	1,100,100	294,100	1,105,500
2-2 Modified IWTP/ Surface Water Discharge	267,900	1,079,300	280,700	1,092,100	288,700	1,100,100	294,100	1,105,500
2-3 Treatment/ Industrial Reuse	1,035,000	2,565,700	1,084,400	2,615,100	1,115,300	2,646,000	1,136,000	2,666,700
2-4 Treatment/ Surface Water Discharge	1,035,000	2,560,000	1,084,400	2,609,200	1,115,300	2,640,100	1,136,000	2,660,800

Notes: The interest rate for each analysis is 8.875%

The baseline useful life used in this report is 30 years.

TABLE 5-11
SUMMARY OF COST SENSITIVITY ANALYSIS
OF WATER SOFTENER SLUDGE DISPOSAL

	Produced Sludge (tons/year)							
	0				113			
Remedial Alternative	Total Capital Cost (dollars)	Total Annual O&M Cost (dollars)	Total Present Worth O&M Cost (dollars)	Total Present Worth (dollars)	Total Capital Cost (dollars)	Total Annual O&M Cost (dollars)	Total Present Worth O&M Cost (dollars)	Total Present Worth (dollars)
2-1 Modified IWTP/ Industrial Reuse	811,400	27,000	280,700	1,092,100	811,400	49,600	515,300	1,326,700
2-2 Modified IWTP/ Surface Water Discharge	811,400	27,000	280,700	1,092,100	811,400	49,600	515,300	1,326,700
2-3 Treatment/ Industrial Reuse	1,530,700	104,300	1,084,400	2,615,100	1,530,700	104,300	1,084,400	2,615,100
2-4 Treatment/ Surface Water Discharge	1,524,800	104,300	1,084,400	2,609,200	1,524,800	104,300	1,084,400	2,609,200

Notes: The interest rate for each analysis is 8.875%

The amount of sludge produced is based on estimates of reducing the hardness from 300 ppm as CaC03 to 150 ppm.

TABLE 5-12
SUMMARY OF COST SENSITIVITY ANALYSIS
WITH VARYING CARBON LIFE

Remedial Alternative	Regeneration Frequency (years) 0.5				1.0				2.0			
	Total Capital Cost (dollars)	Total Annual O&M Cost (dollars)	Total Present Worth O&M Cost (dollars)	Total Present Worth (dollars)	Total Capital Worth (dollars)	Total Annual O&M Cost (dollars)	Total Present Worth O&M Cost (dollars)	Total Present Worth (dollars)	Total Capital Cost (dollars)	Total Annual O&M Cost (dollars)	Total Present Worth O&M Cost (dollars)	Total Present Worth (dollars)
2-1 Modified IWTP/ Industrial Reuse	811,400	27,000	280,700	1,092,100	811,400	27,000	280,700	1,092,100	811,400	27,000	280,700	1,092,100
2-2 Modified IWTP/ Surface Water Discharge	811,400	27,000	280,700	1,092,100	811,400	27,000	280,700	1,092,100	811,400	27,000	280,700	1,092,100
2-3 Treatment/ Industrial Reuse	1,530,700	110,100	1,143,800	2,674,500	1,530,700	104,300	1,084,400	2,615,100	1,530,700	101,400	1,053,400	2,584,100
2-4 Treatment/ Surface Water Discharge	1,524,800	110,100	1,143,800	2,668,600	1,524,800	104,300	1,084,400	2,609,200	1,524,800	101,400	1,053,400	2,578,200

Notes: The interest rate for each analysis is 8.875%.

The baseline regeneration frequency used in this report is once per year.

TABLE 5-13
SUMMARY OF GROUNDWATER TREATMENT
AND DISPOSAL ALTERNATIVES

	Cost ($1,000)		Evaluation Criteria				
Remedial Alternative	Capital	Present Worth	Engineering Feasibility[a]	Public Health Impacts	Environmental Impacts	Institutional Requirements[b]	Comments and Overall Rating[c]
2-1 Modified IWTP/ Industrial Reuse	811	1,092	Long-term solution using proven reliable and effective technology for groundwater remediation. Time to implement cannot be determined.	Tinker AFB personnel may be exposed to low levels of hazardous contaminants during operation and maintenance of the treatment facility and wastewater reuse system.	Adverse environmental impacts are not expected. Release of contaminants into Soldier Creek and its tributaries will be minimized.	Most environmental protection regulations.	Alternative is rejected due to a time for implementation rating of 5. This rating severely limits the alternative's engineering feasibility.
			Rating is 2.75	Rating is 3.00	Rating is 2.00	Rating is 2.00	Overall rating is 2.44
2-2 Modified IWTP/ Surface Water Discharge	811	1,092	Long-term solution using proven reliable and effective technology for groundwater remediation.	Tinker AFB personnel may be exposed to low levels of hazardous contaminants during operation and maintenance of the treatment facility.	Adverse environmental impacts are not expected. Increased flows to Soldier Creek should not adversely affect the aquatic habitat.	Meets environmental protection regulations NPDES and state equivalent discharge permits are a concern.	Alternative is a viable remedial option.
			Rating is 2.38	Rating is 2.00	Rating is 2.00	Rating is 2.50	Overall rating is 2.22

TABLE 5-13 (continued)
SUMMARY OF GROUNDWATER TREATMENT
AND DISPOSAL ALTERNATIVES

Remedial Alternative	Cost ($1,000) Capital	Cost ($1,000) Present Worth	Engineering Feasibility[a]	Public Health Impacts	Environmental Impacts	Institutional Requirements[b]	Comments and Overall Rating[c]
2-3 Treatment/ Industrial Reuse	1,531	2,615	Long-term solution using proven reliable and effective technology for groundwater remediation. Time to implement cannot be determined.	Tinker AFB personnel may be exposed to low levels of hazardous contaminants during operation and maintenance of the treatment facility and wastewater reuse system.	Adverse environmental impacts are not expected. Release of contaminants into Soldier Creek and its tributaries will be minimized.	Meets environmental protection regulations.	Alternative is rejected due to a time for implementation rating of 5. This rating severely limits the alternative's engineering feasibility.
			Rating is 3.00	Rating is 3.00	Rating is 2.00	Rating is 2.00	Overall rating is 2.50
2-4 Treatment/ Surface Water Discharge	1,525	2,609	Long-term solution using proven reliable and effective technology for groundwater remediation.	Tinker AFB personnel may be exposed to low levels of hazardous contaminants during operation and maintenance of the treatment facility.	Adverse environmental impacts are not expected. Increased flows to Soldier Creek should not adversely affect the aquatic habitat.	Meets environmental protection regulations NPDES and state equivalent discharge permits are a concern.	Alternative is a viable remedial option.
			Rating is 2.62	Rating is 2.00	Rating is 2.00	Rating is 2.50	Overall rating is 2.28

TABLE 5-13 (continued)
SUMMARY OF GROUNDWATER TREATMENT
AND DISPOSAL ALTERNATIVES

Evaluation Criteria

---

a - Ratings for Engineering Feasibility are developed by normalizing the ratings of the following subcriteria: effectiveness; useful life; operation and maintenance requirements; demonstrated performance; constructability; time for implementation; time for results; and safety.

b - Ratings for Institutional Requirements are developed by normalizing the ratings of the following subcriteria: conformance with ARARs; and permitting.

c - Overall Ratings are developed by normalizing the ratings of the following four evaluation criteria: Engineering Feasibility; Public Health Impacts; Environmental Impacts; and Institutional Requirements.

evolves, the anticipated capital costs associated with adding the carbon adsorption to the air stripper will be $69,000. This figure does not include operational costs. This cost would be applicable for any of the proposed groundwater treatment alternatives.

5.3 SUMMARY OF ALTERNATIVES

Included in Table 5-13 is an evaluation summary for the four groundwater treatment and disposal alternatives discussed in the previous sections. A limiting factor is apparent in the evaluation of engineering feasibility for the alternatives with industrial reuse options (Alternatives 2-1 and 2-3). In accordance with the evaluation process guidelines, these alternatives should be rejected with regard to noncost criteria solely because they received a rating of 5 for the implementability subcriteria. This rating is due to the fact that no demand has been identified for the reuse water, although the system is operational at the existing IWTP. Until a demand for the reuse water is positively identified, preferably for the entire amount of water available, these alternatives will continue to be technically infeasible.

In general, the various alternatives, are relatively indistinguishable regarding other noncost evaluation criteria. This is attributed to treatment systems that are only slightly different in their effects on public health, the environment, and compliance with institutional requirements. The differences that exist between these alternatives primarily involve releases to surface water and, to a lesser extent, groundwater releases from surface water recharge to the local aquifer system. It will probably be impossible to discern any impact on local ecosystems from the minor contaminant releases of these alternatives (not inclusive of no action).

The cost evaluation shows that the alternatives involving the modified IWTP (Alternatives 2-1 and 2-2) have significantly lower costs than the two alternatives involving construction of a new groundwater treatment plant (Alternatives 2-3 and 2-4).

5.4 RECOMMENDED ALTERNATIVE

The feasibility of each of the alternatives has been evaluated; however, due to uncertainties with future IWTP load conditions, discharge compliance considerations, and other ongoing studies (including industrial reuse of IWTP effluent), an alternative for groundwater treatment and disposal will not be recommended at this time.

6.0 MANAGEMENT CONTROLS

6.1 DEVELOPMENT AND SELECTION OF ALTERNATIVES

Six management control technologies passed the screening performed by PELA. The nature of the management control technologies makes each an alternative by itself, except for right-of-way acquisition, which applies only when used in conjunction with the development of alternative water supplies. Right-of-way acquisition will therefore be combined with the alternative water supplies technology into one alternative, making a total of five management control alternatives (includes the no action alternative) to be evaluated. These five alternatives are listed and described below.

6.1.1 Alternative 3-1 - Land Use Control

This alternative consists of limiting the uses of land in and/or around contaminated areas to minimize human contact with contaminants.

6.1.2 Alternative 3-2 - Alternative Water Supplies

This alternative consists of replacing drinking water from the presently uncontaminated wells in the immediate vicinity of the contaminant plume (wells 12,13,14,15,16), with water from a tie-in to Oklahoma City supply lines or from new water supply wells constructed in uncontaminated areas on Base. These five wells would likely become contaminated by uncontrolled plume movement and represent a lost production capacity of approximately 1.5 million gallons per day.

6.1.3 Alternative 3-3 - Relocation

This alternative would consist of complete abandonment and relocation of all facilities located in contaminated areas.

6.1.4 Alternative 3-4 - Personnel Supervision and Training

This alternative applies only when used in conjunction with other alternatives and consists of training personnel on the operation and maintenance of remediation equipment and programs, thereby assisting in the cleanup of the environment.

6.1.5 Alternative 3-5 - Coordination With Regulatory Agencies

This alternative consists of coordinating investigations, planning, and remedial action with the appropriate regulatory agencies, and would be used in conjunction with other alternatives.

6.2 DETAILED EVALUATION OF ALTERNATIVES

Management control alternatives are typically used in conjunction with other remedial action alternatives in an attempt to limit human exposure to contaminated materials. Due to the nature of these alternatives, it is not necessary or appropriate to assign ratings as was done for the first three alternative groups. Also, the no action alternative will not be evaluated for Management Control. Therefore, the five management control alternatives are evaluated in narrative form only.

6.2.1 Alternative 3-1 - Land Use Control

6.2.1.1 Engineering Feasibility. Land use at the main Building 3001 site is limited to the support of the building, leaving little room for further restriction of land surface use. At the main Building 3001 site, elimination of possible discharges of industrial waste to the subsurface due to improper connections or leaking pipelines is feasible, and is already being implemented as an interim action. Therefore, land use control as an additional remedial action alternative is not feasible at this site and will not be evaluated in terms of environmental and public health effects, regulatory compliance, or cost.

6.2.2 Alternative 3-2 - Alternative Water Supplies

6.2.2.1 Engineering Feasibility. This alternative is both implementable and feasible. It involves the replacement of the water from the five existing water supply wells that would be contaminated by unrestricted movement of the existing contamination plumes. It would require the use of standard construction techniques, normal safety precautions, and frequent operation and maintenance measures. Two options for water supply replacement exist. These are (1) the construction of additional wells in uncontaminated areas, or (2) tie-ins to local municipal supplies.

6.2.2.2 Public Health Impacts. The construction and delivery of alternate water supplies to the installation would meet management objectives of limiting exposure of the work force. The alternative water supply would prevent use of present and future contaminated drinking water wells. As a result, the groundwater exposure pathway, presently completed, would become incomplete over the short term. The alternative, although minimizing risks to the Tinker AFB work force, fails to provide control and cleanup of the groundwater plume. Long-term migration of the contaminated resource will complete a surface water pathway to Soldier Creek and allow inhalation and ingestion routes of exposure to local residents. This management activity would eliminate the groundwater/drinking water route of exposure and minimize risk to the onsite population. Contamination and human health risks associated with the long-term release and exposure from surface water pathway to offsite populations would continue.

6.2.2.3 Environmental Impacts. The construction and delivery of alternate water supplies to the installation would meet management objectives of limiting exposure of the work force but have no beneficial impact on the environment. The alternative does not adversely impact the limited habitat available to wildlife at Tinker AFB, but the failure to prevent completion of the surface pathway and provide long-term exposures through inhalation and ingestion would impact local wildlife residents. Although the alternative does not adversely impact the environment over the no action, it fails to reduce long-term risks to the environment.

6.2.2.4 Institutional Requirements. This alternative alone would not meet ARARs because it does not provide control or cleanup of the contamination. The alternative could, however, be used in conjunction with other alternatives.

6.2.2.5 Cost Analysis. Costs for Option 1 include design, construction, and operation of 1.5 MGD water line from the Oklahoma City network to the Tinker AFB distribution system. Costs for Option 2 include construction and operation of five additional on-base water supply wells. The costs for both options are listed below:

OPTION 1

Capital Costs	Maintenance Costs	Present Worth
$264,800	$40,000	$680,400

OPTION 2

Capital Costs	Maintenance Costs	Present Worth
$625,000	$15,000	$780,800

6.2.3 Alternative 3-3 - Relocation

6.2.3.1 Engineering Feasibility. Due to the highly industrial nature of the Building 3001 and the ever ready nature of the Air Force's mission, this alternative is not feasible or implementable.

6.2.3.2 Public Health Impacts. Relocation would eliminate groundwater as a completed pathway of exposure to the onsite population. Relocation would eliminate the long-term risks identified in the baseline risk assessment. Although risks to Tinker AFB populations would be eliminated, the alternative provides no remediation of the site. Future groundwater contaminant migration would complete the surface water pathway and expose offsite populations through inhalation and ingestion routes of exposure.

6.2.3.3 Environmental Impacts. Relocation, although creating no impacts on the wildlife environment at the site, would create adverse sociological impacts on the surrounding communities providing service support to the installation. Relocation would also create adverse impacts on the relocation site by construction and operation of an installation the size of Tinker AFB.

6.2.3.4 Institutional Requirements. This alternative would not meet ARARs.

6.2.3.5 Cost Analysis. The costs for relocating Tinker AFB would be prohibitive.

6.2.4 Alternative 3-4 - Personnel Supervision and Training

6.2.4.1 Engineering Feasibility. This alternative is feasible and implementable.

6.2.4.2 Public Health Impacts. Tinker AFB work force supervision and training on the contamination problem, potential for exposure, and potential risks as a result of working in and around the Building 3001 site would potentially reduce human health risks. Personnel understanding the sources of contamination and routes of exposure could reduce their risks through limiting their individual exposure to the groundwater. As in other management alternatives, no remediation would take place. The concentrations of contaminants would remain higher than the ARARs and the groundwater pathway would continue to be complete. The implementation of supervision and training would not reduce the overall risks estimated in the baseline risk assessment but may afford a reduction of risk among individuals on the site.

6.2.4.3 Environmental Impacts. Tinker work force supervision and training on the contamination problem, potential for exposure, and potential risks as a result of working in and around the Building 3001 site would not adversely impact the environment. The alternative makes no change over the no action alternative and, therefore, fails to provide a reduction of exposure of wildlife to the contaminants as they migrate to surface waters. As a result, the alternative fails to reduce long-term risks to the environment.

6.2.4.4 Institutional Requirements. This alternative is a requirement of SARA and should be designed to meet all other ARARs.

6.2.4.5 Cost Analysis. Costs for this alternative will vary depending on the operational details of the selected remedial action alternative(s).

6.2.5. Alternative 3-5 - Coordination With Regulatory Agencies

6.2.5.1 Engineering Feasibility. This alternative is feasible, implementable, and required.

6.2.5.2 Public Health Impacts. This management alternative is presently implemented during the interim remedial response activities at the Building 3001 site. The alternative, if used alone, would afford no reduction of human health risks. Contamination of the groundwater and subsurface soils would continue to provide risks presented in the baseline risk assessment. However, when used in conjunction with other alternatives, this alternative does help protect human health.

6.2.5.3 Environmental Impacts. This management alternative is presently implemented during the interim remedial response activities at the Building 3001 site. The alternative makes no physical change in the environmental impacts over the no action alternative. The alternative also fails to produce beneficial impacts by not implementing a cleanup remediation to minimize long-term exposures to wildlife.

6.2.5.4 Institutional Requirements. This alternative is a requirement of the ARARs.

6.2.5.5 Cost Analysis. Costs for this alternative will vary depending on the operational details of the selected remedial action alternative(s).

6.3 SUMMARY OF ALTERNATIVES

The management control alternatives of alternative water supplies, personnel supervision and training, and coordination with regulatory agencies are feasible. The alternatives of land use control and relocation are infeasible.

6.4 RECOMMENDED ALTERNATIVES

The management control alternative of alternative water supplies (Alternative 3-2) is a feasible alternative, and should be used as necessary in conjunction with the selected remedial action. Personnel supervision and training (Alternative 3-4), and coordination with regulatory agencies (Alternative 3-5) are both feasible and mandatory, and are also recommended to be used in conjunction with the other selected remedial actions.

7.0 SUMMARY OF RECOMMENDED ALTERNATIVES

Table 7-1 presents a summary of the recommended alternative(s) for each remedial objective i.e. the groundwater pumping plan, and management control and it provides the costs associated with each alternative. While the feasibility of each of the alternatives associated with groundwater treatment and disposal has been evaluated, an alternative will not be recommended because of uncertainties with future IWTP load conditions, discharge compliance considerations and other ongoing studies.

TABLE 7-1

SUMMARY OF RECOMMENDED ALTERNATIVES

Objective	Recommended Alternative	Capital Cost (dollars)	Annual O&M Cost (dollars)	Present Worth (dollars)
Groundwater Removal and Collection	Alternative 1-3 - Exterior & Interior Groundwater Pumping	3,408,900	142,200	4,886,000
Groundwater Treatment and Disposal	Alternative 2-2 - Modified IWTP/Surface Water Discharge*	811,400	27,000	1,092,100
Management Control	Alternative 3-2 - Alternative Water Supplies (Option 2 - Tie-ins to Local Municipal supplies)**	625,000	15,000	780,800
	Alternative 3-4 - Personnel Supervision and Training	NA	NA	NA
	Alternative 3-5 - Coordination with Regulatory Agencies	NA	NA	NA
	TOTAL COSTS	4,845,300	184,200	6,758,900

* - Although a groundwater treatment and disposal alternative has not been recommended, Alternative 2-2 is included in this table as a representative (lowest) cost for this objective.

** - Two options are available under Alternative 3-2. Option 2, which has a slightly higher present worth, was selected for this analysis; however, operations conducted during detailed design may actually show that Option 1 - Construction of Additional Wells in Uncontaminated Areas - is the preferred alternative.

NA - Not Applicable

REFERENCES

1. U.S. Army Corps of Engineers, Tulsa District, "Building 3001 Remedial Investigation," Volumes 1 and 2, Final Report, January, 1988.

2. P.E. La Moreaux & Associates, Inc. Consulting Hydrogolists, Geologists, and Environmental Scientists, "Screening of Remedial Control Measures and Technologies," Installation Restoration Program, Building 3001, Tinker Air Force Base, Oklahoma, May 1988.

3. U.S. Environmental Protection Agency, Remedial Action Costing Procedures Manual, September 1985.

4. R.S. Means Company, Inc., Building Construction Cost Data, 1988.

5. Black & Veatch Engineers-Architects "Preliminary Development and Evaluation of Groundwater Treatment and Disposal Alternatives," Final Report, Building 3001 Site and Adjacent Fuel Contaminated Areas, Tinker Air Force Base, Oklahoma, September 1988.

6. U.S. Army Corps of Engineers, Tulsa District, "Risk Assessment of the Building 3001 Site, Tinker Air Force Base, Oklahoma," Final Report, August 1988.

7. Black & Veatch Engineers-Architects "Selection of Feasibility Study Alternatives," Final Report, Building 3001 and Adjacent Fuel Contaminated Areas, Tinker Air Force Base, Oklahoma, February 1988.

8. U.S. Environmental Protection Agency, Superfund Exposure Assessment Manual, OSWER Directive 92855-1, April 1988.

9. U.S. Environmental Protection Agency, Superfund Public Health Evaluation Manual, OSWER Directive 9285.4-1, January 1986.

LIST OF ABBREVIATIONS

AFB	Air Force Base
ARARs	Applicable or Relevent and Appropriate Requirements
AWWA	American Water Works Association
Ba	Barium
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COE	Tulsa District Corps of Engineers
Cr	Chromium
DOH	Oklahoma Department of Health
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERAD	Environmental Research and Development, Inc.
FFA	Federal Facility Agreement
FRP	Fiberglass Reinforced Plastic
FS	Feasibility Study
GPD	Gallons Per Day
GPM	Gallons Per Minute
HP	Horsepower
IRP	Installation Restoration Program
IWTP	Industrial Wastewater Treatment Plant
MCLs	Maximum Contaminant Levels
MGD	Million Gallons per Day
mg/kg	milligrams per kilogram
NCP	National Oil and Hazardous Substances Contingency Plan

NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
O & M	Operation and Maintenace
OSDH	Oklahoma State Department of Health
OWRB	Oklahoma Water Resources Board
Pb	Lead
PCE	Perchloroethylene
PELA	P.E. LaMoreaux & Associates
PPB	Parts Per Billion
PPM	Parts Per Million
PSIG	Pounds Per Square Inch Gage
PVC	Polyvinyl Chloride
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SS/FS	Sodium Sulfide/Ferrous Sulfate
TAFB	Tinker Air Force Base
TCA	Trichloroethane
TCE	Trichloroetylene
TRC	Technical Review Committee
USAF	United States Air Force
1,2 DCE	1,2 Dichloroethylene
ug/l	micrograms per liter

APPENDIX A

DETAILS OF THE GROUNDWATER PUMPING PLAN ALTERNATIVES

Appendix A provides the locations in state plane coordinates, pump rates, screen depths and other pertinent information for the alternative groundwater pumping plans for each aquifer of concern.

TABLE A-1 - WELL DATA - PERCHED AQUIFER
ALTERNATIVE 1-2

WELL NUMBER	NORTHING	EASTING	PUMP RATE (GPD)	BOTTOM ELEVATION	WATER ELEVATION	SATURATED THICKNESS	SCREEN LENGTH	GROUND ELEVATION	WELL DEPTH
10A	156180	2184600	500	1216	1250	34	15	1262	46
11A	155970	2184600	500	1214	1249	35	15	1262	48
12A	155760	2184600	500	1216	1249	33	15	1262	46
13A	155550	2184600	500	1224	1250	26	10	1262	38
14A	153990	2184600	500	1231	1253	22	10	1266	35
15A	153780	2184600	360	1233	1253	20	10	1266	33
27A	155970	2184800	150	1219	1252	33	15	1263	44
28A	155760	2184800	500	1219	1252	33	15	1264	45
29A	155580	2184800	500	1224	1252	28	10	1265	41
30A	155370	2184800	500	1229	1254	25	10	1266	37
31A	154380	2184800	360	1231	1256	25	10	1269	38
23A	154200	2184710	360	1231	1254	25	10	1269	38
32A	153990	2184800	360	1233	1256	23	10	1269	36
33A	153780	2184800	360	1234	1256	22	10	1270	36
34A	153570	2184800	360	1236	1256	20	10	1270	34
26A	153360	2184710	360	1237	1254	17	10	1270	33
47A	155880	2184995	150	1225	1255	30	10	1270	45
48A	155670	2184995	500	1225	1255	30	10	1272	47
49A	155460	2184995	500	1228	1255	27	10	1272	44
50A	155250	2184995	500	1233	1256	23	10	1272	39
51A	155040	2184995	500	1236	1257	21	10	1272	36
52A	154800	2184995	500	1235	1257	22	10	1272	37
53A	154590	2184995	500	1233	1257	24	10	1272	39
93A	154380	2184995	500	1231	1257	26	10	1272	41
54A	154200	2184995	360	1231	1257	26	10	1272	41
55A	153990	2184995	360	1232	1257	25	10	1273	41
56A	153780	2184995	360	1233	1257	24	10	1274	41
57A	153570	2184995	280	1236	1257	21	10	1275	39
58A	153360	2184995	360	1236	1257	21	10	1275	39
59A	153180	2184995	500	1238	1257	19	10	1275	37
67A	154670	2185200	500	1234	1257	23	10	1273	39
69A	154410	2185200	500	1232	1257	25	10	1273	41
71A	154230	2185200	500	1232	1257	25	10	1273	41
73A	153990	2185200	500	1233	1257	24	10	1274	41
74A	153810	2185200	480	1234	1257	23	10	1276	42
75A	153480	2185200	500	1237	1257	20	10	1276	39
76A	153270	2185200	480	1238	1257	19	10	1275	37
77A	153090	2185210	360	1241	1257	16	5	1275	34
78A	152880	2185210	280	1245	1257	12	5	1275	30
81A	153390	2185400	520	1237	1257	20	10	1275	38
82A	153180	2185400	500	1240	1257	17	10	1275	35
83A	152970	2185400	360	1245	1257	12	5	1275	30
84A	153360	2185600	500	1238	1257	19	10	1275	37
85A	153180	2185600	500	1241	1257	16	5	1275	34
86A	155190	2186020	400	1245	1254	9	5	1272	27

Table A-2 - Well Data - Top of Regional Aquifer
ALTERNITIVE 1-2

WELL NUMBER	NORTHING	EASTING	PUMP RATE (GPD)	BOTTOM ELEVATION	WATER ELEVATION	SATURATED THICKNESS	SCREEN LENGTH	GROUND ELEVATION	WELL DEPTH
1B	155930	2183800	400	1166	1195	29	30	1259	93
2B	155720	2183800	400	1168	1194	26	25	1260	92
3B	155530	2183800	400	1170	1194	24	25	1261	91
4B	155980	2184500	400	1169	1198	29	30	1262	93
5B	155780	2184500	400	1172	1198	26	25	1262	90
6B	155590	2184500	100	1174	1197	23	25	1263	89
16B	155990	2184710	400	1172	1198	26	25	1265	93
17B	155790	2184710	400	1173	1198	25	25	1264	91
16B	155590	2184710	100	1176	1198	22	20	1264	88
20B	154570	2184710	100	1180	1194	14	15	1268	88
22B	154330	2184710	400	1175	1194	19	20	1269	94
24B	154140	2184710	400	1173	1194	21	20	1269	96
25B	153900	2184710	400	1170	1194	24	25	1270	100
35B	155990	2184900	400	1175	1198	23	25	1270	95
36B	155790	2184900	400	1175	1199	24	25	1272	97
37B	155590	2184900	400	1177	1198	21	20	1272	95
42B	154530	2184900	100	1180	1195	15	15	1272	92
43B	154330	2184900	400	1177	1194	17	15	1272	95
44B	154140	2184900	400	1175	1194	19	20	1273	98
45B	153900	2184900	400	1173	1194	21	20	1274	101
46B	153730	2184900	400	1171	1194	23	25	1274	103
60B	155890	2185040	400	1175	1199	24	25	1272	97
61B	155690	2185040	400	1176	1199	23	25	1272	96
62B	155490	2185040	400	1177	1198	21	20	1272	95
63B	155290	2185040	400	1180	1198	18	20	1272	92
64B	155080	2185040	400	1180	1198	18	20	1272	92
65B	154880	2185040	400	1181	1197	16	15	1272	91
66B	154640	2185100	400	1180	1197	17	15	1275	95
68B	154540	2185200	400	1179	1197	18	20	1275	96
70B	154340	2185200	400	1177	1197	20	20	1275	98
72B	154160	2185200	400	1176	1196	20	20	1276	100
73B	153950	2185200	500	1176	1196	20	20	1276	100
79B	153810	2185320	500	1176	1196	20	20	1276	100
80B	153620	2185320	500	1176	1196	20	20	1275	99

TABLE A-3 - WELL DATA - REGIONAL AQUIFER
ALTERNATIVE 1-2

WELL NUMBER	NORTHING	EASTING	PUMP RATE (GPD)	BOTTOM ELEVATION	WATER ELEVATION	SATURATED THICKNESS	SCREEN LENGTH	GROUND ELEVATION	WELL DEPTH
4C	155980	2184500	1440	1140	1194	19	20	1262	122
5C	155770	2184500	1440	1141	1194	21	20	1262	121
6C	155580	2184500	1440	1143	1194	21	20	1263	120
7C	154470	2184500	720	1143	1187	27	30	1266	123
8C	154290	2184500	1440	1143	1186	22	20	1266	123
9C	154080	2184500	1440	1143	1186	20	20	1266	123
16C	155980	2184710	1440	1140	1195	22	20	1265	125
17C	155780	2184710	1440	1141	1195	22	20	1264	123
18C	155590	2184710	1440	1143	1195	23	25	1264	121
19C	154680	2184710	1440	1145	1194	25	25	1268	123
21C	154470	2184710	720	1145	1193	20	20	1268	123
23C	154230	2184710	1440	1145	1192	18	20	1268	123
35C	155980	2184900	1440	1140	1197	25	25	1270	130
36C	155770	2184900	1440	1141	1197	24	25	1272	131
37C	155580	2184900	1440	1142	1196	25	25	1272	130
38C	155380	2184900	1440	1143	1195	28	30	1272	129
39C	155190	2184900	1440	1144	1195	28	30	1272	128
40C	154990	2184900	1440	1145	1195	26	25	1272	127
41C	154790	2184900	720	1147	1195	14	15	1272	125
42C	154540	2184900	720	1146	1194	14	15	1272	126
43C	154340	2184900	720	1146	1194	21	20	1272	126
60C	155880	2185040	1440	1141	1198	24	25	1272	131
61C	155680	2185040	1440	1142	1198	24	25	1272	130
62C	155480	2185040	1440	1143	1197	24	25	1272	129
63C	155280	2185040	1440	1144	1196	26	25	1272	128
64C	155070	2185040	1440	1145	1196	25	25	1272	127
65C	154870	2185040	1440	1147	1195	24	25	1272	125
66C	154650	2185100	1440	1148	1195	22	20	1275	127
68C	154550	2185200	1440	1148	1195	21	20	1275	127
70C	154950	2185200	1440	1148	1195	19	20	1275	127

TABLE A-4 - WELL DATA - PERCHED AQUIFER
ALTERNATIVE 1-3

WELL NUMBER	NORTHING	EASTING	PUMP RATE (GPD)	BOTTOM ELEVATION	WATER ELEVATION	SATURATED THICKNESS	SCREEN LENGTH	GROUND ELEVATION	WELL DEPTH
10A	156180	2184600	500	1216	1250	34	15	1262	46
11A	155970	2184600	500	1214	1249	35	15	1262	48
12A	155760	2184600	500	1216	1249	33	15	1262	46
13A	155550	2184600	500	1224	1250	26	10	1262	38
14A	153990	2184600	500	1231	1253	22	10	1266	35
15A	153780	2184600	360	1233	1253	20	10	1266	33
27A	155970	2184800	150	1219	1252	33	15	1263	44
28A	155760	2184800	500	1219	1252	33	15	1264	45
29A	155580	2184800	500	1224	1252	28	10	1265	41
30A	155370	2184800	500	1229	1254	25	10	1266	37
31A	154380	2184800	360	1231	1256	25	10	1269	38
23A	154200	2184710	360	1231	1254	25	10	1269	38
32A	153990	2184800	360	1233	1256	23	10	1269	36
33A	153780	2184800	360	1234	1256	22	10	1270	36
34A	153570	2184800	360	1236	1256	20	10	1270	34
26A	153360	2184710	360	1237	1254	17	10	1270	33
47A	155880	2184995	150	1225	1255	30	10	1270	45
48A	155670	2184995	500	1225	1255	30	10	1272	47
49A	155460	2184995	500	1228	1255	27	10	1272	44
50A	155250	2184995	500	1233	1256	23	10	1272	39
51A	155040	2184995	500	1236	1257	21	10	1272	36
52A	154800	2184995	500	1235	1257	22	10	1272	37
53A	154590	2184995	500	1233	1257	24	10	1272	39
93A	154380	2184995	500	1231	1257	26	10	1272	41
54A	154200	2184995	360	1231	1257	26	10	1272	41
55A	153990	2184995	360	1232	1257	25	10	1273	41
56A	153780	2184995	360	1233	1257	24	10	1274	41
57A	153570	2184995	280	1236	1257	21	10	1275	39
58A	153360	2184995	360	1236	1257	21	10	1275	39
59A	153180	2184995	500	1238	1257	19	10	1275	37
67A	154670	2185200	500	1234	1257	23	10	1273	39
69A	154410	2185200	500	1232	1257	25	10	1273	41
71A	154230	2185200	500	1232	1257	25	10	1273	41
73A	153990	2185200	500	1233	1257	24	10	1274	41
74A	153810	2185200	480	1234	1257	23	10	1276	42
75A	153480	2185200	500	1237	1257	20	10	1276	39
76A	153270	2185200	480	1238	1257	19	10	1275	37
82A	153390	2185400	520	1237	1257	20	10	1275	38
83A	153180	2185400	500	1240	1257	17	10	1275	35
84A	152970	2185400	360	1245	1257	12	5	1275	30
93A	153360	2185600	500	1238	1257	19	10	1275	37
94A	153180	2185600	500	1241	1257	16	5	1275	34
77A	153090	2185210	360	1241	1257	16	5	1275	34
78A	152880	2185210	280	1245	1257	12	5	1275	30
92A	155190	2186020	400	1245	1254	9	5	1272	27
86A	155240	2185630	400	1240	1255	15	5	1276	36
87A	155010	2185630	250	1239	1255	16	5	1276	37
88A	154760	2185630	200	1237	1255	18	10	1276	39
90A	155010	2185780	200	1244	1255	11	5	1276	32
79A	155670	2185180	360	1231	1256	25	10	1272	41

Table A-5 - Well Data - Top of Regional Aquifer
ALTERNATIVE 1-3

WELL NUMBER	NORTHING	EASTING	PUMP RATE (GPD)	BOTTOM ELEVATION	WATER ELEVATION	SATURATED THICKNESS	SCREEN LENGTH	GROUND ELEVATION	WELL DEPTH
1B	155930	2183800	400	1166	1195	29	30	1259	93
2B	155720	2183800	400	1168	1194	26	25	1260	92
3B	155530	2183800	400	1170	1194	24	25	1261	91
4B	155980	2184500	400	1169	1198	29	30	1262	93
5B	155780	2184500	400	1172	1198	26	25	1262	90
6B	155590	2184500	100	1174	1197	23	25	1263	89
16B	155990	2184710	400	1172	1198	26	25	1265	93
17B	155790	2184710	400	1173	1198	25	25	1264	91
18B	155590	2184710	100	1176	1198	22	20	1264	88
20B	154570	2184710	100	1180	1194	14	15	1268	88
22B	154330	2184710	400	1175	1194	19	20	1269	94
24B	154140	2184710	400	1173	1194	21	20	1269	96
25B	153900	2184710	400	1170	1194	24	25	1270	100
35B	155990	2184900	400	1175	1198	23	25	1270	95
36B	155790	2184900	400	1175	1199	24	25	1272	97
37B	155590	2184900	400	1177	1198	21	20	1272	95
42B	154530	2184900	100	1180	1195	15	15	1272	92
43B	154330	2184900	400	1177	1194	17	15	1272	95
44B	154140	2184900	400	1175	1194	19	20	1273	98
45B	153900	2184900	400	1173	1194	21	20	1274	101
46B	153730	2184900	400	1171	1194	23	25	1274	103
60B	155890	2185040	400	1175	1199	24	25	1272	97
61B	155690	2185040	400	1176	1199	23	25	1272	96
62B	155490	2185040	400	1177	1198	21	20	1272	95
63B	155290	2185040	400	1180	1198	18	20	1272	92
64B	155080	2185040	400	1180	1198	18	20	1272	92
65B	154880	2185040	400	1181	1197	16	15	1272	91
66B	154640	2185100	400	1180	1197	17	15	1275	95
68B	154540	2185200	400	1179	1197	18	20	1275	96
70B	154340	2185200	400	1177	1197	20	20	1275	98
72B	154160	2185200	400	1176	1196	20	20	1276	100
73B	153950	2185200	500	1176	1196	20	20	1276	100
80B	153810	2185320	500	1176	1196	20	20	1276	100
81B	153620	2185320	500	1176	1196	20	20	1275	99
86B	155200	2185630	500	1174	1200	26	25	1276	102
87B	154990	2185630	500	1176	1200	24	25	1276	100
88B	154750	2185630	500	1177	1200	23	25	1276	99
89B	155200	2185780	500	1174	1201	27	25	1276	102
90B	154990	2185780	500	1176	1201	25	25	1276	100
91B	154750	2185780	500	1177	1200	23	25	1276	99
79B	155680	2185190	500	1175	1200	25	25	1276	101
85B	155590	2185410	500	1174	1200	26	25	1276	102

TABLE A-6 - WELL DATA - REGIONAL AQUIFER
ALTERNATIVE 1-3

WELL NUMBER	NORTHING	EASTING	PUMP RATE (GPD)	BOTTOM ELEVATION	WATER ELEVATION	SATURATED THICKNESS	SCREEN LENGTH	GROUND ELEVATION	WELL DEPTH
4C	155980	2184500	1440	1140	1194	19	20	1262	122
5C	155770	2184500	1440	1141	1194	21	20	1262	121
6C	155580	2184500	1440	1143	1194	21	20	1263	120
7C	154470	2184500	720	1143	1187	27	30	1266	123
8C	154290	2184500	1440	1143	1186	22	20	1266	123
9C	154080	2184500	1440	1143	1186	20	20	1266	123
16C	155980	2184710	1440	1140	1195	22	20	1265	125
17C	155780	2184710	1440	1141	1195	22	20	1264	123
18C	155590	2184710	1440	1143	1195	23	25	1264	121
19C	154680	2184710	1440	1145	1194	25	25	1268	123
21C	154470	2184710	720	1145	1193	20	20	1268	123
23C	154230	2184710	1440	1145	1192	18	20	1268	123
35C	155980	2184900	1440	1140	1197	25	25	1270	130
36C	155770	2184900	1440	1141	1197	24	25	1272	131
37C	155580	2184900	1440	1142	1196	25	25	1272	130
38C	155380	2184900	1440	1143	1195	28	30	1272	129
39C	155190	2184900	1440	1144	1195	28	30	1272	128
40C	154990	2184900	1440	1145	1195	26	25	1272	127
41C	154790	2184900	720	1147	1195	14	15	1272	125
42C	154540	2184900	720	1146	1194	14	15	1272	126
43C	154340	2184900	720	1146	1194	21	20	1272	126
60C	155880	2185040	1440	1141	1198	24	25	1272	131
61C	155680	2185040	1440	1142	1198	24	25	1272	130
62C	155480	2185040	1440	1143	1197	24	25	1272	129
63C	155280	2185040	1440	1144	1196	26	25	1272	128
64C	155070	2185040	1440	1145	1196	25	25	1272	127
65C	154870	2185040	1440	1147	1195	24	25	1272	125
66C	154650	2185100	1440	1148	1195	22	20	1275	127
68C	154550	2185200	1440	1148	1195	21	20	1275	127
70C	154350	2185200	1440	1148	1195	19	20	1275	127
91C	154740	2185780	2880	1141	1198	26	25	1276	135
90C	155000	2185780	2880	1142	1199	24	25	1276	134
88C	154740	2185630	2880	1144	1197	23	25	1276	132
87C	155000	2185630	2880	1143	1198	23	25	1276	133
86C	155190	2185630	2880	1143	1199	21	20	1276	133

TABLE A-7 - CONCENTRATIONS AND HEADS
PERCHED AQUIFER
YEAR 0
DAY 0

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	TOLUENE	BENZENE	TOTAL XYLENES	ACETONE	Cr	Pb	Ba	Ni
10A	1250	200	50	3	3	3	3	5	5	45	700	70
11A	1249	19000	1000	3	3	3	3	5	20	75	700	75
12A	1249	9000	1000	3	3	3	3	5	10	75	700	75
13A	1250	500	50	3	3	3	3	10	5	70	700	65
14A	1253	50	3	3	3	3	3	5	200	75	5000	180
15A	1253	40	3	3	3	3	3	5	150	50	5000	200
27A	1252	990	100	3	3	3	3	5	60	60	800	80
28A	1252	12000	2000	3	3	3	3	5	50	60	800	80
29A	1252	1000	900	3	3	3	3	10	20	60	700	75
30A	1254	90	20	3	3	3	3	100	5	60	700	75
31A	1256	90	3	3	3	3	3	10	300	150	3000	150
23A	1254	80	3	3	3	3	3	10	250	120	4000	150
32A	1256	400	3	3	3	3	3	40	300	120	9000	150
33A	1256	400	3	3	3	3	3	10	250	75	10000	200
34A	1256	400	3	3	3	30	3	5	120	40	3200	150
26A	1254	50	3	3	10	20	10	5	40	30	4500	75
47A	1255	500	80	20	3	3	3	5	90	60	900	100
48A	1255	10000	700	80	3	3	3	5	80	60	850	90
49A	1255	900	2000	70	3	3	3	80	60	60	850	80
50A	1256	150	50	50	3	3	3	200	50	50	8000	50
51A	1257	50	3	12	3	3	3	50	5	30	8000	20
52A	1257	100	3	3	3	3	3	20	100	200	9000	110
53A	1257	300	3	3	3	3	3	10	250	275	1000	120
93A	1257	700	3	3	3	3	3	100	600	300	3000	130
54A	1257	1000	3	3	3	3	3	500	700	300	8000	150
55A	1257	2000	20	3	3	3	3	1200	900	250	15000	175
56A	1257	2000	60	3	3	10	3	1500	900	200	30000	500
57A	1257	1000	80	3	500	900	10	100	300	100	10000	90
58A	1257	500	40	3	1000	100	100	5	85	110	7000	50
59A	1257	200	10	3	3	20	80	5	50	200	3000	90
67A	1257	1000	15	3	3	3	3	200	600	200	1500	125
69A	1257	2000	50	3	3	3	3	500	900	250	3000	150
71A	1257	2500	75	3	3	3	3	800	1200	300	6000	130
73A	1257	3000	200	3	3	3	3	1200	2000	300	10000	110
74A	1257	3000	200	3	3	3	3	1100	900	300	15000	90
75A	1257	1500	100	3	3	3	10	10	200	200	9000	50
76A	1257	800	40	3	3	3	3	5	80	150	3000	110
82A	1257	1500	3	3	3	3	3	5	200	100	3000	200
83A	1257	700	3	3	3	3	3	5	75	90	2000	200
84A	1257	200	3	3	3	3	3	5	55	75	1500	300
93A	1257	1600	20	3	3	3	3	5	100	80	3000	300
94A	1257	500	3	3	3	3	3	5	80	75	2000	300
77A	1257	250	3	3	3	3	3	5	60	100	1500	200
78A	1257	90	3	3	3	3	3	5	25	80	800	300
92A	1254	500	80	20	3	3	3	50	500	250	1900	450
86A	1255	90000	900	300	3	3	3	200	500	130	1500	100
87A	1255	60000	4000	200	3	3	3	200	2000	130	1600	100
88A	1255	20000	3000	150	3	3	3	200	10000	130	1700	60
90A	1255	330000	4500	300	3	3	3	200	80000	130	1600	70
79A	1256	18000	300	200	3	3	3	5	100	60	840	100

TABLE A-7 - CONCENTRATIONS AND HEADS CONT'D
PERCHED AQUIFER
YEAR 1
DAY 387

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	TOLUENE	BENZENE	TOTAL XYLENES	ACETONE	Cr	Pb	Ba	Ni
10A	1246	3	1	0	0	0	0	0	5	45	700	70
11A	1238	3	0	0	0	0	0	0	18	68	630	68
12A	1240	6000	667	2	2	2	2	3	27	203	1890	203
13A	1245	12000	1200	60	60	60	60	240	26	364	3640	338
14A	1249	130	7	7	7	7	7	13	194	73	4850	175
15A	1250	2000	125	125	125	125	125	250	151	50	5033	201
27A	1250	3	0	0	0	0	0	0	30	30	400	40
28A	1248	1100	183	0	0	0	0	0	46	55	736	74
29A	1247	2400	2160	6	6	6	6	24	47	141	1645	176
30A	1248	4000	889	111	111	111	111	4444	41	492	5740	615
31A	1251	100	3	3	3	3	3	11	158	79	1580	79
23A	1250	390	12	12	12	12	12	49	199	96	3184	119
32A	1250	1400	9	9	9	9	9	140	442	177	13260	221
33A	1251	2000	13	13	13	13	13	50	241	72	9640	193
34A	1251	1900	12	12	12	143	12	24	195	65	5200	244
26A	1250	1700	85	85	340	680	340	170	100	75	11250	188
47A	1250	200	32	8	1	1	1	2	52	35	520	58
48A	1249	1500	105	12	0	0	0	1	76	57	808	86
49A	1249	4000	8889	311	11	11	11	356	90	90	1275	120
50A	1250	6000	2000	2000	100	100	100	8000	96	96	15360	96
51A	1251	1200	60	288	60	60	60	1200	90	540	144000	360
52A	1251	600	15	15	15	15	15	120	132	264	11880	145
53A	1251	900	8	8	8	8	8	30	180	198	720	86
93A	1251	200	1	1	1	1	1	29	500	250	2500	108
54A	1251	1100	3	3	3	3	3	550	1149	492	13131	246
55A	1251	2500	25	3	3	3	3	1500	1010	281	16833	196
56A	1252	5000	150	6	6	25	6	3750	497	110	16567	276
57A	1252	3800	304	10	1900	3420	38	380	276	92	9200	83
58A	1252	400	32	2	800	80	80	4	146	189	12024	86
59A	1252	3000	150	38	38	300	1200	75	85	340	5100	153
67A	1251	1100	17	3	3	3	3	220	643	214	1608	134
69A	1252	1500	38	2	2	2	2	375	1553	431	5177	259
71A	1252	2300	69	2	2	2	2	736	2023	506	10115	219
73A	1252	2600	173	2	2	2	2	1040	1717	258	8585	94
74A	1253	7100	473	6	6	6	6	2603	884	295	14733	88
75A	1253	5600	373	9	9	9	37	37	280	280	12600	70
76A	1253	4400	220	14	14	14	14	28	120	225	4500	165
82A	1253	4200	7	7	7	7	7	14	173	87	2595	173
83A	1253	2500	9	9	9	9	9	18	78	94	2080	208
84A	1253	2400	30	30	30	30	30	60	46	63	1255	251
93A	1253	1200	15	2	2	2	2	4	105	84	3150	315
94A	1253	1000	5	5	5	5	5	10	80	75	2000	300
77A	1253	3100	31	31	31	31	31	62	73	122	1825	243
78A	1253	2100	58	58	58	58	58	117	38	122	1216	456
92A	1252	500	80	20	3	3	3	50	3399	1700	12916	3059
86A	1252	9000	90	30	0	0	0	20	7553	1964	22659	1511
87A	1251	150000	10000	500	6	6	6	500	12810	833	10248	641
88A	1251	160000	24000	1200	20	20	20	1600	5304	69	902	32
90A	1252	50000	682	45	0	0	0	30	18000	29	360	16
79A	1252	600	10	7	0	0	0	0	125	75	1050	125

TABLE A-7 - CONCENTRATIONS AND HEADS CONT'D
PERCHED AQUIFER
YEAR 5
DAY 1775

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	TOLUENE	BENZENE	TOTAL XYLENES	ACETONE	Cr	Pb	Ba	Ni
10A	1244	201	50	3	3	3	3	5	9	81	1260	126
11A	1235	1087	57	0	0	0	0	0	15	56	525	56
12A	1237	1950	217	1	1	1	1	1	25	188	1750	188
13A	1239	2026	203	10	10	10	10	41	39	546	5460	507
14A	1240	250	13	13	13	13	13	25	280	105	7000	252
15A	1241	305	19	19	19	19	19	38	250	83	8333	333
27A	1245	217	22	1	1	1	1	1	17	17	227	23
28A	1240	961	160	0	0	0	0	0	24	29	384	38
29A	1240	1193	1074	3	3	3	3	12	34	102	1190	128
30A	1241	826	184	23	23	23	23	918	80	960	11200	1200
31A	1242	420	12	12	12	12	12	47	342	171	3420	171
23A	1240	375	12	12	12	12	12	47	485	233	7760	291
32A	1240	980	6	6	6	6	6	98	668	267	20040	334
33A	1241	700	4	4	4	4	4	18	239	72	9560	191
34A	1243	556	3	3	3	42	3	7	211	70	5627	264
26A	1244	280	14	14	56	112	56	28	137	103	15413	257
47A	1246	877	140	35	4	4	4	9	71	47	710	79
48A	1243	3124	219	25	1	1	1	2	45	34	478	51
49A	1243	3146	6991	245	9	9	9	280	151	151	2139	201
50A	1243	1363	454	454	23	23	23	1817	200	200	32000	200
51A	1244	621	31	149	31	31	31	621	266	1596	425600	1064
52A	1243	1210	30	30	30	30	30	242	529	1058	47610	582
53A	1243	1210	10	10	10	10	10	40	658	724	2632	316
93A	1244	1431	5	5	5	5	5	204	1100	550	5500	238
54A	1243	2836	7	7	7	7	7	1418	2100	900	24000	450
55A	1243	3178	32	4	4	4	4	1907	1700	472	28333	331
56A	1244	2367	71	3	3	12	3	1775	720	160	24000	400
57A	1245	1286	103	3	643	1157	13	129	285	95	9500	86
58A	1246	885	71	4	1770	177	177	9	143	185	11776	84
59A	1246	664	33	8	8	66	266	17	97	388	5820	175
67A	1245	3922	59	10	10	10	10	784	1200	400	3000	250
69A	1245	3437	86	4	4	4	4	859	2200	611	7333	367
71A	1246	4000	120	4	4	4	4	1280	3000	750	15000	325
73A	1246	4500	300	4	4	4	4	1800	2500	375	12500	138
74A	1246	3989	266	3	3	3	3	1463	1200	400	20000	120
75A	1247	1167	78	2	2	2	8	8	250	250	11250	63
76A	1247	1080	54	3	3	3	3	7	138	259	5175	190
82A	1247	800	1	1	1	1	1	3	100	50	1500	100
83A	1247	850	3	3	3	3	3	6	110	132	2933	293
84A	1248	188	2	2	2	2	2	5	50	68	1364	273
93A	1248	413	5	1	1	1	1	1	110	88	3300	330
94A	1248	383	2	2	2	2	2	4	100	94	2500	375
77A	1247	970	10	10	10	10	10	19	100	167	2500	333
78A	1248	150	4	4	4	4	4	8	25	80	800	300
92A	1249	5566	891	223	28	28	28	557	1655	828	6289	1490
86A	1247	13616	136	45	0	0	0	30	2000	520	6000	400
87A	1246	16323	1088	54	1	1	1	54	3100	202	2480	155
88A	1246	16705	2506	125	2	2	2	167	2700	35	459	16
90A	1248	19000	259	17	0	0	0	12	4800	8	96	4
79A	1247	4360	73	48	1	1	1	1	140	84	1176	140

TABLE A-7 - CONCENTRATIONS AND HEADS CONT'D
PERCHED AQUIFER
YEAR 10
DAY 3843

WELL NUMBER	CONCENTRATION (ug/l)										
	TCE	1,2 DCE	PCE	TOLUENE	BENZENE	TOTAL XYLENES	ACETONE	Cr	Pb	Ba	Ni
10A	46	12	1	1	1	1	1	5	45	700	70
11A	189	10	0	0	0	0	0	5	19	175	19
12A	1171	130	0	0	0	0	1	20	150	1400	150
13A	1800	180	9	9	9	9	36	50	700	7000	650
14A	240	12	12	12	12	12	24	150	56	3750	135
15A	200	13	13	13	13	13	25	200	67	6667	267
27A	146	15	0	0	0	0	1	5	5	67	7
28A	804	134	0	0	0	0	0	30	36	480	48
29A	1276	1148	3	3	3	3	13	60	180	2100	225
30A	854	190	24	24	24	24	949	95	1140	13300	1425
31A	355	10	10	10	10	10	39	250	125	2500	125
23A	295	9	9	9	9	9	37	230	110	3680	138
32A	760	5	5	5	5	5	76	420	168	12600	210
33A	586	4	4	4	4	4	15	300	90	12000	240
34A	329	2	2	2	25	2	4	190	63	5067	238
26A	109	5	5	22	44	22	11	127	95	14288	238
47A	634	101	25	3	3	3	6	17	11	170	19
48A	2739	192	22	1	1	1	1	90	68	956	101
49A	2761	6136	215	8	8	8	245	200	200	2833	267
50A	2053	684	684	34	34	34	2737	300	300	48000	300
51A	1100	55	264	55	55	55	1100	360	2160	576000	1440
52A	1500	38	38	38	38	38	300	900	1800	81000	990
53A	1350	11	11	11	11	11	45	900	990	3600	432
93A	1124	4	4	4	4	4	161	860	430	4300	186
54A	2128	5	5	5	5	5	1064	1470	630	16800	315
55A	2796	28	3	3	3	3	1678	1500	417	25000	292
56A	2249	67	3	3	11	3	1687	950	211	31667	528
57A	1087	87	3	544	978	11	109	250	83	8333	75
58A	360	29	2	720	72	72	4	50	65	4118	29
59A	377	19	5	5	38	151	9	37	148	2220	67
67A	3838	58	10	10	10	10	768	1750	583	4375	365
69A	2795	70	3	3	3	3	699	1500	417	5000	250
71A	2921	88	3	3	3	3	935	1900	475	9500	206
73A	3957	264	3	3	3	3	1583	1900	285	9500	105
74A	3520	235	3	3	3	3	1291	1300	433	21667	130
75A	913	61	2	2	2	6	6	110	110	4950	28
76A	531	27	2	2	2	2	3	40	75	1500	55
82A	442	1	1	1	1	1	1	75	38	1125	75
83A	446	2	2	2	2	2	3	79	95	2107	211
84A	107	1	1	1	1	1	3	29	40	791	158
93A	206	3	0	0	0	0	1	110	88	3300	330
94A	237	1	1	1	1	1	2	89	83	2225	334
77A	475	5	5	5	5	5	10	39	65	975	130
78A	110	3	3	3	3	3	6	7	22	224	84
92A	2271	363	91	11	11	11	227	800	400	3040	720
86A	3200	32	11	0	0	0	7	1000	260	3000	200
87A	4398	293	15	0	0	0	15	1400	91	1120	70
88A	9572	1436	72	1	1	1	96	2200	29	374	13
90A	4796	65	4	0	0	0	3	1700	3	34	1
79A	3007	50	33	0	0	0	1	107	64	899	107

TABLE A-7 - CONCENTRATIONS AND HEADS CONT'D
PERCHED AQUIFER
YEAR 15
DAY 5600

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	TOLUENE	BENZENE	TOTAL XYLENES	ACETONE	Cr	Pb	Ba	Ni
10A	1244	967	242	12	12	12	12	24	5	45	700	70
11A	1234	75	4	0	0	0	0	0	5	19	175	19
12A	1236	69	8	0	0	0	0	0	20	150	1400	150
13A	1238	4318	432	22	22	22	22	86	50	700	7000	650
14A	1241	2197	110	110	110	110	110	220	220	83	5500	198
15A	1242	2445	153	153	153	153	153	306	250	83	8333	333
27A	1245	3880	392	10	10	10	10	20	5	5	67	7
28A	1241	4300	717	1	1	1	1	2	20	24	320	32
29A	1241	636	572	2	2	2	2	6	65	195	2275	244
30A	1242*	196	44	5	5	5	5	218	120	1440	16800	1800
31A	1241	273	8	8	8	8	8	30	350	175	3500	175
23A	1241	440	14	14	14	14	14	55	265	127	4240	159
32A	1243	100	1	1	1	1	1	10	650	260	19500	325
33A	1243	185	1	1	1	1	1	5	650	195	26000	520
34A	1244	259	2	2	2	19	2	3	267	89	7120	334
26A	1242	171	9	9	34	68	34	17	97	73	10913	182
47A	1246	32	5	1	0	0	0	0	5	3	50	6
48A	1243	1175	82	9	0	0	0	1	55	41	584	62
49A	1243*	2568	5707	200	7	7	7	228	160	160	2267	213
50A	1243*	2804	935	935	47	47	47	3739	265	265	42400	265
51A	1242	8241	412	1978	412	412	412	8241	316	1896	505600	1264
52A	1242	2868	72	72	72	72	72	574	900	1800	81000	990
53A	1242	3000	25	25	25	25	25	100	950	1045	3800	456
93A	1243	15	0	0	0	0	0	2	820	410	4100	178
54A	1244	181	0	0	0	0	0	91	1300	557	14857	279
55A	1244	1065	11	1	1	1	1	639	1700	472	28333	331
56A	1244	1758	53	2	2	9	2	1319	1450	322	48333	806
57A	1245	360	29	1	180	324	4	36	448	149	14933	134
58A	1245	200	16	1	400	40	40	2	35	45	2882	21
59A	1244	155	8	2	2	16	62	4	11	44	660	20
67A	1243	1201	18	3	3	3	3	240	65	22	163	14
69A	1244	2466	62	3	3	3	3	617	1500	417	5000	250
71A	1244	1500	45	2	2	2	2	480	1300	325	6500	141
73A	1244	445	30	0	0	0	0	178	1500	225	7500	83
74A	1245	545	36	0	0	0	0	200	2000	667	33333	200
75A	1245	740	49	1	1	1	5	5	1800	1800	81000	450
76A	1244	550	28	2	2	2	2	3	175	328	6563	241
82A	1245	145	0	0	0	0	0	0	80	40	1200	80
83A	1245	80	0	0	0	0	0	1	125	150	3333	333
84A	1246	534	7	7	7	7	7	13	29	40	791	158
93A	1246	2850	36	4	4	4	4	9	100	80	3000	300
94A	1246	3500	18	18	18	18	18	35	106	99	2650	398
77A	1245	2300	23	23	23	23	23	46	35	58	875	117
78A	1247	2050	57	57	57	57	57	114	5	16	160	60
92A	1248	2714	434	109	14	14	14	271	486	243	1847	437
86A	1246	1990	20	7	0	0	0	4	800	208	2400	160
87A	1245	1170	78	4	0	0	0	4	1000	65	800	50
88A	1245	2100	315	16	0	0	0	21	1750	23	298	11
90A	1247	3000	41	3	0	0	0	2	1200	2	24	1
79A	1247	2300	38	26	0	0	0	1	75	45	630	75

TABLE A-7 - CONCENTRATIONS AND HEADS CONT'D
PERCHED AQUIFER
YEAR 27
DAY 9787

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	TOLUENE	BENZENE	TOTAL XYLENES	ACETONE	Cr	Pb	Ba	Ni
10A	1244	18	5	0	0	0	0	0	5	45	700	70
11A	1235	187	10	0	0	0	0	0	5	19	175	19
12A	1236	1373	153	0	0	0	0	1	40	300	2800	300
13A	1239	2485	249	12	12	12	12	50	73	1022	10220	949
14A	1242	332	17	17	17	17	17	33	475	178	11875	428
15A	1242	274	17	17	17	17	17	34	450	150	15000	600
27A	1245	162	16	0	0	0	0	1	5	5	67	7
28A	1244	1399	233	0	0	0	0	1	45	54	720	72
29A	1241	2768	2491	7	7	7	7	28	99	297	3465	371
30A	1243	1850	411	51	51	51	51	2056	115	1380	16100	1725
31A	1242	551	15	15	15	15	15	61	450	225	4500	225
23A	1242	550	17	17	17	17	17	69	450	216	7200	270
32A	1243	740	5	5	5	5	5	74	950	380	28500	475
33A	1244	727	5	5	5	5	5	18	950	285	38000	760
34A	1245	286	2	2	2	21	2	4	350	117	9333	438
26A	1243	97	5	5	19	39	19	10	70	53	7875	131
47A	1246	603	96	24	3	3	3	6	15	10	150	17
48A	1244	2900	203	23	1	1	1	1	90	68	956	101
49A	1244	3900	8667	303	11	11	11	347	180	180	2550	240
50A	1244	2734	911	911	46	46	46	3645	260	260	41600	260
51A	1243	2100	105	504	105	105	105	2100	350	2100	560000	1400
52A	1243	1987	50	50	50	50	50	397	675	1350	60750	743
53A	1243	1436	12	12	12	12	12	48	650	715	2600	312
93A	1244	1131	4	4	4	4	4	162	700	350	3500	152
54A	1244	1625	4	4	4	4	4	813	1200	514	13714	257
55A	1244	2215	22	3	3	3	3	1329	1950	542	32500	379
56A	1245	1906	57	2	2	10	2	1430	1850	411	61667	1028
57A	1245	648	52	2	324	583	6	65	500	167	16667	150
58A	1245	60	5	0	120	12	12	1	50	65	4118	29
59A	1244	11	1	0	0	1	4	0	15	60	900	27
67A	1244	3413	51	9	9	9	9	683	950	317	2375	198
69A	1245	1945	49	2	2	2	2	486	775	215	2583	129
71A	1245	2118	64	2	2	2	2	678	1500	375	7500	163
73A	1245	2489	166	2	2	2	2	996	2200	330	11000	121
74A	1246	2763	184	2	2	2	2	1013	1900	633	31667	190
75A	1246	485	32	1	1	1	3	3	150	150	6750	38
76A	1245	55	3	0	0	0	0	0	20	38	750	28
82A	1246	138	0	0	0	0	0	0	50	25	750	50
83A	1245	242	1	1	1	1	1	2	50	60	1333	133
84A	1247	72	1	1	1	1	1	2	15	20	409	82
93A	1246	139	2	0	0	0	0	0	50	40	1500	150
94A	1246	226	1	1	1	1	1	2	50	47	1250	188
77A	1246	38	0	0	0	0	0	1	12	20	300	40
78A	1247	20	1	1	1	1	1	1	5	16	160	60
92A	1248	388	62	16	2	2	2	39	170	85	646	153
86A	1245	956	10	3	0	0	0	2	350	91	1050	70
87A	1245	1885	126	6	0	0	0	6	500	33	400	25
88A	1245	5404	811	41	1	1	1	54	1100	14	187	7
90A	1247	2160	29	2	0	0	0	1	500	1	10	0
79A	1247	3217	54	36	0	0	0	1	90	54	756	90

TABLE A-7 - CONCENTRATIONS AND HEADS CONT'D
PERCHED AQUIFER
YEAR 32
DAY 11774

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	TOLUENE	BENZENE	TOTAL XYLENES	ACETONE	Cr	Pb	Ba	Ni
10A	1244	17	4	0	0	0	0	0	5	45	700	70
11A	1235	181	10	0	0	0	0	0	5	19	175	19
12A	1237	1200	133	0	0	0	0	1	20	150	1400	150
13A	1240	1700	170	9	9	9	9	34	38	532	5320	494
14A	1242	320	16	16	16	16	16	32	220	83	5500	198
15A	1242	201	13	13	13	13	13	25	200	67	6667	267
27A	1246	157	16	0	0	0	0	1	5	5	67	7
28A	1244	1359	227	0	0	0	0	1	16	19	256	26
29A	1241	2450	2205	6	6	6	6	25	38	114	1330	143
30A	1242	1550	344	43	43	43	43	1722	52	624	7280	780
31A	1242	440	12	12	12	12	12	49	250	125	2500	125
23A	1242	490	15	15	15	15	15	61	260	125	4160	156
32A	1244	700	4	4	4	4	4	70	450	180	13500	225
33A	1244	700	4	4	4	4	4	18	403	121	16120	322
34A	1245	280	2	2	2	21	2	4	130	43	3467	163
26A	1243	75	4	4	15	30	15	8	25	19	2813	47
47A	1246	530	85	21	3	3	3	5	5	3	50	6
48A	1244	2700	189	22	1	1	1	1	40	30	425	45
49A	1244	3500	7778	272	10	10	10	311	71	71	1006	95
50A	1244	2300	767	767	38	38	38	3067	104	104	16640	104
51A	1244	1900	95	456	95	95	95	1900	150	900	240000	600
52A	1243	1500	38	38	38	38	38	300	310	620	27900	341
53A	1243	1350	11	11	11	11	11	45	303	333	1212	145
93A	1243	1124	4	4	4	4	4	161	360	180	1800	78
54A	1244	1600	4	4	4	4	4	800	630	270	7200	135
55A	1245	2200	22	3	3	3	3	1320	1020	283	17000	198
56A	1245	1900	57	2	2	10	2	1425	860	191	28667	478
57A	1245	600	48	2	300	540	6	60	240	80	8000	72
58A	1245	60	5	0	120	12	12	1	5	6	412	3
59A	1244	10	1	0	0	1	4	0	5	20	300	9
67A	1244	3400	51	9	9	9	9	680	675	225	1688	141
69A	1245	1900	48	2	2	2	2	475	400	111	1333	67
71A	1245	2100	63	2	2	2	2	672	700	175	3500	76
73A	1245	2400	160	2	2	2	2	960	1100	165	5500	61
74A	1246	2700	180	2	2	2	2	990	1000	333	16667	100
75A	1246	450	30	1	1	1	3	3	100	100	4500	25
76A	1245	50	3	0	0	0	0	0	5	9	188	7
82A	1246	130	0	0	0	0	0	0	18	9	270	18
83A	1245	200	1	1	1	1	1	1	25	30	667	67
84A	1247	70	1	1	1	1	1	2	5	7	136	27
93A	1246	130	2	0	0	0	0	0	20	16	600	60
94A	1246	200	1	1	1	1	1	2	21	20	525	79
77A	1246	35	0	0	0	0	0	1	5	8	125	17
78A	1247	15	0	0	0	0	0	1	5	16	160	60
92A	1248	300	48	12	2	2	2	30	100	50	380	90
86A	1246	900	9	3	0	0	0	2	350	91	1050	70
87A	1245	1800	120	6	0	0	0	6	5	0	4	0
88A	1245	5000	750	38	1	1	1	50	1100	14	187	7
90A	1247	2000	27	2	0	0	0	1	500	1	10	0
79A	1246	3000	50	33	0	0	0	1	90	54	756	90

TABLE A-8 - CONCENTRATIONS AND HEADS
TOP OF REGIONAL AQUIFER
YEAR 0
DAY 0

WELL NUMBER	HEAD (ft)	TCE	1,2 DCE	PCE	ACETONE	Cr	Pb	Ba	Ni
1B	1195	350	58	3	5	5	13	1600	30
2B	1194	400	50	3	5	5	13	1600	30
3B	1194	350	3	3	5	5	50	1500	30
4B	1198	500	12	3	5	5	60	250	30
5B	1198	1200	90	3	10	10	70	1000	30
6B	1197	1200	90	3	12	50	80	1500	100
16B	1198	500	3	3	50	10	50	250	30
17B	1198	4000	120	3	40	40	70	1200	80
18B	1198	5000	200	3	40	100	85	8000	110
20B	1194	500	90	3	100	60	50	900	80
22B	1194	500	40	3	40	40	13	900	30
24B	1194	300	20	3	10	25	13	900	30
25B	1194	75	3	3	5	15	13	800	30
35B	1198	130	3	3	350	55	45	1500	90
36B	1199	7000	200	10	100	90	70	1700	110
37B	1198	8000	300	40	40	250	90	1800	150
42B	1195	2400	220	3	500	85	38	1400	80
43B	1194	1200	80	3	120	60	13	1300	30
44B	1194	1000	50	3	90	50	13	1300	30
45B	1194	400	10	3	30	30	13	1200	30
46B	1194	100	3	3	10	20	13	1000	30
60B	1199	1000	100	30	300	80	50	1600	110
61B	1199	9000	800	500	30	250	80	1700	250
62B	1198	8000	700	90	35	350	120	9000	200
63B	1198	8500	500	50	40	380	120	12000	200
64B	1198	7000	240	10	60	390	80	700	170
65B	1197	6000	200	3	100	250	70	900	130
66B	1197	5000	150	3	300	150	50	2000	100
68B	1197	5000	100	3	400	150	50	2200	100
70B	1197	3500	80	3	400	110	45	2400	100
72B	1196	2000	50	3	200	90	45	2600	100
73B	1196	700	20	3	150	75	55	2800	100
80B	1196	400	10	3	150	50	65	3000	110
81B	1196	90	3	3	200	40	70	3200	110
86B	1200	20000	80	200	100	800	150	12000	300
87B	1200	25000	75	150	100	950	175	12000	400
88B	1200	15000	75	50	100	800	100	11000	300
89B	1201	12000	50	120	50	900	200	12000	400
90B	1201	33000	50	130	5	1700	250	12000	580
91B	1200	12000	40	70	50	400	125	10000	400
79B	1200	14000	930	1200	23	300	80	1800	300
85B	1200	10000	500	500	100	200	100	2000	200

TABLE A-8 - CONCENTRATIONS AND HEADS CONT'D
TOP OF REGIONAL AQUIFER
YEAR 1
DAY 387

WELL NUMBER	HEAD (ft)	TCE	1,2 DCE	PCE	ACETONE	Cr	Pb	Ba	Ni
1B	1192	370	61	3	5	2	5	640	12
2B	1191	600	75	4	8	7	18	2240	42
3B	1191	550	4	4	8	6	60	1800	36
4B	1192	600	14	3	6	7	84	350	42
5B	1193	1200	90	3	10	24	168	2400	72
6B	1193	1500	113	3	15	57	91	1710	114
16B	1192	400	2	2	40	13	65	325	39
17B	1193	1100	33	1	11	43	75	1290	86
18B	1193	1700	68	1	14	84	71	6720	92
20B	1192	1260	227	6	252	64	53	960	85
22B	1192	1500	120	8	120	45	14	1013	34
24B	1191	1000	67	8	33	52	26	1872	62
25B	1191	700	23	23	47	38	32	2027	76
35B	1193	570	11	11	1535	30	25	818	49
36B	1193	3100	89	4	44	64	50	1209	78
37B	1193	5360	201	27	27	100	36	720	60
42B	1193	3000	275	3	625	100	45	1647	94
43B	1193	3100	207	6	310	100	21	2167	50
44B	1192	2000	100	5	180	90	23	2340	54
45B	1192	1270	32	8	95	70	29	2800	70
46B	1192	600	15	15	60	60	38	3000	90
60B	1194	2200	220	66	660	60	38	1200	83
61B	1194	7700	684	428	26	90	29	612	90
62B	1194	8500	744	96	37	130	45	3343	74
63B	1194	5800	341	34	27	150	47	4737	79
64B	1194	3000	103	4	26	130	27	233	57
65B	1194	2500	83	1	42	140	39	504	73
66B	1194	5500	165	3	330	230	77	3067	153
68B	1194	9000	180	5	720	275	92	4033	183
70B	1194	8000	183	6	914	230	94	5018	209
72B	1194	3500	88	4	350	130	65	3756	144
73B	1193	1500	43	5	321	90	66	3360	120
80B	1194	1100	28	7	413	60	78	3600	132
81B	1194	800	22	22	1778	75	131	6000	206
86B	1196	14000	56	140	70	740	139	11100	278
87B	1196	16000	48	96	64	1050	193	13263	442
88B	1196	13000	65	43	87	800	100	11000	300
89B	1196	8000	33	80	33	850	189	11333	378
90B	1196	14000	21	55	2	1280	188	9035	437
91B	1196	7500	25	44	31	750	234	18750	750
79B	1194	12000	797	1029	20	130	35	780	130
85B	1196	11800	590	590	118	270	135	2700	270

TABLE A-8 - CONCENTRATIONS AND HEADS CONT'D
TOP OF REGIONAL AQUIFER
YEAR 5
DAY 1775

WELL NUMBER	HEAD (ft)	TCE	1,2 DCE	PCE	ACETONE	Cr	Pb	Ba	Ni
1B	1186	452	75	3	6	7	18	2240	42
2B	1186	560	70	4	7	7	18	2240	42
3B	1185	500	4	4	7	6	60	1800	36
4B	1183	1040	25	5	10	13	156	650	78
5B	1184	1520	114	3	13	18	126	1800	54
6B	1185	1410	106	3	14	34	54	1020	68
16B	1183	270	1	1	27	2	10	50	6
17B	1184	903	27	1	9	16	28	480	32
18B	1185	1490	60	1	12	45	38	3600	50
20B	1186	730	131	4	146	70	58	1050	93
22B	1185	1100	88	6	88	36	11	810	27
24B	1184	800	53	7	27	23	12	828	28
25B	1184	430	14	14	29	23	19	1227	46
35B	1184	260	5	5	700	0	0	3	0
36B	1184	950	27	1	14	15	12	283	18
37B	1184	1800	68	9	9	46	17	331	28
42B	1185	2000	183	2	417	70	31	1153	66
43B	1185	2200	147	5	220	63	13	1365	32
44B	1185	1200	60	3	108	19	5	494	11
45B	1185	600	15	4	45	19	8	760	19
46B	1185	320	8	8	32	42	26	2100	63
60B	1186	490	49	15	147	5	3	100	7
61B	1186	1170	104	65	4	24	8	163	24
62B	1186	2250	197	25	10	46	16	1183	26
63B	1185	2300	135	14	11	60	19	1895	32
64B	1186	1200	41	2	10	63	13	113	27
65B	1186	700	23	0	12	41	11	148	21
66B	1186	2500	75	1	150	120	40	1600	80
68B	1186	4500	90	2	360	200	67	2933	133
70B	1186	3700	85	3	423	128	52	2793	116
72B	1186	1350	34	2	135	20	10	578	22
73B	1187	530	15	2	114	10	7	373	13
80B	1186	500	13	3	188	25	33	1500	55
81B	1187	480	13	13	1067	50	88	4000	138
86B	1188	4800	19	48	24	130	24	1950	49
87B	1190	4800	14	29	19	185	34	2337	78
88B	1190	5100	26	17	34	250	31	3438	94
89B	1190	2000	8	20	8	65	14	867	29
90B	1190	2100	3	8	0	120	18	847	41
91B	1190	3000	10	18	13	220	69	5500	220
79B	1186	1200	80	103	2	25	7	150	25
85B	1190	3050	153	153	31	70	35	700	70

TABLE A-8 - CONCENTRATIONS AND HEADS CONT'D
TOP OF REGIONAL AQUIFER
YEAR 10
DAY 3843

WELL NUMBER	HEAD (ft)	TCE	1,2 DCE	PCE	ACETONE	Cr	Pb	Ba	Ni
1B	1179	64	11	0	1	0	0	32	1
2B	1179	67	8	0	1	0	0	32	1
3B	1179	50	0	0	1	2	20	600	12
4B	1173	138	3	1	1	18	216	900	108
5B	1173	172	13	0	1	23	161	2300	69
6B	1179*	1260	95	3	13	32	51	960	64
16B	1174	80	0	0	8	0	1	3	0
17B	1177	430	13	0	4	9	16	270	18
18B	1179*	850	34	0	7	35	30	2800	39
20B	1182**		0	0	0		0	0	0
22B	1180	100	8	1	8	0	0	2	0
24B	1178	60	4	1	2	2	1	72	2
25B	1178	50	2	2	3	11	9	587	22
35B	1177*	30	1	1	81	0	0	3	0
36B	1177*	370	11	1	5	9	7	170	11
37B	1179*	850	32	4	4	25	9	180	15
42B	1182*	530	49	1	110	37	17	609	35
43B	1180*	310	21	1	31	10	2	217	5
44B	1179	100	5	0	9	0	0	3	0
45B	1179	60	2	0	5	3	1	120	3
46B	1180	140	4	4	14	26	16	1300	39
60B	1184	140	14	4	42	0	0	2	0
61B	1179	550	49	31	2	6	2	41	6
62B	1181*	650	57	7	3	20	7	514	11
63B	1182*	750	44	4	4	25	8	789	13
64B	1183	700	24	1	6	50	10	90	22
65B	1183*	580	19	0	10	50	14	180	26
66B	1184*	700	21	0	42	35	12	467	23
68B	1182	1300	26	1	104	65	22	953	43
70B	1182	1100	25	1	126	55	23	1200	50
72B	1183	430	11	1	43	17	9	491	19
73B	1181	100	3	0	21	1	1	37	1
80B	1183	140	4	1	53	9	12	540	20
81B	1183	210	6	6	467	28	49	2240	77
86B	1188	890	4	9	4	27	5	405	10
87B	1187	990	3	6	4	36	7	455	15
88B	1187	1000	5	3	7	80	10	1100	30
89B	1189	350	1	4	1	15	3	200	7
90B	1188	300	0	1	0	19	3	134	6
91B	1188	500	2	3	2	50	16	1250	50
79B	1180	400	27	34	1	4	1	24	4
85B	1187	400	20	20	4	19	10	190	19

* - previous pump rate divided by 4
** - pump turns off

TABLE A-8 - CONCENTRATIONS AND HEADS CONT'D
TOP OF REGIONAL AQUIFER
YEAR 15
DAY 5601

WELL NUMBER	HEAD (ft)	TCE	1,2 DCE	PCE	ACETONE	Cr	Pb	Ba	Ni
1B	1178*	150	25	1	2	6	15	1920	36
2B	1177	130	16	1	2	6	15	1920	36
3B	1177	92	1	1	1	8	80	2400	48
4B	1181*	178	4	1	2	23	276	1150	138
5B	1181*	200	15	0	2	36	252	3600	108
6B	1181	1100	83	2	11	42	67	1260	84
16B	1181*	115	1	1	12	2	10	50	6
17B	1182*	400	12	0	4	15	26	450	30
18B	1182	730	29	0	6	34	29	2720	37
20B	1181**	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
22B	1178*	66	5	0	5	10	3	225	8
24B	1176*	50	3	0	2	2	1	72	2
25B	1174	50	2	2	3	9	8	480	18
35B	1182	5	0	0	13	0	0	3	0
36B	1182	250	7	0	4	10	8	189	12
37B	1182	670	25	3	3	25	9	180	15
42B	1180**	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
43B	1178*	130	9	0	13	8	2	173	4
44B	1176	55	3	0	5	0	0	3	0
45B	1175	50	1	0	4	1	0	40	1
46B	1177	130	3	3	13	19	12	950	29
60B	1183	75	8	2	23	1	1	20	1
61B	1182	370	33	21	1	9	3	61	9
62B	1183	640	56	7	3	23	8	591	13
63B	1184	700	41	4	3	40	13	1263	21
64B	1183	530	18	1	5	48	10	86	21
65B	1183	370	12	0	6	21	6	76	11
66B	1182	300	9	0	18	20	7	267	13
68B	1181	500	10	0	40	15	5	220	10
70B	1181	450	10	0	51	30	12	655	27
72B	1182	120	3	0	12	8	4	231	9
73B	1179	40	1	0	9	3	2	112	4
80B	1182	45	1	0	17	8	10	480	18
81B	1182	80	2	2	178	31	54	2480	85
86B	1187	270	1	3	1	9	2	135	3
87B	1187	280	1	2	1	20	4	253	8
88B	1187	340	2	1	2	44	6	605	17
89B	1187	100	0	1	0	5	1	67	2
90B	1187	125	0	0	0	10	1	71	3
91B	1188	140	0	1	1	25	8	625	25
79B	1182	200	13	17	0	1	0	6	1
85B	1187	150	8	8	2	0	0	1	0

* - previous pump rate divided by 4
** - pump turns off

TABLE A-8 - CONCENTRATIONS AND HEADS CONT'D
TOP OF REGIONAL AQUIFER
YEAR 27
DAY 9787

WELL NUMBER	HEAD (ft)	TCE	1,2 DCE	PCE	ACETONE	Cr	Pb	Ba	Ni
1B	1176	160	27	1	2	14	35	4480	84
2B	1174	220	28	1	3	17	43	5440	102
3B	1174	190	1	1	3	16	160	4800	96
4B	1182	240	6	1	2	20	240	1000	120
5B	1181	240	18	1	2	27	189	2700	81
6B	1181	1100	83	2	11	25	40	750	50
16B	1182	400	2	2	40	4	20	100	12
17B	1182	600	18	0	6	12	21	360	24
18B	1182	700	28	0	6	23	20	1840	25
20B	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
22B	1179	160	13	1	13	13	4	293	10
24B	1177	50	3	0	2	41	21	1476	49
25B	1175	8	0	0	1	8	7	427	16
35B	1183	3	0	0	8	3	2	82	5
36B	1182	100	3	0	1	8	6	151	10
37B	1182	210	8	1	1	18	6	130	11
42B	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
43B	1180	140	9	0	14	8	2	173	4
44B	1179	50	3	0	5	4	1	104	2
45B	1178	3	0	0	0	2	1	80	2
46B	1177	5	0	0	1	17	11	850	26
60B	1183	50	5	2	15	3	2	60	4
61B	1182	25	2	1	0	5	2	34	5
62B	1182	150	13	2	1	10	3	257	6
63B	1183	300	18	2	1	20	6	632	11
64B	1183	400	14	1	3	28	6	50	12
65B	1183	330	11	0	6	25	7	90	13
66B	1183	210	6	0	13	9	3	120	6
68B	1182	85	2	0	7	6	2	88	4
70B	1182	85	2	0	10	5	2	109	5
72B	1183	70	2	0	7	6	3	173	7
73B	1182	20	1	0	4	3	2	112	4
80B	1183	5	0	0	2	5	7	300	11
81B	1182	3	0	0	7	8	14	640	22
86B	1187	13	0	0	0	1	0	15	0
87B	1187	5	0	0	0	2	0	25	1
88B	1187	10	0	0	0	10	1	138	4
89B	1188	25	0	0	0	1	0	13	0
90B	1187	2	0	0	0	1	0	7	0
91B	1188	3	0	0	0	3	1	75	3
79B	1182	30	2	3	0	2	1	12	2
85B	1187	4	0	0	0	1	1	10	1

TABLE A-8 - CONCENTRATIONS AND HEADS CONT'D
TOP OF REGIONAL AQUIFER
YEAR 32
DAY 11774

WELL NUMBER	HEAD (ft)	TCE	1,2 DCE	PCE	ACETONE	Cr	Pb	Ba	Ni
1B	1175	160	27	1	2	20	50	6400	120
2B	1172	220	28	1	3	15	38	4800	90
3B	1173	190	1	1	3	10	100	3000	60
4B	1181	240	6	1	2	17	204	850	102
5B	1181	240	18	1	2	27	189	2700	81
6B	1181	600	45	1	6	25	40	750	50
16B	1182	430	2	2	43	1	5	25	3
17B	1182	570	17	0	6	9	16	270	18
18B	1182	570	23	0	5	22	19	1760	24
20B	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
22B	1178	55	4	0	4	4	1	90	3
24B	1176	6	0	0	0	3	2	108	4
25B	1175	6	0	0	0	5	4	267	10
35B	1182	45	1	1	121	0	0	3	0
36B	1182	180	5	0	3	5	4	94	6
37B	1182	400	15	2	2	18	6	130	11
42B	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
43B	1179	10	1	0	1	4	1	87	2
44B	1179	0	0	0	0	0	0	3	0
45B	1177	1	0	0	0	1	0	40	1
46B	1176	14	0	0	1	10	6	500	15
60B	1183	15	2	0	5	1	1	20	1
61B	1182	145	13	8	0	7	2	48	7
62B	1183	250	22	3	1	20	7	514	11
63B	1184	240	14	1	1	27	9	853	14
64B	1183	200	7	0	2	27	6	48	12
65B	1183	190	6	0	3	20	6	72	10
66B	1183	80	2	0	5	8	3	107	5
68B	1182	25	1	0	2	3	1	44	2
70B	1182	15	0	0	2	1	0	22	1
72B	1183	1	0	0	0	1	0	14	1
73B	1182	1	0	0	0	0	0	15	1
80B	1183	2	0	0	1	1	1	60	2
81B	1181	5	0	0	11	7	12	560	19
86B	1187	10	0	0	0	0	0	2	0
87B	1187	11	0	0	0	0	0	1	0
88B	1187	8	0	0	0	0	0	1	0
89B	1188	10	0	0	0	0	0	3	0
90B	1188	12	0	0	0	0	0	1	0
91B	1188	6	0	0	0	0	0	3	0
79B	1182	38	3	3	0	2	1	12	2
85B	1186	5	0	0	0	0	0	1	0

TABLE A-9 - CONCENTRATIONS AND HEADS
REGIONAL AQUIFER
YEAR 0
DAY 0

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	Cr	Pb	Ba	Ni
4C	1194	27	40	3	150	300	18000	300
5C	1194	30	40	3	300	345	12000	390
6C	1194	33	30	3	100	125	5000	150
7C	1187	2	7	3	820	400	27000	1100
8C	1186	2	7	3	700	350	28000	100
9C	1186	2	5	3	100	300	28000	50
16C	1195	20	15	3	110	250	10000	300
17C	1195	30	30	3	180	200	5000	300
18C	1195	50	40	3	120	100	1000	200
19C	1194	12	9	3	110	150	500	100
21C	1193	2	8	3	1000	250	600	1100
23C	1192	2	8	3	200	250	1000	100
35C	1197	20	5	3	90	150	6000	200
36C	1197	50	10	3	150	100	1000	200
37C	1196	80	20	3	200	80	500	120
38C	1195	95	40	3	140	80	500	100
39C	1195	105	40	3	85	80	500	75
40C	1195	100	30	3	90	110	500	80
41C	1195	70	20	3	300	150	500	75
42C	1194	30	10	3	1000	150	500	500
43C	1194	2	7	3	300	150	500	100
60C	1198	40	5	3	90	110	500	150
61C	1198	75	5	3	170	80	580	120
62C	1197	100	20	3	200	80	500	110
63C	1196	200	40	8	150	90	500	90
64C	1196	400	46	9	110	110	500	78
65C	1195	150	30	9	500	300	500	90
66C	1195	90	20	8	1000	300	500	100
68C	1195	80	15	7	700	300	500	300
70C	1195	30	7	3	50	300	500	100
91C	1198	1000	15	15	100	300	5000	100
90C	1199	1000	36	25	1200	90	1100	70
88C	1197	1000	15	18	400	300	1000	90
87C	1198	1000	40	30	1100	100	900	70
86C	1199	900	40	20	700	90	700	70

TABLE A-9 - CONCENTRATIONS AND HEADS CONT'D
REGIONAL AQUIFER
YEAR I
DAY 387

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	Cr	Pb	Ba	Ni
4C	1166	3	4	0	90	180	10800	180
5C	1169	9	12	1	130	150	5200	169
6C	1172	16	15	1	100	125	5000	150
7C	1171	9	32	11	127	62	4182	170
8C	1174	0	0	0	190	95	7600	27
9C	1178	0	0	0	193	579	54040	97
16C	1165	0	0	0	105	239	9545	286
17C	1167	5	5	0	166	184	4611	277
18C	1169	11	9	1	174	145	1450	290
19C	1169	9	7	2	174	237	791	158
21C	1171	10	40	13	241	60	145	265
23C	1177	5	20	6	243	304	1215	122
35C	1167	0	0	0	120	200	8000	267
36C	1167	4	1	0	160	107	1067	213
37C	1168	16	4	1	178	71	445	107
38C	1168	42	18	1	150	86	536	107
39C	1168	60	23	1	100	94	588	88
40C	1168	32	10	1	115	141	639	102
41C	1170	32	9	1	190	95	317	48
42C	1172	28	9	2	334	50	167	167
43C	1176	25	88	31	300	150	500	100
60C	1170	1	0	0	100	122	556	167
61C	1169	7	0	0	125	59	426	88
62C	1169	43	9	1	156	62	390	86
63C	1169	75	15	3	170	102	567	102
64C	1169	67	8	2	180	180	818	128
65C	1170	40	8	2	250	150	250	45
66C	1176	64	14	6	330	99	165	33
68C	1180	100	19	9	315	135	225	135
70C	1182	61	14	5	210	1260	2100	420
91C	1192	1000	15	15	300	900	15000	300
90C	1188	310	11	8	250	19	229	15
88C	1186	1010	15	18	400	300	1000	90
87C	1186	770	31	23	310	28	254	20
86C	1188	450	20	10	161	21	161	16

TABLE A-9 - CONCENTRATIONS AND HEADS CONT'D
REGIONAL AQUIFER
YEAR 5
DAY 1775

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	Cr	Pb	Ba	Ni
4C	1167	2	2	0	53	106	6360	106
5C	1169	7	9	1	56	64	2240	73
6C	1172	12	11	1	48	60	2400	72
7C	1171	4	14	5	136	66	4478	182
8C	1174	2	6	2	170	85	6800	24
9C	1178	0	0	0	148	444	41440	74
16C	1165	0	0	0	60	136	5455	164
17C	1167	6	6	1	67	74	1861	112
18C	1169	14	11	1	50	42	417	83
19C	1170	11	8	2	129	176	586	117
21C	1171	8	32	10	192	48	115	211
23C	1177	4	16	5	167	209	835	84
35C	1167	1	0	0	63	105	4200	140
36C	1168	5	1	0	65	43	433	87
37C	1168	16	4	1	43	17	108	26
38C	1168	30	13	1	33	19	118	24
39C	1168	62	24	1	34	32	200	30
40C	1169	76	23	2	51	62	283	45
41C	1170	41	12	1	110	55	183	28
42C	1172	19	6	2	210	32	105	105
43C	1176	12	42	15	205	103	342	68
60C	1170	1	0	0	50	61	278	83
61C	1170	7	0	0	33	16	113	23
62C	1170	24	5	1	32	13	80	18
63C	1169	56	11	2	51	31	170	31
64C	1169	110	13	2	75	75	341	53
65C	1169	90	18	5	105	63	105	19
66C	1175	62	14	6	197	59	99	20
68C	1180	94	18	8	202	87	144	87
70C	1184	53	12	4	180	1080	1800	360
91C	1192	200	3	3	290	870	14500	290
90C	1190	73	3	2	237	18	217	14
88C	1187	300	5	5	351	263	878	79
87C	1186	310	12	9	275	25	225	18
86C	1186	183	8	4	140	18	140	14

TABLE A-9 - CONCENTRATIONS AND HEADS CONT'D
REGIONAL AQUIFER
YEAR 10
DAY 3843

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	Cr	Pb	Ba	Ni
4C	1166	3	4	0	97	194	11640	194
5C	1169	22	29	2	146	168	5840	190
6C	1171	42	38	3	190	238	9500	285
7C	1171	2	7	3	180	88	5927	241
8C	1174	1	4	1	170	85	6800	24
9C	1179	0	0	0	120	360	33600	60
16C	1165	3	2	0	160	364	14545	436
17C	1167	10	10	1	190	211	5278	317
18C	1169	30	24	2	170	142	1417	283
19C	1170	11	8	2	218	297	991	198
21C	1171	14	56	18	233	58	140	256
23C	1177	6	24	8	168	210	840	84
35C	1167	0	0	0	157	262	10467	349
36C	1167	4	1	0	155	103	1033	207
37C	1168	15	4	0	90	36	225	54
38C	1168	18	8	0	93	53	332	66
39C	1168	20	8	0	207	195	1218	183
40C	1169	15	5	0	286	350	1589	254
41C	1170	21	6	1	266	133	443	67
42C	1172	35	12	3	261	39	131	131
43C	1176	27	95	34	224	112	373	75
60C	1170	0	0	0	95	116	528	158
61C	1169	1	0	0	56	26	191	40
62C	1169	22	4	1	35	14	88	19
63C	1169	40	8	2	110	66	367	66
64C	1169	60	7	1	227	227	1032	161
65C	1170	34	7	2	289	173	289	52
66C	1174	100	22	9	276	83	138	28
68C	1179	200	38	18	245	105	175	105
70C	1181	150	35	13	158	948	1580	316
91C	1192	800	12	12	168	504	8400	168
90C	1190	400	14	10	158	12	145	9
88C	1188	1000	15	18	274	206	685	62
87C	1186	850	34	26	295	27	241	19
86C	1186	480	21	11	173	22	173	17

TABLE A-9 - CONCENTRATIONS AND HEADS CONT'D
REGIONAL AQUIFER
YEAR 15
DAY 5600

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	Cr	Pb	Ba	Ni
4C	1165	0	0	0	16	32	1920	32
5C	1169	5	6	0	19	22	760	25
6C	1172	10	9	1	16	20	800	24
7C	1169	8	28	10	22	11	724	30
8C	1173	5	18	6	37	19	1480	5
9C	1179	0	1	0	43	129	12040	22
16C	1164	0	0	0	18	41	1636	49
17C	1167	3	3	0	20	22	556	33
18C	1169	6	5	0	11	9	92	18
19C	1169	12	9	3	15	20	68	14
21C	1169	26	104	33	23	6	14	25
23C	1177	10	40	13	28	35	140	14
35C	1167	0	0	0	25	42	1667	56
36C	1168	0	0	0	25	17	167	33
37C	1167	2	1	0	8	3	20	5
38C	1168	6	3	0	5	3	18	4
39C	1168	7	3	0	5	5	29	4
40C	1168	2	1	0	6	7	33	5
41C	1169	6	2	0	13	7	22	3
42C	1172	36	12	3	31	5	16	16
43C	1176	55	193	69	30	15	50	10
60C	1169	0	0	0	23	28	128	38
61C	1168	0	0	0	10	5	34	7
62C	1168	10	2	0	0	0	0	0
63C	1168	30	6	1	6	4	20	4
64C	1167	40	5	1	15	15	68	11
65C	1168	25	5	2	20	12	20	4
66C	1174	80	18	7	27	8	14	3
68C	1179	140	26	12	40	17	29	17
70C	1183	120	28	10	27	162	270	54
91C	1192	460	7	7	112	336	5600	112
90C	1187	175	6	4	88	7	81	5
88C	1189	550	8	10	127	95	318	29
87C	1185	370	15	11	130	12	106	8
86C	1186	202	9	4	80	10	80	8

TABLE A-9 - CONCENTRATIONS AND HEADS CONT'D
REGIONAL AQUIFER
YEAR 27
DAY 9787

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	Cr	Pb	Ba	Ni
4C	1165	0	0	0	3	6	360	6
5C	1169	0	0	0	4	5	160	5
6C	1172	4	4	0	3	4	150	5
7C	1169	1	5	2	12	6	395	16
8C	1173	6	21	8	21	11	840	3
9C	1179	7	18	9	21	63	5880	11
16C	1164	0	0	0	11	25	1000	30
17C	1167	0	0	0	12	13	333	20
18C	1169	3	2	0	5	4	42	8
19C	1169	10	8	2	3	4	14	3
21C	1169	21	84	26	7	2	4	8
23C	1177	44	176	55	12	15	60	6
35C	1167	0	0	0	17	28	1133	38
36C	1168	0	0	0	16	11	107	21
37C	1167	0	0	0	5	2	13	3
38C	1168	3	1	0	2	1	7	1
39C	1168	7	3	0	2	2	12	2
40C	1168	9	3	0	1	1	3	0
41C	1169	11	3	0	3	2	5	1
42C	1172	36	12	3	8	1	4	4
43C	1176	75	263	94	12	6	20	4
60C	1169	0	0	0	7	9	39	12
61C	1168	0	0	0	4	2	14	3
62C	1168	5	1	0	1	0	2	0
63C	1168	10	2	0	4	2	13	2
64C	1167	15	2	0	11	11	50	8
65C	1168	15	3	1	13	8	13	2
66C	1174	72	16	6	10	3	5	1
68C	1179	100	19	9	12	5	9	5
70C	1183	130	30	11	9	54	90	18
91C	1192	260	4	4	80	240	4000	80
90C	1187	100	4	3	59	4	54	3
88C	1189	280	4	5	81	61	203	18
87C	1185	138	6	4	73	7	60	5
86C	1186	78	3	2	40	5	40	4

TABLE A-9 - CONCENTRATIONS AND HEADS CONT'D
REGIONAL AQUIFER
YEAR 32
DAY 11774

WELL NUMBER	HEAD (ft)	CONCENTRATION (ug/l) TCE	1,2 DCE	PCE	Cr	Pb	Ba	Ni
4C	1165	0	0	0	2	4	240	4
5C	1169	3	4	0	3	3	120	4
6C	1172	10	9	1	3	4	150	5
7C	1169	5	18	6	3	1	99	4
8C	1173	17	60	21	8	4	320	1
9C	1179	20	50	25	11	33	3080	6
16C	1164	0	0	0	8	18	727	22
17C	1167	3	3	0	9	10	250	15
18C	1169	7	6	0	4	3	33	7
19C	1169	5	4	1	1	1	5	1
21C	1169	23	92	29	5	1	3	6
23C	1177	39	156	49	5	6	25	3
35C	1167	0	0	0	12	20	800	27
36C	1168	0	0	0	13	9	87	17
37C	1167	0	0	0	6	2	15	4
38C	1168	1	0	0	1	1	4	1
39C	1168	6	2	0	0	0	0	0
40C	1168	8	2	0	0	0	0	0
41C	1169	2	1	0	1	0	2	0
42C	1172	34	11	3	8	1	4	4
43C	1176	65	228	81	7	4	12	2
60C	1169	0	0	0	10	12	56	17
61C	1168	0	0	0	7	3	24	5
62C	1168	0	0	0	2	1	5	1
63C	1168	1	0	0	0	0	0	0
64C	1167	9	1	0	0	0	0	0
65C	1168	10	2	1	1	1	1	0
66C	1174	55	12	5	7	2	4	1
68C	1179	110	21	10	10	4	7	4
70C	1183	100	23	8	7	42	70	14
91C	1192	175	3	3	67	201	3350	67
90C	1187	55	2	1	50	4	46	3
88C	1189	238	4	4	62	47	155	14
87C	1185	97	4	3	64	6	52	4
86C	1186	36	2	1	42	5	42	4

APPENDIX B

Detailed Cost Summary for the Groundwater Pumping Plan Alternatives

TABLE B-1
COST SUMMARY FOR THE ALTERNATIVE 1-1 - NO ACTION
GROUNDWATER AND SURFACE WATER MONITORING

Cost Component	Quantity	Unit	Unit Cost ($)	Capital Cost ($)	Annual Cost ($)
Installation					
o GROUNDWATER MONITORING Use of 13 existing wells inside Bldg. 3001*	1	LS	0	0	0
Use of 5 water supply wells near Bldg. 3001*	1	LS	0	0	0
Install approx. 18 additional wells outside Bldg. 3001	1	LS	100,000	100,000	0
o SURFACE WATER MONITORING	3	point	1,000	3,000	0
Monitoring					
o GROUNDWATER MONITORING					
5 water supply wells (sampled quarterly)*	1	annually	0	0	0
Monitor wells (semi-annually)	1	annually	37,000	0	37,000
o SURFACE WATER MONITORING					
Collection (sampled quarterly)	1	annually	3,000	0	3,000
Analysis (sampled quarterly)	1	annually	1,600	0	1,600

Basic

o GROUNDWATER AND SURFACE WATER MONITORING

o Analysis includes: volatile organics, total metals, total organic carbon, pH, conductivity, and temperature

CONSTRUCTION COST SUBTOTAL	$103,000
ANNUAL O&M COST SUBTOTAL	$ 41,600

Basis: COE, 1988 a&b

TABLE B-2
COST SUMMARY FOR ALTERNATIVE 1-2
GROUNDWATER PUMPING PLAN
EXTERIOR WELLS

Cost Component	Capital Cost	Annual O&M	Present Worth
Exterior Wells:			
$3,000/perched zone well x 45 wells.....	$ 135,000		
$4,000/top of regional well x 34 wells..	$ 136,000		
$5,000/regional zone well x 30 wells....	$ 150,000		
Pumps			
$500/pump x 109 pumps..................	$ 54,500		
Subtotal Wells	$ 475,500	$ 86,300	
Collection Piping	$ 986,953		
Groundwater Monitoring...................	$ 100,000	$ 37,000	
Surface Water Monitoring.................	$ 3,000		
CONSTRUCTION COST SUBTOTAL	$1,565,453		
Contingencies and Unknowns			
Add 100% of well cost for contingencies related to handling of toxic wastes	$ 475,500		
Bid Contingence (10%)....................	$ 156,545		
Scope Contingency (10%)..................	$ 156,545		
CONSTRUCTION TOTAL	$2,354,043		
Permitting Legal (5%)	117,702		
Services During Construction (10%)	$ 235,404		
TOTAL IMPLEMENTATION COST	$2,707,149		$2,707,149
TOTAL ANNUAL O&M COST		$ 127,900	
TOTAL PRESENT WORTH O&M COST			$1,328,881
TOTAL PRESENT WORTH			$4,036,030

TABLE B-3
COST SUMMARY FOR ALTERNATIVE 1-3
GROUNDWATER PUMPING PLAN
EXTERIOR AND INTERIOR WELLS

Cost Component	Capital Cost	Annual O&M	Present Worth
Exterior Wells:			
$3,000/perched zone well x 45 wells.....	$ 135,000		
$4,000/top of regional well x 34 wells..	$ 136,000		
$5,000/regional zone well x 30 wells....	$ 150,000		
Interior Wells:			
$6,000/perched zone x 5 wells...........	$ 30,000		
$8,000/top of regional well x 8 wells...	$ 64,000		
$10,000/regional zone well x 5 wells....	$ 50,000		
Pumps - $500/pump x 127 pumps.............	$ 63,500		
Subtotal Wells	$ 628,500	$ 100,500	
Collection Piping	$1,214,970		
Groundwater Monitoring....................	$ 100,000	$ 37,000	
Surface Water Monitoring..................	$ 3,000	4,600	
CONSTRUCTION COST SUBTOTAL	$1,946,470		
Contingencies and Unknowns			
Add 100% of well cost for contingencies related to handling of toxic wastes	$ 628,500		
Bid Contingence (10%).....................	$ 194,647		
Scope Contingency (10%)...................	$ 194,647		
CONSTRUCTION TOTAL	$2,964,264		
Permitting Legal (5%)	148,213		
Services During Construction (10%)	$ 296,426		
TOTAL IMPLEMENTATION COST	$3,408,903		$3,408,903
TOTAL ANNUAL O&M COST			
TOTAL PRESENT WORTH O&M COST		$ 142,100	
TOTAL PRESENT WORTH O&M COST			$1,477,042
TOTAL PRESENT WORTH			$4,885,945

APPENDIX C

Detailed Cost Summary for the
Groundwater Treatment and
Disposal Alternatives

TABLE C-1
COST SUMMARY FOR ALTERNATIVE 2-1
GROUNDWATER TREATMENT AND DISPOSAL
MODIFIED IWTP/INDUSTRIAL REUSE

Cost Component	Capital Cost	Annual O&M	Present Worth
Wetwell, Pumping, and Piping	$ 51,800	$ 4,300	
Air Stripping	$ 58,000	$ 3,400	
Pre IWTP Storage	$ 373,300	$ 2,800	
Existing IWTP Treatment	---	$ 15,800 (item includes sludge disposal)	
Straight Run Piping Between Process Equipment	$ 6,100		
Lighting	$ 5,800	700	
CONSTRUCTION COST SUBTOTAL	$ 495,000		
Bid Contingency (10%)	$ 49,500		
Scope Contingency (10%)	$ 49,500		
CONSTRUCTION TOTAL	$ 594,000		
Permitting Legal (5%)	29,700		
Services During Construction (10%)	$ 59,400		
TOTAL IMPLEMENTATION COST	$ 683,100		
Engineering Design Cost (10%)	$ 68,300		
Excess Capacity Usage	$ 60,000		
TOTAL CAPITAL COST	$ 811,400		$811,400
TOTAL ANNUAL O&M COST		$ 27,000	
TOTAL PRESENT WORTH O&M COST			$280,700
TOTAL PRESENT WORTH			$1,092,100*

TABLE C-2
COST SUMMARY FOR ALTERNATIVE 2-2
GROUNDWATER TREATMENT AND DISPOSAL
MODIFIED IWTP/SURFACE WATER DISCHARGE

Cost Component	Capital Cost	Annual O&M	Present Worth
Wetwell, Pumping, and Piping	$ 51,800	$ 4,300	
Air Stripping	$ 58,000	$ 3,400	
Pre IWTP Storage	$ 373,300	$ 2,800	
Existing IWTP Treatment	---	$ 15,800 (item includes sludge disposal)	
Straight Run Piping Between Process Equipment	$ 6,100	700	
Lighting	$ 5,800	--	
CONSTRUCTION COST SUBTOTAL	$ 495,000		
Bid Contingency (10%)	$ 49,500		
Scope Contingency (10%)	$ 49,500		
CONSTRUCTION TOTAL	$ 594,000		
Permitting Legal (5%)	29,700		
Services During Construction (10%)	$ 59,400		
TOTAL IMPLEMENTATION COST	$ 683,100		
Engineering Design Cost (10%)	$ 68,300		
Excess Capacity Usage	$ 60,000		
TOTAL CAPITAL COST	$ 811,400		$811,400
TOTAL ANNUAL O&M COST		$ 27,000	
TOTAL PRESENT WORTH O&M COST			$280,700
TOTAL PRESENT WORTH			$1,092,100*

SUPPLEMENT TO TABLES C-1, AND C-2
WETWELL 1, PUMPING AND PIPING

Cost Component	Quantity	Unit	Unit Cost	Capital Cost	Annual O&M Cost
Equipment					
Pump, Submersible 3HP	1	EA	$2,450.00	$ 2,450.00	--
Wetwell #1, 6' ID, 9' high	1	LS	$7,200.00	$ 7,200.00	--
Pump Installation (a)	1	EA	$ 366.00	$ 366.00	--
Electrical Cabling in Conduit # 12 Wire	100	FT	$ 1.40	$ 140.00	
Motor Starter (mounted)	1	EA	$ 532.00	$ 532.00	--
Instrumentation Controller, valve, pressure indicators	1	LS	$3,000.00	$ 3,000.00	--
Liner w/Leak Detection System	1	LS	$12,500.00	$ 12,500.00	--
Miscellaneous					
Ladder, 9'	1	EA	$ 95.00	$ 95.00	--
Electrical Requirement	19000	KWHR	$ 0.08	--	$ 1,500.00
Operations & Maintenance Requirement	40	MH	$ 22.00	--	$ 900.00
				$26,200.00	$ 2,400.00

(a) - Includes electrical connection and piping

SUPPLEMENT TO TABLES C-1 AND C-2
WETWELL 2, PUMPING AND PIPING

Cost Component	Quantity	Unit	Unit Cost	Capital Cost	Annual O&M Cost
Equipment					
Pump, Submersible 2HP	1	EA	$2,300.00	$ 2,300.00	--
Wetwell #2, 6' ID, 9' high	1	LS	$7,200.00	$ 7,200.00	--
Pump Installation (a)	1	EA	$ 366.00	$ 366.00	--
Electrical Cabling in Conduit # 12 Wire	100	FT	$ 1.40	$ 140.00	
Motor Starter (mounted)	1	EA	$ 532.00	$ 532.00	--
Instrumentation Controller, valve, pressure indicators	1	LS	$2,500.00	$ 2,500.00	--
Liner w/Leak Detection System	1	LS	$12,500.00	$ 12,500.00	--
Miscellaneous					
Ladder, 9'	1	EA	$ 95.00	$ 95.00	--
Electrical Requirement	12700	KWHR	$ .08	--	$ 1,000.00
Operations & Maintenance Requirement	40	MH	$ 22.00	--	$ 900.00
				$25,600.00	$1,900.00

(a) - Includes electrical connection and piping

SUPPLEMENT TO TABLES C-1 AND C-2
AIR STRIPPING

Cost Component	Quantity	Unit	Unit Cost	Installed Cost	Annual O&M Cost
Equipment(a)					
Air Stripper, 30" ID x 43' high	1	EA	$32,900.00	$32,900.00	--
Foundations					
Air Stripper	30.8	CY	$ 500.00	$15,400.00	--
Recirculation Pump	1	CY	$ 500.00	$ 500.00	--
Air Blower	2	CY	$ 500.00	$ 1,000.00	--
Miscellaneous					
Ladder	1	LS	$ 536.00	$ 536.00	--
Platforms	1	LS	$ 504.00	$ 504.00	--
Grating	1	LS	$ 147.00	$ 147.00	--
Handrail	1	LS	$ 1,613.00	$ 1,613.00	
Pump Installation (b)	1	EA	$ 5,103.00	$ 5,103.00	
Electrical Cabling					
#12 wire	200	FT	$ 1.40	$ 280.00	--
Electrical Requirement	17500	KWhr	$ 0.08	--	$1,400.00
Operations & Maintenance Requirement (c)	90.	MH	$ 22.00	$ --	$2,000.00
				$58,000.00	$3,400.00

(a) Includes tower, cleaning package, control panel, 3/4 HP Recirculation Pump, 2 HP Air Blower, instrumentation, and motor starters via memo from Duall Air-Stripping Columns.

(b) Includes electrical connections for air blower, recirculation pump, and piping.

(c) Based on Duall estimate of operation and maintenance requirement.

SUPPLEMENT TO TABLES C-1 and C-2
PRE ITWP STORAGE

Cost Component	Quantity	Unit	Unit Cost ($)	Installed Cost ($)	Annual O&M Cost ($)
Equipment					
Storage Tank (a)	1	EA	$190,000.00	$190,000.00	--
Pumps, Transfer, 1-1/2 HP	2	EA	$ 2,250.00	$ 4,500.00	--
Foundations					
Dike & Foundation	340	CY	$ 500.00	$170,000.00	--
Instrumentation (b)	1	LS	$ 5,000.00	$ 5,000.00	--
Pump Installation (c)	1	EA	$ 3,100.00	$ 3,100.00	--
Electrical Cabling in Conduit #12 Wire	100	FT	$ 1.40	$ 140.00	--
Motor Starter(Mounted)	1	EA	$ 532.00	$ 532.00	--
Electrical Requirement	19000	KWHR	$ 0.08	--	$1500.
Operation & Maintenance	60	MH	$ 22.00	--	$1300.
				--------	-----
				$373,300.00	$2800.

(a) Price from Aqua Store, includes field erection (62' ID, 23' high).
(b) Includes controller, control valve, pressure indicators,level alarm, gauge, flow element.
(c) Includes electrical connection and piping.

SUPPLEMENT TO TABLES C-1 AND C-2
DETAILED COSTS: EXISTING IWTP TREATMENT

Cost Component	Quantity	Unit	Unit Cost ($)	Capital Cost ($)	Annual O&M Cost ($)
Chemical Usage	1	EA	$15,000	0	15,000
Basis: o Flow Rate: 62 gpm o Representative GW Contaminant Concentrations o Dosages as required in HWHM, 1988					
Sludge Disposal	4	ton	200	0	800
Basis: o Sludge generated rate HWHM, 1988					
CONSTRUCTION COST SUBTOTAL				$ 0	
ANNUAL O&M COST SUBTOTAL					$15,800

Basis: HWHM, 1988

SUPPLEMENT TO TABLES C-1 AND C-2
MISCELLANEOUS ITEMS

Cost Component	Quantity	Unit	Unit Cost	Capital Cost	Annual O&M Cost
Lighting	1	LS	$5800	$5800	$700
Straight Run Piping (a)					
Between Process Equipment					
Piping from Wetwell 1 - Stripper	50	FT	23.55	1177.50	
Piping from Stripper - Wetwell 2	50	FT	23.55	1177.50	
Piping from Wetwell 2 - Storage Tank	60	FT	23.55	1413.00	
Piping from Storage Tank - IWTP	60	FT	39.00	2340.00	
	---	----	-----	-----	----
	220			6108.00	

LS = Lump Sum
CY = Cubic Yard
MH = Man Hours
KWHR = Kilowatt Hours
FT = Feet
EA = Each

(a) 2-1/2" inside 6" PVC Pipe via Ricwill (buried)

SUPPLEMENT TO TABLES C-1 AND C-2
EXCESS CAPACITY USAGE

Assumptions:

1. A new treatment facility comparable in size and treatment capacity to the existing IWTP costs $6,000,000 in 1988 dollars.

2. Because of the age of the IWTP only 10 percent of the useful life remains.

3. Operations and maintenance costs are already included (Tables C-1 and C-2). Current worth of the IWTP is $600,000.

The 100,000 gpd groundwater flow into the IWTP will comprise about 10 percent of the plants' total treatment capacity.

Cost to utilize the excess plant capacity

= 0.10 x $600,000 = $60,000.

TABLE C-3
COST SUMMARY FOR ALTERNATIVE 2-3 GROUNDWATER TREATMENT
AND DISPOSAL ALTERNATIVES
NEW TREATMENT PLANT/INDUSTRIAL REUSE

Cost Component	Capital Cost	Annual O&M ($)	Present Worth ($)
Wetwell, Pumping, and Piping	$ 81,600	$ 7,700	
Air Stripping	$ 58,000	$ 3,400	
Metals Precipitation Unit	$ 708,200	$ 72,800 (includes sludge disposal)	
Adsorption System	$ 124,700	$ 19,000	
Discharge Piping to Reuse	$ 19,300	---	
Lighting	$ 12,800	$ 1,400	
Straight Run Piping Between Process Equipment	$ 3,800	---	
CONSTRUCTION COST SUBTOTAL	$1,008,400		
Bid Contingency (10%)	$ 100,800		
Scope Contingency (10%)	$ 100,800		
CONSTRUCTION TOTAL	$1,210,000		
Permitting and Legal (5%)	$ 60,500		
Services During Construction (10%)	$ 121,000		
TOTAL IMPLEMENTATION COST	$1,391,500		
Engineering Design Cost (10%)	$ 139,200		
TOTAL CAPITAL COST	$1,530,700		$1,530,700
TOTAL ANNUAL O&M COST		$ 104,300	
TOTAL PRESENT WORTH O&M COST			$1,084,400
TOTAL PRESENT WORTH			$2,651,100

TABLE C-4
COST SUMMARY FOR ALTERNATIVE 2-4
GROUNDWATER TREATMENT AND DISPOSAL ALTERNATIVES
NEW TREATMENT PLANT/SURFACE WATER DISCHARGE

Cost Component	Capital Cost	Annual O&M	Present Worth
Wetwell, Pumping, and Piping	$ 81,600	$ 7,700	
Air Stripping	$ 58,000	$ 3,400	
Metals Precipitation Unit	$ 708,200	$ 72,800 (includes sludge disposal)	
Adsorption System	$ 124,700	$ 19,000	
Discharge Piping to Creek	$ 10,400	--	
Lighting	$ 12,800	$ 1,400	
Straight Run Piping Between Process Equipment	$ 3,800	--	
CONSTRUCTION COST SUBTOTAL	$1,004,500		
Bid Contingency (10%)	$ 100,450		
Scope Contingency (10%)	$ 100,450		
CONSTRUCTION TOTAL	$1,205,400		
Permitting Legal (5%)	60,300		
Services During Construction (10%)	$ 120,500		
TOTAL IMPLEMENTATION COST	$1,386,200		
Engineering Design Cost (10%)	$ 138,600		
TOTAL CAPITAL COST	$1,524,800		$1,524,800
TOTAL ANNUAL O&M COST		$ 104,300	
TOTAL PRESENT WORTH O&M COST			$1,084,400
TOTAL PRESENT WORTH			$2,609,200

SUPPLEMENT TO TABLES C-3 AND C-4
AIR STRIPPING

Cost Component	Quantity	Unit	Unit Cost	Installed Cost	Annual O&M Cost
Equipment(a)					
Air Stripper, 30" ID x 43' high	1	EA	$32,900.00	$32,900.00	--
Foundations					
Air Stripper	30.8	CY	$ 500.00	$15,400.00	--
Recirculation Pump	1	CY	$ 500.00	$ 500.00	--
Air Blower	2	CY	$ 500.00	$ 1,000.00	--
Miscellaneous					
Ladder	1	LS	$ 536.00	$ 536.00	--
Platforms	1	LS	$ 504.00	$ 504.00	--
Grating	1	LS	$ 147.00	$ 147.00	--
Handrail	1	LS	$ 1,613.00	$ 1,613.00	
Pump Installation (b)	1	EA	$ 5,103.00	$ 5,103.00	
Electrical Cabling					
#12 wire	200	FT	$ 1.40	$ 280.00	--
Electrical Requirement	17500	KWhr	$ 0.08	--	$1,400.00
Operations & Maintenance Requirement (c)	90.	MH	$ 22.00	$ --	$2,000.00
				$58,000.00	$3,400.00

(a) Includes tower, cleaning package, control panel, 3/4 HP Recirculation Pump, 2 HP Air Blower, instrumentation, and motor starters via memo from Duall Air-Stripping Columns.

(b) Includes electrical connections for air blower, recirculation pump, and piping.

(c) Based on Duall estimate of operation and maintenance requirement.

SUPPLEMENT TO TABLES C-3 AND C-4
WETWELL 2, PUMPING AND PIPING

Cost Component	Quantity	Unit	Unit Cost	Capital Cost	Annual O&M Cost
Equipment					
Pump, Submersible 2HP	1	EA	$2,300.00	$ 2,300.00	--
Wetwell #2, 6' ID, 9' high	1	LS	$7,200.00	$ 7,200.00	--
Pump Installation (a)	1	EA	$ 366.00	$ 366.00	--
Electrical Cabling in Conduit # 12 Wire	100	FT	$ 1.40	$ 140.00	
Motor Starter (mounted)	1	EA	$ 532.00	$ 532.00	--
Instrumentation Controller, valve, pressure indicators	1	LS	$2,500.00	$ 2,500.00	--
Liner w/Leak Detection System	1	LS	$12,500.00	$ 12,500.00	--
Miscellaneous					
Ladder, 9'	1	EA	$ 95.00	$ 95.00	--
Electrical Requirement	12700	KWHR	$ .08	--	$ 1,000.00
Operations & Maintenance Requirement	40	MH	$ 22.00	--	$ 900.00
				$25,600.00	$1,900.00

(a) - Includes electrical connection and piping

SUPPLEMENT TO TABLES C-3 AND C-4
WETWELL 3, PUMPING AND PIPING

Cost Component	Quantity	Unit	Unit Cost ($)	Capital Cost ($)	Annual O&M Cost ($)
Equipment					
Pumps, Submsersible, 5 HP	2	Ea	$ 2,700.00	$ 5,400.00	--
Wetwell 3, 6' ID, 9' high	1	LS	$ 7200.00	$ 7,200.00	
Pump Installation (a)	2	Ea	$ 366.00	$ 732.00	--
Electrical Cabling in Conduit #12 Wire	200	Ft	$ 1.40	$ 280.00	--
Motor Starter (mounted)	2	Ea	$ 532.00	$ 1,064.00	--
Instrumentation					
Controller, Valve, Pressure Indicators	1	LS	$ 2,500.00	$ 2,500.00	--
Liner w/Leak Detection	1	LS	$12,500.00	$12,500.00	--
Miscellaneous					
Ladder, 9'	1	Ea	$95.00	$ 95.00	--
Electrical Requirement	31800	Kwhr	$0.08	--	$2,500.00
Operations & Maintenance Requirement	40	MH	$ 22.00	--	$ 900.00
				$29,800.00	$3,400.00

(a) Includes electrical connection & piping

SUPPLEMENT TO TABLES C-3 AND C-4
METALS PRECIPITATION UNIT

Cost Component	Quantity	Unit	Unit Cost	Capital Cost ($)	Annual O&M Cost ($)
Metals Precip. Unit[a]	1	LS	$653,000.00	$653,000.00	--
Electrical Supply[b]	1	LS	$ 15,000.00	$ 15,000.00	--
Foundation & Dike	61.4	CY	$ 500.00	$ 30,700.00	--
Insulation & Tracing	1	LS	$ 7,500.00	$ 7,500.00	--
Pavement Repair	1	LS	$ 2,000.00	$ 2,000.00	--
Operations & Maintenance Requirement	2190	MH	$ 22.00	--	$ 48,200.00
Chemical Cost	1	LS	$ 15,000.00	--	$ 15,000.00
Sludge Disposal	4	Tons	$ 200.00	--	$ 800.00
Electrical Requirement	110,000	KWHR	$ 0.08	--	$ 8,800.00
				$708,200.00	$ 72,800.00

a - Includes all tanks, mixers, pumps, clarifier, instrumentation, electrical wiring and conduit, piping, valves, and field erection. (ERAD price dated 11-15-88)

b - Includes transformer, 3 power poles, 50 amp circuit breaker, 200 ft. of #6 cable, and installation.

SUPPLEMENT TO TABLES C-3 AND C-4
CARBON ADSORPTION

Cost Component	Quantity	Unit	Unit Cost ($)	Capital Cost ($)	Annual O&M Cost ($)
Carbon Adsorption Units and Pumps(a)	2	ea	53,250q	106,500	0
Carbon MaterialR(b)	16,500	lb	0.80	13,200	0
Regeneration/New	16,500	lb	1.15	0	19,000
Pilot Study	1	EA	5,000	5,000	---

Basis:
o Equipment Sizing and Carbon Usage: Calgon, 1988

CONSTRUCTION COST SUBTOTAL	$124,700	
ANNUAL O&M COST SUBTOTAL		$19,000

Basis: (a) B&V Estimating Group Via Means, 1988
(b) Calgon, 1988

SUPPLEMENT TO TABLES C-3 AND C-4
MISCELLANEOUS ITEMS

Cost Component	Quantity	Unit	Unit Cost ($)	Installed Cost	Annual O&M Cost
Equipment					
Outfall Structure for Creek Discharge	1	LS	5000.00	$5,000.00	
Straight Run Piping Between Process Equipment					
Piping from Wetwell 1-Stripper	50	FT	23.55	1177.50	
Piping from Stripper-Wetwell 2	50	FT	23.55	1177.50	
Piping from Wetwell 2-Treatment Plant	60	FT	23.55	1413.00	
	160			$3768.00	
Lighting	1	LS	$12,800.00	$12,800.00	$1400.00
Discharge Piping To Creek					
2 1/2" PVC under concrete	300	FT			
2 1/2" PVC under dirt	250	FT			
2 1/2" butt weld tie in	1	EA			
2 1/2" PVC Ells	6	EA			
	1	LS	$10,400.00	$10,400.00	
Discharge Piping To Reuse					
2 1/2" PVC under concrete	300	FT			
2 1/2" PVC under dirt	250	FT			
2 1/2" butt weld tie in	1	EA			
2 1/2" PVC Ells	6	EA			
2 1/2" PVC Gate Valves	3	EA			
2 1/2" x 2 1/2" PVC Tee	1	EA			
2 1/2" tie in to 6" PVC existing buried line	1	EA			
	1	LS	$19,300.00	$19,300.00	

APPENDIX D

Technical Memorandum for
Air Stripper Emmissions Dispersion Modeling

Black & Veatch

MEMORANDUM

Tulsa District Core of Engineers — B&V Project 14186.060
Bldg 3001 Site & Adjacent Area Fuel Contaminated Areas, Tinker Air Force Base, Oklahoma — B&V File
Emissions Modeling of Trichloroethene — November 7, 1988

To: K. Warren

From: A. L. Carlson

This memorandum summarizes the air quality modeling analysis of the air stripper vent at the Tinker Air Force Base in Oklahoma.

PURPOSE
A screening-level model was run to determine the impacts resulting from the emission of Trichloroethene on the surrounding areas.

MODELING METHODOLOGY
Associated with screening-level modeling are numerous conservative assumptions to ensure that the predicted maximum concentrations will not be underestimated. Screening-level modeling is a quick way to determine potential air quality levels using basic dispersion techniques and minimal meteorological data. Refined air quality modeling will typically result in lower predicted air quality impacts.

The Industrial Source Complex Short-term (ISCST) dispersion model is a steady-state Gaussian plume model normally used to assess pollutant concentrations from a wide variety of sources. ISCST normally is used with a year of hourly sequential meteorological data for refined air quality modeling analyses. However, the model can also be used as screening-level model with user provided hourly meteorological data.

The ISCST model and a set of worst-case meteorological conditions were used to evaluate the trichloroethene impacts from the proposed air stripper vent at Tinker Air Force Base. Table 1 shows the source parameters that were modeled. Two emission rates were modeled, the EPA required emission rate, as calculated from EPA standards, and the expected emission rate of trichloroethene. Because the proposed stripper vent will be less than GEP stack height, building dimensions were specified, so that the building downwash option would be activated. The pertinent building specification, which determines downwash characteristics, was the building height which was much less than the width. The building height was modeled at 35 feet. Table 2 shows the 20 hours of worst-case meteorological data determined from EPA guidance and assumed for this analysis.

The various air quality impacts were derived from the highest 1-hour predicted concentrations according to EPA guidelines. ISCST was used with 52 discrete receptors oriented along an axis coincident with the wind direction. The receptors were placed at 10 meter (m) intervals from 50 m to 100 m, at 100 m intervals to 2 kilometers (km), including one placed at 150 m, at 500 m intervals to 10 km, and at 1 km intervals to 20 km. Flat terrain was assumed and the ISCST rural and urban option were both selected and modeled separately.

TABLE 1. MODELED SOURCE PARAMETERS

MODEL CASE 1:

Number of Sources	= 1 stripper vent	**VERSION A:** rural option
Stack Height	= 24 ft	
Stack Exit Velocity	= 1082 fpm	**VERSION B:** urban option
Flue Gas Temperature	= 60 F	
Stack Diameter	= 1 ft	
Emission Rate	= 0.0123 g/s (actual)	

MODEL CASE 2:

Number of Sources	= 1 stripper vent	**VERSION A:** rural option
Stack Height	= 43 ft	
Stack Exit Velocity	= 1082 fpm	**VERSION B:** urban option
Flue Gas Temperature	= 60 F	
Stack Diameter	= 1 ft	
Emission Rate	= 0.0123 g/s (actual)	

MODEL CASE 3:

Number of Sources	= 1 stripper vent	**VERSION A:** rural option
Stack Height	= 24 ft	
Stack Exit Velocity	= 1082 fpm	**VERSION B:** urban option
Flue Gas Temperature	= 60 F	
Stack Diameter	= 1 ft	
Emission Rate	= 0.00195 g/s (EPA max)	

MODEL CASE 4:

Number of Sources	= 1 stripper vent	**VERSION A:** rural option
Stack Height	= 43 ft	
Stack Exit Velocity	= 1082 fpm	**VERSION B:** urban option
Flue Gas Temperature	= 60 F	
Stack Diameter	= 1 ft	
Emission Rate	= 0.00195 g/s (EPA max)	

MEMORANDUM

Tulsa District Core of Engineers 3
Bldg 3001 Site and Adjacent Area Fuel Contaminated Areas, Tinker Air Force Base, Oklahoma
Emissions Modeling of Trichloroethene

B&V Project 14186.060
B&V File

November 7, 1988

TABLE 2. WORST-CASE HOURLY METEOROLOGICAL CONDITIONS

Hour	Wind Speed m/s	Mixing Height meters	Temp K	Potential Temperature Gradient K/meter	Stability Category	Wind Profile Exponent rural	urban
1	1	5000	293	0.000	1	0.07	0.15
2	3	5000	293	0.000	1	0.07	0.15
3	1	5000	293	0.000	2	0.07	0.15
4	3	5000	293	0.000	2	0.07	0.15
5	5	5000	293	0.000	2	0.07	0.15
6	1	5000	293	0.000	3	0.10	0.20
7	3	5000	293	0.000	3	0.10	0.20
8	5	5000	293	0.000	3	0.10	0.20
9	10	5000	293	0.000	3	0.10	0.20
10	1	5000	293	0.000	4	0.15	0.25
11	3	5000	293	0.000	4	0.15	0.25
12	5	5000	293	0.000	4	0.15	0.25
13	10	5000	293	0.000	4	0.15	0.25
14	20	5000	293	0.000	4	0.15	0.25
15	1	5000	293	0.020	5	0.35	0.30
16	3	5000	293	0.020	5	0.35	0.30
17	5	5000	293	0.020	5	0.35	0.30
18	1	5000	293	0.035	6	0.55	0.30
19	3	5000	293	0.035	6	0.55	0.30
20	5	5000	293	0.035	6	0.55	0.30

MEMORANDUM

Tulsa District Core of Engineers 4
Bldg 3001 Site and Adjacent Area Fuel Contaminated Areas, Tinker Air Force Base, Oklahoma
Emissions Modeling of Trichloroethene

B&V Project 14186.060
B&V File

November 7, 1988

MODELING RESULTS

The maximum concentrations from the modeling are summarized in Table 3. The concentrations at the proposed plant boundary 60 m (200 ft) are given in Table 4. The worst-case 1-hour ground-level concentration is used to determine the pollutant impact for the one point source. The 3-hour, 8-hour, 24-hour, and annual concentrations are derived from 1-hour worst case concentrations using EPA recommended multipliers of 0.9, 0.7, 0.4, 0.1, respectively.

Black & Veatch

MEMORANDUM

Tulsa District Core of Engineers 5
Bldg 3001 Site and Adjacent Area Fuel Contaminated Areas, Tinker Air Force Base, Oklahoma
Emissions Modeling of Trichloroethene

B&V Project 14186.060
B&V File

November 7, 1988

Table 3. MAXIMUM TRICHLOROETHENE CONCENTRATIONS

Case	Version	Maximum Concentrations (ug/m^3) 1-hr	3-hr	8-hr	24-hr	Annual	Distance meters	Hour
1	A	32.31	29.08	22.62	12.93	3.23	50.0	6
1	B	29.51	26.56	20.66	11.81	2.95	50.0	15
2	A	23.86	21.47	16.70	9.54	2.39	80.0	18
2	B	9.91	8.92	6.94	3.97	0.99	70.0	15
3	A	5.12	4.61	3.59	2.05	0.51	50.0	6
3	B	4.68	4.21	3.28	1.87	0.47	50.0	15
4	A	3.78	3.40	2.65	1.51	0.38	80.0	18
4	B	1.57	1.41	1.10	0.63	0.16	70.0	15

110788
OKEMS

Black & Veatch

MEMORANDUM

Tulsa District Core of Engineers 6
Bldg 3001 Site and Adjacent Area Fuel Contaminated Areas, Tinker Air Force Base, Oklahoma
Emissions Modeling of Trichloroethene

B&V Project 14186.060
B&V File

November 7, 1988

Table 4. MAXIMUM TRICHLOROETHENE CONCENTRATIONS AT 200 FEET (60 m)

		Concentrations (ug/m^3)				
Case	Version	1-hr	3-hr	8-hr	24-hr	Annual
1	A	30.50	27.45	21.35	12.20	3.05
1	B	26.44	23.80	18.51	10.58	2.64
2	A	22.93	20.64	16.05	9.17	2.29
2	B	9.82	8.84	6.87	3.93	0.98
3	A	4.84	4.35	3.39	1.93	0.48
3	B	4.19	3.77	2.94	1.68	0.42
4	A	3.64	3.27	2.55	1.45	0.36
4	B	1.56	1.40	1.09	0.62	0.16

APPENDIX E

Detailed Chronic Carcinogenic Risk Calculations Due To Air Stripper Exposure

DO NOT WRITE IN THIS SPACE

Inhalation of Trichloroethene

CONTACT RATE (1)

		WEIGHT
0 - 1 yr	5 m^3/d	10 kg
1 - 6 yr	7.5 m^3/d	15 kg
6 - 11 yr	12 m^3/d	30 kg
11-76.2 yr	20 m^3/d	70 kg

EXPOSURE FACTOR

0 - 1 yr	Home	1.0	(24 hr/d ; 365 day/yr)
1 - 6 yr	Home	1.0	
6 - 11 yr	Home	.836	
	School	.164	(8 hr/day ; 180 day/yr)
11 - 76.2 yr	Home	.772	
	School/Work	.228	(8 hr/day ; 250 day/yr)

Time Weight

0 - 1 yr	$1 \div 76.2 \simeq 0.01$
1 - 6 yr	$5 \div 76.2 \simeq 0.07$
6 - 11 yr	$5 \div 76.2 \simeq 0.07$
11 - 76.2 yr	$65.2 \div 76.2 \simeq 0.85$

CANCER Potency FACTOR

Trichloroethene - $0.013 \ (mg/kg/d)^{-1}$ source: IRIS (3-1-88)

Ambient Air Concentration at Point of Exposure

Trichloroethene - $0.00991 \ mg/m^3$

REVISED, SUPERSEDED, AND VOID CALCULATIONS MUST BE CLEARLY IDENTIFIED, INITIALED

DO NOT WRITE IN THIS SPACE

TIME WEIGHTED (1)
CHRONIC DAILY INTAKE (CDI) – Trichloroethene

0-1yr $[(0.00991\ mg/m^3 \times 5\ m^3/d) \div 10\ kg] \times 0.01 \times 1.0 = 4.96 \times 10^{-5}$

1-6yr $[(0.00991\ mg/m^3 \times 7.5\ m^3/d) \div 15\ kg] \times 0.07 \times 1.0 = 3.47 \times 10^{-4}$

6-11yr $[(0.00991\ mg/m^3 \times 12\ m^3/d) \div 30\ kg] \times 0.07 \times 0.164 = 4.55 \times 10^{-5}$

11-76.2yr $[(0.00991\ mg/m^3 \times 20\ m^3/d) \div 70\ kg] \times 0.85 \times 0.228 = 5.49 \times 10^{-4}$

CDI(SUM) = 9.91×10^{-4} mg/kg/d

LIFETIME EXCESS CANCER RISK (CDI x PF)

$9.91 \times 10^{-4}\ mg/kg/d \times 0.013\ (mg/kg/d)^{-1} = \underline{1.3 \times 10^{-5}}$

(1) Source: Superfund Public Health Evaluation Manual EPA/540/1-86/060 (OER).