TECHNICAL SCREENING MEMORANDUM

Hassayampa Landfill
Maricopa County, Arizona

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CONESTOGA-ROVERS & ASSOCIATES
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1.0 INTRODUCTION

In accordance with the Administrative Consent Order (United States Environmental Protection Agency (USEPA) Docket No. 88-08), dated February 19, 1988 (Order), this Technical Screening Memorandum (Memorandum) has been prepared to give the preliminary results of the Feasibility Study (FS) for the former hazardous waste area (hazardous waste area) at the Hassayampa Landfill (the Landfill), in Maricopa County, Arizona. The Memorandum is based chiefly on results from the Remedial Investigation (RI) of the hazardous waste area conducted by Errol L. Montgomery & Associates (M&A) and Conestoga-Rovers & Associates (CRA) and reported in February 1991. In addition, the results of supplemental investigations (M&A, 1991 and CRA, 1991) conducted after finalization of the RI are included in the evaluations reported herein.

1.1 BACKGROUND

The background information presented herein is summarized from the RI. The Landfill is located approximately 40 miles west of Phoenix, Arizona, as shown on Figure 1.1. The hazardous waste area, the area considered in the FS, is a 10 acre fenced area which is located in the northeast part of the Landfill, as shown on Figure 1.2.

The Landfill began operation in 1961 and primarily accepted municipal refuse until the first quarter of 1979. On April 20, 1979, Maricopa County (the County) began to accept hazardous wastes for disposal

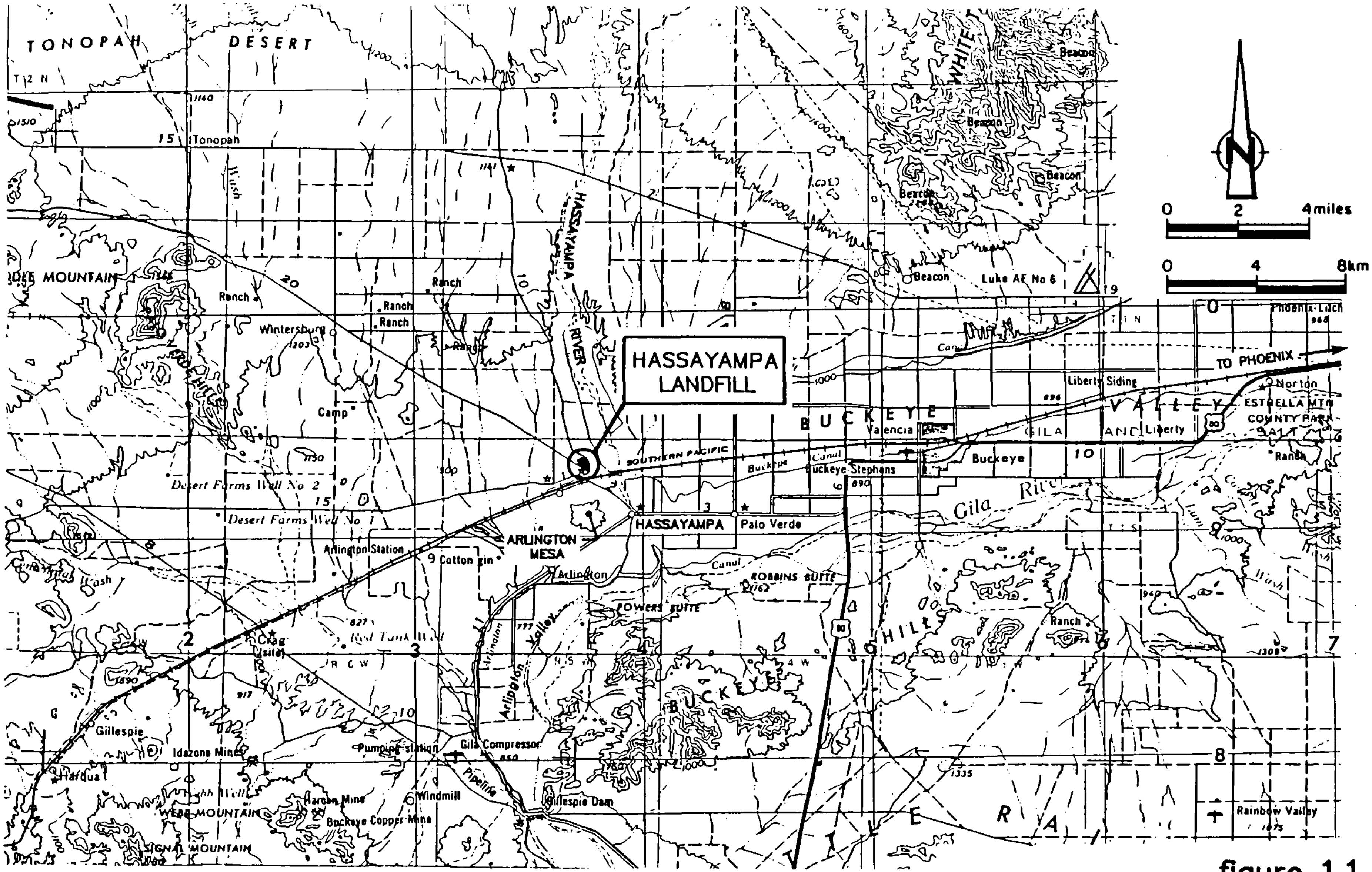

figure 1.1

LOCATION OF HASSAYAMPA LANDFILL
HASSAYAMPA LANDFILL
Maricopa County, Arizona

CRA

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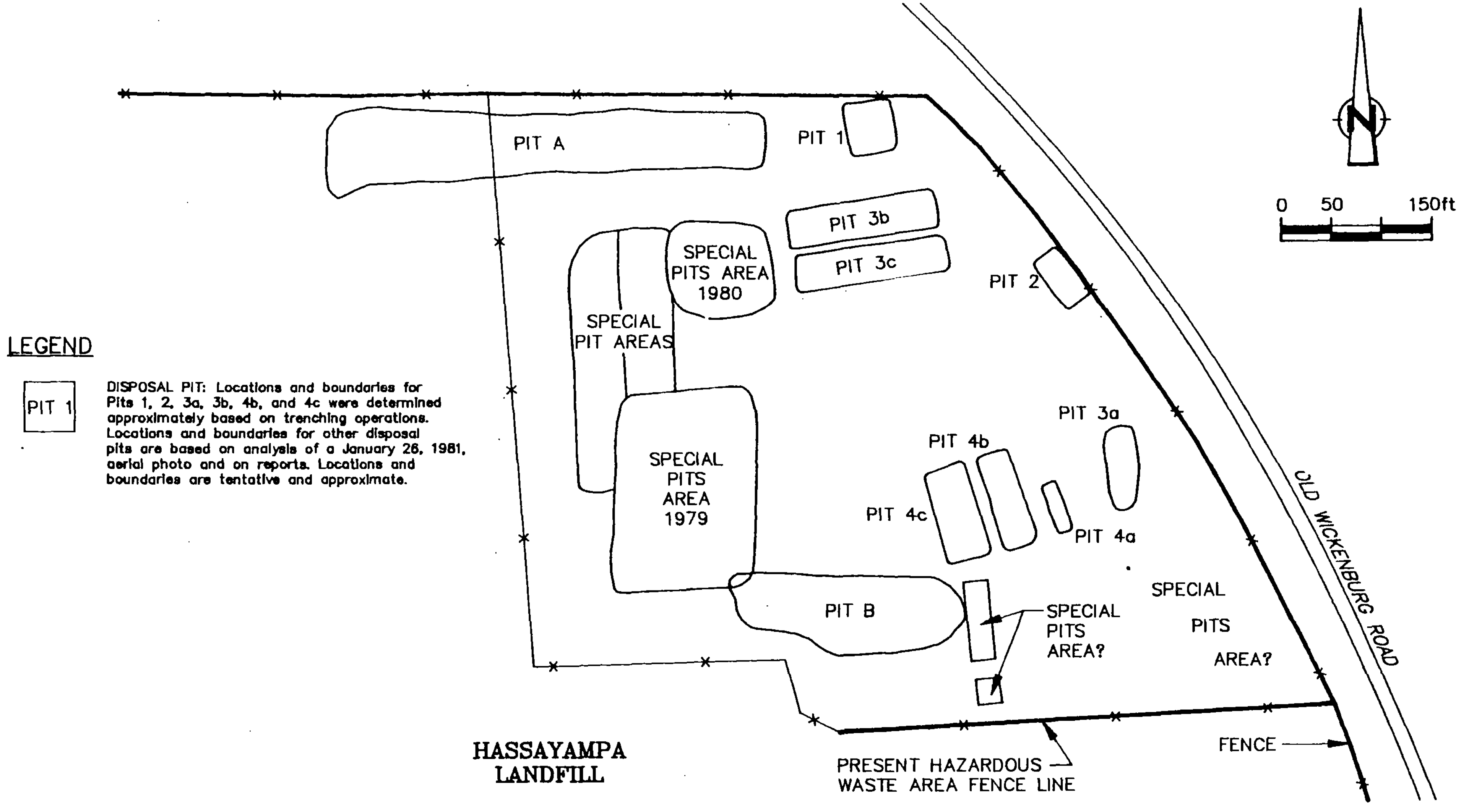

figure 1.2

LOCATION OF FORMER
HAZARDOUS WASTE DISPOSAL AREAS
HASSAYAMPA LANDFILL
Maricopa County, Arizona

REFERENCE:
INFORMATION FOR BASE MAP
FROM ERROL L. MONTGOMERY
AND ASSOCIATES INC.

CRA

2141-28/10/91-12-0 (P-03)

in a segregated area of the Landfill designated as the hazardous waste area. These wastes were accepted for an 18-month period ending October 28, 1980.

The County agreed to allow the disposal of hazardous wastes in the hazardous waste area after the Arizona Department of Health Services (ADHS) established a prohibition on the disposal of hazardous wastes at Phoenix-area landfills. The County's agreement was originally for a 30-day period, but the agreement was extended in stages to 18 months at the request of the ADHS. The disposal process was managed by a manifest program established by the ADHS, which issued and approved the manifests.

The inventory by Bureau of Waste Control (1980) indicates that approximately 3.28 million gallons of liquid wastes and approximately 4,150 tons of solid wastes were approved by ADHS for disposal in several unlined disposal pits (Pit Numbers 1, 2, 3, 4, and the Special Pits area), while an undetermined quantity of non-hazardous wastes, such as cesspool waste, was disposed of in Pits A and B. Hydrate wastes were disposed in Pit B. Figure 1.2 depicts the approximate location and orientation of the disposal pits.

An inventory completed by CRA (Liquid Waste Evaluation, CRA and M&A, September, 1991) indicates that the amount of hazardous waste approved for disposal at the hazardous waste area consisted of approximately 3.44 million gallons of liquid waste and approximately 3,740 tons of solid wastes. A summary of the types and quantities of wastes disposed of in the disposal pits appears in Section 2.1.

Following closure, the hazardous waste area was capped with a soil cover to mitigate potential off-site migration of materials. A soil cover investigation during the RI revealed that, when properly maintained, the cover is effective in retarding the release of gas and vapors from buried waste materials at the hazardous waste area and preventing contact between stormwater drainage and the waste materials. Based on the RI results, the County Landfill Department completed further measures in 1991 to prevent stormwater drainage from entering or leaving the hazardous waste area.

The Landfill lies within the drainage area for the ephemeral Hassayampa River, which drains southward and is located about 3/4 mile east from the Landfill.

In order of increasing depth, the regional hydrogeologic units in the Landfill area include; the recent alluvial deposits, the basin-fill deposits, and the bedrock complex. The thick basin-fill deposits have been classified into the Upper, Middle, and Lower Alluvium units. The Upper Alluvium unit was the target of the hydrogeologic investigation. The Upper Alluvium unit at the hazardous waste area was subdivided in the RI, in order of increasing depth, into the following units for the RI: Upper Alluvium unit; basaltic lava-flow unit; and Units A and B, which are waterbearing deposits. Figure 1.3 shows a schematic hydrogeologic cross-section for the hazardous waste area.

Laboratory measurements for vertical hydraulic conductivity in the Upper Alluvium unit ranged from less than

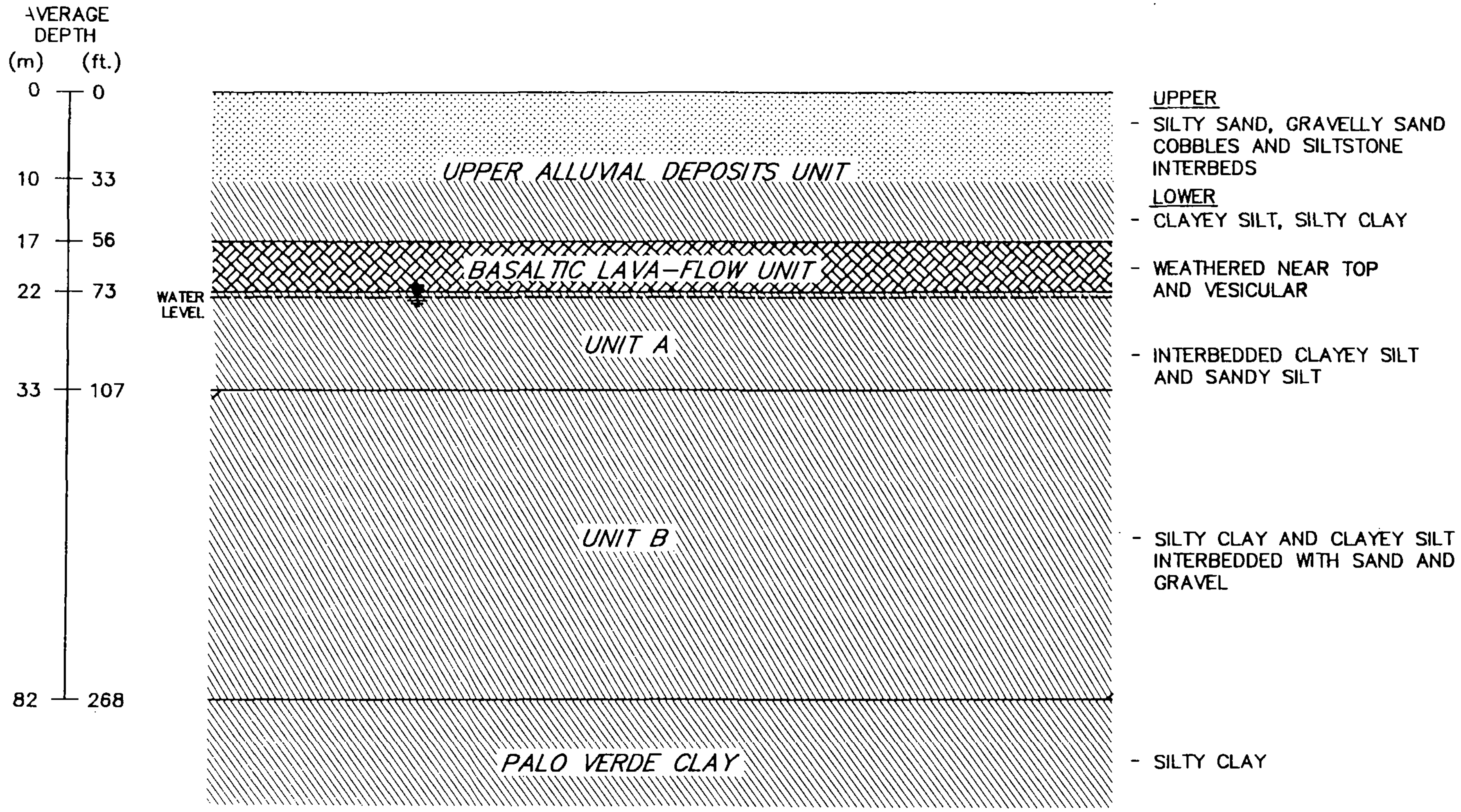

figure 1.3

SCHEMATIC HYDROGEOLOGIC CROSS-SECTION
HASSAYAMPA LANDFILL
Maricopa County, Arizona

CRA

2141-10/10/91-12-0

1×10^{-8} centimeters/second (cm/s) to 1.81×10^{-5} cm/s. Based on data obtained in June 1991, groundwater flow in both units is to the south-southwest at approximately 150 feet per year for Unit A, and approximately 260 feet per year for Unit B (M&A, 1991). The average hydraulic gradients of Units A and B were found to 0.004 and 0.007, respectively.

Soil boring results, used to evaluate the extent of lateral contaminant migration from the disposal pits into the vadose zone, revealed that some contaminant migration had occurred.

Evidence of contaminant release was discovered during the air monitoring investigations; however, these releases were acceptable when compared with a criterion based on a fraction of the threshold limit value (TLV)/300.

Analysis of surface sediments at the hazardous waste area revealed small concentrations of organochlorine pesticides. It is believed that the source of these pesticides is not the hazardous waste area since detected concentrations were similar to background levels of pesticides and agricultural activities near the hazardous waste area employed such pesticides. Polychlorinated biphenyls (PCBs) were not detected in surface sediment samples. Trace metal concentrations were similar to background concentrations. No evidence of significant contaminant release to surface water/sediment was found.

Results for routine constituents indicate that the chemical quality of groundwater in Unit A is consistent with the chemical quality of groundwater in the shallow aquifer zones in the landfill area. Only nitrate exceeded USEPA primary maximum contaminant levels (MCLs) for drinking water. Concentrations of nitrate were generally higher in Unit B than in Unit A (M&A, 1991). It is common to find elevated concentrations of nitrate in aquifer zones in agricultural areas such as those near the Landfill. Nitrate is not attributed to disposal practices at the hazardous waste area. Concentration of trace constituents detected in groundwater samples did not exceed MCLs for drinking water.

Compounds of concern have been identified based on the results of laboratory chemical analyses for groundwater samples obtained during the RI. Concentrations of volatile organic compounds (VOCs) were detected and confirmed solely in groundwater samples obtained from Unit A monitoring wells MW-1UA, MW-5UA, and MW-6UA, and from the abandoned ADHS monitor well HS-1. Except for laboratory contaminants, concentrations of semi-volatile organic compounds (SVOCs) were not detected and confirmed in groundwater samples. Neither organochlorine pesticides nor PCBs were detected in groundwater samples.

The air, surface water/sediment, and groundwater exposure pathways have been determined to be incomplete (PRC Environmental Management, 1991). As long as the soil cover is maintained, the air and surface water/sediment pathways will remain incomplete. Future potential completion of the groundwater pathway is possible.

1.2 RESULTS OF SUPPLEMENTARY FIELD INVESTIGATIONS

The results of supplementary field investigations conducted at the Landfill were reported by M&A (August 1991, and October 1991) and by CRA (October, 1991).

1.2.1 Soil Borings

A soil boring program was undertaken in April and May, 1991, to determine the depth of the former disposal pits 1, 3b and 3c and obtain data for the chemical quality of residual wastes and underlying soils at the pits. The following sections summarize the field data collected during construction of the soil borings. The results were reported in detail to the USEPA by M&A (October, 1991).

Pit 1

The depth to the bottom of Pit 1 was determined to be no more than 15 feet below land surface. Black, bright purple, moist consolidated sediment was encountered eight to nine feet below ground surface. Soils on top of the these residual wastes consisted of gravelly, silty and clayey sand. These soils were slightly moist, non-lithified, and light reddish-brown to tan-brown in color. Soils beneath the waste layer up to a depth of 55 feet below ground surface consisted of silts, clays and clayey sands. These soils were generally slightly moist, non-lithified, and pinkish brown to reddish brown in color.

Pit 3b

The depth to the bottom of Pit 3b was determined to be approximately six feet below ground surface. Bluish-grey, dark greenish-gray, reddish brown, and blue layers of consolidated moist sediment were encountered five to six feet below ground surface. Soils on top of the sludge layer consisted of gravelly, clayey, and silty sands. These soils were non-lithified, slightly moist to moist, and were light reddish-brown and light tan-brown in color. Soils beneath the sludge layers were generally gravelly sand, light reddish-brown to whitish-gray in color, non-lithified to moderately lithified, and slightly moist.

Pit 3c

The depth to the bottom of Pit 3c was determined to be approximately nine feet below land surface. Residual waste was encountered eight to nine feet below ground surface. The sludge was discovered to be in distinct 1 to 2-inch layers, which were non-lithified, moist, consolidated, and firm. Layers of residual waste encountered were dark greenish-gray, bright orangish-brown, dark olive green, and light gray. Soils on top of the residual waste were reddish-brown, non-lithified, slightly moist to very moist gravelly sands. A greenish-brown color sand was encountered from 6.0 to 6.2 feet below ground surface. Sands, gravelly sands, sandy silts, and clays were encountered to a depth of 55 feet below ground surface. These soils were generally light reddish-brown in color, non-lithified, and slightly moist.

Samples of the residual waste and underlying soil samples were analyzed using the USEPA Toxicity Characteristic Leaching Procedure (TCLP). Analyses conducted on the extracted leachate from the TCLP included: VOCs; SVOCs; organochlorine pesticides; PCBs; and metals. The supplementary information obtained from the TCLP testing is incorporated in the development of the overall waste and soil chemical profiles presented in Section 2.0 of this report.

1.2.2 Monitoring Well Construction

Groundwater monitoring wells MW-6UB, MW-9UA, MW-9UB, MW-10UA, and MW-10UB were constructed in the spring of 1991. Four of these wells; MW-9UA, MW-9UB, MW-10UA, and MW-10UB were installed to replace ADHS wells HS-2 and HS-3 after investigation indicated that the design and construction of these ADHS wells could have potentially adversely affected, or could in the future adversely affect, the chemical quality of groundwater. The construction and installation details of these additional monitoring wells are described by M&A (October, 1991).

1.2.3 Groundwater Sampling and Analysis

Supplementary sampling and analysis of groundwater from monitoring wells were conducted in March, May, and June, 1991. All groundwater samples were analyzed for routine constituents and VOCs. The supplementary information obtained from the sampling and analysis was reported to the USEPA by M&A (October, 1991) and is incorporated in the development of the overall groundwater profile presented in Appendix A of this report. Results indicate that, since the RI, VOCs have been additionally detected and confirmed in well MW-4UA.

1.2.4 Soil Gas Survey

A soil gas survey was conducted in July, 1991, and soil gas samples were also obtained from vadose zone monitor borings. The results of the soil gas survey are reported separately (CRA, October, 1991) and they are used to delineate the areal extent of VOC contamination in the soil gas. A summary of the soil gas survey analytical results appear in Section 2.0 of this report.

1.3 RESULTS OF THE USEPA FINAL RISK ASSESSMENT

The Final Risk Assessment (RA), completed by PRC Environmental Management, Inc. in September, 1991, was approved by the USEPA on September 18, 1991. The RA was based on RI monitoring data, groundwater transport modeling and air dispersion modeling. The RI data and modeled data were used to estimate exposure and risks to human health given current land uses and hypothetical future land uses.

The RA indicated that, if at some future time, contaminants migrated through groundwater to potential downgradient residential receptors, a risk significantly less than the USEPA's range of concern (10^{-4} to 10^{-6})[1] would be experienced by these receptors (current land use). In addition, the carcinogenic hazard index (CHI) for 1,1-dichloroethene (DCE) and the non-carcinogenic hazard index (HI) were significantly less than 1.0, the index of concern. This additional risk was associated with exposure to airborne vapors being emitted from the buried wastes, presumably in Pit 1. It should be noted that the CHI for DCE was based upon a modification of a standard reference dose for DCE multiplied by a safety factor of 10 (PRC, 1991). This modification has only recently been proposed by Region IX and therefore should not be considered to be as significant as the other indices evaluated.

The RA evaluated potential carcinogenic and non-carcinogenic hazards associated with current land use conditions and modeled future contaminant transport in groundwater. The RA concluded that the excess cancer risk and non-carcinogenic HI were less than USEPA's range of concern. However, the CHI for DCE exceeded 1.0. This additional risk was associated with potential future exposure to DCE in groundwater.

The RA also evaluated hypothetical potential land use scenarios for the hazardous waste area (residential and industrial) using both RI and modeled data. The RA concluded that, under both scenarios, the potential excess cancer risk was within USEPA's range of concern. Whereas the non-carcinogenic HI was approximately equal to 1.0, potential exposure to covered waste would be considered unacceptable, and whereas the CHI for

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[1] The range of concern is the range of additional cancer risks (one in 10,000 to one in 1,000,000), which, if present at a site, may be motivation for completing remediation.

DCE exceeded 1.0, these additional risks were associated largely with potential exposure to DCE in groundwater and other VOCs in groundwater and air.

RA results are summarized in Table 1.1.

These results do not clearly provide a motivation for completing soil and/or groundwater remediation at the hazardous waste area since the calculated potential risks are within a range considered by the USEPA to be potentially acceptable in lower population areas (USEPA, 1991).

1.4 MEMORANDUM SCOPE

This Memorandum has been assembled in accordance with the RI/FS Work Plan (M&A and CRA, January, 1988), which presented the general scope of work for the FS. The Order described the required technical content of the Memorandum and its requirements are incorporated herein.

In accordance with The National Contingency Plan (NCP) (40 CFR 300), the appropriate remedy is a "cost effective remedial alternative that effectively mitigates and minimizes threats to and provides adequate protection of public health and welfare and the environment". This Memorandum is based on the findings of the RI and the RA.

The process used in this Memorandum is conducted in accordance with the NCP (40 CFR 300) and USEPA guidance documents

TABLE 1.1

RISK SUMMARY(1)
HASSAYAMPA FEASIBILITY STUDY

Target Population	*Excess Cancer Risk*	*CHI(2) for 1,1-Dichloroethene*	*Hazard Index*
1. a) Current off-Site Residential (3)	3×10^{-7}	0.005	0.003
b) Future off-Site Residential (4)	9×10^{-7}	4	0.4
2. Future on-Site Residential (5)	8×10^{-5}	8	1
3. Future on-Site Industrial (5)	5×10^{-5}	2	0.6

Notes:

(1) Draft Final Risk Assessment, PRC Environmental Management Inc., July,1991. Based on the Reasonable Maximum Exposure (RME).

(2) Cancer Hazard Index (CHI). A CHI greater than 1.0 is of concern.

(3) Based on exposure to airborne emissions only.

(4) Based on hypothetical exposure to modeled groundwater contamination.

(5) Hypothetical exposure scenario. Not expected to occur since the hazardous waste area is in the Landfill.

(USEPA, October 1988). Soil and groundwater remediation technologies are evaluated separately herein. Groundwater remediation technologies are presented and evaluated in Appendix A and soil remediation technologies are evaluated in the body of the Memorandum. The report is organized as follows:

- Section 2.0 provides a summary of contaminant characteristics and profiles as derived from analytical data collected in the RI and supplementary field investigations;

- Section 3.0 provides a review of Applicable or Relevant and Appropriate Requirements (ARARs) and identifies specific remedial objectives for waste, soil and groundwater;

- Section 4.0 provides an assessment (including a public health evaluation) of remedial technologies potentially available for the remediation of wastes and soils. (potentially feasible groundwater remedial technologies are discussed in Appendix A);

- Section 5.0 assembles the appropriate remedial technologies into a preliminary list of ten Remedial Action alternatives; and

- Section 6.0 provides a list of references.

1.5 REMEDIAL OBJECTIVES

This Memorandum presents general remedial objectives for screening technologies proposed for use in the development of a remedy. A remedy should:

- provide protection of public health and the environment;
- satisfy ARARs;
- provide practical, cost-effective remediation; and
- utilize permanent remedies, which are completed in a short time frame, where applicable.

Remedial action objectives for Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) sites are established under the CERCLA Section 121 (Cleanup Standards) as amended by the Superfund Amendment and Reauthorization Act (SARA). Remedial actions are to be in accordance with the requirements of CERCLA Section 121, and, to the extent practicable, with the NCP as codified at 40 CFR Part 300. NCP Section 300.68(i) provides that remedies selected must be cost-effective and must effectively mitigate and minimize threats to and provide adequate protection of public health and welfare and the environment. SARA expanded the statutory scope of CERCLA and codified requirements which, prior to the enactment of SARA, were non-promulgated USEPA policies. Additional requirements under CERCLA as amended by SARA include the following:

i) Preference is to be given to remedial actions "in which treatment that permanently and significantly reduces the volume, toxicity, or mobility of the hazardous substances pollutants, and contaminants is a principal element.": (SARA Section 121(b)). Where permanent remedies involving treatment or recovery technologies are not to be considered, such decisions shall be supported by appropriate explanations.

ii) Cleanup standards were refined. Remedial actions "shall attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment and of control of further release at a minimum which assures protection of human health and the environment.": (SARA Section 121(d)).

iii) Requirements were included under Section 121(d)(2)(A) "with respect to any hazardous substances, pollutant, or contaminant that will remain on site" that the residual levels will attain "any standard, requirement, criteria, or limitation under any Federal environmental law" and "any promulgated standard, requirement, criteria or limitation under a State environmental or facility siting law that is more stringent than the Federal" requirements where such goals are relevant and appropriate.

The Federal and State requirements referred to above are collectively referred to as ARARs.

ARARs are discussed in Section 3.0.

The USEPA guidance document entitled "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA", October, 1988, states, "remedial action objectives consist of medium-specific or operable unit-specific goals for protecting human health and the environment." The objectives must not be so specific that the range of remedial alternatives which can be developed becomes overly limited. Remedial action objectives established to protect human health and the environment are to specify:

i) the chemicals of concern;
ii) the exposure routes and receptors; and
iii) an acceptable chemical concentration or range of concentrations for each exposure route.

Specifying remedial action objectives in this manner is deemed to be appropriate since protectiveness may be achieved by reducing exposure to receptors either separately or in conjunction with reducing chemical levels.

The guidance further states that "because remedial action objectives for protecting environmental receptors typically seek to preserve or restore a resource, environmental objectives should be addressed in terms of the medium of interest and target cleanup levels, whenever possible". Specific remedial action objectives are presented in Sections 3.2 and 3.3 for wastes, soils, and groundwater.

The remedial objectives themselves are not the motivation for initiating a remedial action. Rather, remedial objectives are a set of performance standards against which to compare remedial alternatives.

2.0 CONTAMINATION PROFILES

Data from the RI and supplemental investigation activities were reviewed to develop chemical concentration profiles for the different matrices at the hazardous waste area. These profiles are described in the following sections.

2.1 WASTE AND SOIL CONTAMINATION PROFILES

2.1.1 Waste Profile

Table 2.1 presents two analyses of the waste manifests (ADHS, 1985, M&A and CRA, 1991) which were approved by ADHS. These manifests describe the chemical constituents and the maximum weights or volume of waste which was approved for disposal in Pits 1, 2, 3, 4, and in the Special Pits. Pit 1 was approved for organic (solvents) and oil disposal, whereas Pit 2 was approved for acid and acid sludge disposal. Pits 3 and 4 were approved to receive the largest quantities of liquid and solid sludges (primarily metals/alkaline and pesticide sludges). The Special Pits were approved by ADHS to receive the largest quantity of solid wastes.

Table 2.2 presents a summary of calculated waste volumes in each pit. These volumes were calculated from data developed in the RI Stage II trenching program and from the supplementary field investigations. With respect to disposal volumes shown in Table 2.1, Pits 3 and 4 (all cells) were calculated to contain the largest volumes of waste, Pits 1,

TABLE 2.1

SUMMARY OF WASTES APPROVED FOR DISPOSAL
HASSAYAMPA FEASIBILITY STUDY

		Quantity Reported in the Liquid Waste Evaluation Report (CRA AND M&A, 1991)		*Quantity Reported by Arizona Department of Health Services (1985)*	
Pit(s)	*Waste Type Designated*	*Liquid Waste (gallons)*	*Solid Waste (tons)*	*Liquid Waste (gallons)*	*Solid Waste (tons)*
Special Pit	Incompatible Hazardous Waste	174,183	2,123	134,578	308.64
Pit 1	Organics & Oils	373,755	5.0	360,805	0
Pit 2	Acids & Acid Sludges	110,930	0.1	125,597	0.1
Pits 3a, b and c	Alkaline & Metallic Sludges	1,368,991	7.3	1,362,636	24.5
Pits 4a, b and c	Pesticides & Akaline Sludges	1,407,467	1,600	1,295,022.2	3,816.46
	Total	3,435,326	3,735.4	3,278,638.2	4,149.7

Note

Both volume summaries presented above were derived from an analysis of the manifests. These manifests were approved by ADHS.

TABLE 2.2

SUMMARY OF CALCULATED WASTE VOLUMES
HASSAYAMPA FEASIBILITY STUDY

Pit	*Area* *(ft^2)*	*Assumed Soil Cap Depth* *(feet)*	*Assumed Total Depth* *(feet)*	*Assumed Waste Depth* *(ft)*	*Calculated Volume* *(ft^3)*	*(yd^3)*
1	2,850	2	15	13	37,000	1,400
2	1,880	6	20	14	26,300	970
3a	3,600	10	20	10	36,000	1,300
3b	6,000	2	6	4	24,000	900
3c	6,000	2	9	7	42,000	1,600
4 (all cells)	9,440	4	20	16	151,000	5,600
Special Pits	2,500	2	12	10	25,000	900

Sources:

RI and Data Submittal for April 1991

2, and the Special Pits were calculated to contain the smallest volumes of waste.

A contamination profile for the residual pit wastes was developed from the results of the RI trenching program and from the supplementary field investigations. The contamination profile is presented in Table 2.3. Pit 1, which was approved by ADHS to receive organic solvents and oils, exhibits the highest level of VOCs (primarily solvent compounds) and SVOCs as compared to the other pits. Pit 3 (all cells) shows only slightly elevated levels of VOCs and SVOCs compared to Pit 1. Pits 2, 3, and 4 were approved to receive primarily acid/metallic and pesticide sludges and exhibited low level concentrations of VOCs and SVOCs.

The results of the EP toxicity and the TCLP testing of residual wastes from the pits are shown in Table 2.4 and Table 2.5. The EP toxicity testing indicates some metals were detected in the leachate from residual wastes in Pits 1, 2, and 3 but not in Pit 4. The TCLP testing was conducted only on residual waste from Pits 1 and 3. Analytical results indicate that Pit 1 has higher concentrations of leached VOCs, SVOCs and metals than Pit 3. Neither organochlorine pesticides nor PCBs were detected in any of the residual wastes.

TABLE 2.3

REPRESENTATIVE CONCENTRATIONS-WASTES
HASSAYAMPA FEASIBILITY STUDY

Compound	*Representative Concentration (mg/kg)* *Pit 1*	*Pit 2*	*Pit 3a*	*Pit 3c*	*Pit 4b*	*Pit 4c*
VOCs						
o,p-dichlorobenzene	95.5	ND	ND	ND	ND	ND
1,1-dichloroethane	ND	ND	1.5	2.3	ND	ND
1,1-dichloroethene	28	ND	ND	1.2	ND	ND
dichloromethane	16.3	3	8.5	8.5	0.45	1
1,2-dichloropropane	ND	ND	7.6	ND	ND	ND
dimethylbenzenes (total xylenes)	74	ND	1.1	ND	ND	ND
dimethylketone (acetone)	ND	ND	ND	ND	0.25	ND
methyl benzene (toluene)	23	ND	ND	ND	0.06	ND
tetrachloroethene	496	ND	1.4	10.4	ND	ND
1,1,1-trichloroethane	847	ND	ND	3.6	ND	ND
1,1,2-trichloroethane	11.5	ND	ND	ND	ND	ND
trichloroethene	100	ND	ND	ND*	ND	ND
trichlorotrifluoroethane	19	ND	ND	6.7	ND	ND

Notes:

mg/kg = milligrams/kilogram
VOCs = Volatile Organic Compounds
SVOCs = Semi-Volatile Organic Compounds
ND = Not detected
o,p = ortho/para
ND* = Trace concentration confirmed, for calculation purposes, assume 1/2 of Detection Limit (1/2 ND). Detection limits are assumed to be Practical Quantitation Limits (PQLs), to simplify calculations for USEPA Methods 8240 and 8270 respectively. Therefore, representative concentrations for certain compounds may be slightly elevated through the use of PQLs. When concentration has been qualified due to reagent blank contamination (dichloromethane, dimethyl ketone), assume 1/2 of concentration for calculation purpose.

TABLE 2.3

REPRESENTATIVE CONCENTRATIONS-WASTES
HASSAYAMPA FEASIBILITY STUDY

	Representative Concentration (mg/kg)					
Compound	***Pit 1***	***Pit 2***	***Pit 3a***	***Pit 3c***	***Pit 4b***	***Pit 4c***
SVOCs						
bis(2-ethylhexyl)phthalate	12.7	ND	59	ND	ND	ND
1,2-dichlorobenzene	170	ND	ND	ND	ND	ND
1,4-dichlorobenzene	15.0	ND	ND	ND	ND	ND
2-methyl naphthalene	160	69	ND	ND	ND*	ND
2-methylphenol	117.5	ND	ND	ND	ND	ND
napthalene	ND	49	ND	ND	ND	ND*
phenanthrene	ND	3	ND	ND	ND	ND
Non-Targeted Compounds (semi-quantiated)	53,450	20,012	54	40,900	200	300

Notes:

mg/kg = milligrams/kilogram
VOCs = Volatile Organic Compounds
SVOCs = Semi-Volatile Organic Compounds
ND = Not detected
o,p = ortho/para
ND* = Trace concentration confirmed, for calculation purposes, assume 1/2 of Detection Limit (1/2 ND). Detection limits are assumed to be Practical Quantitation Limits (PQLs), to simplify calculations for USEPA Methods 8240 and 8270 respectively. Therefore, representative concentrations for certain compounds may be slightly elevated through the use of PQLs. When concentration has been qualified due to reagent blank contamination (dichloromethane, dimethyl ketone), assume 1/2 of concentration for calculation purpose.

TABLE 2.4

ORGANIC TCLP RESULTS - WASTE
HASSAYAMPA FEASIBILITY STUDY

	Representative Concentration (mg/L)		
Compound	***Pit 1***	***Pit 3b***	***Pit 3c***
VOCs			
dichloromethane	10.4	0.13	0.40
dimethyl ketone (acetone)	16.9	ND *	ND *
1,1-dichloroethene	1.53	0.06	ND *
1,1-dichloroethane	4.03	0.70	0.06
1,1,1-trichloroethane	110.4	0.125	0.03
1,2-dichloropropane	2.03	0.055	ND
trichloroethene	5.1	0.065	ND
tetrachloroethene	5.3	0.52	0.10
methyl benzene (toluene)	6.9	ND	ND
dimethyl benzene (xylenes)	2.0	0.03	0.03
trichlorotrifluoroethane	6.5	0.09	ND
o(p)-dichlorobenzene	0.10	0.025	0.01
methyl ethyl ketone	ND *	ND	ND
1,1,2-trichloroethane	ND *	ND	ND
ethylbenzene	0.20	ND	ND
4-methyl-2-pentanone	ND *	ND	ND
SVOCs			
phenol	5.4	ND	ND
4-methylphenol	1.89	ND	ND
benzoic acid	0.85	ND	ND
1,2-dichlorobenzene	ND	ND *	ND
benzophenone	ND	0.20	ND
Oxygenated Hydrocarbons C7	45	ND	ND
bis (2-ethylhexyl) phthalate	ND	ND	0.086
Total Organic Acids	ND	ND	0.30
Total Extractable Hydrocarbons C8-C20	ND	ND	0.06

Notes:

(1) ND - Not detected
(2) ND * - Trace concentration confirmed below detection limit
(3) NA - Not analyzed
(4) mg/L - milligrams per liter of leachate
(5) TCLP - Toxicity Characteristic Leaching Procedure
(6) TCLP results calculated from data presented in the Supplemental Data Submittal for Soil Borings Report, dated July 29, 1991.
(7) Representative concentration is the arithmetic mean of all results which include one-half the detection limit value of compounds that were not detected.

TABLE 2.5

INORGANIC TCLP AND EP TOXICITY RESULTS - WASTE HASSAYAMPA FEASIBILITY STUDY

	TCLP Representative Concentration (mg/L)			*EP Toxicity Representative Concentration (mg/L)*					
Compound	***Pit 1***	***Pit 3b***	***Pit 3c***	***Pit 1***	***Pit 2***	***Pit 3a***	***Pit 3c***	***Pit 4b***	***Pit 4c***
Metals									
Arsenic	ND	ND	ND	0.044	0.010	ND	ND	ND	ND
Barium	1.68	0.266	0.235	0.85	0.14	0.17	0.50	0.43	ND
Cadmium	0.074	0.017	0.012	0.128	0.013	0.063	0.036	0.020	0.019
Chromium	0.020	0.024	ND	0.03	8.7	0.08	0.15	0.07	0.06
Copper	12.7	64.8	27.2	1.27	2.11	327	272	0.043	0.043
Lead	0.19	0.18	ND	0.63	0.085	1.47	11.5	0.36	0.35
Mercury	0.0006	ND	0.0010	ND	ND	ND	ND	ND	ND
Nickel	0.251	0.830	0.596	NA	NA	NA	NA	NA	NA
Silver	ND	ND	ND	ND	ND	0.015	0.015	0.043	0.039

Notes:

(1) ND - Not detected
(2) NA - Not analyzed
(3) mg/L - milligrams per liter of leachate
(4) TCLP - Toxicity Characteristic Leaching Procedure
(5) TCLP results calculated from data presented in the Supplemental Data Submittal for Soil Borings Report, dated July 29, 1991.
(6) EP Toxicity results calculated from data presented in Volume I of the Remedial Investigation Report, dated February 1, 1991.
(7) Representative concentration is the arithmetic mean of all results which include one-half the detection limit value of compounds that were not detected.

2.1.2 Soil Profile

2.1.2.1 Soil Borings

Results of the RI soil boring program and the supplementary field investigations were used to evaluate the type and depth of contamination in the soils beneath the disposal pits and are presented in Table 2.6. Laboratory chemical analyses indicate that downward percolation of VOCs and SVOCs into the vadose zone has occurred beneath Pit 1, and to a lesser extent beneath Pits 2, 3b, and 3c.

Table 2.7 presents a summary of estimated soil volumes beneath Pits 1, 2, 3, and 4. The volume of soil is greatest beneath Pit 3b and 3c and least beneath Pit 4a, due to the areal extent of the pits.

Concentrations of VOCs and SVOCs were detected in soil samples obtained beneath Pits 1, 3(b and c) at depths of 60 and 55 feet, respectively, below ground surface. Acetone and bis(2-ethylhexyl)phthalate were the sole organic compounds detected in soil samples obtained beneath Pit 2 to a maximum depth of 55 feet below ground surface. Except for suspected laboratory contamination by bis(2-ethylhexyl)phthalate, downward percolation of organic contaminants from Pits 4b and 4c into the vadose zone was not evident.

The extent of contamination in soils is more significant beneath Pit 1 than beneath Pits 3b and 3c. This result can be attributed to the fact that the solvents approved by ADHS for disposal in Pit 1 have a much

TABLE 2.6

REPRESENTATIVE CONCENTRATIONS - SOILS
HASSAYAMPA FEASIBILITY STUDY

	Representative Concentration (mg/kg)			
Compound	*Pit 1*	*Pit 2*	*Pit 3b and 3c*	Pit 4b and 4c
<u>*VOCs*</u>				
benzene	0.09	ND	ND	ND
o,p-dichlorobenzene	2.24	ND	ND	ND
1,1-dichloroethane	7.01	ND	ND	ND
1,1-dichloroethene	175.3	ND	ND	ND
dichloromethane	151.2	ND	ND	ND
1,2-dichloropropane	29.0	ND	ND	ND
dimethyl benzenes (total xylenes)	69.7	ND	ND	ND
dimethyl ketone (acetone)	416.0	0.26	2.11	0.27
ethyl benzene	14.2	ND	ND	ND
methyl benzene (toluene)	109.4	ND	ND	ND
methyl ethyl ketone	89.8	ND	0.45	ND
tetrachloroethene	184.2	ND	ND	ND
1,1,1-trichloroethane	3698.5	ND	0.046	ND
1,1,2-trichloroethane	2.38	ND	ND	ND
trichloroethene	107.0	ND	ND	ND
trichlorotrifluoroethane	1556.0	ND	ND	ND
Non-Targeted Compounds (semi-quantitated)	174.3	ND	ND	ND

TABLE 2.6

REPRESENTATIVE CONCENTRATIONS - SOILS
HASSAYAMPA FEASIBILITY STUDY

	Representative Concentration (mg/kg)			
Compound	*Pit 1*	*Pit 2*	*Pit 3b and 3c*	Pit 4b and 4c
SVOCs				
bis(2-ethylhexyl)phthalate	5.23	0.35	0.15	0.79
1,2-dichlorobenzene	2.16	ND	ND	ND
1,4-dichlorobenzene	ND	ND	ND	ND
2-methyl naphthalene	1.66	ND	ND	ND
2-methylphenol	ND	ND	ND	ND
4-methyl phenol	0.33	ND	ND*	ND
naphthalene	1.35	ND	ND	ND
phenanthrene	ND*	ND	ND	ND
phenol	4.92	ND	0.88	ND
pyrene	ND*	ND	ND	ND
non-targeted compounds (semi-quantiated)	1033.2	ND	1.25	ND

Notes:

mg/kg = milligrams/kilogram
VOC = Volatile Organic Compound
SVOC = Semi-Volatile Organic Compound
ND = Not detected
ND* = Trace concentration confirmed.
For calculation purposes, assume 1/2 of Detection Limit (1/2 ND).
Detection limits are assumed to be Practical Quantitation Limits (PQLs), for USEPA Methods 8240 and 8270 respectively in order to simplify calculations. Therefore, representative concentrations for certain compounds may be slightly elevated through the use of PQLs.

TABLE 2.7

SUMMARY OF CALCULATED SOIL VOLUMES
HASSAYAMPA FEASIBILITY STUDY

Pit	*Area of Waste Pit (ft2)*	*Calculated Soil Volume (yd3)*
1	2,900	8,200
2	1,900	5,100
3a	3,600	8,100
3b	6,000	20,100
3c	6,000	18,700
4a	800	3,000
4b	3,500	8,000
4c	4,400	9,400
Special Pits	2,500	10,800

greater tendency to migrate as compared to the alkali/metal sludges disposed of in Pit 3b and 3c.

The results of EP toxicity and TCLP testing of the subsurface soils are summarized in Table 2.8. The EP toxicity tests indicate that detected levels of all metals are present in leachate from soils beneath all pits. The TCLP test results exhibit detectable concentrations of barium (Pit 1, Pit 3c), chromium (Pit 1, Pit 3c), nickel (Pit 1), and copper (Pit 1, Pit 3c) in the subsurface soils beneath Pits 1 and 3c.

2.1.2.2 Soil Gas Survey

Based on the results of the soil gas survey (CRA, October, 1991), three distinct and significant areas of soil gas contamination exist at the hazardous waste area. The area in and surrounding Pit 1 contains the most significant level of soil gas contamination. Similarly, the concentrations of contaminants detected in soil samples from Pit 1 were the most substantial detections in the RI.

The second distinct area is located around the center of the Special Pits area. The concentrations of contaminants detected in soil gas samples were utilized to estimate concentrations of contaminants in the soil in the Special Pits area, based on a correlation established from Pit 1 data . These estimated soil concentrations indicate that the concentration of target compounds are at least one order of magnitude less than those detected in soil samples from Pit 1.

TABLE 2.8

INORGANIC TCLP AND EP TOXICITY RESULTS - SOIL
HASSAYAMPA FEASIBILITY STUDY

	TCLP Representative Concentration (mg/L)		*EP Toxicity Representative Concentration (mg/L)*			
Compound	***Pit 1***	***Pit 3c***	***Pit 1***	***Pit 2***	***Pits 3b & 3c***	***Pits 4b & 4c***
Metals						
Arsenic	ND	ND	0.010	0.007	0.010	0.020
Barium	0.278	0.298	0.419	0.323	0.742	0.380
Cadmium	ND	ND	0.009	0.012	0.013	0.012
Chromium	ND	0.007	0.018	0.423	0.026	0.023
Copper	0.018	0.008	0.019	0.043	0.031	0.028
Lead	ND	ND	0.140	0.140	0.170	0.170
Nickel	0.012	ND	NA	NA	NA	NA
Silver	ND	ND	0.014	0.016	0.018	0.020

Notes:

(1) ND - Not detected
(2) NA - Not analyzed
(3) mg/L - milligrams per liter of leachate
(4) TCLP - Toxicity Characteristic Leaching Procedure
(5) TCLP results calculated from data presented in the Supplemental Data Submittal for Soil Borings Report, dated July 29, 1991.
(6) EP Toxicity results calculated from data presented in Volume I of the Remedial Investigation Report, dated February 1, 1991.
(7) Representative concentration is the arithmetic mean of all results which include one-half the detection limit value of compounds that were not detected.

The third area of elevated VOC concentrations in soil gas is located in the southwest corner of the hazardous waste area, near the Special Pits area. The concentrations of VOCs in the soil gas in this area are approximately three orders of magnitude less than the highest soil gas concentration in the center of the Special Pits area. Corresponding concentrations of VOCs in the soils in this area would be expected to be at least two orders of magnitude less than those detected in waste samples for Pit 1.

In addition to the above, a single elevated detection appears to the north of the hazardous waste area. An elevated VOC concentration was detected in the soil gas adjacent to the alignment of Old Wickenburg Road. It is improbable that diffusive transport or liquid transport of the contaminants detected in the disposal pits are responsible for this single, discontinuous elevated detection.

Figure 2.1 illustrates the total VOC concentrations detected in the soil gas survey.

2.1.3 Summary of Waste and Soil Profile

The range of compounds detected in samples collected from the disposal pits varies from constituents of organic solvents and oils to acid/metal and pesticide sludges. The number of detected and confirmed compounds and their respective concentrations are greatest for Pit 1 wastes

LEGEND

PIT 1	DISPOSAL PIT : Locations and boundaries for Pits 1, 2, 3a, 4b and 4c were determined approximately based on treching operations. Locations and boundaries for other disposal pits are based on analysis of a January 26, 1981, aerial photo and on reports. Locations and boundaries are tentative and approximate.
● 85	TOTAL CONCENTRATION (ug/L)
▨	*1000 – 4999*
▨	*5000 – 9999*
▨	*10,000 – 99,999*
🟥	*>100,000*

BASE MAP SOURCE : ERROL L. MONTGOMERY AND ASSOCIATES

figure 2.1
TOTAL SOIL GAS CONCENTRATIONS
HASSAYAMPA LANDFILL
Maricopa County, Arizona

CRA

2141–10/10/91–12–0

and soils. The downward percolation of VOCs and SVOCs from Pits 1, 3b, and 3c was evident. The extent of contamination beneath Pit 1, was observed to be substantially greater than that beneath Pits 3b and 3c.

The contamination profiles developed for Pits 2 and 4 indicate that samples from the waste and soils in these pits exhibited concentrations of contaminants which were substantially less than those detected in Pit 1 wastes and soils.

2.2 GROUNDWATER CONTAMINATION PROFILE

Compounds have been identified based on laboratory chemical analyses for groundwater obtained during the RI and supplemental investigative work. Results indicate that compounds for groundwater, excluding laboratory contaminants, were detected and confirmed solely in groundwater samples obtained from Unit A monitoring wells MW-1UA, MW-4UA, MW-5UA, and MW-6UA and from abandoned ADHS monitor well HS-1. These wells are shown on Figure 1.2. The concentrations of the compounds detected in groundwater samples are summarized in Table A.2.3 (Appendix A).

The evaluation of groundwater treatment technologies was based upon analytical data from samples collected from monitoring well HS-1. This well was selected due to the levels of contamination detected in samples from the well which were above those detected in other wells and the expectation that groundwater from the zone surrounding this well may be subject to remediation. Table 2.9 presents a representative contamination profile for use in the assessment of treatment technologies. Representative concentrations are based on the arithmetic mean of unqualified detections for all wells except HS-1. Similarly, representative HS-1 concentrations were calculated using only unqualified detections. Since non-detect values are not used to determine these representative concentrations, the mean HS-1 and representative concentrations are therefore considered worst case concentrations. Design concentrations are based on the representative concentration for HS-1 multiplied by a safety factor of two (2). The treatment flow rate used for design and evaluation purposes was 25 gallons per minute (gpm). The estimated flow is based on hydrogeological data and modeling provided by M&A and are presented in Appendix A.

TABLE 2.9

GROUNDWATER PROFILE
HASSAYAMPA FEASIBILITY STUDY

Compound	*Well Identifier* *Representative Concentration (µg/L)* *MW-1UA*	*MW-1UB*	*MW-2UA*	*MW-2UB*	*MW-3UA*	*MW-3UB*	*MW-4UA*	*MW-4UB*
dichlorodifluoromethane (DCDFM)	0.16	ND	ND	ND	ND	ND	ND	ND
1,1-dichloroethane (1,1-DCA)	10.0	ND	ND	ND	ND	ND	ND	ND
1,1-dichloroethene (1,1-DCE)	143.6	ND	ND	ND	ND	ND	0.3	ND
1,2-dichloroethene (1,2-DCE)	0.4	ND	ND	ND	ND	ND	ND	ND
1,2-dichloropropane (1,2-DCP)	0.25	ND	ND	ND	ND	ND	ND	ND
methyl ethyl ketone (MEK)	17	ND	19	ND	ND	ND	ND	ND
1,1,1-trichloroethane (TCA)	8.3	ND	ND	ND	ND	ND	ND	ND
trichloroethene (TCE)	0.3	ND	ND	ND	ND	ND	ND	ND
trichlorotrifluoroethane (Freon 113)	ND	ND	ND	ND	ND	ND	13.4	ND

Notes:

µg/L - micrograms per liter
MCL - Maximum Contaminant Levels
-- - Not available
ND - Not Detected, not confirmed

Xylenes,acetone,methyl isobutyl ketone,tetrachloroethene,and Freon-11 were not detected

Sources:

(1) Profile - the mean of detections and 1/2 detection limit where two or more detections occurred.

TABLE 2.9

GROUNDWATER PROFILE
HASSAYAMPA FEASIBILITY STUDY

Compound	*Well Identifier* *Representative Concentration (µg/L)* *MW-5UA*	*MW-6UA*	*MW-7UA*	*MW-8UA*	*HS-1*	*HS-2*	*HS-3*
1,1-dichloroethane (1,1-DCA)	ND	4.3	ND	ND	9.7	ND	ND
1,1-dichloroethene (1,1-DCE)	0.6	88.6	ND	ND	744.4	ND	ND
1,2-dichloropropane (1,2-DCP)	ND	0.7	ND	ND	ND	ND	ND
methyl ethyl ketone (MEK)	8.4	ND	ND	ND	ND	ND	ND
tetrachloroethene (PCE)	ND	1.9	ND	ND	10.0	ND	ND
1,1,1-trichloroethane (TCA)	ND	9.0	ND	ND	291.9	ND	ND
trichloroethene (TCE)	0.3	4.8	ND	ND	20.4	ND	ND
trichlorofluoromethane (Freon 11)	ND	3.4	ND	ND	39.7	ND	ND
trichlorotrifluoroethane (Freon 113)	1.6	103.7	ND	ND	142.6	ND	ND

Notes:

µg/L - micrograms per liter
MCL - Maximum Contaminant Levels
-- - Not available
ND - Not Detected, not confirmed

Dichlorodifluoromethane,1,2-DCA,1,2-DCE,xylenes,acetone,and methyl isobutyl ketone were not detected

Sources:

(1) Profile - the mean of detections and 1/2 detection limit where two or more detections occurred.

3.0 ARARs AND SPECIFIC REMEDIAL OBJECTIVES

CERCLA/SARA requires that the applicable or relevant and appropriate requirements (ARARs) of other laws be identified during the RI/FS in order to aid in the preparation of a list of remedial alternatives, the evaluation of remedial alternatives under an FS, and ultimately, the selection of a remedy under the Record of Decision (ROD).

This Memorandum provides a review of environmental regulations to define institutional requirements for remediation.

ARARs represent requirements under Federal or State regulations, which will govern remediation of the hazardous waste area. ARARs fall into three categories as follows:

- Chemical-Specific ARARs which identify and define acceptable exposure levels for chemicals found at a hazardous waste site.
- Action-Specific ARARs which may set controls or restrictions for particular treatment or disposal activities.
- Location-Specific ARARs which may set restrictions on activities within specific locations such as a floodplain.

ARARs are defined below, pursuant to SARA and a letter from the USEPA to CRA (USEPA, October 1991):

Applicable Requirements

Applicable requirements are federal and state requirements such as cleanup standards, standards of control, and other environmental protection criteria or limitations, that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site.

Relevant and Appropriate Requirements

Relevant and appropriate requirements are those federal and state requirements that, while not applicable as defined above, to the circumstances at a site, address problems or situations sufficiently similar to those encountered at a site that their use is well suited. The regulations provide specific criteria for determining whether a requirement is relevant and appropriate.

During the feasibility study process and in the development of remedial alternatives, relevant and appropriate requirements are accorded the same weight and consideration as applicable requirements.

Other Requirements To Be Considered

This category contains other requirements and non-promulgated documents to be considered in the CERCLA process of developing and screening remedial alternatives. The To Be Considered (TBC) category includes federal and state non-regulatory requirements, such as guidance documents, advisories, or criteria. Non-promulgated advisories or guidance documents do not have the status of ARARs. However, if no ARARs for a contaminant or situation exist, guidance or advisories would be identified and used to ensure that a remedy is protective.

Table 3.1 provides a list of potential ARARs for the hazardous waste area.

Table 3.1 contains a summary of the Federal and State environmental and public health regulations potentially related to remediation of the hazardous waste area and an assessment as to the applicability of each. Also shown is an assessment of the effect of the particular law or regulation on a selected remedy (i.e. NDPES permit for surface discharge).

3.1 DISCUSSION OF REGULATIONS

Table 3.1 presents a comprehensive list of laws and regulations which may potentially apply to all matrices at the hazardous waste area. Appendix A discusses only those ARARs, which may impact the extraction and treatment, and discharge of groundwater; these are surface water and groundwater regulations. Certain aspects of air regulations pertaining to groundwater remediation are discussed in Appendix A.

TABLE 3.1

POTENTIALLY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) HASSAYAMPA FEASIBLITY STUDY

	Law or Regulation	*Reference*	*Ambient or Chemical Specific ARAR*	*Performance, Design or Action Specific ARAR*	*Location Specific ARAR*
	FEDERAL				
1.	CERCLA/SARA	42USC 9601 et. seq.	Applicable, relevent and appropriate requirements under Section 121 of SARA.	Applicable, relevent and appropriate requirements of 40 CFR 300.68 (NCP).	N/A
2a.	RCRA	42USC 6901 et. seq.	Not Applicable (N/A), RCRA does not regulate CERCLA sites, site closed before 1980.	Applicable to the construction of an on-site landfill, waste pile, or surface impoundment.	N/A
2b.	Federal Manifest for Transport of Hazardous Waste	RCRA Section 3002(5), 40 CFR 262, 263	N/A	Applicable to transport of hazardous wastes.	N/A
2c.	Standards for Hazardous Waste Treatment, Storage and Disposal Facilities	40 CFR 264	N/A	Applicable to management of hazardous waste facilities.	N/A
2d.	Closure and Post-Closure Standards	40 CFR 265, Subpart G	N/A	Applicable to closure of RCRA regulated units, but N/A to hazardous waste area.	N/A
2e.	Land Disposal Restrictions	40 CFR 268	N/A	Applicable to placement of waste outside of the hazardous waste area, including off-site landfilling.	N/A
2f.	Hazardous Materials Regulations	49 CFR 170 to 179	N/A	Applicable to transport of hazardous materials off site.	N/A
3a.	Clean Water Act	CWA Section 402, 40 CFR 122, 125 Subchapter N	N/A	Applicable to discharges to surface water (regulated by the NDPES permit).	N/A
3b.	Permit for Structure of Work in or Affecting Navigable Waters (Section 10 of Rivers and Harbors Act)	33 CFR 320-330	N/A	Applicable to work involving tributaries to surface water.	N/A

Notes:

(1) N/A - Not Applicable

TABLE 3.1

POTENTIALLY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) HASSAYAMPA FEASIBLITY STUDY

	Law or Regulation	*Reference*	*Ambient or Chemical Specific ARAR*	*Performance, Design or Action Specific ARAR*	*Location Specific ARAR*
	FEDERAL (continued)				
3c.	Response in a Floodplain or Wetlands	40 CFR 6, Appendix A	N/A	Applicable to surface water discharges.	N/A
3d.	Federal Standards for Toxic Pollutant Effluent	40 CFR 129	N/A	Applicable to discharges to tributaries to surface water (regulated by the NPDES permit).	N/A
-4a.	Safe Drinking Water Act	40 CFR 141, 143, Subpart F	Regulates drinking water supplies using MCLs.	Applicable to drinking water as an end use. MCL goals (Subpart F) are not enforceable.	N/A
-4b.	Underground Injection Control (UIC) Program: Criteria and Standards	40 CFR 146	N/A	Applicable to underground injection of wastes.	N/A
5.	Toxic Substances Control Act (TSCA)	40 CFR Parts 702 to 775	N/A	Applicable to transport and disposal of PCB wastes greater than 50 ppm.	N/A
–6.	Clean Air Act and Regulations	42 USC 7401 et. seq., 40 CFR Part 52-62	Applicable to industrial sources.	Applicable to discharges to air.	N/A
7.	National Environmental Policy Act (NEPA)	NEPA Section 102(2)(c)	N/A	CERCLA Feasibility Study guidance documents (1) state that CERCLA actions are exempt.	N/A
–8.	Worker Safety and Health Protection (Occupational Safety and Health Administration (OSHA))	29 USC 651-678	N/A	Applicable to worker safety during Remedial Construction.	N/A
–9.	Conservation of Wildlife Resources	Fish and Wildlife Coordination Act	N/A	Applicable to discharges to tributaries.	N/A

Notes:

(1) N/A - Not Applicable

TABLE 3.1

POTENTIALLY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) HASSAYAMPA FEASIBLITY STUDY

	Law or Regulation	*Reference*	*Ambient or Chemical Specific ARAR*	*Performance, Design or Action Specific ARAR*	*Location Specific ARAR*
	STATE OF ARIZONA				
1.	Arizona Surface Water Discharge Regulations	R18-9-702	N/A	Applicable to the re-use of water and NPDES permits.	N/A
2.	Arizona Surface Water Quality Standards	R18-11-100	Toxic pollutant discharge levels and surface water quality standards.	Applicable to discharged surface water.	N/A
3.	Arizona Groundwater Quality Standards	R9-21-403	N/A	Applicable to discharges to groundwater.	N/A
4.	Arizona Ambient Air Quality Standards	R18-2-200	Certain criteria for air discharges.	Applicable to discharges to air.	N/A
5.	Arizona Clean Water Act	A.R.S. Title 49, Chapter 2, Article 2	Rules governing water supplies that are or might be used as drinking water.	Applicable to discharges to groundwater.	N/A
6.	Arizona Numeric Aquifer Water Quality Standards	R18-11-406	N/A	Applicable to discharges to groundwater.	N/A
7.	Arizona Hazardous Waste Management Regulations	R18-8-200	N/A	Applicable to off-site transport of hazardous waste.	N/A
8.	Arizona Groundwater Management Act	A.R.S. Title 45	N/A	Applicable for the re-use of extracted water.	N/A

Notes:

(1) N/A - Not Applicable

3.2 REMEDIAL OBJECTIVES FOR GROUNDWATER

Groundwater and drinking water regulations which shall be considered applicable at the hazardous waste area will be based on maximum contaminant levels (MCLs) (see Appendix A). Table 3.2 presents specific remedial objectives for groundwater. Compounds detected above respective MCLs include: 1,2-dichloroethane (HS-1) (not confirmed); 1,1-dichloroethene (MW-1UA, MW-6UA, HS-1); tetrachloroethene (HS-1 and MW-1UA); 1,1,1-trichloroethane (HS-1); and trichloroethene (HS-1).

3.3 REMEDIAL OBJECTIVES FOR WASTE AND SOILS

Contaminated subsurface soil represents a potential source of groundwater contamination due to the potential migration and transport of contaminants. A review of regulations indicate that there are no chemical specific ARARs for soil (excluding PCBs) for chemicals, which are identified as a contaminant of concern.

Three different criteria were considered for the development of remedial objectives for soil: risk based Health Based Guidance Levels (HBGLs), the federal TCLP and EP Toxicity tests.

The HBGLs were developed by ADHS (September 1990) using a health-risk analysis methodology which is summarized in the following paragraphs. The HBGLs listed in Table 3.3 are derived from

TABLE 3.2

SPECIFIC REMEDIAL OBJECTIVES - GROUNDWATER HASSAYAMPA FEASIBILITY STUDY

Compound	*Remedial Objective (μg/L)*
1,1-dichloroethene	7
1,1,1-trichloroethane	200
1,2-dichloroethane	5
1,2-dichloropropane	5
1,2-dichloroethene (cis)	70
1,2-dichloroethene (Trans)	100
tetrachloroethene	5
tribromomethane	20
trichloroethene	5

TABLE 3.3

WASTE AND SOIL REMEDIATION GOALS
HASSAYAMPA FEASIBILITY STUDY

Compounds	*Ingestion HBGL (mg/kg)*	*TCLP Regulatory Level (mg/L)*
VOCs		
o,p-dichlorobenzene	4,000	--
1,1-dichloroethane	--	--
1,1-dichloroethene	140	0.7
dichloromethane	94	--
1,2-dichloropropane	12	--
dimethylbenzenes (xylenes)	200,000	--
dimethylketone (acetone)	14,000	--
ethylbenzene	14,000	--
methyl benzene (toluene)	40,000	--
methyl ethyl ketone	3,400	200.0
tetrachloroethene	14	0.7
1,1,1-trichloroethane	4,000	--
1,1,2-trichloroethane	60	--
trichloroethene	64	0.5
trichlorotrifluoroethane	4,200,000	--
SVOCs		
bis(2-ethylhexyl)phthalate	--	--
1,2-dichlorobenzene	12,000	--
1,4-dichlorobenzene	1,500	7.5
2-methylnaphthalene	--	--
2-methylphenol	--	--
4-methylphenol	--	--
naphthalene	280,000	--
phenanthrene	--	--
phenol	70,000	--
pyrene	--	--

TABLE 3.3

WASTE AND SOIL REMEDIATION GOALS
HASSAYAMPA FEASIBILITY STUDY

Compounds	*Ingestion HBGL (mg/kg)*	*TCLP Regulatory Level (mg/L)*
<u>*METALS*</u>		
Arsenic	--	5.0
Barium	--	100.0
Cadium	--	1.0
Chromium	--	5.0
Lead	--	5.0
Mercury	--	0.2
Selenium	--	1.0
Silver	--	5.0

<u>Notes</u>:

mg/kg - milligrams/kilogram
mg/L - milligrams/liter of leachate
VOC - Volatile Organic Compound
SVOC - Semi-Volatile Organic Compound
-- - No guideline or regulatory level
HBGL - Health Based Guidelines
TCLP - Toxicity Characteristic Leaching Procedure

<u>Source</u>:

Human Health Based Guidance Levels for Contaminants in Drinking Water and Soil; Arizona Department of Environmental Quality, September 1990.
TCLP regulatory levels from 5S FR 11862, March 29, 1990, Final Rule.

calculations based on the ingestion of soil. They do not reflect inhalation or direct contact risks, nor are they applicable to aquatic systems and wildlife. Most importantly, the soil and water HBGLs have not been subjected to the Arizona rule-making process. They, therefore, have no official enforcement status as cleanup standards. Rather, HBGLs constitute a set of health-based levels that may be useful for reference in environmental work.

The HBGLs for compounds noted in Table 3.3 were developed by the office of Risk Assessment and Investigation, ADHS, under contract to the Arizona Department of Environmental Quality.

HBGLs for chemical contaminants in soil are expressed in milligrams per kilogram (mg/kg) and were based on an average daily ingestion of soil during a lifetime of 70 years. The average soil ingestion values suggested by USEPA and utilized by ADHS are 0.2 grams per day (g/d) for children 1-6 years of age and 0.1 g/d for ages 7-70. The ingestion HBGLs for soil are calculated to result in the lifetime exposure as would be experienced by ingesting 2 liters per day (l/d) of water containing the contaminant at the drinking water HBGL.

The TCLP test was designed to determine the mobility of both organic and inorganic analytes present in wastes and soil and to assist in characterizing wastes and soil as hazardous or non-hazardous. TCLP involves passing water through contaminated soils and determining compound concentrations in the generated leachate. If the concentration of any compound in the leachate is above its respective regulatory level, then the soil is classified as hazardous. Soils may still be classified as hazardous if the soils are corrosive, ignitable, reactive or are a "listed hazardous wastes".

Table 3.3 presents TCLP regulatory levels for compounds of concern. As shown the majority of the compounds of concern do not have a respective TCLP regulatory level. In these cases, the respective HBGLs are treated as the guidelines for soil and waste remediation objectives, even though the residual wastes are covered by at least two feet of soil and direct contact with the residual wastes is unlikely.

Table 3.4 compares the representative concentrations in the waste of each pit (Table 2.3) with the HBGLs for soil. Wastes within Pit 1 have concentrations of tetrachloroethene (PCE), at 495.5 mg/kg and trichloroethene (TCE), at 100 mg/kg which are above HBGL levels. All other waste concentrations for the remaining pits are below HBGL levels.

Table 3.5 compares the contaminant concentrations reported in soils below each disposal pit with HBGL levels for soil. The concentration of DCE, at 175.3 mg/kg, dichloromethane (at 151.2 mg/kg), 1,2-dichloropropane (at 29.0 mg/kg), PCE (at 184.2 mg/kg), and TCE (at 107.0 mg/kg), beneath Pit 1, were the compounds that exceed HBGL levels. No other contaminants detected in soil samples beneath Pit 1 and the remaining pits exceed HBGL levels.

Table 3.6 presents a comparison of the organic TCLP results with the regulatory levels for the wastes in Pits 1, 3b, and 3c. The concentrations of DCE at 1.53 mg/L, TCE at 5.1 mg/L, and PCE at 5.3 mg/L

TABLE 3.4

COMPARISON OF SOIL HBGL AND WASTE CONCENTRATIONS HASSAYAMPA FEASIBILITY STUDY

	Representative Concentrations(1) (mg/kg)						
Compound	*Pit 1*	*Pit 2*	*Pit 3a*	*Pit 3b and 3c*	*Pit 4b*	*Pit 4c*	*HBGL(2) (mg/kg)*
<u>*VOCs*</u>							
o,p-dichlorobenzene	95.5	ND	ND	ND	ND	ND	4,000
1,1-dichloroethane	ND	ND	1.5	2.3	ND	ND	--
1,1-dichloroethene	28	ND	ND	1.2	ND	ND	140
dichloromethane	16.3	3	8.5	8.5	0.45	1	94
1,2-dichloropropane	ND	ND	7.6	ND	ND	ND	12
dimethyl-benzenes (total xylenes)	74	ND	1.1	ND	ND	ND	200,000
dimethyl-ketone (acetone)	ND	ND	ND	ND	0.25	ND	14,000
ethyl-benzene	ND	ND	ND	ND	ND	ND	14,000
methyl-benzene (toluene)	23	ND	ND	ND	0.06	ND	40,000
methyl ethyl ketone	ND	ND	ND	ND	ND	ND	3,400
tetrachloroethene	495.5	ND	1.4	10.4	ND	ND	14
1,1,1-trichloroethane	847	ND	ND	3.6	ND	ND	4,000
1,1,2-trichloroethane	11.5	ND	ND	ND	ND	ND	60
trichloroethene	100	ND	ND	ND*	ND	ND	64
trichlorotrifluoroethane	19	ND	ND	6.7	ND	ND	4,200,000

TABLE 3.4

COMPARISON OF SOIL HBGL AND WASTE CONCENTRATIONS HASSAYAMPA FEASIBILITY STUDY

Compound	*Pit 1*	*Pit 2*	*Pit 3a*	*Pit 3b and 3c*	*Pit 4b*	*Pit 4c*	*HBGL*[2] *(mg/kg)*
	Representative Concentrations[1] *(mg/kg)*						
SVOCs							
bis-(2-ethylhexyl)-phthalate	12.7	ND	59	ND	ND	ND	--
1,2-dichlorobenzene	170	ND	ND	ND	ND	ND	12,000
1,4-dichlorobenzene	15.0	ND	ND	ND	ND	ND	1,500
2-methyl naphthalene	160	ND	ND	ND	ND	ND	--
2-methylphenol	117.5	ND	ND	ND	ND	ND	--
4-methylphenol	ND	ND	ND	ND	ND	ND	--
naphthalene	ND	49	ND	ND	ND	ND	280,000
phenanthrene	ND	3	ND	ND	ND	ND	--
phenol	ND	ND	ND	ND	ND	ND	70,000
pyrene	ND	ND	ND	ND	ND	ND	--

Notes:

HBGL = Health Based Guidelines
mg/kg = milligrams/kilogram
VOC = Volatile Organic Compound
SVOC = Semi-Volatile Organic Compound
ND = Non-detected
-- = No data available
ND* = Trace concentration confirmed, below detection limit

(1) Contaminant concentrations as noted in Table 2.3.
(2) HBGLs levels as noted in Table 3.3.

TABLE 3.5

COMPARISION OF SOIL HBGL AND SUBSURFACE SOIL CONCENTRATIONS HASSAYAMPA FEASIBILITY STUDY

	Representative Concentration (1) (mg/kg)				
Compound	*Pit 1*	*Pit 2*	*Pit 3b and 3c*	*Pit 4band 4c*	*HBGL(2) (mg/kg)*
VOCs					
o,p-dichlorobenzene	ND	ND	ND	ND	4,000
1,1-dichloroethane	2.24	ND	ND	ND	--
1,1-dichloroethene	175.3	ND	ND	ND	140
dichloromethane	151.2	0.35	0.24	0.4	94
1,2-dichloropropane	29.0	ND	ND	ND	12
dimethyl benzenes (total xylenes)	69.7	ND	ND	ND	200,000
dimethyl ketone (acetone)	416.0	0.26	2.11	0.27	14,000
ethyl benzene	14.2	ND	ND	ND	14,000
methyl benzene (toluene)	109.4	ND	ND	ND	40,000
methyl ethyl ketone	89.8	ND	0.45	ND	3,400
tetrachloroethene	184.2	ND	ND	ND	14
1,1,1-trichloroethane	3,698.5	ND	0.046	ND	4,000
1,1,2-trichloroethane	2.38	ND	ND	ND	60
trichloroethene	107.0	ND	ND	ND	64
trichlorotrifluoroethane	1,556.0	ND	ND	ND	4,200,000
SVOCs					
bis(2-ethylhexyl)phthalate	5.23	0.35	0.15	0.79	--
1,2-dichlorobenzene	2.16	ND	ND	ND	12,000
1,4-dichlorobenzene	ND	ND	ND	ND	1,500
2-methyl naphthalene	1.66	ND	ND	ND	--
2-methylphenol	ND	ND	ND	ND	--
4-mehylphenol	0.33	ND	ND*	ND	--
napthalene	1.35	ND	ND	ND	280,000
phenanthrene	ND*	ND	ND	ND	--
phenol	4.92	ND	0.88	ND	70,000
pyrene	ND*	ND	ND	ND	--

Notes:

HBGL = Health Based Guidelines
mg/kg = milligrams/kilogram
VOC = Volatile Organic Compound
SVOC = Semi-Volatile Organic Compound
ND = Not detected
-- = No data available
ND* = Trace concentration confirmed below detection limit

Sources:

(1) Contaminant concentrations as noted in Table 2.6.
(2) HBGL levels as noted in Table 3.3.

TABLE 3.6

COMPARISON OF ORGANIC TCLP WASTE RESULTS AND REGULATORY LEVELS HASSAYAMPA FEASIBILITY STUDY

Compound	*Representative Concentration (mg/L)* *Pit 1*	*Pit 3b*	*Pit 3c*	*Regulatory Level (mg/L)*
VOCs				
dichloromethane	10.4	0.13	0.40	-
dimethyl ketone (acetone)	16.9	ND *	ND *	-
1,1-dichloroethene	1.53	0.06	ND *	0.7
1,1 dichloroethane	4.03	0.70	0.06	-
1,1,1-trichloroethane	110.4	0.125	0.03	-
1,2-dichloropropane	2.03	0.055	ND	-
trichloroethene	5.1	0.065	ND	0.5
tetrachloroethene	5.3	0.52	0.10	0.7
methyl benzene (toluene)	6.9	ND	ND	-
dimethyl benzene (xylenes)	2.0	0.03	0.03	-
trichlorotrifluoroethane	6.5	0.09	ND	-
o(p)-dichlorobenzene	0.10	0.025	0.01	-
methyl ethyl ketone	ND *	ND	ND	200
1,1,2-trichloroethane	ND *	ND	ND	-
ethylbenzene	0.20	ND	ND	-
4-methyl-2-pentanone	ND *	ND	ND	-
SVOCs				
phenol	5.4	ND	ND	-
4-methylphenol	1.89	ND	ND	-
benzoic acid	0.85	ND	ND	-
1,2-dichlorobenzene	ND	ND *	ND	-
benzophenone	ND	0.20	ND	-
Oxygenated Hydrocarbons C7	45	ND	ND	-
bis (2-ethylhexyl) phthalate	ND	ND	0.086	-
Total Organic Acids	ND	ND	0.30	-
Total Extractable Hydrocarbons C8-C20	ND	ND	0.06	-

Notes:

(1) ND - Not detected
(2) ND * - Trace concentration confirmed below detection limit
(3) NA - Not analyzed
(4) mg/L - milligrams per liter of leachate
(5) TCLP - Toxicity Characteristic Leaching Procedure
(6) TCLP results calculated from data presented in the Supplemental Data Submittal for Soil Borings Report, dated July 29, 1991.
(7) Representative concentration is the arithmetic mean of all results which include one-half the detection limit value of compounds that were not detected, as shown on Table 2.4.
(8) Regulatory Levels from 55 FR 11862, March 29, 1990, Final Rule, as shown on Table 3.3.

exceed the regulatory levels. The remaining compounds of Pit 1 and all compounds of Pits 3b and 3c have either non-detectable concentrations or the detections were below regulatory levels.

Inorganic TCLP and EP Toxicity waste results are presented and compared with regulatory levels in Table 3.7. This comparison indicates that all detected concentrations of contaminants are below regulatory levels with the exception of two compounds. Chromium was detected in Pit 2 at a concentration of 8.7 mg/L, and lead was detected in Pit 3c at a concentration of 11.5 mg/L. However, lead was later analyzed in a sample collected from Pit 3c during the supplemental sampling program and exhibited non-detectable concentrations, utilizing TCLP analyses.

Table 3.8 compares the inorganic TCLP and EP Toxicity soil results with regulatory levels. No analyte from any pit exhibited concentrations of inorganic compounds above regulatory levels.

The results of the soil gas survey (Section 2.1.2.2) do not provide quantitative data which may be useful in developing chemical-specific remedial objectives. However, the results indicate that a performance objective based on soil gas data may be appropriate in this instance because of a concern that VOC vapors may be sufficiently mobile to eventually migrate through the basalt and into groundwater.

Data collected from the vadose zone monitoring wells indicate that VOCs in the vapor phase are present in elevated concentrations beneath Pit 1.

TABLE 3.7

COMPARISON OF INORGANIC TCLP/EP TOXICITY WASTE RESULTS AND REGULATORY LEVELS HASSAYAMPA FEASIBILITY STUDY

	TCLP Representative Concentration (mg/L)			*EP Toxicity Representative Concentration (mg/L)*						***Regulatory Level***
Compound	***Pit 1***	***Pit 3b***	***Pit 3c***	***Pit 1***	***Pit 2***	***Pit 3a***	***Pit 3c***	***Pit 4b***	***Pit 4c***	***(mg/L)***
Metals										
Arsenic	ND	ND	ND	0.044	0.010	ND	ND	ND	ND	5.0
Barium	1.68	0.266	0.235	0.85	0.14	0.17	0.50	0.43	ND	100.0
Cadmium	0.074	0.017	0.012	0.128	0.013	0.063	0.036	0.020	0.019	1.0
Chromium	0.020	0.024	ND	0.03	8.7	0.08	0.15	0.07	0.06	5.0
Copper	12.7	64.8	27.2	1.27	2.11	327	272	0.043	0.043	-
Lead	0.19	0.18	ND	0.63	0.085	1.47	11.5	0.36	0.35	5.0
Mercury	0.0006	ND	0.0010	ND	ND	ND	ND	ND	ND	0.2
Nickel	0.251	0.830	0.596	NA	NA	NA	NA	NA	NA	-
Silver	ND	ND	ND	ND	ND	0.015	0.015	0.043	0.039	5.0

Notes:

(1) ND - Not detected
(2) NA - Not analyzed
(3) mg/L - milligrams per liter of leachate
(4) TCLP - Toxicity Characteristic Leaching Procedure
(5) TCLP results calculated from data presented in the Supplemental Data Submittal for Soil Borings Report, dated July 29, 1991.
(6) EP Toxicity results calculated from data presented in Volume I of the Remedial Investigation Report, dated February 1, 1991.
(7) Representative concentration is the arithmetic mean of all results which include one-half the detection limit value of compounds that were not detected, as shown on Table 2.5.
(8) Regulatory Levels from 55 FR 11862, March 29, 1990, Final Rule, as shown on Table 3.3.

TABLE 3.8

COMPARISON OF INORGANIC TCLP/EP TOXICITY SOIL RESULTS AND REGULATORY LEVELS HASSAYAMPA FEASIBILITY STUDY

Compound	*TCLP Representative Concentration (mg/L)* *Pit 1*	*Pit 3c*	*EP Toxicity Representative Concentration (mg/L)* *Pit 1*	*Pit 2*	*Pits 3b & 3c*	*Pits 4b & 4c*	*Regulatory Level (mg/L)*
Metals							
Arsenic	ND	ND	0.010	0.007	0.010	0.020	5.0
Barium	0.278	0.298	0.419	0.323	0.742	0.380	100.0
Cadmium	ND	ND	0.009	0.012	0.013	0.012	1.0
Chromium	ND	0.007	0.018	0.423	0.026	0.023	5.0
Copper	0.018	0.008	0.019	0.043	0.031	0.028	-
Lead	ND	ND	0.140	0.140	0.170	0.170	5.0
Nickel	0.012	ND	NA	NA	NA	NA	-
Silver	ND	ND	0.014	0.016	0.018	0.020	5.0

Notes:

(1) ND - Not detected
(2) NA - Not analyzed
(3) mg/L - milligrams per liter of leachate
(4) TCLP - Toxicity Characteristic Leaching Procedure
(5) TCLP results calculated from data presented in the Supplemental Data Submittal for Soil Borings Report, dated July 29, 1991.
(6) EP Toxicity results calculated from data presented in Volume I of the Remedial Investigation Report, dated February 1, 1991.
(7) Representative concentration is the arithmetic mean of all results which include one-half the detection limit value of compounds that were not detected, as shown on Table 2.8.
(8) Regulatory Levels from 55 FR 11862, March 29, 1990, Final Rule, as shown on Table 3.3.

Data collected from the soil gas survey indicate that VOCs in the vapor phase are present in elevated concentrations in the immediate area of Pit 1 and in the central portion of the Special Pits area.

Based on the above analysis and the potential exposure pathways identified in the RA, the following solid matrices and remedial criteria are concluded to be targets of remediation:

- Pit 1 wastes - to be remediated to levels below HBGLs or to be covered as to mitigate airborne exposure (VOCs) and prevent waste contact;
- Pit 1 subsurface soils - to be remediated to levels which do not result in a significant future impact to groundwater by VOCs; and
- Special Pits area (centre portion only, see Figure 2.1) - to be remediated in order to mitigate potential future impact on groundwater.

Based on the results of the RA and the analytical data from the RI, the remediation of other disposal pits is not appropriate. The single detection of the immobile metal chromium in a Pit 2 waste sample above the former EP Toxicity regulatory level is not considered significant, nor is it considered sufficient justification to contemplate remediation of the waste. A similar detection of lead in a sample from Pit 3c in excess of the EP Toxicity standard was not reproduced during sampling and analysis by TCLP methodology. Given the apparent relative heterogeneity of the waste samples, this one detection of chromium in Pit 2 is therefore considered to be insufficient justification for remediation, since the remainder of the analytical data for Pit 2 are substantially below all other criteria utilized in the development of the specific soil remedial objectives.

4.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

Prior to developing a list of potential remedial alternatives that could be subjected to detailed analysis and comparison, all available remedial technologies must be identified and screened. Technologies are engineering or procedural components that are grouped together to form an overall remedial alternative. For example, the technologies of soil removal and incineration, groundwater pumping and treatment, when grouped together, form a remedial alternative.

Based on the RI, waste, subsurface soils, and groundwater remediation are considered in this Memorandum and the FS. Table 4.1 presents a summary of available technologies for remediation of soils, waste, and groundwater.

Each of the technologies listed in Table 4.1 for waste and soil remediation is presented and evaluated in the following section. Groundwater remediation technologies are presented and evaluated in Appendix A.

Consistent with the requirements of the Order (Section III, Paragraph 10), each technology is evaluated for its technical feasibility and public health and environmental impact. A cost estimate for each potentially feasible technology is presented in Section 4.2.

TABLE 4.1

REMEDIAL TECHNOLOGIES TO BE CONSIDERED HASSAYAMPA FEASIBILITY STUDY

A.	*Waste and Soil Remediation*
A.1	No Action
A.2	Deed Restriction
A.3	Access Restriction
A.4	Capping
A.5	Removal
A.6	Land Disposal
A.7	Soil Treatment Incineration Fixation/Solidification Soil Washing Bioremediation Soil Vapor Extraction Vitrification Thermal Desorption

B.	*Groundwater Remediation*
B.1	Monitoring
B.2	Deed Restriction
B.3	Capping*
B.4	Hydraulic Containment Extraction Wells Extraction Wells with Reinjection Subsurface Drain
B.5	Water Treatment Biological (Activated Sludge) Activated Carbon Air Stripping Aeration Oxidation Steam Stripping Reverse Osmosis Ultraviolet Oxidation Aerobic lagoons
B.6	Treated Water Discharge Reinjection/Recharge Discharge to Surface Water Discharge to PVNGS

Notes:

PVNGS = Palo Verde Nuclear Generating Station

Groundwater Remediation Technologies are presented and evaluated in Appendix A.

* Considered as part of the waste and soil technologies.

4.1 WASTE AND SOIL REMEDIAL TECHNOLOGIES

4.1.1 No Action

The "No Action" Remedial Action Technology is one that is required by CERCLA (42 USC 9601 et. seq.) to be carried through to the final detailed analysis.

Technical Feasibility

Under this technology, no further remedial actions would be taken. It is anticipated that human contact with the hazardous waste area will be minimal. This is based on the following factors:

- the area is located in a landfill and there is restricted access;
- the existing fence is in a state of relatively good repair inhibiting human contact with the hazardous waste area;
- the hazardous waste area is in a remote location; and
- the hazardous waste area is covered with a two-foot (minimum) soil cap.

Public Health and Environmental Screening

This technology is effective in restricting the current exposure to buried wastes. The RA indicated that, under current land use scenarios, the risks and hazards presented by the hazardous waste area are less than the USEPA's levels of concern, but potential future exposures for some contaminants would result in risks and hazards which exceed USEPA's levels of concern. Further, some concern exists related to the potential future migration of VOCs from the soil gas under Pit 1 to the groundwater. Therefore, in the absence of groundwater remediation, this technology alone may not be acceptable for implementation at the hazardous waste area.

4.1.2 Deed Restriction

Technical Feasibility

This remedial action involves the legal restriction of future uses of the hazardous waste area. This restriction would normally be associated with a remedial alternative that leaves residual levels of contaminated material on the hazardous waste area.

Public Health and Environmental Screening

This technology is effective at minimizing future human exposure to the buried waste. However, a concern exists related to the potential future migration of VOCs from the soil gas under Pit 1 to the groundwater. This migration could, in the absence of groundwater remediation technologies, potentially result in future human exposures to contaminants, which are in excess of the USEPA's range of concern.

Since the hazardous waste area is on County owned property and is within the confines of a municipal sanitary landfill, deed restrictions could be applied to the hazardous waste area.

4.1.3 Access Restriction

Technical Feasibility

The perimeter fence would be upgraded and maintained to restrict unauthorized access to the hazardous waste area. The purpose of the fence is to deter trespassing on the hazardous waste area and to provide security for any remedial components. The fence is considered to be a necessity. Therefore construction and maintenance of the fence will be included in all remedial alternatives except for the No Action alternative. This technology is also normally associated with long-term residual levels of contaminated materials being left on the hazardous waste area.

Public Health and Environmental Screening

This technology possesses similar public health concerns as the No Action technology.

4.1.4 Capping

This technology would involve increasing the quality of the current soil cap at the hazardous waste area. This could be accomplished in one of two ways: a cap over the entire hazardous waste area; or a cap over Pit 1 and the Special Pits area. This technology would be applied to the surface of these pits to reduce the volume of infiltration of water through contaminated soils (not considered to be significant in this case). This reduction would, in turn, reduce the quantity of contaminants that may potentially be leached from the soil into the groundwater. An improved cap would also reduce the release of VOC vapors to the atmosphere.

The construction of a cap is considered a feasible technology.

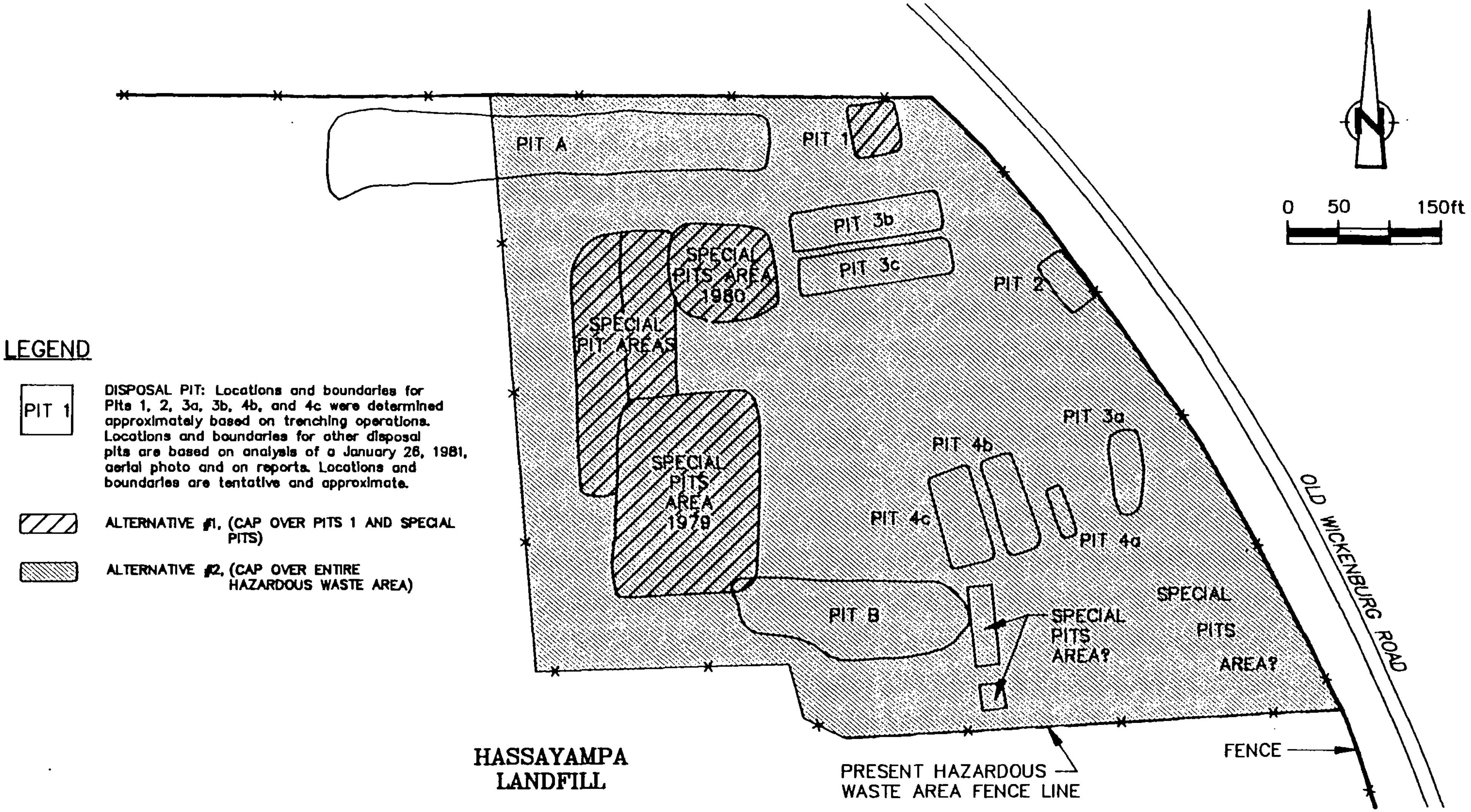
Two types of caps are available for consideration. These caps are a RCRA cover and a soil cover meeting Arizona landfill closure requirements. Cap upgrading will be evaluated for two options:

- upgrading of the cap over the entire hazardous waste area; or
- upgrading of the caps over Pit 1 and the Special Pits area.

Figure 4.1 illustrates the two options.

4.1.4.1 RCRA Cover

A Resource Conservation and Recovery (RCRA) cap consists of the following:



LEGEND

PIT 1	DISPOSAL PIT: Locations and boundaries for Pits 1, 2, 3a, 3b, 4b, and 4c were determined approximately based on trenching operations. Locations and boundaries for other disposal pits are based on analysis of a January 26, 1981, aerial photo and on reports. Locations and boundaries are tentative and approximate.
▨	ALTERNATIVE #1, (CAP OVER PITS 1 AND SPECIAL PITS)
▒	ALTERNATIVE #2, (CAP OVER ENTIRE HAZARDOUS WASTE AREA)

REFERENCE:
INFORMATION FOR BASE MAP
FROM ERROL L. MONTGOMERY
AND ASSOCIATES INC.

CRA

figure 4.1

CAPPING ALTERNATIVES
HASSAYAMPA LANDFILL
Maricopa County, Arizona

2141-28/10/91-12-0

i) Vegetated top cover at least 24 inches thick (typically 6 inches topsoil, 18 inches common fill)
  - minimum slope of 3 to 5 percent

ii) Middle drainage layer at least 12 inches thick
  - permeability $>1 \times 10^{-3}$ cm/sec
  - bottom slope >2 percent
  - overlain by filter fabric to prevent clogging

iii) Low permeability layer
  - synthetic membrane typically 60 mil thickness protected by at least 6 inches of sand on each side
  - low permeability clay layer at least 24 inches in thickness with a hydraulic conductivity not exceeding 1×10^{-7} cm/sec

This cap detail is illustrated on Figure 4.2.

Due to local meteorological conditions, the vegetated cover may not be practicable since irrigation of the cover would be required to maintain its effectiveness. Therefore, the cap improvements will be designed to accommodate the following design of the vegetated cover:

- a shallow root zone;
- drought tolerant; and
- low maintenance and irrigation requirements.

Therefore only local, common fill would be required for the vegetated cover.

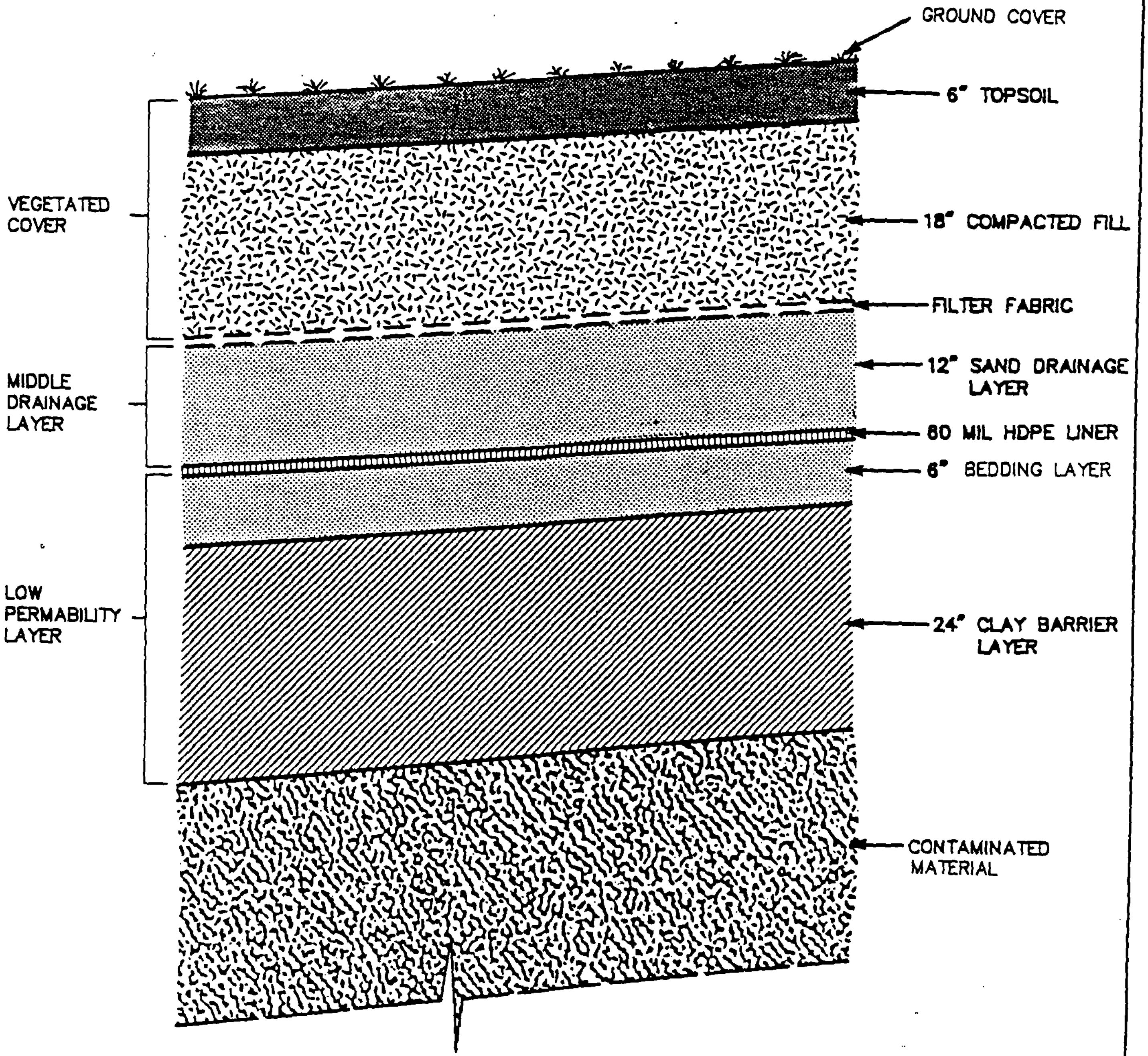


figure 4.2

TYPICAL SECTION
RCRA LANDFILL CAP
HASSAYAMPA LANDFILL
Maricopa County, Arizona

CRA

2141-10/10/91-12-0

Geotextile fabric, liner material, and clay would be imported and can be installed with conventional technology in less than six months.

4.1.4.2 Soil Cap Complying with Arizona Landfill Closure Requirements

In order to comply with Arizona landfill closure requirements, the soil cap would be designed according to following specifications:

i) A low permeability clay or soil layer at least 24 inches thick with hydraulic conductivity not exceeding 1×10^{-6} cm/sec;
ii) Compaction greater than 90% Proctor to prevent run-off and/or surface water from entering;
iii) Cap slopes between 2 and 20% to accommodate effective drainage; and
iv) Cap vegetative cover would have a shallow root zone to prevent erosion, be drought tolerant, and would require low maintenance and irrigation.

This cap detail is illustrated on Figure 4.3.

The soil cover exceeding Arizona landfill closure requirements can be constructed of local materials in less than six months.

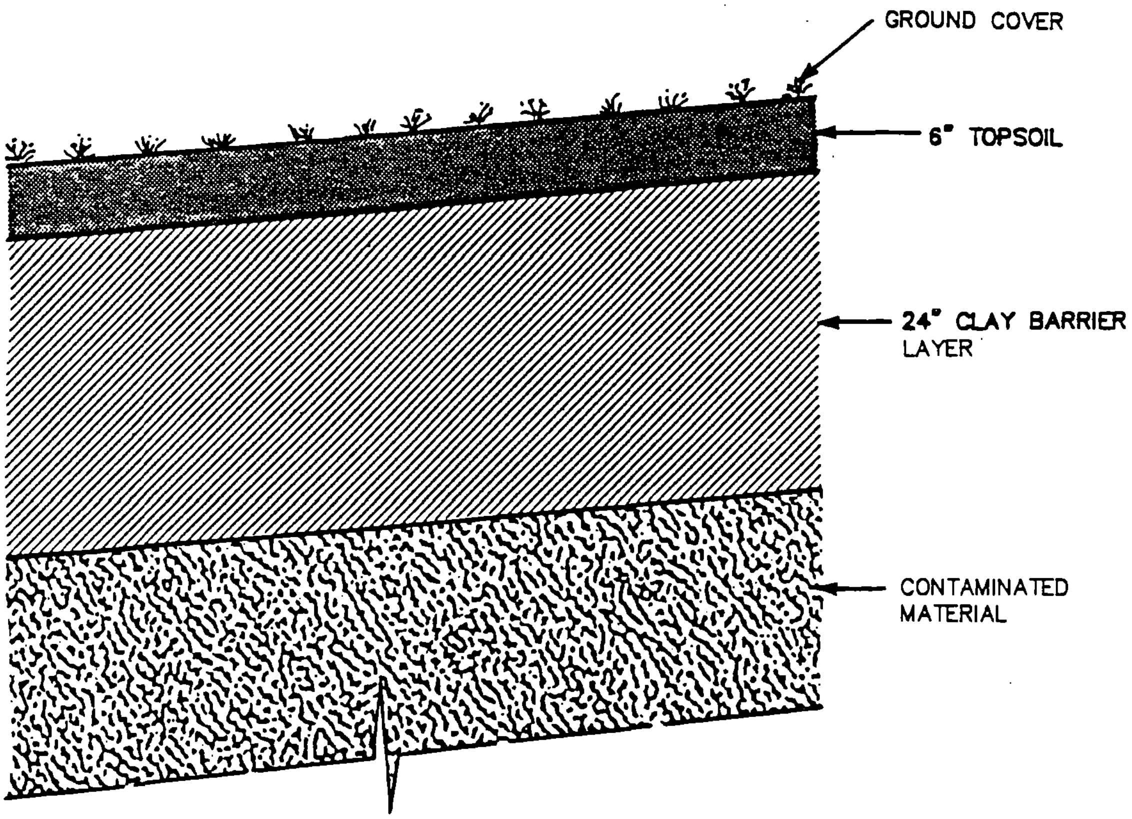


figure 4.3

TYPICAL SECTION
ARIZONA SANITARY LANDFILL CAP
HASSAYAMPA LANDFILL
Maricopa County, Arizona

CRA

4.1.4.3 Selected Cap Option

Technical Feasibility

The preferred capping technology is the cap which complies with Arizona landfill closure requirements. This capping technology was selected over the RCRA cap since the current two-foot soil cover already prevents contact of stormwater with the buried wastes and therefore only upgrading of the cap would be required. This capping technology would meet all technical requirements for mitigating infiltration and is cost effective. The current two-foot soil cap is also effective in mitigating the release of odors and vapors from the buried waste. Rainfall in the area is minimal and, as such, the risk of generating of leachate due to infiltration of precipitation is minimal. The soil cap would be constructed only of local common fill material and the final design would provide a cover with an effective hydraulic conductivity equivalent to 1 x 10^{-6} cm/s. No additional vegetated cover would be provided due to the desert surroundings.

Public Health and Environmental Screening

This capping technology would be effective at mitigating future potential exposure to the buried waste and the ongoing releases of organic vapors to the atmosphere. However, the potential future transport of VOCs from the soil gas to groundwater may result in potential residential exposures to contaminants which exceed the USEPA's ranges of concern.

For use in the development of remedial alternatives, the selected soil cap is feasible for the hazardous waste area and could be applied in the following manner:

- over Pit 1 and the Special Pits area; or
- over the entire hazardous waste area.

4.1.5 Waste Removal

This technology involves the removal of contaminated soil and waste by excavation. Clean soil would be used to backfill excavated areas. Removal is feasible for wastes located in Pit 1.

Technical Feasibility

Removal is generally considered when the contaminated soil is near land surface (within 10 feet of ground surface) and present in low volumes (less than 1,000 C.Y.). The wastes located in Pit 1 are believed to be buried to a maximum depth of 15 feet below ground surface (including a minimum two-foot clean soil cap) with a total waste volume of approximately 1,400 C.Y.

Removal is not considered to be feasible for the soils and/or wastes in the Special Pits area. These wastes are located over a large area in a large number of small, isolated pits. Further, the results of the soil gas survey illustrate that the level of contamination present in these different sources is at least one order of magnitude less than the levels measured in samples from Pit 1. Since the soils in the Special Pits area are observed to meet the specific remedial objectives for soil and remediation of the soils in this area is contemplated on a performance basis only (i.e. to prevent potential future migration of VOCs to the groundwater), removal of this large volume of soil is considered inappropriate and in-situ treatment technologies only should be considered.

Although removal eliminates the presence of contamination in the hazardous waste area, this technology creates three potential problems. First, it creates atmospheric exposure of VOC contaminated soil by allowing contaminant releases to air. Second, it creates a new waste which must be treated or disposed of elsewhere. Thirdly, as noted in Section 3.0, the waste contained in Pit 1 would require incineration prior to disposal.

Public Health and Environmental Screening

Removal of the wastes in Pit 1 would provide a substantial reduction in the potential risk of exposure to buried wastes under hypothetical future land use scenarios developed in the RA. However, this technology is not suited to the excavation of contaminated soils under Pit 1 which would continue to present a potential future source of contamination of the Unit A groundwater.

Short-term occupational health impacts posed by this technology could be managed by appropriate industrial hygiene.

Although this technology may create potential short-term problems, it will be carried through for evaluation since it is an integral part of other technologies such as off-Site incineration and on-Site treatment.

4.1.6 Land Disposal

The technology of land disposal involves placement of contaminated soil into a secure disposal facility.

Technical Feasibility

Excavated soils contaminated with VOCs and SVOCs would be transported to a RCRA landfill. Land disposal does not involve soil treatment, but rather relies on the technologies incorporated in the construction of the landfill to contain the waste and prevent a future release to the environment.

Limitations of this technology include availability of approved space, transportation distance and cost. The nearest available secure landfill is Kettleman Hills Treatment Center, located near Kettleman City, California. The landfill is operated by Chemical Waste Management, Inc. As noted in Section 3.0, land disposal is not applicable to wastes from Pit 1 since the wastes contain greater than 1,000 mg/kg total halogenated VOCs and would, therefore, require incineration prior to disposal.

Alternatively, a RCRA landfill could be constructed at the hazardous waste area to contain contaminated soils. This technology is rarely applied to volumes of contaminated soil less than 10,000 C.Y.

Public Health and Environmental Screening

Since this technology addresses only those soils excavated for Pit 1, the public health and environmental concerns are similar to those presented for removal in Section 4.1.5.

The wastes and soils in Pit 1 contain halogenated VOCs in concentrations exceeding 1,000 mg/kg. The RCRA disposal restrictions (40 CFR 268) prohibit landfilling of these wastes.

Since this technology is not relevant for the buried residual wastes from Pit 1, it will not be carried through for inclusion in the development of remedial alternatives.

4.1.7 Soil Treatment

Seven technologies were evaluated for soil treatment as described below.

4.1.7.1 Incineration

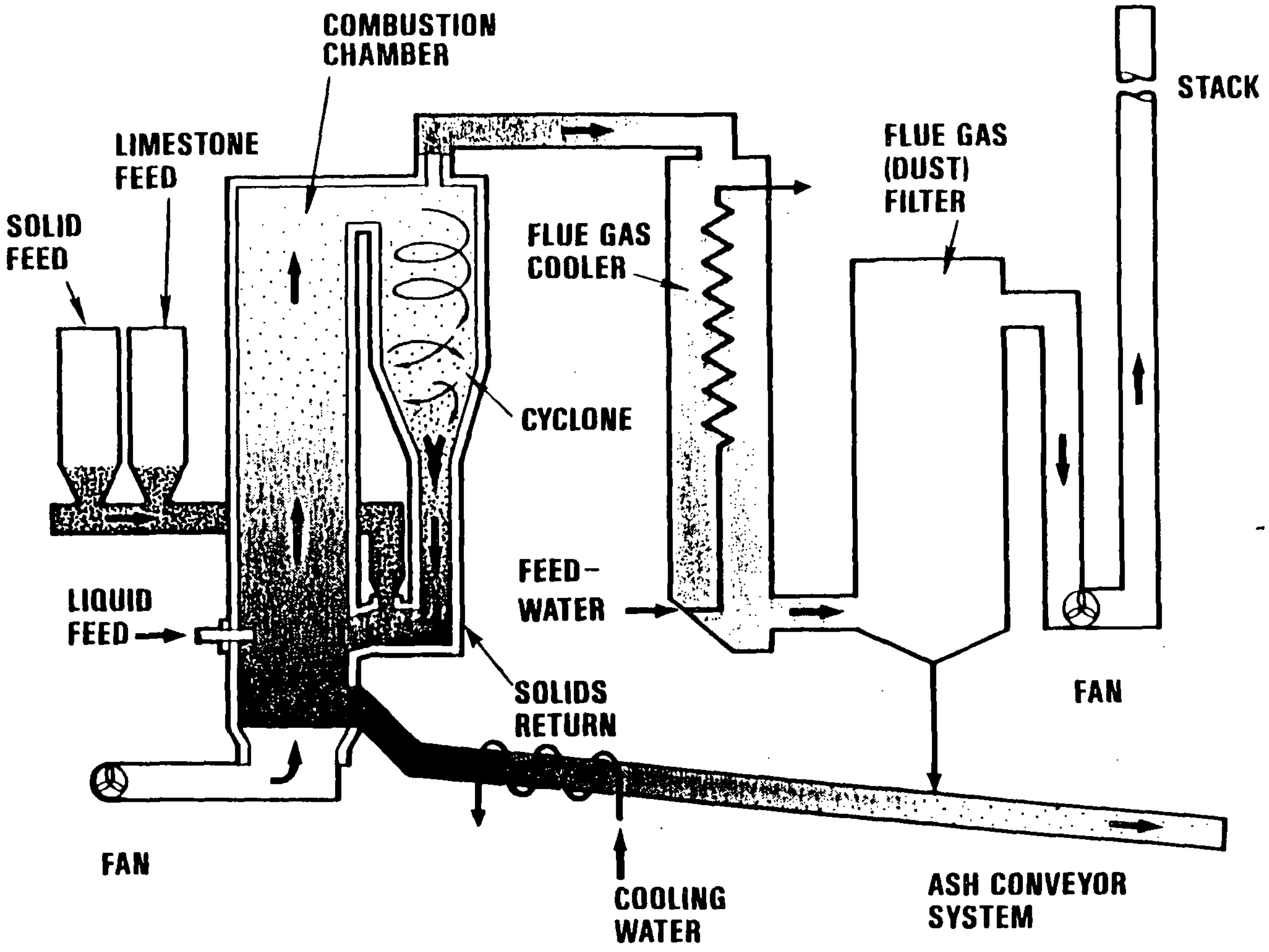
Technical Feasibility

Incineration is a treatment method for organic compounds which uses high temperature oxidation under controlled conditions to degrade a substance into carbon dioxide, water vapor, sulfur dioxide, nitrogen oxides, hydrogen chloride gases, and ash. The hazardous products of incineration, such as particulates, sulfur dioxide, nitrogen oxides, and hydrogen chloride require air emission control equipment (USEPA, October 1988). Incineration can be conducted either on site or off site.

One type of incineration equipment that could be mobilized to the hazardous waste area is the Circulating Bed Combustor (CBC), illustrated on Figure 4.4. The CBC incinerator is based on fluidized bed technology and either liquids or solids may be treated.

A rotary kiln incinerator (RKI) is commonly used for on or off-site incineration and consists of a cylindrical, refractory-lined shell on an incline. The basic type of rotary kiln incinerator, illustrated on Figure 4.5, consists of the kiln and an afterburner.

Wastes are fed into the kiln at the higher end and are passed through the combustion zone as the kiln rotates. The rotation creates turbulence which improves combustion. RKIs are typically fueled by natural gas, propane or oil. Afterburners are often employed to ensure complete

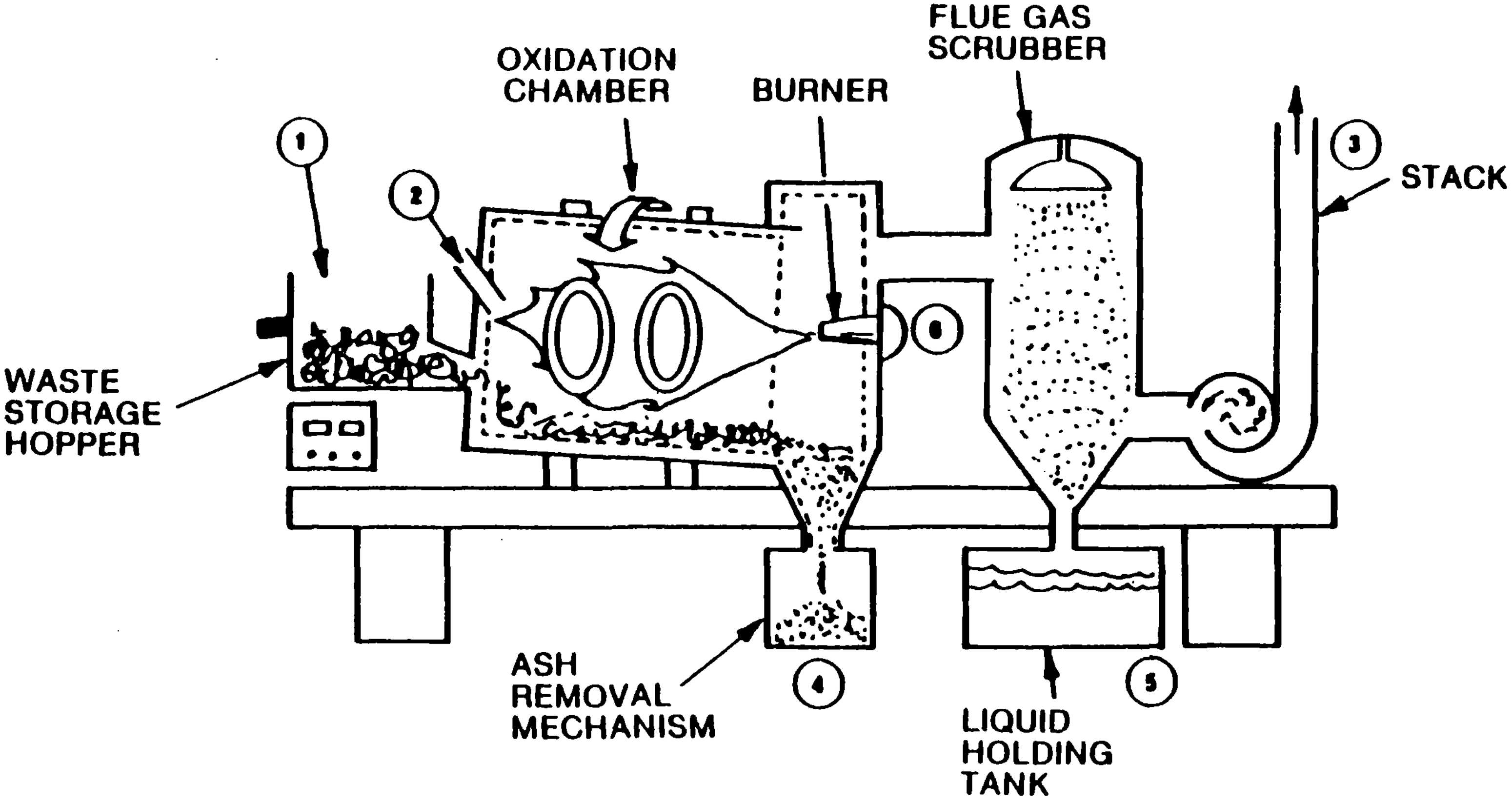


SOURCE: OGDEN ENVIROMENTAL SERVICES INC.

figure 4.4

ON-SITE INCINERATION SCHEMATIC OF CIRCULATING BED COMBUSTION
HASSAYAMPA LANDFILL
Maricopa County, Arizona

CRA



LEGEND:
1. INFLUENT WASTE
2. COMBUSTION AIR
3. FLUE GAS
4. RESIDUALS
5. SCRUBBER WATER
6. FUEL

Source: Ghassami, Yu, and Quinlivan, 1981

figure 4.5

OFF–SITE INCINERATION
SCHEMATIC OF ROTARY KILN
HASSAYAMPA LANDFILL
Maricopa County, Arizona

CRA

combustion. RKIs are usually equipped with wet scrubber and baghouse emission controls.

Incinerator residence times and temperatures are developed from the combustion characteristics and chemical properties of the waste. Residence times can be typically one hour or more for bulk solids and combustion temperature ranges from 1500 to 3000°F.

Both the CBC and RKI have demonstrated removal efficiencies greater than 99.99 percent and, in many cases, contaminants are not detectable in the remaining ash.

When soil is incinerated, there is a small volume reduction and the geologic nature of the soil remains the same, depending on the moisture and organic content of the soil. Wastes, however, from Pit 1 are organic solvents and oils mixed with soils which would result in a large volume reduction; therefore, backfilling with imported material would possibly be required.

Inorganic contaminants (e.g. metals) are generally not removed by incineration and remain in the decontaminated soil at levels similar to initial levels, a significant volume reduction is not achieved. However, incineration may result in a sufficient volume reduction to increase the metals concentration within the decontaminated waste to approach regulatory levels.

It is suspected that the decontaminated wastes would fall below RCRA standards for hazardous waste classification on the basis of metals concentration. However, TCLP leachate testing on the decontaminated waste would have to be conducted to confirm this estimate.

Decontaminated soil would be backfilled into Pit 1. Should the metals content in decontaminated soil exhibit a hazardous characteristic, pretreatment of the soil by solidification may be required prior to backfilling.

Off-site incineration typically costs between $1,800 to $2,400 per ton excluding transportation but including residual soil management. Off-site incineration would be accomplished at the Aptus facility in Salt Lake City, Utah. Therefore, off-site incineration would be considered feasible only for small waste volumes (e.g. incineration of wastes in Pit 1). Backfilling of Pit 1 using off-site soils would also be required.

On-site incineration costs typically range from $300 to $600 per ton with mobilization ranging from $0.75 million to $1.5 million. On-site incineration is clearly more economical than off-site incineration for large waste volumes (approximately 600 tons) when decontaminated soil can be backfilled into Pit 1.

Public Health and Environmental Screening

Since incineration is feasible for only the excavated wastes from Pit 1, the public health and environmental screening concerns are similar to those presented for the waste removal option (Section 4.1.5).

On-site incineration will be carried through for inclusion in the development of remedial alternatives.

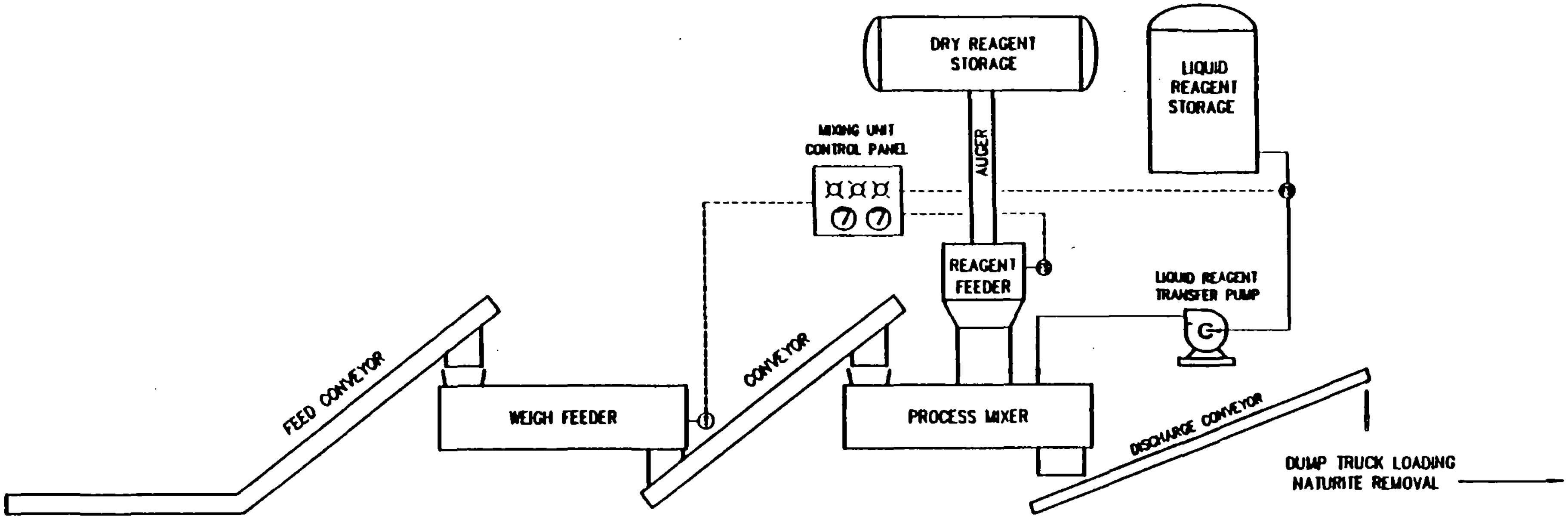
4.1.7.2 Fixation/Solidification

Fixation/solidification is used to describe processes where remediation is obtained primarily, but not exclusively, by production of a monolithic block of waste with high structural integrity. The contaminants do not necessarily interact chemically with the solidification reagents, but are mechanically locked within the solidified matrix. Contaminant loss is minimized by reducing the surface area.

Technical Feasibility

Fixation is an effective method for reducing the mobility of contaminants, but does not reduce the toxicity or volume of contaminants.

The patented Chemfix solidification process, illustrated on Figure 4.6, employs silicate-based reagents and additives. There is considerable research data to suggest that silicates used together with lime,



SOURCE: CHEMFIX TECHNOLOGIES INC.

figure 4.6

FIXATION TECHNOLOGY
CONCEPTUAL FLOW DIAGRAM
HASSAYAMPA LANDFILL
Maricopa County, Arizona

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cement or other setting agents can stabilize a wide range of materials, including metals, waste oil and solvents. However, the feasibility of using silicates must be determined on a site-specific basis. This is best done with a treatability study on the particular characteristic waste under consideration (USEPA, October 1985).

Fixation or solidification is usually applied to the treatment of contaminants which cannot be treated by other technologies for contaminant reduction. Soils having VOC or SVOC contamination are often treated by other technologies such as venting or bioremediation.

Public Health and Environmental Screening

Since fixation is feasible for only the excavated soils from Pit 1, the public health and environmental screening concerns are similar to those presented for the waste removal option (Section 4.1.5).

Given the above, fixation/solidification is not considered a promising technology to overall soil remediation at the hazardous waste area. However, this technology may also be used in conjunction with off-site incineration should the fixation of metals within the incinerated soil be required.

4.1.7.3 Soil Washing

Soil washing could be conducted on excavated wastes and involves contacting the wastes with water to partition the contaminants from the solid phase to the liquid phase. Excavated wastes would be slurried with water to remove contaminants from the wastes and pumped through a filter press to separate the solids from the wastes. The contaminated water is then collected for treatment. Decontaminated soils would then be backfilled into Pit 1.

Technical Feasibility

Soil washing is feasible for only excavated wastes from Pit 1. Soil flushing (in situ soil washing) is deemed infeasible for treatment of soils since adding water to the 80 feet of soils would cause potential groundwater contamination beneath the pits through the infiltration of contaminated wash waters.

The effectiveness of soil washing with water is determined by the solubility of the chemical compound, the tendency of a compound to adsorb to waste or soil, the porosity of waste and the contact time between waste and water. Table 4.2 lists the initial waste concentrations, the partitioning coefficient (Koc) and the solubility of each compound. The natural organic carbon content of excavated wastes ranges from 0.71 to 0.82 percent which is considered to provide little adsorption of most compounds onto waste. As such, solubility and the initial contaminant

TABLE 4.2

TREATABILITY EVALUATION FOR SOIL WASHING
HASSAYAMPA FEASIBILITY STUDY

Compound	*Representative Waste Concentration (Pit 1) (mg/kg)*	*Partitioning Coefficient Koc (mL/g)*	*Water Solubility (mg/L)*	*Probability of Successful Treatment by Soil Washing*
<u>VOCs</u>				
o,p - dichlorobenzene	95.5	--	--	--
1,1 - dichloroethane	ND	30	5500	H
1,1 - dichloroethene	28	65	2250	H
dichloromethane	16.3	--	--	--
dimethyl benzenes (xylene - total)	74	240	198	M
dimethyl ketone (acetone)	ND	2-2	1000000	H
ethylbenzene	ND	1100	152	M
methyl benzene (toluene)	23	535	300	M
methyl ethyl ketone	ND	4.5	2680000	H
tetrachloroethene	496	364	150	M
1,1,1 - trichloroethane	847	152	1500	H
1,1,2 - trichloroethane	11.5	56	4500	H
trichloroethane	100	126	1100	H
trichlorotrifluoroethane	19	--	--	--

TABLE 4.2

TREATABILITY EVALUATION FOR SOIL WASHING HASSAYAMPAFEASIBILITY STUDY

Compound	*Representative Waste Concentration (Pit 1) (mg/kg)*	*Partitioning Coefficient KOC (mL/g)*	*Water Solubility (mg/L)*	*Probability of Successful Treatment by Soil Washing*
SVOCs				
bis(2-ethylhexyl)phthalate	12.7	7244	0.4	L
1,2-dichlorobenzene	170	1700	100	M
1,4-dichlorobenzene	15.0	--	--	--
2-methylnaphthalene	160	--	--	--
2-methylphenol	117.5	--	--	--
naphthalene	ND	1070	31.7	M
phenanthrene	ND	--	--	--
phenol	ND	14.2	93000	H

Notes:

ND - not detected
mg/kg - milligrams/kilogram
-- - no data available
H - ranked as high
M - ranked as medium
L - ranked as low

Sources:

Superfund Public Health Evaluation Manual;
October 1986, Appendix C.
Reference Constants for Priority Pollutants and Selected Chemicals;
Arthur D. Little Inc., March,1981.

concentration are the primary indicators of the potential success for remediation.

The probability of successful treatment by soil washing is categorized as follows:

- high probability of successful treatment (H) for a solubility greater than 1,000 mg/L.
- moderate probability of successful treatment (M) for a solubility from 1 to 999 mg/L.
- low probability of successful treatment (L) for a solubility less than 1 mg/L.

This technology can be enhanced by the use of surfactants to increase contaminant removal.

The soil washing process is associated with the generation of a waste water stream which must be collected and treated off-site.. This treatment can include such technologies as incineration and biological degradation.

Table 4.2 demonstrates that soil washing would be effective for a significant portion of the contaminants found in Pit 1.

Public Health and Environmental Screening

Since soil washing is feasible only for excavated wastes from Pit 1, the public health and environmental concerns are similar to those presented for the waste removal option (Section 4.1.5).

Soil washing will be carried through for inclusion in the development or remedial alternatives.

4.1.7.4 Bioremediation

This technology uses biodegradation techniques to degrade the contaminants in the waste or permit them to volatilize into the air. The basic concept involves providing a favorable environment to enhance microbial metabolism of organic contaminants resulting in the breakdown and detoxification of those contaminants. Bioremediation could be applied to excavated wastes from Pit 1.

Technical Feasibility

Bioremediation can be conducted by Liquid-Solids Treatment (LST) followed by landfarming. LST treatment consists of slurrying the wastes with water in a batch reactor and then seeding the slurry with microbes. LST pretreatment provides odor control and the initiation of biological breakdown of contaminants. The slurry is then pumped onto the landfarm for further biodegradation. The area required for bioremediation would be approximately one acre (assuming the landfarm is located at the hazardous waste area). Landfarming is commonly conducted using a soil/waste thickness of one foot; Landfarming would be feasible for the wastes in Pit 1 only because of the pit volume and high degree of contamination. Bioremediation would be conducted over a period of one to two years. The length of treatment time would be confirmed in treatability studies. Remediation of each batch would be confirmed by sampling and analysis.

A treatability evaluation of Pit 1 contaminants is presented in Table 4.3. As shown, most of the principal contaminants could be successfully bioremediated.

Disadvantages associated with the landfarming of excavated wastes of Pit 1 are:

- it is not effective for the treatment of metals;
- it is only able to treat a small volume of pit contents (i.e. Pit 1 only);
- waters from the LST process would require treatment and/or disposal thereby inhibiting of microbial growth; and
- the desert environment would cause extensive evaporation of landfarm waters thus requiring constant irrigation.

Public Health and Environmental Screening

Since bioremediation is applicable only to excavated waste from Pit 1, the public health and environmental concerns are similar to those presented for the waste removal option (Section 4.1.5).

TABLE 4.3

TREATABILITY EVALUATION FOR BIOREMEDIATION
HASSAYAMPA FEASIBILITY STUDY

Compound	*Representative Waste Concentration (Pit 1) (mg/kg)*	*Probability of Successful Treatment by Bioremediation*	*Probability of Airborne Emissions During Bioremediation*
VOCs			
1,1,1-trichloroethane	847	L	H
1,1,2-trichloroethane	11.5	L	H
trichloroethene	100	L	H
tetrachloroethene	496	L	H
1,1-dichloroethene	28	M	H
dimethylbenzenes (xylene - total)	74	M	H
ethylbenzene	ND	H	H
1,1-dichloroethane	ND	M	H
dimethyl ketone (acetone)	ND	H	H
methyl ethyl ketone	ND	--	H
SVOCs			
bis(2-ethylhexyl)phthalate	12.7	--	L
1,2-dichlorobenzene	170	H	H
naphthalene	ND	--	--
2-methyl naphthalene	160	--	--
phenol	ND	H	H

Notes:

ND - not detected
mg/kg - milligrams/kilogram
-- - no data available
H - ranked as high
M - ranked as medium
L - ranked as low

Sources:

Remediation Technologies,Inc.,memorandum January 16, 1990.

Due to the above technical disadvantages, bioremediation is considered infeasible for treating contaminants in Pit 1.

Bioremediation in conjunction with soil washing described in Section 4.1.4 is possible. This would require premixing a bacterial colony and nutrients with water before application to the excavated soils. This technology is experimental and would require a pilot demonstration. However, it would only be feasible for Pit 1 wastes and possesses the same performance concerns as LST based bioremediation. It is therefore considered not feasible.

4.1.7.5 Soil Vapor Extraction

The vapor extraction process is a technique that removes and vents VOCs and some SVOCs from the unsaturated zone. This technology would involve the installation of extraction vents above the surface of the basalt within the waste and soils similar to the conventional method of landfill gas extraction.

Technical Feasibility

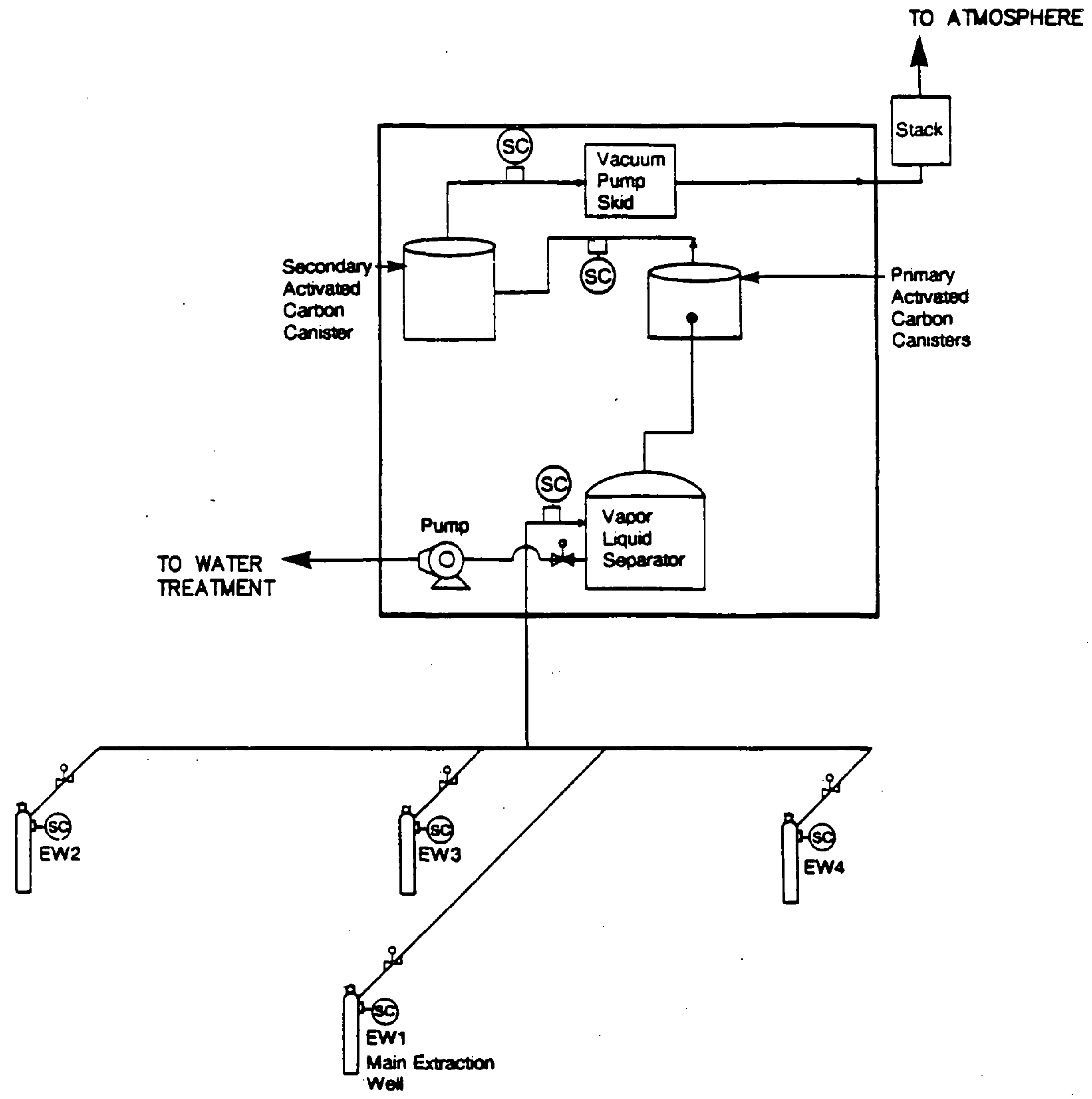
Extraction vents would be installed within the wastes in Pit 1 and the soils in Pit 1 and in the Special Pits area. A vacuum system induces air flow through the soil, stripping and volatilizing the VOCs from the soil matrix into the air stream. Water in the air stream condensed then is separated from the air stream and is transferred to a water treatment system or to waste. The contaminated air stream then flows through an air and vapor treatment system such as two activated carbon units arranged in a series or a catalytic oxidation system. Spent carbon canisters would have to be removed for off-site regeneration or incineration. An example of an equipment layout is shown on Figure 4.7. Table 4.4 presents a treatability evaluation by venting for contaminated soils in Pit 1.

Soil vapor extraction can be considered technically feasible and selected for implementation if the vapor pressure of the target contaminants equals or exceeds 10 mm Hg. (USEPA, March 1991). Based on the data presented in Table 4.4, soil vapor extraction is considered technically feasible for the hazardous waste area.

Treatment costs for venting are approximately $150/ton of contaminated soils which is cost effective if supplemental treatment for other contaminants is not required.

Public Health and Environmental Screening

This technology would reduce the concentrations of VOCs in the wastes and soils thereby effectively eliminating the future potential transport of VOCs to groundwater and associated future potential exposure under all current and hypothetical future land use scenarios. The potential risks associated with exposure to buried wastes from Pit 1 are also significantly mitigated.



SOURCE: SITE REPORT TERRA VAC IN – SITU
VACUUM EXTRACTION SYSTEM

NOTES:
SC – SAMPLING COCK
EW – EXTRACTION WELL

figure 4.7

SOIL VAPOR EXTRACTION
SAMPLE EQUIPMENT LAYOUT
HASSAYAMPA LANDFILL
Maricopa County, Arizona

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TABLE 4.4

TREATABILITY EVALUATION FOR SOIL VAPOR EXTRACTION HASSAYAMPA FEASIBILITY STUDY

Compound	*Representative Waste (Pit 1) Concentration (mg/kg)*	*Representative Soil (Pit 1) Concentration (mg/kg)*	*Vapor Pressure (mm/Hg)*	*Henry's Law Constant (atm m^3/mol)*	*Probability of Successful Treatment by Soil Venting*
<u>VOCs</u>					
o,p-dichlorobenzne	95.5	2.24	2.28	3.59×10^{-3}	--
1,1-dichloroethane	ND	7.01	182 (volatile)	4.31×10^{-3} (high volatility)	H
1,1-dichloroethene	28	175.3	600 (volatile)	3.40×10^{-2} (high volatility)	H
dichloromethane	16.3	151.2	362	2.03×10^{-3}	--
1,2-dichloropropane	ND	29.0	42	2.31×10^{-3}	--
dimethyl benzenes (total xylenes)	74	69.7	10 (volatile)	7.04×10^{-3} (high volatility)	H
dimethyl ketone (acetone)	ND	416	270 (volatile)	2.06×10^{-5} (high volatility)	H
ethylbenzene	ND	14.2	7 (volatile)	6.43×10^{-3} (high volatility)	H
methyl benzene	23	109.4	2.81	6.371×10^{-3}	--
methyl ethyl ketone	ND	89.8	77.5 (volatile)	2.74×10^{-5} (high volatility)	H
tetrachloroethene	496	184.2	17.8 (volatile)	2.59×10^{-2} (high volatility)	H
1,1,1-trichloroethane	847	3,699	123 (volatile)	1.44×10^{-2} (high volatility)	H
1,1,2-trichloroethane	11.5	2.38	30 (volatile)	1.17×10^{-3} (high volatility)	H
trichloroethene	100	107	57.9 (volatile)	9.1×10^{-3} (high volatility)	H
trichlorotrifluoroethane	19	1,556	--	--	--

TABLE 4.4

TREATABILITY EVALUATION FOR SOIL VAPOR EXTRACTION HASSAYAMPA FEASIBILITY STUDY

Compound	*Representative Waste (Pit 1) Concentration (mg/kg)*	*Representative Soil (Pit 1) Concentration (mg/kg)*	*Vapor Pressure (mm/Hg)*	*Henry's Law Constant (atm m^3/mol)*	*Probability of Successful Treatment by Soil Venting*
SVOCs					
bis(2-ethylhexyl)phthalate	12.7	5.23	2×10^{-7} (non-volatile)	2.57×10^{-7} (non-volatile)	L
1,2-dichlorobenzene	170	2.16	1.0 (volatile)	1.93×10^{-3} (high volatility)	H
1,4-dichlorobenzene	15.0	ND	1.18	2.89×10^{-3}	--
2-methyl naphthalene	160	1.66	--	--	--
2-methylphenol	117.5	ND	--	--	--
4-methylphenol	ND	0.33	--	--	--
naphthalene	ND	1.35	9.0×10^{-2} (volatile)	4.78×10^{-4} (high volatility)	H
phenanthrene	ND	ND*	6.80×10^{-4}	1.59×10^{-4}	--
phenol	ND	4.92	0.34 (semi-volatile)	4.54×10^{-7} (volatile)	M
pyrene	ND	ND*	2.50×10^{-6}	5.04×0^{-6}	--

Notes:

ND	-	not detected
ND*	-	trace amounts confirmed,below detection limit
mg/kg	-	milligrams/kilogram
mm Hg	-	millimetres mercury
atm m^3/mol	-	atmospheres metre cubed/mole
--	-	no data available
H	-	high probability of successful treatment
M	-	medium probability of successful treatment
L	-	low probability of successful treatment

Compounds with Henry's Law Constant less than 3×10^{-7} atm m^3/mol are considered to be non-volatile.

Sources: Superfund Public Health Evaluation Manual; Appendix C, October 1986.
Reference Constants for Priority Pollutants and Selected Chemicals;
Arthur D. Little, Inc., March 1981.

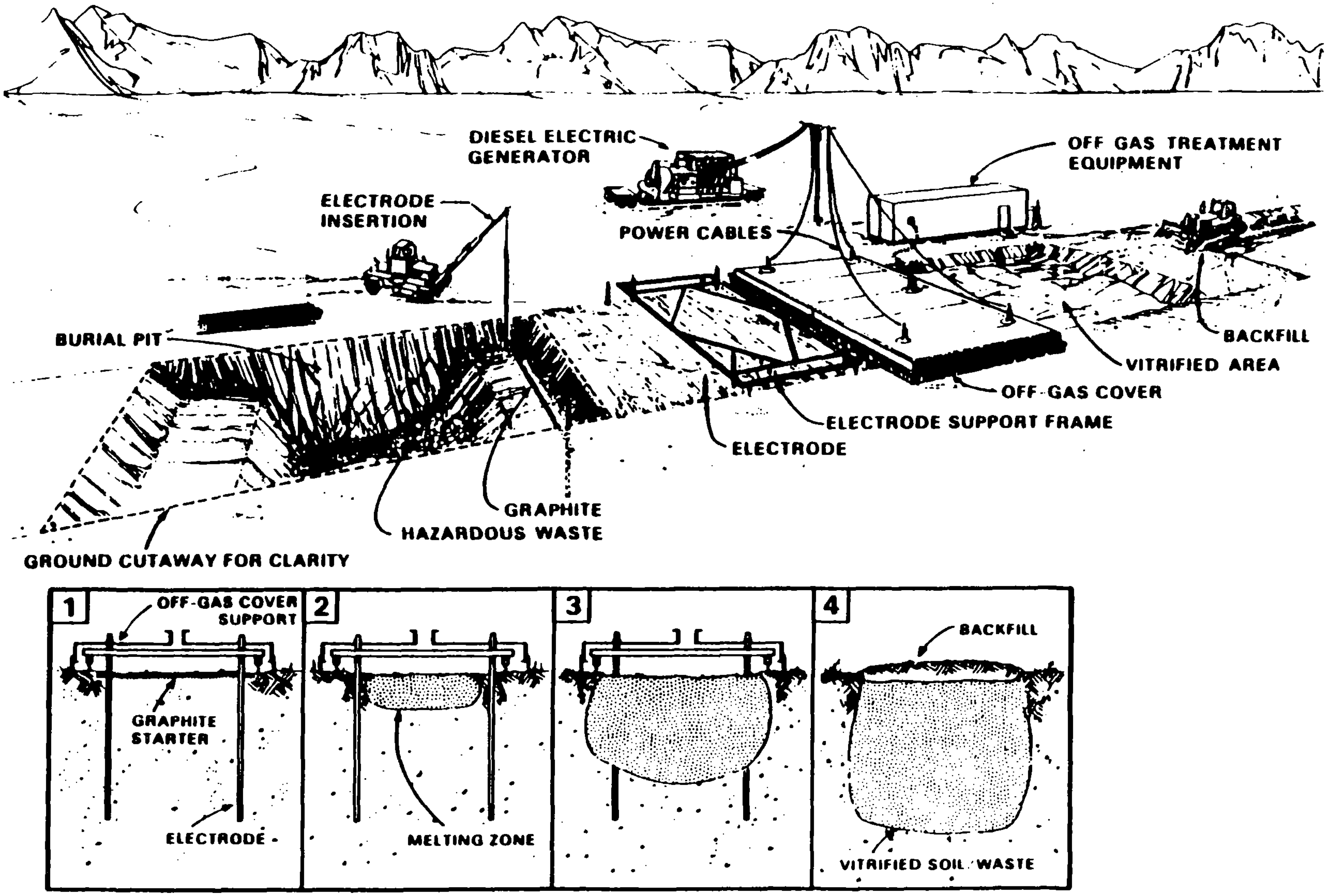
The soil contamination at the hazardous waste area has been found to be largely organic in nature, and the major portion of the contamination was determined to be volatile, so this technology would be feasible for the hazardous waste area.

4.1.7.6 Vitrification

Soil vitrification is a form of stabilization technology, achieving contaminant immobility by producing a block of waste with high structural integrity. The process uses an electric current that is passed between electrodes placed in the ground. It converts soil and contained materials to a stable glass material. Heat from the electric current melts the soil and rocks and decomposes organic materials. During the process, metallics and other inorganic materials are dissolved into or are encapsulated in the vitrified mass. Gases evolve from the melt or go into solution. Convective currents within the melt uniformly mix materials that are present in the soil. When the electric current ceases, the molten volume cools and solidifies (Battelle, 1988). Figure 4.8 provides a schematic of the process.

Technical Feasibility

Vitrification has not yet been fully demonstrated on a wide range of wastes and, when implemented, it has been extremely costly. Capital costs for vitrification of a one-acre landfill with contamination extending 20 feet deep were estimated at $22 million (in 1984), assuming



SOURCE: BATTELLE PACIFIC NORTHWEST LABORATORIES

figure 4.8

IN-SITU VITRIFICATION
SCHEMATIC OF TECHNOLOGY
HASSAYAMPA LANDFILL
Maricopa County, Arizona

CRA

2141-10/10/91-12-0

off-site generation of power (USEPA, 1985). It has been applied to highly toxic or radioactive wastes and its feasibility must be determined on a case by case basis (USEPA, 1985).

Public Health and Environmental Screening

If technically effective, vitrification would result in a significant reduction in potential risks to public health and the environment. This reduction would be associated with immobility of the wastes and reduced exposure potential.

Contaminants at the hazardous waste area are neither highly toxic nor radioactive and can be readily treated by more conventional means. Therefore, vitrification is not feasible for the hazardous waste area.

4.1.7.7 Thermal Desorption

Thermal Desorption (TD) technology encompasses processes that are essentially physical separations based on the differences in vapor pressure between the organic contaminants and the contaminants' matrix.

Technical Feasibility

Heating is used to increase the relative volatilities between the contaminants and the matrix enough to cause vaporization of the organics and moisture into a gas stream. The gas stream is usually an inert gas which is used to lower the oxygen content in the desorber (heater) which will result in the inhibition of combustion reactions. Temperatures used for TD are related to the contaminants boiling points and range up to 1,000°F. TD is the selected remedy for one or more operable units at eight USEPA Superfund sites. Extensive research and development of TD technology in lab, pilot and full-scale remediation application is ongoing.

Figure 4.9 presents a general flow diagram for the thermal desorption process. The wastes usually are dewatered and screened to remove oversize (>2-inch) particles prior to processing. After the contaminants and water are vaporized into the gas stream in a TD process, the gas stream is treated for particulate removal. The vapors are then cooled to low temperatures to condense organics and water out as a liquid mixture. The organics are separated (by gravity) from the water and must be treated further to complete remediation (e.g. by incineration). The separated water is generally treated by carbon adsorption usually to allow discharge to surface or groundwater.

The dry carrier gas after particulate removal and cooling is treated by scrubbers and carbon adsorption to allow venting into the atmosphere or recycling to the desorber. The treated solid matrix from the desorber contains low volatility inorganic compounds, e.g. metals. The metals will be concentrated in the treated solids depending on the amount of water and organics in the untreated solids.

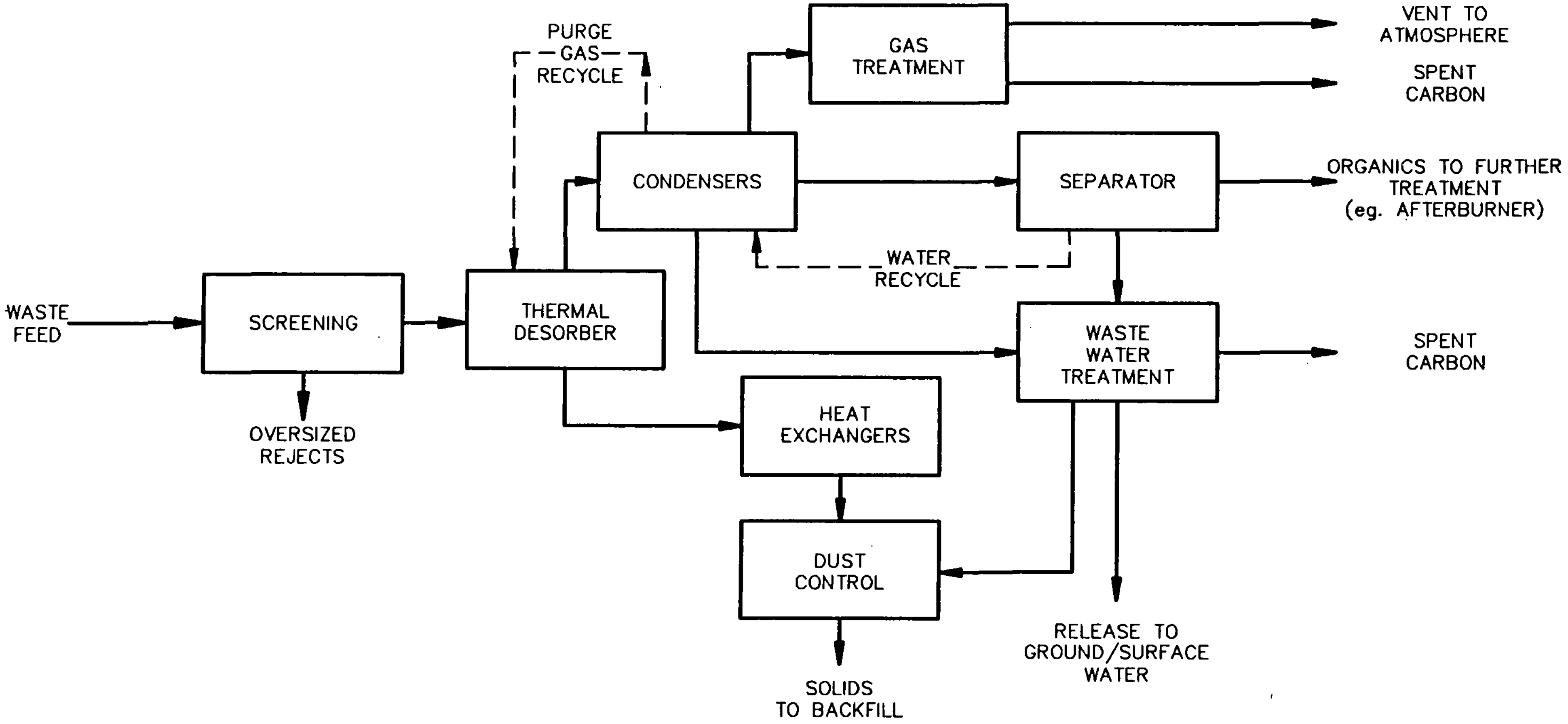


figure 4.9

THERMAL DESORPTION PROCESS
GENERAL FLOW DIAGRAM
HASSAYAMPA LANDFILL
Maricopa County, Arizona

CRA

2141–10/10/91–12–0 (C–02)

The TD process has been successfully applied to solids, sludges, sediments and filter cakes which contain greater than 10 percent organics and less than 30 percent solids. Contaminants that have been successfully treated by TD in laboratory, pilot or full-scale processes include VOCs, SVOCs, polyaromatic hydrocarbons (PAHs), PCBs, dioxins and petroleum contaminates wastes. Treated solids can usually be backfilled on site if the soil passes TCLP analytical testing.

Table 4.5 presents an evaluation of the ability of TD to treat wastes located in Pit 1. As shown, the majority of the contaminants can be successfully treated by thermal desorption.

Decontaminated waste would be backfilled into Pit 1. Should the metals content in the decontaminated waste exhibit a hazardous characteristic, pretreatment of the waste by solidification may be required prior to backfilling.

Collected organics require further remediation. Possible remediation alternatives for the collected organics include:

- off-site incineration at Aptus facility, located near Salt Lake City, Utah;
- on-site vapor incineration in an afterburner in-line with the TD unit;
- fuel reclamation at the Amereco Phoenix facility, located in Phoenix, Arizona; and
- off-site disposal at the Kettleman Hills facility located near Kettleman City, California.

TABLE 4.5

TREATABILITY EVALUATION FOR THERMAL DESPORPTION
HASSAYAMPA FEASIBILITY STUDY

Compounds	*Representative Waste Concentration (Pit 1) (mg/kg)*	*Probability of Successful Treatment By Thermal Desorption*
VOCs		
o,p-dichlorobenzene	95.5	H
1,1-dichloroethane	ND	H
1,1-dichloroethene	28	H
dichloromethane	16.3	H
1,2-dichloropropane	ND	H
dimethylbenzenes (xylenes)	74	H
dimethylketone (acetone)	ND	H
ethylbenzene	ND	H
methylbenzene (toluene)	23	H
methyl ethyl ketone (2-butanone)	ND	H
tetrachloroethene	495.5	H
1,1,1-trichloroethane	84.7	H
1,1,2-trichloroethane	11.5	H
trichloroethene	100	H
trichlorotrifluoroethane	19	H
SVOCs		
bis(2-ethylhexyl)phthalate	12.7	H
1,2-dichlorobenzene	170	H
1,4-dichlorobenzene	15.0	H
2-methyl naphthalene	160	H
2-methylphenol	117.5	H
4-methylphenol	ND	H
naphthalene	ND	H
phenanthrene	ND	H
phenol	ND	H
pyrene	ND	H

Notes:

mg/kg - milligrams/kilogram
VOC - Volatile Organic Compound
SVOC - Semi-Volatile Organic Compound
H - High probability of successful treatment by thermal desorption.

Estimated treatment costs for TD are approximately $250/ton. This cost could be confirmed by treatability studies on waste samples from Pit 1.

The treatment rate for a full-scale TD unit is estimated to be 600 tons/week. Therefore, to treat wastes within Pit 1 would take approximately four weeks. Site preparation, mobilization and testing would take approximately four months.

Public Health and Environmental Screening

Since TD is feasible for the excavated wastes from Pit 1, the public health and environmental concerns are similar to those presented for the waste removal option (Section 4.1.5).

Since waste volumes to be treated are relatively small, collected organics would require further remediation. Since TD is still in its development stages, TD is not considered appropriate for treatment of contaminants at the hazardous waste area.

4.1.7.8 Summary of Soil Treatment Technologies

Seven treatment technologies were evaluated for soil remediation. These were:

- incineration (on site and off site);

- fixation/solidification;
- soil washing and soil flushing ;
- bioremediation (landfarming);
- vitrification;
- soil vapor extraction; and
- thermal desorption.

One technology, in situ vitrification, is clearly impractical, and as such is eliminated from further consideration.

On-site incineration is considered feasible for treatment of wastes in Pit 1 only.

Fixation/solidification was considered not to be feasible as a primary treatment method. Fixation/solidification is considered practical for to areas within the wastes that are liquid in nature and/or for treatment of inorganic contaminants, such as immobilization of metals in treated wastes.

Ex-situ soil washing of excavated wastes from Pit 1 is preferred over in situ soil flushing since the latter could potentially promote contamination of groundwater beneath the pits.

Bioremediation via LST pretreatment and landfarming was eliminated due to LST water disposal/treatment and irrigation requirements for the landfarm.

Bioremediation in combination with soil washing is a potential remedial technology for the hazardous waste area. Pilot studies would be required to demonstrate its effectiveness. However, this technology possesses the same negative aspects as bioremediation and is, therefore, not considered feasible.

Soil vapor extraction is considered infeasible for the hazardous waste area and would be able to treat both wastes and soils.

Thermal desorption (TD) is considered feasible due to the small waste volumes to be treated, the potential requirement for fixation or solidification of treated wastes, the required further remediation of collected organics, and the experimental stage of the technology involved.

Given the above, the following technologies will be incorporated into the remedial alternatives to be considered further:

- on-site incineration;
- soil vapor extraction;
- soil washing; and
- stabilization of areas of high contamination within the wastes and/or incinerated soil, if required.

4.2 SUMMARY OF WASTE AND SOIL REMEDIATION TECHNOLOGIES

Table 4.6 summarizes waste and soil remediation technologies which were considered, and identifies the technologies which are considered acceptable for use in the development of remedial alternatives. Also included in Table 4.6 are the estimated capital costs and present worth of operation and maintenance costs for each alternative using a 5 percent discount rate and a 30 year operating period.

4.3 GROUNDWATER REMEDIATION TECHNOLOGIES

Appendix A discusses groundwater remediation technologies. The proposed groundwater treatment technology will consist of groundwater extraction, treatment by air stripping, and reinjection of treated groundwater or disposal of the treated water in the PVNGS effluent pipeline. This technology is considered the preferred groundwater remediation technology and will be used in all alternatives which require groundwater remediation. Groundwater remediation includes a monitoring program to ensure the extent and amount of contamination can be continuously reviewed.

TABLE 4.6

EVALUATION OF WASTE AND SOIL REMEDIAL ACTION TECHNOLOGIES HASSAYAMPA FEASIBILITY STUDY

Remedial Action Technology	*Feasible for the hazardous waste area*	*Technical and Public Health Screening*	*Estimated Cost*
A.1 No Action	Yes	Levels and extent of contamination are not currently known. Must be carried through to detailed analysis. Under current exposure scenarios, no unacceptable risks present. Future migration and potential exposures unaddressed.	$ 0
A.2 Deed Restriction	Yes	Restricts future land use of area affected by contamination. Under current exposure scenarios, no unacceptable risks present. Future migration and potential exposures unaddressed.	$ 7,000
A.3 Access Restriction (upgrade Site fencing)	Yes	Prevent unauthorized access into contaminated areas. Under current exposure scenarios, no unacceptable risks present. Future migration and potential exposures unaddressed.	$ 8,000
A.4 Capping (entire hazardous waste area or Pit 1 only)	Yes	Reduction of surface water infiltration, prevents exposure to surficial contaminants, incidental ingestion, off-site migration by surface water runoff or wind dispersion. Improved protection against exposure to buried waste. Future migration and potential exposures unaddressed.	$ 946,000
A.5 Removal (excavation)	Yes	Removal of Pit 1 waste results in significant reduction in potential exposure under all scenarios. Potential future migration of contaminants to groundwater unaddressed.	$ 84,000
A.6 Disposal in RCRA Landfill (off-site)	No	Secures waste and minimizes future migration of contaminants. Not feasible for wastes within Pit 1 due to RCRA land disposal restrictions. Removal of Pit 1 waste results in significant reduction in potential exposure under all scenarios. Potential future migration of contaminants to groundwater partially unaddressed.	$ 1,208,000
A.7 Soil Treatment a) Incineration - off-site (Pit 1 wastes only)	No	Provides destruction of organic wastes and would be conducted off-site. Imported soils would be required to backfill Pit 1. Removal of Pit 1 waste results in significant reduction in potential exposure under all scenarios. Potential future migration of contaminants to groundwater partially unaddressed. Not cost effective compared to on-site incineration.	$ 6,641,000
Incineration - on-site (Pit 1 wastes only)	Yes	Provides destruction of organic wastes and would be conducted on-site. Treated wastes may require solidification due to metals content. Potential future migration of contaminants to groundwater partially unaddressed. Removal of Pit 1 waste results in significant reduction in potential exposure under all scenarios.	$ 3,770,000

TABLE 4.6

EVALUATION OF WASTE AND SOIL REMEDIAL ACTION TECHNOLOGIES HASSAYAMPA FEASIBILITY STUDY

Remedial Action Technology	*Feasible for the hazardous waste area*	*Technical and Public Health Screening*	*Estimated Cost*
A.7 Soil Treatment (continued)			
b) Fixation/Solidfication	No	Not feasible as a primary treatment method. This technology could be used in conjunction with incineration or thermal desorption to secure inorganic contaminants in the ash. Removal of Pit 1 waste results in significant reduction in potential exposure under all scenarios. Potential future migration of contaminants to groundwater unaddressed.	$ 2,250,000
c) Soil Washing (Pit 1 wastes only)	Yes	Removes contaminants from soil and waste. Solvent must be collected and disposed of or treated. Can be used in combination with bioremediation (i.e. feeding excavated wastes with bacterial colony and nutrients). Removal of Pit 1 waste results in significant reduction in potential exposure under all scenarios. Potential future migration of contaminants to groundwater partially unaddressed.	$ 853,000
d) Bioremediation (LST pretreatment and landfarming)	No	Limited to wastes which are biologically degradable or are readily volatilized. Odors and vapors are expected to be managed by an LST system. Bioremediation considered infeasible due to landfarm and LST maintenance costs and irrigation requirements. Removal of Pit 1 waste results in signifcant reduction in potential exposure under all scenarios. Potential future migration of contaminants to groundwater partially unaddressed.	$ 3,000,000
e) Soil Vapor Extraction (Pit 1 and Special Pits)	Yes	Treats VOCs which are the majority of contaminants. Able to treat both soil and wastes. Potential exposures and migration of contaminants addressed in both soil and wastes.	$ 2,085,000
f) Vitrification	No	Cost prohibitive, not proven technology. Potential exposures and migration of contaminants addressed in both soil and waste.	$ 10,000,000
g) Thermal desorption	No	Relatively new technology. Removal of Pit 1 wastes results in significant reduction in potential exposure under all scenarios. Potential future migration of contaminants to groundwater partially unaddressed. Eliminated due to small volume of wates to be treated, the necessity for further remediation of collected organics, and treated wastes may require solidification due to metals content.	$ 5,400,000

5.0 PRELIMINARY LIST OF REMEDIAL ALTERNATIVES

5.1 SOIL AND WASTE REMEDIAL ALTERNATIVES

Based on the screening of procedural components and technologies (Section 4.0) available for the remediation of soils and wastes from Pit 1 and the Special Pits, the feasible technologies have been selected. Table 5.1 lists the procedural components and treatment technologies, which will be evaluated in the FS, for the remediation of the hazardous waste area.

5.2 GROUNDWATER REMEDIATION ALTERNATIVES

Based on the screening of procedural components and technologies (Appendix A) available for the remediation of groundwater, the feasible technologies have been selected. Table 5.2 lists the applicable procedural components, treatment technologies, and discharge options which will be evaluated in the FS for the remediation of groundwater under the hazardous waste area.

TABLE 5.1

LIST OF REMEDIAL ALTERNATIVES - WASTE AND SOIL
HASSAYAMPA FEASIBILITY STUDY

Alternative	*No Further Action*	*Deed/Access Restriction*	*Cap*	*Removal*	*Soil Washing*	*On-site Incineration*	*Soil Vapor Extraction*
1.	X						
2.		X					
3.		X	X (1)				
4.		X	X (2)				
5.		X		X	X		
6.		X		X		X	
7.		X					X
8.		X		X		X	X
9.		X	X (2)				X
10.		X	X (2)	X	X		X

Notes:

(1) Entire hazardous waste area
(2) Pit 1 and Special Pits

TABLE 5.2

LIST OF REMEDIAL ALTERNATIVES - GROUNDWATER HASSAYAMPA FEASIBILITY STUDY

Alternative	*Extraction*	*Air Stripping*	*Reinjection*	*Disposal to PVNGS Pipeline*
1.	X	X	X	
2.	X	X		X

Notes:

PVNGS - Palo Verde Nuclear Generating Station

6.0 REFERENCES

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8. "National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule", Federal Register 40 CFR 300, March 8, 1990.
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14. "Handbook-Remedial Action at Waste Disposal Sites (Revised)", USEPA, Office of Emergency and Remedial Response, October 1985.

15. "Guidance on Remedial Actions for Contaminated Groundwater on Superfund Sites", USEPA 1988.

16. "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions", USEPA, Office of Emergency and Remedial Response, OSWER Directive No. 9355.0-30, 1991.

17. "Hassayampa Landfill ARARs", USEPA letter, October 11, 1991.

APPENDIX A

TECHNICAL ASSESSMENT
GROUNDWATER REMEDIATION
TECHNICAL SCREENING MEMORANDUM

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A.1.0 INTRODUCTION

This appendix presents and evaluates technologies to address existing groundwater contamination at the hazardous waste area of the Hassayampa Landfill (Landfill). Samples of the groundwater collected from several monitoring wells constructed in Unit A at the hazardous waste area have been observed during the Remedial Investigation (RI) (Montgomery and Associates (M & A) and Conestoga-Rovers and Associates (CRA), February 1991) to be contaminated with volatile organic compounds (VOCs). Several of the VOCs were present in samples in concentrations exceeding Federal drinking water standards [See Section 3.0 of the Technical Screening Memorandum (Memorandum)].

The RI has documented that vertical hydraulic gradients in Unit A at the hazardous waste area are negative (downwards) and the observed contamination in Unit A will eventually migrate into Unit B. The rate of migration is unknown. Units A and B are hydraulically connected and are sub units of the same aquifer. The uppermost part of Unit B is more permeable than Unit A.

Due to this significant potential of contaminant migration into Unit B and the potential for more rapid lateral migration in Unit B toward wells that supply potable water off of the hazardous waste area , this appendix presents an evaluation of remedial technologies and alternatives and recommends the implementation of a remedial alternative for groundwater. This appendix was prepared at the request of the Hassayampa Steering Committee (HSC) by CRA and M & A.

This appendix discusses applicable or relevant and appropriate requirements (ARARs) for the treatment and discharge of groundwater which were presented in Section 3.0 of the Memorandum, identifies as well as evaluates methods of extraction, treatment and discharge of groundwater, and also proposes a groundwater recovery and treatment system.

Section A.2.0 presents specific remedial objectives for groundwater and a groundwater contamination profile.

Section A.3.0 discusses groundwater extraction, treatment and discharge technologies, and evaluates the feasible technologies against the screening criteria of effectiveness, implementability, and cost.

Section A.4.0 presents the recommended groundwater extraction and treatment technology and discusses design considerations.

A.1.1 REMEDIAL OBJECTIVES

Remedial objectives for the extraction and treatment of groundwater at the hazardous waste area are as follows:

- to mitigate the transport of VOCs from Unit A to Unit B at the hazardous waste area and thereby eliminate the impact of contaminants on human health through exposure to more permeable parts of the aquifer which is a current drinking water source off-site;

- to provide protection of public health and the environment by effectively containing existing groundwater contamination;
- to select a remedy which satisfies ARARs;
- to provide practical, cost-effective groundwater remediation; and
- to utilize permanent remedies which are completed in a short time frame, where feasible.

The above remedial objectives are used as a set of performance standards against which groundwater extraction and treatment technologies are evaluated.

A.2.0 GROUNDWATER (ARARS)

A.2.1 SPECIFIC REMEDIAL OBJECTIVE - GROUNDWATER REMEDIATION

Health protective state and federal drinking water standards are considered to be applicable to groundwater remediation at the hazardous waste area.

The National Contingency Plan and USEPA guidance documents, which address the remediation of contaminated groundwater, discuss the concept of a compliance boundary or a point of compliance (USEPA, 1988; USEPA, 1989). These compliance boundaries are the locations where contaminant concentrations in groundwater may not exceed the hazardous waste area-specific ARARs. For purposes of determining compliance at the hazardous waste area, a compliance boundary of the downgradient Landfill property limit is proposed.

The specific remedial objectives for groundwater are shown in Table A.2.1. These objectives are based on maximum contaminant levels (MCLs) which are presented on Table A.2.2.

The USEPA's discharge limit of 15 pounds of VOCs per day will have to be considered in evaluating any discharges to air from groundwater remediation. Maricopa County (County) does not maintain specific regulations or guidelines which affect the atmospheric discharges from an air stripping system. The County regulates these discharges on a

TABLE A.2.1

SPECIFIC GROUNDWATER REMEDIAL OBJECTIVES
HASSAYAMPA FEASIBILITY STUDY

Compound	*Remedial Objective (µg/L)*
1,1-dichloroethene	7
1,1,1-trichloroethane	200
1,2-dichloroethane	5
1,2-dichloropropane	5
1,2-dichloroethene (cis)	70
1,2-dichloroethene (Trans)	100
tetrachloroethene	5
tribromomethane	20
trichloroethene	5

TABLE A.2.2

FEDERAL MCLs AND ARIZONA WATER QUALITY STANDARDS HASSAYAMPA FEASIBILITY STUDY

Compound	*USEPA MCL (µg/L)*	*AWQs (µg/L)*	*ADEQ MCL (µg/L)*
dichlorodifluoromethane	--	--	--
1,1-dichloroethene	7 (1,2)	7	7.0
1,1-dichloroethane	--	--	--
1,1,1-trichloroethane	200 (1,2)	200	200
1,2-dichloroethane	5 (1,2)	5	5.0
1,2-dichloroethene (cis)	70	--	--
1,2-dichloroethene (trans)	100	--	--
1,2-dichloropropane	5	--	--
acetone	--	--	--
chlorobenzene	--	--	--
trichlorofluoromethane	--	--	--
trichlorotrifluoroethane	--	--	--
methy ethyl ketone	--	--	--
methylene chloride	--	--	--
tetrachloroethene	5	--	--
toluene	--	--	--
tribromomethane	20 (3)	--	--
trichloroethene	5 (1,2)	5	5.0
xylenes (total)	--	--	--

Notes:

µg/L - micrograms per liter
USEPA MCL - Maximum Contaminant Levels USEPA National Primary and Secondary Drinking Water Regulations 40 CFR 141-3 (54 FR 22062) May, 1989
AWQs - Aquifer Water Quality Standards; R18 AAC-11-406
ADEQ MCL - Arizona Dept. of Environmental Quality Maximum Contaminant Level

Sources:

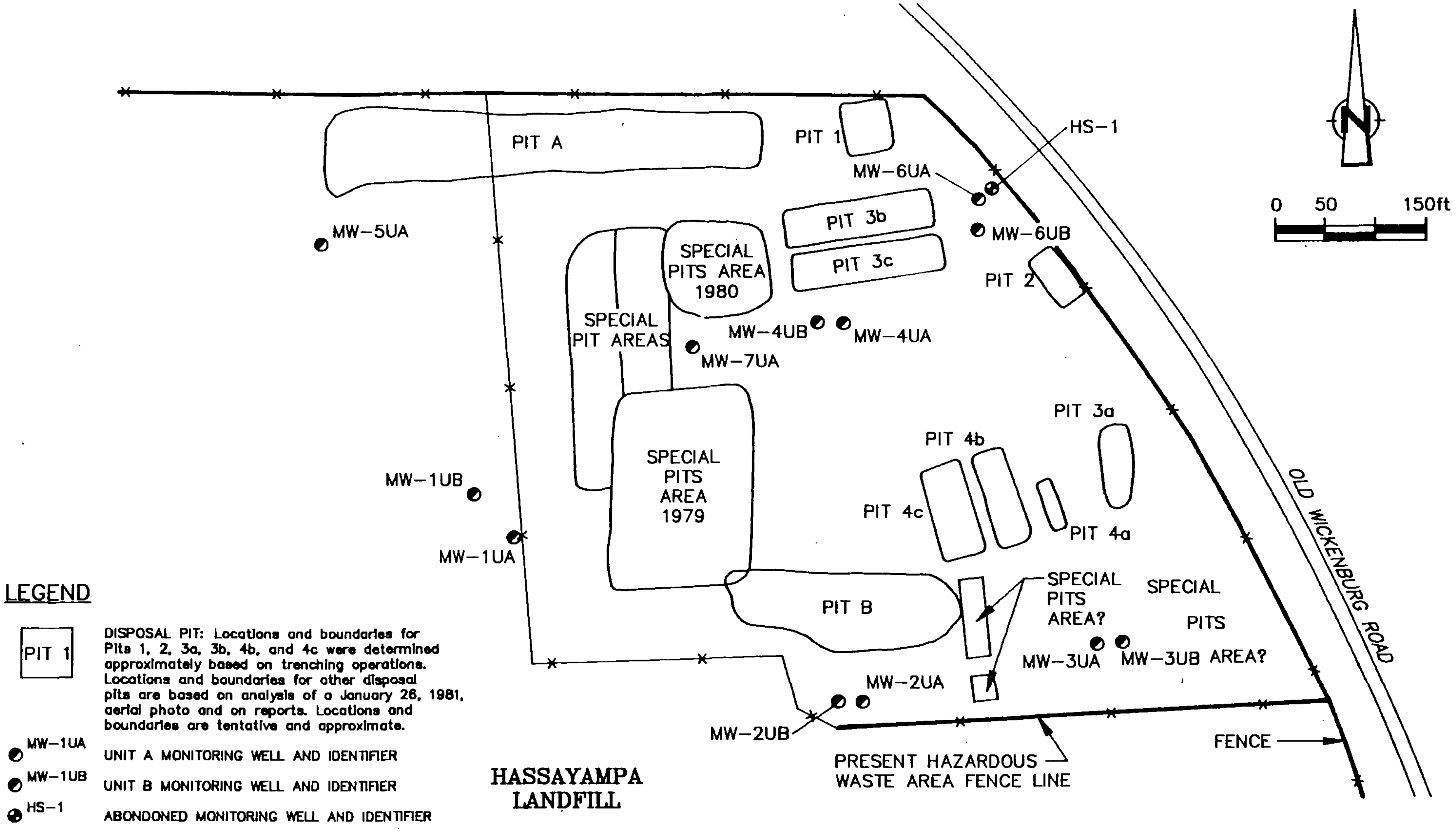
(1) Value confirmed on USEPA IRIS Database
(2) Drinking Water Regulations and Health Advisories, Office of Drinking Water USEPA
(3) The sum of trihalomethanes MCL = 70

case-by-case basis through the issuance of discharge permits. However, a County discharge permit may not be required for this treatment system.

A.2.2 GROUNDWATER CONTAMINATION PROFILE

Compounds of concern have been identified based on results of laboratory chemical analyses for groundwater and soil samples obtained during the RI. Results indicate that compounds of concern for groundwater, excluding laboratory contaminants, were detected and confirmed solely in groundwater samples obtained from Unit A monitor wells MW-1UA, MW-4UA, MW-5UA, and MW-6UA, and from abandoned ADHS monitor well HS-1. These wells are shown on Figure A.1.1. Concentrations of the compounds of concern detected in groundwater samples from all wells are presented in Table A.2.3 and a summary of the ranges of concentrations for the wells of concern are shown in Table A.2.4.

The evaluation of groundwater treatment technologies was based upon analytical data from samples collected from monitoring well HS-1. This well was selected because the highest levels of contamination were detected in samples from this well and because it is expected that groundwater from the zone surrounding this well may be subject to remediation since it exceeds the specific remedial objectives for groundwater. Table A.2.5 presents a representative contamination profile for use in the assessment of treatment technologies. Representative concentrations are based on the arithmetic mean of unqualified detections for all wells at the hazardous waste area except HS-1. Similarly, representative HS-1



DISPOSAL PIT: Locations and boundaries for Pits 1, 2, 3a, 3b, 4b, and 4c were determined approximately based on trenching operations. Locations and boundaries for other disposal pits are based on analysis of a January 26, 1981, aerial photo and on reports. Locations and boundaries are tentative and approximate.

UNIT A MONITORING WELL AND IDENTIFIER

UNIT B MONITORING WELL AND IDENTIFIER

ABONDONED MONITORING WELL AND IDENTIFIER

REFERENCE:
INFORMATION FOR BASE MAP
FROM ERROL L. MONTGOMERY
AND ASSOCIATES INC.

CRA

figure A.1.1

GROUNDWATER MONITORING WELL LOCATIONS
HASSAYAMPA LANDFILL
Maricopa County, Arizona

TABLE A.2.3

GROUNDWATER PROFILE - VOLATILE ORGANIC COMPOUNDS(1)
HASSAYAMPA FEASIBILITY STUDY

	Well Identifier Representative Concentration (µg/L)										
Compound	*MW-1UA*	*MW-1UB*	*MW-2UA*	*MW-2UB*	*MW-3UA*	*MW-3UB*	*MW-4UA*	*MW-4UB*	*Representative Concentration(2)*	*Design Concentration*	*USEPA MCL*
dichlorodifluoromethane (DCDFM)	0.16	ND	ND	ND	ND	ND	ND	ND	0.16	--	--
1,1-dichloroethane (1,1-DCA)	10.0	ND	ND	ND	ND	ND	ND	ND	7.1	25	--
1,2-dichloroethane (1,2-DCA)	ND	ND	ND	ND	ND	ND	ND	ND	ND	1,600	5
1,1-dichloroethene (1,1-DCE)	143.6	ND	ND	ND	ND	ND	0.3	ND	77.5	1,467	7
1,2-dichloroethene (1,2-DCE)	0.4	ND	ND	ND	ND	ND	ND	ND	0.4	320	70 (3)
1,2-dichloropropane (1,2-DCP)	0.25	ND	ND	ND	ND	ND	ND	ND	0.48	--	5
methyl ethyl ketone (MEK)	17	ND	19	ND	ND	ND	ND	ND	14.8	70	--
tetrachloroethene (PCE)	ND	ND	ND	ND	ND	ND	ND	ND	1.9	40	5
1,1,1-trichloroethane (TCA)	8.3	ND	ND	ND	ND	ND	ND	ND	8.7	623	200
trichloroethene (TCE)	0.3	ND	ND	ND	ND	ND	ND	ND	1.8	65	5
trichlorofluoromethane (Freon 11)	ND	ND	ND	ND	ND	ND	ND	ND	3.4	1,160	--
trichlorotrifluoroethane (Freon 113)	ND	ND	ND	ND	ND	ND	13.4	ND	39.6	150	--

Notes:

µg/L - micrograms per liter
MCL - Maximum Contaminant Levels
-- - Not available
ND - Not Detected, not confirmed

(1) Profile - the mean of unqualified detections and 1/2 detection limit where two or more detections occurred.
(2) Representative Concentration - mean of numeric profile concentrations for MW-1UA, MW-2UA, MW-3UA, MW-4UA, MW-5UA, MW-6UA, and MW-7UA.
(3) USEPA MCL shown is for 1,2-dichloroethene(cis).
(4) Methylene chloride, total xylenes, acetone, toluene, and methyl isobutyl ketone were detected but not confirmed in the RI or Supplemental Field investigative activites.

TABLE A.2.3

GROUNDWATER PROFILE - VOLATILE ORGANIC COMPOUNDS(1)
HASSAYAMPA FEASIBILITY STUDY

Compound	*Well Identifier Representative Concentration (µg/L)*							*Representative Concentration(2)*	*Design Concentration*	*USEPA MCL*
	MW-5UA	*MW-6UA*	*MW-7UA*	*MW-8UA*	*HS-1*	*HS-2*	*HS-3*			
dichlorodifluoromethane (DCDFM)	ND	ND	ND	ND	ND	ND	ND	0.16	--	--
1,1-dichloroethane (1,1-DCA)	ND	4.3	ND	ND	9.7	ND	ND	7.1	25	--
1,2-dichloroethane (1,2-DCA)	ND	ND	ND	ND	ND (4)	ND	ND	ND	1,600	5
1,1-dichloroethene (1,1-DCE)	0.6	88.6	ND	ND	744.4	ND	ND	77.5	1,467	7
1,2-dichloroethene (1,2-DCE)	ND	ND	ND	ND	ND	ND	ND	0.4	320	70 (3)
1,2-dichloropropane (1,2-DCP)	ND	0.7	ND	ND	ND	ND	ND	0.48	--	5
methyl ethyl ketone (MEK)	8.4	ND	ND	ND	ND	ND	ND	14.8	70	--
tetrachloroethene (PCE)	ND	1.9	ND	ND	10.0	ND	ND	1.9	40	5
1,1,1-trichloroethane (TCA)	ND	9.0	ND	ND	291.9	ND	ND	8.7	623	200
trichloroethene (TCE)	0.3	4.8	ND	ND	20.4	ND	ND	1.8	65	5
trichlorofluoromethane (Freon 11)	ND	3.4	ND	ND	39.7	ND	ND	3.4	1,160	--
trichlorotrifluoroethane (Freon 113)	1.6	103.7	ND	ND	142.6	ND	ND	39.6	150	--

Notes:

µg/L - micrograms per liter
MCL - Maximum Contaminant Levels
-- - Not available
ND - Not Detected, not confirmed

(1) Profile - the mean of unqualified detections and 1/2 detection limit where two or more detections occurred.
(2) Representative Concentration - mean of numeric profile concentrations for MW-1UA, MW-2UA, MW-3UA, MW-4UA, MW-5UA, MW-6UA, and MW-7UA.
(3) USEPA MCL shown is for 1,2-dichloroethene(cis).
(4) One detection of 1,2-dichloroethane at well HS-1 which is above the USEPA MCL.
(5) Methylene chloride, total xylenes, acetone, toluene, and methyl isobutyl ketone were detected but not confirmed in the RI or Supplemental Field investigative activites.

TABLE A.2.4

SUMMARY OF RANGES OF CONCENTRATIONS
VOLATILE ORGANIC COMPOUNDS (1)
HASSAYAMPA FEASIBILITY STUDY

	Well Identifier *Sample Concentration (µg/L)*				
Compound	*HS-1*	*MW-1UA*	*MW-4UA*	*MW-5UA*	*MW-6UA*
dichlorodifluoromethane	ND	ND - 0.4	ND	ND	ND
1,1-dichloroethene	111 - 2,000	ND - 547	ND - 0.4	ND - 1.8	ND - 266
trichlorotrifluoroethane (Freon 113)	ND - 610	ND	ND - 28	ND - 5.0	ND - 359
1,1,1-trichloroethane	32.2 - 1,500	ND - 25	ND	ND	ND - 46.2
1,1-dichloroethane	ND - 21	ND - 30	ND	ND	ND - 23.7
1,2-dichloropropane	ND	ND	ND	ND	ND - 2.6
trichloroethene	ND - 115	ND - 0.3	ND	ND - 0.2	ND - 30.3
tetrachloroethene	ND - 25	ND	ND	ND	ND - 11.4
trichlorofluoromethane (Freon 11)	ND - 190	ND	ND	ND	ND - 10.3
1,2-dichloroethene	ND	ND - 1.1	ND	ND	ND
1,2-dichloroethane	ND - 800 (3)	ND - 0.2 (3)	ND	ND	ND

Notes:

(1) Compounds exclude laboratory contaminants detected and confirmed in groundwater samples from monitoring wells.
(2) µg/L = micrograms per liter
(3) Compound detected, but not confimed.
(4) ND - Not detected

TABLE A.2.5

GROUNDWATER PROFILE
HASSAYAMPA FEASIBILITY STUDY

Compound	*Representative Concentration (µg/L)*	*Mean HS-1 Concentration (1) (µg/L)*	*Design Concentration (µg/L)*	*Remedial Objective (µg/L)*
1,1-dichloroethane	7.1	12.66	25	–
1,1-dichloroethene	77.5	733.8	1467	7
1,1,1-trichloroethane	8.7	311.83	623	200
1,2-dichloroethane (2)	ND	800	1600	5
1,2-dichloroethene	0.40	160	320	70 (3)
acetone	ND	–	38	–
chlorobenzene	–	13	26	–
trichlorotrifluoroethane	39.6	580	1160	–
trichlorofluoromethane	3.4	75	150	–
methyl ethyl ketone	14.8	–	70	–
methylene chloride	–	–	28	–
tetrachloroethene	1.9	19.56	40	5
toluene	0.92	–	6	–
tribromomethane	–	6	12	20
trichloroethene	1.8	32.55	65	5
xylenes (total)	ND	–	4	–

Notes:

(1) Mean of unqualified detections
(2) Detected, but not confirmed
(3) Remedial objective level shown is for 1,2-dichloroethene(cis)

concentrations were calculated using only unqualified detections. Since non-detect values are not used to determine these representative concentrations, the mean HS-1 and representative concentrations are therefore considered worst case concentrations. Design concentrations are based on the representative concentration for HS-1 multiplied by a safety factor of 2. The treatment flow rate used for design and evaluation purposes was 25 gallons per minute (gpm). The estimated flow is based on hydrogeological data and modeling which were provided by M & A and are presented in Appendix A.A.

The combination of the conservative design concentrations, a design safety factor, and a design flow rate that significantly exceeds the expected flow rate from extraction wells results in a treatment system design basis that provides substantial flexibility to treat substantial changes (increases) in influent concentrations.

A.3.0 IDENTIFICATION AND SCREENING OF GROUNDWATER REMEDIAL TECHNOLOGIES

A.3.1 EXTENT OF GROUNDWATER CONTAMINATION EXCEEDING ARARs

Groundwater contaminants of concern have been detected and confirmed above federal and state drinking water standards in existing Unit A monitoring wells MW-1UA and MW-6UA (replacement well for HS-1). If left unremediated, these zones of contamination would be expected to migrate with groundwater flow to the south. Contamination has not been detected and confirmed at monitoring wells HS-2, HS-3, MW-8UA, MW-9UA, and MW-10UA. Further, contamination has not been detected in MW-2UA and MW-3UA indicating that the contamination detected in MW-6UA has not migrated south of the hazardous waste area. Given that the detected levels of 1,1-dichloroethene were at least two orders of magnitude greater than the specific remedial objective, natural attenuation is not expected to provide remediation of the contamination. Hence, containment and recovery of contaminated groundwater is considered to be necessary.

A.3.2 HYDRAULIC CONTAINMENT AND RECOVERY

M & A have completed an assessment of the groundwater extraction design option and reinjection technology options. This assessment is presented in Appendix A.A.

A.3.3 GROUNDWATER TREATMENT

Nine groundwater treatment technologies were considered for application at the hazardous waste area as shown in Table A.3.1. Table A.3.2 summarizes an evaluation of the removal efficiency of the six retained treatment technologies for contaminants found in wells MW-1UA and HS-1 using the Water Engineering and Research Laboratory (WERL), (USEPA 1989) data base. Appendix A.B presents individual treatment data for the compounds of concern.

Data from Tables A.3.1 and A.3.2 were used to screen groundwater treatment technologies to determine which technologies are suitable for further evaluation. Results of this screening indicate that several technologies are not suited to treat the contaminants in groundwater at the hazardous waste area on a technical feasibility or cost basis. The following technologies are considered feasible for the hazardous waste area and thus require further analysis: ultraviolet (UV) oxidation; air stripping; and carbon adsorption.

These technologies are evaluated in the following sections against the screening criteria of effectiveness, implementability, and cost.

Effectiveness is the ability for an alternative to satisfy remedial objectives and contribute substantially to the protection of public health, welfare, and the environment. This effectiveness evaluation includes a public health and environmental screening. The ability for the alternative

TABLE A.3.1

POTENTIALLY FEASIBLE GROUNDWATER TREATMENT TECHNOLOGIES HASSAYAMPA FEASIBILITY STUDY

Technology	*Description*	*Comments*
1. Reverse Osmosis	• Pressure is applied to contaminated water to force clean water to pass through a semi-permeable membrane. The contaminants are collected and discharged as a concentrated solution.	• able to treat low molecular weight organics • requires extensive pretreatment • high capital cost • considered feasible for further screening
2. Air Stripping	• Contaminated water is brought into intimate contact with air. The volatile contaminants move from the water to the air stream.	• considered appropriate for further screening
3. Ultraviolet Oxidation	• Contaminants are oxidized with ultraviolet light in the presence of a chemical oxidant.	• high capital cost • considered appropriate for further screening
4. Activated Carbon Adsorption	• Technology is associated with use of high surface area carbon adsorbent. Organic species are adsorbed on the surface of the carbon and contaminant reduction results.	• considered appropriate for further screening
5. Activated Sludge	• Associated with the use of publicly owned treatment works (POTWs) for the treatment of low level organic loadings.	• no POTW in area • not considered appropriate for further screening
6. Steam Stripping	• Use of high-temperature high-pressure steam to strip contaminants from liquid phase. The steam is brought into intimate contact with waste stream to strip contaminants.	• best suited for groundwater containing elevated concentrations of contaminants • considered appropriate for further screening

TABLE A.3.1

POTENTIALLY FEASIBLE GROUNDWATER TREATMENT TECHNOLOGIES HASSAYAMPA FEASIBILITY STUDY

Technology	*Description*	*Comments*
7. Aerobic Lagoons	• Use of aerobic sludge ponds to biologically degrade contaminants	• require on-site installation of pond • evaporation of groundwater and volatilization of contaminants will occur • considered appropriate for further screening
8. Discharge to Palo Verde Nuclear Generating Station (PVNGS)	• Discharge of untreated water to pipeline for tertiary treatment by trickling filters	• treatment technology is effective • reuse is beneficial • discharge point is at landfill boundary • rejected initially by the Arizona Public Service Company
9. Ion Exchange	• Ionic contaminants in water are adsorbed onto a bed of resin. The contaminants are flushed out of the resin bed with a highly concentrated salt solution.	• inappropriate for further screening based on its unsuitability for treating organic contaminants

TABLE A.3.2

GROUNDWATER TREATMENT TECHNOLOGY EVALUATION
HASSAYAMPA FEASIBILITY STUDY

Compound	*Design(1) Concentration (µg/L)*	*Discharge(2) Criteria (µg/L)*	% *Removal Reverse Osmosis*	% *Removal Air Stripping*	% *Removal UV Oxidation*	% *Removal Activated Carbon*	% *Removal Steam Stripping*	% *Removal Aerobic Lagoons*	*Comments*
1,1-dichloroethene	1,467	7	–	99.94	–	–	99.97	–	• steam stripping evaluated for industrial influent
1,1-dichloroethane	25	N/A	95.4	> 97.5	–	>80	–	>88	• aerobic lagoons evaluated for domestic influent
1,1,1-trichloroethane	623	200	93.8	99.98	–	99.35	–	–	
1,2-dichloroethane	1,600	5	–	91.8	–	–	–	99.67	• aerobic lagoons evaluated with activated sludge
1,2-dichloroethene (cis)	320	70	–	99.97	–	–	–	–	
acetone	38	N/A	81	> 54	–	95.9	–	–	• technologies evaluated for range 100-1,000 µg/L influent
chlorobenzene	26	N/A	53	> 92.5	–	–	–	–	
trichlorofluoromethane	150	N/A	–	>98.6	–	>98.6	–	–	• technologies evaluated for 0-100 µg/L influent • 98.6% removal effective by combination of air stripping and water phase activated carbon
trichlorotrifluoroethane	1,160	N/A	–	–	–	–	–	–	
methyl ethyl ketone	70	N/A	–	–	–	–	–	–	

Notes:

Evaluation of technologies based upon groundwater except as otherwise noted.

(1) Design concentration as presented in Table A.2.5.
(2) Specific remedial objective as presented in Table A.2.1.
(3) – = No data available from USEPA
(4) N/A = Not applicable

Source:

WERL data [illegible] USEPA, 1989

TABLE A.3.2

GROUNDWATER TREATMENT TECHNOLOGY EVALUATION
HASSAYAMPA FEASIBILITY STUDY

Compound	*Design(1) Concentration (µg/L)*	*Discharge(2) Criteria (µg/L)*	*% Removal Reverse Osmosis*	*% Removal Air Stripping*	*% Removal UV Oxidation*	*% Removal Activated Carbon*	*% Removal Steam Stripping*	*% Removal Aerobic Lagoons*	*Comments*
methylene chloride	28	N/A	–	99.95	–	99.8	–	–	• air stripping and activated carbon evaluated together for range 100-1,000 µg/L influent
tetrachloroethene	40	5	–	99.93	–	95.2	–	–	
toluene	6	N/A	92.5	97	–	>90	–	98.2	• reverse osmosis evaluated for effluent range 100-1,000 µg/L industrial effluent • aerobic lagoons evaluated for effluent range 100-1,000 µg/L industrial effluent
tribromomethane	12	20	–	>75	–	–	–	–	
trichloroethene	65	5	79	99.95	–	98.8	–	–	
xylenes (Total)	4	N/A	–	96.4	–	–	–	–	
Assessment Summary			• may be effective but capital and O&M are high • eliminated	• demonstrated to be effective at similar sites • cost competitive • carried through for evaluation	• recent vendor literature and CRA and M&A experience shows promise • can be cost competitive • carried through for evaluation	• demonstrated to be effective at similar sites • cost competitive • carried through for evaluation	• process suited industrial effluents • *not cost* competitve to stripping • eliminated	• insuffient nutrients in groundwater to operate systems • treatment would be achieved through evaporation • eliminated	

Notes:

Evaluation of technologies based upon groundwater except as otherwise noted.

(1) Design concentration as presented in Table A.2.5.
(2) Specific remedial objective as presented in Table A.2.1.
(3) – = No data available from USEPA
(4) N/A = Not applicable

Source:

WERL database, USEPA, 1989

to accomplish short and long-term effectiveness and a reduction in toxicity, mobility, and volume of contaminants is evaluated.

Implementability is the ability for an alternative to be constructed in a reasonable time frame using accepted technologies. The technical feasibility to construct and reliably operate a remedy is evaluated.

Each alternative will be rated as either readily implemented, implemented with moderate concerns or difficult to implement.

Cost is the estimate of capital, operation, maintenance and monitoring costs. Present worth costs will be estimated based on a 30-year operating period and a five percent discount rate.

A.3.3.1 Ultraviolet (UV) Oxidation

Ultraviolet oxidation utilizes ultraviolet light and an oxidant (typically hydrogen peroxide or ozone) to destroy organic contaminants, producing water and small amounts of hydrochloric acid and carbon dioxide as by-products. There are no substantial air emissions from the process.

Ultraviolet oxidation units can be designed to treat the contamination profile to the discharge criteria. The technology is relatively new but it is being demonstrated to be successful at similar sites in the United States and Canada, including a site in Phoenix.

The necessary capital equipment could be installed in a six to nine month period following design approval. Treatability studies would be required during design.

The size of the Ultraviolet/Oxidation unit and the required treatment dosage is dictated by the compound 1,2-dichloroethane. Based on its relatively slow rate of destruction and its concentration in the groundwater, it is estimated that five 30 Kilowatt (KW) reactors would be required to reduce all contaminants to the discharge criteria. The capital cost for such equipment is estimated to be approximately $374,000. This cost does not include miscellaneous items such as piping, pumps, power supply, surge tank, and installation. The operating cost would be approximately $11.00 per 1,000 gallons, including the cost of power at $0.07/KWHR, lamp replacement, and consumption of chemical reagents such as hydrogen peroxide This results in an estimated annual cost of approximately $184,000.

A.3.3.2 Air Stripping

Air stripping involves the transfer of volatile organic compounds dissolved in water to a stream of air flowing counter-current to a stream of water over a bed of packing material which maximizes the contact surface area between the air and water streams. Contaminants which have been transferred to the air stream can be discharged directly to atmosphere or treated prior to discharge.

Air stripping units can be designed to treat groundwater at the hazardous waste area to meet discharge criteria. The necessary capital equipment could be installed in a three to six month period following design approval.

As in the case of air stripping, the design of the stripping tower is dictated by the compound 1,2-dichloroethane because of its low strippability compared to other contaminants in the groundwater, as well as its elevated concentration as compared to the other compounds. Table A.3.3 indicates that air stripping can be effective in treating all hazardous waste area groundwater contaminants.

Vapor phase treatment would not be required to meet the USEPA's guideline of 15 pounds per day total VOCs. Table A.3.4 indicates that the maximum daily emissions from an air stripping tower would be 1.3 pounds per day. Hence, emissions from an air stripper would be considered to be acceptable for direct atmospheric discharge.

The estimated capital cost for the stripping tower is approximately $81,000, while the estimated annual O&M cost is approximately $45,000. The estimated capital cost does not include power supply, installation, piping, pumps, surge tank, and blower.

TABLE A.3.3

SUMMARY OF PACKED TOWER STRIPPER PERFORMANCE
HASSAYAMPA FEASIBILITY STUDY

Compound	*Initial Concentration (µg/L)*	*Effluent Concentration (µg/L)*	*Effluent Discharge Criteria (µg/L)*	*Removal Efficiency (%)*
1,2-dichloroethane	1,600	5.00	5	91.80
1,1-dichloroethane	25	0.01	N/A	>97.5
1,1-dichloroethene	1,467	0.35	7	99.94
1,1,1-trichloroethane	623	0.31	200	99.98
1,2-dichloroethene (cis)	320	0.11	70	99.97
acetone	38	21.56	N/A	>54
chlorobenzene	26	0.02	N/A	>92.5
methyl ethyl ketone	70	22.18	N/A	--
methylene chloride	28	0.01	N/A	99.95
tetrachloroethene	40	0.03	5	99.93
trichloroethene	65	0.03	5	99.95

Notes:

(1) If Henry's Constants are not available for a particular compound, then the worst case is assumed and the effluent concentration is the same concentration as the influent.

(2) Tower designed for a flow rate of 25 gal/min. and 1,2-dichloroethane concentration of 1,600 µg/L. Initial concentrations are based on specific remedial objectives as presented in Table A.2.1.

(3) N/A = Not applicable

TABLE A.3.4

PACKED TOWER AIR EMISSIONS
HASSAYAMPA FEASIBILITY STUDY

	VOC mass discharged from Stripping Tower			
	per day		*per year*	
Compound	*(kg)*	*(lb)*	*(tonnes)*	*(tons)*
1,2-dichloroethane	0.22	0.48	0.08	0.09
1,1-dichloroethane	0.00	0.01	0.00	0.00
1,1-dichloroethene	0.20	0.44	0.07	0.08
1,1,1-trichloroethane	0.09	0.19	0.03	0.04
dichloroethene (cis)	0.04	0.10	0.02	0.02
acetone	0.00	0.00	0.00	0.00
chlorobenzene	0.00	0.01	0.00	0.00
methylethylketone	0.01	0.01	0.00	0.00
methylene chloride	0.00	0.01	0.00	0.00
phenol	0.00	0.00	0.00	0.00
tetrachloroethene	0.01	0.01	0.00	0.00
trichloroethene	0.01	0.02	0.00	0.00
TOTAL	0.60	1.30	0.20	0.23

Notes:

Assumes removal efficiencies shown in Table A.3.3 and design influent concentrations which are higher than the representative concentrations for the hazardous waste area.

VOC - Volatile Organic Compound
lb - pounds
kg - kilograms

A.3.3.3 Carbon Adsorption

Carbon adsorption involves the passing of contaminated groundwater through a bed of highly porous granular activated carbon. The large surface area of the carbon acts as an adsorption medium and contaminants are transferred from the water to the carbon. The carbon can be taken from the hazardous waste area and regenerated to prevent the compounds of concern to begin to pass through the carbon bed without being adsorbed (breakthrough).

Carbon adsorption systems can be designed to treat all compounds in the groundwater to meet the specific remedial objectives. The necessary capital equipment could be installed in a 6-month period following design approval.

Calculations for the conceptual design of a carbon adsorption system indicate that carbon requirements would be approximately 112 lbs/day or approximately 41,000 lbs/year. These calculations were based on an empty bed contact time (EBCT) of 20 minutes and a hydraulic loading rate of approximately 2.5 gallons per minute/square foot (gpm/ft^2). The concentration of methylene chloride at breakthrough is calculated to be 4.8 μg/L (discharge objective is 5 μg/L), and it would occur after 17 days of operation. The dimensions of the contactor were calculated to be 3.5' dia x 10' high. The carbon bed in such a vessel would have a height of 7 feet. The weight of the carbon in the contactor would be approximately 1,900 lbs.

Based on the above, two 2,000 lbs vessels would be operated in series, with the second vessel being used to polish the effluent from the first vessel. After 17 days of operation, the flow would be directed to the second vessel, and the first vessel would be taken out of operation for carbon regeneration. After the carbon has been regenerated at an off-site regeneration facility, the first vessel would be reloaded and put back in operation as the secondary unit.

It is estimated that the capital cost for this system is approximately $130,000 including the initial carbon charge. This cost does not include piping, power supply, pumps, surge tank, and installation. Subsequent carbon charges are estimated to be $160,000/year, based on cost of $3.00/lb of carbon, including transportation and regeneration. Other O&M costs such as general system maintenance are estimated to be $26,000 per year. This results in an annual cost of $186,000.

A.3.4 GROUNDWATER DISPOSAL OPTIONS

Four groundwater disposal options were evaluated and are discussed below: surface water discharge; industrial reuse; discharge to irrigation use; and subsurface reinjection. Each of these disposal options is discussed below.

A.3.4.1 Surface Water Discharge

Surface discharge of treated groundwater may be the most cost-effective disposal option; however, this is not considered by ADWR to be a beneficial reuse of the resource and was not considered further.

A.3.4.2 Industrial Reuse

Industrial reuse is limited in the immediate area of the hazardous waste area due to the lack of industrial applications requiring large volumes of water. The nearest major water consumer is Palo Verde Nuclear Generating Station (PVNGS), which uses treated effluent from the City of Phoenix for cooling purposes. The effluent is transported from the City of Phoenix to the 91st Avenue Wastewater Treatment Plant and then to PVNGS in a pipeline, which is buried in a right of way adjacent to the Landfill. The effluent has chemical characteristics which were obtained from the City of Phoenix and are shown in Table A.3.5. As shown, the quality of the current effluent is similar to that of the chemical profile in the treated groundwater.

Representatives of the Hassayampa Steering Committee (CRA and M & A) met with the Arizona Public Services (APS), owners of the facility, to propose such a discharge of groundwater into the effluent pipeline. However, APS initially rejected the proposal. Industrial reuse (discharge to the PVNGS pipeline) is considered feasible for the hazardous waste area but would require further discussion and follow up with APS.

TABLE A.3.5

CHEMICAL CHARACTERISTICS (1)
CITY OF PHOENIX 91ST AVENUE EFFLUENT
HASSAYAMPA FEASIBILITY STUDY

Compound	*Concentration (µg/L) on Date Sampled* *02/01/90*	*05/31/90*	*09/12/90 (2)(3)*	*01/03/91*	*04/25/91 (4)(5)*
<u>*VOCs*</u>					
1,1-dichloroethane	2.4	ND	ND	ND	ND
trichloromethane	ND	ND	1.1	4.1	2.0
<u>*SVOCs*</u>					
phenol	ND	ND	11.7	ND	ND
bis (2-ethylhexyl) phthalate	ND	ND	ND	5.5	5.9
dimethyl phthalate	ND	ND	18.0	ND	ND
<u>*Pesticides and PCBs*</u>					
beta-benzene hexachloride	ND	NA	0.05	0.07	ND
gamma-benzene hexachloride	ND	NA	0.07	0.33	ND
<u>*Metals*</u>					
Arsenic	4.0	4.0	4.0	7.0	2.0
Cadmium	0.2	ND	ND	0.1	0.2
Chromium	3.0	2.0	2.0	3.0	2.0
Copper	12	49	7.0	9.0	10
Lead	4.0	ND	ND	6.0	10
Nickel	8.0	16	ND	ND	ND
Selenium	1.0	ND	ND	ND	2.0
Zinc	29	85	50	ND	ND

<u>Notes:</u>

(1) Data provided by Bob Hollander, Acting Water Quality Superintendent, City of Pheonix.
(2) Sample for SVOCs and Pesticides and PCBs analyses was collected on 08/31/90.
(3) Sample for Metals analysis was collected on 10/10/90.
(4) Sample for SVOCs and Pesticides and PCBs analyses was collected on 04/24/91.
(5) Sample for Metals analysis was collected on 04/03/91.
(6) ND - Not detected
(7) NA - Not analyzed
(8) µg/L - micrograms per liter

A.3.4.3 Irrigation

Surface water is used for the irrigation of cotton crops approximately two miles east from the hazardous waste area. Treated water could be pumped in a buried pipeline to local irrigation users and utilized in normal irrigation. The use of treated groundwater is considered acceptable on area crops that are not intended for human consumption. However, use of treated groundwater for irrigation would have to consider the balance between the quantity of water extracted from the hazardous waste area on a daily basis (36,000 gallons), daily and seasonal irrigation patterns, and storage of water not used on a daily basis. Further, obtaining access and right of way to install transportation pipelines would involve considerable time and expense and may not be possible to arrange.

Based on the above implementation concerns, discharge to irrigation users will not be considered further.

A.3.4.4 Reinjection

Treated groundwater could be reinjected into Unit A to the north of the hazardous waste area and into Unit B to the west of the hazardous waste area. Reinjection has been demonstrated to be an effective and accepted technology for the management of treated groundwater in Arizona.

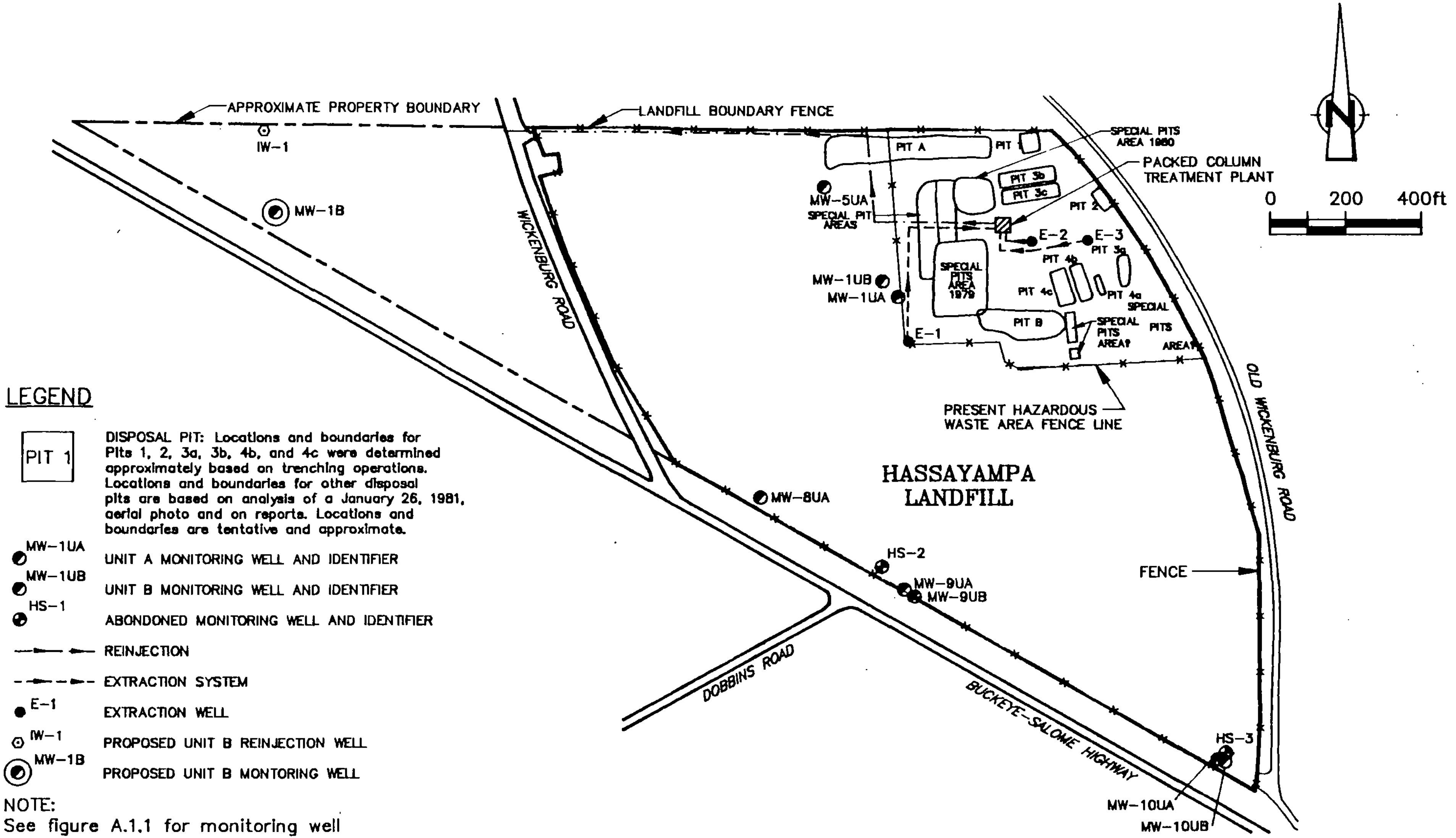
Limitations of the technology include potential maintenance costs for the reinjection wells and the need to place the wells in a location sufficiently distant from the extraction system in order to minimize the impact on the extraction system's areas of influence.

Unit A is defined as the uppermost fine-grained water-bearing strata of the regional aquifer and is similar to the fine-grained strata of Unit B. The division of the aquifer into Units A and B is artificial and does not imply a hydraulic barrier. Unit A and B are sub-units of the same aquifer.

Reinjection is considered feasible for groundwater remediation at the hazardous waste area. Several options for reinjection of treated groundwater were evaluated by M & A in Appendix A.A. Reinjection into Unit B west of the hazardous waste area on County property was selected as the preferred reinjection option based on: availability of land use and access, reduced operation and maintenance costs due to fewer reinjection wells as compared to Unit A reinjection; and reduced capital costs. The reinjection alternative is shown on Figure A.4.1.

A.3.5 EVALUATION OF TREATMENT TECHNOLOGIES

The treatment technologies described above (UV oxidation, air stripping, and carbon adsorption) are effective in reducing the concentration of the contaminants in the groundwater to meet the specific remedial objectives. All three treatment techniques require equipment that



LEGEND

PIT 1	DISPOSAL PIT: Locations and boundaries for Pits 1, 2, 3a, 3b, 4b, and 4c were determined approximately based on trenching operations. Locations and boundaries for other disposal pits are based on analysis of a January 26, 1981, aerial photo and on reports. Locations and boundaries are tentative and approximate.
● MW-1UA	UNIT A MONITORING WELL AND IDENTIFIER
● MW-1UB	UNIT B MONITORING WELL AND IDENTIFIER
● HS-1	ABONDONED MONITORING WELL AND IDENTIFIER
—►—	REINJECTION
-►-	EXTRACTION SYSTEM
● E-1	EXTRACTION WELL
○ IW-1	PROPOSED UNIT B REINJECTION WELL
◉ MW-1B	PROPOSED UNIT B MONTORING WELL

NOTE:
See figure A.1.1 for monitoring well locations within the hazardous waste area.

REFERENCE:
INFORMATION FOR BASE MAP
FROM ERROL L. MONTGOMERY
AND ASSOCIATES INC.

CRA

figure A.4.1

GROUNDWATER EXTRACTION/TREATMENT/
REINJECTION SYSTEM-ALTERNATE A
HASSAYAMPA LANDFILL
Maricopa County, Arizona

2141-11/10/91-12-0 (P-01)

can be constructed and operated in a reasonable time frame. However, an Ultraviolet/Oxidation system will require additional implementation time than an air stripping tower or a carbon contactor to be built and delivered.

Estimated capital and O&M costs are summarized in Table A.3.6 for each treatment alternative. Air stripping has the lowest capital and operating present worth of total implementation cost.

Therefore, air stripping is selected as the treatment technology.

A.3.6 EVALUATION OF DISPOSAL TECHNOLOGIES

Both reinjection to groundwater and discharge to the PVNGS pipeline are appropriate for the hazardous waste area. These two applicable treated groundwater disposal technologies are evaluated in Table A.3.7.

As shown in the Table, discharge to the PVNGS pipeline is more cost effective and is not associated with potential reinjection of residual concentrations into Unit B. Therefore, notwithstanding the full discussion and technical evaluation of reinjection options presented in Appendix A.A, discharge to the PVNGS pipeline is still considered feasible, although this alternative is subject to approval of APS and the resolution of its regulatory concerns.

TABLE A.3.6

DIFFERENTIAL COST ESTIMATE - GROUNDWATER TREATMENT
HASSAYAMPA FEASIBILITY STUDY

Treatment Option	*Treatment Technology*	*Operating Parameters*	*Estimated Capital Cost*	*Estimated Annual Cost*	*Present Worth of Annual Cost*	*Total Differential Cost*
1	U.V/Oxidation	Design Compound = 1,2 dichloroethane Number of Lamps = 5 KW = 30	$ 374,000	$ 184,000	$ 501,000	$ 875,000
2	Air Stripping	Design Compound = 1,2-dichloroethane Type of Packing = 1" Tripacks Operating Pressure = 1 atm. Operating Temperature = 25 C° Air:Water Ratio = 90 Tower Diameter = 1.5 ft Media Heigh = 14.5 ft	$ 81,000	$ 45,000	$ 267,000	$ 348,000
3	Carbon Adsorption	Design Compound = methylene chloride Requirement = 41,000 lbs/year EBCT = 20 minutes Loading Rate = 25 gpm /sq. ft. Time to Breakthrough = 17 days Contractor Dimensions = 3.5' x 10' height Carbon Charge/Vessel = 2,000 lbs	$ 130,000	$ 186,000	$ 1,104,000	$ 1,234,000

<u>Notes:</u>

Present worth of Annual Costs based on 30-year operating period and a 5% discount rate.
Pumps, valves, tanks and controls not included

TABLE A.3.7

EVALUATION OF TREATED GROUNDWATER DISPOSAL OPTIONS HASSAYAMPA FEASIBILITY STUDY

Option	*Effectiveness*	*Implementability*	*Capital Cost (1)*
Reinjection - Unit B	• all treated water could be disposed • beneficial re-use of the treated water • potential residuals move downgradient after reinjection to the west of the hazardous waste area	• readily implemented with receipt of permission from ADEQ for reinjection	• $825,000
Discharge to PVNG Pipeline	• all treated water could be disposed • beneficial re-use of the treated water	• readily implemented if APS accepts discharge.	• $733,000

Note:

(1) O & M costs are similar (see Tables A.4.1 and A.4.2)

A.3.7 MONITORING

Monitoring of the effectiveness of the extraction and treatment system will be required. The extraction wells, the influent and effluent for the treatment system will be sampled and analyzed for VOCs on a weekly basis for the first three months, monthly for the next nine months, quarterly for years two and three, and semi-annually thereafter. Samples of both the influent and effluent will be collected, on an annual basis for Target Compound List/Target Analyte List analyses.

Hydraulic monitoring of all hazardous waste area monitoring wells will be conducted whenever monitoring wells are sampled, but at a minimum on a quarterly basis.

Samples will be collected and analyzed for VOCs from all Unit A monitoring wells on a quarterly basis for one year, semi-annually for years two to three and annually thereafter. The total estimated cost for monitoring ranges from $899,000 (discharge to PVNGS pipeline) to $914,000 (reinjection to Unit B), based on a 30-year operating life and a discount rate of five percent, as shown in Table A.3.8. The monitoring frequency will be adjusted as conditions at the hazardous waste area require.

TABLE A.3.8

COMPONENT COST ESTIMATE
MONITORING
HASSAYAMPA FEASIBILITY STUDY

		Cost Estimate	
		Unit B Reinjection	*Discharge PVNGS Pipeline*
I.	TREATMENT SYSTEM MONITORING		
A.	Weekly Influent/Effluent Monitoring (initial 3 months of first year)		
A.1	Routine Constituents at beginning and end of first 3 months (3 extraction wells, influent, effluent and QA/QC samples)	$ 2,000	$ 2,000
A.2	Volatile Organic Compounds each month (3 extraction wells, influent, effluent and QA/QC samples)	12,000	12,000
A.3	Total Target Compounds (once near startup) (influent, effluent, QA/QC samples)	6,000	6,000
A.4	QA/QC	5,000	5,000
A.5	Data Management and Reporting	10,000	10,000
A.6	Sampling Costs	11,000	11,000
	Subtotal Section IA - Present Worth	$ 46,000	$ 46,000
B.	Monthly influent/effluent monitoring) (first 9 months of Year 1)		
B.1	Volatile Organic Compounds (3 extraction wells, influent, effluent and QA/QC samples)	$ 11,000	$ 11,000
B.2	QA/QC	4,000	4,000
B.3	Data Management and Reporting	10,000	10,000
B.4	Sampling Costs	7,000	7,000
	Subtotal Section IB - Present Worth	$ 32,000	$ 32,000

TABLE A.3.8

COMPONENT COST ESTIMATE
MONITORING
HASSAYAMPA FEASIBILITY STUDY

	Cost Estimate	
	Unit B Reinjection	*Discharge PVNGS Pipeline*
I. TREATMENT SYSTEM MONITORING (cont'd)		
C. Quarterly influent/effluent monitoring (Years 2 and 3)		
C.1 Volatile Organic Compounds (3 extraction wells, influent, effluent and QA/QC samples)	$ 10,000	$ 10,000
C.2 Total Target Compounds (once a year) (influent, effluent and QA/QC samples)	12,000	12,000
C.3 QA/QC	4,000	4,000
C.4 Data Management and Reporting	N/A	N/A
C.5 Sampling Costs	N/A	N/A
Subtotal Section IC	$ 26,000	$ 26,000
Subtotal Section IC - Present Worth	$ 24,000	$ 24,000
D. Semi-Annual Influent/Effluent Monitoring (once a year for Years 4 - 30)		
D.1 Volatile Organic Compounds (3 extraction wells, influent, effluent and QA/QC samples)	$ 5,000	$ 5,000
D.2 Total Target Compounds (influent, effluent and QA/QC samples) (once a year)	6,000	6,000
D.3 QA/QC	2,000	2,000
D.4 Data Management and Reporting	5,000	5,000
D.5 Sampling Costs	2,000	2,000
Subtotal Section ID	$ 20,000	$ 20,000
Subtotal Section ID - Present Worth	$ 253,000	$ 253,000
Subtotal Section I - Present Worth	$ 355,000	$ 355,000
II. GROUNDWATER MONITORING -UNIT A AND UNIT B MONITOR WELLS		
A. Quarterly Sampling Rounds for 1 Year		
A.1 Volatile Organic Compounds	$ 21,000	$ 20,000
A.2 QA/QC	8,000	8,000
A.3 Data Management Reporting	15,000	15,000
A.4 Sampling Costs	23,000	23,000
Subtotal Section IIA - Present Worth	$ 67,000	$ 66,000

TABLE A.3.8

COMPONENT COST ESTIMATE
MONITORING
HASSAYAMPA FEASIBILITY STUDY

	Cost Estimate	
	Unit B Reinjection	*Discharge PVNGS Pipeline*
II. GROUNDWATER MONITORING -UNIT A AND UNIT B MONITOR WELLS (cont'd)		
B. Semi-Annual Sampling Rounds for Years 2 to 3		
B.1 Volatile Organic Compounds	$ 21,000	$ 20,000
B.2 QA/QC	8,000	8,000
B.3 Data Management and Reporting	15,000	15,000
B.4 Sampling Costs	23,000	23,000
Subtotal Section IIB	$ 67,000	$ 66,000
Subtotal Section IIB - Present Worth	$ 62,000	$ 61,000
C. Annual Sampling Rounds,per year for Years 4 - 30		
C.1 Volatile Organic Compounds	$ 11,000	$ 10,000
C.2 QA/QC	4,000	4,000
C.3 Data Management and Reporting	8,000	8,000
C.4 Sampling Costs	11,000	11,000
Subtotal Section IIC	$ 34,000	$ 33,000
Subtotal Section IIC - Present Worth	$ 430,000	$ 417,000
Subtotal Section II - Present Worth	$ 559,000	$ 544,000
III. TOTAL MONITORING COSTS PRESENT WORTH	$ 914,000	$ 899,000

Notes:

Groundwater monitoring Unit B reinjection includes 21 monitoring wells and QA/QC samples.

NA-Not applicable,costs included in general monitoring costs.

A.4.0 GROUNDWATER REMEDIATION ALTERNATIVES

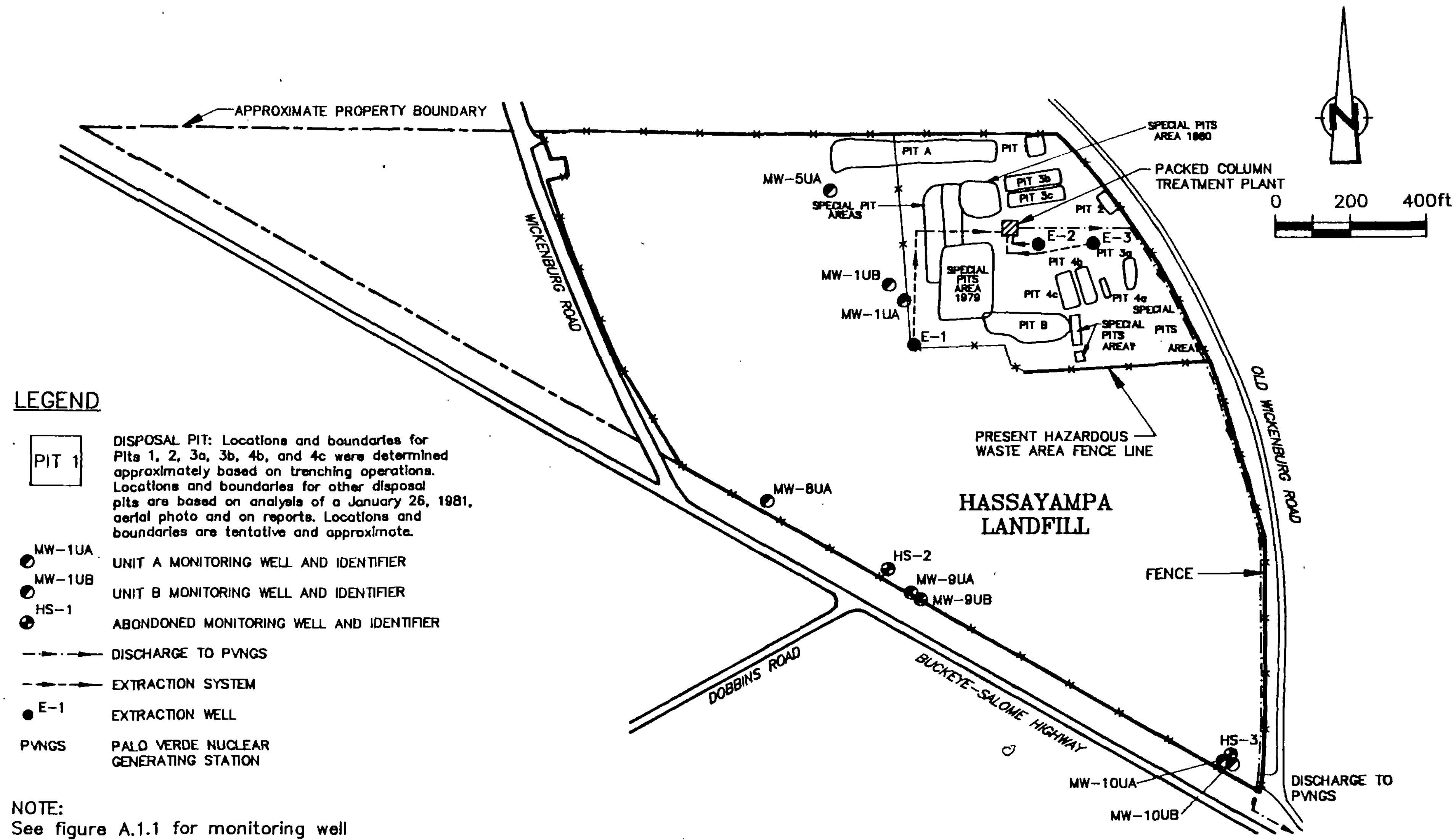
The recommended groundwater extraction and treatment system consists of the following technologies: groundwater extraction; air stripping of extracted water; reinjection of treated water or discharge of the treated water to the PVNGS pipeline; and monitoring. The proposed alternatives are shown on Figure A.4.1 and Figure A.4.2.

A.4.1 PROPOSED TREATMENT DESIGN

The treatment system consists of three extraction wells; one reinjection well for Unit B or a discharge pipeline; two pumps; a 1000 gallon carbon steel surge tank; a packed column (air stripping) and associated equipment; and miscellaneous piping and controls. Individual design details of the extraction wells and the packed column are presented in the following sections. The total estimated implementation costs for the proposed groundwater remediation alternatives are shown in Table A.4.1 (reinjection) and Table A.4.2 (discharge to PVNGS pipeline).

A.4.1.1 Extraction Well Design

The design of a typical extraction well for the hazardous waste area is presented in Appendix A.A.



LEGEND

PIT 1	DISPOSAL PIT: Locations and boundaries for Pits 1, 2, 3a, 3b, 4b, and 4c were determined approximately based on trenching operations. Locations and boundaries for other disposal pits are based on analysis of a January 26, 1981, aerial photo and on reports. Locations and boundaries are tentative and approximate.
MW-1UA	UNIT A MONITORING WELL AND IDENTIFIER
MW-1UB	UNIT B MONITORING WELL AND IDENTIFIER
HS-1	ABONDONED MONITORING WELL AND IDENTIFIER
—·—·—	DISCHARGE TO PVNGS
———	EXTRACTION SYSTEM
● E-1	EXTRACTION WELL
PVNGS	PALO VERDE NUCLEAR GENERATING STATION

NOTE:
See figure A.1.1 for monitoring well locations within the hazardous waste area.

REFERENCE:
INFORMATION FOR BASE MAP
FROM ERROL L. MONTGOMERY
AND ASSOCIATES INC.

CRA

figure A.4.2

GROUNDWATER EXTRACTION/TREATMENT/
DISCHARGE SYSTEM–ALTERNATIVE B
HASSAYAMPA LANDFILL
Maricopa County, Arizona

TABLE A.4.1

COMPONENT COST ESTIMATE
GROUNDWATER EXTRACTION/TREATMEN/REINJECTION (UNIT B)
HASSAYAMPA FEASIBILITY STUDY

Item	*Description*	*Estimated Quantity*	*Unit*	*Estimated Unit Cost*	*Total Estimated Cost*
I	**DIRECT CAPITAL COSTS**				
A.	EXTRACTION AND REINJECTION SYSTEM				
A.1	Mobilization	1	L.S.	$ 5,000	$ 5,000
A.2	Install extraction wells	3	Ea.	57,500	172,500
A.3	Install reinjection wells	1	Ea.	72,000	72,000
A.4	Construct forcemain from wells to treatment system	1,000	L.F.	10	10,000
A.5	Supply electric servicing, controls and flow measurements	1	L.S.	50,000	50,000
A.6	Health and Safety	1	L.S.	10,000	10,000
	SUBTOTAL				$ 319,500
B.	TREATMENT SYSTEM				
B.1	Piping	1	L.S.	10,000	$ 10,000
B.2	Packed Tower	1	L.S.	50,000	50,000
B.3	Surge Tank	1	L.S.	5,000	5,000
B.4	Pumps (25 gpm)	2	Ea.	1,500	3,000
B.5	Fan/Blower	1	Ea.	1,500	1,500
B.6	Mechanical Hookup	1	L.S.	3,000	3,000
B.7	Power Supply	1	L.S.	5,000	5,000
	SUBTOTAL				$ 77,500
C.	MONITORING WELL INSTALLATIONS				
C.1	Unit A Monitoring Wells	3	Ea.	43,500	$ 131,000
C.2	Unit B Monitoring Wells	1	Ea.	65,000	65,000
	SUBTOTAL				$ 196,000
	Total Direct Capital Costs (rounded)				$ 593,000

TABLE A.4.1

COMPONENT COST ESTIMATE
GROUNDWATER EXTRACTION/TREATMEN/REINJECTION (UNIT B)
HASSAYAMPA FEASIBILITY STUDY

Item	*Description*	*Estimated Quantity*	*Unit*	*Estimated Unit Cost*	*Total Estimated Cost*
II	INDIRECT CAPITAL COSTS				
A.1	Administration (5% of Direct Capital Costs)				$ 30,000
A.2	Engineering (10% of Treatment System and Pipelines)				$ 15,000
A.3	Construction Supervision (15% of Treatment System and Pipelines)				$ 22,000
	Total Indirect Capital Costs (rounded)				$ 67,000
	Sub Total Capital Costs				$ 660,000
	Contingency (25%)				$ 165,000
	Total Capital Costs				$ 825,000
III	ANNUAL COSTS - PRESENT WORTH				
A.1	Maintenance Extraction/Treatment/Reinjection System (Present Worth, $52,000 per year for 30 years @ 5%)				$ 800,000
A.2	Monitoring - Present Worth (see Table A.3.8)				$ 914,000
	Subtotal Annual Costs				$ 1,714,000
	Contingency (25%)				$ 429,000
	Total AnnualCosts - Present Worth				$ 2,143,000
	TOTAL SECTIONS I - III (rounded)				**$ 2,968,000**

TABLE A.4.2

COMPONENT COST ESTIMATE
GROUNDWATER EXTRACTION/TREATMENT/DISCHARGE TO PVNGS PIPELINE
HASSAYAMPA FEASIBILITY STUDY

Item	*Description*	*Estimated Quantity*	*Unit*	*Estimated Unit Cost*	*Total Estimated Cost*
I	DIRECT CAPITAL COSTS				
A.	<u>EXTRACTION AND REINJECTION SYSTEM</u>				
A.1	Mobilization	1	L.S.	$ 5,000	$ 5,000
A.2	Install extraction wells	3	Ea.	57,500	172,500
A.3	Install Pipeline to PVNGS pipeline	2,000	L.F.	10	20,000
A.4	Construct forcemain from wells to treatment system	1,000	L.F.	10	10,000
A.5	Construction Pumping Station	1	L.S.	50,000	50,000
A.6	Supply electric servicing, controls and flow measurements	1	L.S.	50,000	50,000
A.7	Health and Safety	1	L.S.	10,000	10,000
	SUBTOTAL				$ 317,500
B.	<u>TREATMENT SYSTEM</u>				
B.1	Piping	1	L.S.	10,000	$ 10,000
B.2	Packed Tower	1	L.S.	50,000	50,000
B.3	Surge Tank	1	L.S.	5,000	5,000
B.4	Pumps (25 gpm)	2	Ea.	1,500	3,000
B.5	Fan/Blower	1	Ea.	1,500	1,500
B.6	Mechanical Hookup	1	L.S.	3,000	3,000
B.7	Power Supply	1	L.S.	5,000	5,000
	SUBTOTAL				$ 77,500
C.	<u>MONITORING WELL INSTALLATIONS</u>				
C.1	Unit A Monitoring Wells	3	Ea.	43,500	$ 131,000
	SUBTOTAL				$ 131,000
	Total Direct Capital Costs (rounded)				$ 526,000

TABLE A.4.2

COMPONENT COST ESTIMATE
GROUNDWATER EXTRACTION/TREATMENT/DISCHARGE TO PVNGS PIPELINE
HASSAYAMPA FEASIBILITY STUDY

Item	*Description*	*Estimated Quantity*	*Unit*	*Estimated Unit Cost*	*Total Estimated Cost*
II	INDIRECT CAPITAL COSTS				
A.1	Administration (5% of Direct Capital Costs)				$ 26,000
A.2	Engineering (10% of Treatment System and Pipelines)				$ 15,000
A.3	Construction Supervision (15% of Treatment System and Pipelines)				$ 22,000
	Total Indirect Capital Costs (rounded)				$ 63,000
	Sub Total Capital Costs				$ 589,000
	Contingency (25%)				$ 147,000
	Total Capital Costs (rounded)				$ 736,000
III	ANNUAL COSTS - PRESENT WORTH				
A.1	Maintenance Extraction/Treatment/Discharge System Present Worth - $52,000 per year for 30 years @ 5%				$ 800,000
A.2	Monitoring -Present Worth (see Table A.3.8)				$ 899,000
	Subtotal Annual Costs - Present Worth				$ 1,699,000
	Contingency (25%)				$ 425,000
	Total Annual Costs				$ 2,124,000
	TOTAL SECTIONS I - III (rounded)				$ 2,860,000

A.4.1.2 Reinjection Well Design

The design of typical reinjection wells is presented in Appendix A.A.

A.4.1.3 Packed Tower Design

A summary of the tower's key operating and design parameters are shown in Table A.4.3.

It must be noted that the design of the tower is based on a worst case groundwater contamination profile multiplied by a factor of two. In addition, the tower is designed to operate at a flowrate of 25 gpm, but the expected groundwater extraction rate is approximately 15 gpm (see Appendix A.A). These conservative design measures result in a tower design that will accept a range of influent flowrates and concentrations without impacting the ability to the treatment system to meet the treatment objectives. However, final design may be modified based on actual sustainable pumping rates for extraction wells.

A.4.1.4 Transmission And Discharge Pipeline Design

The transmission pipeline will be constructed of 2-inch diameter polyvinyl chloride and will incorporate a sufficient number of valves and expansion chambers to permit adequate operation and

TABLE A.4.3

SUMMARY OF PACKED TOWER DESIGN PARAMETERS
HASSAYAMPA FEASIBILITY STUDY

Design Parameter		*Design Value*						
Type of Packing Material	=	1" Plastic Tripacks						
Design Compound	=	1,2-dichloroethane						
Influent Concentration (µg/L)	=	1600						
Effluent Concentration (µg/L)	=	5						
Operating Pressure	=	1 atm	=	760	mmHG			
Operating Temp (K)	=	298.15	=	25	°C			
Air Water Ratio	=	90						
Water Flow Rate (m^3/sec)	=	0.00158	=	.06	cfs	=	25	gpm
Air Flow Rate (m^3/sec)	=	0.14293	=	302.81	cfm	=	2265	gpm
Water Loading Rate (kg/m^2 sec)	=	10.2357	=	7534	lbs/hr ft^2	=	15	g/ft^2
Air Loading Rate (kg/m2 sec)	=	1.0993	=	809	lbs/hr ft^2			
Pressure Drop (N/m2/m)	=	100	=	.12	in. H_2O/ft	=	0.64	lb/ft^2/ft
Area of Tower (m^2)	=	0.15	=	1.66	ft^2			
Diameter of Tower (meters)	=	0.44	=	1.45	ft	=	17	inches
Height of Transfer Unit (meters)	=	0.64	=	2.10	ft	=	25	inches
Number of Transfer Units	=	6.94						
Height of Media (meters)	=	4.43	=	14.55	ft	=	174.6	inches
Volume of Tower (m^3)	=	0.68	=	24.09	ft^3			
Number of Towers	=	1						

maintenance. The connection from the pipeline to the reinjection well or to the PVNGS discharge pipeline will incorporate a sampling port so that periodic groundwater monitoring may be completed. The pipeline will be completed in areas away from vehicular traffic and will accordingly be buried one to two feet below ground surface. In areas where the pipeline is required to cross roadways, a burial depth of four feet will be used.

A.4.2 IMPLEMENTATION COST

The cost range for the groundwater remediation alternatives is $2,860,000 (discharge to PVNGS pipeline) to $2,968,000 (reinjection) as shown in Table A.4.4.

A.4.2.1 Cost Sensitivity Analysis

The sensitivity of the annual costs to changes in discount rate, used to determine present worth, was evaluated. Discount rates of 10%, 15%, and 20% were used. The effects of increased discount rates are presented in Table A.4.5.

TABLE A.4.4

IMPLEMENTATION COST ESTIMATE
HASSAYAMPA FEASIBILITY STUDY

			Unit B Reinjection	*Discharge to PVNGS Pipeline*
A.	DIRECT CAPITAL COSTS			
	A.1	Extraction and Reinjection System	$ 319,500	$ 317,500
	A.2	Treatment System	77,500	77,500
	A.3	Monitoring Wells	196,000	131,000
	Subtotal		$ 593,000	$ 526,000
B.	INDIRECT CAPITAL COSTS			
	B.1	Administration	$ 30,000	$ 26,000
	B.2	Engineering	15,000	15,000
	B.3	Construction Oversight	22,000	22,000
	Subtotal		$ 67,000	$ 63,000
	Subtotal Captial Costs		$ 660,000	$ 589,000
	Contingency (25%)		$ 165,000	$ 147,000
	Total Capital Costs		$ 825,000	$ 736,000
C.	ANNUAL COSTS (1)			
	C.1	Operation and Maintenance (Present Worth)	$ 800,000	$ 800,000
	C.2	Monitoring (Present Worth)(2)	914,000	899,000
	Subtotal		$ 1,714,000	$ 1,699,000
	Contingency (25%)		$ 429,000	$ 425,000
	Subtotal Annual Cost (Present Worth)		$ 2,143,000	$ 2,124,000
	Total Estimated Implementation Costs		$ 2,968,000	$ 2,860,000

Notes:

(1) 5% discount rate and 30-year operation
(2) See Tables A.4.1 and A.4.2

TABLE A.4.5

DISCOUNT RATE SENSITIVITY ANALYSIS HASSAYAMPA FEASIBILITY STUDY

	Annual Cost(1)	*Discount Rate*	*Present Worth(2)*	*Differential Cost Saving*[3]
Reinjection	$ 139,400	5%	$ 2,143,000	$ 0
	139,400	10%	1,314,000	829,000
	139,400	15%	915,000	1,228,000
	139,400	20%	694,000	1,449,000
Discharge to PVNGS Pipeline	$ 138,200	5%	$ 2,124,000	$ 0
	138,200	10%	1,303,000	821,000
	138,200	15%	907,000	1,217,000
	138,200	20%	688,000	1,436,000

Note

(1) Equivalent annual operation, maintenance and monitoring costs.

(2) Over 30-year operating period and includes 25% contingency.

(3) 5% Present Worth Cost - Present Worth Cost in question.

APPENDIX A.A

MODELING REPORT - ERROL L. MONTGOMERY & ASSOCIATES

October 1991

APPENDIX A.A TO THE
TECHNICAL SCREENING MEMORANDUM

RESULTS OF HYDRAULIC CAPTURE ZONE SIMULATIONS AND RECOMMENDATIONS FOR EXTRACTION-INJECTION WELLS FOR THE FORMER HAZARDOUS WASTE DISPOSAL AREA AT THE HASSAYAMPA LANDFILL, MARICOPA COUNTY, ARIZONA

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(* included as transparent overlay in pocket at end of this Appendix)

ERROL L. MONTGOMERY & ASSOCIATES, INC.

October 1991
APPENDIX A.A TO THE
TECHNICAL SCREENING MEMORANDUM

RESULTS OF HYDRAULIC CAPTURE ZONE SIMULATIONS AND RECOMMENDATIONS FOR EXTRACTION-INJECTION WELLS FOR THE FORMER HAZARDOUS WASTE DISPOSAL AREA AT THE HASSAYAMPA LANDFILL, MARICOPA COUNTY, ARIZONA

INTRODUCTION

This report was prepared to give results from groundwater flow modeling investigations and recommendations to support selection of a remedial measure for groundwater in Unit A at the former hazardous waste disposal area (the "hazardous waste area") at the Hassayampa Landfill (the "Landfill"). The report was prepared by Errol L. Montgomery & Associates, Inc. (Montgomery & Associates) for inclusion as Appendix A.A to the Technical Screening Memorandum prepared by Conestoga-Rovers & Associates (CRA). Data for the Landfill given in the final Remedial Investigation (RI) Report (Montgomery & Associates and CRA, 1991) and results from supplemental work (Montgomery & Associates, 1991a and 1991b) conducted at the Landfill provided the basis for conduct of the groundwater modeling operations.

The Landfill is located in the southeast quarter of Section 3, Township 1 South, Range 5 west, Maricopa County, Arizona. The former hazardous waste area comprises a fenced area of about 10 acres in the northeast part of the fenced, 47-acre Landfill. The Landfill is located on a triangular-shaped, 77-acre parcel of land owned by Maricopa County, which is shown on. Locations for the Landfill and the former hazardous waste area are shown on **Figure 1**.

OBJECTIVES AND CONCEPTUAL APPROACH

The objective of a remedial measure for groundwater at the former hazardous waste disposal area is to provide hydraulic control and capture of zones of groundwater that contain elevated concentrations of volatile organic compounds. For this report, it was assumed that a remedial measure would include withdrawal of contaminated groundwater via extraction wells, treatment of the extracted water to reduce concentrations of volatile organic compounds to acceptable levels, and beneficial reuse of the treated water by a method that would either include or exclude artificial recharge to the aquifer via injection wells.

The conceptual approach to the groundwater modeling operations was selected to keep the approach as simple and cost effective as practicable, and to provide appropriate results necessary for the Feasibility Study (FS). The modeling approach used for the Landfill area included use of the program RESSQ (Javandel et al, 1984). RESSQ is an analytical-numerical program based on superposition of mathematical solutions for groundwater movement that would result from pumping extraction and/or injection wells in the presence of a regional hydraulic gradient. This program is widely used in the public domain. Use of this program for the FS is consistent with the amount and type of data available from the RI and is consistent with requirements for proper design of a groundwater remedial measure.

Modeling results given in this report include comparisons of projected hydraulic capture zones for several wellfield design alternatives. The alternatives include arrays of extraction wells ("E" wells), arrays of injection wells ("I" wells), and extraction-injection ("EI") regimens. Selected extraction-injection regimens also simulate the case where no injection wells would be used. Extraction wells, injection wells, and pumping regimens are identified in **Table 1**. Locations for all model extraction wells and injection wells simulated in this report are shown on **Figure 1**. Injection wells were selected for artificial recharge because other recharge alternatives, which include infiltration galleries and dry wells, would result in uncontrolled movement of liquids in the vadose zone and could potentially result in mobilization of any residual contaminants in the vadose zone at the Landfill. Movement of water recharged via injection wells into the saturated zone would be controlled by the southward regional groundwater gradient.

Projected hydraulic capture zones are defined as the aquifer zone from which groundwater would be withdrawn by an extraction well after a pumping period of "t" years. Map and section views of a conceptual hydraulic capture zone are shown on **Figure 2** for a regimen of extraction without injection and on **Figure 3** for a regimen of extraction with injection. The shaded area of the capture zone shown on **Figure 2** indicates the zone of the aquifer from which groundwater would be withdrawn during a "t"-year pumping period at the extraction well. After a "t"-year pumping period, the volume of groundwater withdrawn would comprise one effective pore volume of the part of the aquifer within the capture zone.

Results submitted by Montgomery & Associates (1991b) indicate that concentrations of volatile organic compounds have been detected and confirmed solely in Unit A at monitor wells MW-1UA, MW-4UA, MW-5UA, MW-6UA, and HS-1. Data for chemical quality of groundwater samples obtained during the period from 1982 through June 1991 indicate that, excluding laboratory contaminants, the following ranges for total concentration of volatile organic compounds were detected and confirmed:

MONITOR WELL	TOTAL CONCENTRATION (micrograms per liter)
MW-1UA	ND - 602
MW-4UA	ND - 29.2
MW-5UA	ND - 5.9
MW-6UA	ND - 660.2
HS-1	163.6 - 4,660

The detection of a chemical constituent in groundwater yielded from a monitor well is generally considered to be confirmed when the constituent is reliably detected for two or more sampling rounds. Concentrations of individual volatile organic compounds detected and confirmed at Unit A monitor wells MW-1UA, MW-6UA, and HS-1 exceeded primary maximum contaminant levels (MCLs) established by EPA for drinking water; therefore, the groundwater remedial measure should be designed chiefly to address groundwater in Unit A in the MW-1UA, MW-6UA, and HS-1 areas. Concentrations of individual volatile organic compounds detected and confirmed at Unit A monitor wells MW-4UA and MW-5UA did not exceed EPA MCLs; however, the groundwater remedial measure should be designed to accommodate potential future augmentation of the extraction well network if the MW-4UA and MW-5UA areas become targets for groundwater remedial measures.

EVALUATION OF POTENTIAL LOCATIONS FOR EXTRACTION WELLS

Potential locations for extraction wells were evaluated to provide cost effective hydraulic control and capture of targeted zones of groundwater in Unit A that contain elevated concentrations of volatile organic compounds. Results for two-well, three-well, and four-well extraction alternatives for Unit A are included in this report.

Two-Well Extraction Alternative

For simulating the two-well extraction alternative, model extraction wells were located in the direction of groundwater movement from monitor wells MW-1UA and MW-6UA. Model extraction well E-1 was located about 130 feet south from monitor well MW-1UA, and model extraction well E-2 was located about 150 feet south from monitor well MW-6UA (**Figure 1**). These model well locations were selected using the assumption that the targeted zones of groundwater that contain elevated concentrations of volatile organic compounds extend as much as 150 feet south from these monitor wells. It is believed that these two sites may provide an acceptable balance between distance of the extraction wells from the known "hot spot" locations and width of the capture zone at the known "hot spot". Model extraction well locations E-1 and E-2 were used for all of the model simulations.

Prior to construction of extraction wells, Unit A monitor wells should be constructed and tested at the E-1 and E-2 sites to confirm the validity of the assumption used for southward extent of the targeted zones of groundwater. Depending on results from these monitor wells, extraction wells could be located:

1. at the "hot spots";
2. between the "hot spots" and the E-1 and E-2 sites;
3. at the E-1 and E-2 sites; or
4. south from the E-1 and E-2 sites.

Capture zones for these various location alternatives would be translated north or south from the capture zones, which are simulated herein for the E-1 and E-2 sites. This report provides a means to evaluate capture zones for these various location alternatives.

Three-Well Extraction Alternative

For simulating the three-well extraction alternative, model extraction wells E-1 and E-2 were used together with two alternatives for a third model extraction well. One alternative for the third extraction well is the E-3 site, located about 150 feet south from monitor well MW-4UA **(Figure 1)**. A second alternative for the third extraction well is the E-4 site, located near the MW-4UA site **(Figure 1)**. It is believed that both the E-1/E-2/E-3 combination and the E-1/E-2/E-4 combination may provide acceptable hydraulic control and capture of groundwater in the MW-1UA, MW-5UA, MW-6UA, Pit 1, and MW-4UA areas.

At present, the preferred third extraction well site is E-4 because concentrations of volatile organic compounds detected for monitor well MW-4UA are not sufficiently large to justify an extraction well to the south at the E-3 site. If concentrations of volatile organic compounds in groundwater would increase substantially at monitor well MW-4UA prior to installation of a third extraction well, the appropriate location for a third extraction well could be south from the E-4 site. If these conditions would occur, a Unit A monitor well should be constructed and tested at the E-3 site to determine if the E-3 site is located within a groundwater zone that should be targeted for a groundwater remedial measure. Depending on results from this monitor well, the third extraction well could be located:

1. at the E-4 site;
2. between the E-4 site and the E-3 site;
3. at the E-3 site; or
4. south from the E-3 site.

Capture zones for these various location alternatives would be translated north or south from the capture zone, which is simulated herein for the E-3 site. This report provides a means to evaluate capture zones for the E-1/E-2/E-3 combination and the E-1/E-2/E-4 combination of extraction wells.

Four-Well Extraction Alternative

The four-well extraction alternative was evaluated chiefly to investigate how the two-well and three well extraction alternatives could be adapted, if subsequent augmentation of the extraction well network would be required to address potential contamination of groundwater in the Special Pit areas. For these four-well extraction simulations, three of the four model extraction wells were E-1, E-2, and E-4. The fourth model extraction well was E-5, which was located south from the Special Pit areas and monitor well MW-7UA (Figure 1).

EVALUATION OF POTENTIAL LOCATIONS FOR INJECTION WELLS

Potential injection well sites were evaluated for locations at the hazardous waste area and south, east, west, and north from the hazardous waste area. These evaluations resulted in the selection of sites located north or west from the hazardous waste area.

Chemical Quality of Groundwater in Units A and B

Results of laboratory chemical analyses, which are given by Montgomery & Associates (1991b) for groundwater samples obtained from paired Unit A and Unit B monitor wells during the first half of 1991, indicate that concentrations of certain common constituents were larger for the Unit A well than the Unit B well at some paired sites and were larger for the Unit B well than the Unit A well at other paired sites. In general, concentrations of constituents commonly related to aesthetic water quality, such as chloride, sulfate, and total dissolved solids, were somewhat larger for the Unit A wells than the Unit B wells in the hazardous waste area, and were larger for the Unit B wells than the Unit A wells south from the hazardous waste area.

Results for the first half of 1991 indicate that water type is sodium chloride for monitor wells MW-5UA, MW-9UB, and MW-10UA. Water type for monitor well MW-10UB is calcium chloride. Water type for the remainder of the monitor wells is generally sodium bicarbonate.

Nitrate is the only inorganic constituent analyzed for which concentrations detected for monitor wells exceeded an EPA primary MCL for drinking water. The EPA MCL for nitrate (as nitrogen) is 10.0 milligrams per liter (mg/l). For the paired Unit A and Unit B monitor wells, concentrations of nitrate detected in groundwater samples obtained during the first half of 1991 were larger for the Unit B well than the Unit A well at five of the seven paired sites. For the entire monitor well network, concentrations of nitrate ranged from 2.2 to 38 mg/l for the 10 Unit A wells and ranged from 9.7 to 25 mg/l for the seven Unit B wells; average concentration was 11 mg/l for Unit A wells and 16 mg/l for Unit B wells. The Landfill lies in an area that is transitional in water quality from the intensely cultivated areas north and east from the Landfill, to desert areas west from the Landfill. The nitrate concentrations detected for the Unit A and Unit B monitor wells are not unusual for nitrate in groundwater in the area, and are not believed to result from hazardous waste disposed at the hazardous waste area.

Average concentrations of selected common constituents and routine parameters for groundwater samples obtained from all Unit A and Unit B monitor wells at the Landfill during the first half of 1991 are summarized as follows:

	AVERAGE CONCENTRATION (milligrams per liter)	
CONSTITUENT	Unit A	Unit B
* calcium	30.5	65.9
* magnesium	12.1	18.4
sodium	188	123
* potassium	0.9	2.5
bicarbonate	275	211
* chloride	111	135
sulfate	103	76
* nitrate (as N)	11	16
fluoride	2.04	1.09
alkalinity (as $CaCO_3$)	230	176
silica	32.8	29.9
* total dissolved solids	620	650
temperature (°Celsius)	25.6	25.1
* pH (field)	7.68	7.84

* Indicates constituents or parameters that were detected at higher levels in Unit B than in Unit A.

Carbonate, ammonia, orthophosphate, and phosphorus were also analyzed, but were excluded from this tabulation because these constituents were generally detected only at trace levels. Inspection of the tabulation indicates that, on average, concentrations in Unit A are similar to concentrations in Unit B for most of the analytes, and are smaller than concentrations in Unit B for half of the analytes, including nitrate.

Due to lower permeability in Unit A than in Unit B, injection into Unit A would require more injection wells and higher operating and maintenance costs than injection into Unit B. General chemical quality of groundwater should not be a concern for injecting Unit A groundwater into Unit B. In addition, it must be emphasized that these units are artificial subdivisions of the aquifer and were defined strictly for convenience for the purposes of the RI/FS. Therefore, where possible and appropriate, injection of the treated water into Unit B would be preferred over injection into Unit A.

Injection at the Hazardous Waste Area

Injection of treated groundwater into Unit A at the hazardous waste area would not be appropriate due to impact on capture zones for Unit A extraction wells and due to impact on direction of groundwater movement in Unit A. However, injection of treated groundwater into deeper parts of the regional aquifer at the hazardous waste area might avoid these undesirable impacts. Potential impacts from recharge of all of the treated groundwater via one injection well constructed to yield groundwater to Unit B were projected using the numerical groundwater flow program MODFLOW (McDonald and Harbaugh, 1988). Results of the MODFLOW simulations are outside the scope of this report and are not given herein. However, results suggest that the impact on groundwater levels and on direction of groundwater movement in Unit A and in the uppermost part of Unit B from mounding of groundwater in deeper parts of Unit B would be small. Because some impact was projected and because modeling operations can not project such impacts precisely, the risk of detrimental impact in the hazardous waste area was considered sufficient to reject this injection alternative. Mounding in zones of contaminated groundwater could seriously complicate hydraulic control and monitoring of the zones of contaminated groundwater, and would reduce the effectiveness of the existing groundwater monitoring system.

Injection to the South or East

Injection of treated groundwater into Unit A or Unit B east or south from the hazardous waste area was evaluated and was rejected. Results indicated that injection to the south or east would not provide any advantages over injection to the west or north.

Disadvantages of injection to the east include: land access; detrimental impacts on groundwater movement in Unit A and/or the uppermost part of Unit B at the hazardous waste area; impact on groundwater movement in the south part of the Landfill; and lack of control of the zone of injected water. Although land is available on Maricopa County property east from the hazardous waste area, much of this land is either occupied by a new sanitary Landfill cell or is located in the down-sloping, arroyo-cut margin of the floodplain for the Hassayampa River. Access to the few level sites outside of the new Landfill cell is poor and existing topography could impede construction, operation, and maintenance of the injection system. Model results using the program RESSQ indicated that the desired capture zone development in Unit A for the extraction well system would be impaired by injection east from the hazardous waste area. In addition, model results indicated that a substantial fraction of the injected water would move south and could possibly affect the direction of groundwater movement in the south part of the Landfill, which would impact the effectiveness of the existing groundwater monitoring system. The same concerns regarding injection into Unit B in the hazardous waste area also apply to injection into Unit B to the east.

Disadvantages of injection to the south include impacts on groundwater movement in the south part of the Landfill and lack of control of the zone of injected water. Land is available on Maricopa County property south from the hazardous waste area. However, injection of treated water into Unit A would affect the direction of groundwater movement in Unit A in the south part of the Landfill and would impact the effectiveness of the existing groundwater monitoring system. The same concerns regarding injection into Unit B in the hazardous waste area also apply to injection into Unit B to the south; however, instead of concerns about the movement of the zone of contaminated groundwater, these concerns are for reduced effectiveness of the existing groundwater monitoring system for providing useful data downgradient from the hazardous waste area.

Injection to the West or North

Injection of treated groundwater west or north from the hazardous waste area were considered to be the most favorable alternatives. These alternatives were evaluated using the program RESSQ and results are included herein.

WEST: Treated groundwater could be injected into Unit A or Unit B west from the hazardous waste area without detrimental impact on the hazardous waste area. Due to lower permeability in Unit A than in Unit B, injection into Unit A would require more injection wells and higher operating and maintenance costs than injection into Unit B. Therefore, injection into Unit B is preferred over injection into Unit A west from the Landfill. Advantages of injection of treated groundwater into Unit B to the west include:

1. Sufficient level, undeveloped, easily-accessible land is available on Maricopa County property west from Wickenburg Road for construction, operation, and maintenance of an injection system.
2. Projected impact of injection on the direction of groundwater movement in Unit A or Unit B at the hazardous waste area is negligible.
3. Projected impact of injection on the existing groundwater monitoring system is negligible.
4. Only one deep injection well would be required, thereby minimizing capital, operation, and maintenance costs.

Disadvantages of injection to the west include:

1. Distance for a pipeline from the hazardous waste area is larger for this alternative than for the other injection alternatives. However, the increase in pipeline costs are small and should not be a determining factor for selection of an injection alternative. The pipeline must be constructed beneath Wickenburg Road; however, this road is rural and is not paved, and additional costs to install the pipeline beneath the road would be small.
2. The movement of injected water could not be controlled by the proposed extraction well alternatives. Injected water will mix with ambient groundwater and will not be recirculated in the extraction well system. A Unit B monitor well would be required to monitor chemical quality of groundwater downgradient from the Unit B injection well.

NORTH: Treated water could be injected into Unit A or Unit B north from the hazardous waste area. However, of these options, treated water should be injected only into Unit A because injection of treated groundwater into Unit B to the north has no advantages over injection into Unit B to the west. Advantages of injection of treated groundwater into Unit A to the north include:

1. All or most of the injected water could be captured and recirculated by the proposed extraction alternatives.
2. Injection of water into Unit A directly upgradient from the extraction system could enhance certain conditions in the aquifer, such as: confined conditions if the basaltic lava-flow unit would provide a confining layer; decreased dewatering of the aquifer near the extraction wells; and more rapid movement of groundwater through the aquifer zones targeted for remediation.
3. The existing groundwater monitoring system could monitor the effects of injection to the north. Any augmentation of the monitoring system, if required, would likely be small.

Disadvantages of injection to the north include:

1. Although the land north from the hazardous waste area is physically accessible and undeveloped, the land is not owned by Maricopa County. The land is presently owned by the Bureau of Land Management (BLM). Arrangements with BLM would be required and could include purchase of the land, submittal of an environmental impact assessment, and public hearings. Costs and time required for these arrangements could be substantial.

2. Injection to the north would only be preferred if Unit A would be selected as the target injection zone. Injection into Unit A is expected to require twice as many shallow injection wells as there are extraction wells; this number of shallow injection wells could range from four to eight. The increase in capital costs and operation and maintenance costs for Unit A injection to the north versus Unit B injection to the west could be substantial.

These considerations suggest that injection into Unit B west from the hazardous waste area would be preferred, unless hydraulic control and capture of the zone of injected water is considered to be the most important goal. Hydraulic control and capture of the injected water would occur only for injection into Unit A to the north.

HYDROGEOLOGIC FEATURES PERTINENT TO INTERIM REMEDIAL MEASURE

Descriptions of hydrogeologic features at the Landfill are given in the final RI Report (Montgomery & Associates and CRA, 1991) and in results of supplemental work conducted in 1991 (Montgomery & Associates, 1991b). Hydrogeologic features pertinent to the modeling operations are summarized as follows.

Regional hydrogeologic units in the Landfill area include, in order of increasing depth: the Recent alluvial deposits; the basin-fill deposits; and the bedrock complex. The thick basin-fill deposits have been classified into the Upper, Middle, and Lower Alluvium units. The Upper Alluvium unit was the target of hydrogeologic investigations for the RI. The Upper Alluvium unit at the Landfill was subdivided, in order of increasing depth, into the following units for the RI: upper alluvial deposits unit; basaltic lava-flow unit; and Units A and B, which are water-bearing deposits.

UPPER ALLUVIAL DEPOSITS UNIT

The upper alluvial deposits unit at the Landfill was subdivided for the RI into a coarse-grained part and a fine-grained part. The coarse-grained part consists chiefly of interbedded silty sand and gravelly sand, with caliche, cobbles, and siltstone interbeds. The coarse-grained part occurs from land surface to depths ranging from 24 to 40 feet, where penetrated by monitor wells, soil borings, and exploration borings. Average depth to the base of the coarse-grained part is about 33 feet.

The underlying fine-grained part consists chiefly of interbedded clayey silt, silty clay, and sandy silt, with siltstone and claystone interbeds. Depth to the top of the fine-grained part ranges from 24 to 40 feet below land surface; average depth is about 33 feet. Thickness of the fine-grained part ranges from 11 to 35 feet; average thickness is 22 feet.

BASALTIC LAVA-FLOW UNIT

The basaltic lava-flow unit at the Landfill consists chiefly of basaltic lava-flow rocks, which are generally weathered in the upper part of the unit and are generally vesicular. The unit is part of the Arlington Mesa basalt flows, which erupted from Arlington Mesa. Depth to the top of the basaltic lava-flow unit ranges from 42 to 68 feet below land surface, where penetrated by monitor wells, soil borings, and exploration borings; average depth is about 56 feet. Thickness of the basaltic lava-flow unit ranges from 13 to 29 feet; average thickness is 19 feet.

WATER-BEARING DEPOSITS

At the Landfill, the part of the Upper Alluvium unit from the base of the basaltic lava-flow unit to the top of the Middle Alluvium unit is the uppermost water-bearing part of the regional basin-fill deposits aquifer, and was subdivided into Units A and B for the RI. Unit B is underlain by the Palo Verde clay.

Unit A

Unit A is bounded on the top by the basaltic lava-flow unit and on the bottom by Unit B. Unit A comprises the uppermost fine-grained water-bearing strata of the regional aquifer. The uppermost groundwater level at the Landfill generally occurs in the upper part of Unit A. Where permeability of the basal part of the basaltic lava-flow unit is small and Unit A is completely saturated, the basaltic lava-flow unit may be an upper confining unit for Unit A. Unit A consists chiefly of interbedded clayey silt and silty clay, with a thin layer of interbedded sandy silt and siltstone. Depth to the top of Unit A ranges from 67 to 84 feet below land surface, where penetrated by monitor wells and exploration borings; average depth is about

73 feet. Thickness of Unit A ranges from 32 to 44 feet; average thickness is 35 feet.

Operative transmissivity for Unit A at the landfill is about 2,000 gallons per day per foot width of aquifer at 1:1 hydraulic gradient (gpd/ft). Operative hydraulic conductivity for Unit A is about 100 gallons per day per square foot of aquifer at 1:1 hydraulic gradient (gpd/ft^2). Long-term storage coefficient for Unit A is estimated to be about 0.10; effective porosity is estimated to be about 0.15. In June 1991, direction of groundwater movement in Unit A was to the south. In June 1991, the average hydraulic gradient in Unit A was about 0.004 and the average rate of groundwater movement at the hazardous waste area was about 150 feet per year. It should be emphasized that, due to advection, dispersion, and/or adsorption, dissolved volatile organic compounds may move at different rates than the groundwater.

Unit B

Unit B is bounded on the top by Unit A and on the bottom by the Palo Verde clay, which is the uppermost part of the Middle Alluvium unit. The uppermost strata of Unit B is the uppermost coarse-grained water-bearing strata of the regional aquifer; Unit B monitor wells at the Landfill yield groundwater from this uppermost coarse-grained strata. Unit B consists chiefly of interbedded coarse-grained and fine-grained strata. The fine-grained strata of Unit B are similar to Unit A, and consist chiefly of interbedded silty clay and clayey silt with some sand. The coarse-grained strata of Unit B consist chiefly of sand and gravel. Depth to the top of Unit B ranges from 101 to 116 feet below land surface, where penetrated by monitor wells and exploration borings; average depth is about 107 feet. Where penetrated by on-site exploration boring EX-1, Unit B occurs in the depth interval from 116 to 268 feet below land surface; thickness at this boring is 152 feet.

Operative transmissivity for Unit B at the landfill is about 5,000 gpd/ft. Operative hydraulic conductivity for Unit B is about 160 gpd/ft^2.

Long-term storage coefficient for Unit B is estimated to be about 0.15; effective porosity is estimated to be about 0.20. In June 1991, direction of groundwater movement in Unit B was to the south in the hazardous waste area. The average hydraulic gradient in Unit B in June 1991 was about 0.007 in the hazardous waste area. The hydraulic gradient in Unit B appears to decrease substantially south from the hazardous waste area. In June 1991, average rate of groundwater movement at the hazardous waste area was about 260 feet per year for Unit B.

Palo Verde Clay

A unit consisting chiefly of silty clay was encountered at exploration boring EX-1, and was tentatively classified as the Palo Verde clay. This unit is believed to be the upper part of the Middle Alluvium unit at the Landfill. At exploration boring EX-1, top of the unit was penetrated at a depth of 268 feet below land surface. The Palo Verde clay appears to comprise the basal confining unit for Unit B.

SUMMARY OF STRATIGRAPHY

Stratigraphic data for the hydrogeologic units at the Landfill are summarized as follows:

HYDROGEOLOGIC UNIT	DEPTH TO TOP OF UNIT (feet)		THICKNESS (feet)	
	RANGE	AVERAGE	RANGE	AVERAGE
UPPER ALLUVIAL DEPOSITS UNIT				
coarse-grained part	0	0	24-40	33
fine-grained part	24-40	33	11-35	22
BASALTIC LAVA-FLOW UNIT	42-68	56	13-29	19
UNIT A	67-84	73	32-44	35
UNIT B	101-116	107	152	152
PALO VERDE CLAY	268	268	---	---

MODELING PROCEDURES FOR PROGRAM RESSQ

The modeling approach for the Landfill included use of the computer program RESSQ. RESSQ is an analytical-numerical program based on superposition of mathematical solutions for groundwater movement that would result from pumping extraction and/or injection wells in the presence of a regional hydraulic gradient. This program is widely used and accepted in the public domain. Use of this program for the FS is consistent with the amount and type of data available from the RI and is consistent with requirements for proper design of a groundwater remedial measure.

The computer program RESSQ was used to project hydraulic capture zones in Unit A for potential extraction-injection well alternatives. A description of the conceptual and mathematical basis for the RESSQ program is given by Javandel et al (1984). The software used to operate the RESSQ program was a pre- and post-processing program named RESCUE (Beljin, 1991). The RESSQ program simulates a steady-state, two-dimensional flow field for a homogeneous, isotropic aquifer of uniform thickness. The simulated steady-state flow field may include regional flow caused by a planar hydraulic gradient, together with flow caused by extraction or injection wells. Although the two-dimensional model aquifer includes no vertical spatial dimension, the parameters used for model input are based on vertical thickness given in the final RI Report for Unit A in the hazardous waste area. Wells are assumed to penetrate the complete thickness of the aquifer, and are assumed to operate at constant rates. The steady-state flow field pattern is given as a set of streamlines. Traces of streamlines are used by the program to track particle paths and to determine "t"-year hydraulic capture zones.

The corners of the model area, location of Unit A monitor wells, and well sites for which concentrations of volatile organic compounds have been detected and confirmed in groundwater samples obtained from Unit A are shown on **Figure 4**. **Figure 4** is also included as a transparent overlay in the pocket at the end of Appendix A.A. The corners of the model area are different from the boundary of the map area shown on **Figure 4**. This overlay should be used to compare the capture zones for different extraction-injection regimens. The overlay should generally be used by matching the corners of the model area on the overlay with the boundary of the capture zone maps.

Groundwater flow models require assumptions to be made for aquifer conditions. It is rare for true aquifer conditions to meet all the assumptions of various models that may be used to simulate the aquifer conditions. However, with sufficient knowledge of the true aquifer conditions and careful selection of an appropriate modeling program, groundwater models can be useful tools for projecting impacts from extraction-injection well systems. To properly evaluate modeling results, it is important to understand how the true aquifer conditions deviate from the ideal conditions assumed for the model. Deviations of true aquifer conditions at the Landfill from the assumptions of RESSQ, and possible effects of these deviations on analysis of potential remedial extraction and injection, include:

1. Inspection of lithologic logs for monitor wells and aquifer parameters computed from data obtained during the RI and supplemental work indicates that local variation occurs in lithology, thickness, and hydraulic conductivity for Unit A. These conditions indicate that Unit A is not a homogeneous, isotropic unit of uniform thickness. Local variation of lithology, thickness, and hydraulic conductivity for Unit A could result in streamlines and dimensions of capture zones during remedial extraction and injection that differ from streamlines and dimensions of "t"-year capture zones projected using RESSQ.

2. Results from the RI and supplemental work indicate that a substantial downward component of hydraulic gradient occurs at the Landfill from Unit A to Unit B. The difference between non-pumping groundwater levels at Unit A monitor wells and non-pumping groundwater levels at Unit B monitor wells has ranged from 22 to 29 feet. Measurement of water level response in Unit B monitor wells during pumping tests at Unit A monitor wells in the hazardous waste area indicates that water level drawdown

occurred in some Unit B monitor wells and that water level response was not discernible in other Unit B monitor wells. These relations indicate that, during short-term pumping from Unit A, local upward movement of groundwater may or may not occur from Unit B to Unit A. If upward movement of groundwater from Unit B to Unit A would occur during long-term operation of extraction wells in Unit A, capture zones for the extraction wells could be smaller than the projected "t"-year capture zones projected using RESSQ and streamlines would be different from those projected.

3. Analysis of the trend of groundwater level data for Unit A monitor wells indicates a relatively slow stable rate of decline in water levels. If potential injection wells would be located far from potential extraction wells and the water level decline would continue, then saturated thickness near potential extraction wells could decrease more rapidly than expected during long-term remedial pumping. If potential extraction wells could continue to operate at constant rates, then the decrease in Unit A saturated thickness could result in larger capture zones for extraction wells than the "t"-year capture zones projected using RESSQ. If conditions, such as dewatering of thin permeable zones within Unit A, would result from a decrease in saturated thickness and if potential extraction wells could not continue to operate at constant rates, then the capture zones could be smaller than the "t"-year capture zones projected using RESSQ. These conditions would also result in streamlines different than those projected.

4. After remedial extraction and injection begins, a period of time will be required for development of a stable groundwater level pattern and conditions that approach steady-state. Duration of this "development" period is not known and would depend on the true aquifer conditions, extraction and injection rates, and the location of extraction and injection wells. The "t"-year capture zones projected using RESSQ are based on the assumption that groundwater levels and groundwater movement would instantaneously reach a steady-state at the start of remedial extraction and injection. If duration of this "development" period

would be substantial, capture zones for extraction wells would be smaller than the projected "t"-year capture zones.

Use of this modeling approach is appropriate if the results are evaluated with due consideration for deviations of true aquifer conditions at the Landfill from the assumptions of RESSQ.

HYDROLOGIC INPUT PARAMETERS FOR PROGRAM RESSQ

Aquifer parameters input to RESSQ include: groundwater velocity, in feet per day (ft/d); effective porosity, dimensionless; and aquifer thickness, in feet. Additional input parameters include extraction or injection rates, in gallons per minute (gpm), and locations for extraction and injection wells.

The average velocity of groundwater movement in an aquifer is directly proportional to the aquifer hydraulic conductivity and to hydraulic gradient; and is inversely proportional to effective porosity of the aquifer media. Effective porosity of an aquifer media is the volume of interconnected pore space per unit volume of aquifer that provides pathways for groundwater movement under saturated conditions; effective porosity is generally less than total porosity and greater than specific yield. These relations are expressed as follows:

$$V = \frac{KI}{7.48\,\eta_e}$$

Where: V = Groundwater velocity in feet per day

K = Aquifer hydraulic conductivity in gallons per day per square foot of aquifer at 1:1 hydraulic gradient (gpd/ft^2)

I = Non-pumping hydraulic gradient (dimensionless)

η_e = Effective porosity (dimensionless)

Input parameters for RESSQ are summarized in **Table 1**.

Three simulations were conducted for each extraction-injection regimen. Combinations of aquifer parameters were selected for these simulations to represent plausible least favorable, average, and most favorable aquifer conditions. These simulations resulted in least favorable, average, and most favorable projected capture zones for each extraction-injection regimen. Important features of projected capture zones include: length of the capture zone in the approximate direction of the regional hydraulic gradient; width of the capture zone in the direction approximately perpendicular to the regional hydraulic gradient; and location of a stagnation point downgradient from an extraction well.

For this investigation, the most favorable capture zone for each regimen is generally considered to be the capture zone with the largest width, because the capture zone with the largest width would generally result in the most favorable hydraulic control and capture of the zones of contaminated groundwater. Least favorable aquifer conditions result in the minimum capture zone width, average aquifer conditions result in the average width, and most favorable aquifer conditions result in the maximum width. The three simulations for each extraction-injection regimen are labeled with the identifiers "min", "avg", and "max" to signify if a simulation results in the minimum (least favorable), average, or maximum (most favorable) width, respectively, for the projected capture zones.

Aquifer parameters input to the model include:

AQUIFER CONDITION	HYDRAULIC CONDUCTIVITY (gpd/ft^2)	HYDRAULIC GRADIENT (dimensionless)	AQUIFER THICKNESS (feet)	EFFECTIVE POROSITY (percent)
LEAST FAVORABLE ("min")	150	0.0045	35	20
AVERAGE ("avg")	100	0.0040	35	15
MOST FAVORABLE ("max")	50	0.0035	30	10

Sensitivity of the results to selection of model input parameters is provided by evaluating a "min", "avg", and "max" case for each extraction-injection alternative.

Magnitudes of hydraulic conductivity used for input to the model represent a range of values based on pumping tests conducted for Unit A monitor wells during the RI (Montgomery & Associates and CRA, 1991). Magnitudes of hydraulic gradient used for input to the model represent a range of values based on the groundwater level contour map for Unit A shown on Figure 16 of the final RI Report (Montgomery & Associates and CRA, 1991). The range of effective porosity used for input to the model was believed to be appropriate based on the lithology of Unit A determined during the RI.

Average aquifer thickness of 35 feet for Unit A is based on data obtained during the RI and on anticipated base of the perforated interval for extraction wells at the hazardous waste area.

The pumping rate input to the model for extraction wells was five (gpm). This rate is anticipated to be a sustainable long-term pumping rate based on the average pumping rate of 6.3 gpm for short-term pumping tests conducted at Unit A monitor wells during the RI. The rate of injection input to the model for each injection well was 2.5 gpm. This injection rate is one-half the extraction rate and is believed to be an appropriate general assumption for hydrogeologic conditions in the Salt River Valley. Based on this assumption, the number of Unit A injection wells for simulations would be twice the number of Unit A extraction wells.

Selection of model locations for extraction wells and injection wells for the simulations is described in the introduction section of this modeling report. The extraction-injection alternatives are summarized in **Table 1**. Model locations for the two-well extraction alternatives and various injection well arrays are shown on simulation **Figures 5 through 16**. Model locations for the three-well extraction alternatives and various injection well arrays are shown on simulation **Figures 17 through 34**. Model locations for the four-well extraction alternatives and various injection well arrays are shown on simulation **Figures 35 through 40**. Locations for extraction wells and injection wells for each simulation can be viewed in relation to the hazardous waste area by placing the transparent overlay of **Figure 4** (in pocket at end of report) over each simulation illustration. The corners of the model area are different from the boundary of the map area shown on **Figure 4**. The overlay should generally be used by matching the corners of the model area on the overlay with the boundary of the capture zone maps.

Results for beneficial reuse via injection into Unit B west from the Landfill also represent results for a beneficial reuse that excludes injection wells.

Drawdown of groundwater level at the extraction wells was evaluated to determine if pumping rates input to the model could be sustained. Aquifer conditions input to the model that would result in the largest drawdown at the extraction wells are the most favorable aquifer conditions ("max"). The Theis non-equilibrium equation (Theis, 1935) was used to project theoretical drawdown at the extraction wells. The theoretical drawdown was then divided by a plausible range of well efficiencies to account for borehole losses. Results suggest that the pumping rates input to the model could be sustained for moderate to good well efficiency. However, for poor well efficiency, sustainable pumping rates would be smaller than those input to the model for the most favorable aquifer conditions ("max"). These relations emphasize the importance of obtaining the best well efficiency possible through proper design and construction of extraction wells.

RESSQ SIMULATIONS

Simulations using the program RESSQ were conducted for two-well, three-well, and four-well extraction alternatives. Model input for each extraction alternative included injection of treated groundwater to the west and to the north. However, results for injection into Unit B west from the Landfill also represent results for a beneficial reuse that excludes injection wells. Model input for RESSQ is summarized in **Table 1**. Several other test simulations, which are not given herein, were conducted using the program RESSQ to screen the extraction-injection alternatives and to guide the investigation toward the important results, which are given herein.

TWO-WELL EXTRACTION ALTERNATIVES

Extraction-Injection Regimen EI.1

Extraction-injection regimen EI.1 simulates pumping at extraction wells E-1 and E-2, together with recharge at one injection well completed in Unit B west from the Landfill. Input for the EI.1 simulations did not include injection because, based on MODFLOW results, impact on water levels in Unit A at the hazardous waste area from recharge into this deep west injection well was assumed to be negligible. Therefore, results for injection into Unit B west from the Landfill also represent results for a beneficial reuse that excludes injection wells. Model extraction well E-1 is located about 130 feet south from monitor well MW-1UA and model extraction well E-2 is located about 150 feet south from monitor well MW-6UA. Results from extraction-injection regimen EI.1 are shown on **Figures 5, 6, and 7**, and should be inspected using the transparent overlay located in the pocket at the end of this modeling report.

As discussed in the introductory section on page five of this report, Unit A monitor wells should be constructed and tested near the proposed sites for extraction wells E-1 and E-2 to confirm the assumption that the targeted zones of groundwater that contain elevated concentrations of volatile organic compounds extend as much as 150 feet south from monitor wells MW-1UA and MW-6UA. Depending on results from these monitor wells, extraction wells could be located:

1. at the "hot spots";
2. between the "hot spots" and the E-1 and E-2 sites;
3. at the E-1 and E-2 sites; or
4. south from the E-1 and E-2 sites.

Capture zones for these various location alternatives would be translated north or south from the capture zones simulated herein for the E-1 and E-2 sites. These various alternatives can be evaluated by positioning the transparent overlay on **Figures 5, 6, and 7** to match the model extraction well locations on the transparent overlay with the various potential locations.

Extraction-Injection Regimen EI.2

Extraction-injection regimen EI.2 simulates pumping at extraction wells E-1 and E-2, together with recharge at four injection wells completed in Unit A west from the Landfill. Results from extraction-injection regimen EI.2 are shown on **Figures 8, 9, and 10**, and should be inspected using the transparent overlay located in the pocket at the end of this modeling report.

As for extraction-injection regimen EI.1, capture zones for alternative extraction well locations can be evaluated by positioning the transparent overlay on **Figures 8, 9, and 10** to match the model extraction well locations on the transparent overlay with the various potential locations.

Extraction-Injection Regimen EI.3

Extraction-injection regimen EI.3 simulates pumping at extraction wells E-1 and E-2, together with recharge at four injection wells completed in Unit A north from the Landfill. Extraction-injection regimen EI.3A simulates recharge at four injection wells arranged in a "stacked" two-row array. The row of injection wells nearest to the Landfill is about 100 feet north from the Landfill fence. Results from extraction-injection regimen EI.3A are shown on **Figures 11, 12, and 13.**

Extraction-injection regimen EI.3B simulates recharge at four injection wells arranged in a single row located about 100 feet north from the Landfill fence. Results from extraction-injection regimen EI.3B are shown on **Figures 14, 15, and 16.**

THREE-WELL EXTRACTION ALTERNATIVES

Extraction-Injection Regimen EI.4

Extraction-injection regimen EI.4 simulates pumping at extraction wells E-1, E-2, and E-3, together with recharge at one injection well completed in Unit B west from the Landfill. Input for the EI.4 simulations did not include injection because, based on MODFLOW results, impact on water levels in Unit A at the hazardous waste area from recharge into this deep west injection well was assumed to be negligible. Therefore, results for injection into Unit B west from the Landfill also represent results for a beneficial reuse that excludes injection wells. Model extraction well E-3 is located about 150 feet south from monitor well MW-4UA. Results from extraction-injection regimen EI.4 are shown on **Figures 17, 18, and 19**, and should be inspected using the transparent overlay located in the pocket at the end of this modeling report.

Extraction-Injection Regimen EI.5

Extraction-injection regimen EI.5 simulates pumping at extraction wells E-1, E-2, and E-3, together with recharge at six injection wells completed in Unit A west from the Landfill. Results from extraction-injection regimen EI.5 are shown on **Figures 20, 21, and 22**.

Extraction-Injection Regimen EI.6

Extraction-injection regimen EI.6 simulates pumping at extraction wells E-1, E-2, and E-3, together with recharge at six injection wells completed in Unit A north from the Landfill. Extraction-injection regimen EI.6A simulates recharge at six injection wells arranged in a "stacked" two-row array. The row of injection wells nearest to the Landfill is about 100 feet north from the Landfill fence. Results from extraction-injection regimen EI.6A are shown on **Figures 23, 24, and 25**.

Extraction-injection regimen EI.6B simulates recharge at six injection wells arranged in a single row located about 100 feet north from the Landfill fence. Results from extraction-injection regimen EI.6B are shown on **Figures 26, 27, and 28**.

Extraction-Injection Regimen EI.7

Extraction-injection regimen EI.7 simulates pumping at extraction wells E-1, E-2, and E-4, together with recharge at six injection wells completed in Unit A north from the Landfill. Extraction-injection regimen EI.7A simulates recharge at six injection wells arranged in a "stacked" two-row array. The row of injection wells nearest to the Landfill is about 100 feet north from the Landfill fence. Based on results for capture of injected water for extraction-injection regimen EI.6, a "stacked" two-row array was considered to be slightly more preferable than a single-row array; therefore, a single-row array was not simulated for extraction-injection regimen EI.7.

Results from extraction-injection regimen EI.7A are shown on **Figures 29, 30, and 31**.

Extraction-injection regimen EI.7B simulates pumping at extraction wells E-1, E-2, and E-4, together with recharge at one injection well completed in Unit B west from the Landfill. Input for the EI.7B simulations did not include injection because, based on MODFLOW results, impact on water levels in Unit A at the hazardous waste area from recharge into this deep west injection well was assumed to be negligible. Therefore, results for injection into Unit B west from the Landfill also represent results for a beneficial reuse that excludes injection wells. Results from extraction-injection regimen EI.7B are shown on **Figures 32, 33, and 34.** Based on results of the EI.1, EI.2, EI.4, and EI.5 simulations, projected capture zones for cases including injection wells completed in Unit A west from the Landfill are substantially the same as projected capture zones for cases including an injection well completed in Unit B west from the Landfill or no injection wells. Therefore, results from extraction-injection regimen EI.7B are considered also to effectively represent pumping at extraction wells E-1, E-2, and E-4, together with recharge at six injection wells completed in Unit A west from the Landfill.

FOUR-WELL EXTRACTION ALTERNATIVES

Extraction-Injection Regimen EI.8A

Extraction-injection regimen EI.8A simulates pumping at extraction wells E-1, E-2, E-4, and E-5, together with recharge at eight injection wells completed in Unit A north from the Landfill. Model extraction well E-5 is located south from the Special Pits and monitor well MW-7UA. These injection wells are arranged in two five-spot arrays. The row of injection wells nearest to the Landfill is about 100 feet north from the Landfill fence.

Results from extraction-injection regimen EI.8A are shown on **Figures 35, 36, and 37**.

Extraction-Injection Regimen EI.8B

Extraction-injection regimen EI.8B simulates pumping at extraction wells E-1, E-2, E-4, and E-5, together with one injection well completed in Unit B west from the Landfill. Input for the EI.8B simulations did not include injection because, based on MODFLOW results, impact on water levels in Unit A at the hazardous waste area from recharge into this deep west injection well was assumed to be negligible. Therefore, results for injection into Unit B west from the Landfill also represent results for a beneficial reuse that excludes injection wells. Results from extraction-injection regimen EI.8B are considered also to effectively represent pumping at extraction wells E-1, E-2, E-4, and E-5, together with recharge at eight injection wells completed in Unit A west from the Landfill.

RESSQ SIMULATION RESULTS

Results for simulations using the program RESSQ for two-well, three-well, and four-well extraction alternatives are shown on **Figures 5 through 40**. In general, the following report section evaluates results for the average aquifer conditions ("avg") only. The least favorable aquifer conditions ("min") generally result in less favorable results for projected capture zones than the average aquifer conditions, and the most favorable aquifer conditions ("max") generally result in more favorable results for projected capture zones than the average aquifer conditions.

TWO-WELL EXTRACTION ALTERNATIVES

Extraction-Injection Regimen EI.1

Results for average aquifer conditions ("avg") for extraction-injection regimen EI.1 **(Figure 5)** indicate that the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA are effectively controlled and captured within one year of pumping. Groundwater near monitor well MW-5UA is controlled and part is captured after three years of pumping. Groundwater at monitor well MW-4UA is not controlled or captured after three years of pumping.

To evaluate the case where the two extraction wells would be constructed near monitor wells MW-1UA and MW-6UA, the transparent overlay (in pocket at end of this modeling report) should be positioned to match the E-1 site on **Figure 5** with the MW-1UA site on the transparent overlay. This evaluation indicates that the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA are effectively controlled and captured within one-half year of pumping. Groundwater near monitor well MW-5UA is controlled and captured after three years of pumping. Groundwater at monitor well MW-4UA is not controlled or captured after three years of pumping.

Extraction-Injection Regimen EI.2

Results for average aquifer conditions ("avg") for extraction-injection regimen EI.2 (**Figure 8**) are essentially the same as results for average aquifer conditions for extraction-injection regimen EI.1, except that regimen EI.2 provides better control and capture of the MW-5UA area.

To evaluate the case where the two extraction wells would be constructed near monitor wells MW-1UA and MW-6UA, the transparent overlay (in pocket at end of this modeling report) should be positioned to match the E-1 site on **Figure 8** with the MW-1UA site on the transparent overlay. This evaluation indicates that the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA are effectively controlled and captured within one-half year of pumping. Groundwater near monitor well MW-5UA is controlled and captured after three years of pumping. Groundwater at monitor well MW-4UA is not controlled or captured after three years of pumping.

Extraction-Injection Regimen EI.3

Results for average aquifer conditions ("avg") for extraction-injection regimens EI.3A and EI.3B are shown on **Figures 11 and 14**, respectively. Results for regimen EI.3A indicate that the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA are effectively controlled and captured within one year of pumping. Groundwater at monitor wells MW-4UA and MW-5UA is not controlled or captured after one year of pumping. All streamlines from the injection wells are shown to terminate at the extraction wells and suggest that the injected water is effectively recirculated (**Figure 11**).

Results for regimen EI.3B indicate that the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA are effectively controlled and captured within one year of pumping. Groundwater at monitor wells MW-4UA and MW-5UA is not controlled or captured after one year of pumping. Some streamlines from three of the four injection wells are shown to continue past the extraction wells and suggest that the a fraction of the injected water is not captured by the extraction wells **(Figure 14)**.

THREE-WELL EXTRACTION ALTERNATIVES

Extraction-Injection Regimen EI.4

Results for average aquifer conditions ("avg") for extraction-injection regimen EI.4 **(Figure 17)** indicate that the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA, and groundwater near monitor well MW-4UA, are effectively controlled and captured within one year of pumping. Groundwater near monitor well MW-5UA is controlled and captured after three years of pumping. Hydraulic control and capture of groundwater also occurs for the areas of Pit 1, Pit 3b, and Pit 3c.

Extraction-Injection Regimen EI.5

Results for average aquifer conditions ("avg") for extraction-injection regimen EI.5 **(Figure 20)** are essentially the same as results for average aquifer conditions for extraction-injection regimen EI.4, except that capture zones for regimen EI-5 are shifted slightly to the west from capture zones for regimen EI-4.

Extraction-Injection Regimen EI.6

Results for average aquifer conditions ("avg") for extraction-injection regimens EI.6A and EI.6B are shown on **Figures 23 and 26**, respectively. Results for regimen EI.6A indicate that the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA, and groundwater near monitor well MW-4UA, are effectively controlled and captured within one year of pumping. Groundwater at monitor well MW-5UA is controlled, but not captured after one year of pumping. Hydraulic control and capture of groundwater also occurs for the areas of Pit 1, Pit 3b, and Pit 3c. All except one of the streamlines from the injection wells are shown to terminate at the extraction wells and suggest that the injected water is effectively recirculated (**Figure 23**).

Results for regimen EI.6B indicate that the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA, and groundwater near monitor well MW-4UA, are effectively controlled and captured within one year of pumping. Hydraulic control and capture of groundwater also occurs for the areas of Pit 1, Pit 3b, and Pit 3c. Groundwater at monitor well MW-5UA is not captured after one year of pumping and is at the edge of the area that is hydraulically controlled by the extraction wells. All except two of the streamlines from the injection wells are shown to terminate at the extraction wells and suggest that the injected water is effectively recirculated (**Figure 26**).

Extraction-Injection Regimen EI.7

Results for average aquifer conditions ("avg") for extraction-injection regimens EI.7A and EI.7B are shown on **Figures 29 and 32**, respectively. Results for regimen EI.7A indicate that the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA, and groundwater near monitor well MW-4UA, are effectively controlled and captured within one year of pumping. Hydraulic control and capture of groundwater also occurs for the areas of Pit 1, Pit 3b, and Pit 3c. Groundwater at monitor well MW-5UA is not captured after one year of pumping and is at the edge of the area that is hydraulically controlled by the extraction wells. All except one or two of the streamlines from the injection wells are shown to terminate at the extraction wells and suggest that the injected water is effectively recirculated (**Figure 29**).

Results for regimen EI.7B indicate that the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA, and groundwater near monitor well MW-4UA, are effectively controlled and captured within one year of pumping. Groundwater near monitor well MW-5UA is controlled and captured after three years of pumping. Hydraulic control and capture of groundwater also occurs for the areas of Pit 1, Pit 3b, and Pit 3c within one year of pumping (**Figure 32**).

FOUR-WELL EXTRACTION ALTERNATIVES

Extraction-Injection Regimen EI.8A

Results for average aquifer conditions ("avg") for extraction-injection regimen EI.8A (**Figure 35**) indicate that the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA, and groundwater near monitor well MW-4UA, are effectively controlled and captured within one year of pumping. Hydraulic control and capture of groundwater also occurs for the areas of Pit 1, Pit 3b, and Pit 3c, and for much of the Special Pits area. Groundwater at monitor well MW-5UA is controlled, but not captured, after one year of pumping. All except two of the streamlines from the injection wells are shown to terminate at the extraction wells and suggest that the injected water is effectively recirculated.

Extraction-Injection Regimen EI.8B

Results for average aquifer conditions ("avg") for extraction-injection regimen EI.8B **(Figure 38)** indicate that the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA, and groundwater near monitor well MW-4UA, are effectively controlled and captured within one year of pumping. Hydraulic control and capture of groundwater also occurs for the areas of Pit 1, Pit 3b, and Pit 3c within one year of pumping, and for most of the Special Pits area within two years of pumping. Groundwater at monitor well MW-5UA is controlled, but not captured, after two years of pumping.

SUMMARY OF RESULTS AND RECOMMENDATIONS

Results from evaluation of the RESSQ simulations for the extraction-injection regimens and recommendations for a remedial measure for groundwater include:

1. Recharge of treated water west from the Landfill would likely have a negligible impact on capture zones and direction of groundwater movement at the hazardous waste area. For recharge to the west, an injection well completed in Unit B would be more cost effective than several injection wells completed solely in Unit A. For recharge to the west, an injection well completed in Unit B is recommended.

2. Recharge of treated water via injection wells completed solely in Unit A north from the Landfill could result in hydraulic control and recirculation of injected water. However, injection into Unit A to the north generally results in narrower capture zones, which decreases the effectiveness of the extraction wells. Injection into Unit A to the north may result in smaller water level drawdown at extraction wells, which could increase sustainable yield from the extraction wells. Injection into Unit A to the north may increase the rate of capture of the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA. The "stacked" two-row array is preferred over the single-row array for injection wells to the north.

3. Two extraction wells located at the E-1 and E-2 sites, together with either injection wells west or north from the Landfill or with no injection wells, could provide effective hydraulic control and capture of the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA. Results suggest that, with injection into Unit B west from the Landfill or with no injection, these two extraction wells could provide hydraulic control and capture of groundwater at monitor well MW-5UA, but not for groundwater at monitor well MW-4UA. Results suggest that, with injection into Unit A to the north, groundwater at monitor

wells MW-4UA and MW-5UA would not be controlled or captured. Results suggest that most, if not all, of the water injected into Unit A to the north would be effectively captured and recirculated.

4. For the two-well extraction alternative, extraction well sites E-1 and E-2 are anticipated to be more appropriate than sites nearer to the "hot spots" at monitor wells MW-1UA and MW-6UA. However, Unit A monitor wells should be constructed and tested at the E-1 and E-2 sites prior to construction of the extraction wells to provide a basis to select specific extraction well locations.

5. Results indicate that three extraction wells are required to provide hydraulic control and capture of the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA, of groundwater at monitor wells MW-4UA and MW-5UA, and of groundwater at Pits 1, 3b, and 3c. For the three-well extraction alternative, groundwater at monitor well MW-5UA is controlled more effectively with Unit B injection to the west, or with no injection, than with Unit A injection to the north.

6. For the three-well extraction alternative, extraction well sites E-1, E-2, and E-4 should be selected unless concentrations of volatile organic compounds increase substantially at monitor well MW-4UA prior to implementation of the groundwater remedial measure. If these concentrations increase substantially, a Unit A monitor well should be constructed and tested at the E-3 site prior to construction of the extraction wells to provide a basis to select a specific extraction well location.

7. If the Special Pits area in the west part of the hazardous waste area would become a target for a groundwater remedial measure in the future, an extraction well located at site E-5 could be added to the three-well extraction alternative to provide hydraulic control and capture of groundwater at these Special Pits. Results suggest that effective hydraulic control and capture of groundwater at the Special Pits could occur with Unit B injection to the west, Unit A injection to the north,

or no injection. For the four-well extraction alternative, two adjacent five-spot arrays are preferred for Unit A injection wells to the north. Results suggest that water injected into Unit A to the north would be effectively captured and recirculated.

8. Where more than one extraction well or injection well is used in a remedial program, stagnation points occur between the extraction wells and between the injection wells. A stagnation point is a location where forces that cause groundwater movement counteract each other, resulting in zones of groundwater that do not move. Groundwater at or near stagnation points can be captured by using an appropriate pumping schedule to periodically induce groundwater movement at the stagnation point.

9. Specific recommendations include:

   A. Although results suggest that two extraction wells could address the targeted zones of contaminated groundwater near monitor wells MW-1UA and MW-6UA, three extraction wells are recommended to address zones of groundwater at monitor well MW-4UA and Pits 1, 3b, and 3c. At present, the preferred extraction well sites are E-1, E-2, and E-4. Two Unit A monitor wells should be constructed near the E-1 and E-2 sites to confirm the validity of the assumption used for southward extent of the targeted zones of groundwater. Results from these monitor wells should be used to select specific extraction well locations.

   B. The extraction wells should be tested to determine sustainable yields. If sustainable yields are substantially different from five gpm, additional modeling should be conducted to reanalyze capture zones for the measured sustainable yields. The extraction well program should be re-evaluated based on this analysis.

B. A Unit A monitor well should be constructed near the E-5 site to monitor chemical quality of groundwater south from the Special Pits area in the west part of the hazardous waste area.

C. If recharge is selected as the discharge alternative for treated groundwater, the tested sustainable yields for the extraction wells must be known, and the following are recommended:

1. **RECHARGE TO WEST:** If recharge to the west is selected, an injection well should be constructed into Unit B. A monitor well should be constructed into Unit B on Maricopa County property south from the injection well.

2. **RECHARGE TO NORTH:** If recharge into Unit A to the north is selected, it is anticipated that about six Unit A injection wells would be required. The injection wells should be tested to determine sustainable injection capacity. If sustainable injection capacity is substantially different from that assumed for this report, additional modeling should be conducted to reanalyze the effects of injection and the injection well program should be re-evaluated based on this analysis.

DESIGN OF EXTRACTION WELLS, INJECTION WELLS, AND MONITOR WELLS

Design for construction of Unit A monitor wells would be the same as the design used for Unit A monitor wells constructed during the RI; a schematic diagram for proposed Unit A monitor wells is shown on **Figure 41**. Design for construction of a monitor well completed in Unit B would be the same as the design used for Unit A monitor wells constructed during the RI, except the total depth of the well would extend to the Palo Verde clay; a schematic diagram for the proposed Unit B monitor well is shown on **Figure 42**.

Design for construction of extraction wells and injection wells for Unit A would be the same; a schematic diagram for proposed Unit A extraction and injection wells is shown on **Figure 43**. Each Unit A extraction well and injection well would be constructed to include:

1. 20-inch diameter blank steel casing cemented from land surface to a depth of 19 feet.
2. 20-inch diameter borehole drilled using conventional or air-rotary drilling methods from 19 feet to the base of the basaltic lava-flow unit.
3. 16-inch diameter blank steel casing cemented from land surface to the base of the basaltic lava-flow unit.
4. 15-inch diameter borehole drilled using air-rotary drilling methods from the base of the basaltic lava-flow unit to near the base of Unit A.
5. 8-inch diameter blank steel casing and well screen set from land surface to total depth of the well. Well screen installed from near the top of Unit A to total depth of the well.
6. Gravel pack installed via tremie pipe in the annular space between the 8-inch casing and the borehole wall from total depth to near land surface; a gravel pack access pipe would be installed for the gravel pack.
7. Electric submersible pump installed in the extraction wells.
8. Injection drop pipe installed with orifice in the injection wells.
9. Above-surface well vault installed at the wells.

A schematic diagram for construction of an injection well into Unit B is shown on **Figure 44**. The Unit B injection well would be constructed to include:

1. 20-inch diameter blank steel casing cemented from land surface to a depth of 19 feet.
2. 20-inch diameter borehole drilled using conventional or air-rotary drilling methods from 19 feet to the base of Unit A.
3. 16-inch diameter blank steel casing cemented from land surface to the base of Unit A.
4. 15-inch diameter borehole drilled using air-rotary drilling methods from the base of Unit A to the Palo Verde clay.
5. 8-inch diameter blank steel casing and well screen set from land surface to total depth of the well. Well screen installed from near the base of Unit A to total depth of the well.
6. Gravel pack installed via tremie pipe in the annular space between the 8-inch casing and the borehole wall from total depth to near land surface; a gravel pack access pipe would be installed for the gravel pack.
7. Injection drop pipe installed with orifice.
8. Above-surface well vault installed at the well.

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TABLE 1. SUMMARY OF SELECTED PROGRAM INPUT PARAMETERS FOR RESSQ MODEL EXTRACTION-INJECTION REGIMENS

EXTRACTION-INJECTION REGIMEN[a]	EXTRACTION WELLS	EXTRACTION RATE PER WELL (gpm)[b]	INJECTION WELLS[c]	INJECTION RATE PER WELL (gpm)[b]	HYDRAULIC CONDUCTIVITY (gpd/ft^2)[d]	EFFECTIVE POROSITY[e]	THICKNESS OF AQUIFER (feet)	VELOCITY OF REGIONAL FLOW (feet/year)	T-YEAR CAPTURE ZONES[f] (years)	MAXIMUM SIMULATION TIME (years)	FIGURE NUMBER
EI.1											
EI.1(avg)	E-1,E-2	5	IW-7 to west or no wells	---[g]	100	0.15	35	130	0.5,1,3	20	5
EI.1(min)	E-1,E-2	5	IW-7 to west or no wells	---[g]	150	0.20	35	165	0.5,1,3	20	6
EI.1(max)	E-1,E-2	5	IW-7 to west or no wells	---[g]	50	0.10	30	85	0.5,1,3	50	7
EI.2											
EI.2(avg)	E-1,E-2	5	IW-1 through IW-4 to west	2.5	100	0.15	35	130	0.5,1,3	20	8
EI.2(min)	E-1,E-2	5	IW-1 through IW-4 to west	2.5	150	0.20	35	165	0.5,1,3	20	9
EI.2(max)	E-1,E-2	5	IW-1 through IW-4 to west	2.5	50	0.10	30	85	0.5,1,3	50	10
EI.3A											
EI.3A(avg)	E-1,E-2	5	I-1 through I-4 to north	2.5	100	0.15	35	130	0.5,1	20	11
EI.3A(min)	E-1,E-2	5	I-1 through I-4 to north	2.5	150	0.20	35	165	0.5,1	20	12
EI.3A(max)	E-1,E-2	5	I-1 through I-4 to north	2.5	50	0.10	30	85	0.5,1	40	13
EI.3B											
EI.3B(avg)	E-1,E-2	5	I-5 through I-8 to north	2.5	100	0.15	35	130	0.5,1	20	14
EI.3B(min)	E-1,E-2	5	I-5 through I-8 to north	2.5	150	0.20	35	165	0.5,1	20	15
EI.3B(max)	E-1,E-2	5	I-5 through I-8 to north	2.5	50	0.10	30	85	0.5,1	40	16
EI.4											
EI.4(avg)	E-1,E-2,E-3	5	IW-7 to west or no wells	---[g]	100	0.15	35	130	0.5,1,3	30	17
EI.4(min)	E-1,E-2,E-3	5	IW-7 to west or no wells	---[g]	150	0.20	35	165	0.5,1,3	20	18
EI.4(max)	E-1,E-2,E-3	5	IW-7 to west or no wells	---[g]	50	0.10	30	85	0.5,1,3	60	19
EI.5											
EI.5(avg)	E-1,E-2,E-3	5	IW-1 through IW-6 to west	2.5	100	0.15	35	130	0.5,1,3	30	20
EI.5(min)	E-1,E-2,E-3	5	IW-1 through IW-6 to west	2.5	150	0.20	35	165	0.5,1,3	20	21
EI.5(max)	E-1,E-2,E-3	5	IW-1 through IW-6 to west	2.5	50	0.10	30	85	0.5,1,3	50	22
EI.6A											
EI.6A(avg)	E-1,E-2,E-3	5	I-1 through I-4,I-9,I-10 to north	2.5	100	0.15	35	130	0.5,1	20	23
EI.6A(min)	E-1,E-2,E-3	5	I-1 through I-4,I-9,I-10 to north	2.5	150	0.20	35	165	0.5,1	20	24
EI.6A(max)	E-1,E-2,E-3	5	I-1 through I-4,I-9,I-10 to north	2.5	50	0.10	30	85	0.5,1	40	25
EI.6B											
EI.6B(avg)	E-1,E-2,E-3	5	I-2,I-4,I-11 through I-14 to north	2.5	100	0.15	35	130	0.5,1	30	26
EI.6B(min)	E-1,E-2,E-3	5	I-2,I-4,I-11 through I-14 to north	2.5	150	0.20	35	165	0.5,1	20	27
EI.6B(max)	E-1,E-2,E-3	5	I-2,I-4,I-11 through I-14 to north	2.5	50	0.10	30	85	0.5,1	50	28
EI.7A											
EI.7A(avg)	E-1,E-2,E-4	5	I-1 through I-4,I-9,I-10 to north	2.5	100	0.15	35	130	0.5,1	20	29
EI.7A(min)	E-1,E-2,E-4	5	I-1 through I-4,I-9,I-10 to north	2.5	150	0.20	35	165	0.5,1	20	30
EI.7A(max)	E-1,E-2,E-4	5	I-1 through I-4,I-9,I-10 to north	2.5	50	0.10	30	85	0.5,1	40	31
EI.7B											
EI.7B(avg)	E-1,E-2,E-4	5	IW-7 to west or no wells	---[g]	100	0.15	35	130	0.5,1,3	30	32
EI.7B(min)	E-1,E-2,E-4	5	IW-7 to west or no wells	---[g]	150	0.20	35	165	0.5,1,3	20	33
EI.7B(max)	E-1,E-2,E-4	5	IW-7 to west or no wells	---[g]	50	0.10	30	85	0.5,1,3	60	34

TABLE 1. SUMMARY OF SELECTED PROGRAM INPUT PARAMETERS
FOR RESSQ MODEL EXTRACTION-INJECTION REGIMENS

EXTRACTION-INJECTION REGIMEN[a]	EXTRACTION WELLS	EXTRACTION RATE PER WELL (gpm)[b]	INJECTION WELLS[c]	INJECTION RATE PER WELL (gpm)[b]	HYDRAULIC CONDUCTIVITY (gpd/ft^2)[d]	EFFECTIVE POROSITY[e]	THICKNESS OF AQUIFER (feet)	VELOCITY OF REGIONAL FLOW (feet/year)	T-YEAR CAPTURE ZONES[f] (years)	MAXIMUM SIMULATION TIME (years)	FIGURE NUMBER
EI.8A											
EI.8A(avg)	E-1,E-2,E-4,E-5	5	I-1 through I-4 I-15 through I-18 to north	2.5	100	0.15	35	130	0.5,1	30	35
EI.8A(min)	E-1,E-2,E-4,E-5	5	I-1 through I-4 I-15 through I-18 to north	2.5	150	0.20	35	165	0.5,1	20	36
EI.8A(max)	E-1,E-2,E-4,E-5	5	I-1 through I-4 I-15 through I-18 to north	2.5	50	0.10	30	85	0.5,1	40	37
EI.8B											
EI.8B(avg)	E-1,E-2,E-4,E-5	5	IW-7 to west or no wells	---[g]	100	0.15	35	130	0.5,1,2	30	38
EI.8B(min)	E-1,E-2,E-4,E-5	5	IW-7 to west or no wells	---[g]	150	0.20	35	165	0.5,1,2	20	39
EI.8B(max)	E-1,E-2,E-4,E-5	5	IW-7 to west or no wells	---[g]	50	0.10	30	85	0.5,1,2	60	40

[a] EI = EXTRACTION-INJECTION REGIMEN
avg = average capture zone
min = minimum capture zone
max = maximum capture zone

[b] gpm = gallons per minute

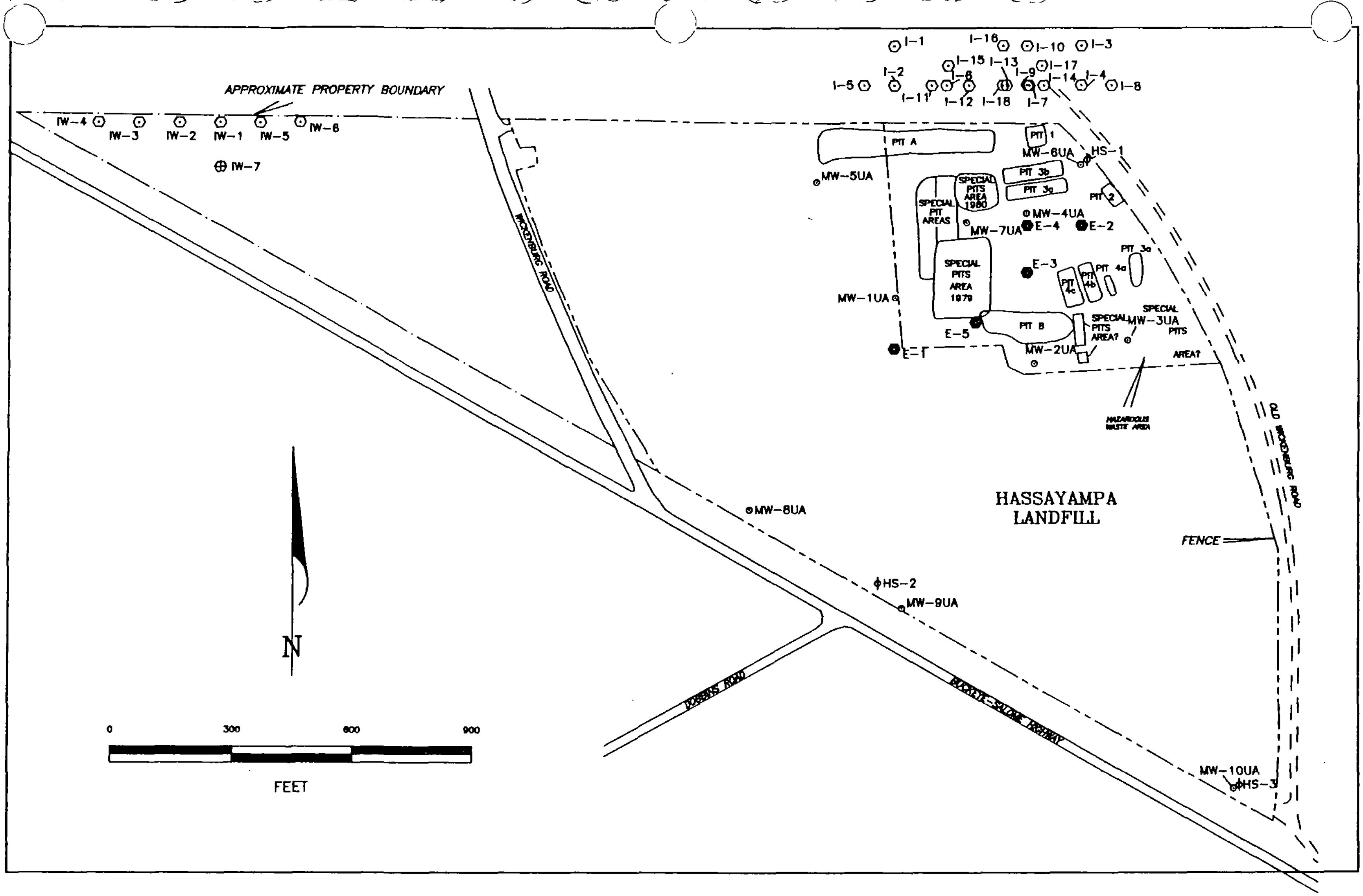
[c] Model locations for injection wells are shown on Figure 1.

[d] gpd/ft^2 = gallons per day per square foot width of aquifer at 1:1 hydraulic gradient

[e] Dimensionless; ratio of volume of interconnected pore space available for groundwater movement per unit volume of aquifer

[f] Time after remedial pumping started, for which hydraulic capture zones were calculated.

[g] All groundwater extracted would be injected into one well completed in Unit B west from the landfill. This regimen also simulates the case where no injection wells would be used.



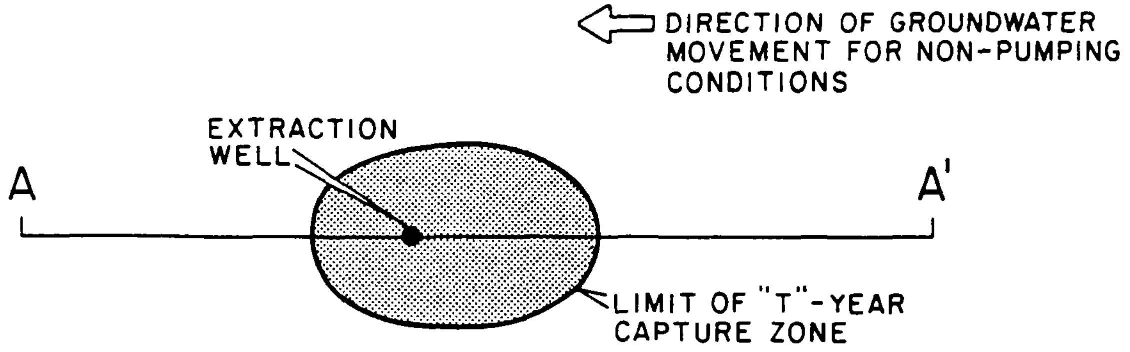
EXPLANATION

⊙ MW-1UA	UNIT A MONITOR WELL
ϕ HS-2	ABANDONED MONITOR WELL CONSTRUCTED BY ARIZONA DEPARTMENT OF HEALTH SERVICES
● E-1	MODEL LOCATION FOR UNIT A EXTRACTION WELL
⊙ I-1	MODEL LOCATION FOR UNIT A INJECTION WELL " I " INDICATES WELL IS NORTH FROM LANDFILL " IW " INDICATES WELL IS WEST FROM LANDFILL
⊕ IW-7	MODEL LOCATION FOR UNIT B INJECTION WELL WEST FROM LANDFILL
▢ PIT 1	DISPOSAL PIT: Locations and boundaries for Pits 1, 2, 3a, 3b, 3c, 4b, and 4c were determined approximately based on trenching operations. Locations and boundaries for other disposal pits are based on analysis of a January 26, 1981, aerial photo and on reports. Locations and boundaries are tentative and approximate.

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

FIGURE 1. LOCATION MAP FOR HASSAYAMPA LANDFILL, MARICOPA COUNTY, ARIZONA

MAP VIEW



VERTICAL SECTION

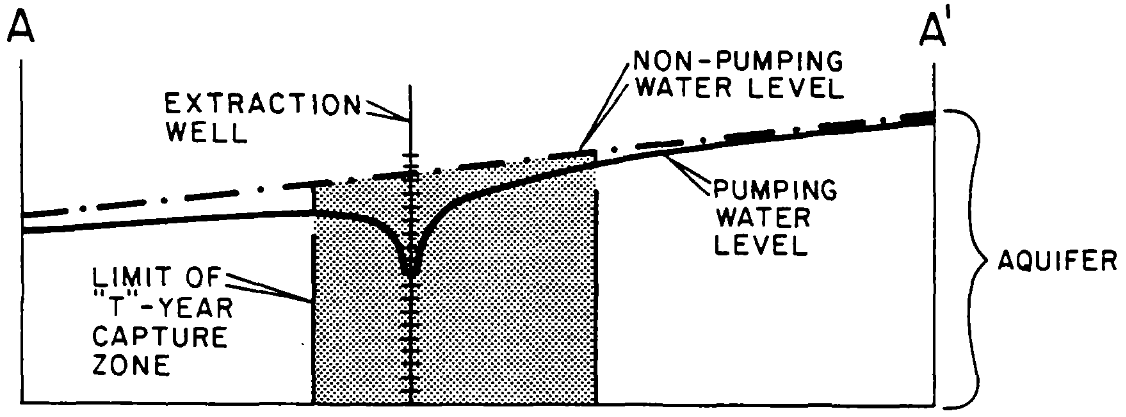
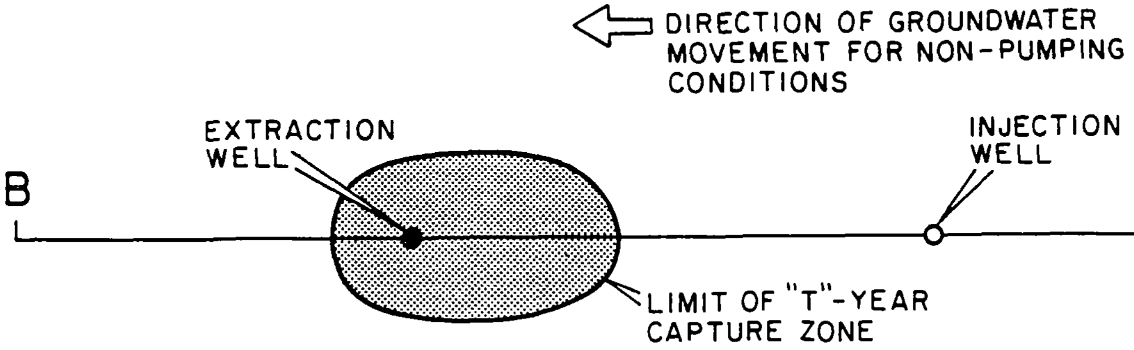


FIGURE 2. CONCEPTUAL DIAGRAM OF TIME-RELATED HYDRAULIC CAPTURE ZONE FOR PUMPING WITHOUT INJECTION

MAP VIEW



VERTICAL SECTION

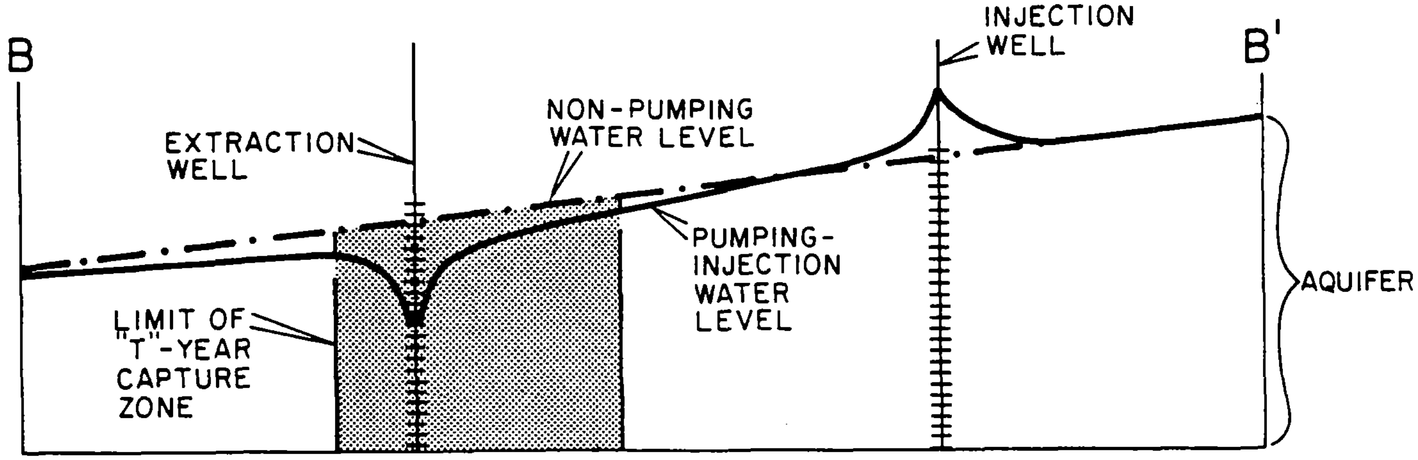
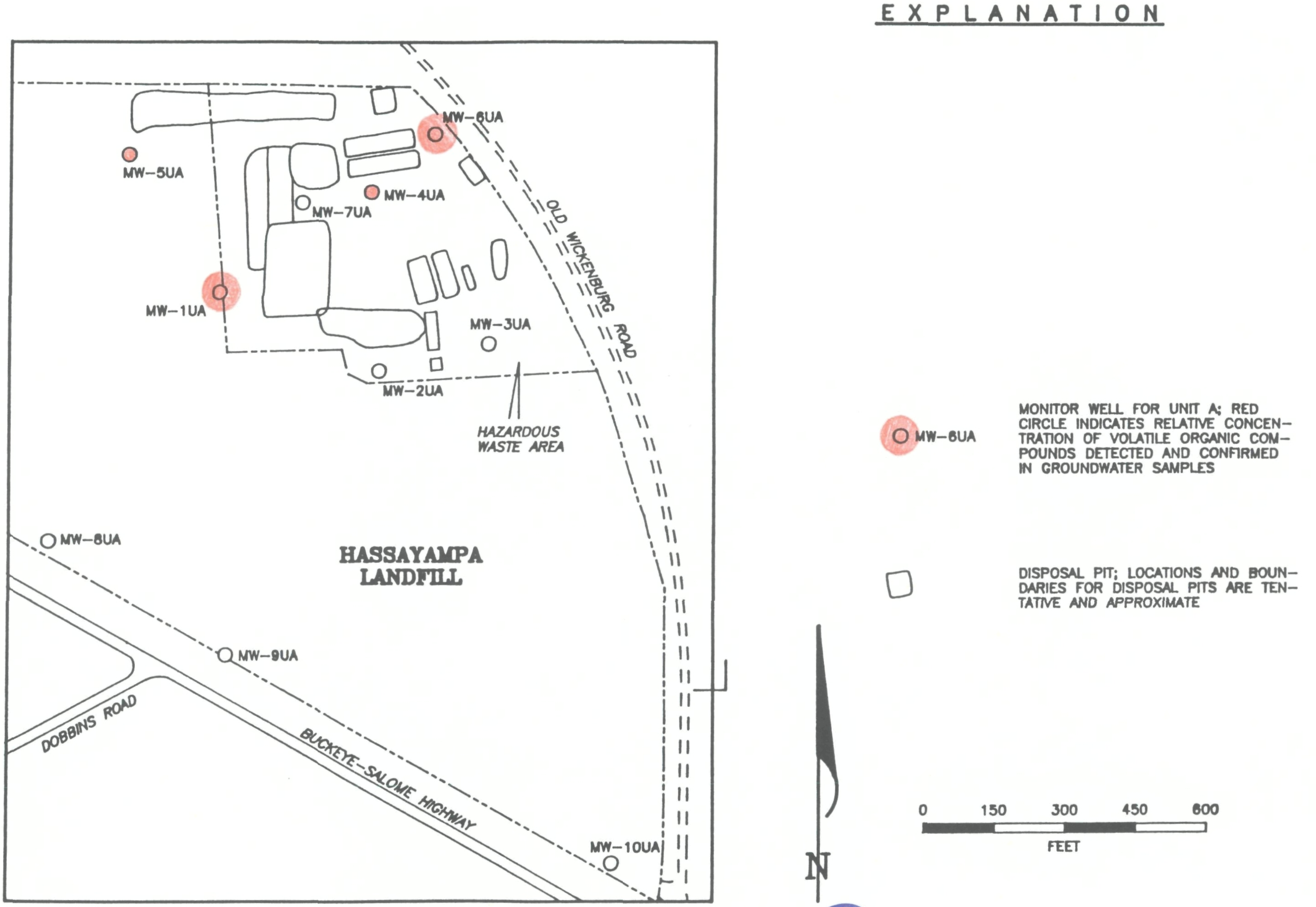


FIGURE 3. CONCEPTUAL DIAGRAM OF TIME-RELATED HYDRAULIC CAPTURE ZONE FOR PUMPING WITH INJECTION



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TUCSON, ARIZONA

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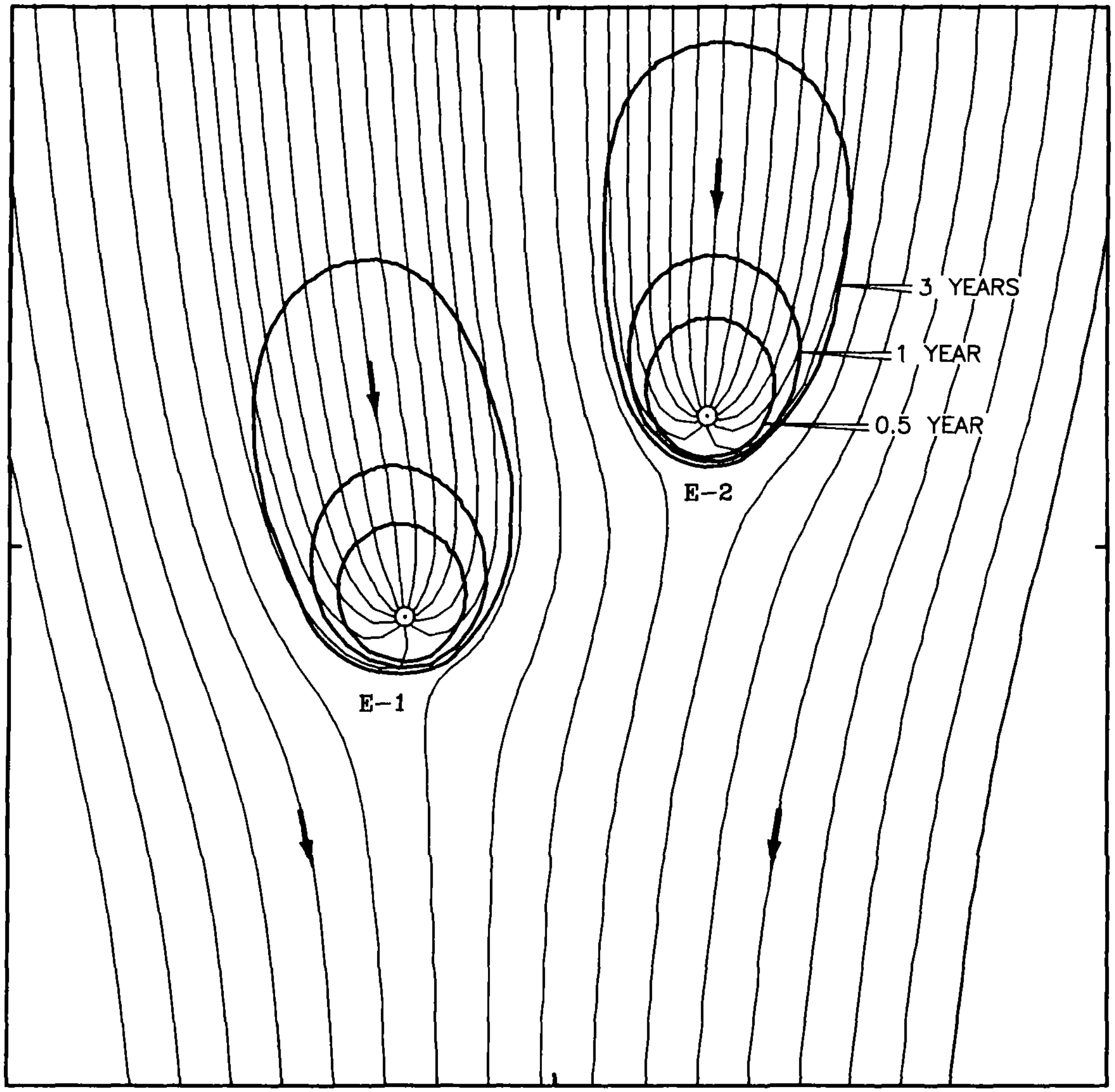


EXPLANATION

⊙ MODEL LOCATION OF EXTRACTION WELL

LIMIT OF CAPTURE ZONE

PROJECTED STREAMLINE AND DIRECTION OF GROUNDWATER MOVEMENT

FIGURE 5. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION–INJECTION REGIMEN EI.1(avg)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

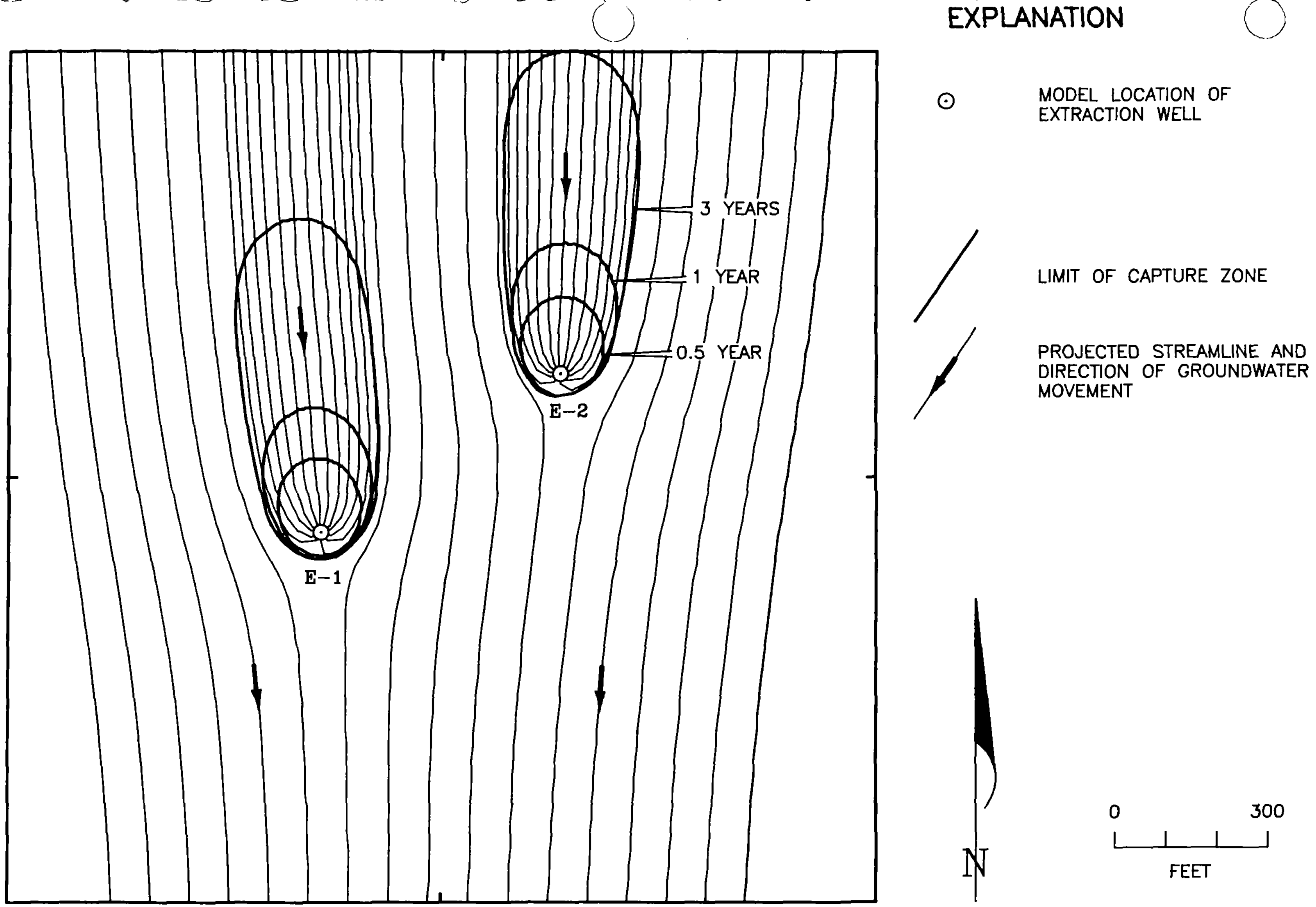


FIGURE 6. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION–INJECTION REGIMEN EI.1(min)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

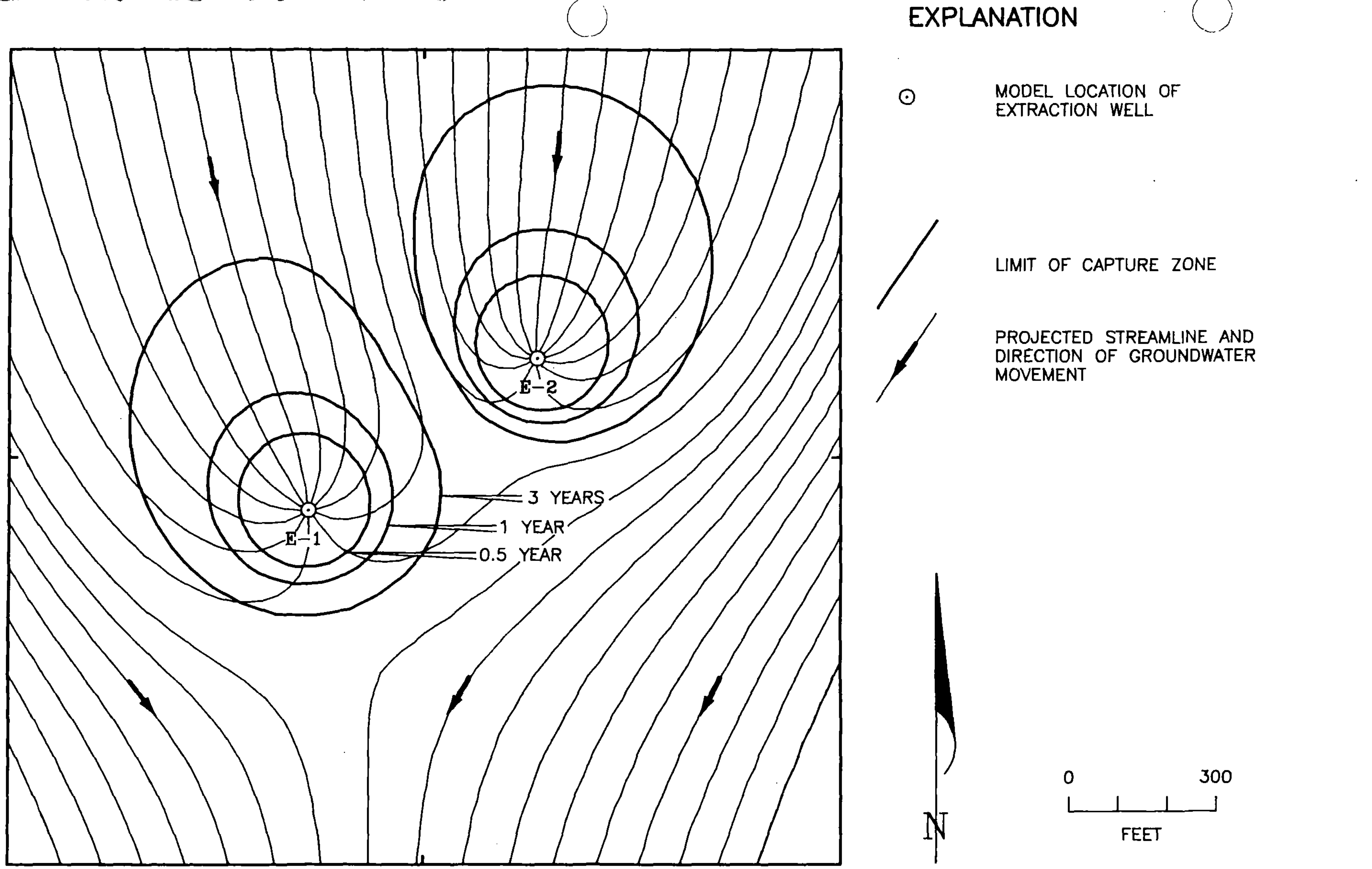


FIGURE 7. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION–INJECTION REGIMEN EI.1(max)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

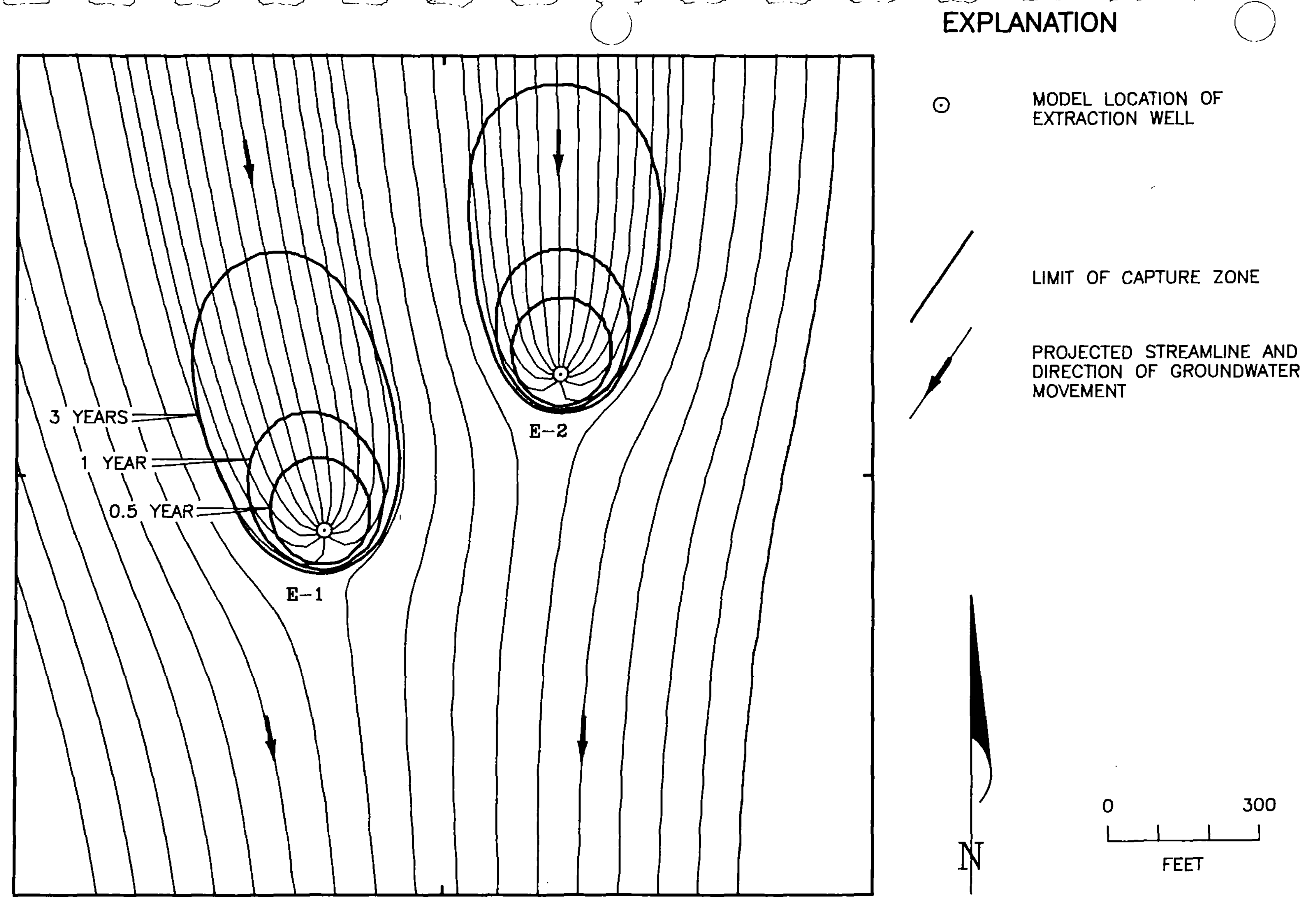


FIGURE 8. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION–INJECTION REGIMEN EI.2(avg)

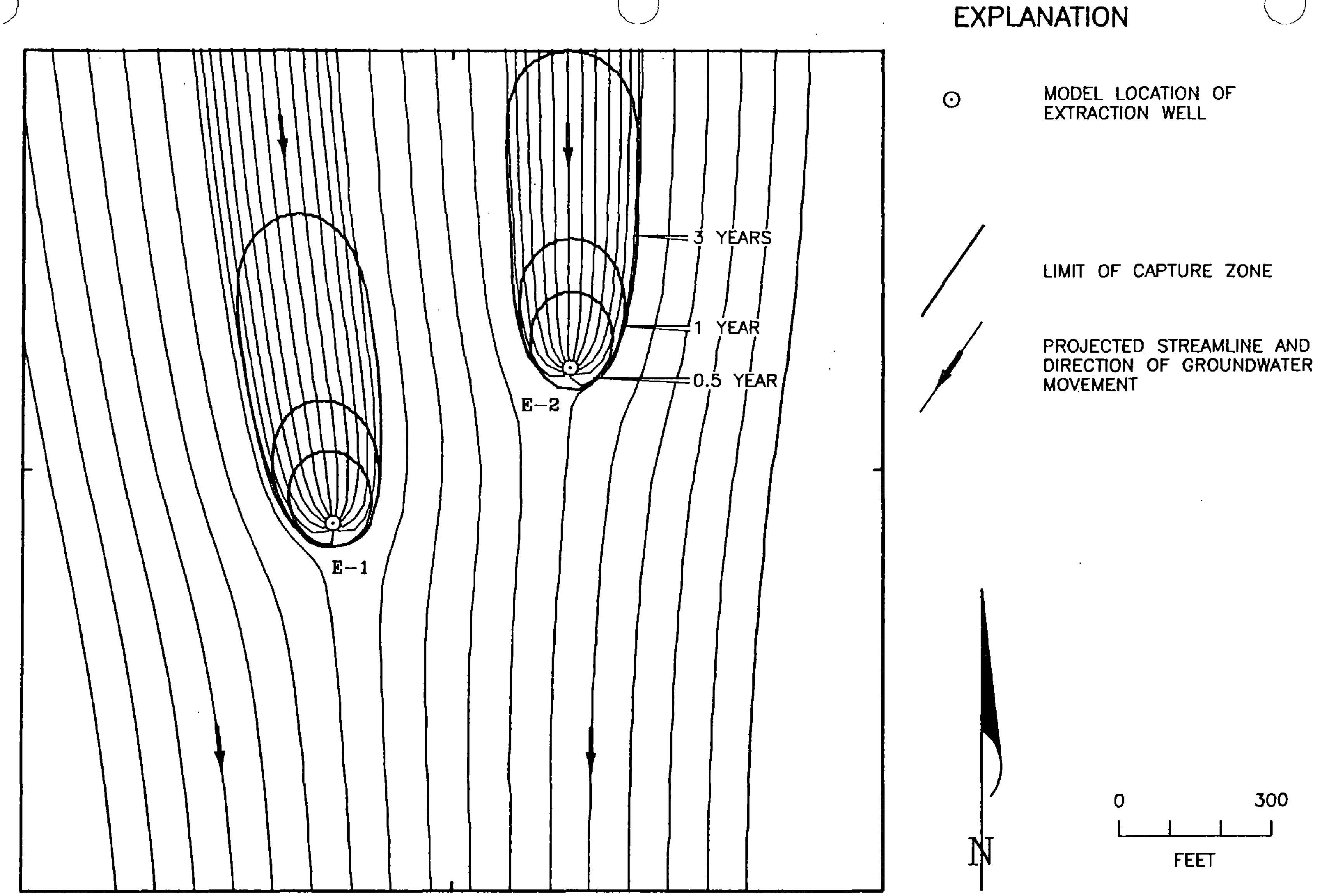
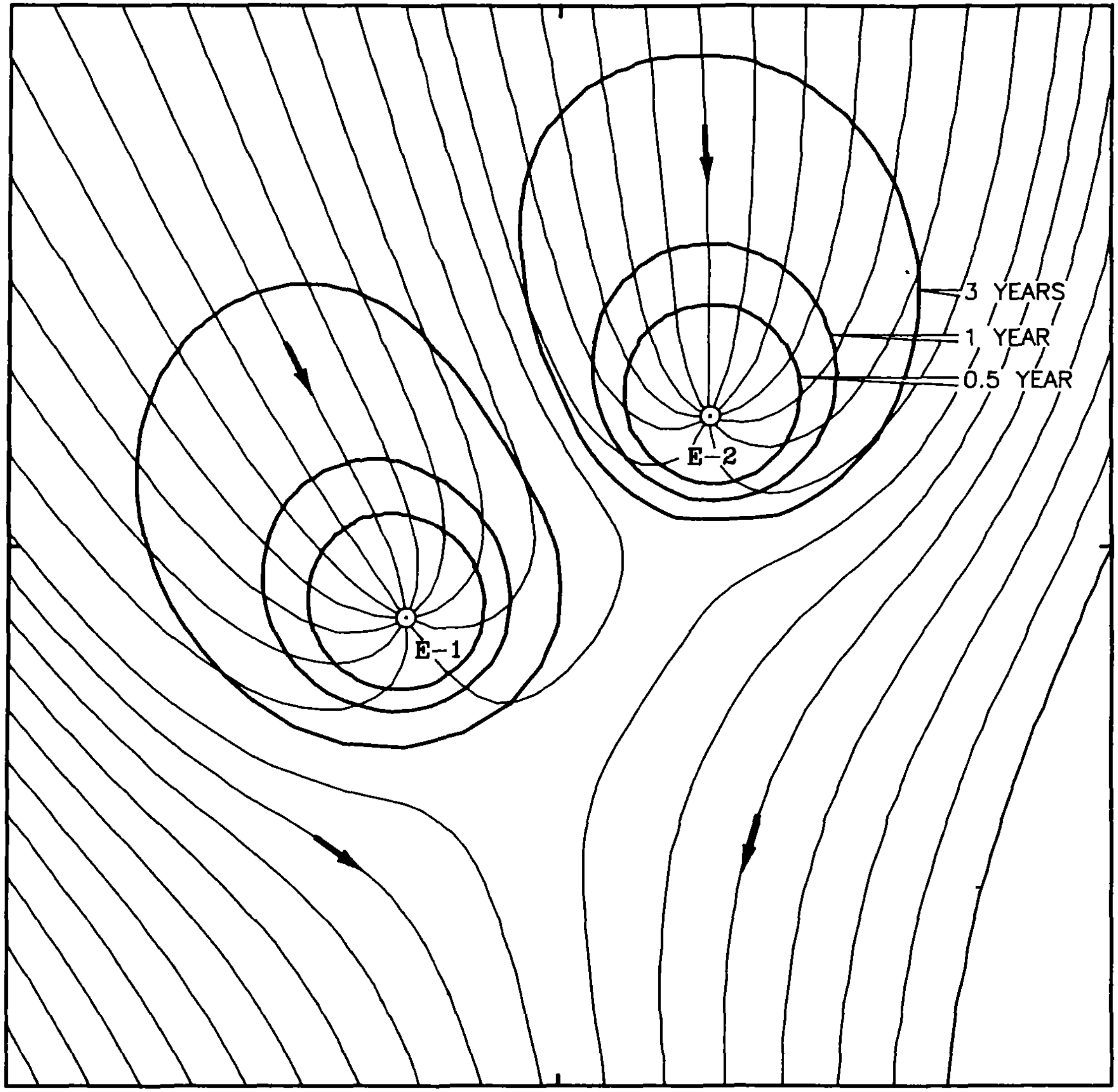


FIGURE 9. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.2(min)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA



EXPLANATION

⊙ MODEL LOCATION OF EXTRACTION WELL

/ LIMIT OF CAPTURE ZONE

↙ PROJECTED STREAMLINE AND DIRECTION OF GROUNDWATER MOVEMENT

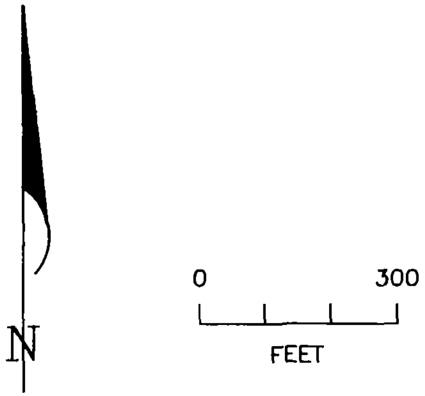


FIGURE 10. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION–INJECTION REGIMEN EI.2(max)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

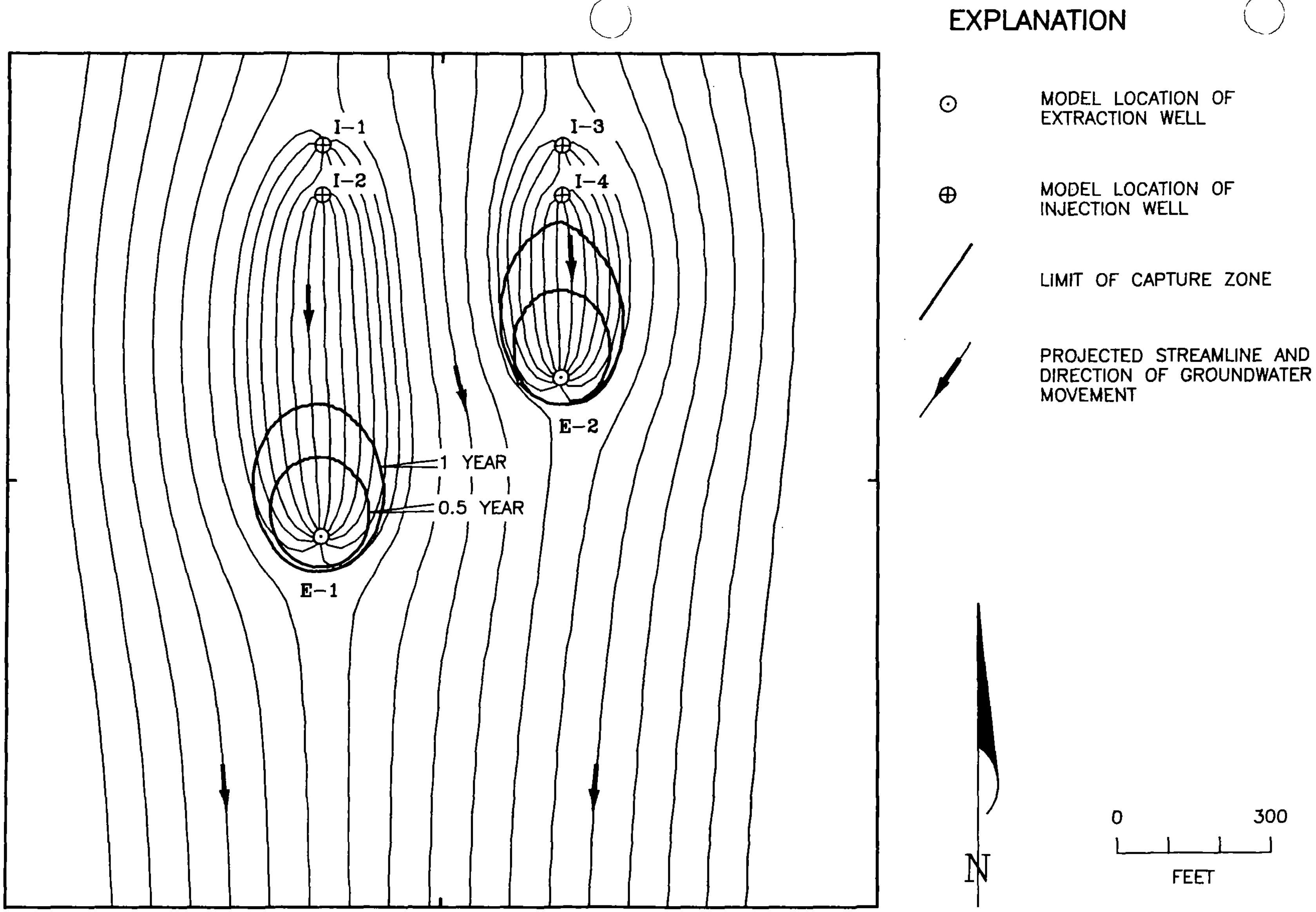


FIGURE 11. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION-INJECTION REGIMEN EI.3A(avg)

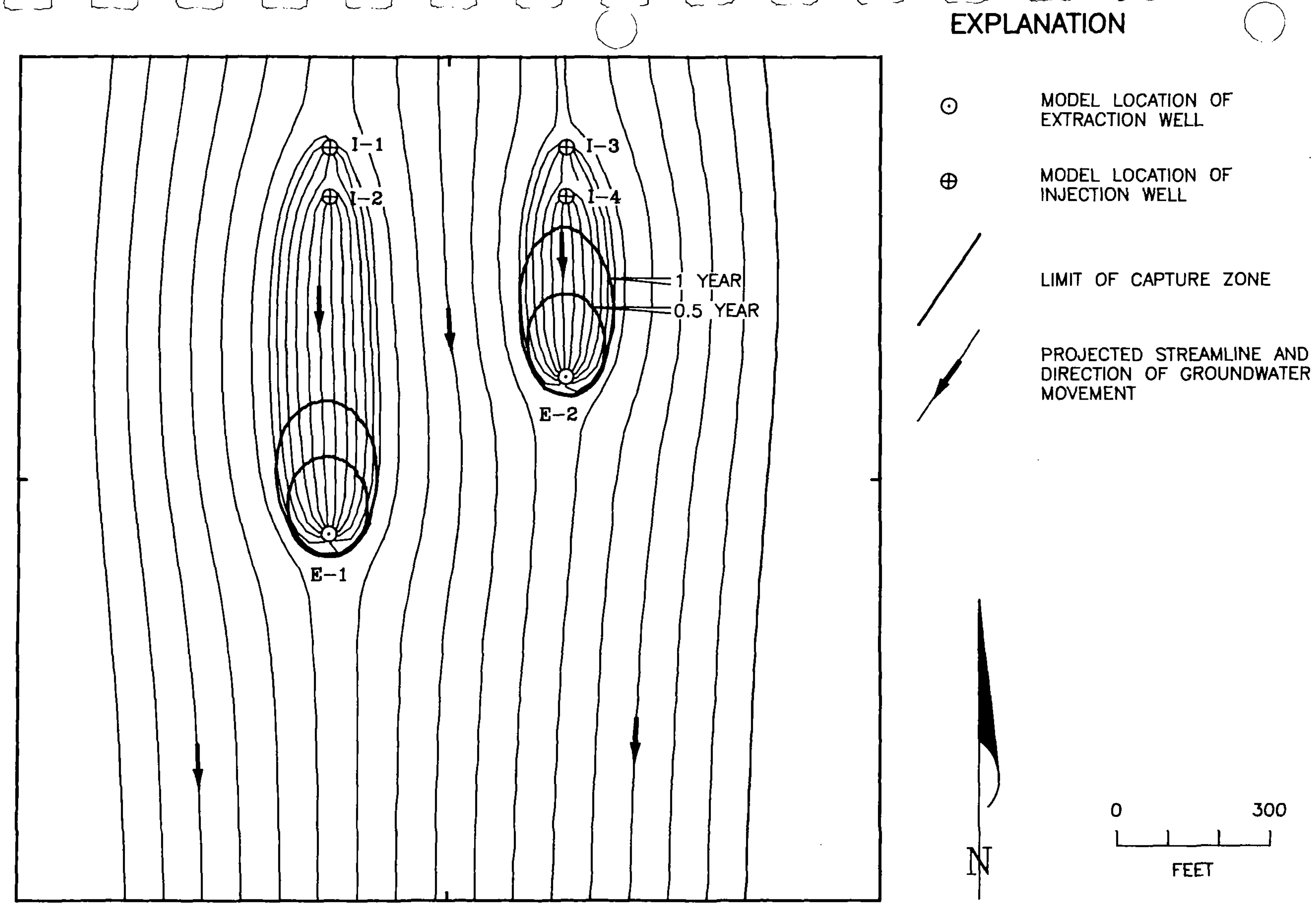
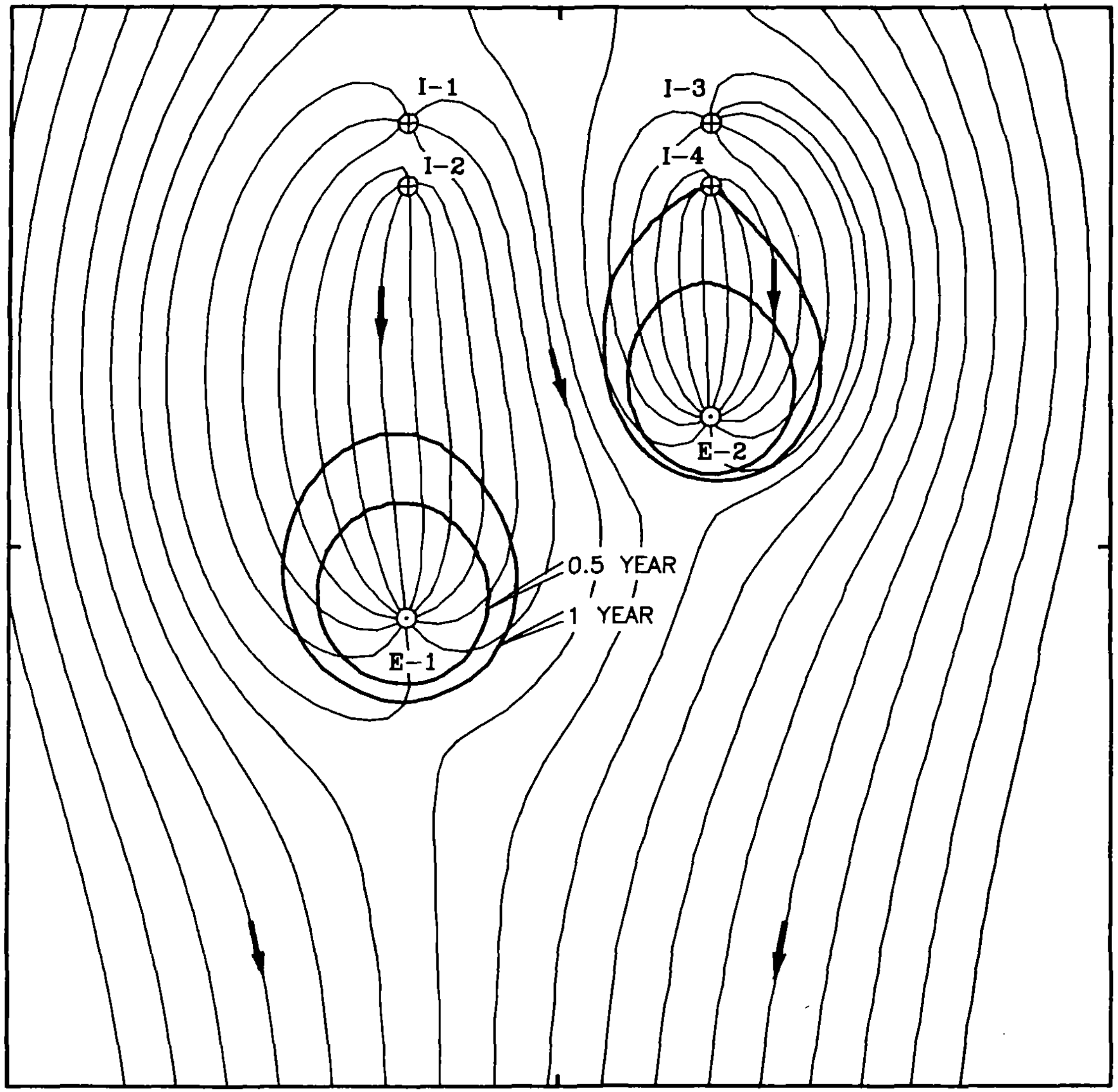


FIGURE 12. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.3A(min)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA



EXPLANATION

⊙ MODEL LOCATION OF EXTRACTION WELL

⊕ MODEL LOCATION OF INJECTION WELL

LIMIT OF CAPTURE ZONE

PROJECTED STREAMLINE AND DIRECTION OF GROUNDWATER MOVEMENT

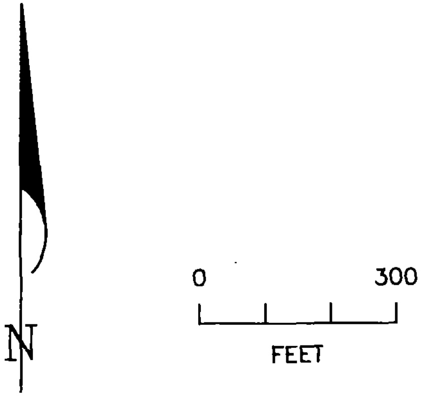


FIGURE 13. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN E1.3A(max)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

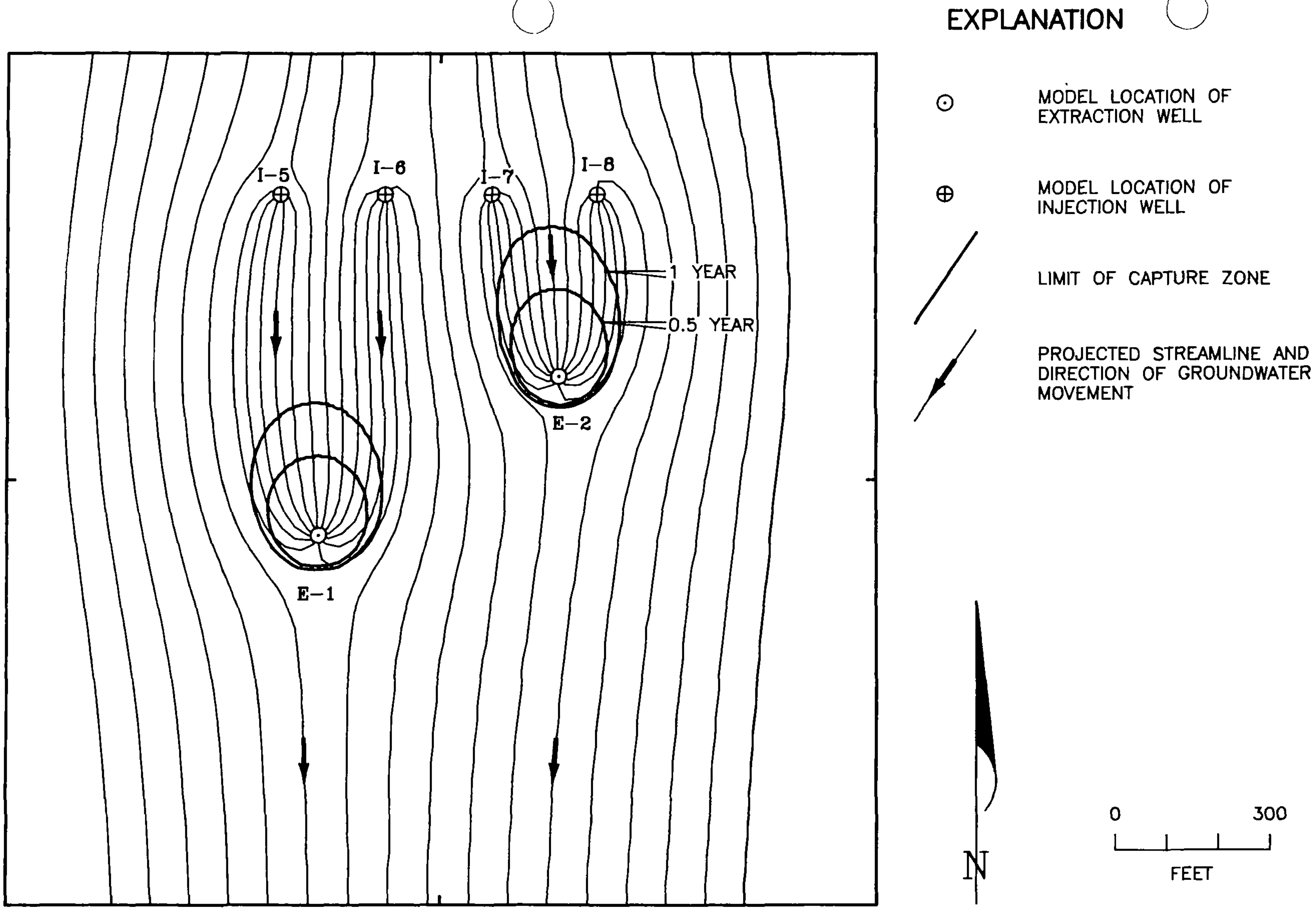


FIGURE 14. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION-INJECTION REGIMEN EI.3B(avg)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

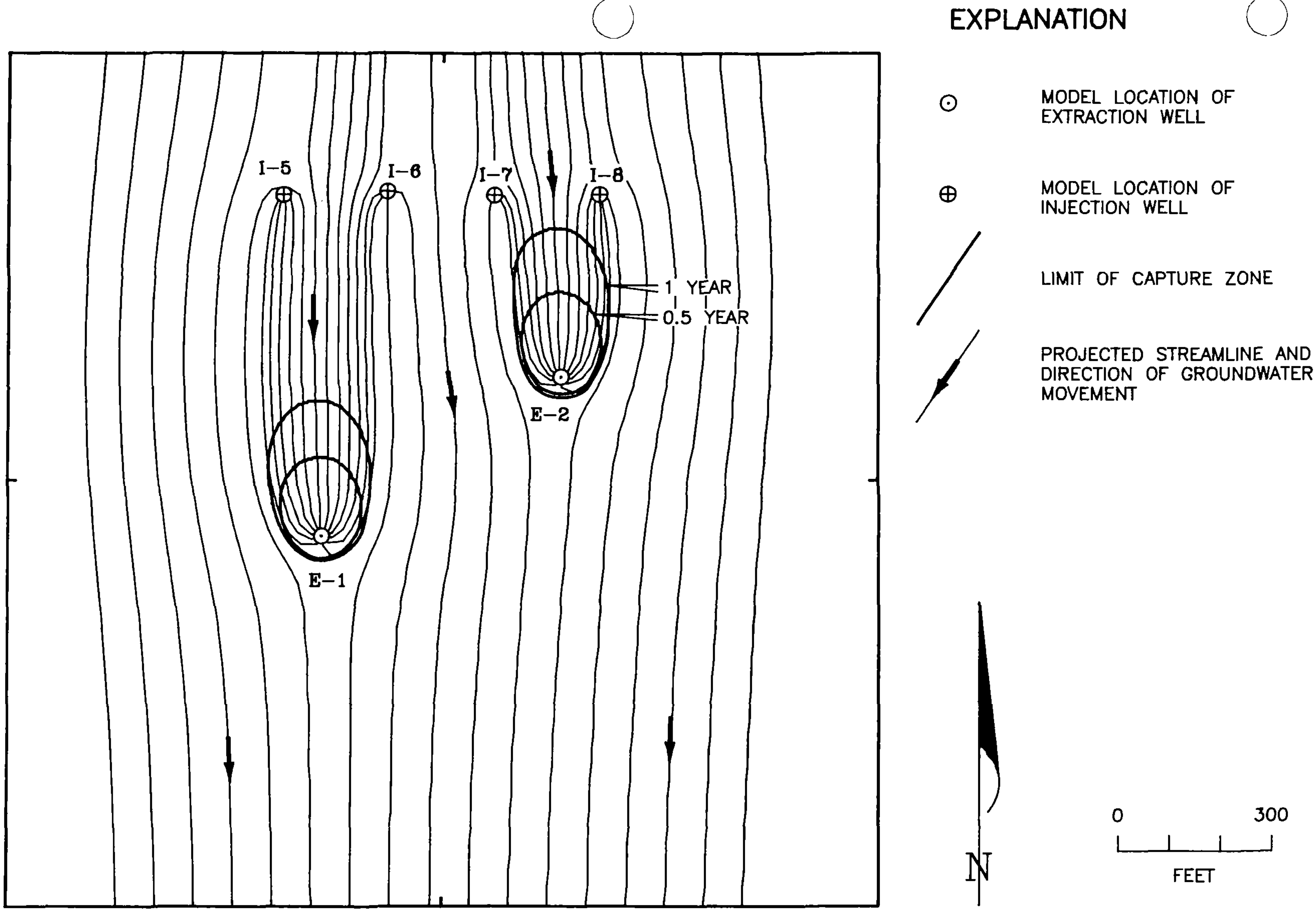


FIGURE 15. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN EI.3B(min)

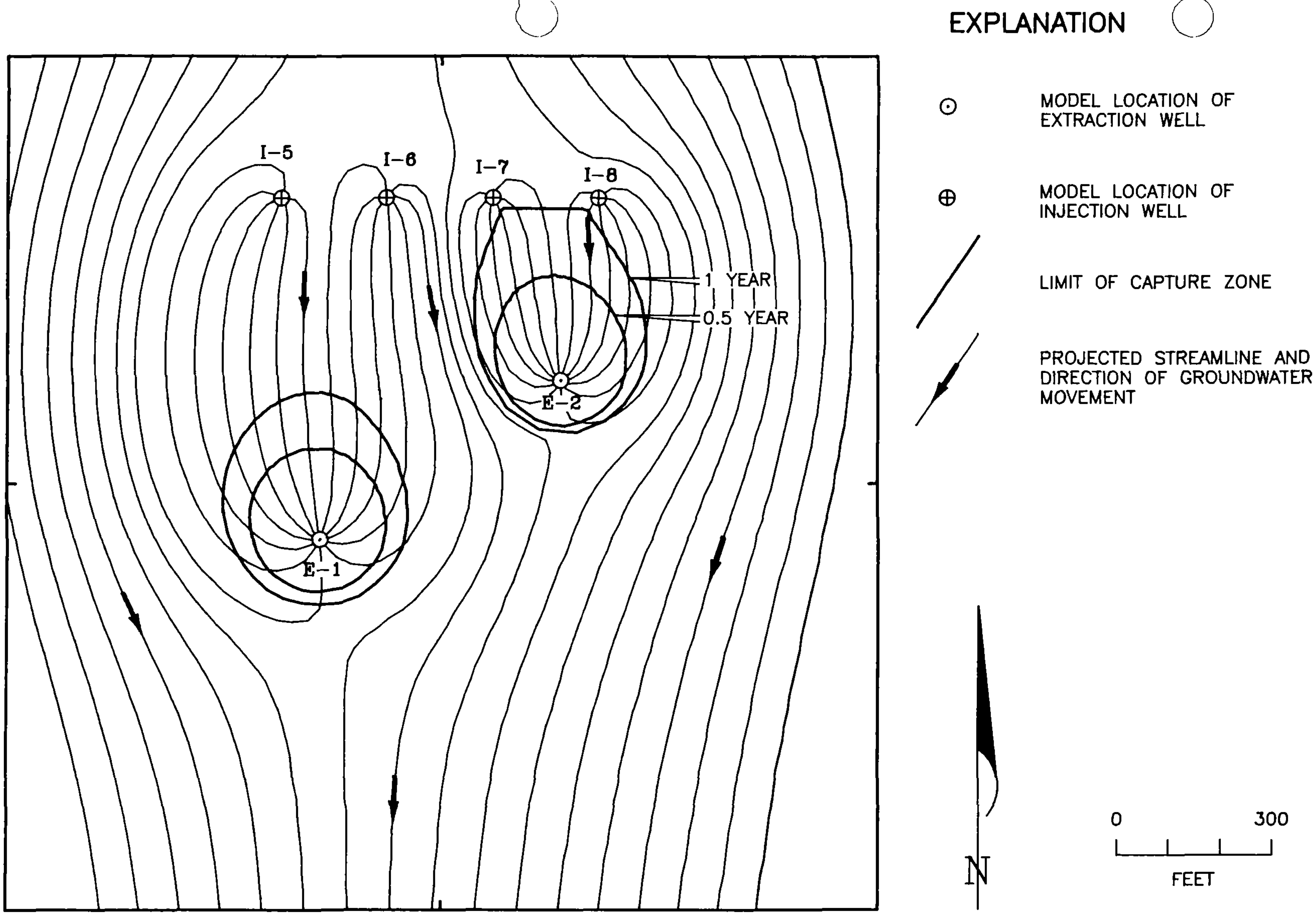


FIGURE 16. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION-INJECTION REGIMEN EI.3B(max)

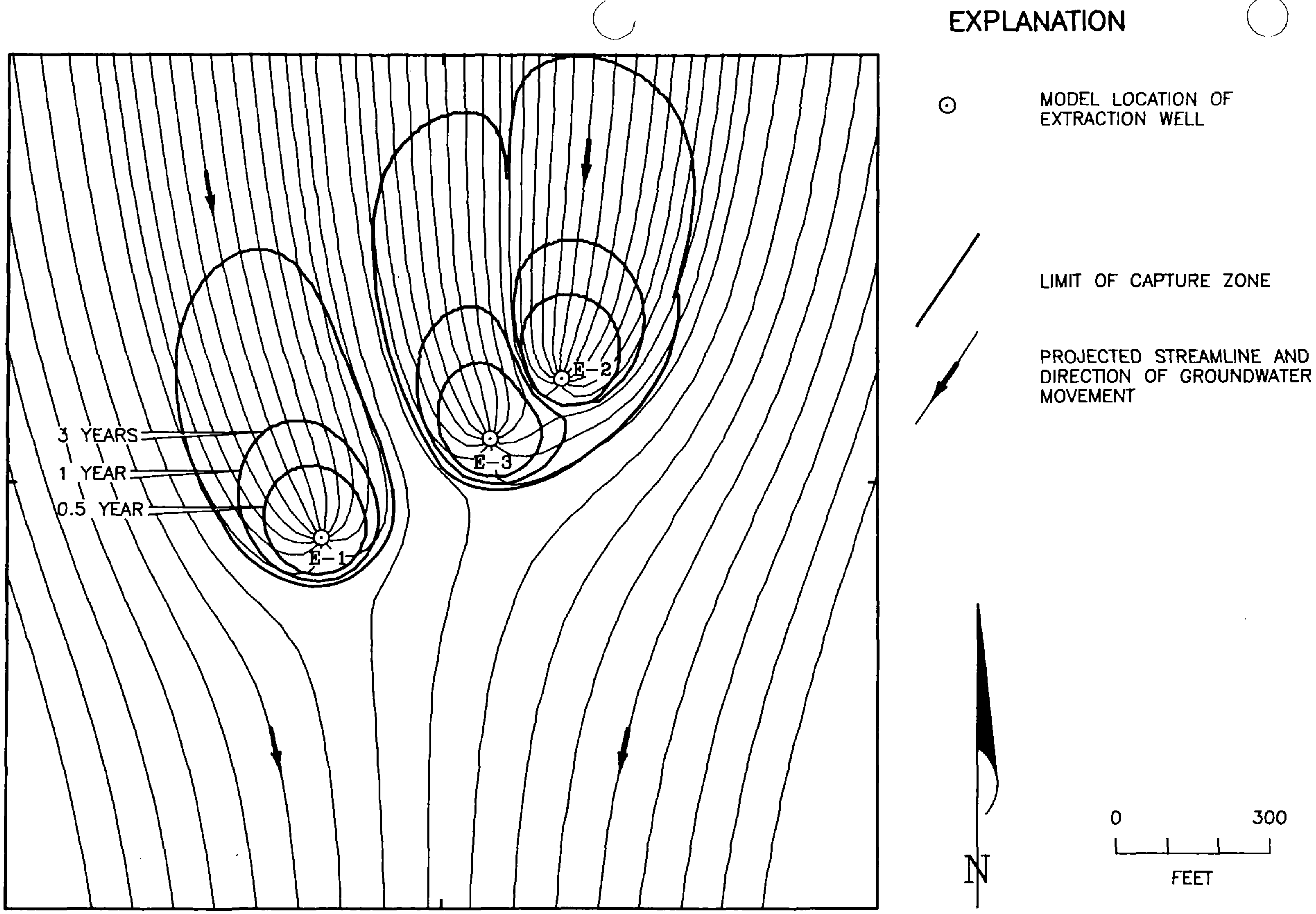


FIGURE 17. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION–INJECTION REGIMEN EI.4(avg)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

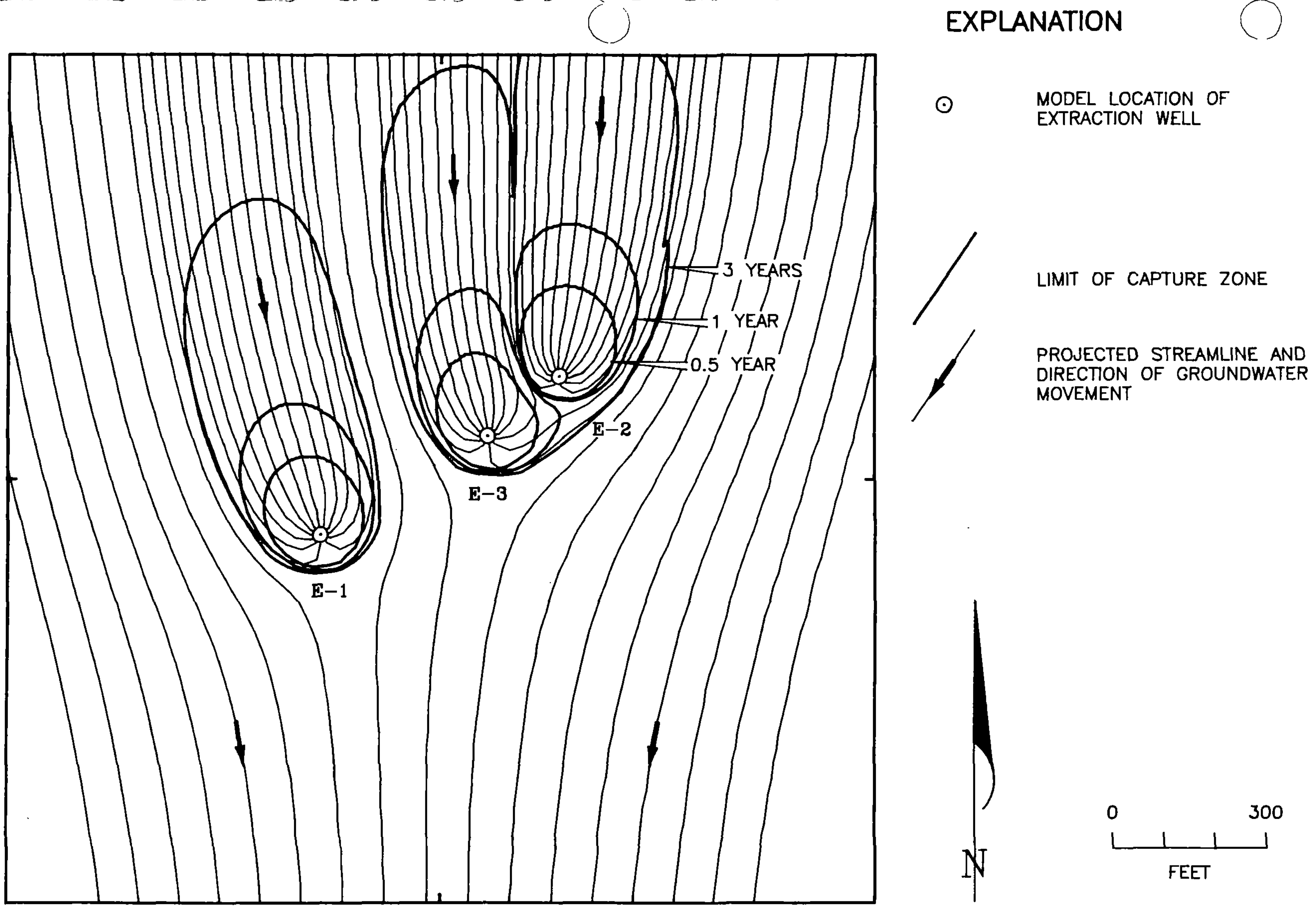


FIGURE 18. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.4(min)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

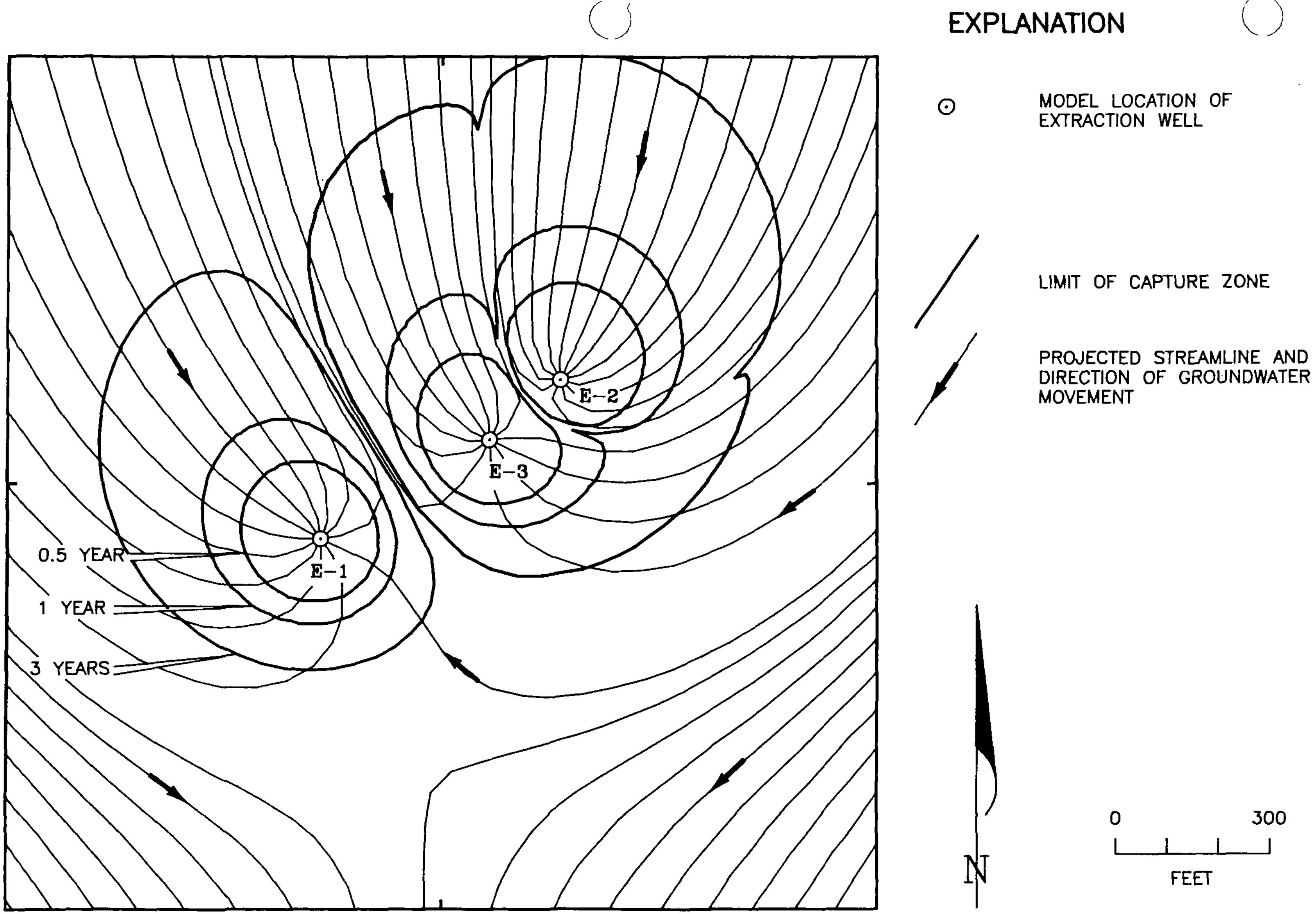


FIGURE 19. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.4(max)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

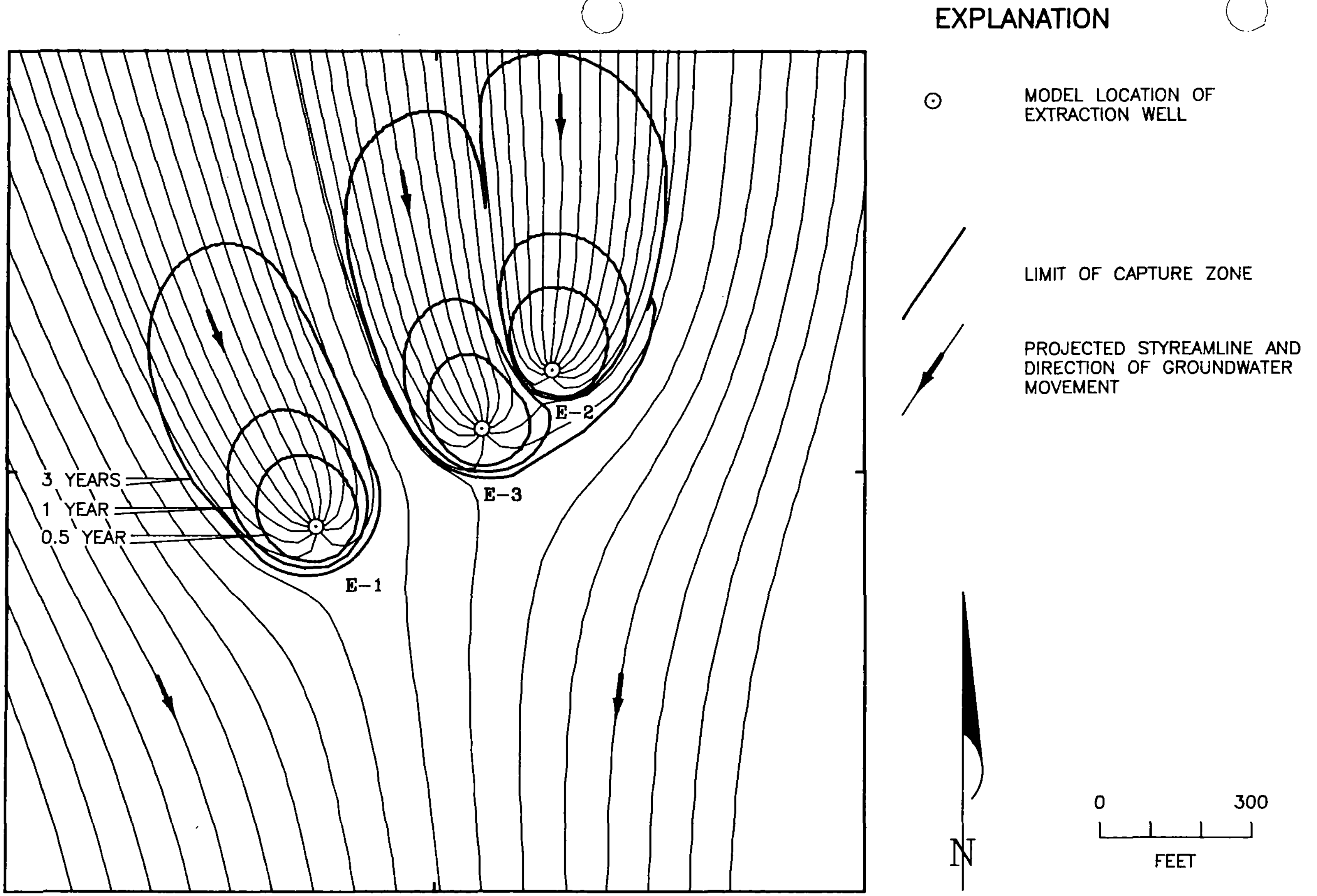


FIGURE 20. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.5(avg)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

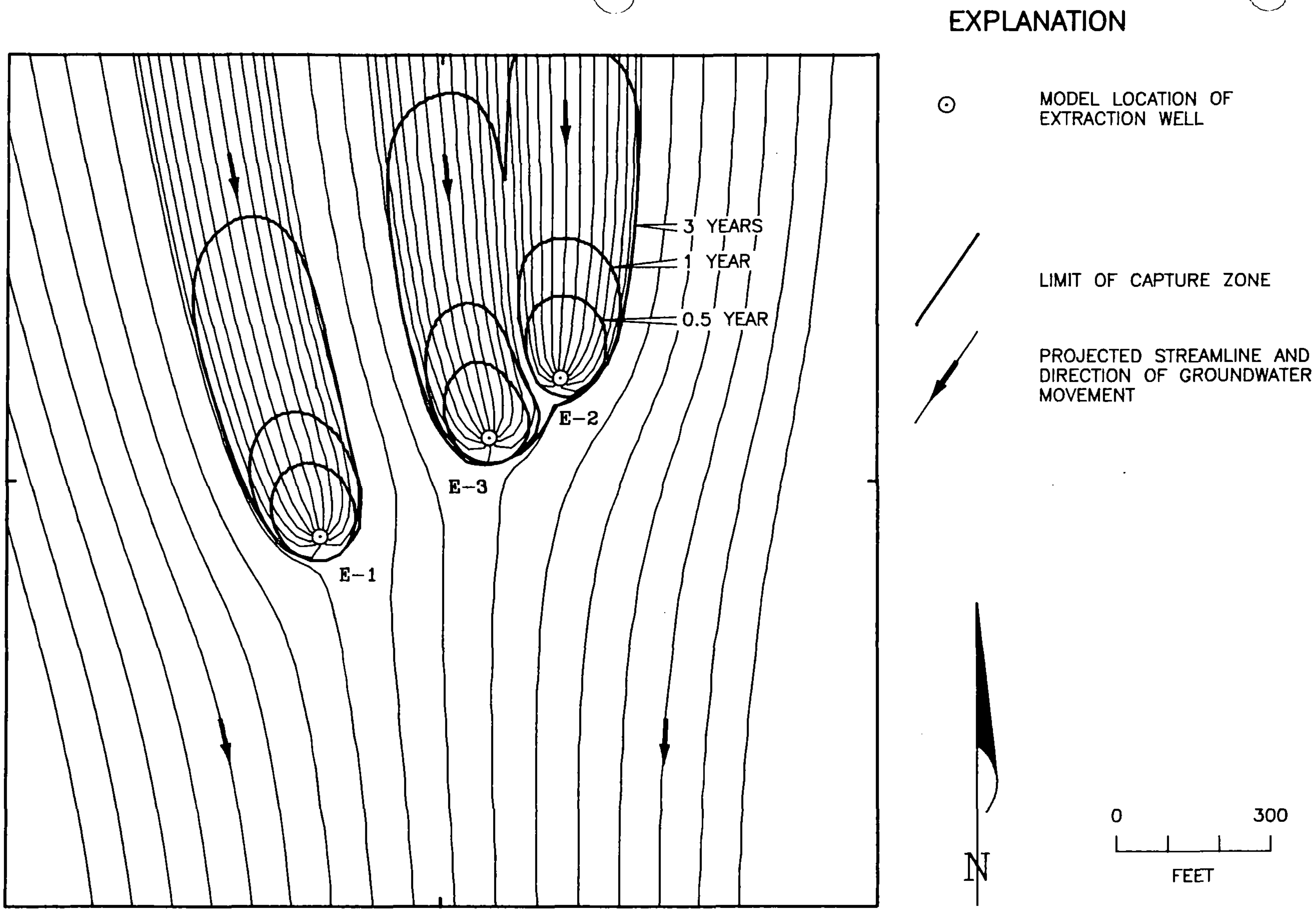


FIGURE 21. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.5(min)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

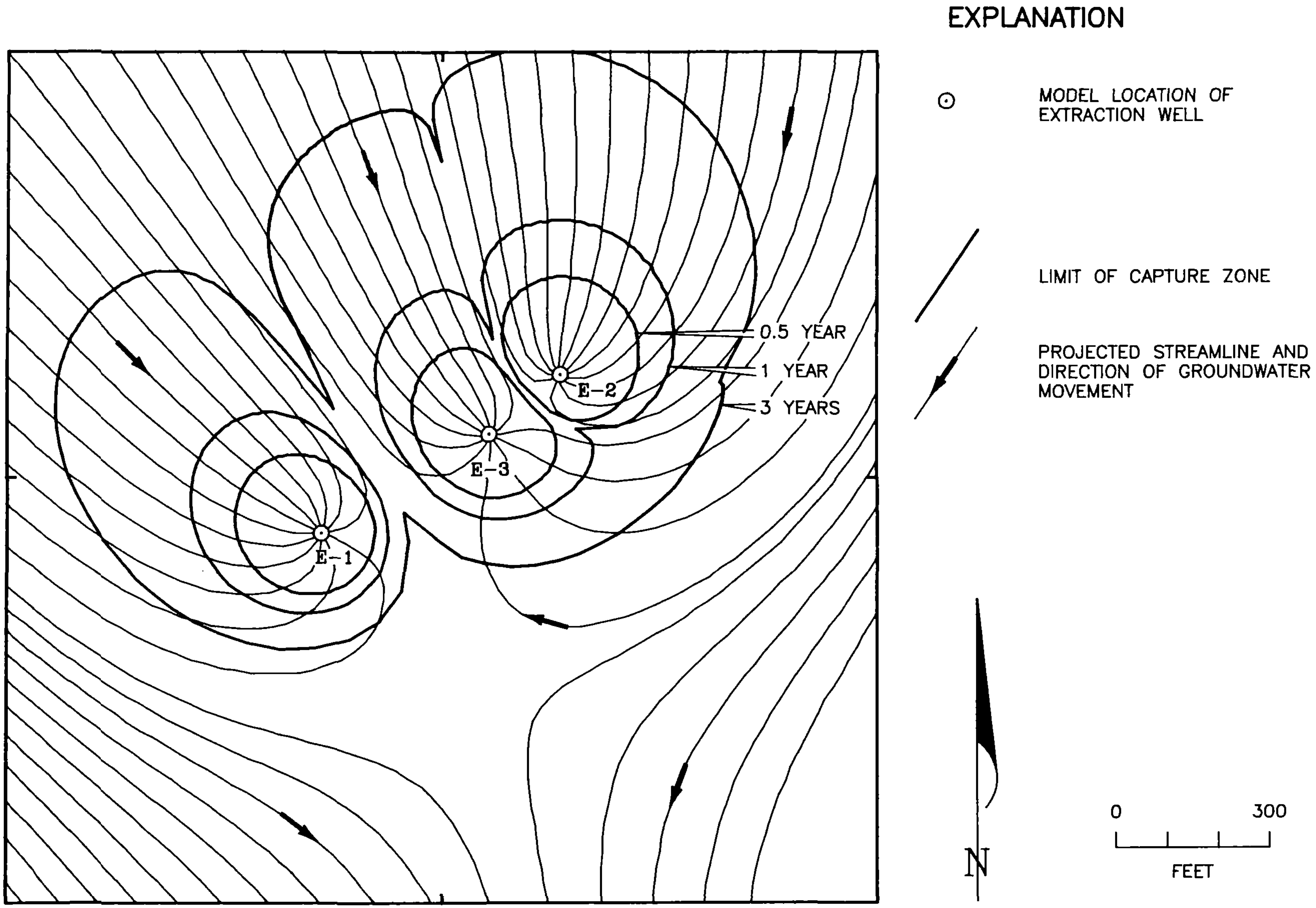
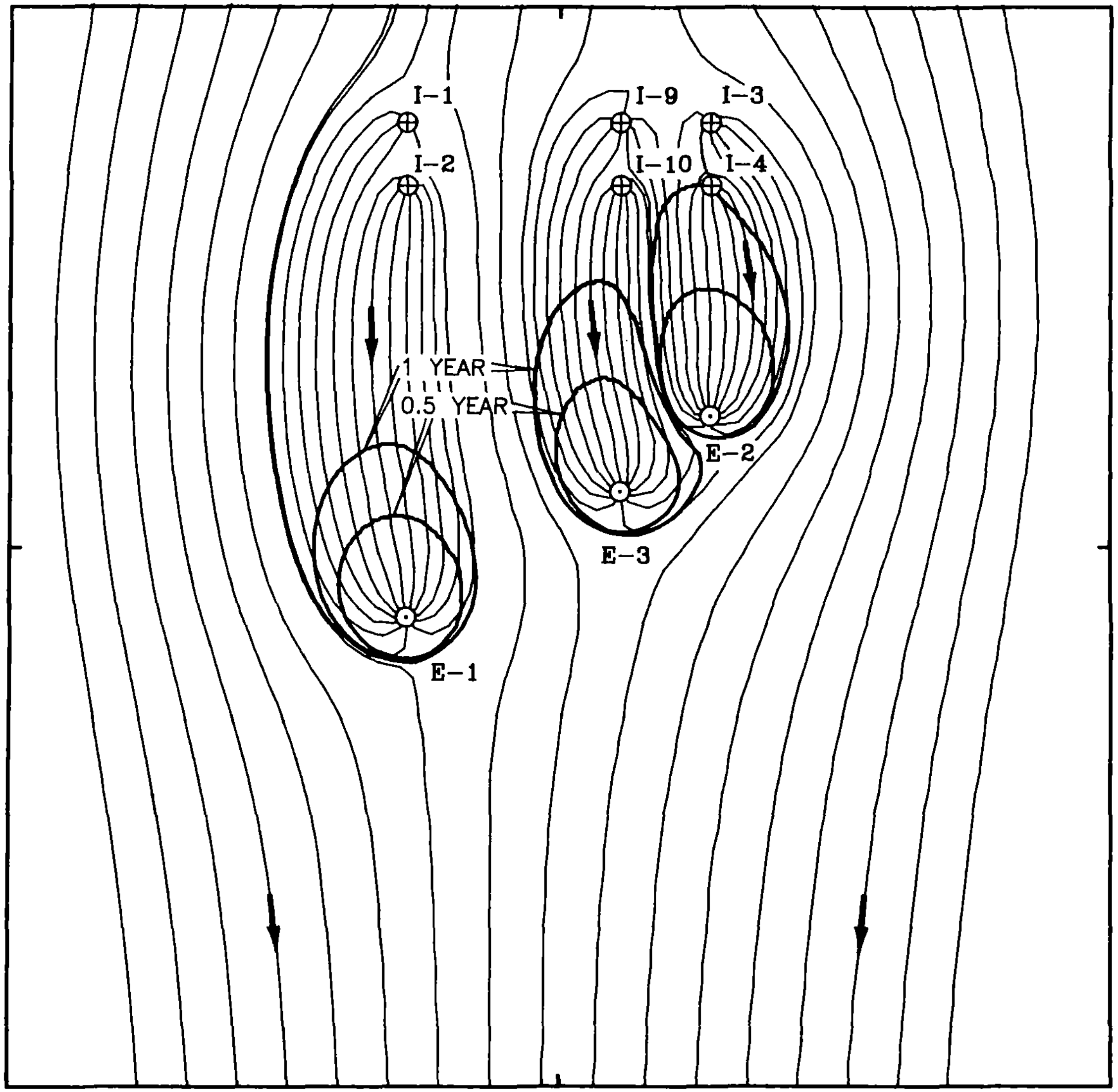


FIGURE 22. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN EI.5(max)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA



EXPLANATION

⊙ MODEL LOCATION OF EXTRACTION WELL

⊕ MODEL LOCATION OF INJECTION WELL

LIMIT OF CAPTURE ZONE

PROJECTED STREAMLINE AND DIRECTION OF GROUNDWATER MOVEMENT

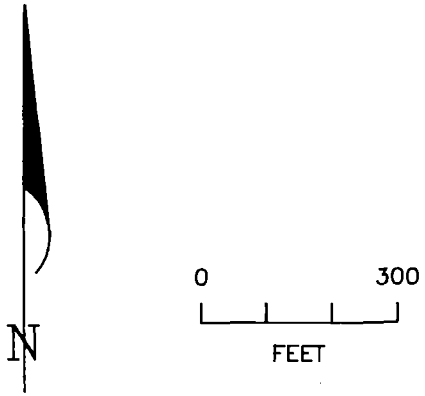


FIGURE 23. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN E1.6A(avg)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

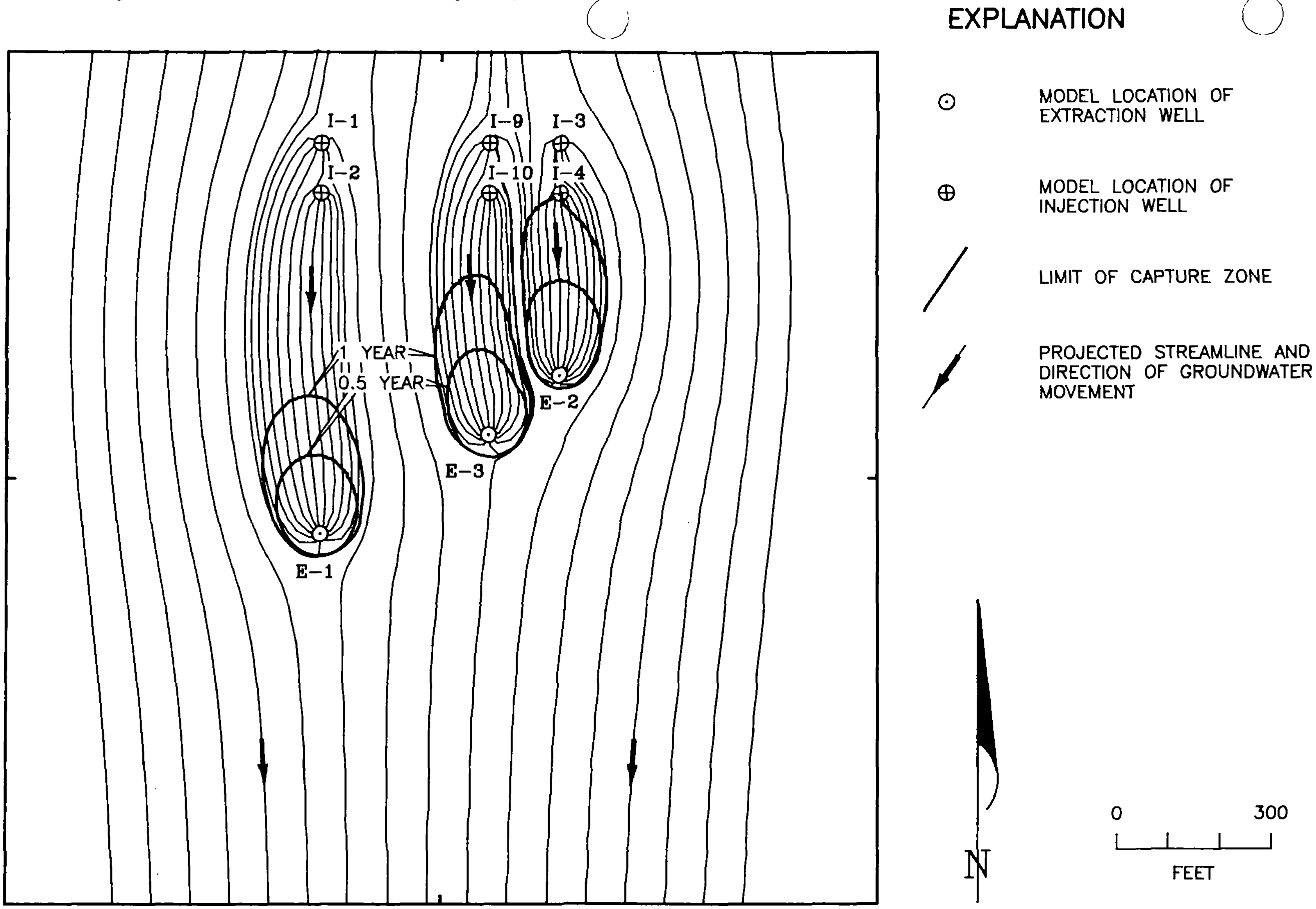


FIGURE 24. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES: EXTRACTION—INJECTION REGIMEN EI.6A(min)

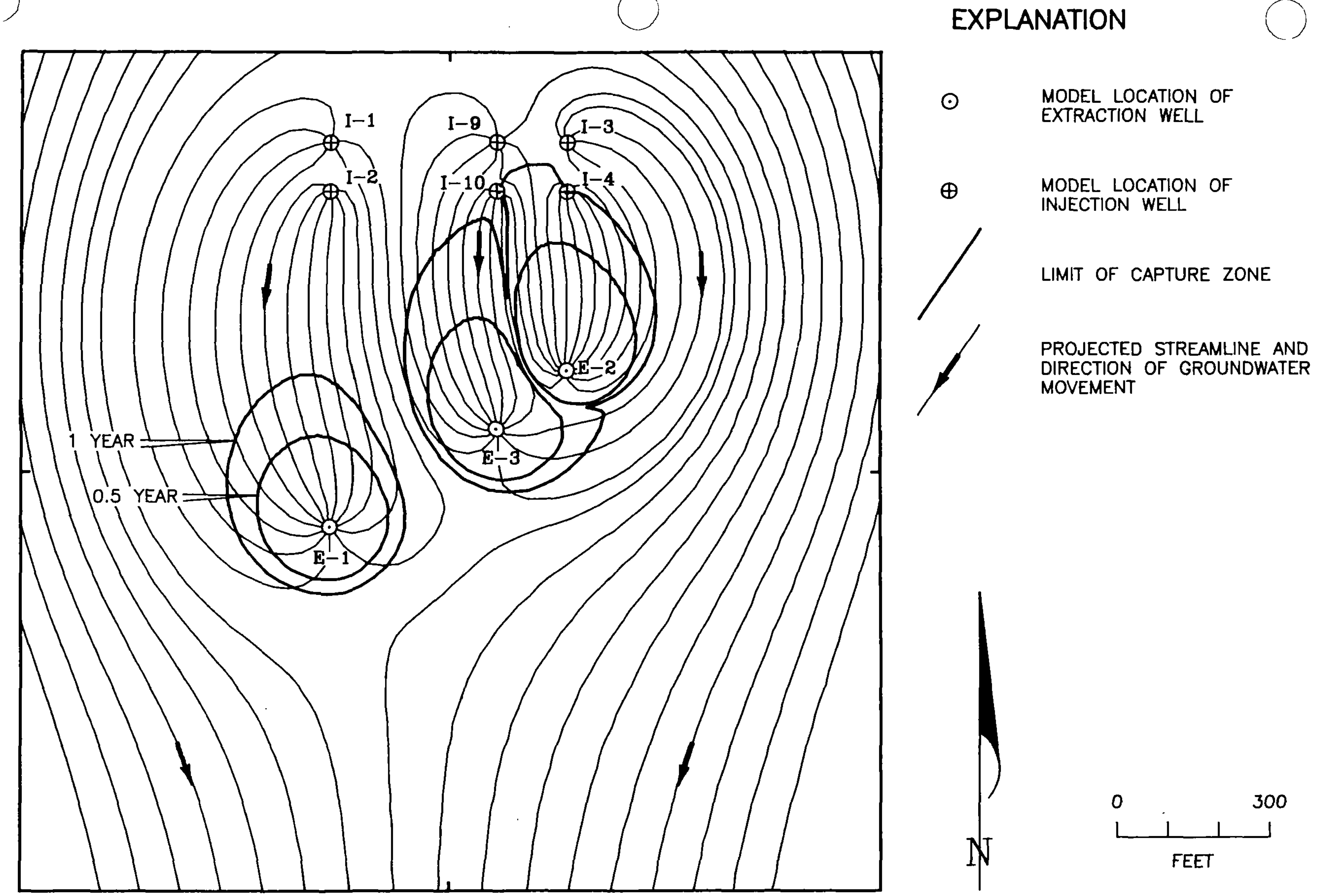
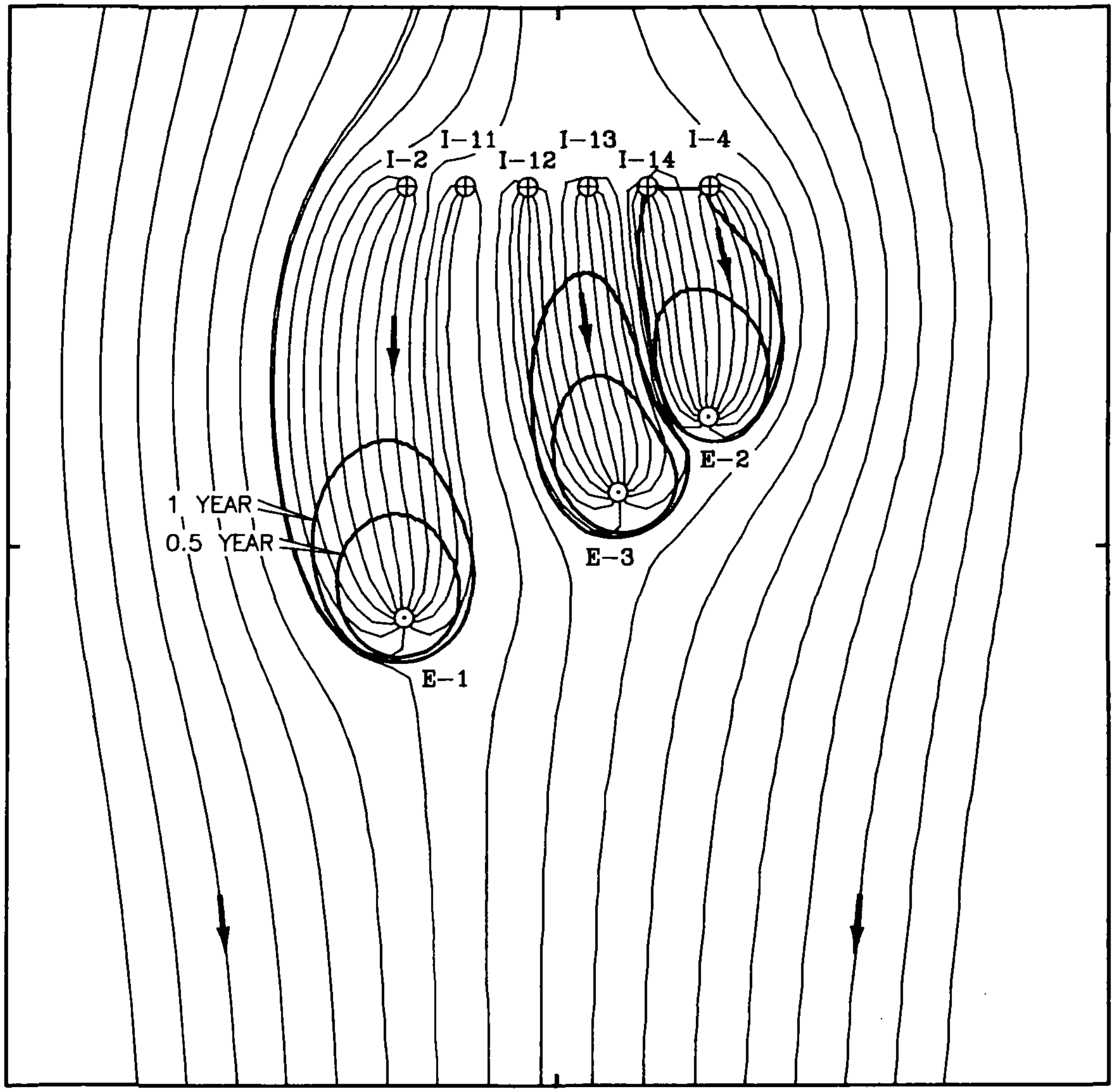


FIGURE 25. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES: EXTRACTION–INJECTION REGIMEN EI.6A(max)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA



EXPLANATION

⊙ MODEL LOCATION OF EXTRACTION WELL

⊕ MODEL LOCATION OF INJECTION WELL

LIMIT OF CAPTURE ZONE

PROJECTED STREAMLINE AND DIRECTION OF GROUNDWATER MOVEMENT

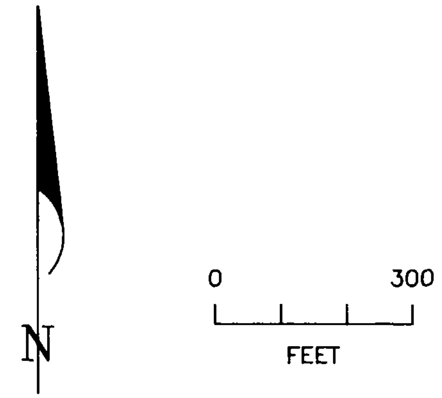


FIGURE 26. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN EI.6B(avg)

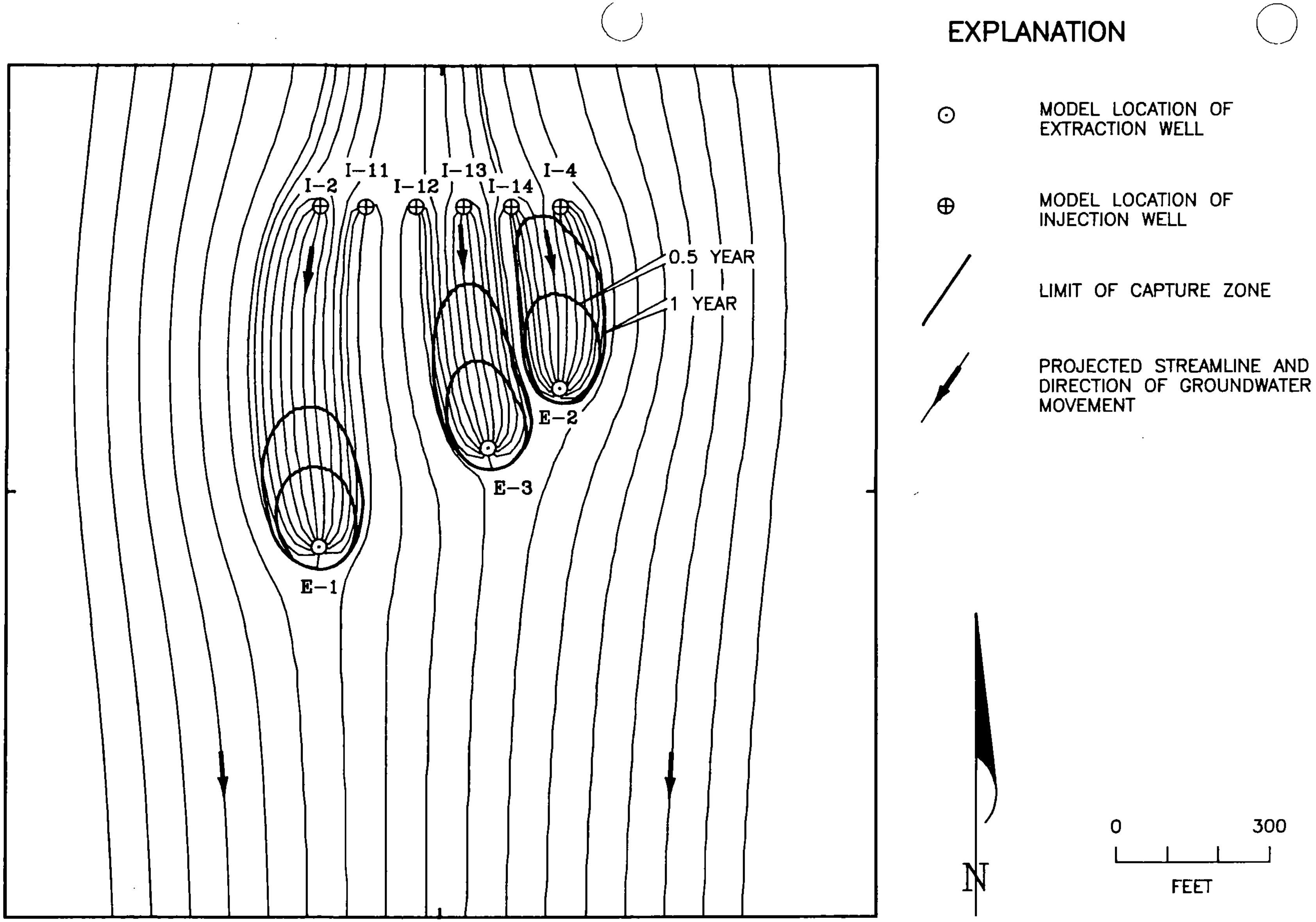


FIGURE 27. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN EI.6B(min)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

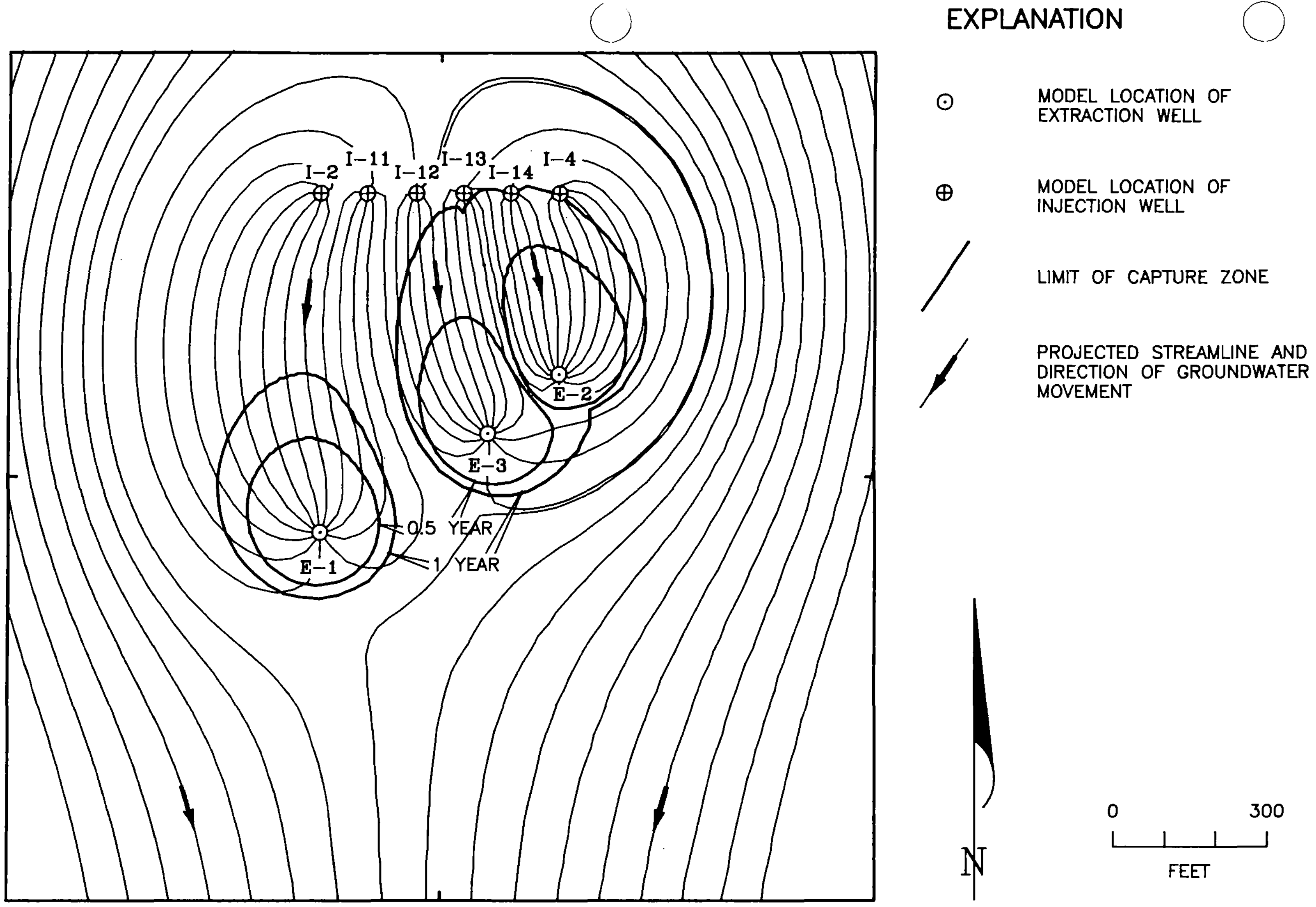


FIGURE 28. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN E1.6B(max)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

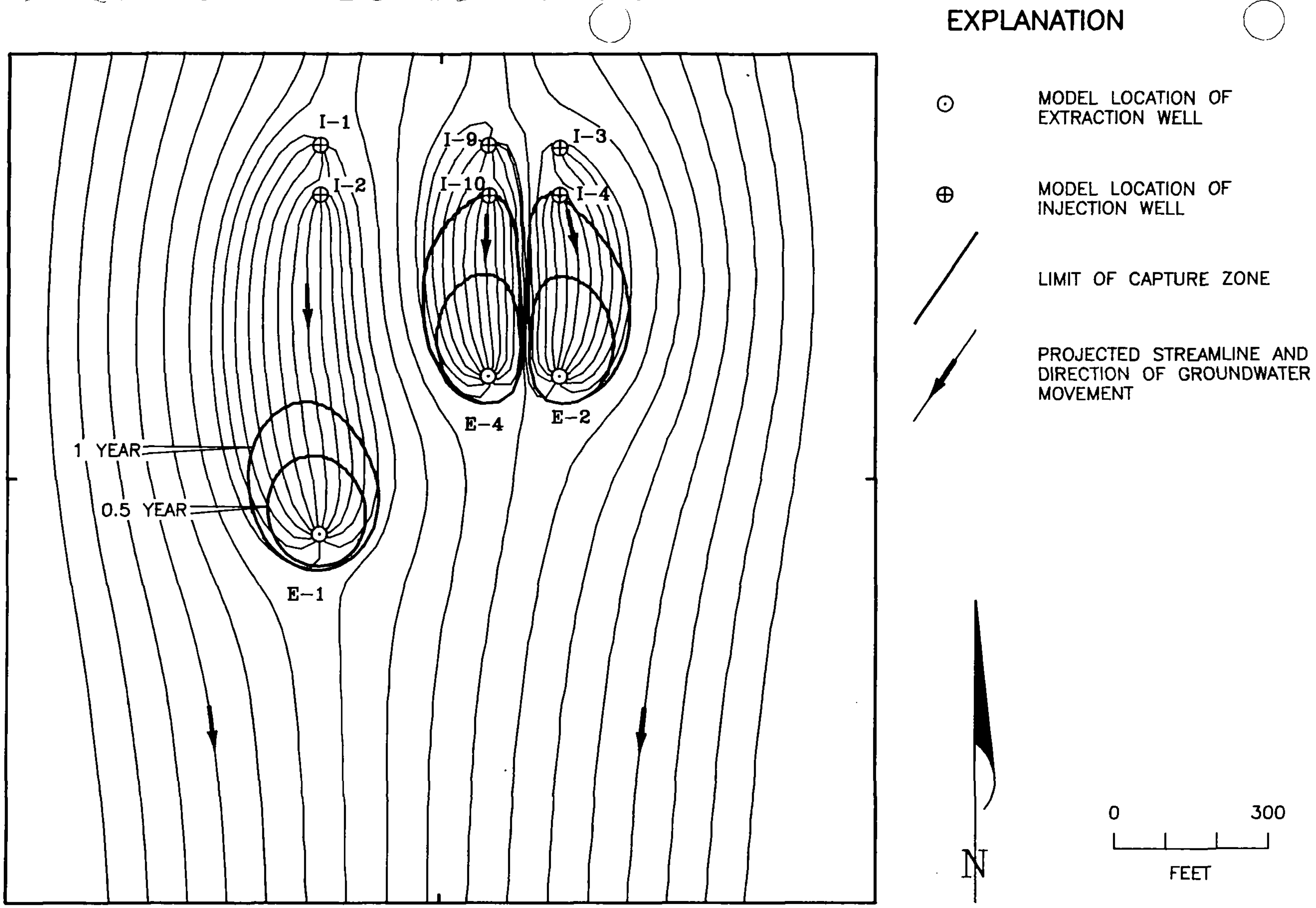


FIGURE 29. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN EI.7A(avg)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

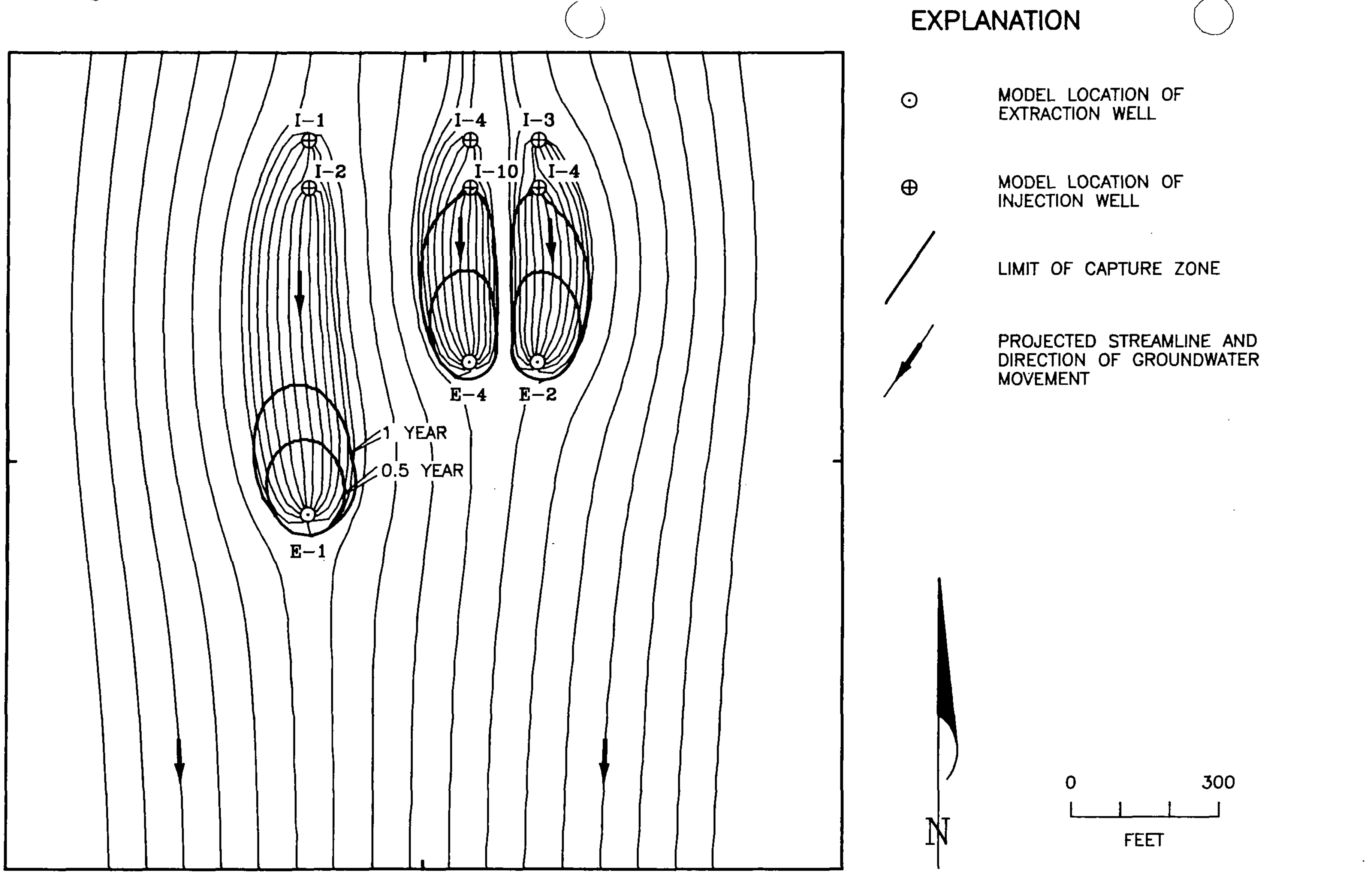


FIGURE 30. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION-INJECTION REGIMEN E1.7A(min)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

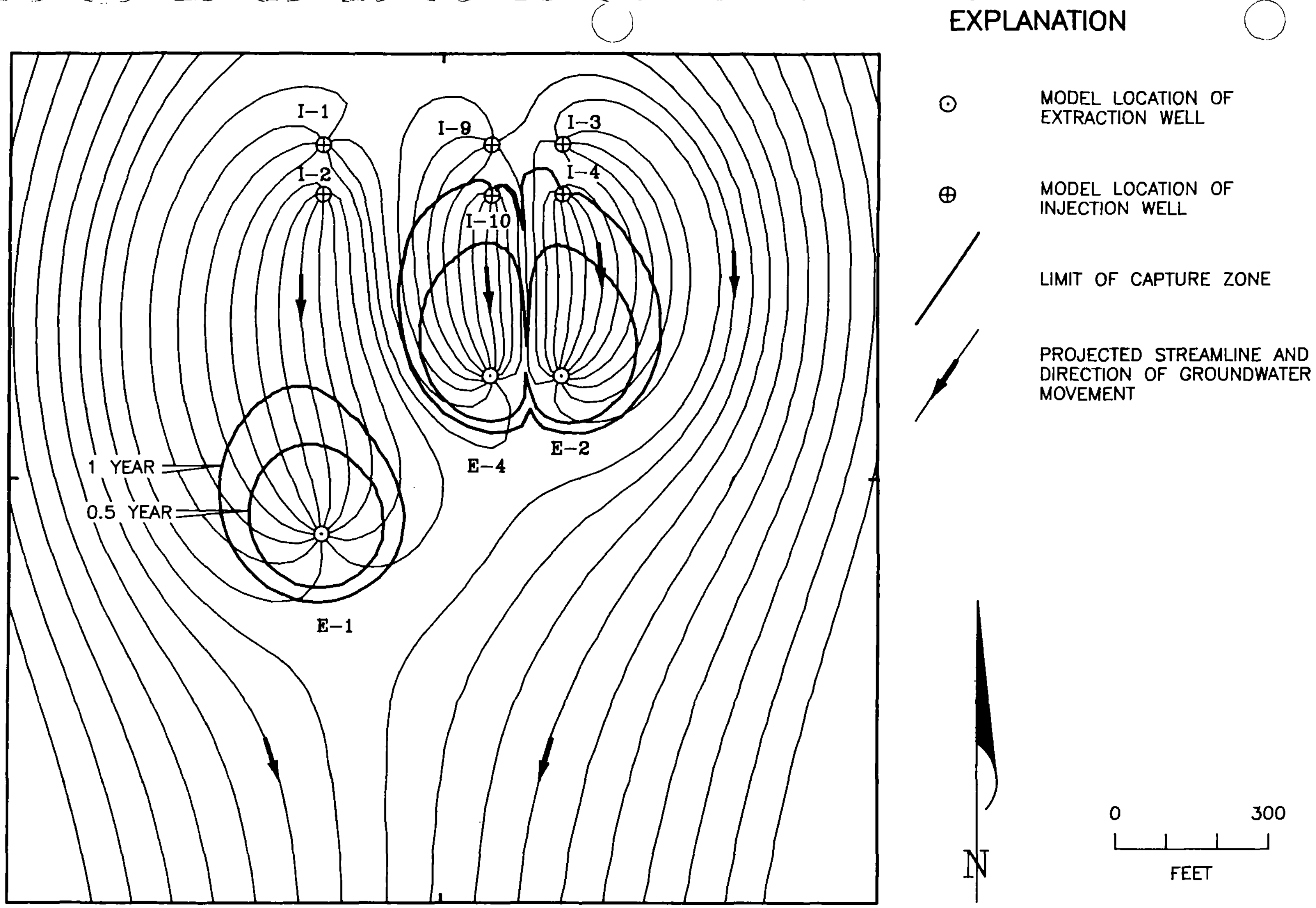


FIGURE 31. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN EI.7A(max)

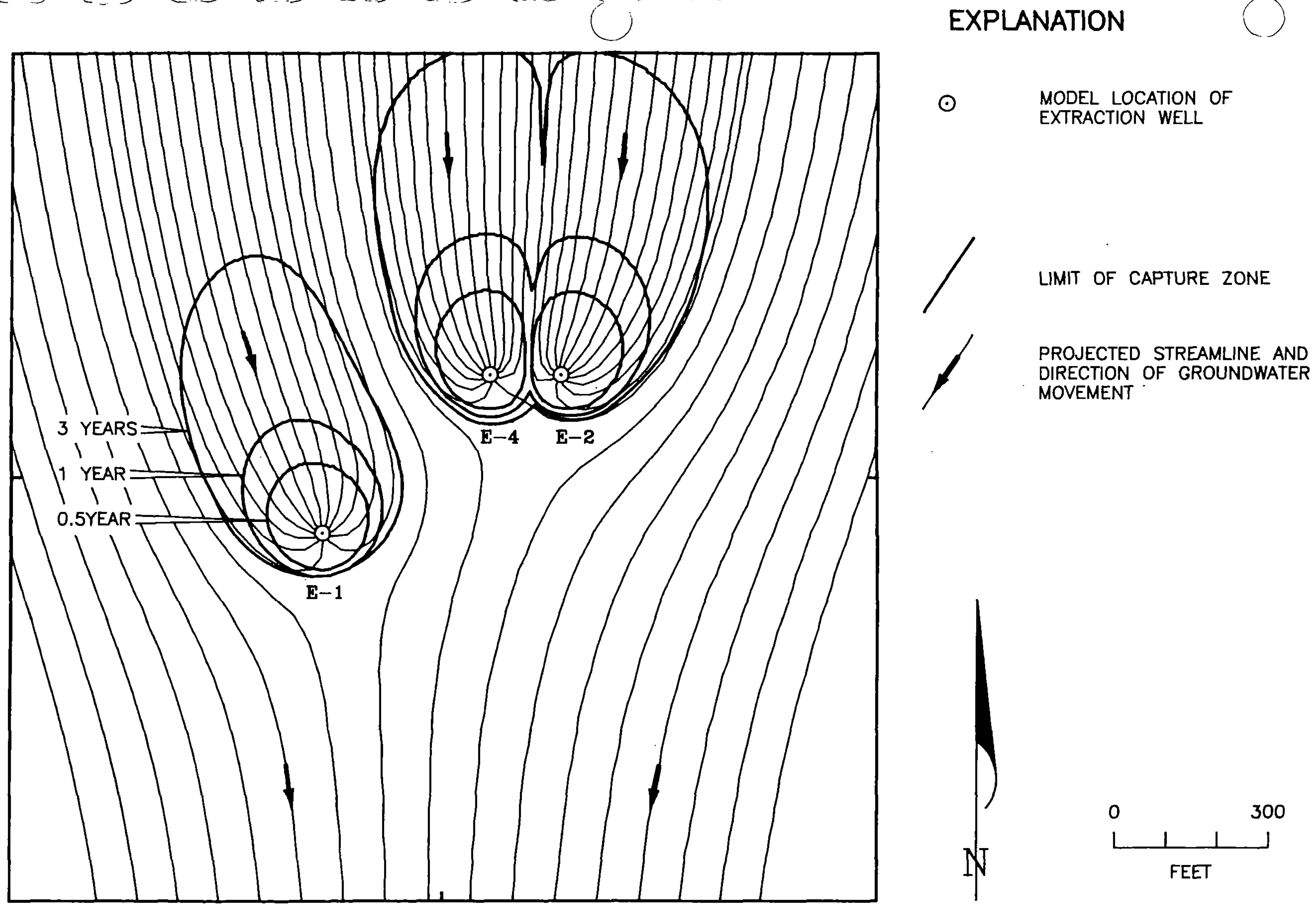
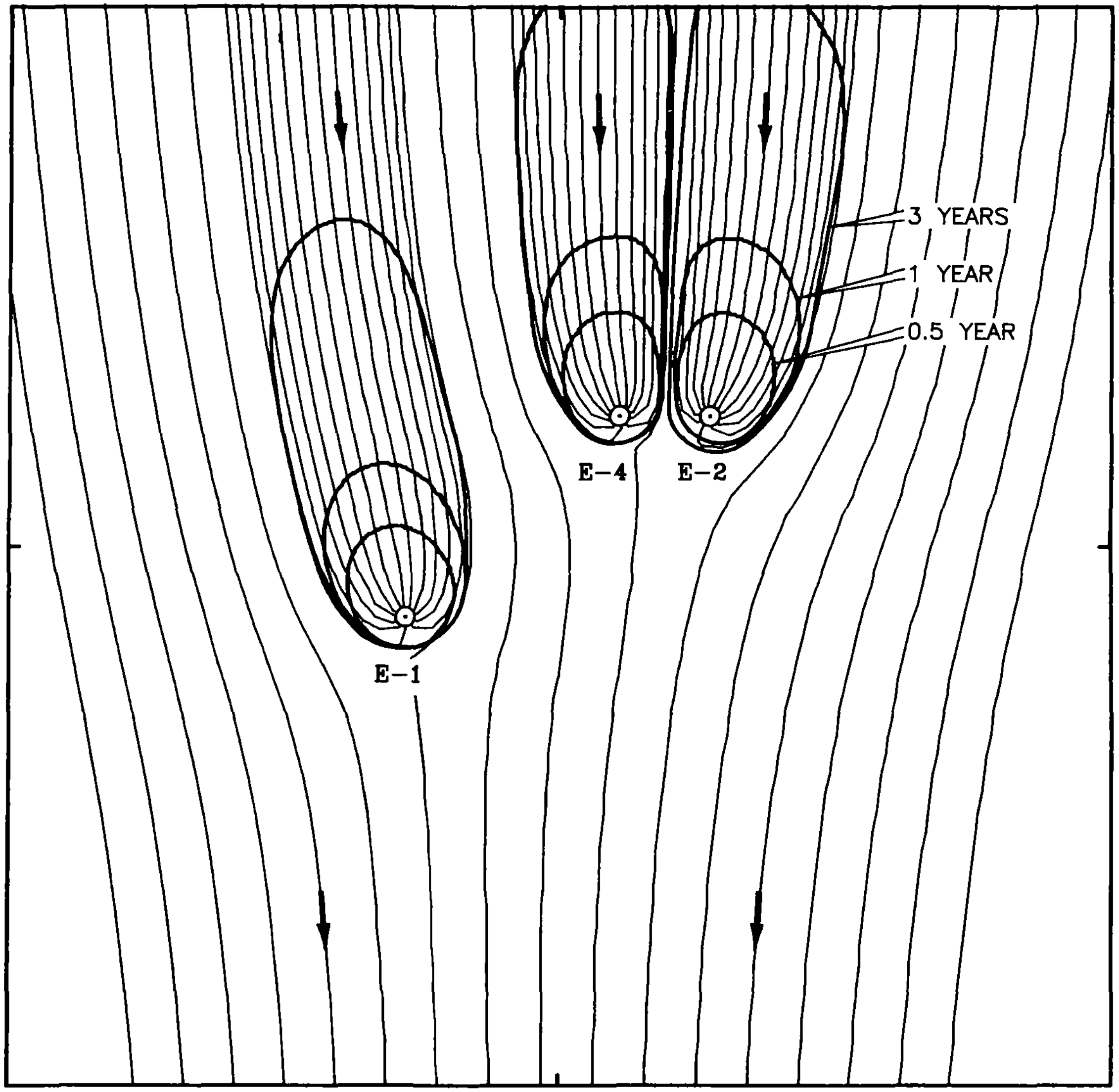


FIGURE 32. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION–INJECTION REGIMEN EI.7B(avg)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA



EXPLANATION

⊙ MODEL LOCATION OF EXTRACTION WELL

LIMIT OF CAPTURE ZONE

PROJECTED STREAMLINE AND DIRECTION OF GROUNDWATER MOVEMENT

FIGURE 33. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.7B(min)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

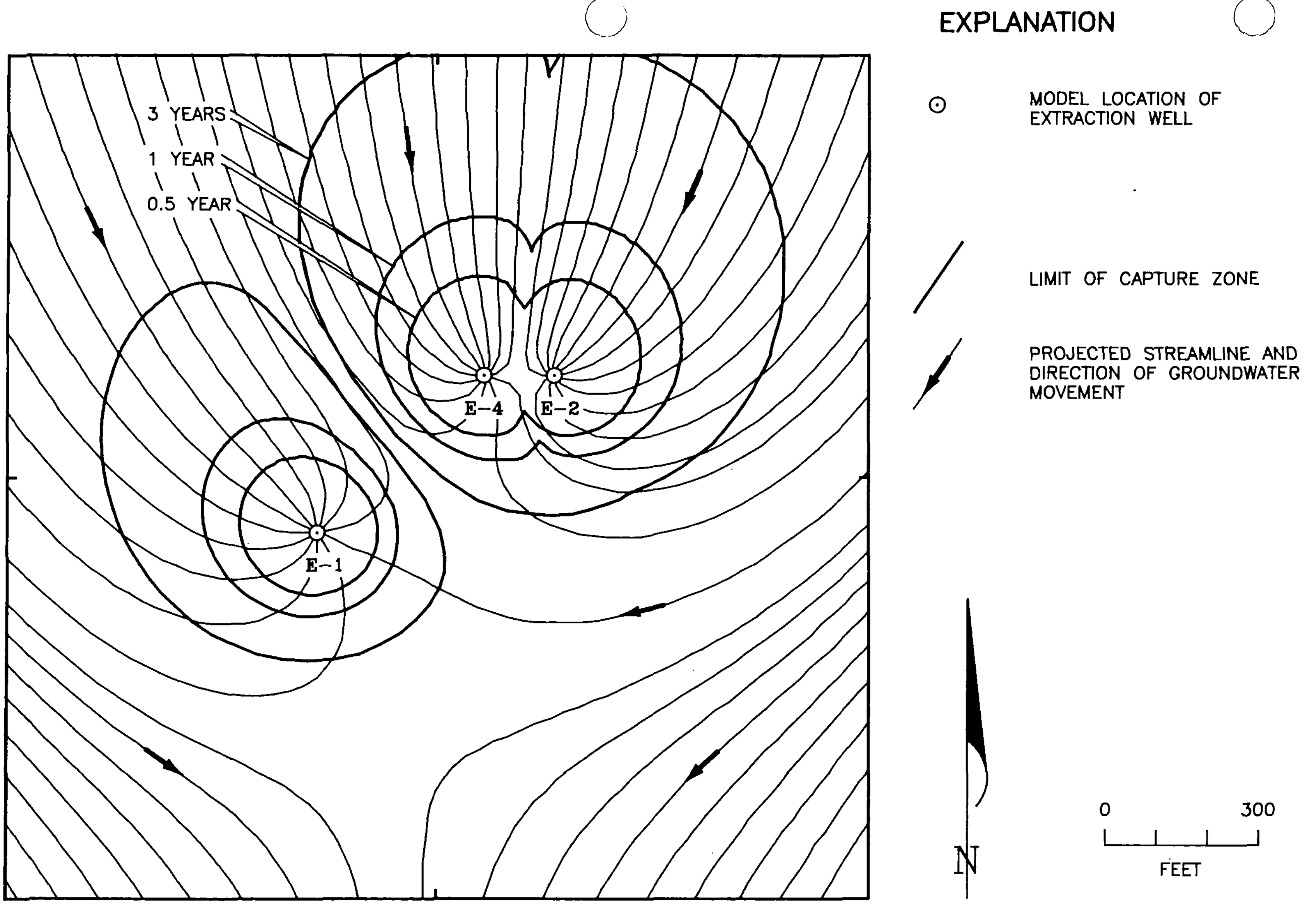


FIGURE 34. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.7B(max)

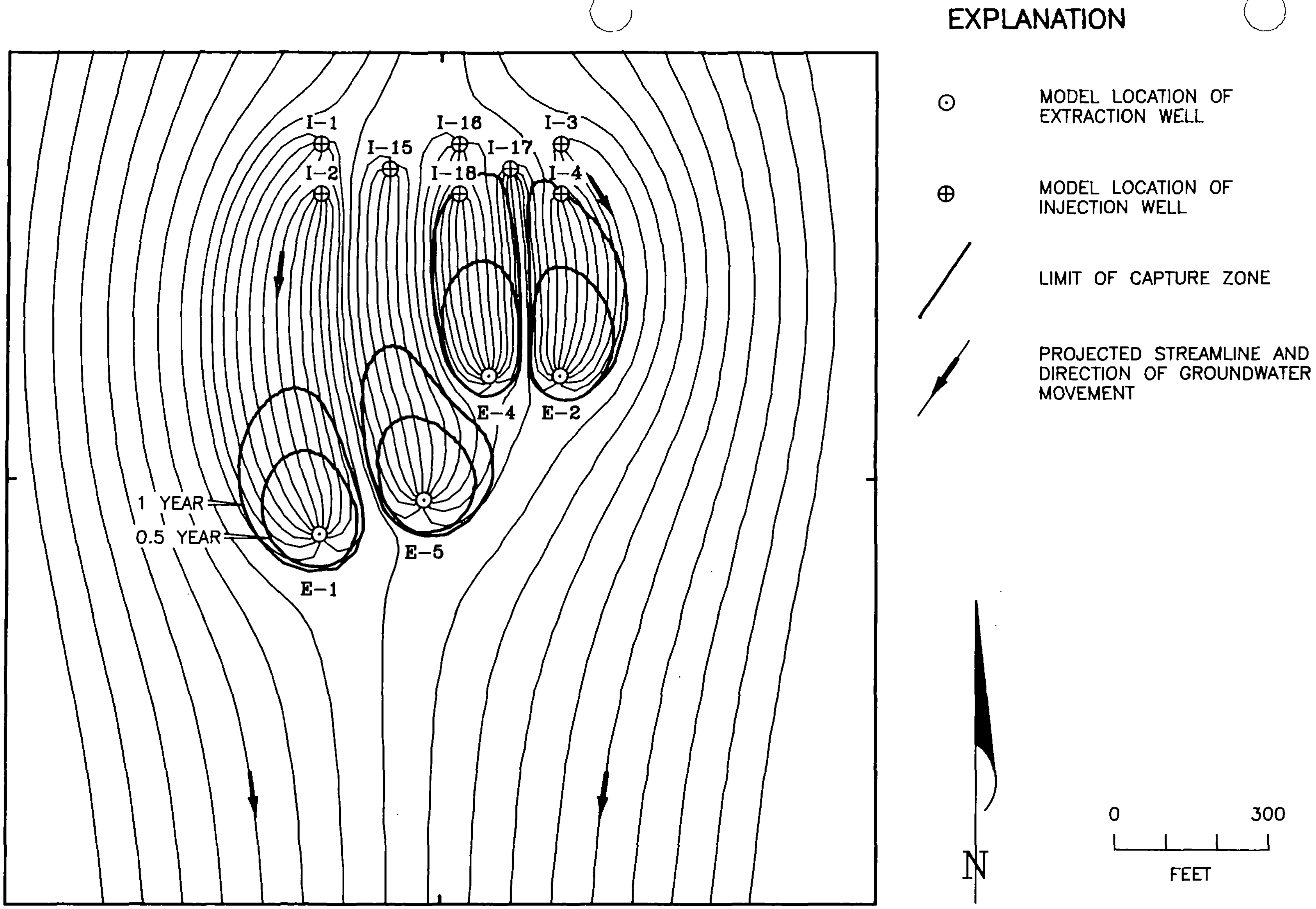


FIGURE 35. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN E1.8A(avg)

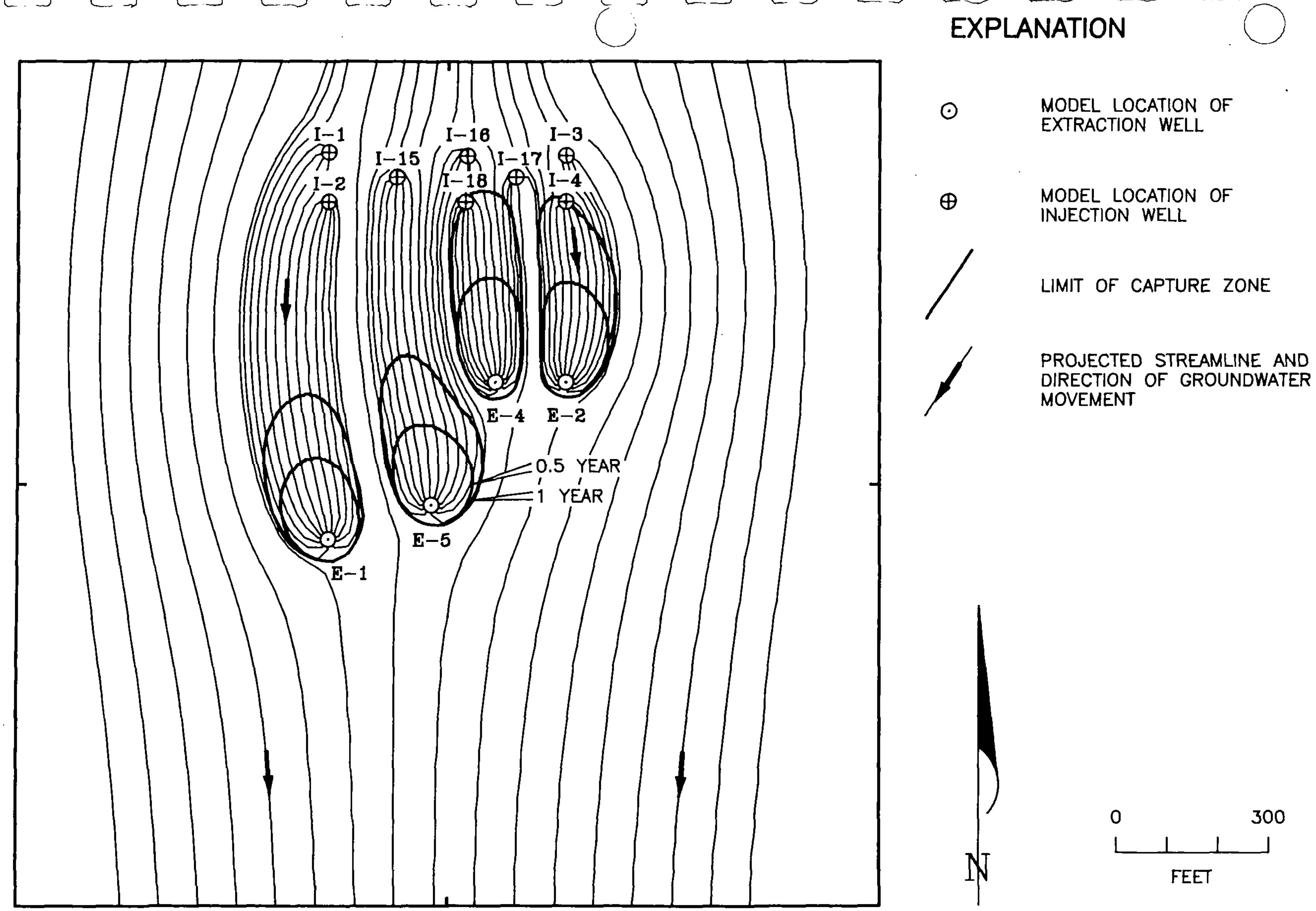


FIGURE 36. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN EI.8A(min)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

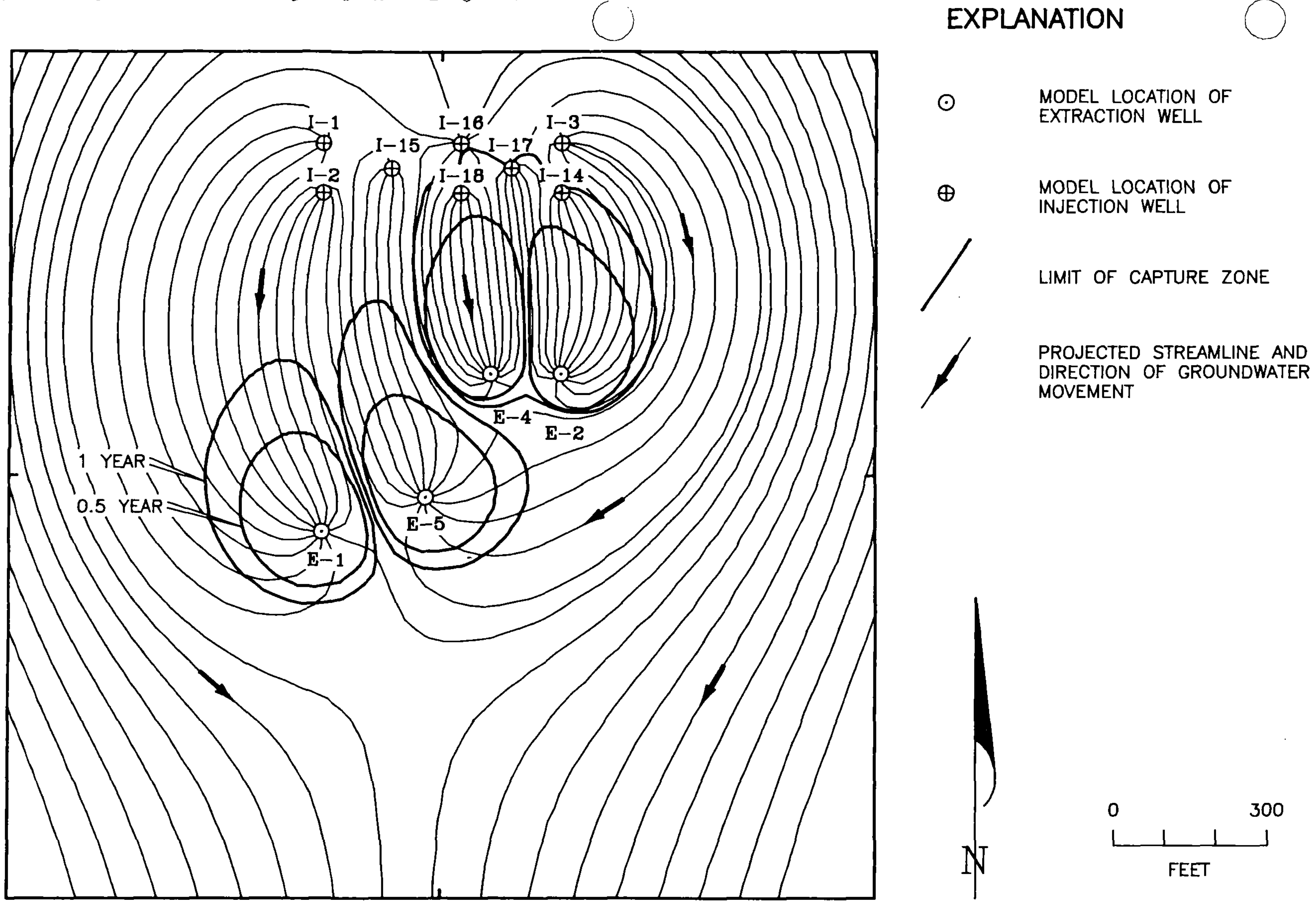


FIGURE 37. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION-INJECTION REGIMEN E1.8A(max)

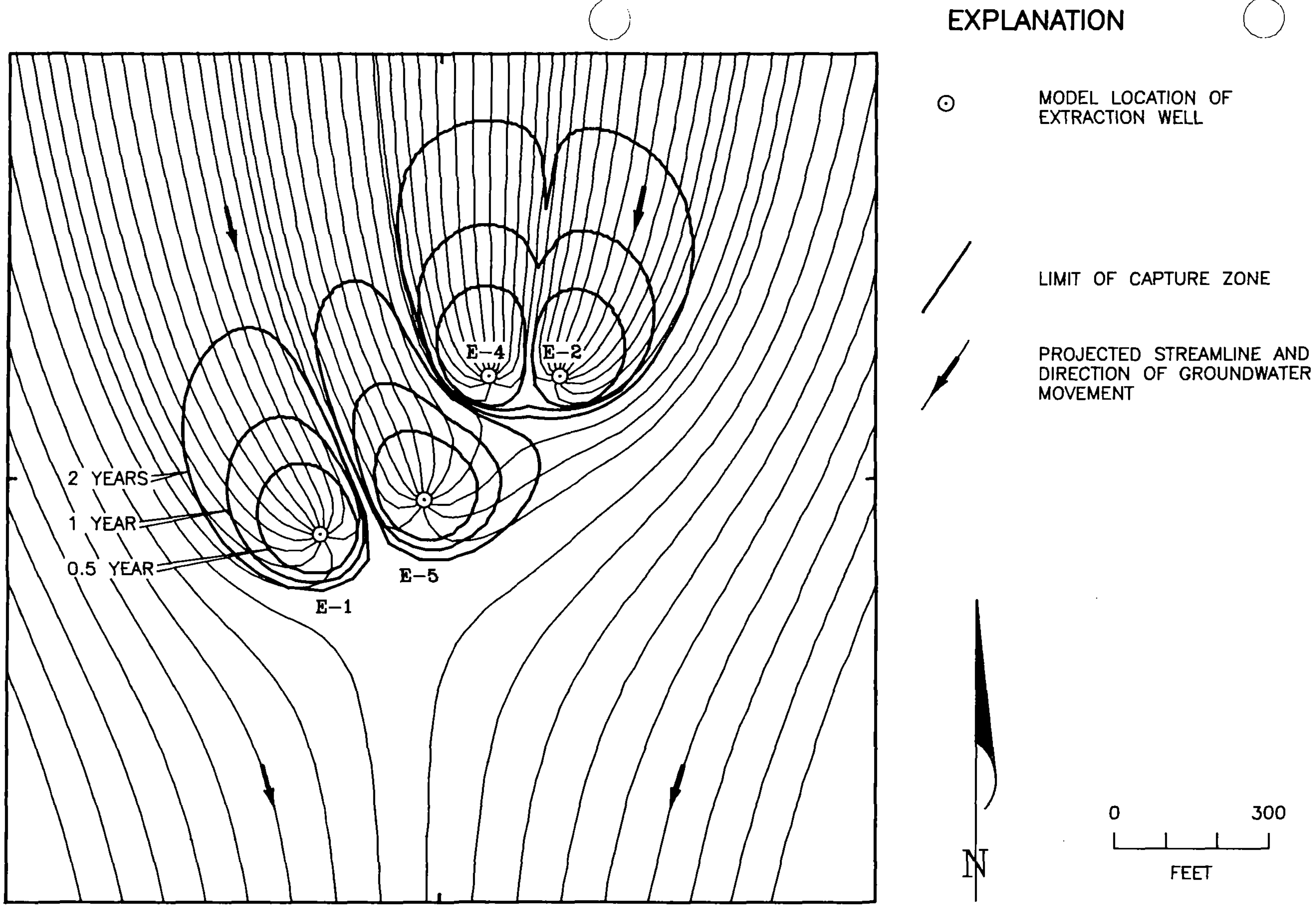
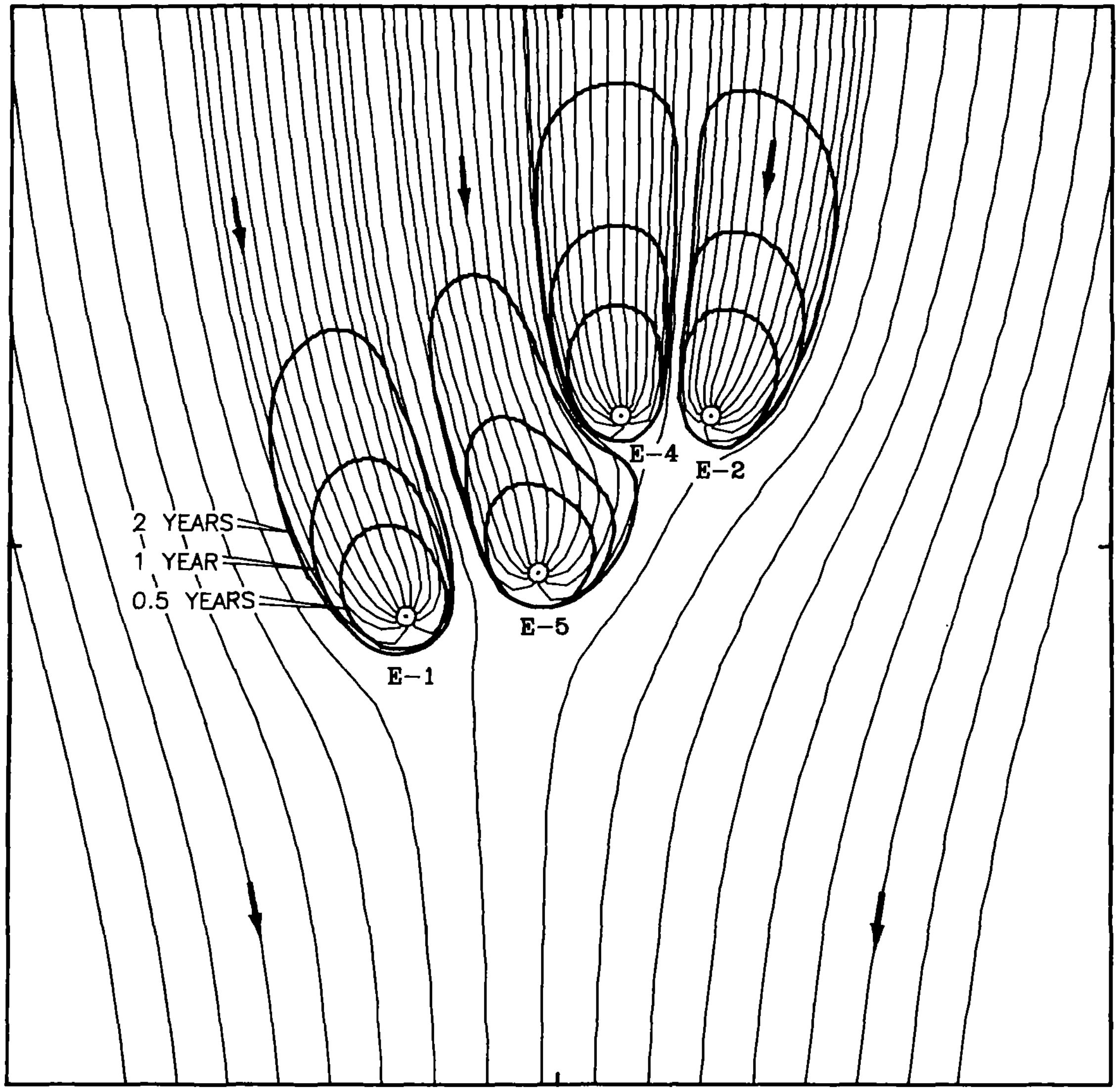


FIGURE 38. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 2 YEAR CAPTURE ZONES: EXTRACTION–INJECTION REGIMEN EI.8B(avg)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA



EXPLANATION

⊙ MODEL LOCATION OF EXTRACTION WELL

LIMIT OF CAPTURE ZONE

PROJECTED STREAMLINE AND DIRECTION OF GROUNDWATER MOVEMENT

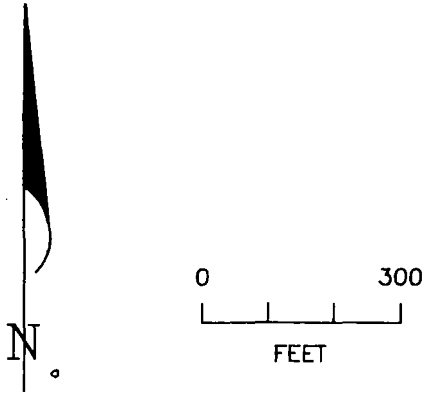


FIGURE 39. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 2 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN E1.8B(min)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

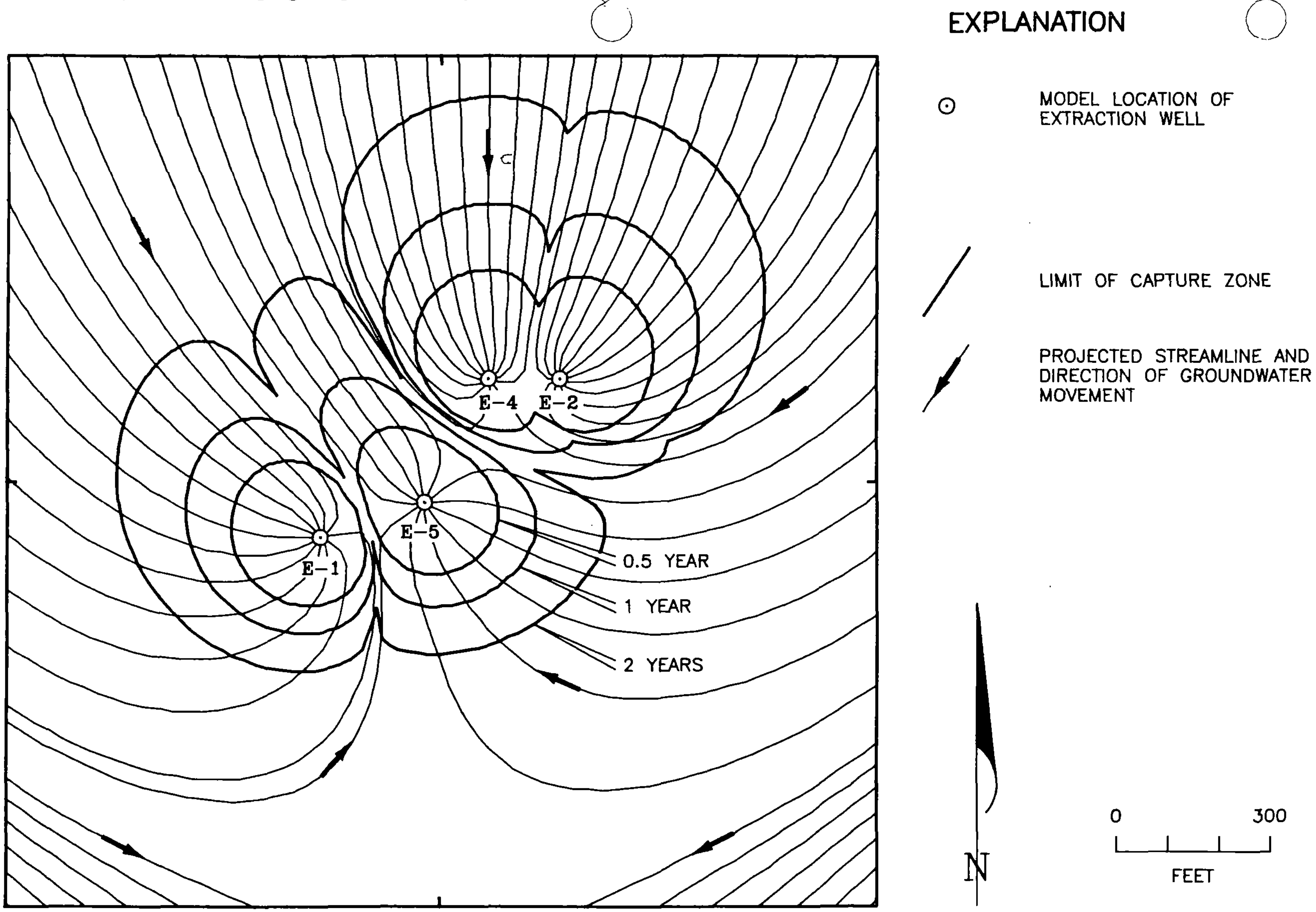
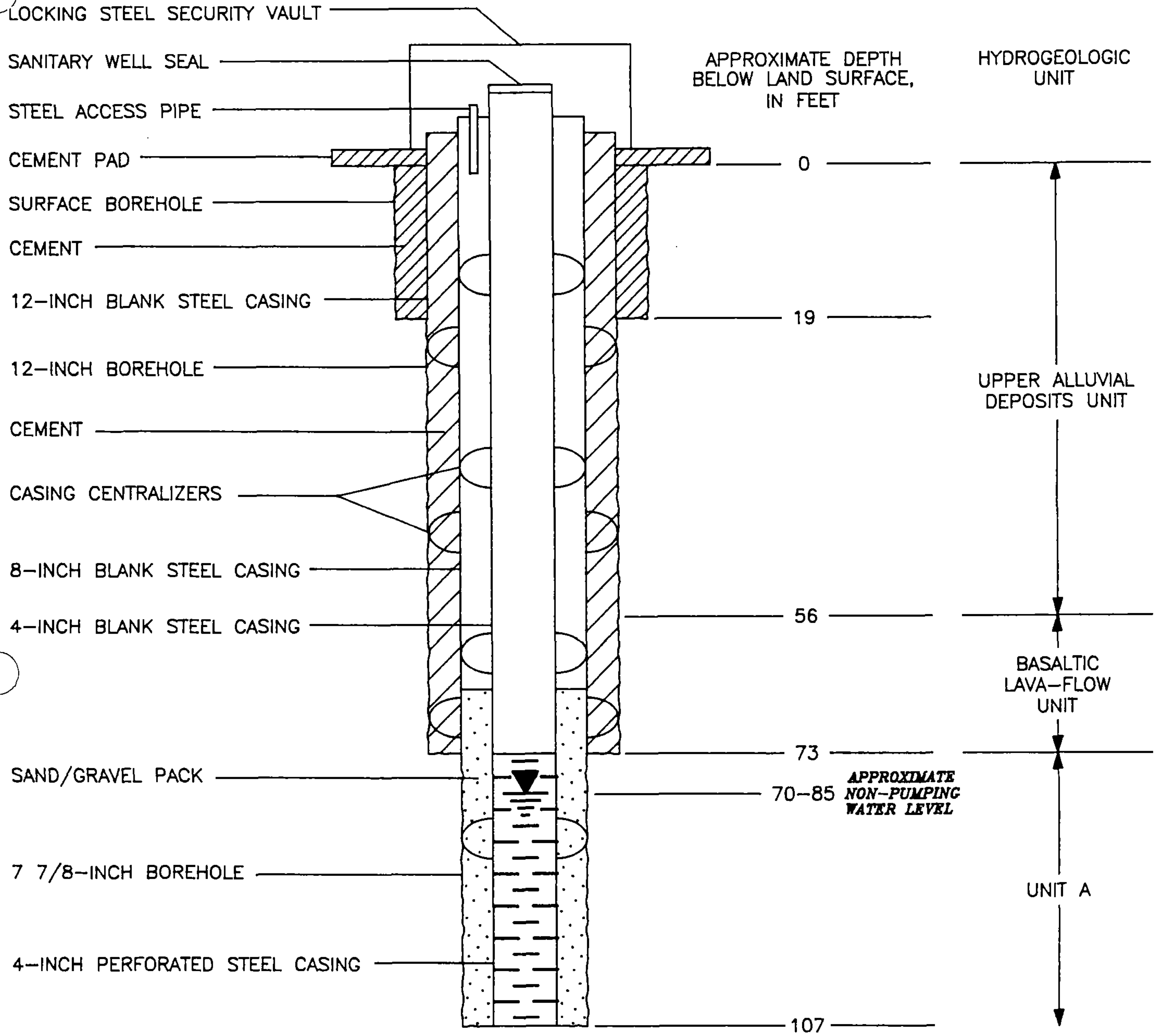
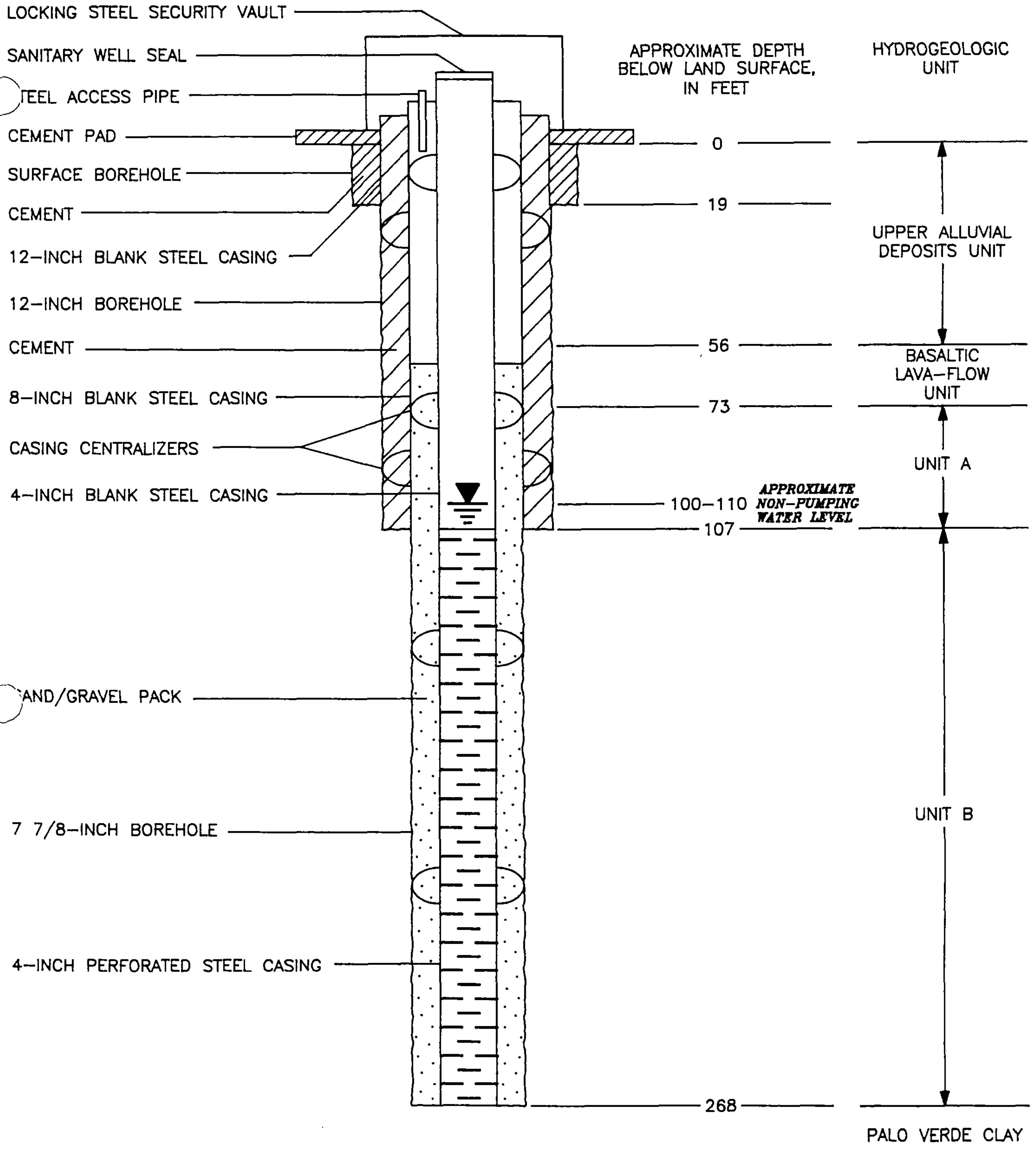


FIGURE 40. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 2 YEAR CAPTURE ZONES: EXTRACTION–INJECTION REGIMEN E1.8B(max)



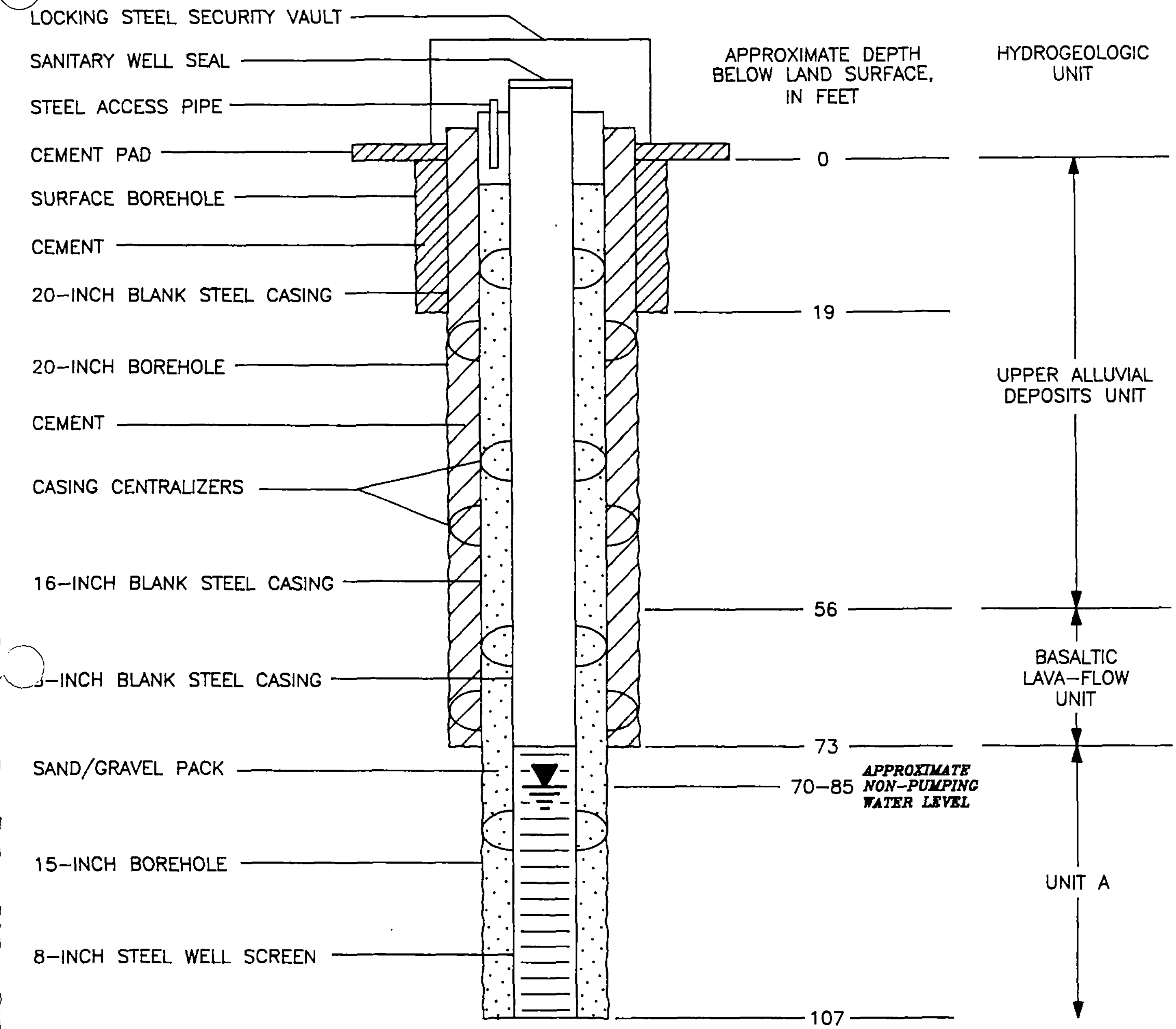
NOTE: CONTRACTOR WILL INSTALL PERMANENT SUBMERSIBLE PUMP

FIGURE 41. SCHEMATIC DIAGRAM OF PROPOSED UNIT A MONITOR WELL



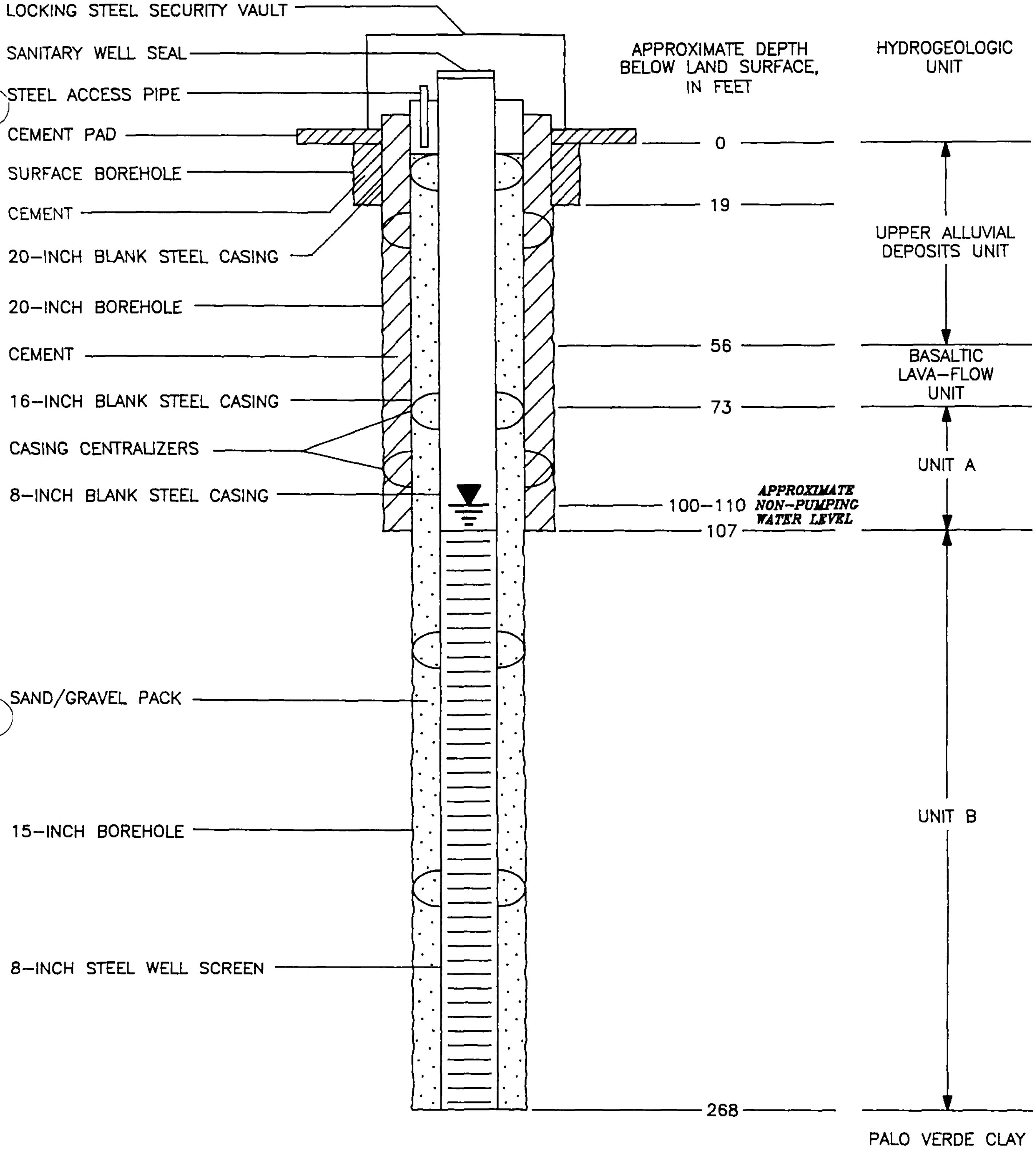
NOTE: CONTRACTOR WILL INSTALL PERMANENT SUBMERSIBLE PUMP

FIGURE 42. SCHEMATIC DIAGRAM OF PROPOSED UNIT B MONITOR WELL



NOTE: CONTRACTOR WILL INSTALL SUBMERSIBLE PUMP FOR EXTRACTION WELL OR DROP PIPE FOR INJECTION WELL

FIGURE 43. SCHEMATIC DIAGRAM OF PROPOSED UNIT A INJECTION AND EXTRACTION WELLS



NOTE: CONTRACTOR WILL INSTALL DROP PIPE

FIGURE 44. SCHEMATIC DIAGRAM OF PROPOSED UNIT B INJECTION WELL

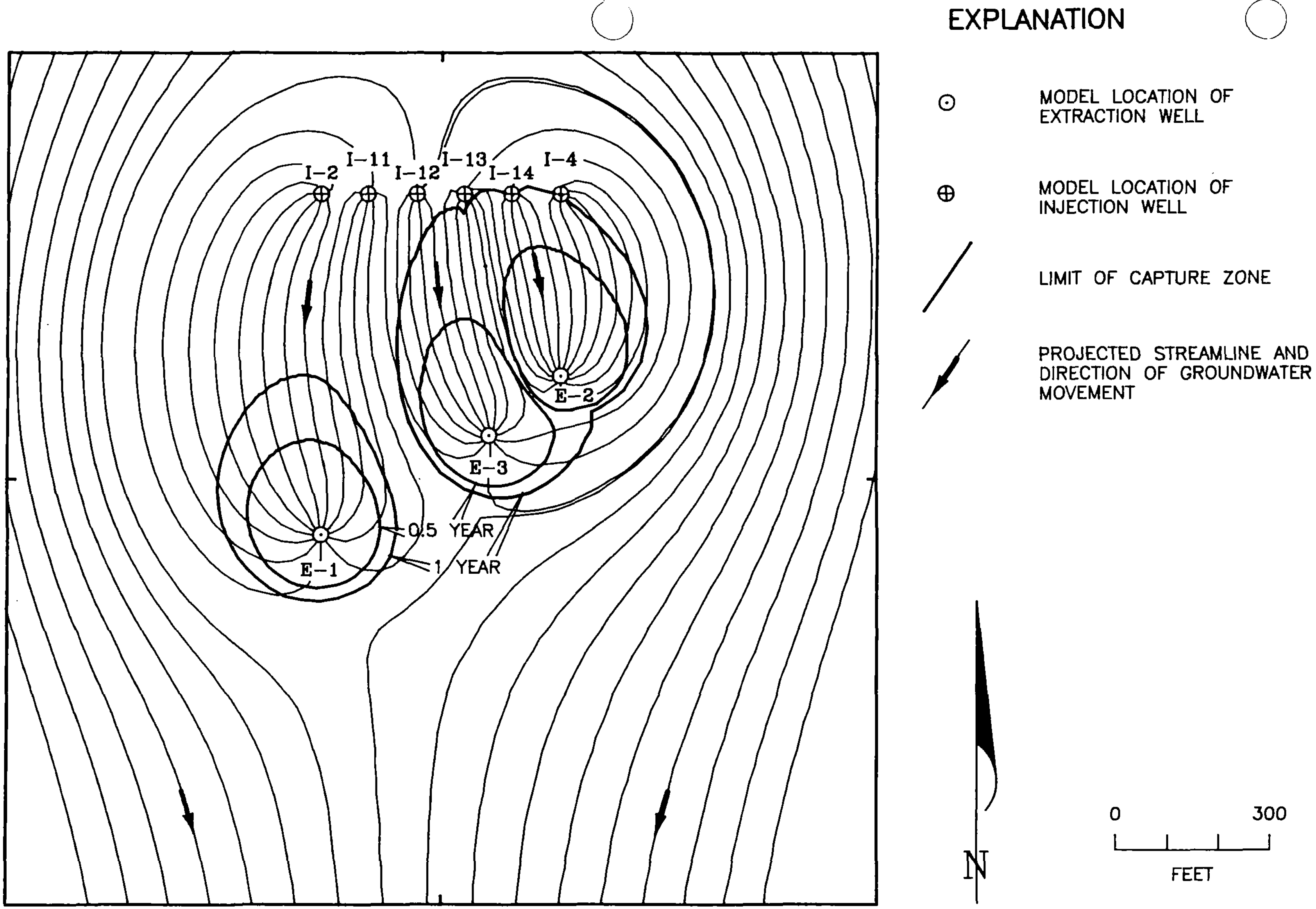


FIGURE 28. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES: EXTRACTION–INJECTION REGIMEN EI.6B(max)

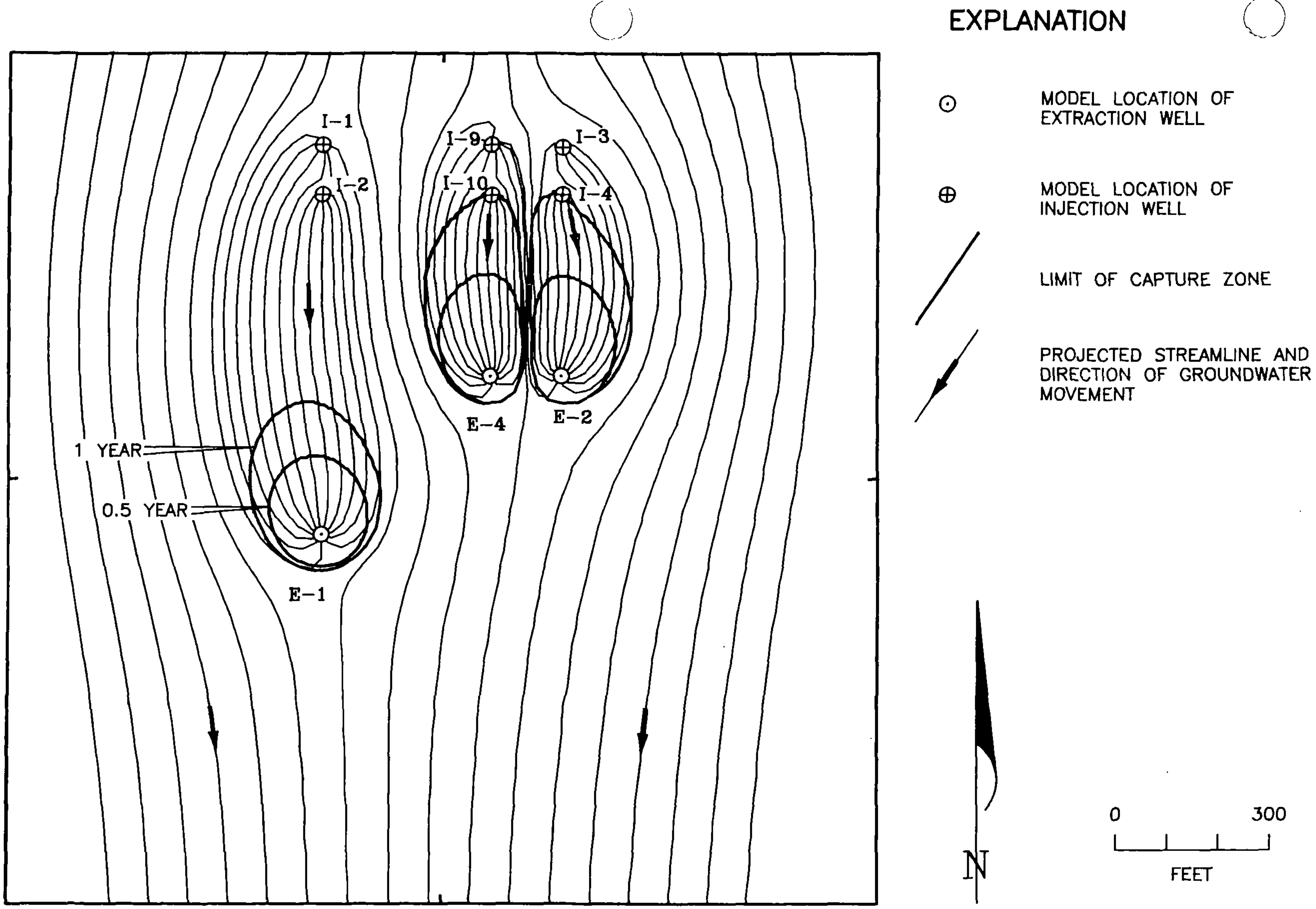


FIGURE 29. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN EI.7A(avg)

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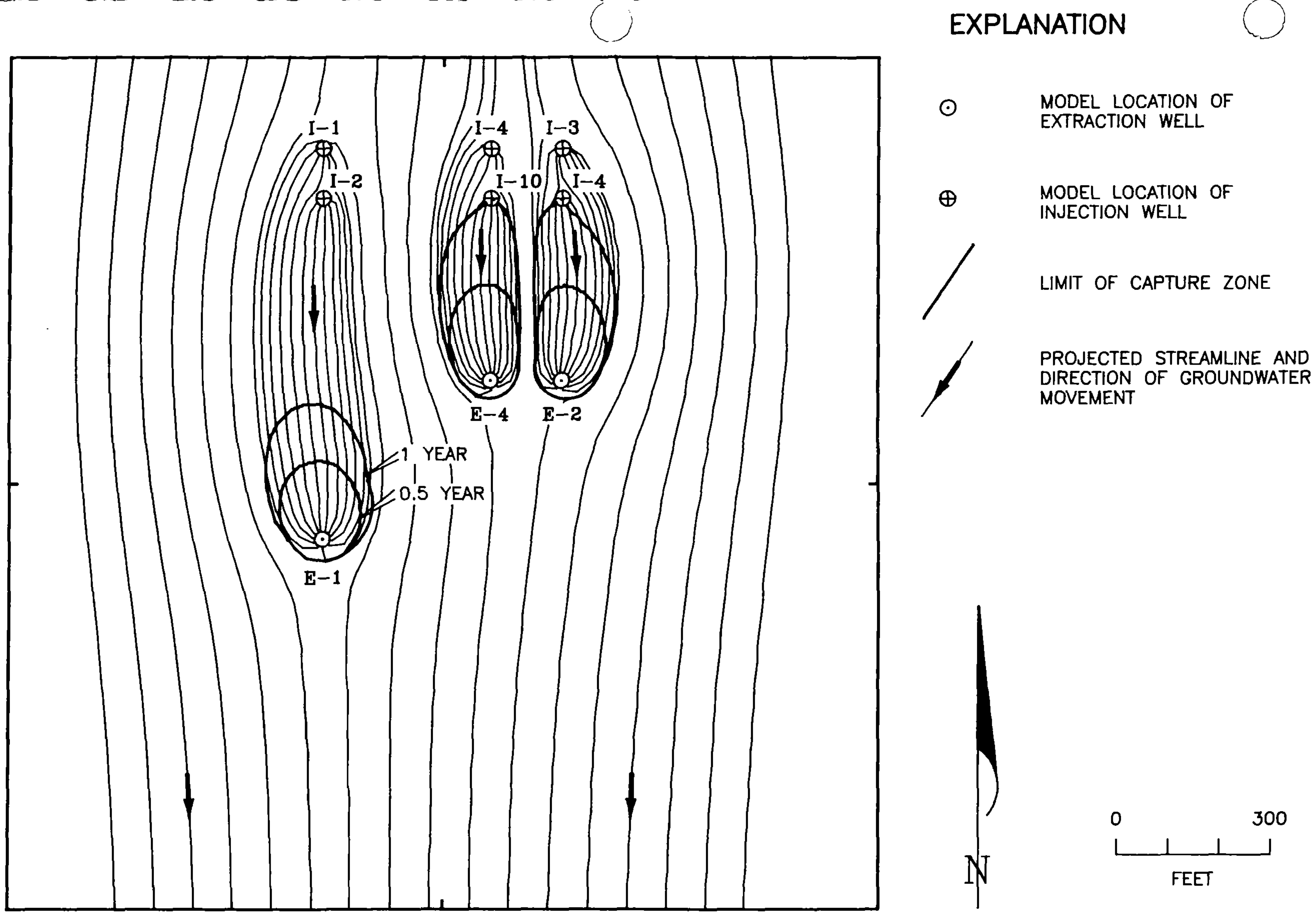
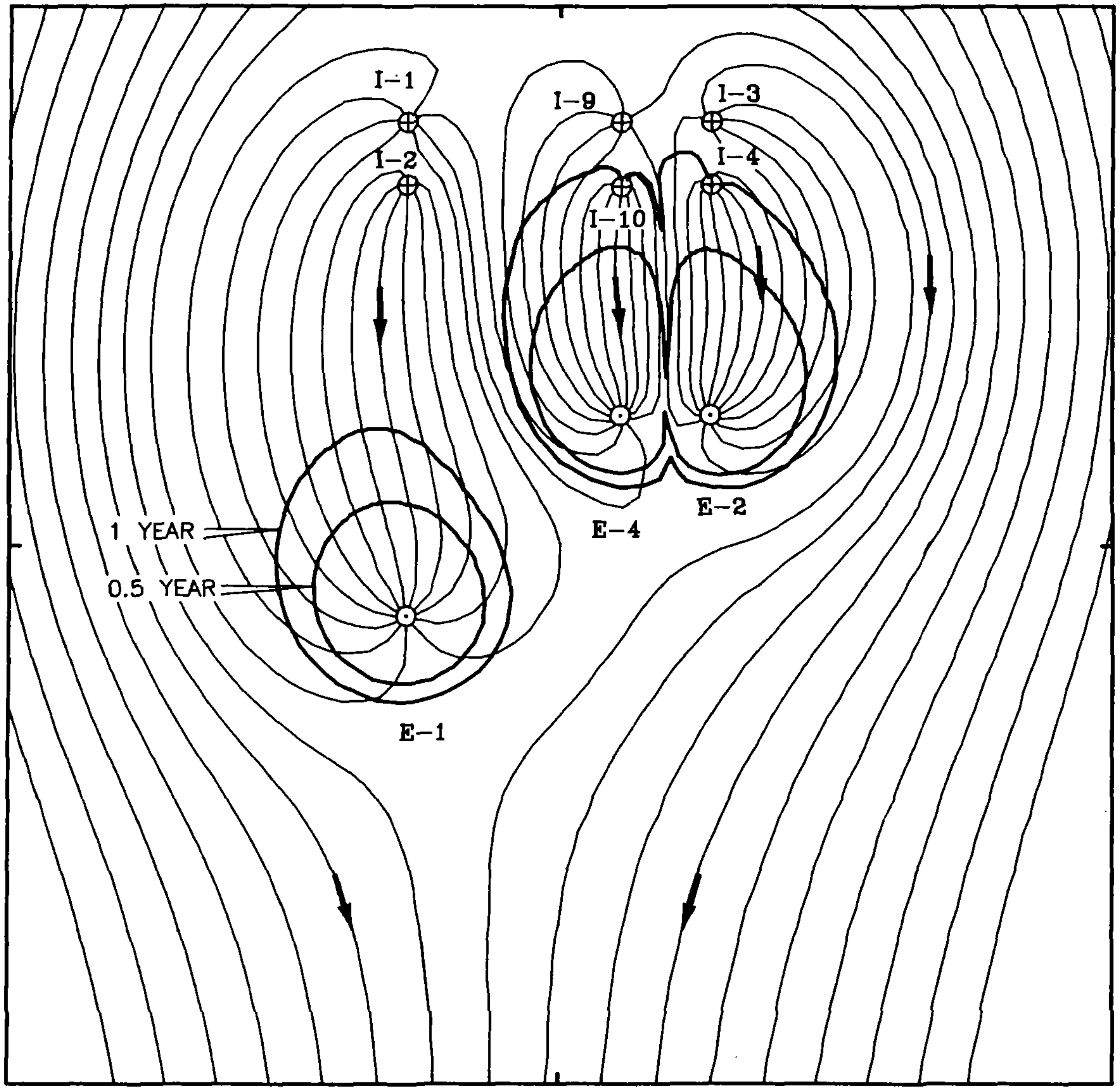


FIGURE 30. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION-INJECTION REGIMEN EI.7A(min)



EXPLANATION

⊙ MODEL LOCATION OF EXTRACTION WELL

⊕ MODEL LOCATION OF INJECTION WELL


LIMIT OF CAPTURE ZONE

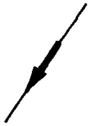

PROJECTED STREAMLINE AND DIRECTION OF GROUNDWATER MOVEMENT

FIGURE 31. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN EI.7A(max)

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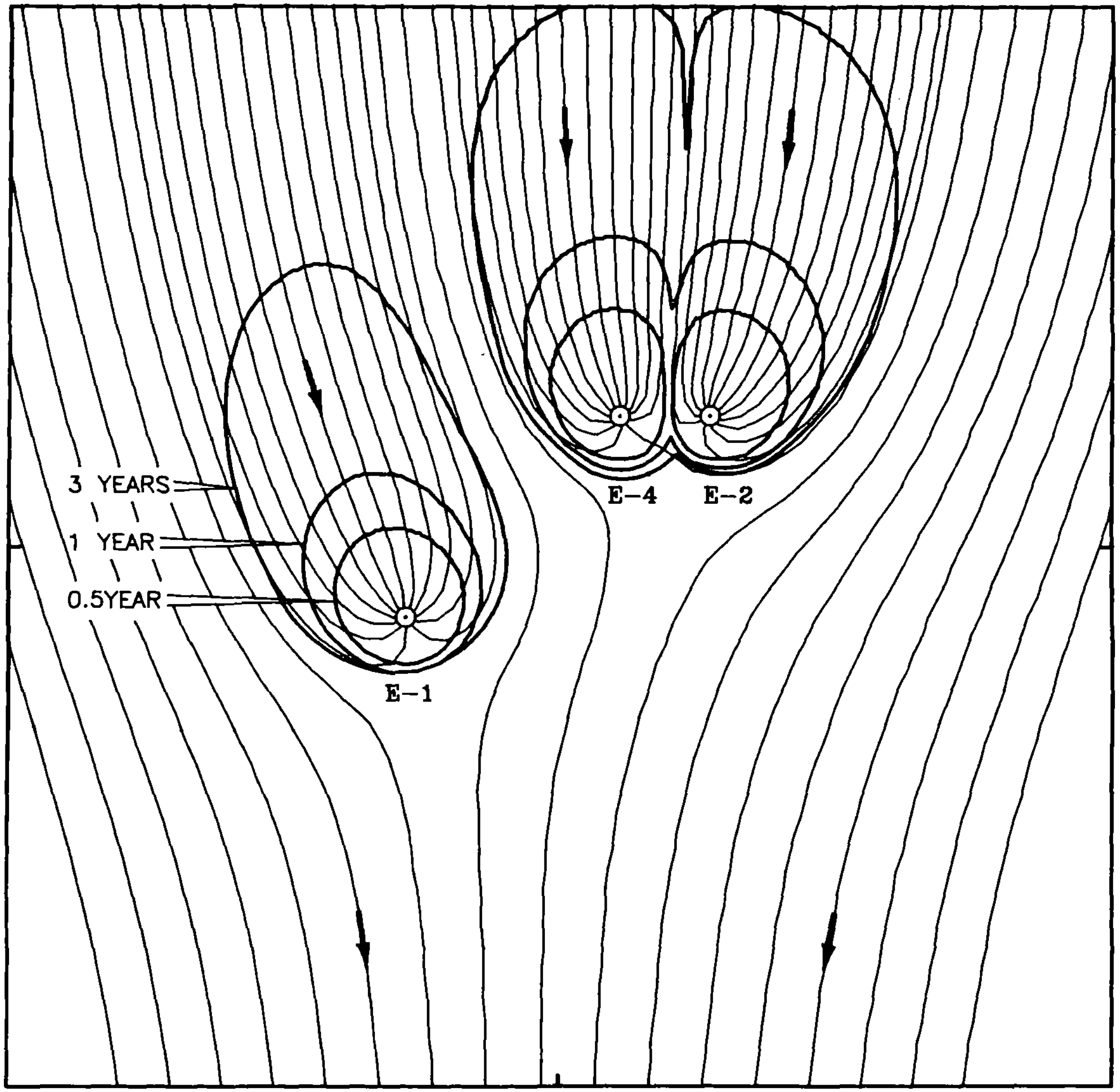

EXPLANATION

⊙ MODEL LOCATION OF EXTRACTION WELL

LIMIT OF CAPTURE ZONE

PROJECTED STREAMLINE AND DIRECTION OF GROUNDWATER MOVEMENT

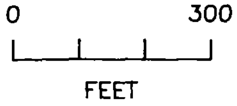

FIGURE 32. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.7B(avg)

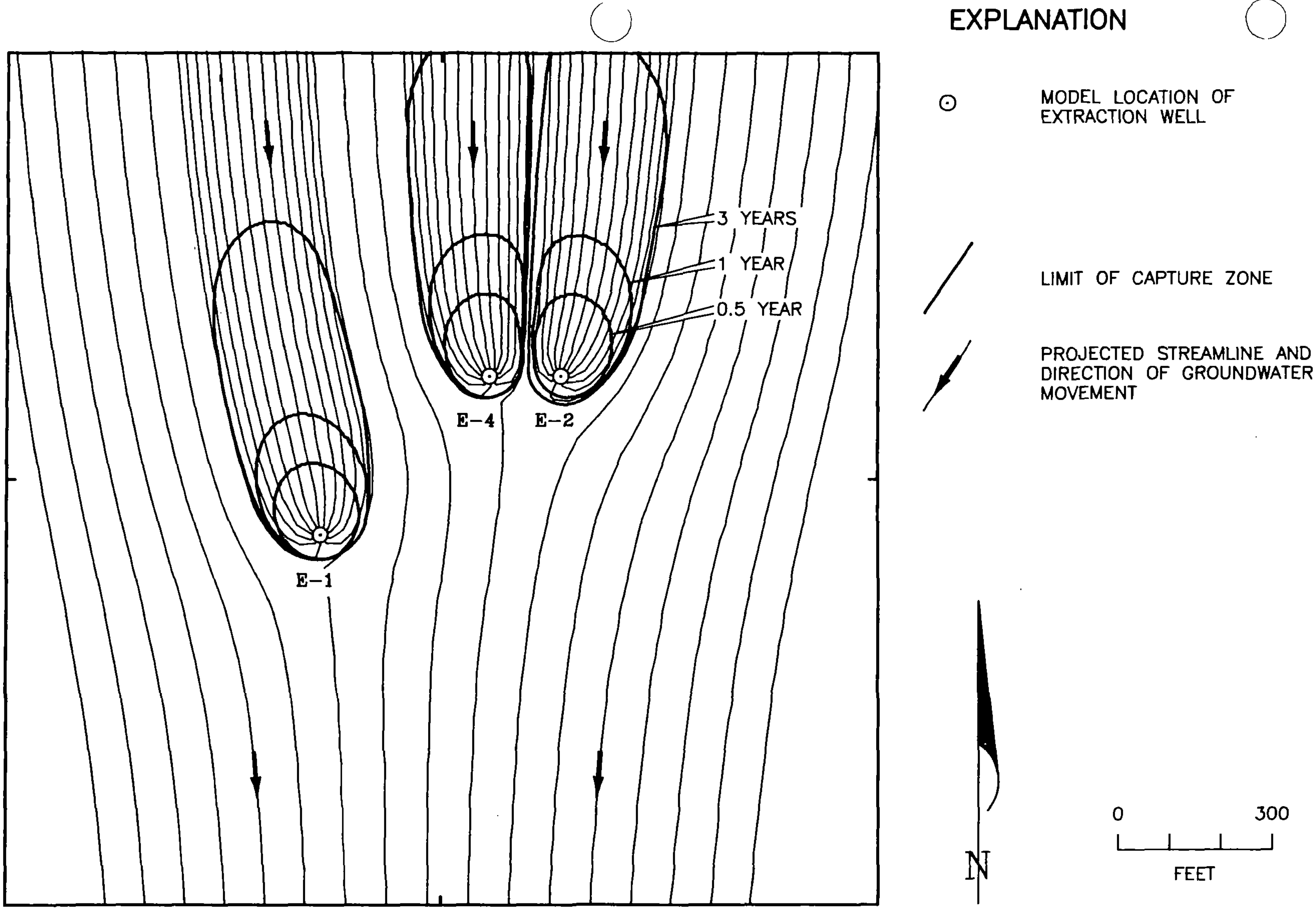

FIGURE 33. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN E1.7B(min)

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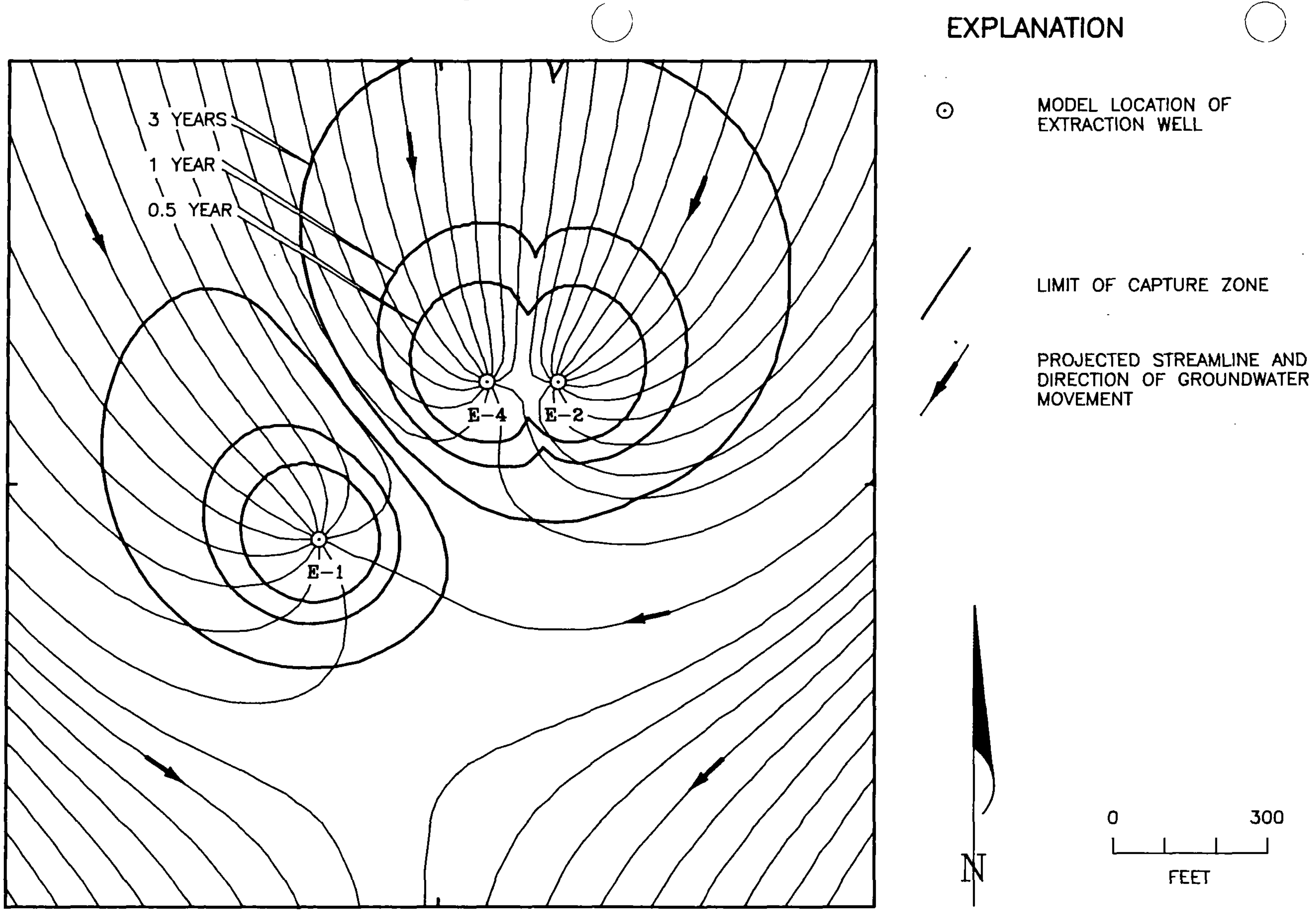

FIGURE 34. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 3 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.7B(max)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
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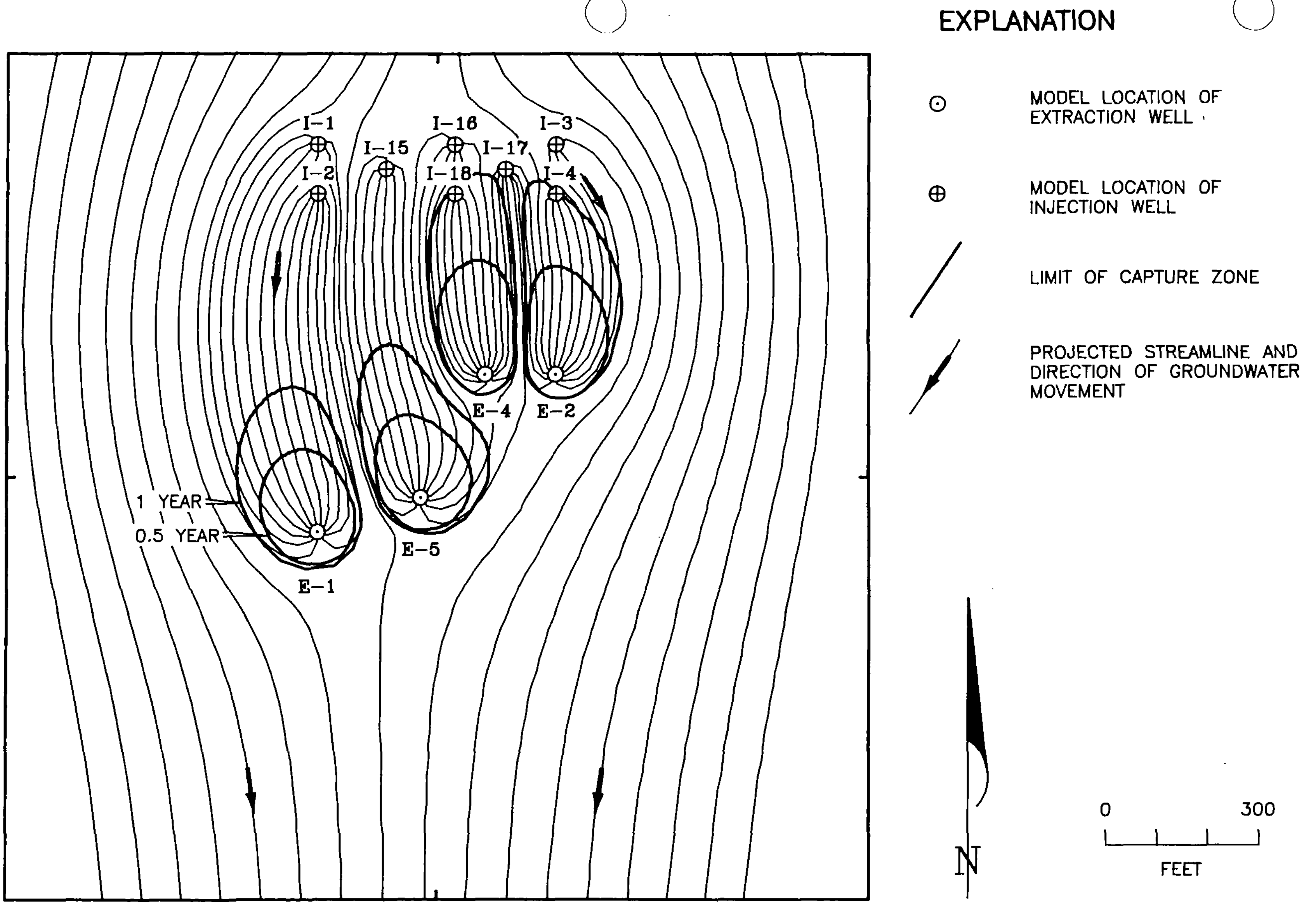

FIGURE 35. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN EI.8A(avg)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
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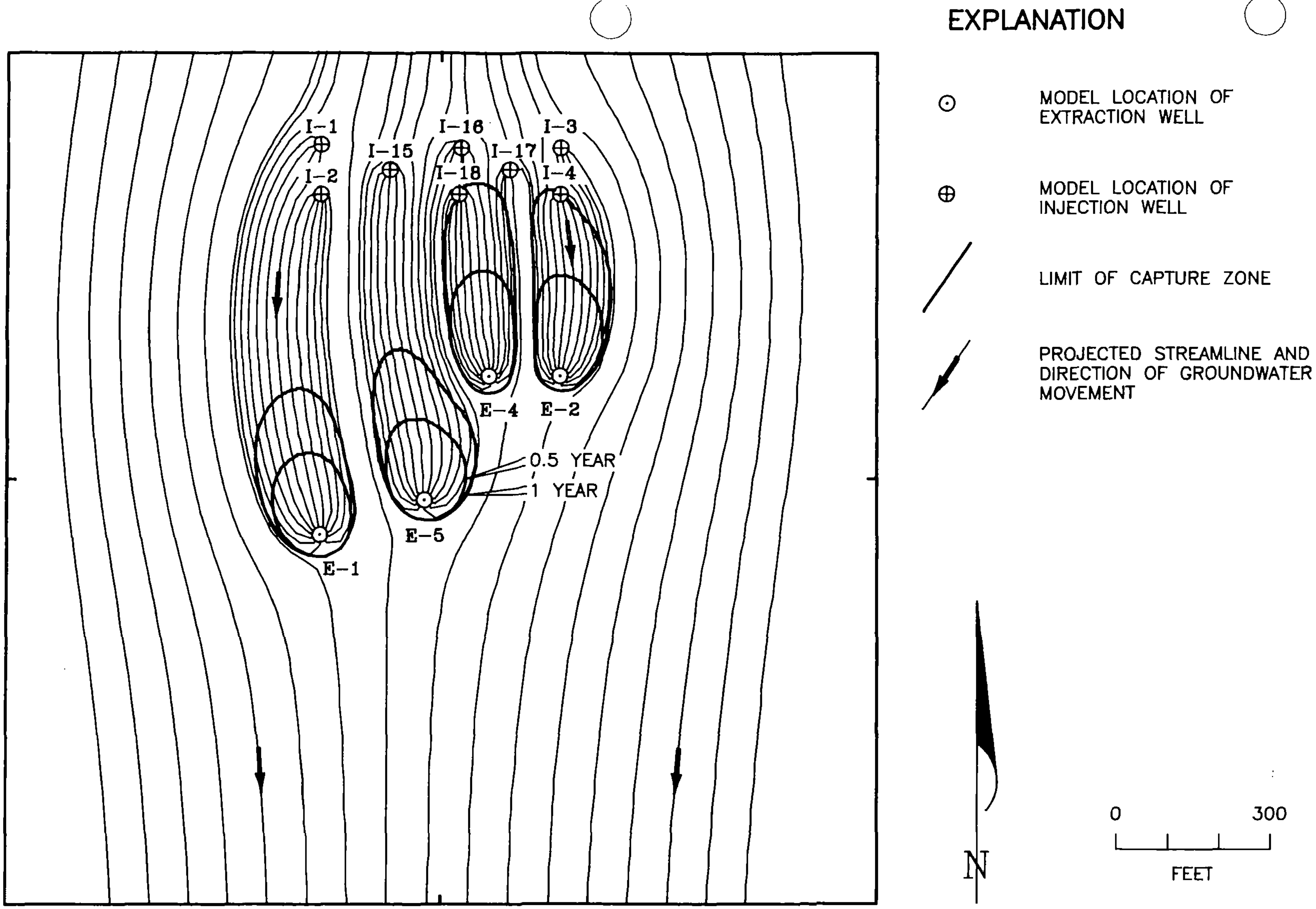

FIGURE 36. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN EI.8A(min)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
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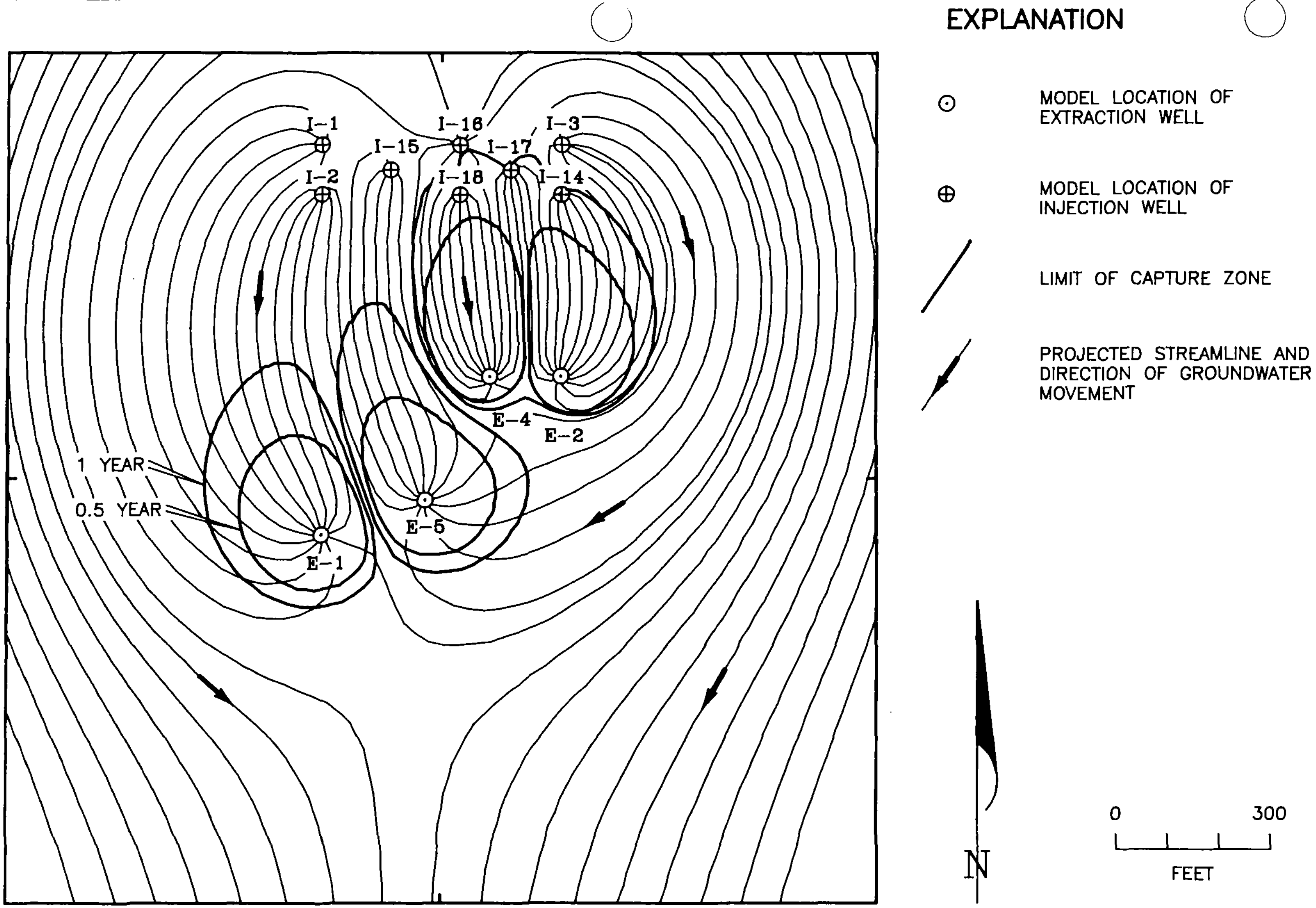


FIGURE 37. PROJECTED STREAMLINES AND LIMIT OF 0.5 AND 1 YEAR CAPTURE ZONES:
EXTRACTION–INJECTION REGIMEN EI.8A(max)

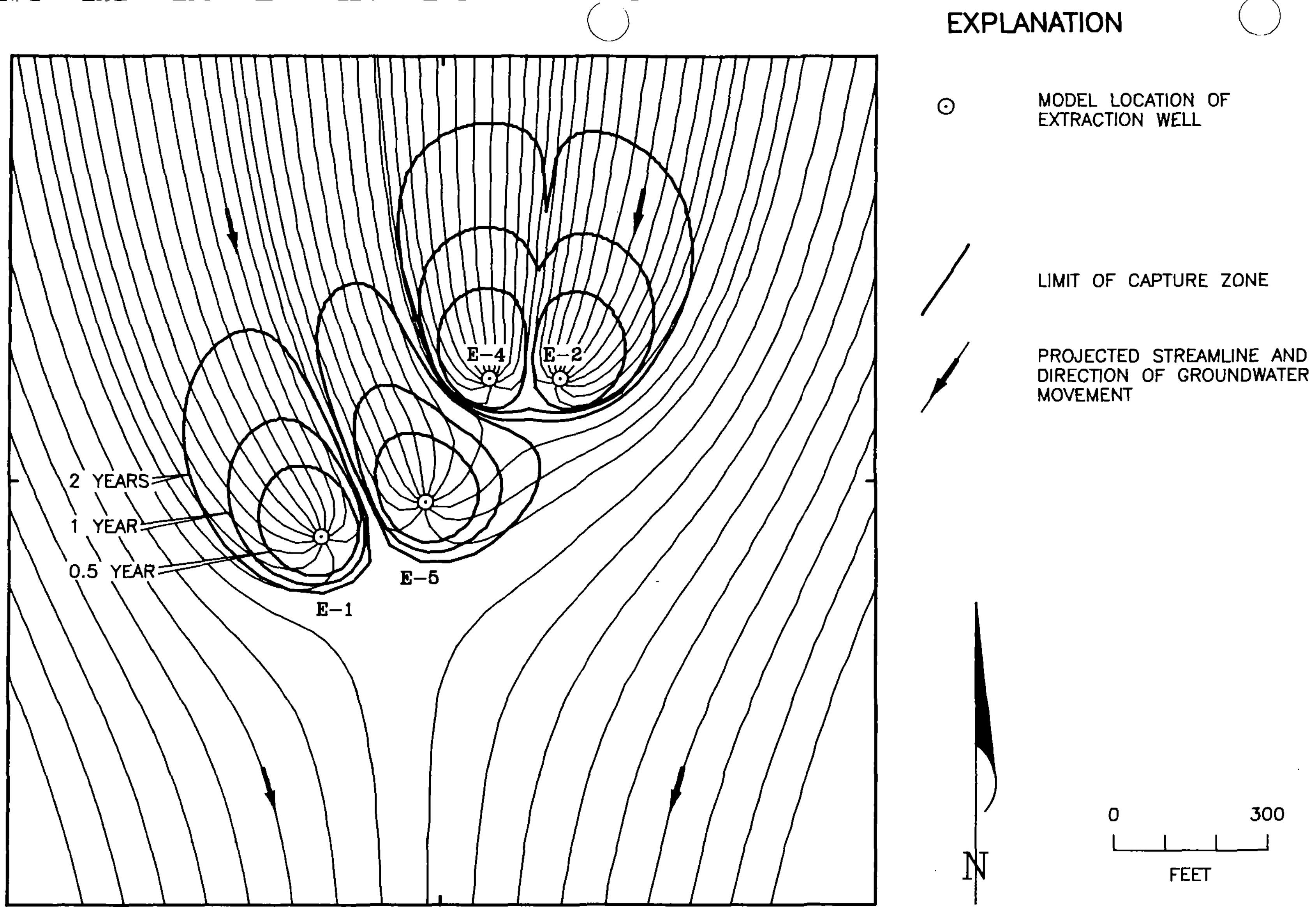


FIGURE 38. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 2 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.8B(avg)

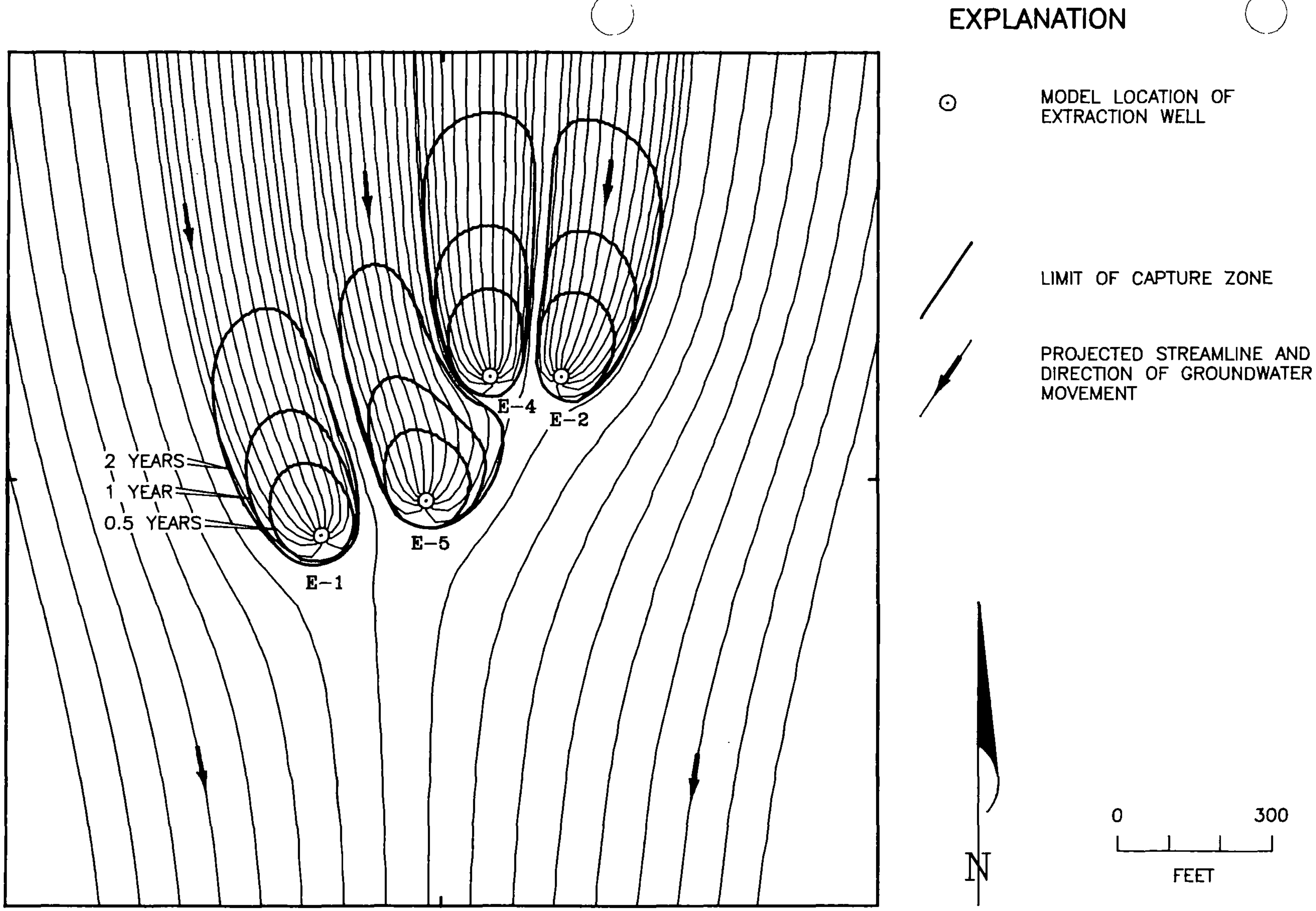


FIGURE 39. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 2 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.8B(min)

ERROL L. MONTGOMERY & ASSOCIATES, INC.
TUCSON, ARIZONA

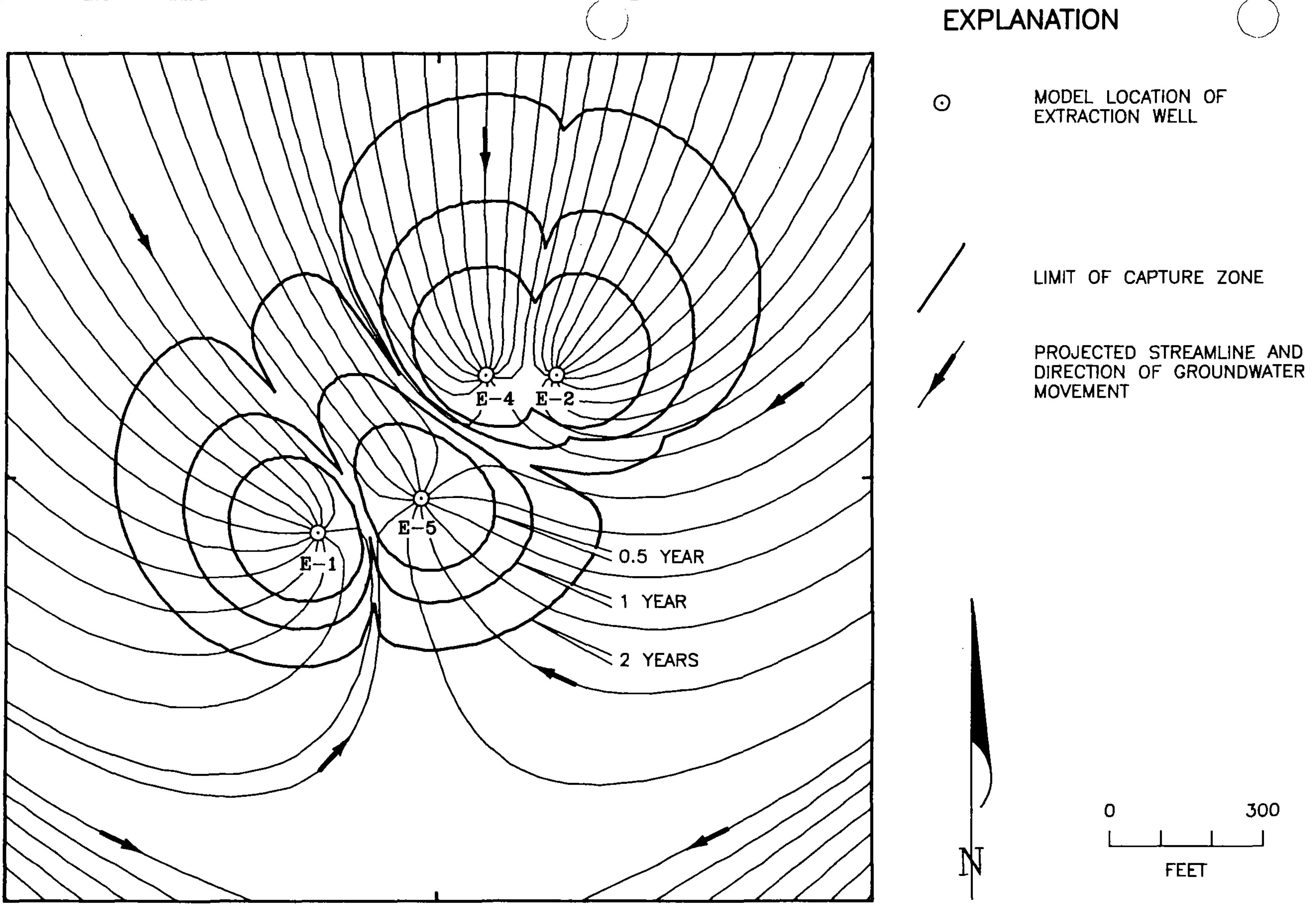
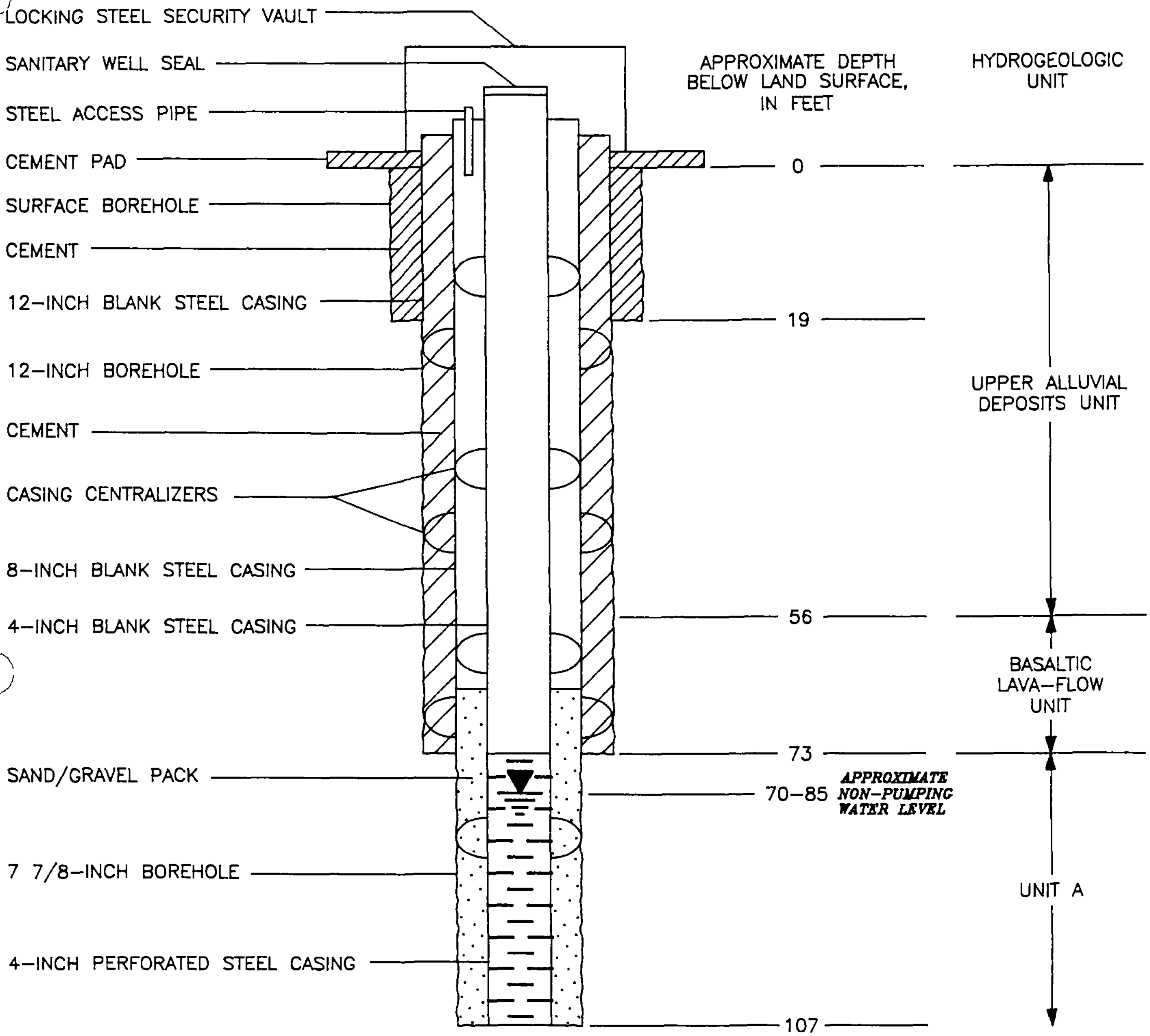
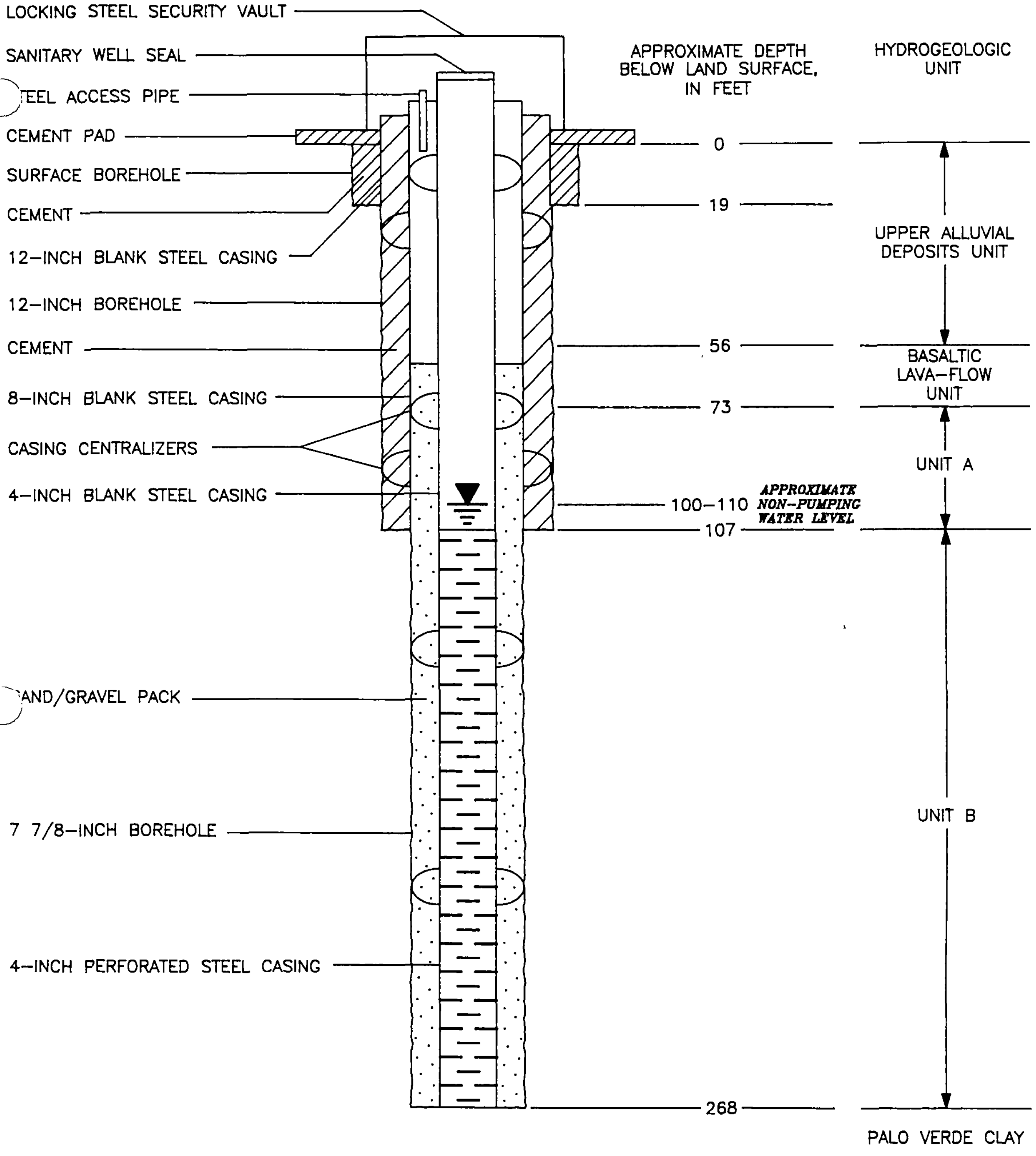


FIGURE 40. PROJECTED STREAMLINES AND LIMIT OF 0.5, 1, AND 2 YEAR CAPTURE ZONES: EXTRACTION-INJECTION REGIMEN EI.8B(max)



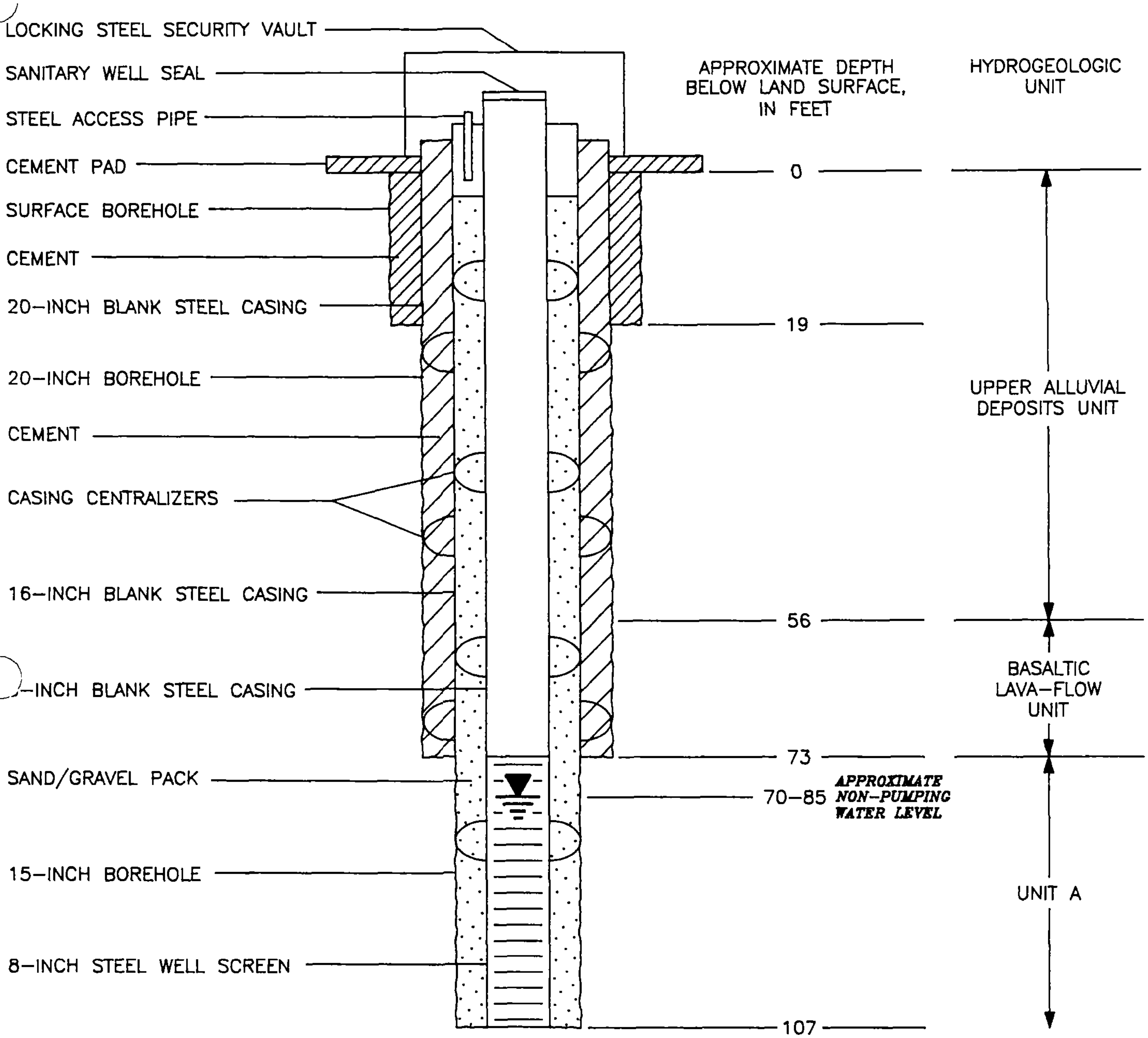
NOTE: CONTRACTOR WILL INSTALL PERMANENT SUBMERSIBLE PUMP

FIGURE 41. SCHEMATIC DIAGRAM OF PROPOSED UNIT A MONITOR WELL



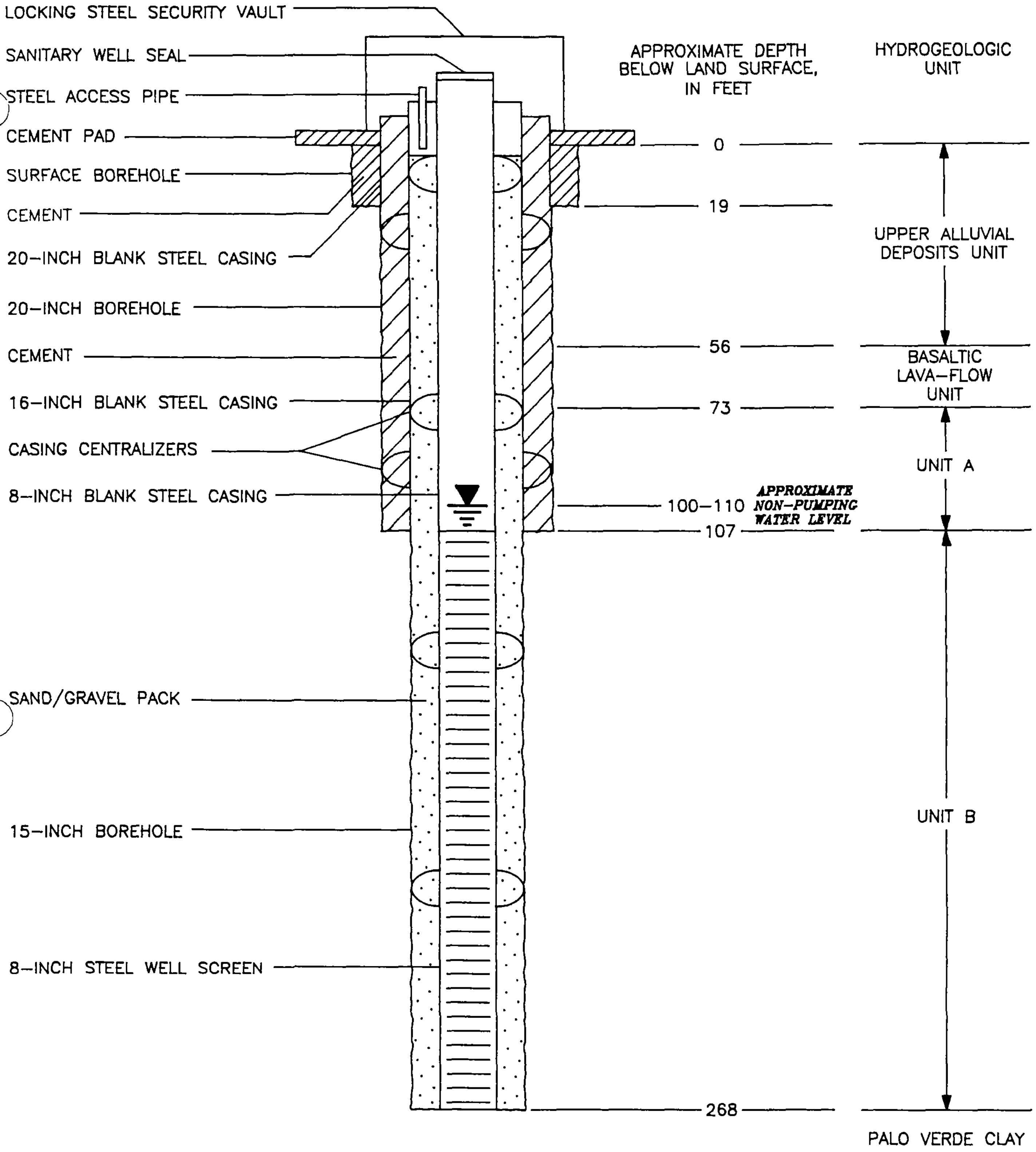
NOTE: CONTRACTOR WILL INSTALL PERMANENT SUBMERSIBLE PUMP

FIGURE 42. SCHEMATIC DIAGRAM OF PROPOSED UNIT B MONITOR WELL



NOTE: CONTRACTOR WILL INSTALL SUBMERSIBLE PUMP FOR EXTRACTION WELL OR DROP PIPE FOR INJECTION WELL

FIGURE 43. SCHEMATIC DIAGRAM OF PROPOSED UNIT A INJECTION AND EXTRACTION WELLS



NOTE: CONTRACTOR WILL INSTALL DROP PIPE

FIGURE 44. SCHEMATIC DIAGRAM OF PROPOSED UNIT B INJECTION WELL

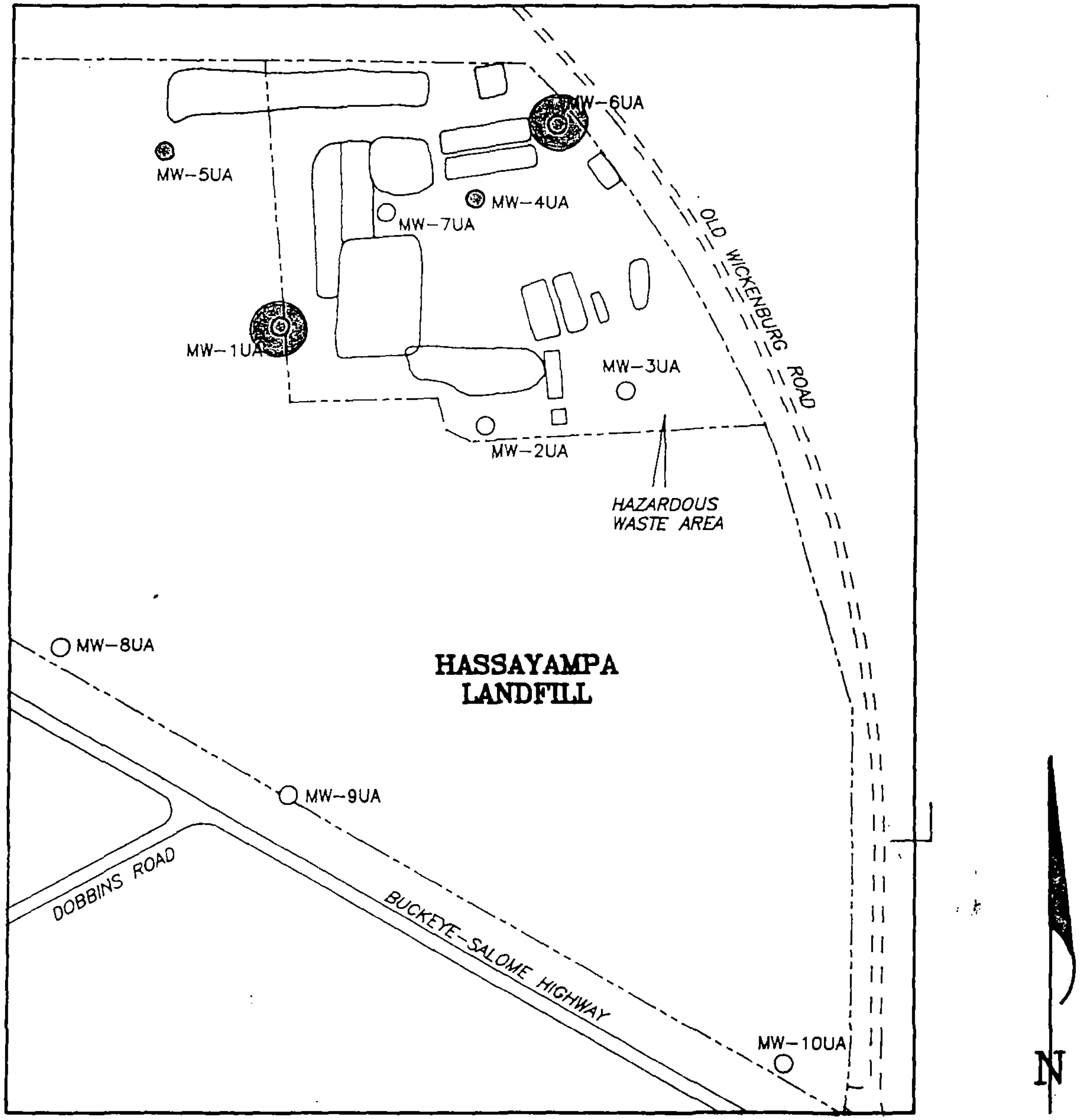
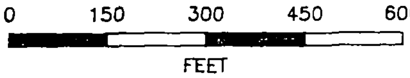


FIGURE 4. LOCATION MAP AND OVERLAY

EXPLANATION

● W-6UA MONITOR WELL FOR UNIT A; RED CIRCLE INDICATES RELATIVE CONCENTRATION OF VOLATILE ORGANIC COMPOUNDS DETECTED AND CONFIRMED IN GROUNDWATER SAMPLES

□ DISPOSAL PIT; LOCATIONS AND BOUNDARIES FOR DISPOSAL PITS ARE TENTATIVE AND APPROXIMATE



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TUCSON, ARIZONA

APPENDIX A.B

WATER ENGINEERING RESEARCH LABORATORY DATABASE INFORMATION FOR SELECTED COMPOUNDS

APPENDIX A.B

EVALUATION OF GROUNDWATER CONTAMINANTS USING USEPA'S TREATABILITY DATABASE

The Water Engineering Research Laboratory (WERL) Treatability Database Versions 2 and 3 printouts are presented for the following compounds:

VOCs

acetone
chlorobenzene
1,1-dichloroethane
1,1-dichloroethene
1,2-dichloroethane
1,2-dichloroethene (cis)
methyl ethyl ketone
1,1,1-trichloroethane
trichlorofluoromethane
trichlorotrifluoroethane

The legend for matrix, Standard Industrial Classification (SIC) codes, and reference codes, is presented at the beginning of the appendix. The legend is constant throughout the database.

The references listed in the compound printouts are contained in the database, therefore, they are not included in this Appendix.

Information contained in the WERL database is used to screen technologies for groundwater treatment. The screening of groundwater treatment technologies is presented in Appendix A.

Matrix

C - clean water (ex. distilled)
D - domestic wastewater
GW - ground water
HL - hazardous leachate
I - industrial wastewater
I+HL - industrial waste combined with leachate from hazardous landfill
ML - municipal leachate
RCRA - RCRA listed wastewater
S - synthetic wastewater
SF - superfund wastewater
SP - spill
T - tap water
W - surface water

SIC (Standard Industrial Classification) Codes

For industrial wastewaters a 2 digit SIC code will be given following the letter code, i.e. I 22 is a Textile Mill Products wastewater. If the SIC code is unknown a U will be shown, I U.

10 - Metal mining
12 - Coal mining
13 - Oil and gas extraction
20 - Food and kindered products
22 - Textile mill products
24 - Lumber and wood products
26 - Paper and allied products
27 - Printing and publishing
28 - Chemicals and allied products
29 - Petroleum refining and related products
30 - Rubber and misc. plastic products
31 - Leather and leather products
33 - Primary metals industries
34 - Fabricated metal products except machinery & transportation equip.
36 - Electronic and electric equipment
39 - Misc. manufacturing industries
47 - Transportation services.
49 - Electric, gas, and sanitary
99 - Nonclassifiable establishments

Effluent Concentration

Effluent concentration will be given as a arithmetic mean to two significant figures. The number of samples used to calculate the mean is given after conc. as (n) (ex. 13 (5) - 13 is the mean of 5 sample values).

% Removal

Percent removal will be calculated on a concentration basis. If data are available, it will also be calculated on a mass basis for physical/chemical systems. Those vaules calculated on a mass basis will be noted by a (m). An example would be:

% Removal: 99.95 99.95 is based on concentration
98(m) 98 is based on mass

where $$\% \text{ removal} = \frac{\text{Influent} - \text{Effluent}}{\text{Influent}}$$

Reference Codes

A - Papers in a peer reviewed journal.
B - Government report or database.
C - Reports and/or papers other than in groups A or B not reviewed.
D - Group C papers and/or reports which have been given a 'good' quality rating by a selected peer review.
E - Group C papers and /or reports which have been given a 'poor' quality rating by a selected peer review. This data will only be used when no other data are available.

Codes Identifying Additional Data Presented In The Reference

V - Volatile Emissions Data
S - Sludge Data
$ - Costs Data

Physical/Chemical Properties Data

(c) - Values presented are values that were reported calculated in the reference as is and are only used where measured are not available.
NA - Values for the particular property have not been found in literature to date.

Treatment Technologies Code and Abreviation Table

Treatment Technologies

AAS - Activated Alumina Sorption
AFF - Aerobic Fixed Film
AL - Aerobic Lagoons
API - API Oil/Water Separator
AS - Activated Sludge
AirS - Air Stripping
AnFF - Anaerobic Fixed Film
AnL - Anaerobic Lagoons
BGAC - Biological Granular Activated Carbon
CAC - Chemically Assisted Clarification
ChOx - Chemical Oxidation (Parantheses shows oxidation chemical ie. ChOx(Oz) - is ozone)
ChOx/Pt - Chemical Oxidation/Precipitation
ChPt - Chemical Precipitation
DAF - Dissolved Air Flotation
Fil - Filtration
GAC - Activated Carbon (Granular)
KPEG - Dechlorination of Toxics using an Alkoxide (Formed by the reaction of potassium hydroxide with polyethylene glycol (PEG400))
IE - Ion Exchange
PACT - Powdered Activated Carbon Addition to Activated Sludge
RBC - Rotating Biological Contactor
RO - Reverse Osmosis
SBR - Sequential Batch Reactor
SCOx - Super Critical Oxidation
SExt - Solvent Extraction
SS - Steam Stripping
Sed - Sedimentation
TF - Trickling Filter
UF - Ultrafiltration
UV - Ultraviolet Radiation
WOx - Wet Air Oxidation

NOTES:

_____ + _____ is the first process unit followed in process train by the second ie. AS + Fil - Activated Sludge followed by Filtration.

_____ w _____ is the two units together ie. UFwPAC - Ultrafiltration using Powdered Activated Carbon.

_____(B) is batch instead of continuous flow.

Scale

B - Bench Top P - Pilot plant F - Full scale

Number after letter refers to the plant number in a specific reference (ex. F7 - plant 7 is the seventh full scale plant in the indicated repor

ACETONE

CAS NO.: 67-64-1

COMPOUND TYPE: KETONE,

FORMULA: C3 H6 O

CHEMICAL AND PHYSICAL PROPERTIES

CHEMICAL AND PHYSICAL PROPERTIES	REF.
MOLECULAR WEIGHT: 58.08	333A
MELTING POINT (C): -95.35	333A
BOILING POINT (C): 56.2	333A
VAPOR PRESSURE @ T(C), TORR: 270 @ 30	463A
SOLUBILITY IN WATER @ T(C), MG/L: MISCIBLE	2031A
LOG OCTANOL/WATER PARTITION COEFFICIENT: -0.24	463A
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1:	NA

ENVIRONMENTAL DATA

ENVIRONMENTAL DATA	REF.
CHRONIC NONCARCINOGENIC SYSTEMIC TOXICITY	4B
RISK ESTIMATES FOR CARCINOGENS	NA
DRINKING WATER HEALTH ADVISORIES/STANDARDS	NA
WATER QUALITY CRITERIA	NA
AQUATIC TOXICITY DATABASE	5B

FREUNDLICH ISOTHERM DATA

FREUNDLICH ISOTHERM DATA NOT AVAILABLE AT THIS TIME !

ACETONE

CAS NO.: 67-64-1

INFLUENT CONCENTRATION - >100-1000 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
PACT	RCRA		B	<20	>91.4	242E ---
AS	SF		F6	<50 (5)	>66	245B ---
AirS	SF		F4	<50 (2)	>54	245B ---
AirS	SF		F6	150 (3)	77	245B ---
ChPt	SF		F6	650 (1)	1	245B ---
Fil	SF		F5	<100 (3)	>25	245B ---
Fil	SF		F6	670 (2)	5	245B ---
GAC	SF		F5	125 (3)	2	245B ---
Fil+GAC	TSDF		F4	<50 (3)	>93.6	28B VS-

INFLUENT CONCENTRATION - >1-10 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AS	D		P1	28 (5)	98.5	241B VS-
RO	GW		F2	200	81	250B ---
AS	I	28	F2	3,800 (1)	39	32B ---
AS	I	28	F5	<1 (1)	>99.938	32B ---
API	SF		F3	2,900 (1)	10	245B ---
ChPt	SF		F2	2,200 (1)	76	245B ---
ChPt	SF		F8	3,100 (5)	53	245B ---
DAF	SF		F3	2,400 (1)	17	245B ---
Fil	SF		F8	5,000 (5)	0	245B ---
Fil	SF		F3	2,400 (1)	3	245B ---
GAC	SF		F2	<50 (1)	>95.9	245B ---
GAC	SF		F3	2,600 (1)	0	245B ---
GAC	SF		F4	910 (5)	52	245B ---
GAC	SF		F8	<50 (5)	>97.2	245B ---

ACETONE

CAS NO.: 67-64-1

INFLUENT CONCENTRATION - >10-100 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AS	GW		F	1,100	97.1	1168E --$
SS	I	49	P	10,000	80	1082E --
RO	SF		F4	5,800	78	250B --

INFLUENT CONCENTRATION - >100-1000 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
Fil+GAC	TSDF		F3	120 (3)	0	28B VS

INFLUENT CONCENTRATION - >1 g/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
WOx (B)	I	U	B2	<10 (1)	>99.40	78E ---
WOx	RCRA		F	0.23	99.992	242E --

CHLOROBENZENE

CAS NO.: 108-90-7

COMPOUND TYPE: AROMATIC,HALOGENATED

FORMULA: C6 H5 CL

CHEMICAL AND PHYSICAL PROPERTIES	REF.
MOLECULAR WEIGHT: 112.56	333A
MELTING POINT (C): -45.6	333A
BOILING POINT (C): 132	333A
VAPOR PRESSURE @ T(C), TORR: 11.8 @ 25	463A
SOLUBILITY IN WATER @ T(C), MG/L: 488 @ 25	463A
LOG OCTANOL/WATER PARTITION COEFFICIENT: 2.84	163A
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1: 3.93 E-3 @ 25	191D

ENVIRONMENTAL DATA	REF.
CHRONIC NONCARCINOGENIC SYSTEMIC TOXICITY	NA
RISK ESTIMATES FOR CARCINOGENS	NA
DRINKING WATER HEALTH ADVISORIES/STANDARDS	346B
WATER QUALITY CRITERIA	345B
AQUATIC TOXICITY DATABASE	5B

FREUNDLICH ISOTHERM DATA

ADSORBENT	MATRIX	K	1/N	Ce UNITS	X/M UNITS	REF.
FILTRASORB 300	C	91	0.99	mg/L	mg/gm	3B
MLSS	C	0.285	0.96	mg/L	mg/gm	246B
FILTRASORB 400	C	9.17	0.348	ug/L	mg/gm	79A

CHLOROBENZENE

CAS NO.: 108-90-7

INFLUENT CONCENTRATION - 0-100 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
GAC	D		F	0.25	56	1421D ---
RO	GW		F3	4.0	53	250B --
AS	I 28		F4	<6	>84	975B --$
AS	I 28		F4	<1 (1)	>83	32B ---
PACT	RCRA		B	<5	>84	242E ---
AFF	S		B	1.0 (9)	90.7	501A --
AS	S		B	0.2 (8)	99.23	200B VS
BGAC	S		B	0.29 (23)	97.6	501A ---
RO	S		P	12 (1)	50	323B --
AS	SF		F6	<10 (1)	>66	245B --

INFLUENT CONCENTRATION - >100-1000 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AS	D		F30	3 (6)	98.9	1B -S
AS	D		P	<1.3 (20)	>99.34	206B VS
AS	D		P1	<4 (5)	>98.6	241B VS-
AS	I 28		F2	12	97.8	975B --$
AS	I 28		F28	<10 (4)	>98.9	6B --
AS	I 28		F1	<10	>94.6	975B --$
AS	I 28		F3	<6	>94.6	975B --$
CAC	I 28		F8	180 (1)	63	32B --
PACT	I 28		F8	5 (1)	97.2	32B --
SS	I 28		F1	<10 (10)	>97.4	251B V-$
AS	S		B	1.1 (12)	99.17	200B VS
AS	S		B	1.3 (6)	99.81	200B VS
PACT	S		B	0.8 (11)	99.37	200B VS-
AirS	SF		F6	<14 (5)	>92.5	245B ---
ChPt	SF		F6	190 (5)	18	245B --
ChPt	SF		F8	660 (5)	34	245B --
Fil	SF		F8	620 (5)	6	245B ---
Fil	SF		F6	190 (5)	2	245B --
GAC	SF		F2	<10 (1)	>96.6	245B --
GAC	SF		F8	<10 (5)	>97.4	245B ---

CHLOROBENZENE

CAS NO.: 108-90-7

INFLUENT CONCENTRATION - >1-10 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
GAC	HL		F	<10 (1)	>99.17	237A ---
GAC	HL		F1	<10 (1)	>99.70	245B ---
PACT	I	28	F40	<10 (4)	>99.38	6B ---
AL	S		B	160	94.7	371D VS-
AirS	S		B2	1,800 (5)	77	1328E ---
RO	SF		F4	120	91.6	250B ---

INFLUENT CONCENTRATION - >10-100 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AirS	S		B2	3,300 (5)	89	1328E ---

INFLUENT CONCENTRATION - >100-1000 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
WOx (B)	I	U	B2	61 (1)	92.3	78E ---

INFLUENT CONCENTRATION - >1 g/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
WOx (B)	S		B1	1600 (1)	72	78E ---

DICHLOROETHANE,1,1-

CAS NO.: 75-34-3

COMPOUND TYPE: HYDROCARBON,HALOGENATED

FORMULA: C2 H4 CL2

CHEMICAL AND PHYSICAL PROPERTIES	REF.
MOLECULAR WEIGHT: 98.96	333A
MELTING POINT (C): -97.0	333A
BOILING POINT (C): 57.3	333A
VAPOR PRESSURE @ T(C), TORR: 234 @ 25	463A
SOLUBILITY IN WATER @ T(C), MG/L: 5500 @ 20	463A
LOG OCTANOL/WATER PARTITION COEFFICIENT: 1.79	338D
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1: 5.45 E-3 @ 25	191D

ENVIRONMENTAL DATA	REF.
CHRONIC NONCARCINOGENIC SYSTEMIC TOXICITY	NA
RISK ESTIMATES FOR CARCINOGENS	NA
DRINKING WATER HEALTH ADVISORIES/STANDARDS	NA
WATER QUALITY CRITERIA	345B
AQUATIC TOXICITY DATABASE	5B

FREUNDLICH ISOTHERM DATA

ADSORBENT	MATRIX	K	1/N	Ce UNITS	X/M UNITS	REF.
FILTRASORB 300	C	1.79	0.53	mg/L	mg/gm	3B
FILTRASORB 400	C	64.6	0.706	ug/L	ug/gm	79A

DICHLOROETHANE,1,1-

CAS NO.: 75-34-3

INFLUENT CONCENTRATION - 0-100 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AL	D		F55	<10 (2)	>88	1B -S-
AS	D		P	<2 (14)	>97.5	240A -S-
TF	D		P	7 (14)	91.3	240A -S-
AirS	GW		P	<0.3 (1)	>97.5	222B --$
AirS+GAC	GW		F1	<1 (19)	>97.4	229A ---
GAC	GW		F2	<1.0	>80	1264B --$
RO	GW		F2	3.0	95.4	250B ---
AS	SF		F6	<10 (1)	>78	245B ---
AirS+GAC	SF		F2	<1	>95.2	229A ---

INFLUENT CONCENTRATION - >100-1000 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AL	D		P2	19 (14)	87	203A -S-
AL	D		P1	45 (14)	69	203A -S-
AS	D		P	8 (14)	94.4	203A -S-
CAC	D		P	111 (14)	23	203A -S-
TF	D		P	94 (14)	35	203A -S-
RO	GW		F3	64	89	250B ---
AirS	SF		F6	<17 (5)	>92.0	245B ---
ChPt	SF		F6	210 (5)	21	245B ---
Fil	SF		F6	210 (5)	0	245B ---

INFLUENT CONCENTRATION - >1-10 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
SS	I	28	F35	<10 (2)	>99.900	6B ---
AirS	SF		P	630 (3)	75	1362E --$
GAC	SF		B	<1	>99.967	1362E --$
RO	SF		F4	84	92.4	250B ---

DICHLOROETHANE,1,1-

CAS NO.: 75-34-3

INFLUENT CONCENTRATION - >10-100 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
SS	I 28		F1	<10 (10)	>99.909	251B V-$

DICHLOROETHYLENE,1,1-

CAS NO.: 75-35-4

COMPOUND TYPE: HYDROCARBON,HALOGENATED

FORMULA: C2 H2 CL2

CHEMICAL AND PHYSICAL PROPERTIES

Property	REF.
MOLECULAR WEIGHT: 96.94	333A
MELTING POINT (C): -122.6	462A
BOILING POINT (C): 31.6	462A
VAPOR PRESSURE @ T(C), TORR: 591 @ 25	463A
SOLUBILITY IN WATER @ T(C), MG/L: 210 @ 25	462A
LOG OCTANOL/WATER PARTITION COEFFICIENT: 1.48	379B
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1: 1.49 E-2 @ 25	191D

ENVIRONMENTAL DATA

Data	REF.
CHRONIC NONCARCINOGENIC SYSTEMIC TOXICITY	4B
RISK ESTIMATES FOR CARCINOGENS	4B
DRINKING WATER HEALTH ADVISORIES/STANDARDS	346B
WATER QUALITY CRITERIA	4B
AQUATIC TOXICITY DATABASE	5B

FREUNDLICH ISOTHERM DATA

ADSORBENT	MATRIX	K	1/N	Ce UNITS	X/M UNITS	REF.
FILTRASORB 300	C	4.91	0.54	mg/L	mg/gm	3B
MLSS	C	0.150	0.71	mg/L	mg/gm	246B
FILTRASORB 400	C	470	0.515	ug/L	ug/gm	79A

DICHLOROETHYLENE,1,1-

CAS NO.: 75-35-4

INFLUENT CONCENTRATION - 0-100 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENC
AS	D		F14	<5 (2)	>86	1B -S-
AS	D		P	<0.2 (20)	>99.75	206B VS-
AS	D		F28	6 (2)	92.9	1B -S
AS	D		F	<1 (2)	>97.5	201B -S
AS	D		P	<1 (12)	>98.3	240A -S-
TF	D		P	<1 (12)	>98.3	240A -S
AirS	GW		P	<0.3 (1)	>95.6	217B --
AirS	GW		P	<1 (1)	>92.3	222B --$
AirS	GW		P2	<1 (2)	>98.6	1139E --
GAC	GW		P	<1	>97.0	1139E --
GAC	GW		F2	<1.0	>70	1264B --$
RO	GW		F2	1.2	98.4	250B ---
RO	GW		F3	3.1	72	250B --
GAC	HL		F	<10 (1)	>64	237A --
AirS+GAC	SF		F2	<1	>88	229A ---

INFLUENT CONCENTRATION - >100-1000 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AL	D		P2	35 (14)	84	203A -S
AL	D		P1	83 (14)	61	203A -S-
AS	D		P	14 (14)	93.4	203A -S
CAC	D		P	150 (14)	29	203A -S
TF	D		P	85 (14)	60	203A -S-
AirS	GW		P1	7.4 (6)	92.7	1139E --
AS	I	28	F1	25 (3)	97.0	6B --
AS	I	28	F3	<10 (22)	>97.0	6B ---
AS	I	28	F11	<10 (3)	>97.2	6B ---

DICHLOROETHYLENE,1,1-

CAS NO.: 75-35-4

INFLUENT CONCENTRATION - >1-10 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AirS	GW		F	2.0	99.937	1344E ---
SS	I 28		F1	<10 (10)	>99.79	251B V-$
SS	I 28		F35	<10 (2)	>99.87	6B ---
SS	I 28		F32	<10 (15)	>99.77	6B ---
AirS	SF		P	4 (3)	99.82	1362E --$
RO	SF		F4	240	78	250B ---

DICHLOROETHANE,1,2-

CAS NO.: 107-06-2

COMPOUND TYPE: HYDROCARBON,HALOGENATED

FORMULA: C2 H4 CL2

CHEMICAL AND PHYSICAL PROPERTIES

	REF.
MOLECULAR WEIGHT: 98.96	333A
MELTING POINT (C): -35.3	333A
BOILING POINT (C): 83.5	333A
VAPOR PRESSURE @ T(C), TORR: 79 @ 25	462A
SOLUBILITY IN WATER @ T(C), MG/L: 8690 @ 20	463A
LOG OCTANOL/WATER PARTITION COEFFICIENT: 1.45	1226A
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1: 1.10 E-3 @ 25	191D

ENVIRONMENTAL DATA

	REF.
CHRONIC NONCARCINOGENIC SYSTEMIC TOXICITY	NA
RISK ESTIMATES FOR CARCINOGENS	4B
DRINKING WATER HEALTH ADVISORIES/STANDARDS	346B
WATER QUALITY CRITERIA	345B
AQUATIC TOXICITY DATABASE	5B

FREUNDLICH ISOTHERM DATA

ADSORBENT	MATRIX	K	1/N	Ce UNITS	X/M UNITS	REF.
FILTRASORB 300	C	3.57	0.83	mg/L	mg/gm	3B
FILTRASORB 400	C	129	0.533	ug/L	ug/gm	79A

DICHLOROETHANE,1,2-

CAS NO.: 107-06-2

INFLUENT CONCENTRATION - 0-100 ug/L

TECHNOLOGY	MATRIX		SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AS	D			P	<5 (13)	>94.3	240A -S-
TF	D			P	12 (13)	86	240A -S-
RO	GW			F2	13	79	250B ---
AS	I	28		F5	<1 (1)	>67	32B ---
GAC	I	28		F1	52 (1)	0	32B ---
GAC+ChOx(Cl)	I	33		F	<10	>83	9E --$
RO	S			P	32 (1)	37	323B ---
AS	SF			F6	<10 (1)	>17	245B ---
AirS	SF			F4	<10 (5)	>17	245B ---
GAC	SF			F4	64 (5)	0	245B ---

INFLUENT CONCENTRATION - >100-1000 ug/L

TECHNOLOGY	MATRIX		SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AL	D			P2	15 (14)	90.2	203A -S-
AL	D			P1	45 (14)	71	203A -S-
AS	D			P	22 (14)	86	203A -S-
AS	D			P1	140 (3)	57	241B VS-
AS	D			F5	74 (7)	82	375E -S-
CAC	D			P	109 (14)	29	203A -S-
TF	D			P	93 (14)	39	203A -S-
TF	D			F1	45 (7)	65	375E -S-
AirS	GW			F	55 (5)	89	322B --$
RO	GW			F3	43	76	250B ---
AS	I	28		F3	<15 (12)	>98.5	6B ---
AS	I	28		F11	<12 (3)	>98.1	6B ---
AS	I	28		F1	24 (1)	84	32B ---
AS	I	28		F32	94 (13)	84	6B ---
AirS+GAC	SF			F2	<1	>99.01	229A ---

DICHLOROETHANE,1,2-

CAS NO.: 107-06-2

INFLUENT CONCENTRATION - >1-10 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AL	D		F55	<10 (6)	>99.75	1B -S-
AS	D		F28	4,400 (6)	33	1B -S
AirS	GW		F	189 (5)	91.8	322B --
AL+AS	I 28		F	8 (21)	99.67	233D VS-
AS	I 28		F1	<29 (25)	>98.6	6B ---
RO	SF		F4	350	84	250B --

INFLUENT CONCENTRATION - >10-100 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AS	D		F30	1,800 (6)	89	1B -S-
AS+Fil	I 28		F9	1,200 (3)	98.5	6B

INFLUENT CONCENTRATION - >100-1000 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
SS	I 28		F35	0.050 (2)	99.981	6B ---
AS	S		B	3.7	98.6	202D VS

INFLUENT CONCENTRATION - >1 g/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
SS	I 28		F32	0.056 (15)	>99.999	6B ---
SS	I 28		F1	0.097 (10)	99.998	251B V-
WOx (B)	S		B1	230	93.6	1054E V-
WOx (B)	S		B1	13 (1)	99.79	78E ---

DICHLOROETHYLENE,1,2-CIS-

CAS NO.: 156-59-2

COMPOUND TYPE: HYDROCARBON,HALOGENATED

FORMULA: C2 H2 CL2

CHEMICAL AND PHYSICAL PROPERTIES

CHEMICAL AND PHYSICAL PROPERTIES	REF.
MOLECULAR WEIGHT: 96.94	333A
MELTING POINT (C): -81.5	2031A
BOILING POINT (C): 60	2031A
VAPOR PRESSURE @ T(C), TORR: 202 @ 25	462A
SOLUBILITY IN WATER @ T(C), MG/L: 800 @ 20	463A
LOG OCTANOL/WATER PARTITION COEFFICIENT:	NA
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1: 4.08 E-3 @ 24.8	1034A

ENVIRONMENTAL DATA

ENVIRONMENTAL DATA	REF.
CHRONIC NONCARCINOGENIC SYSTEMIC TOXICITY	NA
RISK ESTIMATES FOR CARCINOGENS	NA
DRINKING WATER HEALTH ADVISORIES/STANDARDS	346B
WATER QUALITY CRITERIA	345B
AQUATIC TOXICITY DATABASE	NA

FREUNDLICH ISOTHERM DATA

ADSORBENT	MATRIX	K	1/N	Ce UNITS	X/M UNITS	REF.
FILTRASORB 400	C	151	0.70	ug/L	ug/gm	73A
WESTVACO WV-G	C	180	0.64	ug/L	ug/gm	73A
FILTRASORB 400	C	202	0.587	ug/L	ug/gm	79A

DICHLOROETHYLENE,1,2-CIS-

CAS NO.: 156-59-2

INFLUENT CONCENTRATION - 0-100 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AirS	GW		P	<0.5 (1)	>92.3	219B --$
AirS	GW		P	0.7 (1)	97.4	208B --$
AirS	GW		P	<0.3 (1)	>97.3	222B --$
AirS	GW		F	0.5 (1)	99.19	223B --$
AirS	GW		P1	6.3	92.6	369A ---
AirS	GW		F	2.6	96.8	69A --$
RO	S		P	52 (1)	20	323B ---

INFLUENT CONCENTRATION - >100-1000 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AirS	GW		P	0.6 (1)	99.63	217B --$
AirS	GW		P	<0.2 (1)	>99.86	220B
AirS	GW		F	0.1	99.972	1344E ---

METHYL ETHYL KETONE

CAS NO.: 78-93-3

COMPOUND TYPE: KETONE,

FORMULA: C4 H8 O

CHEMICAL AND PHYSICAL PROPERTIES

	REF.
MOLECULAR WEIGHT: 72.11	333A
MELTING POINT (C): -86.3	333A
BOILING POINT (C): 79.6	333A
VAPOR PRESSURE @ T(C), TORR: 100 @ 25	333A
SOLUBILITY IN WATER @ T(C), MG/L: 2.75 E 5	2031A
LOG OCTANOL/WATER PARTITION COEFFICIENT: 0.26	463A
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1:	NA

ENVIRONMENTAL DATA

	REF.
CHRONIC NONCARCINOGENIC SYSTEMIC TOXICITY	4B
RISK ESTIMATES FOR CARCINOGENS	NA
DRINKING WATER HEALTH ADVISORIES/STANDARDS	346B
WATER QUALITY CRITERIA	NA
AQUATIC TOXICITY DATABASE	5B

FREUNDLICH ISOTHERM DATA

ADSORBENT	MATRIX	K	1/N	Ce UNITS	X/M UNITS	REF.
FILTRASORB 400	C	2.42	0.546	mg/L	mg/gm	172D

METHYL ETHYL KETONE

CAS NO.: 78-93-3

INFLUENT CONCENTRATION - >100-1000 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AS	D		P1	<9 (5)	>96.6	241B VS-
GAC	SF		F4	<54 (5)	>86	245B ---
GAC	SF		F8	<50 (5)	>92.8	245B ---
Fil+GAC	TSDF		F4	<10 (2)	>96.6	28B VS-

INFLUENT CONCENTRATION - >1-10 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
PACT	RCRA		B	14	99.39	242E ---
ChPt	SF		F8	1,200 (5)	19	245B ---
Fil	SF		F8	1,100 (5)	6	245B ---
Fil+GAC	TSDF		F3	<5,000 (2)	>26	28B VS-

INFLUENT CONCENTRATION - >10-100 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AS	S		P1	500 (7)	99.09	252E VS-

INFLUENT CONCENTRATION - >100-1000 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
WOx (B)	I U		B2	1 (1)	99.64	78E ---
AS	S		P2	0.90 (6)	99.79	252E VS-

METHYL ETHYL KETONE

CAS NO.: 78-93-3

INFLUENT CONCENTRATION - >1 g/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
WOx	I U		P	1.0 (1)	99.983	78E ---
WOx (B)	I 49		B2	<1 (1)	>99.988	78E ---
WOx	RCRA		F	2.3	99.942	242E ---

TRICHLOROETHANE,1,1,1-

CAS NO.: 71-55-6

COMPOUND TYPE: HYDROCARBON,HALOGENATED

FORMULA: C2 H3 CL3

CHEMICAL AND PHYSICAL PROPERTIES

	REF.
MOLECULAR WEIGHT: 133.40	333A
MELTING POINT (C): -30.4	333A
BOILING POINT (C): 74.1	333A
VAPOR PRESSURE @ T(C), TORR: 100 @ 20	333A
SOLUBILITY IN WATER @ T(C), MG/L: 4400 @ 20	463A
LOG OCTANOL/WATER PARTITION COEFFICIENT: 2.47	1226A
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1: 4.08 E-3 @ 25	191D

ENVIRONMENTAL DATA

	REF.
CHRONIC NONCARCINOGENIC SYSTEMIC TOXICITY	4B
RISK ESTIMATES FOR CARCINOGENS	NA
DRINKING WATER HEALTH ADVISORIES/STANDARDS	346B
WATER QUALITY CRITERIA	4B
AQUATIC TOXICITY DATABASE	5B

FREUNDLICH ISOTHERM DATA

ADSORBENT	MATRIX	K	1/N	Ce UNITS	X/M UNITS	REF.
FILTRASORB 300	C	2.48	0.34	mg/L	mg/gm	3B
FILTRASORB 400	C	1240	0.47	ug/L	ug/gm	73A
FILTRASORB 400	C	335	0.531	ug/L	ug/gm	79A

TRICHLOROETHANE,1,1,1-

CAS NO.: 71-55-6

INFLUENT CONCENTRATION - 0-100 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AL	D		F55	<10 (5)	>90.0	1B -S-
AS	D		F	21 (6)	79	201B -S-
AS	D		F12	10 (4)	89	1B -S-
AS	D		F17	<1 (5)	>98.4	1B -S-
AS	D		F3	<10 (4)	>84	1B -S-
AS	D		F7	<9 (5)	>84	1B -S-
AS	D		F3	<1 (7)	>92.3	375E -S-
AS	D		F3	1.0 (7)	97.6	234A ---
AS	D		F6	<1.3 (7)	>73	234A ---
AS	D		F2	2.2 (3)	85	238A ---
AS	D		F18	12 (4)	87	1B -S-
AS	D		F1	2.9 (3)	77	238A ---
AS	D		F19	30 (6)	39	1B -S-
AS	D		F20	<2 (3)	>95.8	1B -S-
AS	D		F5	<1.3 (7)	>88	234A ---
AS	D		F31	4 (3)	88	1B -S-
AS	D		F36	2 (3)	95.8	1B -S-
AS	D		F59	7 (3)	83	1B -S-
AS	D		F4	<1.3 (7)	>76	234A ---
AS	D		F14	<5 (4)	>95.0	1B -S-
AS	D		F57	<8 (3)	>84	1B -S-
AS	D		F25	10 (5)	81	1B -S-
AS	D		F4	<1 (7)	>92.3	375E -S-
AirS	D		F1	0.09 (7)	90.4	1682B ---
AirS	D		F2	0.43 (11)	90.9	1682B ---
CAC	D		F	17 (3)	19	15B ---
ChPt	D		F1	0.94 (7)	80	1682B ---
RO	D		P	0.05	98.2	180A --$
TF	D		F2	<1 (7)	>50	375E -S-
TF	D		F40	2 (5)	92.6	1B -S-
TF	D		F17	5 (5)	92.2	1B -S-
AirS	GW		P	<0.5 (1)	>96.7	219B --$
AirS	GW		P	<1 (1)	>98.8	211B --$
AirS	GW		P	<0.3 (1)	>97.0	217B --$
AirS	GW		P	<0.5 (1)	>97.5	207B ---
AirS	GW		P1	3.0	92.9	812E ---
GAC	GW		F3	<1.0	>96.6	1264B --$
AS	I	28	F5	<1 (1)	>97.8	32B ---
AS+AS	I	26	F	0.10 (6)	17	23A ---
PACT	I	28	F8	7 (1)	61	32B ---
RO	S		P	2 (1)	97.8	323B ---
AirS	SF		F4	<10 (5)	>52	245B ---
UV (B)	T		B	30	40	1138E ---
Fil+GAC	TSDF		F4	<2 (1)	>94.1	28B VS-

TRICHLOROETHANE,1,1,1-

CAS NO.: 71-55-6

INFLUENT CONCENTRATION - >100-1000 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AS	D		F38	5 (6)	96.2	1B -S-
AS	D		F6	54 (5)	89	1B -S-
AS	D		F60	28 (6)	94.3	1B -S-
AS	D		P1	<8 (5)	>97.2	241B VS-
AS	D		F	0.27	99.73	1587E ---
AS	D		P	<0.3 (20)	>99.77	206B VS-
AS	D		F37	12 (6)	90.0	1B -S-
AS	D		F4	100 (5)	70	1B -S-
TF	D		F37	2 (6)	98.3	1B -S-
AirS	GW		P	1.7 (1)	99.50	211B --$
AirS	GW		P	1.1 (1)	99.75	222B --$
AirS	GW		P1	12	89	812E ---
AirS	GW		F	0.2	99.984	1344E --
GAC	GW		F2	<1.0	>99.35	1264B --$
GAC	GW		P	<1.0	>99.05	812E ---
RO	GW		F3	10	93.8	250B
AS	I	28	F1	<10 (3)	>98.9	6B
AS	I	28	F4	<4	>98.1	975B --$
AirS	I	U	P	7	96.8	205E --
PACT	RCRA		B	25	93.8	242E --
AS	SF		F6	<10 (1)	>93.3	245B ---
AirS	SF		F6	<38 (5)	>93.7	245B ---
ChPt	SF		F6	620 (5)	34	245B --
Fil	SF		F6	600 (5)	2	245B --
GAC	SF		F4	90 (5)	75	245B ---
RO	SF		F4	36	95.6	250B --

INFLUENT CONCENTRATION - >1-10 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AS	D		F1	<1.3 (7)	>99.88	234A ---
AS	D		F28	850 (6)	87	1B -S-
AirS	GW		P2	49	95.9	812E ---
AirS	SF		P	130 (3)	97.8	1362E --$
Fil+GAC	TSDF		F3	<1,300 (2)	>36	28B VS-

TRICHLOROETHANE,1,1,1-

CAS NO.: 71-55-6

INFLUENT CONCENTRATION - >10-100 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
SS	I	28	F35	<10 (2)	>99.941	6B ---
GAC	SF		B	<1	>99.991	1362E --$

INFLUENT CONCENTRATION - >100-1000 mg/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
WOx	RCRA		F	0.40	99.955	242E ---
AS	S		B	1.6	98.6	202D VS-

TRICHLOROMONOFLUOROMETHANE

CAS NO.: 75-69-4

COMPOUND TYPE: HYDROCARBON,HALOGENATED

FORMULA: C CL3 F

CHEMICAL AND PHYSICAL PROPERTIES

	REF.
MOLECULAR WEIGHT: 137.4	462A
MELTING POINT (C): -111	462A
BOILING POINT (C): 23.8	462A
VAPOR PRESSURE @ T(C), TORR: 687 @ 20	463A
SOLUBILITY IN WATER @ T(C), MG/L: 1100 @ 25	463A
LOG OCTANOL/WATER PARTITION COEFFICIENT: 2.53	338D
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1: 5.83 E-2 @ 25	191D

ENVIRONMENTAL DATA

	REF.
CHRONIC NONCARCINOGENIC SYSTEMIC TOXICITY	4B
RISK ESTIMATES FOR CARCINOGENS	NA
DRINKING WATER HEALTH ADVISORIES/STANDARDS	NA
WATER QUALITY CRITERIA	345B
AQUATIC TOXICITY DATABASE	NA

FREUNDLICH ISOTHERM DATA

ADSORBENT	MATRIX	K	1/N	Ce UNITS	X/M UNITS	REF.
FILTRASORB 300	C	5.6	0.24	mg/L	mg/gm	3B

TRICHLOROMONOFLUOROMETHANE

CAS NO.: 75-69-4

INFLUENT CONCENTRATION - 0-100 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
CAC	D		F	<10 (1)	>62	15B ---
AirS+GAC	GW		F1	<1 (19)	>98.6	229A ---
PACT	I 28		F8	2 (1)	97.1	32B ---

INFLUENT CONCENTRATION - >100-1000 ug/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (ug/L)	PERCENT REMOVAL	REFERENCE
AS	D		F28	4 (1)	97.9	1B -S-

TRICHLORO-1,2,2-TRIFLUOROETHANE,1,1,2-

CAS NO.: 76-13-1

COMPOUND TYPE: HYDROCARBON,HALOGENATED

FORMULA: C2 CL3 F3

CHEMICAL AND PHYSICAL PROPERTIES	REF.
MOLECULAR WEIGHT: 187.38	462A
MELTING POINT (C): -36.4	462A
BOILING POINT (C): 47.6	462A
VAPOR PRESSURE @ T(C), TORR: 273 @ 20	462A
SOLUBILITY IN WATER @ T(C), MG/L: 170 @ 25	462A
LOG OCTANOL/WATER PARTITION COEFFICIENT:	NA
HENRY'S LAW CONSTANT, ATM x M3 MOLE-1:	NA

ENVIRONMENTAL DATA	REF.
CHRONIC NONCARCINOGENIC SYSTEMIC TOXICITY	4B
RISK ESTIMATES FOR CARCINOGENS	NA
DRINKING WATER HEALTH ADVISORIES/STANDARDS	NA
WATER QUALITY CRITERIA	NA
AQUATIC TOXICITY DATABASE	5B

FREUNDLICH ISOTHERM DATA

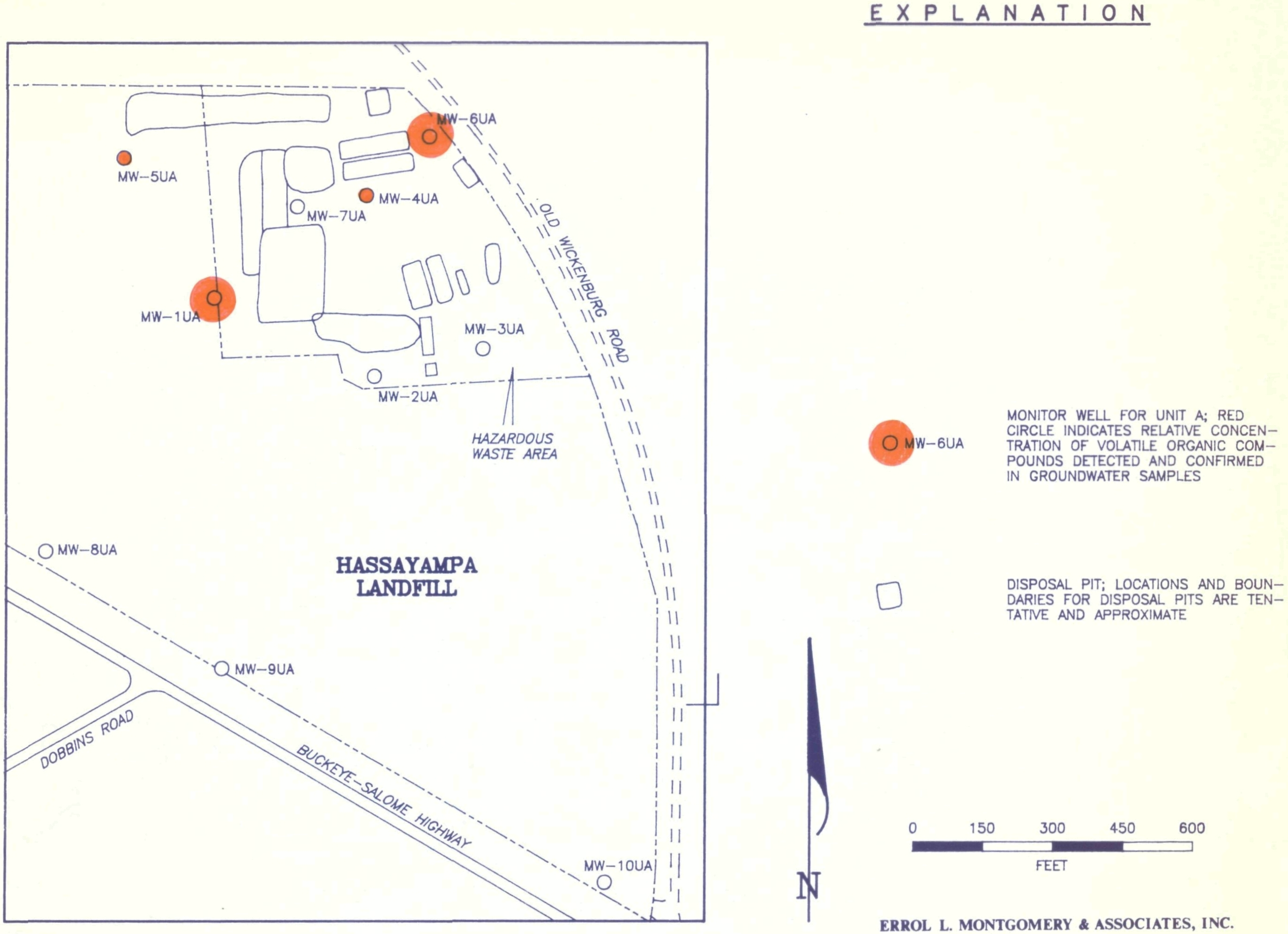
FREUNDLICH ISOTHERM DATA NOT AVAILABLE AT THIS TIME !

TRICHLORO-1,2,2-TRIFLUOROETHANE,1,1,2-

CAS NO.: 76-13-1

INFLUENT CONCENTRATION - >1 g/L

TECHNOLOGY	MATRIX	SIC CODE	SCALE	EFFLUENT CONCENTRATION (mg/L)	PERCENT REMOVAL	REFERENCE
WOx	I U		P	2 (1)	99.933	78E ---



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CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA

FIGURE 4. LOCATION MAP AND OVERLAY