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Primary Document

Feasibility Study for the Groundwater Operable Unit at Paducah Gaseous Diffusion Plant Paducah, Kentucky

Volume 4. Appendix C Supporting Information for Feasibility Study

Cleared for Public Release

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By
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Environmental Management Activities at the
Paducah Gaseous Diffusion Plant
Paducah, Kentucky 42001
managed by
Bechtel Jacobs Company LLC
for the
U.S. Department of Energy
under contract DE-AC05-98OR22700

APPENDIX C1

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RESTORATION TIMEFRAME ANALYSIS USING GROUNDWATER MODELING PREDICTIVE SIMULATIONS

This appendix contains the preliminary modeling results for predictive simulations conducted in support of the Groundwater OU Feasibility Study. The predictive transport simulations were run using the most recently calibrated flow model (June 1999). The transport code employed is MODFLOWT, an enhanced version of the USGS's MODFLOW code (MacDonald and Harbaugh 1988). The simulations were conducted to provide a basis for comparison between a range of options to evaluate possible restoration timeframes for the Regional Gravel Aquifer for Trichlorethylene (TCE) and Technetium-99 (Tc-99) contamination at the Paducah Gaseous Diffusion Plant (PGDP). Following six scenarios were run for TCE and Tc99:

1. **No Action**: No source containment (a continuous source loading is assumed) and passive flushing without the current Northwest and Northeast plume wells operating.

2. **No Action**: No source containment (a continuous source loading is assumed) and passive flushing with the current Northwest and Northeast plume wells operating.

3. **Source Containment**: Source is removed (plume concentrations are initialized) with passive flushing without the current Northwest and Northeast plume wells operating.

4. **Source Containment**: Source is removed (plume concentrations are initialized) with passive flushing with the current Northwest and Northeast plume wells operating.

5. **Pump-and-Treat**: No source containment (a continuous source loading is assumed) but active extraction and treatment only. Constraints were that the total number of wells had to be less than 20, with none operating any higher than 150 gpm. Locations were selected to minimize residual concentrations.

6. **Pump-and-Treat with Source Containment**: Source is removed (plume concentrations are initialized) and active extraction and treatment is in place. Same details of wells as previous scenario apply here.

For these six scenarios, a total of twelve distinct predictive simulations were necessary to fully evaluate the alternatives for both TCE and Tc-99. Table C1.1 summarizes these simulations. The extraction rates used for the Northwest and Northeast Plume pumping wells are presented in Table C1.2.

Table C1.1. Summary of Predictive Simulations Conducted for GWOU FS at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Constituents	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
TCE	1TCESP2T	12TCESP2T	2TCESP2T	22TCESP2T	3TCESP2T	4TCESP2T
Tc-99	1T99SP2	12T99SP2	2T99SP2	22T99SP2	3T99SP2	4T99SP2

Table C1.2. Extraction Rates for the Northwest Plume and Northeast Plume Extraction Wells used for Predictive Simulations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

	PGDP Coordinates		Model Coordinates		Northwest Plume Extraction Rate	
Well ID	X	Y	X	Y	[ft^3/day]	[gpm]
EW-228	-5347.4	7599.463	12640.07	21246.76	9240.64	48.00
EW-229	-5196.9	7337.24	12790.59	20984.537	8663.1	45.00
EW-230	-7301.5	1405.806	10686.01	15053.103	11550.8	60.00
EW-231	-7439.9	1351.924	10547.56	14999.221	10588.2	55.00
			Northeast Plume Extraction Wells			
EW-331	1574.41	837.03	19561.91	14484.327	19251.3	100.00
EW-332	1764.4	754.19	19751.9	14401.487	15401.1	80.00

For the Pump-and-Treat options, a total of 18 additional wells were simulated around the plant property, each pumping at 100 gpm. Figure C1-1 depicts the locations of these pumping wells. The total pumping rate for these scenarios, including the Northwest and Northeast Plume extraction wells is 2,188 gpm.

All simulations were conducted using 2 stress periods. Stress period 1 is defined from 0 to 10 years, and boundary conditions were representative of median 1992 conditions. Stress period 2 is defined from 10 to 100 years where boundary conditions for the Ohio River and recharge are modified to represent stage changes due to the completions of the Olmsted lock and dam, and the closing of the PGDP, respectively. The Ohio River stage in layer 3 of the model was changed to 306.86 ft amsl. Recharge in layer 1 was changed to 0 where building and concrete cover exists, and to the regional value (1.5E-3 ft/day) where no concrete cover exists. Layer 1 wells representing anthropogenic recharge in stress period 1, were changed to 0 in stress period 2.

SOURCES

Sources for TCE and Tc-99 were initialized in model layer 3 (RGA) using existing groundwater concentration data. Table C1.3 presents the TCE and Tc-99 source term locations and values within the model. The locations of these sources are depicted in Fig. C1-2. All sources are modeled as constant concentrations, and do not therefore simulate a degrading source term.

Table C1.3. TCE and Tc-99 Source Term Information for Predictive Simulations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Source	Plant Location	Model Location*	Constant Source Concentration (µg/L)	Constant Source Concentration (pCi/L)
		TCE		
	C-720 Area	A	10,000	
	C-720 Area	B	1,230	
	SW Corner, C-400 Building	C	100,000	
	SE Corner, C-400 Building	D	700,000	
	NE Corner, C-400 Building	E	19,000	
		Tc-99		
	NW Corner, C-400 Building	F		43,000

* For model location see map in Fig. C1-2.

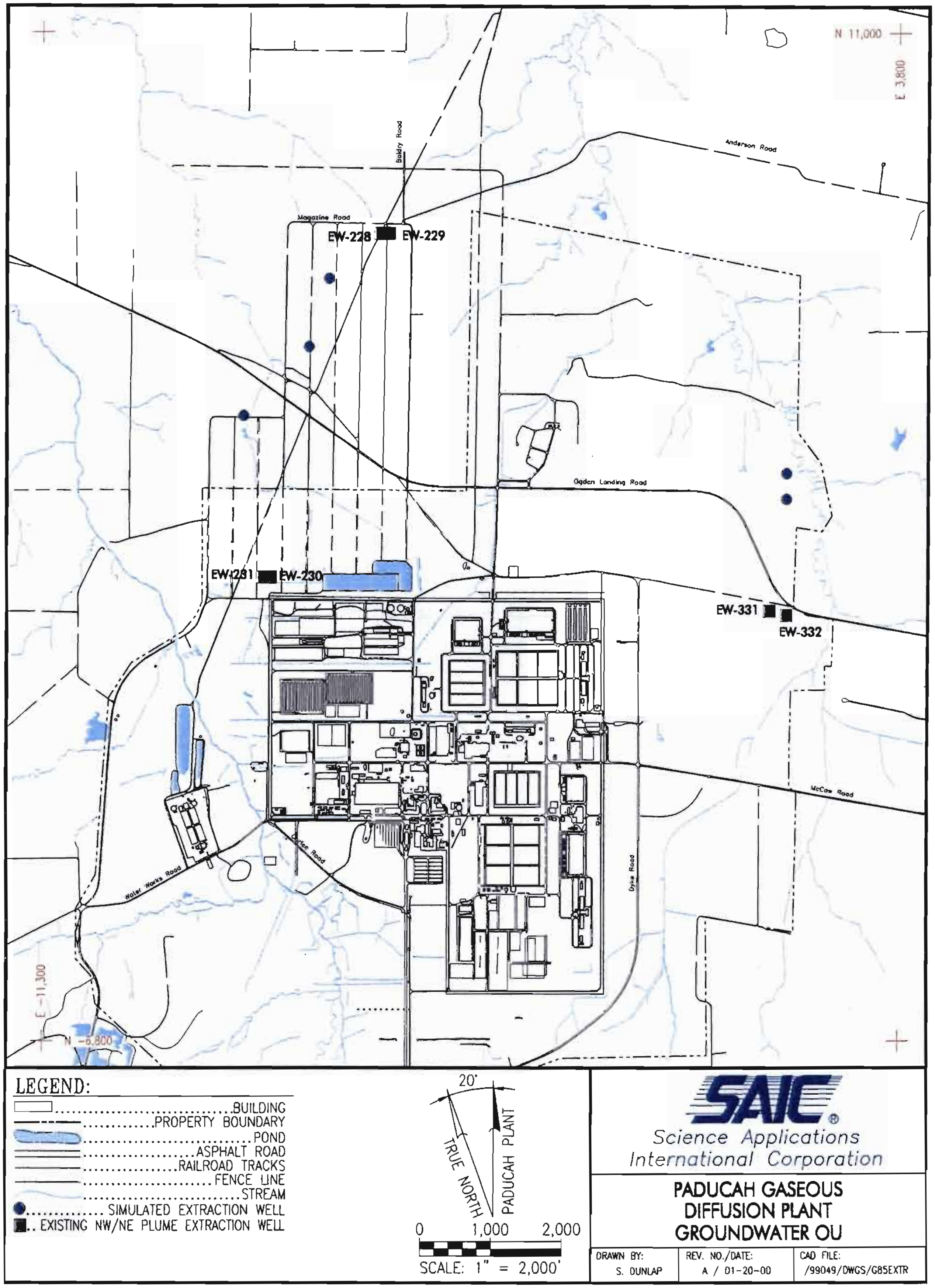

Fig. C1-1. Extraction well locations for Pump and Treat alternatives simulated at the PGDP, Paducah, Kentucky.

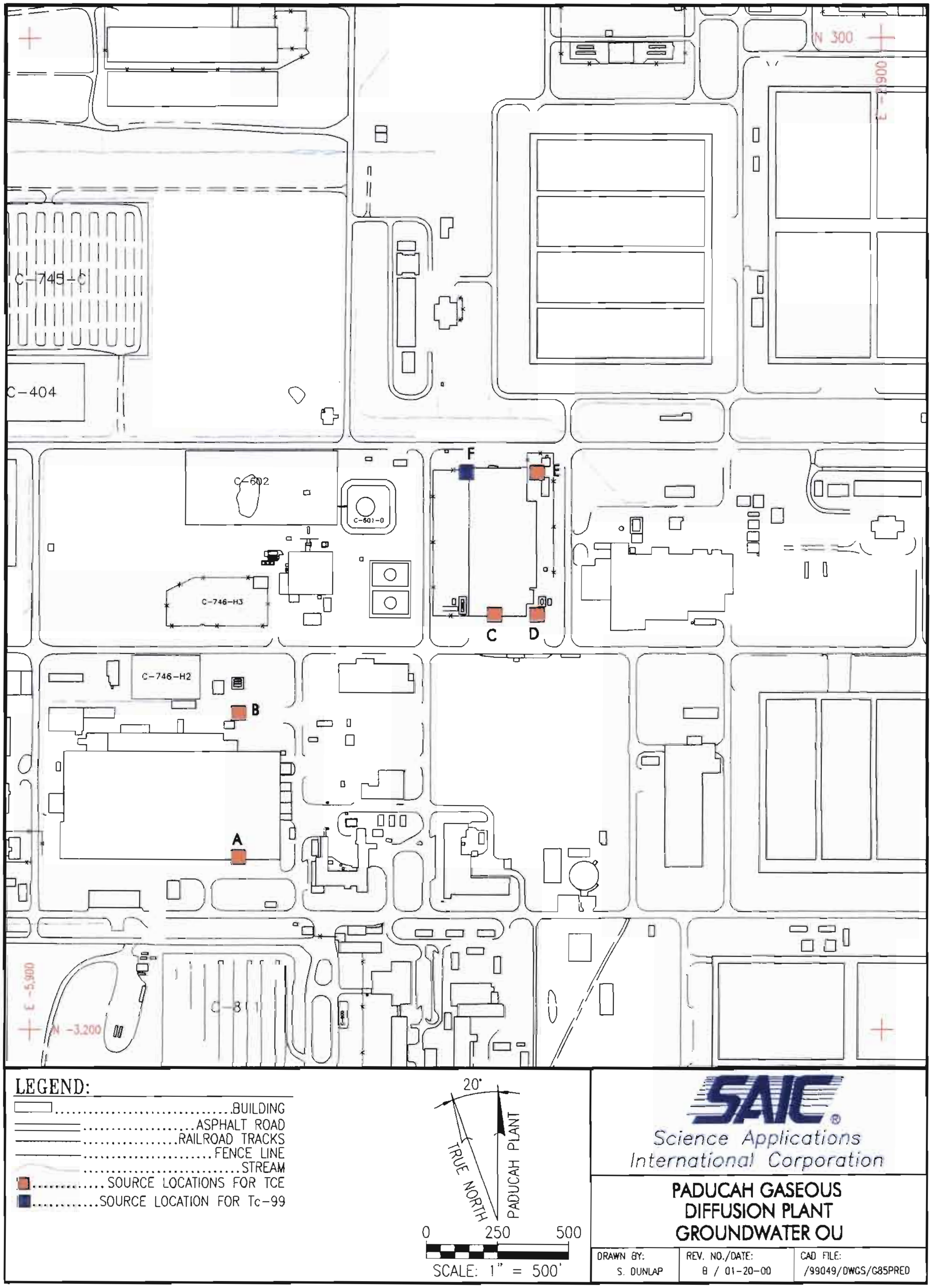

Fig. C1-2. TCE and Tc-99 sources for predictive simulations at the PGDP, Paducah, Kentucky.

TRANSPORT PARAMETERS

Transport parameters for TCE and Tc-99 used for the predictive simulations are presented in Table C1.4. The K_d-value of TCE was determined through a series of trial and error runs. The half-life was calculated from the degradation rate presented in a *Evaluation of Natural Attenuation Processes for Trichloroethylene and Technetium-99 in the Northeast and Northwest Plumes at the Paducah Gaseous Diffusion Plant Paducah, Kentucky* (LMES 1997). The bulk density of the soil and the effective porosity were taken from the results of the WAG 6 RI investigation (DOE 1999). To be conservative, negligible retardation of Tc-99 without any decay was considered. Therefore, the model was run with zero K_d-value and decay constant for Tc-99.

Table C1.4. TCE and Tc- 99 Transport Parameters for Predictive Simulations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Parameters	TCE	Tc- 99
Distribution coefficient (K_d), L/kg	0.05	0
Half Life, days	9730	No decay
Bulk Density, g/cm^3	1.9	1.9
Porosity, %	30	30

RESULTS

Results for the predictive simulations were generated in the form of simulated concentration maps for the PGDP and vicinity. Results are generated at increments of 5, 10, 30, 60 and 100 year time periods. Figures C1-3a through C1-14c depict these results.

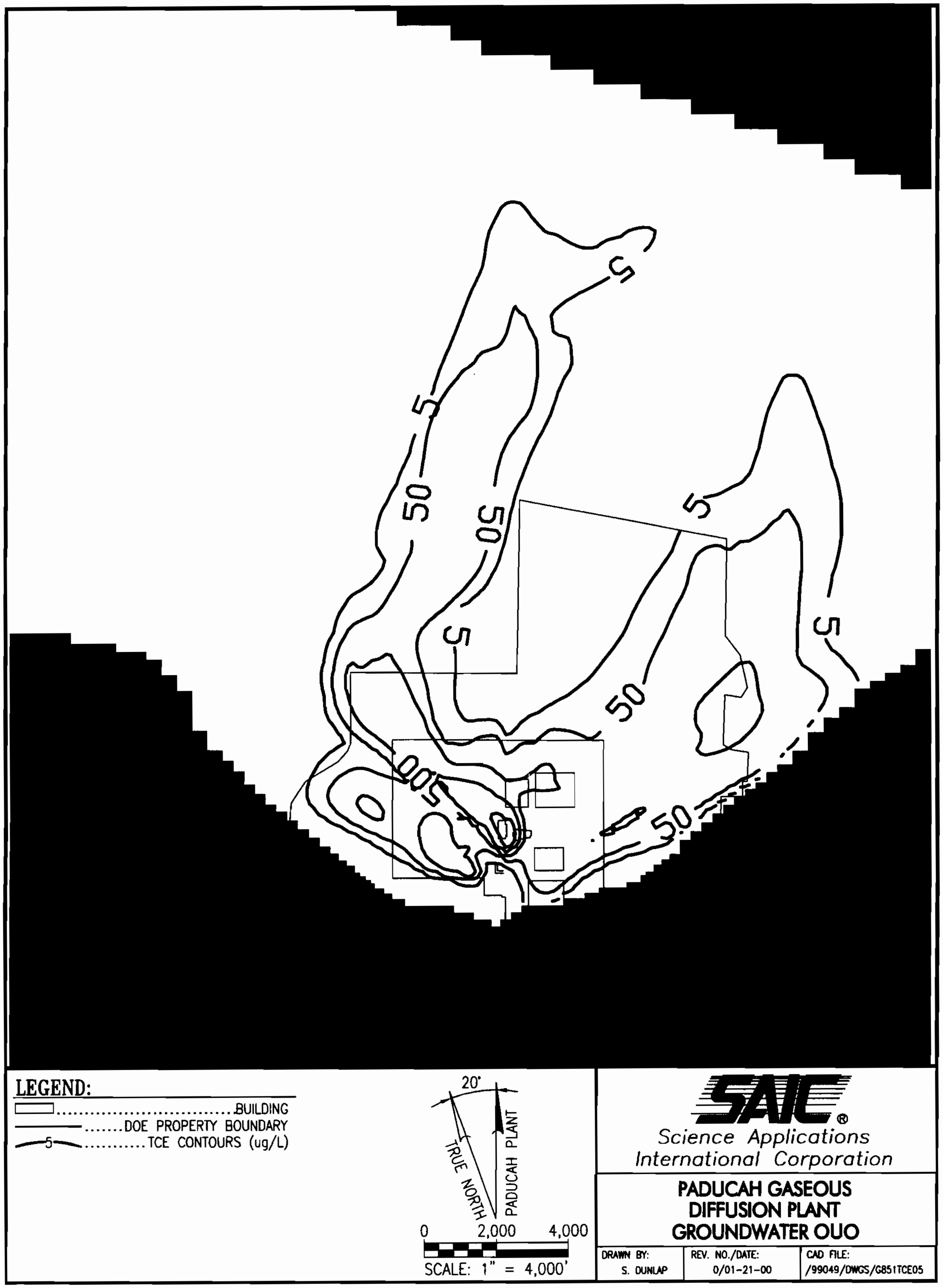

Fig. C1-3a. Predicted TCE concentration contours in μg/L at the end of 5-year simulation period for the No Action Alternative (1TCESP2T) at the PGDP, Paducah, Kentucky.

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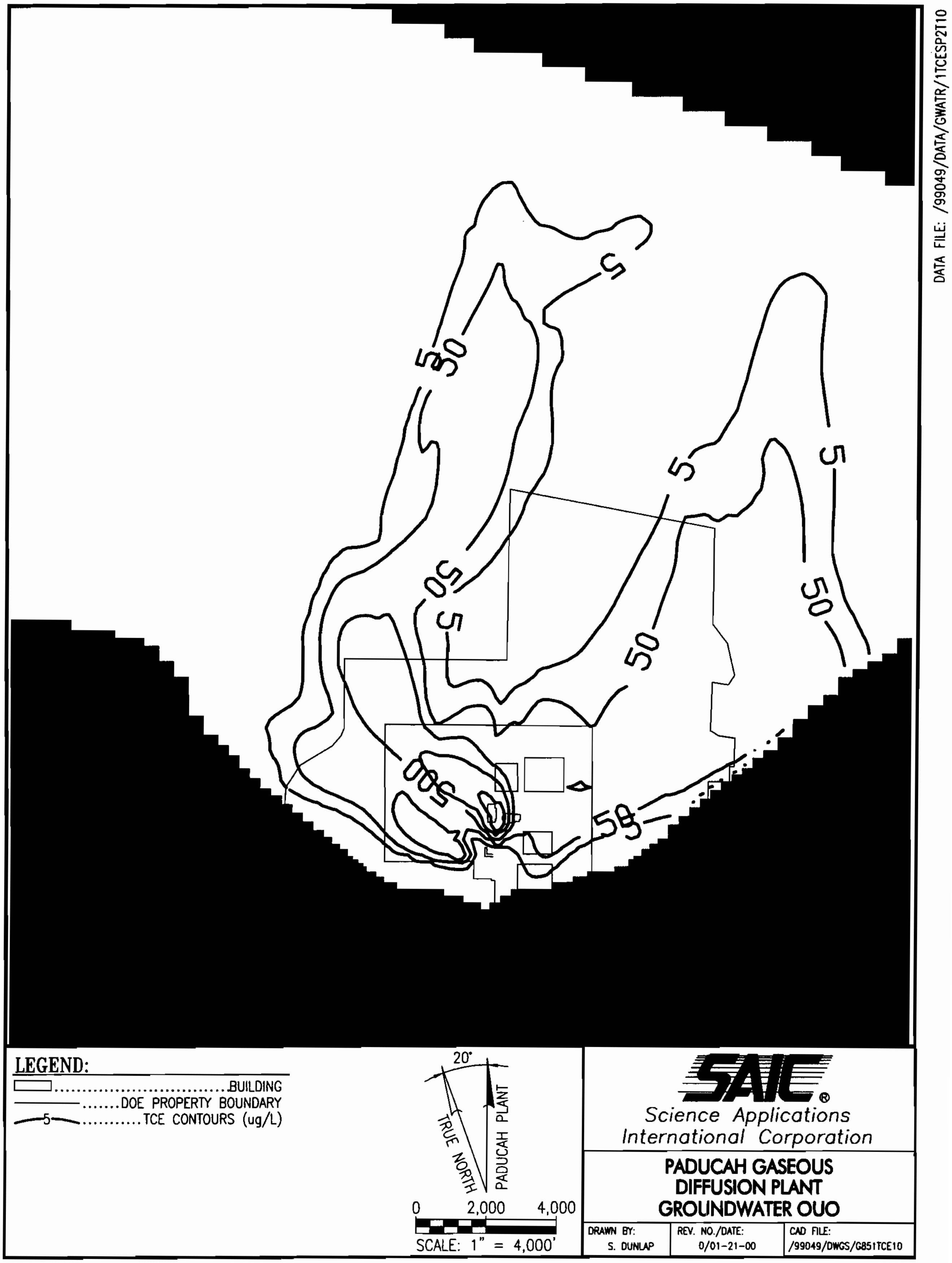

Fig. C1-3b. Predicted TCE concentration contours in μg/L at the end of 10-year simulation period for the No Action Alternative (1TCESP2T) at the PGDP, Paducah, Kentucky.

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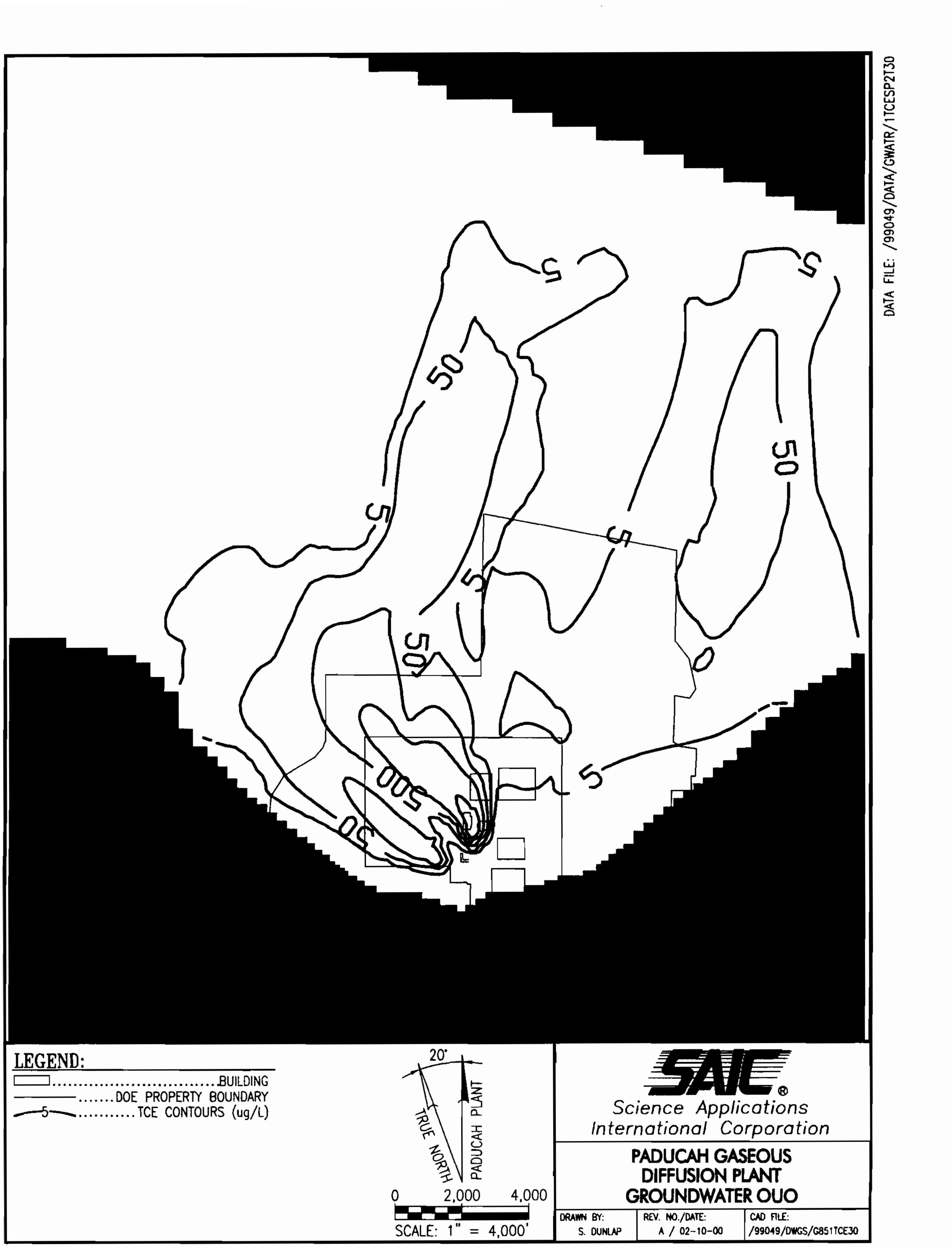

Fig. C1-3c. Predicted TCE concentration contours in μg/L at the end of 30-year simulation period for the No Action Alternative (1TCESP2T) at the PGDP, Paducah Kentucky.

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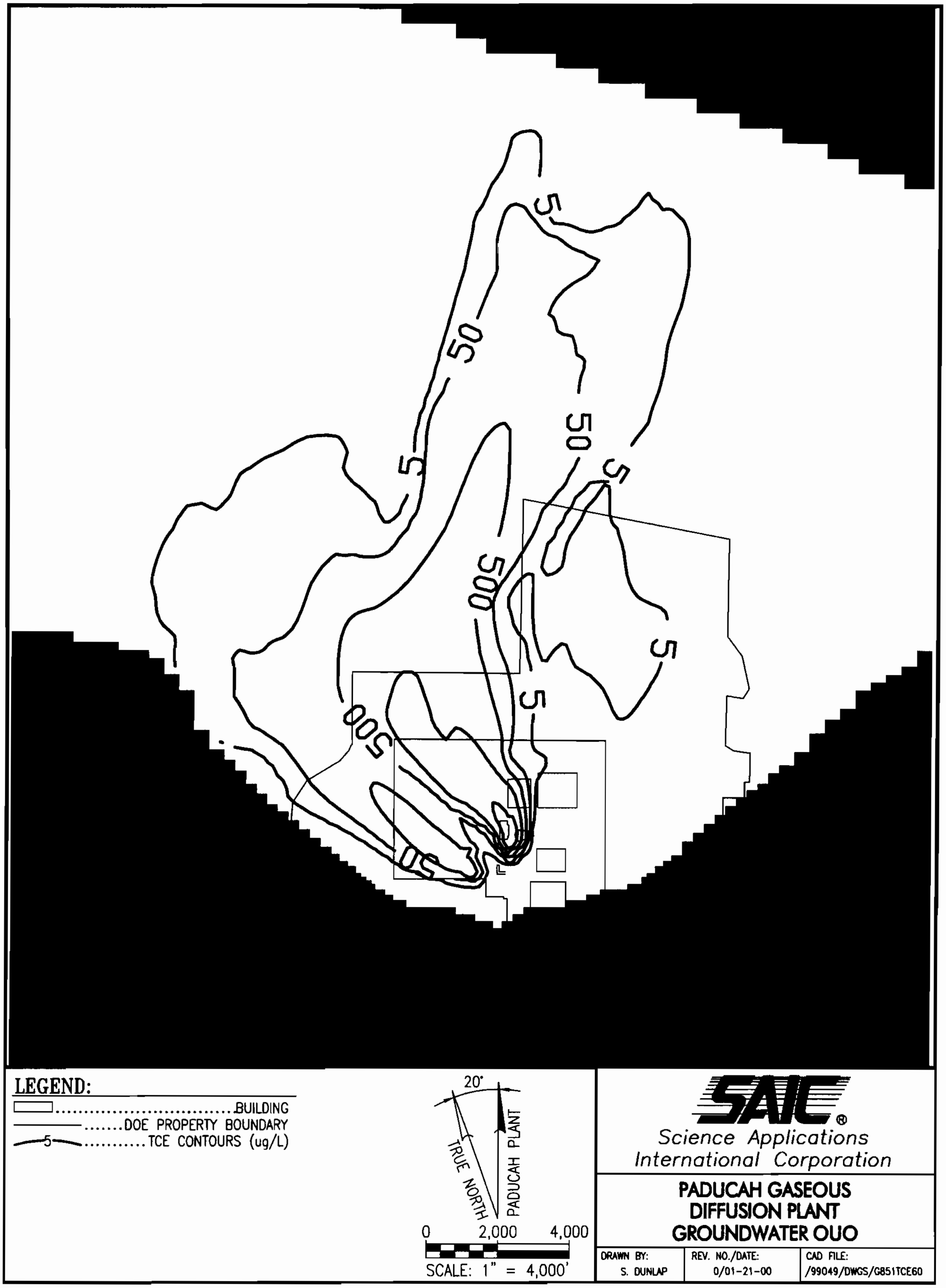

Fig. C1-3d. Predicted TCE concentration contours in μg/L at the end of 60-year simulation period for the No Action Alternative (1TCESP2T) at the PGDP, Paducah Kentucky.

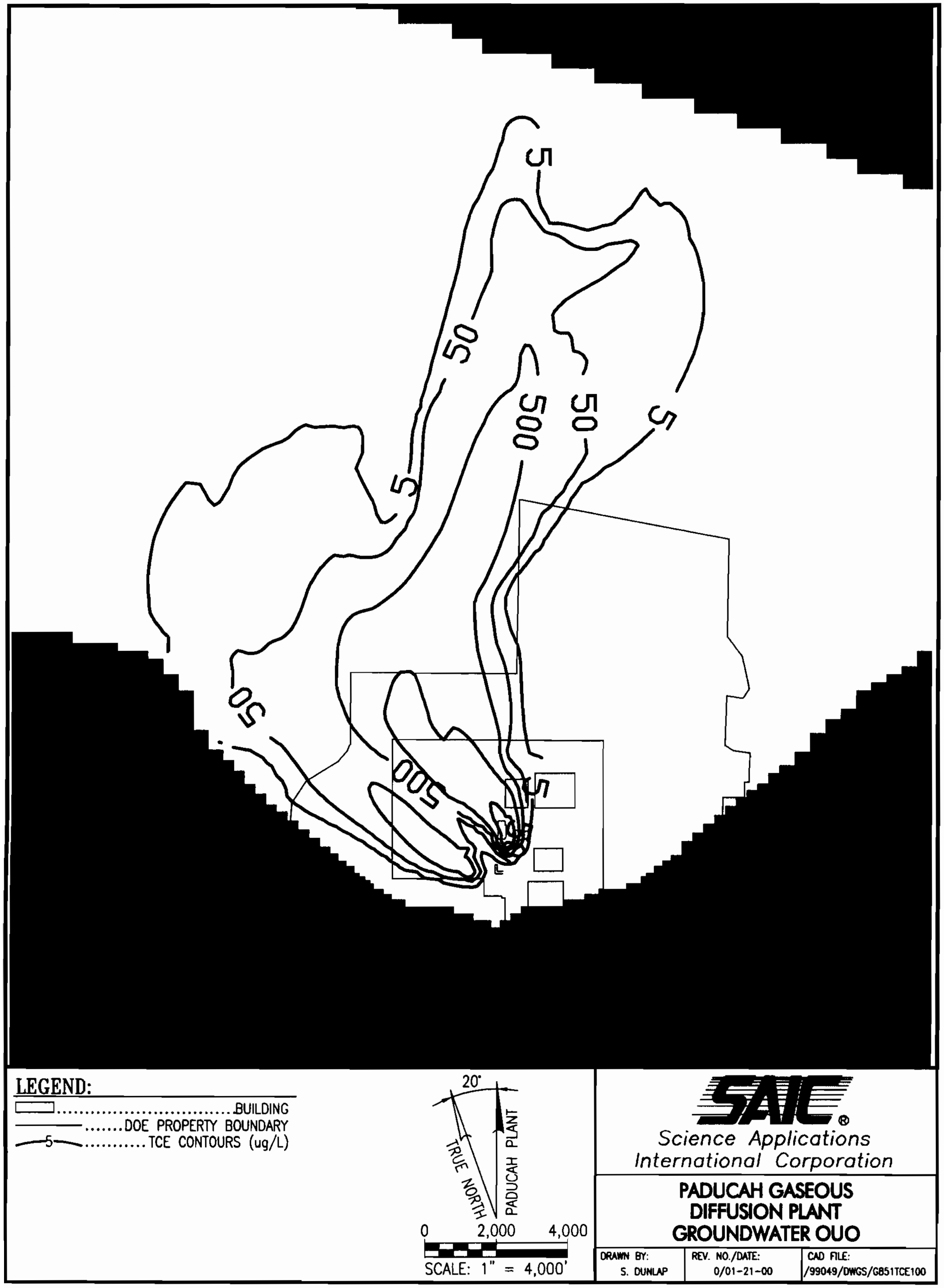

Fig. C1-3e. Predicted TCE concentration contours in μg/L at the end of 100-year simulation period for the No Action Alternative (1TCESP2T) at the PGDP, Paducah Kentucky.

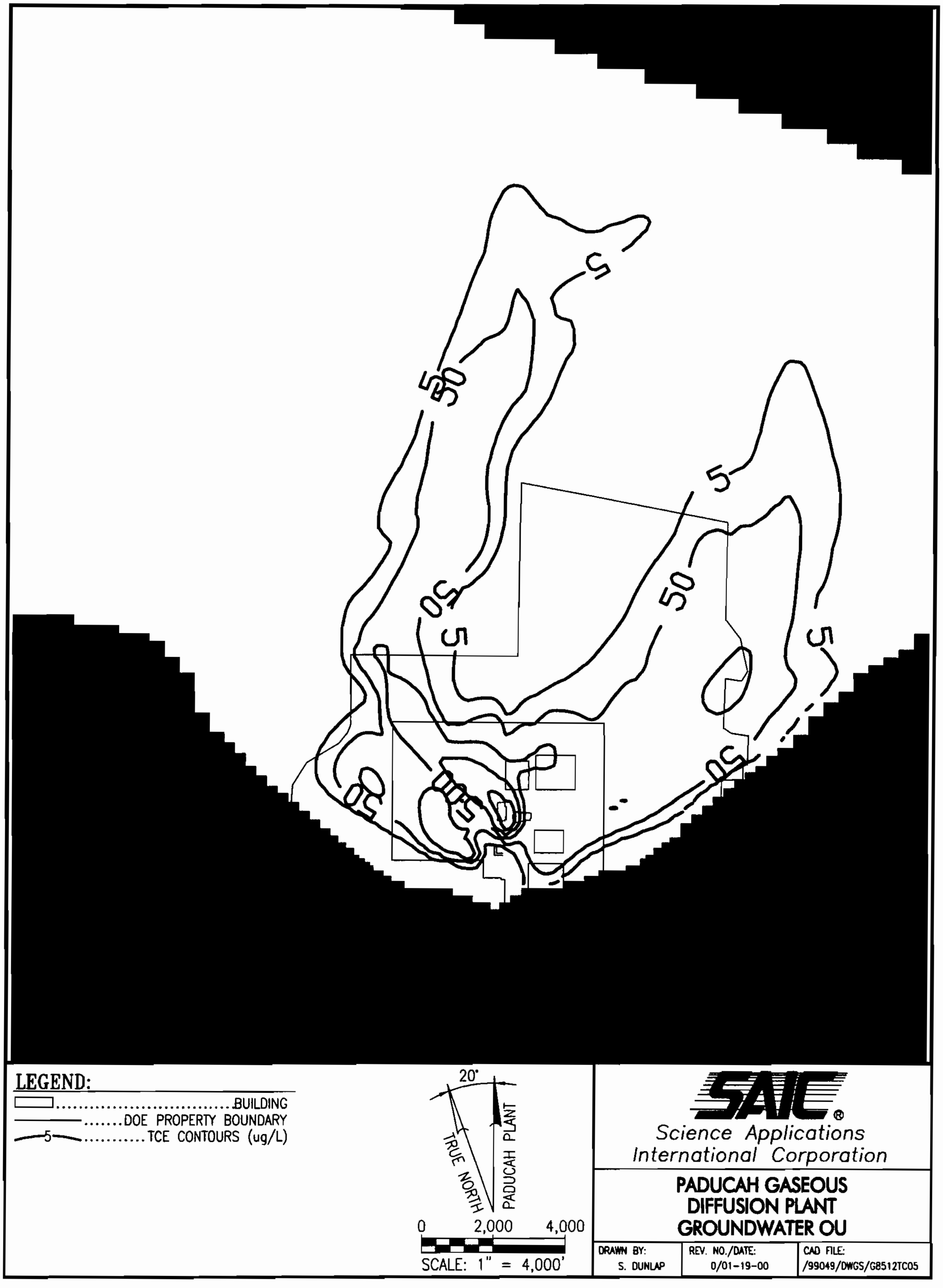

Fig. C1-4a. Predicted TCE concentration contours in μg/L at the end of 5-year simulation period for the No Action Alternative with NW/NE Wells pumping (12TCESP2T) at the PGDP, Paducah, Kentucky.

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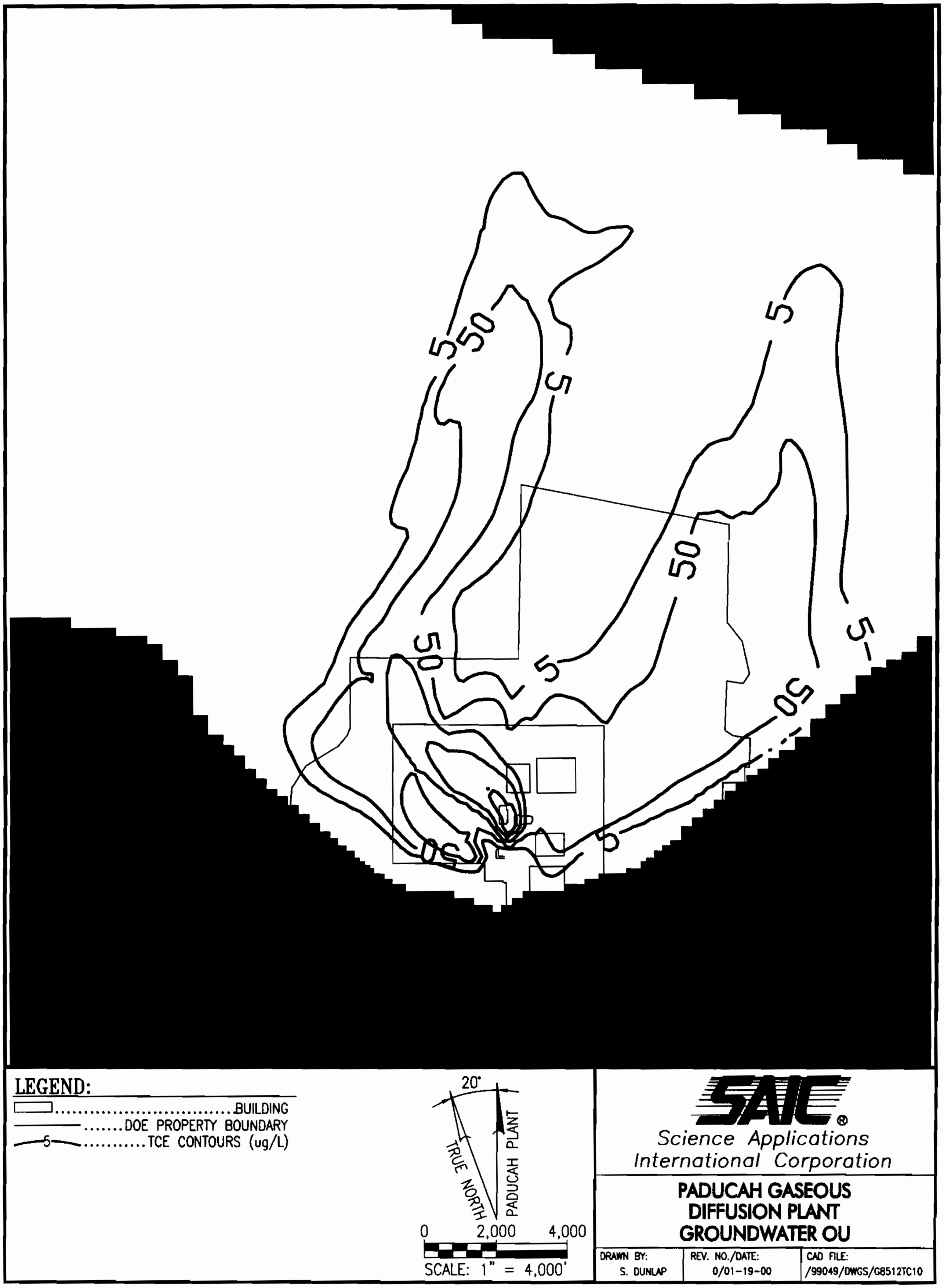

Fig. C1-4b. Predicted TCE concentration contours in μg/L at the end of 10-year simulation period for the No Action Alternative with NW/NE Wells pumping (12TCESP2T) at the PGDP, Paducah, Kentucky.

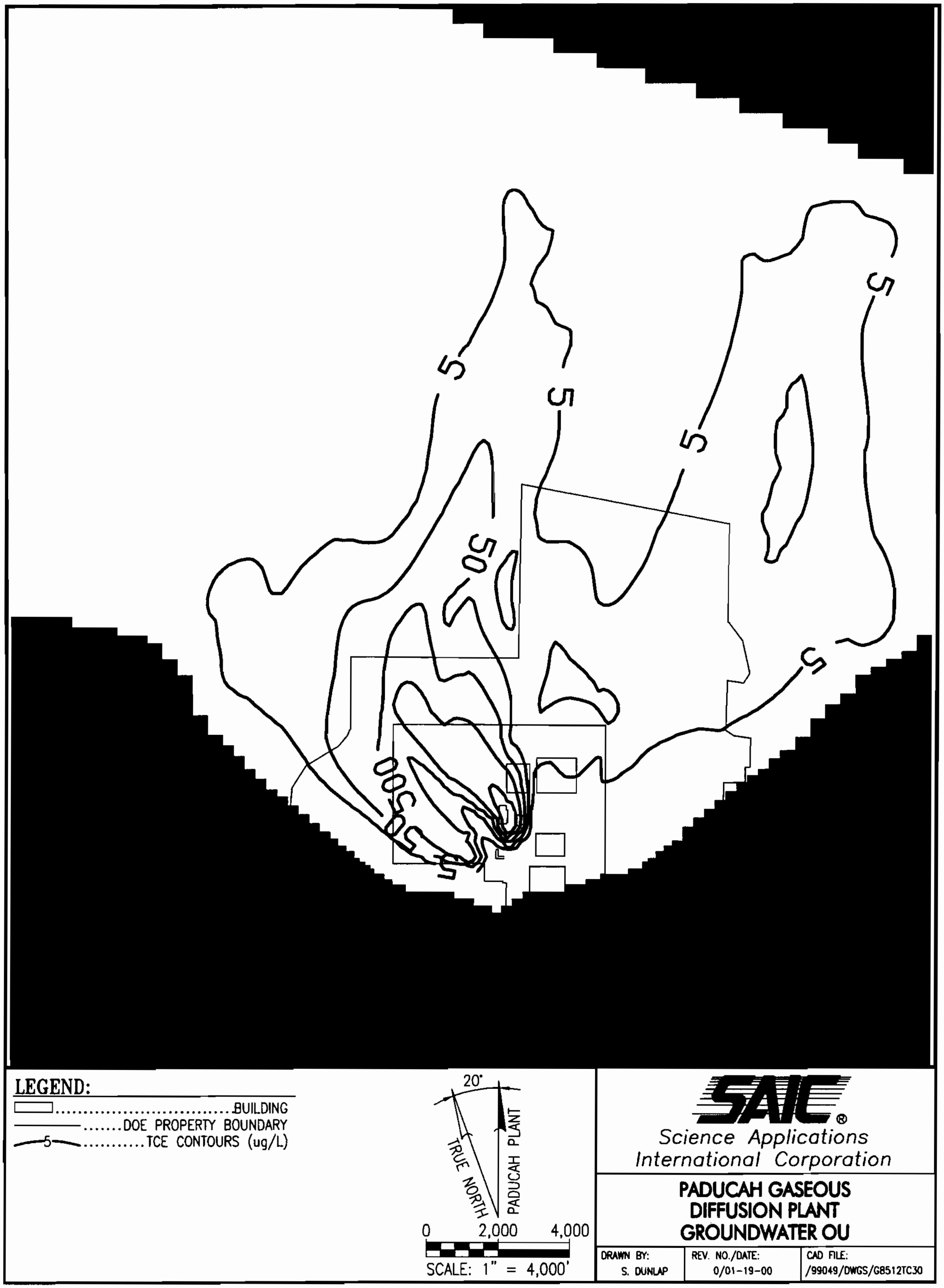

Fig. C1-4c. Predicted TCE concentration contours in μg/L at the end of 30-year simulation period for the No Action Alternative with NW/NE Wells pumping (12TCESP2T) at the PGDP, Paducah Kentucky.

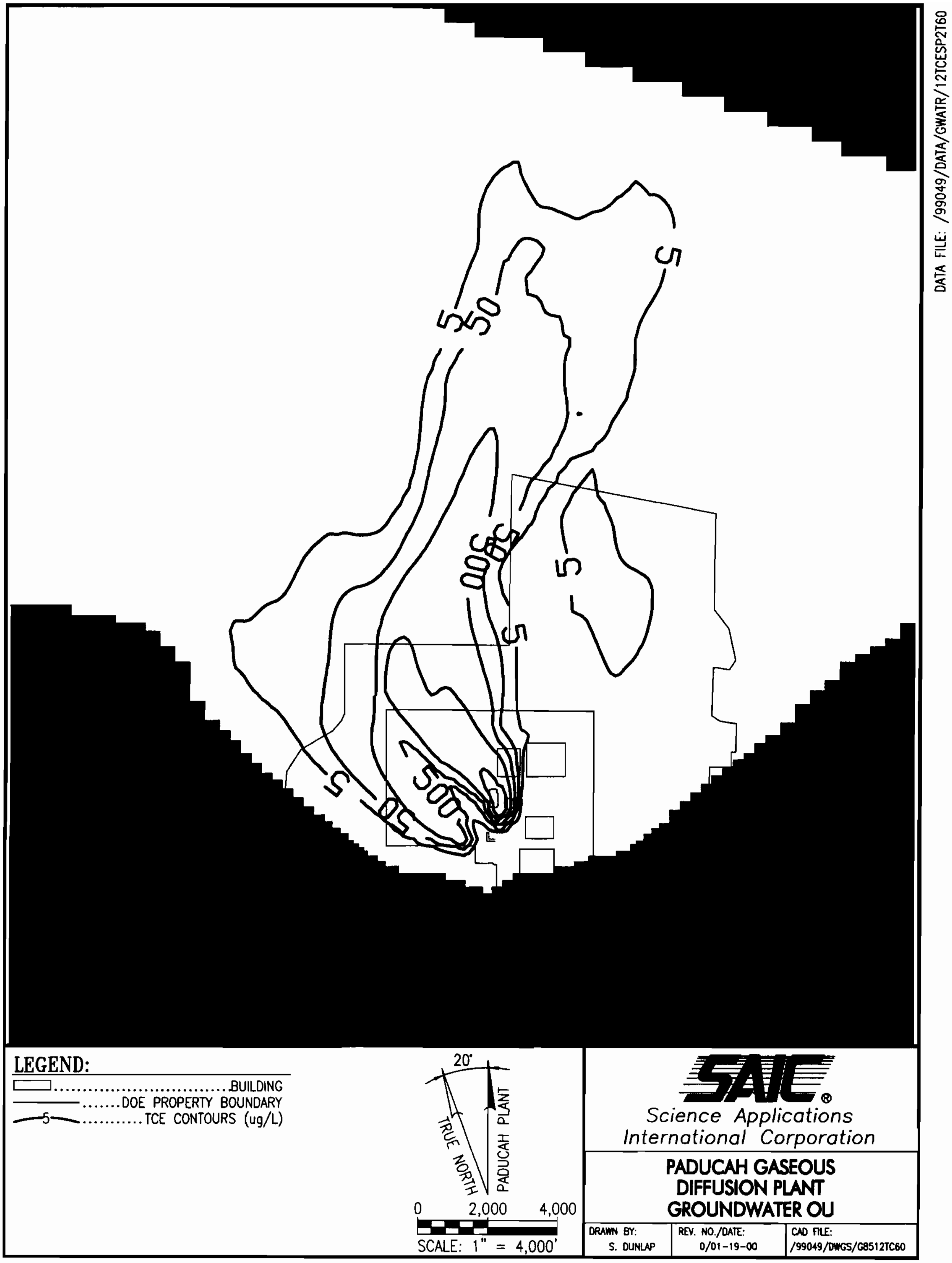

Fig. C1-4d. Predicted TCE concentration contours in μg/L at the end of 60-year simulation period for the No Action Alternative with NW/NE Wells pumping (12TCESP2T) at the PGDP, Paducah, Kentucky.

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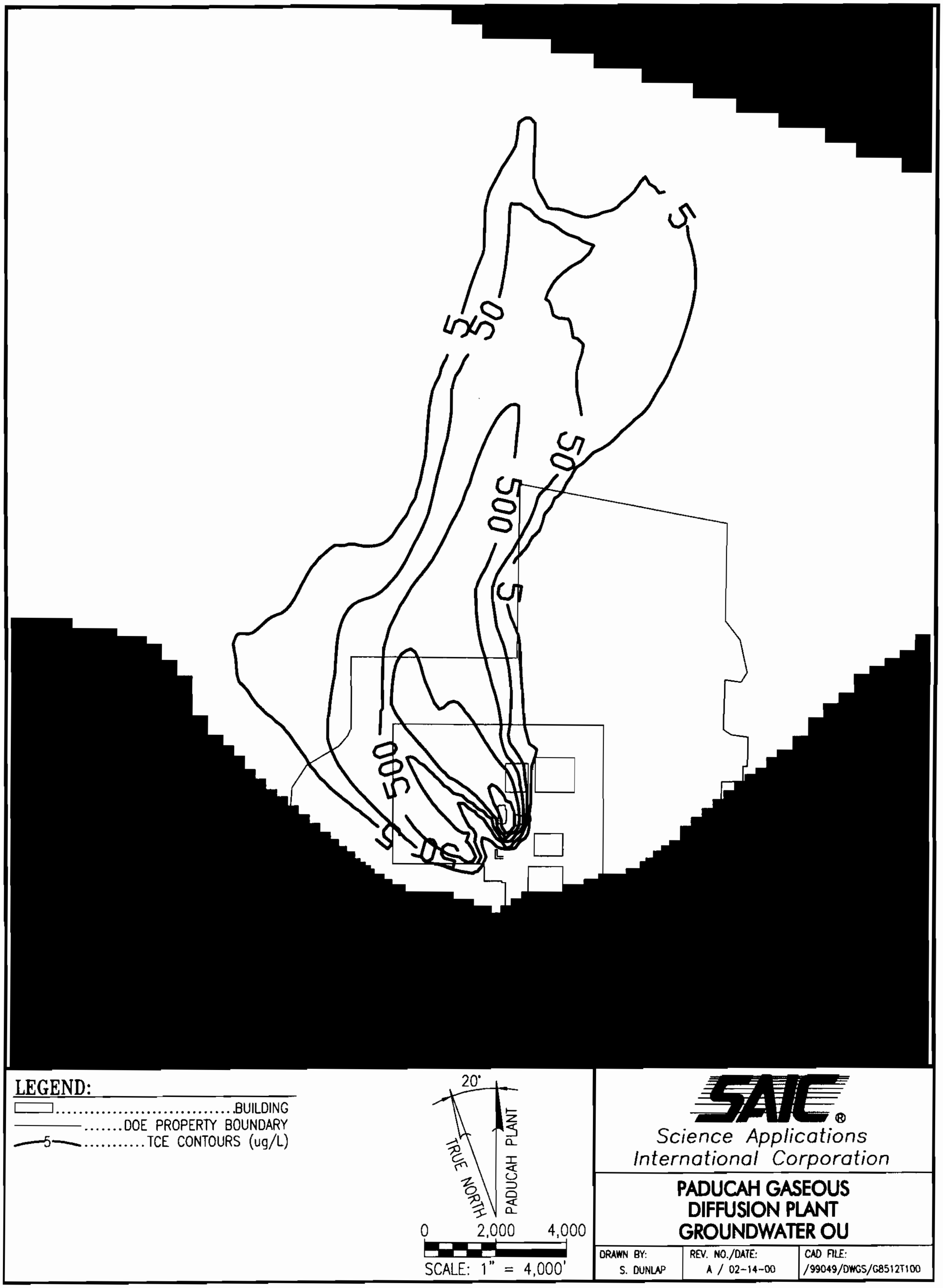

Fig. C1-4e. Predicted TCE concentration contours in μg/L at the end of 100-year simulation period for the No Action Alternative with NW/NE Wells pumping (12TCESP2T) at the PGDP, Paducah, Kentucky.

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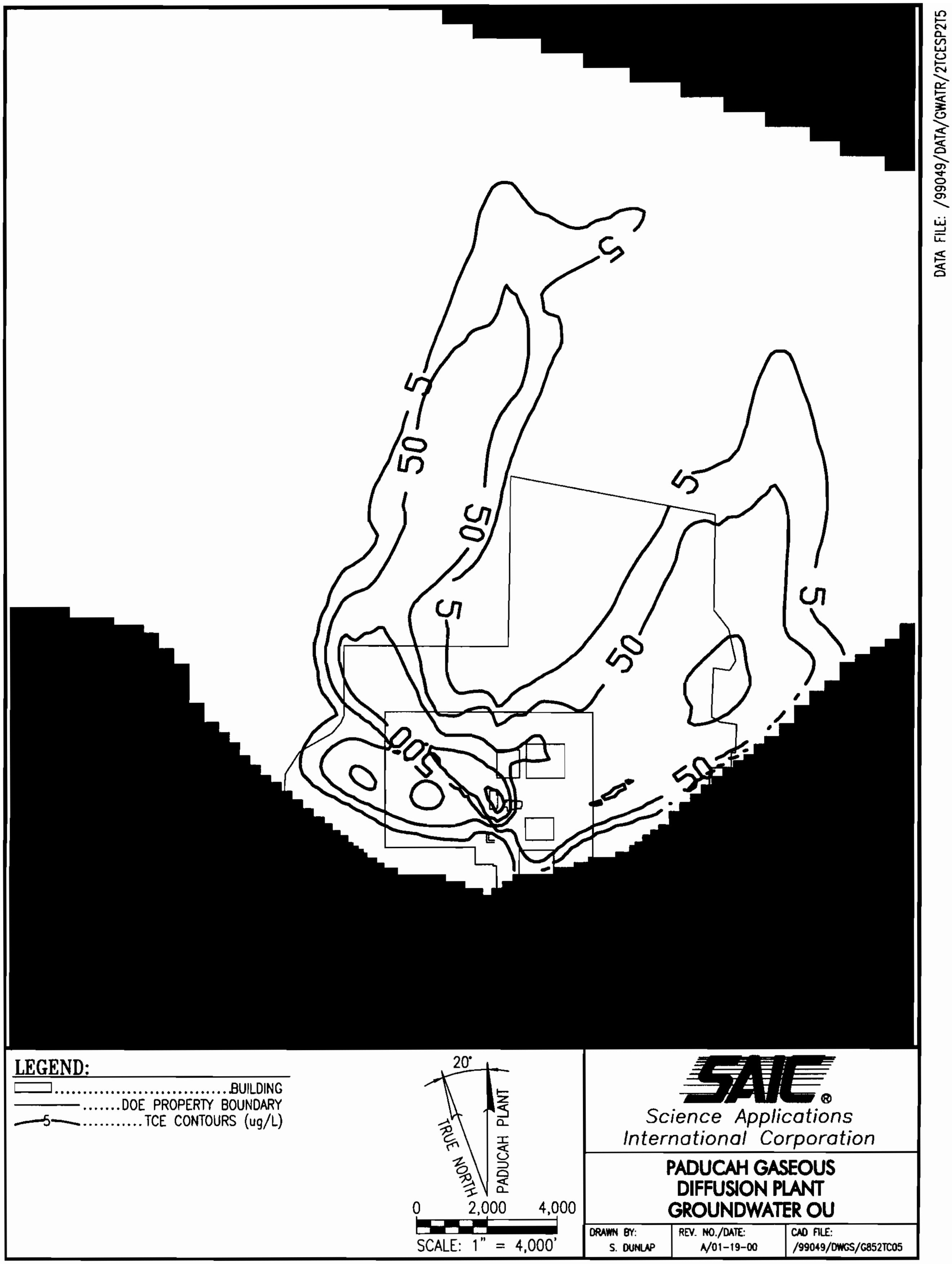


Fig. C1-5a. Predicted TCE concentration contours in μg/L at the end of 5-year simulation period for the Source Containment Alternative (2TCESP2T) at the PGDP, Paducah, Kentucky.

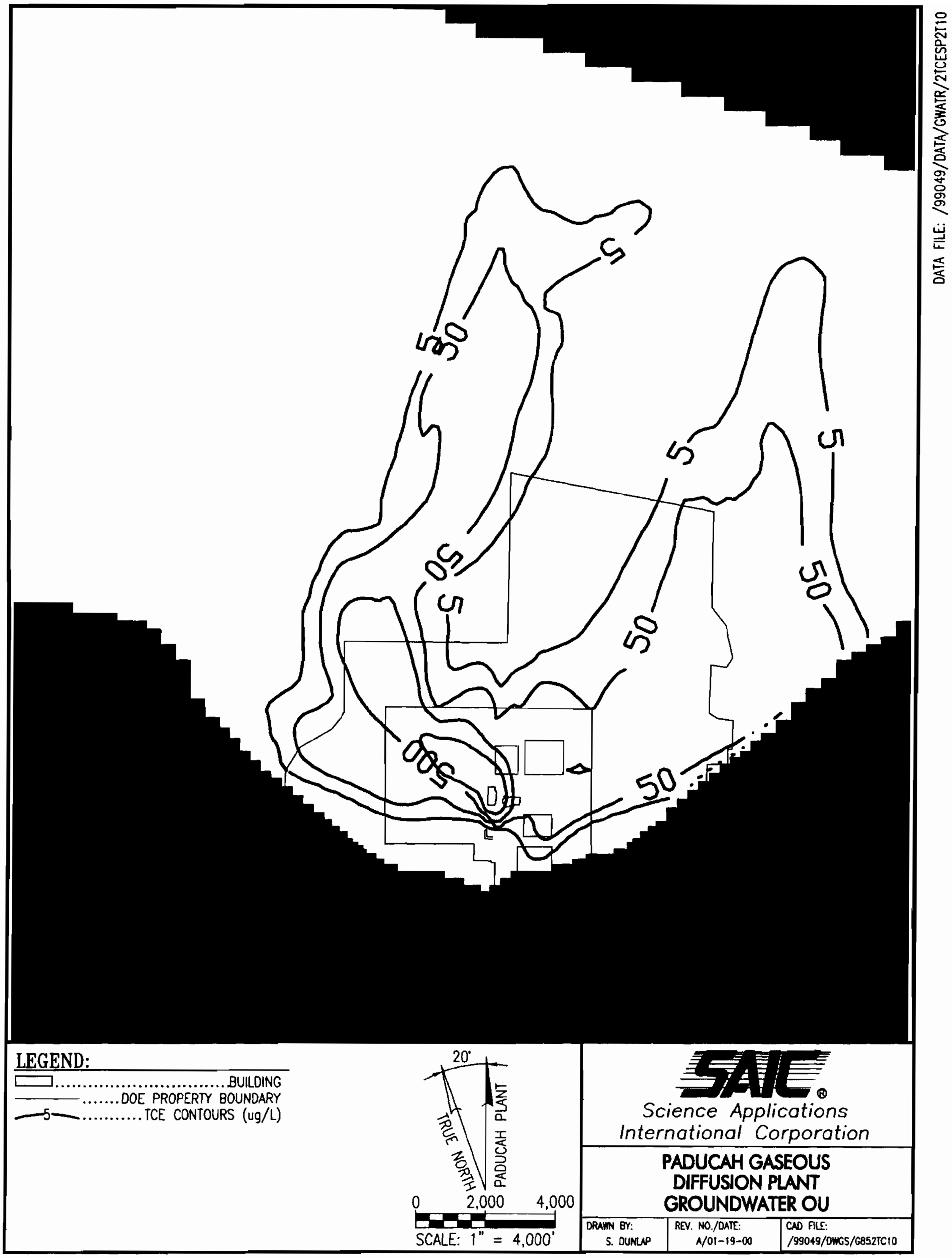


Fig. C1-5b. Predicted TCE concentration contours in μg/L at the end of 10-year simulation period for the Source Containment Alternative (2TCESP2T) at the PGDP, Paducah, Kentucky.

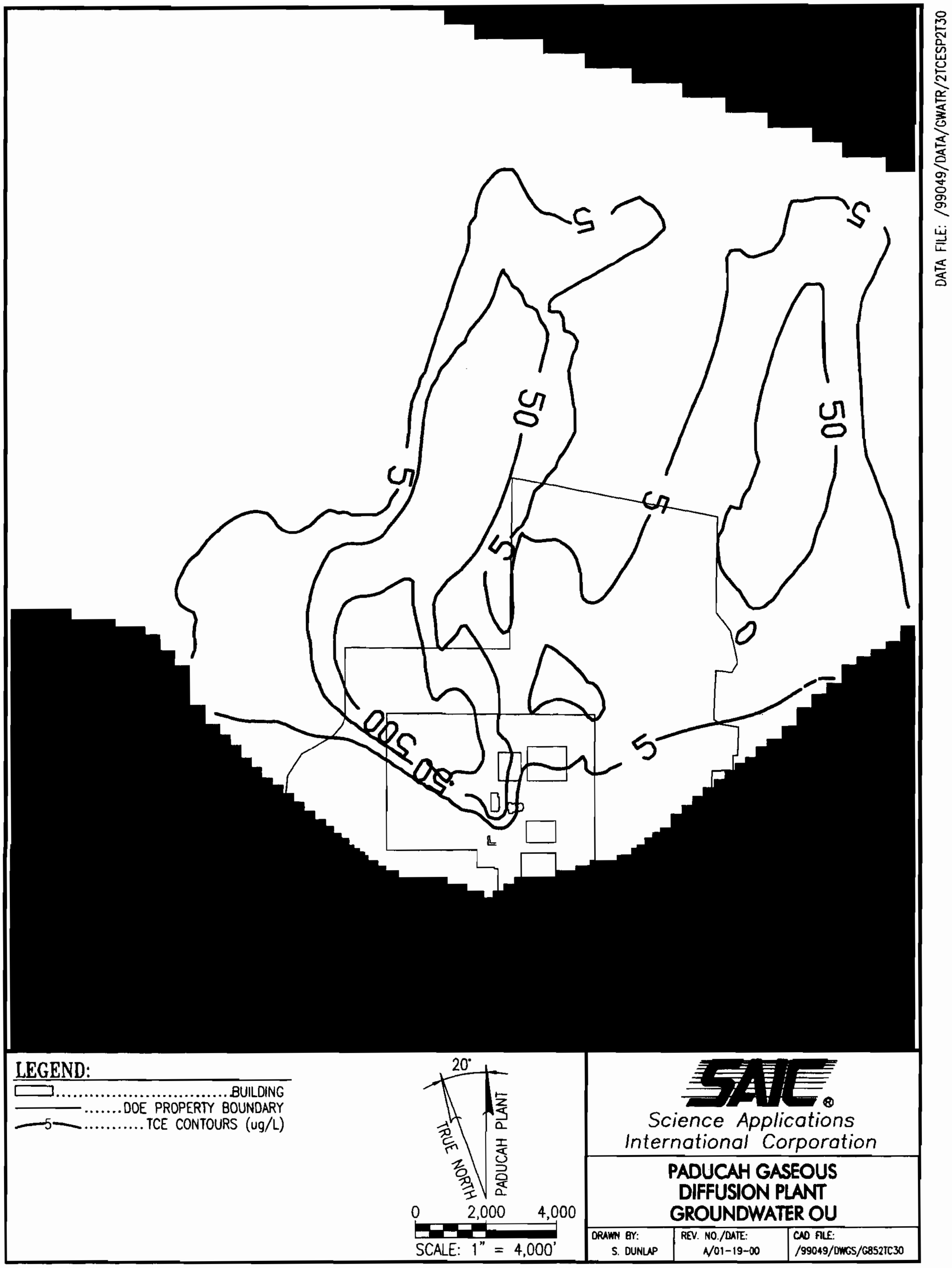


Fig. C1-5c. Predicted TCE concentration contours in μg/L at the end of 30-year simulation period for the Source Containment Alternative (2TCESP2T) at the PGDP, Paducah, Kentucky.

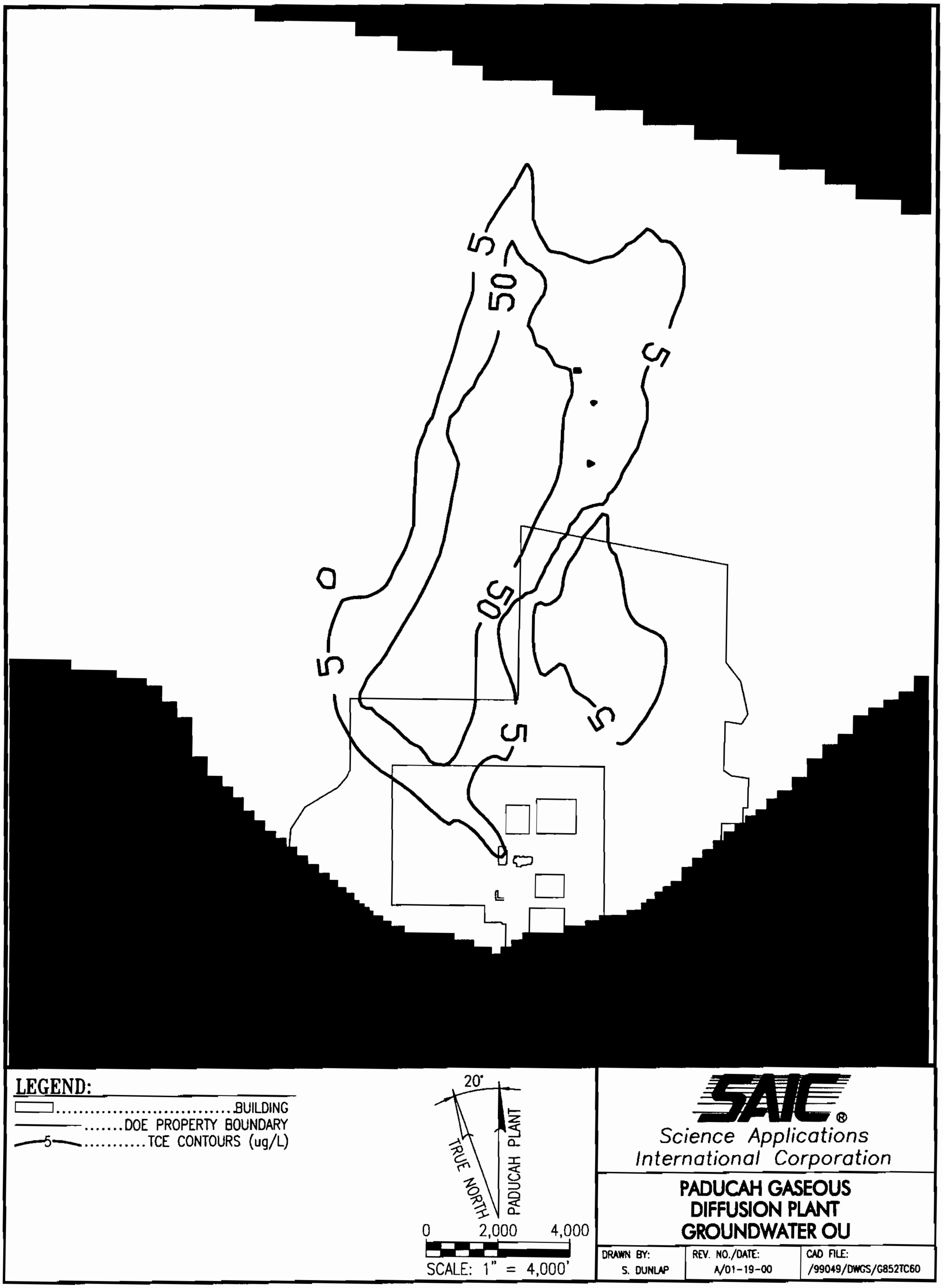


Fig. C1-5d. Predicted TCE concentration contours in μg/L at the end of 60-year simulation period for the Source Containment Alternative (2TCESP2T) at the PGDP, Paducah, Kentucky.

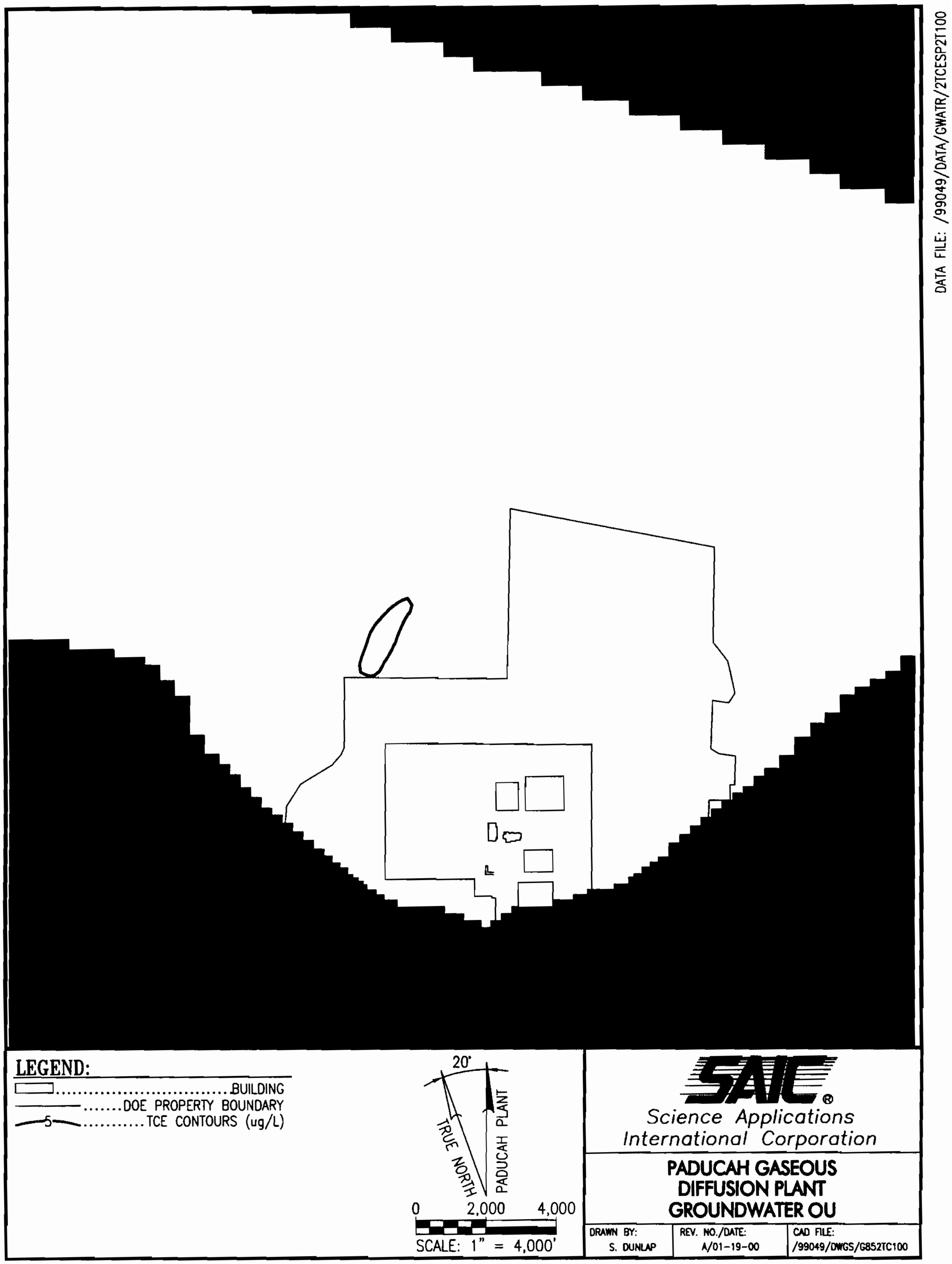


Fig. C1-5e. Predicted TCE concentration contours in μg/L at the end of 100-year simulation period for the Source Containment Alternative (2TCESP2T) at the PGDP, Paducah, Kentucky.

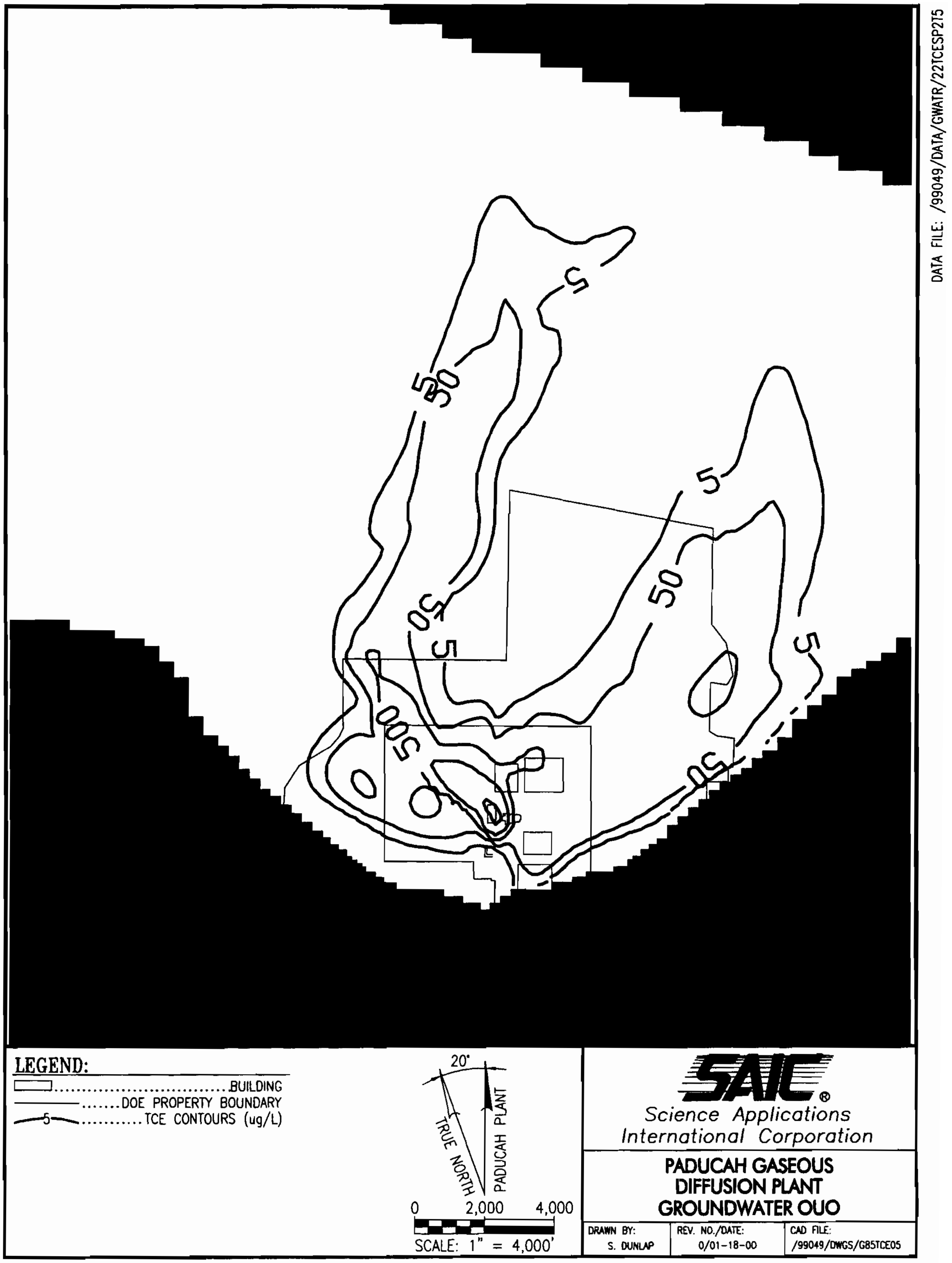
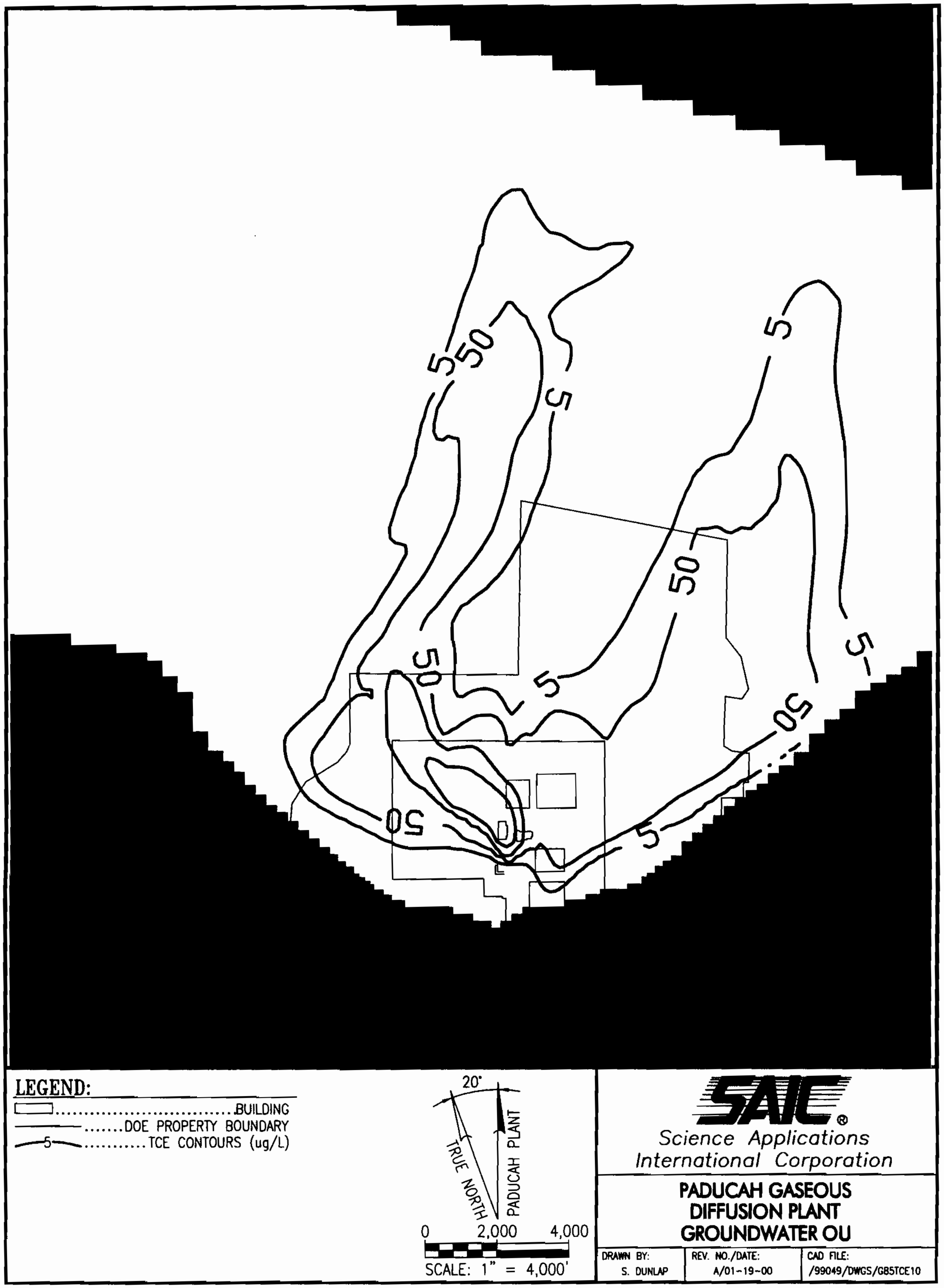


Fig. C1-6a. Predicted TCE concentration contours in μg/L at the end of 5-year simulation period for the Source Containment Alternative with NW/NE Wells pumping (22TCESP2T) at the PGDP, Paducah, Kentucky.



DATA FILE: /99049/DATA/GWATR/22TCESP2T10

Fig. C1-6b. Predicted TCE concentration contours in μg/L at the end of 10-year simulation period for the Source Containment Alternative with NW/NE Wells pumping (22TCESP2T) at the PGDP, Paducah, Kentucky.

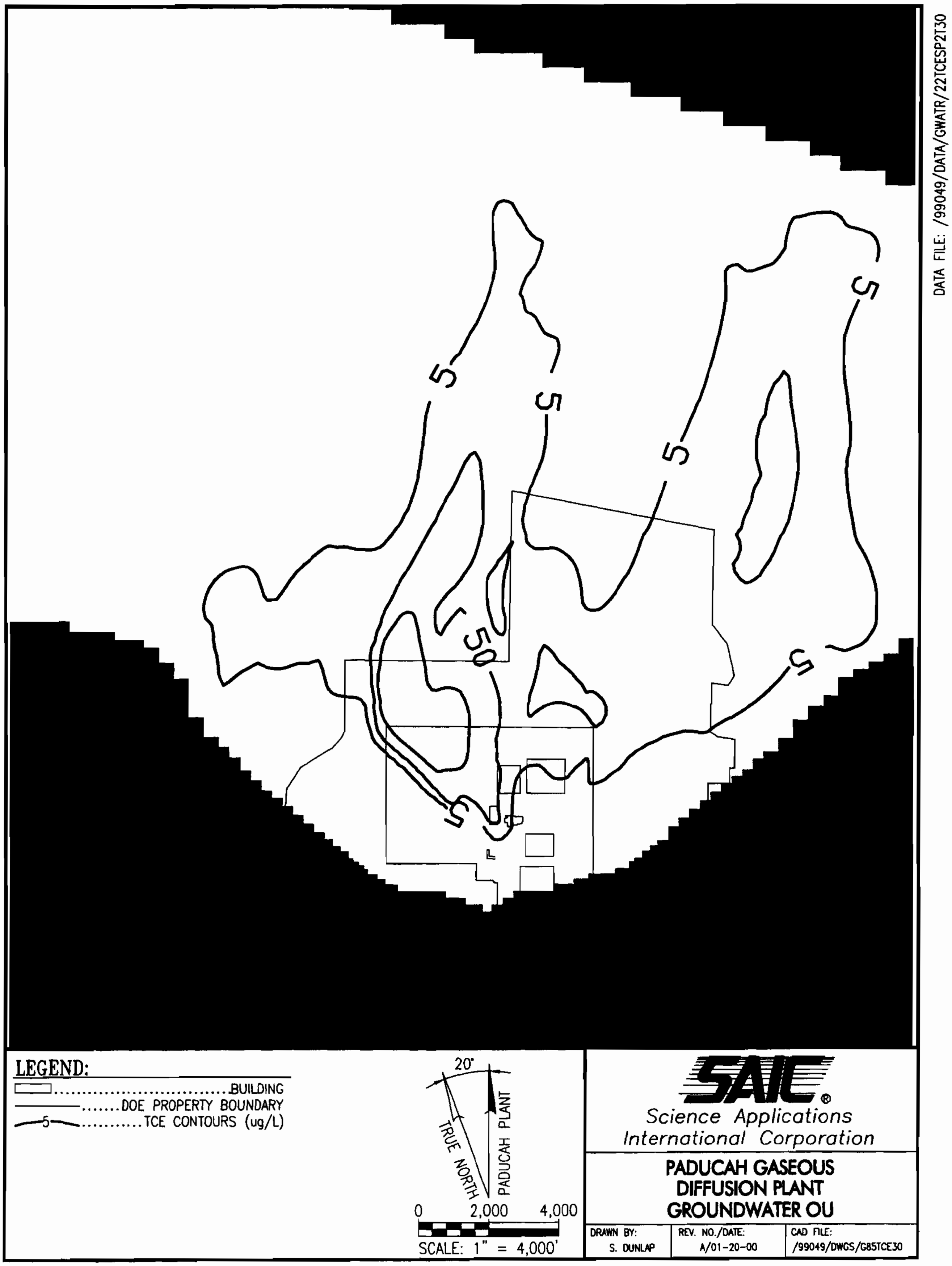


Fig. C1-6c. Predicted TCE concentration contours in μg/L at the end of 30-year simulation period for the Source Containment Alternative with NW/NE Wells pumping (22TCESP2T) at the PGDP, Paducah, Kentucky.

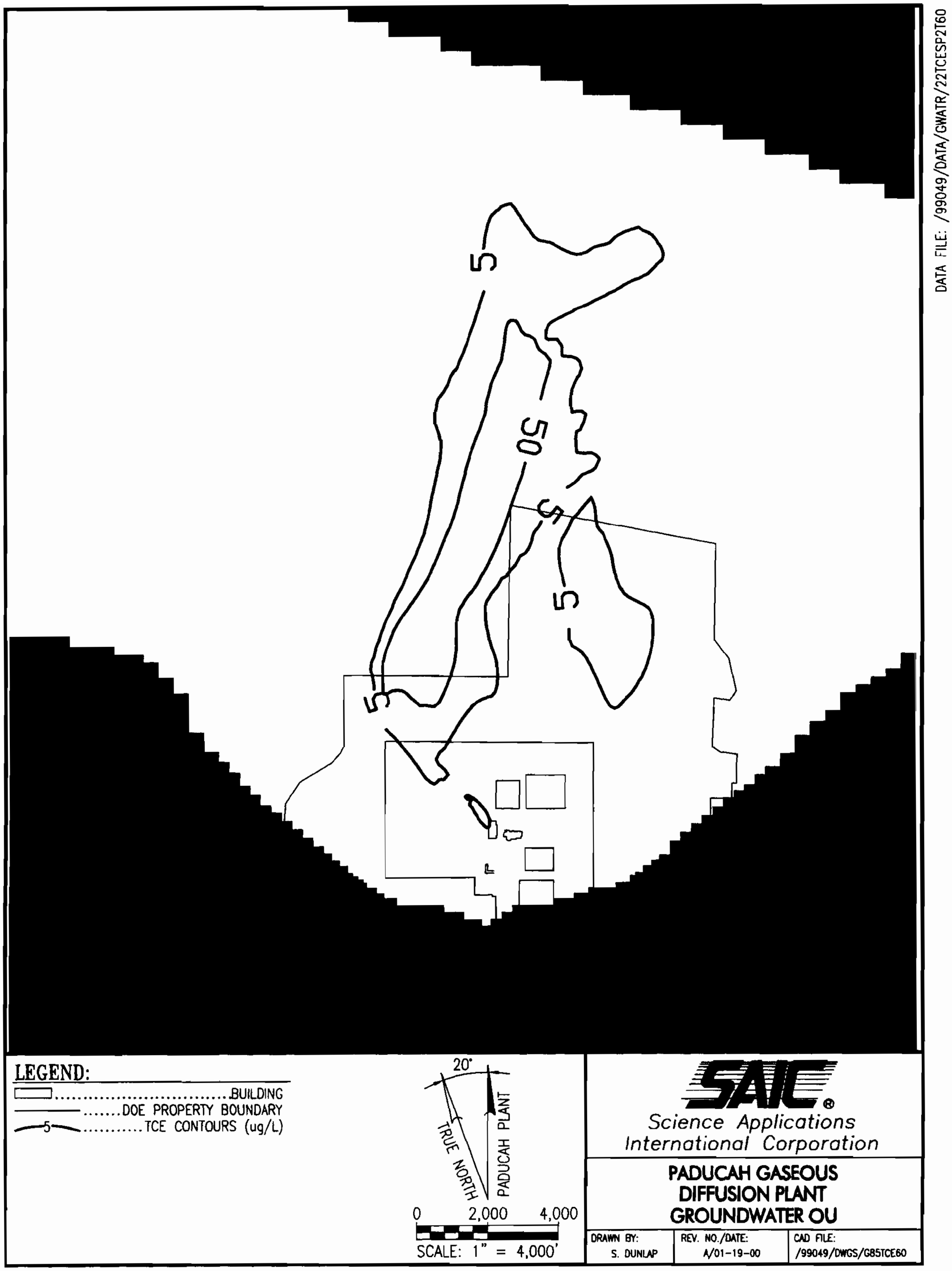


Fig. C1-6d. Predicted TCE concentration contours in μg/L at the end of 60-year simulation period for the Source Containment Alternative with NW/NE Wells pumping (22TCESP2T) at the PGDP, Paducah, Kentucky.

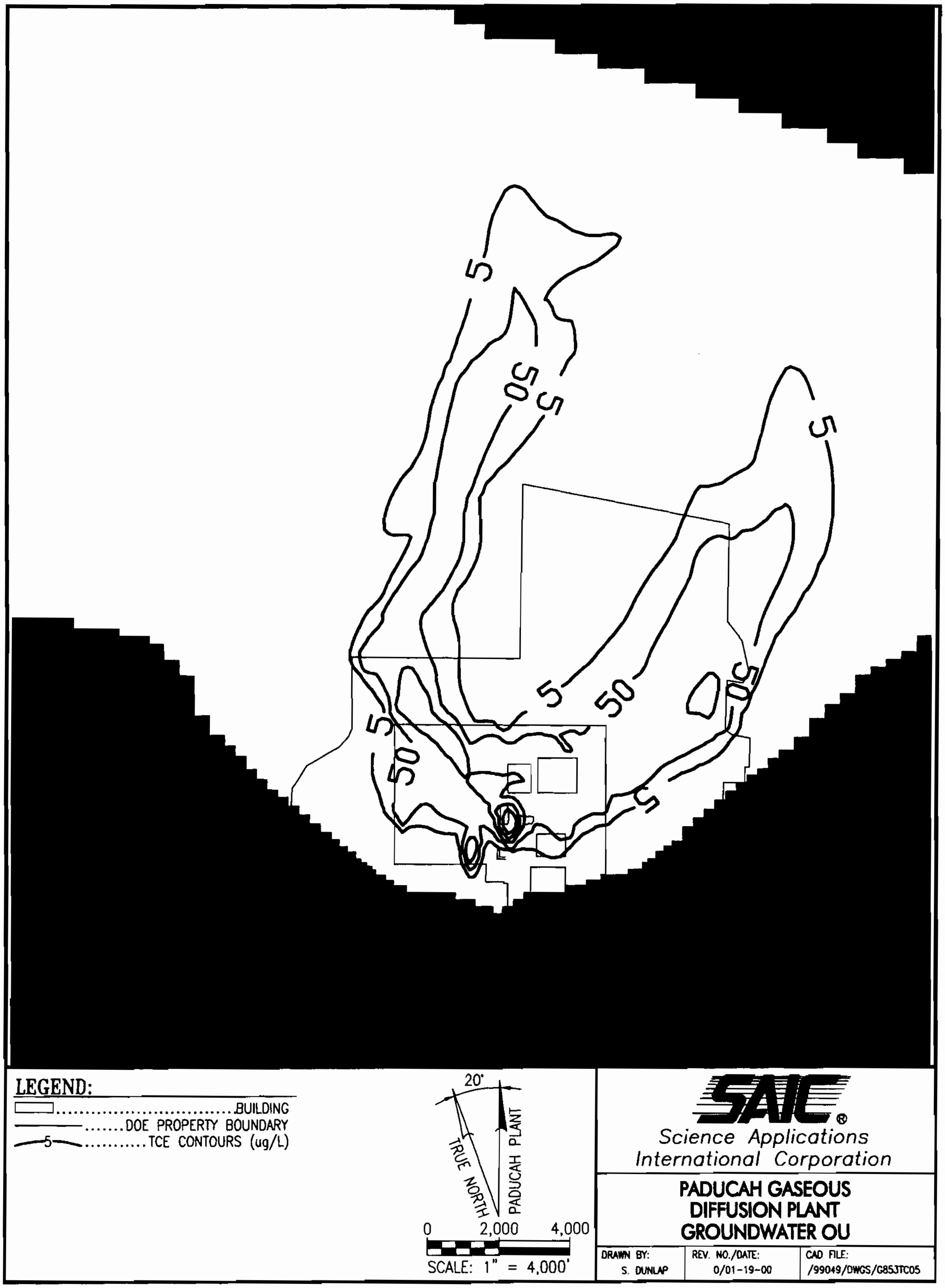


Fig. C1-7a. Predicted TCE concentration contours in μg/L at the end of 5-year simulation period for the Pump and Treat Alternative (3TCESP2T) at the PGDP, Paducah, Kentucky.

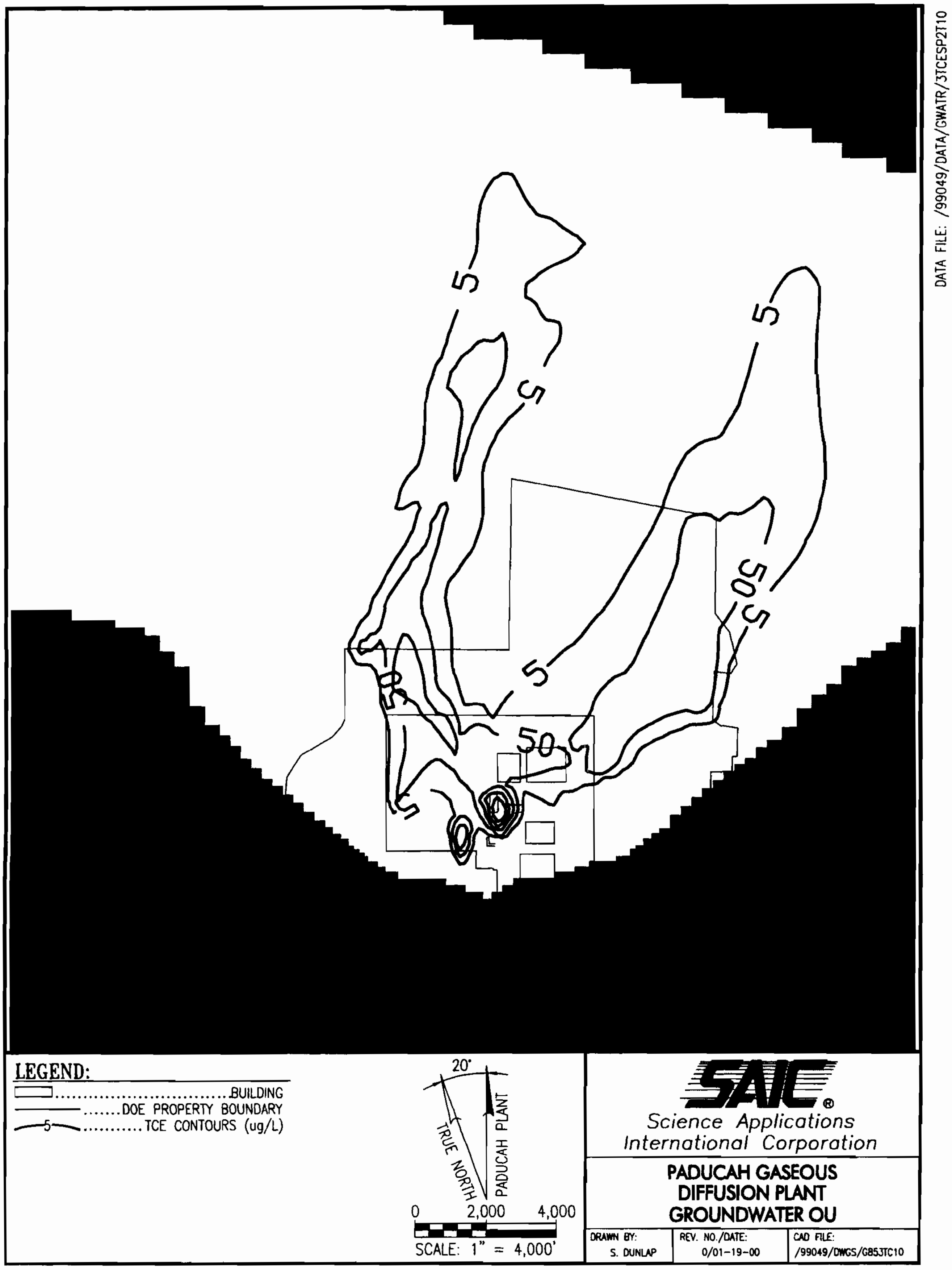


Fig. C1-7b. Predicted TCE concentration contours in μg/L at the end of 10-year simulation period for the pump and treat Alternative (3TCESP2T) at the PGDP, Paducah, Kentucky.

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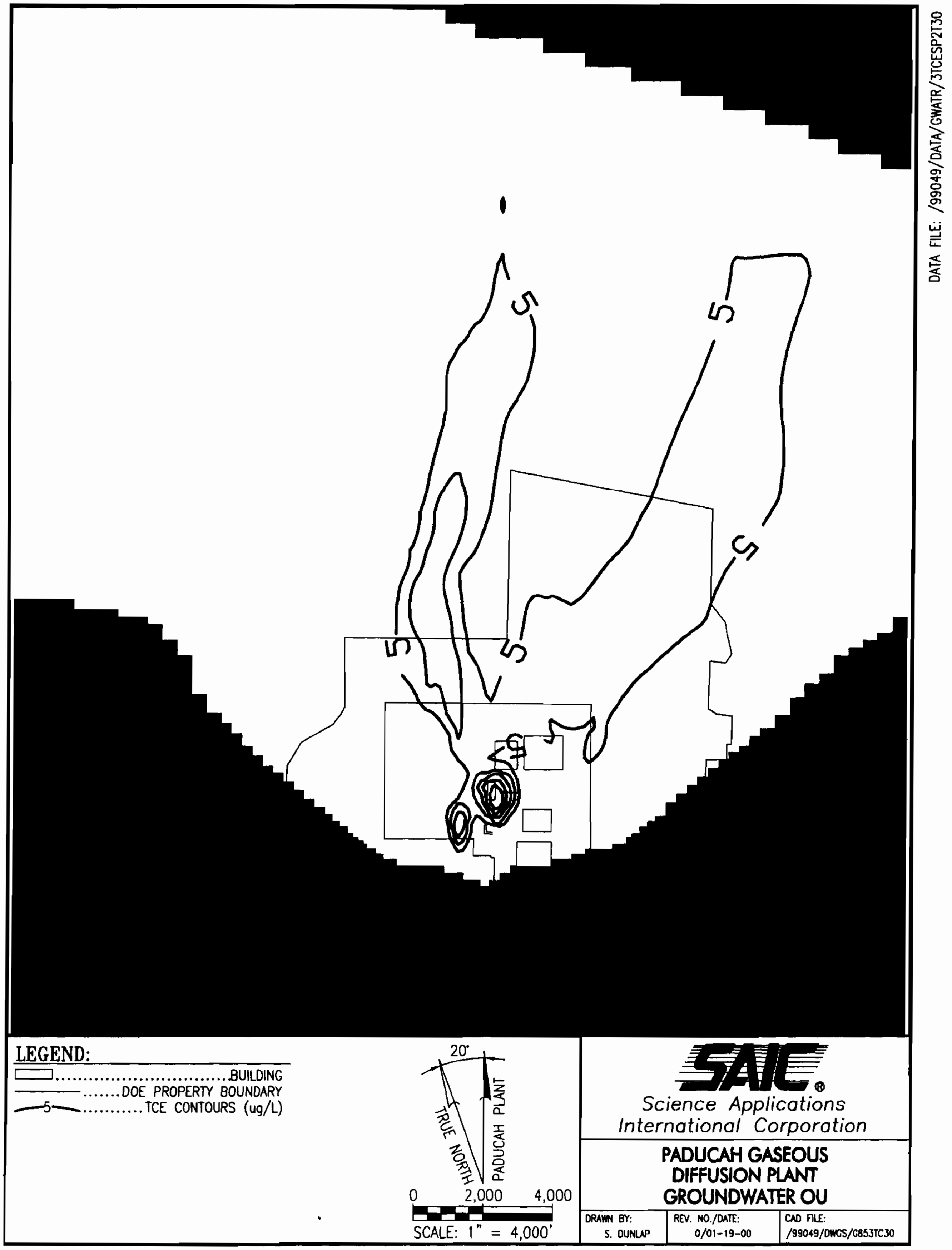

Fig. C1-7c. Predicted TCE concentration contours in μg/L at the end of 30-year simulation period for the Pump and Treat Alternative (3TCESP2T) at the PGDP, Paducah, Kentucky.

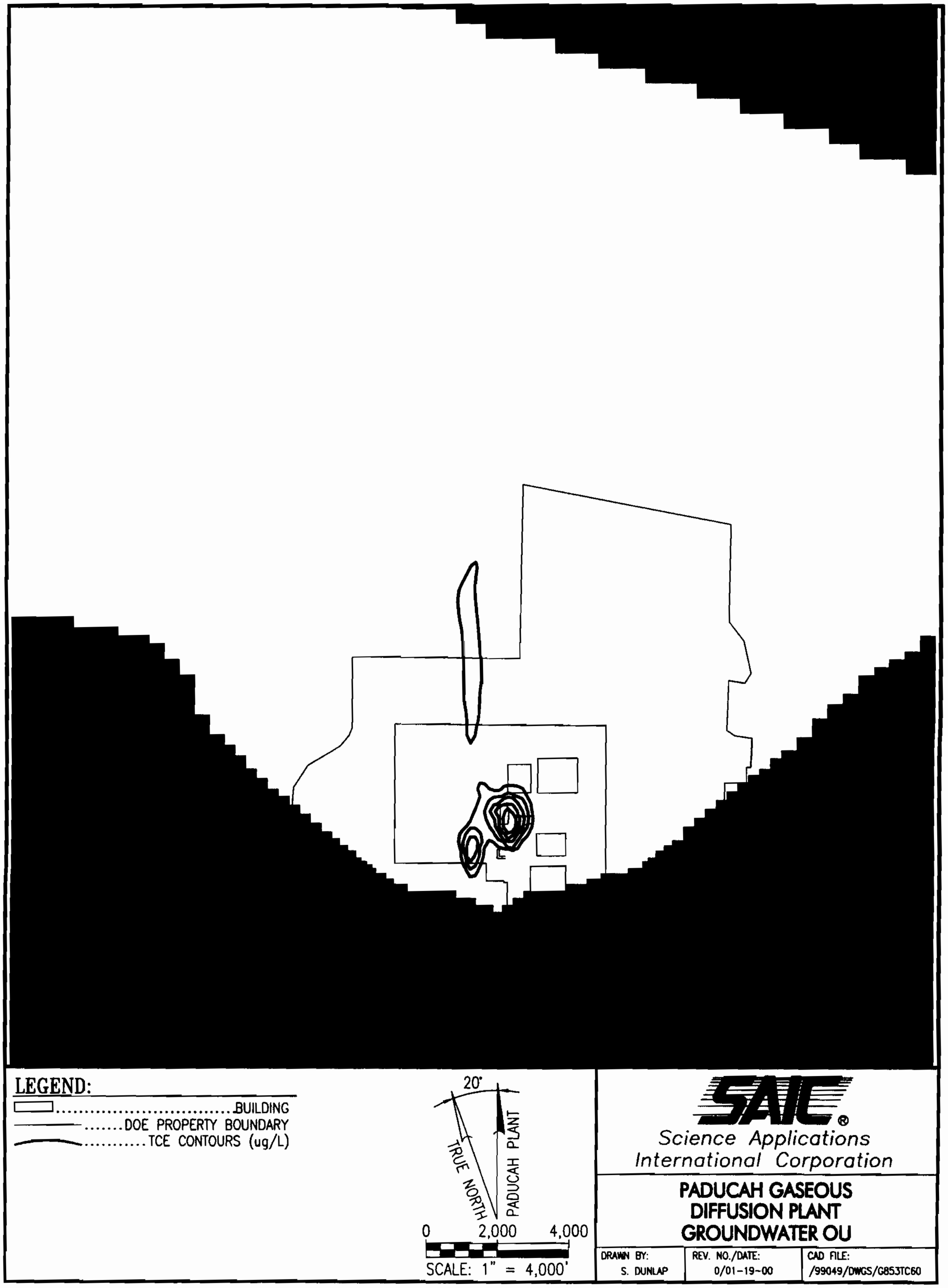

Fig. C1-7d. Predicted TCE concentration contours in μg/L at the end of 60-year simulation period for the Pump and Treat Alternative (3TCESP2T) at the PGDP, Paducah, Kentucky.

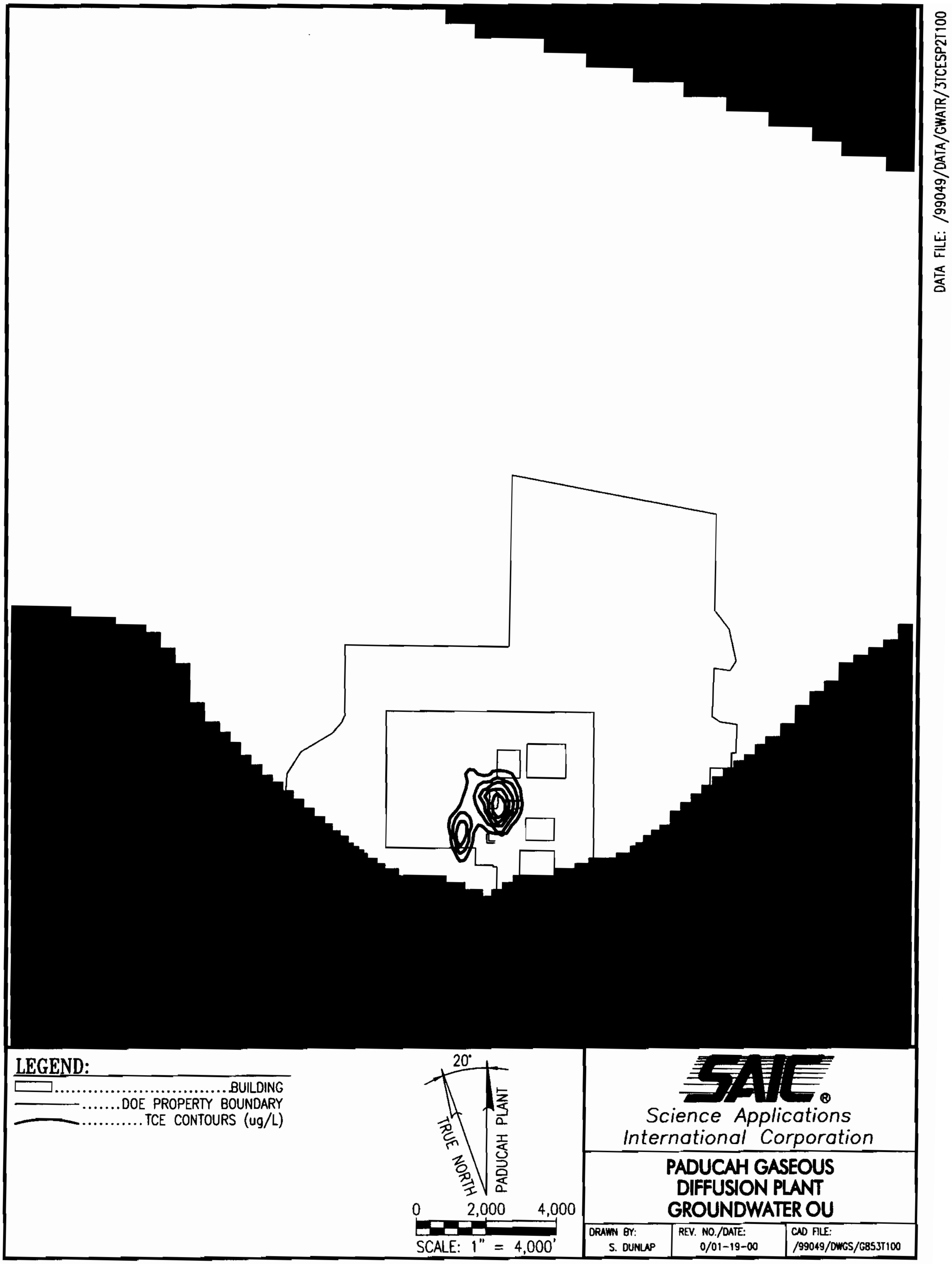

Fig. C1-7e. Predicted TCE concentration contours in μg/L at the end of 100-year simulation period for the Pump and Treat Alternative (3TCESP2T) at the PGDP, Paducah, Kentucky.

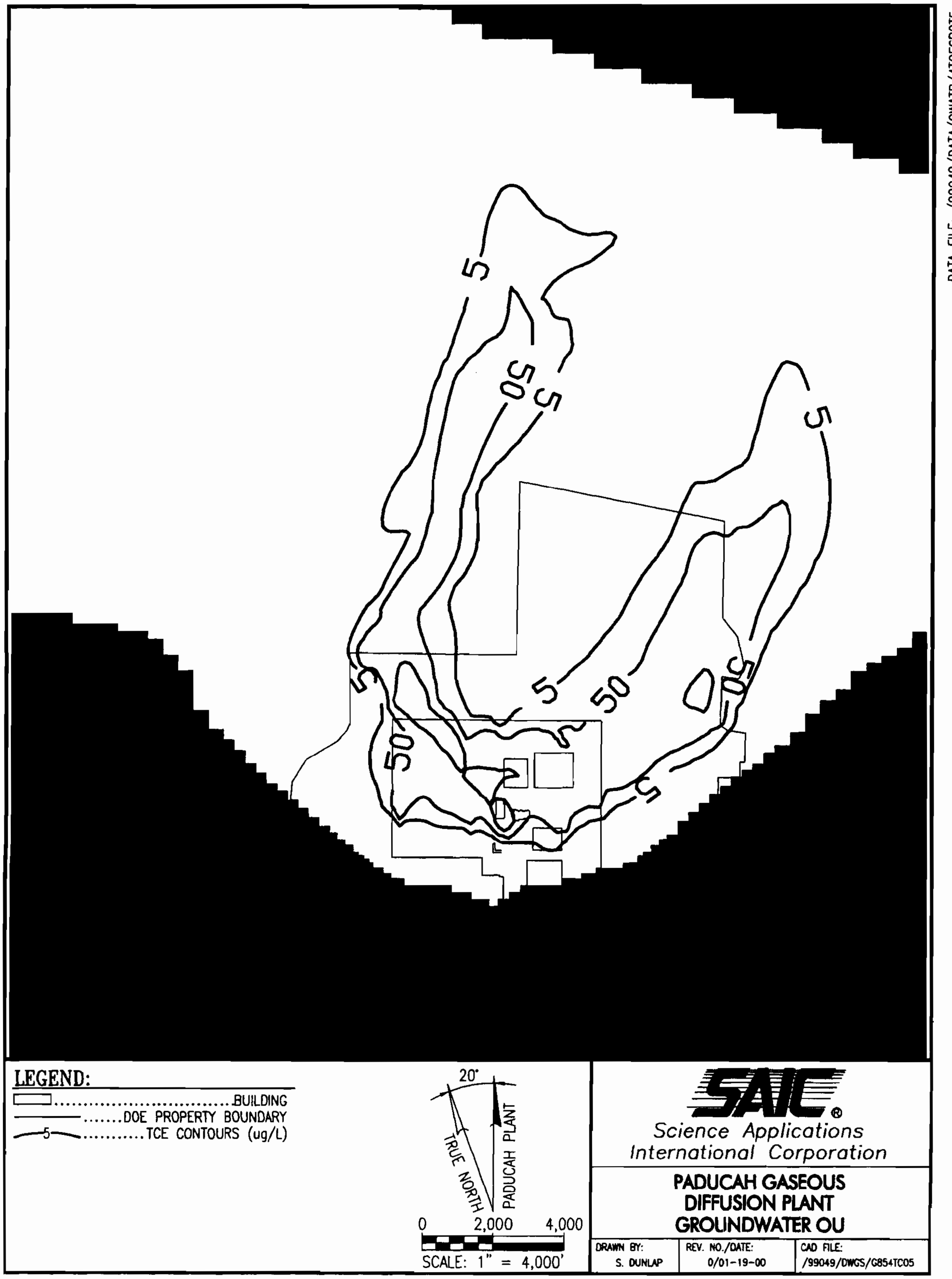

Fig. C1-8a. Predicted TCE concentration contours in μg/L at the end of 5-year simulation period for the Source Containment Alternative with Pump and Treat (4TCESP2T) at the PGDP, Paducah, Kentucky.

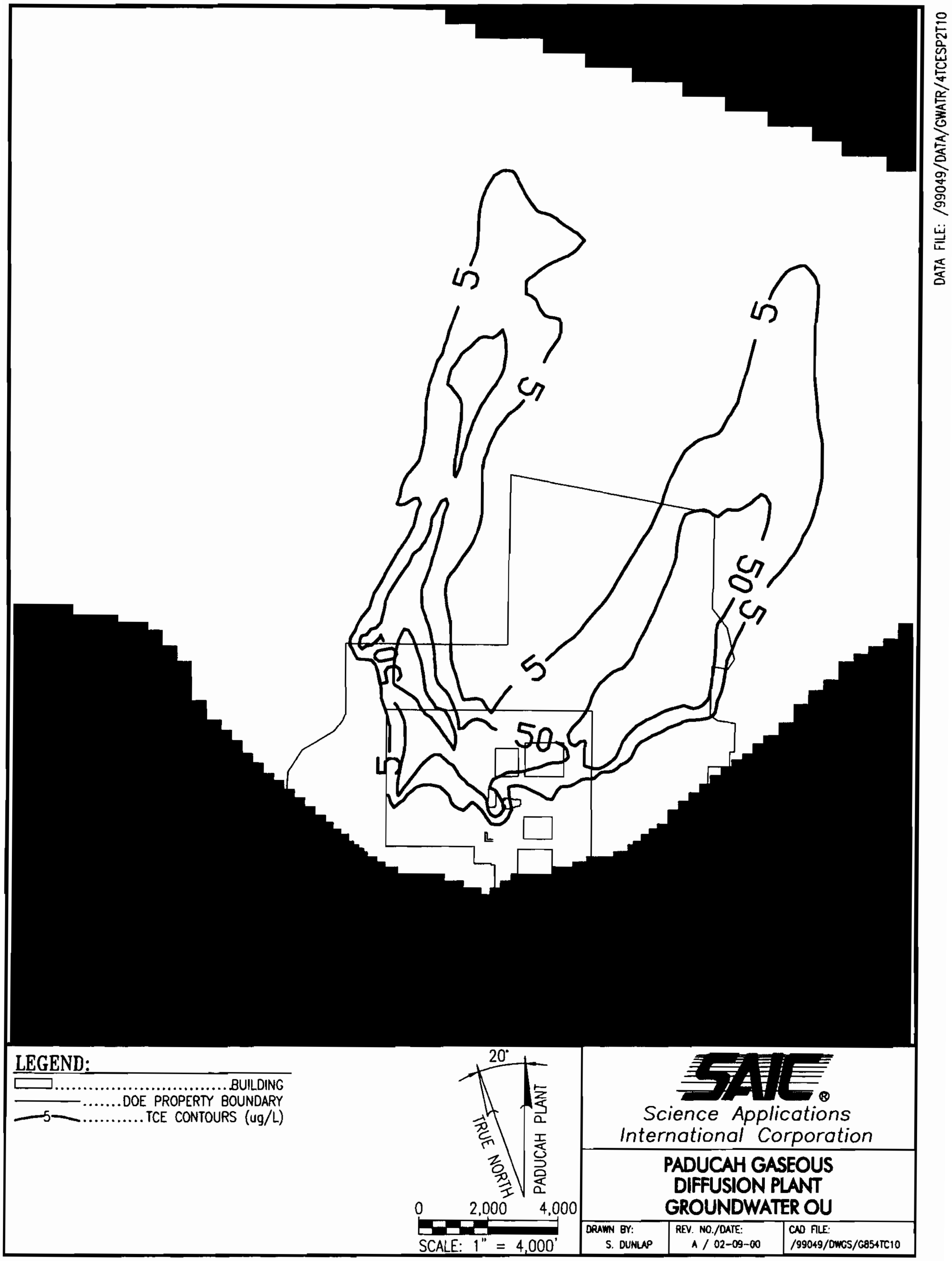

Fig. C1-8b. Predicted TCE concentration contours in μg/L at the end of 10-year simulation period for the Source Containment Alternative with Pump and Treat (4TCESP2T) at the PGDP, Paducah, Kentucky.

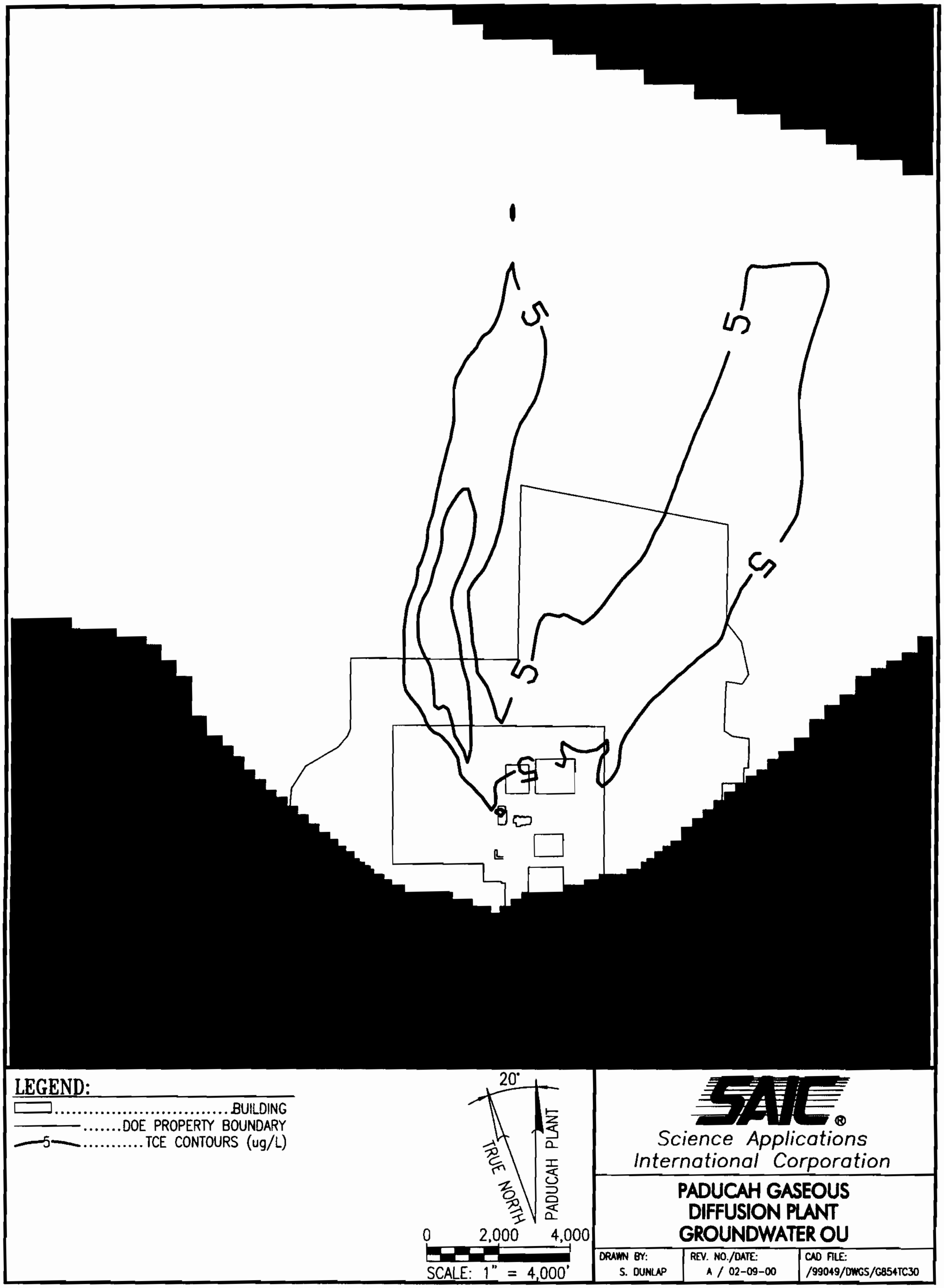

Fig. C1-8c. Predicted TCE concentration contours in μg/L at the end of 30-year simulation period for the Source Containment Alternative with Pump and Treat (4TCESP2T) at the PGDP, Paducah, Kentucky.

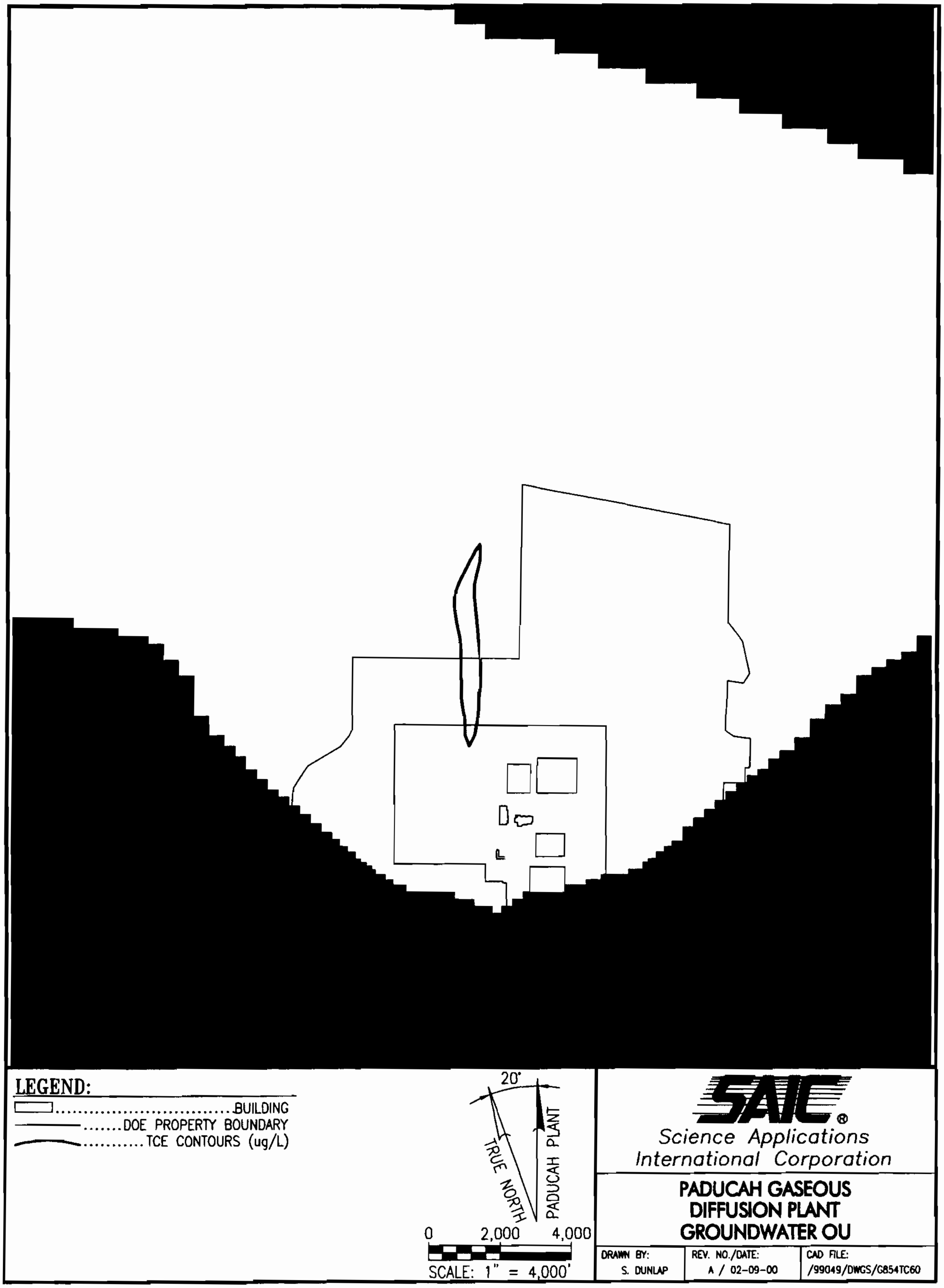

Fig. C1-8d. Predicted TCE concentration contours in μg/L at the end of 60-year simulation period for the Source Containment Alternative with Pump and Treat (4TCESP2T) at the PGDP, Paducah, Kentucky.

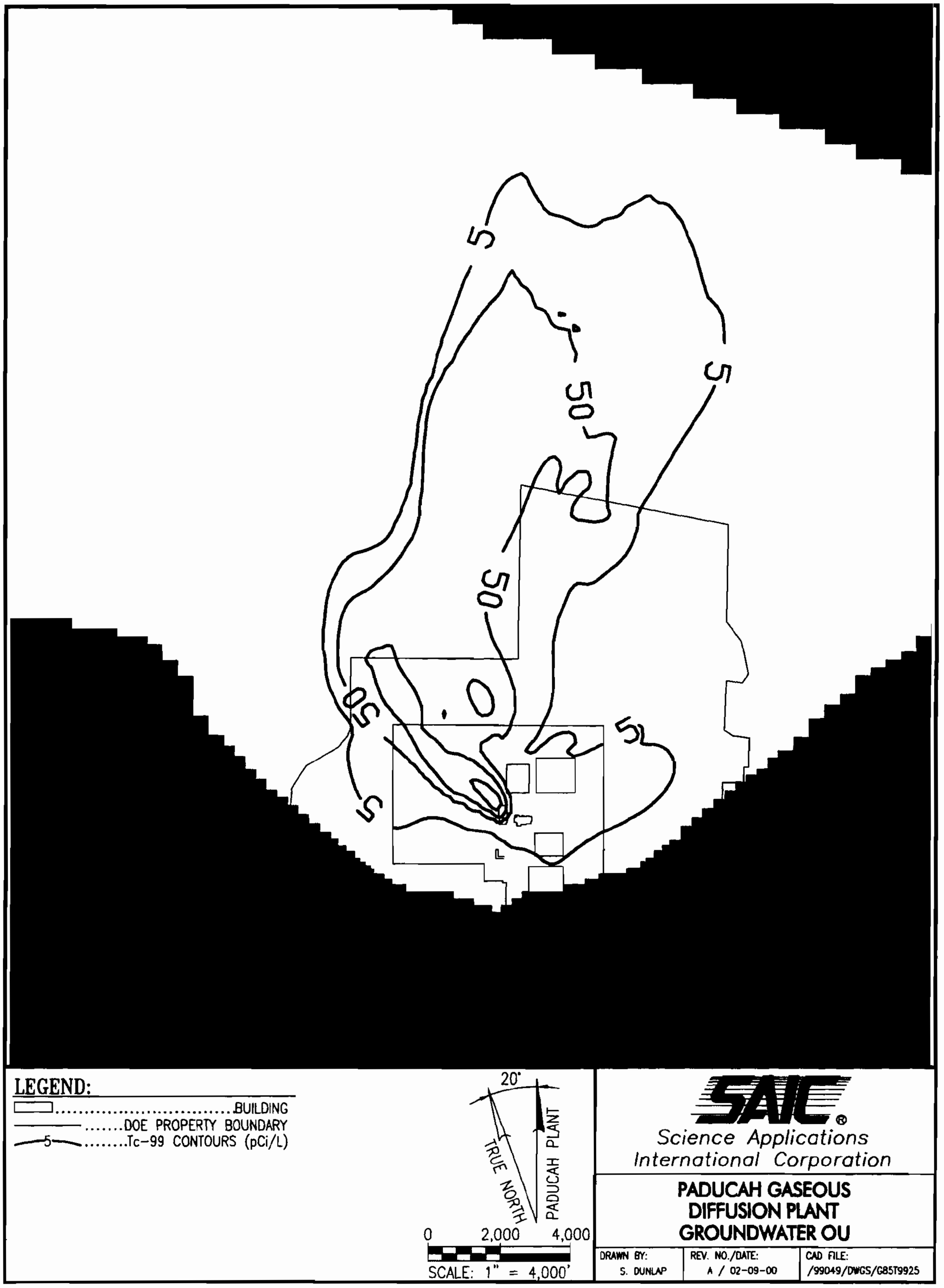

Fig. C1-9a. Predicted Tc-99 concentration contours in pCi/L at the end of 5-year simulation period for the No Action Alternative (1T99SP2) at the PGDP, Paducah, Kentucky.

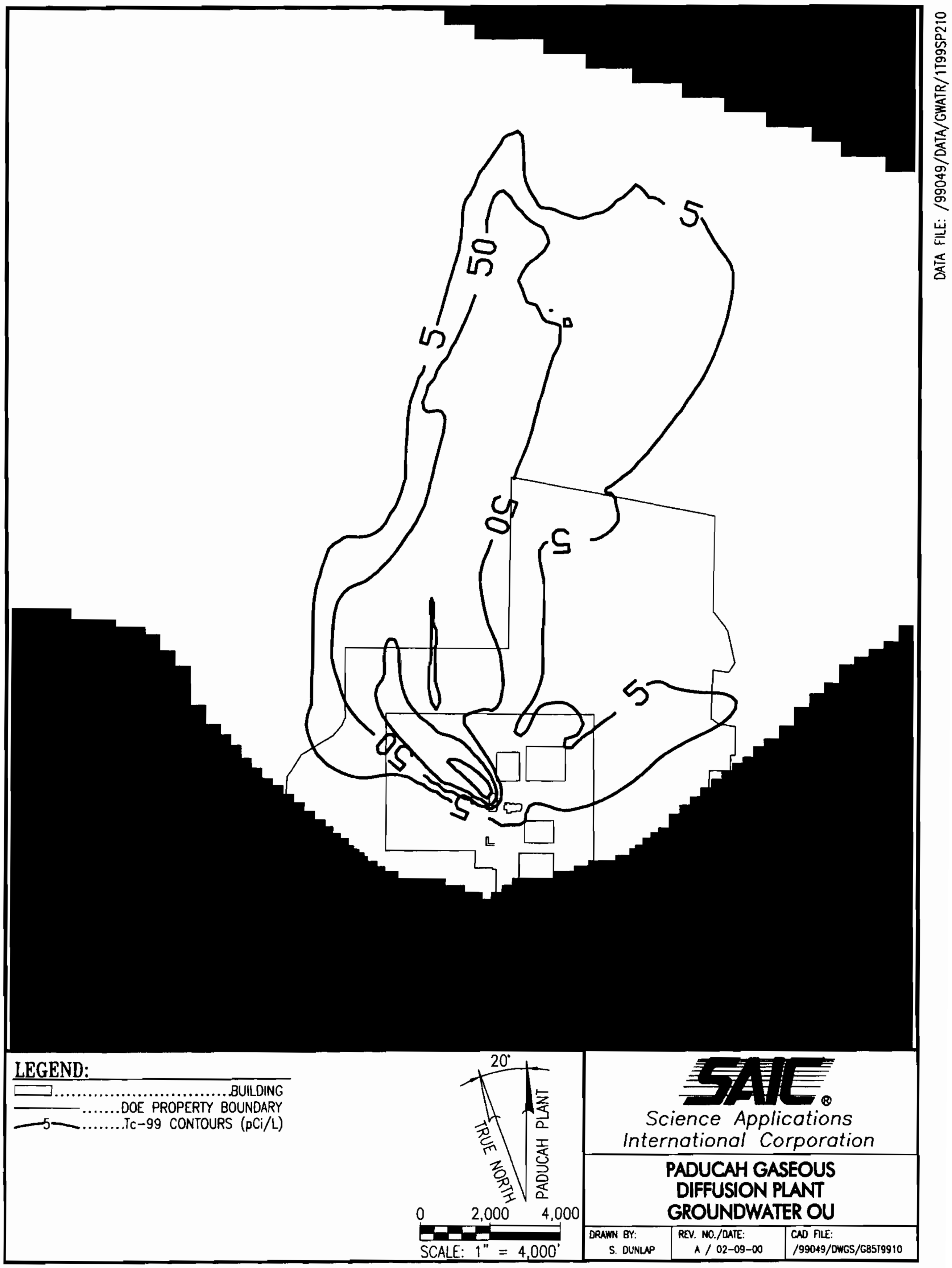

Fig. C1-9b. Predicted Tc-99 concentration contours in pCi/L at the end of 10-year simulation period for the No Action Alternative (1T99SP2) at the PGDP, Paducah, Kentucky.

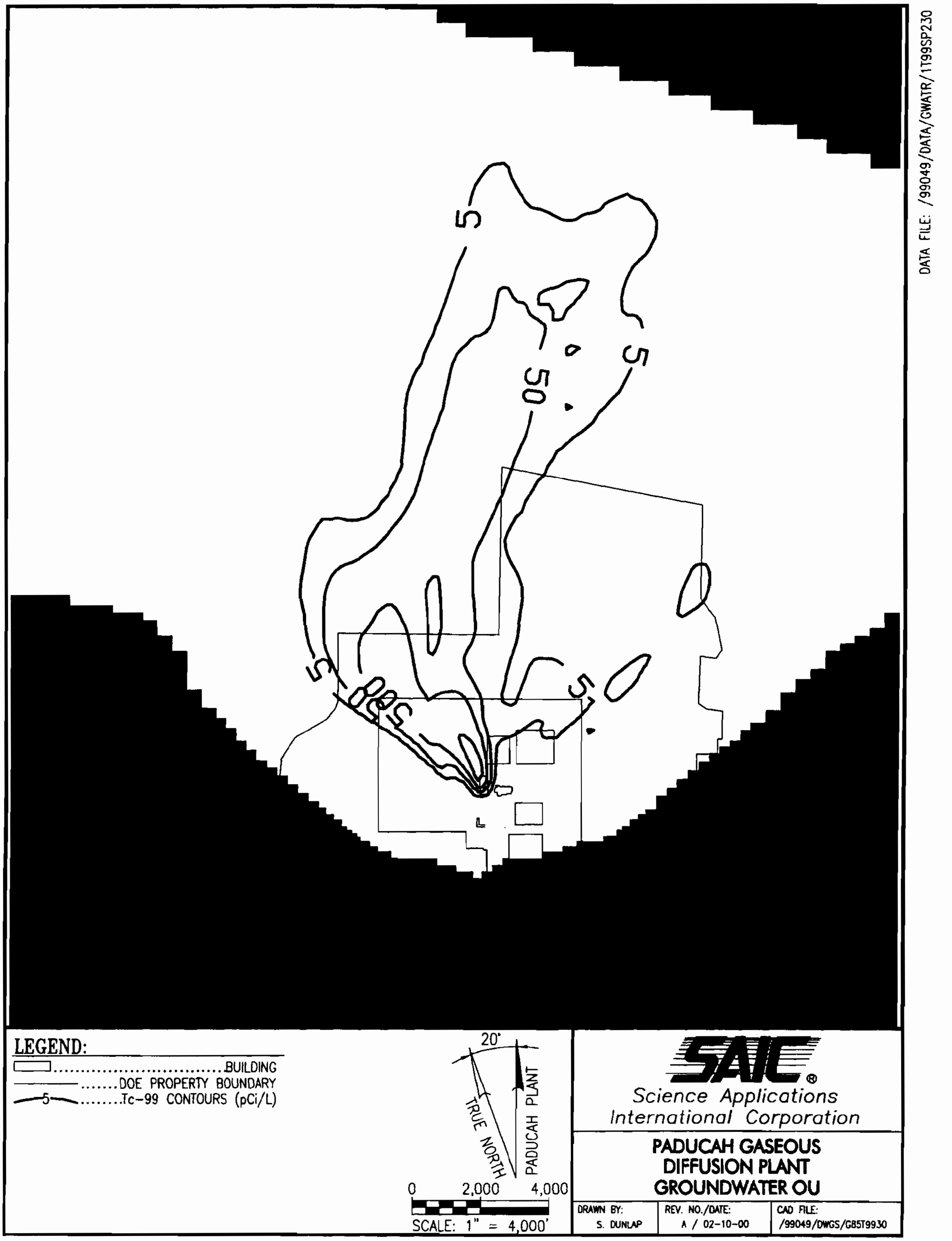

Fig. C1-9c. Predicted Tc-99 concentration contours in pCi/L at the end of 30-year simulation period for the No Action Alternative (1T99SP2) at the PGDP, Paducah Kentucky.

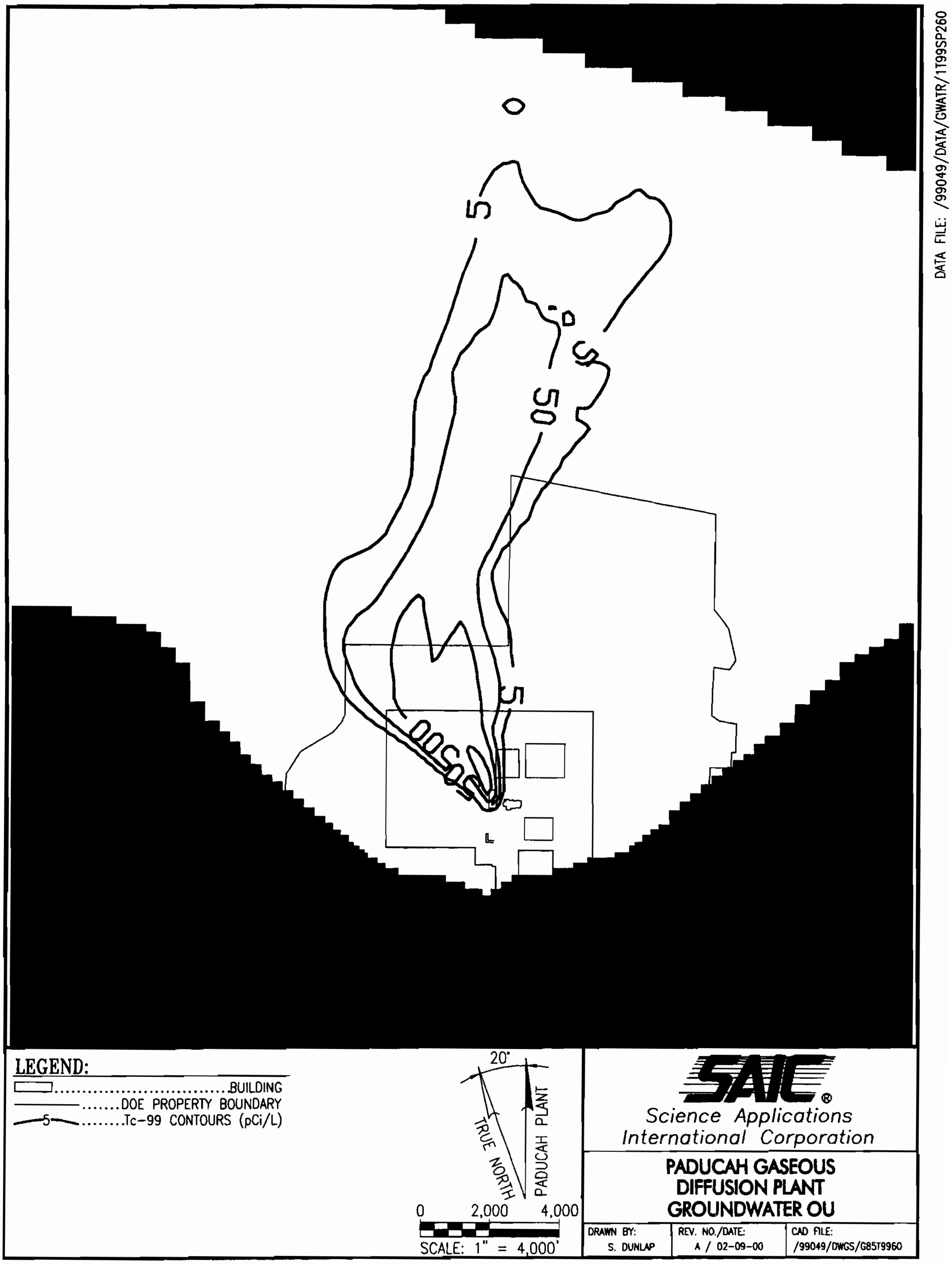

Fig. C1-9d. Predicted Tc-99 concentration contours in pCi/L at the end of 60-year simulation period for the No Action Alternative (1T99SP2) at the PGDP, Paducah Kentucky.

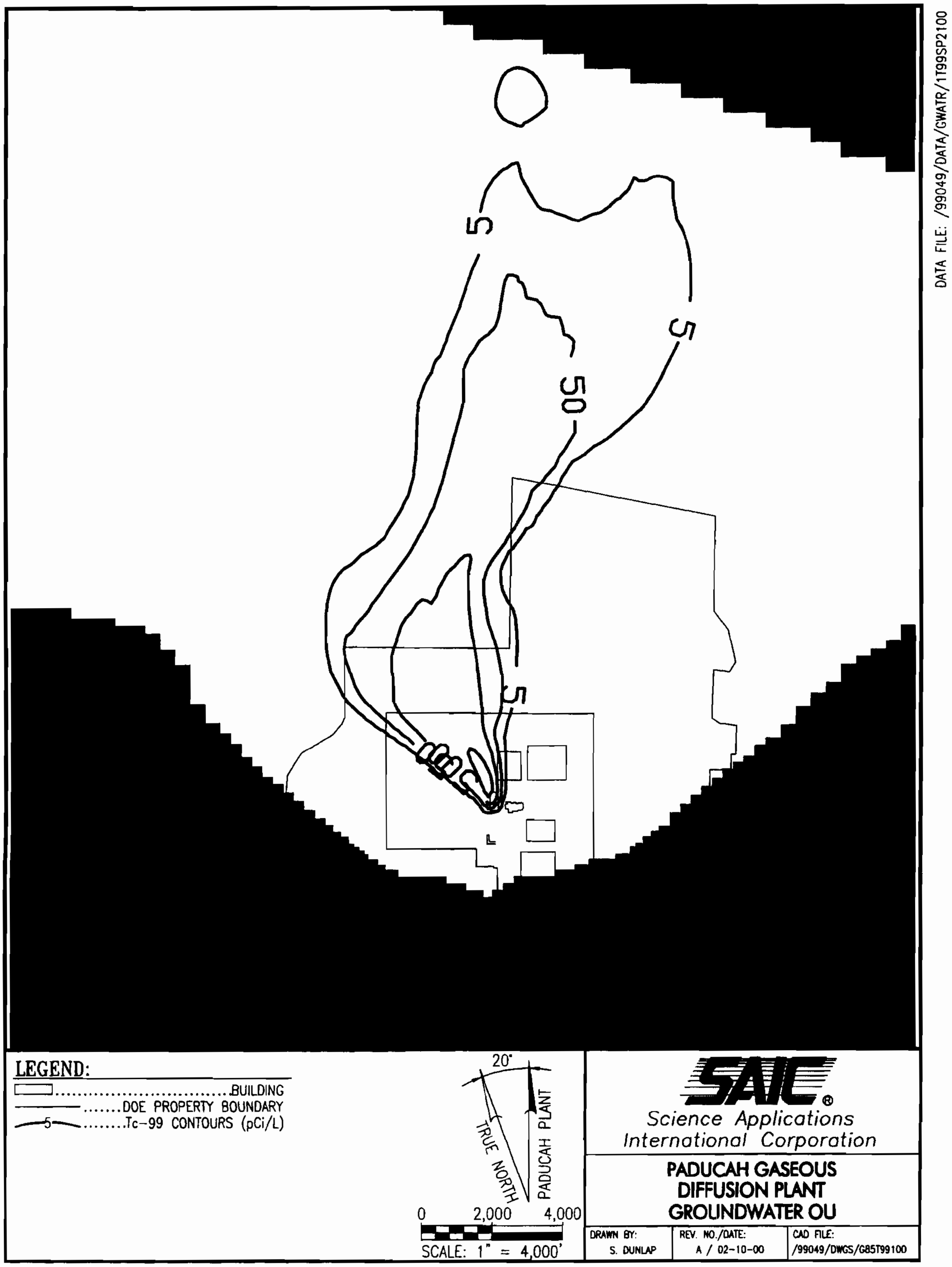

Fig. C1-9e. Predicted Tc-99 concentration contours in pCi/L at the end of 100-year simulation period for the No Action Alternative (1T99SP2) at the PGDP, Paducah Kentucky.

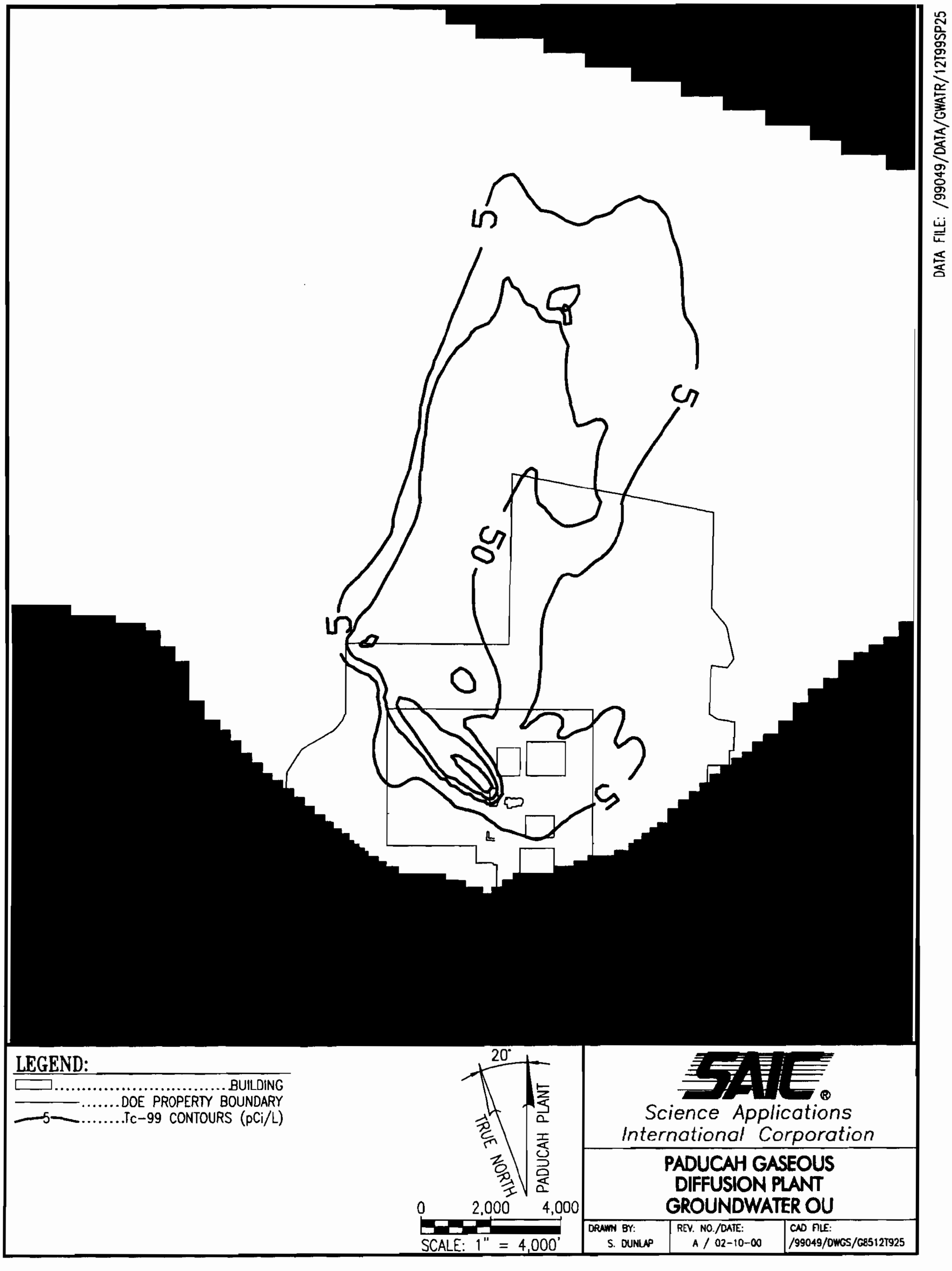

Fig. C1-10a. Predicted Tc-99 concentration contours in pCi/L at the end of 5-year simulation period for the No Action Alternative with NW/NE Wells pumping (12T99SP2) at the PGDP, Paducah, Kentucky.

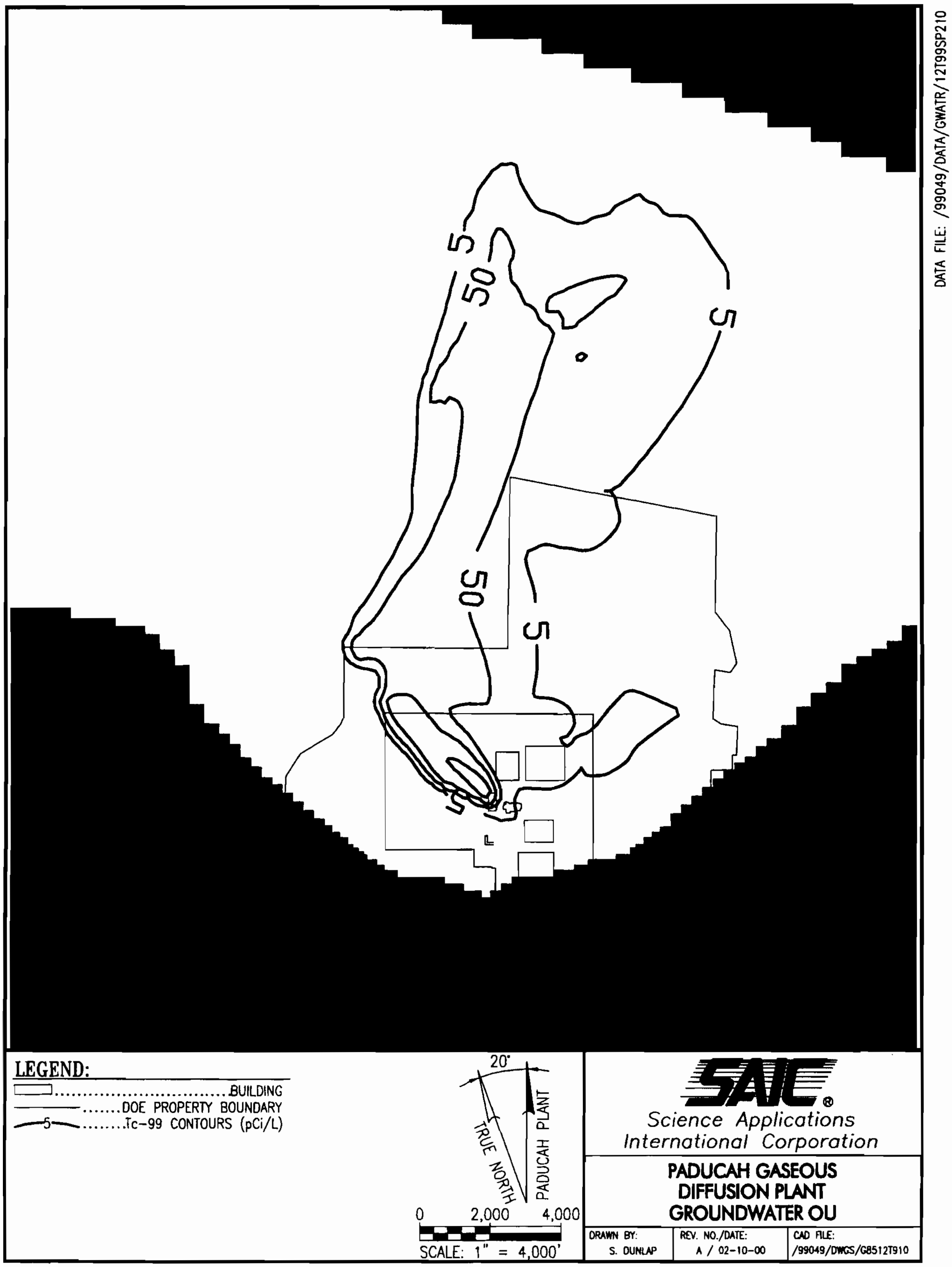

Fig. C1-10b. Predicted Tc-99 concentration contours in pCi/L at the end of 10-year simulation period for the No Action Alternative with NW/NE Wells pumping (12T99SP2) at the PGDP, Paducah, Kentucky.

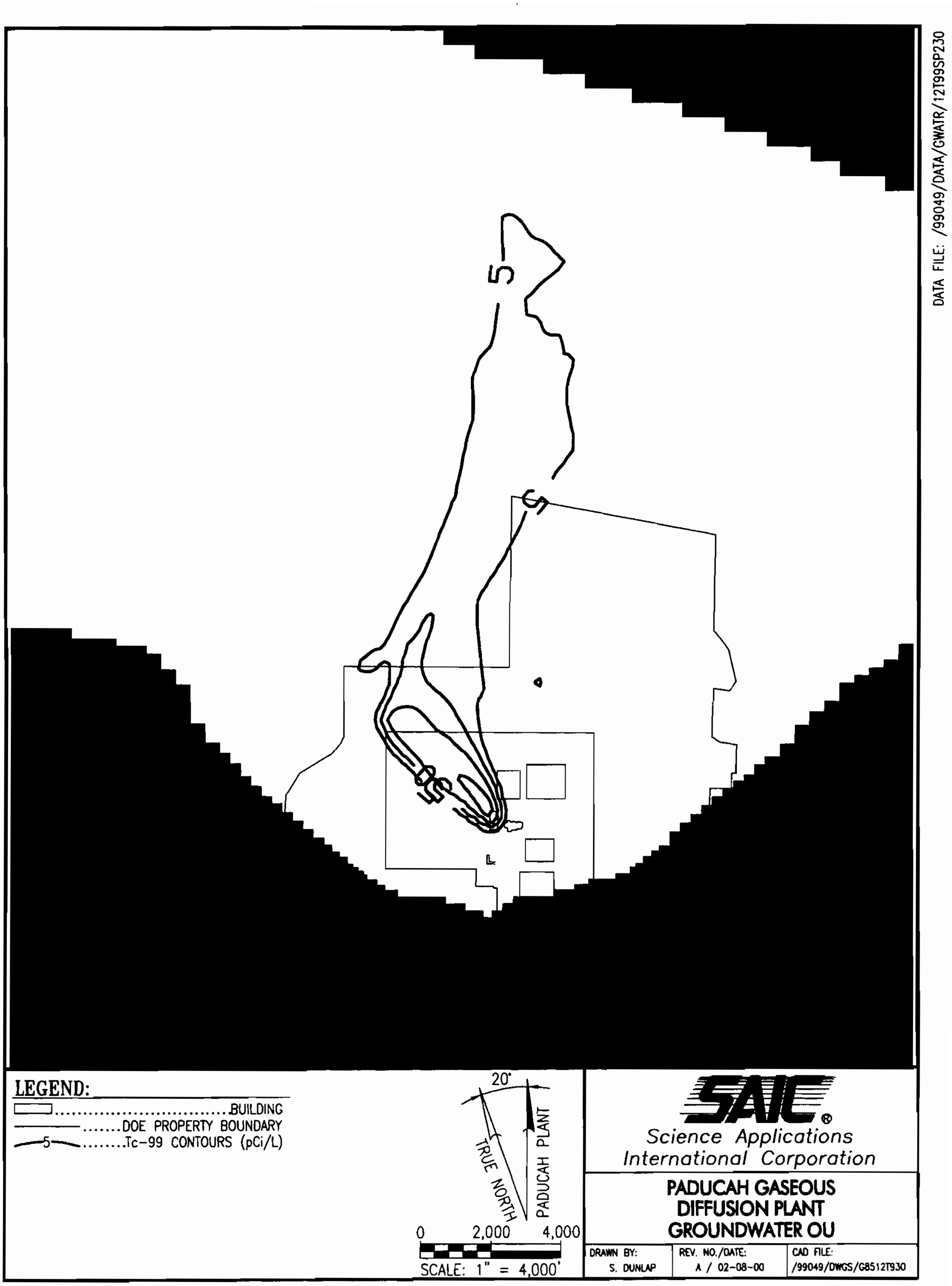

Fig. C1-10c. Predicted Tc-99 concentration contours in pCi/L at the end of 30-year simulation period for the No Action Alternative with NW/NE Wells pumping (12T99SP2) at the PGDP, Paducah, Kentucky.

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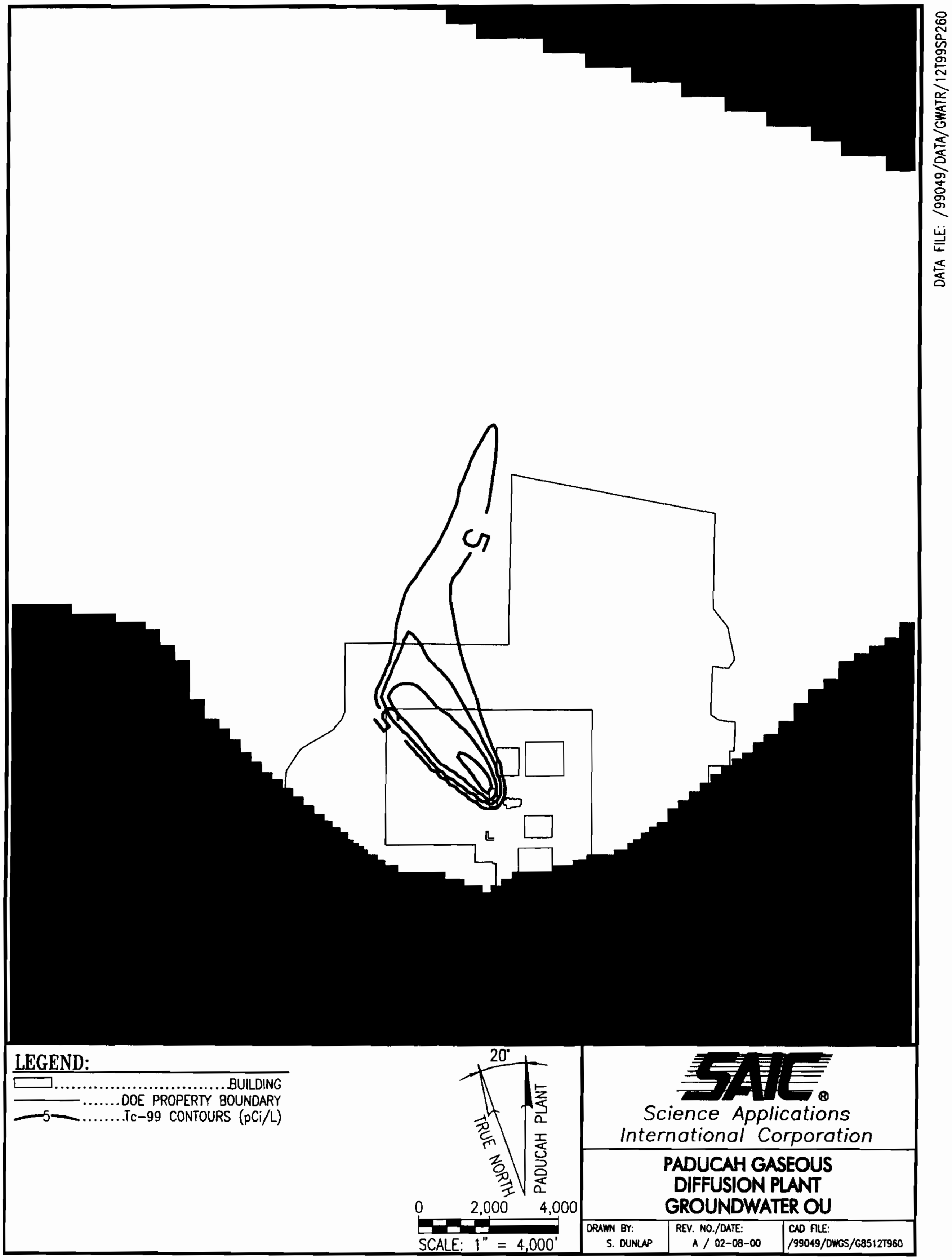

Fig. C1-10d. Predicted Tc-99 concentration contours in pCi/L at the end of 60-year simulation period for the No Action Alternative with NW/NE Wells pumping (12T99SP2) at the PGDP, Paducah, Kentucky.

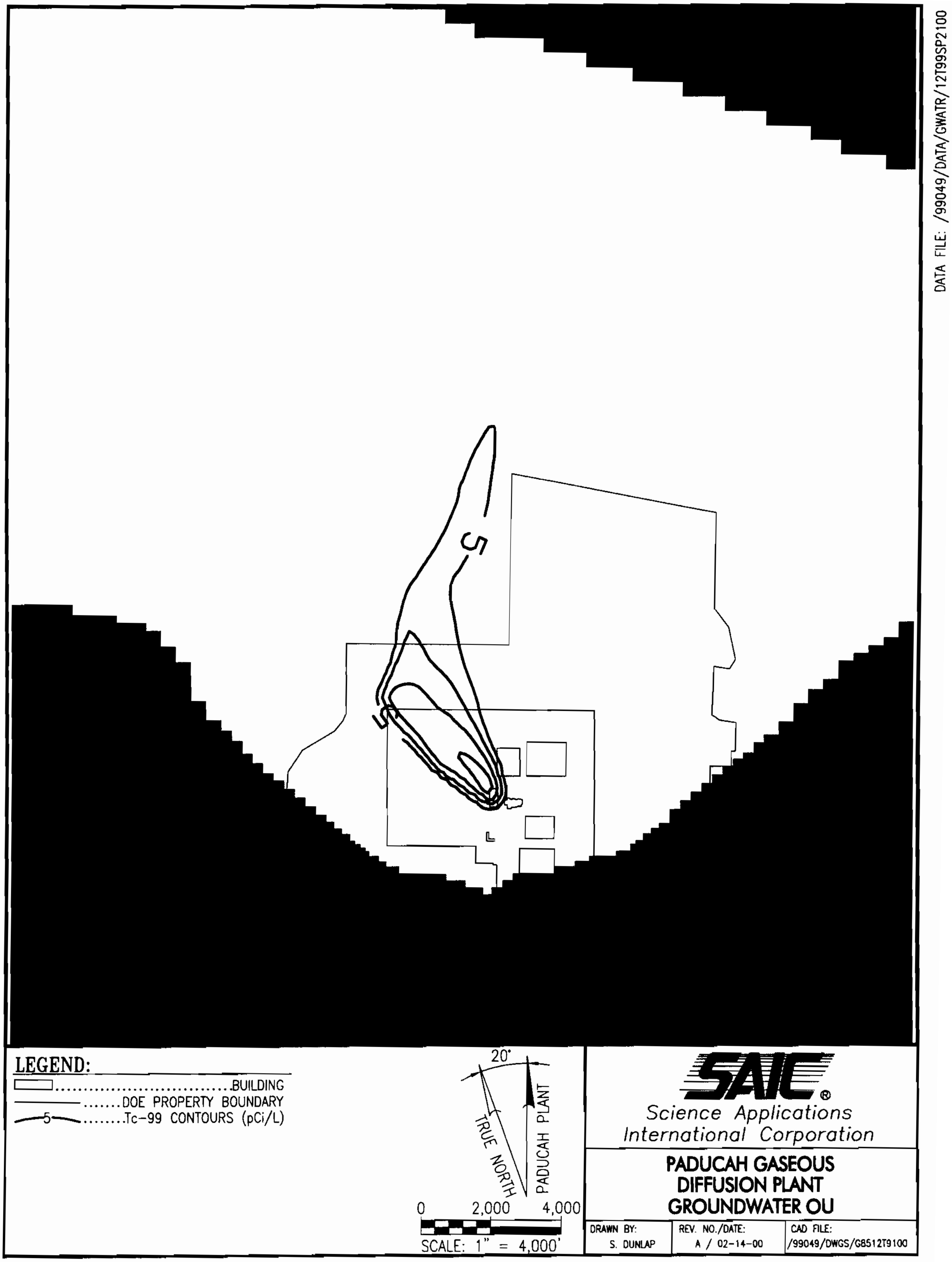

Fig. C1-10e. Predicted Tc-99 concentration contours in pCi/L at the end of 100-year simulation period for the No Action Alternative with NW/NE Wells pumping (12T99SP2) at the PGDP, Paducah, Kentucky.

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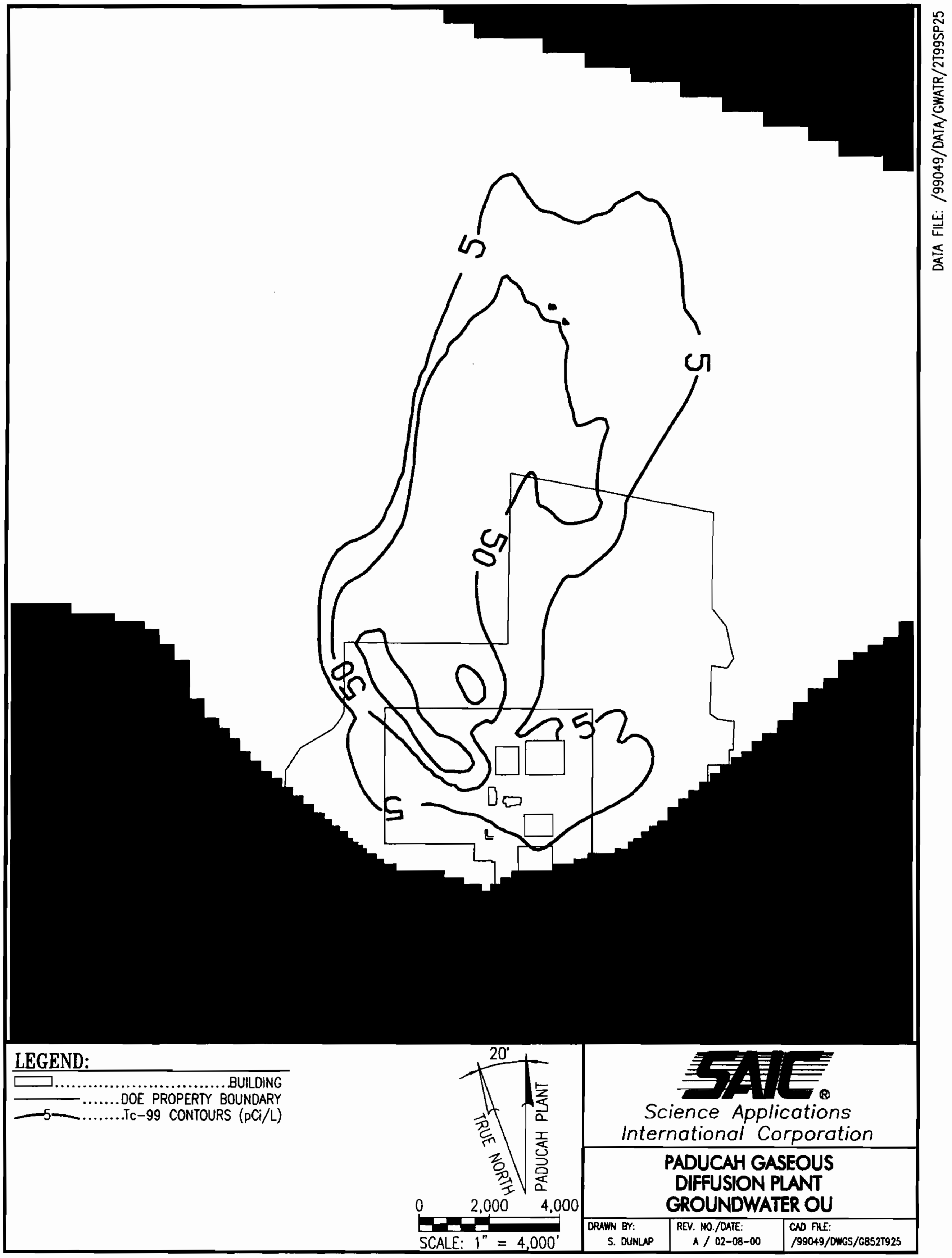

Fig. C1-11a. Predicted Tc-99 concentration contours in pCi/L at the end of 5-year simulation period for the Source Containment Alternative (12T99SP2) at the PGDP, Paducah, Kentucky.

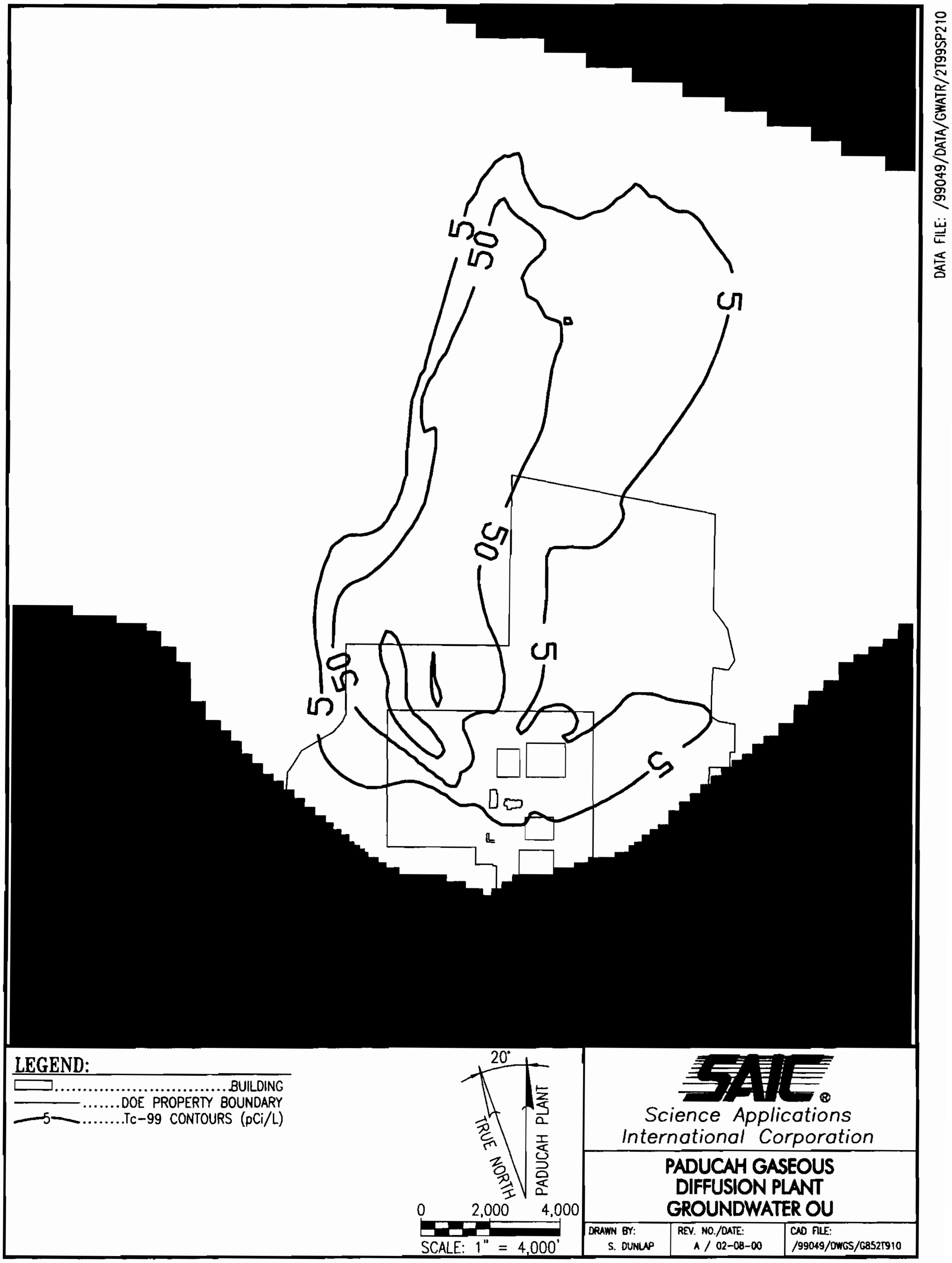

Fig. C1-11b. Predicted Tc-99 concentration contours in pCi/L at the end of 10-year simulation period for the Source Containment Alternative (2T99SP2) at the PGDP, Paducah, Kentucky.

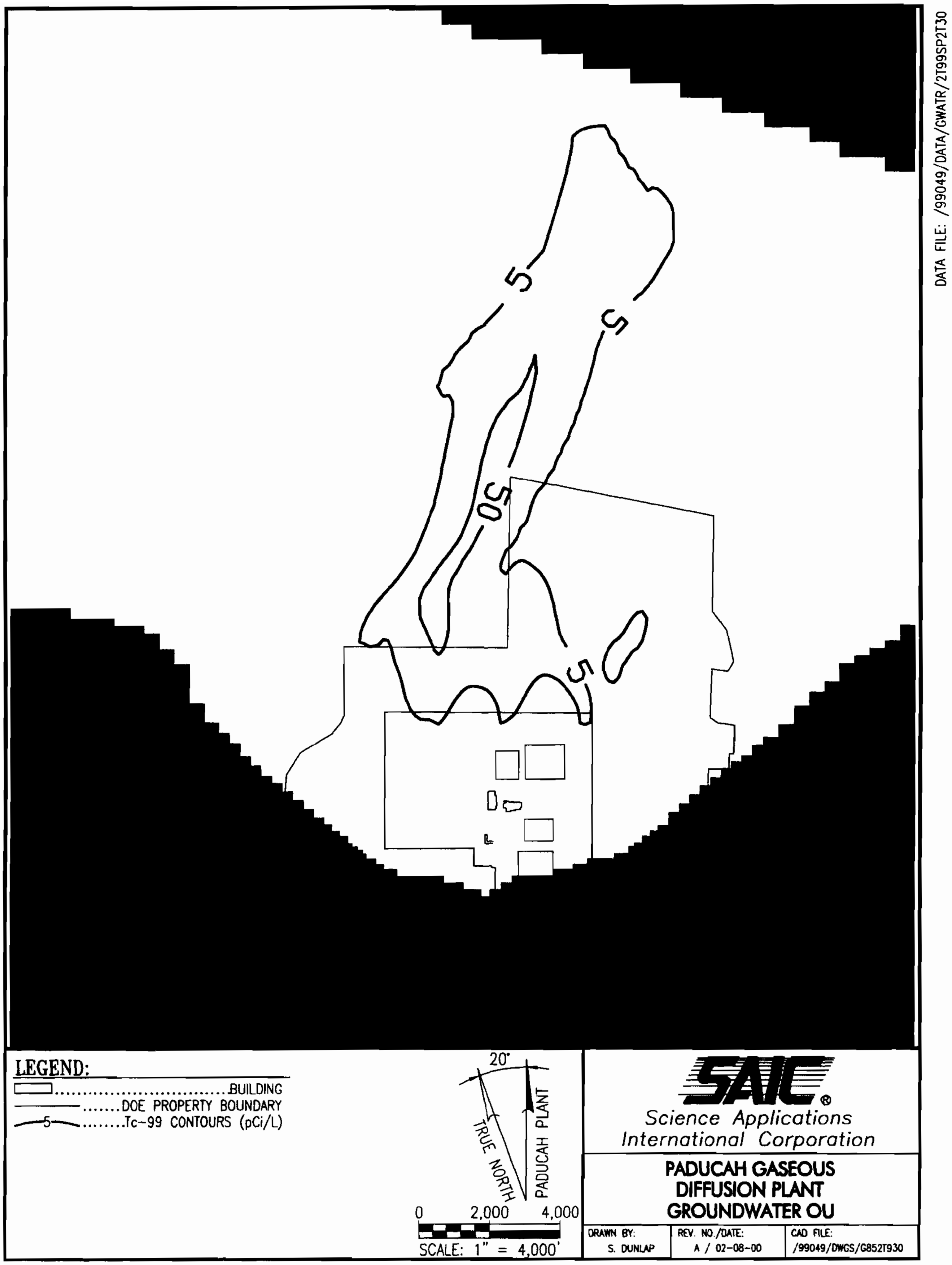

Fig. C1-11c. Predicted Tc-99 concentration contours in pCi/L at the end of 30-year simulation period for the Source Containment Alternative (2T99SP2) at the PGDP, Paducah, Kentucky.

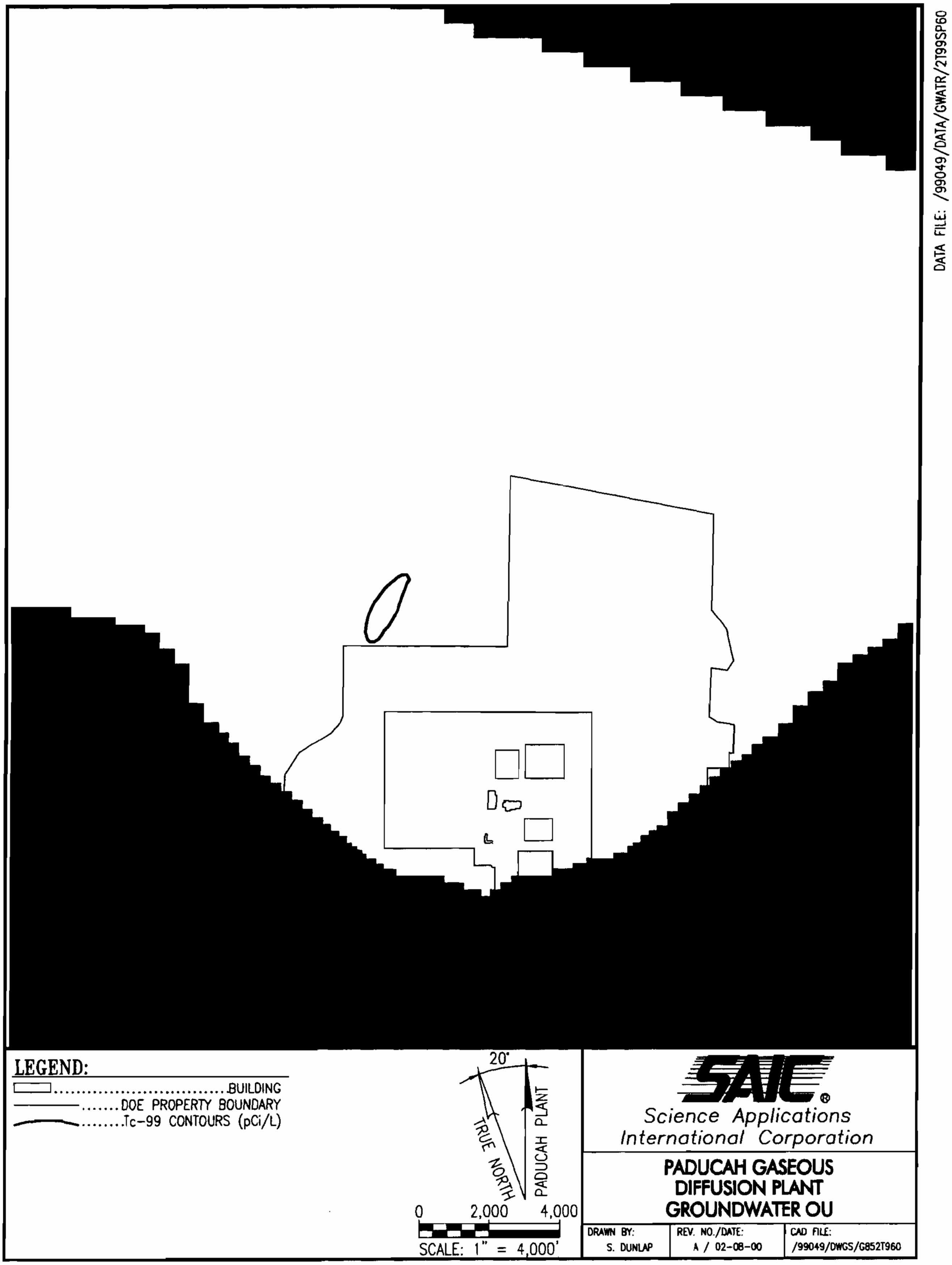

Fig. C1-11d. Predicted Tc-99 concentration contours in pCi/L at the end of 60-year simulation period for the Source Containment Alternative (2T99SP2) at the PGDP, Paducah, Kentucky.

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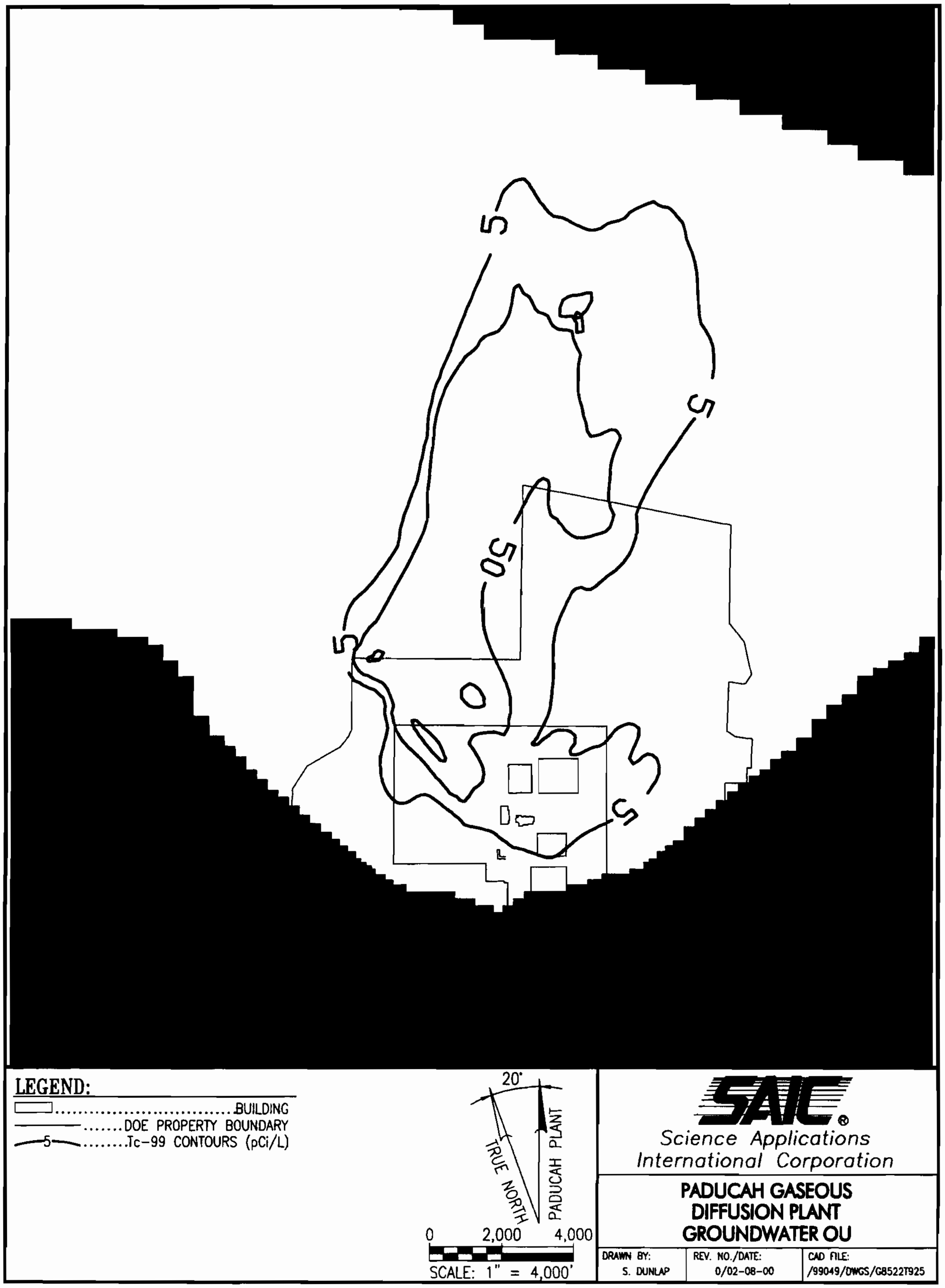

Fig. C1-12a. Predicted Tc-99 concentration contours in pCi/L at the end of 5-year simulation period for the Source Containment Alternative with NW/NE Wells pumping (22T99SP2) at the PGDP, Paducah, Kentucky.

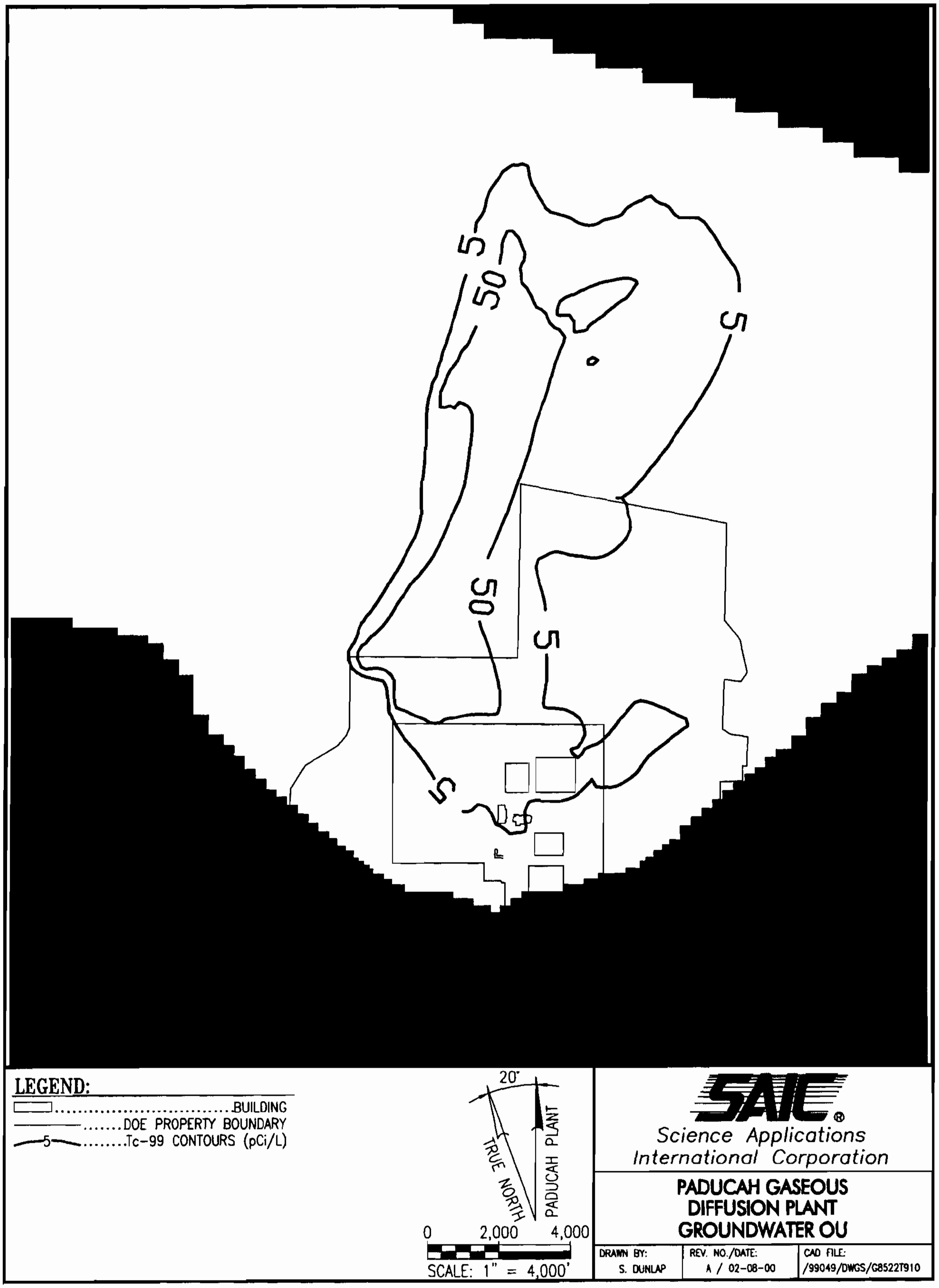

Fig. C1-12b. Predicted Tc-99 concentration contours in pCi/L at the end of 10-year simulation period for the Source Containment Alternative with NW/NE Wells pumping (22T99SP2) at the PGDP, Paducah, Kentucky.

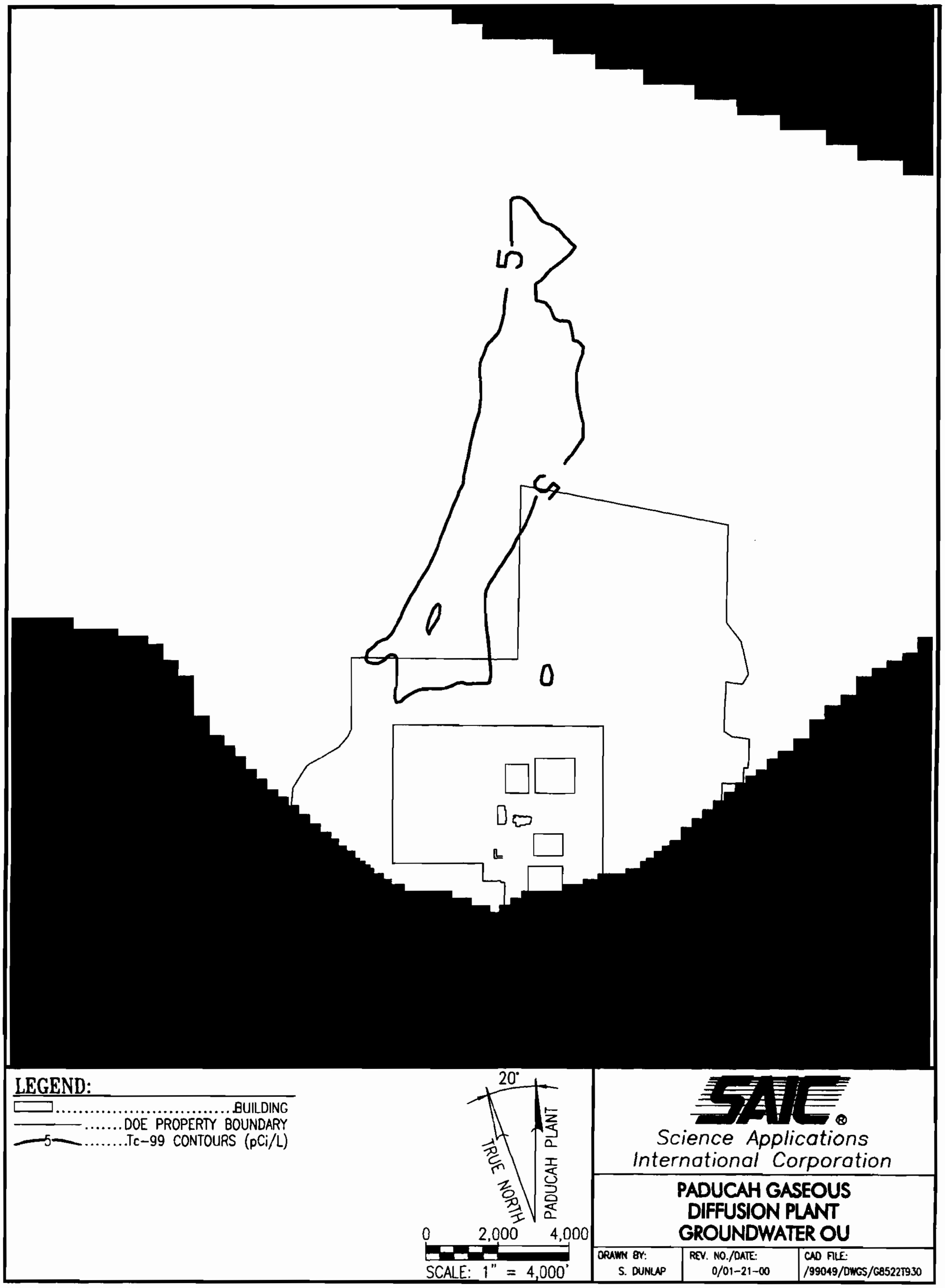

Fig. C1-12c. Predicted Tc-99 concentration contours in pCi/L at the end of 30-year simulation period for the Source Containment Alternative with NW/NE Wells pumping (22T99SP2) at the PGDP, Paducah, Kentucky.

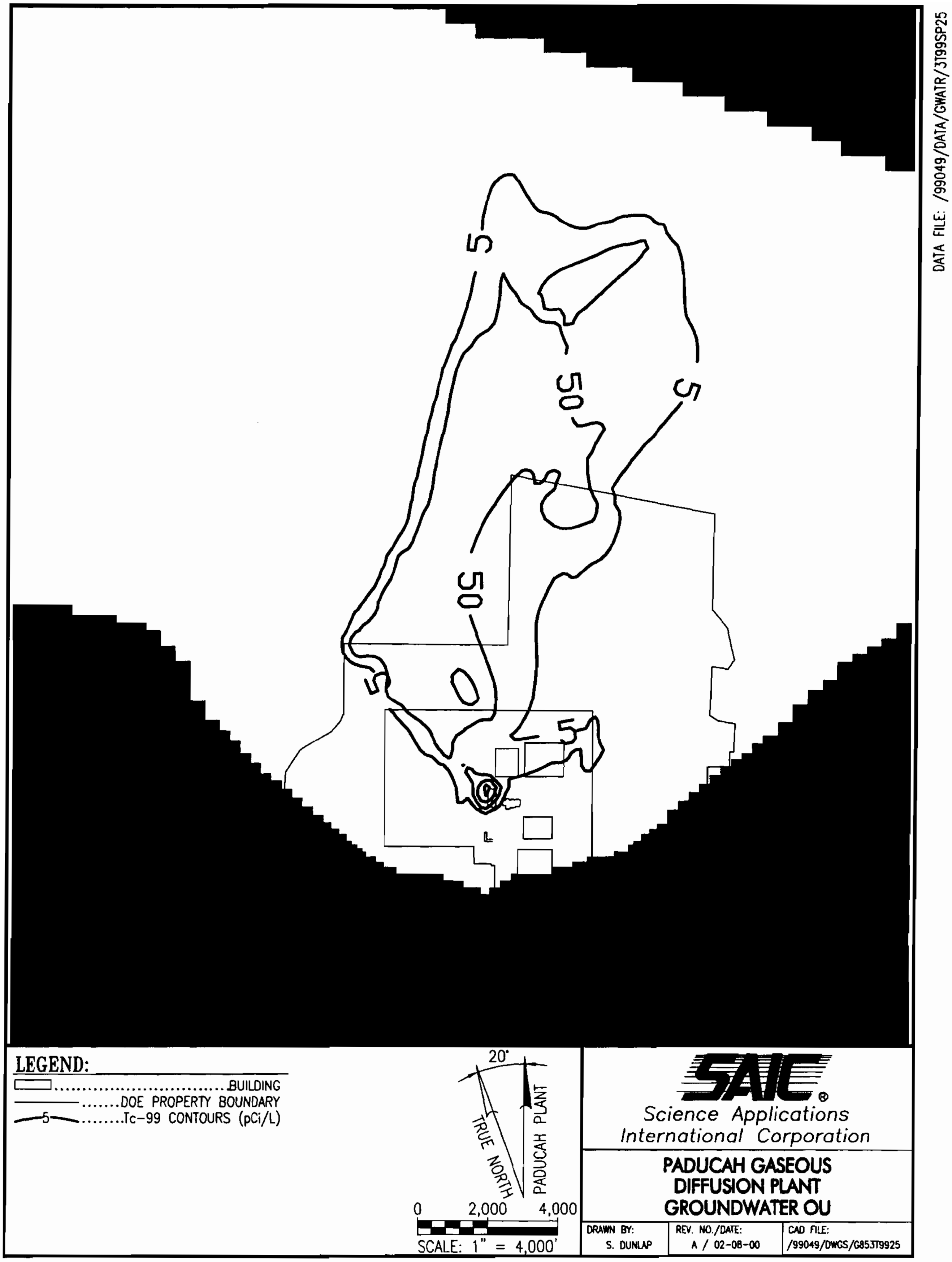

Fig. C1-13a. Predicted Tc-99 concentration contours in pCi/L at the end of 5-year simulation period for the Pump and Treat Alternative (3T99SP2) at the PGDP, Paducah, Kentucky.

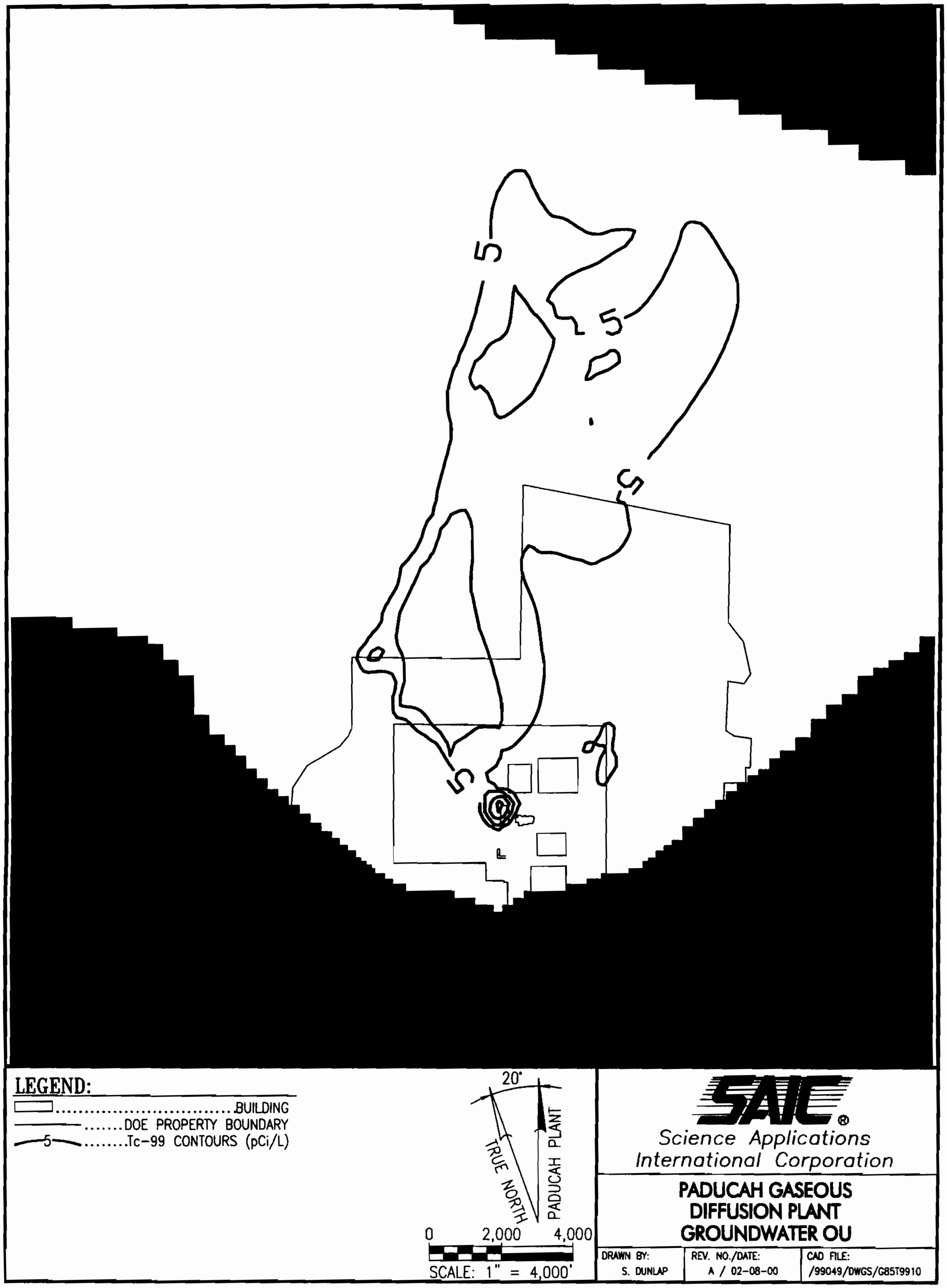

Fig. C1-13b. Predicted Tc-99 concentration contours in pCi/L at the end of 10-year simulation period for the Pump and Treat Alternative (3T99SP2) at the PGDP, Paducah, Kentucky.

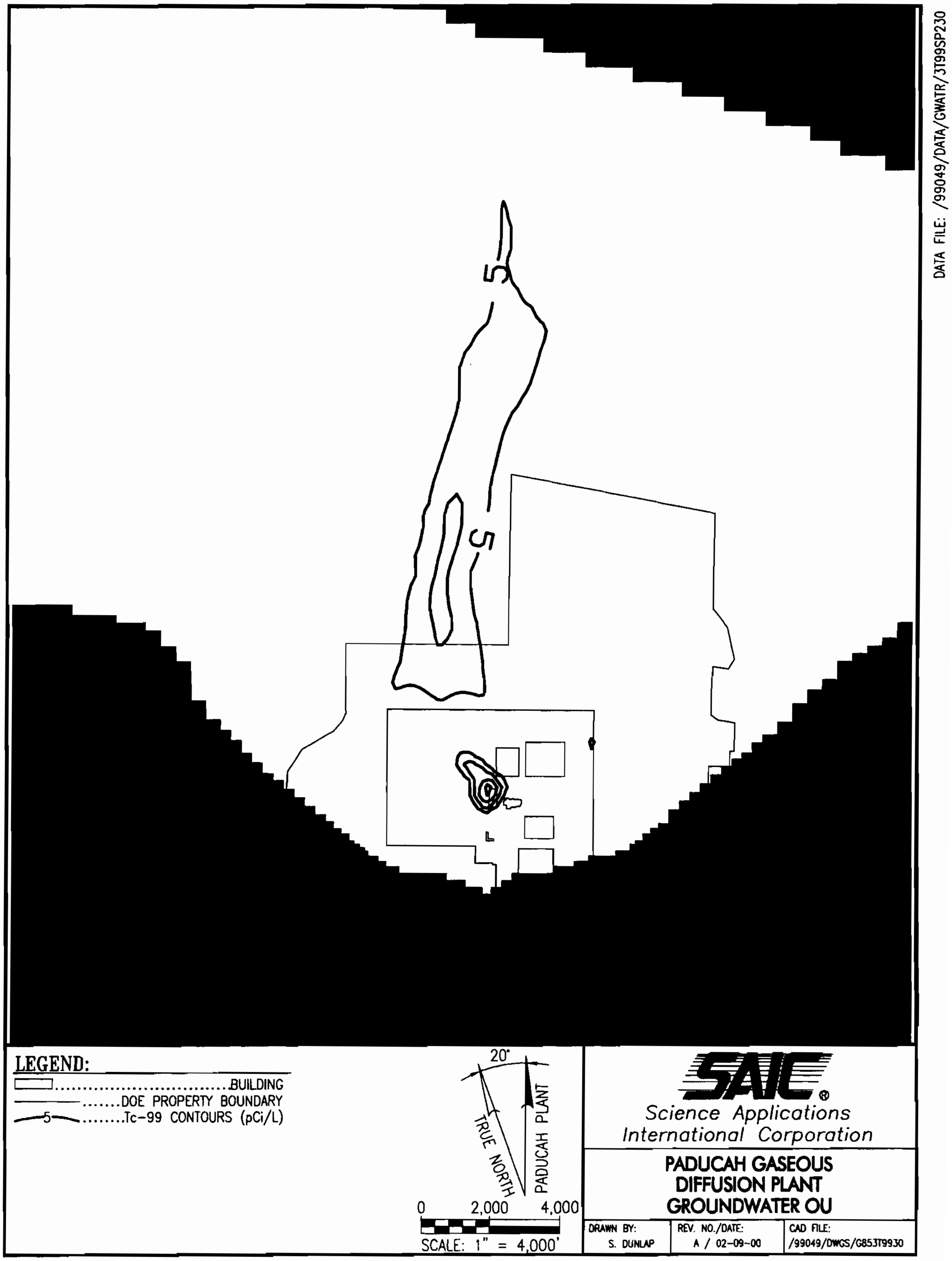

Fig. C1-13c. Predicted Tc-99 concentration contours in pCi/L at the end of 30-year simulation period for the Pump and Treat Alternative (3T99SP2) at the PGDP, Paducah, Kentucky.

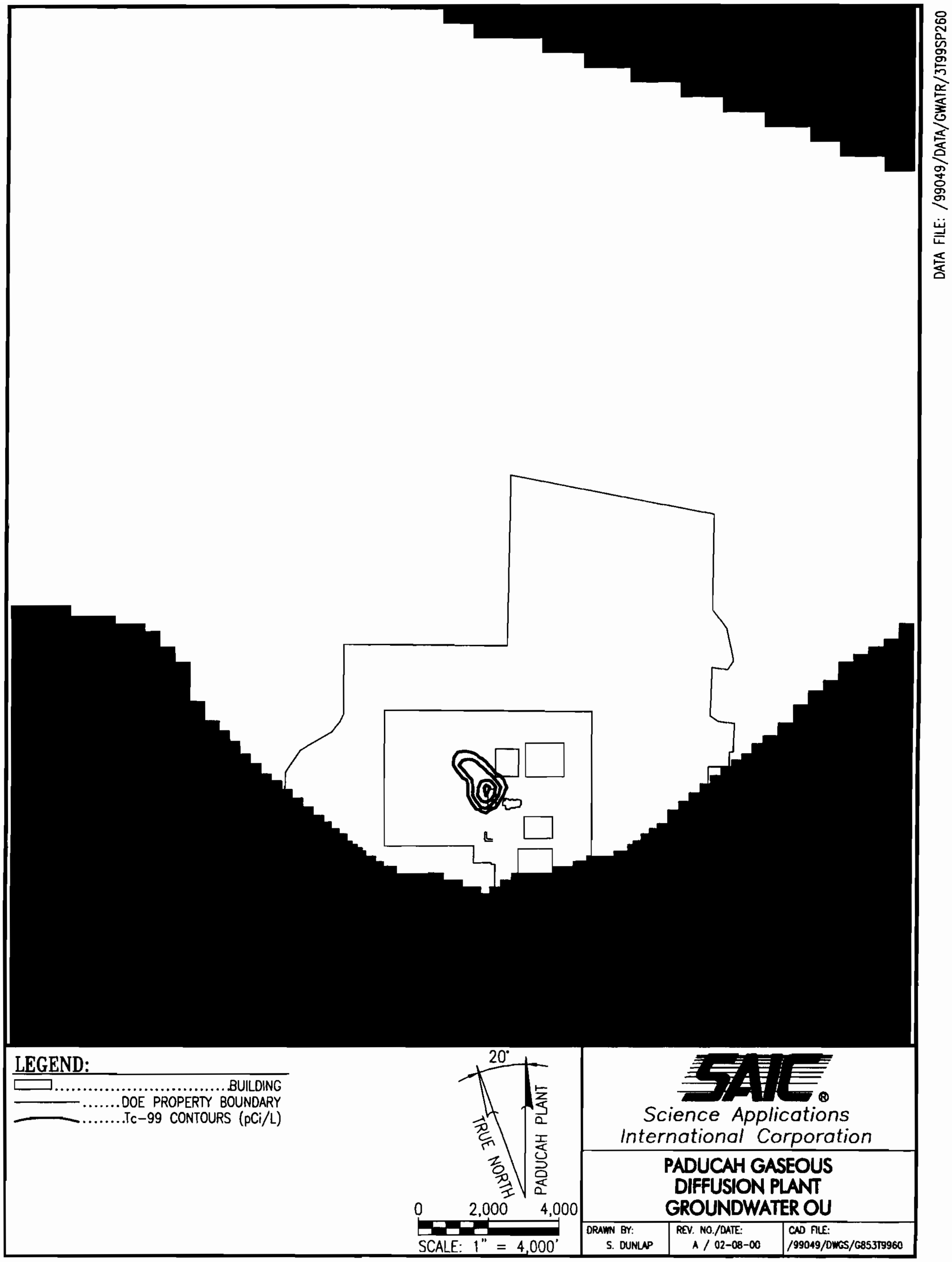

Fig. C1-13d. Predicted Tc-99 concentration contours in pCi/L at the end of 60-year simulation period for the Pump and Treat Alternative (3T99SP2) at the PGDP, Paducah, Kentucky.

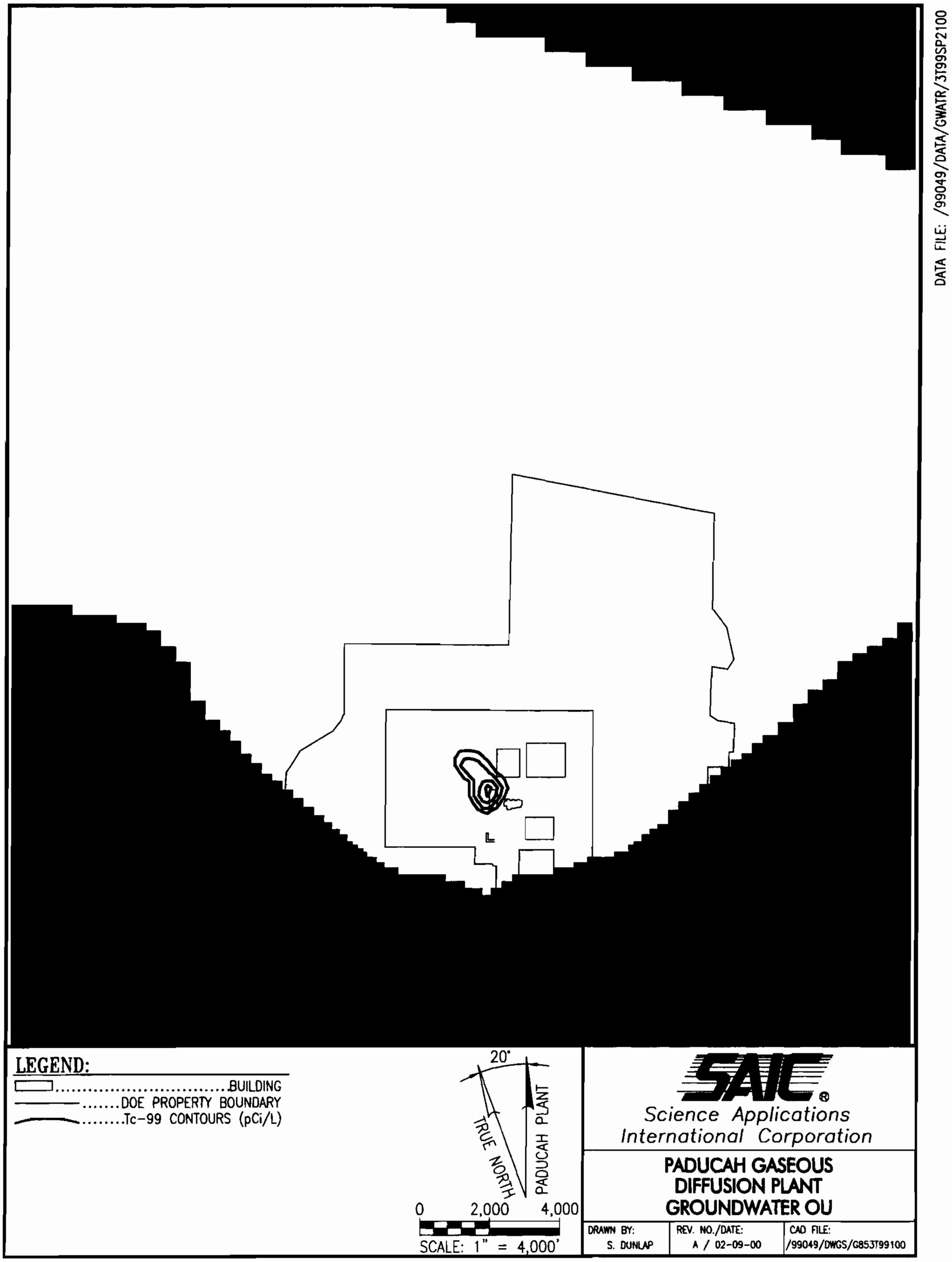

Fig. C1-13e. Predicted Tc-99 concentration contours in pCi/L at the end of 100-year simulation period for the Pump and Treat Alternative (3T99SP2) at the PGDP, Paducah, Kentucky.

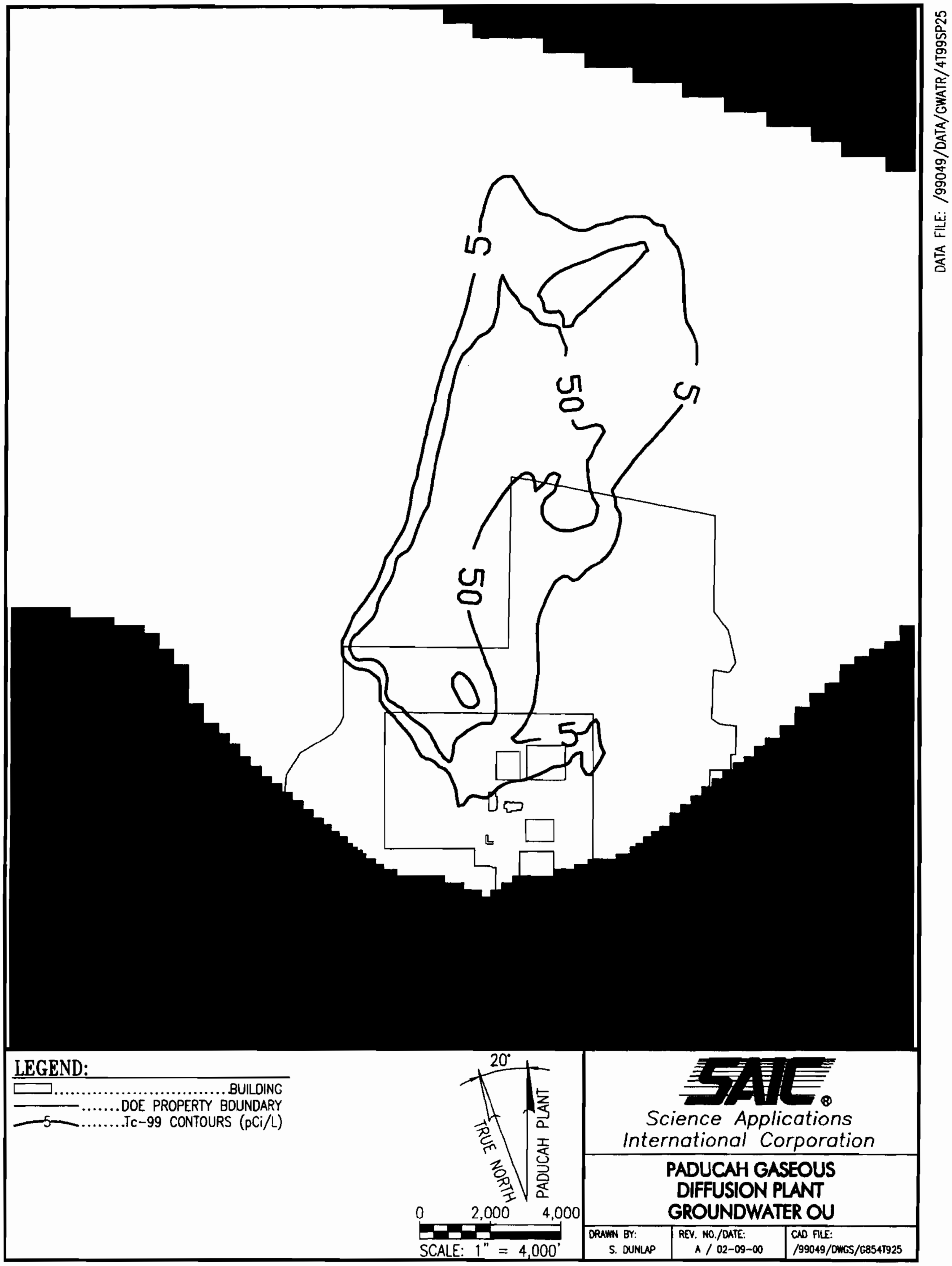

Fig. C1-14a. Predicted Tc-99 concentration contours in pCi/L at the end of 5-year simulation period for the Source Containment Alternative with Pump and Treat (4T99SP2) at the PGDP, Paducah, Kentucky.

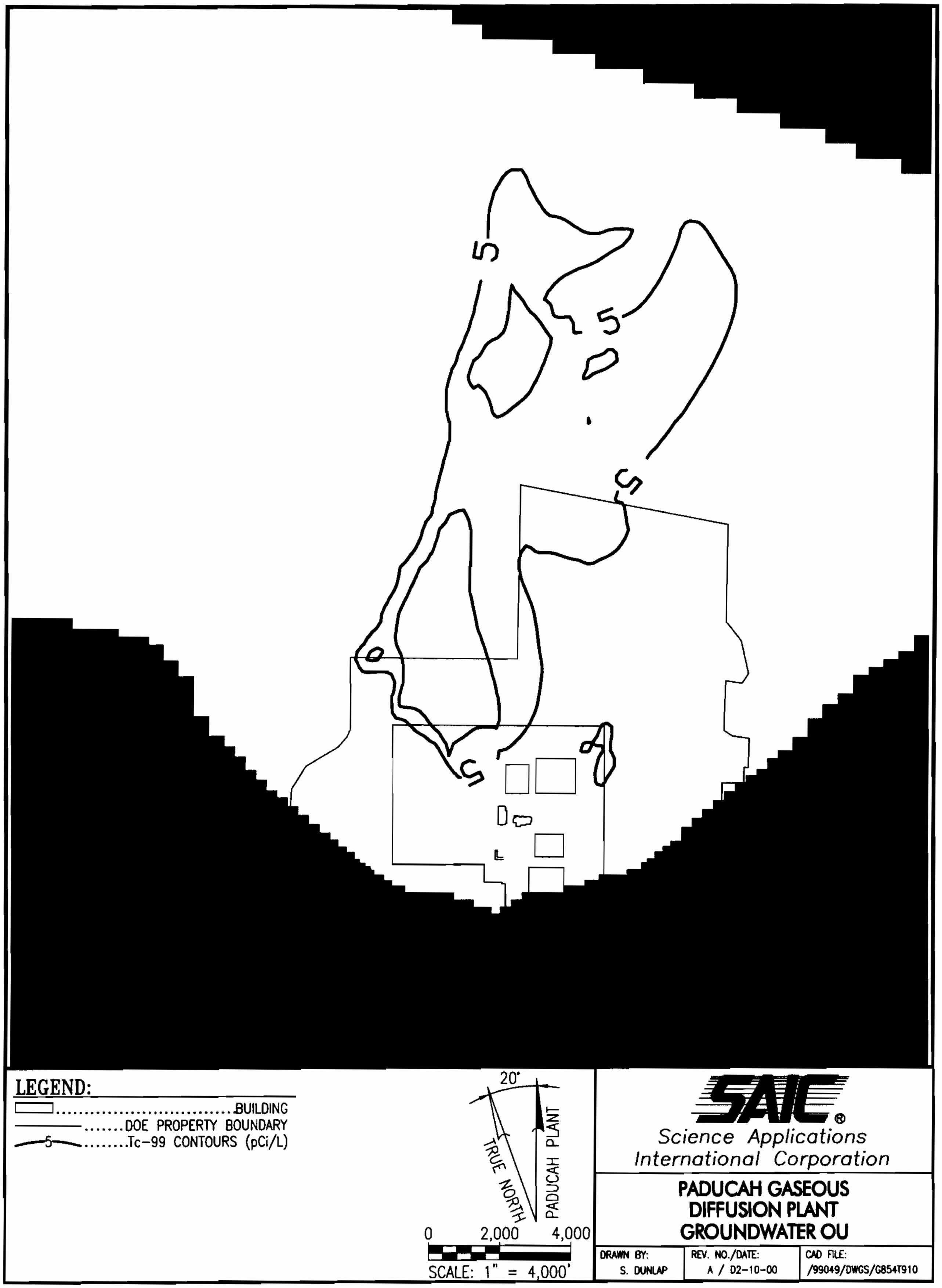

Fig. C1-14b. Predicted Tc-99 concentration contours in pCi/L at the end of 10-year simulation period for the Source Containment Alternative (4T99SP2) at the PGDP, Paducah, Kentucky.

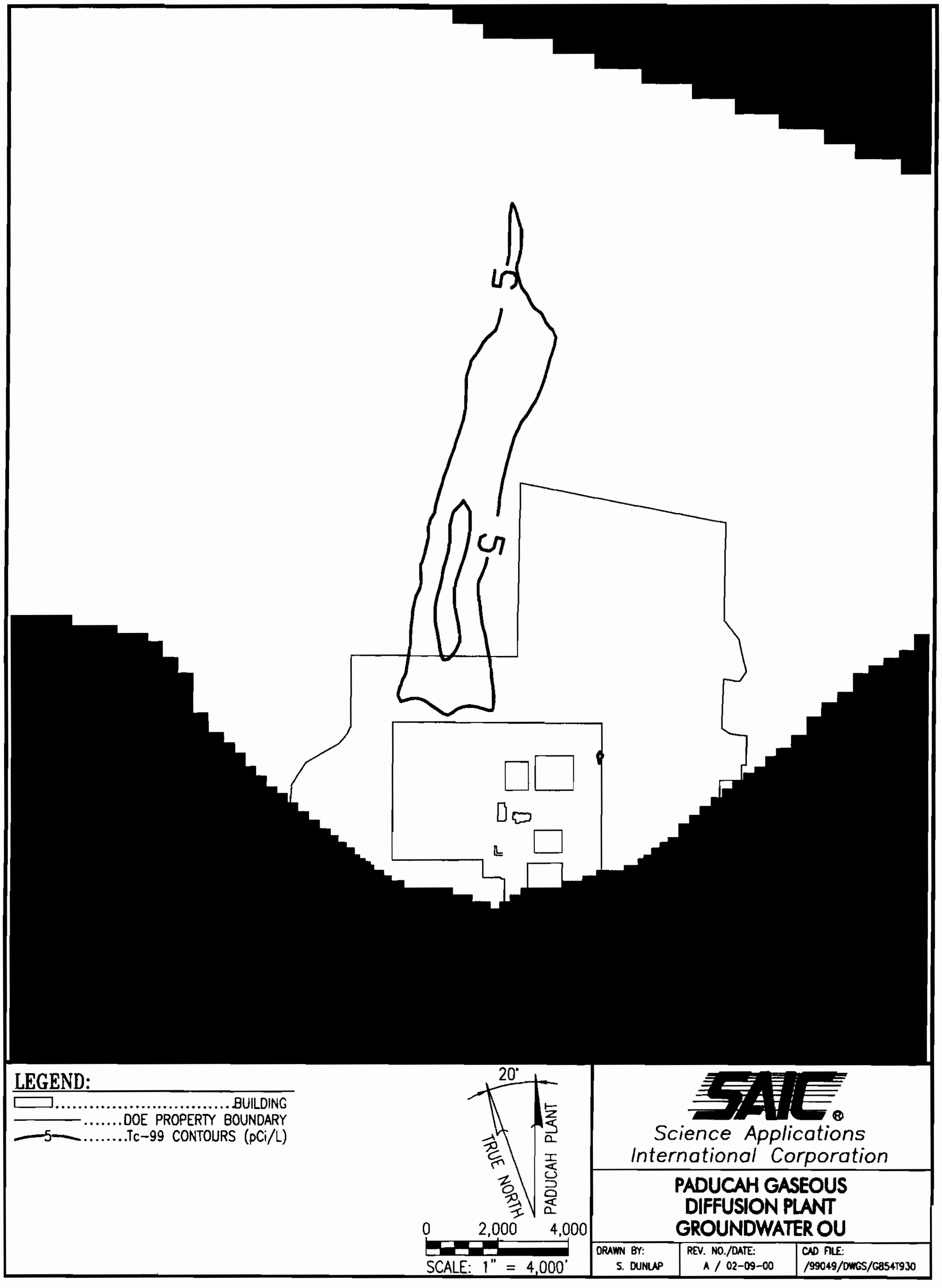

Fig. C1-14c. Predicted Tc-99 concentration contours in pCi/L at the end of 30-year simulation period for the Source Containment Alternative with Pump and Treat (4T99SP2) at the PGDP, Paducah, Kentucky.

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McDonald and Harbaugh, 1988. McDonald, M.G., and A.W. Harbaugh, "A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model," *Techniques of Water-Resources Investigations*, Book 6, Chapter A1, United States Geological Survey, Reston, VA, 1988.

APPENDIX C2

INNOVATIVE TREATMENT & REMEDIATION DEMONSTRATION

Paducah Groundwater Project Innovative Technology Review

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ABSTRACT

Groundwater plumes containing trichloroethylene (TCE) and technetium-99 (Tc-99) have been found at the Paducah Gaseous Diffusion Plant site in Paducah, Kentucky. The Innovative Treatment and Remediation Demonstration Program (ITRD) Technical Advisory Group (TAG) was tasked with assisting in the investigation of treatment options for remediating the source area and the plume inside of the site boundary to prevent further contaminant off-site migration. The TAG's charter did not include investigation of treatment options for the off-site portion of the plume.

Technologies were examined for their applicability to treatment of the Upper Continental Recharge System (UCRS) and the Regional Groundwater Aquifer (RGA). Technology and materials for fence-line reactive barriers were also investigated. For the UCRS, the technologies rated highest by the TAG were Rotary Treatment (including rotary steam) in areas where infrastructure would not preclude its use, Chemical Oxidation or Ozone Treatment with Soil Fracturing, Direct Heating, and Soil Vapor Extraction with Soil Fracturing. For the RGA, the

technologies rated highest were Chemical Oxidation using the C-Sparge method for circulating ozone, Direct Heating, Steam/DUS/HPO, and Chemical Oxidation using Permanganate. For the fence-line reactive barrier, the highest rated technologies were Zero Valent Iron in a passive wall and C-Sparge recirculating wells.

In addition to making technology recommendations, the TAG also recommended the performance of pilot studies to collect cost and performance data related to selected technologies. The TAG recommended a pilot study using C-Sparge in the RGA with ion exchange resin placed in the well to test its ability to remove Tc-99 around Building C-752A. The TAG also recommended a pilot study of Six Phase Heating in the UCRS and RGA southeast of building C-400.

Acknowledgment

The authors thank members of the Paducah project Technical Advisory Group for their contributions to the technology review effort and to the writing of this report.

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Paducah Groundwater Project Innovative Technology Review

1. INTRODUCTION

This document discusses the efforts of the Paducah Project ITRD Technical Advisory Group to identify and assess technologies capable of enhancing and accelerating the remediation of chlorinated solvent and radionuclide contamination, specifically trichloroethene (TCE) and technetium-99 (Tc-99) at the Paducah Gaseous Diffusion Plant. TCE and Tc-99 levels of up to 10 mg/L and 1000 pCi/L, respectively, have been identified in the groundwater at the DOE property boundaries. Drinking water standards are 5 μg/L for TCE and 900 pCi/L for Tc-99. Based on a review of the site contamination, site conditions, and the remediation goals of the Paducah ER Program, potentially applicable technologies were considered for detailed evaluation, treatability studies, engineering evaluation and cost and performance analysis.

The criteria used to screen technologies included; cost and ease of implementation, technology maturity and appropriateness, life-cycle costs and overall cost-effectiveness, ability to reduce the contaminants of concern to regulatory levels at identified points of compliance, compatibility with existing site constraints and existing treatment systems, stakeholder considerations, and regulatory permitting issues. The TAG identified and reviewed approximately thirty technologies that might be applicable to remediation of the TCE and Tc-99 contamination at Paducah. The technology categories considered included: *in situ* treatment of contaminated low-permeability soils in both the saturated and vadose zones; in situ treatment of contaminated groundwater; and in situ treatment of high-permeability saturated soils and gravel. The general maturity, cost, and performance characteristics of the technologies identified as they apply to Paducah are reviewed in detail in the following sections. Based on this information, the most promising technologies were further assessed through engineering evaluations with several technology vendors. These assessments were reviewed by the TAG and used to identify the most appropriate technologies and strategies for implementation at Paducah.

2. SITE INFORMATION

The DOE's Paducah Gaseous Diffusion Plant (PGDP) is an active uranium enrichment plant located on approximately 3556 acres in western Kentucky along the Ohio River, of which 748 acres are located inside a fenced security area. Enrichment operations at the plant began in 1952, and became fully operational in 1955. Plant operations included the generation and disposal of both hazardous and radioactive wastes. Several areas associated with these past operations and disposal practices at the plant have contributed to soil and groundwater contamination that has migrated over a mile off-site (US DOE 1999).

Three large plumes of groundwater contamination have migrated outside the plant boundaries as shown in Figures 1 and 2. The primary contaminants in these plumes, TCE and Tc-99, have migrated down through the top sixty feet of low permeability silt and clay soil lenses in the Upper Continental Recharge System (UCRS) to contaminate a high permeability regional groundwater aquifer (RGA). The water table at the site is approximately 10-30 feet below the surface. Below the upper unit is an aerobic, high permeability, sandy-gravel aquifer that varies in thickness from about 30' to 60'. The hydraulic conductivity of the upper clay soils is about 0.01 to 0.28 ft/day while the hydraulic conductivity of the regional groundwater gravel varies from about 1 to 3 ft/day. Though contaminant concentrations in the aquifer vary widely (see Figures 1 and 2) TCE and Tc-99 levels of up to10,000 μg/L and 1000 pCi/L, respectively, have been identified at the DOE property boundaries. Drinking water standards are 5 μg/L for TCE and 900 pCi/L for Tc-99.

Because of the large extent of the contamination, the baseline remediation technology for the site is source removal in the C-400 area and the installation of reactive treatment zones at site boundaries. The original baseline technology was pump-and-treat. Assessment of a pump-and-treat system has shown that to contain the existing plumes and prevent additional off-site contaminant migration as much as 3000-4000 gallons per minute will have to be pumped. The capital and operating costs associated with this large a system are high. The ITRD project was established to help identify ways to accelerate the remediation of the site while significantly reducing overall remediation costs.

3. INITIAL REVIEW OF INNOVATIVE TECHNOLOGIES

The initial Paducah ITRD Project meeting was held on February 10-11, 1999 in Paducah, Kentucky. Twenty-seven participants representing the DOE, national laboratories, EPA laboratories, State of Kentucky regulators, Paducah site management and integrating contractor, and U.S. EPA Region IV attended this initial meeting. Technical presentations covered the history of the site and the Groundwater Operable Unit, the hydrologic setting, the contaminants of concern and their concentrations, site accessibility issues, and baseline technologies. A site tour of the facility was also conducted. The twenty nine technologies identified at this meeting, listed in Table 1, address characterization, treatment of the contaminated soil, the groundwater, or a combination of the two, and improvements to the baseline pump-and-treat system. Contact persons on the TAG were charged with obtaining additional information on each technology listed.

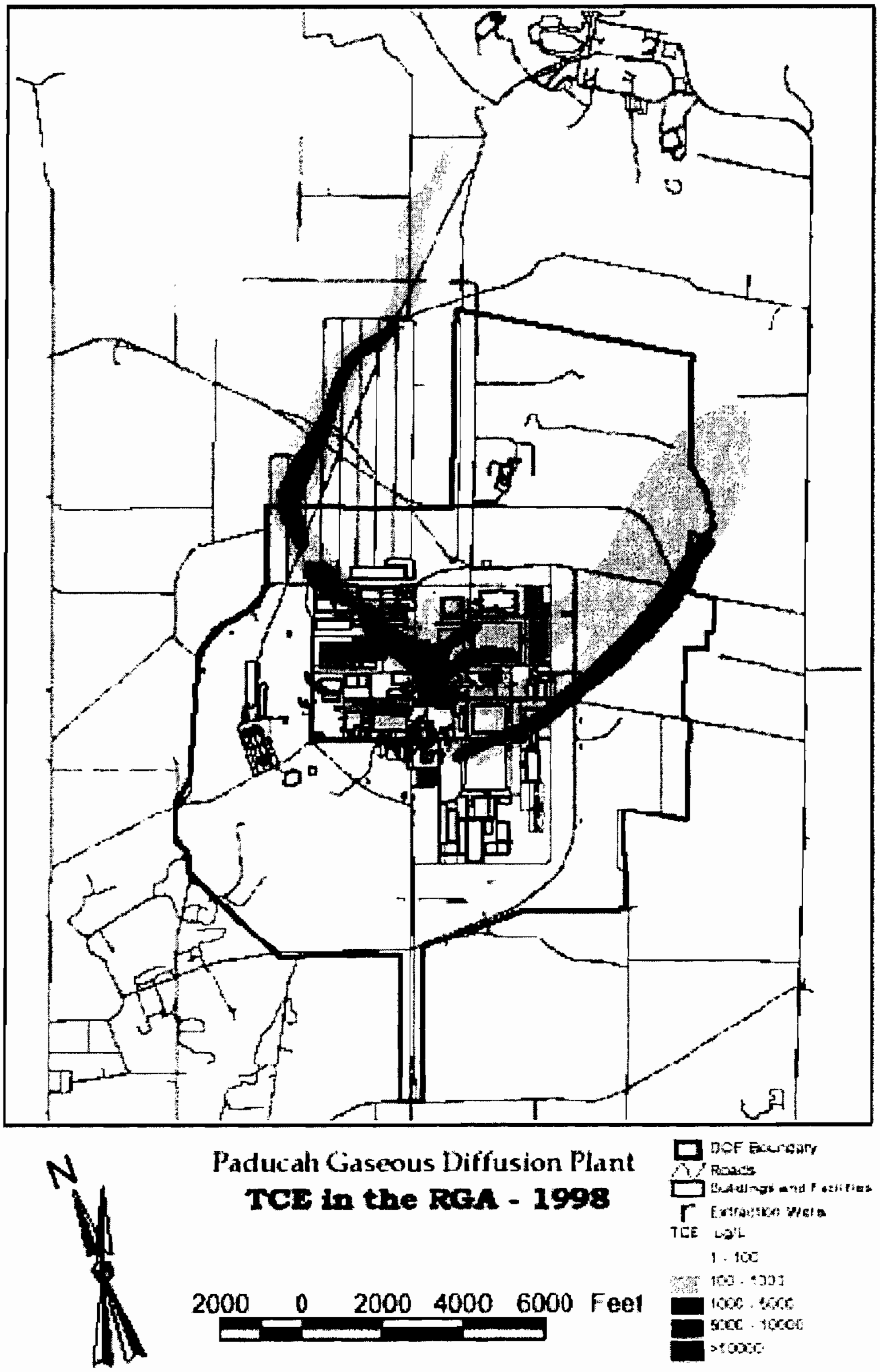

Figure 1. Trichlorethene Contamination in Groundwater at the Paducah Gaseous Diffusion Plant[1]

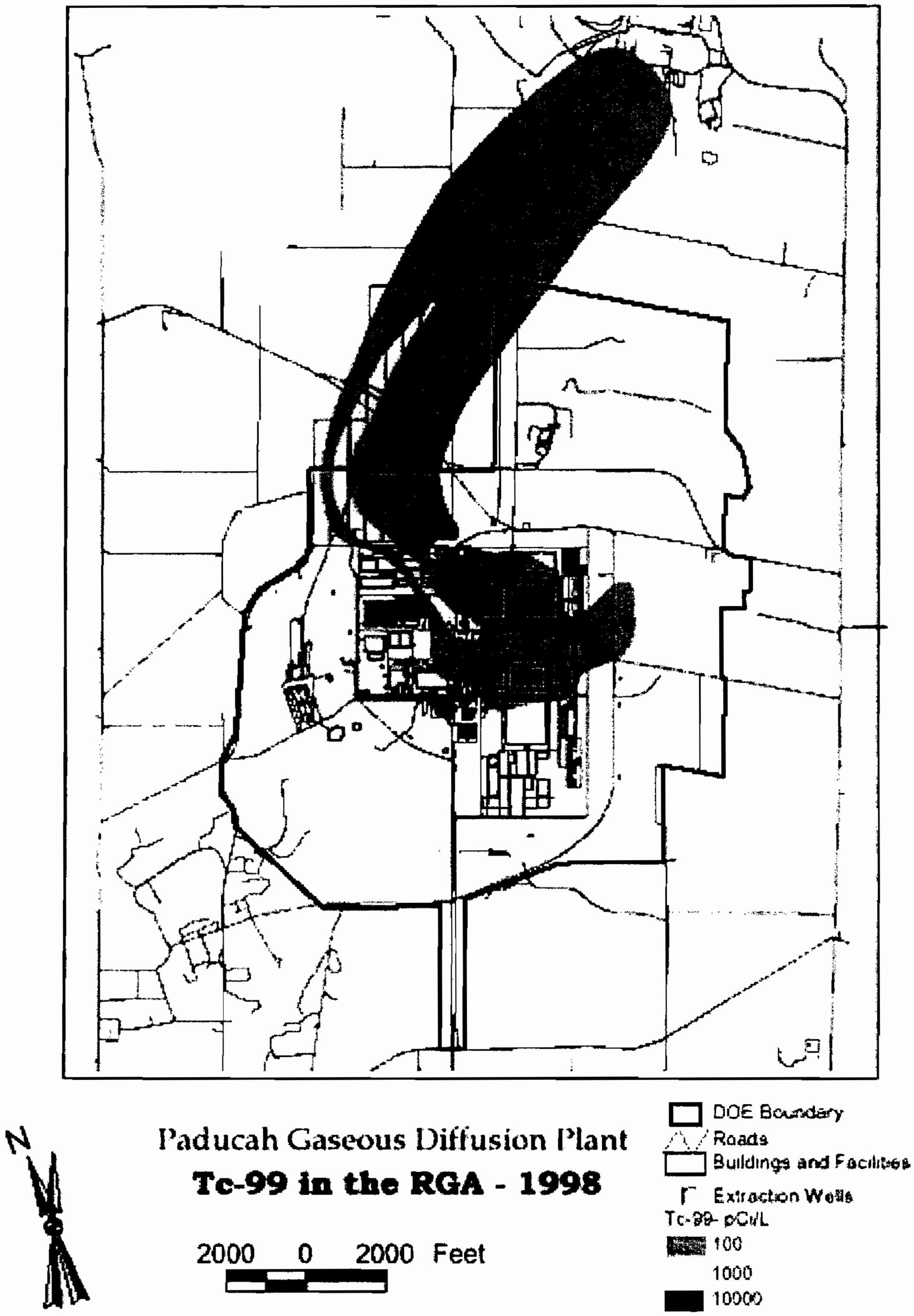

Figure 2. Technetium-99 Contamination in Groundwater at the Paducah Gaseous Diffusion Plant[1]

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Table 1: Candidate Technologies for Characterization and Remediation

Technology	Application Identified in Initial Screening
Sonic-assisted Cone Penetrometer	Characterization
Redox Manipulation	Treatment of dissolved phase plume
Huma-Sorb™	Treatment for TCE, may sorb Tc-99
Iron Reactive Wall (Vertical hydraulic fracture)	Tc-99 capture, TCE destruction
Chemical Oxidation	Dissolved phase and source removal
Underground Steam Stripping	Source removal
Flushing technologies [solvents; surfactants]	Source removal
Direct thermal approaches (6 phase heating, etc)	Dissolved phase and source removal
Pump and Treat with Reinjection	Tc-99 and TCE removal
High Vacuum Enhanced Recovery	TCE removal
Steam injection with high vacuum extraction	Dissolved phase removal
Microwave heating	Dissolved phase and source removal
Aerobic Bioremediation	TCE treatment
Air Sparging (In-well vapor stripping)	TCE stripping
Gaseous Reduction	Tc-99 removal
Horizontal Reactive Barriers [Hydrofracture (or permanganate grout)]	Containment
Multi-Phase Extraction	Dissolved phase and source treatment
Horizontal Wells	Characterization and enabling technology
Natural Attenuation with source control	All areas
Aquifer Leveling	Reduce hydraulic gradient in RGA
Horizontal Wells/Multi-Phase Extraction	RGA
Grout Walls/Barriers	Containment
Permeation Grouting	Containment
Electrokinetic recovery (Electromigration)	Tc-99 and TCE treatment
Rotary Steam Stripping	Treatment of TCE and Tc-99 in UCRS
Deep Injection Passive Barriers (Iron or Bio)	Reactive media or nutrient injection for dissolved plume
Bio-sparging	Dissolved phase plume
Barometric Pumping	Dissolved phase in soil

Based on this initial identification of technologies, the TAG moved forward to assess the applicability of these technologies for remediation at Paducah (Kuzio April, June, August 1999). Existing Remedial Investigation/Feasibility Study (RI/FS) data and information was provided to the TAG to assist in this effort.

During the next several meetings, TAG discussions focused on the applicability of proposed treatment technologies. Additional technologies showing potential for site application were also introduced and evaluated. The Paducah ITRD project schedule was designed to provide timely input to the Feasibility Study technology selection process, thereby aiding the site in meeting its Federal Facility Agreement milestones. The leading four or five candidate technologies needed to be identified in time to allow treatability studies and the resulting performance data to be included in the Internal Review version of the site Feasibility Study.

TAG members agreed that, due to the complexity of the hydrogeology and infrastructure at the site, well-understood and readily available technologies would be required. Because of these complex issues, multiple technologies may be needed to address all remediation objectives. The TAG's technology review is summarized in the following sections, and has been separated into two categories:

- technologies for treatment or containment of contaminants in the low-permeability vadose soils
- technologies for treatment of the saturated low-permeability and high-permeability soils and groundwater

The preliminary application of each of the technologies initially identified by the TAG is presented in Table 2 below.

Ex situ treatment technologies for contaminated soils, in which the soil would have to be excavated for treatment, were not considered realistic options for this project because of the proximity to building foundations and utilities, and most importantly costs. *Ex situ* treatment technologies for contaminated groundwater, in which the water would be pumped to the surface, were not specifically considered. The existing pump-and-treat systems used for plume control, which consists of air strippers for TCE and ion exchange for Tc-99, are effective, but costly, *ex situ* treatment techniques for the contaminated groundwater. Containment of the existing plumes on-site would require a significantly larger and costlier pump-and-treat system and a significant period of time to approach reasonable site cleanup levels.

Table 2. Preliminary Technology Applications

Formation	Source (Easy Access)	Source (Hard Access)	Low Concentration Zones
UCRS Vadose Zone K= $1x10^{-4}$ to $3.5x10^{-5}$ cm/s Depth 0-40 ft bgs	• Direct Heating • Rotary Steam Stripping • Electrokinetics • Horizontal Reactive Barriers • HVSVE • Gaseous Chemical Oxidation • Natural Attenuation & Containment	• HVSVE (with enhancements) • Gaseous Chemical Oxidation • Horizontal Reactive Barriers • Direct Heating • Electrokinetics • Natural Attenuation & Containment	• Rotary Steam Stripping • Electrokinetics • HVSVE • Gaseous Chemical Oxidation • Direct Heating • Natural Attenuation & Containment • Horizontal Reactive Barriers
UCRS/Saturated K = 1×10^{-4} to 3.5×10^{-6} cm/s Depth 30-60 ft bgs	• Two Phase Vapor Extraction • Direct Heating • Rotary Steam Stripping • Electrokinetics • Horizontal Reactive Barriers		• Rotary Steam Stripping • Electrokinetics • Multi-Phase Extraction • HVSVE • Horizontal Reactive Barriers
RGA K= $1x10^{-0}$ to 10^{-2} cm/s Depth 60-130 ft bgs	• Dynamic Underground Stripping/Hydrous Pyrolysis-Oxidation • Chemical Oxidation • Soil Flushing • Direct Heating • Air Sparging (w/o ozone) • Pump and Treat		• Aerobic Bio; Bio-venting • Air Sparging/SVE • Chemical Oxidation • Steam Stripping • Reactive Walls • Pump and Treat • Natural Attenuation

4. Innovative *In Situ* Vadose Zone Soil Treatment Technologies

One group of innovative technologies reviewed by the TAG were those with the capability of remediating the contaminated lower permeability soils in the UCRS. Based on the site characterization data, the consensus of the TAG was that the TCE concentration levels in some areas are high enough to act as a continuing source of groundwater contamination unless treated or contained. Therefore, the TAG worked at identifying technologies that could effectively address the low permeability contaminated vadose zone soil in the UCRS. Treatment of Tc-99 in the vadose zone was not considered because, TAG members believed that Tc-99 will not be mobile in the vadose zone. Regulators on the TAG indicated that removal of TCE from the vadose zone could potentially be considered adequate remediation without addressing Tc-99 in the vadose zone. Nevertheless, Electrokinetics and Rotary Steam Stripping with injection of Zero-Valent Iron, which could potentially remove (or immobilize) Tc-99 from (in) the vadose zone soil, were still considered.

The technologies reviewed for removal of TCE included High Vacuum Extraction, Thermal Treatment, Steam Stripping, Chemical Oxidation, Electrokinetics, Horizontal Reactive Barriers, and Natural Attenuation with Source Term Containment. A limited list of previous deployments of these technologies is shown in Table 3. The table indicates if the technology has been demonstrated in the vadose zone, a low permeability saturated zone or a high permeability saturated zone. Details concerning each of these technologies are discussed below.

4.1. High Vacuum Extraction

This commercially available technology consists of three types of soil vapor extraction (SVE) processes: Passive SVE, Standard SVE (5-10 inches Hg vacuum), and High Vacuum SVE (15-29 inches Hg vacuum) for the removal of volatile or semi-volatile organic compounds. Neither SVE nor High Vacuum SVE can remediate Tc-99 in the soil. The High Vacuum technology is primarily used in tight vadose zone soils with hydraulic conductivities ranging from 10^{-6} to 10^{-7} cm/sec to remove VOCs. This technology can be used in layered soils with varying hydraulic conductivities for VOC concentrations up to 10,000 ppm, although most common applications are for VOC concentrations of 500 ppm. The radius of influence of High Vacuum SVE's is 10'-20' in tight soils, and 30'-50' in more permeable soils. Contaminant removal efficiencies of greater than 90% are achievable with typical treatment periods of 2-4 years. High Vacuum soil vapor extraction has been successfully applied by many vendors to soils with permeabilities as low as those seen in the UCRS. After the VOCs are extracted from the subsurface, they are either sorbed onto activated carbon or destroyed by catalytic oxidation. Several vendors including Haley & Aldrich, IT, and McLaren-Hart are using this technology to remediate contamination in tight soils, often in conjunction with soil fracturing. Some of the vendors require the purchase of a license in order to use their technology. Since this technology seemed to be appropriate for this site and could potentially address the UCRS soils, the TAG conducted an engineering evaluation for the application of this technology at Paducah. The results of that evaluation are discussed in Sections 5 and 6.

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4.2. Thermal Treatment Technologies

The TAG considered both direct or resistive heating and microwave heating of the soil and groundwater as treatment options. Although a vendor could not be identified with adequate experience and equipment for full-scale microwave heating, initial pilot tests using this technology have been conducted. Therefore, the TAG concentrated on direct heating applications, particularly Six-Phase Heating available through Current Environmental Solutions (CES).

The CES technology typically uses a Six-Phase Array (SPA) with 6 electrodes located in a hexagonal shape and a neutral electrode located in the center of the hexagon which also serves as a vapor extraction well. A typical array diameter is 25-35' with the heated zone being approximately 40% larger than the array diameter. The deepest installation of this technology to date is to 60' below ground surface (bgs). Application of electrical voltage to electrodes causes *in situ* heating. The soil matrix becomes a resistive heater, raising the temperature of the soil to a level such that the target contaminant(s) are volatilized. The technology can be deployed in the vadose and saturated zones, and may be used in low permeability or highly heterogeneous soils. Common power sources (60 Hz) may be used to heat the ground (typical sub-surface applied voltages range from 150-600 volts), producing *in situ* steam to liberate the contaminants, which are removed by the center vapor extraction well. The vapor treatment train consists of a condenser/knock out drum to remove a substantial portion of the water and either activated carbon or a catalytic oxidation unit to capture/destroy VOCs. If activated carbon is used, the spent carbon becomes a secondary waste stream.

The technology produces uniform soil heating, which leads to uniform removal of VOCs. Key issues concerning this technology include the effects of soil heating on surrounding plastic-encased utilities and effective treatment of infrastructure-laden areas. While PVC piping may be damaged by the elevated temperatures produced in the soil by this technology, CPVC will not sustain significant damage. Angle borings can be used to accommodate infrastructure concerns. Cleanup efficiencies typically reach 99+%. The technology may be used to heat aquifers, however large amounts of water increase overall project costs and extend project completion times. The process does not adversely impact any metals of radionuclides present in the soil or groundwater. Similarly, the presence of these elements or materials has no adverse impact on the heating process. Because of the relative maturity and somewhat low overall costs, the technology remains a candidate for soil and groundwater treatment in several areas. The applicability of Six-Phase Heating to the UCRS soils was reviewed in detail by the TAG. An engineering evaluation of application of this technology at Paducah is presented in Sections 5 and 6.

From a regulatory perspective, the power sources for Six-Phase Heating are considered to be portable sub-stations and are subject to comprehensive IEEE guidelines for electrical sub-stations, including grounding practices, voltage measurements for surrounding ground, and provisions for lightning strikes. CES has experience working at industrialized sites with extensive gas and sewer piping and under roadways. At sites where the location of infrastructure is not explicitly known, magnetometer and/or ground penetrating radar surveys are used to locate the utilities.

4.3. Rotary Steam Stripping

This technology uses deep soil mixing equipment to inject a range of materials including stabilization media, bioremediation nutrients, hot air and steam and reactive media. Three companies provide this technology: In-Situ Fixation, Geo-Solutions and Geo-Con. Volatilized organic contaminants are forced to the surface via steam injection, then collected and treated. The technology is applicable to soil and groundwater contamination in both the vadose and saturated zones, and in low permeability soils. It can be applied to high contamination areas (i.e., 100-300,000 ppm of VOCs). Although this technology applies primarily to VOCs, reactive media such as zero-valent iron can be injected to retard the migration of Tc-99.

Treatment rates range from 20-40 yd^3/hr with typical contaminant removal efficiencies of 80-90%. Residual contaminant concentrations range from 20-50 ppm using steam injection only; using steam followed by iron injection, residual concentrations range from 5-10 ppm. Working with chemical oxidation companies, some vendors are working on injection of Fenton's reagent as an additional treatment method. Typical treatment depths range to 40', although depths to 70' are possible. The effective treatment area is approximately 40-75 ft^2 per borehole. If oxidizing agents (such as Fenton's reagent) or reducing agents (such as zero valent iron) are not used, above ground treatment is required to remove the VOCs from the condensed steam. This can be accomplished by sorption on activated carbon, for example. Because of the maturity of the technology, the TAG conducted an engineering evaluation of the application of the technology at Paducah which is presented in Sections 5 and 6.

4.4. Chemical Oxidation

In this process, low concentrations of oxidants are injected to oxidize organic contaminants in the subsurface (Tc-99 is not expected to be addressed). Commercially available chemical oxidation technologies include:

- Fenton's reagents: high concentrations of hydrogen peroxide in combination with iron sulfate
- Low concentration hydrogen peroxide: injected with iron and a catalyst
- Ozonation: applicable in either the saturated or vadose zone
- Permanganate

Off-gas control is often important with chemical oxidation technologies to reduce unintentional violent reactions with soil organics. The Fenton's process appears to be more hazardous and costly to implement in this site's vadose zone due to the high organic content and the technology's high reactivity with organic material. Of the technologies identified, those using ozone and permanganate appear to be the best options for Paducah. The benefits of using ozone and permanganate include low material cost and handling safety. Permanganate solution does not burn human skin; a spray solution of vinegar, hydrogen peroxide and water removes coloration. Facemasks are used for splash protection, eyewash neutralizes permanganate solution in case of accidents.

The use of permanganate to degrade DNAPLs causes the generation of salts and hydrogen or hydroxyl ions (acids or bases) with no significant pH shifts. The direct application of

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permanganate has commonly been used for contaminant levels up to 100 ppm to avoid off-gassing. It has only recently been applied to contaminant levels exceeding 1000 ppm. The material should be applied after a heavy mass of contaminant has been removed by other means. Once applied to an aquifer, the path of permanganate migration may be tracked using the material's electrical resistance. Permanganate has been used in tight clays and for soil and groundwater injection. Oxidation of permanganate by-product compounds occurs faster than oxidation of DNAPLs. Although current research shows no adverse reactions, the compatibility of humic materials with permanganate products may be a concern.

Because this technology has potential application to all the contaminated soil and groundwater at the Paducah site, the TAG conducted an engineering evaluation for cost and performance of the different oxidants on the contaminants of concern. The results of this evaluation are presented in Sections 5 and 6.

Waste generated by the chemical oxidation process consists of personal protection equipment and possibly drill cuttings; an estimated 1 ft^3 of soil cuttings is generated per linear foot of well. It is expected that wells would be required for chemical injection into the RGA because initial tests determined that geoprobes were not able to penetrate the RGA. Another waste stream generated by the process is the water used for decontamination of drill bits. It is estimated that less than 20 gallons of water will be used for each hole drilled.

4.5. Electrokinetics

This technology uses electrical current to move charged particles through subsurface soil. Positive and negative electrodes are placed in the soil to move charged contaminants to a collection or treatment point. The technology has been used extensively over the past 50 years to dewater clays for the construction industry, and has only recently been applied to treatment of contaminated soils to move a variety of charged species including nutrients, VOCs, and heavy metals. Other applications include *in situ* destruction of volatile organic contaminants.

Applications considered included *in situ* treatment such as the LASAGNA Process and Weiss and Associates. Advantages of the technology are that both TCE and Tc-99 could possibly be removed at the same time. The LASAGNA Process has been demonstrated at Paducah with some success. Based on past performance, an engineering evaluation of the technology was conducted for widespread use at Paducah. The results are presented in Sections 5 and 6.

4.6. Horizontal Reactive Treatment Zones

The Horizontal Reactive Treatment Zones approach combines the recently maturing remediation techniques hydraulic fracturing, and jet grouting with reactive treatment media such as zero-valent iron or permanganate. A high-permeability mixture containing either a chemical oxidant (such as permanganate) or another reactive media (such as zero-valent iron) is injected in a horizontal layer at the bottom of a vadose zone soil right above the water table. The mixture reacts with the contaminants in source-term areas that migrate down through the reactive zone. As long as the treatment zone remains active, this technique can reduce the potential for residual soil contamination to act as a continuing source for aquifer and groundwater contamination. The reactive mixture or grout concept, developed by McLaren-Hart, Foremost Solutions, IT and other companies, has been demonstrated in a few field demonstrations and has shown significant promise.

This technology presents the site with concerns about fracturing the soil near utilities. The TAG decided to retain the technology for consideration as a remediation strategy because it provides an alternative if an area of high-concentration can not be fully remediated by other means. An engineering evaluation of the application of the technique suggested that active treatment of vadose soils might be only slightly more costly than a passive horizontal reactive barrier. This technique may be reconsidered for application if other remedial techniques are shown to be ineffective at the site.

4.7. Source Term Containment

The TAG reviewed a set of technologies capable of containing the contaminated soil and groundwater source term areas. Contamination levels identified in these areas suggested the potential for large areas of non-aqueous phase TCE in both the soil and groundwater. If not treated or contained, these areas have the potential to be a continuing source of contamination. Several containment technologies were reviewed including biological barriers and grouting.

4.7.1. Biological Barriers

Used in the petroleum industry for several decades to manipulate fluid flow and media permeability, biological barriers have been the subject of recent laboratory research for environmental applications. The addition of nutrients and biological amendments to soil and groundwater creates a dense biological growth that has been shown in the laboratory to reduce the hydraulic conductivity of the soil on the order of 10^{-7} cm/sec. This level of reduction is roughly equivalent to the hydraulic conductivity created through permeation or injection grouting techniques. Suggested environmental applications include containment barriers, flow control for pump-and-treat systems, or as part of a funnel and gate system. The benefits of this technique include simple maintenance consisting of periodic nutrient addition, cost-effectiveness and removability.

The work to date for environmental applications has been at laboratory-scale. Biological barriers present three issues of concern to TAG members: 1) full-scale costs and performance have not yet been determined, 2) there is no data on microbe viability in the presence of high levels of TCE contamination, and 3) it is unknown if nutrients could be supplied to the microbes in the tight clay soils of the UCRS. It may be several years before system optimization data would be available. Therefore, the TAG suggested that the technology be considered in more detail only if cost-effective treatment technologies could not be identified for treatment of high concentration or source areas.

4.7.2. Grouting

Both permeation and jet grouting are mature technologies widely used for environmental applications. Typically, cementitious or plastic based grouts are used to fill voids in the soil and create a zone of relatively low permeability, on the order of 10^{-7} cm/sec. For environmental applications, the technology has most often been used to create cut-off walls and containment walls to reduce the migration of both metal and organic contaminants. Grouting can also be used in concert with fracturing for source term containment. Permeation grouting is most commonly applied at shallow depths and in soils or aquifers of relatively high permeability. Jet grouting is being applied to depths from 70-120 feet. Some companies suggest that depths of 300 feet can be achieved. Major concerns at the Paducah site are the relative permanence of the grout barriers

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and the difficulties of creating a successful barrier around the many utilities at the (grouting requires injection holes at about 5-foot centers). As with the biological barrier technology, the TAG suggested that the technology be considered in more detail only if cost-effective treatment technologies could not be identified for treatment of the high concentration or source areas.

4.8. Summary

The TAG decided to perform further evaluation on the following technologies for application in the unsaturated UCRS:

- High Vacuum Extraction
- Thermal (Six-Phase Heating) Technology
- Rotary Steam Stripping
- Chemical Oxidation
- Electrokinetics
- Horizontal Reactive Treatment Zones

The other technical options [source-term containment, biological barriers and grouting] will not be pursued any further.

Table 3 Selected List of Technology Deployments

Technology	Demo Site Owner	Site Location	Area	Vadose or Saturated Zone	Contaminant	Source of Information
Thermal Processes						
Six-Phase Heating	**DOE**	**Hanford**				**Kuzio 4/99**
	DOE	**Savannah River**			**TCE, PCE**	**Kuzio 4/99**
		Skokie, IL				**Kuzio 4/99**
	NASA	**Cape Canaveral**	**Launch Complex 34**	**Saturated**	**TCE**	**SCFA 1999**
Dynamic Underground Stripping Hydrous Pyrolysis-Oxidation	**DOE**	**Portsmouth, OH**	**X-701B Plume Site**		**TCE**	**Kuzio 4/99**
	Commercial	**Visalia, CA**	**Southern California Edison Power Pole Treatment Yard**		**Creosote, Penta-chlorophenol**	**SCFA 1999**
	NASA	**Cape Canaveral**	**Launch Complex 34**	**Saturated**	**TCE**	**SCFA 1999**
	DOE	**Lawrence Livermore Lab**			**BTEX**	
Oxidation Processes						
In-Situ Chemical Oxidation - Permanganate	**DOE**	**Kansas City Plant, MO**				**SCFA 1999**
	DOE	**Portsmouth, OH**	**X-701B Plume Site**	**Saturated**	**TCE/PCE**	**SCFA 1999**
	DoD	**US Army Cold regions research Lab**				**US EPA 1998a**
	Private Sites	**BMC Olen Site, CRREEL, (Gafton County, NY), Union Chemical (ME), Dry Cleaning Facility (FL)**				**US EPA 1998a**
	NASA	**Cape Canaveral**	**Launch Complex 34**	**Saturated**	**TCE**	**TIE 1999**

Table 3 Selected List of Technology Deployments (continued)

Technology	Demo Site Owner	Site Location	Area	Vadose or Saturated Zone	Contaminant	Source of Information
Pumping Processes						
Pump and Treat	**DOE**	**Paducah Gaseous Diffusion Plant**	**Northwest and Northeast Plumes**	**Saturated**	**TCE, Tc-99**	**Kuzio 2/99**
	USAF	**McClellan Air Force Base, Sacramento, CA**	**Operable Unite B/C**	**Saturated**	**TCE, DCE, PCE, DCA**	**EPA 1995**
	USAF	**McClellan Air Force Base, Sacramento, CA**	**Operable Unit D**	**Saturated**	**TCE, DCE, PCE, DCA**	**EPA 1995**
	US Army	**Twin cities Army Ammunition Plant, New Brighton, MN**		**Saturated**	**TCE, DCE, DCA, DCE, TCA, PCE**	**EPA 1995**
Two-Phase/Dual Phase Extraction	**Xerox**	**Ontario, Canada**		**Vadose and Saturated**	**Chlorinated Solvents blend**	**Weber 2000**
	USAF	**McClellan Air Force Base, Sacramento, CA**		**Vadose and Saturated**	**TCE, PCE, Freon 113**	**Weber 2000**
Contaminant Flow Control: Gradient Management	**Ponca City**					**Kuzio 4/99**
Recirculation Well Technology	**Commercial**					**Kuzio 4/99**
	Airforce	**Hill Air Force Base**				**Kuzio 4/99**
C-Sparge	**Commercial**	**Carson City, NV**	**Crossroads Mall**	**Saturated**	**PCE**	**Ehleringer 2000**
	Commercial	**Falmouth, MA**	**Plymouth Savings Bank**	**Saturated**	**PCE**	**Ehleringer 2000**
	Commercial	**Hinderliter, IN**				**Ehleringer 2000**
	Commercial	**Lake Tahoe, CA**	**Dames and Moore**			**Elheringer 2000**
Biological Processes						
Enhanced In-Situ Bioremediation	**DOE**	**INEEL**	**Test Area North**		**TCE**	**TIE 99**
		Savannah River	**Sanitary Landfill**			**SCFA 1999**
		Hanford			**Carbon Tetrachloride**	**SCFA 1999**
	Army	**Vicksburg, MS**	**Army Waterways Experimental Station**			**SCFA 1999**
		Dover Air Force Base	**Nat'L Envirnmt'L Tech. Test Site**			**SCFA 1999**
	Airforce	**McClellan Air Force Base, Sacramento,CA**				**SCFA 1999**

Table 3 Selected List of Technology Deployments (continued)

Technology	Demo Site Owner	Site Location	Area	Vadose or Saturated Zone	Contaminant	Source of Information
Permeable Reactive Zones						
Zero-Valent Iron	DOE	Rocky Flats				Kuzio 4/99
		Caldwell, NJ	Operating Unit 2		Pb, TCE	EPA 4/99
Horizontal Permeable Treatment Zone	DOE	Portsmouth				Kuzio 4/99
C-Sparge		Hutchinson, Kansas	Drycleaning Facility		PCE	Burns and McDonnell
Electrokinetics						
LASAGNA	DOE	Paducah	Solid Waste Management Unit 91		TCE	SCFA 1999
Electrokinetics	DOE	Sandia National Laboratories, NM	Chemical Waste Landfill	Vadose	Cr	Mattson 1999
Extraction and Air Sparging						
Soil Vapor Extraction		Commencement Bay, Tacoma, Washington	South Tacoma Channel (Well 12A)	Vadose	DCE, PCA, PCE, TCE	EPA 1995
	USAF	McClellan Air Force Base, Sacramento, CA	Site S, Operable Unit D	Vadose	TCE, 1,1-DCE, TCA	EPA 1995
Soil Vapor Extaction with Bioventing	USAF	Hill Air Force Base, Ogden, Utah	Site 914	Vadose	Petroleum Hydrocarbon	EPA 1995
High Vacuum Extraction	Superfund	Fairchild Semiconductor Corporation, San Jose, CA		Vadose	TCA, DCE, IPA, xylenes, acetone, PCE	EPA 1995
In-Situ Air Sparging and Soil Vapor Extraction	Savannah River	C-Area Burning Rubble Pit				SCFA 1999
Enabling Technologies						
Pneumatic Fracturing	DOE	Portsmouth				SCFA 1998
Hydraulic Fracturing for Treatment of DNAPL in Low Permeability Media	DOE	Portsmouth			TCE/PCE	SCFA 1998
Surfactant Flushing						
Surfactant-Enhanced Aquifer Remediation	Air Force	Hill Air Force Base	OU2	Saturated	TCE	Jackson 1999
	Navy	Camp Lejeune	Dry Cleaning Facility	Saturated	PCE	Yeh 1999
	DOE	Portsmouth		Saturated	TCE, PCB	Jackson 1999

5. INNOVATIVE *IN SITU* GROUNDWATER AND SATURATED SOIL TREATMENT TECHNOLOGIES

The TAG reviewed a set of technologies capable of enhancing or accelerating the treatment of the contaminated groundwater and the associated wet contaminated soils of the UCRS and RGA. A wide variety of contamination levels were identified at the site. TCE concentrations over 1000 ppm have been measured near the source term areas. As contamination enters the RGA and is dispersed by the high flow velocities in the aquifer, TCE concentrations generally vary from 1-10 ppm at the distal plume. Concentrations of Tc-99 as high as 40,000 pCi/L in the source area southeast of building C-400 fall to 1000 pCi/L at the distal plume. This suggests that technologies or combinations of technologies should be considered for treatment of the source term areas and the contaminant plumes at the site boundaries.

Both active and passive treatment technologies were reviewed in detail to help identify the expected cost and performance of various combinations of techniques. The technologies evaluated included: Multi-Phase Extraction, In-well Sparging, Air Sparging/Soil Vapor Extraction, Soil Venting, Bioremediation, Chemical Oxidation, Soil Flushing with surfactants, Thermal Remediation, Dynamic Underground Stripping with Hydrous Pyrolysis Oxidation (DUS/HPO), and several reactive treatment zone concepts. Each of these technologies is summarized below. After reviewing these technologies several were identified for detailed engineering evaluation with commercial vendors. The results of those evaluations are presented in Sections 5 and 6.

5.1. Multi-Phase Extraction

Multi-Phase Extraction, defined as extraction of more than one phase, includes three different technologies. The first of these is Dual-Phase Extraction, a technology developed by Groundwater Technologies, which uses an in-well pump to extract groundwater while using an above-ground vacuum pump to extract vapor from the draw-down zone. A second similar technique uses a high vacuum extraction well to extract vapors and a small liquid pump to extract the water from the zone of uplifted water caused by the vacuum. The third Multi-Phase Extraction technology is Two-Phase Extraction which consists of a small diameter "straw" inside of a screened well. A liquid ring pump attached to the straw simultaneously extracts liquid and vapor through the straw. The TAG considered all three configuration options.

The TAG views Dual-Phase Extraction as a way to treat contaminated groundwater and soil simultaneously. The extracted water can be treated for Tc-99 as well as TCE. The vapor phase is not expected to contain significant amount of Tc-99. The technology has been most commonly applied where the contaminants of concern are lighter than water and float on the water table. In this case, the contaminant layer and the contaminated soil at the water table/vadose zone interface will be treated at the same time. Dual Phase Extraction has also been used for gasoline tank problems and DNAPL applications. However, the technology will probably not be as effective in the high permeability RGA where a very large volume of water would need to be pumped. The technology's effective radius is approximately 10-50' depending upon site-specific conditions. The process has been used to depths of approximately 100-120' bgs. For the

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Paducah application, this technology would not significantly improve remediation schedules or costs over a standard pump-and-treat system.

Two-phase vacuum extraction has been successfully applied to soils with permeabilities as low as those seen in the saturated UCRS. The technology uses a very high vacuum (approximately 15 to 29 inches of mercury) to withdraw volatile organics from the vadose zone above the water table and a method to extract water drawn in by the vacuum. Several vendors, including Haley & Aldrich, Radian, and McLaren-Hart, are using variations of this technology to clean up contamination in saturated tight soils, sometimes in conjunction with soil fracturing. Since this technology seems to be appropriate for this site, and could potentially address the saturated UCRS soils, the TAG attempted to conduct an engineering evaluation of the application of this technology at Paducah. However, only McLaren-Hart provided cost data. The results of the evaluation are discussed in Sections 5 and 6.

5.2. Recirculating Wells

Several available technologies use the same general concept of pumping, treating, and then reinjecting air or water within the same well in order to set up a recirculation cell within the aquifer. The recirculation pattern theoretically treats the same water over and over without drawing in non-contaminated groundwater for treatment. In essence, the systems continuously flush the local area around the well, increasing contaminant removal efficiency. Removal efficiencies of up to 90-95% have been reported in as little as eighteen months for some systems. A radius of influence for the wells of as much as 80-100 feet has been demonstrated. For those wells that recirculate the groundwater, flushing of the vadose zone soils can sometimes be obtained. Appropriate subsurface geology without any low permeability lenses is required for any of these systems to work effectively.

The EPA recently published a report on numerous pilot and full-scale applications of recirculation technologies (US EPA 1998). The TAG reviewed the technologies and their performance data. Based on this review, C-Sparge appears to be the best technology for this site. It provides *in situ* remediation of chlorinated solvents and hydrocarbons by combining air stripping and encapsulated ozone processes. A typical system uses a compressor to pump an air/ozone mixture through a patented discharge device placed in either the vadose or saturated zone. In aquifers, the resulting "microfine" bubbles penetrate the interstitial spaces of saturated formations and surrounding water under low pressure, becoming part of the fluid flow and minimizing channeling. This process allows concurrent stripping of VOCs, chemical oxidation, and oxygenation to enhance microbial activity. The system has been successfully used in over 60 field applications where soil permeabilities ranged from 10^{-1} to 10^{-6} cm/sec at depths up to of 350 ft bgs.

It is possible that the C-Sparge system can be modified for removal of Tc-99 by the addition of ion exchange media in the well casing. Based on C-Sparge's applicability to vadose and saturated soils with either high or low contaminant concentrations, the TAG conducted an engineering evaluation of the technology. The results of that evaluation are provided in Sections 5 and 6.

Waste generated consists of resin contaminated with Tc-99, which is radioactive waste, and well cuttings from below the water table, which would be considered to be mixed waste. Resin costs and disposal costs for resin and cuttings are small (see footnotes in Table 4, Section 5) compared

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to the costs for the overall process. In general, the quantity of well cuttings is about 1 ft^3 per linear foot of well. The offgas from C-Sparge does not contain significant amounts of VOCs.

5.3. Air Sparging/Soil Vapor Extraction

An Air Sparging/Soil Vapor Extraction (AS/SVE) system is a series of simple air injection and extraction wells. The injection wells inject air into the contaminated groundwater, essentially stripping the contaminants while the extraction wells use a low vacuum system to extract the volatilized contaminants from the permeable vadose zone soil above the groundwater. In this way, the contaminated groundwater and soil are remediated at the same time. Since only vapor is moved by this type of system, the operating and installation costs are very low and have made this technology a common technique for remediation of low concentration contaminated soils and groundwater. The typical radius of influence in gravel aquifers is 30-40 feet. Recent data from some vendors show that this technology has been used to reduce contaminants to the 5 µg/L level. Application of the technology must be compatible with the site geochemistry. Based on available data, *in situ* sparging of the high quality water in the RGA would probably not degrade or foul the system. It is not known how the tight UCRS soils that overlay the RGA may affect the performance of the process at Paducah.

The technology has recently been applied with lines of up to 20 sparge wells to create a sparge-curtain at several sites. The curtain behaves as a reactive treatment wall. Sparge-curtains are applicable for groundwater contaminant concentrations in the few tens of mg/L, such as the occurrences at Paducah site boundaries. This active reactive wall reduces the need to treat the entire on-site plume, and has the potential to significantly reduce overall remediation costs. Because of the success of this technology in similar applications, its probable low cost, and its ability to speed up remediation, the TAG conducted an engineering evaluation of the expected cost and performance of this type of system at Paducah. The results of that study are provided in Sections 5 and 6.

5.4. Biological Treatment

Because of its potential low cost implementation, *in situ* bioremediation is being considered more often for both VOC and metal reduction in groundwater as the factors that control microbial degradation of VOCs become better understood. Biodegradation reactions involve either oxidation or reduction of the contaminant under aerobic or anaerobic conditions, respectively. Aerobic bioremediation is applicable to low concentrations of TCE, in the 1 to 10 ppm range, whereas anaerobic bioremediation is possible for higher concentrations of TCE, up to 200 or 500 ppm. At high concentrations of TCE near DNAPL (in the several hundreds and thousands of ppm levels), anaerobic microbes will not thrive (Starr 2000). Therefore, anaerobic bioremediation is not applicable to the high concentration source zones except as a polishing step.

The groundwater aquifer at Paducah is aerobic. In some cases, aerobic aquifers can be driven to anaerobic conditions by injection of large quantities of organic substrates. Initial estimates suggest that it would not be cost effective to convert the Paducah aquifer to an anaerobic state. Therefore, anaerobic bioremediation, like aerobic bioremediation, does not seem appropriate for the source zones.

However, aerobic bioremediation should be more closely investigated in the less contaminated zone. Low levels of TCE (up to tens of ppm) have been degraded aerobically by injecting cometabolites such as methane, propane, or toluene into contaminated aquifers. Aerobic biodegradation of chlorinated solvents does not create any of the toxic by-products that anaerobic biodegradation does. However, some members of the TAG questioned whether biological treatment would be applicable in the saturated UCRS where the low permeability soil would hinder distribution of nutrients.

Overall, aerobic bioremediation application costs are similar to/or somewhat lower than equivalent Air Sparging systems. Several companies are considering the combined application of bioremediation and air sparging to create a biosparging curtain that could reduce site remediation costs. Cost and performance studies could be performed to determine if the application of this technique at Paducah would be cost-effective. An engineering evaluation of the expected cost and performance of this technology was coordinated with two technology vendors who have conducted several aerobic remediations of chlorinated solvents. The results of that evaluation are discussed in Sections 5 and 6.

5.5. Surfactant Flushing Technologies

EPA and others are pursuing soil flushing as a method to remove high concentrations of chlorinated solvents. Successful demonstrations of the technology have been obtained with the use of food grade surfactants, co-solvents, surfactant/co-solvent mixtures, and macromolecules. This technology is intended for removal of TCE in source zones. Tc-99 will also be removed by surfactant flushing in the saturated zone since it will be carried with the pumped liquid.

This technology is commercially available through Duke Engineering, Surbec/ART, and other vendors. It is most commonly applied to non-aqueous phase contaminants in which concentration levels exceed the contaminant solubility and the soil is capable of effectively adsorbing contaminants. Initial studies have shown that approximately 3 to 4 pore volume flushes can reduce contaminant levels by over 90%. To date, several pilot and a few full-scale applications have been conducted (Jackson 1999). Because the contaminants are rendered mobile by the process, adequate hydraulic control of the remediation area is required for effective treatment . Surfactant flushing is most applicable to source areas, permeable formations, and sparingly soluble contaminants. For less permeable formations, effectiveness is significantly decreased as indicated by results at the Camp Lejune, CA project (Yeh 1999). This experience implies that surfactant flushing is only applicable to the RGA.

The Partitioning Interwell Tracer Test (PITT) is a proprietary partnering technology marketed by Duke Engineering and Services that can be used prior to surfactant flushing to assess DNAPL volumes. The PITT uses surfactant techniques to measure the volume and describe the spatial distribution of sub-surface DNAPL contamination zones. The PITT may be used in both the vadose and saturated zones, and can locate low volume quantities (1 gallon) of DNAPL.

At Paducah, the technology has most application in areas of high contaminant concentration in the RGA. The cost of the technology can often be quite high and should be compared to the costs of similar technologies. Costs estimates of the technology were developed by a commercial vendor and are presented in Section 5.

5.6. Chemical Oxidation

In the Chemical oxidation process, low concentrations of oxidants are injected in the subsurface to oxidize organic contaminants. Tc-99 is not expected to be remediated by chemical oxidation. As discussed previously, commercially available chemical oxidation technologies include: Fenton's processes that use high concentrations of hydrogen peroxide together with iron sulfate; low concentration hydrogen peroxide that can be injected with iron and a catalyst; ozonation that can be used in either the saturated or vadose zone, and permanganate. The technology has potential application to both contaminated soil and groundwater problems at the site. However, it is expected to be more effective in the RGA than in the saturated UCRS because the lower permeability in the saturated UCRS will hinder distribution of the reactant. Costs at a site will depend on contaminant concentration. The TAG tried to identify the expected costs and treatment performance for the different oxidants on the contaminants of concern. Cost and performance estimates were obtained for application of the technology in several areas and are presented in Section 5.

5.7. Thermal Treatment Technologies

The TAG considered both direct / resistive heating and microwave heating of the soil and groundwater as treatment options for TCE and other VOCs. Tc-99 is not remediated by thermal treatment technologies. As discussed previously, a vendor with the experience and equipment for microwave heating could not be identified and the TAG concentrated on direct heating applications, particularly Six-Phase Heating. Some description of Six-Phase Heating is provided in Section 3.

Because of the relative maturity and low overall costs, Six-Phase Heating remains a candidate for groundwater treatment. Costs are expected to be higher for treatment in the saturated zones than in the vadose zone. The TAG believes Six-Phase Heating is applicable to the vadose and saturated zones of the UCRS and may be used in the RGA. Costs may be higher for application in the RGA due to heat removal by the higher water flows in the RGA. Cost estimates were obtained for applying Six-Phase Heating to the contaminated groundwater and presented in Section 5.

Safety issues related to high voltage are discussed in Section 3 and not repeated here.

5.8. Steam Stripping

Steam Stripping uses a 3-phase (i.e., NAPL/water/gas phase) extraction approach. The technology cycle alternatively injects low-pressure steam (12-25 psig) and oxygen (air) into contaminated zones to displace contaminated groundwater and create a thermal destruction zone. Contaminated ground-water flows into the hot reaction zone when injection stops and the contaminants are destroyed. The cycle is repeated until remediation objectives are met. The use of steam at lower pressures reduces the steam's potential to rise vertically and encourages horizontal penetration/contaminant mobilization. Near-surface technology concerns include elevated pressures and temperatures, and adequate overburden characterization to ensure steam breakthrough does not occur. Vendors of the technology include IT, IWT, and Steam Tech. Some vendors use electro-resistance technology [ERT] (similar to CAT scan; resolution to 1 yd^3) to monitor the sub-surface flow of steam. Monitoring is crucial for guiding the remediation.

The technology works best in permeable soils such as the RGA. A typical remediation pattern is to work from outside the contamination zone inwards. Horizontal drilling has been used to maneuver under building foundations to enhance contamination zone access. Several recent large-scale applications have been conducted. The technology appears appropriate for application to the RGA in the areas with high contaminant concentrations but not appropriate for the low-permeability UCRS. Estimates of the cost of using the technology at Paducah were assessed and are presented in Section 5.

5.9. Aquifer Leveling

Aquifer leveling includes the use of vertical or horizontal wells to reduce the hydraulic heads often driving contaminant migration. In many cases the pumped water is not contaminated and therefore does not require treatment. By decreasing the hydraulic heads, migration can often be stopped or reversed, minimizing the areas needing treatment. At Paducah it appears that large volumes of process water (possibly up to 1 MGD) might be lost on-site. This volume of water could be contributing to or modifying contaminant migration. If this is the case, then aquifer leveling may be an appropriate technique to include in an overall site remediation strategy. The TAG chose to continue to look at the process water infiltration volumes to determine if aquifer leveling would be a cost-effective enhancement to the site remediation strategy. System costs will vary based on the volume and area of groundwater to be manipulated.

5.10. Permeable Reactive Treatment Zones

This technology has been demonstrated to be a low-cost passive *in situ* treatment option by several commercial firms including Golder-Sierra, Foremost Solutions, and McLaren-Hart. For deep applications such as those needed at Paducah, the technology typically uses jet grouting or hydraulic fracturing with injection of iron filings or other reactive media to create reactive treatment zones. At shallow depths, the standard reactive zone thickness is approximately 3'. Deep zones of approximately 4"-6"(?) thickness of reactive media can be emplaced with hydraulic fracturing. Multiple parallel zones can be emplaced to increase effectiveness. Four deep projects addressing chlorinated solvent contamination of groundwater have been completed to date. The technology has been used in depths ranging from 50'-120' bgs. Most reactive wall applications are designed to address contamination levels in the 1-10 ppm range because the size of the treatment zone required to address higher contaminant concentrations is prohibitive. Typical VOC reductions can be as much as 50 ppm, and the expected life of an iron filing zone can exceed 10 years. The number of deep reactive zones needed for an application depends on the residence time required for contaminant treatment/removal.

Treatment wall performance is very site-specific. It is essential to have good geochemical characterization of groundwaters to understand barrier wall treatment processes and expected performance. Issues of concern for this technology include:

- Reactive media may create by-products (e.g., vinyl chloride, methylene chloride) that must be addressed
- Potential long-term effects of leaving captured concentrated Tc-99/iron media in RGA.
- Capacity of the reactive media and expected life.
- Hydraulic concerns associated with groundwater bypassing the treatment zone.

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If the appropriate reactive media for both TCE and Tc-99 can be identified for installation, the technique appears to have application at Paducah. The TAG decided to use laboratory column studies to investigate several reactive media with the potential to remove both Tc-99 and TCE from the groundwater plumes. An estimate of reactive treatment zone costs and performance for several options and techniques are presented in Section 5.

5.11. Aquifer Redox Manipulation

The DOE has demonstrated the Aquifer Redox Manipulation technology that creates a reducing environment in the subsurface. The injection of dithionite has been used in a few applications to reduce *in situ* iron to develop a reactive treatment cell zone. Application of the technology depends on soil mineralogy that allows the available iron to be effectively reduced. The technology has had some success in large-scale applications, and commercial vendors are being asked to help commercialize it. The TAG considered this technology to be applicable as a reactive treatment zone in the RGA, but not in the UCRS where the water flow rates are low. Because the technology is not quite as mature as other chemical treatment or reactive zone technologies, the TAG continues to watch its development but chooses to concentrate on the more mature technologies with available vendors.

5.12. Pump and Treat with Reinjection

This technique has been used successfully to accelerate cleanup of dissolved phase contaminants and limit off-site migration of contaminants using reinjected water as a containment system. Paducah has a pump and treat system in operation that removes both TCE and Tc-99 from the groundwater. The reinjection technique is often limited in its ability to treat areas of high contaminant concentration and therefore would probably be used in conjunction with other technologies.

5.13. Natural Attenuation with Source Control

EPA has established monitored natural attenuation protocols to allow a site to take credit for reduction in contaminants from natural processes such as radioactive decay, sorption, dilution and intrinsic bioremediation. Application of this technique in conjunction with source term removal, containment or control would appear to be a potentially cost-effective strategy. However, review of Paducah site parameters suggests that few if any of the accepted natural attenuation processes are taking place in the groundwater aquifer to a large and quantifiable extent (Clausen et al. 1997). Therefore, application of this technique could be very difficult to justify. The TAG proposes concentrating on assessing the cost-effectiveness of more aggressive remediation techniques first.

5.14. Summary Discussion

The TAG decided to carry forward for further evaluation the application of the following technologies in the RGA:

- Dual-Phase/Two-Phase Extraction
- Recirculating Wells (C-Sparge)
- Air Sparging

- Biological Treatment
- Surfactant Flushing
- Chemical Oxidation
- Thermal (Six Phase Heating) Technology
- Rotary Steam Stripping
- Aquifer Leveling
- Permeable Reactive Treatment Zones
- Pump and Treat.

In addition to their potential effectiveness in the RGA, the following technologies are also potentially effective in the saturated zone of the UCRS (the lower permeability in the saturated UCRS may preclude uniform distribution of reactants whether it be an oxidant, a biological nutrient, or air):

- Dual-Phase/Two-Phase Extraction
- Thermal (Six-Phase Heating) Technology
- Rotary Steam Stripping

6. SUMMARY OF TECHNOLOGY IMPLEMENTATION COST AND PERFORMANCE ESTIMATES AT THE PADUCAH SITE

Based on the technologies identified and reviewed, several were considered for detailed engineering evaluations for full-scale application. Detailed information was provided to representative vendors for these promising technologies to develop cost and performance estimates for application at Paducah. Information was provided for three areas at Paducah representative of the soil and groundwater contamination problems that need to be addressed: the C400 Area, the C720 Area, and the C747-C Area (Hightower 1999). The data provided included contaminant concentration contours and depths, information on utility corridors, overhead obstructions, and facility locations that might affect application of a technology in a specific area. Information was provided on the contamination in the UCRS soils and the groundwater contamination in the RGA.

The engineering cost and performance estimates of the different technologies presented in Table 4 are based on contaminant concentration levels and volumes identified by the TAG as representative of the range of expected values across several sites at Paducah. For example, remediating soil in the UCRS with TCE concentrations above 100 ppm will remove the majority of the inventory of TCE in the UCRS. In looking at the soil contamination to be remediated in the UCRS, several sites had individual areas with volumes that range from about 10,000 yd^3 up to 40,000 yd^3. By obtaining cost data for these two volumes, volume scale effects for remediation cost could be evaluated. That is, this approach allows cost and performance estimates to be made for small, intermediate, and large sites by simply combining the costs of the appropriate treatment areas. The two contamination levels identified in the UCRS to be treated, greater than 100 ppm and greater than 1000 ppm, are representative of the range of levels that should be addressed by remediation. It was expected that different technologies would have greater utility in one or the

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other concentration ranges and that the data could be used to mix and match techniques to develop the optimum treatment strategy.

A similar approach was used in the evaluation of RGA treatment technologies. The concentration levels identified were based on the general plume concentrations and the probability of DNAPL presence. It was expected that most areas over approximately 1 ppm for TCE would need to be treated in order to minimize further contaminant migration. The areas at the site with this level of contamination in the groundwater can be relatively large and therefore larger systems would be needed to address them. It is a rule-of-thumb that areas with concentrations of greater than 10% of the contaminant solubility (for TCE ~ 100 ppm) are generally indicative of DNAPL. Therefore, the TAG identified these areas for special consideration knowing that they are most likely to provide a continuing source of contamination to the groundwater.

In evaluating the application of reactive walls or associated technologies, it was important to make sure that the technologies were appropriate for the scale of the containment problem and met the needs of the multiple plumes at the site. It was also important that the reactive wall technologies be able to treat both the TCE and Tc-99 to insure the reduction of both contaminants offsite.

Based upon a review of the information and knowledge of previous applications of the technologies, the TAG compiled vendor-supplied technology cost and performance estimates into Table 4. The vendors and the technology cost and performance data provided include:

- Rotary Steam Stripping: In-situ Fixation (Murry 1999)
- Chemical Oxidation: IT Corp (Lewis 1999 and Wilson 1999)
- Chemical Oxidation/Air Sparging: Morrison Knudsen/K-V Associates (Ehleringer 1999)
- Biological Treatment: WMI (Zielinski 1999) and Enzyme Technologies (Laughlin 1999)
- Steam Stripping: Steam Tech (La Brecque 1999)
- Electrokinetics: Weiss Associates (Ivanetti 1999) and Bechtel Jacobs (Ford 1999)
- High Vacuum Soil Vapor Extraction with Pneumatic Fracturing: McLaren/Hart (King 1999)
- Direct Heating: Current Environmental Solutions (Beyke 1999)
- Surfactant Remediation: Duke Engineering (Jackson 1999)
- Reactive Walls: Foremost Solutions (Meiggs 1999), McLaren/Hart (King 1999), and Weiss Associates (Ivanetti 1999)

The matrix of factors presented in Table 4, such as performance, expected cost, and implementation difficulty, provides an objective basis for developing recommendations for an overall remediation strategy for the site. EPA Region IV, the State of Kentucky and DOE have not collectively decided on an acceptable cleanup level for the source zones. Risk assessment and risk management analyses need to be conducted, taking into consideration technological feasibility and future land/water use, before remedial action decisions can be made. For instance, a technology that accomplishes 95% removal of TCE from soil containing 1000 ppm TCE would result in 50 ppm TCE in the soil, leaving leachate containing more than the drinking water standard of 5 μg/L

TCE. Clean up objectives must be set before it can be decided whether polishing technologies are required.

Although many of the vendors did not include costs associated with access under buildings and removal of Tc-99 in entrained or pumped water when applicable, the cost comparison nonetheless provides useful information for developing overall remediation strategies. Costs for ion-exchange resin for treating Tc-99, disposal of the resin and for transportation and disposal of well cuttings as mixed waste were all relatively small for C-Sparge. These costs for other technologies should not be significantly different. More explicit requirements for under-building access and treatment of Tc-99 contaminated water can be included in formal requests for proposals for recommended technologies. The comparisons in the table provide an objective basis for recommendations of additional data or pilot-studies needed to verify the performance of the most promising technologies or to assist in optimizing a technology performance or cost. The evaluation and discussion of the results of Table 4 are presented in Section 6.

Table 4a. Engineering Cost and Performance Estimates for Technology Applications at Paducah UCRS – Vadose and Saturated Zones

Technology	TCE in Soil, ppm	Volume, yd^3	Capital Cost⁺, $	Treatment Cost⁺, $	Treatment Period/Rate	Residual TCE in Soil, ppm	Implement Difficulty	Waste* Generation	Tc-99 Treatment	Total Costs ³, $
UCRS – Vadose Zone Only										
SVE w/ Fracturing	> 100	10,000	0.606 M	0.091 M 0.077 M 0.070 M	1 yr 2 yrs 3 yrs	30 10 5	Medium (TAG not sure fractures will stay open)	Water from steam regeneration of GAC; drill cuttings	No	0.697 M 0.774 M 0.844 M
	> 100	40,000	1.1M	0.099 M 0.091 M 0.081 M	1 yr 2 yrs 3 yrs	30 10 5	"	"	No	1.2 M 1.3 M 1.4 M
	> 1,000	10,000	0.614 M	0.053 M 0.050 M 0.047 M	1 yr 2 yrs 3 yrs	30 10 5	"	"	No	0.667 M 0.717 M 0.764 M
Ozone Sparge	> 100	10,000	ND	40/yd	1 yr	~ 5-10	Med (effectiveness in clay)	Drill cuttings	No	0.4 M
	> 100	40,000	ND	35/yd	1 yr	~ 5-10	"	"	No	1.4 M
	> 1,000	10,000	ND	55/yd	1 yr	~ 20-30	"	"	No	0.55 M
UCRS – Vadose Zone and Saturated Zone										
Rotary Steam	> 100	10,000	0.2 M		2 mo/250 yd^3/day	~ 5-10	Low (in easy access)	PPE and NaCl solution	Partial recovery if condensate is subjected to IX	0.55 M
	> 100	40,000	0.2 M	1.2 M	7 mo/250 yd^3/day	~ 5-10	High (utilities probs.)	PPE and NaCl solution	"	1.6 M
	> 1,000	10,000	0.2 M	0.8 M	4 mo/100 yd^3/day	~ 50	High (utilities probs.)	PPE and NaCl solution	"	1 M

Table 4a. Engineering Cost and Performance Estimates for Technology Applications at Paducah UCRS – Vadose and Saturated Zones (Continued)

Technology	TCE in Soil, ppm	Volume, yd^3	Capital Cost⁺, $	Treatment Cost⁺, $	Treatment Period/Rate	Residual TCE in Soil, ppm	Implement Difficulty	Waste* Generation	Tc-99 Treatment	Total Costs‡, $
C-Sparge	> 100	10,000	0.15 M	0.05 M	1 yr	~ 1-5	Med (effectiveness in clay)	Drill cuttings; GAC	Possible with resin in well	0.2 M
	> 100	40,000	0.25 M	0.09 M	1 yr	~ 5	"	"	"	0.34 M
	> 1,000	10,000	0.15 M	0.06 M/yr	2 yrs	< 50	"	"	"	0.27 M
Bio	> 100	40,000	0.35 M	0.5 M	1 yr	~ 1-5	High: Effectiveness in clay questionable; Fouling	Trenching Waste	No	0.85 M
Steam Enhanced Extraction & Destruction (SEED)	> 100	10,000	ND	137/yd	2-3 yrs (6-8 mos. [steam] w/ 1½ yrs [HPO])	< 0.1	Medium-High Effectiveness in clay?	Drill cuttings; operational filter cake; PPE; contaminated equipment	Yes, entrained water will contain some Tc-99	1.4M Excludes ion-exchange of extracted Tc-99
	> 1,000	10,000	ND	113/yd	2-3 yrs (6-8 mos. [steam] w/ 1½ yrs [HPO])	<10	High (utilities probs.)	Drill cuttings; operational filter cake; PPE; contaminated equipment	"	1.1M

Table 4a. Engineering Cost and Performance Estimates for Technology Applications at Paducah UCRS – Vadose and Saturated Zones (Continued)

Technology	TCE in Soil, ppm	Volume, yd^3	Capital Costs[+], $	Treatment Cost[+], $	Treatment Period/Rate	Residual TCE in Soil, ppm	Implement Difficulty	Waste* Generation	Tc-99 Treatment	Total Costs[3], $
ECGO (Electro-Chemical-Geo-Oxidation)	> 100	10,000	0.37 M	0.54 M	1 yr	0.010	Medium (trenching & drilling for cables & electrodes)	Electrodes plated with ^{99}Tc; drill cuttings	Yes	0.91 M
	> 100	40,000	1.3 M	1.6 M	1 yr	0.1	Medium (trenching & drilling for cables & electrodes)	Electrodes plated with Tc-99; drill cuttings	Yes	2.9 M
	> 1,000	10,000	0.35 M	0.6 M	1 yr	0.1	Medium (trenching & drilling for cables & electrodes)	Electrodes plated with ^{99}Tc; drill cuttings	Yes	0.95 M
LASAGNA (electro-kinetics)	> 100	10,000	ND	140/yd	14 yrs	~ 1-50	Med-High (access probs.)	Ground water treatment, Iron(?) GAC(?)	Yes	1.4 M
	> 100	40,000	ND	140/yd	62 yrs	~ 1-50	Med-High (access probs.)	Ground water treatment, Iron(?) GAC(?)	Yes	5.6 M
	> 1,000	10,000	ND	115/yd	12 yrs	~ 10-500	Med-High (access probs.)	Ground water treatment, Iron(?) GAC(?)	Yes	1.2 M

Table 4a. Engineering Cost and Performance Estimates for Technology Applications at Paducah UCRS – Vadose and Saturated Zones (Concluded)

Technology	TCE in Soil, ppm	Volume, yd^3	Capital Cost[4], $	Treatment Cost[4], $	Treatment Period/Rate	Residual TCE in Soil, ppm	Implement Difficulty	Waste* Generation	Tc-99 Treatment	Total Costs[3], $
ChemOx/ Permanganate	> 100	10,000	Did Not Estimate – Vendor suggests ozone oxidation would be more cost-effective in the vadose zone							
	> 100	40,000								
	> 1,000	10,000								
Six Phase Heating	> 100	10,000	0.315 M	0.120 M	6-12 mos.	~ 1	Low	Vapor/steam condensate; drill cuttings	No	0.435 M
	> 1,000 (UCRS and RGA)	40,000	0.950 M	0.900 M	8 mos.	~ 1	Med	"	No	1.9 M
Surfactant Flush	> 100	10,000	NA							
	> 100	40,000								
	> 1,000	10,000								

[1] Resin use costs \$0.14/yd^3 of treated volume and resin disposal costs \$0.22/yd^3 of treated volume assuming 40,000 pCi/L water, soil porosity of 0.3, resin ion exchange capacity of 0.0133 Ci/ft^3 and resin cost of \$200/ft^3. Resin transportation cost is negligible. Decontamination water for drilling is less than 20 gallons per hole drilled.

[2] Assuming cuttings into RGA is mixed waste, cuttings disposal cost is \$0.90/yd^3 of treated volume and transportation is \$0.54/yd^3 of treated volume.

[3] Cost excludes horizontal drilling for access under buildings where applicable

[4] All costs are in millions, M. ND = Not Determined

*PPE = Personnel Protection Equipment NA = Not Applicable GAC = Granulated Activated Carbon IX = Ion Exchange

Table 4b. Engineering Cost and Performance Estimates for Technology Applications at Paducah RGA

RGA										
Technology	**TCE in Water, mg/L**	**Volume, yd^3**	**Capital Cost⁺, $**	**Treatment Cost⁺, $**	**Treatment Period/Rate**	**Residual TCE in Water, mg/L**	**Implement Difficulty**	**Waste* Generation**	**Tc-99 Treatment**	**Total Costs[3], $**
C-Sparge	> 1	50,000	0.193 M	0.032 M/yr	2 yrs	< 0.005	Low	Spent IX resin[1] Well Cuttings[2] GAC	Yes	0.257 M
	> 100	5,000	0.212 M	0.059 M	1 yr	< 0.005	Low	"	Yes	0.271 M
Ozone Sparge	> 1	50,000	Did not estimate; Vendor suggests permanganate more efficient							
	> 100	5,000	"							
Rotary Steam	**Depth generally limited to 40'; not applicable to RGA**									
Aerobic Bio	> 1	50,000	0.300 M	0.450 M	1 yr	< 0.002	Medium	Drill cuttings	No	0.750 M
	> 100	Not applicable in this high concentration								
Steam Enhanced Extraction & Destruction	> 1	50,000	Not applicable in this large volume							
	> 100	5,000	ND	113/yd	2-3 yrs (6-8 mos. [steam] w/ 1½ yrs [HPO])	~ 1	High (utilities probs.)	Drill cuttings; operational filter cake; PPE; contaminated equipment	No	0.565 M

Table 4b. Engineering Cost and Performance Estimates for Technology Applications at Paducah RGA (Continued)

RGA										
Technology	**TCE in Water, mg/L**	**Volume, yd^3**	**Capital Cost+, $**	**Treatment Cost+, $**	**Treatment Period/Rate**	**Residual TCE in Water, mg/L**	**Implement Difficulty**	**Waste* Generation**	**Tc-99 Treatment**	**Total Costs[3], $**
ECGO (Electro-Chemical-Geo-Oxidation) [electro-kinetics] w/ in-well CO_2 stripping & GAC offgas treatment	> 1 (saturated UCRS & RGA)	2.4×10^6	52 M	19.2 M	10 mos.	~ 0.005	Medium (trenching & drilling for conduits, cables & electrodes)	Liquid waste from GAC regeneration; electrodes plated with ^{99}Tc; drill cuttings	Yes	71 M
	> 100 (saturated UCRS & RGA)	3.0×10^6	60 M	24 M	10 mos.	~ 0.005	Medium (trenching & drilling for conduits, cables & electrodes)	Liquid waste from GAC regeneration; electrodes plated with ^{99}Tc; drill cuttings	Yes	84 M
Chemical Oxidation/ Permanganate	> 100	18.1 M (NW Plume)	ND	1.50-2.50/yd	-	< 0.1	Medium (Geology causes preferential flow paths)	Drill cuttings	No	27-45M
	> 100	8.8 M (NE Plume)	ND	1.00-2.00/yd	-	< 0.1	"	Drill cuttings	No	9-17M
	> 100	1.5 M (SW Plume)	ND	3.00-6.00/yd	-	< 0.1	"	Drill cuttings	No	4-9 M

Table 4b. Engineering Cost and Performance Estimates for Technology Applications at Paducah RGA (Concluded)

RGA										
Technology	**TCE in Water, mg/L**	**Volume, yd[3]**	**Capital Cost[+], $**	**Treatment Cost[+], $**	**Treatment Period/Rate**	**Residual TCE in Water, mg/L**	**Implement Difficulty**	**Waste* Generation**	**Tc-99 Treatment**	**Total Costs[3], $**
Six Phase Heating	> 100	20,000 (UCRS) + 20,000 (RGA)	0.950 M	0.900 M	1 yr	~ 0.01	Low	Vapor/steam condensate, drill cuttings.	No	1.9 M
Surfactant Flush	> 1	50,000	ND							
Surfactant Flush	> 100	5,000	0.317 M	1,202	1 mo/35 gpm	< 2	-	Waste Water Trmt $4.2M including GAC and IX. Drill cuttings.	No	6 M

[1] Resin use costs $0.14/yd³ of treated volume and resin disposal costs $0.22/yd³ of treated volume assuming 40,000 pCi/L water, soil porosity of 0.3, resin ion exchange capacity of 0.0133 Ci/ft³ and resin cost of $200/ft³. Resin transportation cost is negligible. Decontamination water for drilling is less than 20 gallons per hole drilled.

[2] Assuming cuttings into RGA is mixed waste, cuttings disposal cost is $0.90/yd³ of treated volume and transportation is $0.54/yd³ of treated volume.

[3] Cost excludes horizontal drilling for access under buildings where applicable

[+] Costs in Millions, M

*ND = Not Determined   NA = Not Applicable   GAC = Granulated Activated Carbon   IX = Ion Exchange

Table 4c. Engineering Cost and Performance Estimates for Technology Applications at Paducah Reactive Treatment Zones

Technology	TCE Concentration in Water, mg/L	Area	Capital Costs, $	Mainte-nance Costs, $	Useful Life, years	Contaminant Reduction	Implement Difficulty	Waste Generation	Tc-99 Treatment	Total Costs, $
Reactive Treatment Zones										
Fe (jet grout)	1-10	4000'x50'	3 M ($15/ft^2)	0.100 M/yr	10 yr/wall (2 walls needed)	TCE 99% ^{99}Tc 99%	Medium Depth and continuity concerns	Spent iron may have to be removed or encapsulated. Drill cuttings	Yes	8 M (2 walls)
	1-10	1000'x50'	0.500 M ($15/ft^2)	0.050 M/yr	10 yrs/wall (2 walls needed)	TCE 99% ^{99}Tc 99%	"	"	Yes	2.5 M
C-Sparge	1	4000'x50'	0.850 M	0.285 M/yr	20	TCE 99.5% ^{99}Tc 97%	Low	Spent IX resin[1] drill cuttings[2]	Yes	6.6 M
ECGO	< 10	900K yd^3	25 M	1 M/yr	20	TCE 99.95% ^{99}Tc 99.95%	Medium	Liquid waste from GAC regeneration; electrodes plated with ^{99}Tc; drill cuttings	Yes	45 M
Pneumatic Injection of Fe	1-10	1000'x60'	8.5 M	0.300 M	20	TCE > 90% ^{99}Tc > 90%	Medium	Spent iron may have to be removed or encapsulated; drill cuttings	Yes	8.8 M

[1] Ion Exchange Resin use costs $0.14/yd^3 of treated volume and resin disposal costs $0.22/yd^3 of treated volume assuming 40,000 pCi/L water, soil porosity of 0.3, resin ion exchange capacity of 0.0133 Ci/ft^3 and resin cost of $200/ft^3. Resin transportation cost is negligible. Decontamination water for drilling is less than 20 gallons per hole drilled.

[2] Assuming cuttings into RGA is mixed waste, cuttings disposal cost is $0.90/yd^3 of treated volume and transportation is $0.54/yd^3 of treated volume.

*PPE = Personnel Protection Equipment   ND = Not Determined   NA = Not Applicable

GAC = Granulated Activated Carbon   IX = Ion Exchange

7. Summary of Technologies Suggested for Possible Implementation at Paducah

The TAG discussed the information provided in Tables 4a, 4b, and 4c in detail. Technologies were screened for potential application in the vadose UCRS, the saturated UCRS, the RGA source zones and as a reactive treatment zone, based on expected cost and performance. The reactive treatment zone is located in the distal RGA plume. The TAG recommended several technologies to cover the range of anticipated concentrations, difficulty/ease of access, and use on both vadose and saturated soils. Another factor distinguishing the technologies was whether they would be applicable to the saturated UCRS, the RGA or both. The technologies suggested are generally lower in cost, have less waste generation, or greater maturity than competing technologies in a treatment area. The resulting ranking is as follows:

Zone	Technology Recommendations
UCRS - Vadose	• Rotary Treatment • Chemical Oxidation – Ozone with Fracturing • Direct Heating – Six Phase • Vacuum-Enhanced Recovery with or without Fracturing
UCRS - Saturated	• Direct Heating – Six Phase • Chemical Oxidation - C-Sparge • Dual-Phase/Two-Phase Extraction
RGA	• Chemical Oxidation - C-Sparge • Chemical Oxidation - Permanganate • Direct Heating – Six Phase • Steam/DUS/HPO
Reactive Zone	• Passive Reactive Media - Iron • Active System - C-Sparge

It should be noted that "Rotary Treatment" refers to processes that are facilitated by auger mixing of soil with the reactive agent; that is, the reactive agent could be steam, ozone, permanganate, or iron filings. Rotary Steam Treatment will be applicable only in open areas because of utilities and overhead obstructions in some of the contaminated sites of concern. Vacuum-Enhanced Recovery includes SVE and Dual-Phase/Two-Phase extraction.

7.1. UCRS – Vadose Zone

Some of the technologies recommended for the UCRS, such as Six-Phase Heating, Rotary Steam and Dual-Phase/Two-Phase Extraction, provide the option to treat both vadose and saturated zones. However, others, such as Soil Vapor Extraction with Fracturing, address only the vadose zone. More detailed estimates of performance in the UCRS must be made for each technology in cooperation with Paducah site personnel. Some form of fracturing may be necessary to adequately treat the UCRS soils with ozone or SVE technologies. The feasibility of fracturing high-density utility areas needs to be evaluated.

None of the technologies identified for the UCRS will remove Tc-99 from the vadose zone. However, the regulators in the TAG consider treatment of TCE in the vadose zone adequate remediation because the Paducah site baseline remediation plan includes a reactive barrier that addresses Tc-99 migration to the groundwater. *In situ* destruction of contaminants is of major interest to the TAG to minimize waste generation. If extraction technologies (such as SVE or direct heating) are used, the TAG prefers the direct treatment of collected gasses and water in order to minimize potential mixed-waste generation.

7.2. UCRS – Saturated Zone

Six-Phase Heating, Dual-Phase/Two-Phase Extraction and C-Sparge were retained for application to the Saturated Zone of the UCRS. The C-Sparge technology was retained because it may be able to treat both the TCE and Tc-99 in the saturated zone of the UCRS. However, the concept of using ion exchange resin in the well casing of a C-Sparge unit for removal of Tc-99 needs to be tested.

7.3. RGA

Suggested RGA technologies provide a range of options to treat potential DNAPL areas and the large lower-concentration areas. *In situ* contaminant destruction is again preferred. Each of the identified technologies has been recommended because they appear to be able to meet these expectations more cost-effectively than other systems. The C-Sparge system is suggested because TCE and Tc-99 may be treated concurrently in the RGA. The technologies identified also provide options for the areas with access issues.

Few technologies were identified to treat the Tc-99 in the RGA effectively *in situ*. Two reactive zone treatment technologies, Zero-valent iron and C-Sparge, were retained with the potential to treat both the TCE and Tc-99. The maturity of both technologies for this application at Paducah is limited; therefore the TAG thought having two alternatives would be prudent. Additionally, it is possible that the two technologies could complement each other in an actual deployment. Iron reactive media may retard the movement of Tc-99 either through sorption or precipitation following reduction. The Tc-99 can subsequently be released if the geochemical conditions in the groundwater changes. However, the kinetics of the release will likely be much slower than the uptake. Data from the ITRD-funded treatability study provide release rates. To be effective, the C-Sparge system would require the development of the ion exchange module, as suggested in KVA's report.

7.4. Characterization and Pilot Studies

The TAG suggests that a range of characterization technologies able to examine wide areas of contamination be investigated to help optimize the overall remedial design at the different areas. Effective subsurface and 'under building' characterization would help minimize remediation costs at Paducah. The types of technologies that need to be reviewed include geophysical, electromagnetic, magnetic resonance imaging, and other methods.

The TAG endorsed the pilot study planned by the Paducah site for an iron reactive barrier. This should provide the additional data needed to optimize the final remedial strategy for Paducah.

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The TAG initially ranked the pilot studies that are the most crucial for a final technology or strategy selection. These consist of:

- **Priority 1:**
  C-Sparge in the RGA with ion exchange for Tc-99
  Fracturing with ozone and SVE in the UCRS

- **Priority 2:**
  Direct Heating
  Permanganate

The latter two technologies should be considered for pilot deployment if the results of the Interagency DNAPL Consortium Program at Cape Canaveral suggest that they will be useful at Paducah. It should be noted that the priority assigned to the technologies listed for potential pilot studies did not constitute favoring that technology but rather signifies a need for further information regarding that technology's performance under the site-specific conditions at Paducah. Both of the top priority pilot studies were estimated by the vendors to cost $100-200K At the last TAG meeting on April 25-26, 2000, the TAG decided to pursue C-Sparge and Six-Phase Heating pilots at the C-752A and C-400 areas, respectively.

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APPENDIX A

COST ESTIMATES FROM TECHNOLOGY VENDORS

- IT Chemical Oxidation Using Ozone
- IT Chemical Oxidation Using Permanganate
- In-Situ Fixation – Rotary Steam Stripping
- Current Environmental Solutions – Six Phase Heating
- McLaren/Hart – Soil Vapor Extraction with Pneumatic Fracturing
- Morrison Knudsen/ K-V Associates – C-Sparge
- SteamTech - Steam Enhanced Extraction and in-situ Destruction (SEED)

IT CORPORATION
CHEMICAL OXIDATION IN THE VADOSE ZONE USING OZONE

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the group

IT Corporation

5600 S. Quebec Street,
Englewood, Colorado 80111
Tel. 303.793.5200
Fax. 303.793.5222

A Member of the IT Group

December 13, 1999

Mr. Mike Hightower
Sandia National Laboratories
Department 6233 MS-0755
P. 0. Box 5800
Albuquerque, NM 87185-0755

Subject Pilot Scale Deployment of in-situ chemical oxidation using ozone
Paducah ITRD Project

Dear Mike,

Following our previous correspondence of November 12, 1999, and our telephone conversation last week, IT Corporation provides the following input about the potential costs for pilot scale deployment of in-situ ozonation treatment of TCE contamination at Paducah.

As we discussed, based on the site geology and contaminant distribution, IT recommends that *in situ* ozonation is probably the most cost effective (compared to other available technologies) for vadose zone contamination in the UCRS. While potentially applicable for the saturated zone RGA, in that setting *in situ* ozonation would probably require more intensive operation and maintenance efforts than use of permanganate oxidation.

As we mentioned in out November 12, 1999 correspondence, there are many variable that control the treatment cost for in-situ ozonation, as with all oxidation technologies. Absent extreme conditions such as very highly organic soils, full-scale treatment costs will typically be estimated in the range of $20 to $40 per cubic yard. The primary uncertainties in such a 'rule of thumb" relate to depth of contaminant, subsurface permeability, injection well drilling costs, matrix oxidant demand, contaminant mass, and scale of treatment. Generally, larger scale treatments are more cost effective.

IT Corporation has considered preliminary costs for a pilot scale deployment of in-situ ozonation at Paducah. Our preliminary estimate is based an limited site data, and is not a proposal for services. We considered the effort involved to meet the following criteria:

- **Perform lab treatability testing to design an appropriate pilot scale deployment system.**
- **Inject ozone at a sufficient mass flux to obtain 90% treatment in a 6 to 12 month time frame.**
- **Treat a soil volume of 10,000 cubic yards, in-situ within the unsaturated zone UCRS**
- **2 cases of starting TCE concentrations (A) TCE < 100 mg/kg, and (B) TCE -1,000 mg/kg**

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We estimate that a pilot scale deployment to treat 10,000 cubic yards, starting at < 100 mg/kg TCE would probably cost in the range of $35 to $45 per cubic yard (i.e. $350,000 to $450,000). For a 10,000 cubic yard area, starting at 1,000 mg/kg TCE, pilot scale deployment costs may be as high as $50 to $60 per cubic yard (i.e. potentially $500,000 to $600,000).

Please understand that our rough cost data is not based on any detailed site data, and may have significant error, either high or low. We suggest that you do not rely on these cost data for any purpose other than technology screening and cursory planning. We would be happy to provide a more detailed cost estimate and proposal for services in response to a formal request for proposal.

We appreciate the opportunity to contribute to the Paducah ITRD project.

Thank you.

Sincerely,
IT Corporation

Wilson S. Clayton, Ph.D.
Principal Geological Engineer
Technology Applications Group

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IT Corporation
Chemical Oxidation in the RGA using Permanganate

the IT group

November 12, 1999
Refer: 770869/00000059

Mr. Mike Hightower
Paducah ITRD Project
Sandia National Laboratories
Albuquerque, New Mexico 87185-0755

Mr. Ken Kuzio
Paducah ITRD Project
Sandia National Laboratories
Albuquerque, New Mexico 87185-0755

Subject: Field Demonstration of In Situ Chemical Oxidation for Treatment of Trichloroethylene Impacted Soils
Paducah Gaseous Diffusion Plant (PGDP)
Paducah, Kentucky

Dear Sirs:

The following are IT Groups ideas for the treatment of chlorinated contamination at the Paducah, Kentucky Gas Diffusion Facility. Our approach and work plan has been prepared as a conceptual document, providing our thoughts on the field application of permanganate as a treatment for TCE detected in the soil and groundwater at this site. Our approach would include pilot testing the technology at two test cells, selected as discrete treatment areas treating the unsaturated (i.e., source area) and saturated (i.e., plume migration) portions of the site. Using the data collected in the pilot demonstrations, IT would complete a data review and technology evaluation to determine the potential for scale-up application at larger portions of the site. At this time, IT believes that the completion of the pilot projects is prudent to evaluate the effectiveness of the permanganate using actual site conditions. As we have discussed, a significant part of the proposed evaluation will be for the potential mobilization of radioactive isotopes (particularly uranium) by the permanganate. Thus, the pilot projects were developed not only to evaluate the efficacy of TCE oxidation at this site, but also to evaluate the potential for impacting other oxidizable species present at the site.

The effectiveness of treatment depends on three factors: the reaction kinetics between the permanganate and the contaminant(s), the contact between the oxidant and the contaminant(s), and competitive reactions between permanganate ant other reduced/oxidizable species. If the contaminant being targeted for in situ chemical oxidation is reactive (i.e., chlorinated ethenes such as TCE), and sufficient oxidant has been added to overcome the demand from other reduced species, the limiting factor to the successful application of in situ oxidation is the transport of the oxidant to the areas of contamination and not the reaction itself between the permanganate and the contaminant. The oxidation of TCE by permanganate is, compared to the time to transport the permanganate to the treatment zone, an essentially instantaneous reaction. The Paducah site provides several challenges to the application of permanganate - the geology is heterogeneous, the potential presence of hazardous radioactive species and site access limitations. As a result, the

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application of permanganate at this site would involve several different approaches for oxidant delivery to the contaminated areas. Push wells (e.g. GeoprobeSTM) may be a good means to apply the permanganate in open areas. An alternative application approach is horizontal wells to distribute the permanganate beneath buildings or other poor access areas.

Based upon our knowledge of the site, coupled with these potential challenges, IT recommends proceeding by completing the pilot projects. Field pilot studies would clarify several technical issues so we could scope and cost a full-scale program.

IT looks forward to discussing the implementation of this demonstration following your approval. If you have any questions regarding these submittals or the project, please call me at 781-769-7600, Ext. 205.

Sincerely,
IT Corporation

Richard Lewis, CPG
Vice President – Technology Project Director

cc: Project File

Enclosure

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IT Corporation

100 River Ridge Drive
Norwood MA 02062-5045
Tel. 781.769.7600
Fax. 781.769.7992

MEMORANDUM

TO: **Mike Hightower**
Via FAX: **505-844-1480**

Copy: **Ken Kuzio**

Date: **November 24, 1999**

Subject: **Supplemental Information**

The following information is to address the questions submitted to IT on November 8, 1999.

Costs - include:

Capital Costs
Engineering and design - Yes
Permitting - Yes (UIC permits only)
Mobilization or installation - Yes
Hardware, piping, wells, storage, etc., - Yes
Utility connections, upgrades, or extensions needed - We assumed that water would be made available at no cost at the site. In addition, power usage was not included since this would be a minor expense. The power usage could be determined and added in at a nominal amount if necessary.
Instrumentation and process monitoring equipment, - Yes
Demobilization - Yes, however nothing was budgeted for well abandonment.

Operating and Maintenance Costs
System operation manpower - Yes
Energy and Utilities - We did not include any cost for electrical or water. We assumed that both would be provided at the site. Neither would add an appreciable cost to the overall budget.
Process materials and conumables - Yes
Treatment Process monitoring - Yes
Waste Treatment, storage and waste disposal - none required since no hazardous waste materials are generated in the process. There may be soils generated in well construction process if Geoprobe points can not be used. No funds were allocated for soil cutting disposal if alternative drilling methods are required.
Hardware or equipment replacement - No, but none is anticipated.

Performance - includes:

Expected treatment area - All areas in having TCE in excess of 1 ppm in groundwater.
Expected treatment rate and /or expected treatment period? - Anticipate treatment would take place for 4 to 6 months of the year (late spring through fall) for each application. Two applications are anticipated with one year of post treatment monitoring.
Estimated amount of contaminant reduction - Anticipate two applications would be required to reach 90% reduction in TCE concentrations in groundwater.
Wastes generated volumes, and disposal or treatment - No hazardous wastes requiring disposal will be generated. Small quantities of sampling equipment materials and personal protection equipment

will be the only waste requiring disposal. IT plans to apply the permanganate through Geoprobe drill methods. If alternative drilling methods are required then drill cuttings will require disposal. No cost for drill cuttings disposal has been budgeted at this time.

application of in situ oxidation is the transport of the oxidant to the areas of contamination and not the reaction itself between the permanganate and the contaminant. The oxidation of TCE by permanganate is, compared to the time to transport the permanganate to the treatment zone, an essentially instantaneous reaction. The Paducah site provides several challenges to the application of permanganate - the geology is heterogeneous, the potential presence of hazardous radioactive species and site access limitations. As a result, the application of permanganate at this site would involve several different approaches for oxidant delivery to the contaminated areas. Push wells (e.g. Geoprobes™ may be a good means to apply the permanganate in open areas. An alternative application approach is horizontal wells to distribute the permanganate beneath buildings or other poor access areas.

Based upon our knowledge of the site, coupled with these potential challenges, IT recommends proceeding by completing the pilot projects. Field pilot studies would clarify several technical issues so we could scope and cost a full-scale program.

IT looks forward to discussing the implementation of this demonstration following your approval. If you have any questions regarding these submittals or the project, please call me at 781-769-7600, Ext. 205.

Sincerely,
IT Corporation

Richard Lewis, CPG
Vice President –Technology Project Director

cc: **Project File**

Enclosure

Conceptual Technical Proposal

Field Demonstration of In Situ Chemical Oxidation for Treatment of Trichloroethylene Impacted Soils

Paducah Gaseous Diffusion Plant (PGDP)
Paducah, Kentucky

Prepared by:
IT Corporation
100 River Ridge Road
Norwood, MA 02062

Submitted to:
Mr. Mike Hightower and Mr. Ken Kuzio
Paducah ITRD Project
Sandia National Laboratories
Albuquerque, New Mexico 87185-0755

1.0 INTRODUCTION

This proposal provides a description of the general approach offered by IT Corporation for the implementation of an oxidation treatment remedy for chlorinated solvent contamination detected at the Paducah Gaseous Diffusion Plant (PGDP) in Paducah, Kentucky. IT has reviewed a limited amount of information provided by Sandia Laboratories on the facility and has developed a conceptual approach to the treatment of both vadose and aquifer contamination. IT believes that a substantial proportion of the contamination at this facility can be cost effectively treated with potassium or sodium permanganate. Our experience at other sites with the same chlorinated solvents has shown that impacted media can be treated for costs ranging between 10 and 50 dollars per yard. The specific cost of treatment is highly dependent on the depth of treatment and the contaminant concentrations.

The facility in Paducah does have other considerations for the application of oxidant. A critical aspect of our technology evaluation would not only be on chlorinated solvent destruction, but would also be on increasing the solubility of any radioactive materials. Oxidants including potassium permanganate can change the oxidation state of metal ions in the formation. This generally results in the precipitation of most metals. However, certain ions solubility's can be increased through oxidation. One such ion is uranium.

For this reason, we recommend that we undertake a field demonstration at two test cells selected at the site. One test cell will evaluate permanganate oxidation of adsorbed source material in the vadose zone, while the second test cell will treat a portion of the saturated aquifer. This approach was selected to not only prove out the application and effectiveness of the treatment technology, but also to collect pilot test information on the potential mobilization of uranium.

1.1 Conceptual Technical Approach

Our conceptual technical approach is to provide two pilot demonstrations to treat and evaluate the field application of permanganate in the vadose and saturated zones. Through this approach, the results of each test can be evaluated using the site-specific data, to ascertain not only the effectiveness of the test cell treatment, but also the cost and scale up necessary to apply the technology to a larger portion of the site. IT understands that a great deal of information has already been collected at the subject site, most of which was unavailable for review prior to the development of this conceptual approach. Prior to field application or mobilization, IT understands that additional time would be devoted to meeting with site representatives and reviewing historical information. Furthermore, IT also understands that all personnel and contractors working at the subject site will need to attend site-specific radioactive material instruction and training. In order to complete this conceptual plan, IT has assumed that all project teams will require a health and safety person (provided by IT) at all times. Implicit in this assumption is that additional site monitoring and non-IT personnel, if required during completion of project activities, will provide equipment decontamination.

We have considered the appropriate approach for test applications in light of the available technical data and our previous experience. The site consists of discontinuous sand/gravel in a silt/clay matrix collectively referred to as the Regional Gravel Aquifer (RGA), overlying a semi-confining layer of lower permeability silt/clay. Based on the cross-sections provided, the geology is both vertically and laterally non-homogenous resulting in the potential for channeled and preferential flow paths that may inhibit the permeation of permanganate. Therefore, in order to increase the contact between the permanganate and deliver an adequate volume of solution, IT Corporation proposes permanganate solution delivery a series of closely spaced addition points, adding the permanganate to the formation under pressure (although not at high enough pressures to induce hydraulic fracturing). We have used this technique previously in similar lithologies, and found that it was required for delivery of an adequate volume of fluid into the low permeability formation, and provided enhanced transport of permanganate away from the injection points.

our approach was developed based on a goal to optimize the balance between cost-effective treatment and confidence in decreasing the concentrations sufficiently to meet a treatment objective of greater than 90% removal in soil and groundwater. A primary objective of hydraulic delivery of permanganate solution is to achieve maximum contact of injected solution with subsurface contaminants. This can potentially be achieved by various combinations of addition well spacing, well construction, duration of injection and injection parameters (i.e., pressure and flow). Ultimately, an optimum strategy must consider subsurface permanganate transport mechanism, provide sufficient engineering controls to ensure adequate control over the injection process, and provide reproducible and cost-effective deployment.

Permanganate loading requirements are related to permanganate consumption by TCE contamination as well as oxidation of naturally occurring materials within the aquifer matrix. The total mass of TCE within the treatment zones was estimated using the information provided to provide a basis to evaluate permanganate loading requirements. The estimate of TCE mass is highly simplified, based on the limited characterization data provided. Reasonable estimates were made of aquifer properties in order to perform the calculations to estimate application volumes.

There is considerable uncertainty in the estimates of permanganate loading requirements. This uncertainty is related to difficulty in estimating:

- TCE mass present (i.e., potential losses during the sample collection and handling prior to analysis);
- field-scale matrix demand (i.e., non TCE contaminants, natural metals, organics and other consumers); and,
- a general inability to account for aquifer heterogeneity and anticipated non-homogeneity of the TCE distribution.

IT therefore recommends a conservative approach, where the "likely" estimate of possible permanganate consumption is used for design purposes. Furthermore, this is a more cost-effective approach, since permanganate chemical costs are small compared to labor, equipment and analytical costs involved in fluid delivery.

1.2 Estimated Costs

An estimate of project costs follows in Appendix A. Please note that in order to prepare this estimate, IT had to make a series of assumptions (see Appendix B). Our proposed pilot test area for the vadose treatment area is approximately 30 by 50 feet to evaluate the optimum permanganate mass loading. Our proposed pilot test area for the saturated zone is approximately 50 by 100 feet.

Within this overall treatment cost, we have included an optimization of the fluid delivery process, and collection of substantial injection performance data. We have assumed the subsurface monitoring as specified above and have included a significant level of effort for technical personnel to be on site to evaluate real-time subsurface data.

1.3 Potential Scale-Up Costs

If this technology proves acceptable in the pilot evaluations, the technology could be applied similarly at other impacted portions of the facility. Applications at other portions however will be much more site specific, necessitating the use of directional or horizontal boring (to access beneath the slabs of buildings), interior drilling (to access the subslab areas in impacted buildings (where possible) while providing a competent permanganate distribution system and minimize interference with ongoing activities.

An approximate estimate of project costs is based on treatment of areas of the saturated zone with more than 1,000 μg/L of TCE. Based on this criteria, IT reviewed the three major plumes at the Paducah facility. We developed rages for the treatment of each of these plumes based on the contamination levels reported and on our prior experience with similar contamination levels. The Northwest plume having a length of approximately 14,000 feet and width of 700 feet (portion >1,000μg/1), is estimated to be between 25 to 45 million dollars. The Northeast plume having a length of 12,000 feet and width of 400 feet would be between nine and 17 million dollars. The Southwest plume, which is approximately 4,000 feet long and 200 feet wide, would be between four and nine million dollars. These ranges are very large due to the uncertainties associated with the actual quantities to be treated with in these large areas. But can serve as reasonable order of magnitude estimate based on the available data.

The estimates to treat the vadose source areas can not be estimated until we establish site specific performance data from the proposed demonstration project.

1.4 Past Performance and Waste Management

IT Corporation is an industry leader in the application of in-situ oxidation technology. We have completed approximately 20 field projects using in-situ chemical oxidation by permanganate, and an equal number are in the design or field implementation stage. About 75% of these projects have utilized permeation of permanganate fluid by direct push drilling. This experience includes the ongoing work performed by IT Corporation for TCE treatment at Cape Canaveral Launch Complex 34 for the Interagency DNAPL Consortium (IDC) and at various Superfund sites across the country.

2.0 TECHNICAL APPROACH

2.1 Test Cell #1 - TCE Impacted Vadose Zone Soil

This test well was selected to provide a manageable test location, believed to be readily accessible and limited in extent to evaluate the application. The area selected is the northwest TCE lobe in the SWMU001 area, approximately bounded by borings 001 -109, 001-108, 001-115 and 001 -114. The test area is approximately 50 feet (East-West) by 30 feet (North-South) and consists of a portion of the unsaturated impacted soils at this location. The data provided suggests that total TCE may be approximately 330 to 340 pounds, requiring the addition of 4,100 pounds of permanganate for oxidation (assuming no competing or additional contaminants are present). For application, a 5X factor was assumed for the other soil demands (lesser concentrations of potential daughter degradation products, minor organic material and reduced metals species), thus approximately 21,000 pounds of oxidant is required.

To apply the permanganate, IT has assumed injection points will have a seven-foot radius of influence, resulting in an injection point spacing of approximately 10 feet. This spacing requires 24 points. Again, assuming six treatment layers (at depths of 5, 10, 20, 30, 40, and 50 feet below grade), a total of 144 individual injection locations are thus proposed, each receiving 145.8 pound of oxidant:

- if 2% KMn04 is used, 870.3 gallons of fluid should be injected in each location
- if 20% NaMn04 is used, 87 gallons of fluid should be injected in each location (selected option).

Each layer should require 2 days to complete. This also allows one day to sample prior to treatment of each layer, plus one remobilization for post treatment sampling, therefore injection will require 3 to 4 weeks to complete.

In addition to the oxidant addition, IT also proposes to inject fluoride along with the permanganate as a non-reactive tracer. This trace will allow delineation of the areas of influence. Four monitoring locations will be installed with four lysimeters and one monitoring well per location. Baseline soil moisture and groundwater samples will be collected before the first injection. Subsequent soil moisture and groundwater samples will then be collected at the end of each layer injection cycle. Samples will be analyzed for ORP, temperature, TCE, uranium, NaMn04, CI and F. Post injection soil moisture and groundwater samples will be collected 2 and 4 weeks after final application. One contingency soil moisture and groundwater sample event may be collected 6 weeks after the final treatment. Soil samples will be collected from locations adjacent to previously collected soil samples (001-155, 001-165 and 001166). Soil samples will be collected every five feet from 5 feet to 50 feet below grade and analyzed for TCE and uranium. Soil samples will be collected 3 weeks and 6 weeks after final injection

2.2 Test Cell #2 - TCE Impacted Saturated Zone

This demonstration test is proposed to be conducted in the southwest portion of building C-400. We selected that area due to the number of monitoring points in the area and the degree of characterization that has already been completed on this release area. The TCE levels in this are substantial (>1,000 ug/kg at boring 400-015) but the contamination is in a relatively limited area (a treatment cell 200 feet long by 100 foot width would treat the majority of this release). The treatment program would extend to a depth of 100 feet which would encounter a variety of the geologic units that would be characteristic of this site.

If site access is an issue in this area we could conduct a test in other portions of the impacted aquifer. An alternative may be a similar size area, selected further down gradient, away from the building structures in either the Northeast or Northwest plumes.

The testing program would utilize an application of permanganate on a 50-foot spacing (based on an assumed individual radius of influence of 35 feet). Therefore, to treat a 200 by 100-foot area we would drill 6 borings through which we would add permanganate in a solution ranging between 2 and 20 % depending on the TCE concentrations detected. This application would be repeated every 10 vertical feet (6 applications) in the saturated zone from a depth of 50 feet to a depth of 100 feet below ground surface or the base of the Regional Gravel Aquifer (RGA).

To establish a monitoring program in the aquifer six wells be constructed as multi level (5 port samplers) monitoring wells in the treatment cell. A field GC would be utilized to characterize aquifer conditions in each of the wells prior to the treatment program. This water quality data would be used to establish depth and area specific application rate for the permanganate. The monitoring parameters would be the same parameters as described in Test Cell 1.

Two rounds of post treatment sampling will be conducted on existing monitoring wells after the treatment period is completed. The timing of the sampling events will depend on the field monitoring results but we would anticipate sampling 3 and 6 weeks after final application. This data would then be complied into a three dimensional model to aid in the development of the final report.

2.3 Description of Generalized Work Tasks

The following presents a detailed description of the project work tasks. At this time, these tasks provide only generalized information; more specific information and work plans will be developed to support the actual field applications when more information is provided.

Task 1.0 Engineering Design and Permits

IT understands that regulatory approval will be needed for permits necessary for the execution of the project scope. IT will be responsible for providing an engineering plan for submittal to the agencies for the demonstration project. IT will also provide evidence of any regulatory licenses or certifications (e.g. OSHA certificates, previous experience, personnel qualifications) for the staff involved in the project.

Task 1.1 Technical Consultation with PDGP (Conceptual Design Meeting)

IT Corporation recognizes that additional technical input from and interaction with PDDP staff and the project Technical Director will improve the overall technical work plan. In order to maximize this interaction, we propose a working meeting between IT and PGDP personnel. At this time, IT will present our conceptual approach and lead a discussion to allow engineering modifications to be incorporated into the fieldwork based on the site-specific knowledge. Potential modifications include, but are not limited to:

- amount of MnO_4, solution loading;
- variations in concentration of $NaMn0_4$ solution injected over the treatment area;
- variations in lateral spacing of injection locations;
- variations in vertical intervals for injection; and,
- injection pressures and flow rates.

Task 1.2 Prepare Technical Work Plan

Following this initial strategizing meeting and the review of further information, IT will prepare a technical work plan for approval. This plan will encompass a detailed description and methodology for the NaMn04 injection. Issues to be covered include:

- design basis summary for the work scope (including mass estimates);
- delivery and control of the permanganate;
- permanganate mixing and handling;
- injection spacing rationale and description;
- vertical interval spacing rationale and description;
- design injection volumes, pressures, and feed concentrations;
- injection timing parameters;
- equipment specifications;

- costs;
- waste generation and management;
- deployment procedures (including utility/subsurface obstruction protocols);
- contingency plans;
- proposed process monitoring parameters and schedule; and,
- data management plans.

IT understands that the Work Plan must be approved prior to initiation of the field effort. Ten copies of the Plan will be prepared. This technical work plan will include subsections for a Quality Assurance Plan (QAP), a Health and Safety Plan (HASP) and other supporting plans as necessary. The following summarizes these additional plans.

Quality Assurance Plan

IT will develop a quality organization structured so that IT's Quality Management Program and specific customer quality requirements are fully integrated. The designated on-site QA representative works closely with the project manager to translate the company's (and Client) quality requirements into achievable implementation steps. The Quality organization provides support for the following functions: quality control, inspection, training, quality engineering, equipment reliability/maintainability, standards, and their components, environmental tests, laboratory services, internal and vendor quality audits, calibration and control and measuring and test equipment. Organizational independence (with stop work authority) of all QA personnel will be assured so that they can perform their duties. A list of the project personnel for the PGDP site and their qualifications is included in Appendix A.

Health and Safety Plan

A Health and Safety Plan (HASP) will be prepared that will reference or include the requirements of the facility HASP for this work and include requirements and controls specific to the permanganate mixing and application system.

Waste Management Plan

IT or its subcontractors will produce soil cuttings, well development water, well purge water and PPE as Investigatory Derived Wastes (IDW) during the completion of project activities. Dispositions of these materials will require characterizations and disposal. At this time, IT has not included any costs associated with IDW characterization or disposal. Based upon the further work and initial discussions with the site personnel, IT will develop or reference an existing Waste Management Plan for approval.

Task 2.0 Finalize Design

The system design will be finalized and incorporated into the Technical Work Plan. The design basis will be initially discussed at the Conceptual Design meeting and issues and decisions reached at this meeting will be incorporated into the design.

Two bench scale tests are proposed to refine the design basis for permanganate consumption. A bench scale tests for permanganate consumption by the aquifer matrix (background reductants) will be performed on a soil sample slurry from a non-impacted area of the site. A second bench scale test will be performed to quantify an expected "use ratio" for permanganate consumption by the TCE impacted soil matrix within the treatment cells. These samples will also be analyzed for metals (uranium only) to provide a baseline to measure oxidant-induced changes in the geochemistry. The bench scale studies will be run at IT's Technology Development Laboratory in Knoxville. The Technical Work Plan will contain a bench scale study report for each of these tests as appendices.

Task 3.0 Mobilization of Equipment and Supplies

Task 3.1 Procurement

IT will provide all procurement services for sodium permanganate, storage and mixing facilities, drill rig vendor, secondary containment and all materials and supplies. IT Corporations policy is to procure goods and services in an ethical manner, using sound business practices, from sources that provide maximum value for each expenditure. The procurement process and assessment of value consider cost, delivery, reliability and applicable regulations. Upon completion of the final design, IT Corporation will complete procurement of all subcontractors, materials and services to be used for the field demonstration. Purchase orders, material lists, and subcontractor bid unit costs will be finalized.

Task 3.2 Mobilization of Equipment

It will be responsible for packaging, transport, unloading, installation/set-up and checkout of all equipment and materials for the project. It is understood that the equipment and materials will need to be mobilized to a PGDP designated location for required equipment checks and radiological surveys prior to installation and set-up at the site. IT has assumed that all site personnel will attend the RAD Worker I training and site safety and security orientation. The costs presented herein do not include the costs associated with completing this onsite training.

Task 4.0 Field Demonstration and Deployment

IT Corporation will install and operate the permanganate oxidation system for duration of approximately three weeks (test Cell #1) and three weeks (Test Cell #2). This period will include equipment mobilization and setup, on-site testing, application of the oxidant, in-well data analysis and demobilization. Monitoring of the treatment performance will continue periodically over a 6 to 9 week period after the final application is completed.

The understood goal for this operation is to maximize the mass removal of TCE and to attempt to "target" goals. However, the purpose of this project is to demonstrate the cost effectiveness and technical viability for reaching these targets using in-situ chemical oxidation with sodium permanganate. Successfully obtaining these goals is neither stated nor implied as the perceived effectiveness of this technology is highly dependent upon the site specific lithology, mass of contaminant, distribution of contaminant, and timeframe of application. The distribution of the contaminant, site specific lithology, and innovative nature of this work precludes the ability to evaluate the expected final result of the remedy with sufficient accuracy. The endpoint of the demonstration project will be considered met when the proposed scope of work has been met by completion of the specified tasks.

The installation and operation of the sodium permanganate oxidation system will include:

- all equipment, parts, instrumentation, electricity, fuels, chemicals, and other items required for completion of the project;
- all direct and indirect labor including supervisory personnel required for the installation and operation of the system;
- all subcontract charges;

- all mobilization, installation, operations, demobilization, and site restoration activities; and,
- other miscellaneous items.

<u>Task 5.0 Final Technical Repo</u>

Ten (10) copies of a Final Report will be prepared and delivered, An electronic copy (Word or Adobe) will also be provided. The report will contain all of the monitoring results including field and laboratory parameters. The TCE concentrations over time, as well as associated breakdown product concentrations, will be presented. Data tables contour maps and graphs will be used to illustrate the results. The NaMnO, loading rates and utilization rates will be compared to design values. Recommendations for any future changes to the remedial technology application will be presented. Additional features of the report will include:

- treatment process description and history;
- treatment system design summary;
- descriptions of the equipment, operation procedures, and process operation monitoring; operation results including summaries of al data collected, all QA data and documentation; listing of types and amounts of secondary waste; discussion of results detailed cost analysis including mobilization and deployment costs; unit cost breakdown for cubic yard (meter) of soil treated and groundwater; recommendations for monitoring to detect potential rebound; and, conclusions and recommendations.

3.0 Past Performance

IT Corporation has extensive experience in all aspects of the proposed project including project management, project financial control, QA/QC, and health and safety. IT Corporation is also an industry leader in the development and deployment of in-situ remediation technologies. We are recognized as an industry leader in the application of in-situ oxidation, using ozone and permanganate. We have pioneered in-situ ozonation, and have leaded the industry in commercialization of permanganate technology.

3.1 IDC Permanganate Demonstration Project, Cape Canaveral

Ongoing work with permanganate includes the demonstration of TCE DNAPL treatment using permanganate at Cape Canaveral. This ongoing project for the Interagency DNAPL Consortium (IDC) involves direct permeation of permanganate solution along depth discrete intervals using direct push drilling. Field data from this site have not yet been analyzed and reported. We have currently completed preliminary tests involving injection of permanganate solution and fluoride tracer. These results have indicated that tracer transport exceeds permanganate transport. This expected result reflects the limitations of permanganate reactions on permanganate transport. These results have indicated a greater mass of TCE in the subsurface than expected, and are currently being used as a basis to refine our estimate of permanganate loading requirements.

3.2 Lance Permeation in Clays, Australia

The scale of our field efforts with permanganate has ranged from small-scale field pilot tests to full-scale treatment over a 2,000 square meter (0.5 acre) area using 27,000 kg (61,700 lb.) of potassium permanganate. This large-scale project is similar to the proposed lance permeation of the Minford at PORTS. The project involved lance permeation injection of permanganate via 330 injection points, on a 2.5 meter (8 ft) spacing into an overconsolidated low permeability clay. The site is located in Australia. Data from this project have not yet been published, but samples of representative site data are included in Appendix D.

A preliminary test was conducted to compare results on injection under Darcy flow conditions (into PVC wells) to injection by lance permeation at pressures which induced hydraulic fracturing. The hydraulic fracture approach resulted in much greater permanganate transport distances, and allowed injection of significantly greater volumes of fluid in shorter time frames. Peak injection pressures of 1,000 to 3,000 kPa (145 to 400 psi) resulted in hydraulic fracturing, and allowed delivery of 600 liters (158 gal) of solution in a 20 minute time frame.

Based on the results of the preliminary testing, fluid injection was performed at two depths (19 feet and 28 feet) at each lance location. (Note that the vertical spacing of these injection intervals is significantly greater than that proposed for the Minford at PORTS.) Over the 330 lance locations, a total of 396,00 liters (104,600 gallons) of 7% permanganate solution was delivered. Extreme high temperatures in the Australian summer facilitated mixing of the 7% (essentially saturated) potassium permanganate solution.

Following the full scale treatment, initial TCE concentrations in groundwater as high as 5,000 µg/I (indicating the presence of non-aqueous phase liquid TCE) were reduced below detection limits (< 5 µg/1) at many locations. An overall mass reduction of 80% was observed. Significantly better result can be expected for the proposed Minford treatment at PORTS, because of the ten-fold smaller vertical spacing of lance injection intervals.

IT - Appendix B

ASSUMPTIONS

IT has estimated the costs associated with this proposed scope of work based on assumptions and cost for similar projects. This scope of work will be governed by the terms and conditions contained in Groundwater Technology Agreement/Proposal for Environmental Services. Any change in work scope and/or unforeseen field conditions will require a corresponding change in project costs. Any additional services requested of Groundwater Technology that are not described in this proposal will also be billed on a time and materials basis and a request for these services will authorize us to increase the budget accordingly.

As this proposal was designed to provide only approximate costs, the estimated values herein are for discussion only. Should the project proceed forward, IT can generate more refined estimates for approval.

The following assumptions were made to estimate the costs of activities for this project:

- **All employees working at the site will be provides with a one day indoctrination (i.e., awareness training). Upon completion of this training, employees will have unrestricted access to the work area and sanitation facilities**
- **Site personnel will provide all decontamination (if required), soil and residual disposal, marking of buried utilities and access to the property;**
- **the auger and geoprobe techniques can be utilized to collect soil samples and install monitoring wells, lysimeters, addition points and all other subsurface appurtenances;**
- **All work may be completed using standard level D personal protective equipment. Contingencies for upgrade to level C conditions (respirators and tyvek suits) will be provided and accessible;**
- **Office and storage facilities suitable for short term use are available in close proximity to the work areas for temporary use during the field portions of activities;**
- **Site activities will not require generation or disposal of any material;**
- **No landscaping repair of any area disturbed on properties;**
- **All laboratory analyses are to be completed at standard laboratory turn-around time;**
- **Work will commence within 10 business days from our receipt of signed authorization;**
- **The work areas will be demarked by temporary traffic cones or plastic fencing and no further traffic control provisions will be required;**
- **IT will provide three project personnel for two one day meetings to be held on site at the start of the project (for logistical coordination and partnering) at the conclusion of activities after generation of a draft report (for comment to review the technical findings prior to issuance of any final report);**
- **Five copies of all reports, one draft and final, will be provided with attachments and supporting documentation;**
- **PGDP or its representatives will provide and make accessible additional information concerning the demonstration sites sufficient to establish potential contaminants of concern and develop plans for site activities including surveyed site plan showing wells, buildings, curb**

cuts, concrete or paved areas, significant structures, drainage ways, dry wells, UST/AST locations, and utilities;

- **Soil bearing capacity is adequate for support the temporary usage of remedial system components;**
- **Remedial goals have not been stipulated for the demonstration project;**
- **Utilities are available at the demonstration sites sufficient to facilitate small capacity pumps and portable equipment;**
- **Other than a state Underground Injection Control (UIC) Permit, no permits will be required to conduct this work; 0**
- **10 copies of report deliverables**
- **Potable water is available on site readily accessible to the demonstration areas at no charge to IT;**
- **Site will provide security badge access for its personnel and vendors on-site.**

Because this proposal contains information which is proprietary to IT, its contents shall not be disclosed by you to others outside your own organization, nor shall this proposal be duplicated, used, or disclosed by you or others for any purpose other than your evaluation. However, if a contract is awarded to IT, as a result of the submission of this proposal, you will have the right to duplicate, use or disclose any information contained in this proposal which IT agrees, in writing, is not proprietary.

IN-SITU FIXATION
ROTARY STEAM STRIPPING

630446

In-Situ Fixation
P. 0. Box 516
Chandler, AZ. 85244
602-821-0409
602-786-3184 - FAX

Fax

To: **Mr. Mike Hightower**
Fax: **505-844-0968**
Phone: **505-844-5499**
Re: **Cost Breakdown**

From: **Jan Stevens**
Pages: 4
Date: **June 21, 1999**

Mr. Hightower:

Per your request, here is the information Dick e-mailed to you last Thursday. If you need any other information, please let me know.

Jan Stevens

BACKGROUND

What I have tried to complete for you Is a realistic project itemized cost breakdown.

You will notice that I have broken down the indirect costs (i.e. mobilization, site preparation, reports, etc.) You can take out any phase you feel is not appropriate in your presentation. I did not include these in the cubic yard costs because they vary by project condition.

The cubic yard unit cost is based upon our new auger which is larger in size, 48 sq. foot per cell vs 35 sq. foot cell (six foot diameter augers vs five foot). Also experience have shown that the depth used in this estimate, 40 feet, should require between one and two hours per cell for treatment. Treatment time over two hours starts to become uneconomical.

COST BREAKDOWN

1 A.	**Mobilization/Setup/Decon/Teardown/Demob**	**$120,000 - 170,000**
1 B.	**Documentation**	**$ 10,000 - 38,000**
2.	**Production cost estimate Steam Only** **Average cost per cubic yard =**	 **$36.00**
3.	**Cost to inject Iron Fillngs**	
	2% Iron = 60 # C.Y.	**$ 15.00 per cubic yard**
	Additional equipment/labor	**$ 5.00 per cubic yard**
		$ 20.00 per cubic yard

Steam / Iron Simultaneous Treatment The finer sized grade of Zero Valent Iron costs approximately $ 500.00 per ton(.25 lb). Assuming a soil density of I 10 lb per cubic foot (3000lbs per C.Y.) our experience has shown that 2% iron works successfully. Once on the project you might be able to reduce the Iron percentage to as low as 1 % if the soils and contamination are favorable. The simultaneous application of steam and iron adds five major cost items to the steam application. These costs are iron, guar, mixing, pumping, and labor. I have used a $20.00 per cubic yard cost figure however as more experience is gained working with the iron fillings slurry the possibility could exist where a coarser sized iron ($350.00 ton) could be used. This could represent a savings of $4.00 to $5.00 per cubic yard.

SUMMARY

Indirect costs	**$120,000.00**	**-**	**170,000.00**	
Reports	**10,000.00**	**-**	**38,000.00**	
Steam Only	**28.00**	**-**	**49.00**	**per C.Y.**
Steam & Iron	**48.00**	**-**	**69.00**	**per C.Y.**
Overhead	**7%**	**-**	**12%**	
Profit	**10%**	**-**	**23%**	

The Indirect Costs can vary, but I believe the range I have presented is realistic. The items for submittals, reports, etc. are not always bid items, but as you know there can be significant time spent on these items. I have outlined these In order for you to pick and choose what you feel is

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appropriate for your presentation. The range in the cubic yard unit costs reflect one to two hours of treatment time per 70 cubic yard cell. The Steam & Iron range includes the addition of the iron costs to the Steam Only cubic yard costs. The overhead and profit ranges are what I think the bidders would use. Remember these Summary Costs above do not include overhead and profit.

If you came across any "special" places in the Charleston area let me know, I'll be there sometime in the next month.

Take Care,
Dick

CURRENT ENVIRONMENTAL SOLUTIONS (CES)
SIX-PHASE HEATING

630452

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Technology/ Application Area	Capital Cost	Operating Cost	Treatment Rate (ft^3/hr)	Treatment Period (days)	TCE Reduction	Effectiveness	Implementation Difficulty	Cost ($/yd^3$)
Six Phase Heating - Direct Heating Application								
WAG 6 - UCRS and RGA (955,656 ft^3)	$ 943,000	$ 712,000	228	175	99%	Excellent	Moderate	$47
WAG 6 - UCRS and RGA (955,656 ft^3)	$ 943,000	$ 923,000	176	226	99.9%	Excellent	Moderate	$53
SWMUs 2 & 7 (1,950,000 ft^3)	$ 890,000	$ 987,000	323	251	99%	Excellent	Low	$26
SWMUs 2 & 7 (1,950,000 ft^3)	$ 890,000	$ 1,286,000	245	331	99.9%	Excellent	Low	$30
SWMU 3 (2,606,800 ft^3)	$ 1,053,000	$ 1,457,000	293	370	99%	Excellent	Low	$26
SWMU 3 (2,606,800 ft^3)	$ 1,053,000	$ 1,904,000	222	488	99.9%	Excellent	Low	$31
WAGs 27 & 1 (225,285 ft^3)	$ 315,000	$ 80,000	400	23	99%	Excellent	Low	$47
WAGs 27 & 1 (225,285 ft^3)	$ 315,000	$ 113,000	296	32	99.9%	Excellent	Low	$51
WAG 28 - UCRS and RGA					99%	Excellent	Moderate	$45 to $60
WAG 28 - UCRS and RGA					99.9%	Excellent	Moderate	$50 to $65

Assumptions:
1) Routine groundwater monitoring and post-remediation monitoring are assumed to be provided by others.
2) Boring subcontractor costs are assumed to be $54 per foot (12" o.d. borehole).
3) Includes drill cutting disposal at $1000/ton.
4) Does not include cost for security clearances or escorts.
5) Includes $10,000 to connect electrical power to SPH equipment. Includes $0.05/kW-hr for electrical usage (conservative).
6) WAG 6, WAGs 27 & 1, and WAG 28 include vapor treatment by oxidation with no acid gas scrubber.
7) SWMUs include vapor treatment by activated carbon with offsite regeneration.
8) Costs assume that surface equipment does not become radioactively contaminated.
9) WAG 6, Building C-720, and WAG 28 assume below-grade piping and electrical cables.
10) SWMUs and WAGs 27 & 1 assume above-grade piping and electrical cables within fenced areas.
11) Assumes each site is stand-alone. Remediating multiple sites would lead to cost efficiences.
12) Remediation of multiple sites can be performed in parallel or in series.

McLaren/Hart
Soil Vapor Extraction with Pneumatic Fracturing

630456

July 1, 1999

Mr. Mike Hightower
Sandia National Laboratories
P.O. Box 5800, MS 0720
Albuquerque, NM 87185

RE: SOIL VAPOR EXTRACTION/PNEUMATIC FRACTURING REMEDIAL OPTION
Paducah ITRD Project
Paducah, KY

Dear Mr. Hightower:

Thank you for the opportunity of presenting the capabilities of pneumatic fracturing to you and your technical committee at the recent ITRD meeting in Paducah. As you know, Dr. John Schuring and others developed this technology at the New Jersey Institute of Technology (NJIT) in the early 1990s. In 1992, McLaren/Hart became involved with the development, testing and commercialization of the technology. In 1997, McLaren/Hart obtained a license from NJIT to use the technology for pneumatic enhancement of soil and rock formations and to inject dry or liquid media (e.g., reactive media, proppants, oxidizing liquids) into subsurface soils.

McLaren/Hart has successfully used this technology to enhance the permeability of soil and rock formations impacted with chlorinated solvents. A preliminary review of the information downloaded from the Internet and sent by Ken Kuzio, indicates that the unsaturated soils at the Paducah site can be pneumatically fractured to improve permeability and, consequently, air flow rates for in situ remedial options. These options may be limited by the heterogeneity of the geologic formation.

This improvement in subsurface permeability would lower the operating and maintenance cost for the remediation system and will also reduce the treatment time (i.e., time to move "X" pore volumes through the formation and/or reach asymptotic conditions). For example, this benefit could make a soil vapor extraction (SVE) system more effective and efficient.

In order to provide a more accurate estimate of the costs for conducting a pilot test, and for a full-scale system (i.e., installation, operation and maintenance), McLaren/Hart is requesting that you provide the following:

1) A map showing the treatment areas and volumes for each location at PGDF (e.g., for WAG 6 - C400 Bldg.)
2) A map showing the vertical and horizontal delineation for each location of unsaturated soils at each location (i.e., source)
3) The composition of the contaminants of concern (volatile and nonvolatile)
4) The maximum and average concentrations of the contaminants of concern
5) The soil geology in the unsaturated treatment zone, including transition zones
6) The depth to water and capillary fringe
7) Any geotechnical engineering information (e.g., grain size, bulk density, porosity, intrinsic permeability)
8) Information on utilities and structures if available, and
9) The proposed location for the unsaturated zone pilot

During our presentation last week, we indicated that McLaren/Hart has worked with NJIT to evaluate reactive media and also successfully deliver reactive media to a depth of 37 feet at a site located in Kansas City. Based on the success of this pilot test, a reactive treatment wall will be installed as the remedial option for the site.

To date, I am not aware of any sites where reactive media has been successfully delivered to depths greater than 100 feet for the reductive dechlorination of chlorinated COCs. McLaren/Hart believes that the pneumatic delivery system is an extremely viable method for emplacement of media at depth, and is confident that we can engineer and design a system to cost efficiently deliver the media to the targeted saturated treatment zone at the Paducah site.

In order to demonstrate our confidence in using this technology, and to illustrate the level of technical study and testing that has been performed to support the application of pneumatic fracturing and pneumatic injection, we have enclosed three theses from graduate students at NJIT. They are: McLaren/Hart employee, Deborah Schnell's thesis on reactive media and pneumatic injection (Section 3); a thesis on the study of potential effects of pneumatic fracturing on existing structures and utilities; and a thesis that discusses the mechanisms for fracture propagation and particle transport in pneumatically fractured formations

Again, thank you for the opportunity of meeting with you and your technical team. If Jim Mack or I can be of any assistance, or if we can provide you with additional information on the technology or on McLaren/Hart's remedial engineering or risk capabilities, please do not hesitate to contact us at (908) 647-8111.

Sincerely

Trevor King
Sr. Engineer
Trevor King

Marc Cicalese
Principal Engineer

Encl.
c: J. Mack (M/H)

_.Q.WAFRTY.INGVaducah\m*e-h.doe

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Mclaren
Hart

FAX COVER SHEET

TO: Mike Hightown/
Wu Ching Cheng

FROM: Kumar Selvakumar

DATE: December 07, 1999

FAX NO.: 505/844-0968
NO. OF PAGES: 05
(including this page)

RE: Cost Estimate for C-400 Source Area (B400-200)

We have included the Table 1.la for the remediation of the source area and updated summary Table 1.0. This cost will be included in the overall remediation in Table 1. 1. If you have any questions, please call us.

Thank you,
Kumar

SENT BY: Kumar Selvakumar **TIME:**

BILLING CODE:

(PLEASE FILL IN BILLING CODE)

25 Independence Boulevard, Warren, NJ 07059 (908) 647-8111 FAX (908) 647-8162

630460

PNEUMATIC FRACTURING ENHANCED SOIL VAPOR EXTRACTION
PADUCAH ITRD PROJECT
PADUCAH KENTUCKY

CAPITAL COSTS

	Subtotal	**$364,000**
	Contingency (25	**$912,000**
	Subtotal	**$455,000**
Administrative & legal *coMs* (10%)		**$45,500**
Construction oversight and certification (10 %)		**$45,500**
Engineering (IS %)		**$68,300**
TOTAL CAPITAL COST		$614,000

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Table 1.1a
Preliminary Engineering Cost Estimate for C-400 Source(B400-200) Area
Pneumatic Fracturing Enhanced Soil Vapor Extraction
Paducah ITRD Project
Paducah, Kentucky

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
ANNUAL OPERATION AND MAINTENANCE (O&M) COSTS				
(For Year 1):				
Annual monitoring report	1	EA.	$20,000	$20,000
TS monthly air sampling and analysis	24	EA.	$120	$2,880
Quarterly GW monitoring	3	EA.	$110	$330
Maintenance and replacement	1	L.S.	$500	$500
Operator cost (4 hrs/week)	208	Hour	$60	$12,480
Water disposal (75 gallons/month)	900	Gallon	$3	$2,700
Electric power	15	H.P.	$400	$6,000
	Subtotal			$45,000
	Contingency (25%)			$11,000
	TOTAL ANNUAL O&M COST			$56,000
(For Year 2):				
Annual monitoring report	1	EA.	$20,000	$20,000
TS monthly air sampling and analysis	24	EA.	$120	$2,880
Quarterly GW monitoring	3	EA.	$110	$330
Maintenance and replacement	1	L.S.	$500	$500
Operator cost (4 hrs/week)	208	Hour	$60	$12,480
Water disposal (75 gallons/month)	900	Gallon	$3	$2,700
Electric power	12	H.P.	$400	$4,800
	Subtotal			$44,000
	Contingency (25%)			$11,000
	TOTAL ANNUAL O&M COST			$55,000
(For Year 3):				
Annual monitoring report	1	EA.	$20,000	$20,000
TS monthly air sampling and analysis	24	EA.	$120	$2,880
Quarterly GW monitoring	3	EA.	$110	$330
Maintenance and replacement	1	L.S.	$500	$500
Operator cost (4 hrs/week)	208	Hour	$60	$12,480
Water disposal (75 gallons/month)	900	Gallon	$3	$2,700
Electric power	10	H.P.	$400	$4,000
	Subtotal			$43,000
	Contingency (25%)			$11,000
	TOTAL ANNUAL O&M COST			$54,000

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Table 1.1a

Preliminary Engineering Cost Estimate for C-400 Source(B400-200) Area
Pneumatic Fracturing Enhanced Soil Vapor Extraction
Paducah ITRD Project
Paducah, Kentucky

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
O&M PRESENT WORTH (5% discount rate)		Year 1		$53,000
		Year 2		$50,000
		Year 3		$47,000
	TOTAL COST FOR 3 YEAR OPERATION			$764,000

L.S.	Lump sum	H.P.	Horse power
EA.	Each	GW	Groundwater
FT.	Feet	TS	Treatment system

Assumptions:

1. Monthly treatment system air monitoring, sampling, and analysis is included in the O&M cost.
2. Piping for the system is installed below ground and finished with paving.
3. Blower will provide 10" Hg vacuum at well heads.
4. Pilot testing is required to verify applicability and obtain engineering parameters for the full scale design and will be performed in the C745 Area.
5. Water is available to be used in the system operation.
6. No reduction in sampling frequency have been assumed.
7. Expected airflow is 400 scfm.
8. Half of the TCE from the air stream will be removed as liquid in the knockout tank and the separated product can be sent for recovery and recycling with no cost.
9. Treatment system operator time of 4 hours/week for this component.
10. Treatment air system samples and GW monitoring samples are analyzed for VOCs.
11. Water collected during the installation and operation will be sent for offsite disposal.
12. Assumed design parameters for the cost estimation are as follows:

Design/Cost Estimating Parameter	Hot Area
Area (Sq. Ft.)	5625
Average concentration (mg/kg)	1000
Radius of influence (ft.)	20
Air flow (scfm)	400

* Part of these costs will be included in the cumulative cost of overall remediation at the site.

630464

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MORRISON KNUDSEN/K-V ASSOCIATES
C-SPARGE

630466

MORRISON KNUDSEN CORPORATION

ENGINEERS & CONSTRUCTORS
Mk FERGUSON PLAZA
ISM WEST 3RD STREET V
CLEVELAND. OHIO U.S.A. 44113-1408
PHONE: (216) 523-5600
FAX-. (216) 523-5822

December 14, 1999

Mr. Michael Hightower
Sandia National laboratories
P.O. Box 5800
Albuquerque, NM 87195-0755

RE: Summary of Estimated Costs for Ozone Sparging Using the C-Sparge Process

Paducah ITRD Project~ Paducah, KY

Dear Mike:

Attached is a table summarizing the estimated costs for installation and operation of ozone sparging using the C-Sparge Process at the U. S, Department of Energy Paducah Gaseous Diffusion Plant, Paducah, Kentucky. The attached table is arranged in general conformance with your requested format.

Cost scenarios

As requested we have developed costs for seven different site condition scenarios. These scenarios are as follows:

1) **Treatment of saturated soil in the Upper Continental Recharge System (UCRS). Treatment volume equals 10,000 cubic yards (yd^3). Trichloroethylene (TCE) is the only contaminant and is present at a concentration of greater than 100 parts per million (ppm).**

   System Design
   C-Sparge wall mounted unit with 2 groundwater recirculation sparge wells.

2) **Treatment of non-saturated soil in the UCRS. Treatment volume equals 10,000 yd^3 TCE is the only contaminant and is present at concentration of greater than 100 ppm.**

   System Design
   High vacuum extraction with C-Sparge wall mounted unit. Design includes 4 vapor extraction wells and 6 ozone injection sparge points. Ozone is mixed with TCE in the soil and the combined mixture is oxidized under vacuum extraction The extracted soil

Morrison Knudsen and K-V Associates

gas contains TCE levels acceptable for discharge to the atmosphere. Carbon adsorption costs are included in the estimate as a contingency.

3) Treatment of soil near the C-400 Building, Treatment volume equals 40,000 yd. TCE is the only contaminant and *is present* at a concentration of greater than 1,000 ppm.

> **<u>System Design</u> - High vacuum extraction, with C-Sparge palletized unit *in a protected* enclosure. Design includes 3 vapor extraction wells and 5 ozone injection sparge points for treatment of the unsaturated *zone* and 4 recirculation wells for treatment of saturated materials. Ozone is mixed with TCE in the soil and the combined mixture is oxidized under vacuum extinction. The extracted soil gas contains TCE levels acceptable *for discharge to* the atmosphere. Carbon adsorption costs are included in the estimate as a contingency.**

4) Treatment of additional soil near the C-400 Building. Treatment volume equals 10,000 yd^3. TCE is the only contaminant and is present at a concentration of greater than 10,000 PPM.

> **<u>System-Design</u>**
> **Perozone (combination of peroxide and ozone treatment) injection for addressing and treating possible DNAPL's. C-Sparge trailer unit equipped with ozone generator capable of producing 1,500 grams ozone per day. Hydrogen peroxide and ozone are fed simultaneously into special spargepoints® which are placed at shallow and deeper depths in the aquifer. Design includes 1.2 spargepoints® placed at 20 foot spacings within the treatment area. During treatment temperature will be monitored.**

5) Treatment of groundwater within the Regional Gravel Aquifer (RGA) near the contaminant source. Treatment volume equals 50,000 yd^3. TCE and Technetium. (Tc-99) are the only contaminants present. The TCE concentration is greater than 1,000 parts per billion (ppb) and the Tc-99 concentration ranges from 100 to 1,000 pico Curies per liter (pCi/L).

> **<u>System Design</u>**
> **C-Sparge 4-well palletized unit in an enclosure and 4 groundwater recirculation sparge wells. Recirculation wells are equipped with ion exchange cartridges for Tc-99 removal. Design is based on an 85-foot radius of influence (170 foot zone of capture). Well spacing includes 30% overlap as a factor of safety.**

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6) Treatment of additional groundwater within the RGA near the source. Treatment volume equals 5,000 yd^3. TCE and Tc-99 are the only contaminants present. The TCE concentration is greater than 100,000 ppb and the Tc-99 concentration ranges from 100 to 1,000 pCi/L.

<u>System Design:</u>
Perozone (combination of peroxide and ozone treatment) injection for addressing and treating possible DNAPL's. C-Sparge trailer unit equipped with ozone generator capable of producing 1,500 grams ozone per day. Hydrogen peroxide and oxone are fed simultaneously into special spargepoints® which are placed at shallow and deeper depths in the aquifer. Design includes 10 spargepoints® placed at 15 foot spacings and 2 recirculation wells within the treatment area. Recirculation wells are equipped with ion exchange cartridges for Tc-99 removal

7) Treatment of groundwater within the RGA downgradient of the source. The treatment scheme will involve placing sparge welts in a linear arrangement to contain the plume The containment wall (interceptor fence) is 4,000 feet long. The TCE concentration is less than 1,000 ppb and the Tc-99 concentration ranges from 100 To 1,000 pCi/L

<u>System Design:</u>
Three C-Sparge 10-well palletized units in an enclosure and 30 groundwater recirculation sparge wells. Recirculation wells are equipped with ion exchange cartridges for Tc-99 removal. Design is based on an 85-foot radius of influence (170 foot zone of capture). Well spacing includes 30% overlap as a factor of safety.

Should you have any questions regarding this letter or the attached table, please do not hesitate to call me at (216) 523-5286 or Bill Kerfoot at (508) 539-3002.

Sincerely yours,

Bruce B. Ehleringer
Hydrogeologist / Program Manager

CC: William Kerfoot, President K-V Associates

attachments

SUMMARY OF ESTIMATED COSTS C-SPARGE OZONE SPARGING PADUCAH - ITRD PROJECT

Paducah Cost Summary.xls, Morrison Knudsen and K-V Associate

Cost Item	**UCRS**		**C-400**			**RGA**	
	Saturated 10,000 yd³ 100 ppm	Non-Saturated 10,000 yd³ 100 ppm	40,000 yd³ 1,000 ppm	10,000 yd³ 1,000 ppm	50,000 yd³ 1,000 ppb	5,000 yd³ 100,000 ppb	4,000 LF 1,000 ppb
Capital Costs							
Number of Wells	2 Wells	1 Wells	12 Wells	12 Wells	4 Wells	12 Wells	30 Wells
Engineering and Design	$10,000	$10,000	$15,000	$10,000	$15,000	$10,000	$20,000
Permits / KVA Licensing Fee	$$2,600	$1,500	$6,600	$4,800	$8,400	$4,800	$42,000
Mobilization	$5,000	$5,000	$8,000	$5,000	$8,000	$8.000	$14.000
System Cost	$34,500	$41.500	$82,000	$99,300	$82,000	$99,300	$410,000
Drilling and Well Construction	$20.500	$35,000	$70.000	$70,O00	$80,000	S70,000	$300,000
Utility Connections (Electrical Hookup	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
System Installation	$10.000	$10.000	$25,000	$10.000	$10.000	$10.000	$45,000
Demobilization	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Estimated Total Capital Costs	$92,600	$113,000	216,500	$209,100	$193,400	$212,100	$851.000
							$213/Lin. Ft
Cost per Yd³	$9.26	$11.30	$5.41	$20.91	$3.87	$42.42	$1.44
Operation and Maintenance Coals							
System Operation Manpower	$20,000	$20,000	$,35,000	$50,000	$20.000	$20,000	$100,000
Energy and Utilities	$6,000	$8,000	$12,000	S8,000	$7.000	$8,000	$35,000
Process Materials and Consumables (on Exchange Resin)	NA	NA	NA	NA	$8,000	$2,000	$30,000
Treatment Process Monitoring arid Reporting	$8,000	$8,000	$25,000	$15,000	$10,000	$15,000	$50,000
Waste Treatment Storage, Disposal	$2,500	$6.500	$10,000	$8,000	$8,000	$8,000	$40,000
Hardware or Equipment Replacement	$2,000	$2,000	$6.000	$8000	$6,000	$6,000	$30,000
Estimated Annual 0 & M Costs	$37,500	$44,500	$88,000	$87,000	$57,000	$59,000	$285,000
Performance							
Expected Treatment Period	1 Year	1 Year	2 Year	2 Year	2 Year	1 Year	30 Year
Estimated Amount of Contaminant Reduction							
TCE	99.5%	95%	95%	95%	>99.5%	95%	>99.5%
Tc-99	NA	NA	NA	NA	>97%	>97%	>97.0%
Estimated Level of Residual Contaminant							
TCE	0.1 ppm	5 ppm	5 ppm	<500 ppm	<5 ppb	<5 ppb	<5ppb
Tc-99	NA	NA	NA	NA	<30 pCi/L	<30 pCi/L	<30pCi/L
Wastes Generated							
TCE (Carbon)	0	4 Drums	10 Drums	0	0	0	0
Tc-99 (Ion Exchange Resin)	NA	NA	NA	NA	4 ft³/year/well	4 ft³/year/well	4 ft³/year/well

MORRISON KNUDSEN CORPORATION
MK-Ferguson Plaza
1500 West 3rd Street
Cleveland, OR 44113-1406

FAX COVER SHEET

Date: October 19,1999

Number of pages transmitted: 26 +/-
(including cover sheet)

To: Mike Hightower
Company: Sandia National Laboratories
Fax No.: 505-844-0968
Phone No.: 505-844-5499

From: Bruce Ehleringer

Fax No.: 216-523-5201
Phone No.: 216-523-5286

Subject: **Proposal for Ozone Sparging Demonstration Using the KVA C-Sparge Process at the PGDP, Paducah, Kentucky**

Message

Mike-

Attached is a fax copy of the demonstration proposal that KVA and NM have jointly prepared. Section 6 presents the one page write-up pertaining to "budgetary unit costs" for ozone sparging that we discussed yesterday.

This proposal is incomplete in that it does not include costs for the demonstration (Section 6) or schedule (Section 7). I am still awaiting some cost information.

If you could review this document and provide comments (expansions and/or deletions) I would appreciate it. In the mean time, I will continue to work on the cost estimate.

Thank you,

Bruce

million hours without a lost time accident. Two other MK projects surpassed 1,000,000 hours without a lost time accident during 1999: the Rocky Mountain Arsenal and the ALCOA Massena projects.

1.1 C-Sparge Process

The C-Sparge® process involves micro-sparging with an ozone/air mixture to remove dissolved VOCs in groundwater. The extracted VOCs then react with the encapsulated ozone in a gas/gas reaction described by the crigee mechanism (the "C" in C-Sparge). Halogenated VOCs decompose to a short-lived (milliseconds) intermediate (carboxyl oxide) which reacts with water (hydrolyzes) as it exits the bubble to yield reaction end products Cl, H_20, and $C0_2$. With aromatic VOCs, the decomposition products are H_20, and $C0_2$. This is a very clean reaction sequence since the VOC is concentrated in the fine bubbles and reacts with the ozone on a mole to mole basis. The concentration of ozone in the bubbles is matched to the expected VOC concentration and field checked by "bubble traps".

The reaction for decomposition of trichloroethylene (TCE) is presented as.

$$H_20 + HC_2CI_3 + 0_3 \sim 2CO_2 + 3HC\,I$$

Assuming an ozone injection rate of 200 grams per day (4.17 moles/day) yields the following:

$$4.17\ \textit{mol/day}\ H_20 + 4.17\ \textit{mol/day}\ HC_2CI_3 + 4.17\ \textit{mol/day}\ 0_3 = \\ 8.34\ \textit{mo/lday}\ C0_2 + 12.51\ \textit{mol/day}\ HCl$$

and that:

$$12.51\ \textit{mol/day}\ HCl + 12.51\ \textit{mol/day}\ HCO_3, \\ 12.51\ \textit{mol/day}\ H_20 + 12.51\ \textit{mol/day}\ C0_2 + 12.51\ \textit{mol/day}\ Ct$$

To determine the amount of HCO_3, which may be consumed it is necessary to know the groundwater pH and the bicarbonate alkalinity.

The C-Sparge-Process® process focuses ozone reaction selectively to air strippable compounds which invade the bubbles. As a result, if the encapsulated ozone concentration is maintained at a low multiplier of the strippable VOCs, then no ozone is available for side reactions with other dissolved organic compounds which have low Henry's numbers. Primary reactions do not create toxic by-products because the reactions proceed so rapidly and bubble rise times are quite

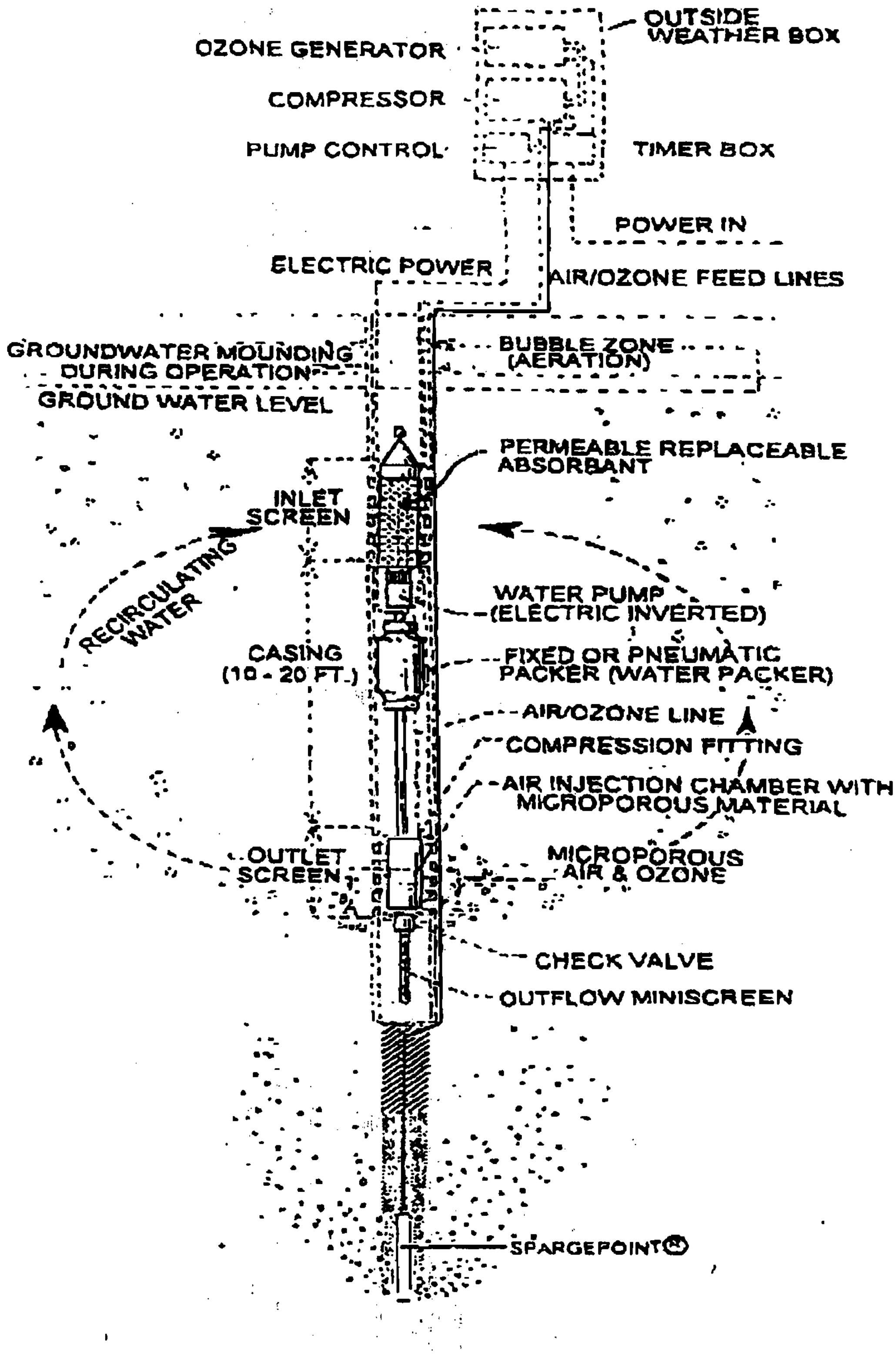
long. As of yet, the only identified end products have been chloride and carbon dioxide. Dissolved oxygen concentrations can also be expected to increase.

One possible concern with ozone sparging is the incomplete oxidation of VOCS and transfer of the stripped VOCs to the unsaturated zone. This is not an issue if the ozone concentration is matched to the groundwater VOC concentration. Depending on regulatory requirements, a vapor control unit within the well may be required during pilot testing or during initial system startup to demonstrate that this situation is not occurring.

The C-Sparge system is designed to efficiently remove VOCs from groundwater and to maximize the radius of influence of the sparge wells. The sparge well design includes placement of a spargepoint® below the well casing and the construction of a 4- or 6-inch diameter well with two screened intervals. The purpose of the two screened intervals is to allow groundwater extraction and re-injection to occur in the same well, thus creating a recirculation flow cell that increases the well radius of influence. An in-well unit consisting of a spargepoint, packer, and groundwater pump is placed within each well. Groundwater is extracted from the upper screened interval, and re-injected in the lower screen. The lower screen interval is also used for sparging. Groundwater extraction/injection and sparging from the two spargepoints® in each sparge well is cycled (pulsed) and each well is operated sequentially to allow greater ozone spreading outward from the well, mixing of the water column to reduce stratification, and increased ozone contact time, thus facilitating more complete VOC removal. Figure I is a drawing showing the C-Sparge® dual well screen design; placement of the spargepoints®, groundwater pump, and replaceable adsorbent (ion exchange resin); the movement of micro-fine bubbles; and groundwater flow in the vicinity of the C-Sparge® wells.

The spargepoints® have openings that vary in size from 20 to 40 microns (0.0008 to 0.002 inch) and generate microfine bubbles that move laterally outward from the sparge well into the aquifer. The bubbles generated are five to 12 times smaller that those generated through conventional sparging using a 0.010-inch slotted well screen and are small enough that they will move through the aquifer intergranular spaces. By combining groundwater re-injection and sparging, lateral movement of bubbles from the sparge well into the formation is substantially greater than with a conventional sparge well and short-circuiting near the well is not an issue.

Results with the C-Sparge® system show that 3-dimensional flow of microfine bubbles increases over time and results in a large effective treatment area. The recirculating bubble cloud treats both dissolved VOCs in groundwater and removes VOCs that may be adsorbed onto the soil matrix. Velocity changes created by the cycling of ozone sparging and



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groundwater extraction/injection within each sparge well and the sequencing of the individual sparge wells increases groundwater circulation. The re-circulation zone created for each sparge well allows multiple treatment passes through the sparge well and ozone bubble cloud before groundwater exits the area of sparge well influence.

C-Sparge® master control units are designed to control one to 10 sparge wells. Electrical power requirement are single-phase 110 volt. The master control units allow sparging with an ozone/air mixture; increased oxygen/air mixture; or air. Depending on the thickness of the saturated water interval or the remedial strategy, the C-Sparge® master control unit can be used for conventional sparging without groundwater extraction/injection and the creation of a groundwater recirculation cell. Ozone sparging using this mode of operation is effective for treatment of VOCs present in perched water, thin water-bearing intervals, and saturated soil in the capillary fringe.

Implementation of the C-Sparge® ozone injection requires performance of a pilot test to obtain optimal operational parameters and to determine the radius of influence of the sparge wells, Pilot testing generally involves the construction of one or two sparge wells and monitoring of three or more monitoring wells positioned at distances ranging from 20 to 80 feet from the sparge wells. Pilot testing is generally performed in areas where 1) existing monitoring wells are present to reduce monitoring well construction cost and to take advantage of historical water quality data, or 2) in the area where the planned sparge wells are to be located so diat the sparge wells can be used in the long-term remedial design.

Prior to pilot testing baseline groundwater samples are collected and analyzed from each well to be used in the pilot study and the depth to water measured. Groundwater flow direction is also determined in each sparge and monitoring well using a KVA groundwater flow meter. Groundwater flow direction determined by the flow meter may differ from that determined using groundwater elevation data and is useful for evaluating aquifer heterogeneity and preferred flow paths.

Pilot study testing involves the performance of a step pressure test and a steady pressure test of each sparge well. After completion of individual well testing and determination of optimal operation parameters, the sparge wells are continuously operated for a three to 14 day period. The testing duration is based on site specific issues: aquifer thickness, aquifer heterogeneity, groundwater velocity, VOC stratification within the aquifer, etc. This longer term test is to evaluate site specific conditions that may impact system performance and to obtain additional groundwater VOC field screening and analytical data. The VOC data provides a preliminary indication of the VOC oxidation rate and information on VOC stratification that may be present within the aquifer.

7.0 UNIT COST BUDGETARY ESTIMATE FOR IMPLEMENTATION OF OZONE SPARGING WITH THE C-SPARGEO SYSTEM

A unit cost on the order of $16 per cubic yard is estimated if the C-Sparge® process is implemented for in-situ groundwater oxidation of VOCs and removal of Tc-99 using an in-well ion exchange resin cartridge. This unit cost estimate is based on a sparge well radius of influence of 50 feet and a saturated aquifer thickness of 30 feet, which equates to a treatment volume of roughly 8,700 cubic yards. The demonstration test is designed to evaluate a radius of influence of up to 80 feet and this unit cost estimate can be expected to decrease based on the actual radius of influence.

Our experience indicates that mobilization of a trailer system to treat only VOCs in groundwater would cost about $75,000, or about $ 8.60 per cubic yard of saturated aquifer material (cost includes equipment, installation, startup, and sparge well drilling cost). With Tc-99 removal and normal DOE decontamination procedures, disposal of spent ion exchange resin, the unit cost will increase but most-likely not above $16 per cubic yard.

The above unit cost estimate does not include operation and maintenance (O&M), compliance monitoring, administrative support, or preparation of design documents and reports. These additional costs are scale dependent, and are higher if distributed over a small treatment volume site versus a large treatment volume site.

Table 1.1a
Preliminary Engineering Cost Estimate for C-400 Source(B400-200) Area
Pneumatic Fracturing Enhanced Soil Vapor Extraction
Paducah ITRD Project
Paducah, Kentucky

ITEMS	**QUANTITY**	**MT**	**UNIT COST**	**TOTAL COST**
ANNUAL OPERATION AND MAINTENANCE		**(O & M COSTS)**		
(For Year I) -.				
	Subtotal			**$45,000**
Contingency (25%)				**$11,000**
TOTAL ANNUAL O&M COST				**$56,000**
(For Year 2):				
	Subtotal			**$44,000**
Contingency (25 %)				**$11,000**
TOTAL ANNUAL O&M COST				**$55,000**
(For Year 3),				
	Subtotal			**$43,000**
Contingency (25%)				**$11,000**
TOTAL ANNUAL O&M COST				**$54,000**

STEAMTECH
STEAM ENHANCED EXTRACTION AND IN-SITU DESTRUCTION (SEED)

630480

By Fax: 5 pages

November 5, 1999

Mr. Kenneth Kuzio
Sandia National Laboratories
P.0, Box 5800, MS 0926
Phone; (505) 284-3145
Fax: (505) W-8237

Dear Mr. Kuzio

I have spent some time going over the documents that you provided to Deldra- I've tried to give an overall assessment of the sites based on the information available to me at this time. Attached is a brief report giving my analysis of these sites. At each of the sites, I tried to outline some of the concerns with applying these technologies. While all of the sites are potential candidates for steam enhanced remediation, it is not possible to make a definite decision without more detailed information- For example, one of the sites contains power and telephone cables. If the cables are buried directly in the ground within the remediation. area, they are likely to be damaged during thermal remediation. However, if the cables are in metal or concrete vaults or nms, they can be adequately protected.

I have also tried to provide reasonably accurate cost estimates of remediating these sites. Note that the pilot say we conducted at the Portsmouth Site was comparable in size to many of the sites in the document discussed here. These estimates reflect the cost of deployment with today's technology improvements in technology over the next few years may reduce these costs significantly. Unfortunately, we have found that a nuclear fuel plant is a difficult and thus expensive environment to work in. I have seen some rather questionable estimates on what it might cost for full scale implementations of other technologies that obviously do not take into account the additional overhead associated with working on a secure DOE facility.

I hope the information provided will be useful to you. If you have any questions you can reach me at: (775) 351-2442 (direct line); (775) 351-2443 (main office line) or (775) (843-0696) cell or by e-mail at labrwaueAstewntecb-cam. Please not that I will be travelling much of the week of November 8, but can generally be reached via my cell phone,

Sincerely,

Douglas I La Brecque, Ph.D
Principal Scientist
SteamTech Environmental Services Inc.

Cost Estimates for the Paducah ITRD Project Contaminant Information

Overview

We believe that Steam Enhanced Extraction and in-situ Destruction (SEED) is potentially applicable to a number of sites at Paducah. In Table 1, we have tried to make our best estimates of cost based on the information available. However, these estimates are for information purposes only; they are not bids and are not legally or contractually binding. More accurate estimates will require additional site characterization data and the completion of an engineering design and are therefore outside the scope of the present effort.

These cost estimates in part are based on SteamTech Environmental Services' experience in working at the Portsmouth Gaseous Diffusion Plant and reflect the unfortunate fad that operating on a secure DOE facility increases costs substantially over those of civilian sites. Some examples of issues that increase costs (that are included in these estimates) are:

1) On site construction and operation will fall under Davis-Bacon wage rules or site-specific wage rules which are generally higher than common labor rates.
2) DOE sites require rigorous documentation of health and safety, QA, QC, Waste Management and project progress. Creating and maintaining these documents requires additional personnel and thus cost. Generally, one or more personnel are required simply to handle and maintain this documentation.
3) The sites will be secure and require a significant number of personnel with security clearances. In this era of downsizing and cost savings, it is becoming difficult to find personnel with clearances and to obtain clearances for our existing personnel. Also, a significant amount of time is spent simply moving people and materials in and out of a secure site.
4) All of the sites are mixed waste containing measurable amounts of Technetium. All workers on the site will need specialized training and monitoring. Workers in contact with subsurface materials or effluent will need rad-worker training.

These cost estimates do not reflect the cost of ultimate disposal of cuttings generated during well drilling & filter cake accrued during operations, and other waste such as personal protective equipment- The amounts of these will depend heavily an the number of wells, size of the site and drilling contractor and technique used.

The cost estimates also do not reflect the cost of equipment that becomes radiologically contaminated and must remain on site. However, every attempt will be made to minimize the amount and likelihood of contamination. For example, designs will minimize or eliminated water treatment components with exposed iron or steel surfaces on which Technetium tends to accumulate.

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Goals of SEED

Steam enhanced remedition would address areas of relatively high contamination- For this document, we chose areas with contamination levels greater than 5,000 micrograms per kilogram- The approach would be to remove the bulk of the contaminants (about 99%) by direct removal using steam enhanced extraction during operations of 6 months to 8 months. The remaining contaminants would be reduced by in-situ Hydrous Pyrolysis and Oxidation and enhanced bi-o-remediation. Overall goals would be for a 99% reduction of TCE within the DNAPL bearing zones and reduction to less than 100 micrograms per kilogram within lower concentration zones within the cleanup area within two years of completing steam injection.

Overview of Geology

The geology at Paducah is divided into three major units. From the surface to about 60 feet in depth is the Upper Continental Recharge System (UCRS). The information package provides shows the UCRS to be dominantly clay but has a complex structure with numerous interbedded layers of gravel, sand, and silt that are poorly correlated from borehole to borehole. Most wells have a static water level that is near the base of the UCRS indicating that it is largely unsaturated.

Below the MRS is the Regional Gravel Aquifer (RGA). The RGA is about 40 feet thick, In most of the sections, the boundary between the UCRS and the RGA is a sand layer about 10 ft thick. Below this layer the RGA is mainly gravel with some interbedded sands.

Below the RGA is the McNairy Flow System. The boundary between the McNairy and the RGA is generally a clay layer. The McNairy mountains interbedded sands. The data provided generally show low levels of contaminants in the McNairy and we do not address remediation within this zone.

C400 Building

Steam Enhanced Extraction and in-situ Destruction of TCE (SEED) appears applicable to the source areas around building C400- The major concern at building C400 is the presence of buried utilities within the contaminated zone. As these utilities appear to serve as sources or conduits of contaminant movement, remediation will have to address cleaning the utility corridors. The existing water and sewer lines are probably not a concern as long as they are good repair. However, the electrical and phone conduits and the propane pipe are major concerns. It is not possible with the information provided to determine if these can be adequately protected during the remediation.

The Phase I Independent Investigation Report indicates that storm sewers received TCE from building 400 from 1950s to 1986, Substantial contamination exists on this site exceeding 11,000,000 micrograms per kilogram in soil near the southeast comer of the building. Data provided in this package shows three distinct areas of contamination.

SteamTech EnvironmentalServices
11/5/1999. Paducah cost estimate

Area 1) Area I is considered the spill site and is a rectangular area about 100 feet wide and 300 ft long elongated in the north-south direction along the south and east of building 400. The maximum Toe level is 11,000,000 micrograms per Oograrn in the UCRS, 2,8000,000 micrograms per liter in the RGA and 86,000 micrograms per kilogram in the top of the McNairy (note that concentrations are less than 60 micrograms per liter for depths greater than 10 ft into the McNairy).

Area 2) Area 2 is south and west of the building, 100 ft wide and 200 ft long elongated in the east-west direction. Maximum WE levels in the UCRS is 170,000 micrograms per kilogram at a depth of 24 feet. No data was provided for the RGA or McNairy but the values are deamed to be low.

Area 3) Area 3 is north and west of the 400 building. The extent of this contamination is not fully defined by the data provided. A rough guestimate of the extent is 100 by 200 feet elongated in the north-south direction. No data was provided for the UCRS. The maximum value in the RGA is 92,000 micrograms per liter.

Cost estimates for all three areas are given in Table 1.

C-720 Building

The best application of SEED would be the removal of the TCE source area within the UCRS near the southeast comer of the building. The source area appears to be fairly small, of the order of 90 by 80 feet and is adjacent to or below the southeast comer of the building. The major concern is gaining access to all sides of the source area so that it could be surrounded by steam injection wells an all four sides. It appears that some wells have been drilled within C-720 in the past indicating access is possible. Alternatively, horizontal wells could be used. In general, it should not be a problem to steam below a building unless there are plastic cased utiMes, such as PVC or ABS sewage lines below the building. Foundation problems should not occur if the material below the building was properly compacted during construction of the building.

Table I gives cost estimates for the UCRS. No infbn-nation was provided on the presence of contamination within the RGA. The SEED technique -is applicable both above and below the water table and could be applied to contamination in the RGA. These costs could not be estimated here without additional information.

C-745 Building

The information provided shows an area of substantial TCE contamination at in the UCRS south of building C-745A below the former oil land farm. TCE levels as high as 439,000 micrograms per kilogram are shown in the cross-sections. TCE levels tend to decrease with depth but are still quite high 25,000 micrograms per kilogram, at the base of the UCRS. No specific data was provided for the RGA although the conceptual diagram shows the possible presence of DNAPL

in the RGA. Again, SEED could be applied for the DNAPL within the RGA but was not addressed here due to lack of sufficient information.

An additional consideration not addressed within the documentation is the presence of other organic contaminants. It is our understanding that Phase H site investigations at Paducah indicated the presence of substantial amounts of PCB *and* other semi-volatile organic compounds at this site near the C-745 Building, and that PCB concentrations are often in excess of the TCE concentrations. Cleanup of PCBs using SEED is not a proven the PCBs have much higher boiling points and lower vapor pressures than TCE and are much more difficult to remediate with this technology. Despite these problems, we believe significant amounts of PCB can be removed but the operational times would be longer and it is difficult to establish reduction goals and operational times.

The suggested clean-up area is approximately 100 feet -in the north-south direction and 150 feet in the east-west direction *and* extends from the surface to a depth of 60 fed. Ignoring the presence of other contaminants, the estimated cleanup time for the TCE plume is 6 months. Additional characterization work is needed but the existing cross-sections show the presence of a number of sand layers within the UCRS that would serve as conduits for steam The cost estimate is given below in Table 1. Again, a cost estimate could not be generated for the RGA without additional information.

Table I Cost Estimates for Paducah Areas

Area/ Geology	**Delta X**	**Delta Y**	**Delta Z**	**Volume**	**Cost Estimate**
	Ft	Ft	Ft	yd^3	
C400 Area I UCRS	100	300	80	68,557	$6,700,000
C400 Area 2 UCRS	200	100	60	44,444	$5,600,000
C400 Area 3 UCRS	no data				
C400 UCRS Total	100	200	40	29,630	$12,300.000
C400 Area I RGA	100	300	40	44,444	$4,400,000
C400 Area 2 RGA	no data				
C400 Area 3 RGA	100	200	40	29,630	$3,700,000
C400 RGA Total	100	200	40	29,630	$2,100,000
C-720 Building	50	80	60	14,222	$2,100,000
UCRS					
C-720 Building	no data				
RGA					
C-745A Building	100	150	60	33,333	$4,200,000
UCRS					
C-745A Building	no data				

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APPENDIX C3

Fig. C3.1. Predicted Tc-99 Activity Concentrations at the PGDP Receptor Locations due to loading from WAG 22, PGDP

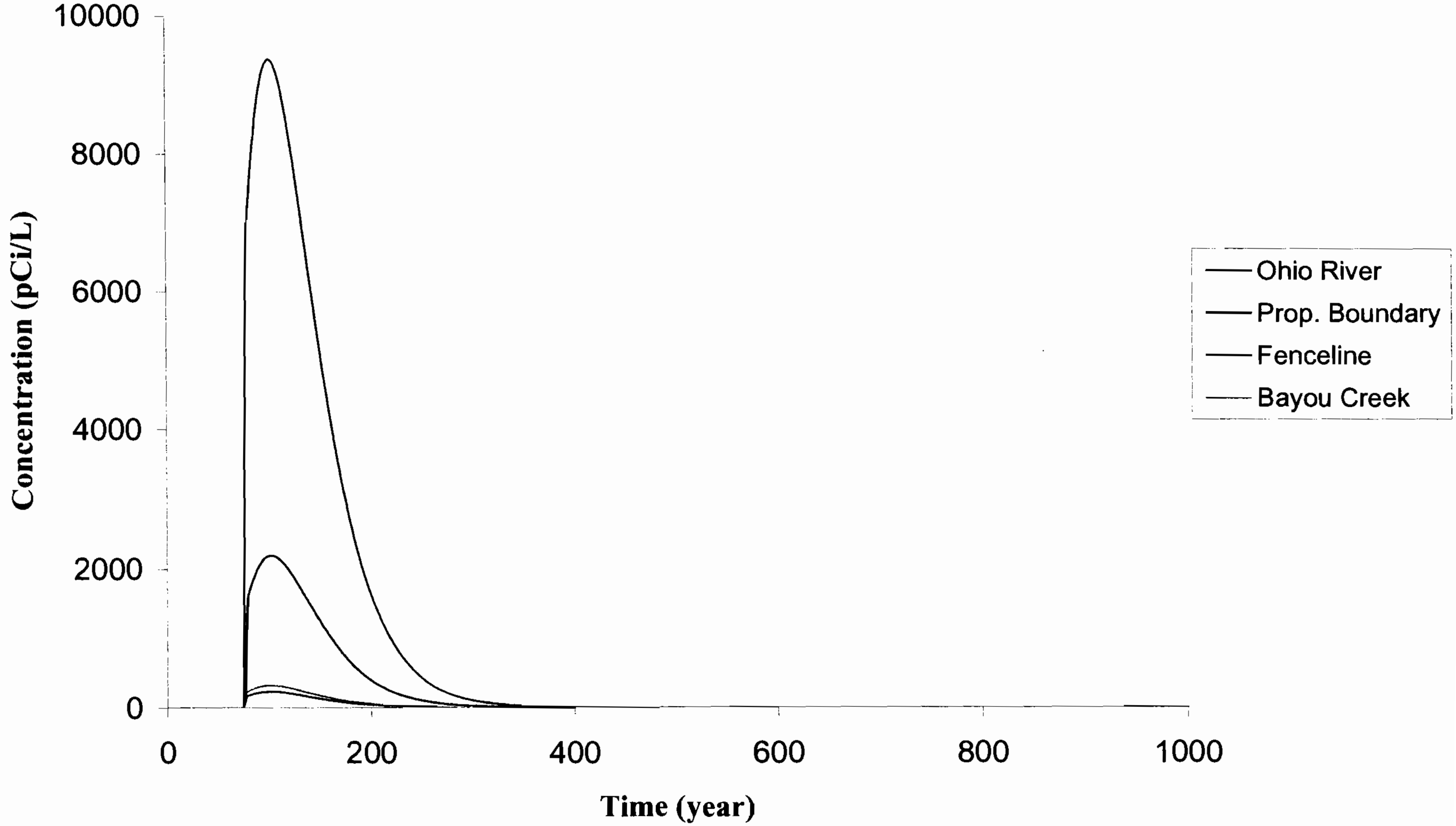


Figure C3.2. Predicted Tc-99 Activity Concentrations at the PGDP Receptor Locations due to loading from WAG 6

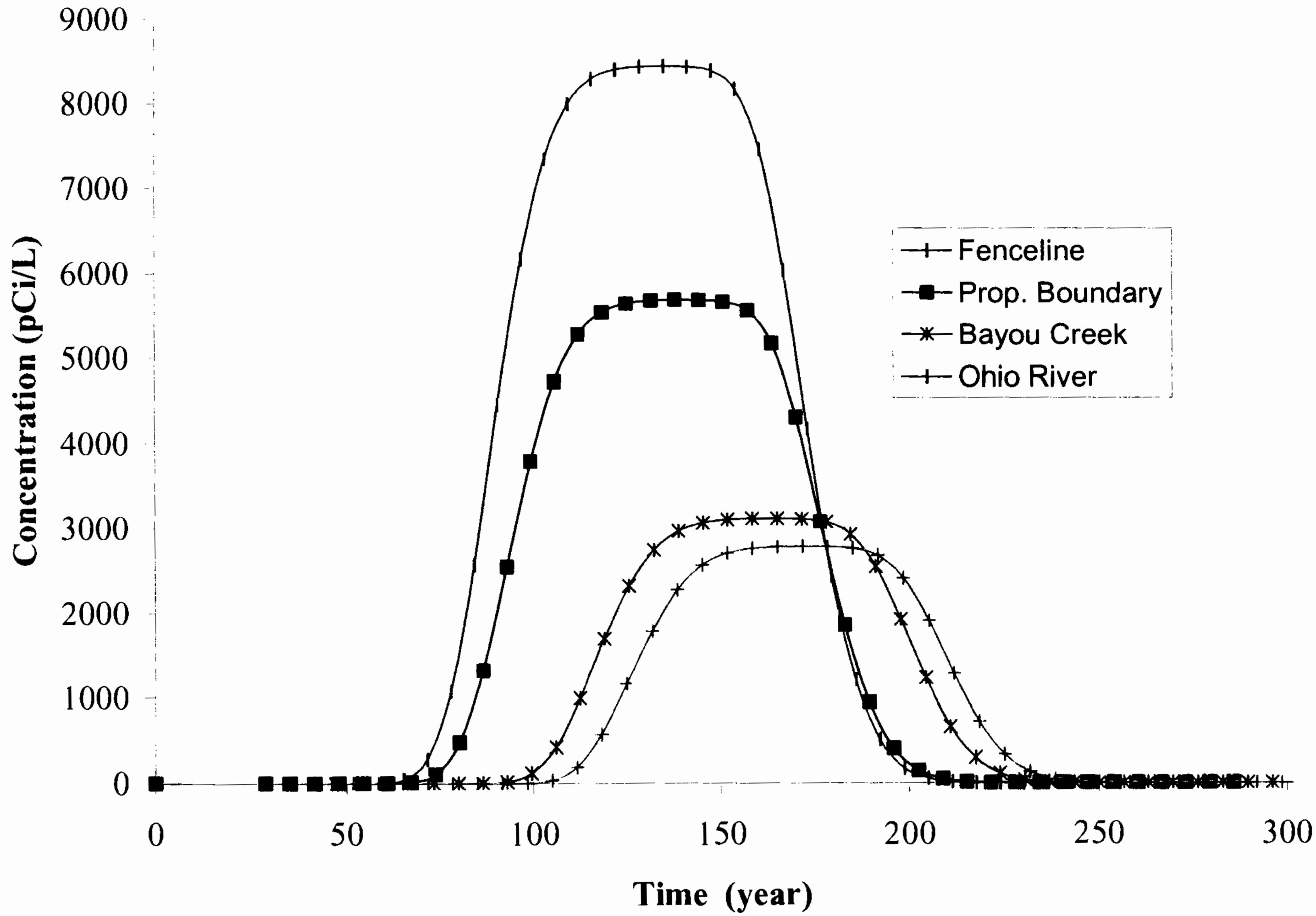


Figure C3.3. Predicted TCE Concentrations at the PGDP Receptor Locations due to loading from WAG 6

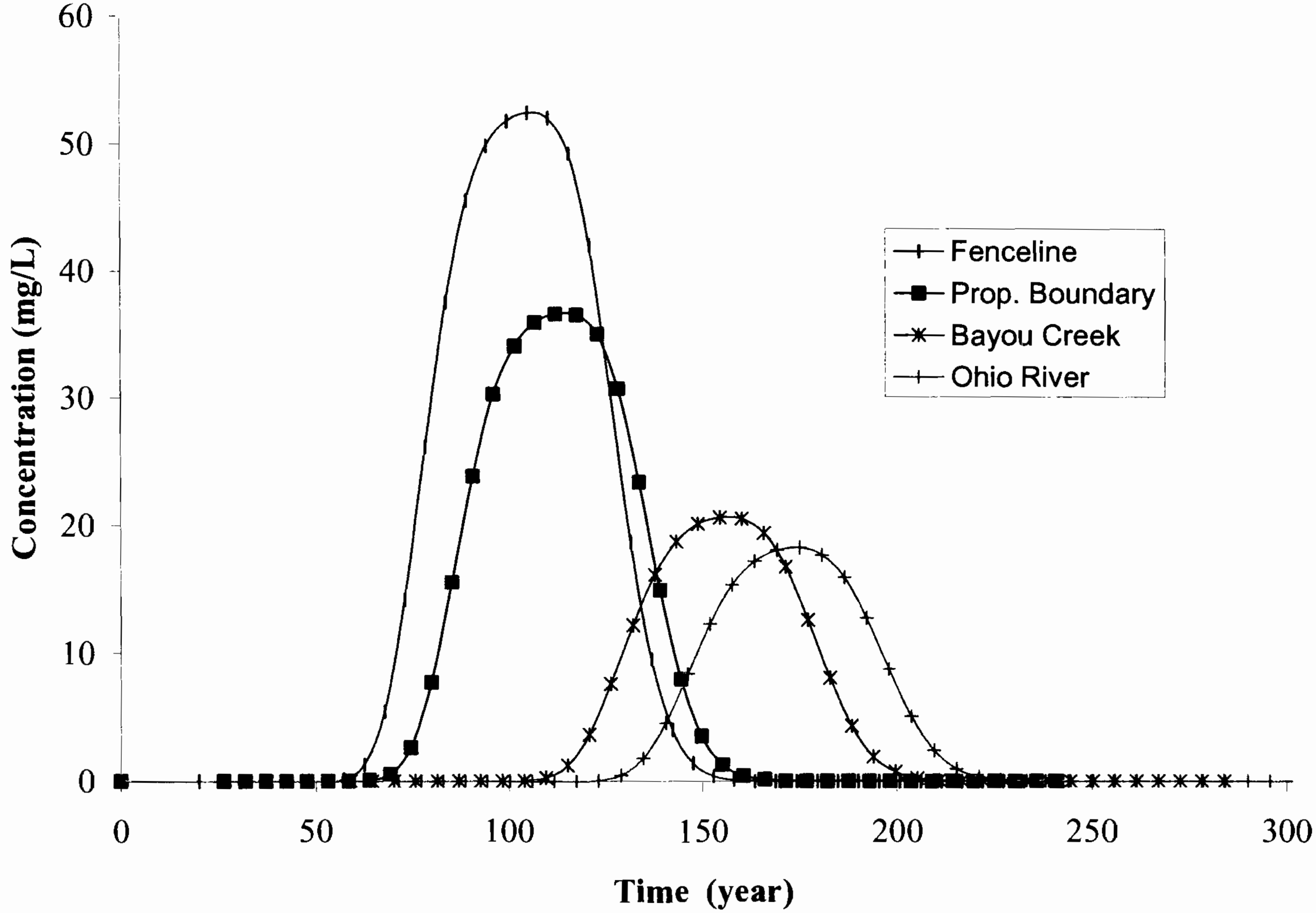


Fig. C3.4. Predicted Vinyl Chloride Concentrations at the PGDP Receptor Locations due to loading from WAG 6

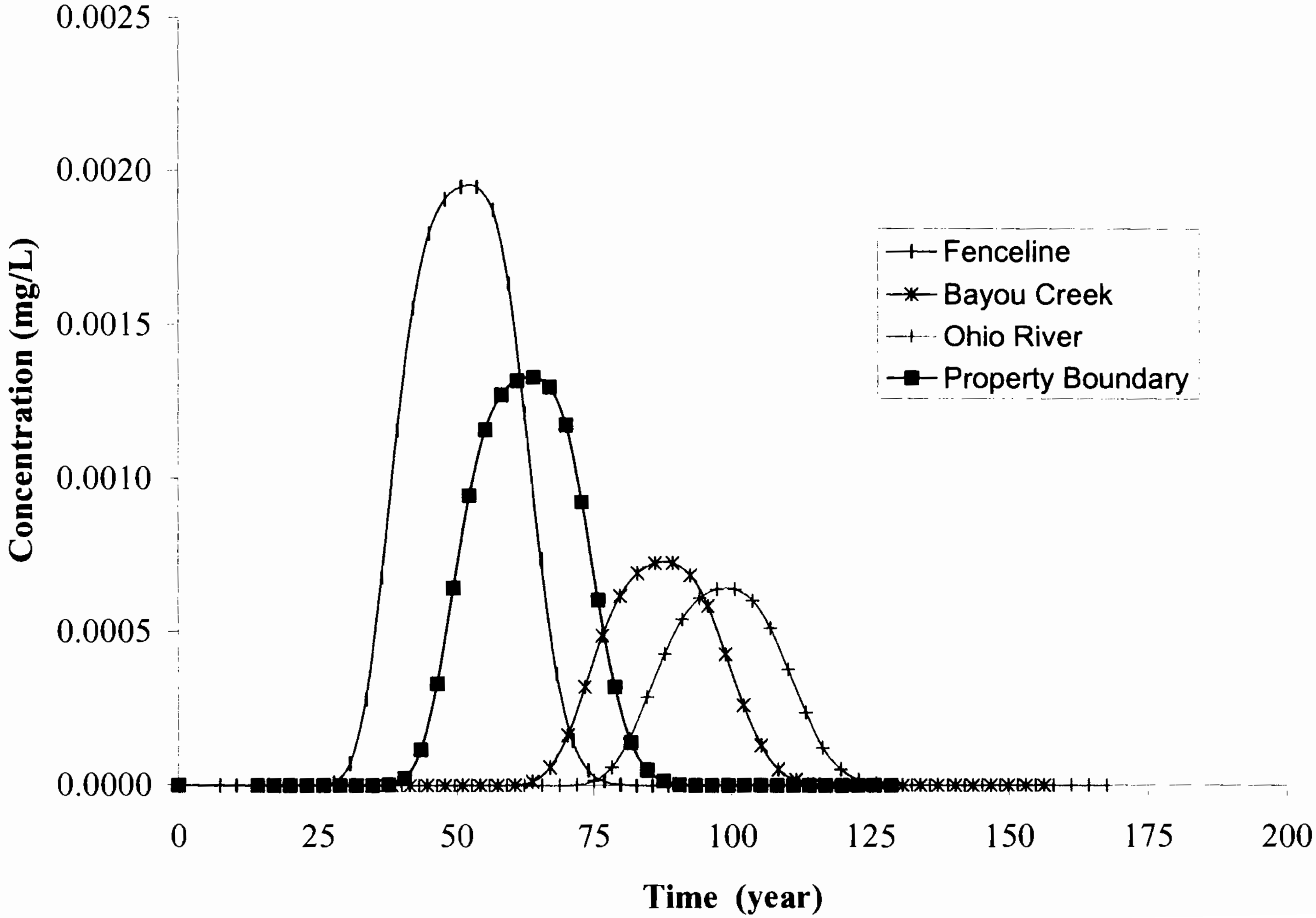


Figure C3.5. Predicted Antimony Concentrations in the RGA Groundwater at the PGDP Receptor Locations due to loading from WAG 6

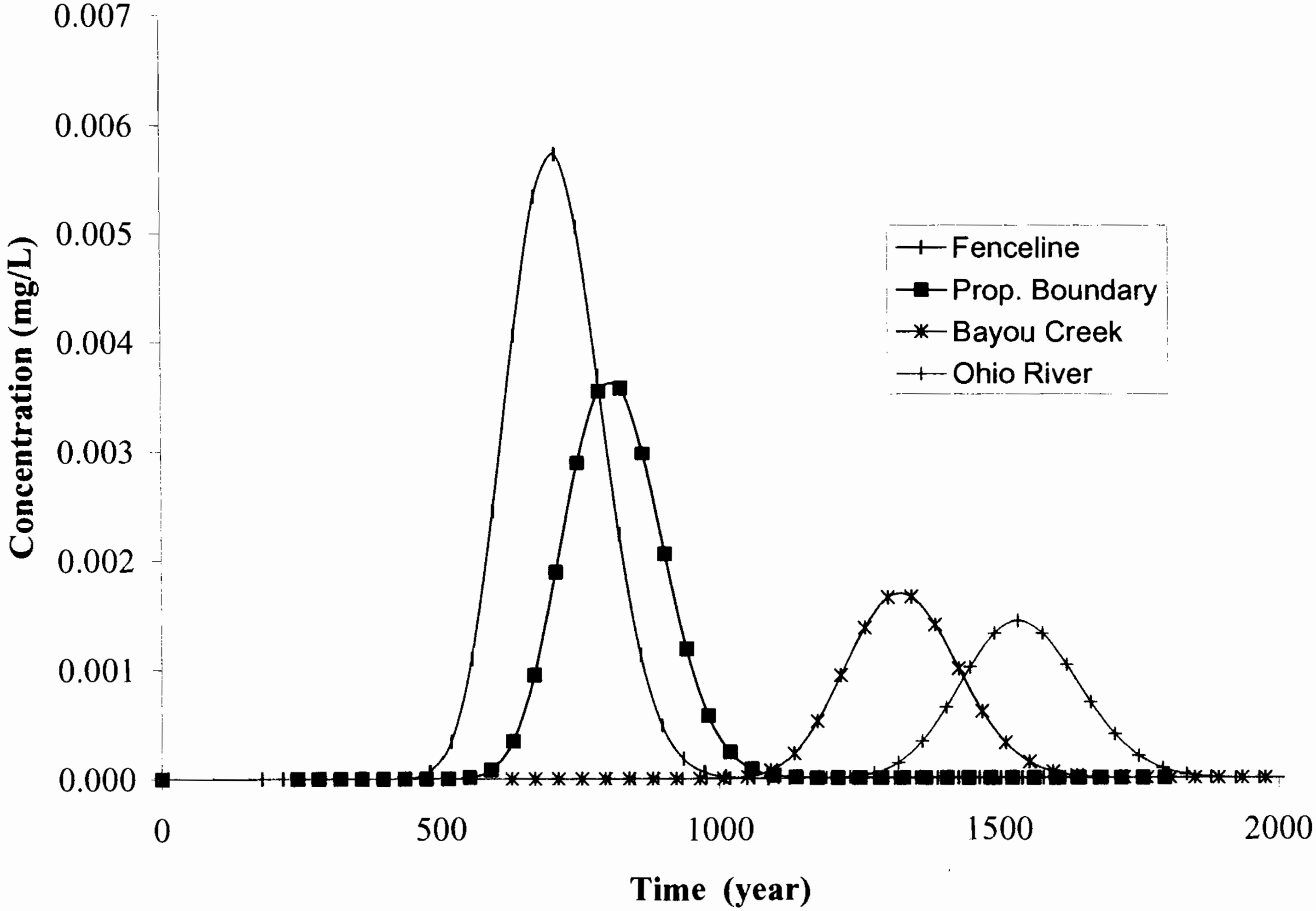


Figure C3.6. Predicted U-238 Activity Concentrations at the PGDP Receptor Locations due to loading from WAG 6

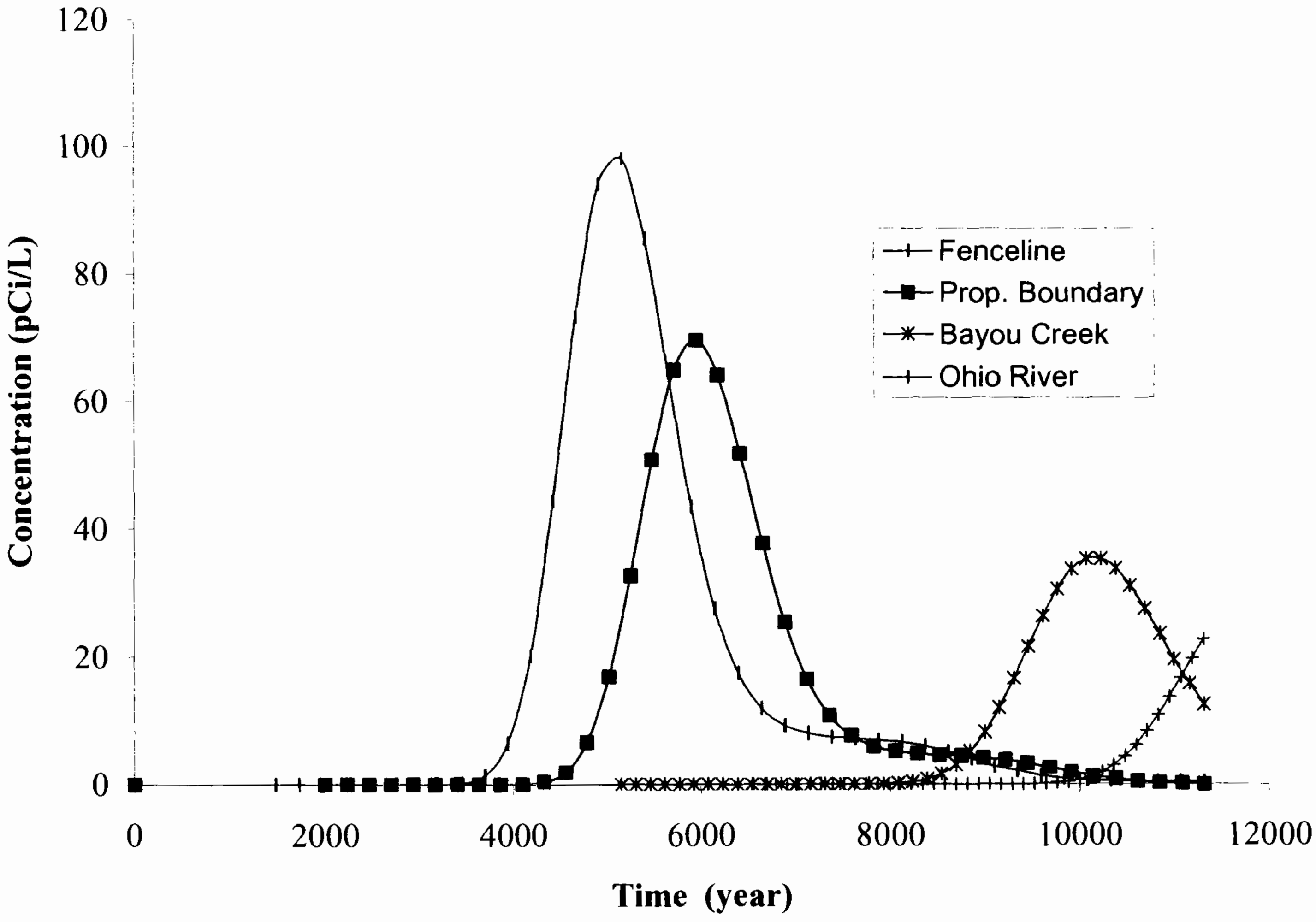


Figure C3.7. Predicted U-235 Activity Concentrations at the PGDP Receptor Locations due to loading from WAG 6

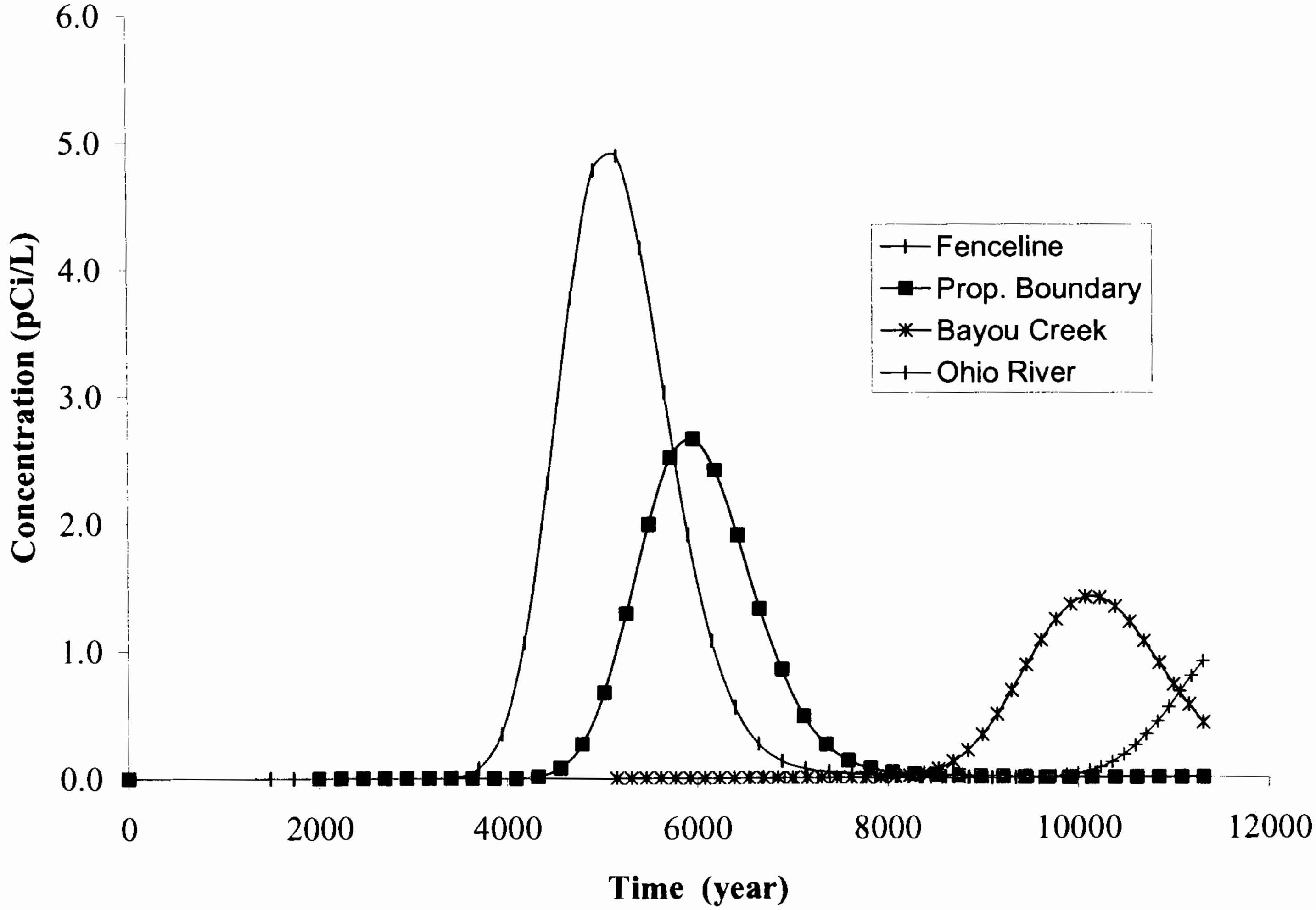


Figure C3.8. Predicted U-234 Activity Concentrations at the PGDP Receptor Locations due to loading from WAG 6

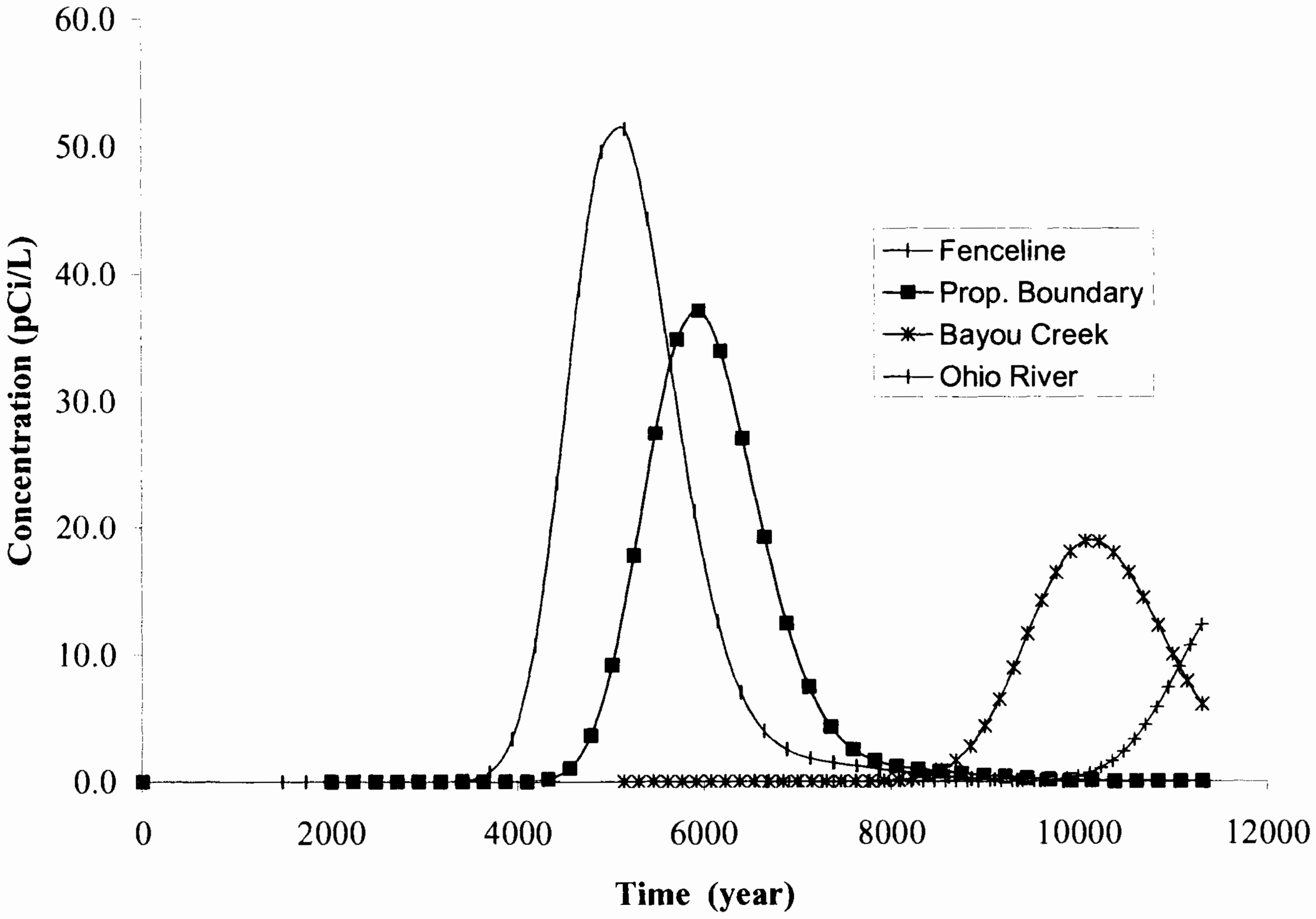


Fig. C3.9. Predicted Antimony Concentrations in the RGA Groundwater at the PGDP Receptor Locations due to loading from WAG 27

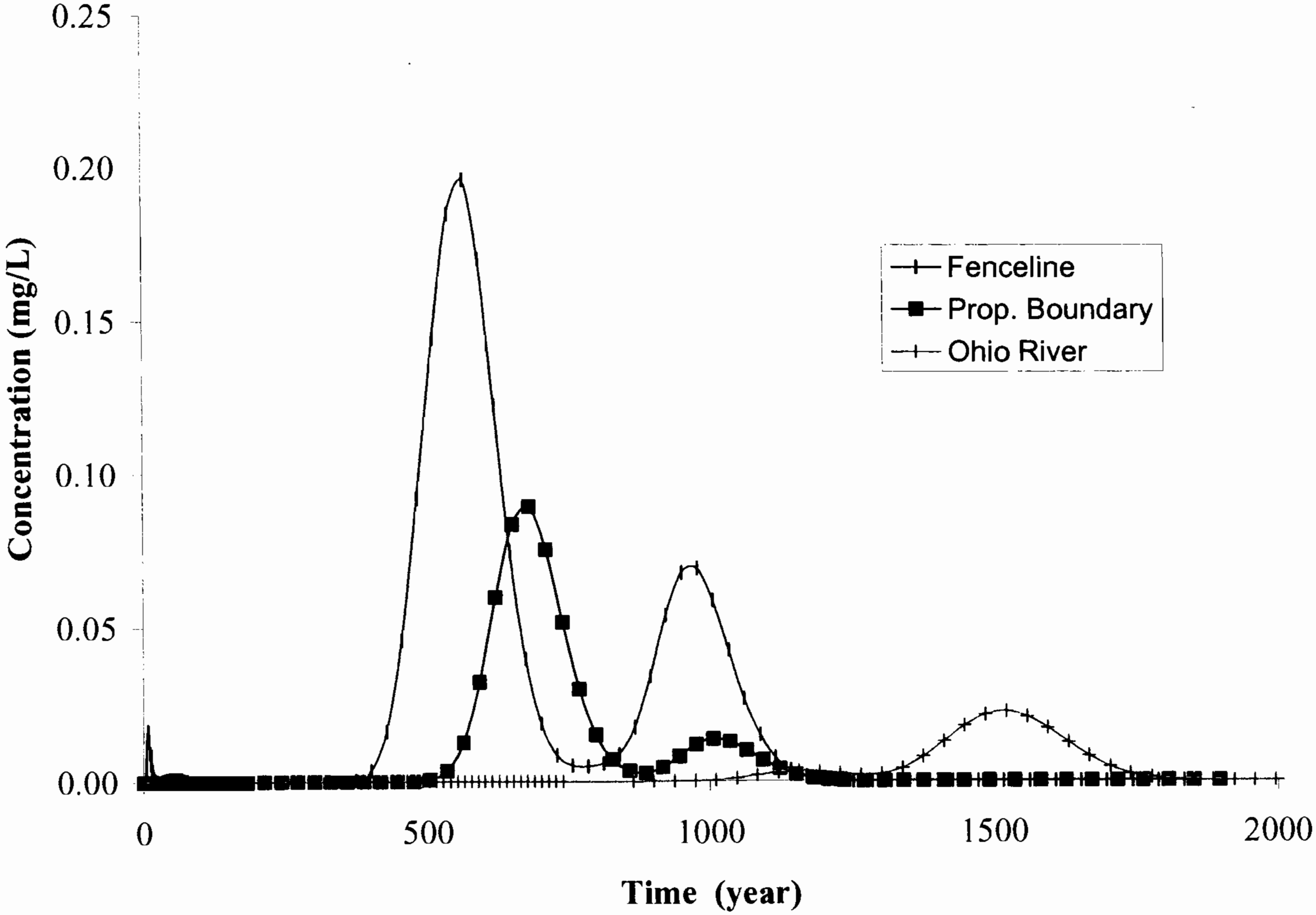


Figure C3.10. Predicted TCE Concentrations at the PGDP Receptor Locations due to loading from WAG 27

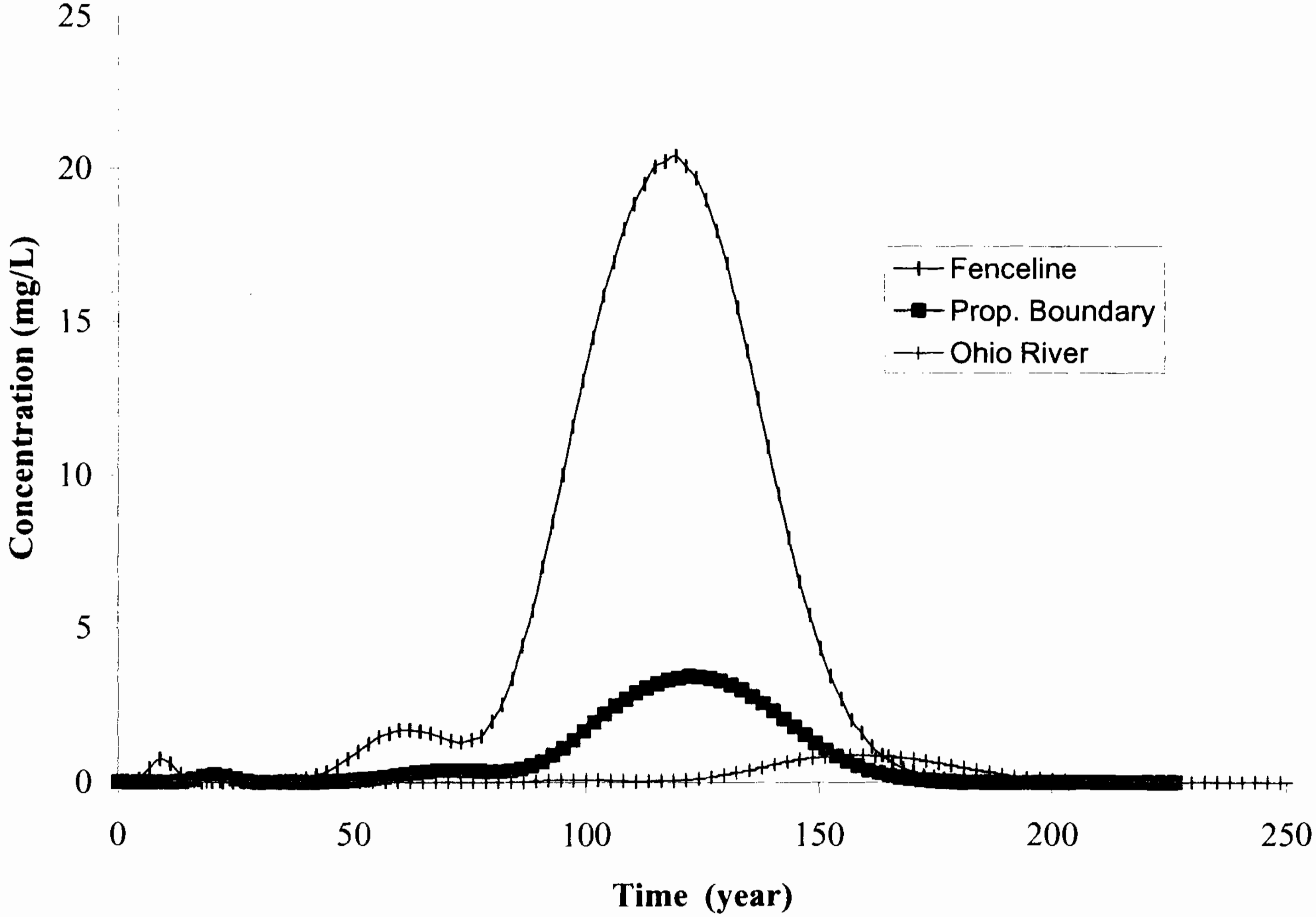


Fig. C3.11. Predicted Vinyl Chloride Concentrations at the PGDP Receptor Locations due to loading from WAG 27

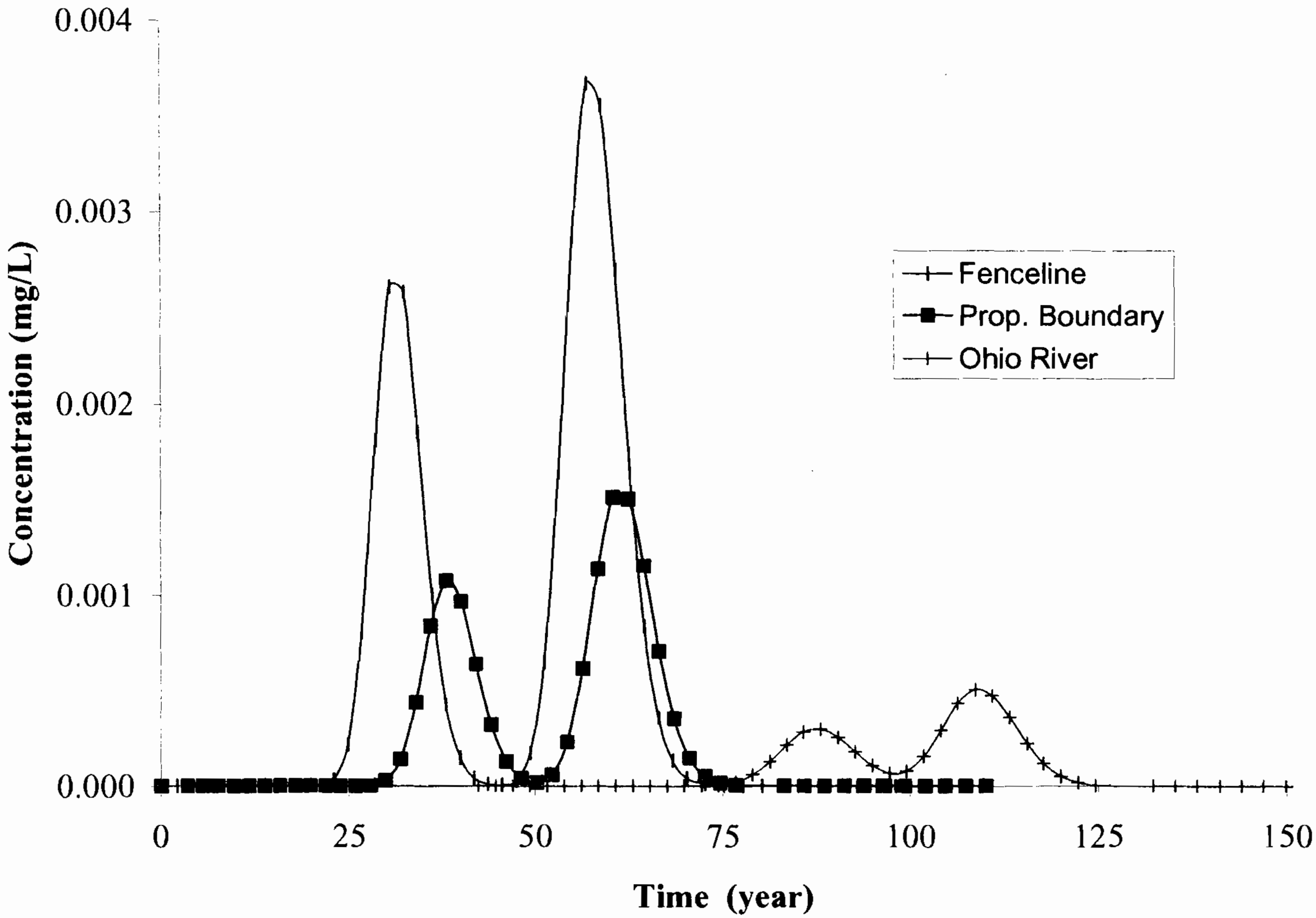


Fig. C3.12. Predicted Tc-99 Activity Concentrations at the PGDP Receptor Locations due to loading from WAG 28

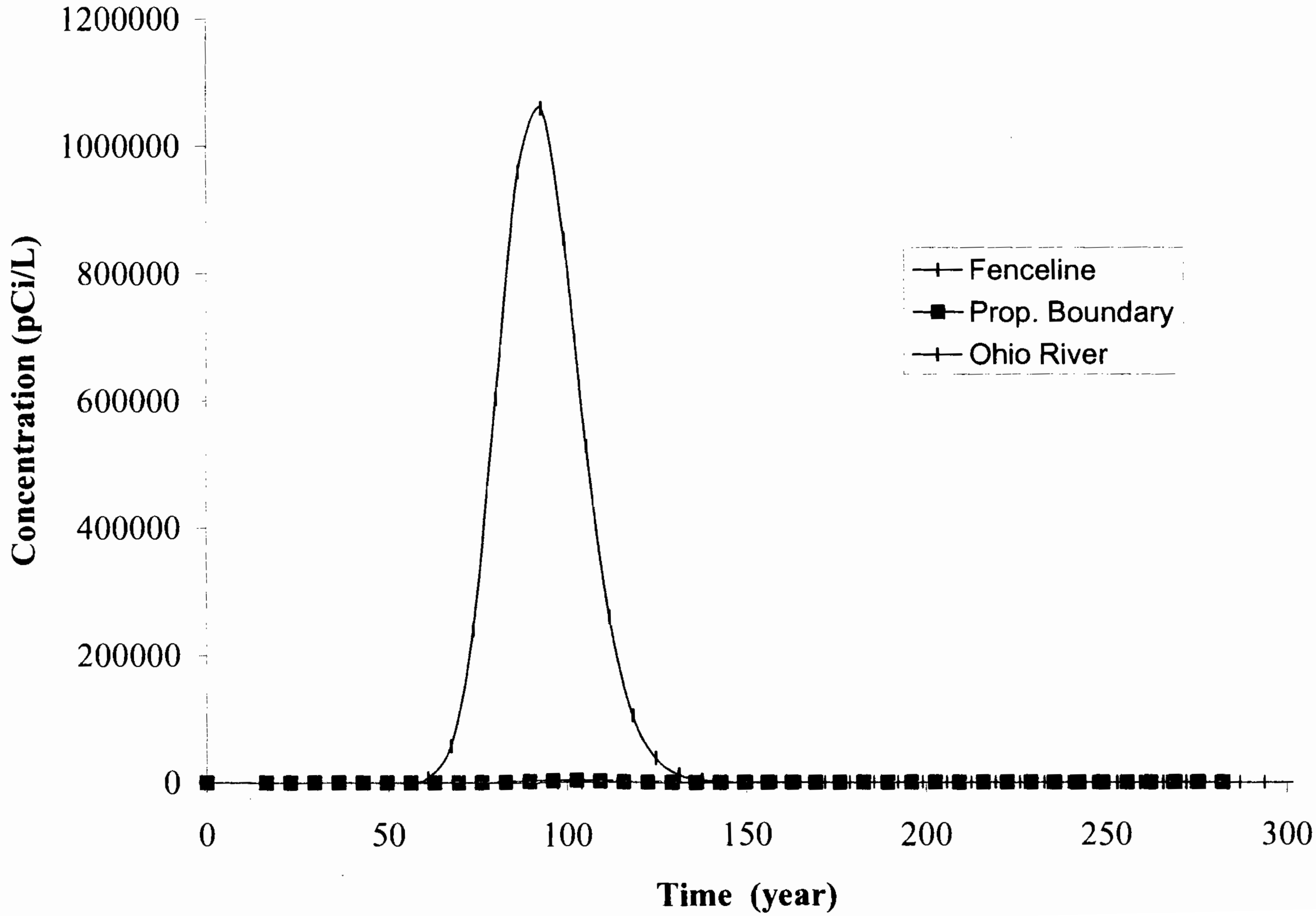


Fig. C3.13. Predicted TCE Concentrations at the PGDP Receptor Locations due to loading from WAG 28 (AOC204)

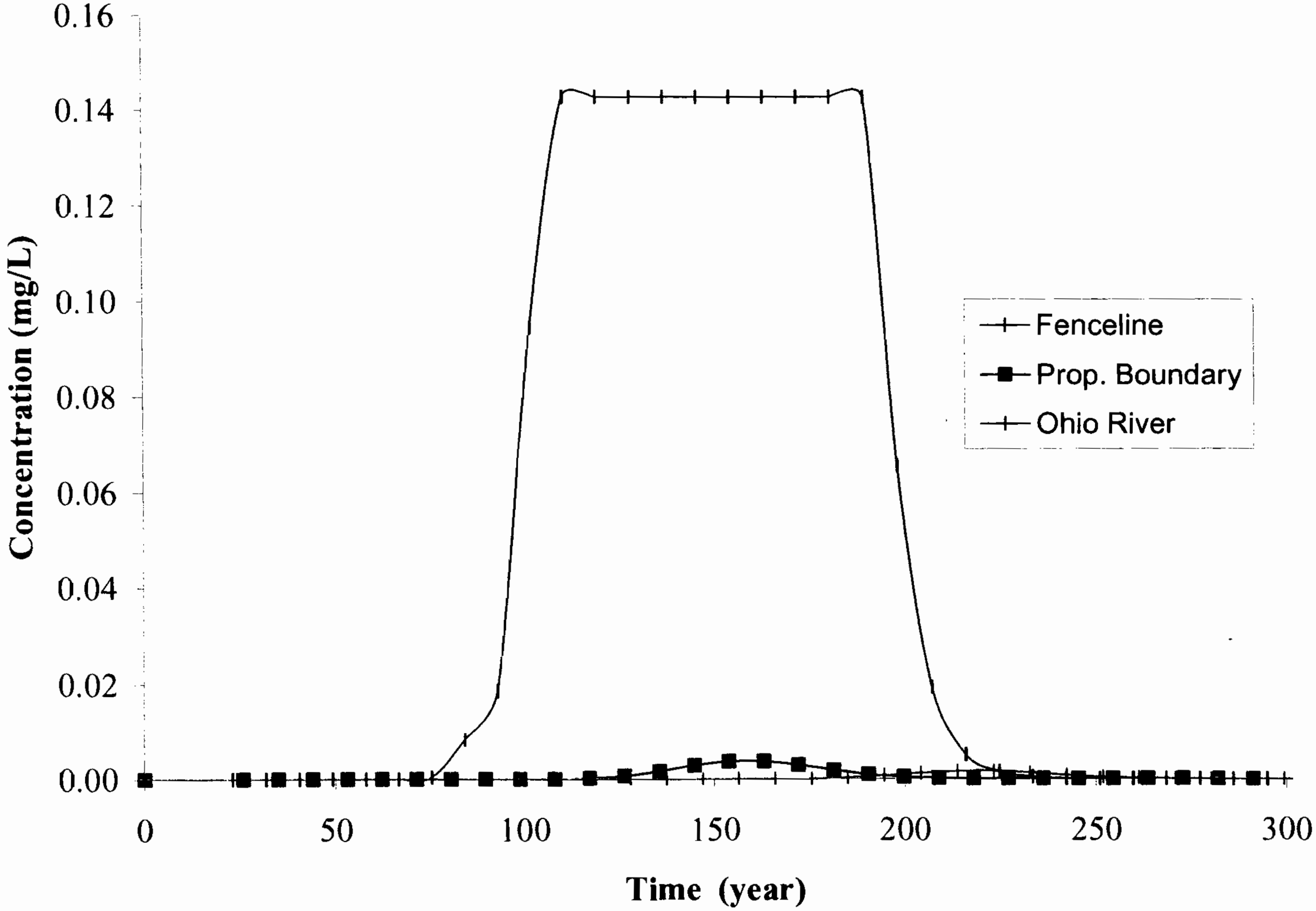


Fig. C3.14. Predicted Manganese Concentrations in the RGA Groundwater at the PGDP Receptor Locations due to loading from WAG 28

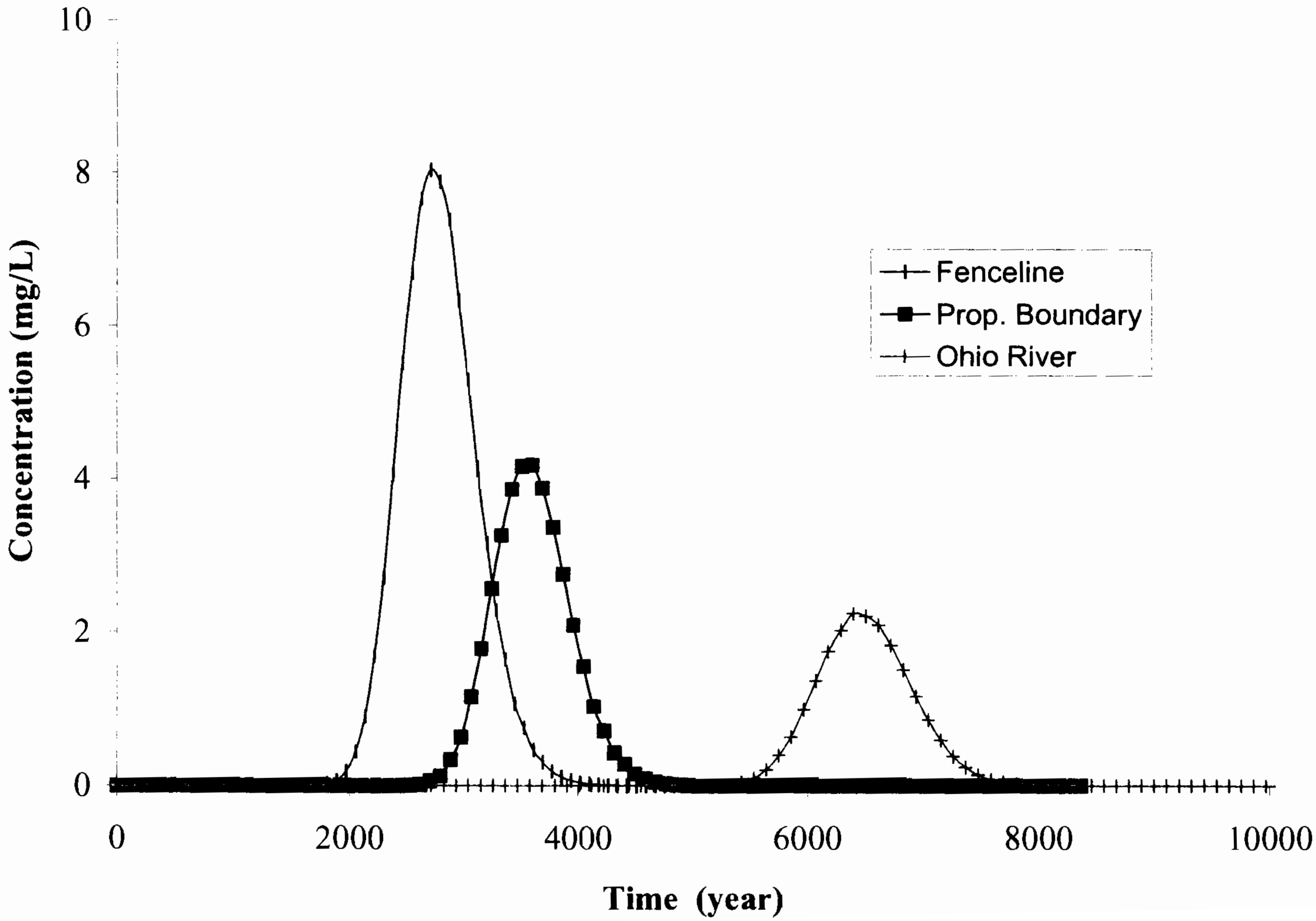


Fig. C3.15. Predicted Lithium Concentrations in the RGA Groundwater at the PGDP Receptor Locations due to loading from WAG 28

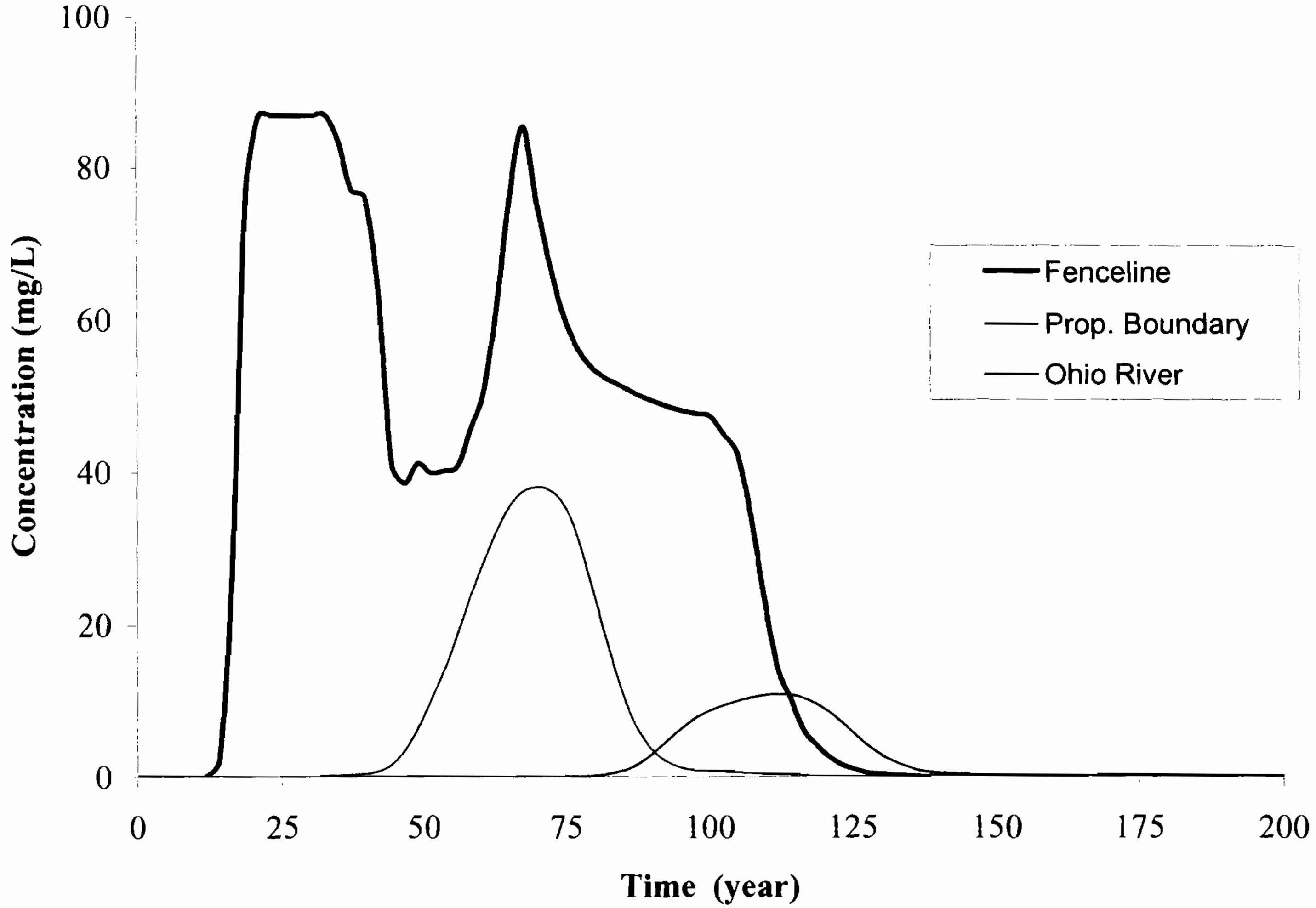


Fig. C3.16. Predicted Strontium Concentrations in the RGA Groundwater at the PGDP Receptor Locations due to loading from WAG 28

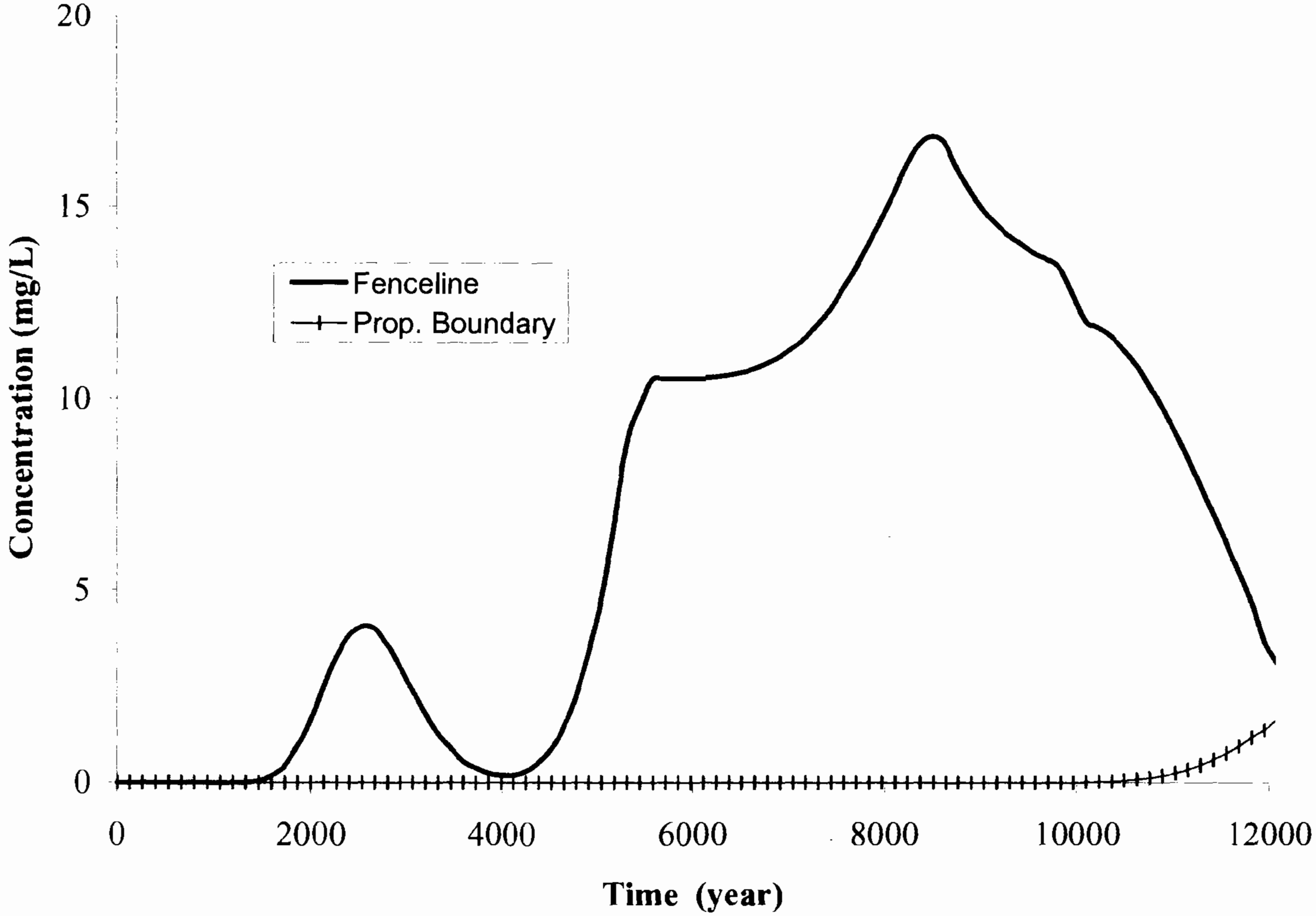


Figure C3.17. Predicted Chromium Concentrations in the RGA Groundwater at the PGDP Receptor Locations due to loading from WAG 28

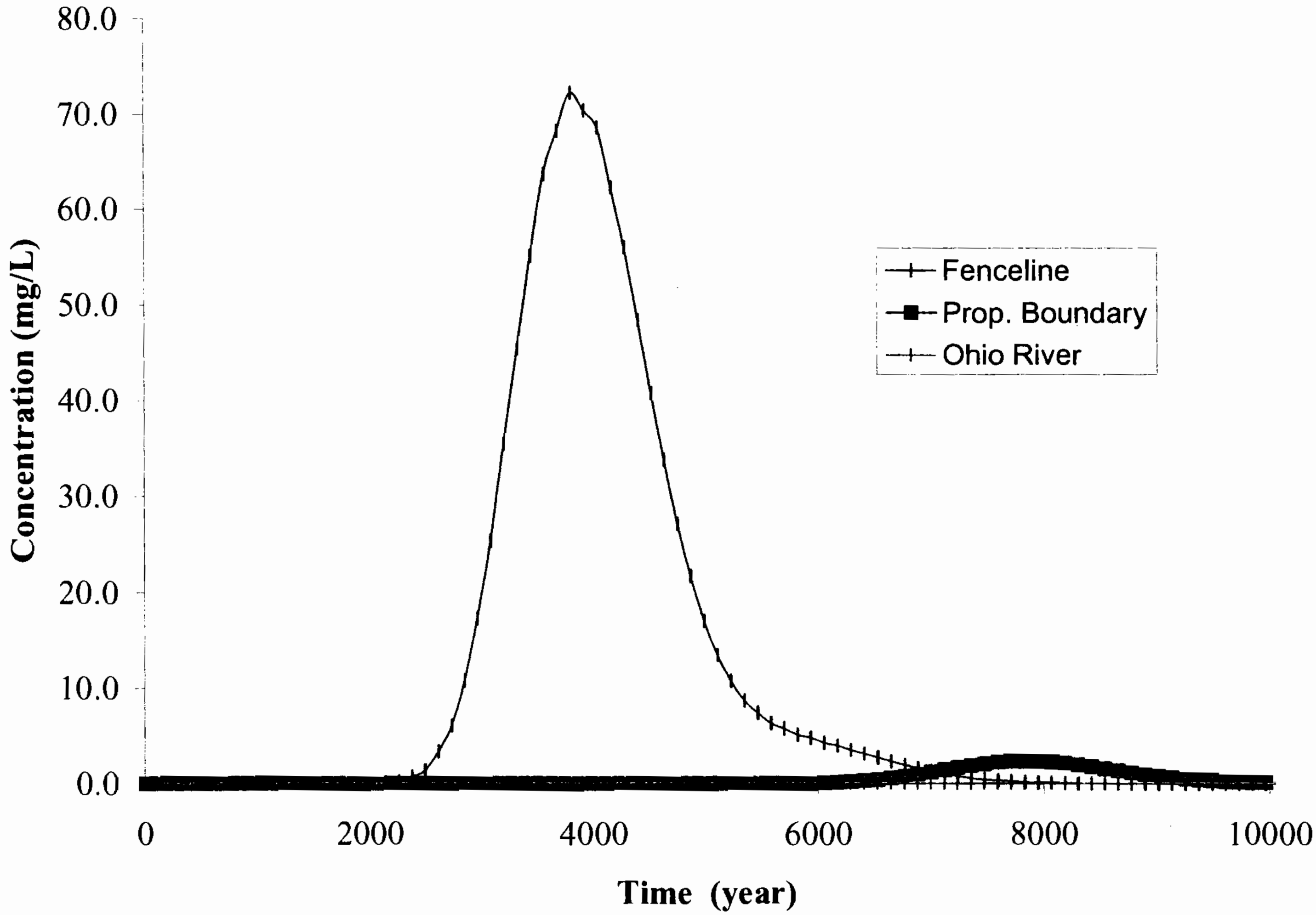


Figure C3.18. Predicted Cobalt Concentrations in the RGA Groundwater at the PGDP Receptor Locations due to loading from WAG 28

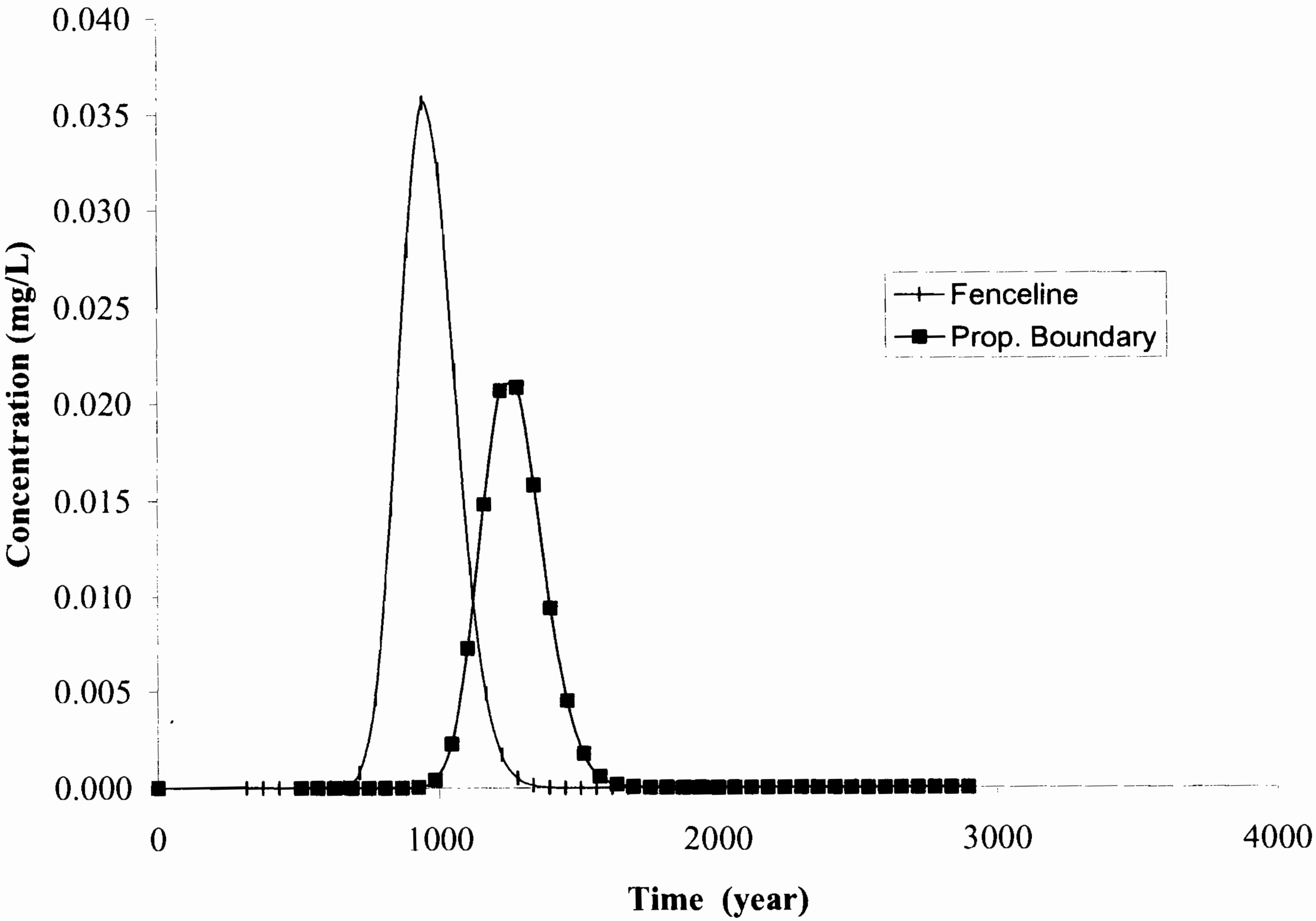


Fig. C3.19. Predicted Tc-99 Activity Concentrations at the DOE Fenceline due to Loading from PGDP Source Areas

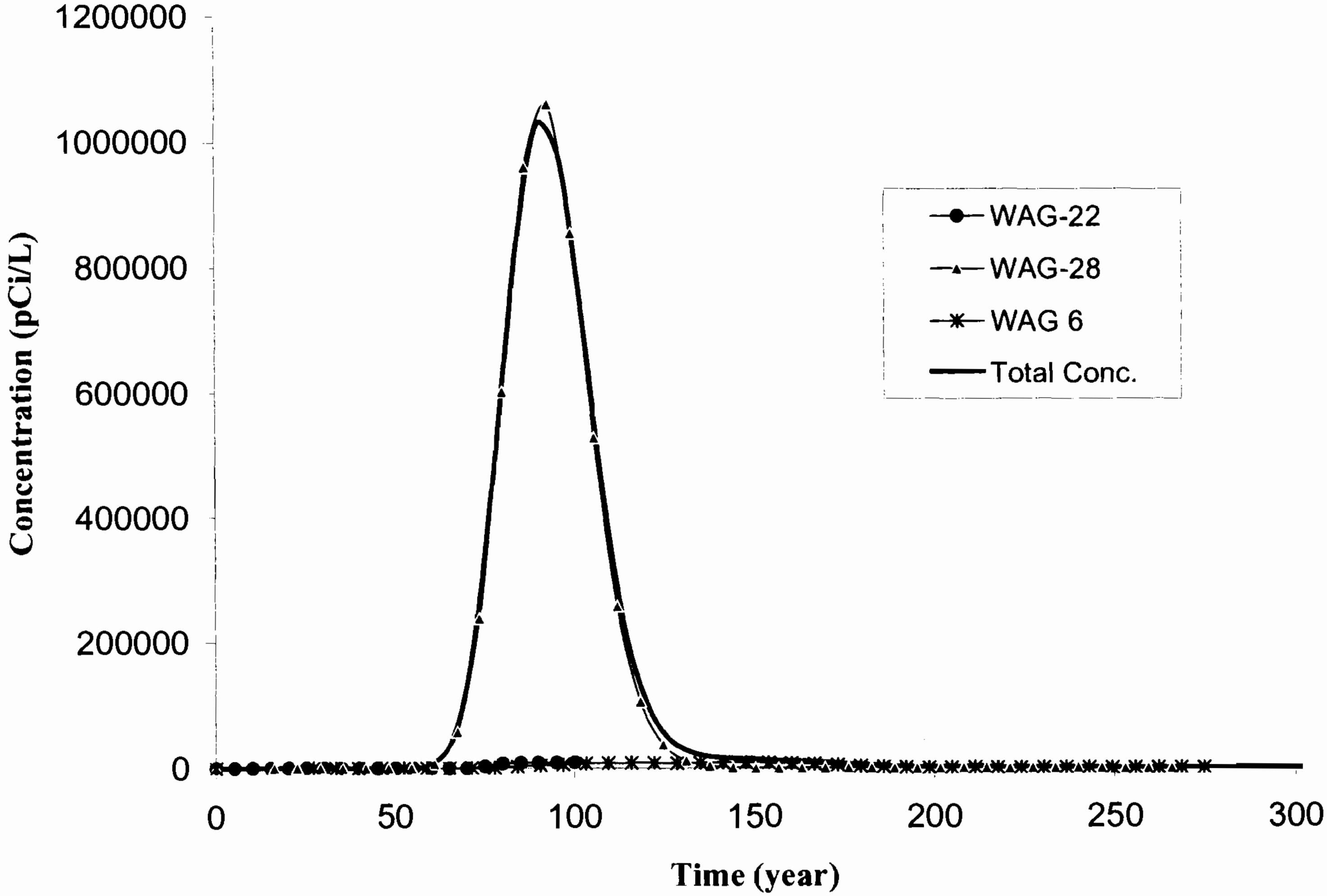


Fig. C3.20. Predicted Tc-99 Activity Concentrations at the DOE Property Boundary due to loading from PGDP Source Areas

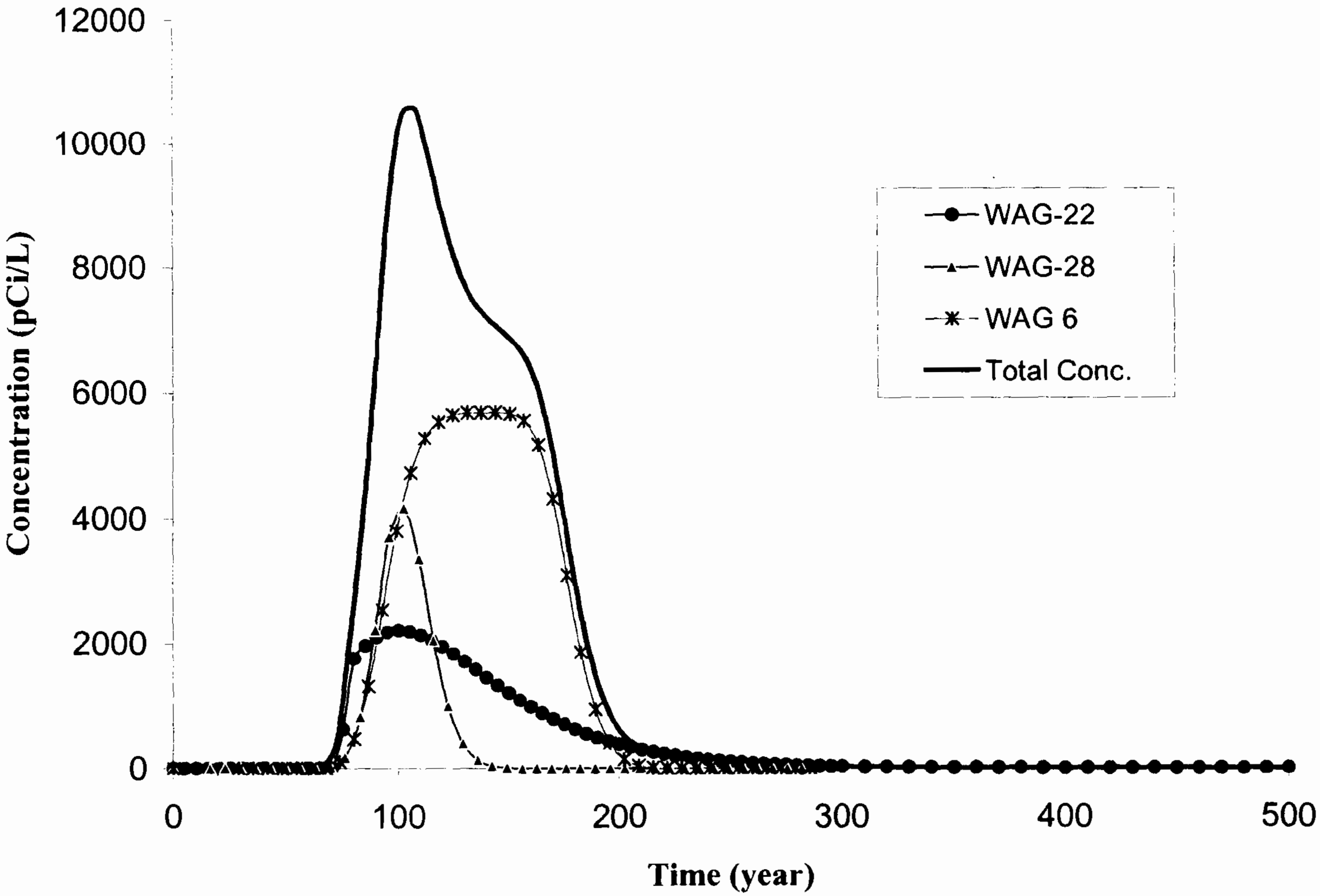


Fig. C3.21. Predicted Tc-99 Activity Concentrations at the Bayou Creek due to loading from PGDP Source Areas

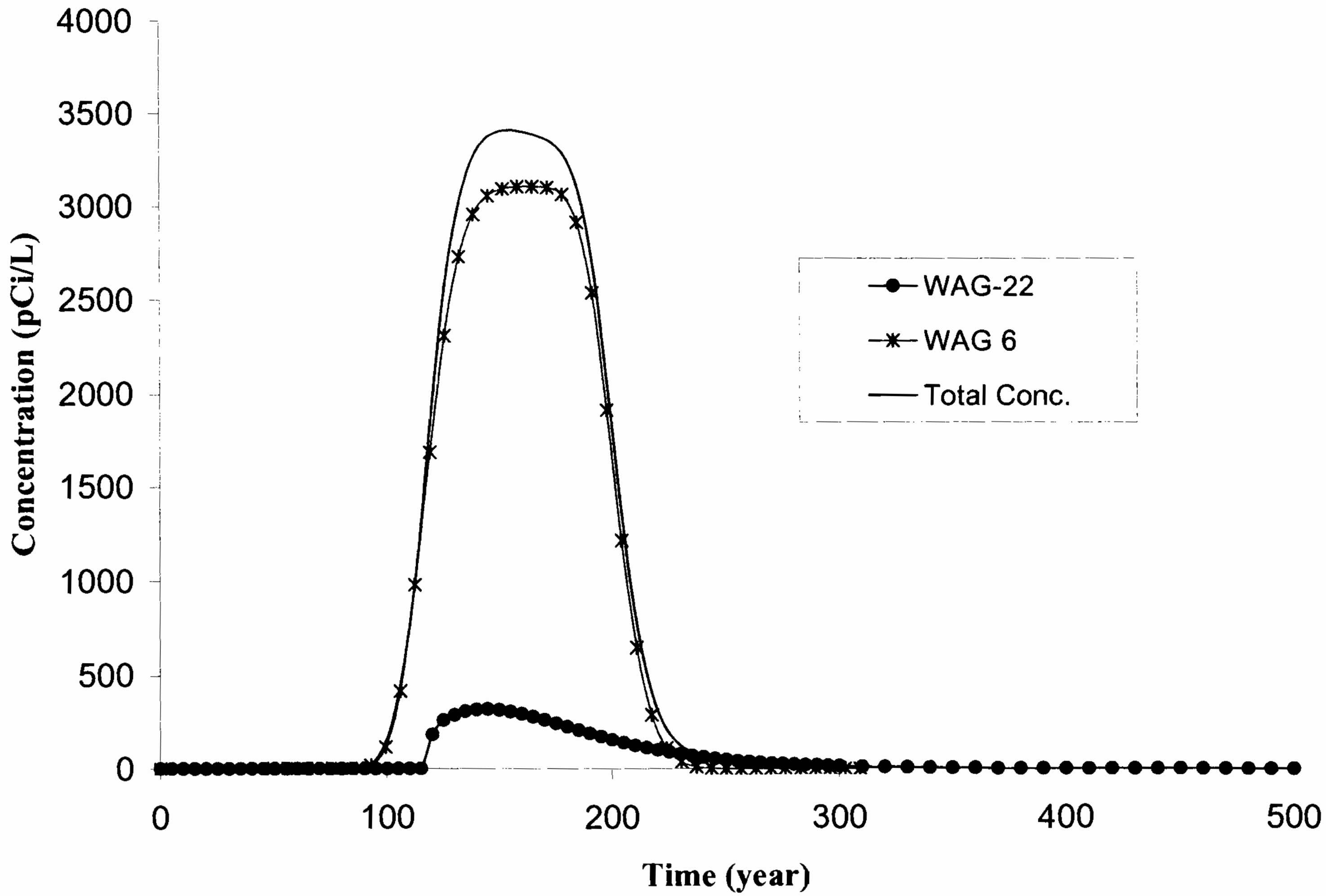


Fig. C3.22. Predicted Tc-99 Activity Concentrations at the Ohio River due to Loading from PGDP Source Areas

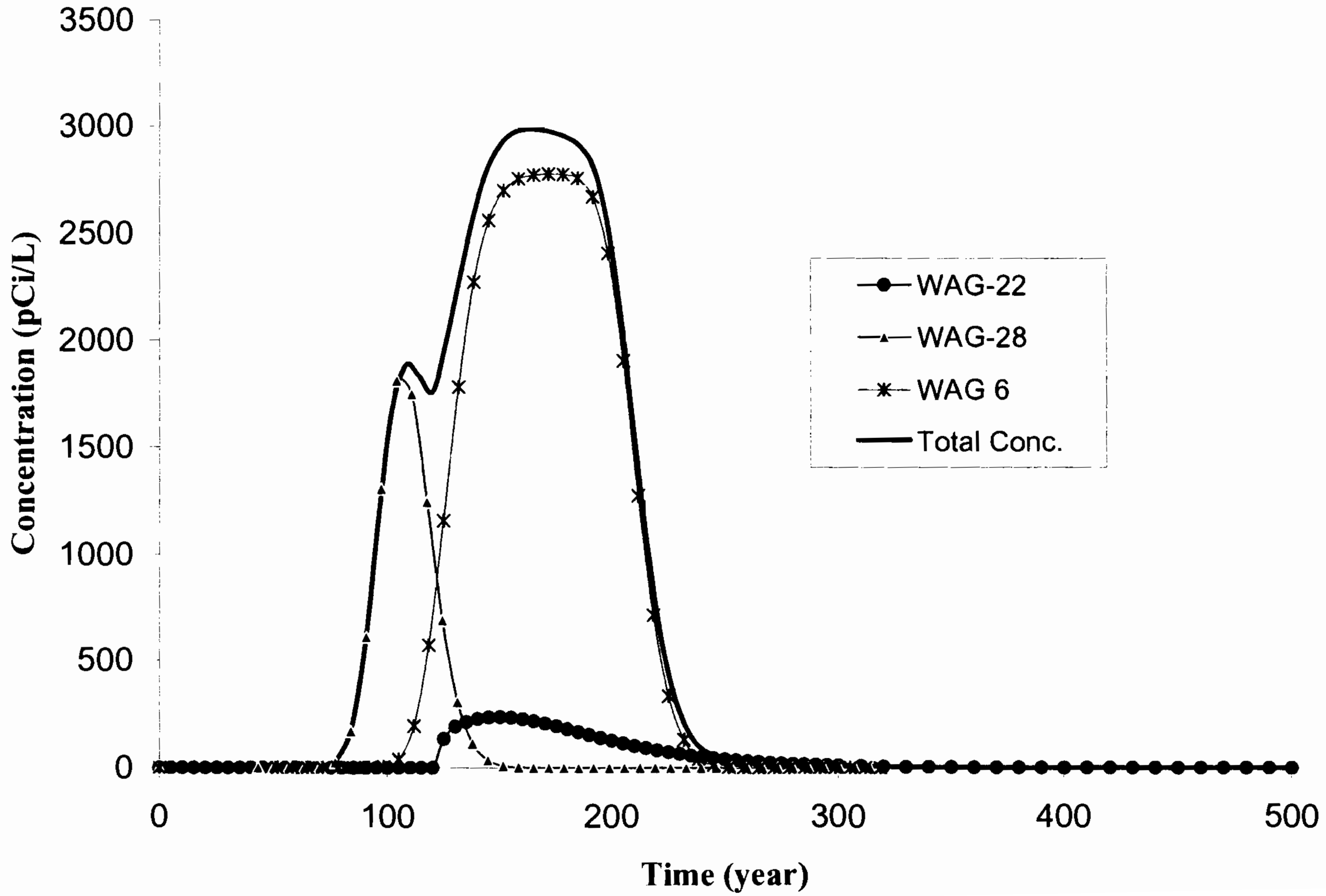


Fig. C3.23. Predicted TCE Concentrations at the Fenceline due to loading from PGDP Source Areas

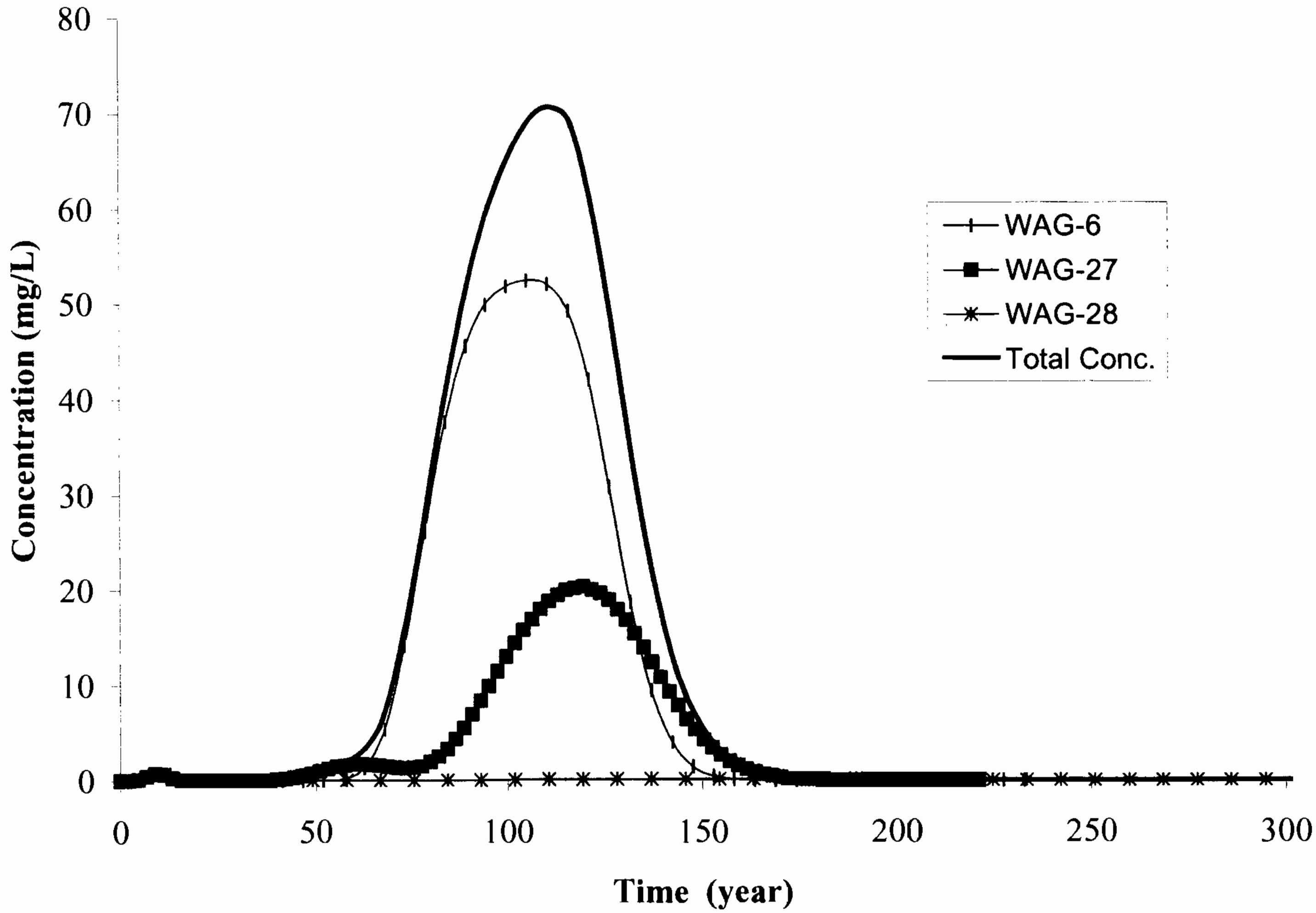


Fig. C3.24. Predicted TCE Concentrations at the Property Boundary due to loading from PGDP Source Areas

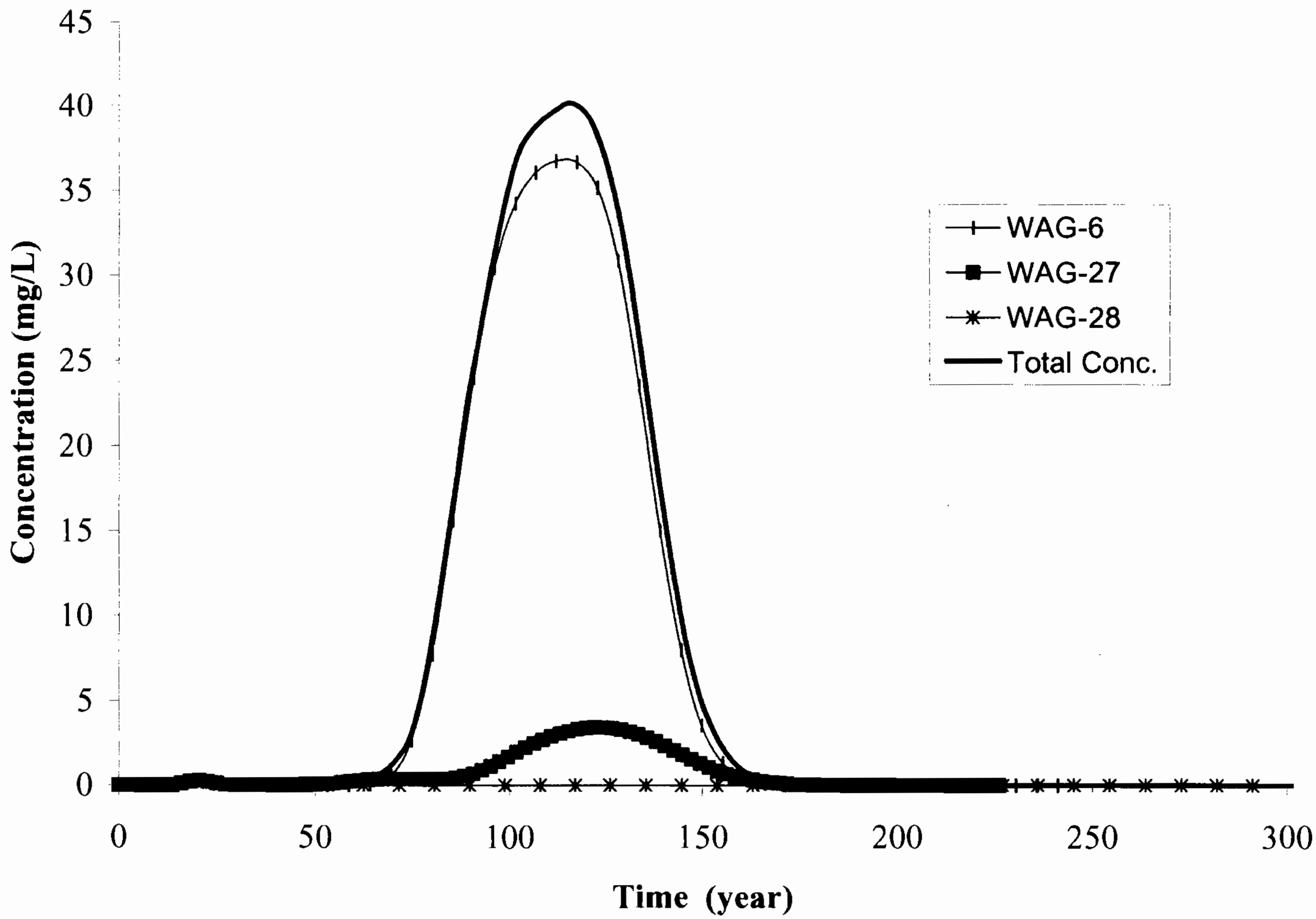


Fig. C3.25. Predicted TCE Concentrations at the Bayou Creek due to loading from PGDP Source Areas

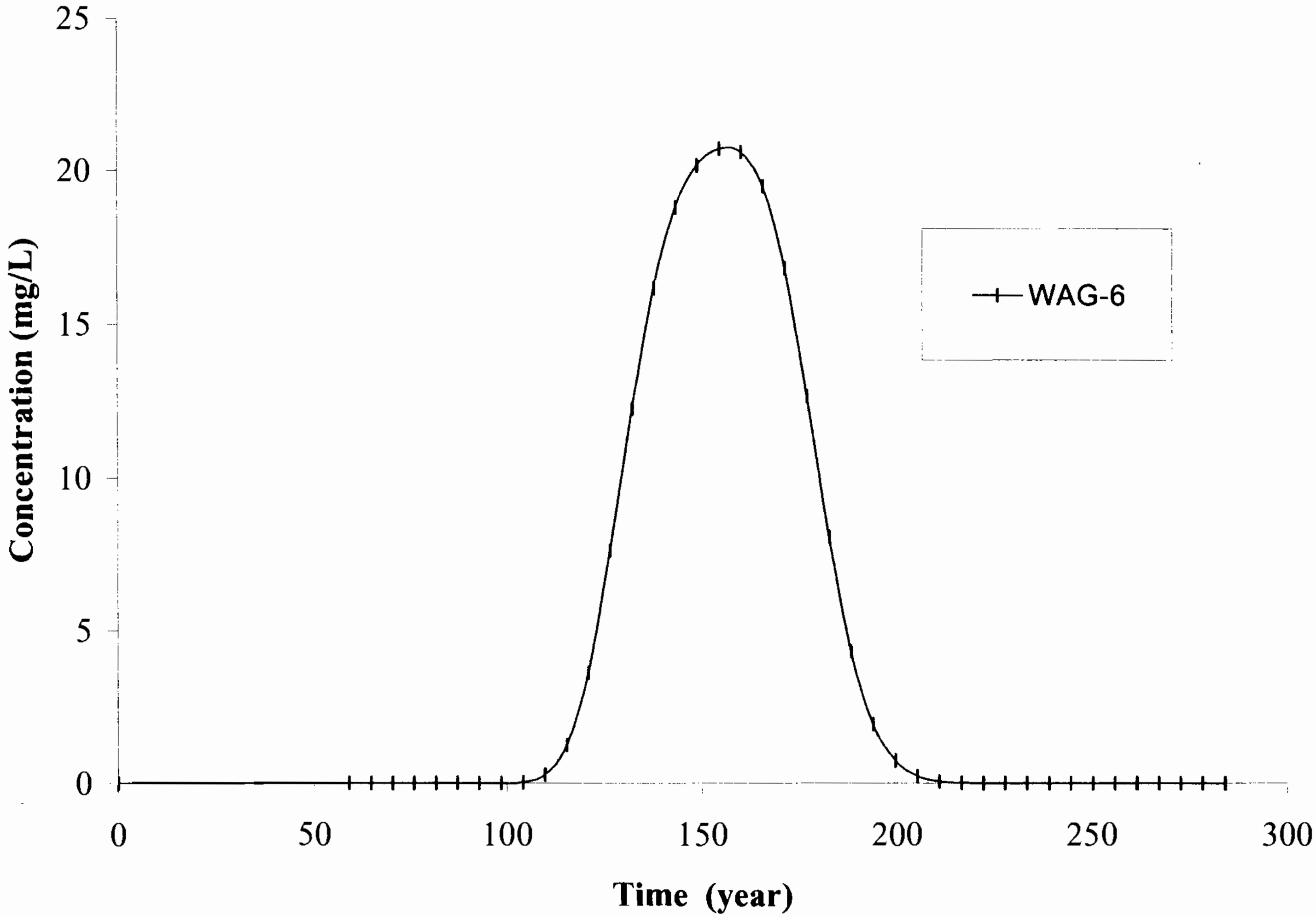


Fig. C3.26. Predicted TCE Concentrations at the Ohio River due to loading from PGDP Source Areas

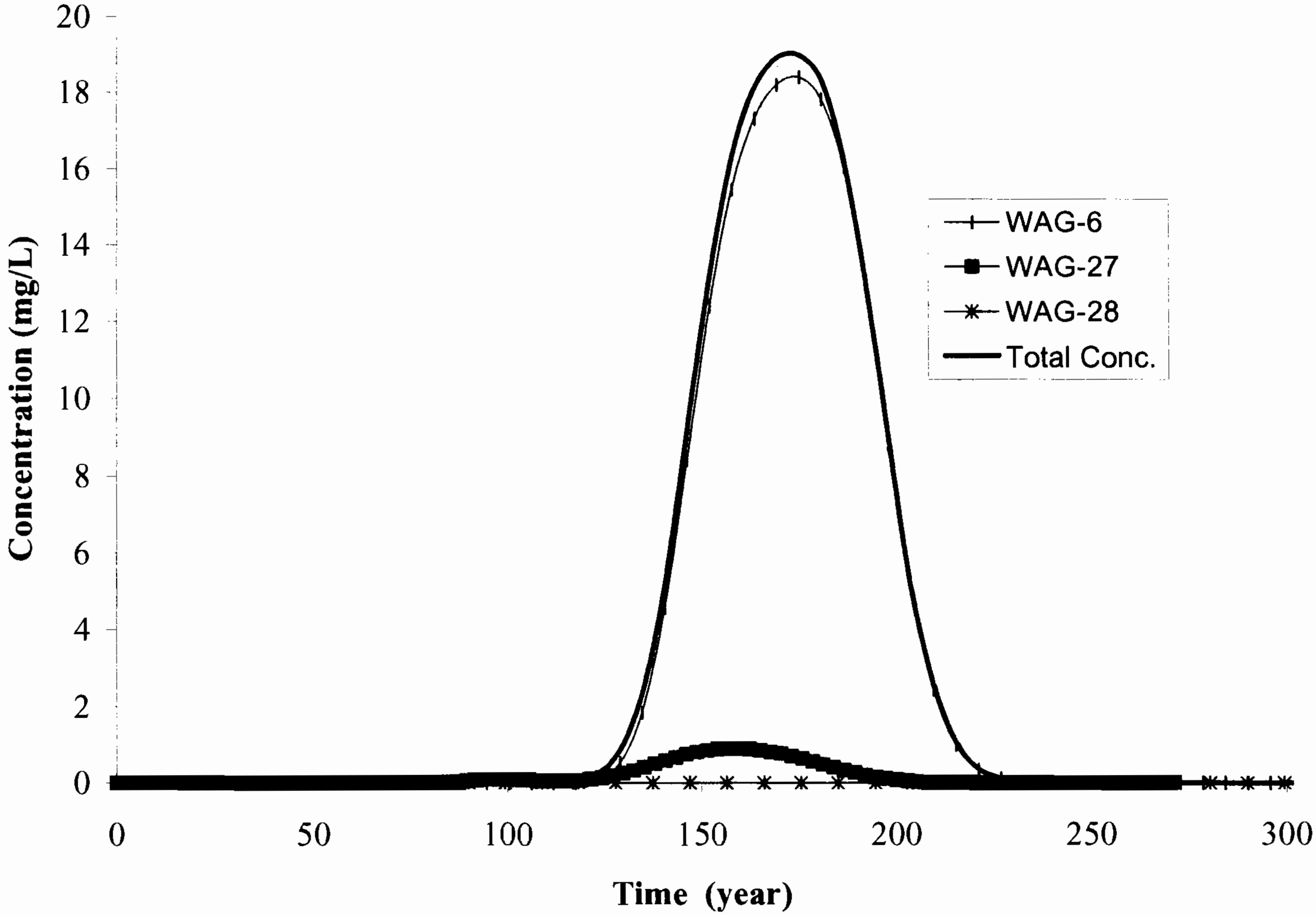


Fig. C3.27. Predicted Vinyl Chloride Concentrations at the PGDP Fenceline due to loading from PGDP Source Areas

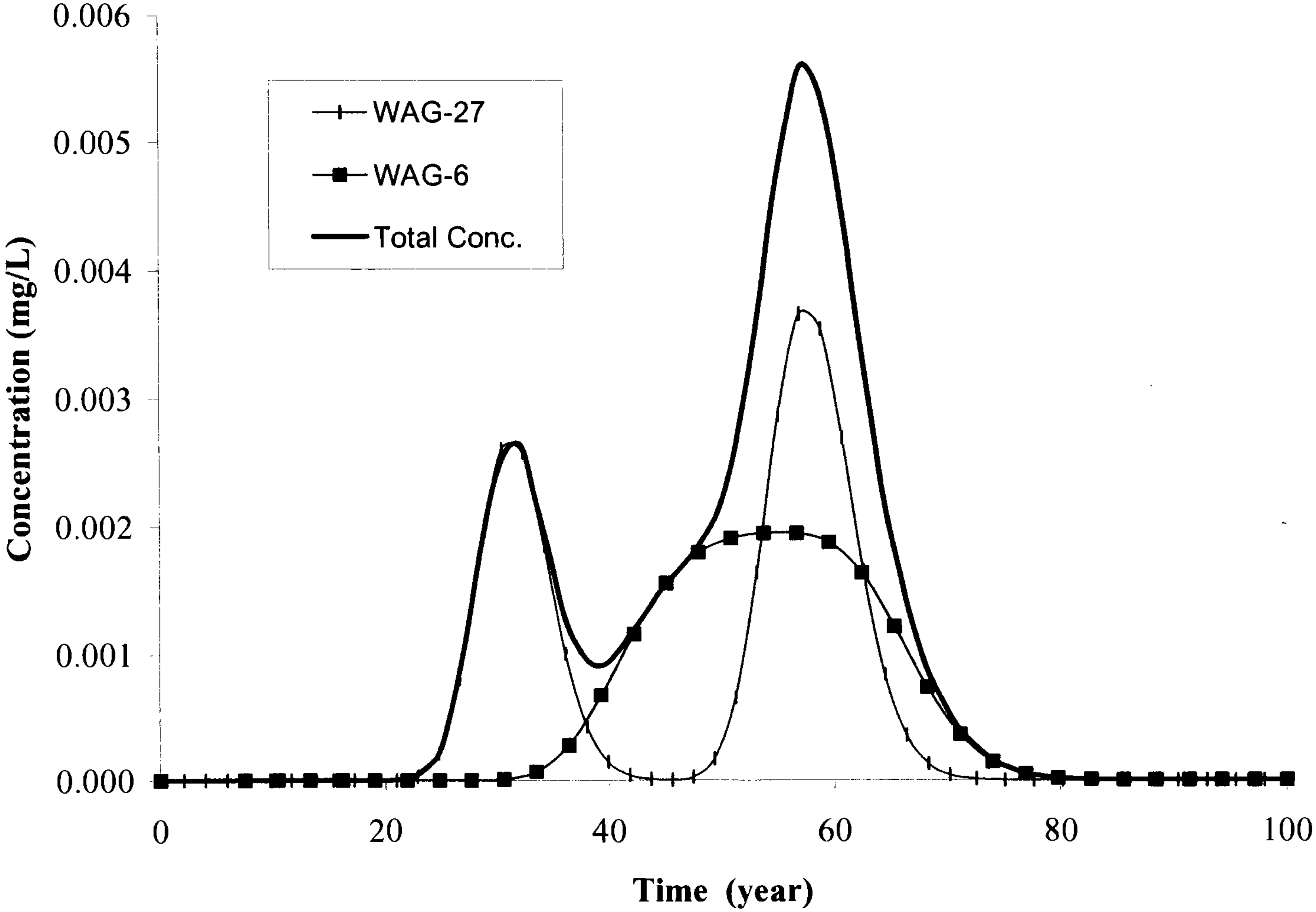


Fig. C3.28. Predicted Vinyl Chloride Concentrations at the DOE Property Boundary due to loading from PGDP Source Areas

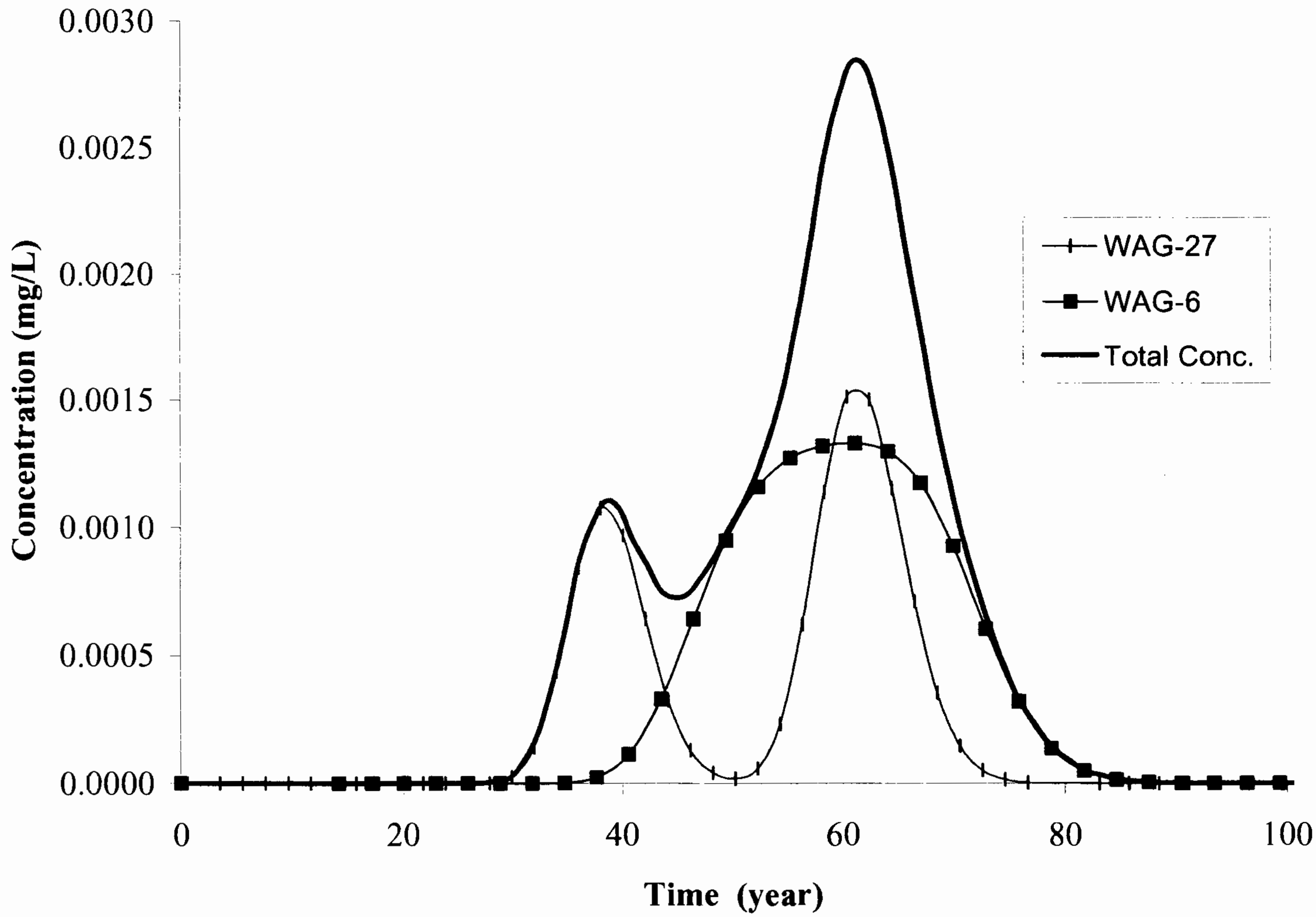


Fig. C3.29. Predicted Vinyl Chloride Concentrations at the Bayou Creek due to loading from PGDP Source Areas

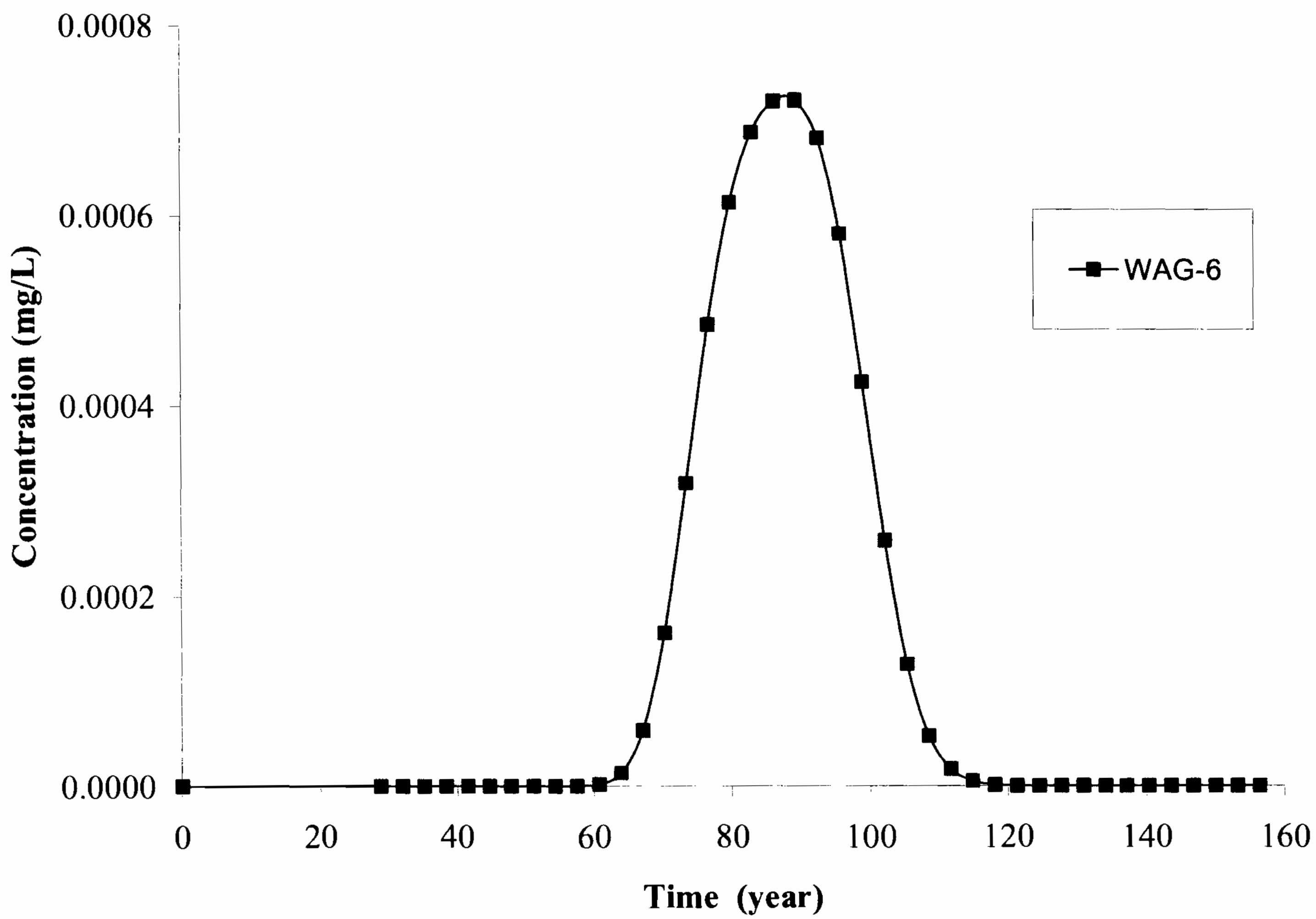


Fig. C3.30. Predicted Vinyl Chloride Concentrations at the Ohio River due to loading from PGDP Source Areas

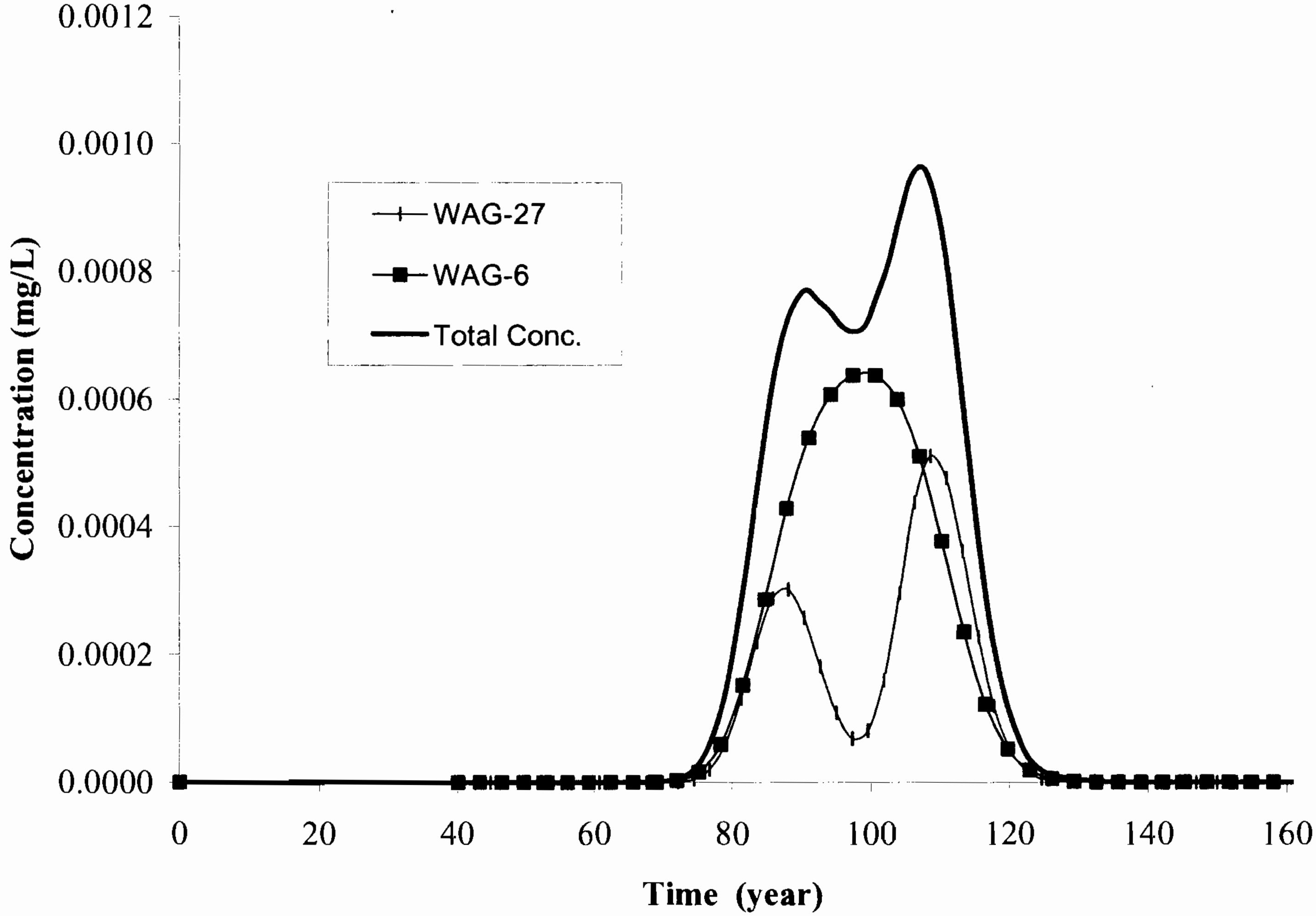


Fig. C3.31. Predicted Antimony Concentrations in the RGA Groundwater at the PGDP Fenceline due to loading from PGDP Source Areas

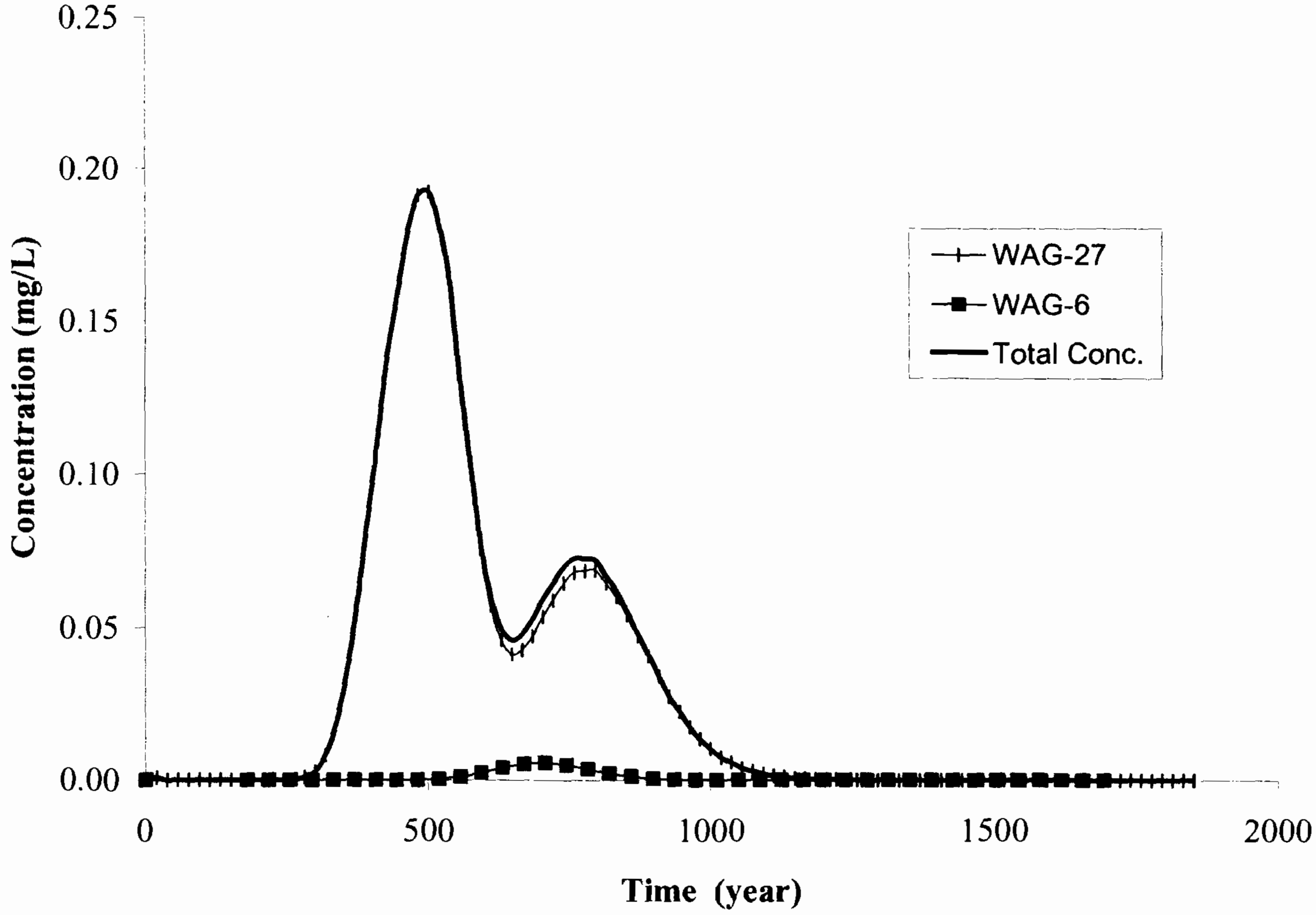


Fig. C3.32. Predicted Antimony Concentrations in the RGA Groundwater at the DOE Property Boundary due to Loading from PGDP Source Areas

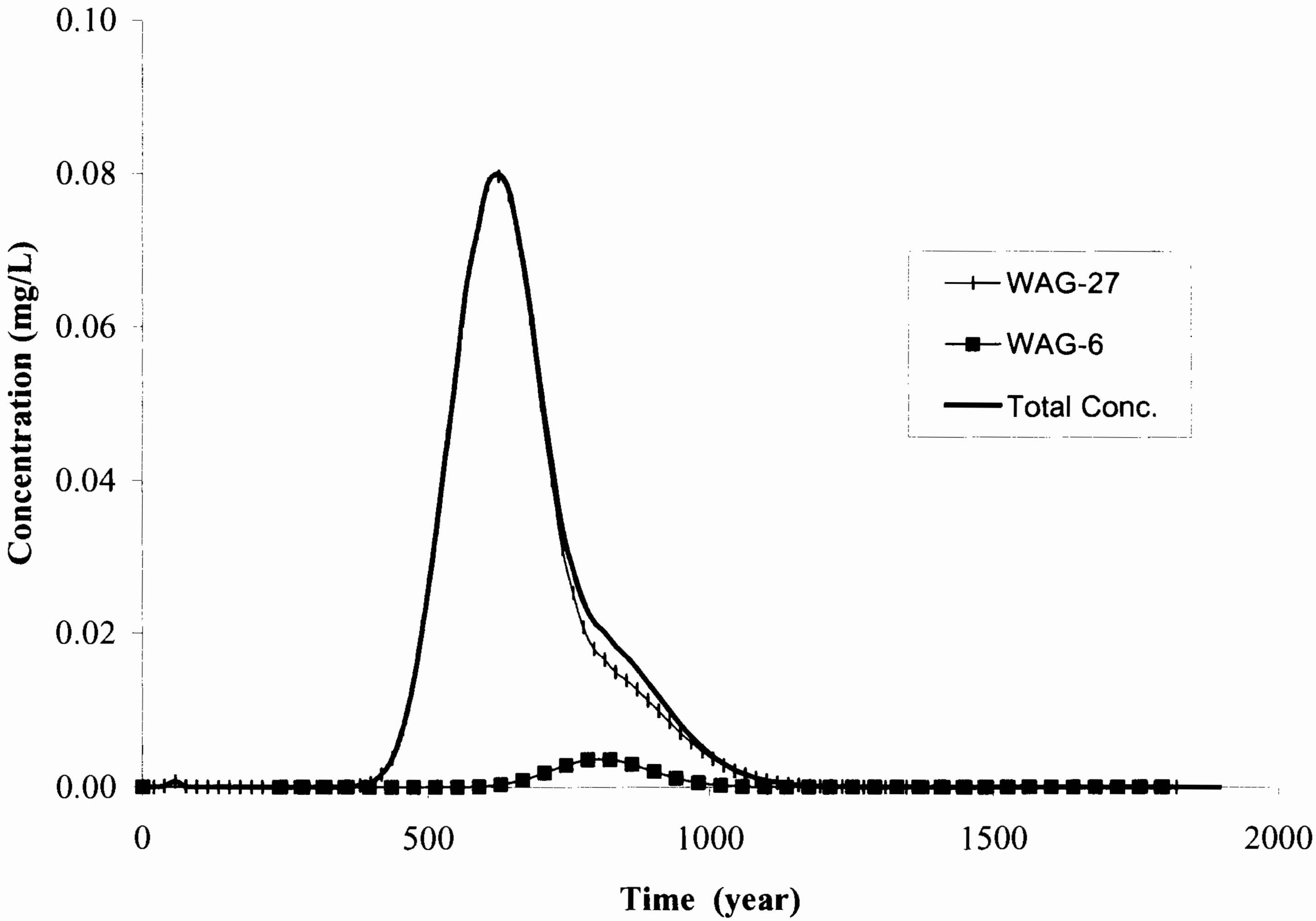
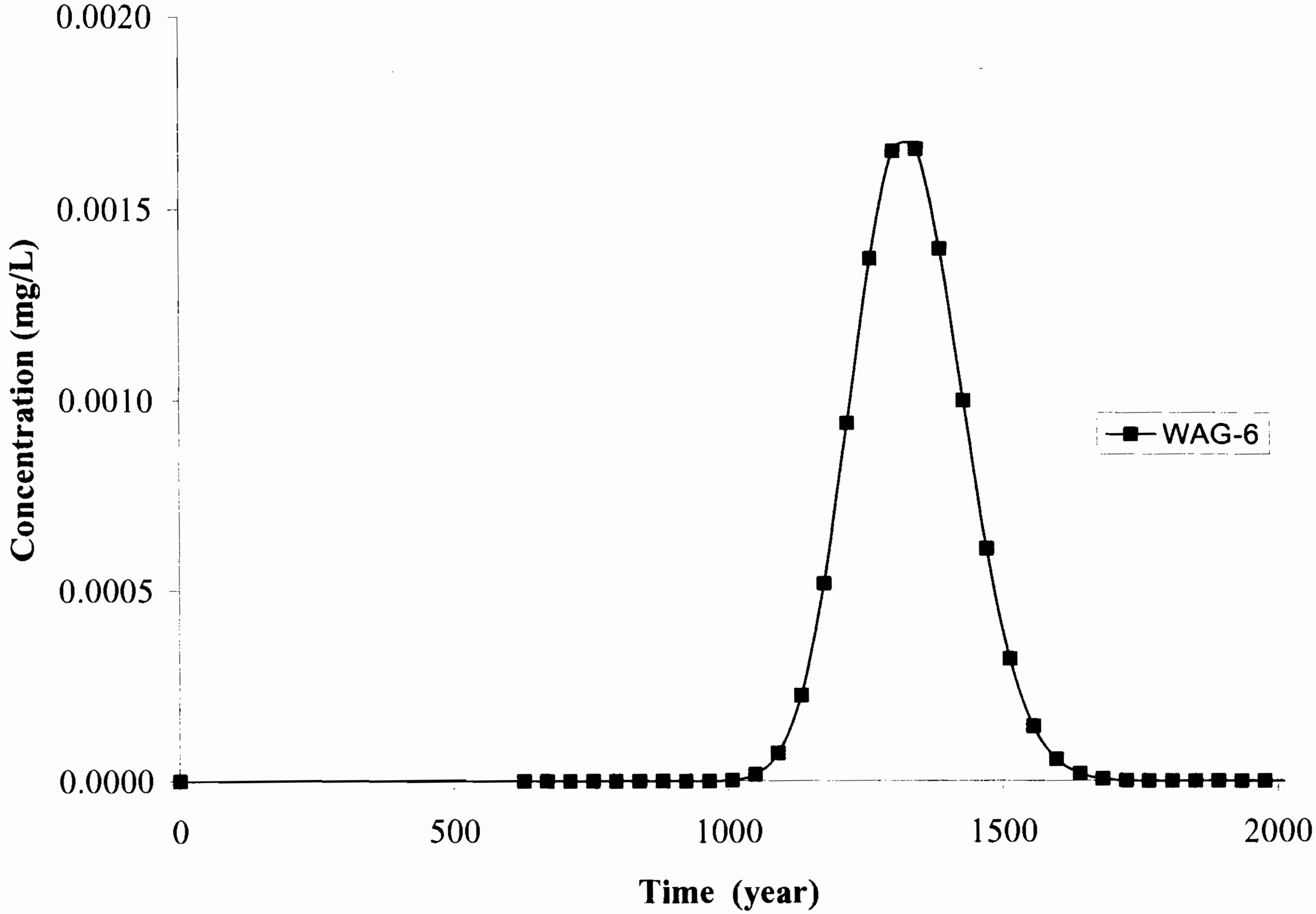
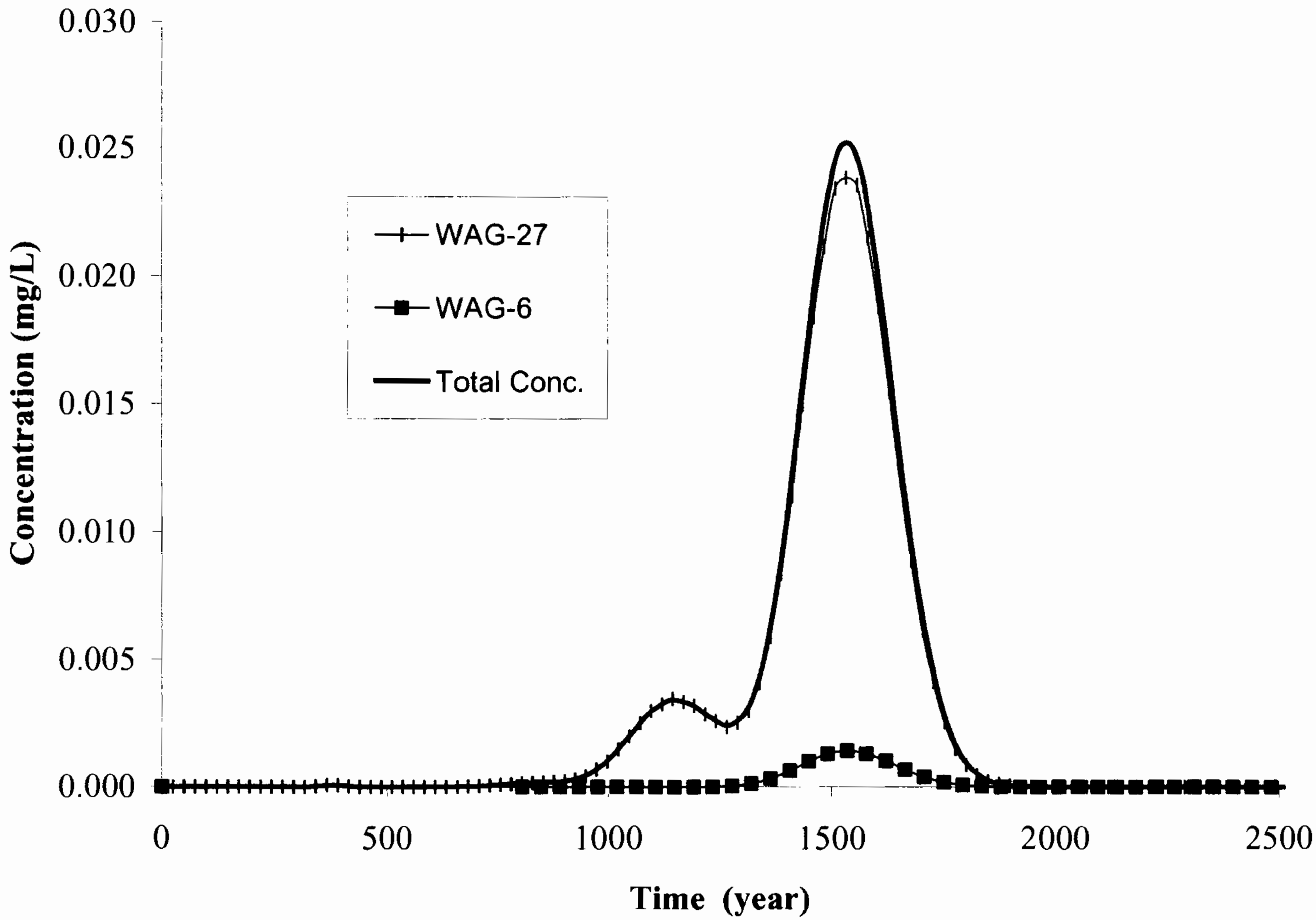


Fig. C3.33. Predicted Antimony Concentrations in the RGA Groundwater at the Bayou Creek due to Loading from PGDP Source Areas



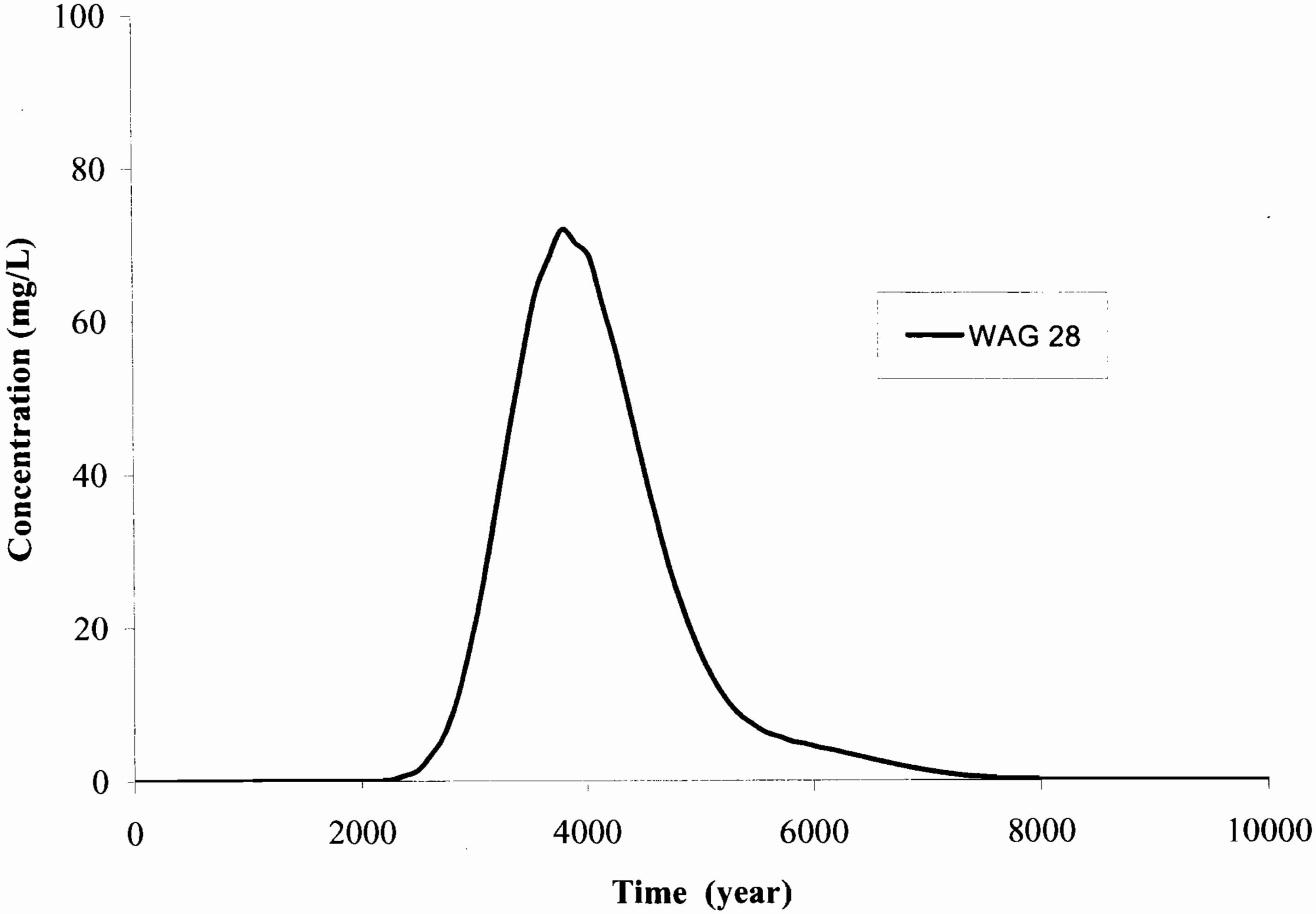
225039

Fig. C3.34. Predicted Antimony Concentrations in the RGA Groundwater at the Ohio River due to Loading from PGDP Source Areas



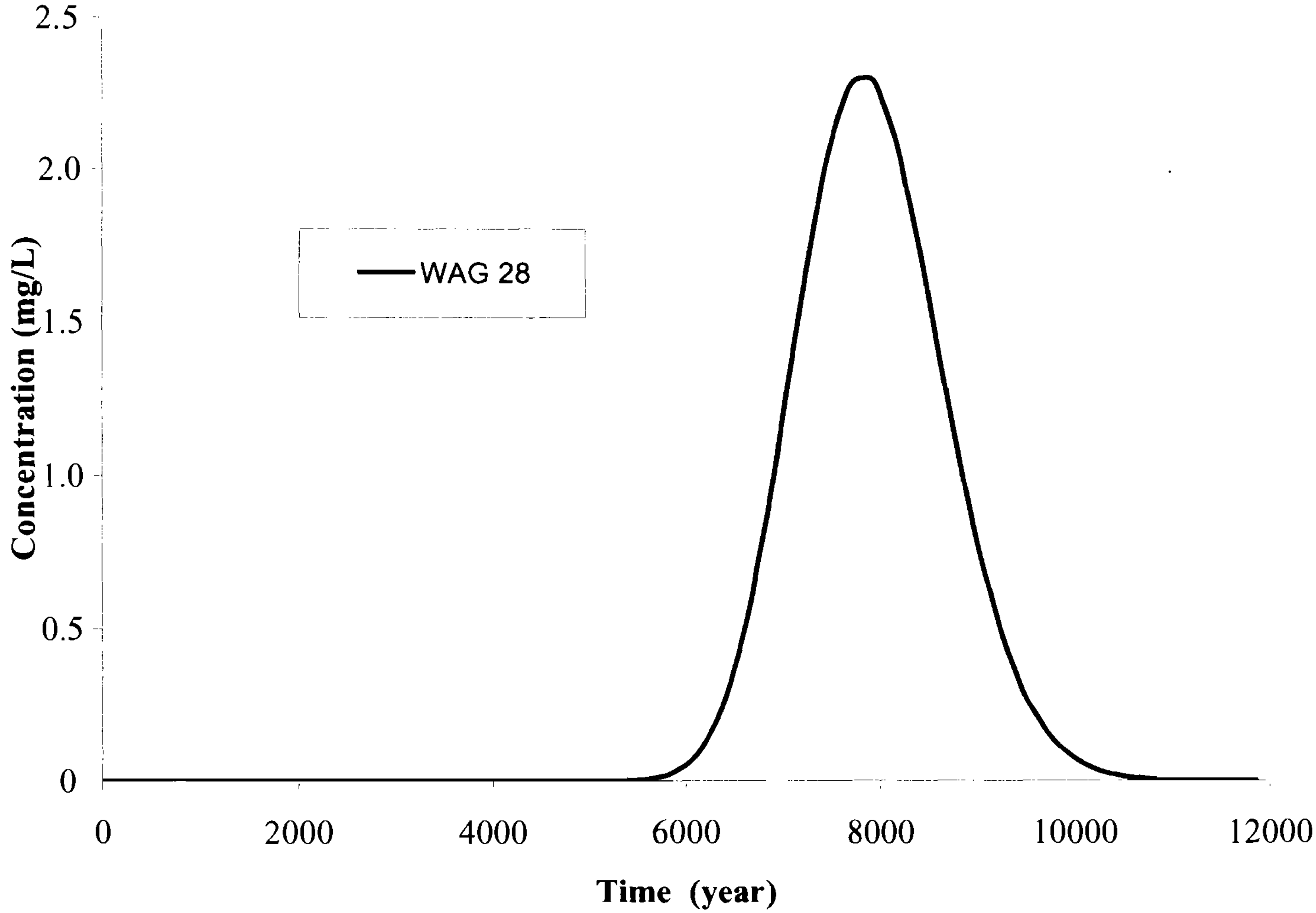
830251

Fig. C3.35. Predicted Chromium Concentrations at the PGDP Fenceline due to loading from PGDP Source Areas



630524

Fig. C3.36. Predicted Chromium Concentrations at the DOE Property Boundary due to loading from PGDP Source Areas



630253

Fig. C3.37. Predicted Chromium Concentrations at the Ohio River due to loading from PGDP Source Areas

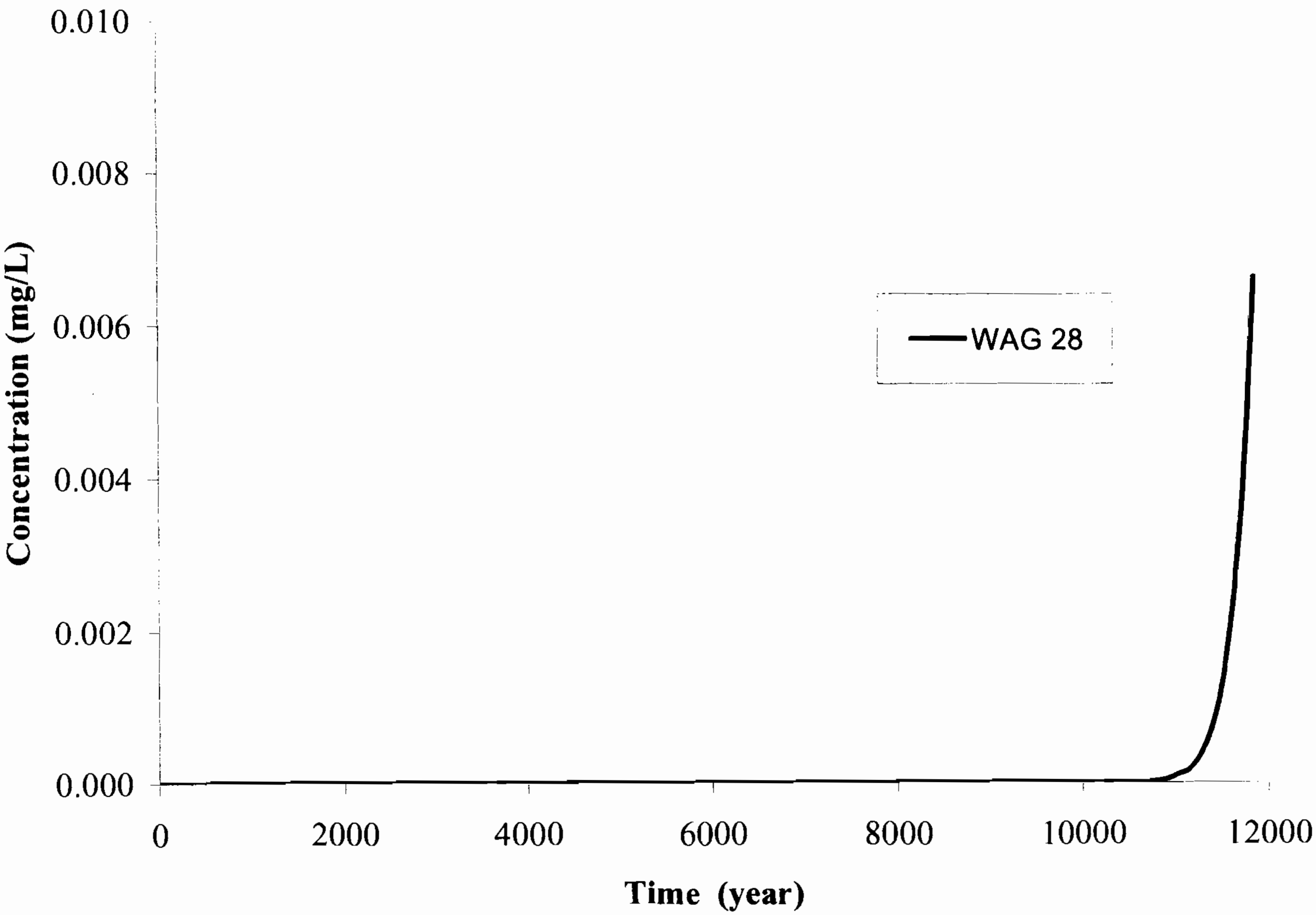


Fig. C3.38. Predicted Lithium Concentrations at the PGDP Fenceline due to loading from PGDP Source Areas

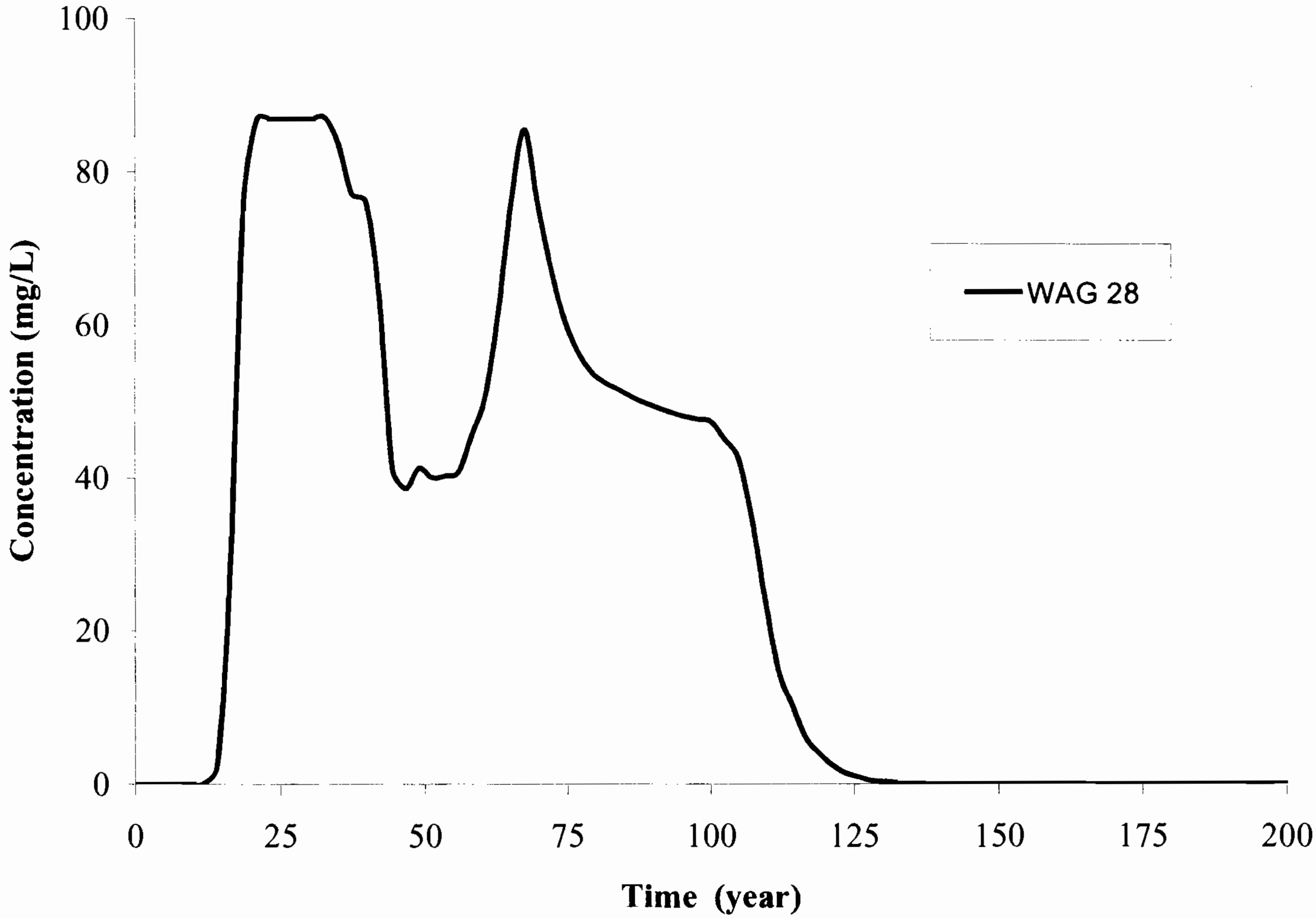


Fig. C3.39. Predicted Lithium Concentrations at the DOE Property Boundary due to loading from PGDP Source Areas

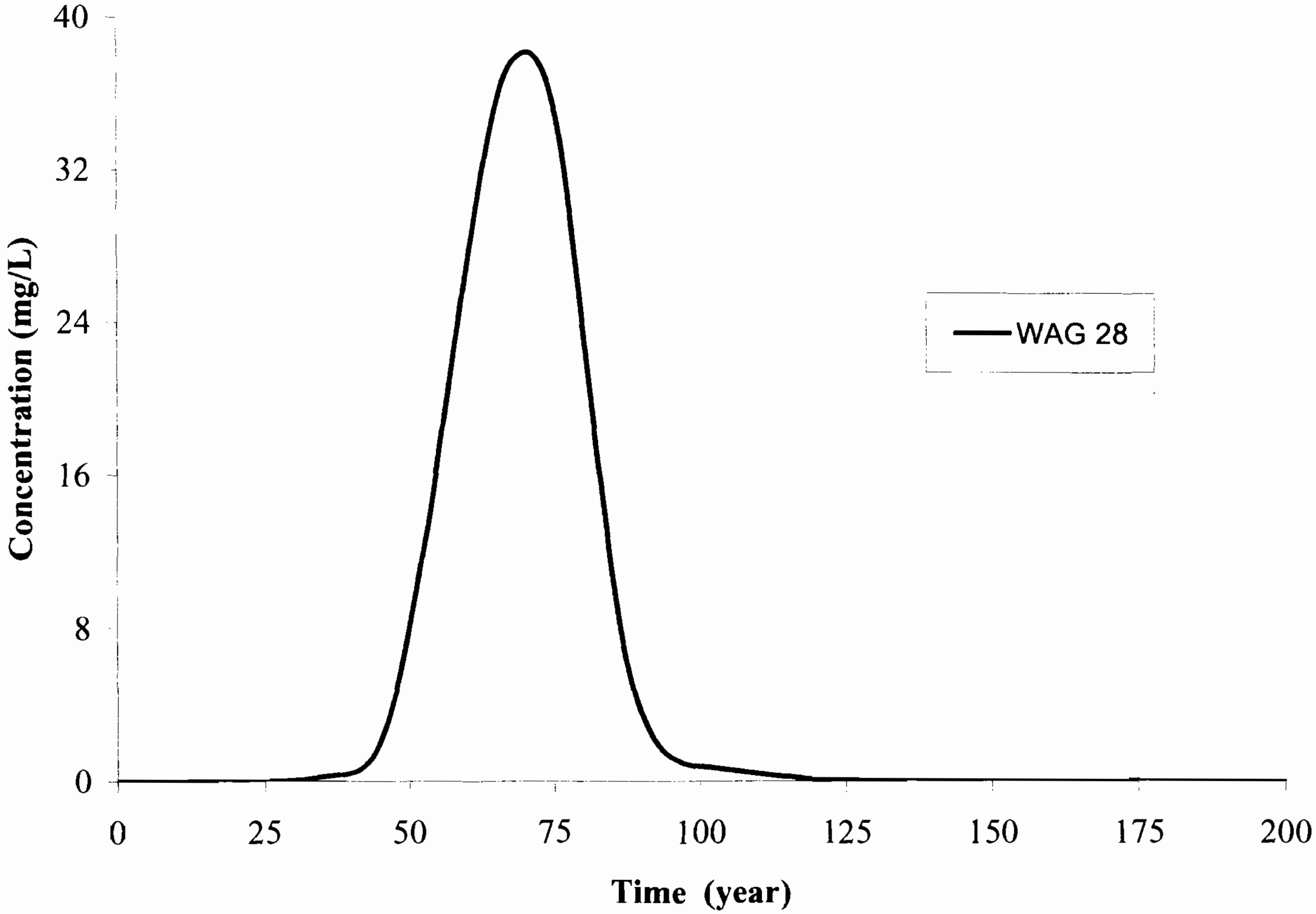


Fig. C3.40. Predicted Lithium Concentrations at the Ohio River due to loading from PGDP Source Areas

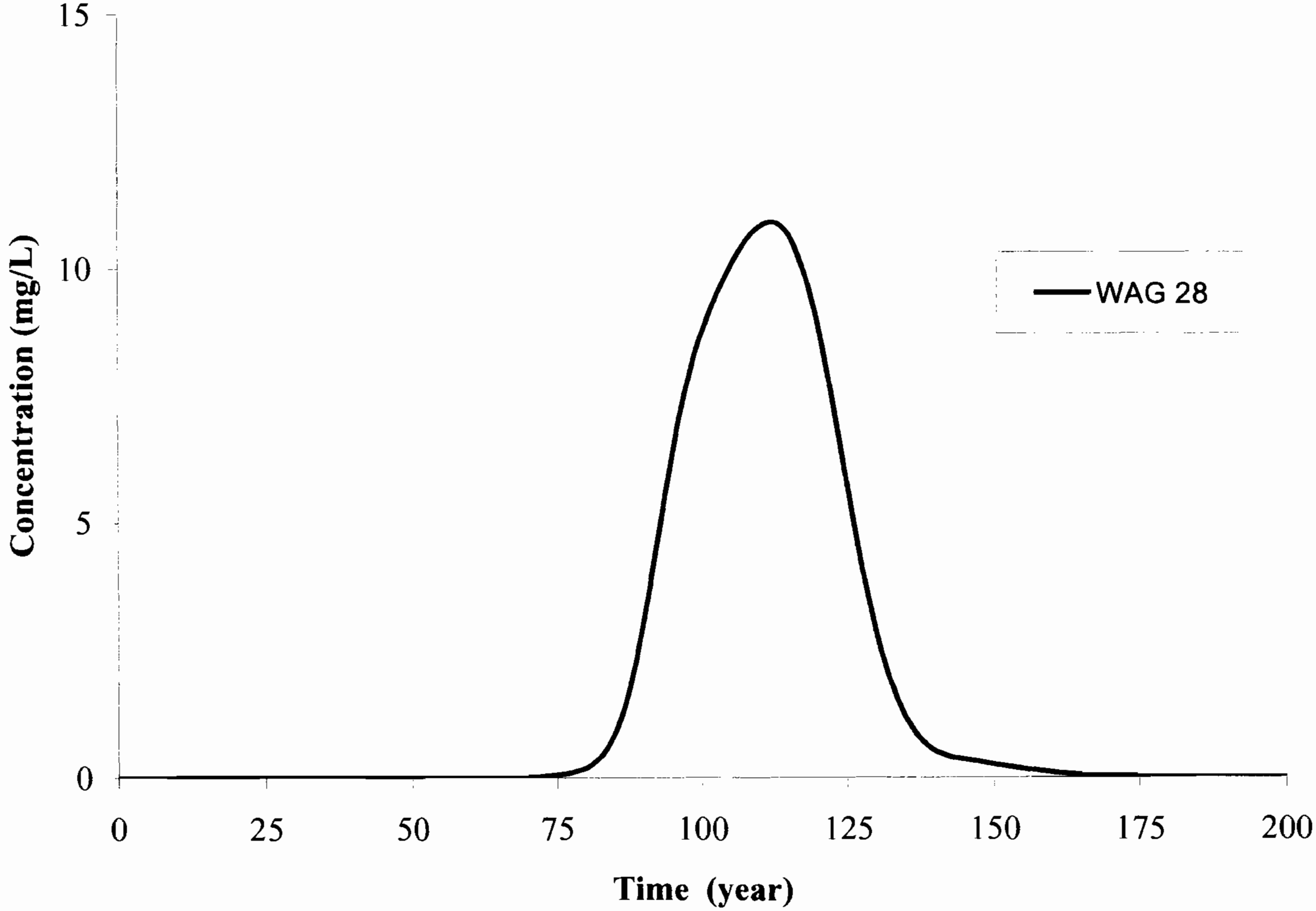


Fig. C3.41. Predicted Manganese Concentrations at the PGDP Fenceline due to loading from PGDP Source Areas

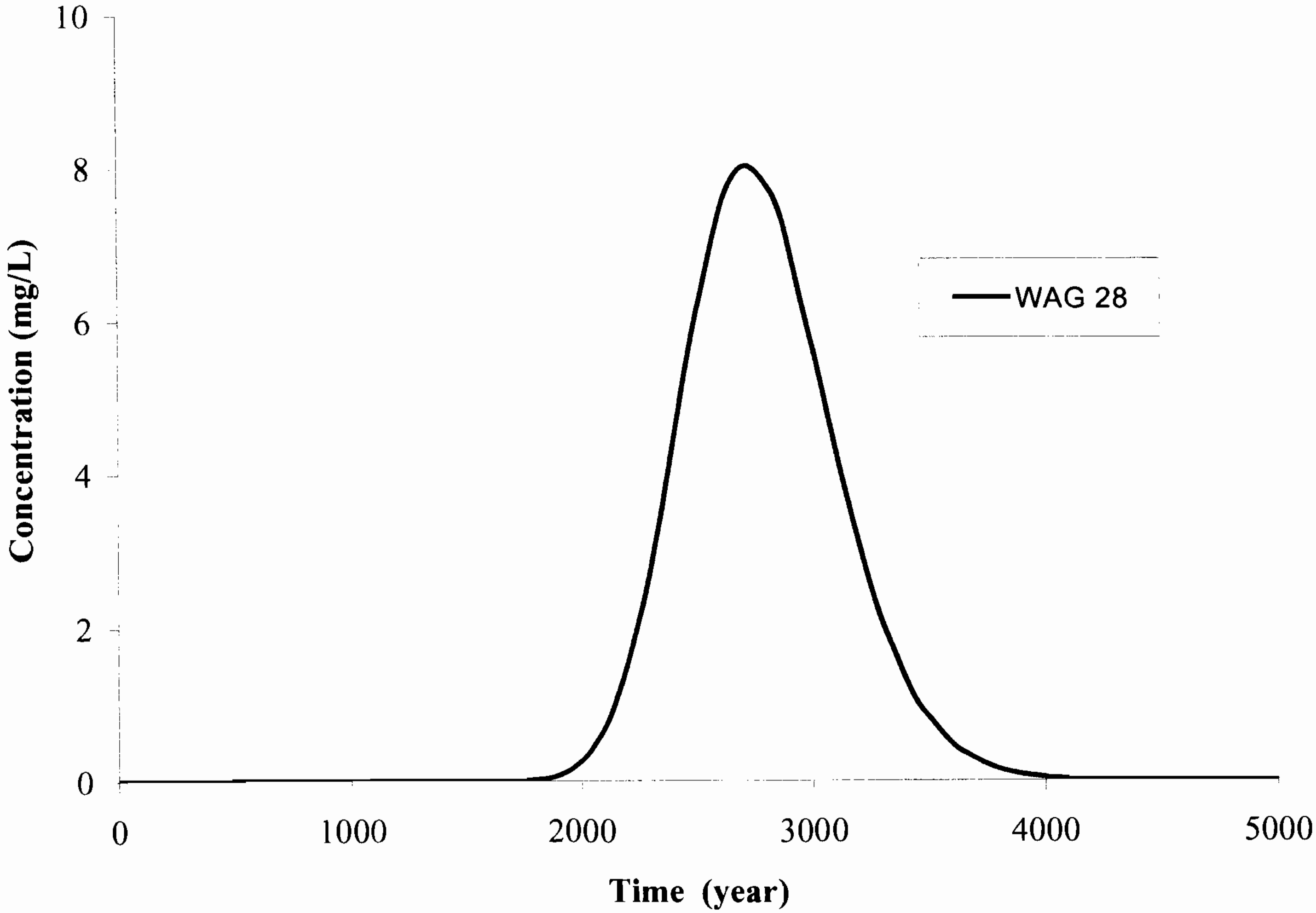
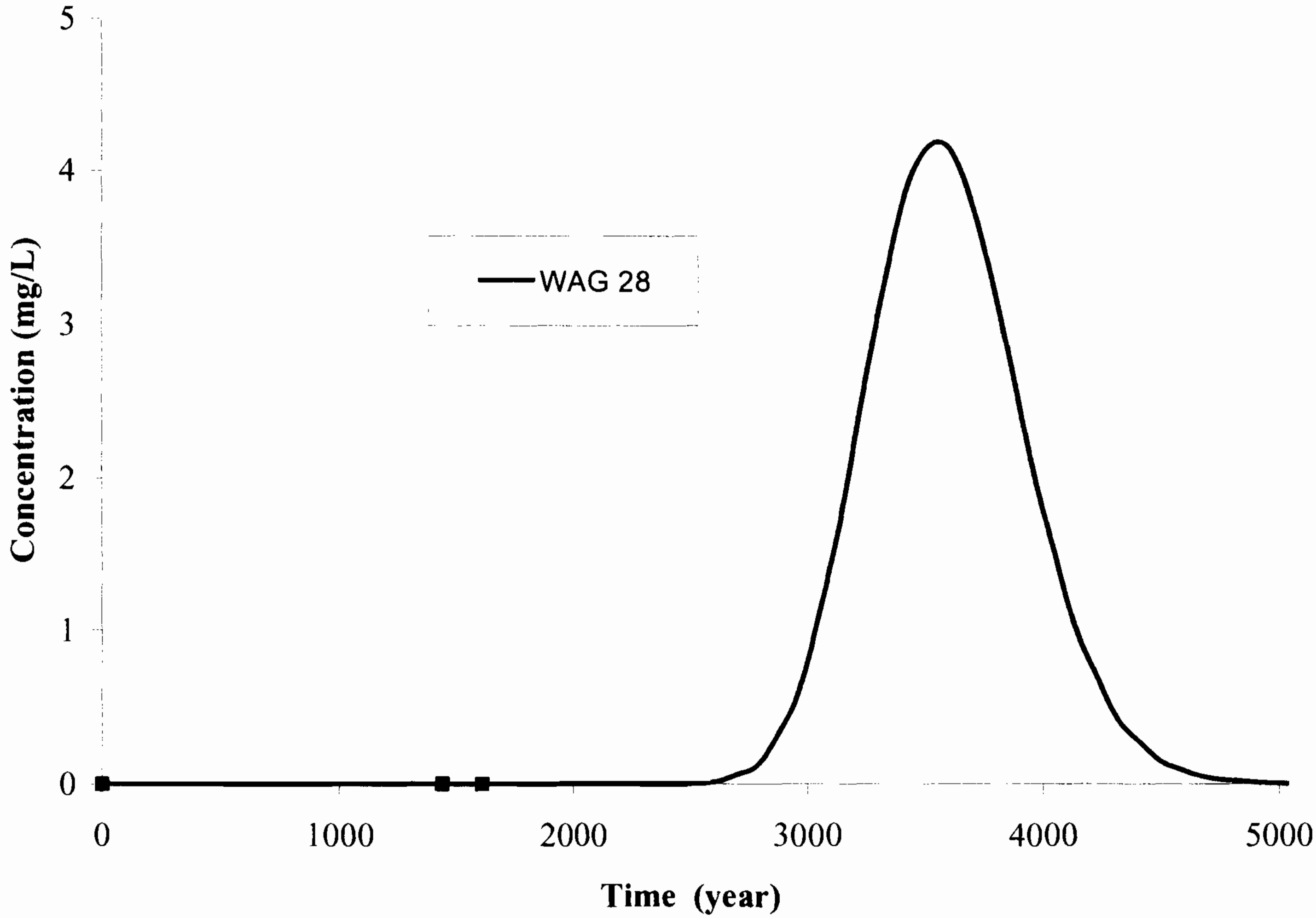


Fig. C3.42. Predicted Manganese Concentrations at the DOE Property Boundary due to loading from PGDP Source Areas



035069

230253

Fig. C3.43. Predicted Manganese Concentrations at the Ohio River due to loading from PGDP Source Areas

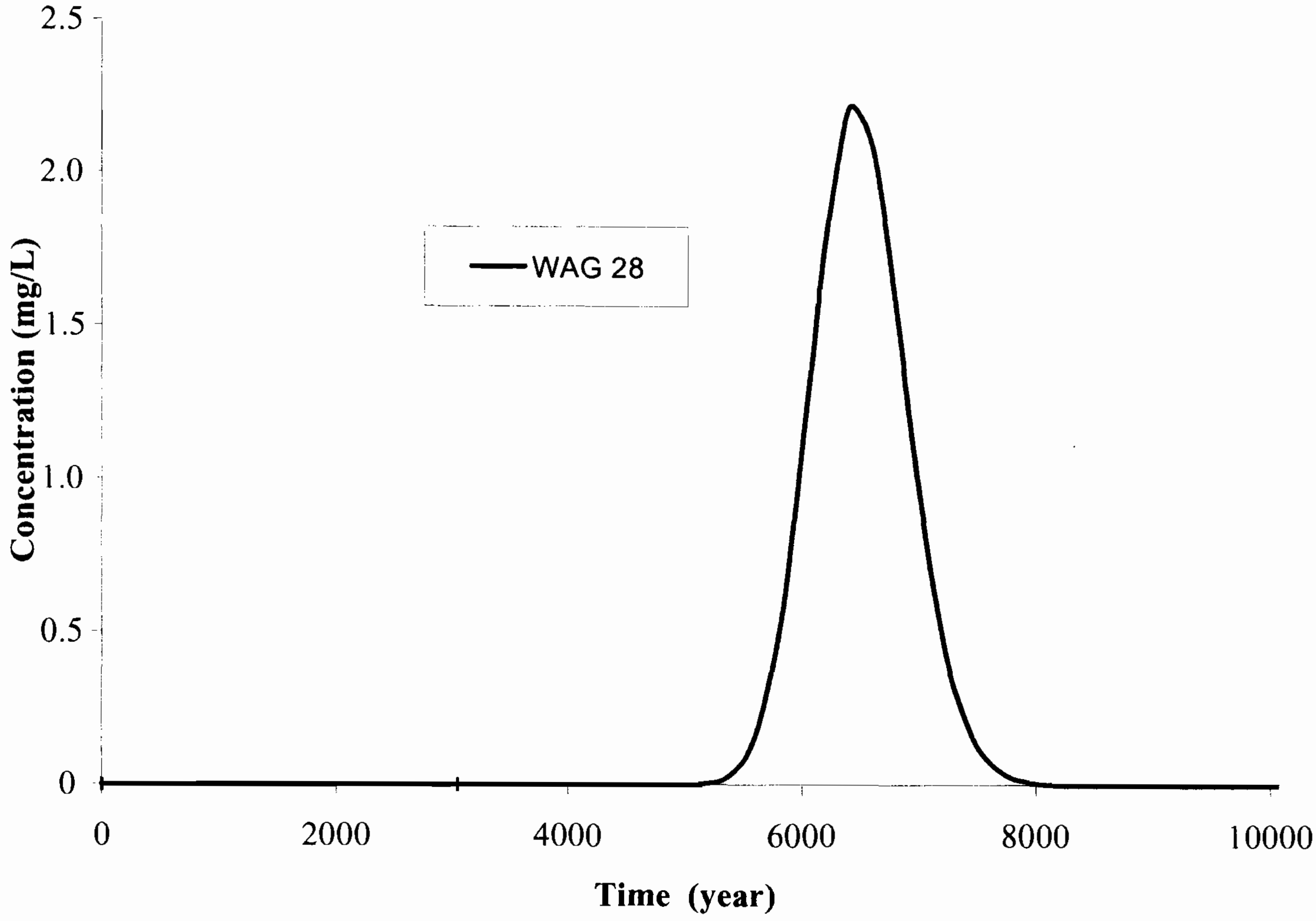


Fig. C3.44. Predicted Strontium Concentrations at the PGDP Fenceline due to loading from PGDP Source Areas

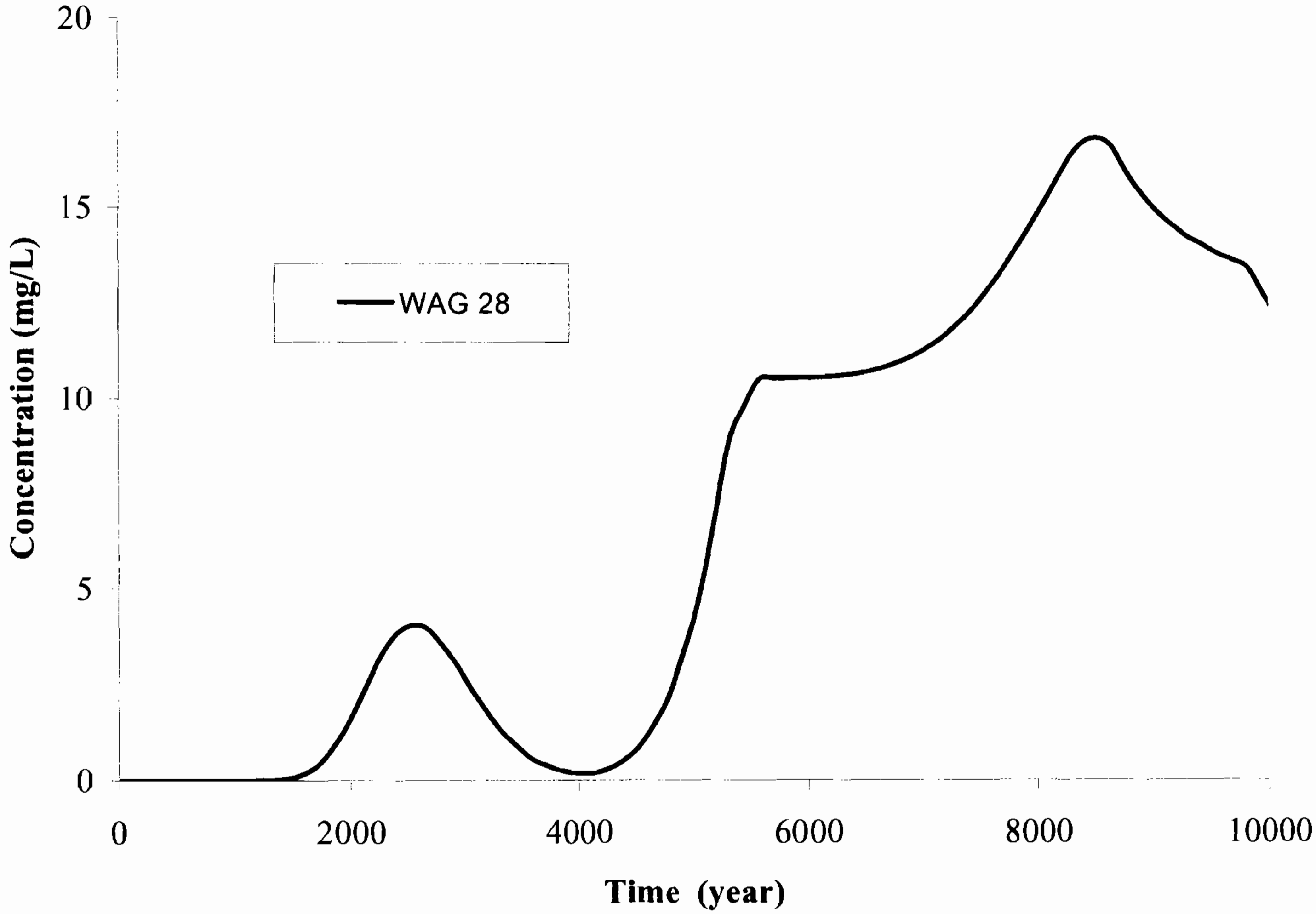


Fig. C3.45. Predicted Strontium Concentrations at the DOE Property Boundary due to loading from PGDP Source Areas

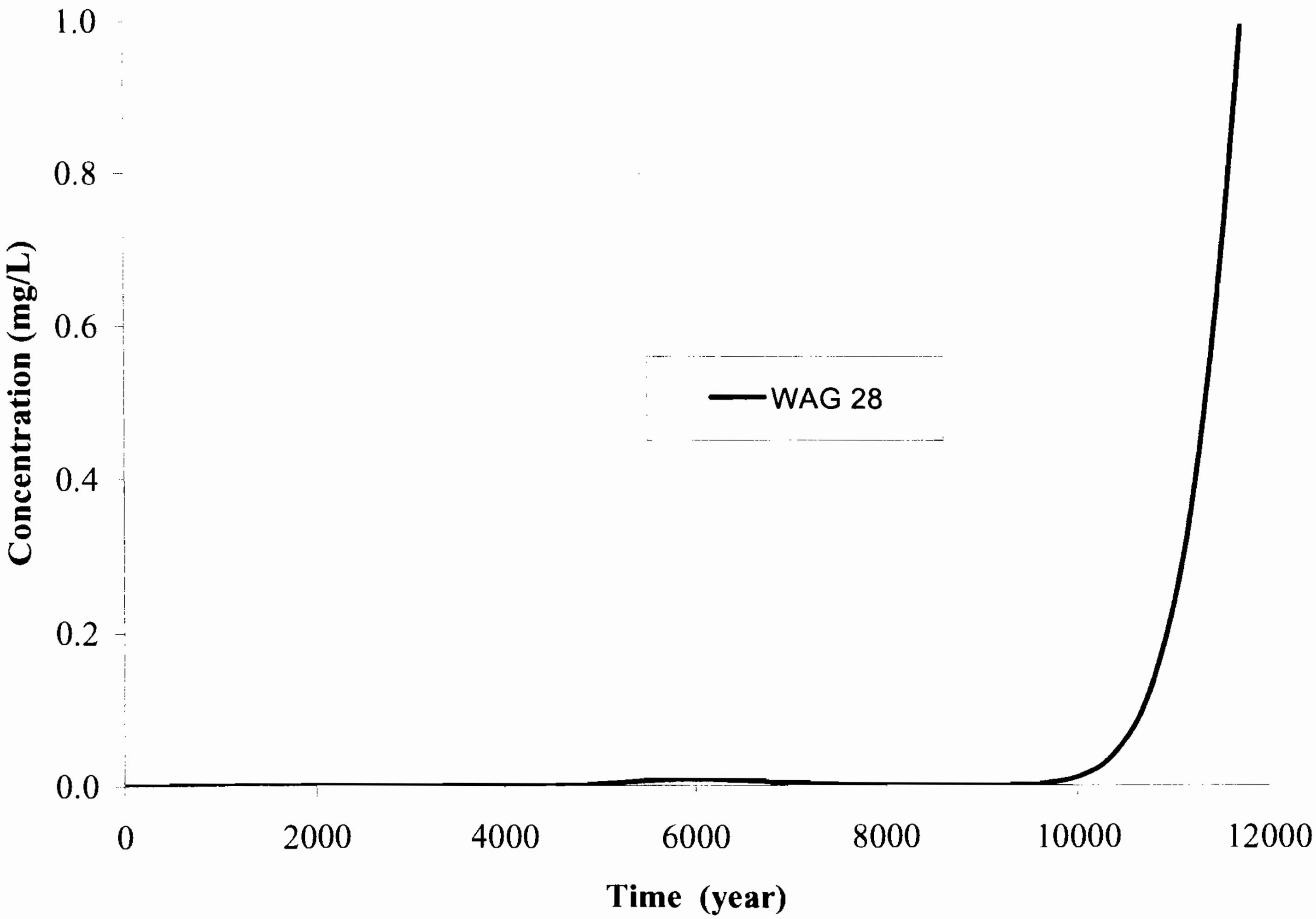


Fig. 3.46. Predicted Uranium-234 Activity Concentrations at the PGDP Fenceline due to loading from PGDP Source Areas

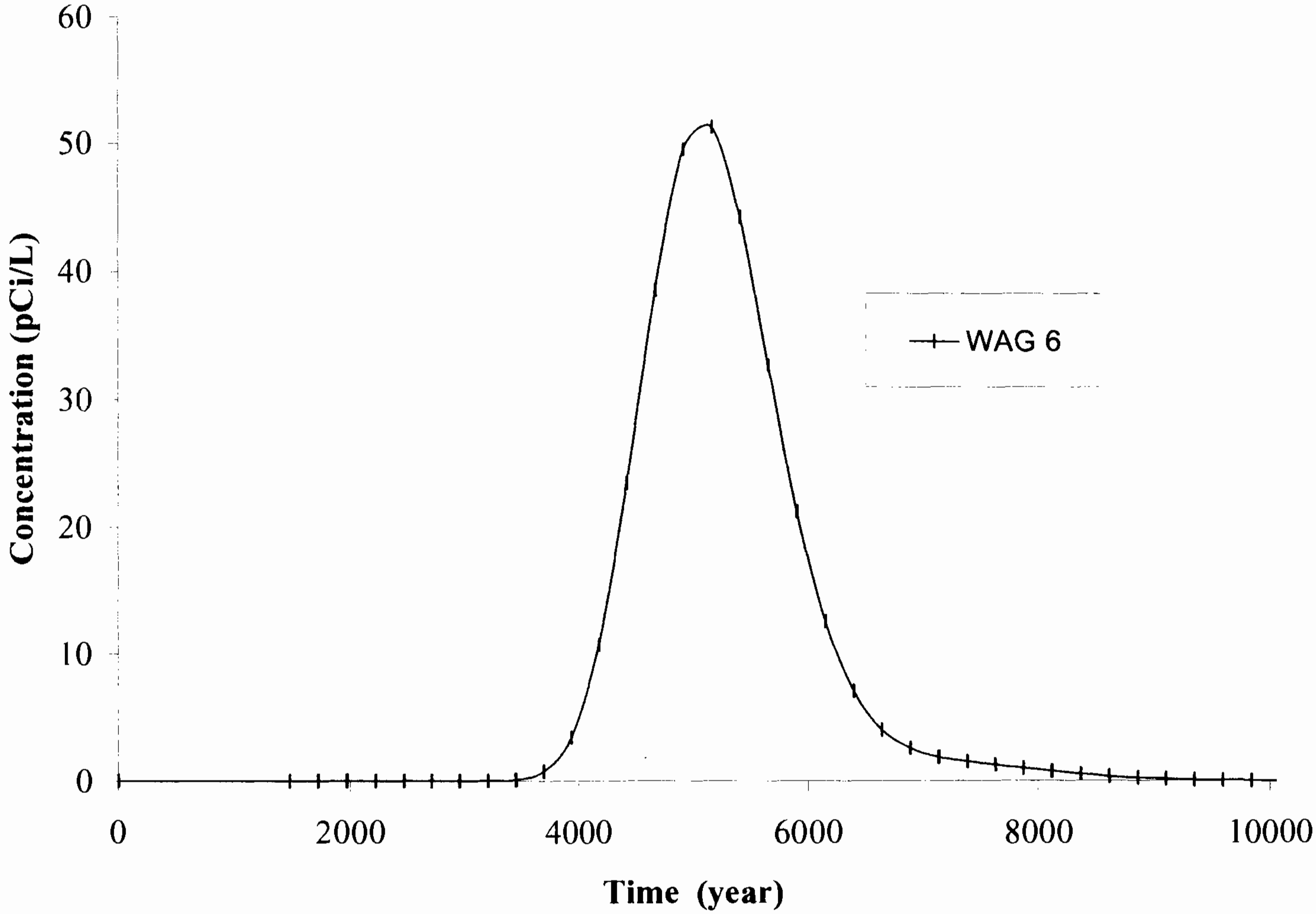


Fig. C3.47. Predicted Uranium-234 Activity Concentrations at the DOE Property Boundary due to loading from PGDP Source Areas

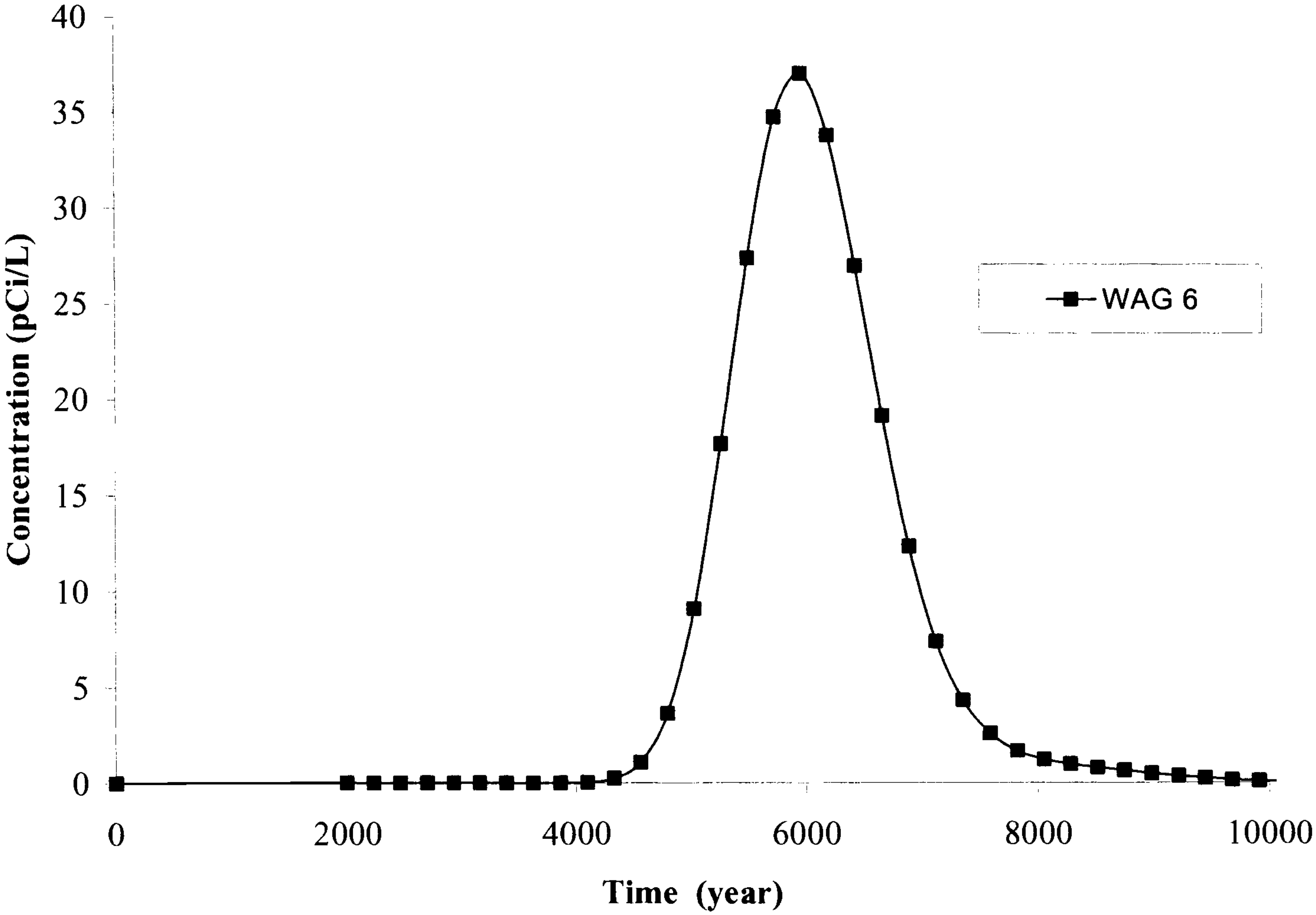


Fig. C3.48. Predicted Uranium-234 Activity Concentrations at the Bayou Creek due to loading from PGDP Source Areas

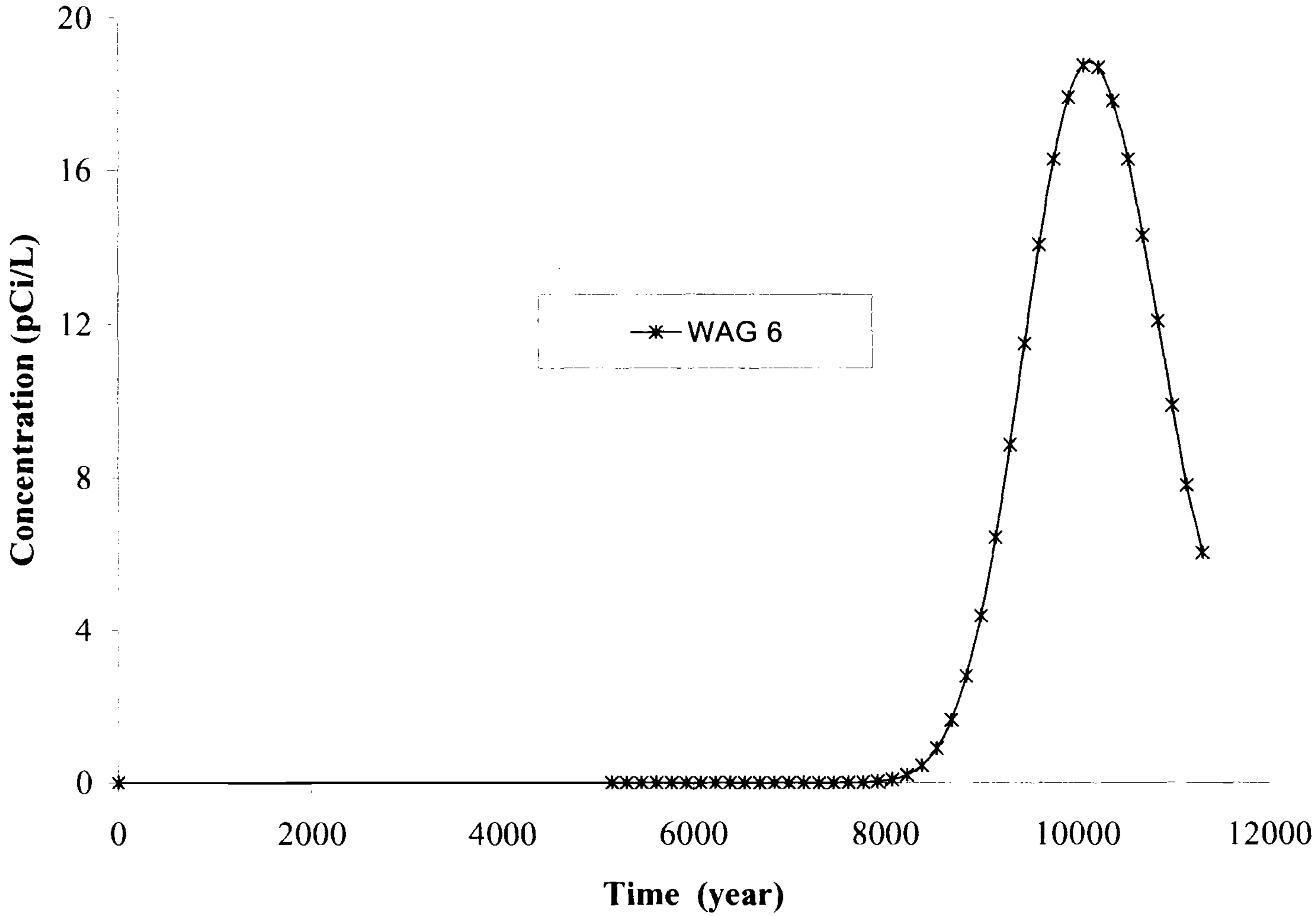


Fig. C3.49. Predicted Uranium-234 Activity Concentrations at the Ohio River due to loading from PGDP Source Areas

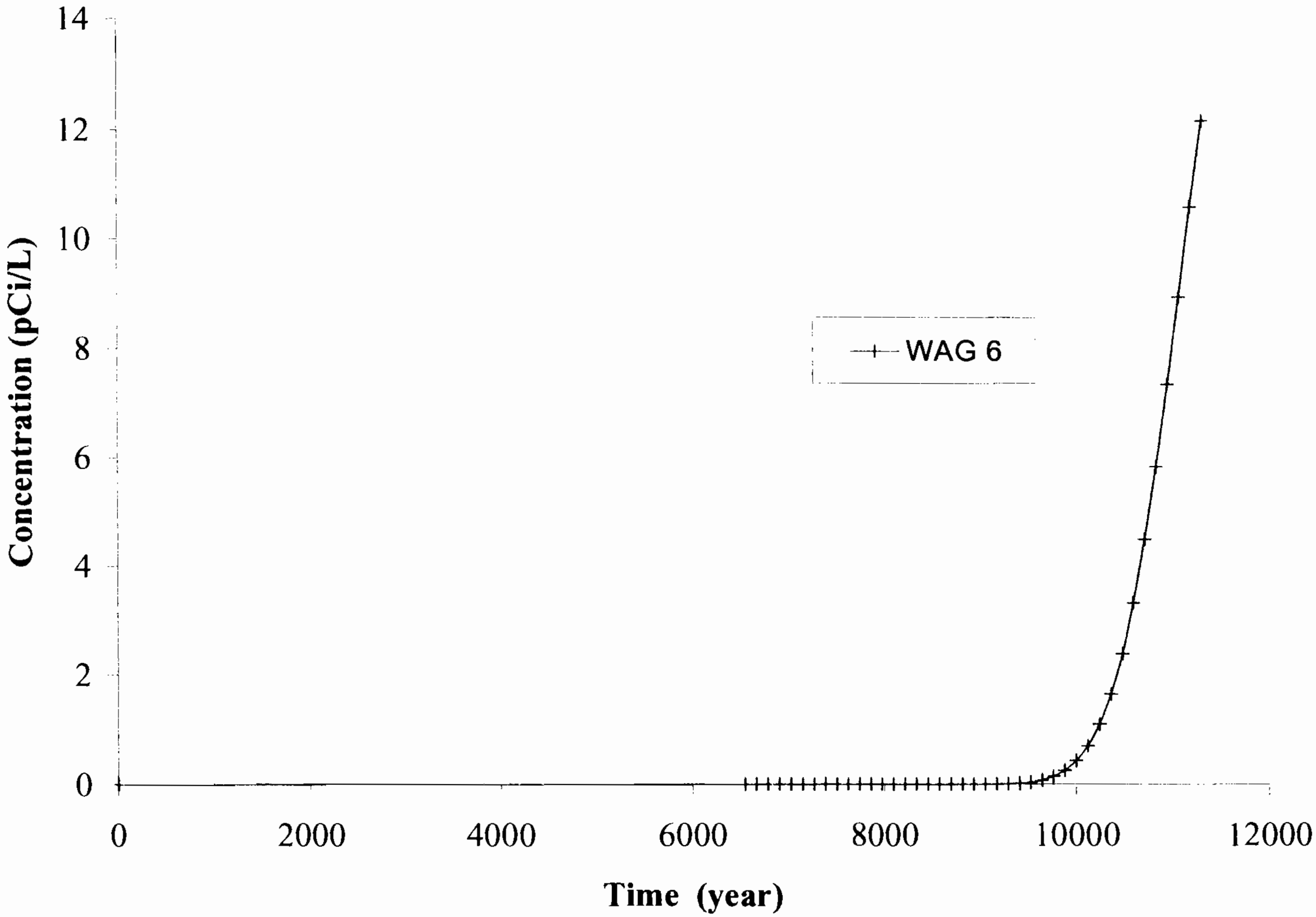


Fig. C3.50. Predicted Uranium-235 Activity Concentrations at the PGDP Fenceline due to loading from PGDP Source Areas

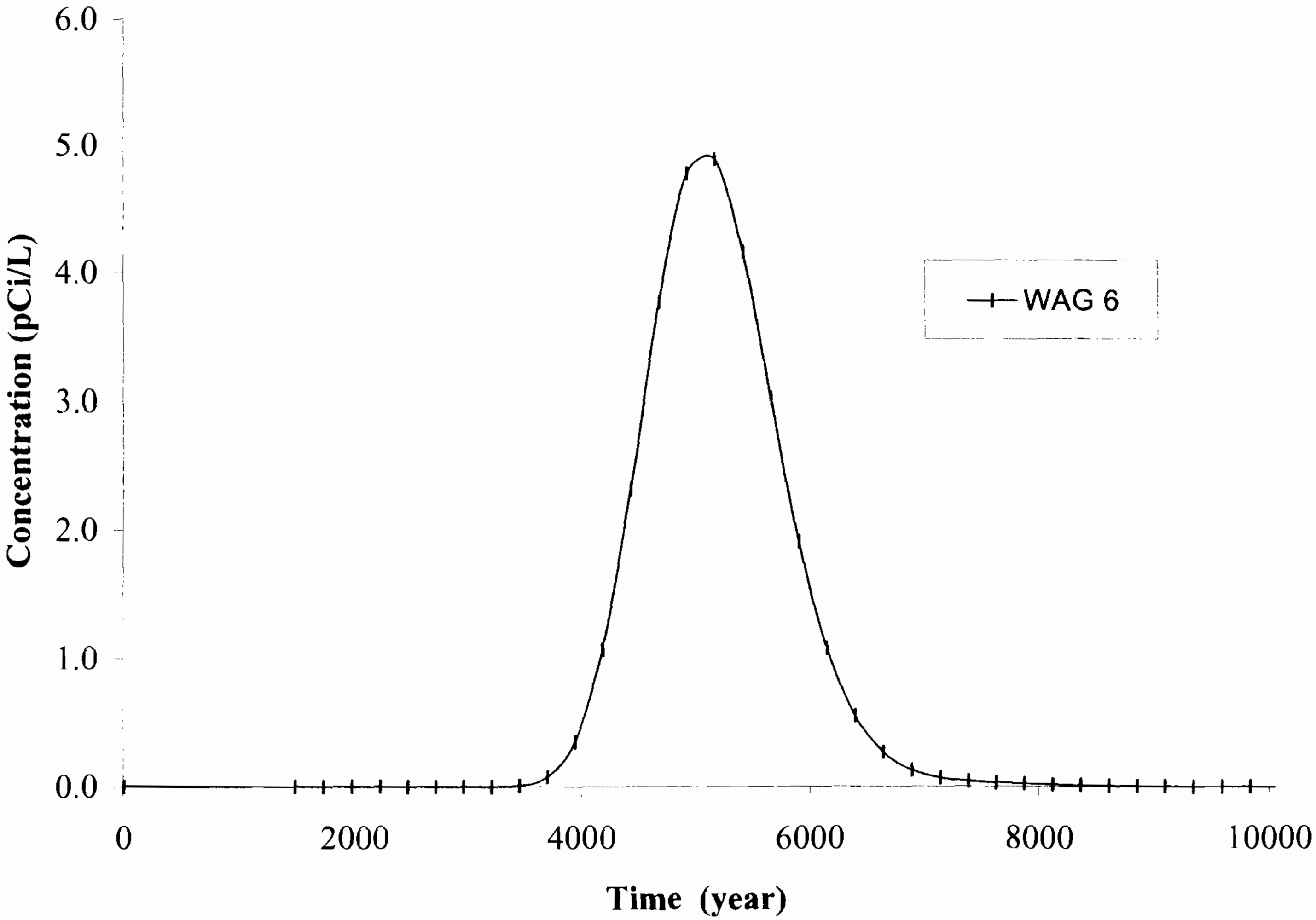


Fig. C3.51. Predicted Uranium-235 Activity Concentrations at the DOE Property Boundary due to loading from PGDP Source Areas

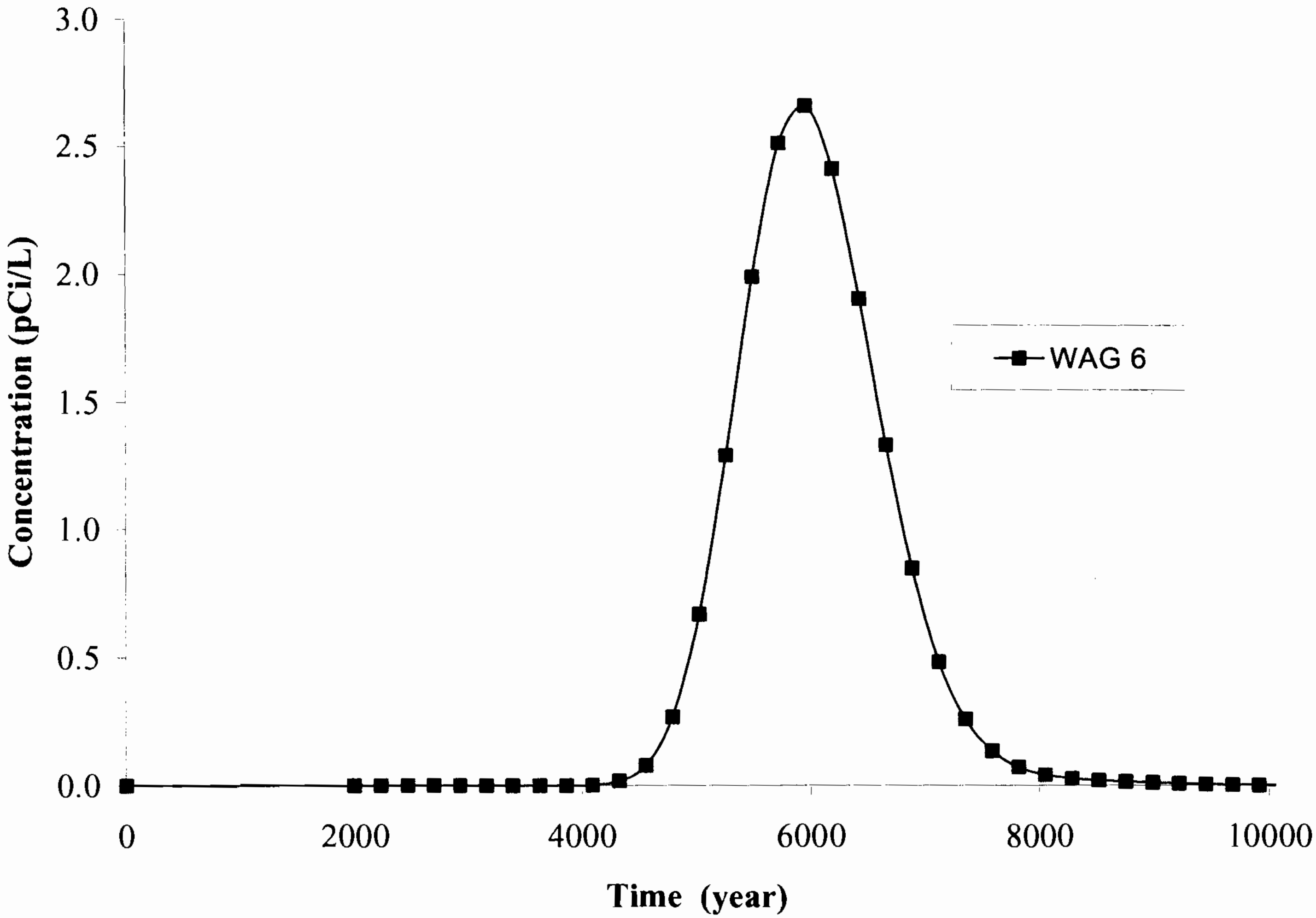
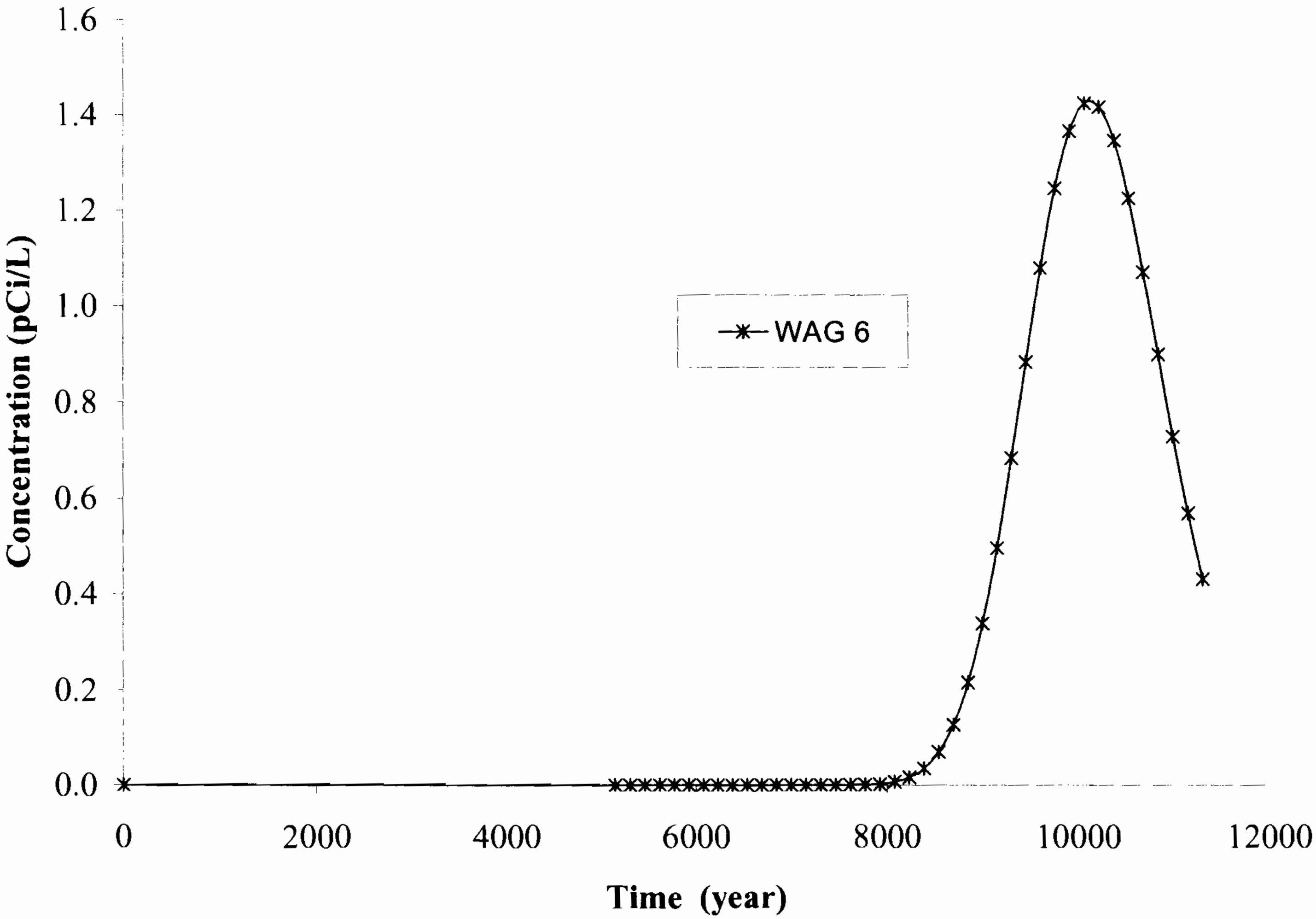
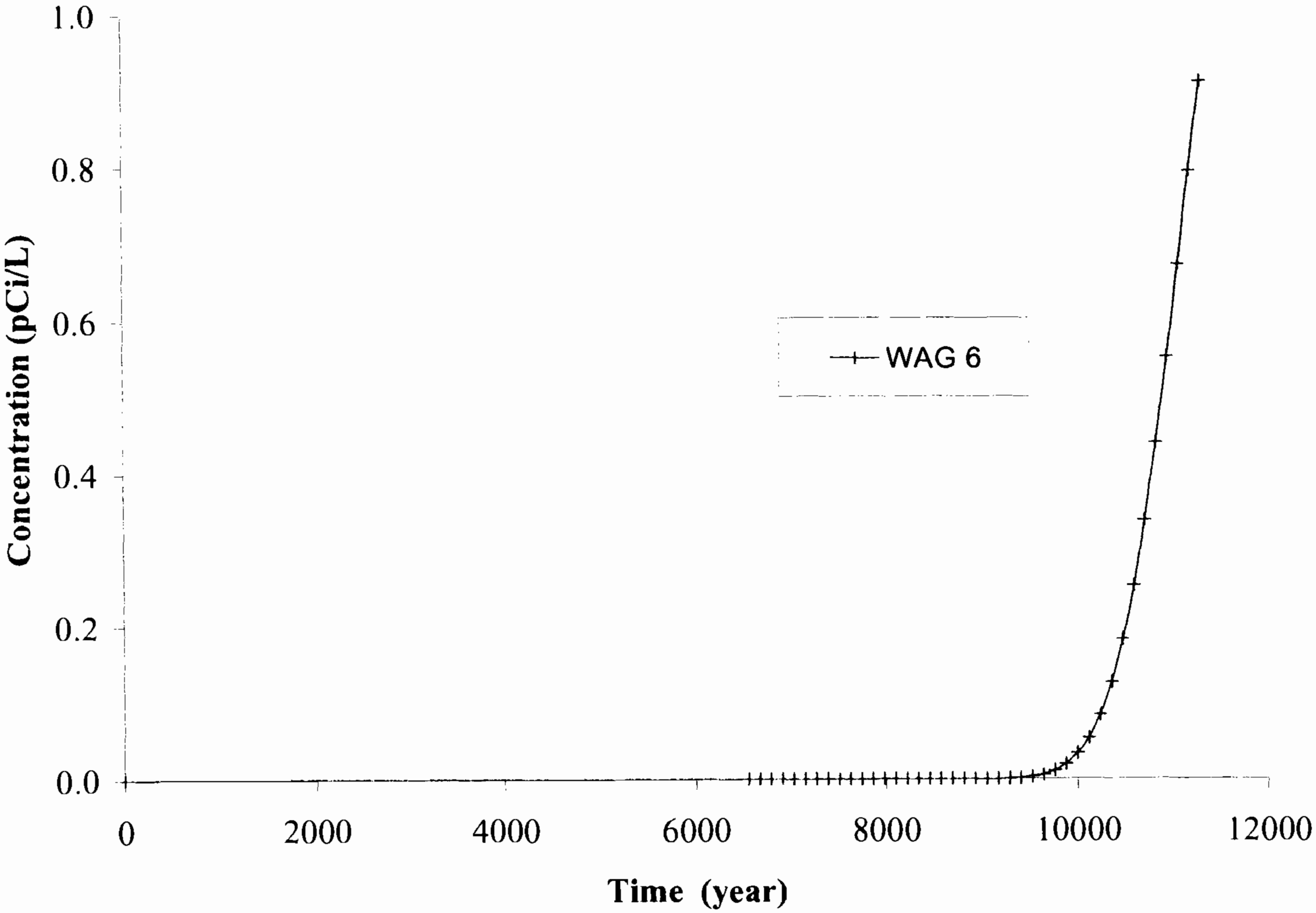


Fig. C3.52. Predicted Uranium-235 Activity Concentrations at the Bayou Creek due to loading from PGDP Source Areas



630541

Fig. C3.53. Predicted Uranium-235 Activity Concentrations at the Ohio River due to loading from PGDP Source Areas



630545

Fig. C3.54. Predicted Uranium-238 Activity Concentrations at the PGDP Fenceline due to loading from PGDP Source Areas

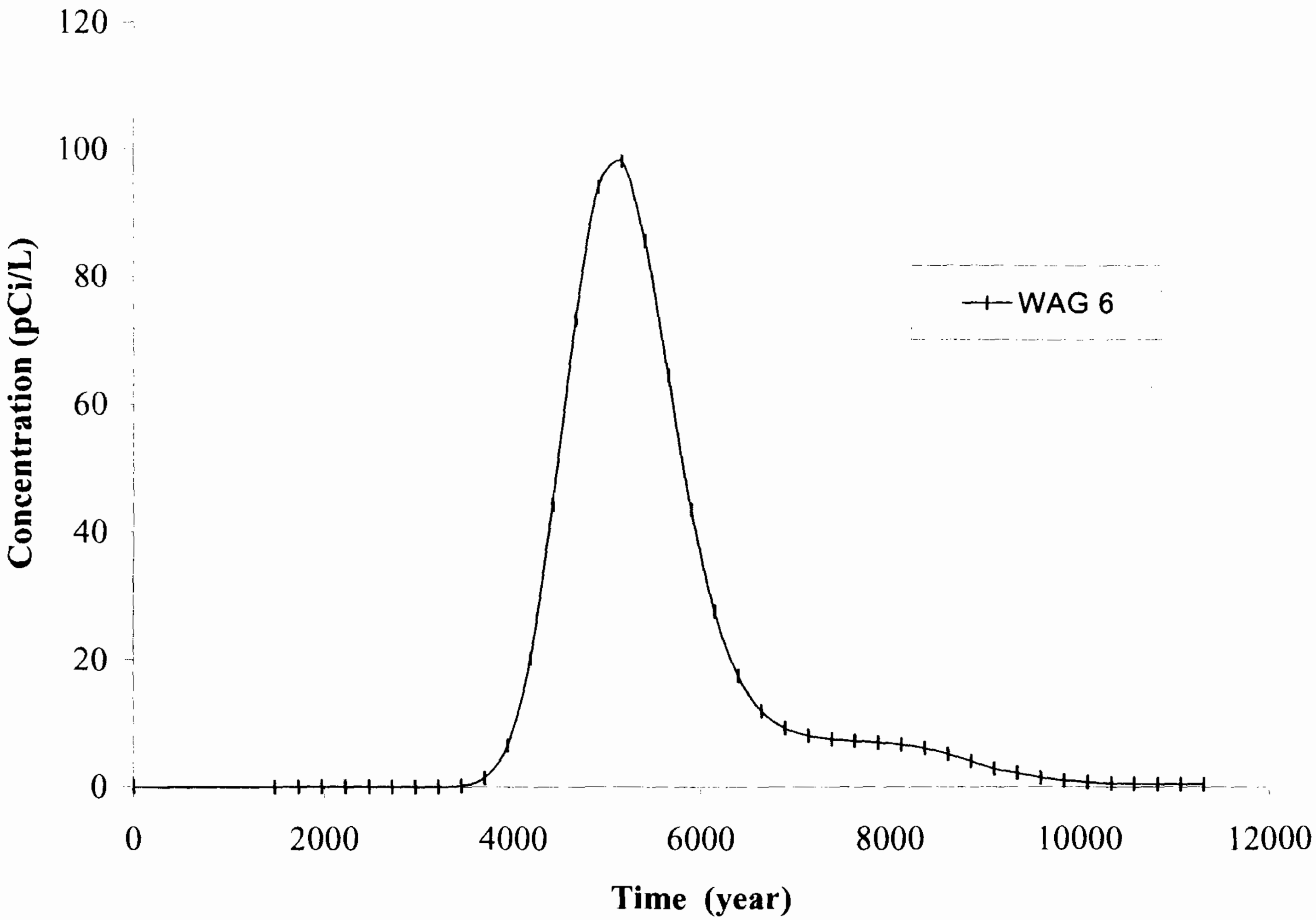


Fig. C3.55. Predicted Uranium-238 Activity Concentrations at the DOE Property Boundary due to loading from PGDP Source Areas

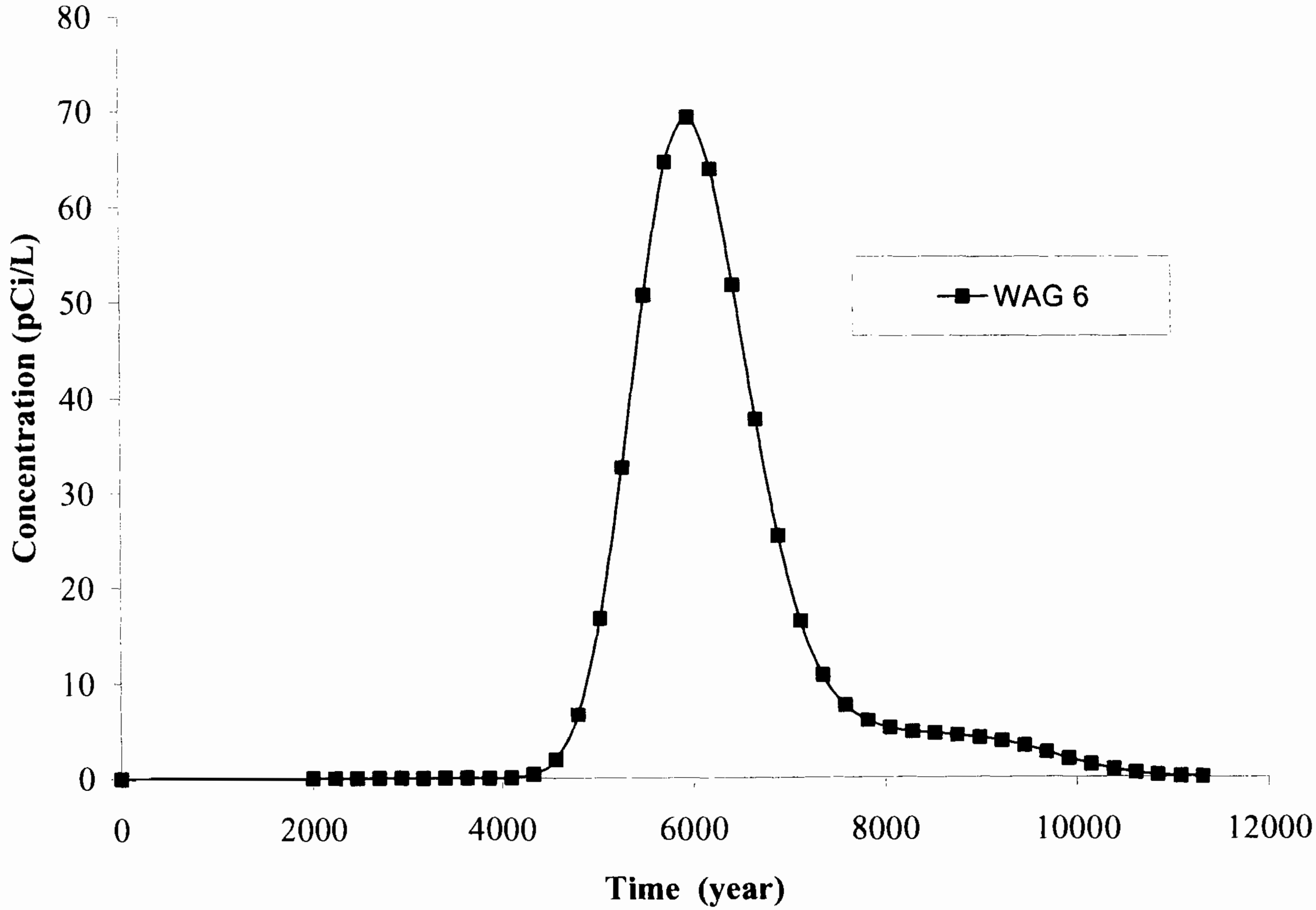


Fig. C3.56. Predicted Uranium-238 Activity Concentrations at the Bayou Creek due to loading from PGDP Sources

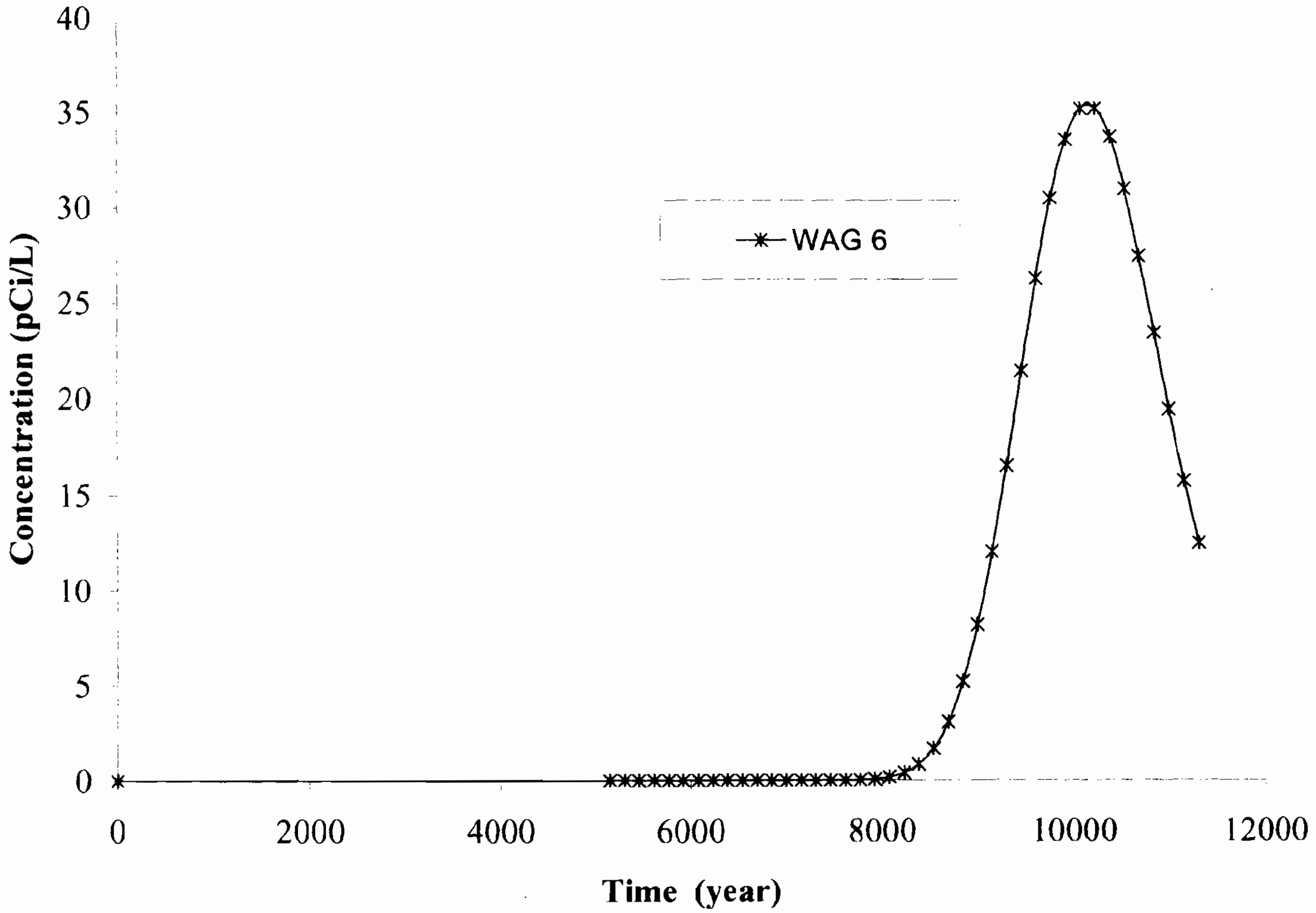


Fig. C3.57. Predicted Uranium-238 Activity Concentrations at the Ohio River due to loading from PGDP Sources

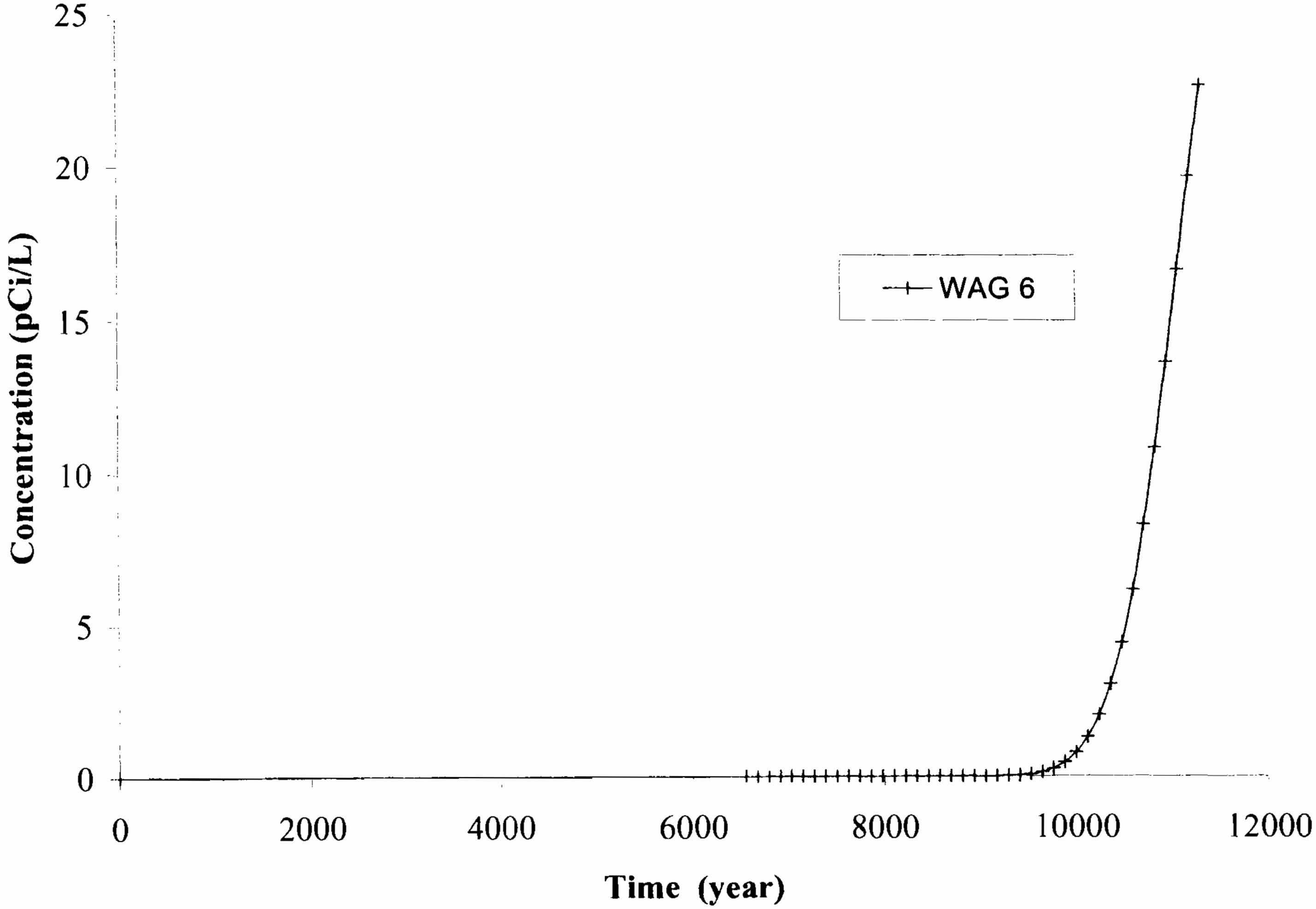


Fig. C3.58. Predicted TCE Concentrations in the Surface Air due to Contaminated Soil in the WAG 6 (Sector 4)

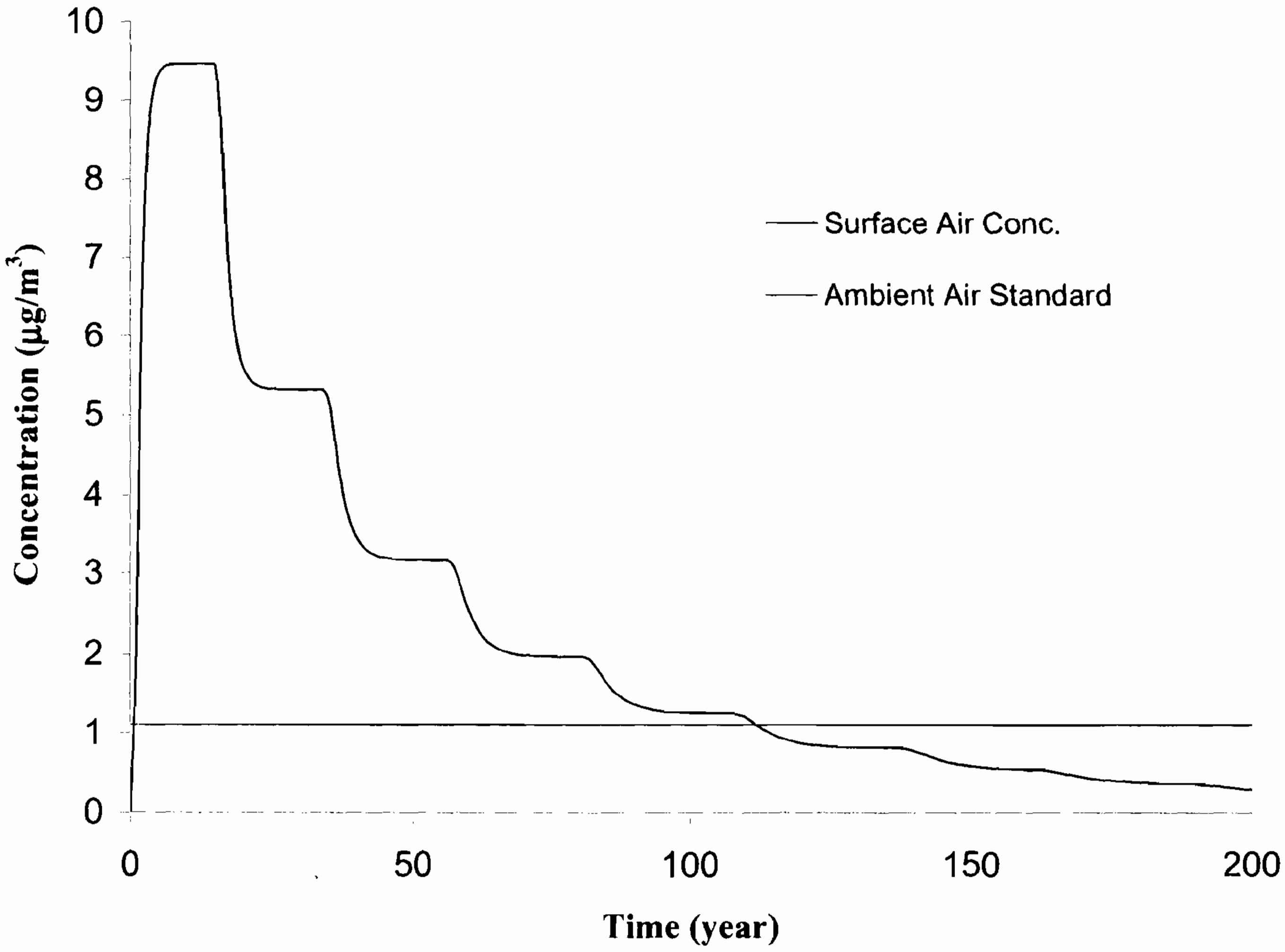
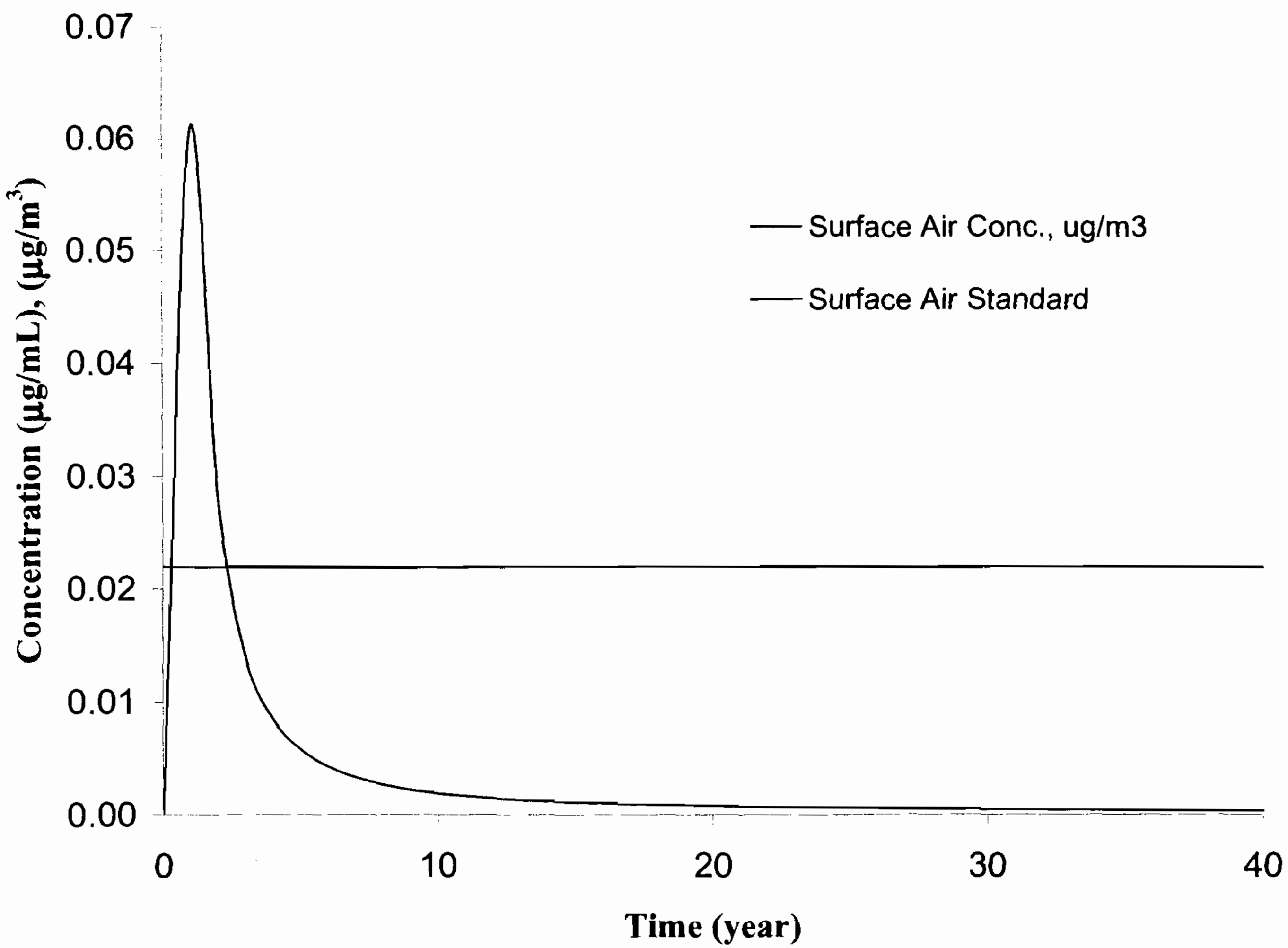


Fig. C3.59. Predicted Vinyl Chloride Concentrations in the Atmosphere due to Contaminated Soil in the WAG 6 (Sector 4)



630547

830268

Fig. C3.60. Predicted Cobalt concentrations at the PGDP fenceline due to loading from WAG 3.

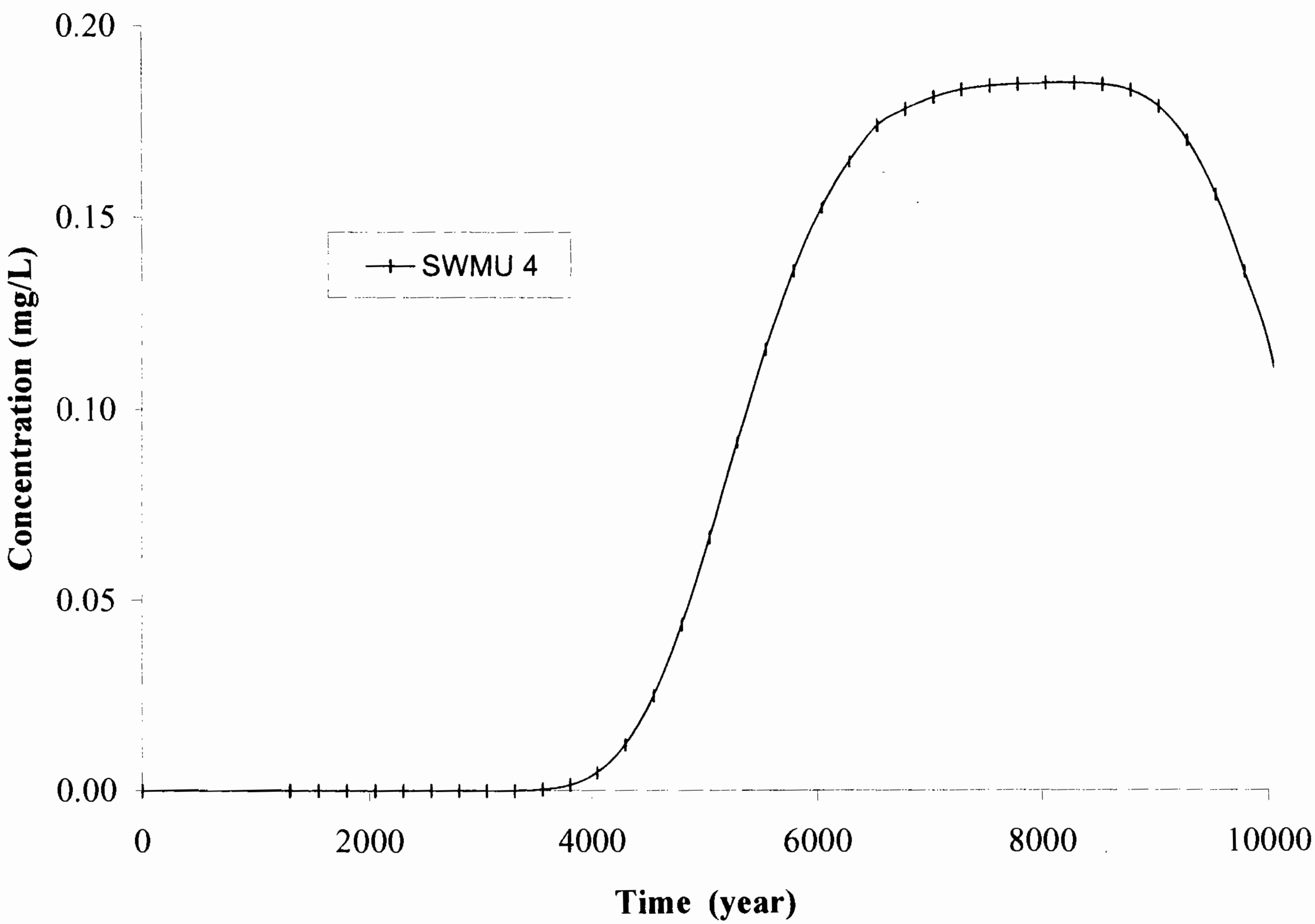


Fig. C3.61. Predicted Copper concentrations at the PGDP fenceline due to loading from WAG 3.

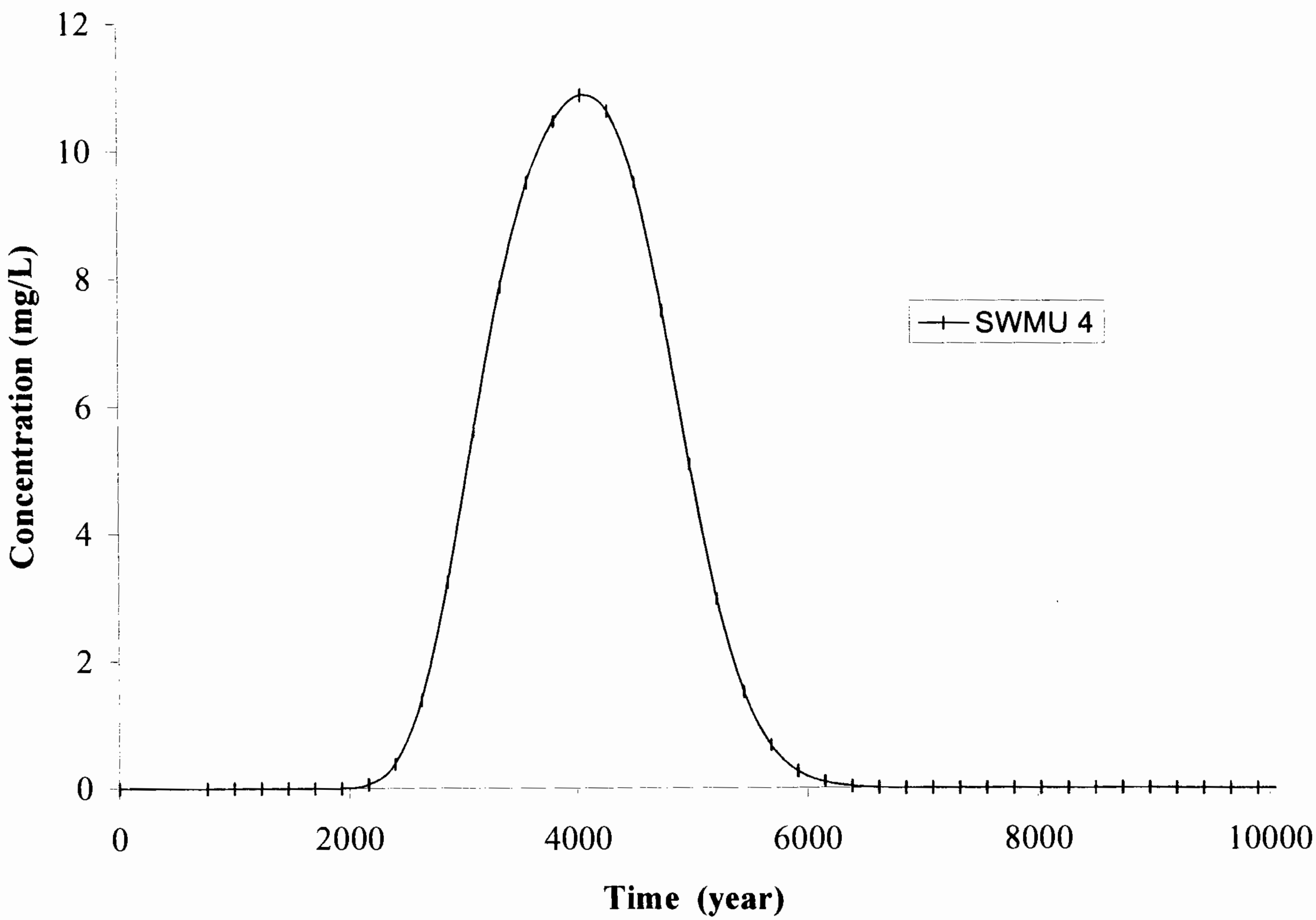
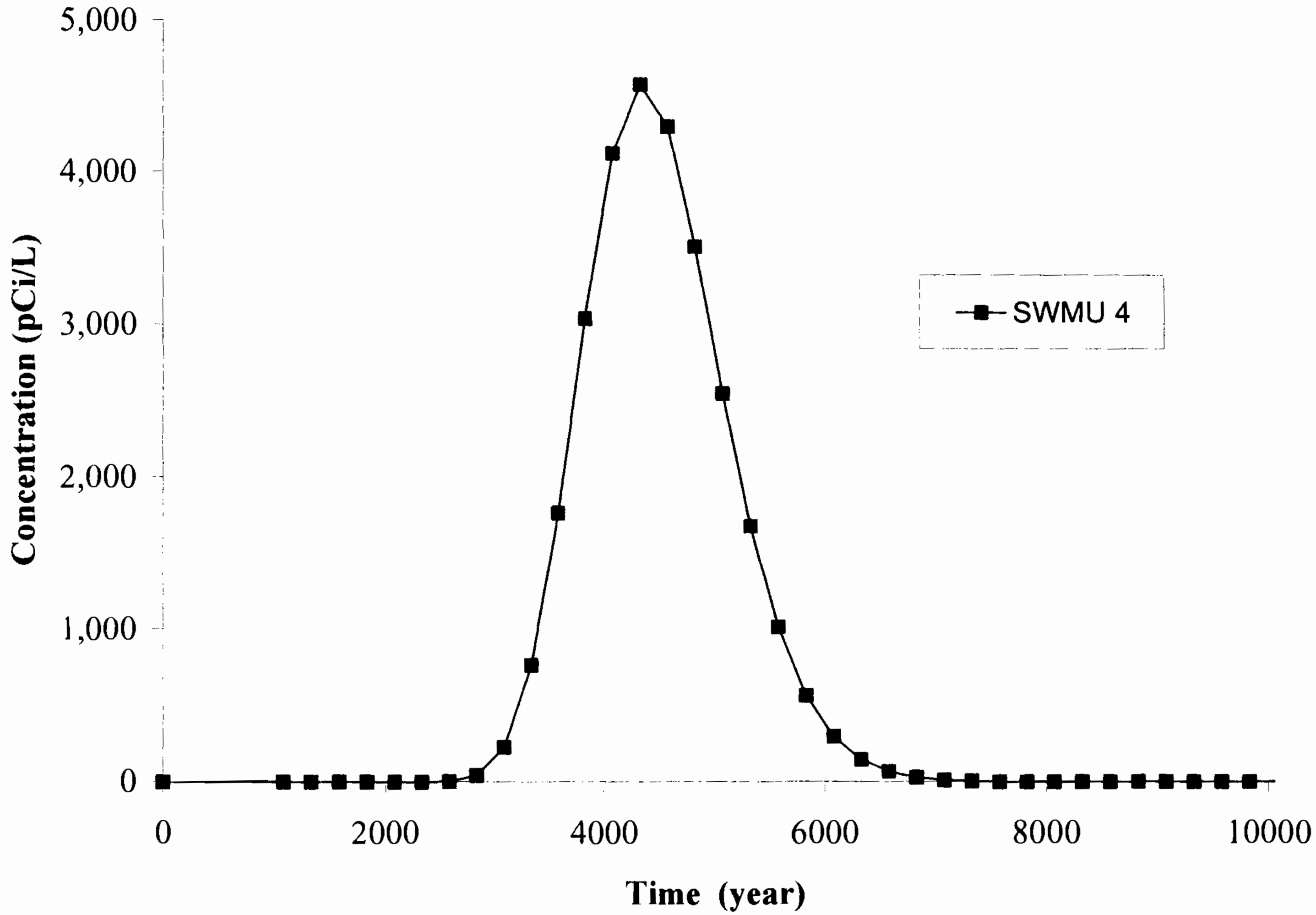
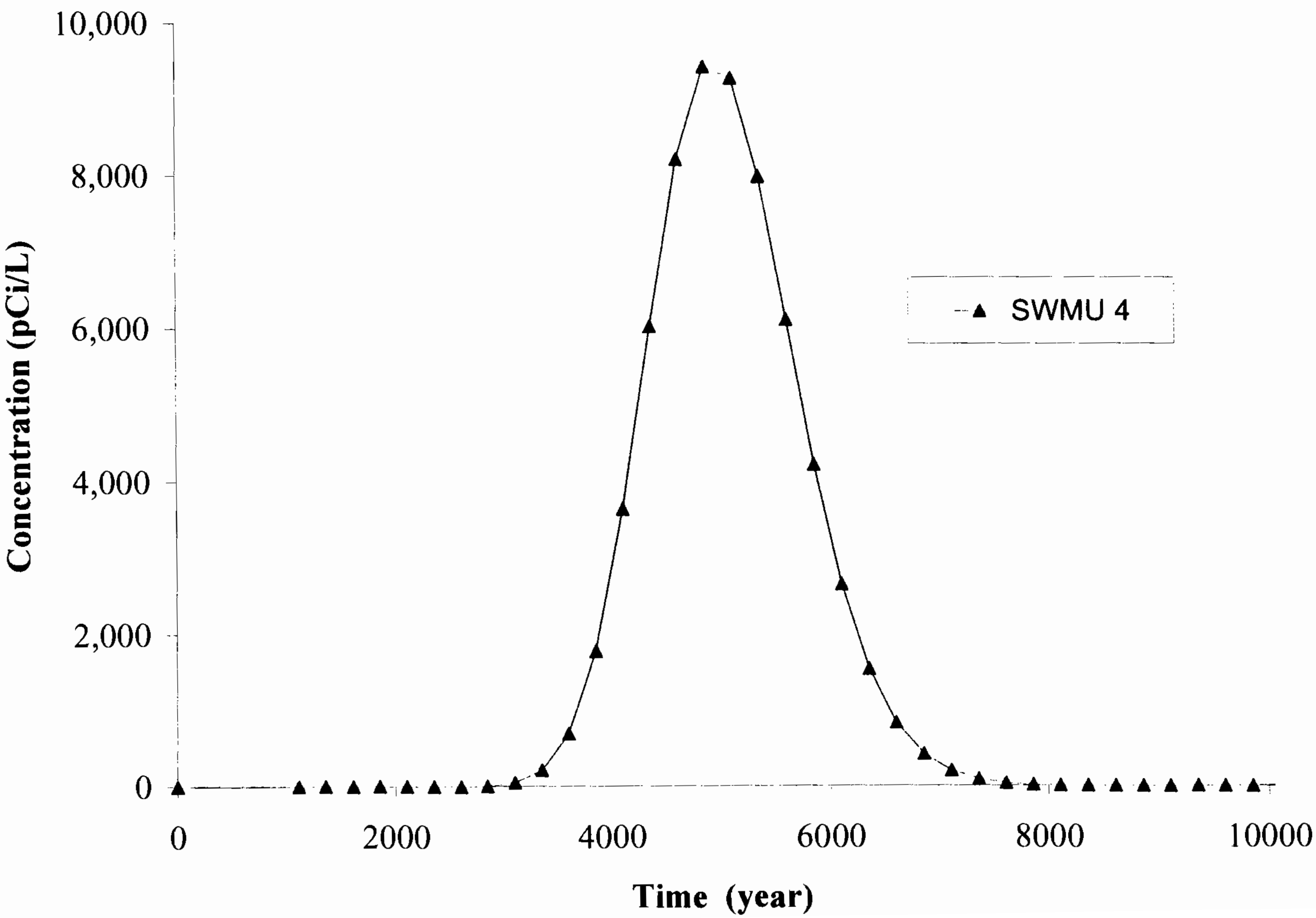


Fig. C3.62. Predicted U-234 activity concentrations at the PGDP fenceline due to loading from WAG 3.



630551

Fig. C3.63. Predicted U-238 activity concentrations at the PGDP fenceline due to loading from WAG 3.



APPENDIX C4

Table C4-1. Identification of Remedial Technologies and Process Options For Upper Continental Recharge System Vadose Zone Soils (0 to 15 ft deep)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
No Action	None	Not Applicable	No further action to address contaminated media.	Required for consideration by the NCP and NEPA.
Institutional Actions	Access Restrictions	Deed Restrictions	Restrictions on property in the deed and title.	Could be implemented as a component of the ROD or on a site-wide basis.
		Site Protection/Security	Guards to restrict and monitor plant access.	Currently conducted for the PGDP as an operating facility.
		Physical Barriers/ Restrictions	Fencing, warning signs, permits, etc.	Potentially applicable; the PGDP currently is fenced, and "no trespassing" signs are posted. Additional barriers could be located at isolated areas within the PGDP security fence to protect workers, and PGDP permitting could be required before working at the SWMU.
	Monitoring	Surface Soil and Water Monitoring	Periodic monitoring of site conditions through environmental sampling.	Surface-soil monitoring could be enacted as a component of the ROD. Groundwater and surface water monitoring already is conducted routinely at the PGDP on a site-wide basis.
Containment Actions	Capping	Clay/Soil or Asphalt/Concrete	Single or multi-layered soil, clay, and/or pavement (concrete, asphalt) cap designed to minimize dermal contact, exposure, or re-entrainment and/or to provide some reduction of infiltration/vertical movement of precipitation or contaminants into the subsurface.	Potentially applicable as a barrier to mitigate direct contact to COCs. Potentially applicable for reducing infiltration of precipitation since surface water could be directed to storm sewers.
		Multimedia	Multi-layered cap with low permeability, designed for highest degree of reduction of infiltration/ vertical movement of precipitation into contaminated soil.	Potentially applicable as a barrier to mitigate direct contact to COCs. Potentially applicable for reducing infiltration of precipitation, since surface water could be directed to storm sewers.
		Lead Shield	Cap containing lead to reduce exposure to radioactive contamination (gamma-emitting particles).	Potentially applicable to protect workers by reducing radioactivity from surface soils.
	Surface Controls	Grading	Reshaping the topography to manage surface water runoff, control erosion, and reduce infiltration.	Potentially applicable, especially in combination with other technologies.
		Revegetation	Re-vegetating soil can assist with reducing infiltration and erosion control.	Potentially applicable to manage surface water runoff, control erosion, and reduce infiltration.
		Flow Diversion	Collection and diversion systems can divert storm water and runoff to prevent erosion and reduce contaminant migration (infiltration).	Potentially applicable as compatible with other medium technologies to reduce infiltration of precipitation to lower media.
	Bottom Barriers	Jet grouting; Slanted Grout columns; cryogenics	An impermeable layer is placed below the contaminated area to prevent vertical migration/ leaching of contaminants.	Potentially applicable for containment of wastes or in conjunction with process options that could mobilize vapors.

Table C4-1. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
Containment Actions (Continued)	Vertical Barriers	Slurry Walls	Slurry walls are constructed around the contaminated area to prevent horizontal migration of contaminants.	Potentially applicable for containment of wastes or in conjunction with process options that could mobilize vapors.
		Grout Curtains	Grout curtains are constructed around the contaminated area to prevent horizontal migration of contaminants.	Potentially applicable for containment of wastes or in conjunction with process options that could mobilize vapors.
		Sheet Piles/Vibrating Beam	Pilings or beams are driven around the contaminated area to prevent horizontal migration of contaminants.	Potentially applicable for containment of wastes or in conjunction with process options that could mobilize vapors.
		Cryogenic Walls	Liquid nitrogen or other cryogenic fluids are used to construct a frozen barrier around the contaminated area to prevent horizontal migration of contaminants.	Potentially applicable for containment of wastes or in conjunction with process options that could mobilize vapors.
Removal	Water Collection	Wells and Subsurface Drains	Wells and/or subsurface drains can be installed to collect perched water or water leaking from utilities.	Potentially applicable depending upon each SWMU's specific conditions.
	Excavation	Solids and Semisolids Excavation	Contaminated solids and semisolids can be excavated by ordinary construction equipment (backhoes, trackhoes, bulldozers).	Potentially applicable to the surface soils, especially those contaminated with radiological contamination. Various *ex situ* treatment technologies are available, depending on the contaminants present. (See *Ex Situ* Treatment).
		Solidify and Mine (Freeze and Mine)	Cryogenic fluids are used to freeze or immobilize contaminants within the contaminated area to allow excavation.	Potentially applicable to soils containing a number of contaminants, including DNAPLs or radioactive liquids.
	Site Equipment/ Debris Removal	Equipment/Debris Removal and Decontamination	Equipment and/or structures along with debris may require removal and decontamination before surface soils can be removed.	Potentially applicable depending upon each particular SWMU's rate and extent of contamination and the type of contamination.
	Bulk Liquid Removal	Drain or Pump Tanks/Pits and Lines Containing Liquids	Liquids would be drained or pumped from tanks/pits and lines that require removal and treatment/disposal prior to surface soil remediation.	Potentially applicable if liquids are located within tanks/pits and lines prior to remediation of surface soils and other media.
	Bulk Solid/ Liquid Removal	Vacuum Loader	Vacuum system used to pneumatically collect and load solid, semi-solid, sludge, and/or liquid wastes.	Potentially applicable to remove contaminated surface soil and sludge.
In Situ Treatment	Physical/ Chemical Treatment	Solidification/ Stabilization	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).	Potentially applicable to inorganically contaminated soils.

Table C4-1. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
In Situ Treatment (Continued)	Physical/ Chemical Treatment (Continued)	Chemical Mixing (Deep Soil Mixing)	Remediation agents are added to contaminated soil and physically mixed into soil at varying depths. A wide range of treatment agents may be used, including solvents, precipitating and neutralizing chemicals, hot air, steam, and stabilizing agents.	Potentially applicable to physical mix surface soil contamination. Use of solvents or surfactants preferred.
		Soil Vapor Extraction/Soil Venting	Vacuum is applied through piping to create a pressure gradient that induces gas-phase volatiles to diffuse through soil to extraction wells. This technology also is known as in situ soil venting, in situ volatilization, enhanced volatilization, or soil vacuum extraction.	Potentially applicable to soils contaminated with VOCs. Not effective for PCBs, dioxins/furans, inorganics, or radionuclides.
	Thermal Treatment	Vitrification	Contaminated soils and wastes are melted at a high temperature using electrodes to form a large glass monolith with very low leaching characteristics.	Potentially applicable to inorganic-contaminated soil.
	Biological Treatment	Bioventing/ Barometric Venting	Oxygen is delivered to contaminated unsaturated soils by forces air movement (either extraction or injection of air) to increase oxygen concentrations and stimulate biodegradation. The system also may include the injection of contaminated gases, using the soil system for remediation.	Potentially applicable to soils contaminated by VOCs, SVOCs, and PCBs.
		Enhanced Bioremediation	Naturally occurring microbes are stimulated by circulating water-based solutions through contaminated soils to enhance *in situ* biological degradation of organic contaminants. Nutrients, oxygen, or other amendments may be used to enhance biodegradation and contaminant desorption from subsurface materials.	Potentially applicable to soils contaminated by VOCs, SVOCs, and PCBs.
		Phytoremediation	Plants are selected, planted, and managed to uptake contaminants for digestion or degradation.	Potentially applicable to shallow soils contaminated by VOCs, SVOCs, PCBs, and radionuclides.
Ex Situ Treatment	Refer to Table C-4 for identification of *ex situ* treatment technologies.			
Disposal Actions	Refer to Table C-6 for identification of disposal actions.			

Notes:
Shaded process options have been screened out.
Identification of copyrighted, patented, or trademarked names does not signify endorsement.

Table C4-2. Identification of Remedial Technologies and Process Options For Upper Continental Recharge System Subsurface Saturated Soils

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
No Action	None	Not Applicable	No further action to address contaminated media.	Required for consideration by the NCP and NEPA.
Institutional Actions	Access Restrictions	Deed Restrictions	Restriction on property in the deed and title.	Could be implemented as a component of the ROD or on a site-wide basis.
		Site Protection/Security	Guards to restrict and monitor plant access.	Currently conducted for the PGDP as an operating facility.
		Physical Barriers/Restrictions	Fencing, warning signs, permits, etc.	Potentially applicable; the PGDP currently is fenced and "no trespassing" signs are posted. Additional barriers could be located at isolated areas within the PGDP security fence to protect workers and PGDP permitting could be required before working at the SWMU.
	Monitoring	Groundwater Monitoring	Periodic monitoring of site conditions through environmental sampling.	Soil monitoring could be enacted as a component of the ROD. Groundwater and surface water monitoring already is conducted routinely at PGDP on a site-wide basis.
Containment Actions	Bottom Barriers	Jet Grouting; Slanted Grout Columns; Cryogenics	An impermeable layer is placed below the contaminated area to prevent vertical migration/ leaching of contaminants.	Potentially applicable for containment of wastes or in conjunction with process options that could mobilize vapors.
	Vertical Barriers	Slurry Walls	Slurry walls are constructed around the contaminated area to prevent horizontal migration of contaminants.	Potentially applicable for containment of wastes or in conjunction with process options that could mobilize vapors.
		Grout Curtains	Grout curtains are constructed around the contaminated area to prevent horizontal migration of contaminants.	Potentially applicable for containment of wastes or in conjunction with process options that could mobilize vapors.
		Sheet Piles/Vibrating Beam	Pilings or beams are driven around the contaminated area to prevent horizontal migration of contaminants.	Potentially applicable for containment of wastes or in conjunction with process options that could mobilize vapors.
		Cryogenic Walls	Liquid nitrogen or other cryogenic fluids are used to construct a frozen barrier around the contaminated area to prevent horizontal migration of contaminants.	Potentially applicable for containment of wastes or in conjunction with process options that could mobilize vapors.
Removal	Groundwater Collection	Wells and Subsurface Drains	Wells and/or subsurface drains can be installed to collect perched water or water leaking from utilities.	Potentially applicable depending upon the saturated zone of concern.

Table C4-2. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
Removal (Continued)	Groundwater Collection (continued)	Vacuum Enhanced Recovery (2 Phase or Dual Phase)	Vacuum enhanced recover is an enhancement of soil vapor extraction, although groundwater and soil vapor are both extracted. The 2-Phase system uses a high-vacuum pump to extract both groundwater and vapor. The Dual Phase system uses a vacuum pump for vapors and a submersible or pneumatic pump for groundwater.	Potentially applicable.
	Excavation	Solids and Semisolids Excavation	Contaminated solids and semi-solids can be excavated by ordinary construction equipment (backhoes, trackhoes, bulldozers).	Potentially applicable to some of the saturated soils. The depth capacity of conventional excavation equipment [~9 meters (30 feet)] is limited.
		Solidify and Mine (Freeze and Mine)	Patented process in which waste is immobilized for excavation by cryogenic freezing methods.	Potentially applicable to excavate contaminated soil.
In Situ *Treatment*	Physical/ Chemical Treatment	Solidification/ Stabilization	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).	Potentially applicable to inorganically-contaminated soils.
		Hydrous Pyrolysis Oxidation (used in conjunction with *in situ* steam stripping)	Steam and possible oxygen are injected together, building a heated oxygenated zone in the subsurface. When the injection is stopped, the steam condenses and contaminated groundwater returns to the heated zone and mixes with the condensate and oxygen, destroying any dissolves contaminants.	Unable to treat the full UCRS. Limited to 30 feet -- technically unfeasible.
		Oxidation	Oxidants are injected to treat/destroy organic contaminants.	Cannot inject oxidant due to low permeability.
		Electroosmosis (Lasagna™)	The Lasagna™ technology was developed to remediate soils and groundwater contaminated with TCE and is especially suited to sites with low-permeability soils. The process uses electro-osmosis to move soil contaminants by flushing multiple pore volumes of water through treatment zones where the TCE can be captured or chemically altered to nontoxic products.	Potentially applicable.

Table C4-2. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
In Situ *Treatment* (continued)	Physical/ Chemical Treatment (continued)	Air Sparging and Vacuum Extraction	Air sparging and vacuum extraction rely on the air-stripping mechanism to remove volatile contaminants from the saturated zone. The injection of air into the saturated zone is coupled with vacuum extraction to recover volatile contaminants within the vadose zone.	Potentially applicable.
		In Situ Aeration in the Saturated Zone (Air Sparging and UVB Wells)	Volatile contaminants below the water table can be stripped by injecting air through wells (Air Sparging). Vaporized volatiles move with the air to the unsaturated zone and are recovered using a vacuum extraction system. Another *in situ* groundwater stripping process is known as the Underpressure-Vaporizer-Well (UVB) method in which contaminated groundwater is stripped by air at negative pressures in a special filtered well. The contaminated gas is collected and treated at the well head.	Potentially applicable.
		Permeable Treatment Zones (Horizontal or Vertical)	*In situ* treatment zones are permeable and reactive structures using conventional installation technologies. The walls are constructed of granular material or a slurry that permits groundwater flow through the structure under ambient gradients. Treatment is achieved by the contaminant coming in contact with the reactive media (i.e., iron nutrients, bacteria, redox controls carbon) as it passes through wall.	Potentially applicable for sand lenses; however, an induced gradient likely would be required.
		Chemical Mixing (Deep Soil Mixing)	Remediation agents are added to contaminated soil and physically mixed into soil at varying depths using augers. A wide range of treatment agents my be used, including solvents, precipitating chemicals, neutralizing chemicals, hot air, steam, oxidizing agents, and stabilizing agents, depending upon the contaminants of concern.	Potentially applicable to physical mix soil, providing surface and subsurface locations/conditions do not obstruct operation.
	Thermal Treatment	Vacuum/Steam Extraction	Similar to vapor extraction with steam injected for heating the formation. Steam drives the soil, (clay) which increases the permeability of the formation and volatilizes organic contaminants. Vapors re extracted for treatment/storage. The process includes systems for handling offgases.	Potentially applicable to soils contaminated with VOCs. Not effective for PCBs, dioxins/ furans, inorganics, or radionuclides.

Table C4-2. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
In Situ Treatment (Continued)	Thermal Treatment (Continued)	Vitrification	Contaminated soils and wastes are melted at a high temperature using electrodes to form a large glass monolith with very low leaching characteristics.	Potentially applicable to inorganically contaminated soil.
		EM/RF or Six-Phase Soil Heating	Heats the soil by splitting conventional three-phase electricity into six separate phases, producing a heated environment. Each phase is delivered to a single electrode place din a hexagonal pattern. Heat dries the soil, (clay) which increases the permeability of the formation and volitalizes organic contaminants. Vapors are extracted for treatment, storage, or disposal. The process includes systems for handling offgases.	Potentially applicable to soils contaminated with VOCs. Not effective for PCBs, dioxins/furans, inorganics, or radionuclides.
	Biological Treatment	Monitored Natural Attenuation	Naturally-occurring process in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in those media. These *in situ* processes include biodegradation, dispersion, dilution, adsorption, volatilization, and chemical or biological stabilization or destruction of contaminants. Sampling and analysis are required throughout the process.	Potentially applicable to soils contaminated by VOCs, some SVOCs, and PCBs.
		Bioventing/ Barometric Venting	Oxygen is delivered to contaminated saturated soils by forced air movement (either extraction or injection of air) to increase oxygen concentrations and stimulate biodegradation. The system also may include the injection of contaminated gases, using the soil system for remediation.	Potentially applicable to soils contaminated by VOCs, SVOCs, and PCBs.
		Enhanced Bioremediation	Naturally occurring microbes are stimulated by circulating water-based solution through contaminated soils to enhance *in situ* biological degradation of organic contaminants. Nutrients, oxygen, or other amendments may be used to enhance biodegradation and contaminant desorption from subsurface materials.	Potentially applicable to soils contaminated by VOCs, some SVOCs, and PCBs.
		Phytoremediation	Plants are selected, planted, and managed to uptake contaminants for digestion or degradation.	Potentially applicable to shallow groundwater contaminated by VOCs, SVOCs, PCBs, and radionuclides.

Table C4-2. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
Ex Situ Treatment	Refer to Table C-4 for identification of *ex situ* treatment technologies.			
Disposal Actions	Refer to Table C-6 for identification of disposal actions.			

Notes:
Shaded process options have been screened out.
Identification of copyrighted, patented, or trademarked names does not signify endorsement.

Table C4-3. Identification of Remedial Technologies and Process Options For Regional Gravel Aquifer (60 to 100 feet deep) and McNairy (> 100 feet deep) Groundwater

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
No Action	None	Not Applicable	No further action to address contaminated media.	Required for consideration by the NCP and NEPA.
Institutional Actions	Access Restrictions	Deed Restrictions	Restrictions on property in the deed and title.	Potentially applicable as one component of a remedial alternative.
		Site Protection/Security	Guards to restrict and monitor plant access.	Potentially applicable as one component of a remedial alternative. As an operating facility, full-time security measures are conducted at the PGDP.
		Physical Barriers/ Restrictions	Fencing, warning signs, permits, etc.	Potentially applicable as one component of a remedial alternative. The PGDP currently is fenced and "no trespassing" signs are posted.
	Administrative Options	Alternate Concentration Limits (ACLs)	Involves establishing ACLs for groundwater under CERCLA or RCRA in lieu of existing groundwater standards (e.g., MCLs).	Potentially applicable as one component of a remedial alternative.
		Technical Impracticability (TI) Waivers	A waiver under CERCLA or RCRA that may be imposed when remediation of contaminants is agreed to be technically impracticable.	Potentially applicable as one component of a remedial alternative. Presence of NDAPL may increase justification for A TI waiver.
	Monitoring	Water Monitoring	Periodic monitoring of site condition through environmental sampling of surface water and/or groundwater.	Potentially applicable as one component of a remedial alternative. Periodic groundwater and surface water monitoring is conducted at PGDP on a site-wide basis.
Groundwater Containment Actions	Subsurface Vertical Barriers	Slurry/Grout Walls	Low permeability, underground barriers constructed to contain or divert groundwater flow. Slurry/grout material is pumped into a trench or injected into soil voids to form a continuous subsurface barrier. Slurry and grout mixtures vary, but generally include fine clays (e.g., bentonite) or cementeous compounds (e.g., Portland cement). Many installation techniques exist, including trenching, vibrating beam, high-pressure injection, low-pressure (permeation) injection, hydromill, and deep soil mixing. Horizontal, low-permeability subsurface barriers have been constructed using slurry/grouting through innovative installation techniques.	Potentially applicable t contaminated groundwater in the RGA and/or McNairy.

Table C4-3. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
Groundwater Containment Actions (Continued)	Subsurface Vertical Barriers (Continued)	Sheet Piling	A steel pile wall is constructed by driving (with an impact or vibratory hammer) individual steel panels through the soil. Various methods exist to from an interlock between panels and help maintain integrity along the sidewalls of the steel sections. This technology has been used for conventional excavations that require support of side slopes and some degree of hydraulic control.	Potentially applicable to contaminated groundwater in the RGA and/or McNairy.
		Polyethylene Wall	Polyethylene walls are fixed, subsurface barriers formed by either insertion of continuous polyethylene liner into an excavated trench or vibration of panels into place with an insertion plate. Polyethylene and other polymer materials are chemically resistant and can be manufactured to exhibit extremely low permeabilities (i.e., on the order of 10^{-13} cm/s).	Potentially applicable to contaminated groundwater in the RGA and/or McNairy.
		Cryogenic Barriers	A refrigerant (e.g., aqueous ammonia, propylene glycol, liquid nitrogen) is used to freeze a soil layer to form a continuous, low-permeability wall that provides geotechnical stabilization and hydraulic control. Theoretically, horizontal cryogenic barriers may be constructed utilizing innovative installation techniques (e.g., horizontal drilling and casing).	Potentially applicable to contaminated groundwater in the RGA and/or McNairy.
		Bio-barrier	Starved microorganisms are mixed into a slurry and injected into a porous media. Through monitored injection of nutrients, the micro-organisms flourish and form a "slime" wall within the pores of the soil matrix. As the nutrient supply is diminished and the microorganisms go dormant, the low-permeability "slime" wall remains.	Potentially applicable to contaminated groundwater in the RGA and/or McNairy.
	Hydraulic Containment	Hydraulic Containment	Hydraulic containment of dissolved chemicals may be achieved by pumping groundwater from wells and/or grains. Fluid flow control can be augmented by injecting water through wells and/or drains and by the installation of physical barriers (cut-off) walls. Monitoring wells are utilized to determine whether or not the specified hydraulic gradients have been obtained and chemical migration has been arrested. (Methods may include hydraulic bypass, hydraulic isolation, hydraulic manipulation, or aquifer leveling.)	Potentially applicable to contaminated groundwater in the RGA and/or McNairy.

Table C4-3. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
Removal Actions (Groundwater and/or Contaminant)	Extraction	Soil Vapor Extraction (SVE)	A vacuum is applied through piping to create a pressure gradient that induces gas-phase volatiles to diffuse through permeable media to extraction wells. This technology also is known as *in situ* soil venting, *in situ* volatilization, enhanced volatilization, or soil vacuum extraction. (One passive form of SVE is titled barometric pumping.)	Not applicable to the RGA or McNairy since they are aquifers.
		Vacuum-Enhanced Recovery (Dual Phase or 2-Phase)	This option is an enhancement of soil vapor extraction, although groundwater and soil vapor both are extracted. The 2-Phase system uses a high-vacuum pump to extract both groundwater and vapor. The Dual Phase system uses a vacuum pump to extract vapors and a submersible pneumatic pump to extract groundwater.	Soil vapor extraction, with or without enhancements, is not applicable to the RGA or McNairy since they are aquifers.
		In-well Stripping **[includes: UVB; No VOCs]**	Air is injected into the saturated zone, which causes volatile contaminants to be mobilized from the saturated zone by the air-stripping mechanism, and vacuum extraction is used to recover volatile contaminants within the vadose zone. (Bio-sparging may be added to enhance air sparging.)	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved VOCs, but either would require installation of a recovery mechanism at depth (instead of in the vadose zone).
			A significant, *in situ* variation, known as the Underpressure-Vaporizer-Well (UVB) method, utilizes air at negative pressures to strip volatile contaminants from the groundwater inside specially designed wells. As the groundwater flows through the wells, the volatilized contaminants are recovered at the surface for treatment/disposal and the groundwater remains in the saturated zone(s).	Potentially applicable to groundwater in the RGA contaminated with dissolved VOCs. Not applicable to the McNairy due to the low hydraulic conductivity.

Table C4-3. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
Removal Actions (Groundwater and/or Contaminant) (Continued)	Extraction (Continued)	Electrokinetics (including Lasagna^{TM})	An electric potential is established between electrodes in contaminated groundwater to cause contaminant ions to move to the electrodes. The contaminant can be recovered as plating on a solid electrode or, in the case of liquid electrodes, contaminants in the electrolysis fluids.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with metals or radionuclides.
			The LasagnaTM technology was developed to remediate soils and groundwater contaminated with TCE and is especially suited to sites with low-permeability soils. The process uses electro-osmosis to move soil contaminants by flushing multiple pore volumes of water through treatment zones where the TCE can be captured or chemically altered to nontoxic products.	Not applicable to the McNairy due to large pore size. Potentially applicable to groundwater in the McNairy contaminated with dissolved VOCs.
		"Pump and Treat"	Contaminated groundwater is pumped from wells or drains, followed by *ex situ* treatment. Recovery rates can be optimized by fine-tuning pumping rates, well locations, etc. Extraction wells may be installed vertically or horizontally.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved contaminants.
		In Situ Steam Injection/Vacuum Extraction (including Dynamic Underground Stripping)	Similar to soil vapor extraction with steam injected for heating the formation. Steam dries the soil, increases the permeability of the formation, decreases the viscosity and surface tension of liquids, and volatilizes organic contaminants. Vapors are extracted for treatment.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with VOCs (dissolved or DNAPL).
		Radio Frequency Heating (RFH)	This method involves heating soil with electromagnetic energy in the radio frequency band. Using a modified radio transmitter, the zone of interest is targeted for heating via electrodes placed in an array of boreholes. This energy heats the soil to temperatures between 150°C and 300°C.	Not applicable for use in saturated media, such as the RGA or McNairy.
		Six-Phase Soil Heating	This method involves heating soil by splitting conventional three-phase electricity into six separate phases, producing a heated environment. Each phase is delivered to a single electrode placed in a hexagonal pattern. Heat dries the soil, which increases the permeability of the formation and volatilizes organic contaminants.	Potentially applicable as an enhancement to some other groundwater remediation system in the RGA and/or McNairy, where heating of a low-permeability area needs to be targeted.

Table C4-3. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
Removal Actions (Groundwater and/or Contaminant) (Continued)	Extraction (Continued)	Microwave	Microwave energy is used to heat the contaminated groundwater, causing it to volatilize. Contaminant and groundwater vapors are extracted for treatment/disposal.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with VOCs (dissolved or DNAPL).
	Secondary/ Enhanced Recovery	Waterflooding or Injection	Referred to as secondary recovery by the oil industry, waterflooding involves the injection of water into strategically-placed wells or drains to move DNAPL hydraulically toward extraction wells. The injection/extraction systems (i.e., line-drive and five spot systems) enhance recovery by allowing development and sustenance of increased hydraulic gradients and flow rates, elimination of dead zones, and overall improved flow control management. This option may be used in combination with other process options (e.g., injected water may include oxidants as an enhancement).	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved contaminants.
		Surfactant Flooding and Pumping	A surfactant solution is injected as a slug in a flooding sequence to decrease the interfacial tension between DNAPL and water by several orders of magnitude. Ultra-low interfacial tension and higher capillary numbers improve the DNAPL displacement efficiency of a flood, promote the coalescence of DNAPL ganglia and development of a DNAPL bank in front of the surfactant slug, and result in increased DNAPL recovery and reduced DNAPL residual saturation. Surfactant flooding also can enhance DNAPL recovery by causing increased wetting, solubilization, and emulsification. (Some surfactants used in operations by the oil industry include petroleum surfactants, synthetic surfactants, ethoxylated surfactants, and ethoxylated alcohols. Environmental surfactants may include beta-cyclodextrins.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved contaminants.

Table C4-3. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
Removal Actions (Groundwater and/or Contaminant) (Continued)	Secondary/ Enhanced Recovery (Continued)	Polymer Waterflooding and Pumping	Polymers are large molecules that can be dispersed in a waterflood to increase the viscosity of the flood, thereby reducing the mobility ratio and improving the volumetric sweep efficiency (DNAPL recovery). The mobility ratio is defined as the mobility of the displacing fluid (effective permeability/viscosity for water) divided by the mobility of the displaced fluid (effective permeability/viscosity for DNAPL). Lower mobility ratios favor DNAPL displacement and recovery. An effective polymer will impart a high viscosity at low concentration. In operation, polymer flooding often is used as part of a phased injection sequence consisting of the following: a preflush to adjust the pH and salinity (if required), surfactants and/or alkaline agents to reduce interfacial tension, a polymer solution to increase viscosity and improve the displacement efficiency, and the waterflood to displace the mobilized contaminant solutions.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved contaminants.
		Chemically Enhanced Dissolution and Pumping (Cosolvents)	Co-solvents are injected into a contaminated zone via wells or drains to increase the dissolution of DNAPLs and adsorbed chemicals. Continued flooding of the contamination zone with co-solvents or another flood (water, polymers, etc.) drives the contaminants to extraction wells or drains.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved contaminants.
In Situ Groundwater Treatment	Physical/ Chemical Treatment	Solidification/ Stabilization	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization). Methods for solidification/ stabilization include deep soil mixing, grout injection, hydromill, permeation grouting; and materials include bentonite, epoxy, thermplastic, or cementious materials.	Potentially applicable to the RGA and/or McNairy.
		Hydrous Pyrolysis/ Oxidation	Steam and possibly oxygen are injected together, building a heated, oxygenated zone in the subsurface. When the injection is stopped, the steam condenses and contaminated groundwater returns to the heated zone and mixes with the condensate and oxygen, destroying any dissolved contaminants.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved VOCs.

Table C4-3. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
In Situ Groundwater Treatment (Continued)	Physical/ Chemical Treatment (Continued)	Permeable Treatment Walls	Subsurface walls are constructed using reactive granular material or a reactive slurry that permits groundwater flow through the structure under ambient or induced gradients. The contaminant is treated as it comes into contract with the reactive media (i.e., iron, nutrients, bacteria, redox control agent, carbon, humic acids, or other sorptive or reactive materials) as it passes through the wall.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved VOCs or metals.
		In Situ Chemical Treatment (Oxidation)	Oxidizing agents are injected into the contaminated groundwater, resulting in chemical oxidation of targeted contaminants. A wide range of treatment agents may be used, including solvents or precipitating, oxidizing, or stabilizing agents.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved VOCs.
		Ozone Injection (C-Sparge)	Ozone is injected into the contaminated groundwater, resulting in chemical oxidation of targeted VOC contaminants. C-Sparge uses a patented process for small bubble injection, which allows for deeper penetration laterally into the aquifer than normal sparging. This increases efficiency and prevents plugging.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved VOCs
		Sodium Dithionate Injection	The injection of the reducing agent produces a highly reduced treatment zone which can cause dehalogenation of CVOC contaminants. Continued agent addition is needed to maintain the zone.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved VOCs
	Biological Treatment	Monitored Natural Attenuation	Naturally-occurring processes in soil and groundwater environments that act to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in those media. These *in situ* processes include biodegradation, dispersion, dilution, adsorption, volatilization, and chemical or biological stabilization or destruction of contaminants. Sampling and analysis are required throughout the process.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved VOCs, some SVOCs, PCBs, and possibly with metals and/or radionuclides.

Table C4-3. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
In Situ Groundwater Treatment (Continued)	Biological Treatment (Continued)	*In Situ* Biodegradation	The activity of naturally-occurring microbes is stimulated by circulating water-based solutions through contaminated soils to enhance *in situ* biological degradation of organic contaminants. Nutrients, oxygen, or other amendments may be used to enhance biodegradation and contaminant desorption from subsurface materials. Process options may include co-metabolic, nitrate enhancement, or oxygen enhancement.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved VOCs, SVOCs, and PCBs.
		Bio-sparging	Amendments may be added to air sparging options to stimulate or enhance biodegradation.	Potentially applicable to groundwater in the RGA and/or McNairy contaminated with dissolved VOCs and possibly with metals and/or radionuclides.
	Thermal Treatment	Vitrification (*in situ*)	Contaminated soils and wastes are melted at a high temperature using electrodes to form a large glass monolith with very low leaching characteristics.	Potentially applicable to inorganically contaminated soil.
Ex Situ Groundwater Treatment	Refer to Table C-5 for identification of *ex situ* groundwater treatment technologies			
Disposal Action	Refer to Table C-6 for identification of disposal actions.			

Notes:
Shaded process options have been screened out.
Identification of copyrighted, patented, or trademarked processes does not signify endorsement.

Table C4-4. Identification of Remedial Technologies and Process Options for *Ex Situ* Treatment Technologies for Soils and Solids

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
Ex Situ Treatment	Solids Handling	Magnetic Processes, Crushing and Grinding, Shredding and Chipping, and Screening	Solids handling equipment is used to screen magnet and non-magnet waste, prepare brittle and non-brittle waste, and segment solids for further treatment or disposal.	Potentially applicable to process excavated solids for treatment or storage.
	Solids Dewatering	Gravity Settling, Filter Press, Dewatering Beds, Belt Filters, Vacuum Filtration, Centrifuges	All methods are used to dewater solids prior to further treatment or storage.	Potentially applicable to process excavated soil for treatment, storage, or disposal.
	Physical Separation	Screening, Classification, Gravity Concentration, Magnetics	*Ex situ* volume reduction process used to segregate waste streams into components for further treatment, storage, or disposal.	Potentially applicable to extracted groundwater prior to further treatment or storage.
	Physical/ Chemical Separation	Solidification/ Stabilization	Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).	Potentially applicable to inorganic soils.
		Chemical Extraction (Solvent Extraction)	Waste and solvent are mixed in an extractor, dissolving the organic contaminant into the solvent. The extracted organics and solvent are then placed in a separator, where the contaminants and solvent are separated for treatment and further use.	Potentially applicable to excavated surface soils contaminated with VOCs, SVOCs, PCBs, dioxins/furans, and radiological contaminants.
		Electrokinetic Removal	Electrical current is past through soil to separate contaminants.	Potentially applicable to excavated soils contaminated with chlorinated VOCs, SVOCs, or metals.
		Soil Washing/Leaching	Contaminants sorbed onto soil particles are separated from soil in an aqueous-based system. The wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics and heavy metals.	Potentially applicable to excavated soils contaminated with VOCs, PCBs, and dioxins/furans; some techniques may be applicable to uranium and other radionuclides.

Table C4-4. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
Ex Situ Treatment (Continued)	Physical/ Chemical Separation (Continued)	Dechlorination: Glycolate/Base-catalyzed	An alkaline polyethylene glycolate (APEG) reagent is used to dehalogenate halogenated aromatic compounds in a batch reactor. Potassium polyethylene glycolate (KPEG) is the most common APEG reagent. Contaminated soils and the reagent are mixed and heated in a treatment vessel. In the APEG process, the reaction causes the polyethylene glycolate to replace halogen molecules and render the compound nonhazardous. For example, the reaction between chlorinated organics and KPEG causes replacement of a chlorine molecule and results in a reduction in toxicity.	Potentially applicable to excavated soils contaminated with halogenated VOCs, PCBs, and dioxins/furans. Not effective for radionuclides.
			Contaminated soil is screened, processed with a crusher and pug mill, and mixed with sodium bicarbonate. The mixture is heated in a rotary reactor to decompose and partially volatilized the contaminants.	Potentially applicable to excavated soils contaminated with halogenated VOCs, PCBs, and dioxins/furans. Not effective for radionuclides.
		Neutralization	Acids are added to an alkaline waste or base added to an acidic water to adjust the pH.	Not applicable for remediation since the majority of the soils do not need pH adjustment.
		Chemical Reduction-Oxidation	Reduction/oxidation chemically converts hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. The reducing/oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, potassium permanganate chlorine, and chlorine dioxide.	Potentially applicable to excavated souls contaminated with TCE, PCBs, or radionuclides.
	Biological Treatment	Biodegradation: Composting (Land-farming)	Contaminated soils are mixed with soil amendments and placed in aboveground enclosures that have leachate collection systems and some form of aeration. Processes include prepared treatment beds, biotreatment cells, soil piles, and composting. Moisture, heat, nutrients, oxygen, and pH may be controlled to enhance biodegradation.	Potentially applicable to excavated soils contaminated with VOCs, SVOCs, or PCBs.
			Contaminated soils are applied onto the soil surface or an above grade system and periodically tilled into the soil or turned over to aerate the waste and microbes.	Potentially applicable to some excavated soils contaminated with VOCs, SVOCs, or PCBs.

Table C4-4. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
Ex Situ Treatment (Continued)	Biological Treatment (Continued)	Biodegradation: Slurry-Phase Treatment	An aqueous slurry is created by combining soil or sludge with water and other additives. The slurry is mixed to keep solids suspended and microorganisms in contact with the soil contaminants. Nutrients, oxygen and pH in the bioreactor may be controlled to enhance biodegradation. Upon completion of the process, the slurry is dewatered and the treated soil is disposed of.	Potentially applicable to some excavated soils contaminated with VOCs, SVOCs, or PCBs.
	Thermal Treatment	Incineration	High temperatures, 871°C to 1,204°C (1,600°F to 2,200 °F), are used to volatilized and combust (in the presence of oxygen) organic constituents.	Potentially applicable to excavated soils contaminated with VOCs, SVOCs, or PCBs.
		Pyrolysis	Chemical decomposition is induced in organic material by heat in the absence of oxygen. Organic materials are transformed into gaseous components and a solid residue (coke) containing fixed carbon and ash.	Potentially applicable to excavated organic soils and some excavated wastes.
		Thermal Desorption	Wastes are heated to 93°C to 538°C (200°F to 4,000°F), are used to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized vapors to the treatment system.	Potentially applicable to excavated soils contaminated with VOCs, SVOCs, PCBs, and dioxins/furans. Not effective for radionuclides and inorganics.
		Vitrification (*ex situ*)	Contaminated soil and sludge are melted at a high temperature to form a glass with very low leaching characteristics.	Potentially applicable to excavated inorganic soils and some excavated wastes.

Notes:
Shaded process options have been screened out.
Identification of copyrighted, patented, or trademarked names does not signify endorsement.

Table C4-5. Identification of Presumptive Technologies for Treatment of Extracted Groundwater

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Comments
Ex Situ Treatment Actions	Physical/ Chemical/ Biological Treatment	Air Stripping	A separation process in which volatile contaminants are partitioned to the gas phase process and rate are a function of the difference in contaminant concentration in each phase. Aeration methods include packed towers, diffused aeration, try aeration, and spray aeration.	Presumptive technology for treatment of extracted groundwater; potentially applicable for treatment of dissolved organic contaminants (e.g., VOCs, halogenated SVOCs). (EPA, 1996. *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996.)
		Granular Activated Carbon	A separation process in which groundwater contaminants are sorbed onto activated carbon. Periodic replacement or regeneration of saturated carbon is required.	Presumptive technology for treatment of extracted groundwater; potentially applicable for treatment of dissolved organic contaminants (e.g., VOCs, SVOCs). (EPA, 1996. *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996.
		Chemical/UV Oxidation	A treatment process in which chemicals (e.g., oxygen, ozone, hydrogen peroxide, chlorine) and/or ultraviolet (UV) radiation are used to oxidize organic contaminants as water flows into a treatment tank. An ozone destruction unit is used to treat off-gases from the treatment tank.	Presumptive technology for treatment of extracted groundwater; potentially applicable for treatment of dissolved organic contaminants (e.g., VOCs, SVOCs). Also may be applicable to cyanides. (EPA, 1996. *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996.)
		Aerobic Biological Reactors	A treatment process in which contaminated groundwater is treated using fixed or suspended microbiological systems, In fixed or attached systems, such as rotating biological contactors and tricking filters, microorganism are established on an inert support matrix to aerobically degrade groundwater contaminants. In suspended systems, such as activated sludge, contaminated groundwater is circulated in an aeration basin where a microbial population aerobically degrades organic matter and produces new cells.	Presumptive technology for treatment of extracted groundwater; potentially applicable for treatment of dissolved organic contaminants (*e.g., VOCs SVOC). (EPA, 1996. Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996.)
		Chemical Precipitation	A separation technology in which chemicals are added to encourage dissolved metals and suspended particles to form insoluble (or precipitated) metal hydroxides, sulfides, carbonates, or other salts.	Presumptive technology for treatment of extracted groundwater; potentially applicable for treatment of dissolved metals. (EPA, 1996. *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996.

Table C4-5. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Comments
Ex Situ Treatment Actions (Continued)	Physical/ Chemical/ Biological Treatment (Continued)	Ion Exchange/Adsorption	A separation technology in which a resin media adsorbs, or removes, contaminants from groundwater or leachate. Cation resins, anion resins, or chelating resins may be used, depending upon the contaminant(s). The resins are contained in a pressurized vessel and may require regeneration.	Presumptive technology for treatment of extracted groundwater; potentially applicable for treatment of dissolved metals. Also, potentially applicable for sulfates, nitrates, and radionuclides. (EPA, 1996. *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996.
		Electrochemical Methods	A separation technology in which direct electrical current is placed between two immersed electrodes to drive chemical oxidation-reduction reactions in an aqueous solution. Dissolved metals (e.g., hexavalent chromium, arsenic, cadmium, molybdenum, aluminum, zinc, copper) either deposit on the cathode or precipitate from the solution. (EPA, 1996. *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996.	Presumptive technology for treatment of extracted groundwater; potentially applicable for treatment of dissolved metals. Also, potentially applicable for sulfates, nitrates, and radionuclides. (EPA, 1996. *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996.
		Aeration of Background Metals	A separation technology in which aeration removes some metals (e.g., iron, manganese) from water by promoting chemical oxidation and the formation of insoluble hydroxides that precipitate from the water. The precipitants then may be removed by flocculation, sedimentation, and/or filtration. Methods of aeration include aeration tanks, aeration basins, or cascade aeration. (EPA, 1996. *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996.)	Presumptive technology for treatment of extracted groundwater; potentially applicable for treatment of dissolved metals. Also, potentially applicable for sulfates, nitrates, and radionuclides. (EPA, 1996. *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996.
		Membrane Separation	A selective semipermeable membrane is used to separate, or remove, dissolved solids from water. Types of membrane separation include the following processes: microfiltration, ultrafiltration, reverse osmosis, dialysis, and electrodialysis. (McGraw-Hill, 1988. *The NALCO Water Handbook,* 2nd edition.)	Potentially applicable for treatment of radionuclides.

Table C4-5. (continued)

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Comments
Pretreatment Actions	Solids Dewatering	Gravity Settling, Filter Press, Dewatering Beds, Belt Filters, Vacuum Filtration, Centrifuges, *In Situ* Dewatering	Separation methods which are used to dewater solids prior to further treatment or storage.	Potentially applicable to support other treatment technologies.
	Physical Separation	Screening, Classification, Gravity Concentration, Coagulation/Flocculation, Magnetic separation	Separation methods which are used to segregate waste streams into components for further treatment, storage, or disposal.	Potentially applicable to support other treatment technologies.
	Physical/Chemical Treatment	Neutralization	Treatment method in which either an acid is added to an alkaline waste or a base is added to an acidic water to adjust the pH.	Potentially applicable to support other treatment technologies.
		Solidification/ Stabilization	Contaminants are bound Physically or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization).	Potentially applicable to process sludge.

Notes:
Shaded process options have been screened out.
Identification of copyrighted, patented, or trademarked names does not signify endorsement.

Table C4-6. Identification of Remedial Technologies and Process Options for Disposal Actions

General Response Actions	Remedial Technology Types	Process Options	Descriptions	Screening Comments
Disposal Actions	On-Site Disposal	Permitted Facility	Wastes placed in an approved DOE-owned facility at the PGDP.	Potentially applicable for excavated soil/waste or treatment residuals. The C-746-U Contained Landfill is limited to 49 ppm PCBs and <30 pCi/g radionuclides (average total uranium).
		Constructed Disposal Cell	Excavate and place the generated wastes in a disposal cell specifically constructed for this purpose.	Depending upon the availability of a suitable location, potentially applicable for excavated soil.
	Off-Site Disposal	RCRA Facility	RCRA-hazardous wastes transported to a permitted, commercial RCRA disposal facility.	Potentially applicable to process residuals identified as hazardous waste. Must meet facility's waste acceptance criteria and land disposal restrictions.
		TSCA Facility	TSCA wastes transported to a permitted, commercial TSCA disposal facility.	Potentially applicable to soil and/or process residuals containing >50 ppm PCBs. (Currently limited to DOE-owned facilities if material contains radionuclides.) Must meet facility's waste acceptance criteria.
		(Low-Level) Radioactive Waste Facility	Low-level radioactive wastes transported to a DOE-approved facility.	Potentially applicable to soil and/or process residuals identified as low-level radioactive waste. Currently limited to DOE-owned facilities. Must meet facility's waste acceptance criteria.
		Mixed-Waste Facility	Mixed waste (RCRA-hazardous waste plus low-level radioactive waste) transported to a DOE-approved facility.	Potentially applicable to process residuals identified as mixed waste. Currently limited to DOE-owned facilities (due to radioactive component). Must meet facility's waste acceptance criteria.
	Interim Storage	On-Site Storage	Interim storage for an indefinite period in a DOE-owned facility at the PGDP.	Potentially applicable, but PGDP currently does not have such a facility available.

Notes:
Shaded process options have been screened out.
Identification of copyrighted, patented, or trademarked names does not signify endorsement.

Table C4-7. Evaluation of Remedial Technologies and Process Options for Upper Continental Recharge System Vadose Zone Soils (0 to 15 ft deep)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
No Action	None	Not Applicable	○	●	NA	●	●	●	●
			Option does not achieve RAOs. Option poses no short-term risks.			No action involved with this option; therefore, it is technically and administratively feasible to implement.		Option requires minimal ("baseline") or no cost.	
Institutional Actions	Access Restrictions	Deed Restrictions	●	●	●	●	●	●	●
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option produces no short-term impacts. Option is proven and reliable for restricting access.			Option is technically and administratively feasible to implement.		Option requires relatively little capital to implement and little or no O&M, compared to other access restriction technologies.	
		Site Protection/ Security	●	●	●	●	●	⊕	○
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option produces no short-term impacts. Option is proven and reliable for restricting access.			Option is technically and administratively feasible to implement. A full security program already is implemented at the PGDP.		Option requires moderate capital to implement and significant O&M, compared to other access restriction technologies.	
		Physical Barriers/ Restrictions	●	●	●	●	●	⊕	⊕
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option may produce minimal short-term impacts. Option is proven and reliable for restricting access.			Option is technically and administratively feasible to implement. Physical barriers are already implemented at the PGDP (i.e., a security fence surrounds the entire PGDP).		Option requires moderate capital to implement and moderate O&M, compared to other access restriction technologies.	
	Monitoring	Surface Soil and Water Monitoring	●	●	●	●	●	●	⊕
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option may produce minimal short-term impacts, depending upon the level of construction required. Option is proven and reliable for evaluating groundwater and/or surface water characteristics, contaminants, and trends.			Option is technically and administratively feasible to implement. Routine groundwater and surface- water monitoring is conducted at the PGDP.		Option may require relatively moderate to low capital to implement and moderate O&M. Costs are dependent upon the number of samples and analyses conducted.	

Table C4-7. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Containment Actions	Capping	Clay/Soil or Asphalt/Concrete	●	●	⊕	●	●	●	⊕
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option may produce short-term impacts, depending upon the level of construction required. Option is proven and reliable for reducing exposure potential and reducing infiltration/vertical movement of contaminants into the subsurface. These types of caps require regular maintenance to ensure effectiveness.			Option is technically and administratively feasible to implement in most areas. Could include using existing floor slabs in developed areas.		Option requires moderate costs to implement. Costs for soil cover are low. O&M costs are moderate for cap inspection and maintenance.	
		Multimedia	●	●	●	●	●	⊕	●
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option may produce short-term impacts, depending upon the level of construction required. Option is proven and reliable for reducing exposure potential and reducing infiltration/vertical movement of contaminants into the subsurface.			Option is technically and administratively feasible to implement in most areas.		Option requires moderate costs to implement. O&M costs are moderate for cap inspection and maintenance.	
		Lead Shield	⊕	⊕	●	●	●	○	⊕
			Option applicable to gamma-emitting radionuclides only. Probably applies to smaller areas only. Provides no contaminant reduction. Option would produce some short term impacts, especially in developed areas.			Option is technically and administratively feasible to implement.		Option is costly to implement and maintain.	
	Surface Controls	Grading	⊕	●	⊕	●	●	●	●
			Option available to all volumes, media, and contaminants, but provides no contaminant reduction. May produce short term impacts if surficial soils are contaminated. Could increase soil erosion. Option is proven and reliable for reducing infiltration/vertical movement of contaminants. Option does not limit surface exposure.			Option is technically and administratively feasible to implement.		Option is of low cost with little O&M.	

Table C4-7. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Containment Actions (Continued)	Surface Controls (Continued)	Revegetation	⊕	●	●	●	●	●	●
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option may produce short-term impacts, depending upon the level of grading and required and degree of site development. Could cause increased erosion of surface contamination and short term exposure to workers during implementation. Option is proven and reliable for reducing infiltration/vertical movement of contaminants into the subsurface. Option does not limit surface exposure.			Option is technically and administratively feasible to implement.		Option is of low cost with little O&M.	
		Flow Diversion	⊕	●	●	●	●	●	●
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option produces few short-term impacts, depending upon the degree of construction required. Should cause minimal worker exposure. Option is proven and reliable for reducing infiltration/vertical movement of contaminants into the subsurface. Option does not limit surface exposure.			Option is technically and administratively feasible to implement. Could be incorporated as improvements to existing stormwater drainage network.		Option is of low cost with little O&M.	
	Bottom Barriers	Jet grouting; Slanted Grout columns; cryogenics	●	●	○	●	●	○	⊕
			Option available for all volumes and media. Grout may be degraded in presence of high concentrations of VOCs. Few short-term impacts or exposure risks. Options are neither proven or known to be reliable at PGDP.			Option is technically and administratively feasible to implement in most areas.		Options are high in capital costs. O&M costs are comparable to other containment options.	
	Vertical Barriers	Slurry Walls	⊕	●	●	●	●	⊕	⊕
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction and is not effective in limiting vertical migration. Option produces few short-term impacts. Technology is proven and reliable in many settings. Use of vertical barrier in vadose zone limited to perched matter systems.			Option is technically and administratively feasible to implement		Costs are moderate compared to other vertical barriers.	

Table C4-7. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Containment Actions (Continued)	Vertical Barriers (Continued)	Grout Curtains	⊕	●	●	●	●	⊕	⊕
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction and is not effective in limiting vertical migration. Option produces few short-term impacts. Technology is proven and reliable in many settings. Use of vertical barrier in vadose zone limited to perched matter systems.			Option is technically and administratively feasible to implement		Costs are moderate compared to other vertical barriers.	
		Sheet Piles/ Vibrating Beam	⊕	●	⊕	●	●	●	●
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction and is not effective in limiting vertical migration. Option produces no short-term impacts. May be limited by site conditions. Use of vertical barrier in vadose zone limited to perched matter systems.			Option is technically and administratively feasible to implement		Option requires relatively low capital and O&M, compared to vertical barriers.	
		Cryogenic Walls	⊕	●	●	●	●	⊕	⊕
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction and is not effective in limiting vertical migration. Option produces few short-term impacts. Technology is proven and reliable in many settings. Use of vertical barrier in vadose zone limited to perched matter systems.			Option is technically and administratively feasible to implement		Costs are moderate compared to other vertical barriers.	
Removal	Water Collection	Wells and Subsurface Drains	⊕	●	⊕	●	●	●	●
			Option available for areas of high recharge, leaking utilities, or perched groundwater, otherwise not effective for vadose zone contaminants. Would cause minimal to moderate short-term impacts or worker exposure. Generally unproven to remediate vadose contaminants.			Option is technically and administratively feasible to implement.		Option requires relatively low capital to implement and low to moderate O&M compared to other collection technologies.	
	Excavation	Solids and Semisolids Excavation	⊕	⊕	●	●	●	●	●
			Option applicable to shallow (< 30 ft.) volumes, media, and contaminants only. Relies on *ex situ* means of treatment or disposal. Option produces short-term impacts, of worker exposure and other construction-related impacts. Option is proven and reliable for contaminant mass reduction.			Option is readily implementable but not feasible beneath permanent buildings/structures. Option is administrative feasible.		Capital costs generally low depending on amount of worker protection required and method of disposal or treatment. Little O&M is required.	

Table C4-7. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Removal (Continued)	Excavation (Continued)	Solidify and Mine (Freeze and Mine)	⊕	●	○	⊕	⊕	⊕	●
			Option available for rather homogeneous, specialized wastes. Most applicable for explosive or reactive wastes. Minimal worker exposure and site impacts. Option is proven only for controlled environments. It is unproven for large scale applications.			Technology unproven for many of these applications. Handling highly toxic or dangerous material could result in permitting issues.		Capital costs are moderate to high, while O&M can be quite low compared to other *ex situ* separation technologies.	
	Site Equipment/ Debris Removal	Equipment/Debris Removal and Decontamination	⊕	⊕	●	●	●	⊕	⊕
			Option limited only to removable equipment, structures and debris of material emitting <200mR/hr. Relies on *ex situ* decontamination and disposal. Potential for short-term exposures to workers. Option is proven effective and reliable.			Option is technically and administratively feasible to implement.		Costs are highly variable due to ease of removal and nature and degree of contamination.	
	Bulk Liquid Removal	Drain or Pump Tanks/Pits and Lines Containing Liquids	●	⊕	●	●	●	●	●
			Option limited to containment structures and their appurtenances. Could cause short-term impacts depending on location of containment structure and nature of material.			Location of containment structure could impede removal actions. Option is administratively feasible.		Capital costs are low providing easy access to containment structure. O&M costs are comparable to or lower than other removal options.	
	Bulk Solid/ Liquid Removal	Vacuum Loader	⊕	●	●	●	●	●	●
			Option limited to containment structures and their appurtenances. May not be effective on all sludges. Should cause minimal worker exposure. Generally proven for liquids and semi-solids.			Option is technically and administratively feasible to implement.		Low cost compared to other removal options.	
In Situ Treatment	Physical/ Chemical Treatment	Solidification/ Stabilization	⊕	●	●	●	●	⊕	●
			Option uses several methods to that could be applied to all volumes, all media and all contaminants. NAPL could limit effectiveness. Carbonate-based gravels could mobilize radionuclides (e.g., uranium). Possible limitations in areas of buried materials. Produces little opportunity for worker exposure. Most methods are proven and reliable.			Technology is technically and administratively feasible.		Capital costs are variable with the technology employed but overall similar to other *in situ* technologies. Generally moderate to low O&M.	
		Chemical Mixing (Deep Soil Mixing)	●	⊕	⊕	⊕	⊕	⊕	●
			Option available to all volumes, all media and most contaminants. Possible limitations in areas of buried materials. Produces some opportunity for worker exposure. Most methods are proven and reliable.			Must use care not to mix incompatible wastes or introduce reactive substances. Accessibility is problematic in areas of dense infrastructure. Option is administratively feasible.		Capital costs are comparable to low compared to other *in situ* technologies. O&M costs are low.	

Table C4-7. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
In Situ	Physical	Soil Vapor Extraction/Soil Venting	◈	●	●	●	●	●	●
			Option available for all volumes and media. Applicable to VOCs and some SVOCs only. Produces few short-term impacts. Method is proven and reliable.			Technology is technically and administratively feasible.		Capital and O&M costs are low compared to other *in situ* technologies.	
	Thermal Treatment	Vitrification	●	◈	○	●	◈	○	◈
			Option available for most volumes, media and contaminants, but generally not feasible below ~ 25ft. Releases hot gases and potential for contaminant release. Has not proven to be reliable in field demonstrations.			Technology is technically feasible. Potential administrative difficulties based on perceived safety concerns.		High capital costs compared to other *in situ* technologies. O&M is moderate to high during operations. Long- term O&M is very low.	
	Biological Treatment	Bioventing/ Barometric Venting	◈	●	●	●	●	◈	●
			Option available for all volumes and media. Applicable to VOCs and some SVOCs. Produces few short-term impacts. Method is proven and reliable. Not applicable to radionuclides.			Technology is technically and administratively feasible.		Capital costs are low to moderate and O&M costs are comparable to other biological treatment technologies.	
	Biological	Enhanced Bioremediation	◈	●	●	◈	◈	◈	◈
			Option available for all volumes and media. Applicable to VOCs and some SVOCs. Produces few short-term impacts. Method is proven and reliable.			Technology is technically difficult in vadose zone. Addition of amendments (e.g., toluene) for co-metabolic reactions may cause permitting problems.		High costs compared to other biological treatment technologies.	
		Phytoremediation	◈	◈	◈	●	●	◈	◈
			Option is applicable to shallow to moderate depths and many contaminants in soil. Could produce vegetation containing radionuclides. Largely proven and reliable, but not for all applications.			Technology is technically and administratively feasible.		Capital and O&M costs are moderate compared to other biological treatment technologies.	
Ex Situ Treatment	Refer to Table C-10 for evaluation of *ex situ* treatment technologies.								
Disposal Actions	Refer to Table C-12 for evaluation of disposal actions.								

Notes:
Shaded process options have been screened out.
Identification of copyrighted, patented, or trademarked names does not signify endorsement.

Table C4-7. (continued)

Legend					
Effectiveness		**Implementability**		**Cost**	
●	Satisfies effectiveness criteria	●	Feasible to implement	●	Low cost compared to other options within the same technology type
⌖	Satisfies some, but not all, criteria	⌖	May be feasible to implement	⌖	Moderate cost compared to other options within the same technology type
○	Does not satisfy effectiveness criteria	○	Unfeasible to implement	○	High cost compared to other options within the same technology type

<u>Explanation of Evaluation Criteria</u>

- Effectiveness (primary focus) includes:
  - Potential effectiveness in handling the areas/volumes of media or recovering contaminated media and meeting remediation goals,
  - Potential impacts to human health and environment during construction and implementation phase, and
  - How proven and reliable the process is with respect to site contaminants and conditions.
- Implementability includes:
  - Technical feasibility (e.g., availability of TSD and adequate capacity, availability of equipment and workers) and
  - Administrative feasibility (e.g., ability to obtain permits).
- Cost includes:
  - Capital cost and
  - O&M cost.

Table C4-8. Evaluation of Remedial Technologies and Process Options For Upper Continental Recharge System Subsurface Saturated Soils (15 to 60 ft deep)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
No Action	None	Not Applicable	○	●	NA	●	●	●	●
			Evaluation of this alternative is required by the NCP. Option does not achieve RAOs. Option poses no short-term risks.			No action involved with this option; therefore, it is technically and administratively feasible to implement.		Option requires minimal ("baseline") or no cost.	
Institutional Actions	Access Restrictions	Deed Restrictions	●	●	●	●	●	●	●
			Option applicable to all volumes and contaminants, but provides no contaminant reduction. Option produces no short-term impacts. Option is proven and reliable for restricting access to groundwater.			Option is technically and administratively feasible to implement. Option may require approval by the public.		Option requires relatively little capital to implement and little or no O&M, compared to other access restriction technologies.	
		Site Protection/ Security	●	●	●	●	●	⌖	○
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option produces no short-term impacts. Option is proven and reliable for restricting access.			Option is technically and administratively feasible to implement. A full security program already is implemented at the PGDP.		Option requires moderate capital to implement because existing system in place, but significant O&M, compared to other access restriction measures.	
		Physical Barriers/ Restrictions	●	●	●	●	●	⌖	⌖
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option may produce minimal short-term impacts. Option is proven and reliable for restricting access.			Option is technically and administratively feasible to implement. Physical barriers is already implemented at the PGDP (i.e., a security fence surrounds the entire PGDP).		Option requires some expenditures capital to implement and moderate O&M, compared to other access restriction technologies.	
	Monitoring	Groundwater Monitoring	●	●	●	●	●	⌖	⌖
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option may produce minimal short-term impacts, depending upon the level of construction required. Option is proven and reliable for evaluating groundwater characteristics, contaminants, and trends.			Option is technically and administratively feasible to implement. Routine groundwater monitoring is conducted at the PGDP.		Option may require additional wells to implement and moderate O&M. Costs are dependent upon the number of samples and analyses conducted.	
Containment Actions	Bottom Barriers	Jet Grouting; Slanted Grout Columns; Cryogenics	●	●	○	⌖	●	○	⌖
			Option available for all volumes and media. Grout may be degraded in presence of high concentrations of VOCs. Few short term impacts or exposure risks. Options are not proven at PGDP.			Option is technically and administratively feasible to implement in most areas.		Options are high in capital costs. O&M costs are comparable to other containment options.	

Table C4-8. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Containment Actions (Continued)	Vertical Barriers	Slurry Walls	⌖	●	●	●	●	⌖	⌖
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction and is not effective in limiting vertical migration. Option produces few short-term impacts. Technology is proven and reliable in many settings.			Option is technically and administratively feasible to implement		Costs are moderate compared to other vertical barriers.	
		Grout Curtains	⌖	●	●	●	●	⌖	⌖
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction and is not effective in limiting vertical migration. Option produces few short-term impacts. Technology is proven and reliable in many settings.			Option is technically and administratively feasible to implement		Costs are moderate compared to other vertical barriers.	
		Sheet Piles/ Vibrating Beam	⌖	●	⌖	●	●	●	●
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction and is not effective in limiting vertical migration. Option produces no short-term impacts. May be limited by site conditions.			Option is technically and administratively feasible to implement		Option requires relatively low capital and O&M compared to vertical barriers.	
		Cryogenic Walls	⌖	●	●	●	●	⌖	⌖
			Option applicable to all volumes, media and contaminants, but provides no contaminant reduction and is not effective in limiting vertical migration. Option produces few short-term impacts. Technology is proven and reliable in many settings.			Option is technically and administratively feasible to implement		Costs are moderate compared to other vertical barriers.	
Removal	Groundwater Collection	Wells and Subsurface Drains	⌖	●	⌖	●	●	⌖	⌖
			Available to all volumes and saturated media. However, only that portion of UCRS with appreciable permeability would cause minimal short-term impacts or worker exposure. Technology is proven and reliable, but extraction may not be effective in low permeability material of the UCRS.			Option is technically and administratively feasible to implement.		Option requires moderate to low capital to implement and moderate to low O&M compared to other removal technologies.	
		Vacuum Enhanced Recovery (2 Phase or Dual Phase)	●	●	●	●	●	⌖	⌖
			Available to all volumes and media only. Minimal short-term impacts or worker exposure. Technology is proven and reliable. Low permeability of UCRS may limit effectiveness but is more effective than simple extraction.			Option is technically and administratively feasible to implement.		Option requires moderate capital to implement and moderate O&M compared to other removal technologies.	

Table C4-8. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Removal (Continued)	Excavation	Solids and Semisolids Excavation	⊕	⊕	●	⊕	●	●	●
			Option applicable to shallow (< 30 ft.) volumes, media, and contaminants only. Limited to only those areas with limited infrastructure. Relies on *ex situ* means of treatment or disposal. Option produces short-term impacts, of worker exposure and other construction-related impacts. Option is proven but difficult in saturated zone.			Option is readily implementable but not feasible beneath permanent buildings/structures. Option is administratively feasible.		Capital costs generally low depending on amount of worker protection required and method of disposal or treatment. Little O&M is required.	
		Solidify and Mine (Freeze and Mine)	⊕	⊕	○	⊕	⊕	⊕	●
			Option available for rather homogeneous, specialized wastes. Most applicable for explosive or reactive wastes. Minimal worker exposure and site impacts. Option is proven only for controlled environments. It is unproven for large-scale applications.			Technology is implementable. Handling highly toxic or dangerous material could result in permitting issues.		Capital costs are moderate to high, while O&M can be quite low compared to other *ex situ* separation technologies.	
In Situ Treatment	Physical/ Chemical Treatment	Solidification/ Stabilization	⊕	⊕	●	●	●	⊕	●
			Option uses several methods to that could be applied to all volumes, all media and all contaminants. NAPL could limit effectiveness. Carbonate-based gravel could mobilize certain radionuclides (e.g., uranium). Possible limitations in areas of buried materials. Produces some opportunity for worker exposure. Most methods are proven and reliable.			Technology is technically and administratively feasible.		Capital costs are variable with the technology employed but overall similar to other *in situ* technologies. Generally moderate to low O&M.	
		Electroosmosis (Lasagna™)	⊕	●	⊕	⊕	●	⊕	⊕
			Option available for all volumes and media. Applicable to VOCs and some SVOCs only. Produces some off-gas but relatively few short-term impacts. Method is proven and reliable for limited applications at PGDP.			Technology is not as effective below 30 ft, but is administratively feasible.		Capital and O&M costs are comparable to other *in situ* technologies.	
		Air Sparging and Vacuum Extraction	⊕	●	●	⊕	●	●	●
			Option available for all volumes and media. Applicable to VOCs only. Produces few short-term impacts. Method is proven and reliable.			Technology is technically and administratively feasible. Technology must be used in conjunction with hydraulic fracturing.		Capital and O&M costs are low to moderate compared to other *in situ* physico-chemical technologies.	
		In Situ Aeration in the Saturated Zone (Air Sparging and UVB Wells)	⊕	●	⊕	⊕	●	●	●
			Option is available to VOCs only, probably limited to gravel zones in UCRS. Few short- term impacts. Air sparging technology is widely proven and reliable, but UVB wells are not widely used. Not proven in low-permeability materials.			Technology is technically and administratively feasible.		Capital and O&M costs are low to moderate compared to other *in situ* physico-chemical technologies.	

Table C4-8. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
In Situ Treatment (Continued)	Physical	Permeable Treatment Zones (Horizontal or Vertical)	●	●	⊕	●	●	⊕	⊕
			Option available to all groundwater volumes and many contaminants. Few short-term impacts. Technology is proven and generally reliable, but some problems with long-term effectiveness.			Technology is technically and administratively feasible.		Capital and O&M costs are comparable to other *in situ* physio-chemical technologies.	
		Chemical Mixing (Deep Soil Mixing)	●	⊕	⊕	⊕	⊕	⊕	●
			Option available to all volumes, all media and most contaminants. Possible limitations in areas of buried materials. Produces little opportunity for worker exposure. Most methods are proven and reliable.			Must use care not to mix incompatible wastes or introduce reactive substances. Accessibility limited in some areas with in intricate intrastructive. Option is administratively feasible.		Capital costs are comparable to low compared to other *in situ* technologies. O&M costs are low.	
	Thermal Treatment	Vacuum/Steam Extraction	⊕	⊕	⊕	●	●	⊕	⊕
			Option available for all volumes and media. Potential for surface expulsion at these depths. Applicable to VOCs and some SVOCs only. Produces few short-term impacts. Method is proven and reliable.			Technology is technically and administratively feasible. Will require hydraulic fracturing to be implemented in low permeability zones.		Capital and O&M costs are comparable to other *in situ* technologies.	
		Vitrification	⊕	⊕	○	⊕	○	○	●
			Option available for all volumes, media and contaminants, but generally not feasible below ~25 ft. Releases hot gases and potential for contaminant release. Has not proven to be reliable in field demonstrations.			Technology is technically feasible but only at shallow portions of UCRS. Potential administrative difficulties based on perceived safety concerns.		High capital costs compared to other in situ technologies. O&M is moderate to high during operations. Long term O&M is very low.	
		EM/RF or Six-Phase Soil Heating	⊕	●	⊕	⊕	●	⊕	⊕
			Option available for VOCs and some SVOCs only. Few short-term impacts except for completion and operation of off-gas treatment system. Not a widely used technology. Not proven in this environment.			Technology is technically difficult in areas with substantial debris or structures. Administratively feasible.		Costs are comparable with other thermal technologies.	
	Biological Treatment	Monitored Natural Attenuation	⊕	●	●	⊕	●	●	●
			Option available to VOCs and many radionuclides. Produces few short-term impacts, proven and reliable for many constituents. May require long time frames.			Technology is technically and administratively feasible.		Capital and O&M costs are low compared to other biological treatment technologies.	
		Bioventing/ Barometric Venting	⊕	●	●	●	●	⊕	●
			Option available for all volumes and media. May require co-metabolic processes, (ex. addition of chemicals). Applicable to VOCs and some SVOCs. Produces few short-term impacts. Method is proven and reliable.			Technology is technically and administratively feasible.		Capital costs are low to moderate and O&M costs are comparable to other biological treatment technologies.	

Table C4-8. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
In Situ (Continued)	Biological Treatment (Continued)	Enhanced Bioremediation	⌖	●	●	●	●	⌖	⌖
			Option available for all volumes and media. Applicable to VOCs and some SVOCs. Produces few short-term impacts. Method is proven and reliable.			Technology is technically and administratively feasible.		Capital and O&M costs are comparable to other biological treatment technologies.	
		Phytoremediation	⌖	●	⌖	●	●	⌖	⌖
			Option is applicable to shallow to moderate depths and many contaminants in soil and shallow groundwater. Produces few short-term impacts and is largely proven and reliable, but not for all applications.			Technology is technically and administratively feasible.		Capital and O&M costs are moderate compared to other biological treatment technologies.	
Ex Situ Treatment	Refer to Table 3-J for evaluation of ex situ treatment technologies.								
Disposal Actions	Refer to Table 3-L for evaluation of disposal actions.								

Notes:
Shaded process options have been screened out.
Identification of copyrighted, patented, or trademarked names does not signify endorsement.

Effectiveness		Implementability		Cost	
●	Satisfies effectiveness criteria	●	Feasible to implement	●	Low cost compared to other options within the same technology type
⌖	Satisfies some, but not all, criteria	⌖	May be feasible to implement	⌖	Moderate cost compared to other options within the same technology type
○	Does not satisfy effectiveness criteria	○	Unfeasible to implement	○	High cost compared to other options within the same technology type

Explanation of Evaluation Criteria

- Effectiveness (primary focus) includes:
  - — Potential effectiveness in handling the areas/volumes of media or recovering contaminated media and meeting remediation goals,
  - — Potential impacts to human health and environment during construction and implementation phase, and
  - — How proven and reliable the process is with respect to site contaminants and conditions.
- Implementability includes:
  - — Technical feasibility (e.g., availability of TSD and adequate capacity, availability of equipment and workers) and
  - — Administrative feasibility (e.g., ability to obtain permits).
- Cost includes:
  - — Capital cost and
  - — O&M cost.

Table C4-9. Evaluation of Remedial Technologies and Process Options For Regional Gravel Aquifer (60 to 100 feet deep) and McNairy (> 100 feet deep) Groundwater

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
No Action	None	Not Applicable	○	●	NA	●	●	●	●
			Option does not achieve RAQ. Option poses no short-term risks.			No action involved with this option; therefore, it is technically and administratively feasible to implement.		Option requires minimal ("baseline") or no cost.	
Institutional Actions	Access Restrictions	Deed Restrictions	●	●	●	●	●	●	●
			Option applicable to all volumes and contaminants, but provides no contaminant reduction. Option produces no short-term impacts. Option is proven and reliable for restricting access.			Option is technically and administratively feasible to implement. Option may require approval by the public.		Option requires relatively little capital to implement and little or no O&M, compared to other access restriction technologies.	
		Site Protection/Security	●	●	●	●	●	⊕	○
			Option applicable to all volumes and contaminants, but provides no contaminant reduction. Option produces no short-term impacts. Option is proven and reliable for restricting access.			Option is technically and administratively feasible to implement. A full security program is already implemented at the PGDP.		Option requires relatively high capital to implement and significant O&M, compared to other access restriction technologies.	
		Physical Barriers/Restrictions	●	●	●	●	●	○	⊕
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option may produce minimal short-term impacts. Option is proven and reliable for restricting access.			Option is technically and administratively feasible to implement. Physical barriers are already implemented at the PGDP (i.e., a security fence surrounds the entire PGDP).		Option requires relatively high capital to implement and moderate O&M, compared to other access restriction technologies.	
	Administrative Options	Alternate Concentration Limits (ACLs)	⊕ ●	⊕		●		⊕	⊕
			Option applicable to limited volumes of dissolved phase contamination. Option may produce limited short-term impacts. Provenness and reliability may be questionable for use in the RGA; prospects may be better in the McNairy.			Option does not appear to be technically implementable throughout the RGA; may be technically implementable in the McNairy. Option should be administratively implementable.		Will require groundwater monitoring.	
		Technical Impracticability (TI) Waivers	●	●	●	●	⊕	⊕	⊕
			Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option would not provide short-term impacts during "implementation." Option is proven and reliable.			Option likely to be used only as a contingency action.		Will require groundwater monitoring.	

Table C4-9. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Institutional Actions (Continued)	Monitoring	Water Monitoring	● Option applicable to all volumes, media, and contaminants, but provides no contaminant reduction. Option may produce minimal short-term impacts, depending upon the level of construction required. Option is proven and reliable for evaluating groundwater and/or surface water characteristics, contaminants, and trends.	●	●	● Option is technically and administratively feasible to implement. Routine groundwater and surface water monitoring is conducted at the PGDP.	●	⊕ Option may require relatively moderate to high capital to implement and moderate to high O&M. Cost is dependent upon the number of samples and analyses conducted.	⊕
Groundwater Containment Actions	Subsurface Vertical Barriers	Slurry/Grout Walls	● Option applicable to all volumes, media, and contaminants. Various installation methods exist; installation of a vertical barrier into the RGA/McNairy could produce significant short-term impacts, depending upon the installation method. Although this option is proven and reliable for reducing horizontal migration of groundwater and dissolved contaminants, this option is unproven at depths > 60 feet, and the continuity of a deep installation may be questionable.	⊕	⊕	● Option is technically and administratively feasible to implement; however, installation near underground utilities may require significant design consideration. Option is commercially available from several vendors that may be capable of installation to depths > 100 feet.	●	○ Capital costs may range from $15 to $300/ft^2 (*DOE, 1993a, ORNL Technology Logic Diagram, Vol 1, Pt B, ORNL Technology Logic Diagram, Vol 1, Pt B*). Costs are likely to be greater for depths > 60 feet. Option may generate wastes that require additional handling and disposal. Other than use of groundwater monitoring to evaluate effectiveness, this option requires minimal O&M.	●
		Sheet Piling	⊕ Option applicable to all volumes, media, and contaminants. Installation of a vertical barrier into the RGA/McNairy using pile driving or vibratory hammer methods will produce less waste than installation of slurry/grout walls. Although this option is proven and reliable for reducing horizontal migration of groundwater and dissolved contaminants, this option is unproven at depths > 60 feet, and the hydraulic integrity of joints in a deep installation may be of concern.	⊕	○	○ Option is administratively feasible to implement; however, installation near underground utilities may require significant design consideration. Option is commercially available from several vendors that may be capable of installation to depths > 100 feet, however, installation of sheet piling into/through the RGA has proven nearly impossible.	⊕	○ Capital costs may range from $30 to $40/ft^2 (*DOE, 1993a, ORNL Technology Logic Diagram, Vol 1, Pt B, ORNL Technology Logic Diagram, Vol 1, Pt B*). Costs are likely be greater for depths > 60 feet. Other than use of groundwater monitoring to evaluate effectiveness, this option requires minimal O&M.	●

Table C4-9. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Groundwater Containment Actions (Continued)	Subsurface Vertical Barriers (Continued)	Polyethylene Wall	⊕	⊕	●	⊕	●	○	●
			Option applicable to all volumes, media, and contaminants. Installation requires use of trenching/excavation techniques; installation of a vertical barrier into the RGA/McNairy could produce significant short-term impacts, depending upon the installation method. Although this option is proven and reliable for reducing horizontal migration of groundwater and dissolved contaminants, this option is unproven at depths > 40 feet. Continuity of poly walls may be better than other subsurface barriers.			Option is technically and administratively feasible to implement; however, installation near underground utilities may require significant design consideration. Option is commercially available from vendors that may be capable of installation to depths > 100 feet. Option may require a bottom seal (e.g., bentonite) to minimize underflow.		Capital costs may range from \$12 to \$45/ft^2 *(Gundwall)*. Costs are likely to be greater for depths > 40 feet. Option may generate wastes that require additional handling and disposal. Other than use of groundwater monitoring to evaluate effectiveness, this option requires minimal O&M.	
		Cryogenic Barriers	⊕	⊕	●	●		○	○
			Option applicable to all volumes, media, and contaminants. Installation requires use of augering/excavation techniques and high electrical power usage; installation of a barrier into the RGA/McNairy could produce significant short-term impacts, depending upon the installation method. Although this option is proven and reliable for reducing horizontal migration of groundwater and dissolved contaminants, this option is unproven at depths > 40 feet.			Option is technically and administratively feasible to implement; however, installation near underground utilities may require significant design consideration. Option is commercially available from vendors that may be capable of installation to depths > 100 feet. May be more effective as an interim action.		Capital costs may be higher than other containment walls. Costs are likely to be greater for depths > 40 feet. Active operation requires relatively high O&M costs which are greaer than all other alternatives.	

Table C4-9. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Groundwater Containment Actions (Continued)	Subsurface Vertical Barriers (Continued)	Bio-barrier	⌖	●	○	○	⌖	○	○
			Option may be applicable to all volumes, media, and contaminants. Requires installation of injection system for implementation, which may generate wastes and could produce minimal short-term impacts. Although this option is effective for reducing horizontal migration of ground water and dissolved contaminants, this option is unproven at depths > 20 feet. Microbes susceptible to high concentrations of VOCs. Option may not be effective in the RGA.			Option has not been installed > 20 feet deep, and high VOC or metals may affect microorganisms adversely; therefore, option may not be technically feasible; therefore, option may not be technically feasible to implement. Option may be considered administratively feasible to implement. Option is commercially available from vendors that may be capable of installation to depths > 100 feet. Option may be better suited for formations with smaller pore sizes and lower flow velocities (e.g., UCRS). Option has not been utilized for environmental applications (i.e., oil field use only).		Capital costs may be higher than all except the cryogenic barrier due to preliminary – engineering requirements. Costs are likely to be greater for depths > 20 feet. Installation may generate wastes that require additional handling and disposal. Active operation requires relatively high O&M costs. Other than use of groundwater monitoring to evaluate effectiveness, this option requires minimal O&M.	
	Hydraulic Containment	Hydraulic Containment	●	⌖	●	●	●	⌖	○
			Option applicable to all volumes, media, and contaminants. With the exception of installing additional groundwater extraction wells or monitoring wells, no significant short-term impacts expected. Proven effective at controlling migration of groundwater and dissolved phase contaminants using pump and treat technology. Effectiveness in the McNairy Formation is less certain due to the low hydraulic conductivity of the formation. The overall effectiveness depends on the design and operation of the system (injection wells can be utilized to enhance effectiveness).			Option is technically and administratively feasible to implement (in the RGA using pump and treat technology). Option may be operated indefinitely or until contaminant sources are removed/depleted. Materials necessary for implementation are readily available.		Typically low to moderate capital cost and high O&M cost due to the long-term operations needed to maintain and verify containment.	

Table C4-9. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Removal Actions (Groundwater and/or Contaminant)	Extraction	In-well Stripping [includes: UVB; No VOCs]	⊕ Option applicable to all volumes and media. Option applicable to VOCs; option not effective for metals or radionuclides. With the exception of installing additional groundwater extraction wells or monitoring wells, no significant short-term impacts expected. Option has been used at several sites, but is less-proven than P&T.	⊕	⊕	● Option is technically and administratively feasible to implement. (Installation near underground utilities should not require significant design modifications.) Option is commercially available from vendors. May be useful for source control, but not source (DNAPL) removal.	●	⊕ Capital costs may range from $50K to 120K per well (*EG&G*). Operations may generate wastes during installation that require additional handling and disposal. Operations require moderate O&M (including electricity to power the pumps). O&M may be less than for pump-and-treat.	⊕
		Electrokinetics (including Lasagna™)	⊕ Option applicable to all volumes. Option effective for moving groundwater with dissolved contaminants in fine-grained soil such as the McNairy Formation; technology would be ineffective in the RGA. Option applicable to VOCs (including DNAPL), metals, and/or radionuclides. Some short-term impacts expected; degree of impact is dependent upon installation methods. The Lasagna™ electroosmosis technology has been demonstrated at the PGDP in the UCRS (i.e., < 50 feet deep).	○	○	○ Although implementability in shallow soils (< 50 ft deep) is proven, installation in the McNairy Formation may require fracturing technologies to emplace electrodes and in the situ treatment zones (for Lasagna™ Standard electroosmosis may be implementable by installing electrodes in well bores that allow contaminated groundwater to be pumped to the surface for treatment. Therefore, this option is believed to be technically feasible to implement. Option may be considered administratively feasible to implement. Standard electroosmosis is commercially available.	●	○ Option requires low to moderate capital and low O&M costs, but costs are dependent on the energy supply and duration of remediation time. Costs may range from $20 to $225/yd³ (GWRTAC, Electrokinetics, TO-97-03, July 1997; also Draft *Rapid Commercialization Initiative Verification Statement for Lasagna™*, undated). Option may generate wastes during installation that require additional handling and disposal.	⊕

Table C4-9. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Removal Actions (Groundwater and/or Contaminant) (Continued)	Extraction (Continued)	"Pump and Treat"	⊕	⊕	●	●	●	⊕	○
			Option applicable to all volumes and contaminants (including DNAPL). Minimal short-term impacts expected during implementation. Extensive time may be required to achieve remedial goals. Option proven and utilized at > 90% of Superfund sites with groundwater contamination, including two interim actions at the PGDP.			Option is technically and administratively feasible to implement. Option may be operated indefinitely or until contaminant sources are removed/depleted. Materials necessary for implementation are readily available. Two pump and treat projects are being conducted at the PGDP. Option useful for source control, but source (DNAPL) removal.		Capital costs may range from < $50 to $100 *(Evaluation of Technologies for In-situ cleanup of DNAPL Contaminated Sites, EPA/600/R-94/120, August 1994)*. Costs are likely to be greater for depths > 60 feet. Installation of this option may generate wastes that require additional handling and disposal. Current pump and treat O&M costs at the PGDP range from $5/1,000 gal water treated (Northeast Plume facility) to $16/1,000 gal water treated (Northwest Plume facility) *(B. Ford 4/19/99 telephone call to D. Jolly, BJC)*.	
		In Situ Steam Injection/Vacuum Extraction (including Dynamic Underground Stripping)	⊕	⊕	⊕	⊕	●	⊕	⊕
			Option applicable to all volumes, dissolved contaminants, and DNAPL. Option effective in permeable zones, and it may achieve remedial objectives in clay zones, also. Option may achieve remedial action objectives quicker than other options. Moderate short-term impacts related to use of steam are expected during implementation. Option demonstrated at three to four sites with favorable results on dissolved phase and NAPL contaminants.			Option is technically and administratively feasible to implement; however, installation near underground utilities may require significant design consideration. Steam injection option is commercially available for several vendors; DUS option is available from two licensed vendors. Most appropriate for source zone reduction; may not be cost-effective for dissolved-phase plumes.		Option may require relatively high capital and O&M costs, but the high costs may be offset by a shorter remediation time frame. Costs may range from $46 to $166/yd^3 (EPA, 1997, *Analysis of Selected enhancements for SVE*). Option may generate wastes during installation that require additional handling and disposal.	

Table C4-9. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Removal Actions (Groundwater and/or Contaminant) (Continued)	Extraction (Continued)	Six-Phase Soil Heating	⊕	⊕	O	O	●	⊕	⊕
			Option applicable to all volumes. Option is effective for extraction of VOCs from low-permeability zones, but ineffective for metals and radionuclides. Moderate short-term impacts may be expected during implementation due to safety concerns associated with use of high voltages. Option has been demonstrated in unsaturated and saturated soils. Option may be used in a flowing aquifer, but cost-effectiveness is reduced as the depth below the water table is increased.			Option may be technically and administratively feasible to implement; however, installation near underground utilities may require significant design consideration. Option is commercially available from one licensed vendor. Option has not been installed to depths > 40 ft.		Low to moderate capital and O&M costs, but may be offset by a shorter remediation time frame. Costs may range from $40 to $99 yd^3, including treatment of secondary wastes (*Initiatives Online,* Vol. 5, Spring 1998), but may increase with depth. Option likely is not cost effective in the RGA or McNairy, since it would involve high energy requirements to adequately heat the aquifer and contaminants.	
		Microwave	Option unproven, and effectiveness is unknown. Option is not available commercially.			Vendor, equipment, and experts are unavailable.		Cost information is unavailable.	
	Secondary/ Enhanced Recovery	Waterflooding or Injection	⊕	⊕	⊕	●	●	⊕	⊕
			Option applicable to all volumes and contaminants except DNAPL. Minimal short-term impacts expected during implementation, but extensive O&M period may be required. Option likely incapable of achieving remedial goals. Hydraulic conductivity of the RGA may be too great for this option to be effective. Option considered proven and reliable.			Option is technically and administratively feasible to implement. Materials necessary for implementation are readily available.		Capital costs may range from $75 to $125 (*Evaluation of Technologies for In-situ cleanup of DNAPL Contaminated Sites,* EPA/600/R-94/120, August 1994). This option may generate wastes that require additional handling and disposal.	

Table C4-9. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Removal Actions (Groundwater and/or Contaminant) (Continued)	Secondary/ Enhanced Recovery (Continued)	Surfactant Flooding and Pumping	⌖ Option applicable to al columns. Pumping applicable for all contaminants, but surfactant flooding is specific to VOCs (including DNAPL). Minimal short-term impacts expected during implementation. Option not fully proven. Treatability testing may be required to ensure that the selected surfactant does not react adversely with the McNairy Formation.	⌖	⌖	⌖ Option is technically and administratively feasible to implement. Option is commercially available from a limited number of vendors. Option requires permits for inject for surfactants.	⌖	⌖ Capital costs may range from $75 to $125 (*Evaluation of Technologies for In-situ cleanup of DNAPL Contaminated Sites*, EPA/600/R-94/120, August 1994). This option may generate wastes that require additional handling and disposal.	O
		Polymer Waterflooding and Pumping	⌖ Option applicable to all volumes and media (including DNAPL). Minimal short-term impacts expected during implementation. Option not fully proven; it appears to have been demonstrated at only one environmental project.	⌖	O	O Option not commercially available from vendors may be limited. Option is administratively feasible to implement. Option requires permits for injection of polymer(s).	⌖	⌖ Costs are unavailable. This option may generate wastes that require additional handling and disposal.	O
		Chemically Enhanced Dissolution and Pumping (Cosolvents)	⌖ Option applicable to all volumes. Pumping applicable for all contaminants, but cosolvents are effective only for VOCs (including DNAPL). Minimal short-term impacts expected during implementation. Option not fully proven. Treatability testing is suggested.	⌖	O	⌖ Option not commercially available; vendors may be limited. Option is administratively feasible to implement. Option requires permits for injection of cosolvents.	⌖	⌖ Capital costs may range from $75 to $125 (*Evaluation of Technologies for In-situ cleanup of DNAPL Contaminated Sites,* EPA/600/R-94/120, August 1994). This option may generate wastes that require additional handling and disposal.	O
In Situ Groundwater Treatment	Physical/ Chemical Treatment	Solidification/ Stabilization	⌖ Option uses several methods that could be applied to all contaminants. NAPL could limit effectiveness. Carbonate-based gravel could mobilize certain radionuclides (e.g., uranium). Possible limitations in areas of buried materials. Produces some opportunity for worker exposure. Most methods are proven and reliable. May not be effective in the RGA.	⌖	⌖	⌖ Technical feasibility in RGA is questionable. Option is administratively feasible.	●	⌖ Greater than $70/m^3 (DOE, 1993b, ORNAL Technology Logic Diagram, Vol 2, Pt b) to $150/yd^3 (DOE, 1993a, ORNL Technology Logic Diagram, Vol 1, Pt B, ORNL Technology Logic Diagram, Vol 1, Pt B).	●

Table C4-9. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
In Situ Groundwater Treatment (Continued)	Physical/ Chemical Treatment (Continued)	Hydrous Pyrolysis/ Oxidation	●	⊕	⊕	⊕	●	●	●
			Requires installation of injection network and electrodes; potential for generation of contaminated wastes. Case study indicates very high effectiveness for removing residual contamination. Option used at only two sites.			Innovative technology which has only be assessed empirically. Has not been evaluated without implementing DUS at same site. Requires a relatively dense strata to ensure thermal acceleration of media and entrapment of condensate.		< $20 per cubic yard (Faster Cleanup of Contaminated Soil and Groundwater, *Science & Technology Review*, May 1998); potential for no O&M costs. Option patented by LLNL.	
		Permeable Treatment Walls	●	●	⊕	●	●	⊕	●
			Option available to all groundwater volumes and many contaminants. Few short-term impacts. Technology is proven and generally reliable, but some problems with long-term effectiveness may exist. Geochemical and biological concerns may limit effectiveness. TS is being conducted in FY 2000 at Southwest Plume site.			Technology is technically and administratively feasible.		Capital and O&M costs are comparable to other *in situ* physico-chemical technologies. Costs have wide range from < $2/SF to > $30/SF	
		In Situ Chemical Treatment (Oxidation)	⊕	⊕	⊕	⊕	⊕	⊕	⊕
			Effective for dissolved phase TCE. Not effective for DNAPL. Not effective for ^{99}Tc. Potential concern regarding possible reactions with organic carbon in the McNairy.			Requires injection of oxidant into aquifer(s).		Low Capital and intensive O&M.	
		Ozone Injection (C-Sparge)	⊕	●	●	●	●	●	●
			Effective for dissolved phase TCE. Not effective for DNAPL. Not effective for ^{99}Tc, vendor claims add-on option can treat ^{99}Tc.			Technically and administratively feasible.		Low capital and O & M	
		Sodium Dithionate Injection	⊕	O	O	⊕	O	⊕	O
			Effective for ^{99}Tc, but unproven. Not applicable for DNAPL. Reaction may be reversible.			Option believed to be technically feasible. Option requires permits for injection of reducing agent.		Option patented by PNNL. Commercial costs unavailable.	
	Biological Treatment	Monitored Natural Attenuation	⊕	●	⊕	⊕	⊕	⊕	●
			Ineffective for ^{99}Tc or DNAPLs. Not effective for removing VOCs from the RGA. Additional site characterization would be required to determine if it is able to address low concentrations of TCE in the McNairy .			Implementable. Requires additional groundwater monitoring data to define decay rates and to monitor effectiveness. MNA accepted by EPA, but never used in Kentucky.		Low capital and low to moderate O&M costs associated with long-term groundwater monitoring. Extensive monitoring and modeling required.	

Table C4-9. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
In Situ Groundwater Treatment (Continued)	Biological Treatment (Continued)	*In Situ* Biodegradation	● Both co-metabolic and anaerobic biodegradation are effective in removing TCE from the groundwater. UCRS without DNAPL is a prime target, but RGA or McNairy could be another target. Anaerobic bioremediation will require larger quantities of electron donor to render RGA anaerobic and provide environment for degradation of TCE. Technology will not remove metals or radioactive contaminants.	●	⌖	● Technology is implementable with appropriate approvals and UIC permits or approvals.	●	● Costs are uncertain due to limited information on Anaerobic Bioremediation. Costs for similar operations at Dover AFB and INEEL TEN North Site are not yet published.	⌖
		Bio-sparging	⌖ Co-metabolic, see above for TCE.	●	⌖	⌖ See above	⌖	⌖ See above	⌖
Ex Situ Groundwater Treatment	Refer to Table 3-E for identification of *ex situ* groundwater treatment technologies								
Disposal Action	Refer to Table 3-L for evaluation of disposal actions.								

Notes:
Shaded process options have been screened out.
Identification of copyrighted, patented, or trademarked names does not signify endorsement.

Effectiveness		Implementability		Cost	
●	Satisfies effectiveness criteria	●	Feasible to implement	●	Low cost compared to other options within the same technology type
⌖	Satisfies some, but not all, criteria	⌖	May be feasible to implement	⌖	Moderate cost compared to other options within the same technology type
○	Does not satisfy effectiveness criteria	○	Unfeasible to implement	○	High cost compared to other options within the same technology type

Table C4-9. (continued)

Explanation of Evaluation Criteria
• Effectiveness (primary focus) includes: — Potential effectiveness in handling the areas/volumes of media or recovering contaminated media and meeting remediation goals, — Potential impacts to human health and environment during construction and implementation phase, and — How proven and reliable the process is with respect to site contaminants and conditions. • Implementability includes: — Technical feasibility (e.g., availability of TSD and adequate capacity, availability of equipment and workers) and — Administrative feasibility (e.g., ability to obtain permits). • Cost includes: — Capital cost and — O&M cost.

Table C4-10. Evaluation of Remedial Technologies and Process Options for *Ex Situ* Treatment Technologies for Soils and Solids

General Response Actions	Remedial Technology Types	Process Options	Effectiveness			Implementability		Cost	
			Volumes, Media, & Rem. Goals	Short-term Impacts	Provenness & Reliability	Technical Feasibility	Administrative Feasibility	Capital Cost	O&M Cost
Ex Situ Treatment	Solids Handling	Magnetic Processes, Crushing and Grinding, Shredding and Chipping, and Screening	⌖	○	⌖	●	●	⌖	⌖
			Option available for soils and other solids in conjunction with excavation. Worker exposure could result during handling; erosion of material could occur. Waste segregation elsewhere has increased waste volumes. Option not proven for most waste areas.			Option is technically and administratively feasible. Would require a large, secure area as a staging and processing area.		Capital costs for equipment and labor; O&M on equipment and residual material are comparable or higher compared to other *ex situ* treatment technologies.	
	Solids Dewatering	Gravity Settling, Filter Press, Dewatering Beds, Belt Filters, Vacuum Filtration, Centrifuges	⌖	⌖	●	⌖	●	⌖	⌖
			Option available for soils and semisolids in conjunction with excavation to segregate saturated wastes. Worker exposure could result during handling. Option requires long time intervals in clayey soils.			Option is technically feasible. May be difficult for large waste volumes. Option is administratively feasible.		Moderate capital costs. O&M costs are comparable to other *ex situ* treatment technologies.	
	Physical Separation	Screening, Classification, Gravity Concentration, Magnetics	⌖	⌖	●	●	●	●	⌖
			Option available for saturated soils and solids and most contaminants. Also applicable for NAPL in groundwater. Worker exposure could occur for manual methods. Option is proven and effective for most material.			Option is technically and administratively feasible to implement.		Capital costs are low compared to other *ex situ* technologies. Labor intensive operation results in moderate O&M costs.	
	Physical/ Chemical Separation	Solidification/ Stabilization	⌖	●	●	●	●	⌖	⌖
			Option available for most volumes, media, and many contaminants; however there is no volume reduction. Option is largely proven but long-term effectiveness is uncertain.			Option is technically and administratively feasible for most applications.		Capital and O&M costs comparable to other *ex situ* separation technologies.	
		Chemical Extraction (Solvent Extraction)	⌖	⌖	●	⌖	⌖	⌖	⌖
			Option available for most small to medium volumes, some media, and certain contaminants. Could increase waste volumes. Possible worker exposure and site impacts. Option is proven and reliable for some wastes.			Technology unproven for many of these applications. Technology may be administratively difficult due to permitting.		Capital costs are moderate to high, while O&M also could be high compared to other *ex situ* separation technologies.	
		Electrokinetic Removal	⌖	⌖	○	⌖	●	⌖	●
			Option available for most small to medium volumes some media, and certain contaminants. Possible worker exposure and site impacts. Option is not proven or known to be reliable in this environment.			Technology unproven for many of these applications. Technology is administratively feasible.		Capital costs are moderate to high, while O&M can be quite low compared to other *ex situ* separation technologies.	

Table C4-10. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Ex Situ Treatment (Continued)	Physical/ Chemical Separation (Continued)	Soil Washing/Leaching	⊕	⊕	●	⊕	●	⊕	⊕
			Option available for small to medium volumes, and the most critical media (soil, sediment and some sludges). Could result in increased waste volumes. Could result in worker exposure. Operation is proven and reliable.			Technology is not proven for all materials, but is feasible. Option is administratively feasible but leachate may have permitting issues.		Capital costs and O&M are comparable to or lower than other *ex situ* separation technologies. O&M costs can be high due to long processing times.	
		Dechlorination: Glycolate/Base-catalyzed	⊕	⊕	⊕	⊕	⊕	⊕	⊕
			Option available for small to medium volumes, and most media. Applicable only to constituents that benefit from dehalogenation (i.e., solvent-related organics, PCBs, dioxin, etc.). Could result in worker exposure. Option is unproven for large volumes.			Technology is feasible for limited applications. Handling of highly toxic material could generate permitting issues.		Capital and O&M costs are comparable to other *ex situ* separation technologies.	
		Chemical Reduction-Oxidation	⊕	⊕	●	●	⊕	⊕	⊕
			Option available for small to medium volumes, most media. Typically used for organics. Could result in worker exposure.			Technology is technically feasible. Permitting may be problematic.		Capital and O&M costs are comparable to other *ex situ* separation technologies.	
	Biological Treatment	Biodegradation: Composting (Land-farming)	⊕	⊕	⊕	●	●	●	⊕
			Option available for small to medium volumes of some soils/sludges contaminated with organics. Option not proven or reliable for all wastes.			Technology is technically and administratively feasible.		Capital costs are relatively low compared to other biological treatment technologies. Moderate O&M costs due to long time frames.	
		Biodegradation: Slurry-Phase Treatment	⊕	⊕	⊕	●	●	⊕	⊕
			Option available for small to medium volumes of some soils/sludges contaminated with organics. Option not proven or reliable for all wastes.			Technology is technically and administratively feasible.		Capital and O&M costs are comparable with other *ex situ* biological technologies.	
	Thermal Treatment	Incineration	⊕	⊕	●	●	⊕	⊕	⊕
			Option available for most volumes of soils/sludges contaminated with organics, metals, and radionuclides. Could cause worker exposure. Option is proven and reliable.			Technology is technically and administratively feasible. Permitting may be difficult.		Capital costs are moderate compared to other *ex situ* thermal technologies. O&M high due to fuel costs and monitoring requirements.	
		Pyrolysis	⊕	⊕	●	●	⊕	⊕	⊕
			Option available for small to medium volumes of some soils/sludges contaminated with organics. Option is proven and reliable.			Technology is technically and administratively feasible. Permitting may be difficult.		Capital and O&M costs are comparable with other *ex situ* thermal technologies.	

Table C4-10. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Ex Situ Treatment (Continued)	Thermal Treatment (Continued)	Thermal Desorption	⌖	●	●	●	●	●	●
			Option available for most volumes of soils and sludges contaminated with organics and volatile metals. Option is proven and reliable.			Technology is technically and administratively feasible.		Capital and O&M costs are lower compared to other *ex situ* thermal technologies.	
		Vitrification (*ex situ*)	⌖	⌖	●	●	●	○	●
			Option available for smaller volumes, solid or semisolid media, and all contaminants. NAPL could limit effectiveness. Carbonate-based gravel could release certain radionuclides (e.g., uranium). Technology produces manageable short-term impacts and is proven and reliable.			Technology is technically and administratively feasible.		High capital and O&M costs compared to other *ex situ* thermal technologies. O&M includes power consumption and disposal/ storage of monoliths.	

Notes:
Shaded process options have been screened out.
Identification of copyrighted, patented, or trademarked names does not signify endorsement.

Effectiveness		Implementability		Cost	
●	Satisfies effectiveness criteria	●	Feasible to implement	●	Low cost compared to other options within the same technology type
⌖	Satisfies some, but not all, criteria	⌖	May be feasible to implement	⌖	Moderate cost compared to other options within the same technology type
○	Does not satisfy effectiveness criteria	○	Unfeasible to implement	○	High cost compared to other options within the same technology type

Explanation of Evaluation Criteria

- Effectiveness (primary focus) includes:
  - — Potential effectiveness in handling the areas/volumes of media or recovering contaminated media and meeting remediation goals,
  - — Potential impacts to human health and environment during construction and implementation phase, and
  - — How proven and reliable the process is with respect to site contaminants and conditions.
- Implementability includes:
  - — Technical feasibility (e.g., availability of TSD and adequate capacity, availability of equipment and workers) and
  - — Administrative feasibility (e.g., ability to obtain permits).
- Cost includes:
  - — Capital cost and
  - — O&M cost.

Table C4-11. Evaluation of Presumptive Technologies for Treatment of Extracted Groundwater

General Response Actions	Remedial Technology Types	Process Options	Effectiveness, Implementability, and Cost Screening Comments
Ex Situ Treatment Actions	Physical/Chemical/ Biological Treatment	Air Stripping	This is a presumptive technology for treatment of extracted groundwater. The *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996, constitutes this phase of the screening for this process option.
		Granular Activated Carbon	This is a presumptive technology for treatment of extracted groundwater. The *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996, constitutes this phase of the screening for this process option.
		Chemical/UV Oxidation	This is a presumptive technology for treatment of extracted groundwater. The *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996, constitutes this phase of the screening for this process option.
		Aerobic Biological Reactors	This is a presumptive technology for treatment of extracted groundwater. The *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996, constitutes this phase of the screening for this process option.
		Chemical Precipitation	This is a presumptive technology for treatment of extracted groundwater. The *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996, constitutes this phase of the screening for this process option.
		Ion Exchange/Adsorption	This is a presumptive technology for treatment of extracted groundwater. The *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996, constitutes this phase of the screening for this process option.
		Electrochemical Methods	This is a presumptive technology for treatment of extracted groundwater. The *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996, constitutes this phase of the screening for this process option.
		Aeration of Background Metals	This is a presumptive technology for treatment of extracted groundwater. The *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996, constitutes this phase of the screening for this process option.
		Membrane Separation	This is a presumptive technology for treatment of extracted groundwater. The *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance,* EPA 540/R-96/023, October 1996, constitutes this phase of the screening for this process option.

Table C4-11. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness, Implementability, and Cost Screening Comments
Pretreatment Actions	Solids Dewatering	Gravity Settling, Filter Press, Dewatering Beds, Belt Filters, Vacuum Filtration, Centrifuges, *In Situ* Dewatering	These pre-treatments are retained as-needed to support other ex situ treatment process options.
	Physical Separation	Screening, Classification, Gravity Concentration, Coagulation/Flocculation, Magnetic separation	These pre-treatments are retained as-needed to support other ex situ treatment process options.
	Physical/Chemical Treatment	Neutralization	This pre-treatment is retained as-needed to support other ex situ treatment process options.
		Solidification/Stabilization	This pre-treatment is retained as-needed to support other ex situ treatment process options.

Notes:
Shaded process options have been screened out.
Identification of copyrighted, patented, or trademarked names does not signify endorsement.

Table C4-12. Evaluation of Remedial Technologies and Process Options for Disposal Actions

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Disposal Actions	On-Site Disposal	Permitted Facility	⊕	●	●	●	●	●	●
			The only on-site permitted disposal facility at PGDP is the C-746-U Landfill. Only non-RCRA hazardous and low-level waste containing less that 30 pCi/g uranium are allowed to be disposed. May not be applicable for media with ≥ 30 pCi/g radionuclides.			Disposal at this facility is technically and administratively feasible. But applicable only to a narrow range on contaminant concentrations.		Low cost compared to other disposal actions.	
		Constructed Disposal Cell	⊕	●	●	○	⊕	○	○
			Effective for all volumes, media, and contaminants (depending on construction). Construction should have few short-term impacts if located outside main plant area. Constructed cells are proven and reliable.			Facility does not exist. Could be implementable but will require extensive permitting. Public opposition may delay or halt construction of facility. May not be cost effective.		High cost compared to other disposal actions.	
	Off-Site Disposal	RCRA Facility	⊕	⊕	●	●	●	○	NA
			Effective for disposal of RCRA Hazardous Waste. Not suitable for most radionuclides or TSCA wastes. May cause worker or public exposure from transport. RCRA landfills are proven and reliable.			Technologically and administratively feasible. Transport requires additional permitting.		High cost compared to other disposal actions.	
		TSCA Facility	⊕	⊕	●	●	⊕	○	NA
			Applies only to TSCA wastes. Threat of worker or public exposure during loading and transport. Technology is proven and reliable.			Technologically and administratively feasible. Transport requires additional permitting.		High cost compared to other disposal actions.	
		(Low-Level) Radioactive Waste Facility	⊕	⊕	●	●	⊕	⊕	NA
			Effective disposal for low-level wastes comprising most media. Worker and public exposure is possible during transport. Technology is proven and reliable.			Substantial waste volumes could be disposed of in such a facility. Transport requires additional permitting.		Moderately high cost compared to other disposal actions.	
		Mixed-Waste Facility	●	⊕	●	●	●	○	NA
			Effective for disposal of waste containing TCE, PCBs, and low-level constituents. This includes solids, stabilized sludges, soils, building rubble, concrete, ash, and asbestos. Potential worker/public exposure during transport. Proven and reliable option.			Substantial waste volumes could be disposed of in such a facility. Transport requires permits from all affected states.		Very high cost compared to other disposal actions.	

Table C4-12. (continued)

General Response Actions	Remedial Technology Types	Process Options	Effectiveness: Volumes, Media, & Rem. Goals	Effectiveness: Short-term Impacts	Effectiveness: Provenness & Reliability	Implementability: Technical Feasibility	Implementability: Administrative Feasibility	Cost: Capital Cost	Cost: O&M Cost
Disposal Actions (Continued)	Interim Storage	On-Site Storage	⊕	⊕	●	⊕	●	⊕	⊕
			Does not provide final disposition of wastes. Large volumes could produce perception problems. Potential for worker exposure during implementation. Option is proven and reliable.			Interim storage facility currently unavailable. May require additional permitting.		Capital costs are comparable to other options. O&M includes inspection/ monitoring requirements.	

Notes:
Shaded process options have been screened out.
Identification of copyrighted, patented, or trademarked names does not signify endorsement.

Effectiveness		Implementability		Cost	
●	Satisfies effectiveness criteria	●	Feasible to implement	●	Low cost compared to other options within the same technology type
⊕	Satisfies some, but not all, criteria	⊕	May be feasible to implement	⊕	Moderate cost compared to other options within the same technology type
O	Does not satisfy effectiveness criteria	O	Unfeasible to implement	O	High cost compared to other options within the same technology type

Explanation of Evaluation Criteria

- Effectiveness (primary focus) includes:
  - Potential effectiveness in handling the areas/volumes of media or recovering contaminated media and meeting remediation goals,
  - Potential impacts to human health and environment during construction and implementation phase, and
  - How proven and reliable the process is with respect to site contaminants and conditions.
- Implementability includes:
  - Technical feasibility (e.g., availability of TSD and adequate capacity, availability of equipment and workers) and
  - Administrative feasibility (e.g., ability to obtain permits).
- Cost includes:
  - Capital cost and
  - O&M cost.

APPENDIX C5

ERRATTA SHEET

1) On page 8, paragraph 2, change

> "As an approximation, it is assumed that the mass of TCE is 190 l (50 gal)."
>
> to
>
> "As an approximation, it is assumed that the volume of TCE is 190 l (50 gal)."

2) On page 42, paragraph 1, change

> "The upgradient 100 mg/L (ppm) TCE isoconcentration contour appears to map the DNAPL source zones of the RGA. Moreover, the US Environmental Protection Agency recommends the use of 1% of the solubility of DNAPL (1% of the solubility of TCE is 110 mg/L) as an indication of DNAPL presence (EPA, 1992)."
>
> to
>
> "The upgradient 100 mg/L (ppm) TCE isoconcentration contour appears to map the DNAPL source zones of the RGA. Moreover, the US Environmental Protection Agency recommends the use of 1% of the solubility of DNAPL (1% of the solubility of TCE is 11 mg/L) as an indication of DNAPL presence (EPA, 1992)."

JE JACOBS ENGINEERING
Engineers and Constructors
Jacobs Engineering Group Inc.

MEMORANDUM

DATE: November 18, 1999 JE/PAD/99-0019

TO: Bryan Clayton, Bechtel Jacobs Company LLC

FROM: Bruce M. Ford Bruce Ford

SUBJECT: Task 116 — Waste Area Group 27 Trichloroethene Source Estimates

Attached is the final version of the *Waste Area Group 27 Trichloroethene Source Estimates*. These estimates were developed in support of the Groundwater Operable Unit (GWOU) Feasibility Study (FS) and incorporate comments from the GWOU FS team.

If you have any questions please contact me at (270) 462-2550.

Attachment

cc: Bruce Phillips, SAIC
Sarah Maudlin, SAIC
Document Control

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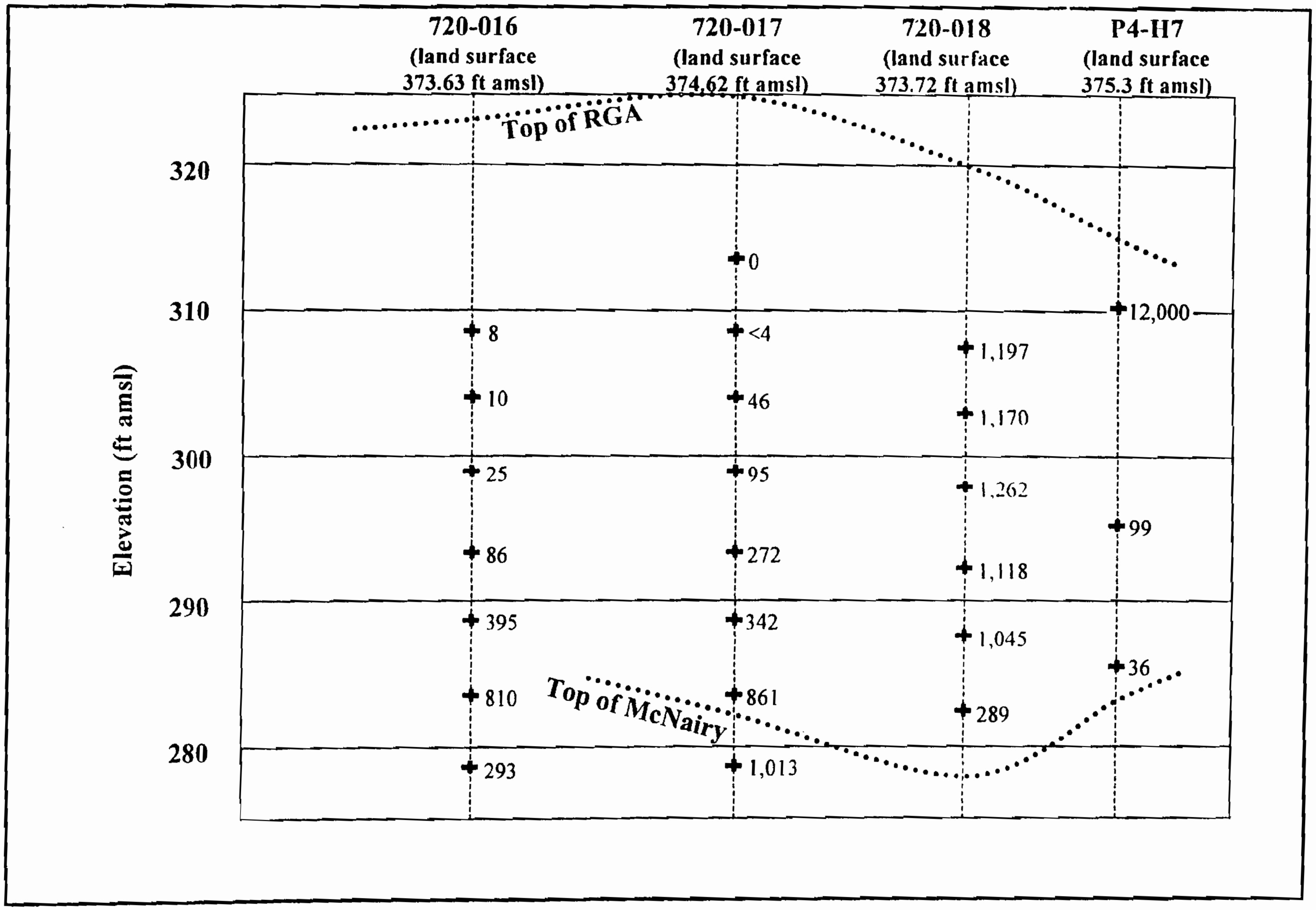

Figure 1. Trichloroethene Levels (µg/l) in the Regional Gravel Aquifer on the North Side of the C-720 Building

extent of elevated dissolved TCE levels indicates the DNAPL source zone is relatively small and restricted to the UCRS. (Similar trends associated with UCRS source zones occur at the C-400 Building.) Three process areas in the vicinity of Boring P4-H7 must be considered initially as the potential original source of the TCE DNAPL: C-409, C-720, and C-728.

The C-409 Stabilization Building is located approximately 68.6 m (225 ft) northeast of Boring P4-H7. C-409 Building activities included testing of waste handling processes. A TCE recovery system was housed in the building (but experienced little use). The building is designed to retain any spills from process leaks.

The WAG 27 RI Borings 720-029 and 720-030 are located immediately west of the C-409 Building. Soil and water samples from the borings indicate that only low concentrations of TCE exist in the subsurface of the C-409 area. Trichloroethene levels in all UCRS soil samples are less than the WAG 27 RI laboratory detection limits and the maximum dissolved TCE level in RGA water samples is 33 µg/l. Moreover, the RGA potentiometric surface in the C-720 Building area, as measured during the WAG 27 RI, shows the C-409 Building is cross-gradient to Boring P4-H7. Thus, the C-409 Building does not appear to be the source of TCE observed in Boring P4-H7.

The C-728 Motor Cleaning Facility is approximately 53.3 m (175 ft) northwest of Boring P4-H7. No use of TCE is reported in descriptions of C-728 facility processes. Mineral spirits were used as the cleaning agent; thus, it is unlikely that the C-728 Building is the source of TCE to an area DNAPL zone.

Boring P4-H7 is adjacent to an outside concrete pad that is contiguous with the C-720 Building. Anecdotal evidence suggests that machinery/equipment being brought into the C-720 Building for repair occasionally was cleaned (degreased) on the concrete pad prior to entry into C-720. Runoff of TCE, used as the degreasing agent, is a likely source of DNAPL in the vicinity of Boring P4-H7.

As part of the WAG 27 RI, Boring 720-027 sampled UCRS soils to a depth of 14.6 m (48 ft) [elevation 99.4 m (326 ft) amsl] adjacent to Boring P4-H7 [0.84 m (2.8 ft) to the west]. Sample analyses reveal elevated TCE levels beginning at a depth of 6.1 m (20 ft) that range up to 8,100 µg/kg. Well MW204 is screened in the UCRS and located approximately 30.5 m (100 ft) to the south. Analyses of dissolved TCE levels in MW204 range up to 320 µg/l. These data suggest that Boring P4-H7 is near the DNAPL source zone but not located within it. Soil concentrations within the heart of the DNAPL zone can be expected to be approximately 65,000,000 µg/kg (assuming 30% DNAPL saturation), declining to 10,000 µg/kg and less within a distance of 3 to 6.1 m (10 to 20 ft) (refer to Attachments 1 and 2). The dissolved TCE levels observed in MW204 are much less than expected of a UCRS DNAPL source zone. Characterization sampling of the Cylinder Drop Test DNAPL zone, for comparison, commonly revealed TCE concentrations of 300,000 µg/l in UCRS water samples.

For the purposes of estimating a source volume, the conceptual model of the DNAPL source is a small volume of TCE runoff from an undocumented degreasing operation on the C-720 concrete pad. In the conceptual model, the TCE runoff infiltrated over a small area at the edge of the concrete pad to the base of the HU2 horizon sands in the UCRS, where the interface with the underlying HU3 clay horizon would halt further migration.

Boring 720-018: 720-018 is located at the northwest corner of the same concrete pad. Table 2 presents the results of TCE analyses of water samples from the boring. The consistent dissolved TCE level throughout most of the RGA is difficult to interpret.

Contaminant trends in Boring P4-H7 and at the southwest and northeast corners of Building C-400 show that a UCRS DNAPL typically will result in elevated dissolved TCE levels only in the uppermost RGA. However, a DNAPL source distributed throughout most of the thickness of the RGA would be expected to result in much higher levels of dissolved TCE. The sample density in the C-720 area, and downgradient to the northwest, appears to be sufficient to rule out the occurrence of an undetected core of much higher dissolved TCE levels.

Table 2. Trichloroethene Analyses for Boring 720-018

Location	Elevation (m amsl)	Elevation (ft amsl)	TCE (μg/l)
Upper RGA	93.9	308	1197
Upper RGA	92.4	303	1170
Middle RGA	90.8	298	1262
Middle RGA	89.3	293	1118
Lower RGA	87.8	288	1045
Lower RGA	86.3	283	289

This apparent contradiction of source effects can be resolved in the context of the hydrology of the C-720 area. The subcrop of the Porters Creek Clay, which defines the southern extent of the RGA, occurs nearby and south of the C-720 Building. Most of the area south of the C-720 Building that overlies the RGA is paved. Thus, little area recharge to the RGA is realized south of the C-720 Building (upgradient of Boring 720-018) and little lateral throughflow is developed. In consequence, sources of recharge south of the C-720 Building "fan" across the thickness of the RGA.

The conceptual model to account for the dissolved TCE levels in Boring 720-018 is a DNAPL zone located in the UCRS and upgradient (via flow in the RGA) of the boring. This potential DNAPL source is restricted to the east side of the C-720 Building and most likely occurs south of the building.

The WAG 27 RI report identified a storm sewer exiting near the southeast corner of the C-720 building as a likely DNAPL source, based on TCE-in-soil levels observed in Boring 720-002. For the dissolved TCE contamination found in Boring 720-018, the conceptual model of the DNAPL source is a leak in the storm sewer system servicing the C-720 Compressor Shop Pit area, at the point where the storm sewer passes from beneath the building (adjacent to Boring 720-002). Because dissolved TCE concentrations in the RGA at Boring 720-018 do not approach levels that would be expected to be derived from an RGA source zone, it is assumed that the DNAPL migrated downward no further than the base of the HU2 sand horizon in the UCRS.

DNAPL Source Zone Volumes: C-720 Area

Boring P4-H7 Area: WAG 27 Boring 720-027, located adjacent to Boring P4-H7, sampled TCE levels in soils through the UCRS. Trichloroethene levels were highest in HU2 sandy silt and silty sandy gravel layers to a depth of 10.7 m (35 ft), elevation 103.6 m (340 ft) amsl. Table 3 summarizes the lithologic log and TCE analyses from Boring 720-027.

Two lines of evidence suggest the DNAPL mass is relatively small. The lack of significant TCE-in-soil levels at the Boring 720-027 location, adjacent to Boring P4-H7 (the presumed source area), demonstrates little lateral extent of the DNAPL zone. TCE-in-soil levels and the limited extent of the dissolved-phase plume indicate the DNAPL source is restricted to the UCRS. Apparently inadequate DNAPL mass was available to penetrate beyond a depth of 10.7 m (35 ft). The available data is insufficient to derive a mass or volume of the DNAPL source zone.

Table 3. Lithology and Trichloroethene Levels in Boring 720-027

DEPTH		ELEVATION		LITHOLOGY SUMMARY	TCE LEVELS (µg/kg)
(m)	(ft)	(m)	(ft)		
1.5-5.5	5-18	108.5-112.5	356-369	Silty clay	<900; <900; <900
6.1-7.0	20-23	107.0-107.9	351-354	Gravely clay	5,000
7.0-7.9	23-26	106.1-107.0	348-351	Sandy gravel	500
7.9-8.5	26-28	105.5-106.1	346-348	Gravely sand	not sampled
8.5-9.4	28-31	104.5-105.5	343-346	Clay	not sampled
9.4-10.1	31-33	103.9-104.5	341-343	Silty, clayey sand	8,100
10.1-10.7	33-35	103.3-103.9	339-341	Gravely sand	not sampled
10.7-14.6	35-48	99.4-103.3	326-339	Clay	1,800; 300; <900

As an approximation, it is assumed that the mass of TCE is 190 l (50 gal). The average TCE saturation for the UCRS DNAPL source zones at WAG 6 (including both the high-saturation core and the surrounding soils with greater than 0.1% TCE saturation) was found to be 5.7%. Using a DNAPL saturation of 5.7%, the DNAPL zone would encompass 9.2 m^3 (326 ft^3) (assuming a soil porosity of 36%). If distributed evenly over the 10.7 m (35 ft) depth, the plan view area of the DNAPL zone would be 0.8 m^2 (9 ft^2).

Southeast C-720 Storm Sewer: WAG 27 Borings 720-022 and 720-002 define the lithology and TCE levels in the area of the Southeast C-720 storm sewer. Table 4 summarizes the data for this area:

Table 4. Lithology and Trichloroethene Levels Near the Southeast C-720 Storm Sewer

DEPTH		ELEVATION		LITHOLOGY SUMMARY (720-022)	TCE LEVELS (720-002) (µg/kg)
(m)	(ft)	(m)	(ft)		
1.5-3.7	5-12	109.7-111.9	360-367	Silty clay	37; 17,000
3.7-5.5	12-18	107.9-109.7	354-360	Gravely clay	19,000
6.1-10.1	20-33	103.3-107.3	339-352	Gravely sand	32,000; 68,000
10.1-15.2	33-50	98.1-103.3	322-339	Silty clay	not sampled

The following assumptions are used to estimate the volume of the DNAPL source zone.

(1) The TCE leak occurred at the point where the storm sewer passes from beneath the building [4.0 m (13 ft) from Boring 720-002].

(2) The source begins at a depth of 2.6 m (8.5 ft) (depth of the area storm sewers).

(3) The depth to water table is 5.8 m (19 ft) (based on a conceptual water table map for the PGDP).

(4) The base of the DNAPL zone coincides with the base of the HU2 sand horizon.

For the purpose of estimating the volume of the vadose DNAPL zone, the DNAPL zone is assumed to approximate a cylinder with height of 3.2 m (10.5 ft) [depth to water table/5.8 m (19 ft), less depth to source zone/2.6 m (8.5 ft)] and radius of 4.0 m (13 ft) (distance from Boring 720-002 to assumed leak source). This cylinder (the vadose DNAPL zone) has a volume of 157.9 m^3 (5,575 ft^3).

The DNAPL zone below the water table will again be assumed to approximate a cylinder. The height of the cylinder is 4.3 m (14 ft) [depth to base of the HU2 sand horizon/10.1 m (33 ft), less depth to the water table/5.8 m (19 ft)] and the radius remains 4.0 m (13 ft). Thus, the saturated DNAPL zone has a volume of 210.5 m^3 (7,433 ft^3).

The following assumptions are used to determine the mass of TCE and the average DNAPL saturation of the DNAPL zone.

(1) The average DNAPL saturations of the vadose and saturated zones are different.

(2) The vadose zone has an average water saturation of 50%.

(3) TCE levels of 18,000 µg/kg characterize the vadose DNAPL zone and 68,000 µg/kg characterize the saturated DNAPL zone at Boring 720-002.

(4) The DNAPL saturation of the center of the DNAPL zone (where vertical migration occurred) is 30%

(5) The zone of vertical migration has minimal width.

Attachment 1 presents the calculation of the TCE-in-soil level for water saturations of 10%, 30%, 50%, and 70% and a DNAPL saturation of 30%. The TCE concentration for a 50% water saturated soil is 66,992,964 µg/kg. A soil with DNAPL saturation of 30% occurring below the water table (water saturation of 70%) has a TCE-in-soil level of 61,746,186 µg/kg. By assuming that the decline in DNAPL saturation (and TCE concentration) with distance from the zone of vertical migration is similar to dispersion, the DNAPL saturation (TCE concentration) at a given location can be determined through application of a fixed multiplier per unit distance. Attachment 2 documents the multiplier (derived through iteration) required to match TCE concentrations in the core of the DNAPL zone and at Boring 720-002 for both above and below the water table. The total distance used in these calculations is the radius of the DNAPL zone [4.0 m (13 ft)]. The average TCE concentration of the DNAPL zone is derived by averaging the TCE concentrations over all of the unit distances [0.3 m (1 ft) increments] and an average DNAPL saturation is determined, based on the TCE level. Table 5 presents the average derived DNAPL saturation and, assuming a UCRS soil porosity of 36%, the volume of DNAPL present above and below the water table.

Table 5. Dense Nonaqueous Phase Liquid Volume in the Southeast C-720 Storm Sewer Source

	ELEVATION		DNAPL SATURATION	DNAPL VOLUME			
	(m)	(ft)	(%)	(m^3)	(ft^3)	(l)	(gal)
Vadose Zone	107.6-110.8	353-363.5	3.7	2.1	74	2,103	556
Saturated Zone	103.3-107.6	339-353	4.2	3.2	112	3,183	841

<u>Other DNAPL Zones</u>: WAG 27 soil borings at other locations proximal to the storm sewer system around the C-720 Building sampled soils with TCE-in-soil levels less than 20,000 µg/kg. The above DNAPL source zones and their dissolved-phase plume do not account for additional occurrences of dissolved TCE in the upper RGA (up to 10 µg/l). TCE has not been used in a plant process at the PGDP for over five years. Thus, these occurrences likely attest to other DNAPL occurrences. It is anticipated that the storm sewer network around the C-720 Building, in general, is a DNAPL source zone with very low DNAPL saturation.

Conceptual Model: C-747-C Former Oil Landfarm

The WAG 27 investigation of the C-747-C Former Oil Landfarm included seven soil borings yielding soil samples with 10,000 µg/kg TCE or greater (see attached Figure 4.4 from the WAG 27 RI Report for a map of area boreholes). These soil borings define a "hotspot" area with greater than 10,000 µg/kg TCE of up to 471.5 m^2 (5,075 ft^2). By assuming these TCE occurrences result from DNAPL presence, a DNAPL (liquid) volume of 56.4 m^3 (1,991 ft^3 or 56,379 l/14,895 gal) can be derived using the same procedures as above. However, there is no evidence, otherwise, of mass disposal of TCE at C-747-C. More likely, the TCE release was the disposal of a single drum of spent solvent.

As a conceptual model, the TCE release has been assumed to occur into a single plow "lane" of the former landfarm. Highest TCE-in-soil concentrations were routinely found in Boring 001-065. Thus, the route of vertical DNAPL migration appears to have occurred near Boring 001-065.

DNAPL Source Zone Volume Assessment: C-747-C Former Oil Landfarm

The Cylinder Drop Test Area, a nearby TCE spill site with adequate characterization, provides a useful comparison for the Former Oil Landfarm. At the Cylinder Drop Test Area, dissolved-phase TCE concentrations are 300,000 µg/l or greater in the DNAPL source zone. For water saturated soil with 36% porosity and 300,000 µg/l TCE in the water, the TCE-in-soil concentration would be 52,000 µg/kg (assuming no sorbed TCE is present).

With one exception, [a soil sample from Boring 001-065, at 4.7 m (15.5 ft) depth, with 400,000 µg/kg TCE] the highest TCE-in-soil levels in the "hot spot" ranged between 10,000 and 87,000 µg/kg. These levels are easily accounted for by dissolved phase contamination derived from a small DNAPL source zone. For the lone sample outlier with 400,000 µg/kg, the DNAPL saturation may have been as much as 0.13%, assuming a dry soil. The TCE mass represented in the WAG 27 samples from the Former Oil Landfarm is diminishingly small.

ATTACHMENT 1

Derivation of TCE in soil (µg/kg) for 30% DNAPL Saturation
(expected only in the core of the DNAPL source zone)

Assumptions:

- Soil grain density = 2.65 g/cm^3
- TCE specific gravity = 1.46 g/cm^3
- Water specific gravity = 1.00 g/cm^3
- Soil porosity = 36%

Water Saturation (%)	Total Density (g/cm^3)	TCE* (g/cm^3)	TCE (µg/kg)
10	1.95	0.16	80,709,226
30	2.15	0.16	73,214,219
50	2.35	0.16	66,992,964
70	2.55	0.16	61,746,186

*TCE (g/cm^3) = specific gravity x (porosity x DNAPL saturation)
=1.46 x (0.36 x 0.30) = 0.157

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ATTACHMENT 2

Derivation of TCE in soil (μg/kg) for the DNAPL Zones

Boring 720-002 Area

Depth to water = 5.8 m (19 ft)

Distance to presumed source = 4.0 m (13 ft)

Sample Data Summary

Depth		TCE
(m)	(ft)	(μg/kg)
2.1	7	37
3.0	10	17,000
4.3	14	19,000
6.7	22	68,000
6.7	22	32,000

Vadose Zone Saturation = 50% Multiplier = 0.531283			Saturated Zone Multiplier = 0.5921803		
Distance		TCE	Distatnce		TCE
(m)	(ft)	(μg/kg)	(m)	(ft)	(μg/kg)
0.0	0	66,992,964	0.0	0	61,746,186
0.3	1	35,592,223	0.3	1	36,564,875
0.6	2	18,909,543	0.6	2	21,652,999
0.9	3	10,046,319	0.9	3	12,822,479
1.2	4	5,337,438	1.2	4	7,593,220
1.5	5	2,835,690	1.5	5	4,496,555
1.8	6	1,506,554	1.8	6	2,662,771
2.1	7	800,407	2.1	7	1,576,841
2.4	8	425,242	2.4	8	933,774
2.7	9	225,924	2.7	9	552,963
3.0	10	120,030	3.0	10	327,454
3.4	11	63,770	3.4	11	193,912
3.7	12	33,880	3.7	12	114,831
4.0	13	18,000	4.0	13	68,000
Average =		10,207,713	Average =		10,807,633
DNAPL Saturation =		3.7%	DNAPL Saturation =		4.2%

* The multiplier is an approximation of the percentage of DNAPL mass remaining with unit distance (1 ft interval, in this case) from the core of the DNAPL zone.

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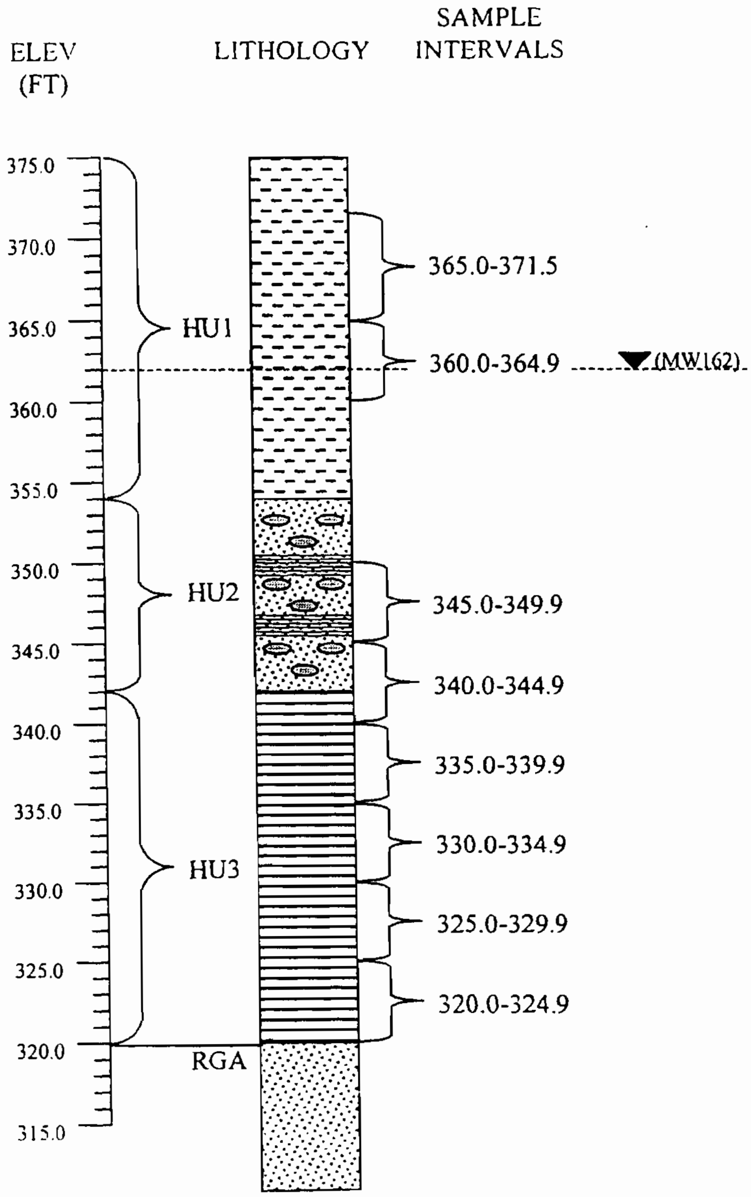
ATTACHMENT 3

TCE in Soil (µg/kg) at the C-747-C Former Oil Land Farm

(contour intervals are 1,000 and 10,000 µg/kg)

✱ without a value = non detect



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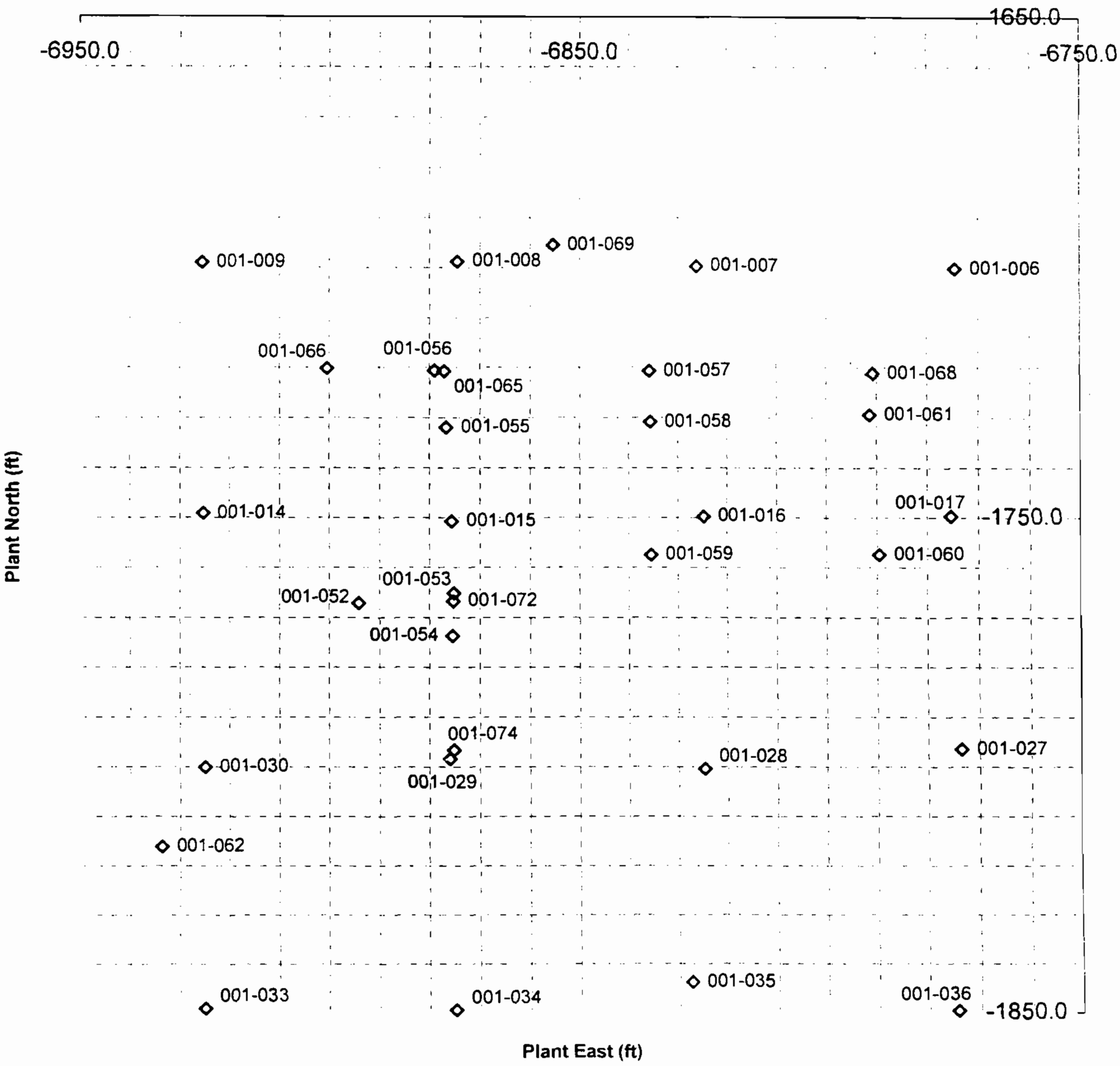
C-747-C "HOT SPOT" SOIL BORINGS



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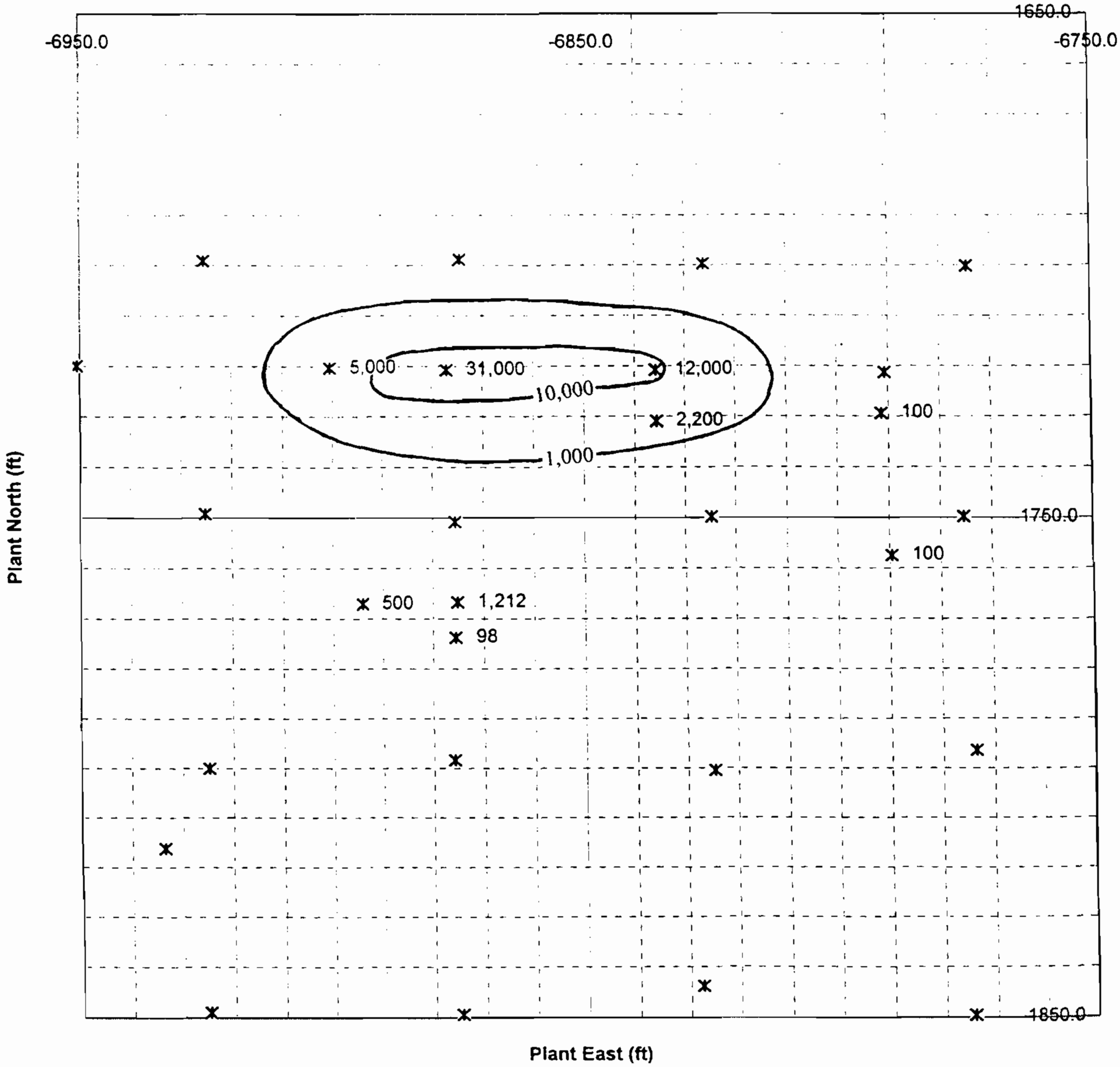
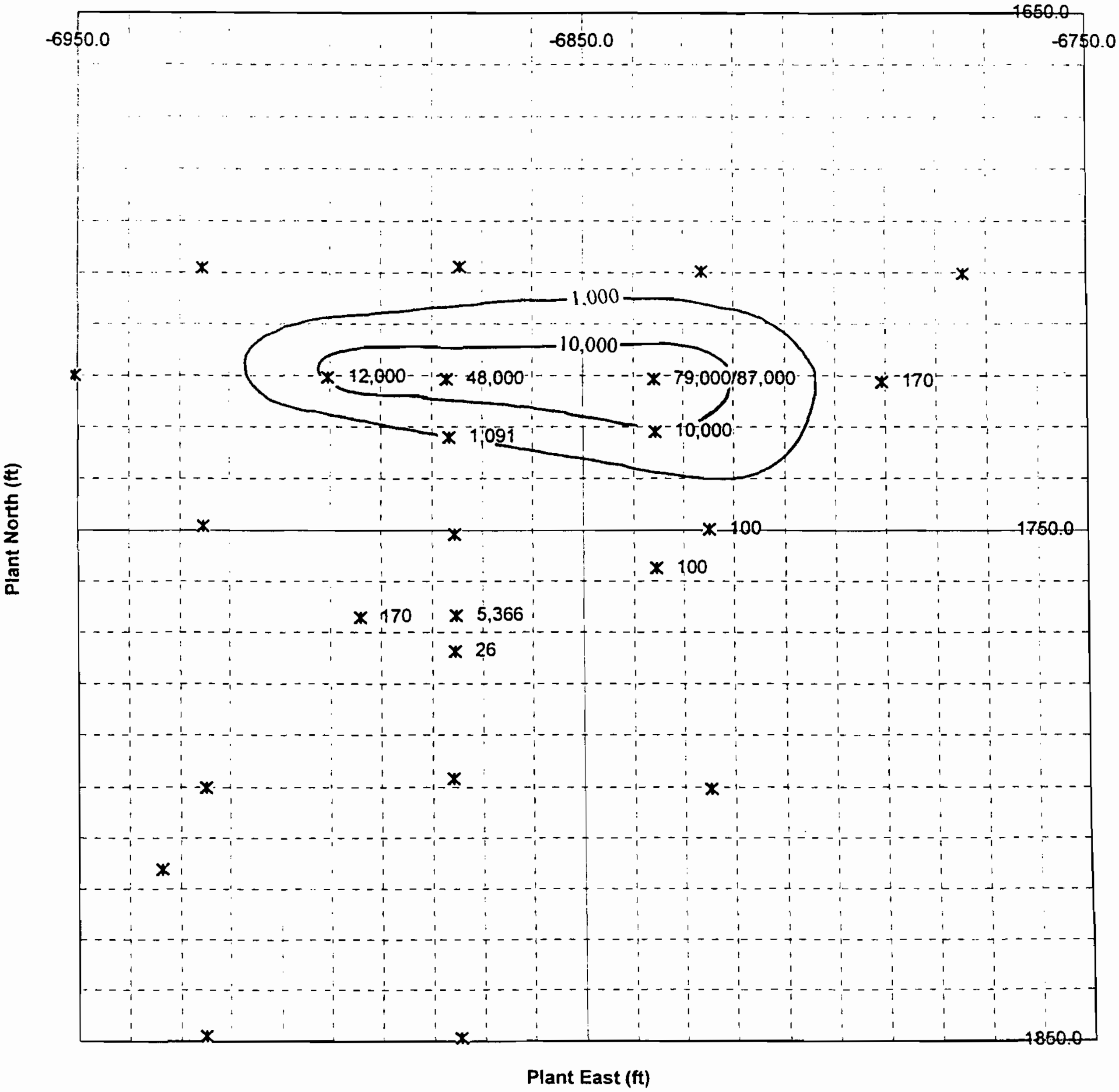
TCE LEVEL (365.0 - 371.5)



TCE LEVEL (360.0 - 364.9)



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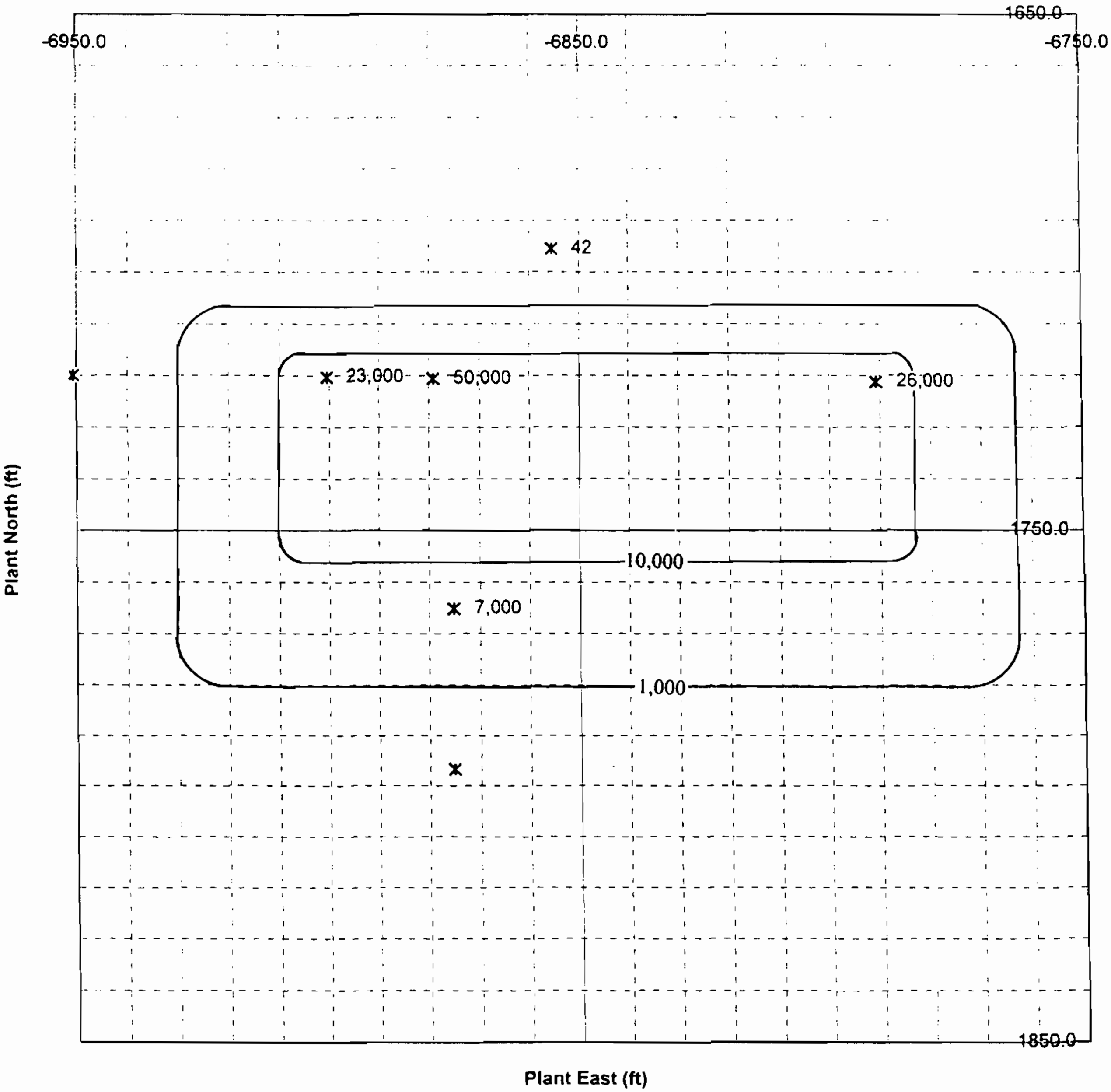
TCE LEVEL (345.0 - 349.9)



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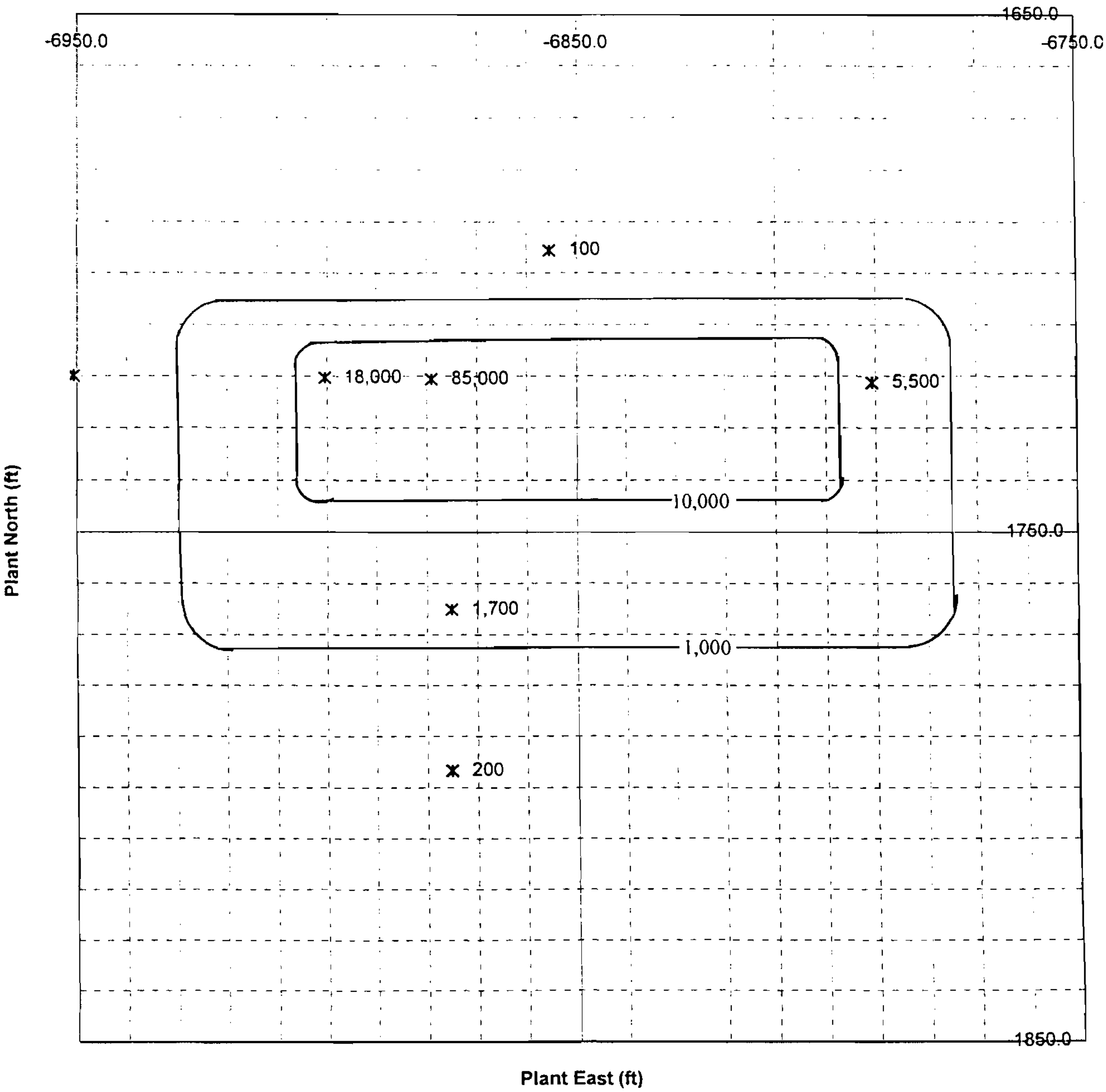
TCE LEVEL (340.0 - 344.9)



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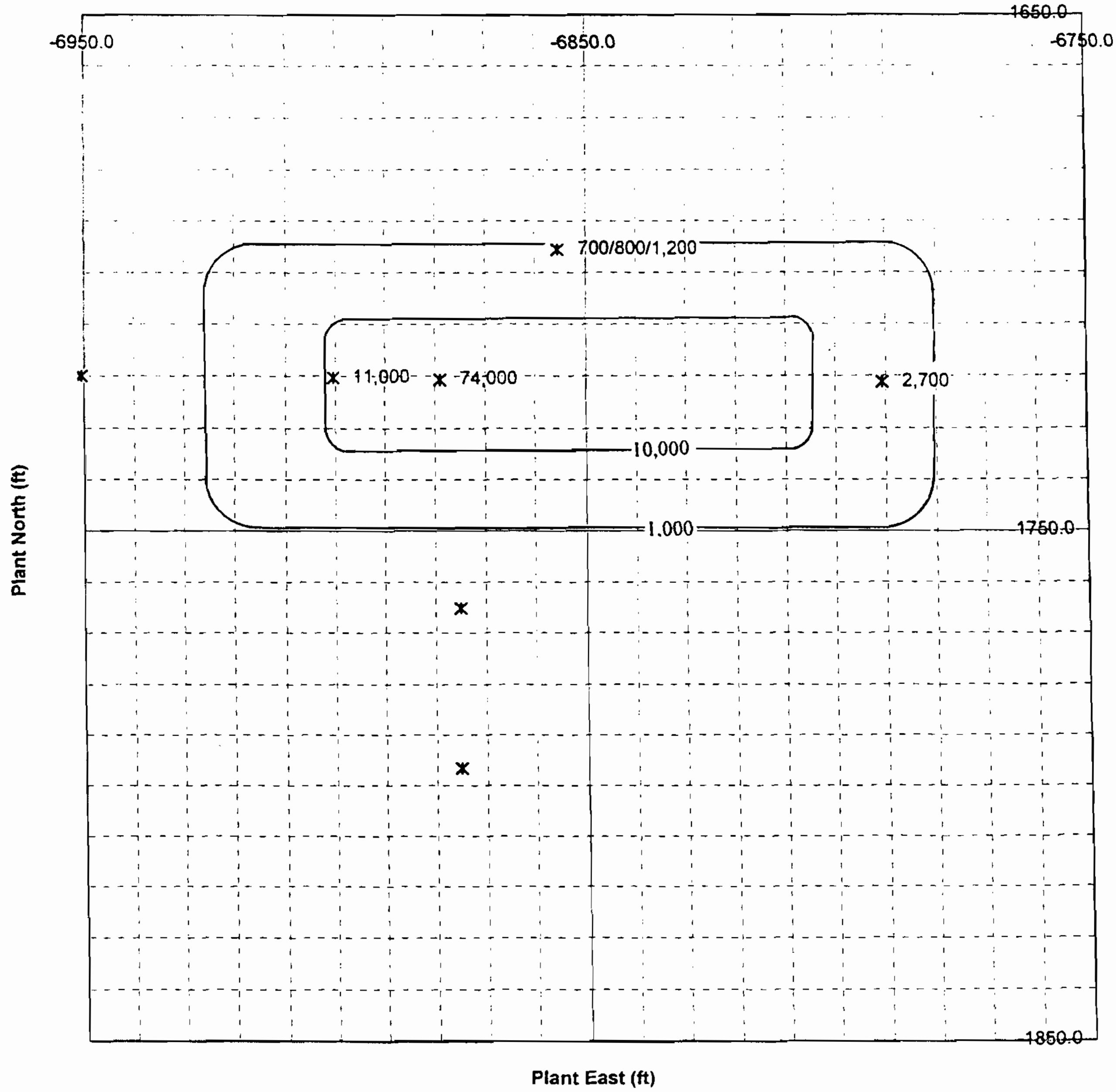
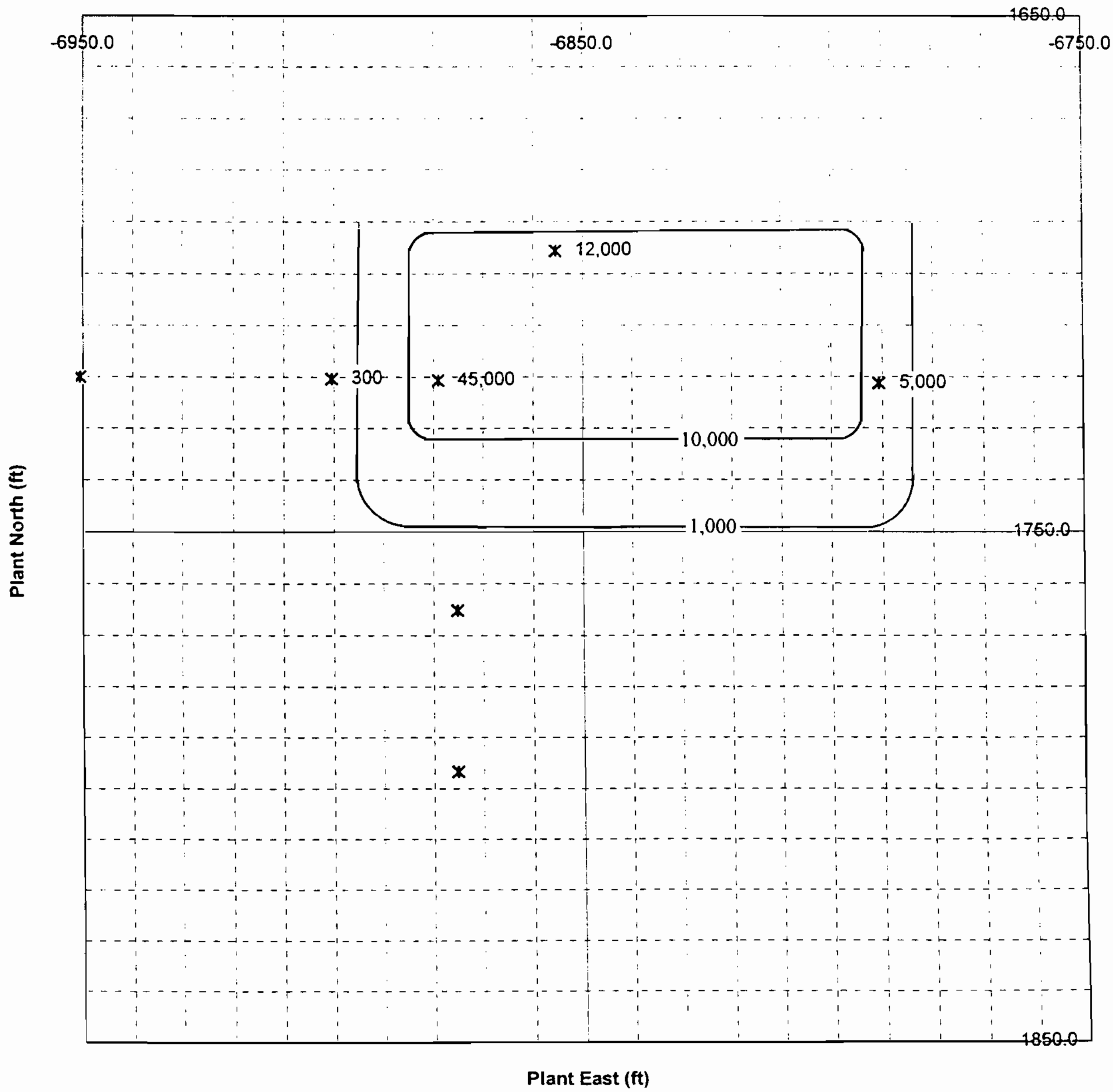
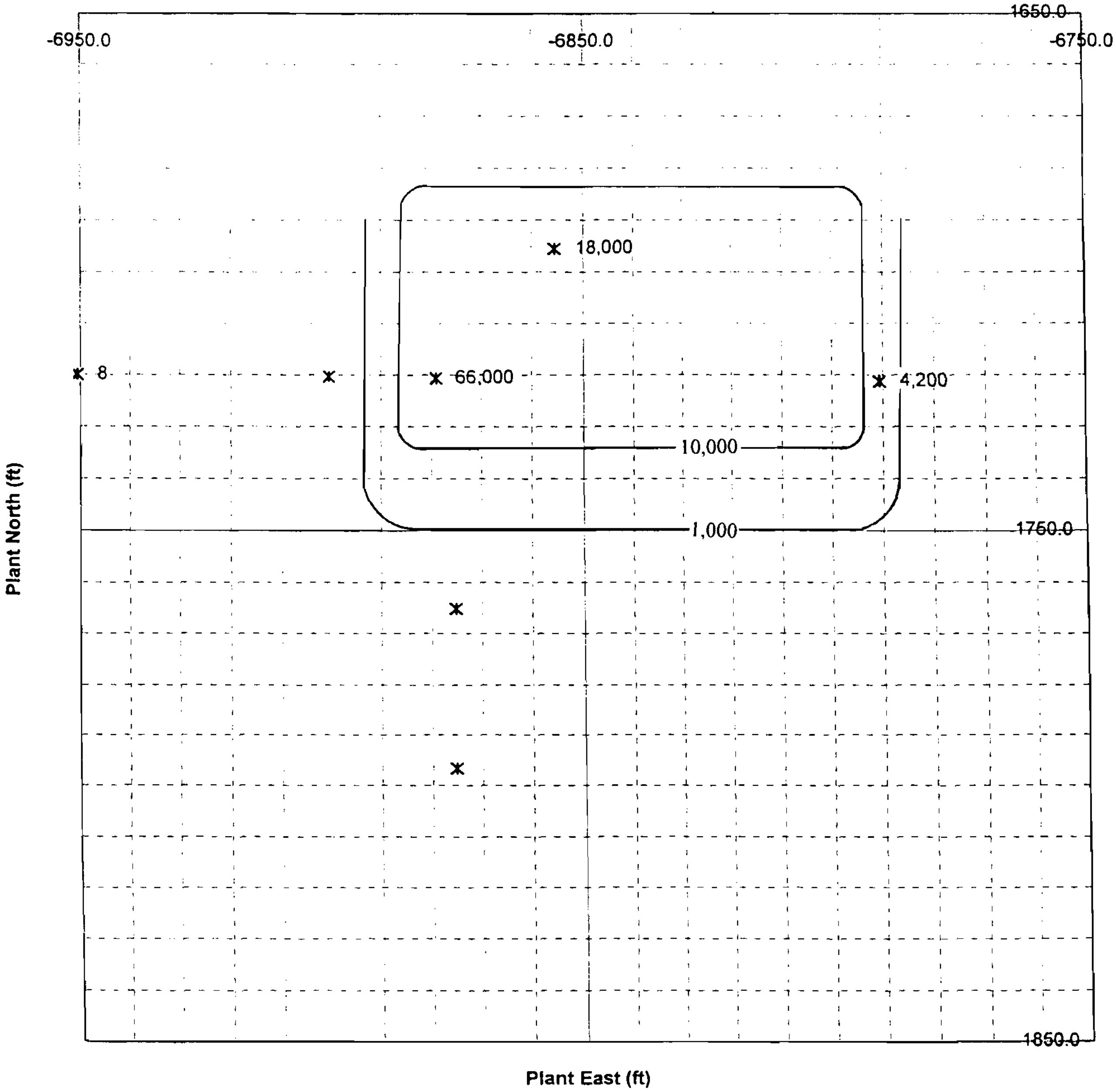
TCE LEVEL (335.0 - 339.9)



TCE LEVEL (330.0 - 334.9)



TCE LEVEL (325.0 - 329.9)



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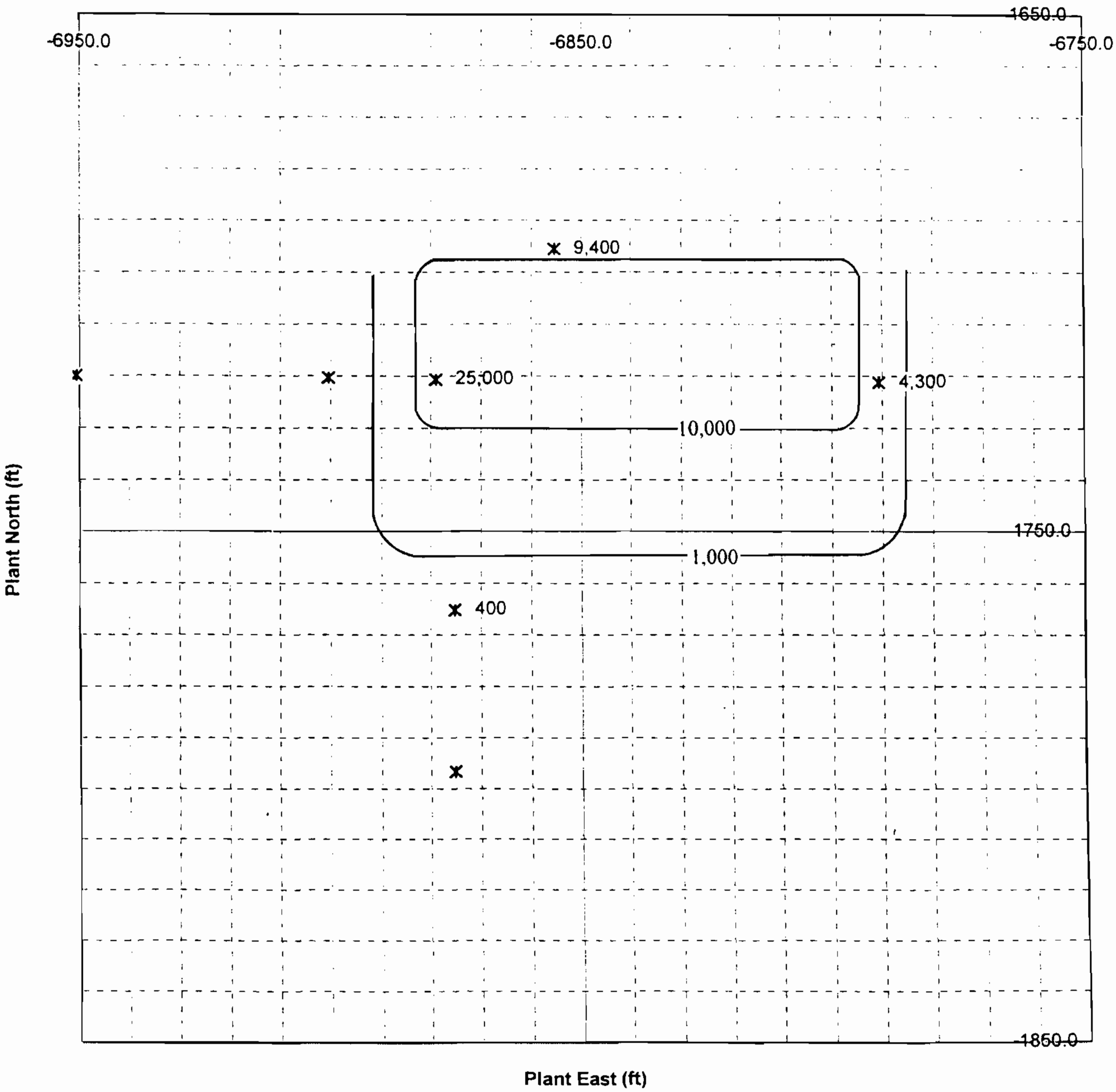
TCE LEVEL (320.0 - 324.9)



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DERIVATION OF

TRICHLOROETHENE AND ^{99}TECHNETIUM

SOURCE ZONE VOLUMES

FOR THE WAG 6 AREA

PADUCAH GASEOUS DIFFUSION PLANT

PADUCAH, KENTUCKY

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DERIVATION OF SOURCE ZONE VOLUMES

INTRODUCTION

The WAG 6 Remedial Investigation (RI) collected subsurface soil and water samples from 133 boreholes within and adjacent to the C-400 block. As anticipated and documented in this calculation package, the data confirm that the C-400 area contains the primary sources of trichloroethene (TCE) and ^{99}technetium (^{99}Tc) to the Northwest Plume and a plume trending east from the north corner of the C-400 block. Useful characterization data are largely derived from soil samples in the UCRS and water samples within the RGA.

Taken together, the data indicate the presence of four discrete sources of TCE and two discrete sources of ^{99}Tc near C-400. In addition, there is a diffuse source of ^{99}Tc on the east side of the C-400 building and an undefined source of ^{99}Tc south of the C-400 block that impacts water quality in the lower RGA on the east side of the C-400 Building.

TCE DNAPL SOURCE ZONES

This analysis of the WAG 6 data infers the presence of four TCE DNAPL source zones located: 1) at the site of a former TCE transfer pump (southeast C-400 block), 2) along the storm sewer at the C-400 Leak Site/SWMU 11 (southeast C-400 block), 3) along the storm sewer exiting the south end of the C-400 Building (southwest C-400 block), and 4) beneath the C-403 Neutralization Pit/SWUM 40 (northeast corner C-400 block).

Only the southeast corner of the C-400 block is sufficiently sampled in 3-dimensions to map/model TCE levels within the UCRS DNAPL zone. Because no meaningful data regarding TCE levels in RGA soils could be collected by the WAG 6 RI, the depth and width of the RGA source zone must be inferred from the dimensions and vertical trends of the resulting dissolved-phase plumes and conceptual models. Appendix A presents isoconcentration maps of TCE in soil for the southeast C-400 block.

For the DNAPL source zone associated with the C-400 Building southwest storm sewer, the UCRS soil data define TCE in soil concentrations near the edge of the DNAPL zone and a perimeter of very low to nondetect levels of TCE in soil. Appendix B presents the TCE-in-soil analyses for this area. The presence of DNAPL at the C-403 Neutralization Pit (SWMU 40) is inferred solely from levels of dissolved-phase TCE, both in the RGA and in water that collected within the C-403 Neutralization Pit during the RI.

^{99}TECHNETIUM SOURCE ZONES

The dimensions of the ^{99}Tc source zones in the UCRS are based on conceptual models. Too few ^{99}Tc analyses resulted from the WAG 6 RI. However, the plot of dissolved beta activity to ^{99}Tc activity shows a strong, near 1:1, relationship (Figure 1). The RI provides sufficient analyses of dissolved beta activity to map the primary ^{99}Tc source to the Northwest Plume in the northwest corner of the C-400 block. This source zone is south of the Waste Discard Sump/SWMU 203 (located at the northwest corner of the C-400 Building). The former Technetium Storage Tank/SWMU 47 appears to be the likely remaining candidate spill source. Elevated ^{99}Tc activity in soil was detected in soil borings at the former tank location.

Dissolved beta activity suggests a second discrete source of ^{99}Tc exists at the northeast corner of the C-400 Building. The C-403 Neutralization Pit/SWMU 40 appears to be the ^{99}Tc source. High dissolved ^{99}Tc activity has been reported from a shallow well adjacent to C-403. The water that collected in the C-403 Pit during the RI had high beta activity.

The upper RGA on the east side of the C-400 Building has a near uniform beta activity of 100-200 pCi/L. This activity appears to be derived from a diffuse source. The fan room plenum basement on the east side of the building is a potential release mechanism with appropriate size to generate an UCRS source with low activity.

Much higher dissolved beta activity, 800-900 pCi/L appears near the base of the RGA on the east side of the C-400 Building. This increase in beta activity appears to be due to a separate plume flowing into the C-400 area from the south. The source of this plume remains undefined.

DISSOLVED PHASE PLUMES

Appendix C provides TCE isoconcentration contour maps and beta isoactivity contour maps of the RGA in the C-400 area. Previous interpretations of the groundwater contaminant plumes at PGDP, consistent with the present interpretation, indicate significant lateral and vertical development of the plumes. Consequently, the data set was discretized vertically to generate 'slice' maps. As determined by the sampling frequency, the dissolved phase contaminant levels are grouped for mapping in five ft thick intervals between the elevations of 285 ft and 315 ft above mean sea level.

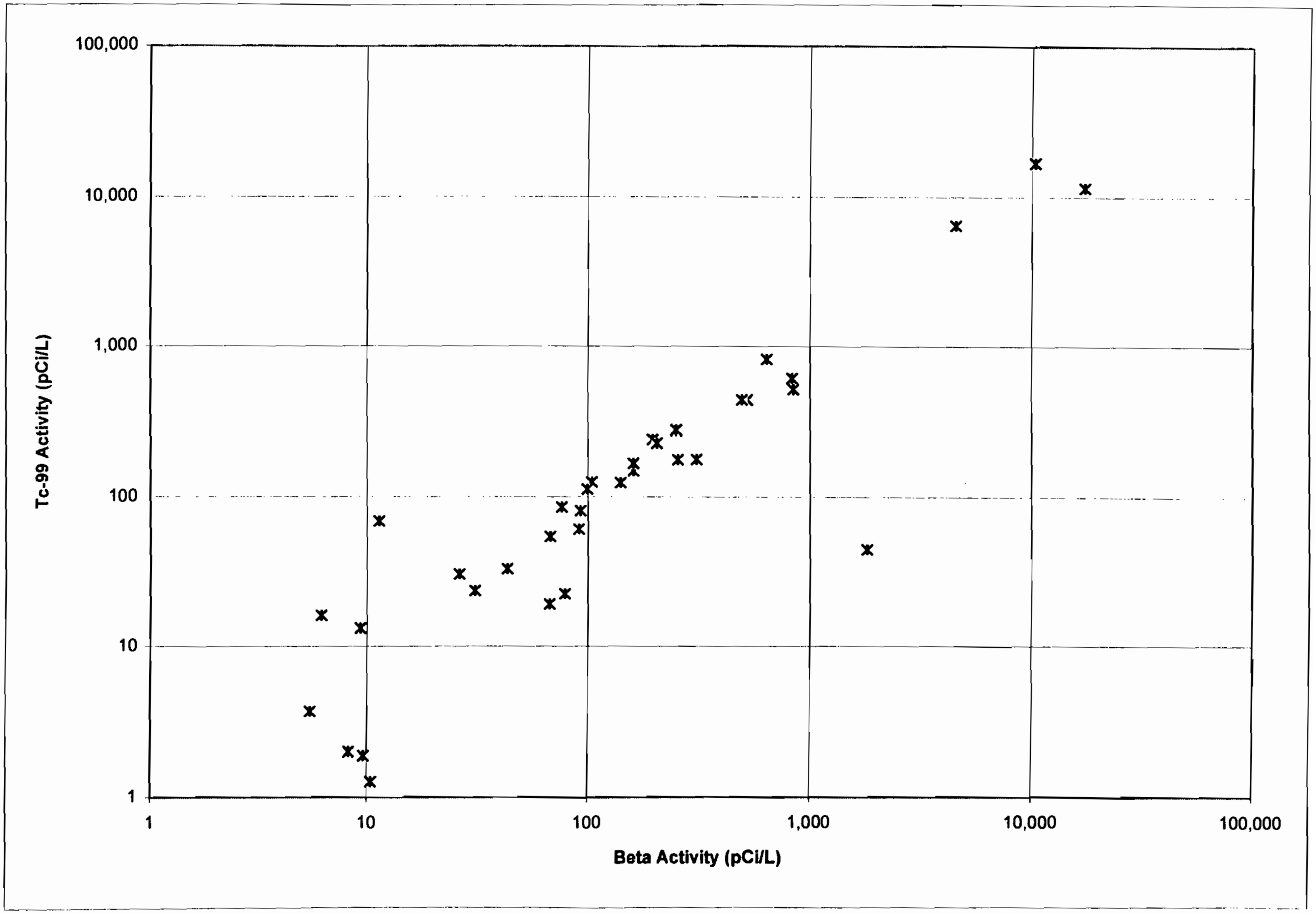

Figure 1. Plot of Dissolved Beta Activity Versus Dissolved Technetium-99 Activity from the WAG 6 Data Base

To constrain the possibilities regarding the number and locations of source areas and location and orientation of plumes, these maps have been contoured to be compatible (flow directions inferred from dissolved TCE trends match flow directions inferred from dissolved ^{99}Tc trends). An additional constraint placed on the contour maps was that the inferred flow direction could not significantly change between adjacent depth intervals. Thus, data from adjacent depth intervals biases the contour interpretation, maximizing the use of the available data.

Vertical flow predominates in the UCRS and has significant impact in the uppermost RGA, where the sediments typically are finer grained than the middle and lower RGA (interpreted to mean the upper RGA has a lower hydraulic conductivity than the middle and lower RGA). Thus, the high contaminant levels in the top 'slice' interval mark the entry point of the DNAPL or core of dissolved contamination into the RGA and help to point to the spill location.

Lateral trends of the main contaminant plumes sourced in the C-400 area are well developed in the next lower interval, 305.0 - 309.9 ft. With increasing depth, the impact of the shallow DNAPL sources are diminished and the areal extent of the high concentration TCE core of the plume becomes smaller.

DEPTH OF MIGRATION OF TCE DNAPL

As interpreted by these vertical trends, the C-403 DNAPL source is constrained to the UCRS. (This site impacts dissolved phase TCE levels only down to an elevation of 310 ft). It appears that the DNAPL source zones associated with the TCE Leak Site/ SWMU 11 and the south-end storm sewer penetrate to the upper RGA. (These sites influence dissolved phase TCE levels down to an elevation of 300 ft.) TCE, as DNAPL, from the TCE transfer pump appears to have migrated to the base of the RGA where a small DNAPL pool has formed. (TCE levels in nearby boring 400-037 increase at the base of the RGA.)

DEPTH OF ^{99}TECHNETIUM SOURCE

Dissolved-phase beta activity is limited to the upper RGA beneath C-403, suggestive of a source term in the UCRS. This is consistent with the expected behavior of ^{99}Tc. The high solubility of ^{99}Tc in oxidized water, such as the RGA, would tend to inhibit the development of a secondary source in the RGA.

The depth of penetration of the ^{99}Tc source tentatively associated with the Technetium Storage Tank (SWUM 47) remains uncertain.

Here, the dissolved-phase beta activity penetrates to the base of the RGA. One possible interpretation is that the oil containing the ^{99}Tc concentrate (a mixture of polyaromatic hydrocarbons) also was a DNAPL that has penetrated to the base of the RGA. No indications of a polyaromatic hydrocarbon source are known from the northwest C-400 Building area. Presumably, these oils have very low solubilities that would not result in an appreciable dissolved-phase plume of polyaromatic hydrocarbons.

DNAPL VOLUME CALCULATION IN THE UCRS

Southeast C-400 Block (TCE Transfer Pump and TCE Leak Site/ SWMU 11 Source Zones

Table 1 summarizes the soil textures described from boring 400-207. This boring is being used to represent the geology of the UCRS for the source zones in the southeast C-400 area. The assumed porosity for the UCRS sediments is the mean of measurements from 16 UCRS samples collected for the WAG 6 RI.

Table 1. Summary of UCRS Properties in the Southeast C-400 Area

Depth Interval (ft)	Elevation of Base of Interval (ft)	Representative Lithology	Assumed Porosity (%)
0-33	346	silt to silty clay	36
33-45	334	gravely sand	36
45-57	322	silty sand to fine sand	36

For the purpose of calculating a TCE DNAPL volume in the UCRS for the southeast C-400 block, the maps of Appendix A have been used to define the area containing soil with 100 µg/g or greater TCE. Assuming the density of the TCE DNAPL is 1.46 g cm^3, the specific gravity of the UCRS soil grains is 2.65 g/cm^3, and the soil has a porosity of 36% with a 0.1% DNAPL saturation, the associated soil TCE concentration is 308,948 µg/Kg or 309 µg/g. Thus, the maps define the area containing soils with approximately 0.1% saturation and greater.

Note: In *Estimating Potential for Occurrence of DNAPL at Superfund Sites* (EPA, 1992), a DNAPL saturation of 1% in soil is presented as an indication of DNAPL presence. The use of a 0.1% saturation level to define the DNAPL zone is due to the limits of resolution capable with the data set. The WAG 6 RI analyzed soils from the southeast C-400 block with greater than 1% DNAPL saturation.

The approximate area for each depth interval slice is presented in Table 2.

Table 2. Area and Volume of the TCE DNAPL Zone in the UCRS in the Southeast C-400 Area

Depth Interval (ft)	Area Containing 100 PPM TCE or Greater (ft^2)	Thickness Represented (ft)	Volume Represented (ft^3)
365.0 - 369.9	4,000	14*	56,000
360.0 - 364.9	3,400	5	17,000
355.0 - 359.9	5,070	5	25,350
350-0 - 354.9	3,730	5	18,650
345.0 - 349.9	2,500	5	12,500
340.0 - 344.9	3,560	5	17,800
335.0 - 339.9	2,130	5	10,650
330.0 - 334.9	3,330	8**	26,640

* Land surface to subsurface elevation 365.0 ft.

** Elevation 334.9 ft to top of the RGA at 327 ft elevation.

Characterization data from the original SWMU 11 investigation and the WAG 6 and WAG 27 RIs all suggest the DNAPL migration pathways through the UCRS are essentially straight down. This is consistent with the general texture of the UCRS silts and clays which have no observable lateral-to-vertical anisotropy. Thus, the 'footprint' of the leak source is the width of the source zone with highest DNAPL saturation.

The distribution of TCE levels in the southeast C-400 block suggests the TCE concentration declines near-logarithmically with distance from the DNAPL migration pathway. Several assumptions have been made to derive a representative DNAPL saturation of the source zone:

- The DNAPL volume in the area containing less than 100 µg/g (~0.1% saturation) of TCE in soil is insignificant.
- The vertical migration pathway of the DNAPL has an insignificant width.
- The residual TCE saturation of the vertical DNAPL migration pathway (center of the DNAPL zone) is 30% (the maximum residual saturation suggested for the PGDP site by Dr. B. H. Kueper, 1991).
- DNAPL levels decline at a uniform percentage per unit distance from the source zones (similar to dispersion effects). Thus, for a DNAPL zone with a 30% saturation at the center and a 0.1 % saturation at the edge, the average DNAPL saturation in soil is 5.7% (Figure 2).

The calculation of volume of TCE DNAPL is the product of the volume of the TCE DNAPL source zone, the porosity, and the saturation. Table 3 documents the calculation of volume of DNAPL for the southeast C-400 block.

Unit Factor = 0.751872

Unit Distance	DNAPL Saturation (%)
0	30.00
1	22.56
2	16.96
3	12.75
4	9.59
5	7.21
6	5.42
7	4.08
8	3.06
9	2.30
10	1.73
11	1.30
12	0.98
13	0.74
14	0.55
15	0.42
16	0.31
17	0.24
18	0.18
19	0.13
20	0.10

Avg. DNAPL Saturation: **5.74**

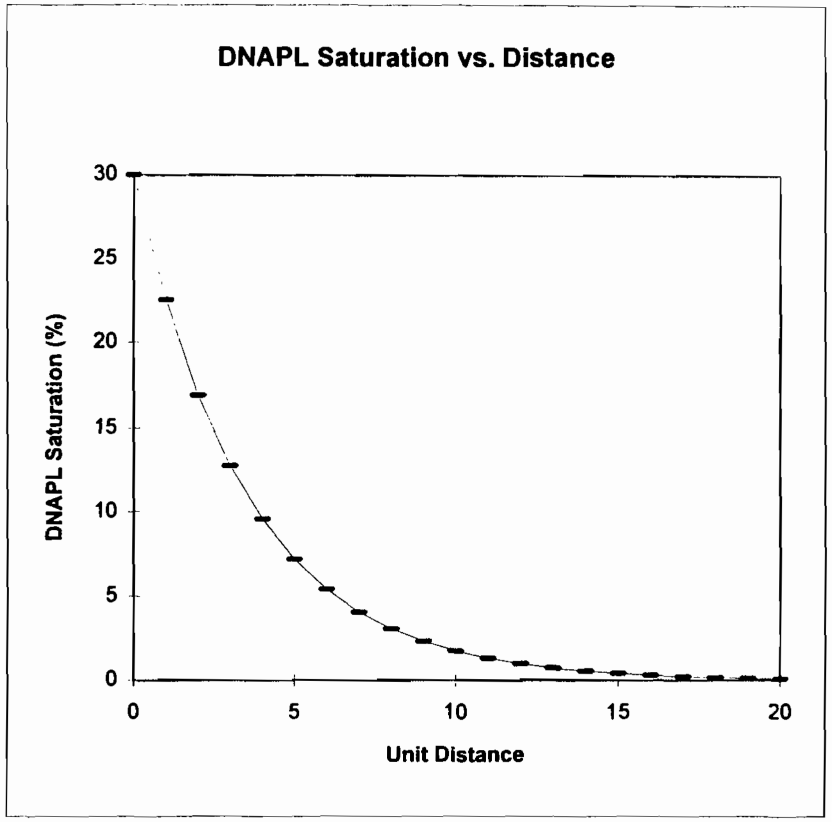

Figure 2. Average DNAPL Saturation of UCRS DNAPL Source Zone

Table 3. Calculation of TCE DNAPL for the Southeast C-400 Block

Depth Interval (ft)	Volume Represented (ft^3)	Assumed Porosity (%)	Assumed Saturation (%)	TCE DNAPL Volume (ft^3)
322 - 379	184,590	36	5.7	3,788

A volume of 3,788 ft^3 is equal to 28,338 gallons (107,259 liters).

South-End C-400 Building Storm Sewer and C-403 Neutralization Pit/SWMU 40 Source Zones

Soil characterization data are sufficient for the south-end C-400 Building storm sewer to determine that a DNAPL source zone exists at the point where the storm sewer exits from beneath the building. However, the data are inadequate to define the TCE DNAPL levels in three dimensions. The inference that a DNAPL source zone exists at the C-403 Neutralization Pit is based only on dissolved TCE levels, in the upper RGA and in the fill water that collected within the pit during the RI.

As previously discussed, the DNAPL source zone associated with the south-end storm sewer apparently extends to the RGA whereas the C-403 source zone is constrained within the UCRS. Borings 400-045 and 400-042 will be used to represent the geology of the UCRS for the south-end storm sewer and C-403 DNAPL source zones, respectively.

Table 4. Summary of UCRS Properties in the Southwest C-400 Area and the North C-400 Area

Depth Interval (ft)	Elevation of Base of Interval (ft)	Representative Lithology	Assumed Porosity (%)
Boring 400-045 (Southwest C-400 Area)			
0-16	360.5	silt to silty clay	36
16-47	329.5	silty sand and gravel?	36
47-52	324.5	silt and clay	36
Boring 400-042 (North C-400 Area)			
0-20	358.5	silt to silty clay	36
20-42	336.5	silty sand and gravel	36
42-62	316.5	silty clay with sand and gravel	36

It will be assumed that the UCRS DNAPL zone extends the full 52 ft depth of the UCRS soils in the southwest C-400 block but is limited to a depth of 42 ft beneath C-403.

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The width of these TCE DNAPL zones remains largely undefined.

South-End Storm Sewer Source

Boring density is sufficient to determine that the width of the south-end sewer system DNAPL zone does not extend 100 ft from the source. If we assume that 100 µg/g (~0.1% saturation) of TCE in soil defines the DNAPL source zone, only one WAG 6 boring was completed in the source zone. The TCE levels (94 and 200 µg/g) suggest the boring, located approximately 30 ft south of the C-400 Building, is near the edge of the source zone.

Following calculations of the south-end storm sewer source will be based on the assumption that the DNAPL leak occurred at the edge of the building footprint and that the source zone is symmetrical. Thus, the south-end storm sewer source will be a cylinder with a 30 ft radius, centered on the south end of the C-400 Building where the storm sewer exits from beneath the building.

C-403 Source

WAG 6 borings around the perimeter of the C-403 Neutralization Pit did not return soil samples with TCE levels approaching 100 µg/g. As a default value, the following calculations of the C-403 source zone will be based on the assumption that the source zone (defined by TCE levels in soil greater than 100 µg/g) extends half the width of C-403. The C-403 Neutralization Pit measures 25 ft square in plan view. The C-403 Neutralization Pit source zone will be approximated as a cylinder centered below C-403, with a radius of 6.25 ft.

Table 5. Calculation of TCE DNAPL for the South-End Storm Sewer and C-403 Sources

Height (ft)	Radius (ft)	Volume Represented (ft^3)	Assumed Porosity (%)	Assumed Saturation* (%)	TCE DNAPL Volume (ft^3)
South-End Storm Sewer Source (324.5-376.5 ft elevation)					
52	30	147,027	36	5.7	3,017
C-403 Neutralization Pit Source (336.5-378.5 ft elevation)					
42	6.25	5,154	36	5.7	106

* From the derived saturation of the southeast C-400 area source zones.

The 3,017 ft^3 of DNAPL in the south-end storm sewer source is equal to 22,570 gallons (85,427 liters)and the 82 ft^3 of DNAPL in the C-403 source is equal to 793 gallons (3,002 liters).

DNAPL VOLUME CALCULATION IN THE RGA

The upgradient 100 mg/L (ppm) TCE isoconcentration contour appears to map the DNAPL source zones of the RGA. Moreover, the US Environmental Protection Agency recommends the use of 1% of the solubility of DNAPL (1% of the solubility of TCE is 110 mg/L) as an indication of DNAPL presence (EPA, 1992). Table 6 presents the assumptions used to define the area of the DNAPL source zones in the upper RGA (based on the TCE isoconcentration contour map for the elevation interval 310.0 - 314.9 ft).

Table 6. Upper RGA DNAPL Source Zone Assumptions

TCE DNAPL Source Zone	Areal Extent Assumption	Area (ft^2)
TCE Transfer Pump	cylinder with radius of 90 ft	25,447
TCE Leak Site (SWMU 11)	line source 200 ft long by 5 ft wide	1,000
South-End Storm Sewer	cylinder with radius of 25 ft	1,963

The geologist's logs and geophysical logs of WAG 6 borings 400-038 and 400-207 provide the most detailed description of soil properties for the south end of the C-400 Building. These borings will be used to represent the RGA DNAPL source zones. In both borings, an upper fine to medium grained sand horizon (base at elevation 323 ft in boring 400-038 and elevation 322 ft in boring 400-207) overlies a thick interval of coarse sand and gravel.

As previously discussed, the slice maps of dissolved-phase TCE levels suggest different depths of penetration for the DNAPL source zones. All three of the RGA source zones are represented in the slice map for the elevation range 310.0 - 314.9 ft. The influence of the south-end storm sewer diminishes rapidly with depth. For the approximation of the south-end storm sewer DNAPL zone, the base of the DNAPL zone will be assumed to be the base of the upper sand horizon at 322 ft.

The influence of the TCE Leak Site (SWMU 11) DNAPL source zone is evident down to an elevation of approximately 305 ft in the slice maps of dissolved-phase TCE levels. This depth closely corresponds to the depth (307 ft elevation) of an anomaly on the neutron porosity log of boring 400-207 and the depth (302 ft elevation) of an abrupt decline in field measurements of volatile organic compound levels (FID) in the soil core of boring 400-207. The base of the TCE Leak Site DNAPL zone will be assigned an elevation of 305 ft.

TCE isoconcentration contours indicate a DNAPL source zone extends to the base of the RGA near the location of the TCE

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transfer pump. Moreover, an increase in dissolved-phase TCE levels from boring 400-207 at the base of the RGA may signify the presence of a DNAPL pool at the base of the RGA. For the estimate of the DNAPL source zone below 305 ft elevation, the source zone will be assumed to approximate a cylinder measuring 25 ft in radius (based on the TCE isoconcentration contour map for the elevation interval 290.0 - 294.9 ft) and to extend to the base of the RGA, at an elevation of 286 ft.

Table 7. Calculation of the Volume of the RGA DNAPL Source Zones

TCE DNAPL Source Zone	Areal Dimensions (ft)	Area (ft^2)	Thickness (ft)	Volume (ft^3)
TCE Transfer Pump (305-327 ft elevation)	radius = 90	25,447	22	559,834
TCE Transfer Pump (286-305 ft elevation)	radius = 25	1,963	19	37,297
TCE Leak Site/SWMU 11 (305-327 ft elevation)	length = 200 width = 5	1,000	22	22,000
South-End Storm Sewer (322-324.5 ft elevation)	radius = 25	1,963	2.5	4,908

The WAG 6 RI characterized soil properties around the C-400 Building. The mean of 26 measurements of porosity of RGA soils is 40%. An average TCE saturation level is required for the calculation of DNAPL volume. Unfortunately, no suitable samples for measurement of TCE levels in soil have been recovered from the coarse sand and gravel of the RGA.

The only available data related to DNAPL saturation in the RGA are the dissolved-phase levels of TCE. These limited measurements cannot be directly linked to a saturation level. However, the decline of dissolved-phase TCE levels with lateral distance from the center of the DNAPL source zone (with the exception of the direction of groundwater flow) may be a model of decrease of DNAPL saturation.

The following derivation of average DNAPL saturation for the source zone (upgradient area with dissolved-phase TCE levels greater than 100 mg/L) assumes that the profile of dissolved-phase TCE levels in a direction normal to groundwater flow is a direct measure of the distribution of DNAPL saturation. Dispersion will also reduce dissolved-phase TCE levels away from the source zone. For this derivation, the effect of DNAPL distribution is assumed to be dominant.

This derivation is based on a conceptual model of a narrow pathway of vertical migration at the center of the DNAPL source zone. The coarse sand and gravel of the RGA is assumed to retain a DNAPL saturation of 20% (33% less than expected in the UCRS) in the core of the DNAPL source zone. As in the UCRS, DNAPL saturation in the RGA soils is assumed to decrease away from the center of the source zone by a uniform factor per unit distance.

The profile of dissolved-phase TCE levels for this derivation is taken east of the location of the former TCE transfer pump from the elevation slice 310.0 - 314.9 ft. Table 8 summarizes the relevant data from this transect.

Table 8. Distance to TCE Isoconcentration Contours Along Transect

Dissolved-Phase TCE Level (mg/L)	Lateral Distance From TCE Transfer Pump (ft)
1,100	0
100	60
10	120
1	160

Table 9 demonstrates the fit of the chosen unit factor (multiplier to derive the decline in dissolved-phase TCE levels for unit distance) for the transect. The unit distance arbitrarily has been selected as 10 ft.

Table 9. Fit of Unit Factor (0.67) to Transect Data

Lateral Distance From TCE Transfer Pump (ft)	Derived Dissolved-Phase TCE Level (mg/L)	Transect Dissolved-Phase TCE Level (mg/L)
0	1,100.0	1,100
10	737.0	
20	493.8	
30	330.8	
40	221.7	
50	148.5	
60	99.5	100
70	66.7	
80	44.7	
90	29.9	
100	20.1	
110	13.4	
120	9.0	10
130	6.0	
140	4.0	
150	2.7	
160	1.8	1

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By assuming the decline in TCE concentration is directly related to decrease in DNAPL saturation and that the residual DNAPL saturation of the center of the source zone is 20%, the derived unit factor is a multiplier to calculate DNAPL saturation in the source zone along the transect. Table 10 presents the calculated saturation levels.

Table 10. Derived DNAPL Saturation of the Source Zone

Lateral Distance From TCE Transfer Pump (ft)	Derived DNAPL Saturation (%)
0	20.0
10	13.4
20	9.0
30	6.0
40	4.0
50	2.7
60	1.8
Average DNAPL Saturation	**8.1**

By applying this derived average saturation to all RGA DNAPL zones, Table 11 presents the calculation of DNAPL volume in the RGA.

Table 11. Calculation of the Volume of DNAPL in the RGA Source Zones

TCE DNAPL Source Zone	Volume (ft^3)	Assumed Porosity (%)	Assumed Saturation (%)	TCE DNAPL Volume (ft^3)
TCE Transfer Pump (305-327 ft elevation)	559,834	40	8.1	18,139
TCE Transfer Pump (286-305 ft elevation)	37,297	40	8.1	1,208
TCE Leak Site (SWMU 11) (305-327 ft elevation)	22,000	40	8.1	713
South-End Storm Sewer (322-324.5 ft elevation)	4,908	40	8.1	159

Table 12. Volume of DNAPL in the RGA Source Zones

TCE DNAPL Source Zone	TCE DNAPL Volume (ft^3)	TCE DNAPL Volume (gallons)	TCE DNAPL Volume (liters)
TCE Transfer Pump (305-327 ft elevation)	18,139	135,698	513,696
TCE Transfer Pump (286-305 ft elevation	1,208	9,037	34,210
TCE Leak Site (SWMU 11) (305-327 ft elevation)	713	5,334	20,189
South-End Storm Sewer (322-324.5 ft elevation)	159	1,189	4,503

NOTES ON CALCULATION OF DNAPL VOLUMES

The above calculations ignore the presence of pooled DNAPL. Where pooled DNAPL occurs, the DNAPL volume will be significantly greater than the derived volumes. Dissolved-phase TCE levels in WAG 6 boring 400-207 increase at the base of the RGA, suggesting a DNAPL pool may be present at the base of the RGA. The WAG 6 data are insufficient to quantify the dimensions or volume of pooled DNAPL.

DNAPL pools tend to develop at the interface of permeability barriers. The base of the sand and gravel horizon in the UCRS is another horizon where significant DNAPL pools should be expected.

^{99}TECHNETIUM SOURCE ZONE CALCULATION IN THE UCRS

Technetium Storage Tank/SWMU 47 Source Zone

The lithologic log of the soil boring for well MW175 will be used to represent the soil textures of the Technetium Storage Tank source zone. Table 13 summarizes the dominant UCRS textures with depth.

Table 13. Summary of UCRS Soil Textures for the Former Location of the Technetium Storage Tank

Depth Interval (ft)	Elevation of Base of Interval (ft)	Representative Lithology
0-20	358	clay
20-30	348	gravely sand
30-32	346	sandy clay
32-39	339	gravely sand
39-49	329	clay and sandy silt

The WAG 6 RI found the UCRS soils were unsaturated in the vicinity of the Technetium Storage Tank location down to an elevation of approximately 335 ft. Because ^{99}Tc has a high solubility in oxidized waters (approximately 4,300 pCi/L), this calculation assumes that the only soils retaining ^{99}Tc are in the unsaturated zone. Thus, the base of the ^{99}Tc source zone is at an elevation of 335 ft, a depth of 43 ft.

All of the seven surface soil samples collected within and adjacent to the bermed area that marks the former location of the Technetium Storage Tank exhibit high ^{99}Tc activity. The surface soil ^{99}Tc activity ranges from 4.5 to 53 pCi/g. The only subsurface soil ^{99}Tc activity data comes from analysis of samples from boring 047-002. Table 14 presents the ^{99}Tc analyses for subsurface soil samples of 047-002.

Table 14. ^{99}Technetium in Subsurface Soil Analyses for Boring 047-002

Depth Interval (ft)	^{99}Technetium Activity (pCi/g)
1.0-4.5	8.1
8.5-12.0	0.5
15.5-19	2.2
26-29.5	0.4
Average ^{99}Technetium Activity	**2.8**

The average ^{99}Tc activity of soils from boring 047-002 will be used as the measure of ^{99}Tc activity of the source zone soils.

The three-dimensional distribution of data is insufficient to define the limits of the Technetium Storage Tank source zone. As a default value, the area enclosed by the berm will be used to define the lateral dimensions of the source zone. The basis for this assumption is that spills or leaks from the storage tank are not expected to spread beyond the berm at the land surface and groundwater flow (the likely mechanism for ^{99}Tc migration) is predominately vertical in the UCRS.

The bermed area has a surface area of approximately 625 ft^2. Thus, approximately 26,875 ft^3 of soil is contained within the ^{99}Tc source area. At an average ^{99}Tc activity of 2.8 pCi/g and a bulk density of approximately 1.70 g/cm^3 (specific gravity of 2.65 g/cm^3 and porosity of 36%), the total ^{99}Tc activity of the source zone is:

$$26{,}875 \text{ ft}^3 \times 28{,}317 \text{ cm}^3/\text{ft}^3 \times 1.70 \text{ g/cm}^3 \times 2.8 \text{ pCi/g} = \mathbf{3.62 \times 10^9 \text{ pCi}}$$

C-403 Neutralization Pit/SWMU 40 Source Zone

The lithologic logs of the soil boring for well MW178 and boring 040-008 represent the soil textures of the C-403 Neutralization Pit source area. Table 15 presents a summary of the area geology.

Table 15. Summary of UCRS Textures for the Area of the C-403 Neutralization Pit

Depth Interval (ft)	Elevation of Base of Interval (ft)	Representative Lithology
0-17	359	fill (clayey gravel)
17-24	352	clayey silt
24-38	338	gravely sand
38-52	324	clayey silt

One soil boring sampling the backfill of the C-403 Neutralization Pit found water at shallow depth. However, nearby piezometers document the depth of the UCRS saturated zone to be much deeper, at an elevation of approximately 341 ft. Apparently, the depth to water in the saturated backfill of the C-403 pit represents a localized perched water table. For the purposes of approximating a ^{99}Tc source zone, the source zone will be assumed to extend between the base of the C-403 Neutralization Pit (elevation 351 ft) and an elevation of 341 ft.

The only ^{99}Tc in soil analyses for the source zone depths at SWMU 40 are for single samples taken from the east and west sides of the C-403 pit. In both samples, the ^{99}Tc activity was minimal (0.1 and 0.4 pCi/g). For the purposes of defining a source zone volume for the C-403 Neutralization Pit, it will be assumed that the source zone approximates a cylinder with a diameter extending one half of the width of the pit (the pit is 25 ft wide).

For lack of better data, it will also be assumed that the average ^{99}Tc activity in soil and the bulk density of the soil is the same as the average for the Technetium Storage Tank area, 2.8 pCi/g and 1.70 g/cm^3, respectively. The total ^{99}Tc activity of the source zone is:

$$1{,}227 \text{ ft}^3 \times 28{,}317 \text{ cm}^3/\text{ft}^3 \times 1.70 \text{ g/cm}^3 \times 2.8 \text{ pCi/g} = \mathbf{1.65 \times 10^8 \text{ pCi}}$$

MASS OF ^{99}TECHNETIUM IN THE UCRS SOURCE ZONES

Table 16 summarizes the volume and total activity of the two discrete UCRS ^{99}Tc source zones as well as the mass of ^{99}Tc present, assuming a specific activity of 0.017 Ci/g (Shleien, 1992).

Table 16. Summary of UCRS ^{99}Technetium Source Zones

^{99}Tc Source Zone	^{99}Tc Source Zone Volume (ft^3)	Total ^{99}Tc Activity in ^{99}Tc Source Zone (Ci)	Total ^{99}Tc Mass in ^{99}Tc Source Zone (g)
Technetium Storage Tank (SWMU 47)	26,875	3.62×10^{-3}	2.13×10^{-1}
C-403 Neutralization Pit (SWMU 40)	1,227	1.65×10^{-4}	9.71×10^{-3}

REFERENCES

EPA, 1992. *Estimating Potential for Occurrence of DNAPL at Superfund Sites*, Publication 9355.4-07FS, United States Environmental Protection Agency, R.S. Kerr Environmental Research Laboratory, January, 1992.

Kueper, B.H., 1991. *The Occurrence of Dense, Non-Aqueous Phase Liquids in the Subsurface at the Paducah Gaseous Diffusion Plant*, KY/ER/Sub/0815-1015/91/2, Queens University, Kingston, Canada, November, 1991.

Shleien, 1992. Shleien, Bernard, ed., *The Health Physics and Radiological Health Handbook*, Scinta, Inc., Silver Springs, MD, 1992.

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Appendix A

Isoconcentration Maps of TCE in Soil (µg/g or *ppm*)

for the Southeast C-400 Block

- • soil sample
- Ж water sample

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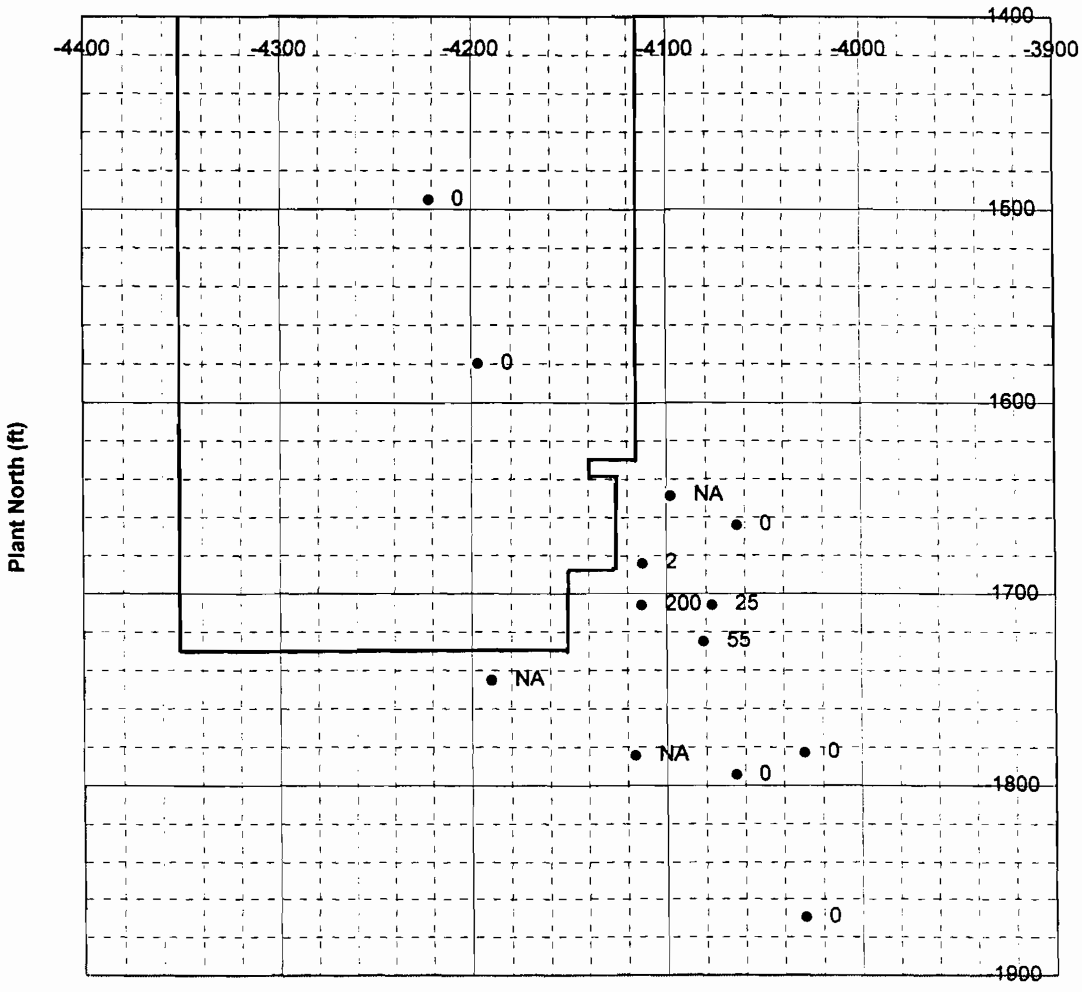
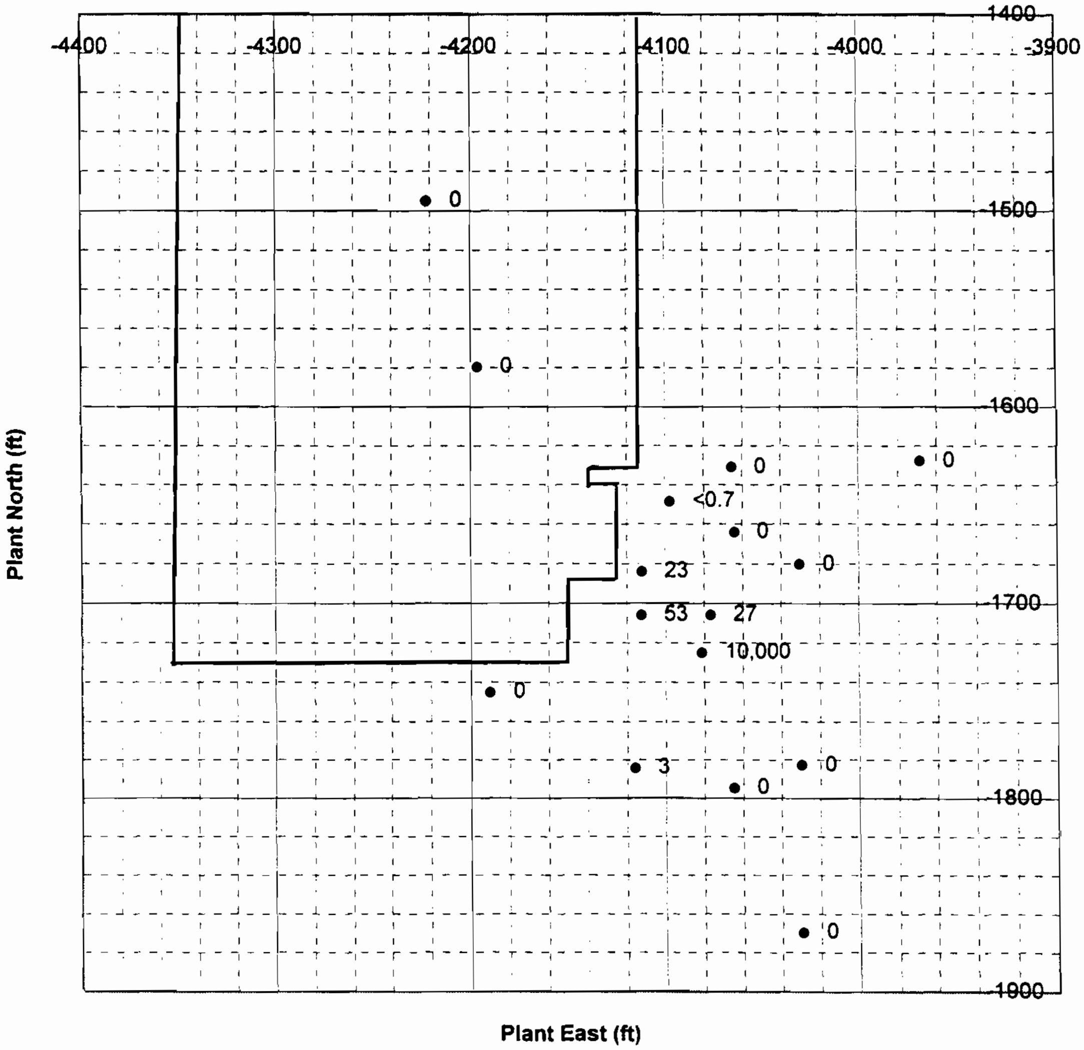
TCE LEVEL (375.0 - 379.9)



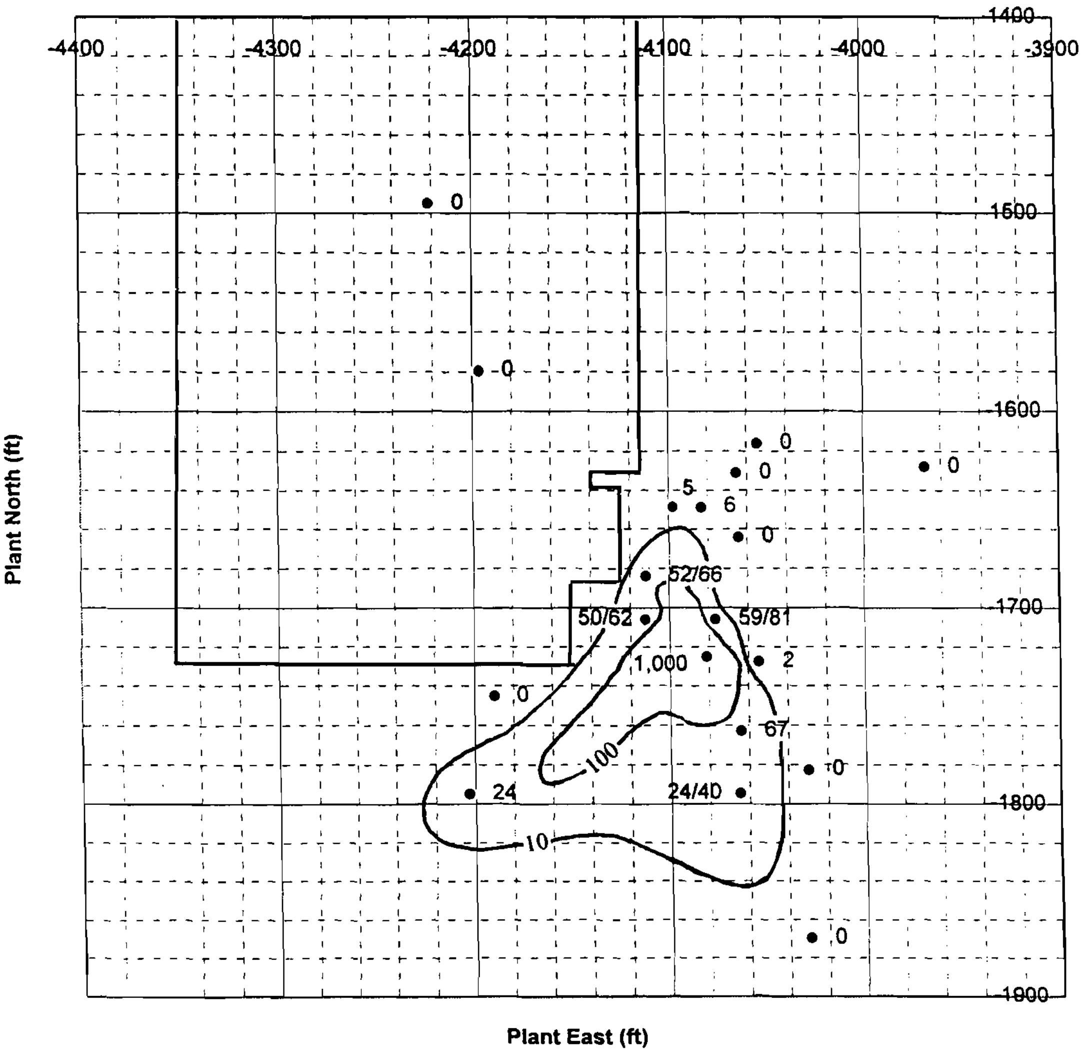
630658

TCE LEVEL (370.0 - 374.9)



630659

TCE LEVEL (365.0 - 369.9)



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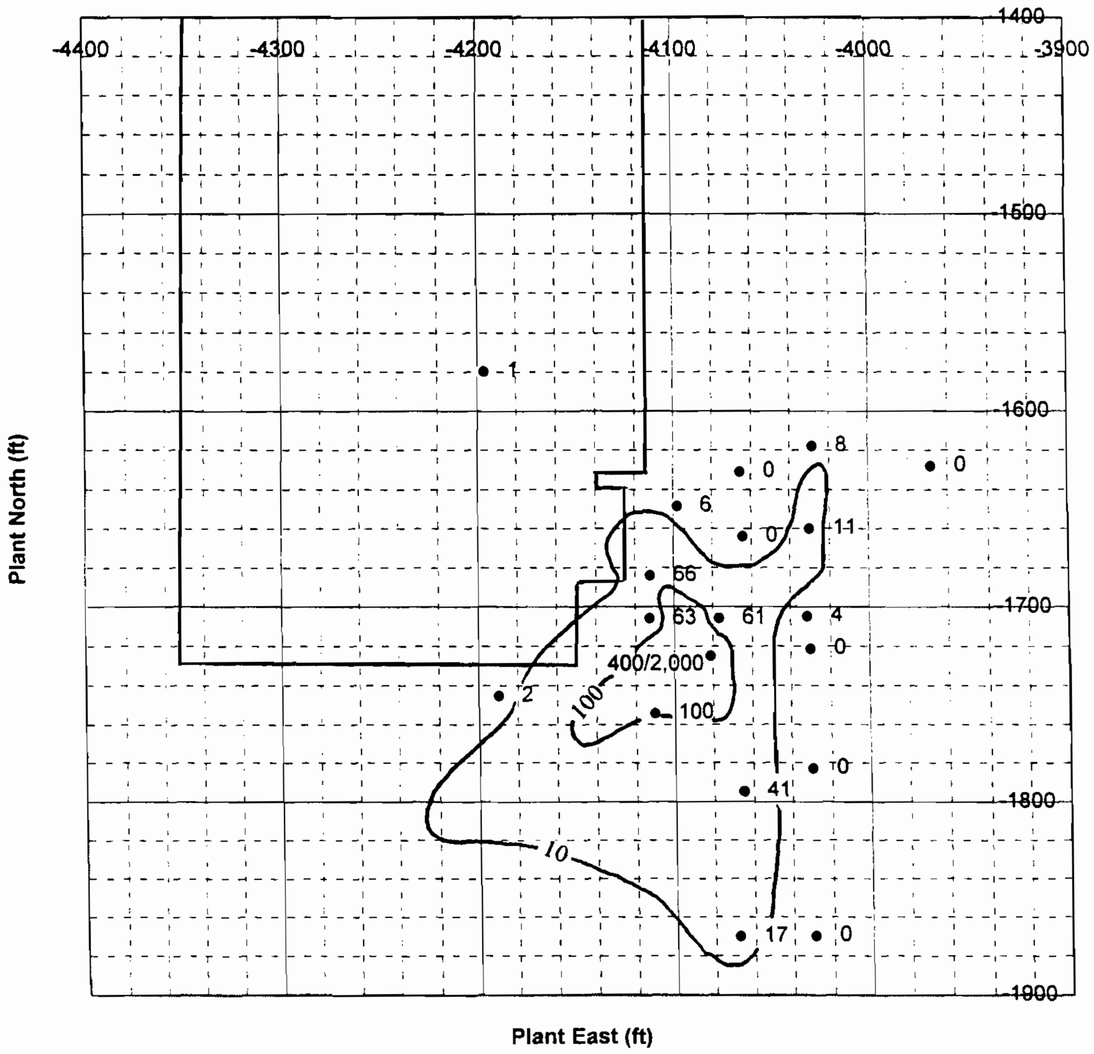
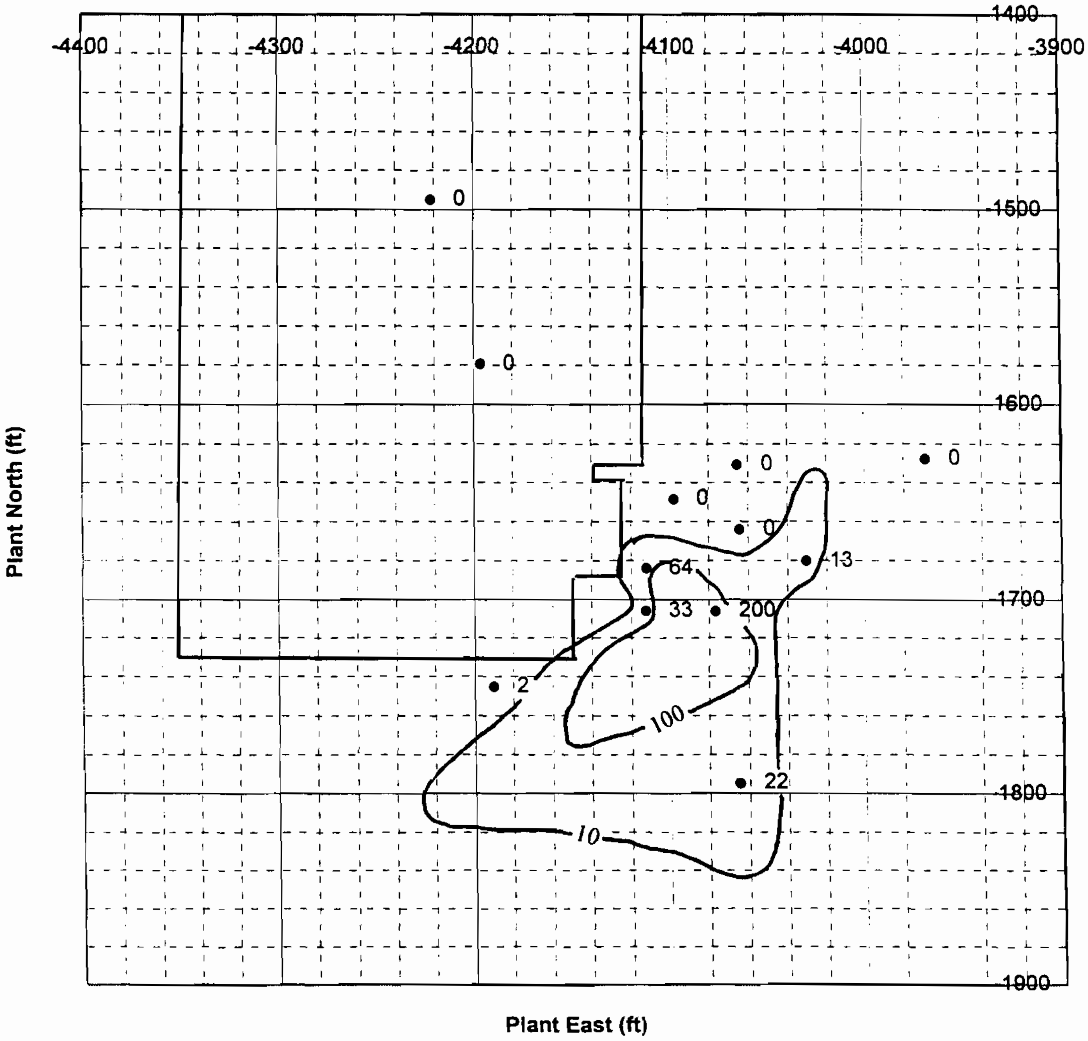
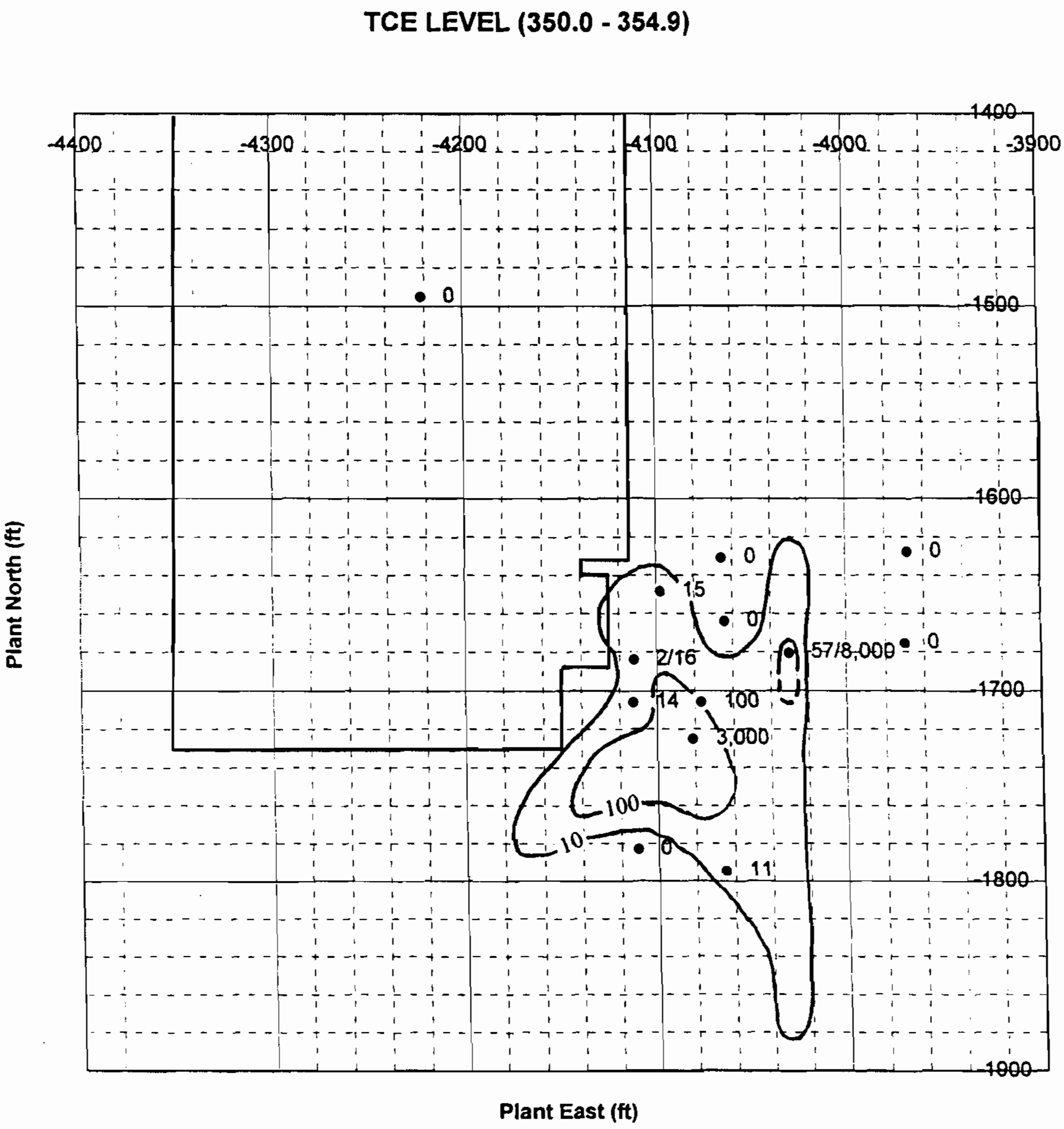
TCE LEVEL (360.0 - 364.9)



630661

TCE LEVEL (355.0 - 359.9)





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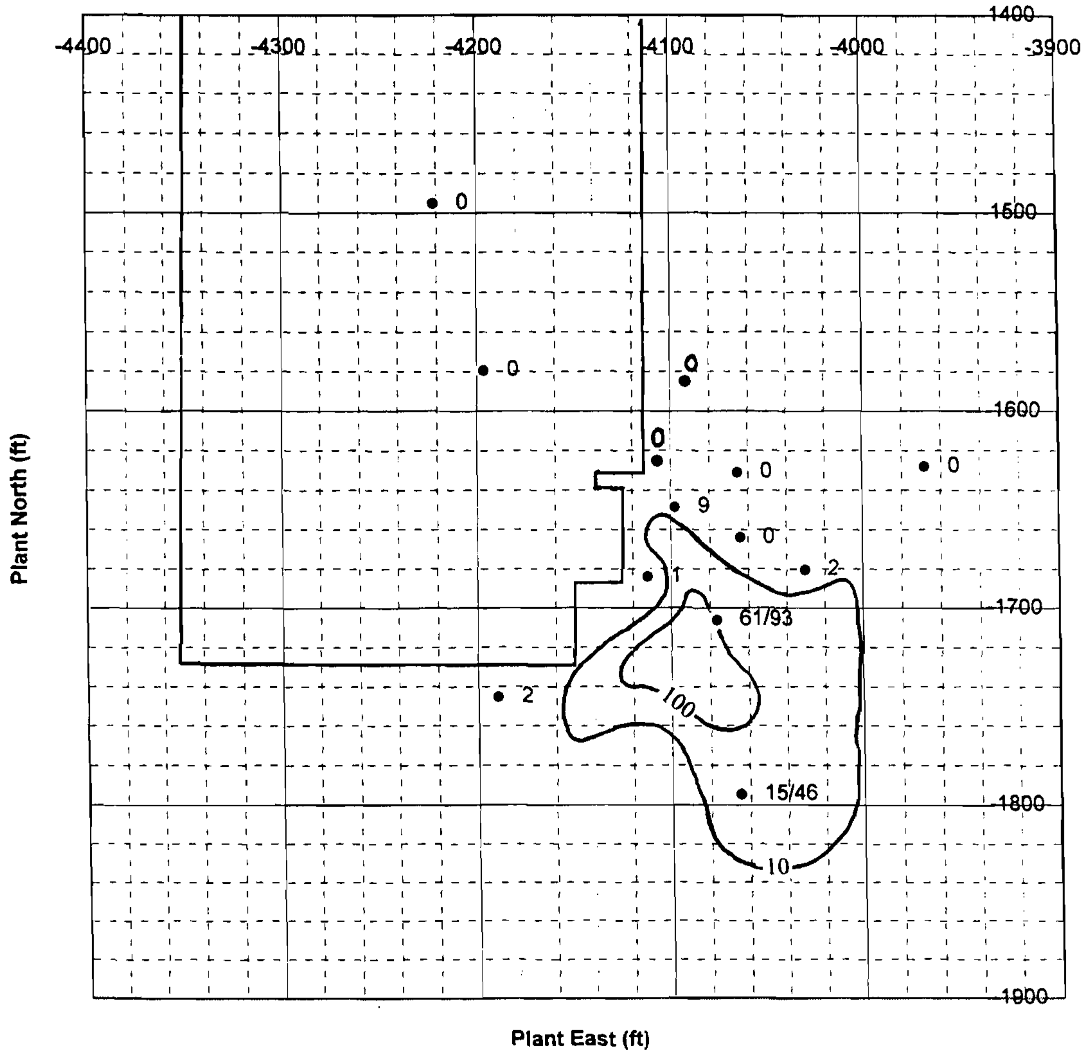
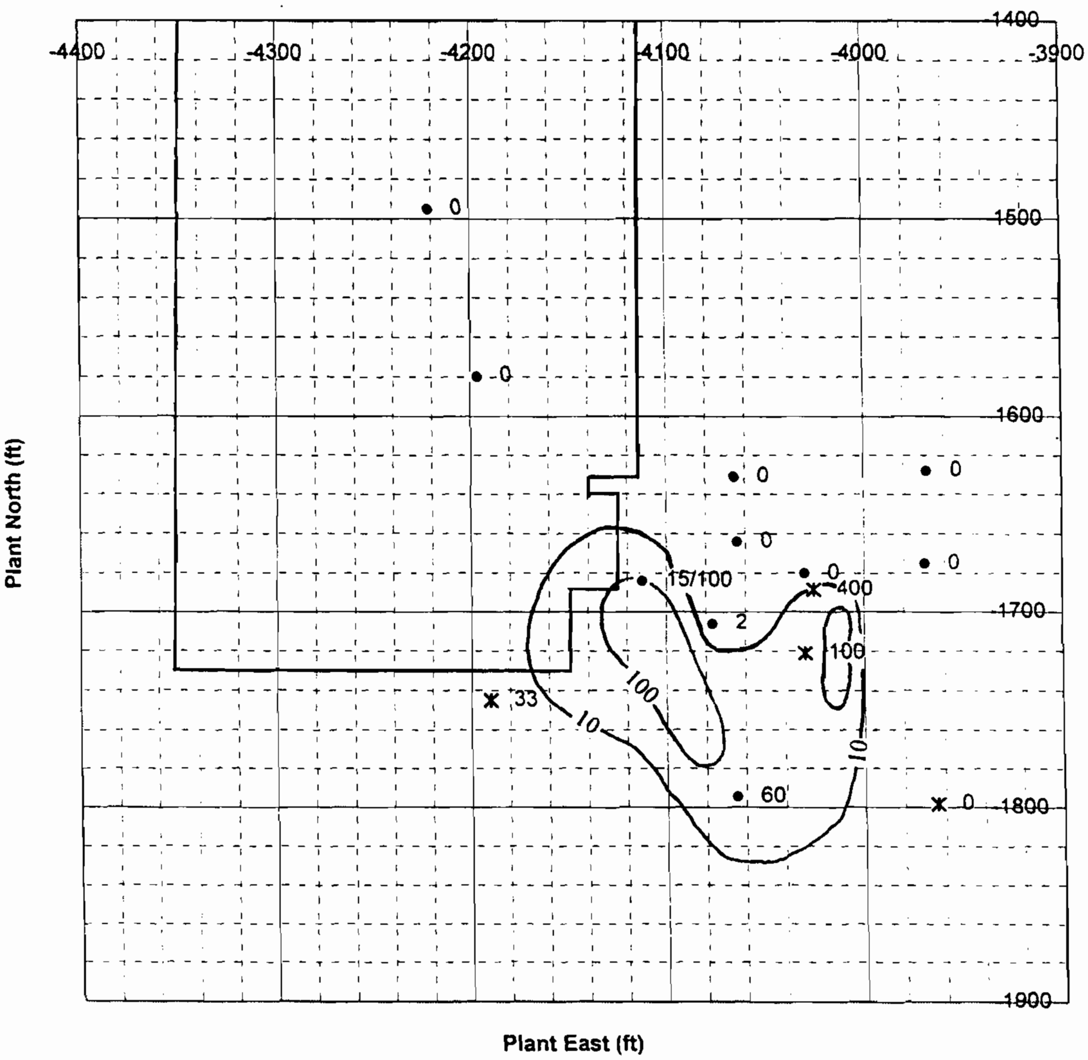
TCE LEVEL (345.0 - 349.9)

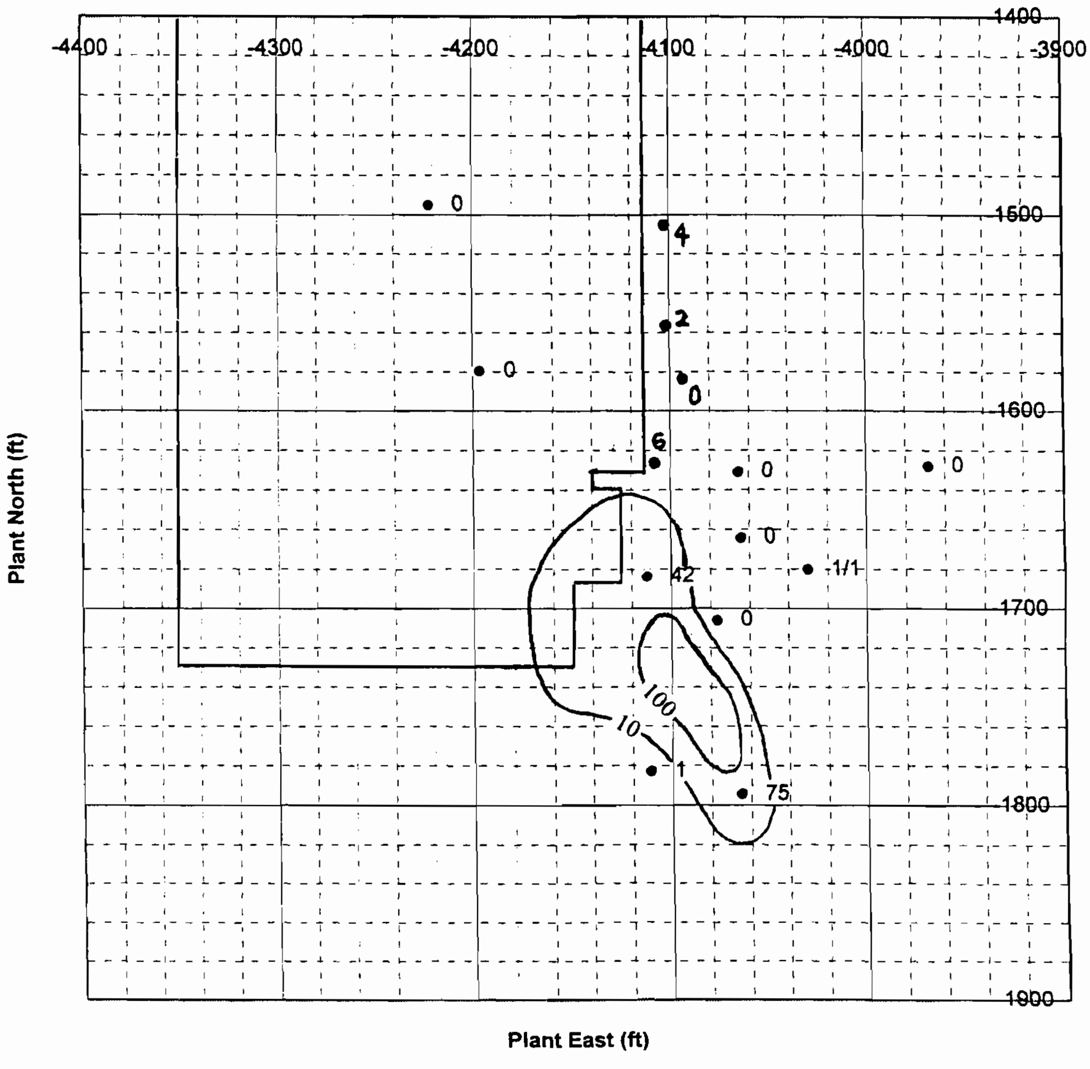


TCE LEVEL (340.0 - 344.9)

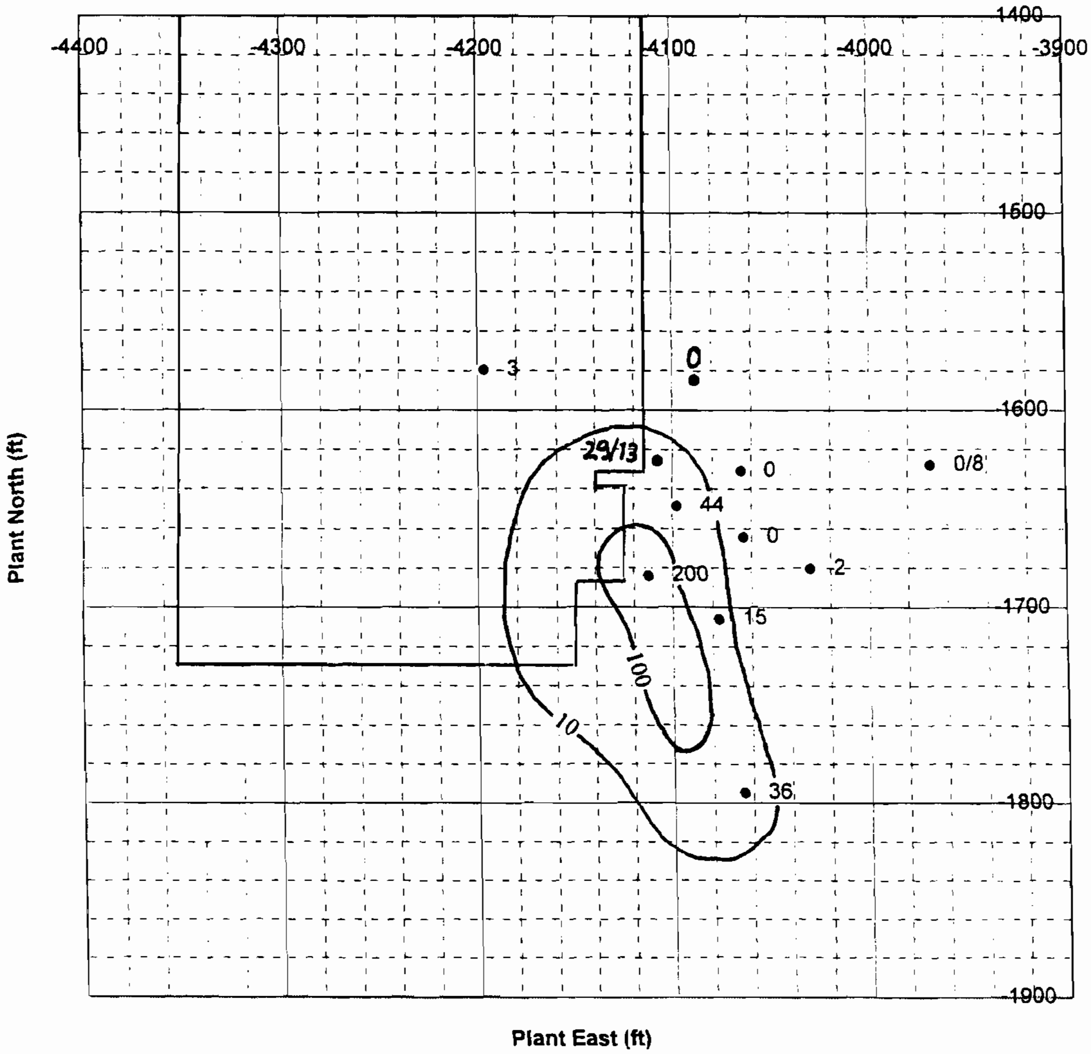


630665

TCE LEVEL (335.0 - 339.9)



TCE LEVEL (330.0 - 334.9)



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Appendix B

TCE in Soil Analyses (μg/g *or ppm)* for the Area of the C-400 Building Southwest Storm Sewer

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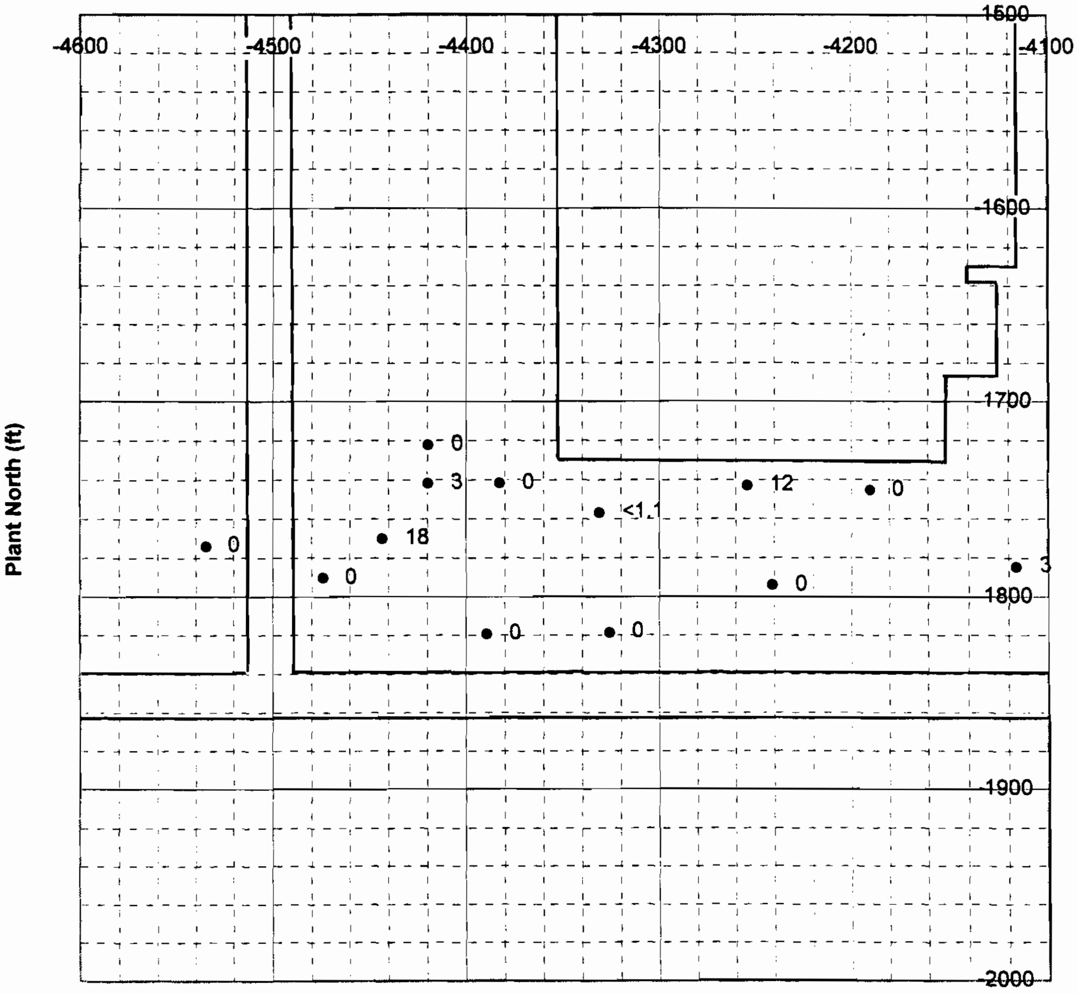
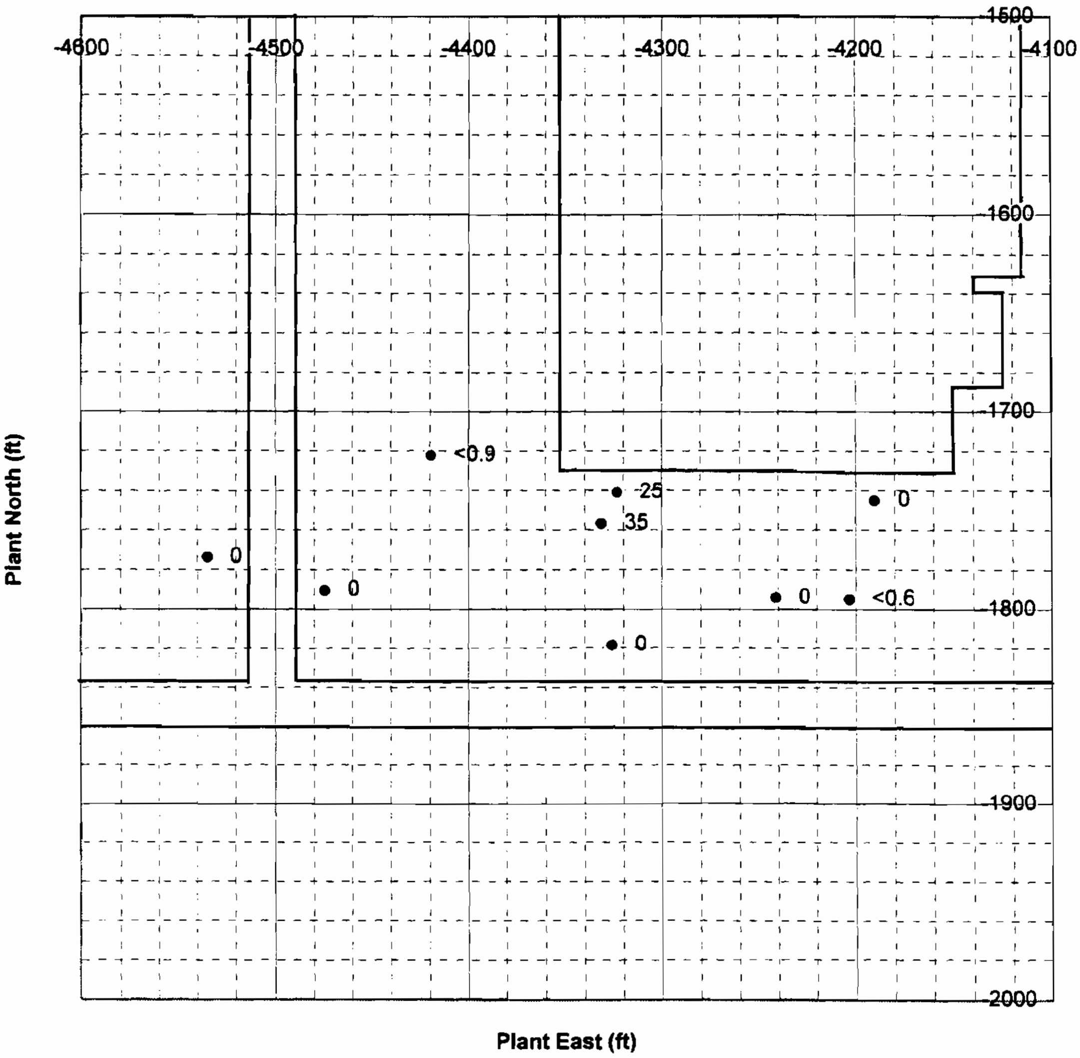
TCE LEVEL (370.0 - 374.9)

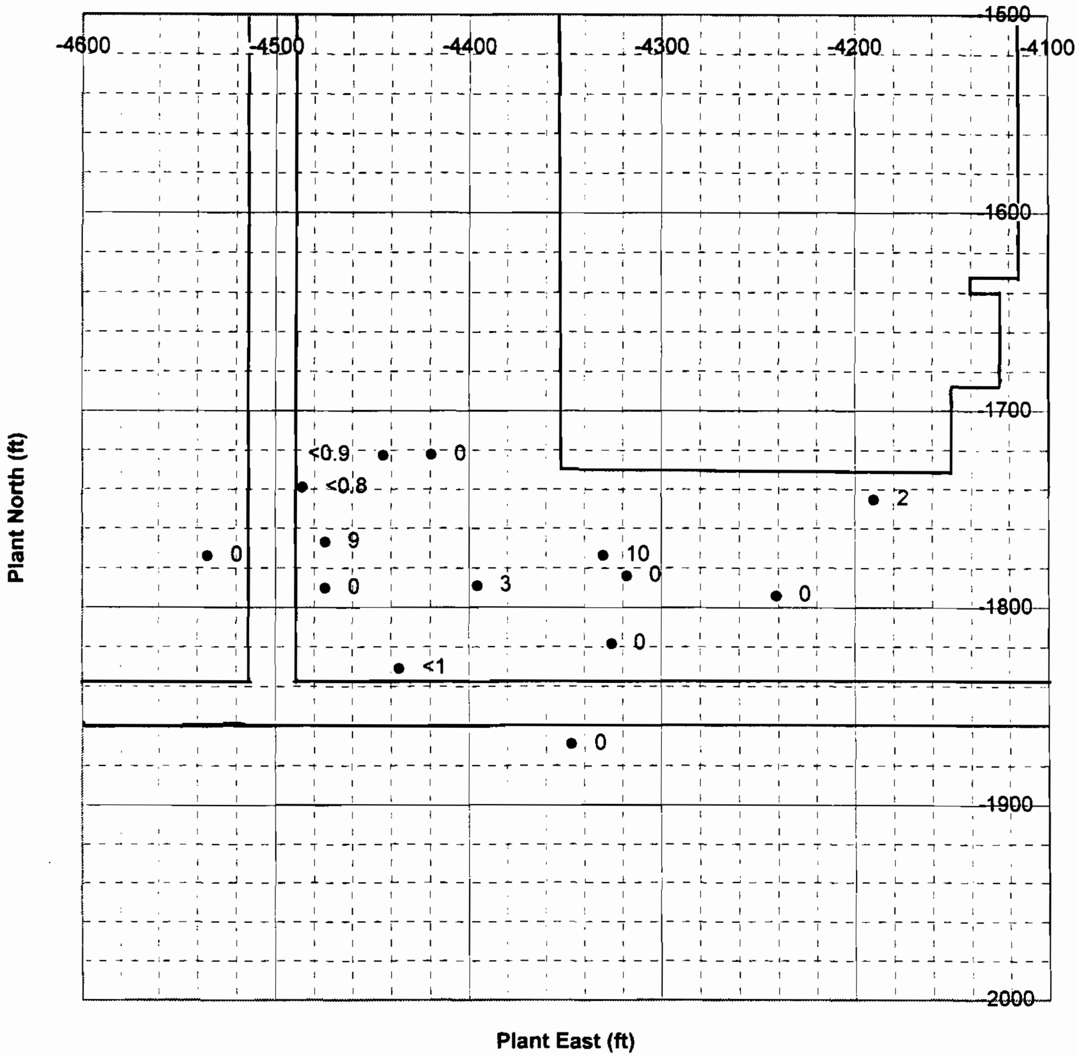


TCE LEVEL (365.0 - 369.9)

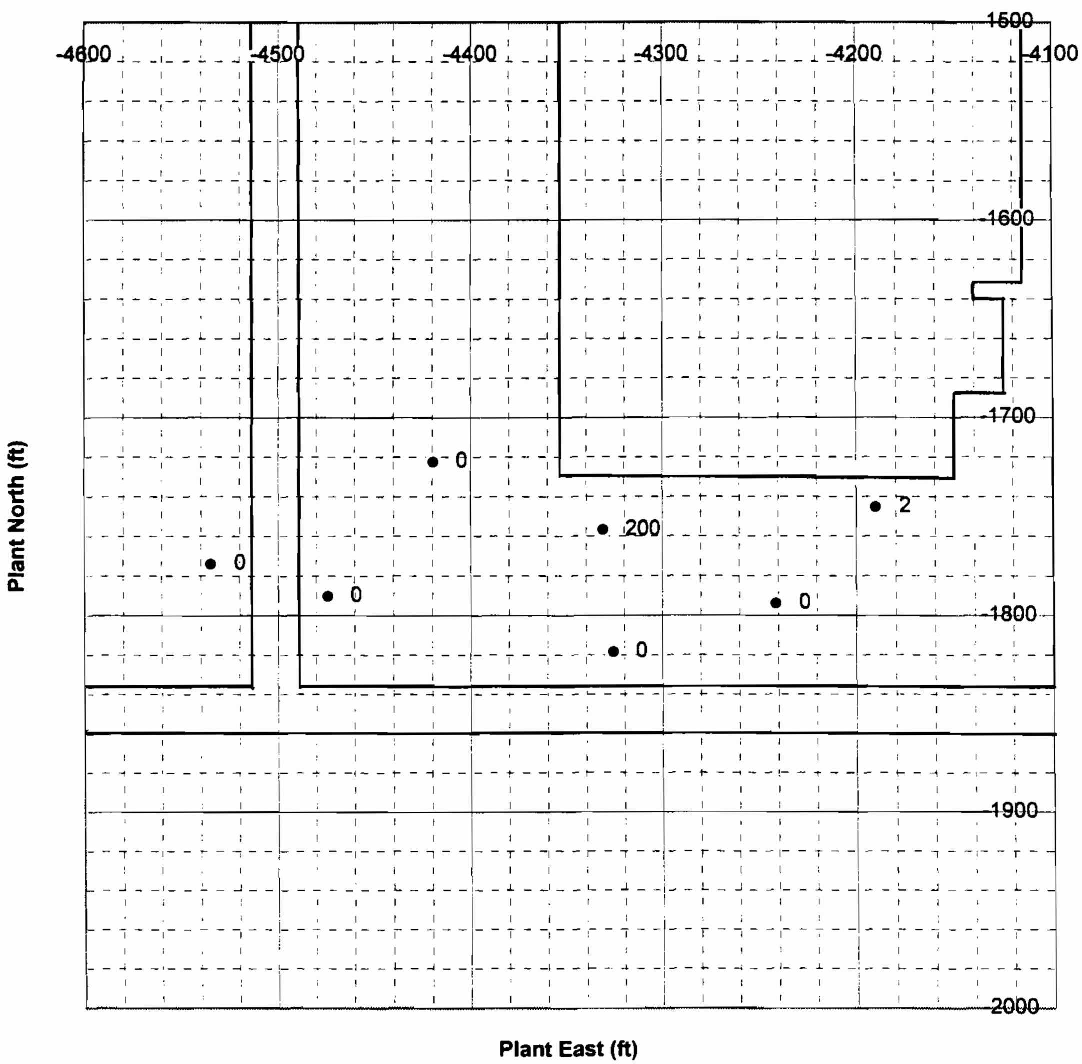


630670

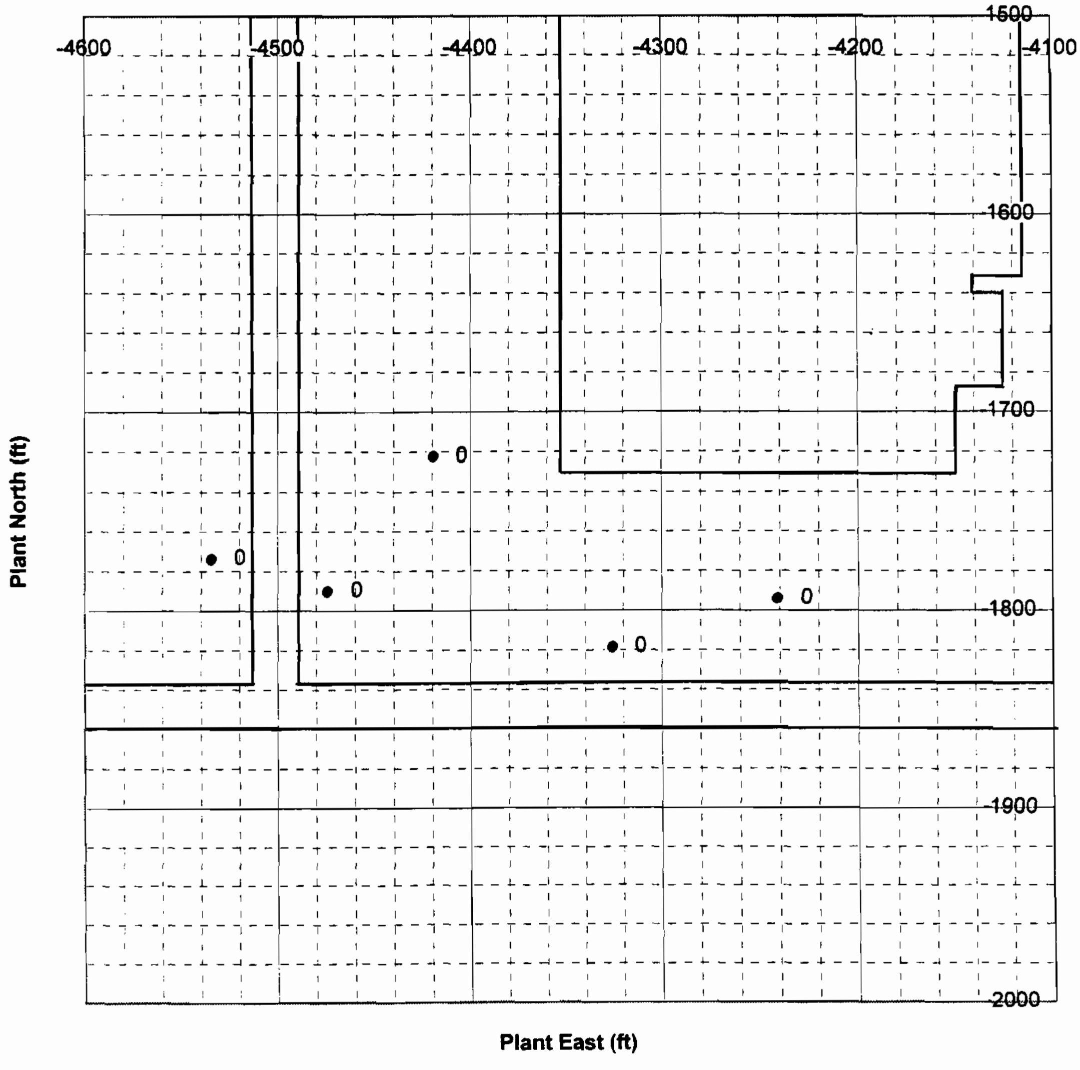
TCE LEVEL (360.0 - 364.9)



TCE LEVEL (355.0 - 359.9)



TCE LEVEL (350.0 - 354.9)



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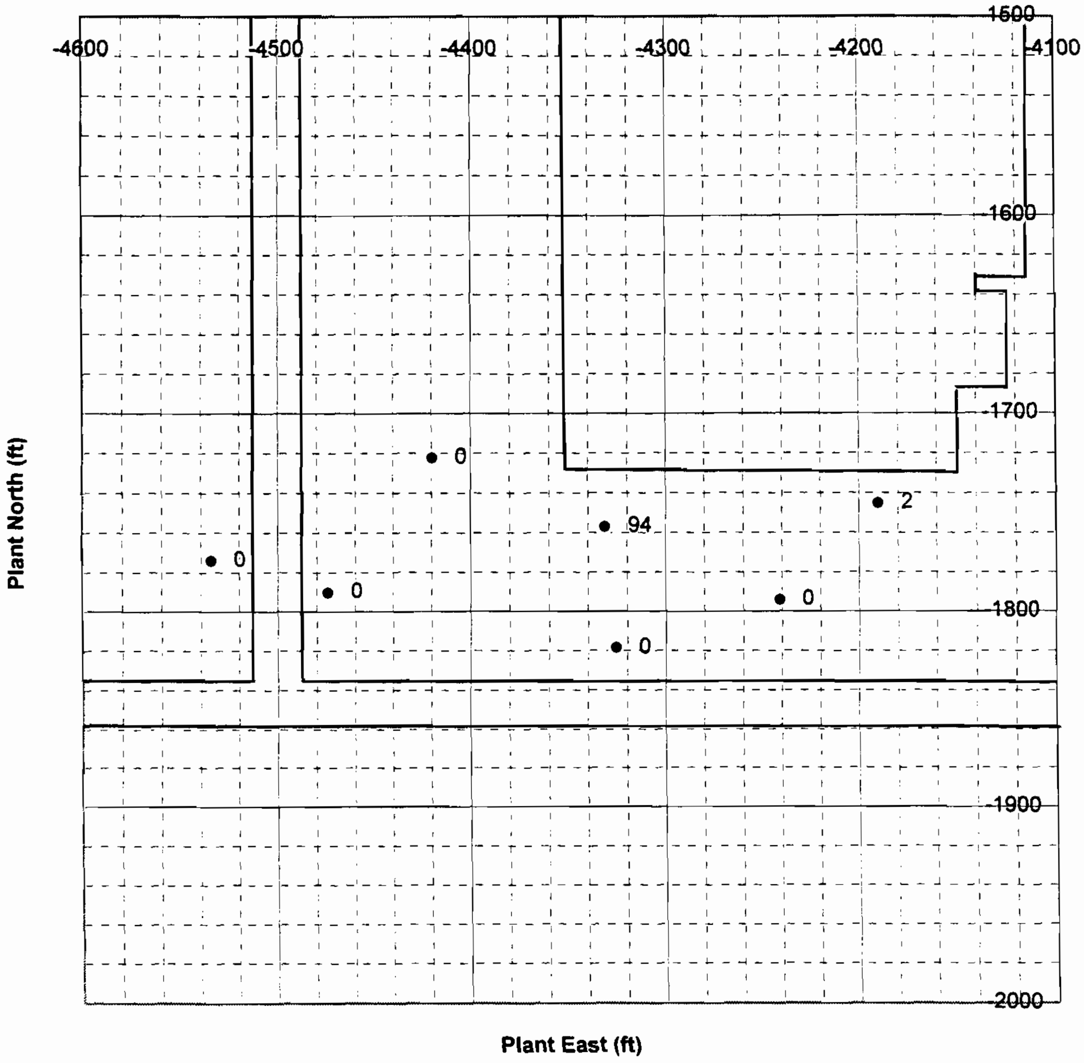
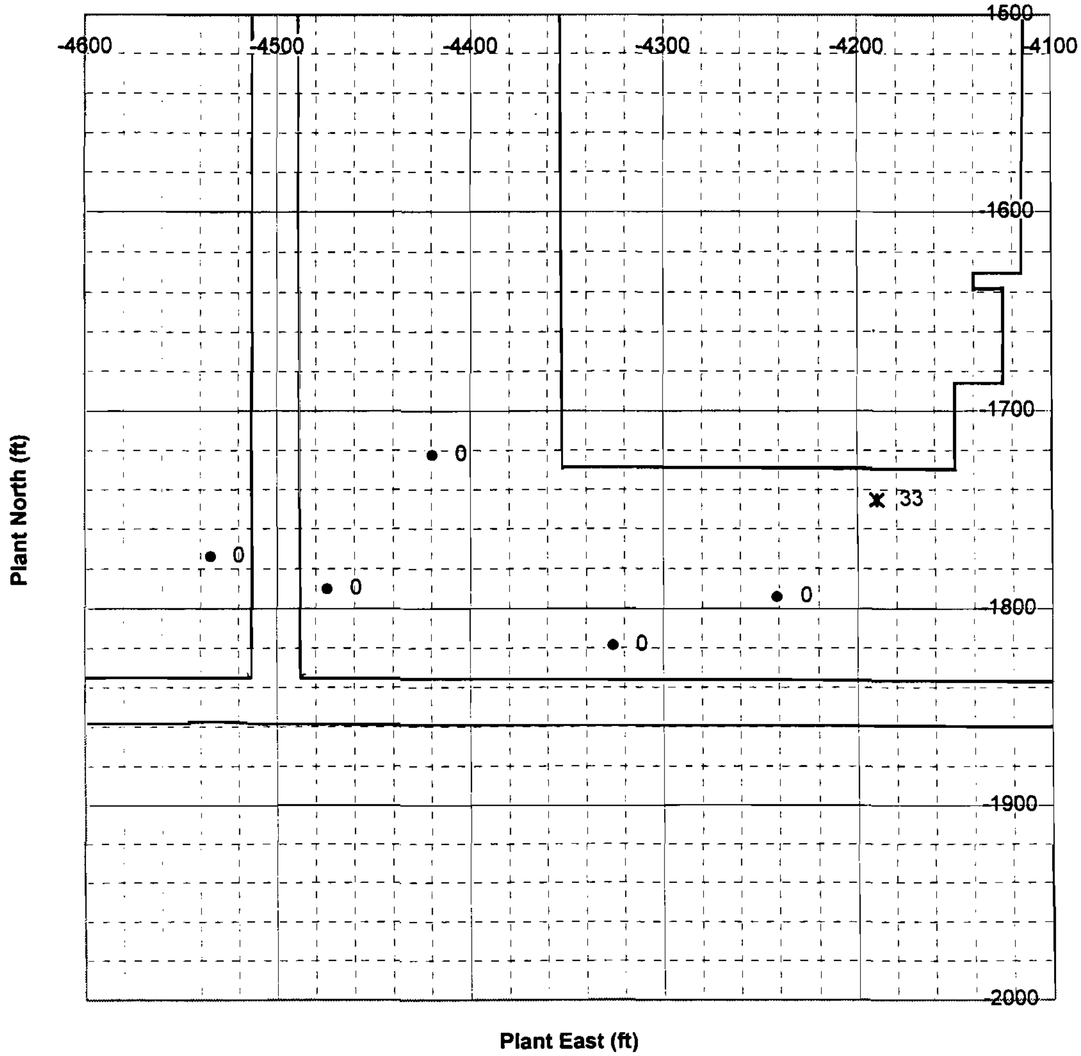
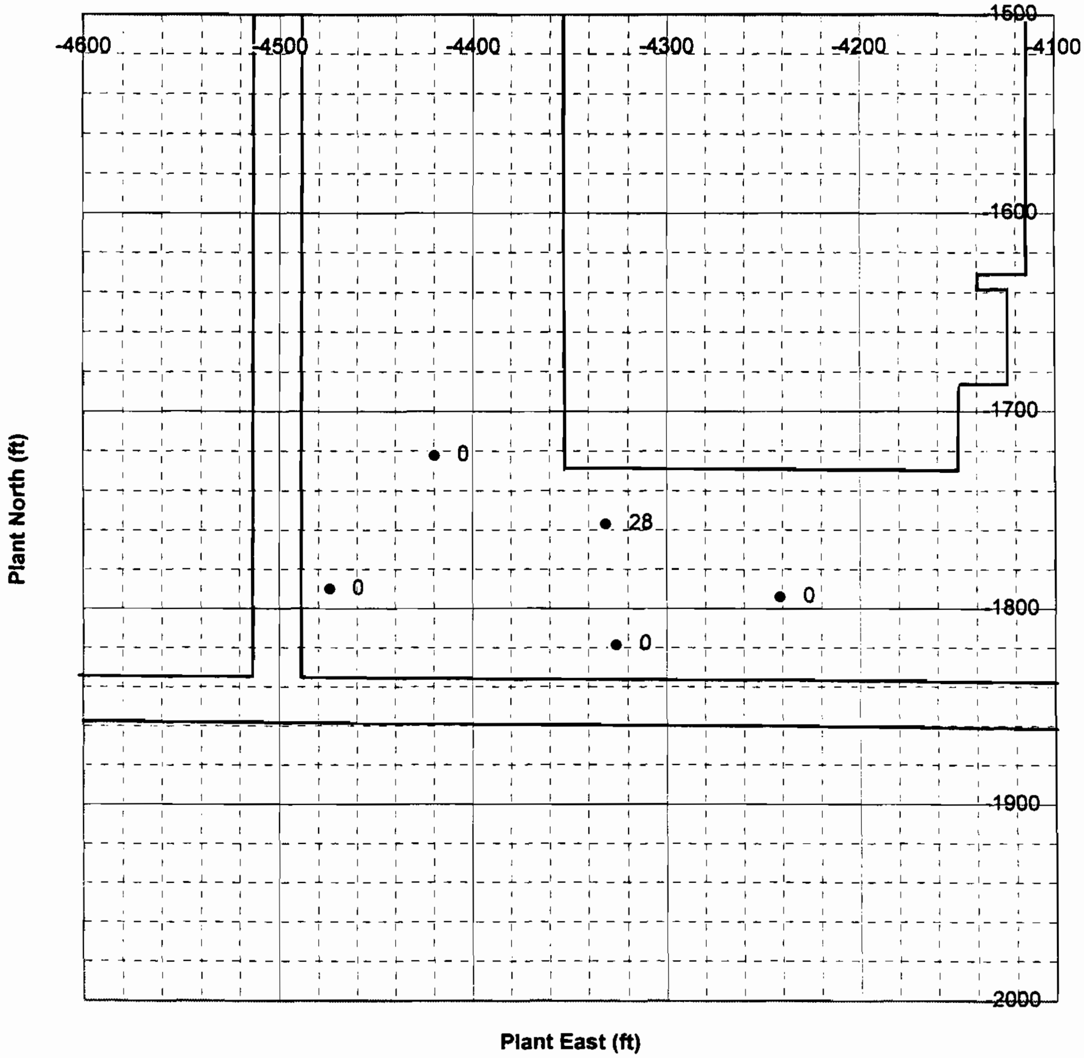
TCE LEVEL (345.0 - 349.9)



TCE LEVEL (340.0 - 344.9)



TCE LEVEL (335.0 - 339.9)



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Appendix C
Contoured Isoconcentration Maps of Dissolved-Phase TCE (µg/L *or ppb)*
and
Contoured Isoactivity Maps of Dissolved Beta Activity (pCi/L) for the RGA

Ж water sample

$\overline{\#}$ value is biased low by sampling or analytical methods

$\underline{\#}$ value is biased high by sampling or anlytical methods

DNAPL source zone associated with the TCE transfer pump leak site

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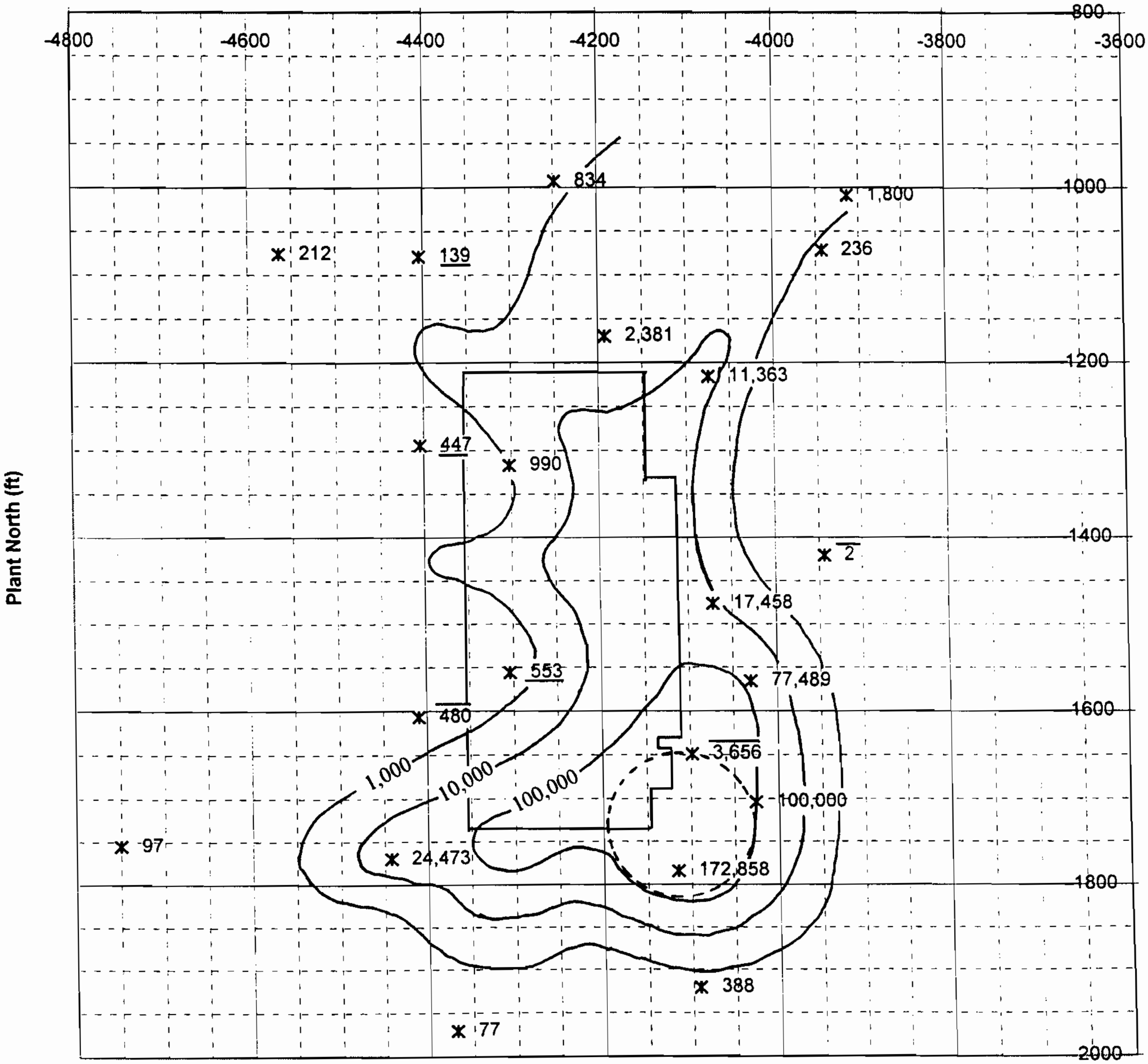
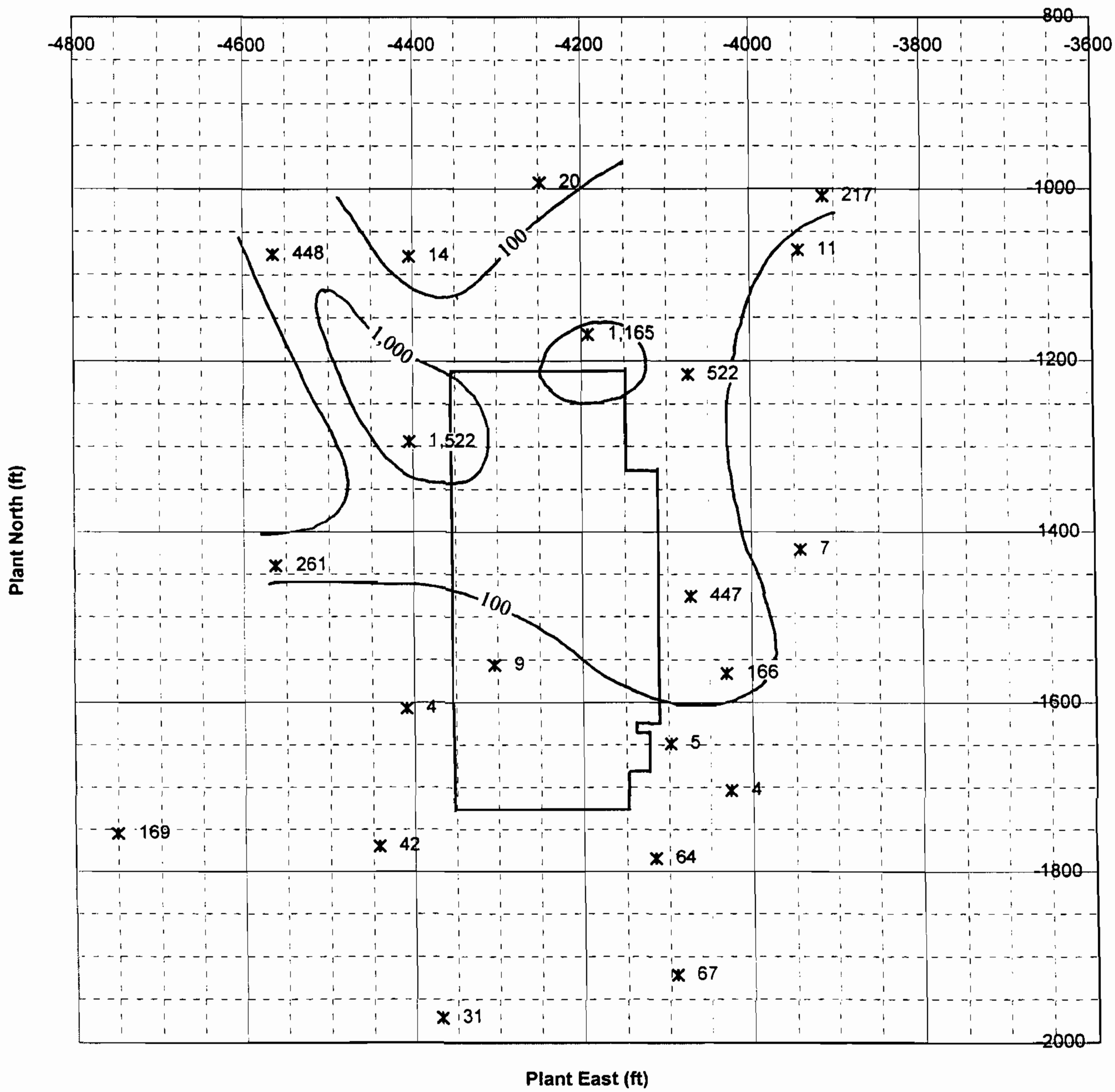
TCE LEVEL (310.0 - 314.9)



Plant East (ft)

BETA ACTIVITY (310.0 - 314.9)



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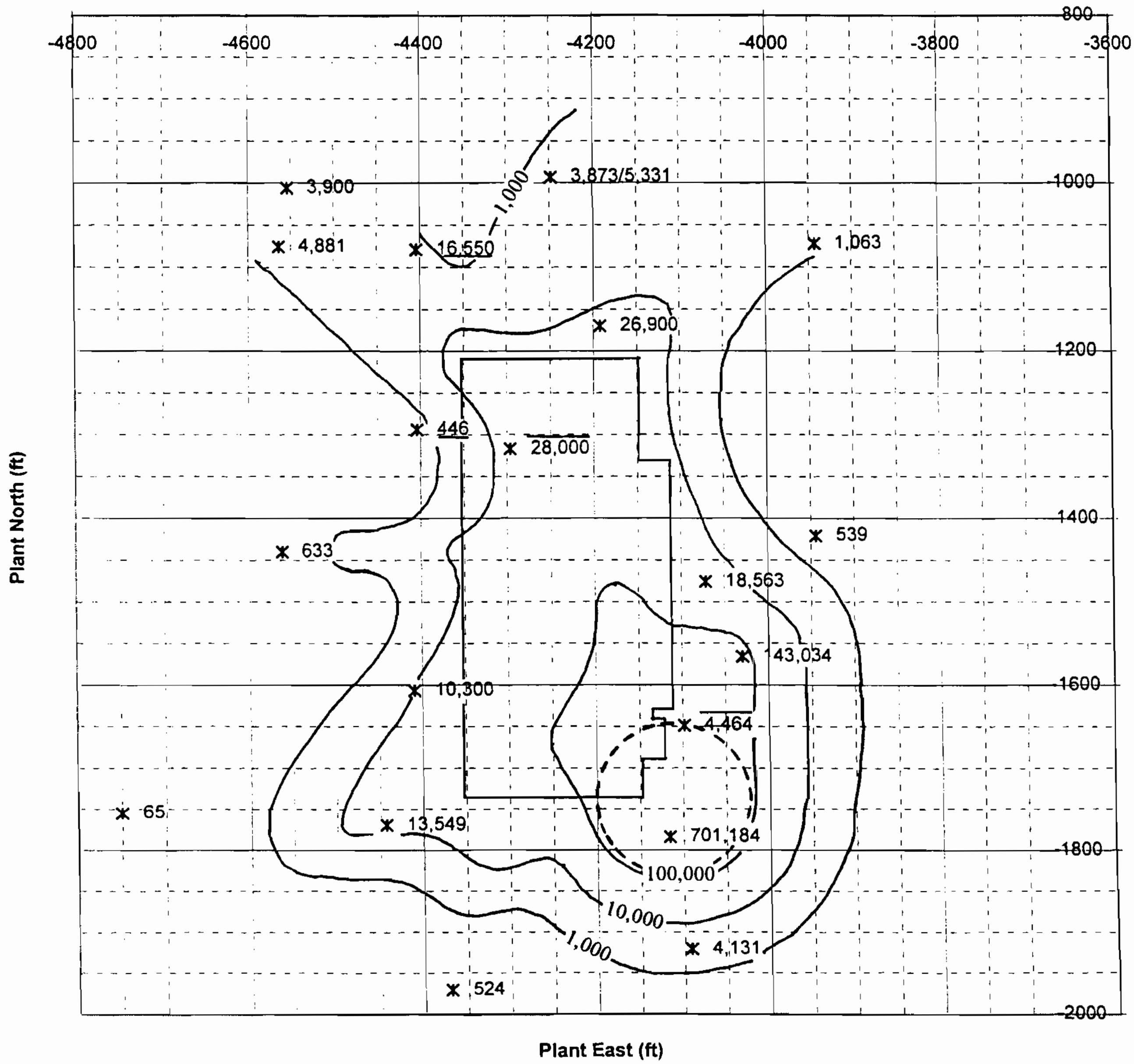
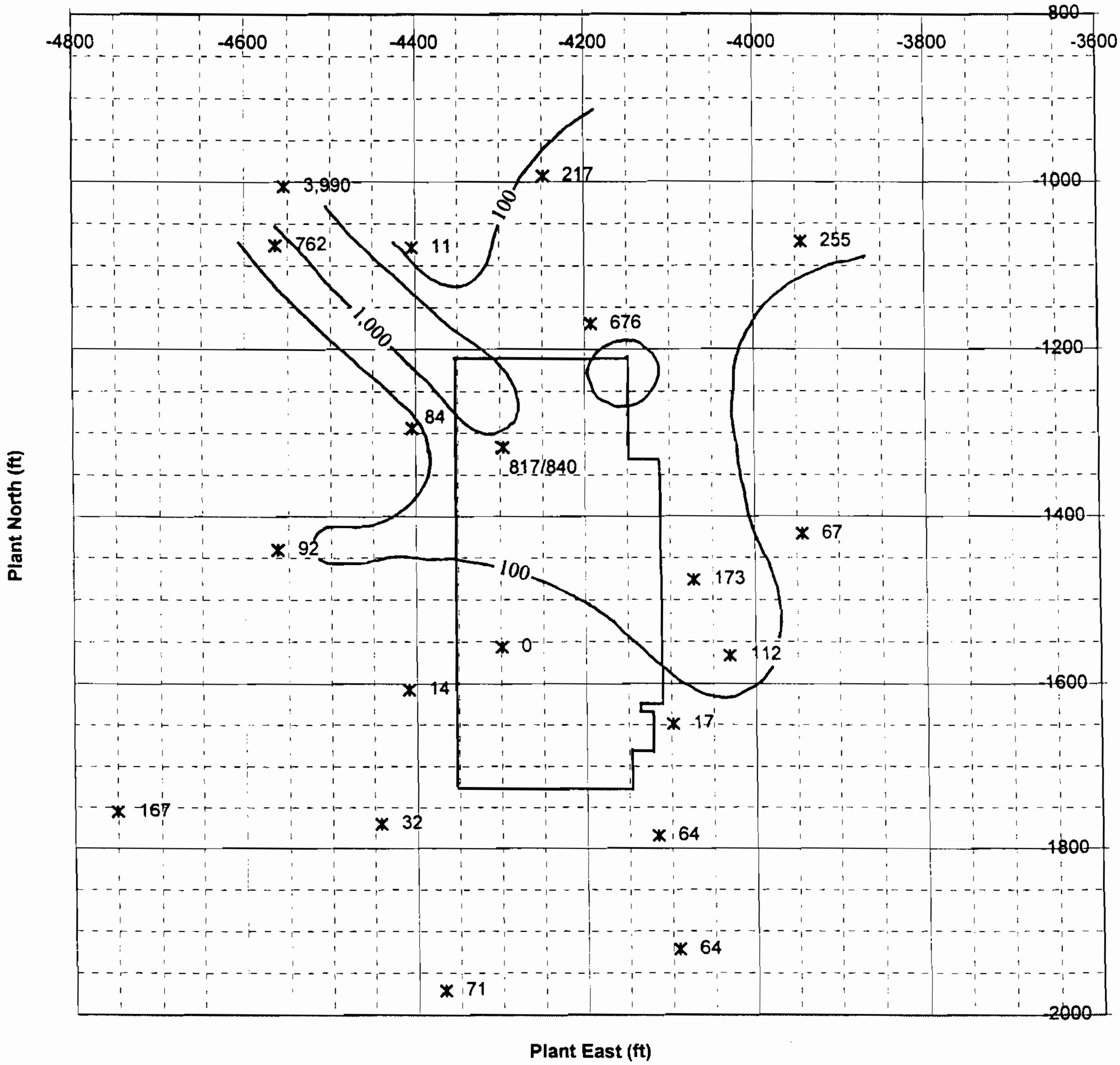
0890E9

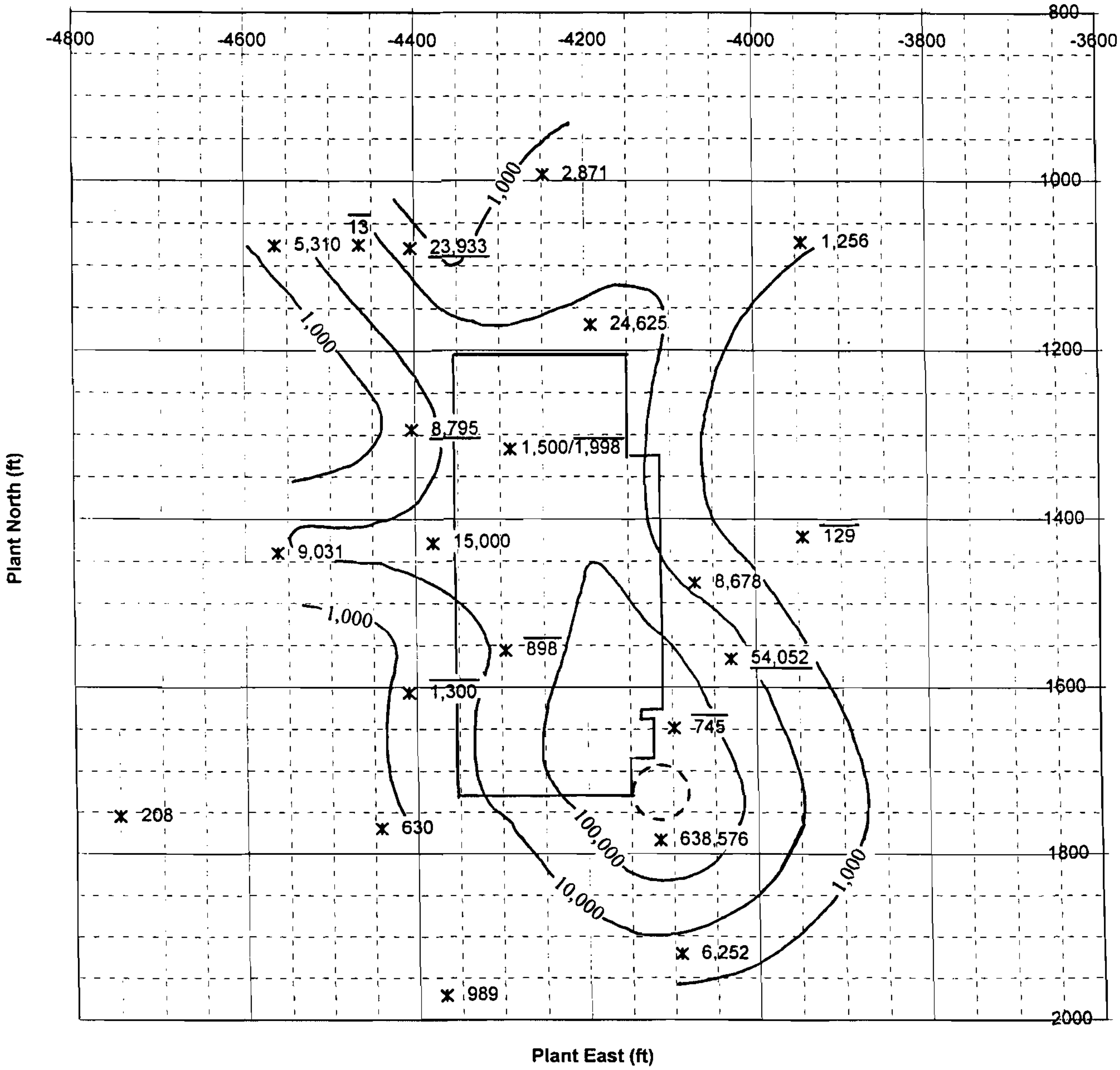
TCE LEVEL (305.0 - 309.9)



BETA ACTIVITY (305 - 309.9 ft amsl)



TCE LEVEL (300.0 - 304.9)



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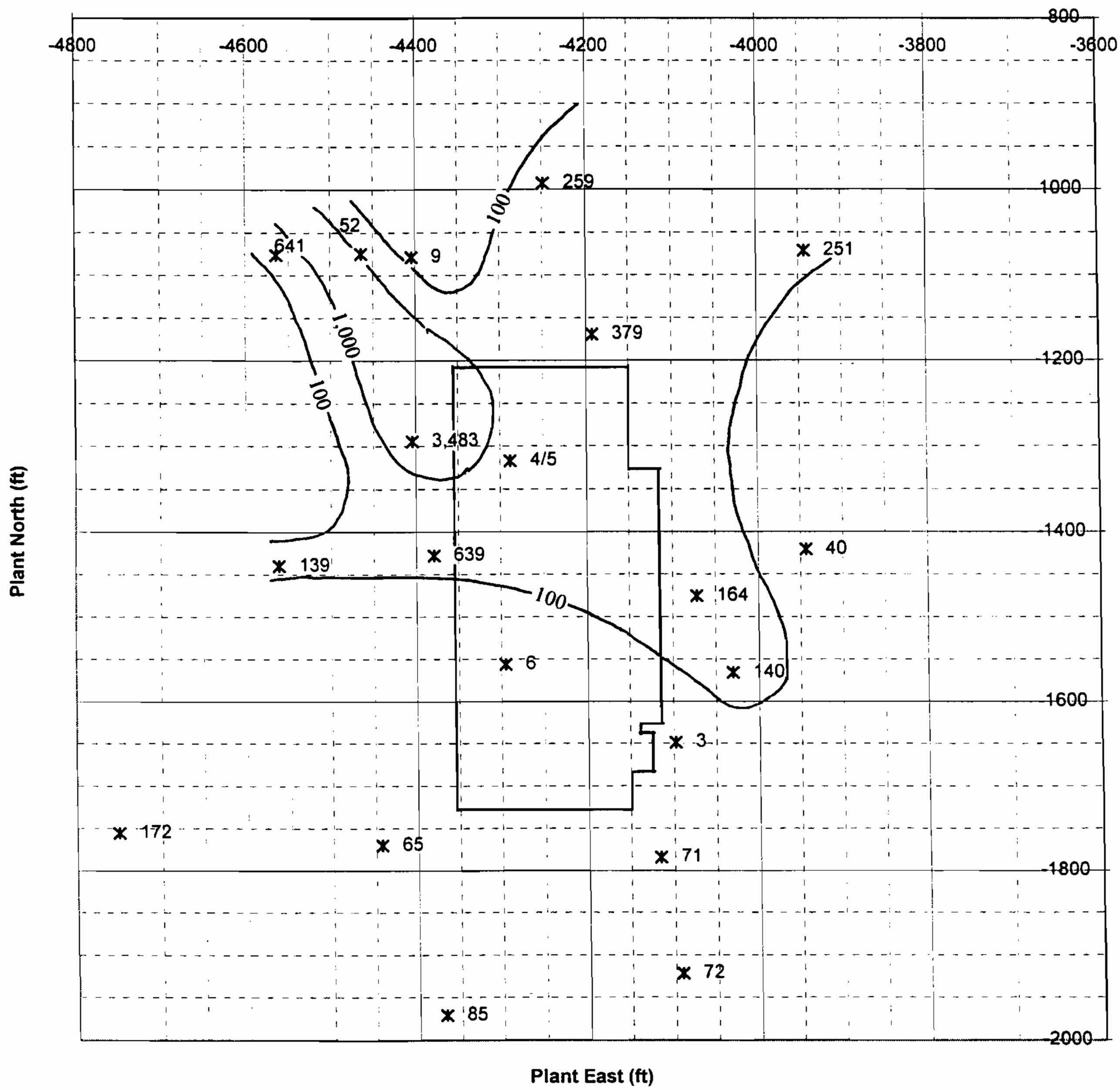
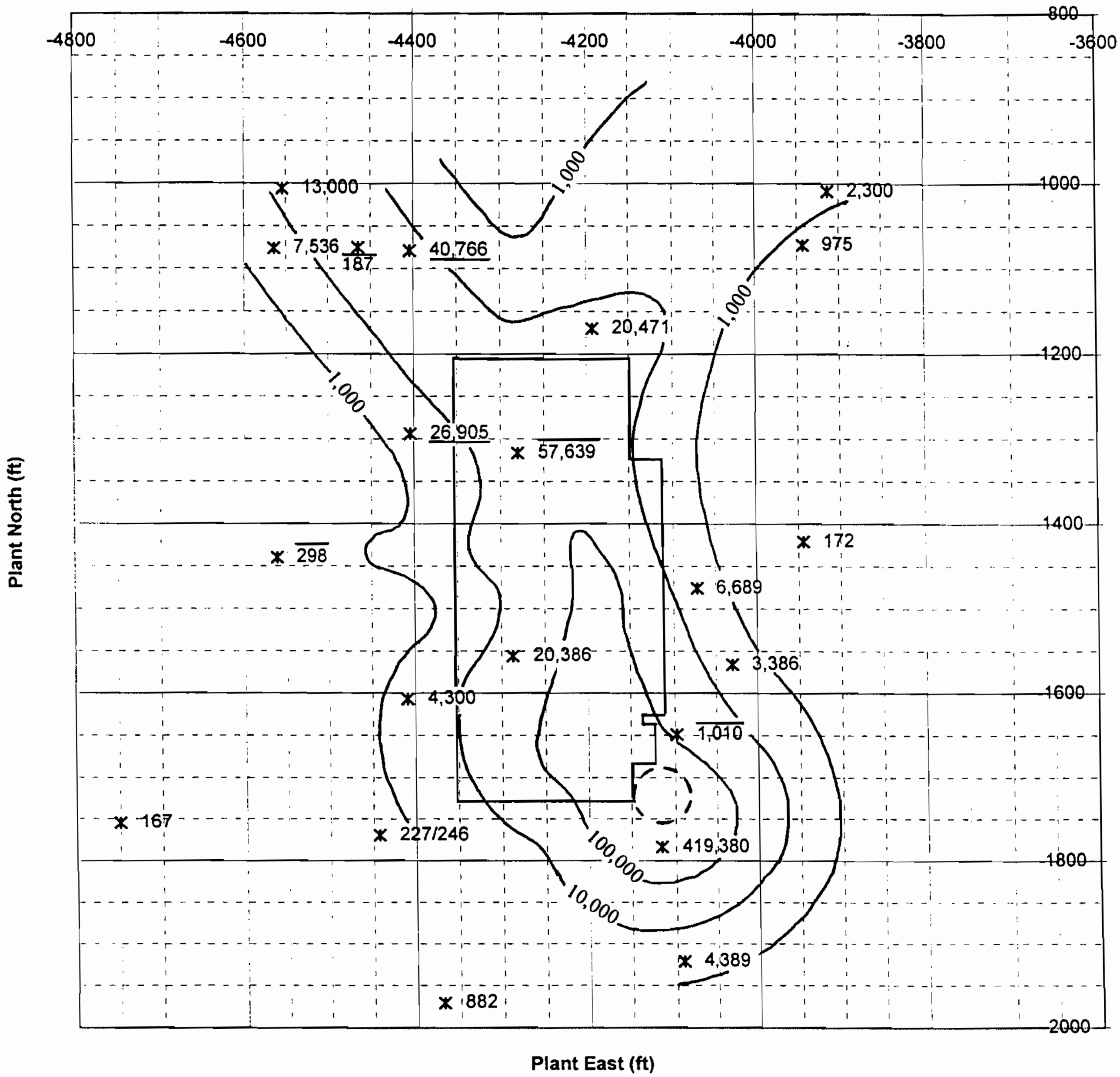
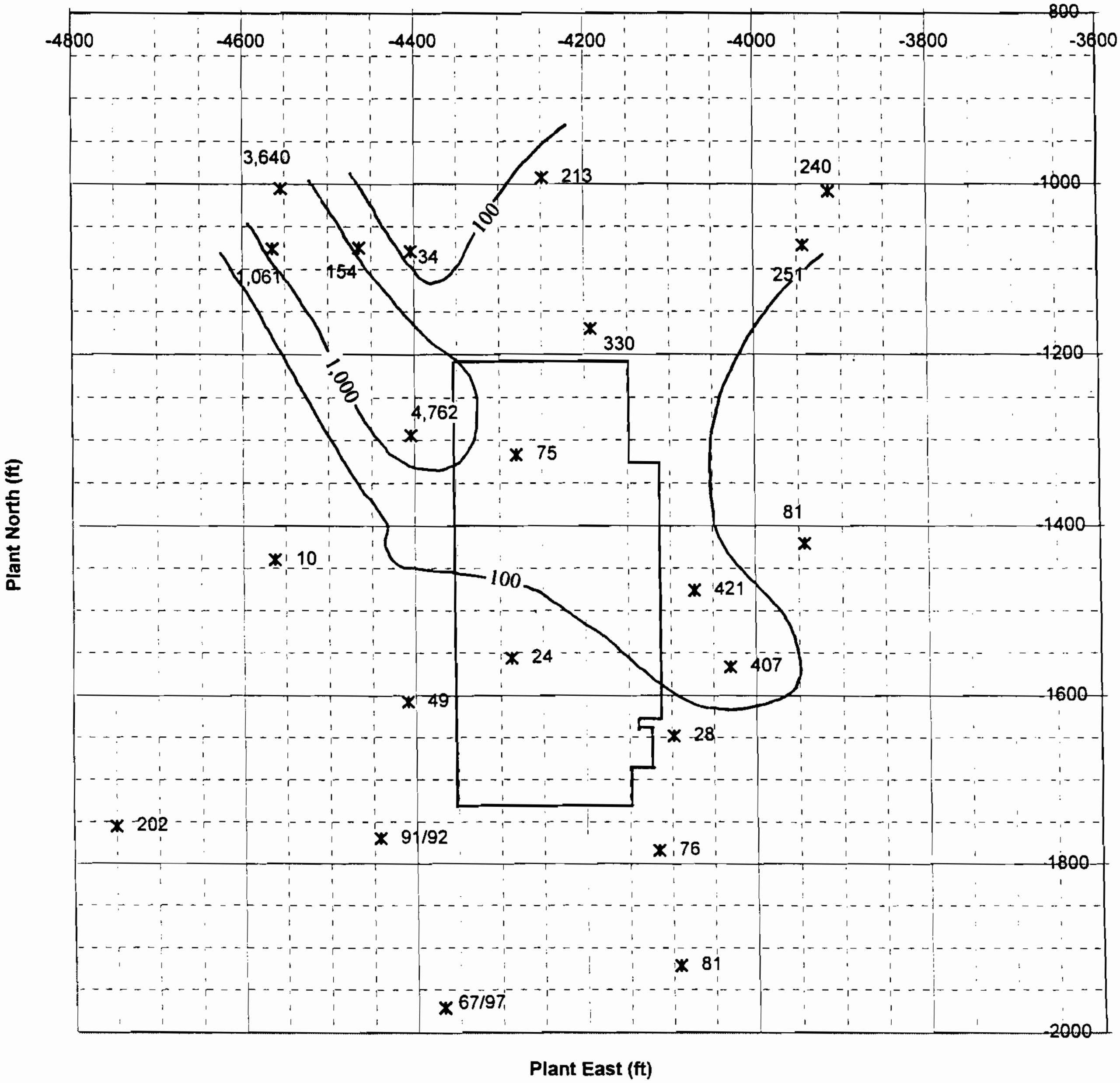
BETA ACTIVITY (300-304.9 ft amsl)



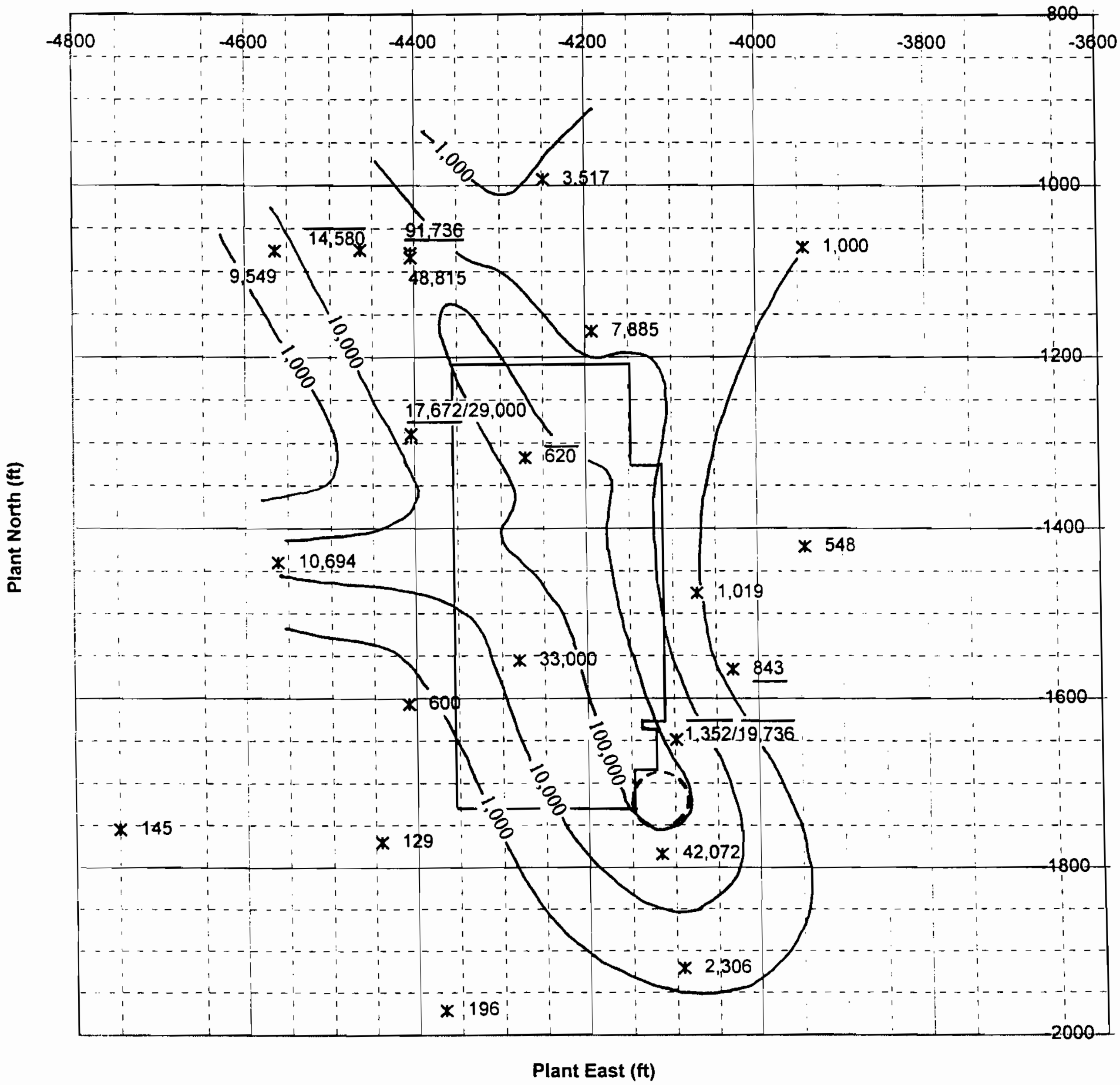
TCE LEVEL (295.0 - 299.9)



BETA ACTIVITY (295 - 299.9 ft amsl)



TCE LEVEL (290.0 - 294.9)



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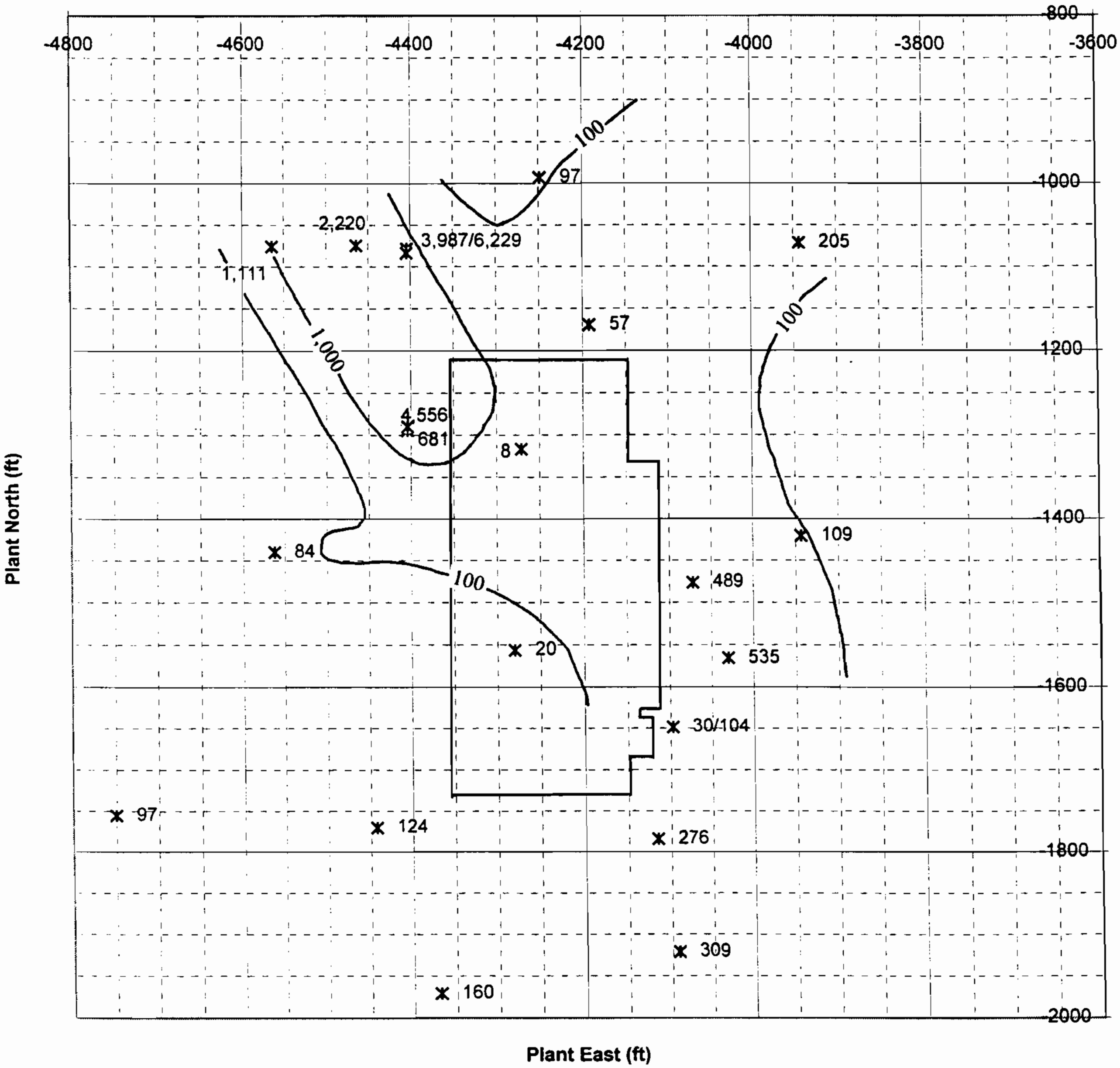
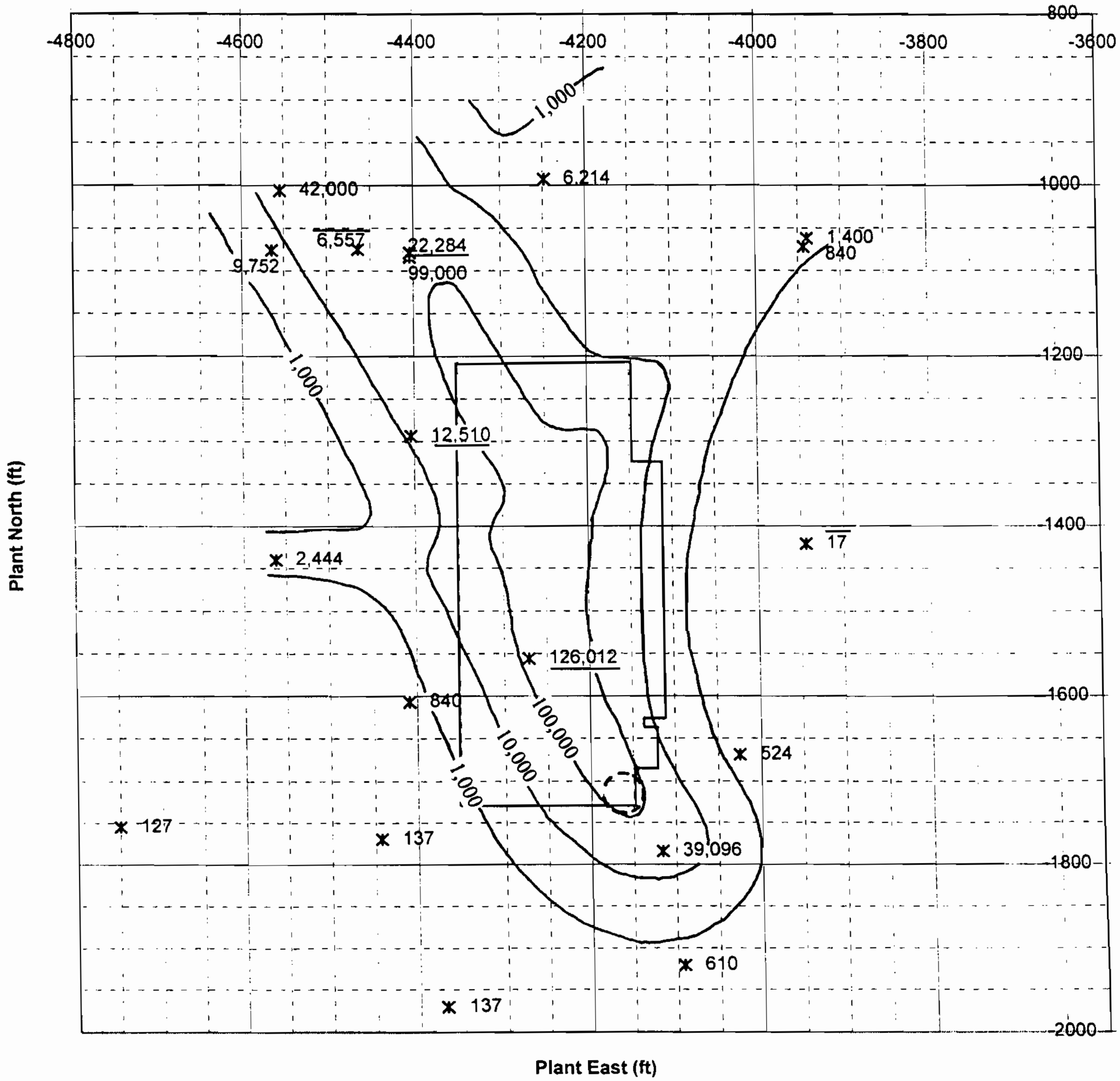
BETA ACTIVITY (290 - 294.9 ft amsl)



TCE LEVEL (285.0 - 289.9)



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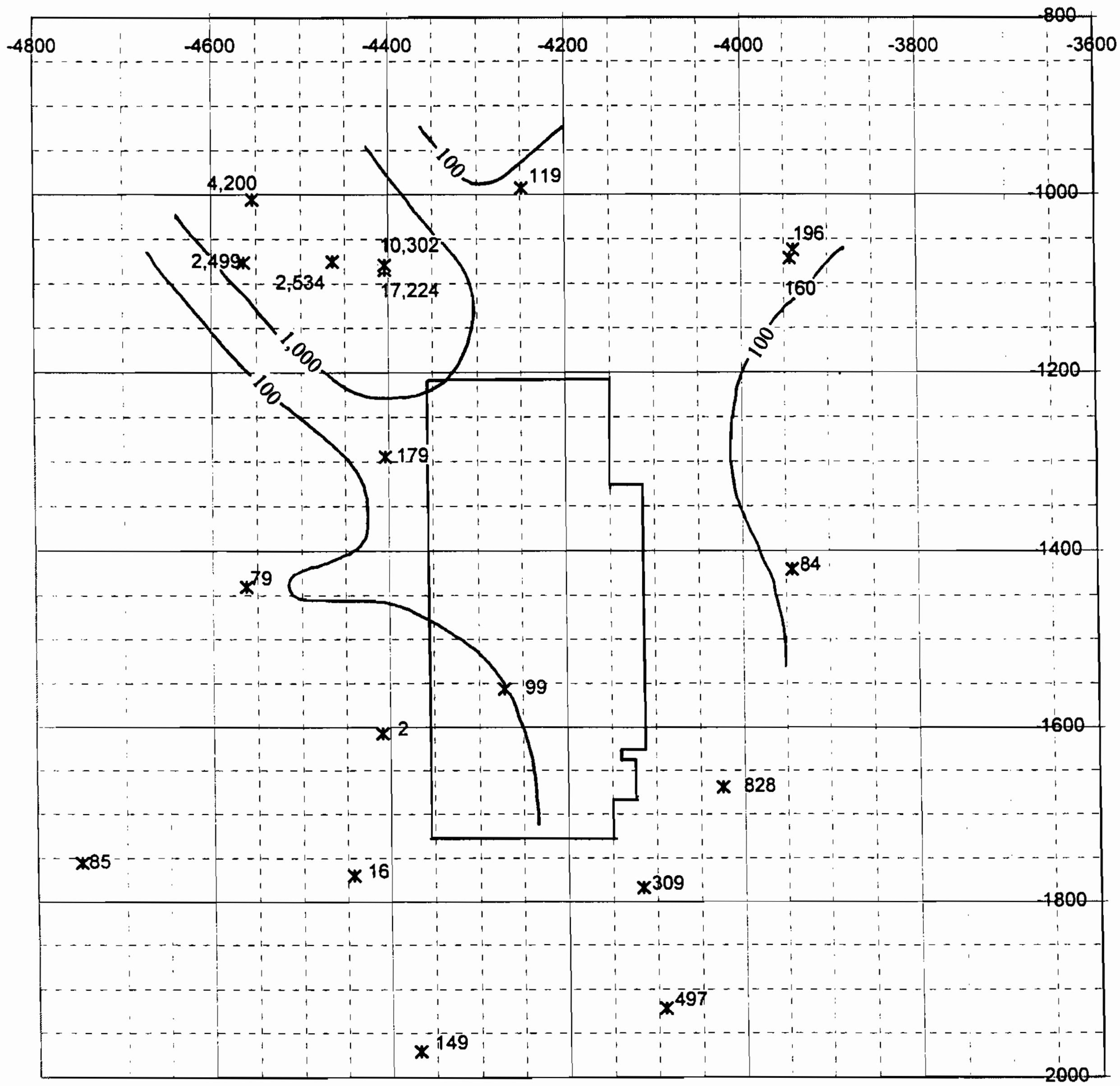
BETA ACTIVITY (285-289.9 ft amsl)



Plant North (ft)

Plant East (ft)

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APPENDIX C6

GWOU

WAG	SWMU	Description
WAG 6	11	C-400 Trichloroethylene Leak Site (GW)
	26	C-400 to C-404 Underground Transfer Line (GW)
	40	C-403 Neutralization Tank (GW)
	47	C-400 Technetium Storage Tank Area (GW)
	203	C-400 Sump (GW)
WAG 27	1	C-747-C Oil Land Farm
	209	C-720 Compressor Shop Pit Sump (GW)
	211	C-720 TCE Spill Site Northwest
WAG 28	99	C-745 Kellogg Building Site (previously AOC #C) (GW)
	183	McGraw UST (GW)
	193	McGraw Const Facilities (Southside Cylinder Yards) (GW)
	194	McGraw Construction Facilities (Southside) (GW)
	204	Dykes Road Historical Staging Area (GW)
WAG 22	2	C-749 Uranium Burial Ground [A]
	3	C-404 Low-Level Radioactive Waste Burial Ground [A]
	7	C-747-A Burial Ground (GW)
	30	C-747-A Burn Area (GW)
WAG 26	201	Northwest Groundwater Plume
	202	Northeast Groundwater Plume
	210	Southwest Groundwater Plume
WAG 3	4s	C-747 Contaminated Burial Ground (GW) [A]
Lasagna	91	UF6 Cylinder Drop Test Area

Footnotes:

A - Remedial action decisions for contaminated groundwater beneath these burial grounds will be deferred until the burial grounds are remediated; and DNAPL subsurface sources are to be addressed under BGOU.

SWOU

WAG	SWMU	Description
WAG 30	70	C-333-A Vaporizer [C]
	71	C-337-A Vaporizer [C]
WAG 8	82	C-531 Switchyard [C]
	83	C-533 Switchyard [C]
	84	C-535 Switchyard [C]
	85	C-537 Switchyard [C]
WAG 25	58	N-S Diversion Ditch (Outside Plt Security Area)
	59	N-S Diversion Ditch (Inside Plt Security Area) [A]
	60	C-375-E2 Effluent Ditch (KPDES 002) [B, C]
	61	C-375-E5 Effluent Ditch (KPDES 013) [B, C]
	64	Little Bayou Creek
	66	C-375-E3 Effluent Ditch (KPDES 010) [B, C]
	67	C-375-E4 Effluent Ditch (C-340 Ditch) [C]
	93	Concrete Disposal Area East of Plant Security Area
	105	Concrete Rubble Pile (3)
	106	Concrete Rubble Pile (4)
	107	Concrete Rubble Pile (5)
	108	Concrete Rubble Pile (6)
	109	Concrete Rubble Pile (7)
	113	Concrete Rubble Pile (11)
	168	KPDES Outfall Ditch 012 [C]
	171	C-617-A Lagoons [C]
WAG 29	102	Plant Storm Sewer (previously 96a, 96b, and 96c) [B, C, D]
WAG 18	62	C-375-S6 Southwest Ditch (KPDES 009) [B, C]
	63	C-375-W7 Oil Skimmer Ditch (KPDES 008) [B, C]
	65	Big Bayou Creek
	68	C-375-W8 Effluent Ditch (KPDES 015) [B, C]
	69	C-375-W9 Effluent Ditch (KPDES 001) [B, C]
	129	Concrete Rubble Pile (27)
	175	Concrete Rubble Pile (28)
	199	Big Bayou Creek Monitoring Station
	205	Eastern Portion of Yellow Water Line
WAG 7	8	C-746-K Inactive Sanitary Landfill [E]
N/A	N/A	Internal Ditches
N/A	N/A	C-340 Building Complex
WAG 12	17	C-616-E Sludge Lagoon [C]
	18	C-616-F Full-Flow Lagoon [C]
	42	C-616 Chromate Reduction Facility [C]

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SWOU

WAG	SWMU	Description
WAG 13	21	C-611-W Sludge Lagoon [C]
	22	C-611-Y Overflow Lagoon [C]
	23	C-611-V Lagoons [C]
	185	C-611-4 Horseshoe Lagoon [C]
WAG 24	12s	C-747-A UF4 Drum Yard (SW) [F]
	14s	C-746-E Contaminated Scrapyard (SW) [F]
	15s	C-746-C Scrapyard (SW) [F]
WAG 14	13s	C-746-P Clean Scrapyard (SW) [F]
	16s	C-746-D Classified Scrapyard (SW) [F]

Footnotes:

A - Groundwater will be addressed under the GWOU.

B - Pipes and sewers under buildings will be addressed as part of the D&D scope.

C - Active facility.

D - Sanitary portion included in Soils OU.

E - Existing ROD focused on surface soils.

F - Scrap is scope of ongoing early action; underlying soil will fall within BGOU scope.

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SSOU

WAG	SWMU	Description
WAG 2	86	C-631 Pumphouse and Cooling Tower [A]
	87	C-633 Pumphouse and Cooling Tower [A]
	88	C-635 Pumphouse and Cooling Tower [A]
	89	C-637 Pumphouse and Cooling Tower [A]
WAG 5	31	C-720 Compressor Pit Water Storage Tank
	76	C-632-B Sulfuric Acid (H_2SO_4) Storage Tank
	77	C-634-B Sulfuric Acid (H_2SO_4) Storage Tank
	169	C-410-E HF Vent Surge Protection Tank
WAG 6	11s	C-400 Trichloroethylene Leak Site (SS)
	26s	C-400 to C-404 Underground Transfer Line (SS)
	40s	C-403 Neutralization Tank (SS)
	47s	C-400 Technetium Storage Tank Area (SS)
	203s	C-400 Sump (SS)
WAGs 9&11	27	C-722 Acid Neutralization Tank [A]
	28	C-712 Acid Neutralization Tank [A]
	165	C-616-L Pipeline and Vault Soil Contamination [A]
	170	C-729 Acetylene Building Drain Pits
	19	C-410-B Neutralization Lagoon
	20	C-410-E H Emergency Holding Pond
	41	C-410-C Neutralization Tank
WAGs 16&19	78	C-420 PCB Spill Site
	137	C-746-A Inactive PCB Transformer/Sump
	153	C-331 PCB Soil Contamination (West side)
	155	C-333 PCB Soil Contamination (West side)
	156	C-310 PCB Soil Contamination (West side)
	161	C-743-T01 Trailer Site (Soil Backfill)
	164	KPDES Outfall Ditch 017 Flume (Soil Backfill)
	75	C-633 PCB Spill Site
	92	Fill Area for Dirt from the C-420 PCB Spill Site
	135	C-333 PCB Soil Contamination (North side of C-333)
	154	C-331 PCB Soil Contamination (Southeast side)
	160	C-745 Cylinder Yard Spoils Area (PCB Soil Contamination)
	162	C-617-A Sanitary Water Line (Soil Backfill) [A]
	163	C-304 Bldg/HVAC Piping System (Soil Backfill)
WAG 20	166	C-100 Trailer Complex Soil Contamination (East side)
	172	C-726 Sandblasting Facility
	195	Curlee Road Contaminated Soil Mound
	200	Soil Contamination South of TSCA Waste Storage Facility
	212	C-745-A Radiological Contamination Area

SSOU

WAG	SWMU	Description
WAG 21	138	C-100 Southside Berm
	158	Chilled Water System Leak Site
	176	C-331 RCW Leak Northwest Side
	177	C-331 RCW Leak East Side
	180	Outdoor Firing Range (WKWMA) [A]
	181	Outdoor Firing Range (PGDP) [A]
WAG 27	196	C-746-A Septic System
	209s	C-720 Compressor Shop Pit Sump (SS)
WAG 28	99s	C-745 Kellogg Building Site (previously AOC #C) (SS)
	183s	McGraw UST (SS)
	193s	McGraw Construciton Facilities (Southside Cylinder Yards) (SS)
	194s	McGraw Construction Facilities (Southside) (SS)
	204s	Dykes Road Historical Staging Area (SS)
WAG 23	32	C-728 Clean Waste Oil Tank [A]
	33	C-728 Motor Cleaning Facility [A]
	56	C-540-A PCB Waste Staging Area
	57	C-541-A PCB Waste Staging Area
	74	C-340 PCB Spill Site
	79	C-611 PCB Spill Site
	80	C-540 PCB Spill Site
	81	C-541 PCB Spill Site
	1s	C-747-C Oil Land Farm (SS)
WAG 29	38	C-615 Sewage Treatment Plant
	159	C-746-H3 Storage Pad
	178	C-724-A Paint Spray Booth
	179	Plant Sanitary Sewer System
WAG 30	55	C-405 Incinerator
	98	C-400 Basement Sump (previously AOC #B)
	101	C-340 Hydraulic System (previously AOC #E)
	167	C-720 Whiteroom Sump
	192	C-710 Acid Interceptor Pit
	198	C-410-D Area Soil Contamination
N/A	N/A	Site-Wide RAD
N/A	N/A	Site-Wide PCBs

Footnotes:
A - Active facility.

BGOU

WAG	SWMU	Description
WAG 3	4	C-747 Contaminated Burial Ground [A]
	5	C-746-F Classified Burial Ground
	6	C-747-B Burial Ground
WAG 14	13	C-746-P Clean Scrapyard
	16	C-746-D Classified Scrapyard
WAG 22	2	C-749 Uranium Burial Ground [A]
	3s	C-404 Low-Level Radioactive Waste Burial Ground [A]
	7s	C-747-A Burial Ground (BG)
	30s	C-747-A Burn Area (BG)
WAG 24	12	C-747-A UF4 Drum Yard
	14	C-746-E Contaminated Scrapyard
	15	C-746-C Scrapyard
N/A	145	Residential/Inert Landfill Borrow Area

Footnotes:

A - DNAPL subsurface source from GWOU is to be addressed under BGOU.

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APPENDIX C7

Basis of Estimate
Feasibility Study for the GWOU
Alternative 2

Description: This alternative will continue the groundwater monitoring program currently in place plus an expansion by 32 monitoring wells. Also, 15 existing monitoring wells will be plugged and abandoned. In addition to the above, the Northwest and Northeast Plume treatment actions will continue for 30 years, pumping and treating the cores (1,000 ppb). The Southwest Plume will be added to the Northwest Plume treatment facility. It also is assumed that the Paducah Gaseous Diffusion Plant (PGDP) will shut down after seven years, requiring a new Northeast Plume treatment system to be put into place. The period of the action is 30 years. Although not costed in this estimate, the action will be required to be repeated for a period of approximately 7,000 years until the remediation is complete.

General: The estimate was generated with the Automated Estimating System (AES) using the standard value file RRB2668A.val.
Management and Integration (M&I) contract management is included at 20% of all costs.
Overhead is included at 41.96%.
Contingency is included at 25%.

Schedule: Initial installation is assumed to last nine months.
Reconstruction of treatment system after seven years is assumed to last six months.
Operation and Maintenance (O&M) is assumed to last 30 years.

Work Breakdown Structure (WBS)

WBS 2.01.01 General Conditions (initial):

- Includes mobilization and set-up and utility hook-ups for a construction trailer and a shower/change trailer. Nine months rental cost is included for trailers and a port-o-let.

- A safety and health officer is included for the 9-month duration.

- Training and security requirements are included for 8 workers at 28 hours each.

- Includes general safety plan, QA plan, waste management plan, work plan, hoisting and rigging plan, and site-specific safety and health plan.

WBS 2.01.02 Monitoring Wells:

- Wells are separated as 27 inside and 5 outside the fence.

- Three hundred feet per well of access roads includes clearing and grubbing of light trees, grading, a filter fabric underlayment, and a 6-inch gravel base.

- Monitoring wells are 100 ft deep, with stainless steel tubing and screen and are included at $14,500 each, based on a vendor quote. Mobilization is included at $150,000.

- Disposal of water includes a 5,000 gal tanker truck with driver on-site full time (no disposal fee). Water is included at 1,000 gal per well. (27 wells I/S fence = 27,000 gal = 6 tankers) (5 wells O/S fence = 5,000 gal = 1 tanker)

- Disposal of solids includes 2 laborers, a fork truck with operator, and a flatbed truck with driver to load and haul the drums to the landfill (no tipping fee). Solids are included at 4 drums per well. Estimate assumes 50 drums per load and 1 load per day. (27 wells I/S fence = 3 loads, 5 wells O/S = 1 load.)

- Sampling of water assumes 1 per well and includes $25 and 2 hours each with modified Level D personal protective equipment (PPE).

- Sampling of solids assumes 1 per well and includes $25 and 2 hours each with modified Level D PPE.

- Analysis of the samples includes volatile organic compounds (VOCs) (8260), gross alpha, gross beta, and ^{99}Tc at a total cost of $400 per sample. Costs are included for Site Management Office (SMO) oversight at 16.4%.

- Two extraction wells with 8-inch polyvinyl chloride (PVC) risers. Estimate includes clearing and grubbing, labor, and waste disposal.

WBS 2.01.03 Plug and Abandon Wells:

- Plugging and abandoning of 15 existing wells is included at $40,833 each. Cost is based on a feasibility study for White Oak Creek.

- Disposal of water includes a 5,000-gal tanker truck with driver on-site full time (no disposal fee). Water is included at 1,000 gal per well. (15 wells = 15,000 gal = 3 tankers)

- Disposal of solids includes 2 laborers, a fork truck with operator, and a flatbed truck with driver to load and haul the drums to the landfill (no tipping fee). Solids are included at 5 drums per well. Estimate assumes 50 drums per load and 1 load per day (15 wells = 2 loads). Drums are included assuming 5 per well at $55 each.

- Sampling of water assumes 1 per well and includes $25 and 2 hours each with modified Level D PPE.

- Sampling of solids assumes 1 per well and includes $25 and 2 hours each with modified Level D PPE.

- Analysis of the samples includes VOCs (8260), gross alpha, gross beta, and ^{99}Tc at a total cost of $400 per sample. Costs are included for SMO oversight at 16.4%.

WBS 2.01.04.01 General Conditions for Water Treatment Plant Reconstruction (7 Years):

- Includes mobilization and set-up and utility hook-ups for a construction trailer and a shower/change trailer. Six months rental cost is included for trailers and a port-o-let.

- A safety and health officer is included for the 6-month duration.

- Training and security requirements are included for 8 workers at 28 hours each.

- Includes general safety plan, quality assurance (QA) plan, waste management plan, work plan, hoisting and rigging plan, and site-specific safety and health plan.

WBS 2.01.04.02 New Northeast Treatment Systems [includes excavation of Solid Waste Management Unit (SWMU) 99]:

- Two new 200 GPM, skid mounted air strippers are included at $35,000 based on a vendor quote.
- A new permitted outfall is included at $25,000 based on estimator's judgment.
- Breaking, loading, and hauling a concrete pad of 120 ft by 240 ft at SWMU 99.
- Excavation of 6,019 yds^3 of earth.

WBS 2.02 Indirect Costs:

- Indirect costs include design, project integration, and M&I oversight. These costs are dependent on level of effort and project schedule.

- Indirect costs are included for initial capital work and are included separately for installation of the treatment system in 7 years.

WBS 2.03.01.01 Operation and Maintenance (O&M) (First 3 Years):

- Maintenance is included for the 32 new and 90 existing monitoring wells. Costs are included at 2% of the well capital cost annually (122 × $14,500 × .02 = $35,380/year). Two percent annually is equivalent to total replacement every 50 years.

- O&M of the existing northwest treatment system is included at $1,098,774 per year based on information from Bechtel Jacobs Company LLC (BJC).

- O&M of the existing northeast treatment system is included at $346,362 per year based on information from BJC.

WBS 2.03.01.02 Sample Collection (First 3 Years):

- Sample collection is included quarterly for the 32 new and 90 existing monitoring wells. A cost of $1,059 per sample is included as provided by BJC. Quarterly sampling of 122 wells = 488 samples per year × $1,059 = $516,792 per year.

WBS 2.03.01.03 Sample Analysis (First 3 Years):

- Sample analysis is included quarterly for the 32 new and 90 existing monitoring wells. A cost of $400 per sample is included for VOCs (8260), gross alpha, gross beta, and ^{99}Tc. Quarterly analysis of 122 wells = 488 samples per year × $400 = $195,200 per year. Costs are included for SMO oversight at 16.4%.

WBS 2.03.01.04 Management and Integration (M&I) on Operation and Maintenance (O&M) (First 3 Years):

- M&I contract management is included at 8% of all other O&M costs.

WBS 2.03.02.01 Operation and Maintenance (O&M) (Years 4-7):

- Maintenance is included for the 32 new and 90 existing monitoring wells. Costs are included at 2% of the well capital cost annually (122 × $14,500 × .02 = $35,380/year). Two percent annually is equivalent to total replacement every 50 years.

- O&M of the existing northwest treatment system is included at $1,098,774 per year based on information from BJC.

- O&M of the existing northeast treatment system is included at $346,362 per year based on information from BJC.

WBS 2.03.02.02 Sample Collection (Years 4-7):

- Sample collection is included semiannually for the 32 new and 90 existing monitoring wells. A cost of $1,059 per sample is included as provided by BJC. Semiannual sampling of 122 wells = 244 samples per year × $1,059 = $258,396 per year.

WBS 2.03.02.03 Sample Analysis (Years 4-7):

- Sample analysis is included semiannually for the 32 new and 90 existing monitoring wells. A cost of $400 per sample is included for VOCs (8260), gross alpha, gross beta, and ^{99}Tc. Semiannual analysis of 122 wells = 244 samples per year × $400 = $97,600 per year. Costs are included for SMO oversight at 16.4%.

WBS 2.03.02.04 Management and Integration (M&I) on Operation and Maintenance (O&M) (Years 4-7):

- M&I contract management is included at 8% of all other O&M costs.

WBS 2.03.03.01 Operation and Maintenance (O&M) (Years 8-30):

- Maintenance is included for the 32 new and 90 existing monitoring wells. Costs are included at 2% of the well capital cost annually (122 × $14,500 × .02 = $35,380/year). Two percent annually is equivalent to total replacement every 50 years.

- O&M of the existing northwest treatment system is included at $1,098,774 per year based on information from BJC.

- O&M of the new northeast treatment system is assumed to be equal to the O&M of the existing system at $346,362 per year.

WBS 2.03.03.02 Sample Collection (Years 8-30):

- Sample collection is included semiannually for the 32 new and 90 existing monitoring wells. A cost of $1,059 per sample is included as provided by BJC. Semiannual sampling of 122 wells = 244 samples per year × $1,059 = $258,396 per year.

WBS 2.03.03.03 Sample Analysis (Years 8-30):

- Sample analysis is included semiannually for the 32 new and 90 existing monitoring wells. A cost of $400 per sample is included for VOCs (8260), gross alpha, gross beta, and ^{99}Tc. Semiannual analysis of 122 wells = 244 samples per year × $400 = $97,600 per year. Costs are included for SMO oversight at 16.4%.

WBS 2.03.03.04 Management and Integration (M&I) on Operation and Maintenance (O&M) (Years 8-30):

- M&I contract management is included at 8% of all other O&M costs.

Line items within the detailed estimate contain references to cost guides. The following is a glossary for those references.

FCM-845	Facility Construction Means		Page 845
HCM-41	Heavy Construction Means		Page 41
BCM-21	Building Construction Means		Page 21
ECHOS-8-107	ECHOS Cost Guide	Section 8	Page 107
RRBB-20-7	Rental Rate Blue Book	Section 20	Page 7
E.J.	Estimator's Judgment		

SUMMARY REPORT
Project Number: 35T08116
PGDP GWOU ALT 2

Project ESO Number......NA
Revision Number.........1
Last Update.............05/31/2000

Sort Order
1. WBS - Level 3
2. WBS - Level 4
3. Building/Area

Approved by:

Project Estimator Date

Estimating Manager Date

Base Fiscal Year/Quarter: 99/4
STANDARD VALUE: C:®ESTIMA™1®RRB2668A.val EXPIRES: 09/15/1999
ESTIMATE FILE: C:®ESTIMA™1®ATL2®2ALT2.Est 05/31/2000
SCHEDULE FILE: 2ALT2
REPORT FILE: C:®ESTIMA™1®ATL2®ALT2SUM.Out 05/31/2000 09:07:10 AES Version 6.1

PGDP GWOU ALT 2

SUMMARY REPORT
$1 = $1

05/31/2000

Arranged By: WBS / WBS / Building

	Unescalated Material $	Unescalated Labor $	Unescalated Total $	Escalated Material $	Escalated Labor $	Escalated Total $
2.01.01 GENERAL CONDITIONS (INITIAL)						
2.01.01.01 VARIABLE COSTS (INITIAL)						
GWOU	10074	82320	92394	11164	91228	102392
TOTAL VARIABLE COSTS (INITIAL)	10074	82320	92394	11164	91228	102392
2.01.01.02 FIXED COSTS (INITIAL)						
GWOU	26076	6941	33017	28898	7692	36590
TOTAL FIXED COSTS (INITIAL)	26076	6941	33017	28898	7692	36590
TOTAL GENERAL CONDITIONS (INITIAL)	36150	89261	125411	40062	98920	138982
2.01.02 MONITORING WELLS						
2.01.02.01 MONITORING WELLS (I/S FENCE)						
GWOU	907731	50989	958720	1005960	56507	1062467
.L MONITORING WELLS (I/S FENCE)	907731	50989	958720	1005960	56507	1062467
2.01.02.02 MONITORING WELLS (O/S FENCE)						
GWOU	280070	13729	293799	310377	15215	325592
TOTAL MONITORING WELLS (O/S FENCE)	280070	13729	293799	310377	15215	325592
TOTAL MONITORING WELLS	1187801	64718	1252519	1316337	71722	1388059
2.01.03 P&A WELLS						
2.01.03 P&A WELLS						
GWOU	811186	7037	818223	898967	7798	906765
TOTAL P&A WELLS	811186	7037	818223	898967	7798	906765
TOTAL P&A WELLS	811186	7037	818223	898967	7798	906765

PGDP GWOU ALT 2

SUMMARY REPORT
$1 = $1

05/31/2000

Arranged By: WBS / WBS / Building

	Unescalated Material $	Unescalated Labor $	Unescalated Total $	Escalated Material $	Escalated Labor $	Escalated Total $
2.01.04 EXCAVATION OF SWMU 099						
2.01.04 EXCAVATION OF SWMU 099						
GWOU	34060	38378	72438	38132	42967	81099
TOTAL EXCAVATION OF SWMU 099	34060	38378	72438	38132	42967	81099
2.01.04.01 GENERAL CONDITIONS (7 YRS)						
GWOU	32792	64061	96853	36712	71720	108432
TOTAL GENERAL CONDITIONS (7 YRS)	32792	64061	96853	36712	71720	108432
2.01.04.02 NEW NE TRTMT SYSTEM						
GWOU	152640	21120	173760	170890	23645	194535
TOTAL NEW NE TRTMT SYSTEM	152640	21120	173760	170890	23645	194535
TOTAL EXCAVATION OF SWMU 099	219492	123559	343051	245734	138332	384066
2.02.01 INDIRECTS (INITIAL)						
2.02.01.01 DESIGN (INITIAL)						
2ALT 2 IND	0	46660	46660	0	50946	50946
TOTAL DESIGN (INITIAL)	0	46660	46660	0	50946	50946
2.02.01.02 PROJECT INTEGRATION (INITIAL)						
2ALT 2 IND	0	129300	129300	0	143292	143292
TOTAL PROJECT INTEGRATION (INITIAL)	0	129300	129300	0	143292	143292
TOTAL INDIRECTS (INITIAL)	0	175960	175960	0	194238	194238
2.02.02 INDIRECTS (7 YRS)						
2.02.02.01 DESIGN (7 YRS)						
2ALT 2 IND	0	24620	24620	0	32347	32347
TOTAL DESIGN (7 YRS)	0	24620	24620	0	32347	32347

PGDP GWOU ALT 2

SUMMARY REPORT
$1 = $1

05/31/2000

Arranged By: WBS / WBS / Building

	Unescalated Material $	Unescalated Labor $	Unescalated Total $	Escalated Material $	Escalated Labor $	Escalated Total $
2.02.02 INDIRECTS (7 YRS)						
2.02.02.02 PROJECT INTEGRATION (7 YRS)						
2ALT 2 IND	0	29420	29420	0	39101	39101
TOTAL PROJECT INTEGRATION (7 YRS)	0	29420	29420	0	39101	39101
TOTAL INDIRECTS (7 YRS)	0	54040	54040	0	71448	71448
2.03.01 1ST 3 YRS O&M						
2.03.01.01 OPS & MAINT 1ST 3 YRS						
2ALT 2 O&M	5649649	0	5649649	6459842	0	6459842
TOTAL OPS & MAINT 1ST 3 YRS	5649649	0	5649649	6459842	0	6459842
2.03.01.02 SAMPLE COLLECTION 1ST 3 YRS						
2ALT 2 O&M	1972079	0	1972079	2254886	0	2254886
TOTAL SAMPLE COLLECTION 1ST 3 YRS	1972079	0	1972079	2254886	0	2254886
‘.01.03 SAMPLE ANALYSIS 1ST 3 YRS						
.ALT 2 O&M	722536	0	722536	826152	0	826152
TOTAL SAMPLE ANALYSIS 1ST 3 YRS	722536	0	722536	826152	0	826152
TOTAL 1ST 3 YRS O&M	8344264	0	8344264	9540880	0	9540880
2.03.02 YRS 4-7 O&M						
2.03.02.01 OPS & MAINT YRS 4-7						
2ALT 2 O&M	7532866	0	7532866	9521349	0	9521349
TOTAL OPS & MAINT YRS 4-7	7532866	0	7532866	9521349	0	9521349
2.03.02.02 SAMPLE COLLECTION YRS 4-7						
2ALT 2 O&M	1314719	0	1314719	1661771	0	1661771
TOTAL SAMPLE COLLECTION YRS 4-7	1314719	0	1314719	1661771	0	1661771

630710

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PGDP GWOU ALT 2

SUMMARY REPORT
$1 = $1

05/31/2000

Arranged By: WBS / WBS / Building

	Unescalated Material $	Unescalated Labor $	Unescalated Total $	Escalated Material $	Escalated Labor $	Escalated Total $
2.03.02 YRS 4-7 O&M						
2.03.02.03 SAMPLE ANALYSIS YRS 4-7						
2ALT 2 O&M	481692	0	481692	608846	0	608846
TOTAL SAMPLE ANALYSIS YRS 4-7	481692	0	481692	608846	0	608846
TOTAL YRS 4-7 O&M	9329277	0	9329277	11791966	0	11791966
2.03.03 YRS 8-30 O&M						
2.03.03.01 OPS & MAINT YRS 8-30						
2ALT 2 O&M	43313976	0	43313976	81947819	0	81947819
TOTAL OPS & MAINT YRS 8-30	43313976	0	43313976	81947819	0	81947819
2.03.03.02 SAMPLE COLLECTION YRS 8-30						
2ALT 2 O&M	7559633	0	7559633	14302438	0	14302438
TOTAL SAMPLE COLLECTION YRS 8-30	7559633	0	7559633	14302438	0	14302438
2.03.03.03 SAMPLE ANALYSIS YRS 8-30						
2ALT 2 O&M	2769724	0	2769724	5240175	0	5240.
TOTAL SAMPLE ANALYSIS YRS 8-30	2769724	0	2769724	5240175	0	5240175
TOTAL YRS 8-30 O&M	53643333	0	53643333	101490432	0	101490432
SUB - TOTAL	73571503	514575	74086078	125324378	582458	125906836
OVERHEAD	30870602	215916	31086518	52586109	244399	52830508
SUB - TOTAL	104442105	730491	105172596	177910487	826857	178737344
CONTINGENCY	26110526	182623	26293149	44477622	206714	44684336
GRAND TOTAL	130552631	913114	131465745	222388109	1033571	223421680

DETAIL REPORT
Project Number: 35T08116
PGDP GWOU ALT 2

Project ESO Number......NA
Revision Number.........1
Last Update.............05/31/2000

Sort Order
1. WBS - Level 9
2. Participant
3. Discipline

Approved by:

Project Estimator	Date
Estimating Manager	Date

Base Fiscal Year/Quarter: 99/4
STANDARD VALUE: C:®ESTIMA™1®RRB2668A.val EXPIRES: 09/15/1999
ESTIMATE FILE: C:®ESTIMA™1®ATL2®2ALT2.Est 05/31/2000
SCHEDULE FILE: 2ALT2
REPORT FILE: C:®ESTIMA™1®ATL2®ALT2DET.Out 05/31/2000 09:06:12 AES Version 6.1

Creation Date 09/07/1999
Revision Number ... 1

Estimating Job Number .. 0116-20

F ct Estimator.. J LOLLAR/NLE
WBS .... 2.01.01.01 VARIABLE COSTS (INITIAL)
Cost Code .... 6100 REMEDIAL ACTION
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
S/M Attribute 2ALT 2
Discipline .... C CIVIL AND SITE
B/M Title .... MOB/DEMOB/GEN COND - VAR
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Project Engineer .... S MAUDLIN
Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... GEN CONDITIONS
Quantity Take-Off By ...
Trace Number C.1.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	GENERAL CONDITIONS - VARIABLE COST						
1 -A	CONSTRUCTION TRAILER RENTAL	Matl.	9.00	MON	300.00	2,700	
		Labor	0		0.00	0	2,700
2 -A	SHOWER/CHANGE TRAILER RENTAL	Matl.	9.00	MON	500.00	4,500	
		Labor	0		0.00	0	4,500
-A	PORT-O-LET (1 @ $80 FOR 2 MONTHS)	Matl.	9.00	MON	40.00 ~~80.00~~	720	
		Labor	0		0.00	0	720
4 -A	SAFETY & HEALTH OFFICER	Matl.	9.00	MON	0.00	0	
		Labor	1,575	X	40.00	63,000	63,000
5 -A	TRAINING:SECURITY REQMNT, GET ETC (28 HOURS/PERSON)	Matl.	8.00	EA	0.00	0	
		Labor	224	Z2	25.00	5,600	5,600
****	SUBTOTAL ****	Matl.				7,920	
		Labor	1,799			68,600	76,520

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BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		7,920		68,600	76,520
SALES TAX		475			475
SUBTOTAL		8,395		68,600	76,995
TOTAL INDIRECT	20.00%	1,679	20.00%	13,720	15,399
TOTAL		10,074	(hrs. 1,799)	82,320	92,394
TOTAL (ESCALATED COST)		11,164		91,228	102,392

WBS .... 2.01.01.02 FIXED COSTS (INITIAL)
Cost Code .... 6100 REMEDIAL ACTION
cipant .... FP51 FIXED PRICE SUBCONT
. of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... C CIVIL AND SITE
B/M Title .... MOB/DEMOB/GEN COND - FIXED
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... GEN CONDITIONS
Quantity Take-Off By ...
Trace Number C.1.2 0

Expiration Date: 09/15/1999

Item		Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
		GENERAL CONDITIONS - FIXED COST						
1	-A	CONSTRUCTION TRAILER MOB/DEMOB	Matl.	1.00	LS	0.00	0	
			Labor	40	TD	22.60	904	904
2	-A	MOB/DEMOB SUPPORT LABOR	Matl.	1.00	LS	0.00	0	
			Labor	40	L	24.85	994	994
3	~~-A~~	~~SET-UP LABOR~~ DELETE	~~Matl.~~	~~1.00~~	~~LS~~	~~250.00~~	~~250~~	
			~~Labor~~	~~40~~	~~L~~	~~24.85~~	~~994~~	~~1,244~~
4	-A	UTILITIES HOOK UP (ELEC, WATER, SEWER)	Matl.	1.00	LS	3,000.00	3,000	
			Labor	0		0.00	0	3,000
	-A	SHOWER/CHANGE TRAILER MOB/DEMOB	Matl.	1.00	LS	0.00	0	
			Labor	40	TD	22.60	904	904
6	-A	MOB/DEMOB SUPPORT LABOR	Matl.	1.00	LS	0.00	0	
			Labor	40	L	24.85	994	994
7	-A	SET-UP LABOR	Matl.	1.00	LS	250.00	250	
			Labor	40	L	24.85	994	1,244
8	-A	UTILITIES HOOK-UP (ELEC, WATER, SEWER)	Matl.	1.00	LS	3,000.00	3,000	
			Labor	0		0.00	0	3,000
****		SUBTOTAL ****	Matl.				6,500	
			Labor	240			5,784	12,284
9	-A	GENERAL SAFETY PLAN	Matl.	1.00	LS	2,000.00	2,000	
			Labor	0		0.00	0	2,000
10	-A	QUALITY ASSURANCE PLAN	Matl.	1.00	LS	1,000.00	1,000	
			Labor	0		0.00	0	1,000
11	-A	WASTE MANAGEMENT PLAN	Matl.	1.00	LS	2,000.00	2,000	
			Labor	0		0.00	0	2,000
12	-A	WORK PLAN	Matl.	1.00	LS	3,000.00	3,000	
			Labor	0		0.00	0	3,000

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630714

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
13 -A	HOISTING & RIGGING PLAN	Matl.	1.00	LS	1,000.00	1,000	
		Labor	0		0.00	0	1,000
14 -A	SITE SPECIFIC SAFETY & HEALTH PLAN	Matl.	1.00	LS	5,000.00	5,000	
		Labor	0		0.00	0	5,000
****	SUBTOTAL ****	Matl.				14,000	
		Labor	0			0	14,000

BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		20,500		5,784	26,284
SALES TAX		1,230			1,230
SUBTOTAL		21,730		5,784	27,514
TOTAL INDIRECT	20.00%	4,346	20.00%	1,157	5,503
TOTAL		26,076	(hrs. 240)	6,941	33,017
⁻L (ESCALATED COST)		28,898		7,692	36,590

630716

630717

WBS .... 2.01.02.01 MONITORING WELLS (I/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... C CIVIL AND SITE
B/M Title .... MON WELLS (I/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.1 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	27 WELLS INSIDE FENCE						
	(143 DAYS PER VENDOR)						
	ACCESS ROAD (300'/WELL)						
1 -A	SITE PREP: CLEAR & GRUB LIGHT TREES,	Matl.	0.95	ACRE	1,975.00	1,876	
	GRUB & RMV STUMPS (HCM-41)	Labor	57	OP	30.95	1,764	3,640
2 -A	GRADER RENTAL (HCM-17)	Matl.	5.00	DAYS	670.00	3,350	
		Labor	0		0.00	0	3,350
3 -A	OPERATING COST & OPERATOR (HCM-17)	Matl.	40.00	HRS	16.92	677	
		Labor	40	OP	30.95	1,238	1,915
4 -A	FILTER FABRIC UNDERLAYMENT	Matl.	18,150.00	SY	1.03	18,695	
	(ECHOS-8-107)	Labor	227	L	24.85	5,641	24,336
5 -A	GRAVEL BASE - 6" DP, SPREAD & COMPACT	Matl.	18,150.00	SY	2.62	47,553	
	(HCM-58)	Labor	91	OP	30.95	2,816	50,369
****	SUBTOTAL ****	Matl.				72,151	
		Labor	415			11,459	83,610
	INSTALL MONITORING WELLS						
	(COST FROM VENDOR QUOTE)						
6 -A	MOBILIZATION (INCL. MOB. 1 RIG,	Matl.	1.00	LS	150,000.00	150,000	
	SET-UP, DECON PAD, PPE, ETC)	Labor	0		0.00	0	150,000
7 -A	MONITORING WELL W/ 2" SS TUBING, 6"	Matl.	27.00	EA	14,500.00	391,500	
	OPEN HOLE, 10' SS SCREEN, 100' DP, 4	Labor	0		0.00	0	391,500
	DRUMS/WELL SOLIDS,						

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	1000 GAL/WELL PURGE WATER						
****	SUBTOTAL ****	Matl.				541,500	
		Labor	0			0	541,500
	DISPOSAL OF WATER						
	(1000 GAL/WELL)						
8 -A	5000 GAL TANKER RENTAL FOR	Matl.	143.00	DAYS	320.00	45,760	
	DEVELOPMENT WATER (RRBB-20-7)	Labor	0		0.00	0	45,760
9 -A	OPERATING COST & DRIVER (RRBB-20-7)	Matl.	1,144.00	HRS	20.70	23,681	
		Labor	1,144	TD	22.60	25,854	49,535
10 -A	SAMPLE COLLECTION (27,000 GAL @	Matl.	27.00	EA	25.00	675	
	ONE/WELL)	Labor	54	X	25.00	1,350	2,025
11 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	54.00	HRS	8.00	432	
		Labor	0		0.00	0	432
	SUBTOTAL ****	Matl.				70,548	
		Labor	1,198			27,204	97,752
	DISPOSAL OF SOLIDS						
	(4 DRUMS/WELL, 50 DRUMS/LOAD, 1 LOAD/DAY)						
12 -A	2 LABORERS TO LOAD & HAUL DRUMMED	Matl.	24.00	HRS	0.00	0	
	SOLIDS TO LANDFILL (NO TIPPING FEE)	Labor	48	L	24.85	1,193	1,193
13 -A	55 GALLON DRUMS	Matl.	108.00	EA	55.00	5,940	
		Labor	0		0.00	0	5,940
14 -A	FORK TRUCK RENTAL (BCM-21)	Matl.	3.00	DAYS	175.00	525	
		Labor	0		0.00	0	525
15 -A	OPERATING COST & OPERATOR (BCM-21)	Matl.	24.00	HRS	9.20	221	
		Labor	24	OP	30.95	743	964
16 -A	FLATBED TRUCK RENTAL (BCM-20)	Matl.	3.00	DAYS	138.00	414	
		Labor	0		0.00	0	414
17 -A	OPERATING COST & DRIVER (BCM-20)	Matl.	24.00	HRS	11.13	267	
		Labor	24	TD	22.60	542	809

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
18 -A	SAMPLE COLLECTION (1/WELL)	Matl.	27.00	EA	25.00	675	
		Labor	54	X	25.00	1,350	2,025
19 -A	LEVEL MODIFIED D PPE (SAMPLING ONLY)	Matl.	54.00	HRS	8.00	432	
		Labor	0		0.00	0	432
****	SUBTOTAL ****	Matl.				8,474	
		Labor	150			3,828	12,302

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		692,673		42,491	735,164
SALES TAX		41,560			41,560
SUBTOTAL		734,233		42,491	776,724
TOTAL INDIRECT	20.00%	146,847	20.00%	8,498	155,345
TOTAL		881,080	(hrs. 1,763)	50,989	932,069
TOTAL (ESCALATED COST)		976,425		56,507	1,032,9'

630719 630719

WBS .... 2.01.02.01 MONITORING WELLS (I/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
' 'cipant .... SC01 OFFSITE SUB #1
. . of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... C CIVIL AND SITE
B/M Title .... MON WELLS (I/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	ANALYSIS OF SOLID WASTE SAMPLES	Matl.	27.00	EA	400.00	10,800	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	10,800
2 -A	ANALYSIS OF LIQUID WASTE SAMPLES	Matl.	27.00	EA	400.00	10,800	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	10,800
****	SUBTOTAL ****	Matl.				21,600	
		Labor	0			0	21,600
-A	SMO OVERSIGHT (16.4%)	Matl.	21.60	K$	164.00	3,542	
		Labor	0		0.00	0	3,542

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	25,142	0	25,142
SALES TAX	1,509		1,509
SUBTOTAL	26,651	0	26,651
TOTAL	26,651	(hrs. 0) 0	26,651
TOTAL (ESCALATED COST)	29,535	0	29,535

630720

630721

WBS .... 2.01.02.02 MONITORING WELLS (O/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... C CIVIL AND SITE
B/M Title .... MON WELLS (O/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.3 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	2 WELLS ADDED FOR S.W. PLUME INCLUSION						
	5 WELLS OUTSIDE FENCE						
	(27 DAYS PER VENDOR)						
	ACCESS ROAD (300'/WELL)						
1 -A	SITE PREP: CLEAR & GRUB LIGHT TREES,	Matl.	0.28	ACRE	1,975.00	553	
	GRUB & RMV STUMPS (HCM-41)	Labor	17	OP	30.95	526	1,079
2 -A	GRADER RENTAL (HCM-17)	Matl.	2.00	DAYS	670.00	1,340	
		Labor	0		0.00	0	1,34[illegible]
3 -A	OPERATING COST & OPERATOR (HCM-17)	Matl.	11.00	HRS	16.92	186	
		Labor	11	OP	30.95	340	526
4 -A	FILTER FABRIC UNDERLAYMENT	Matl.	4,690.00	SY	1.03	4,831	
	(ECHOS-8-107)	Labor	59	L	24.85	1,466	6,297
5 -A	GRAVEL BASE - 6" DP, SPREAD & COMPACT	Matl.	4,690.00	SY	2.62	12,288	
	(HCM-58)	Labor	23	OP	30.95	712	13,000
6 -A	UTILITIES FOR 2-EA WELLS IN S.W.	Matl.	2.00	EA	28,100.00	56,200	
	PLUME	Labor	0		0.00	0	56,200
	500 LF FROM EXIST. 13200 KW ELECTRICAL SERVICE, AND 2000 LF. OF 4" HDPE PIPE (DIRECT BURIED) TO C-612 FOR TREATMENT AND DISPOSAL.						
****	SUBTOTAL ****	Matl.				75,398	
		Labor	110			3,044	78,442
	INSTALL MONITORING WELLS						

630721

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	(COST FROM VENDOR QUOTE)						
	(MOB. INCL. W/ WELLS I/S FENCE)						
7 -A	MONITORING WELL W/ 2" SS TUBING, 6" OPEN HOLE, 10' SS SCREEN, 100' DP, 4 DRUMS/WELL SOLIDS, 1000 GAL/WELL PURGE WATER	Matl.	5.00	EA	14,500.00	72,500	
		Labor	0		0.00	0	72,500
8 -A	MONITORING WELL W/8" HDPE PIPE RISER, 14" OPEN HOLE, 8"X 30'SS SCREAN, 100'DP 8 DRUMS/WELL SOLIDS, AND 2000 GAL./WELL PURGE WATER.	Matl.	2.00	EA	25,400.00	50,800	
		Labor	0		0.00	0	50,800
****	SUBTOTAL ****	Matl.				123,300	
		Labor	0			0	123,300
	DISPOSAL OF WATER						
	(1000 GAL/WELL)						
9 -A	5000 GAL TANKER RENTAL FOR DEVELOPMENT WATER (RRBB-20-7)	Matl.	38.00	DAYS	320.00	12,160	
		Labor	0		0.00	0	12,160
10 -A	OPERATING COST & DRIVER (RRBB-20-7)	Matl.	304.00	HRS	20.70	6,293	
		Labor	304	TD	22.60	6,870	13,163
11 -A	SAMPLE COLLECTION (5,000 GAL @ ONE/WELL)	Matl.	7.00	EA	25.00	175	
		Labor	14	X	25.00	350	525
12 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	14.00	HRS	8.00	112	
		Labor	0		0.00	0	112
****	SUBTOTAL ****	Matl.				18,740	
		Labor	318			7,220	25,960
	DISPOSAL OF SOLIDS						
	(4 DRUMS/WELL, 50 DRUMS/LOAD, 1 LOAD/DAY) (+8 DRUMS/ADDED WELL=16 DRUMS. . TOTAL=36)						
13 -A	2 LABORERS TO LOAD & HAUL DRUMMED SOLIDS TO LANDFILL (NO TIPPING FEE)	Matl.	8.00	HRS	0.00	0	
		Labor	16	L	24.85	398	398

630722

630723

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
14 -A	55 GALLON DRUMS	Matl.	36.00	EA	55.00	1,980	
		Labor	0		0.00	0	1,980
15 -A	FORK TRUCK RENTAL (BCM-21)	Matl.	1.00	DAYS	175.00	175	
		Labor	0		0.00	0	175
16 -A	OPERATING COST & OPERATOR (BCM-21)	Matl.	8.00	HRS	9.20	74	
		Labor	8	OP	30.95	248	322
17 -A	FLATBED TRUCK RENTAL (BCM-20)	Matl.	1.00	DAYS	138.00	138	
		Labor	0		0.00	0	138
18 -A	OPERATING COST & DRIVER (BCM-20)	Matl.	8.00	HRS	11.13	89	
		Labor	8	TD	22.60	181	270
19 -A	SAMPLE COLLECTION (1/WELL)	Matl.	7.00	EA	25.00	175	
		Labor	14	X	25.00	350	525
20 -A	LEVEL MODIFIED D PPE (SAMPLING ONLY)	Matl.	14.00	HRS	8.00	112	
		Labor	0		0.00	0	112
****	SUBTOTAL ****	Matl.				2,743	
		Labor	46			1,177	3,920

BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		220,181		11,441	231,622
SALES TAX		13,211			13,211
SUBTOTAL		233,392		11,441	244,833
TOTAL INDIRECT	20.00%	46,678	20.00%	2,288	48,966
TOTAL		280,070	(hrs. 474)	13,729	293,799
TOTAL (ESCALATED COST)		310,377		15,215	325,592

630723

WBS .... 2.01.03 P&A WELLS
Cost Code .... 6100 REMEDIAL ACTION
'cipant .... FP51 FIXED PRICE SUBCONT
. of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2Alt 2
Discipline .... C CIVIL AND SITE
B/M Title .... P&A WELLS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... P&A EXIST WELLS
Quantity Take-Off By ...
Trace Number C.3.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	P&A WELLS (BASED ON VENDOR QUOTE)						
	(OVERHEAD & PROFIT INCLUDED BELOW AS INDIRECTS)						
	(USE 1 WELL/DAY = 15 DAYS)						
1 -A	P&A CEMENT-FILL AND SQUEEZE	Matl.	15.00	WELL	40,833.00	612,495	
		Labor	0		0.00	0	612,495
	DISPOSAL OF WATER						
	(USE 1000 GAL/WELL)						
2 -A	5000 GAL TANKER RENTAL FOR	Matl.	15.00	DAYS	320.00	4,800	
	DEVELOPMENT WATER (RRBB-20-7)	Labor	0		0.00	0	4,800
3 -A	OPERATING COST & DRIVER (RRBB-20-7)	Matl.	120.00	HRS	20.70	2,484	
		Labor	120	TD	22.60	2,712	5,196
4 -A	SAMPLE COLLECTION (15,000 GAL @	Matl.	15.00	EA	25.00	375	
	ONE/WELL)	Labor	30	X	25.00	750	1,125
5 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	30.00	HRS	8.00	240	
		Labor	0		0.00	0	240
****	SUBTOTAL ****	Matl.				620,394	
		Labor	150			3,462	623,856
	DISPOSAL OF SOLIDS						
	(USE 5 DRUMS/WELL, 50 DRUMS/LOAD, 1 LOAD/DAY = 2 DAYS)						
6 -A	2 LABORERS TO LOAD & HAUL DRUMMED	Matl.	16.00	HRS	0.00	0	
	SOLIDS TO LANDFILL (NO TIPPING FEE)	Labor	32	L	24.85	795	795

630724

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
7 -A	55 GALLON DRUMS	Matl.	75.00	EA	55.00	4,125	
		Labor	0		0.00	0	4,125
8 -A	FORK TRUCK RENTAL (BCM-21)	Matl.	2.00	DAYS	175.00	350	
		Labor	0		0.00	0	350
9 -A	OPERATING COST & OPERATOR (BCM-21)	Matl.	16.00	HRS	9.20	147	
		Labor	16	OP	30.95	495	642
10 -A	FLATBED TRUCK RENTAL (BCM-20)	Matl.	2.00	DAYS	138.00	276	
		Labor	0		0.00	0	276
11 -A	OPERATING COST & DRIVER (BCM-20)	Matl.	16.00	HRS	11.13	178	
		Labor	16	TD	22.60	362	540
12 -A	SAMPLE COLLECTION (1/WELL)	Matl.	15.00	EA	25.00	375	
		Labor	30	X	25.00	750	1,125
13 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	30.00	HRS	8.00	240	
		Labor	0		0.00	0	240
****	SUBTOTAL ****	Matl.				5,691	
		Labor	94			2,402	8,093

BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		626,085		5,864	631,949
SALES TAX		37,565			37,565
SUBTOTAL		663,650		5,864	669,514
TOTAL INDIRECT	20.00%	132,730	20.00%	1,173	133,903
TOTAL		796,380	(hrs. 244)	7,037	803,417
TOTAL (ESCALATED COST)		882,559		7,798	890,357

630725

WBS .... 2.01.03 P&A WELLS
Cost Code .... 6100 REMEDIAL ACTION
'cipant .... SC01 OFFSITE SUB #1
of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... C CIVIL AND SITE
B/M Title .... P&A WELLS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... P&A EXIST WELLS
Quantity Take-Off By ...
Trace Number C.3.2 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	ANALYSIS OF SOLID WASTE SAMPLES	Matl.	15.00	EA	400.00	6,000	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	6,000
2 -A	ANALYSIS OF LIQUID WASTE SAMPLES	Matl.	15.00	EA	400.00	6,000	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	6,000
****	SUBTOTAL ****	Matl.				12,000	
		Labor	0			0	12,000
-A	SMO OVERSIGHT (16.4%)	Matl.	12.00	K$	164.00	1,968	
		Labor	0		0.00	0	1,968

BILL OF MATERIAL SUMMARY	Material		Labor	Total Cost M + L
TOTAL DIRECT	13,968		0	13,968
SALES TAX	838			838
SUBTOTAL	14,806		0	14,806
TOTAL	14,806	(hrs. 0)	0	14,806
TOTAL (ESCALATED COST)	16,408		0	16,408

630726

630727

WBS	2.01.04 EXCAVATION OF SWMU 099
Cost Code	6100 REMEDIAL ACTION
cipant	FP51 FIXED PRICE SUBCONT
L .. of Estimate .	P Planning/Feasibility Estimate
B/M Attribute	2ALT 2
Discipline	C CIVIL AND SITE
B/M Title	EXCAVATION OF SWMU 099
Receiving Site	PADUCAH
Cross-Cut Code	
Standard Value File	C:●ESTIMA~1●RRB2668A.val
Estimate File	C:●ESTIMA~1●ATL2●2ALT2.Est 5-31-00 9:05a

Building/Area	GWOU
Plant Site	R
Contracting Type	G General
Funding Type	EXPENSE
Source Site	PADUCAH
Discipline Estimator ...	NEW NE SYSTEM
Quantity Take-Off By ...	
Trace Number	C.4.2 0
Expiration Date:	09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	EXCAVATION OF EXISTING CONCRETE PAD SWMU 099						
1 -A	BREAK, LOAD AND HAUL PAD 120' X 240'	Matl.	1,067.00	CY	3.50	3,735	
		Labor	160	OP	30.95	4,952	8,687
2 -A	SUPPORT CRAFT	Matl.	1.00	LS	1,000.00	1,000	
		Labor	160	L	24.85	3,976	4,976
3 -A	DUMP TRUCK AND DRIVER HAUL TO LANDFILL AT PGDP	Matl.	12 ~~3.00~~	WK	500.00	1,500	
		Labor	360	TD	22.60	8,136	9,636
4 -A	EXCAVATION OF EARTH UNDRER PAD AND 5' AROUND PEREMITER TO A DEPTH OF 5'	Matl.	6,019.00	CY	2.80	16,853	
		Labor	482	OP	30.95	14,918	31,771
- -A	MOD. C PROTECTIVE CLOTHING PPE @ 50%	Matl.	461.00		8.00	3,688	
		Labor	0		0.00	0	3,688

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		26,776		31,982	58,758
SALES TAX		1,607			1,607
SUBTOTAL		28,383		31,982	60,365
TOTAL INDIRECT	20.00%	5,677	20.00%	6,396	12,073
TOTAL		34,060	(hrs. 1,162)	38,378	72,438
TOTAL (ESCALATED COST)		38,132		42,967	81,099

630727

WBS .... 2.01.04.01 GENERAL CONDITIONS (7 YRS)
Cost Code .... 6100 REMEDIAL ACTION
'cipant .... FP51 FIXED PRICE SUBCONT
. of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... C CIVIL AND SITE
B/M Title .... MOB/DEMOB/GEN COND (7 YRS)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... NEW NE SYSTEM
Quantity Take-Off By ...
Trace Number C.4.3 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	GENERAL CONDITIONS - FIXED COST						
1 -A	CONSTRUCTION TRAILER MOB/DEMOB	Matl.	1.00	LS	0.00	0	
		Labor	40	TD	22.60	904	904
2 -A	MOB/DEMOB SUPPORT LABOR	Matl.	1.00	LS	0.00	0	
		Labor	40	L	24.85	994	994
3 -A	SET-UP LABOR	Matl.	1.00	LS	250.00	250	
		Labor	40	L	24.85	994	1,244
4 -A	UTILITIES HOOK UP (ELEC, WATER, SEWER)	Matl.	1.00	LS	3,000.00	3,000	
		Labor	0		0.00	0	3,000
[illegible] -A	SHOWER/CHANGE TRAILER MOB/DEMOB	Matl.	1.00	LS	0.00	0	
		Labor	40	TD	22.60	904	904
6 -A	MOB/DEMOB SUPPORT LABOR	Matl.	1.00	LS	0.00	0	
		Labor	40	L	24.85	994	994
7 -A	SET-UP LABOR	Matl.	1.00	LS	250.00	250	
		Labor	40	L	24.85	994	1,244
8 -A	UTILITIES HOOK-UP (ELEC, WATER, SEWER)	Matl.	1.00	LS	3,000.00	3,000	
		Labor	0		0.00	0	3,000
****	SUBTOTAL ****	Matl.				6,500	
		Labor	240			5,784	12,284
9 -A	GENERAL SAFETY PLAN	Matl.	1.00	LS	2,000.00	2,000	
		Labor	0		0.00	0	2,000
10 -A	QUALITY ASSURANCE PLAN	Matl.	1.00	LS	1,000.00	1,000	
		Labor	0		0.00	0	1,000
11 -A	WASTE MANAGEMENT PLAN	Matl.	1.00	LS	2,000.00	2,000	
		Labor	0		0.00	0	2,000
12 -A	WORK PLAN	Matl.	1.00	LS	3,000.00	3,000	
		Labor	0		0.00	0	3,000

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
13 -A	HOISTING & RIGGING PLAN	Matl.	1.00	LS	1,000.00	1,000	
		Labor	0		0.00	0	1,000
14 -A	SITE SPECIFIC SAFETY & HEALTH PLAN	Matl.	1.00	LS	5,000.00	5,000	
		Labor	0		0.00	0	5,000
****	SUBTOTAL ****	Matl.				14,000	
		Labor	0			0	14,000

BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		20,500		5,784	26,284
SALES TAX		1,230			1,230
SUBTOTAL		21,730		5,784	27,514
TOTAL INDIRECT	20.00%	4,346	20.00%	1,157	5,503
TOTAL		26,076	(hrs. 240)	6,941	33,017
TOTAL (ESCALATED COST)		29,194		7,771	36,9

630729

630728

WBS .... 2.01.04.01 GENERAL CONDITIONS (7 YRS)
Cost Code .... 6100 REMEDIAL ACTION
r 'cipant .... FP51 FIXED PRICE SUBCONT
. of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... C CIVIL AND SITE
B/M Title .... MOB/DEMOB/GEN COND (7 YRS)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... NEW NE SYSTEM
Quantity Take-Off By ...
Trace Number C.4.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	GENERAL CONDITIONS - VARIABLE COST						
1 -A	CONSTRUCTION TRAILER RENTAL	Matl.	6.00	MON	300.00	1,800	
		Labor	0		0.00	0	1,800
2 -A	SHOWER/CHANGE TRAILER RENTAL	Matl.	6.00	MON	500.00	3,000	
		Labor	0		0.00	0	3,000
3 -A	PORT-O-LET (1 @ $80 FOR 2 MONTHS)	Matl.	6.00	MON	80.00	480	
		Labor	0		0.00	0	480
-A	SAFETY & HEALTH OFFICER	Matl.	6.00	MON	0.00	0	
		Labor	1,050	X	40.00	42,000	42,000
5 -A	TRAINING:SECURITY REQMNT, GET ETC (28 HOURS/PERSON)	Matl.	8.00	EA	0.00	0	
		Labor	224	ZZ	25.00	5,600	5,600
****	SUBTOTAL ****	Matl.				5,280	
		Labor	1,274			47,600	52,880

630730

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		5,280		47,600	52,880
SALES TAX		317			317
SUBTOTAL		5,597		47,600	53,197
TOTAL INDIRECT	20.00%	1,119	20.00%	9,520	10,639
TOTAL		6,716	(hrs. 1,274)	57,120	63,836
TOTAL (ESCALATED COST)		7,519		63,949	71,468

630731

WBS .... 2.01.04.02 NEW NE TRTMT SYSTEM
Cost Code .... 6100 REMEDIAL ACTION
ˊ ˋicipant .... FP51 FIXED PRICE SUBCONT
ı of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... C CIVIL AND SITE
B/M Title .... NEW NE TRTMT SYSTEMS (7 YRS)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... NEW NE SYSTEM
Quantity Take-Off By ...
Trace Number C.4.4 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	VENDOR QUOTE						
1 -A	400 GPM AIR STRIPPER (2 @ 200 GPM/EA)	Matl.	2.00	EA	35,000.00	70,000	
		Labor	500	PF	35.20	17,600	87,600
2 -A	CONTAINMENT STRUCTURE FOR AIR STRIPPERS (E.J.)	Matl.	1.00	EA	25,000.00	25,000	
		Labor	0		0.00	0	25,000
3 -A	PERMITTED OUTFALL (E.J.)	Matl.	1.00	LS	25,000.00	25,000	
		Labor	0		0.00	0	25,000

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		120,000		17,600	137,600
SALES TAX		7,200			7,200
SUBTOTAL		127,200		17,600	144,800
TOTAL INDIRECT	20.00%	25,440	20.00%	3,520	28,960
TOTAL		152,640	(hrs. 500)	21,120	173,760
TOTAL (ESCALATED COST)		170,890		23,645	194,535

630732

630733

WBS .... 2.02.01.01 DESIGN (INITIAL)
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... AE01 A-E, ENVIRONMENTAL
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... X ENGINEERING
B/M Title .... AE RD REPORT
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-I
Quantity Take-Off By ...
Trace Number X.5.3 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	AE TITLE II DESIGN						
1 -A	RD REPORT (TITLE II) (1 FTE X 3 MOS)	Matl.	520.00	HOUR	0.00	0	
		Labor	520	T2	65.00	33,800	33,800

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	33,800	33,800
TOTAL	0	(hrs. 520) 33,800	33,8
TOTAL (ESCALATED COST)	0	36,905	36,905

630733

630732

WBS	2.02.01.01 DESIGN (INITIAL)	Building/Area	2ALT 2 IND
Cost Code	9100 PROJECT MANAGEMENT	Plant Site	R
P 'cipant	AE01 A-E, ENVIRONMENTAL	Contracting Type	G General
L of Estimate	P Planning/Feasibility Estimate	Funding Type	EXPENSE
B/M Attribute	2ALT 2	Source Site	PADUCAH
Discipline	X ENGINEERING	Discipline Estimator	INDIRECTS-I
B/M Title	AE REVIEW RA WORK PLAN	Quantity Take-Off By	
Receiving Site	PADUCAH	Trace Number	X.5.5 0
Cross-Cut Code			
Standard Value File	C:®ESTIMA™1®RRB2668A.val	Expiration Date:	09/15/1999
Estimate File	C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a		

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -C	AE REVIEW RA WORK PLAN	Matl.	20.00	HOUR	0.00	0	
		Labor	20	T2	65.00	1,300	1,300

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	1,300	1,300
TOTAL	0	(hrs. 20) 1,300	1,300
'L (ESCALATED COST)	0	1,419	1,419

630734

WBS .... 2.02.01.01 DESIGN (INITIAL)
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... AE01 A-E, ENVIRONMENTAL
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... X ENGINEERING
B/M Title .... AE RD WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-I
Quantity Take-Off By ...
Trace Number X.5.1 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1	-C AE WRITE RD WORK PLAN	Matl.	40.00	HOUR	0.00	0	
		Labor	40	T2	65.00	2,600	2,600

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	2,600	2,600
TOTAL	0	(hrs. 40) 2,600	2,600
TOTAL (ESCALATED COST)	0	2,839	2,8

630735

WBS .... 2.02.01.01 DESIGN (INITIAL)
Cost Code .... 9100 PROJECT MANAGEMENT
ticipant .... R032 PAD ENG & TECH SVCS
l of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... X ENGINEERING
B/M Title .... CM RA WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-I
Quantity Take-Off By ...
Trace Number X.5.6 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM WRITE RA WORK PLAN	Matl.	40.00	HOUR	0.00	0	
		Labor	40	MX	64.00	2,560	2,560

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	2,560	2,560
TOTAL	0	(hrs. 40) 2,560	2,560
AL (ESCALATED COST)	0	2,795	2,795

630736

WBS .... 2.02.01.01 DESIGN (INITIAL)
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... R032 PAD ENG & TECH SVCS
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... X ENGINEERING
B/M Title .... CM REVIEW RD WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-I
Quantity Take-Off By ...
Trace Number X.5.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM REVIEW RD WORK PLAN	Matl.	20.00	HOUR	0.00	0	
		Labor	20	MX	64.00	1,280	1,280

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	1,280	1,280
TOTAL	0	(hrs. 20) 1,280	1,280
TOTAL (ESCALATED COST)	0	1,398	1,3

630737

630736

WBS .... 2.02.01.01 DESIGN (INITIAL)
Cost Code .... 9100 PROJECT MANAGEMENT
icipant .... R032 PAD ENG & TECH SVCS
of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... X ENGINEERING
B/M Title .... CM REVIEW RD REPORT
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-I
Quantity Take-Off By ...
Trace Number X.5.4 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM REVIEW RD REPORT	Matl.	80.00	HOUR	0.00	0	
		Labor	80	MX	64.00	5,120	5,120

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	5,120	5,120
TOTAL	0	(hrs. 80) 5,120	5,120
'AL (ESCALATED COST)	0	5,590	5,590

630738

WBS .... 2.02.01.02 PROJECT INTEGRATION (INITIAL)
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... AE01 A-E, ENVIRONMENTAL
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... U PROJECT ENGINEERING
B/M Title .... AE T-III ENGINEERING
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-I
Quantity Take-Off By ...
Trace Number U.7.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	AE TITLE III ENGINEERING (1/2 FTE X 9	Matl.	780.00	HOUR	0.00	0	
	MOS)	Labor	780	T3	55.00	42,900	42,900

BILL OF MATERIAL SUMMARY	Material	Labor		Total Cost M + L
TOTAL DIRECT	0		42,900	42,900
TOTAL	0	(hrs. 780)	42,900	42,900
TOTAL (ESCALATED COST)	0		47,542	47,5

630739

WBS	2.02.01.02 PROJECT INTEGRATION (INITIAL)	Building/Area	2ALT 2 IND
Cost Code	9100 PROJECT MANAGEMENT	Plant Site	R
r 'cipant	R032 PAD ENG & TECH SVCS	Contracting Type	G General
of Estimate .	P Planning/Feasibility Estimate	Funding Type	EXPENSE
B/M Attribute	2ALT 2	Source Site	PADUCAH
Discipline	U PROJECT ENGINEERING	Discipline Estimator ...	INDIRECTS-I
B/M Title	CM FINAL REPORTS	Quantity Take-Off By ...	
Receiving Site	PADUCAH	Trace Number	U.7.3 0
Cross-Cut Code			
Standard Value File	C:®ESTIMA™1®RRB2668A.val	Expiration Date: 09/15/1999	
Estimate File	C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a		

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM FINAL CONSTRUCTION REPORTS	Matl.	40.00	HOUR	0.00	0	
		Labor	40	MR	54.00	2,160	2,160

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	2,160	2,160
TOTAL	0	(hrs. 40) 2,160	2,160
L (ESCALATED COST)	0	2,394	2,394

630740

630741

WBS .... 2.02.01.02 PROJECT INTEGRATION (INITIAL)
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... R053 PAD FIELD SERVICES
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... U PROJECT ENGINEERING
B/M Title .... CM CONST OVERSIGHT
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-I
Quantity Take-Off By ...
Trace Number U.7.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM CONSTRUCTION OVERSIGHT (1 FTE X 9 MOS)	Matl.	1,560.00	HOUR	0.00	0	
		Labor	1,560	MR	54.00	84,240	84,240

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	84,240	84,240
TOTAL	0	(hrs. 1,560) 84,240	84,240
TOTAL (ESCALATED COST)	0	93,356	93,3

630741

630740

WBS .... 2.02.02.01 DESIGN (7 YRS)
Cost Code .... 9100 PROJECT MANAGEMENT
r ˈcipant .... AE01 A-E, ENVIRONMENTAL
, of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... X ENGINEERING
B/M Title .... AE REVIEW RA WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-7
Quantity Take-Off By ...
Trace Number X.6.5 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -C	AE REVIEW RA WORK PLAN	Matl.	20.00	HOUR	0.00	0	
		Labor	20	T2	65.00	1,300	1,300

BILL OF MATERIAL SUMMARY	Material	Labor		Total Cost M + L
TOTAL DIRECT	0		1,300	1,300
TOTAL	0	(hrs. 20)	1,300	1,300
ՙ ՙL (ESCALATED COST)	0		1,708	1,708

630742 630743

WBS .... 2.02.02.01 DESIGN (7 YRS)
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... AE01 A-E, ENVIRONMENTAL
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... X ENGINEERING
B/M Title .... AE RD WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-7
Quantity Take-Off By ...
Trace Number X.6.1 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1	-C AE WRITE RD WORK PLAN	Matl.	20.00	HOUR	0.00	0	
		Labor	20	T2	65.00	1,300	1,300

BILL OF MATERIAL SUMMARY	Material	Labor		Total Cost M + L
TOTAL DIRECT	0		1,300	1,300
TOTAL	0	(hrs. 20)	1,300	1,300
TOTAL (ESCALATED COST)	0		1,708	1,[illegible]

630743

WBS .... 2.02.02.01 DESIGN (7 YRS)
Cost Code .... 9100 PROJECT MANAGEMENT
'icipant .... AE01 A-E, ENVIRONMENTAL
.l of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... X ENGINEERING
B/M Title .... AE RD REPORT
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-7
Quantity Take-Off By ...
Trace Number X.6.3 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	AE TITLE II DESIGN						
1 -A	RD REPORT (TITLE II) (1/2 FTE X 3	Matl.	260.00	HOUR	0.00	0	
	MOS)	Labor	260	T2	65.00	16,900	16,900

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	16,900	16,900
'AL	0	(hrs. 260) 16,900	16,900
TOTAL (ESCALATED COST)	0	22,204	22,204

630744

630745

WBS .... 2.02.02.01 DESIGN (7 YRS)
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... R032 PAD ENG & TECH SVCS
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... X ENGINEERING
B/M Title .... CM REVIEW RD WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-7
Quantity Take-Off By ...
Trace Number X.6.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM REVIEW RD WORK PLAN	Matl.	20.00	HOUR	0.00	0	
		Labor	20	MX	64.00	1,280	1,280

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	1,280	1,280
TOTAL	0	(hrs. 20) 1,280	1,280
TOTAL (ESCALATED COST)	0	1,682	1,(

630745

WBS	2.02.02.01 DESIGN (7 YRS)	Building/Area	2ALT 2 IND
Cost Code	9100 PROJECT MANAGEMENT	Plant Site	R
F cipant	R032 PAD ENG & TECH SVCS	Contracting Type	G General
of Estimate	P Planning/Feasibility Estimate	Funding Type	EXPENSE
B/M Attribute	2ALT 2	Source Site	PADUCAH
Discipline	X ENGINEERING	Discipline Estimator	INDIRECTS-7
B/M Title	CM REVIEW RD REPORT	Quantity Take-Off By	
Receiving Site	PADUCAH	Trace Number	X.6.4 0
Cross-Cut Code			
Standard Value File	C:®ESTIMA™1®RRB2668A.val	Expiration Date:	09/15/1999
Estimate File	C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a		

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM REVIEW RD REPORT	Matl.	40.00	HOUR	0.00	0	
		Labor	40	MX	64.00	2,560	2,560

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	2,560	2,560
TOTAL	0	(hrs. 40) 2,560	2,560
L (ESCALATED COST)	0	3,363	3,363

630746

WBS .... 2.02.02.01 DESIGN (7 YRS)
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... R032 PAD ENG & TECH SVCS
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... X ENGINEERING
B/M Title .... CM RA WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-7
Quantity Take-Off By ...
Trace Number X.6.6 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM WRITE RA WORK PLAN	Matl.	20.00	HOUR	0.00	0	
		Labor	20	MX	64.00	1,280	1,280

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	1,280	1,280
TOTAL	0	(hrs. 20) 1,280	1,280
TOTAL (ESCALATED COST)	0	1,682	1,68

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WBS .... 2.02.02.02 PROJECT INTEGRATION (7 YRS)
Cost Code .... 9100 PROJECT MANAGEMENT
icipant .... AE01 A-E, ENVIRONMENTAL
of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... U PROJECT ENGINEERING
B/M Title .... AE T-III ENGINEERING
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-7
Quantity Take-Off By ...
Trace Number U.8.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	AE TITLE III ENGINEERING (1/2 FTE X 3	Matl.	260.00	HOUR	0.00	0	
	MOS)	Labor	260	T3	55.00	14,300	14,300

BILL OF MATERIAL SUMMARY	Material		Labor	Total Cost M + L
TOTAL DIRECT	0		14,300	14,300
TOTAL	0	(hrs. 260)	14,300	14,300
AL (ESCALATED COST)	0		19,005	19,005

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WBS .... 2.02.02.02 PROJECT INTEGRATION (7 YRS)
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... R032 PAD ENG & TECH SVCS
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... U PROJECT ENGINEERING
B/M Title .... CM FINAL REPORTS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-7
Quantity Take-Off By ...
Trace Number U.8.3 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM FINAL CONSTRUCTION REPORTS	Matl.	20.00	HOUR	0.00	0	
		Labor	20	MR	54.00	1,080	1,080

BILL OF MATERIAL SUMMARY	Material	Labor		Total Cost M + L
TOTAL DIRECT	0		1,080	1,080
TOTAL	0	(hrs. 20)	1,080	1,080
TOTAL (ESCALATED COST)	0		1,435	1,

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630748

WBS .... 2.02.02.02 PROJECT INTEGRATION (7 YRS)
Cost Code .... 9100 PROJECT MANAGEMENT
P ·icipant .... R053 PAD FIELD SERVICES
of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... U PROJECT ENGINEERING
B/M Title .... CM CONST OVERSIGHT
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS-7
Quantity Take-Off By ...
Trace Number U.8.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM CONSTRUCTION OVERSIGHT (1/2 FTE X 3 MOS)	Matl.	260.00	HOUR	0.00	0	
		Labor	260	MR	54.00	14,040	14,040

BILL OF MATERIAL SUMMARY	Material	Labor		Total Cost M + L
TOTAL DIRECT	0		14,040	14,040
TOTAL	0	(hrs. 260)	14,040	14,040
·AL (ESCALATED COST)	0		18,660	18,660

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WBS .... 2.03.01.01 OPS & MAINT 1ST 3 YRS
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... O OTHER
B/M Title .... OPS & MAIN 1ST 3 YRS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 O&M
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.9.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	MAINTENANCE OF MONITORING WELLS INCLUDED AT 2% OF CAPITAL COST PER YEAR, EQUALS COMPLETE REPLACEMENT EVERY 50 YEARS						
	(90 EXISTING AND 32 NEW WELLS = 122 X $14,500/EA = $1,769,000)						
1 -A	MAINTENANCE OF MONITORING WELLS (2% X	Matl.	3.00	YRS	35,380.00	106,140	
	3 YRS)	Labor	0		0.00	0	106,140
2 -A	O&M OF NW SYSTEM (COST FROM BECHTEL	Matl.	3.00	YRS	1,098,774.00	3,296,322	
	JACOBS - MINUS OVERHEAD =	Labor	0		0.00	0	3,296,[illegible]
	$1,098,774/YR)						
3 -A	O&M OF NE SYSTEM (COST FROM BECHTEL	Matl.	3.00	YRS	346,362.00	1,039,086	
	JACOBS - MINUS OVERHEAD =	Labor	0		0.00	0	1,039,086
	$346,362/YR)						
****	SUBTOTAL ****	Matl.				4,441,548	
		Labor	0			0	4,441,548

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		4,441,548		0	4,441,548
SALES TAX		266,493			266,493
SUBTOTAL		4,708,041		0	4,708,041
TOTAL INDIRECT	20.00%	941,608	20.00%	0	941,608
TOTAL		5,649,649	(hrs. 0)	0	5,649,649
TOTAL (ESCALATED COST)		6,459,842		0	6,459,842

WBS .... 2.03.01.02 SAMPLE COLLECTION 1ST 3 YRS
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... 0 OTHER
B/M Title .... MONITORING 1ST 3 YEARS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 O&M
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.9.2 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	MONITORING - 3 YEARS						
	-SAMPLE COLLECTION-						
	(COST BY BECHTEL JACOBS)						
1 -A	QUARTERLY SAMPLING OF 122 WELLS =	Matl.	3.00	YRS	516,792.00	1,550,376	
	488/YR X $1,059/EA	Labor	0		0.00	0	1,550,376
****	SUBTOTAL ****	Matl.				1,550,376	
		Labor	0			0	1,550,376

BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		1,550,376		0	1,550,376
SALES TAX		93,023			93,023
SUBTOTAL		1,643,399		0	1,643,399
TOTAL INDIRECT	20.00%	328,680	20.00%	0	328,680
TOTAL		1,972,079	(hrs. 0)	0	1,972,079
TOTAL (ESCALATED COST)		2,254,887		0	2,254,887

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WBS .... 2.03.01.03 SAMPLE ANALYSIS 1ST 3 YRS
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
' 'cipant .... SC01 OFFSITE SUB #1
. . of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... O OTHER
B/M Title .... MONIT 1ST 3 YEARS (ANALYSIS)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 O&M
Plant Site .... R
Contracting Type .... S Subcontractor
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.9.3 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	LAB ANALYSIS - 3 YEARS						
1 -A	QUARTERLY ANALYSIS OF 122 WELLS =	Matl.	3.00	YRS	195,200.00	585,600	
	488/YR X $400/EA	Labor	0		0.00	0	585,600
****	SUBTOTAL ****	Matl.				585,600	
		Labor	0			0	585,600
2 -A	SMO OVERSIGHT (16.4%)	Matl.	585.60	K$	164.00	96,038	
		Labor	0		0.00	0	96,038

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	681,638	0	681,638
SALES TAX	40,898		40,898
SUBTOTAL	722,536	0	722,536
TOTAL	722,536	(hrs. 0) 0	722,536
TOTAL (ESCALATED COST)	826,152	0	826,152

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WBS .... 2.03.02.01 OPS & MAINT YRS 4-7
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... O OTHER
B/M Title .... OPS & MAIN YRS 4-7
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 O&M
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.9.4 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	MAINTENANCE OF MONITORING WELLS INCLUDED AT 2% OF CAPITAL COST PER YEAR, EQUALS COMPLETE REPLACEMENT EVERY 50 YEARS						
	(90 EXISTING AND 32 NEW WELLS = 122 X $14,500/EA = $1,769,000)						
1 -A	MAINTENANCE OF MONITORING WELLS (2% X 4 YRS)	Matl.	4.00	YRS	35,380.00	141,520	
		Labor	0		0.00	0	141,520
2 -A	O&M OF NW SYSTEM (COST FROM BECHTEL JACOBS - MINUS OVERHEAD = $1,098,774/YR)	Matl.	4.00	YRS	1,098,774.00	4,395,096	
		Labor	0		0.00	0	4,395,
3 -A	O&M OF NE SYSTEM (COST FROM BECHTEL JACOBS - MINUS OVERHEAD = $346,362/YR)	Matl.	4.00	YRS	346,362.00	1,385,448	
		Labor	0		0.00	0	1,385,448
****	SUBTOTAL ****	Matl.				5,922,064	
		Labor	0			0	5,922,064

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BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		5,922,064		0	5,922,064
SALES TAX		355,324			355,324
SUBTOTAL		6,277,388		0	6,277,388
TOTAL INDIRECT	20.00%	1,255,478	20.00%	0	1,255,478
TOTAL		7,532,866	(hrs. 0)	0	7,532,866
TOTAL (ESCALATED COST)		9,521,349		0	9,521,349

WBS .... 2.03.02.02 SAMPLE COLLECTION YRS 4-7
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... O OTHER
B/M Title .... MONITORING YRS 4-7
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 O&M
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.9.5 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	MONITORING - 4 YEARS						
	-SAMPLE COLLECTION-						
	(COST BY BECHTEL JACOBS)						
1 -A	SEMI-ANNUAL SAMPLING OF 122 WELLS =	Matl.	4.00	YRS	258,396.00	1,033,584	
	244/YR X $1,059/EA	Labor	0		0.00	0	1,033,584
****	SUBTOTAL ****	Matl.				1,033,584	
		Labor	0			0	1,033,584

BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		1,033,584		0	1,033,584
SALES TAX		62,015			62,015
SUBTOTAL		1,095,599		0	1,095,599
TOTAL INDIRECT	20.00%	219,120	20.00%	0	219,120
TOTAL		1,314,719	(hrs. 0)	0	1,314,719
TOTAL (ESCALATED COST)		1,661,771		0	1,661,771

WBS .... 2.03.03.01 OPS & MAINT YRS 8-30
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
P :ipant .... FP51 FIXED PRICE SUBCONT
L of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... O OTHER
B/M Title .... OPS & MAIN YRS 8-30
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 O&M
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.9.7 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	MAINTENANCE OF MONITORING WELLS INCLUDED AT 2% OF CAPITAL COST PER YEAR, EQUALS COMPLETE REPLACEMENT EVERY 50 YEARS						
	(90 EXISTING AND 32 NEW WELLS = 122 X $14,500/EA = $1,769,000)						
1 -A	MAINTENANCE OF MONITORING WELLS (2% X 23 YRS)	Matl.	23.00	YRS	35,380.00	813,740	
		Labor	0		0.00	0	813,740
	O&M OF NEW NE TRTMT SYSTEM EQUALS O&M OF EXISTING SYSTEM						
2 -A	O&M OF NEW NE TREATMENT SYSTEM (2% X 23 YRS)	Matl.	23.00	YRS	346,362.00	7,966,326	
		Labor	0		0.00	0	7,966,326
3 -A	O&M OF NW SYSTEM (COST FROM BECHTEL JACOBS - MINUS OVERHEAD = $1,098,774/YR)	Matl.	23.00	YRS	1,098,774.00	25,271,802	
		Labor	0		0.00	0	25,271,802
****	SUBTOTAL ****	Matl.				34,051,868	
		Labor	0			0	34,051,868

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BILL OF MATERIAL SUMMARY	Material		Labor			Total Cost M + L
TOTAL DIRECT		34,051,868			0	34,051,868
SALES TAX		2,043,112				2,043,112
SUBTOTAL		36,094,980			0	36,094,980
TOTAL INDIRECT	20.00%	7,218,996	20.00%		0	7,218,996
TOTAL		43,313,976	(hrs.	0)	0	43,313,976
TOTAL (ESCALATED COST)		81,947,819			0	81,947,819

WBS .... 2.03.03.02 SAMPLE COLLECTION YRS 8-30
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
icipant .... FP51 FIXED PRICE SUBCONT
(of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... O OTHER
B/M Title .... MONITORING YRS 8-30
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 O&M
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.9.8 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	MONITORING - 23 YEARS						
	-SAMPLE COLLECTION-						
	(COST BY BECHTEL JACOBS)						
1 -A	SEMI-ANNUAL SAMPLING OF 122 WELLS =	Matl.	23.00	YRS	258,396.00	5,943,108	
	244/YR X $1,059/EA	Labor	0		0.00	0	5,943,108
****	SUBTOTAL ****	Matl.				5,943,108	
		Labor	0			0	5,943,108

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		5,943,108		0	5,943,108
SALES TAX		356,586			356,586
SUBTOTAL		6,299,694		0	6,299,694
TOTAL INDIRECT	20.00%	1,259,939	20.00%	0	1,259,939
TOTAL		7,559,633	(hrs. 0)	0	7,559,633
TOTAL (ESCALATED COST)		14,302,438		0	14,302,438

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WBS .... 2.03.03.03 SAMPLE ANALYSIS YRS 8-30
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
Participant .... SC01 OFFSITE SUB #1
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 2ALT 2
Discipline .... O OTHER
B/M Title .... MONIT YRS 8-30 (ANALYSIS)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL2®2ALT2.Est 5-31-00 9:05a

Building/Area .... 2ALT 2 O&M
Plant Site .... R
Contracting Type .... S Subcontract
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.9.9 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	LAB ANALYSIS - 23 YEARS						
1 -A	SEMI-ANNUAL ANALYSIS OF 122 WELLS =	Matl.	23.00	YRS	97,600.00	2,244,800	
	244/YR X $400/EA	Labor	0		0.00	0	2,244,800
****	SUBTOTAL ****	Matl.				2,244,800	
		Labor	0			0	2,244,800
2 -A	SMO OVERSIGHT (16.4%)	Matl.	2,244.80	K$	164.00	368,147	
		Labor	0		0.00	0	368,147

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	2,612,947	0	2,612,947
SALES TAX	156,777		156,777
SUBTOTAL	2,769,724	0	2,769,724
TOTAL	2,769,724	(hrs. 0) 0	2,769,724
TOTAL (ESCALATED COST)	5,240,176	0	5,240,176

Disciplines
C: CIVIL AND SITE
O: OTHER
U: PROJECT ENGINEERING
X: ENGINEERING

Total Labor Hours: 11,716

COST SUMMARY

COST SUMMARY	Material	Labor	Total Cost M + L
Line Item Cost	58,470,584	467,146	58,937,730
Total Sales Tax	3,508,236		3,508,236
SUBTOTAL	61,978,820	467,146	62,445,966
Total Indirect	11,592,683	47,429	11,640,112
SUBTOTAL	73,571,503	514,575	74,086,078
Overhead	30,870,603	215,916	31,086,519
SUBTOTAL	104,442,106	730,491	105,172,597
Contingency	26,110,526	182,623	26,293,149
'OTAL	130,552,632	913,114	131,465,746
,arket Adjustment			0
TOTAL			131,465,746

TOTAL (ESCALATED DOLLARS) including overhead & contingency	222,388,113	1,033,568	223,421,681

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Basis of Estimate
Feasibility Study for the GWOU
Alternative 3

Description: This alternative will continue the groundwater monitoring program currently in place plus an expansion by 32 monitoring wells. Also, 15 existing monitoring wells will be plugged and abandoned. Source areas will be treated by Dual Phase Extraction for the Upper Continental Recharge System (UCRS) unsaturated soils and by Dynamic Underground Stripping for the Regional Gravel Aquifer (RGA). The on-site Northwest, Southwest, and Northeast Plumes dissolved phases that are between the source zone and the fence will be C-Sparged. Additionally, the cores of the Northwest, Southwest, and Northeast Plumes located outside the security fence also will be C-Sparged. The period of the action is 30 years. Although not costed in this estimate, the action will be required to be repeated for a period of approximately 2,000 years until the remediation is complete.

General: The estimate was generated with Automated Estimating System (AES), using the standard value file RRB2668A.val.
Management and Integration (M&I) contract management is included at 20% of all costs.
Overhead is included at 41.96%.
Contingency is included at 25%.

Schedule: Installation is assumed to last 9 months.
Operation and Maintenance (O&M) is assumed to last 30 years.

Work Breakdown Structure (WBS)

WBS 3.01.01 General Conditions:

- Includes mobilization and set-up and utility hook-ups for a construction trailer and a shower/change trailer. Nine months rental cost is included for trailers and a port-o-let.
- A safety and health officer is included for the 9-month duration.
- Training and security requirements are included for 8 workers at 28 hours each.
- Includes general safety plan, quality assurance (QA) plan, waste management plan, work plan, hoisting and rigging plan, and site-specific safety and health plan.

WBS 3.01.02 Monitoring Wells (includes C-Sparge wells):

- Wells are separated as 27 inside and 5 outside the fence.
- Three hundred feet per well of access roads includes clearing and grubbing of light trees, grading, a filter fabric underlayment, and a 6-inch gravel base.
- Monitoring wells are 100 ft deep with stainless steel tubing and screen and are included at $14,500 each based on a vendor quote. Mobilization is included at $150,000.

- Disposal of water includes a 5,000 gal tanker truck with driver on-site full time (no disposal fee). Water is included at 1,000 gal per well. (27 wells I/S fence = 27,000 gal = 6 tankers) (5 wells O/S fence = 5,000 gal = 1 tanker)

- Disposal of solids includes 2 laborers, a fork truck with operator, and a flatbed truck with driver to load and haul the drums to the landfill (no tipping fee). Solids are included at 4 drums per well. Estimate assumes 50 drums per load and 1 load per day. (27 wells I/S fence = 3 loads, 5 wells O/S = 1 load)

- Sampling of water assumes 1 per well and includes $25 and 2 hours each with modified Level D personal protective equipment (PPE).

- Sampling of solids assumes 1 per well and includes $25 and 2 hours each with modified Level D PPE.

- Analysis of the samples includes volatile organic compounds (VOCs) (8260), gross alpha, gross beta, and ^{99}Tc at a total cost of $400 per sample. Costs are included for Site Management Office (SMO) oversight at 16.4%.

- Seven injection wells inside the secured area. 6-inch polyvinyl chloride (PVC) pipe with 10-inch drilled hole.

- Electrical service, power, and equipment assumed for all 7 wells.

- Twelve injection wells outside the secured area. 6-inch PVC pipe with 10-inch drilled hole.

- Electrical service, power, and equipment assumed for 12 wells outside secured area.

WBS 3.01.03 Plug and Abandon Wells:

- Plugging and abandoning of 15 existing wells is included at $40,833 each. Cost is based on a feasibility study for White Oak Creek.

- Disposal of water includes a 5,000-gal tanker truck with driver on-site full time (no disposal fee). Water is included at 1,000 gal per well. (15 wells = 15,000 gal = 3 tankers)

- Disposal of solids includes 2 laborers, a fork truck with operator, and a flatbed truck with driver to load and haul the drums to the landfill (no tipping fee). Solids are included at 5 drums per well. Estimate assumes 50 drums per load and 1 load per day (15 wells = 2 loads). Drums are included assuming 5 per well at $55 each.

- Sampling of water assumes 1 per well and includes $25 and 2 hours each with modified Level D PPE.

- Sampling of solids assumes 1 per well and includes $25 and 2 hours each with modified Level D PPE.

- Analysis of the samples includes VOCs (8260), gross alpha, gross beta, and ^{99}Tc at a total cost of $400 per sample. Costs are included for SMO oversight at 16.4%.

WBS 3.01.04 Shut Down Northeast Northwest Systems [includes excavation of Solid Waste Management Unit (SWMU) 99]:

- The cost to shut down the Northeast and Northwest treatment systems (cold stand-by) is included at $65,000 and is based on costs from CDM Federal as provided by Bechtel Jacobs Company LLC (BJC).

- Breaking, loading, and hauling a concrete pad of 120 ft by 240 ft at SWMU 99.
- Excavation of 6,019 yds^3 of earth.

WBS 3.01.05 Source Remedial Actions:

- Dual Phase extraction at the following locations: C-400 Northeast, C-400 Southeast, C-720 East, and SWMU 1. Lump sum costs using previous estimates developed by Science Applications International Corporation (SAIC) include the following: royalty fees, surface and subsurface piping, pumps, electrical substation, on-site monitoring equipment, ion exchanges system, activated carbon, and instruments and controls.
- Dynamic Underground Stripping in the RGA at C-400. Lump sum cost of $4,850,000 using previous estimates developed by SAIC includes the following: 16 steel wells 8 inches in diameter, 8 extraction wells, steam generator and water conditioning system, Catalytic Oxidation off-gas system and scrubber, air monitoring system, ion exchange, air compressor, steam piping and equipment, instruments and controls, electrical substation, and gas line installation.

WBS 3.02 Indirect Costs:

- Indirect costs include design, project integration, and M&I oversight. These costs are dependent on level of effort and project schedule.

WBS 3.03.01.01 Maintenance (30 Years):

- Maintenance is included for the 32 new and 90 existing monitoring wells. Costs are included at 2% of the well capital cost annually for 30 years (122 × $14,500 × .02 = $35,380/year). Two percent annually is equivalent to total replacement every 50 years.

WBS 3.03.01.02 Sample Collection (30 Years):

- Sample collection is included quarterly for the 32 new and 90 existing monitoring wells. A cost of $1,059 per sample is included as provided by BJC. Quarterly sampling of 122 wells = 488 samples per year × $1,059 = $516,792 per year for 30 years.

WBS 3.03.01.03 Sample Analysis (30 Years):

- Sample analysis is included quarterly for the 32 new and 90 existing monitoring wells. A cost of $400 per sample is included for VOCs (8260), gross alpha, gross beta, and ^{99}Tc. Quarterly analysis of 122 wells = 488 samples per year × $400 = $195,200 per year for 30 years. Costs are included for SMO oversight at 16.4%.

WBS 3.03.01.04 Management and Integration (M&I) on Operation and Maintenance (O&M) (30 Years):

- M&I contract management is included at 8% of all other O&M costs.

Line items within the detailed estimate contain references to cost guides. The following is a glossary for those references.

FCM-845	Facility Construction Means		Page 845
HCM-41	Heavy Construction Means		Page 41
BCM-21	Building Construction Means		Page 21
ECHOS-8-107	ECHOS Cost Guide	Section 8	Page 107
RRBB-20-7	Rental Rate Blue Book	Section 20	Page 7
E.J.	Estimator's Judgment		

SUMMARY REPORT
Project Number: 35T08116
PGDP GWOU 1ALT 3

Project ESO Number......NA
Revision Number.........1
Last Update.............05/31/2000

Sort Order
1. WBS - Level 3
2. WBS - Level 4
3. Building/Area

Approved by:

Project Estimator Date

Estimating Manager Date

Base Fiscal Year/Quarter: 99/4
STANDARD VALUE: C:®ESTIMA™1®RRB2668A.val EXPIRES: 09/15/1999
ESTIMATE FILE: C:®ESTIMA™1®ATL3®1ALT3.Est 05/31/2000
SCHEDULE FILE: 1ALT3
REPORT FILE: C:®ESTIMA™1®ATL3®ALT3SUM.Out 05/31/2000 08:53:04

AES Version 6.1

PGDP GWOU 1ALT 3

SUMMARY REPORT
$1 = $1

05/31/2000

Arranged By: WBS / WBS / Building

	Unescalated Material $	Unescalated Labor $	Unescalated Total $	Escalated Material $	Escalated Labor $	Escalated Total $
3.03.01 30 YRS O&M						
3.03.01.01 MAINTENANCE (30 YRS)						
1ALT 3 O&M	1350101	0	1350101	2340204	0	2340204
TOTAL MAINTENANCE (30 YRS)	1350101	0	1350101	2340204	0	2340204
3.03.01.02 SAMPLE COLLECTION (30 YRS)						
1ALT 3 O&M	19720783	0	19720783	34183110	0	34183110
TOTAL SAMPLE COLLECTION (30 YRS)	19720783	0	19720783	34183110	0	34183110
3.03.01.03 SAMPLE ANALYSIS (30 YRS)						
1ALT 3 O&M	7225367	0	7225367	12524123	0	12524123
TOTAL SAMPLE ANALYSIS (30 YRS)	7225367	0	7225367	12524123	0	12524123
TOTAL 30 YRS O&M	28296251	0	28296251	49047437	0	49047437
SUB - TOTAL	41480427	401105	41881532	63725688	451853	64177[illegible]
OVERHEAD	17405187	168304	17573491	26739299	189598	2692[illegible]
SUB - TOTAL	58885614	569409	59455023	90464987	641451	91106438
CONTINGENCY	14721403	142352	14863755	22616247	160363	22776610
GRAND TOTAL	73607017	711761	74318778	113081234	801814	113883048

DETAIL REPORT
Project Number: 35T08116
PGDP GWOU 1ALT 3

Project ESO Number......NA
Revision Number.........1
Last Update............05/31/2000

Sort Order
1. WBS - Level 9
2. Participant
3. Discipline

Approved by:

Project Estimator — Date

Estimating Manager — Date

Base Fiscal Year/Quarter: 99/4
STANDARD VALUE: C:®ESTIMA™1®RRB2668A.val EXPIRES: 09/15/1999
ESTIMATE FILE: C:®ESTIMA™1®ATL3®1ALT3.Est 05/31/2000
SCHEDULE FILE: 1ALT3
REPORT FILE: C:®ESTIMA™1®ATL3®ALT3DETA.Out 05/31/2000 08:51:56 AES Version 6.1

Creation Date 09/07/1999
Revision Number ... 1

Estimating Job Number .. 0116-20

Project Estimator.. J LOLLAR/NLE
WBS .... 3.01.01.01 VARIABLE COSTS
Cost Code .... 6100 REMEDIAL ACTION
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... C CIVIL AND SITE
B/M Title .... MOB/DEMOB/GEN COND - VAR
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Project Engineer .... S MAUDLIN
Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... GEN CONDITIONS
Quantity Take-Off By ...
Trace Number C.1.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	GENERAL CONDITIONS - VARIABLE COST						
1 -A	CONSTRUCTION TRAILER RENTAL	Matl.	9.00	MON	300.00	2,700	
		Labor	0		0.00	0	2,700
2 -A	SHOWER/CHANGE TRAILER RENTAL	Matl.	9.00	MON	500.00	4,500	
		Labor	0		0.00	0	4,500
3 -A	PORT-O-LET (1 @ $80 FOR 2 MONTHS)	Matl.	9.00	MON	80.00	720	
		Labor	0		0.00	0	720
4 -A	SAFETY & HEALTH OFFICER	Matl.	9.00	MON	0.00	0	
		Labor	1,575	X	40.00	63,000	63,000
5 -A	TRAINING:SECURITY REQMNT, GET ETC (28 HOURS/PERSON)	Matl.	8.00	EA	0.00	0	
		Labor	224	ZZ	25.00	5,600	5,600
****	SUBTOTAL ****	Matl.				7,920	
		Labor	1,799			68,600	76,520

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630769

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		7,920		68,600	76,520
SALES TAX		475			475
SUBTOTAL		8,395		68,600	76,995
TOTAL INDIRECT	20.00%	1,679	20.00%	13,720	15,399
TOTAL		10,074	(hrs. 1,799)	82,320	92,394
TOTAL (ESCALATED COST)		11,164		91,228	102,392

WBS .... 3.01.01.02 FIXED COSTS
Cost Code .... 6100 REMEDIAL ACTION
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... C CIVIL AND SITE
B/M Title .... MOB/DEMOB/GEN COND - FIXED
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... GEN CONDITIONS
Quantity Take-Off By ...
Trace Number C.1.2 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	GENERAL CONDITIONS - FIXED COST						
1 -A	CONSTRUCTION TRAILER MOB/DEMOB	Matl.	1.00	LS	0.00	0	
		Labor	40	TD	22.60	904	904
2 -A	MOB/DEMOB SUPPORT LABOR	Matl.	1.00	LS	0.00	0	
		Labor	40	L	24.85	994	994
3 -A	SET-UP LABOR	Matl.	1.00	LS	250.00	250	
		Labor	40	L	24.85	994	1,244
4 -A	UTILITIES HOOK UP (ELEC, WATER, SEWER)	Matl.	1.00	LS	3,000.00	3,000	
		Labor	0		0.00	0	3,000
5 -A	SHOWER/CHANGE TRAILER MOB/DEMOB	Matl.	1.00	LS	0.00	0	
		Labor	40	TD	22.60	904	904
6 -A	MOB/DEMOB SUPPORT LABOR	Matl.	1.00	LS	0.00	0	
		Labor	40	L	24.85	994	994
7 -A	SET-UP LABOR	Matl.	1.00	LS	250.00	250	
		Labor	40	L	24.85	994	1,244
8 -A	UTILITIES HOOK-UP (ELEC, WATER, SEWER)	Matl.	1.00	LS	3,000.00	3,000	
		Labor	0		0.00	0	3,000
****	SUBTOTAL ****	Matl.				6,500	
		Labor	240			5,784	12,284
9 -A	GENERAL SAFETY PLAN	Matl.	1.00	LS	2,000.00	2,000	
		Labor	0		0.00	0	2,000
10 -A	QUALITY ASSURANCE PLAN	Matl.	1.00	LS	1,000.00	1,000	
		Labor	0		0.00	0	1,000
11 -A	WASTE MANAGEMENT PLAN	Matl.	1.00	LS	2,000.00	2,000	
		Labor	0		0.00	0	2,000
12 -A	WORK PLAN	Matl.	1.00	LS	3,000.00	3,000	
		Labor	0		0.00	0	3,000

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
13 -A	HOISTING & RIGGING PLAN	Matl.	1.00	LS	1,000.00	1,000	
		Labor	0		0.00	0	1,000
14 -A	SITE SPECIFIC SAFETY & HEALTH PLAN	Matl.	1.00	LS	5,000.00	5,000	
		Labor	0		0.00	0	5,000
****	SUBTOTAL ****	Matl.				14,000	
		Labor	0			0	14,000

BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		20,500		5,784	26,284
SALES TAX		1,230			1,230
SUBTOTAL		21,730		5,784	27,514
TOTAL INDIRECT	20.00%	4,346	20.00%	1,157	5,503
TOTAL		26,076	(hrs. 240)	6,941	33,017
L (ESCALATED COST)		28,898		7,692	36,590

630773

WBS .... 3.01.02.01 MONITORING WELLS (I/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... C CIVIL AND SITE
B/M Title .... MON WELLS (I/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	27 WELLS INSIDE FENCE						
	7 ADDITIONAL INJECTION WELLS INSIDE FENCE						
	(143 DAYS PER VENDOR)						
	(180 DAYS/WITH 7 INJ. WELLS)						
	ACCESS ROAD (300'/WELL)						
1 -A	SITE PREP: CLEAR & GRUB LIGHT TREES,	Matl.	1.20	ACRE	1,975.00	2,370	
	GRUB & RMV STUMPS (HCM-41)	Labor	72	OP	30.95	2,228	4,[illegible]
2 -A	GRADER RENTAL (HCM-17)	Matl.	7.00	DAYS	670.00	4,690	
		Labor	0		0.00	0	4,690
3 -A	OPERATING COST & OPERATOR (HCM-17)	Matl.	50.00	HRS	16.92	846	
		Labor	50	OP	30.95	1,548	2,394
4 -A	FILTER FABRIC UNDERLAYMENT	Matl.	22,855.00	SY	1.03	23,541	
	(ECHOS-8-107)	Labor	286	L	24.85	7,107	30,648
5 -A	GRAVEL BASE - 6" DP, SPREAD & COMPACT	Matl.	22,855.00	SY	2.62	59,880	
	(HCM-58)	Labor	114	OP	30.95	3,528	63,408
****	SUBTOTAL ****	Matl.				91,327	
		Labor	522			14,411	105,738
	INSTALL MONITORING WELLS						
	INSTALL INJECTION WELLS-ALT.3						
	(COST FROM VENDOR QUOTE)						
6 -A	MOBILIZATION (INCL. MOB. 1 RIG,	Matl.	1.00	LS	150,000.00	150,000	
	SET-UP, DECON PAD, PPE, ETC)	Labor	0		0.00	0	150,000

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
7 -A	MOB.OF ADDITIONAL CREW AND EQUIPMENT FOR INJECTION WELLS	Matl.	1.00	LS	27,000.00	27,000	
		Labor	0		0.00	0	27,000
8 -A	MONITORING WELL W/ 2" SS TUBING, 6" OPEN HOLE, 10' SS SCREEN, 100' DP, 4 DRUMS/WELL SOLIDS, 1000 GAL/WELL PURGE WATER	Matl.	27.00	EA	14,500.00	391,500	
		Labor	0		0.00	0	391,500
****	SUBTOTAL ****	Matl.				568,500	
		Labor	0			0	568,500
9 -A	INJECTION WELL W/6"PVC PIPE, AND 10" DRILL HOLE, 100' DP.	Matl.	7.00	EA	52,000.00	364,000	
		Labor	0		0.00	0	364,000
10 -A	ASSOCIATED PIPING AND EQUIPMENT	Matl.	7.00	EA	12,500.00	87,500	
		Labor	0		0.00	0	87,500
11 -A	ELECTRICAL SERVICE,POWER AND EQUIPMENT	Matl.	7.00	EA	22,850.00	159,950	
		Labor	0		0.00	0	159,950
****	SUBTOTAL ****	Matl.				611,450	
		Labor	0			0	611,450
	DISPOSAL OF WATER						
	(1000 GAL/WELL)						
12 -A	5000 GAL TANKER RENTAL FOR DEVELOPMENT WATER (RRBB-20-7)	Matl.	180.00	DAYS	320.00	57,600	
		Labor	0		0.00	0	57,600
13 -A	OPERATING COST & DRIVER (RRBB-20-7)	Matl.	1,440.00	HRS	20.70	29,808	
		Labor	1,440	TD	22.60	32,544	62,352
14 -A	SAMPLE COLLECTION (27,000 GAL @ ONE/WELL)	Matl.	34.00	EA	25.00	850	
		Labor	68	X	25.00	1,700	2,550
15 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	68.00	HRS	8.00	544	
		Labor	0		0.00	0	544
****	SUBTOTAL ****	Matl.				88,802	
		Labor	1,508			34,244	123,046
	DISPOSAL OF SOLIDS						
	(**2 DRUMS/WELL FOR 7 ADDITIONAL WELLS**)						

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Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	(4 DRUMS/WELL, 50 DRUMS/LOAD, 1 LOAD/DAY)						
16 -A	2 LABORERS TO LOAD & HAUL DRUMMED	Matl.	38.00	HRS	0.00	0	
	SOLIDS TO LANDFILL (NO TIPPING FEE)	Labor	76	L	24.85	1,889	1,889
17 -A	55 GALLON DRUMS	Matl.	122.00	EA	55.00	6,710	
		Labor	0		0.00	0	6,710
18 -A	FORK TRUCK RENTAL (BCM-21)	Matl.	3.00	DAYS	175.00	525	
		Labor	0		0.00	0	525
19 -A	OPERATING COST & OPERATOR (BCM-21)	Matl.	24.00	HRS	9.20	221	
		Labor	24	OP	30.95	743	964
20 -A	FLATBED TRUCK RENTAL (BCM-20)	Matl.	3.00	DAYS	138.00	414	
		Labor	0		0.00	0	414
21 -A	OPERATING COST & DRIVER (BCM-20)	Matl.	24.00	HRS	11.13	267	
		Labor	24	TD	22.60	542	809
22 -A	SAMPLE COLLECTION (1/WELL)	Matl.	34.00	EA	25.00	850	
		Labor	68	X	25.00	1,700	2,550
23 -A	LEVEL MODIFIED D PPE (SAMPLING ONLY)	Matl.	68.00	HRS	8.00	544	
		Labor	0		0.00	0	[illegible]
****	SUBTOTAL ****	Matl.				9,531	
		Labor	192			4,874	14,405

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		1,369,610		53,529	1,423,139
SALES TAX		82,177			82,177
SUBTOTAL		1,451,787		53,529	1,505,316
TOTAL INDIRECT	20.00%	290,357	20.00%	10,706	301,063
TOTAL		1,742,144	(hrs. 2,222)	64,235	1,806,379
TOTAL (ESCALATED COST)		1,930,667		71,186	2,001,853

630776

WBS .... 3.01.02.01 MONITORING WELLS (I/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
ʳ `cipant .... SC01 OFFSITE SUB #1
ʟ of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... C CIVIL AND SITE
B/M Title .... MON WELLS (I/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	ANALYSIS OF SOLID WASTE SAMPLES	Matl.	34.00	EA	400.00	13,600	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	13,600
2 -A	ANALYSIS OF LIQUID WASTE SAMPLES	Matl.	34.00	EA	400.00	13,600	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	13,600
****	SUBTOTAL ****	Matl.				27,200	
		Labor	0			0	27,200
-A	SMO OVERSIGHT (16.4%)	Matl.	27.20	K$	164.00	4,461	
		Labor	0		0.00	0	4,461

BILL OF MATERIAL SUMMARY	Material		Labor	Total Cost M + L
TOTAL DIRECT	31,661		0	31,661
SALES TAX	1,900			1,900
SUBTOTAL	33,561		0	33,561
TOTAL	33,561	(hrs. 0)	0	33,561
TOTAL (ESCALATED COST)	37,193		0	37,193

630777

630778

WBS .... 3.01.02.02 MONITORING WELLS (O/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... C CIVIL AND SITE
B/M Title .... MON WELLS (O/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.3 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	5 WELLS OUTSIDE FENCE						
	** 12 INJECTION WELLS OUTSIDE FENCE **						
	(27 DAYS PER VENDOR)						
	(92 DAYS W/12 ADDED INJ. WELLS)						
	ACCESS ROAD (300'TO 500 /WELL)						
1 -A	SITE PREP: CLEAR & GRUB LIGHT TREES,	Matl.	0.68	ACRE	1,975.00	1,343	
	GRUB & RMV STUMPS (HCM-41)	Labor	41	OP	30.95	1,269	2,6
2 -A	GRADER RENTAL (HCM-17)	Matl.	4.00	DAYS	670.00	2,680	
		Labor	0		0.00	0	2,680
3 -A	OPERATING COST & OPERATOR (HCM-17)	Matl.	32.00	HRS	16.92	541	
		Labor	32	OP	30.95	990	1,531
4 -A	FILTER FABRIC UNDERLAYMENT	Matl.	11,390.00	SY	1.03	11,732	
	(ECHOS-8-107)	Labor	142	L	24.85	3,529	15,261
5 -A	GRAVEL BASE - 6" DP, SPREAD & COMPACT	Matl.	11,390.00	SY	2.62	29,842	
	(HCM-58)	Labor	57	OP	30.95	1,764	31,606
****	SUBTOTAL ****	Matl.				46,138	
		Labor	272			7,552	53,690
6 -A	ADDED FOR INJECTION WELL REQUIRMENTS	Matl.	53.69	K$	600.00	32,214	
	60% OF TOT.	Labor	0		0.00	0	32,214
****	SUBTOTAL ****	Matl.				32,214	
		Labor	0			0	32,214

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	*INSTALL MONITORING WELLS*5EA*						
	(COST FROM VENDOR QUOTE)						
	(MOB. INCL. W/ WELLS I/S FENCE)						
7 -A	MONITORING WELL W/ 2" SS TUBING, 6"	Matl.	5.00	EA	14,500.00	72,500	
	OPEN HOLE, 10' SS SCREEN, 100' DP, 4	Labor	0		0.00	0	72,500
	DRUMS/WELL SOLIDS,						
	1000 GAL/WELL PURGE WATER						
8 -A	INJECTION WELL W/6" PVC PIPE, AND 10"	Matl.	12.00	EA	52,000.00	624,000	
	DRILLED HOLE,EACH YIELDS 2 DRUMS OF	Labor	0		0.00	0	624,000
	SOLIDS & 1000 GAL. PURGE						
9 -A	EQUIPMENT, PIPE,& INSTRUMENTATION	Matl.	12.00	EA	12,500.00	150,000	
		Labor	0		0.00	0	150,000
10 -A	ELECTRICAL SERVICE	Matl.	12.00	EA	22,823.00	273,876	
		Labor	0		0.00	0	273,876
****	SUBTOTAL ****	Matl.				1,120,376	
		Labor	0			0	1,120,376
	DISPOSAL OF WATER						
	(1000 GAL/WELL)						
11 -A	5000 GAL TANKER RENTAL FOR	Matl.	91.00	DAYS	320.00	29,120	
	DEVELOPMENT WATER (RRBB-20-7)	Labor	0		0.00	0	29,120
12 -A	OPERATING COST & DRIVER (RRBB-20-7)	Matl.	728.00	HRS	20.70	15,070	
		Labor	728	TD	22.60	16,453	31,523
13 -A	SAMPLE COLLECTION (5,000 GAL @	Matl.	5.00	EA	25.00	125	
	ONE/WELL)	Labor	10	X	25.00	250	375
14 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	10.00	HRS	8.00	80	
		Labor	0		0.00	0	80
****	SUBTOTAL ****	Matl.				44,395	
		Labor	738			16,703	61,098
	DISPOSAL OF SOLIDS						

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Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	(4 DRUMS/WELL, 50 DRUMS/LOAD, 1 LOAD/DAY)						
15 -A	2 LABORERS TO LOAD & HAUL DRUMMED	Matl.	18.00	HRS	0.00	0	
	SOLIDS TO LANDFILL (NO TIPPING FEE)	Labor	36	L	24.85	895	895
16 -A	55 GALLON DRUMS	Matl.	44.00	EA	55.00	2,420	
		Labor	0		0.00	0	2,420
17 -A	FORK TRUCK RENTAL (BCM-21)	Matl.	3.00	DAYS	175.00	525	
		Labor	0		0.00	0	525
18 -A	OPERATING COST & OPERATOR (BCM-21)	Matl.	24.00	HRS	9.20	221	
		Labor	24	OP	30.95	743	964
19 -A	FLATBED TRUCK RENTAL (BCM-20)	Matl.	3.00	DAYS	138.00	414	
		Labor	0		0.00	0	414
20 -A	OPERATING COST & DRIVER (BCM-20)	Matl.	24.00	HRS	11.13	267	
		Labor	24	TD	22.60	542	809
21 -A	SAMPLE COLLECTION (1/WELL)	Matl.	17.00	EA	25.00	425	
		Labor	34	X	25.00	850	1,275
22 -A	LEVEL MODIFIED D PPE (SAMPLING ONLY)	Matl.	34.00	HRS	8.00	272	
		Labor	0		0.00	0	
****	SUBTOTAL ****	Matl.				4,544	
		Labor	118			3,030	7,574

BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		1,247,667		27,285	1,274,952
SALES TAX		74,860			74,860
SUBTOTAL		1,322,527		27,285	1,349,812
TOTAL INDIRECT	20.00%	264,505	20.00%	5,457	269,962
TOTAL		1,587,032	(hrs. 1,128)	32,742	1,619,774
TOTAL (ESCALATED COST)		1,758,770		36,285	1,795,055

WBS .... 3.01.02.02 MONITORING WELLS (O/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
' icipant .... SC01 OFFSITE SUB #1
. of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... C CIVIL AND SITE
B/M Title .... MON WELLS (O/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.4 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	ANALYSIS OF SOLID WASTE SAMPLES	Matl.	17.00	EA	400.00	6,800	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	6,800
2 -A	ANALYSIS OF LIQUID WASTE SAMPLES	Matl.	5.00	EA	400.00	2,000	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	2,000
****	SUBTOTAL ****	Matl.				8,800	
		Labor	0			0	8,800
-A	SMO OVERSIGHT (16.4%)	Matl.	8.80	K$	164.00	1,443	
		Labor	0		0.00	0	1,443

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	10,243	0	10,243
SALES TAX	615		615
SUBTOTAL	10,858	0	10,858
TOTAL	10,858	(hrs. 0) 0	10,858
TOTAL (ESCALATED COST)	12,033	0	12,033

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WBS .... 3.01.03 P&A WELLS
Cost Code .... 6100 REMEDIAL ACTION
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1Alt 3
Discipline .... C CIVIL AND SITE
B/M Title .... P&A WELLS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... P&A EXIST WELLS
Quantity Take-Off By ...
Trace Number C.3.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	P&A WELLS (BASED ON VENDOR QUOTE)						
	(OVERHEAD & PROFIT INCLUDED BELOW AS INDIRECTS)						
	(USE 1 WELL/DAY = 15 DAYS)						
1 -A	P&A CEMENT-FILL AND SQUEEZE	Matl.	15.00	WELL	40,833.00	612,495	
		Labor	0		0.00	0	612,495
	DISPOSAL OF WATER						
	(USE 1000 GAL/WELL)						
2 -A	5000 GAL TANKER RENTAL FOR	Matl.	15.00	DAYS	320.00	4,800	
	DEVELOPMENT WATER (RRBB-20-7)	Labor	0		0.00	0	4,800
3 -A	OPERATING COST & DRIVER (RRBB-20-7)	Matl.	120.00	HRS	20.70	2,484	
		Labor	120	TD	22.60	2,712	5,196
4 -A	SAMPLE COLLECTION (15,000 GAL @	Matl.	15.00	EA	25.00	375	
	ONE/WELL)	Labor	30	X	25.00	750	1,125
5 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	30.00	HRS	8.00	240	
		Labor	0		0.00	0	240
****	SUBTOTAL ****	Matl.				620,394	
		Labor	150			3,462	623,856
	DISPOSAL OF SOLIDS						
	(USE 5 DRUMS/WELL, 50 DRUMS/LOAD, 1 LOAD/DAY = 2 DAYS)						
6 -A	2 LABORERS TO LOAD & HAUL DRUMMED	Matl.	16.00	HRS	0.00	0	
	SOLIDS TO LANDFILL (NO TIPPING FEE)	Labor	32	L	24.85	795	795

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
7 -A	55 GALLON DRUMS	Matl.	75.00	EA	55.00	4,125	
		Labor	0		0.00	0	4,125
8 -A	FORK TRUCK RENTAL (BCM-21)	Matl.	2.00	DAYS	175.00	350	
		Labor	0		0.00	0	350
9 -A	OPERATING COST & OPERATOR (BCM-21)	Matl.	16.00	HRS	9.20	147	
		Labor	16	OP	30.95	495	642
10 -A	FLATBED TRUCK RENTAL (BCM-20)	Matl.	2.00	DAYS	138.00	276	
		Labor	0		0.00	0	276
11 -A	OPERATING COST & DRIVER (BCM-20)	Matl.	16.00	HRS	11.13	178	
		Labor	16	TD	22.60	362	540
12 -A	SAMPLE COLLECTION (1/WELL)	Matl.	15.00	EA	25.00	375	
		Labor	30	X	25.00	750	1,125
13 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	30.00	HRS	8.00	240	
		Labor	0		0.00	0	240
****	SUBTOTAL ****	Matl.				5,691	
		Labor	94			2,402	8,093

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		626,085		5,864	631,949
SALES TAX		37,565			37,565
SUBTOTAL		663,650		5,864	669,514
TOTAL INDIRECT	20.00%	132,730	20.00%	1,173	133,903
TOTAL		796,380	(hrs. 244)	7,037	803,417
TOTAL (ESCALATED COST)		882,559		7,798	890,357

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WBS .... 3.01.03 P&A WELLS
Cost Code .... 6100 REMEDIAL ACTION
Participant .... SC01 OFFSITE SUB #1
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... C CIVIL AND SITE
B/M Title .... P&A WELLS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... P&A EXIST WELLS
Quantity Take-Off By ...
Trace Number C.3.2 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	ANALYSIS OF SOLID WASTE SAMPLES	Matl.	15.00	EA	400.00	6,000	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	6,000
2 -A	ANALYSIS OF LIQUID WASTE SAMPLES	Matl.	15.00	EA	400.00	6,000	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	6,000
****	SUBTOTAL ****	Matl.				12,000	
		Labor	0			0	12,000
3 -A	SMO OVERSIGHT (16.4%)	Matl.	12.00	K$	164.00	1,968	
		Labor	0		0.00	0	1,968

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	13,968	0	13,968
SALES TAX	838		838
SUBTOTAL	14,806	0	14,806
TOTAL	14,806	(hrs. 0) 0	14,806
TOTAL (ESCALATED COST)	16,408	0	16,408

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WBS .... 3.01.04 SHUT DN NE/NW SYSTEMS
Cost Code .... 6100 REMEDIAL ACTION
P ticipant .... FP51 FIXED PRICE SUBCONT
. of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... C CIVIL AND SITE
B/M Title .... SHUT DN NE/NW SYSTEMS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... SHUT DN NE/NW
Quantity Take-Off By ...
Trace Number C.4.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	(BASED ON CDM COST - DOES NOT INCLUDE WELL ABANDONMENT)						
1 -A	SHUT DOWN NE/NW TREATMENT SYSTEMS	Matl.	1.00	LOT	65,000.00	65,000	
	(COLD STAND-BY)	Labor	0		0.00	0	65,000
****	SUBTOTAL ****	Matl.				65,000	
		Labor	0			0	65,000
	EXCAVATION OF EXISTING CONCRETE PAD AND SOIL AT SWMU 99						
2 -A	BREAK, LOAD AND HAUL PAD 120' X 240'	Matl.	1,067.00	CY	3.50	3,735	
		Labor	160	OP	30.95	4,952	8,687
-A	SUPPORT CRAFT	Matl.	1.00	LS	1,000.00	1,000	
		Labor	160	L	24.85	3,976	4,976
4 -A	DUMP TRUCK AND DRIVER HAUL TO	Matl.	3.00	WKS	500.00	1,500	
	LANDFILL AT PGDP	Labor	120	TD	22.60	2,712	4,212
5 -A	EXCAVATION OF EARTH UNDER PAD AND 5'	Matl.	6,019.00	CY	2.80	16,853	
	AROUND PEREMITER TO A DEPTH OF 5'	Labor	482	OP	30.95	14,918	31,771
****	SUBTOTAL ****	Matl.				23,088	
		Labor	922			26,558	49,646
6 -A	MOD.C PROTECTIVE CLOTHING PPE @ 50%	Matl.	461.00	HRS	8.00	3,688	
		Labor	0		0.00	0	3,688

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BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		91,776		26,558	118,334
SALES TAX		5,507			5,507
SUBTOTAL		97,283		26,558	123,841
TOTAL INDIRECT	20.00%	19,457	20.00%	5,312	24,769
TOTAL		116,740	(hrs. 922)	31,870	148,610
TOTAL (ESCALATED COST)		159,070		43,426	202,496

630786

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WBS .... 3.01.05 SOURCE REMEDIAL ACTIONS
Cost Code .... 9999 OTHER PROGRAM ACTIVITIES
P :ipant .... FP51 FIXED PRICE SUBCONT
L of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... C CIVIL AND SITE
B/M Title .... SHUT DN NE/NW SYSTEMS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... SHUT DN NE/NW
Quantity Take-Off By ...
Trace Number C.4.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	2 PHASE EXTRACTION SOURCE AREAS (BASE ON SAIC ESTIMATE)						
1 -A	2 PHASE EXTRACTION AT C-400 NE	Matl.	1.00	0	270,600.00	270,600	
		Labor	0		0.00	0	270,600
2 -A	2 PHASE EXTRACTION AT C-400 SE	Matl.	1.00	0	1,100,200.00	1,100,200	
		Labor	0		0.00	0	1,100,200
3 -A	2 PHASE EXTRACTION AT C-720 SE	Matl.	1.00		367,000.00	367,000	
		Labor	0		0.00	0	367,000
4 -A	2 PHASE EXTRACTION AT SWMU 001	Matl.	1.00		367,000.00	367,000	
		Labor	0		0.00	0	367,000
-A	DUS AT C-400	Matl.	1.00		4,850,000.00	4,850,000	
		Labor	0		0.00	0	4,850,000

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		6,954,800		0	6,954,800
SALES TAX		417,288			417,288
SUBTOTAL		7,372,088		0	7,372,088
TOTAL INDIRECT	20.00%	1,474,418	20.00%	0	1,474,418
TOTAL		8,846,506	(hrs. 0)	0	8,846,506
TOTAL (ESCALATED COST)		9,841,490		0	9,841,490

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630788

WBS .... 3.02.01 DESIGN
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... AE01 A-E, ENVIRONMENTAL
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... X ENGINEERING
B/M Title .... AE RD REPORT
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... 1ALT 3 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number X.5.3 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	AE TITLE II DESIGN						
1 -A	RD REPORT (TITLE II) (1 FTE X 3 MOS)	Matl.	520.00	HOUR	0.00	0	
		Labor	520	T2	65.00	33,800	33,800

BILL OF MATERIAL SUMMARY	Material	Labor		Total Cost M + L
TOTAL DIRECT	0		33,800	33,800
TOTAL	0	(hrs. 520)	33,800	33,[illegible]
TOTAL (ESCALATED COST)	0		36,905	36,905

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WBS .... 3.02.01 DESIGN
Cost Code .... 9100 PROJECT MANAGEMENT
P 'cipant .... AE01 A-E, ENVIRONMENTAL
. of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... X ENGINEERING
B/M Title .... AE REVIEW RA WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... 1ALT 3 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number X.5.5 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -C	AE REVIEW RA WORK PLAN	Matl.	20.00	HOUR	0.00	0	
		Labor	20	T2	65.00	1,300	1,300

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	1,300	1,300
TOTAL	0	(hrs. 20) 1,300	1,300
¶L (ESCALATED COST)	0	1,419	1,419

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WBS .... 3.02.01 DESIGN
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... AE01 A-E, ENVIRONMENTAL
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... X ENGINEERING
B/M Title .... AE RD WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... 1ALT 3 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... OTHER (NO OH)
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number X.5.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -C	AE WRITE RD WORK PLAN	Matl.	40.00	HOUR	0.00	0	
		Labor	40	T2	65.00	2,600	2,600

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	2,600	2,600
TOTAL	0	(hrs. 40) 2,600	2,600
TOTAL (ESCALATED COST)	0	2,839	2,[illegible]

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WBS .... 3.02.01 DESIGN
Cost Code .... 9100 PROJECT MANAGEMENT
P 'cipant .... R032 PAD ENG & TECH SVCS
ι of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... X ENGINEERING
B/M Title .... CM RA WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... 1ALT 3 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number X.5.6 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM WRITE RA WORK PLAN	Matl.	40.00	HOUR	0.00	0	
		Labor	40	MX	64.00	2,560	2,560

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	2,560	2,560
TOTAL	0	(hrs. 40) 2,560	2,560
'L (ESCALATED COST)	0	2,795	2,795

630791

WBS .... 3.02.01 DESIGN
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... R032 PAD ENG & TECH SVCS
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... X ENGINEERING
B/M Title .... CM REVIEW RD WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... 1ALT 3 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number X.5.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM REVIEW RD WORK PLAN	Matl.	20.00	HOUR	0.00	0	
		Labor	20	MX	64.00	1,280	1,280

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	1,280	1,280
TOTAL	0	(hrs. 20) 1,280	1,280
TOTAL (ESCALATED COST)	0	1,398	1,[illegible]

630792

WBS .... 3.02.01 DESIGN
Cost Code .... 9100 PROJECT MANAGEMENT
P ˘icipant .... R032 PAD ENG & TECH SVCS
of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... X ENGINEERING
B/M Title .... CM REVIEW RD REPORT
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... 1ALT 3 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number X.5.4 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM REVIEW RD REPORT	Matl.	80.00	HOUR	0.00	0	
		Labor	80	MX	64.00	5,120	5,120

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	5,120	5,120
TOTAL	0	(hrs. 80) 5,120	5,120
˘AL (ESCALATED COST)	0	5,590	5,590

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WBS .... 3.02.02 PROJECT INTEGRATION
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... AE01 A-E, ENVIRONMENTAL
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... U PROJECT ENGINEERING
B/M Title .... AE T-III ENGINEERING
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... 1ALT 3 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number U.6.1 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	AE TITLE III ENGINEERING (1/2 FTE X 9 MOS)	Matl.	780.00	HOUR	0.00	0	
		Labor	780	T3	55.00	42,900	42,900

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	42,900	42,900
TOTAL	0	(hrs. 780) 42,900	42,900
TOTAL (ESCALATED COST)	0	47,542	47,5

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WBS .... 3.02.02 PROJECT INTEGRATION
Cost Code .... 9100 PROJECT MANAGEMENT
P 'cipant .... R032 PAD ENG & TECH SVCS
L of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... U PROJECT ENGINEERING
B/M Title .... CM FINAL REPORTS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... 1ALT 3 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number U.6.3 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM FINAL CONSTRUCTION REPORTS	Matl.	40.00	HOUR	0.00	0	
		Labor	40	MR	54.00	2,160	2,160

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	2,160	2,160
TOTAL	0	(hrs. 40) 2,160	2,160
'L (ESCALATED COST)	0	2,394	2,394

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WBS .... 3.02.02 PROJECT INTEGRATION
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... R053 PAD FIELD SERVICES
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... U PROJECT ENGINEERING
B/M Title .... CM CONST OVERSIGHT
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... 1ALT 3 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number U.6.2 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM CONSTRUCTION OVERSIGHT (1 FTE X 9 MOS)	Matl.	1,560.00	HOUR	0.00	0	
		Labor	1,560	MR	54.00	84,240	84,240

BILL OF MATERIAL SUMMARY	Material	Labor		Total Cost M + L
TOTAL DIRECT	0		84,240	84,240
TOTAL	0	(hrs. 1,560)	84,240	84,240
TOTAL (ESCALATED COST)	0		93,356	93,3ʳ

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WBS .... 3.03.01.01 MAINTENANCE (30 YRS)
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
Participant .... FP51 FIXED PRICE SUBCONT
L of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... O OTHER
B/M Title .... MAINTENANCE - 30 YEARS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... 1ALT 3 O&M
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.7.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	MAINTENANCE OF MONITORING WELLS INCLUDED AT 2% OF CAPITAL COST PER YEAR, EQUALS COMPLETE REPLACEMENT REPLACEMENT EVERY 50 YEARS						
	(90 EXISTING AND 32 NEW WELLS = 122 X $14,500/EA = $1,769,000)						
1 -A	MAINTENANCE OF MONITORING WELLS (2% X 30 YRS)	Matl.	30.00	YRS	35,380.00	1,061,400	
		Labor	0		0.00	0	1,061,400

BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		1,061,400		0	1,061,400
SALES TAX		63,684			63,684
SUBTOTAL		1,125,084		0	1,125,084
TOTAL INDIRECT	20.00%	225,017	20.00%	0	225,017
TOTAL		1,350,101	(hrs. 0)	0	1,350,101
TOTAL (ESCALATED COST)		2,340,204		0	2,340,204

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WBS .... 3.03.01.02 SAMPLE COLLECTION (30 YRS)
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... O OTHER
B/M Title .... MONITORING - 30 YEARS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... 1ALT 3 O&M
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.7.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	MONITORING - 30 YEARS						
	-SAMPLE COLLECTION-						
	(COST BY BECHTEL JACOBS)						
1 -A	QUARTERLY SAMPLING OF 122 WELLS =	Matl.	30.00	YRS	516,792.00	15,503,760	
	488/YR X $1,059/EA	Labor	0		0.00	0	15,503,760
****	SUBTOTAL ****	Matl.				15,503,760	
		Labor	0			0	15,503,760

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		15,503,760		0	15,503,760
SALES TAX		930,226			930,226
SUBTOTAL		16,433,986		0	16,433,986
TOTAL INDIRECT	20.00%	3,286,797	20.00%	0	3,286,797
TOTAL		19,720,783	(hrs. 0)	0	19,720,783
TOTAL (ESCALATED COST)		34,183,110		0	34,183,110

WBS .... 3.03.01.03 SAMPLE ANALYSIS (30 YRS)
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
icipant .... SC01 OFFSITE SUB #1
(of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 3
Discipline .... 0 OTHER
B/M Title .... MONIT- 30 YEARS (ANALYSIS)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL3®1ALT3.Est 5-31-00 8:51a

Building/Area .... 1ALT 3 O&M
Plant Site .... R
Contracting Type .... S Subcontractor
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.7.3 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	LAB ANALYSIS - 30 YEARS						
1 -A	QUARTERLY ANALYSIS OF 122 WELLS = 488/YR X $400/EA	Matl.	30.00	YRS	195,200.00	5,856,000	
		Labor	0		0.00	0	5,856,000
****	SUBTOTAL ****	Matl.				5,856,000	
		Labor	0			0	5,856,000
2 -A	SMO OVERSIGHT (16.4%)	Matl.	5,856.00	K$	164.00	960,384	
		Labor	0		0.00	0	960,384

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	6,816,384	0	6,816,384
SALES TAX	408,983		408,983
SUBTOTAL	7,225,367	0	7,225,367
TOTAL	7,225,367	(hrs. 0) 0	7,225,367
TOTAL (ESCALATED COST)	12,524,123	0	12,524,123

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Disciplines
- C: CIVIL AND SITE
- O: OTHER
- U: PROJECT ENGINEERING
- X: ENGINEERING

Total Labor Hours: 9,655

COST SUMMARY

COST SUMMARY	Material	Labor	Total Cost M + L
Line Item Cost	33,755,774	363,580	34,119,354
Total Sales Tax	2,025,348		2,025,348
SUBTOTAL	35,781,122	363,580	36,144,702
Total Indirect	5,699,306	37,525	5,736,831
SUBTOTAL	41,480,428	401,105	41,881,533
Overhead	17,405,188	168,304	17,573,492
SUBTOTAL	58,885,616	569,409	59,455,025
Contingency	14,721,404	142,352	14,863,756
SUBTOTAL	73,607,020	711,761	74,318,7'
Market Adjustment			
TOTAL			74,318,781

TOTAL (ESCALATED DOLLARS) including overhead & contingency	113,081,239	801,815	113,883,054

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Basis of Estimate
Feasibility Study for the GWOU
Alternative 4

Description: This alternative will continue the groundwater monitoring program currently in place plus an expansion by 32 monitoring wells. Also, 15 existing monitoring wells will be plugged and abandoned. In addition to the above, a permeable treatment zone (PTZ) will be constructed at the security fence area to remove contaminants from the Regional Gravel Aquifer (RGA) in the Southwest, Northwest, and Northeast Plumes. Also, PTZs will be constructed in the area where the Regional Gravel Aquifer recharges the Little Bayou Creek. The cores (>1,000 ppb) of the Northwest, Southwest, and Northeast off-site plumes also will be captured by a PTZ. The period of the action is 30 years. Although not costed in this estimate, the action will be required to be repeated for a period of approximately 7,000 years until the remediation is complete.

General: The estimate was generated with Automated Estimating System (AES), using the standard value file RRB2668A.val.
Management and Integration (M&I) contract management is included at 20% of all costs.
Overhead is included at 41.96%.
Contingency is included at 25%.

Schedule: Installation is assumed to last 9 months.
Operation and Maintenance (O&M) is assumed to last 30 years.

Work Breakdown Structure (WBS)

WBS 4.01.01 General Conditions:

- Includes mobilization and set-up and utility hook-ups for a construction trailer and a shower/change trailer. Nine months rental cost is included for trailers and a port-o-let.
- A safety and health officer is included for the 9-month duration.
- Training and security requirements are included for 8 workers at 28 hours each.
- Includes general safety plan, quality assurance (QA) plan, waste management plan, work plan, hoisting and rigging plan, and site-specific safety and health plan.

WBS 4.01.02 Monitoring Wells (includes PTZ wells):

- Wells are separated as 27 inside and 5 outside the fence.
- Three hundred feet per well of access roads includes clearing and grubbing of light trees, grading, a filter fabric underlayment, and a 6-inch gravel base.
- Monitoring wells are 100 ft deep with stainless steel tubing and screen and are included at $14,500 each based on a vendor quote. Mobilization is included at $150,000.
- Disposal of water includes a 5,000-gal tanker truck with driver on-site full time (no disposal fee). Water is included at 1,000 gal per well. (27 wells I/S fence = 27,000 gal = 6 tankers) (5 wells O/S fence = 5,000 gal = 1 tanker)

- Disposal of solids includes 2 laborers, a fork truck with operator, and a flatbed truck with driver to load and haul the drums to the landfill (no tipping fee). Solids are included at 4 drums per well. Estimate assumes 50 drums per load and 1 load per day. (27 wells I/S fence = 3 loads, 5 wells O/S = 1 load)

- Sampling of water assumes 1 per well and includes $25 and 2 hours each with modified Level D personal protective equipment (PPE).

- Sampling of solids assumes 1 per well and includes $25 and 2 hours each with modified Level D PPE.

- Analysis of the samples includes volatile organic compounds (VOCs) (8260), gross alpha, gross beta, and ^{99}Tc at a total cost of $400 per sample. Costs are included for Site Management Office (SMO) oversight at 16.4%.

- Two hundred fifty wells for the PTZ. Wells are 6-inch polyvinyl chloride (PVC) casing with a total depth of 120 ft.

- Two thousand eight hundred thirty-three yds^3 of granular iron and 100,000 pounds of guar gum for PTZ.

- Four hundred 3.5-inch cased holes for resistivity probes.

- Four hundred 5-sensor nodes with 1-inch-diameter connections and wire.

WBS 4.01.03 Plug and Abandon Wells:

- Plugging and abandoning of 15 existing wells is included at $40,833 each. Cost is based on a feasibility study for White Oak Creek.

- Disposal of water includes a 5,000 gal tanker truck with driver on-site full time (no disposal fee). Water is included at 1,000 gal per well. (15 wells = 15,000 gal = 3 tankers)

- Disposal of solids includes 2 laborers, a fork truck with operator, and a flatbed truck with driver to load and haul the drums to the landfill (no tipping fee). Solids are included at 5 drums per well. Estimate assumes 50 drums per load and 1 load per day (15 wells = 2 loads). Drums are included assuming 5 per well at $55 each.

- Sampling of water assumes 1 per well and includes $25 and 2 hours each with modified Level D PPE.

- Sampling of solids assumes 1 per well and includes $25 and 2 hours each with modified Level D PPE.

- Analysis of the samples includes VOCs (8260), gross alpha, gross beta, and ^{99}Tc at a total cost of $400 per sample. Costs are included for SMO oversight at 16.4%.

WBS 4.01.04 Shut Down Northeast and Northwest Systems [includes excavation of Solid Waste Management Unit (SWMU) 99]:

- The cost to shut down the Northeast and Northwest treatment systems (cold stand-by) is included at $65,000 and is based on costs from CDM Federal as provided by Bechtel Jacobs Company LLC (BJC).

- Breaking, loading, and hauling a concrete pad of 120 ft by 240 ft at SWMU 99.

- Excavation of 6,019 yds^3 of earth.

WBS 4.02 Indirect Costs:

- Indirect costs include design, project integration, and M&I oversight. These costs are dependent on level of effort and project schedule.

WBS 4.03.01.01 Maintenance (30 Years):

- Maintenance is included for the 32 new and 90 existing monitoring wells. Costs are included at 2% of the well capital cost annually for 30 years (122 × \$14,500 × .02 = \$35,380/year). Two percent annually is equivalent to total replacement every 50 years.

WBS 4.03.01.02 Sample Collection (30 Years):

- Sample collection is included quarterly for the 32 new and 90 existing monitoring wells. A cost of \$1,059 per sample is included as provided by BJC. Quarterly sampling of 122 wells = 488 samples per year × \$1,059 = \$516,792 per year for 30 years.

WBS 4.03.01.03 Sample Analysis (30 Years):

- Sample analysis is included quarterly for the 32 new and 90 existing monitoring wells. A cost of \$400 per sample is included for VOCs (8260), gross alpha, gross beta, and ^{99}Tc. Quarterly analysis of 122 wells = 488 samples per year × \$400 = \$195,200 per year for 30 years. Costs are included for SMO oversight at 16.4%.

WBS 4.03.01.04 Management and Integration (M&I) on Operation and Maintenance (O&M) (30 Years):

- M&I contract management is included at 20% of all O&M costs.

Line items within the detailed estimate contain references to cost guides. The following is a glossary for those references.

FCM-845	Facility Construction Means		Page 845
HCM-41	Heavy Construction Means		Page 41
BCM-21	Building Construction Means		Page 21
ECHOS-8-107	ECHOS Cost Guide	Section 8	Page 107
RRBB-20-7	Rental Rate Blue Book	Section 20	Page 7
E.J.	Estimator's Judgment		

SUMMARY REPORT
Project Number: 35T08116
PGDP GWOU 1ALT 4

Project ESO Number......NA
Revision Number.........1
Last Update.............05/31/2000

Sort Order
1. WBS - Level 3
2. WBS - Level 4
3. Building/Area

Approved by:

Project Estimator   Date

Estimating Manager   Date

Base Fiscal Year/Quarter: 99/4
STANDARD VALUE: C:®ESTIMA™1®RRB2668A.val EXPIRES: 09/15/1999
ESTIMATE FILE: C:®ESTIMA™1®ATL4®ALT4.Est 05/31/2000
SCHEDULE FILE: 1ALT4
REPORT FILE: C:®ESTIMA™1®ATL4®ALT4SUM.Out 05/31/2000 09:33:34   AES Version 6.1

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PGDP GWOU 1ALT 4

SUMMARY REPORT
$1 = $1

05/31/2000

Arranged By: WBS / WBS / Building

	--------- Unescalated ----------			---------- Escalated -----------		
	Material $	Labor $	Total $	Material $	Labor $	Total $
4.01.01 GENERAL CONDITIONS						
4.01.01.01 VARIABLE COSTS						
GWOU	10074	82320	92394	11164	91228	102392
TOTAL VARIABLE COSTS	10074	82320	92394	11164	91228	102392
4.01.01.02 FIXED COSTS						
GWOU	26076	6941	33017	28898	7692	36590
TOTAL FIXED COSTS	26076	6941	33017	28898	7692	36590
TOTAL GENERAL CONDITIONS	36150	89261	125411	40062	98920	138982
4.01.02 MONITORING WELLS						
4.01.02.01 MONITORING WELLS (I/S FENCE)						
GWOU	22374743	188124	22562867	24795991	208482	25004473
L MONITORING WELLS (I/S FENCE)	22374743	188124	22562867	24795991	208482	25004473
4.01.02.02 MONITORING WELLS (O/S FENCE)						
GWOU	335888	14213	350101	372236	15751	387987
TOTAL MONITORING WELLS (O/S FENCE)	335888	14213	350101	372236	15751	387987
TOTAL MONITORING WELLS	22710631	202337	22912968	25168227	224233	25392460
4.01.03 P&A WELLS						
4.01.03 P&A WELLS						
GWOU	811186	7037	818223	898967	7798	906765
TOTAL P&A WELLS	811186	7037	818223	898967	7798	906765
TOTAL P&A WELLS	811186	7037	818223	898967	7798	906765

PGDP GWOU 1ALT 4

SUMMARY REPORT
$1 = $1

05/31/2000

Arranged By: WBS / WBS / Building

	Unescalated Material $	Unescalated Labor $	Unescalated Total $	Escalated Material $	Escalated Labor $	Escalated Total $
4.01.04 SHUT DN NE/NW SYSTEMS						
4.01.04 SHUT DN NE/NW SYSTEMS						
GWOU	116740	38378	155118	129372	42531	171903
TOTAL SHUT DN NE/NW SYSTEMS	116740	38378	155118	129372	42531	171903
TOTAL SHUT DN NE/NW SYSTEMS	116740	38378	155118	129372	42531	171903
4.02.01 DESIGN						
4.02.01 DESIGN						
1ALT 4 IND	0	46660	46660	0	50946	50946
TOTAL DESIGN	0	46660	46660	0	50946	50946
TOTAL DESIGN	0	46660	46660	0	50946	50946
4.02.02 PROJECT INTEGRATION						
4.02.02 PROJECT INTEGRATION						
1ALT 4 IND	0	129300	129300	0	143292	14[illegible]
TOTAL PROJECT INTEGRATION	0	129300	129300	0	143292	143292
TOTAL PROJECT INTEGRATION	0	129300	129300	0	143292	143292
4.03.01 30 YRS O&M						
4.03.01.01 MAINTENANCE (30 YRS)						
1ALT 4 O&M	1350101	0	1350101	2340204	0	2340204
TOTAL MAINTENANCE (30 YRS)	1350101	0	1350101	2340204	0	2340204
4.03.01.02 SAMPLE COLLECTION (30 YRS)						
1ALT 4 O&M	19720783	0	19720783	34183110	0	34183110
TOTAL SAMPLE COLLECTION (30 YRS)	19720783	0	19720783	34183110	0	34183110

PGDP GWOU 1ALT 4

SUMMARY REPORT
$1 = $1

05/31/2000

Arranged By: WBS / WBS / Building

	Unescalated Material $	Unescalated Labor $	Unescalated Total $	Escalated Material $	Escalated Labor $	Escalated Total $
4.03.01 30 YRS O&M						
4.03.01.03 SAMPLE ANALYSIS (30 YRS)						
1ALT 4 O&M	7225367	0	7225367	12524123	0	12524123
TOTAL SAMPLE ANALYSIS (30 YRS)	7225367	0	7225367	12524123	0	12524123
TOTAL 30 YRS O&M	28296251	0	28296251	49047437	0	49047437
SUB - TOTAL	51970958	512973	52483931	75284065	567720	75851785
OVERHEAD	21807014	215243	22022257	31589194	238215	31827409
SUB - TOTAL	73777972	728216	74506188	106873259	805935	107679194
CONTINGENCY	18444493	182054	18626547	26718315	201484	26919799
GRAND TOTAL	92222465	910270	93132735	133591574	1007419	134598993

DETAIL REPORT
Project Number: 35T08116
PGDP GWOU 1ALT 4

Project ESO Number......NA
Revision Number.........1
Last Update.............05/31/2000

Sort Order
1. WBS - Level 9
2. Participant
3. Discipline

Approved by:

Project Estimator — Date

Estimating Manager — Date

Base Fiscal Year/Quarter: 99/4
STANDARD VALUE: C:®ESTIMA™1®RRB2668A.val EXPIRES: 09/15/1999
ESTIMATE FILE: C:®ESTIMA™1®ATL4®ALT4.Est 05/31/2000
SCHEDULE FILE: 1ALT4
REPORT FILE: C:®ESTIMA™1®ATL4®ALT4DET.Out 05/31/2000 09:33:12

AES Version 6.1

Creation Date 09/07/1999
Revision Number ... 1

Estimating Job Number .. 0116-20

ject Estimator.. J LOLLAR/nle
WBS .... 4.01.01.01 VARIABLE COSTS
Cost Code .... 6100 REMEDIAL ACTION
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... C CIVIL AND SITE
B/M Title .... MOB/DEMOB/GEN COND - VAR
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Project Engineer .... S MAUDLIN
Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... GEN CONDITIONS
Quantity Take-Off By ...
Trace Number C.1.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	GENERAL CONDITIONS - VARIABLE COST						
1 -A	CONSTRUCTION TRAILER RENTAL	Matl.	9.00	MON	300.00	2,700	
		Labor	0		0.00	0	2,700
2 -A	SHOWER/CHANGE TRAILER RENTAL	Matl.	9.00	MON	500.00	4,500	
		Labor	0		0.00	0	4,500
3 -A	PORT-O-LET (1 @ $80 FOR 2 MONTHS)	Matl.	9.00	MON	80.00	720	
		Labor	0		0.00	0	720
4 -A	SAFETY & HEALTH OFFICER	Matl.	9.00	MON	0.00	0	
		Labor	1,575	X	40.00	63,000	63,000
5 -A	TRAINING:SECURITY REQMNT, GET ETC (28 HOURS/PERSON)	Matl.	8.00	EA	0.00	0	
		Labor	224	ZZ	25.00	5,600	5,600
****	SUBTOTAL ****	Matl.				7,920	
		Labor	1,799			68,600	76,520

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BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		7,920		68,600	76,520
SALES TAX		475			475
SUBTOTAL		8,395		68,600	76,995
TOTAL INDIRECT	20.00%	1,679	20.00%	13,720	15,399
TOTAL		10,074	(hrs. 1,799)	82,320	92,394
TOTAL (ESCALATED COST)		11,164		91,228	102,392

630809

WBS .... 4.01.01.02 FIXED COSTS
Cost Code .... 6100 REMEDIAL ACTION
icipant .... FP51 FIXED PRICE SUBCONT
. of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... C CIVIL AND SITE
B/M Title .... MOB/DEMOB/GEN COND - FIXED
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... GEN CONDITIONS
Quantity Take-Off By ...
Trace Number C.1.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	GENERAL CONDITIONS - FIXED COST						
1 -A	CONSTRUCTION TRAILER MOB/DEMOB	Matl.	1.00	LS	0.00	0	
		Labor	40	TD	22.60	904	904
2 -A	MOB/DEMOB SUPPORT LABOR	Matl.	1.00	LS	0.00	0	
		Labor	40	L	24.85	994	994
3 -A	SET-UP LABOR	Matl.	1.00	LS	250.00	250	
		Labor	40	L	24.85	994	1,244
4 -A	UTILITIES HOOK UP (ELEC, WATER, SEWER)	Matl.	1.00	LS	3,000.00	3,000	
		Labor	0		0.00	0	3,000
-A	SHOWER/CHANGE TRAILER MOB/DEMOB	Matl.	1.00	LS	0.00	0	
		Labor	40	TD	22.60	904	904
6 -A	MOB/DEMOB SUPPORT LABOR	Matl.	1.00	LS	0.00	0	
		Labor	40	L	24.85	994	994
7 -A	SET-UP LABOR	Matl.	1.00	LS	250.00	250	
		Labor	40	L	24.85	994	1,244
8 -A	UTILITIES HOOK-UP (ELEC, WATER, SEWER)	Matl.	1.00	LS	3,000.00	3,000	
		Labor	0		0.00	0	3,000
****	SUBTOTAL ****	Matl.				6,500	
		Labor	240			5,784	12,284
9 -A	GENERAL SAFETY PLAN	Matl.	1.00	LS	2,000.00	2,000	
		Labor	0		0.00	0	2,000
10 -A	QUALITY ASSURANCE PLAN	Matl.	1.00	LS	1,000.00	1,000	
		Labor	0		0.00	0	1,000
11 -A	WASTE MANAGEMENT PLAN	Matl.	1.00	LS	2,000.00	2,000	
		Labor	0		0.00	0	2,000
12 -A	WORK PLAN	Matl.	1.00	LS	3,000.00	3,000	
		Labor	0		0.00	0	3,000

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
13 -A	HOISTING & RIGGING PLAN	Matl.	1.00	LS	1,000.00	1,000	
		Labor	0		0.00	0	1,000
14 -A	SITE SPECIFIC SAFETY & HEALTH PLAN	Matl.	1.00	LS	5,000.00	5,000	
		Labor	0		0.00	0	5,000
****	SUBTOTAL ****	Matl.				14,000	
		Labor	0			0	14,000

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		20,500		5,784	26,284
SALES TAX		1,230			1,230
SUBTOTAL		21,730		5,784	27,514
TOTAL INDIRECT	20.00%	4,346	20.00%	1,157	5,503
TOTAL		26,076	(hrs. 240)	6,941	33,017
TOTAL (ESCALATED COST)		28,898		7,692	36,

630812

WBS .... 4.01.02.01 MONITORING WELLS (I/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
Pr ipant .... FP51 FIXED PRICE SUBCONT
Lt of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... C CIVIL AND SITE
B/M Title .... resistivity wells(I/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.3 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	400 RESISTIVITY PROBE WELLS						
	DRILL W/ISOLATION CASING, ≥ 3.5" OPEN HOLE, 120' DP.						
	PROBE IS 1" DIA.						
	ACCESS ROAD (100'/WELL)						
1 -A	SITE PREP: CLEAR & GRUB LIGHT TREES,	Matl.	2.38	ACRE	1,975.00	4,701	
	GRUB & RMV STUMPS (HCM-41)	Labor	143	OP	30.95	4,426	9,127
2 -A	GRADER RENTAL (HCM-17)	Matl.	21.00	DAYS	670.00	14,070	
		Labor	0		0.00	0	14,070
3 -A	OPERATING COST & OPERATOR (HCM-17)	Matl.	160.00	HRS	16.92	2,707	
		Labor	160	OP	30.95	4,952	7,659
4 -A	FILTER FABRIC UNDERLAYMENT	Matl.	45,520.00	SY	1.03	46,886	
	(ECHOS-8-107)	Labor	569	L	24.85	14,140	61,026
5 -A	GRAVEL BASE - 6" DP, SPREAD & COMPACT	Matl.	45,520.00	SY	2.62	119,262	
	(HCM-58)	Labor	228	OP	30.95	7,057	126,319
****	SUBTOTAL ****	Matl.				187,626	
		Labor	1,100			30,575	218,201
	INSTALL RESISTIVITY WELLS						
	* 190 WELLS*						
6 -A	MOBILIZATION (INCL. MOB. 1 RIG,	Matl.	1.00	LS	150,000.00	150,000	
	SET-UP, DECON PAD, PPE, ETC)	Labor	0		0.00	0	150,000

630813

630814

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
7 -A	RESISTIVITY WELL W/ 3.5" OPEN HOLE, 120' DP, 2 DRUMS/WELL SOLIDS, 500 GAL/WELL PURGE WATER	Matl.	400.00	EA	7,250.00	2,900,000	
		Labor	0		0.00	0	2,900,000
8 -A	INSTRUMENTATION, PROBES-1" DIA., CONNECTIONS, AND FILL MATERIAL	Matl.	400.00	EA	1,800.00	720,000	
		Labor	0		0.00	0	720,000
****	SUBTOTAL ****	Matl.				3,770,000	
		Labor	0			0	3,770,000
	DISPOSAL OF SOLIDS						
	(2 DRUMS/WELL, 50 DRUMS/LOAD, 1 LOAD/DAY)						
9 -A	2 LABORERS TO LOAD & HAUL DRUMMED SOLIDS TO LANDFILL (NO TIPPING FEE)	Matl.	134.00	HRS	0.00	0	
		Labor	268	L	24.85	6,660	6,660
10 -A	55 GALLON DRUMS	Matl.	380.00	EA	55.00	20,900	
		Labor	0		0.00	0	20,900
11 -A	FORK TRUCK RENTAL (BCM-21)	Matl.	17.00	DAYS	175.00	2,975	
		Labor	0		0.00	0	2,975
12 -A	OPERATING COST & OPERATOR (BCM-21)	Matl.	136.00	HRS	9.20	1,251	
		Labor	136	OP	30.95	4,209	5,460
13 -A	FLATBED TRUCK RENTAL (BCM-20)	Matl.	17.00	DAYS	138.00	2,346	
		Labor	0		0.00	0	2,346
14 -A	OPERATING COST & DRIVER (BCM-20)	Matl.	136.00	HRS	11.13	1,514	
		Labor	136	TD	22.60	3,074	4,588
15 -A	SAMPLE COLLECTION (1/WELL)	Matl.	190.00	EA	25.00	4,750	
		Labor	380	X	25.00	9,500	14,250
16 -A	LEVEL MODIFIED D PPE (SAMPLING ONLY)	Matl.	380.00	HRS	8.00	3,040	
		Labor	0		0.00	0	3,040

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
**** SUBTOTAL ****		Matl.				36,776	
		Labor	920			23,443	60,219

BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		3,994,402		54,018	4,048,420
SALES TAX		239,664			239,664
SUBTOTAL		4,234,066		54,018	4,288,084
TOTAL INDIRECT	20.00%	846,813	20.00%	10,804	857,617
TOTAL		5,080,879	(hrs. 2,020)	64,822	5,145,701
TOTAL (ESCALATED COST)		5,630,698		71,837	5,702,535

WBS .... 4.01.02.01 MONITORING WELLS (I/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute ..... ALT 1
Discipline .... C CIVIL AND SITE
B/M Title .... Inj. WELLS (I/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	INJECTION WELLS TO FORM PTZ AT SECURITY FENCE						
1 -A	INJECTION WELL, 6" PVC CASING W/ 10" OPEN HOLE, 120' DP.(PER PHONE CALL 2-9-00)	Matl.	250.00	EA	10,000.00	2,500,000	
		Labor	0		0.00	0	2,500,000
2 -A	ADDITIONAL PIPE, PUMPS AND EQUIPMENT	Matl.	114.00	EA	35,000.00	3,990,000	
		Labor	0		0.00	0	3,990,000
3 -A	ADDITIONAL MOB.DEMOB, AND STAFFING	Matl.	1.00	LS	27,000.00	27,000	
		Labor	0		0.00	0	27,000
	PTZ MATERIAL OF CONSTRUCTION						
4 -A	258,000 GAL. OF GUAR GUM	Matl.	100,000.00	LBS	2.00	200,000	
		Labor	0		0.00	0	200,000
5 -A	2,300,000 LBS. OF GRANULAR IRON (MASTERBUILDERS)	Matl.	2,833.00	CY	2,000.00	5,666,000	
		Labor	0		0.00	0	5,666,000
6 -A	PORTABLE 10 KW GENERATOR TO POWER OPERATIONS TRAILERS	Matl.	2.00	EA	4,360.00	8,720	
		Labor	0		0.00	0	8,720
****	SUBTOTAL ****	Matl.				12,391,720	
		Labor	0			0	12,391,720
	DISPOSAL OF WATER						
	(1000 GAL/WELL)						
7 -A	5000 GAL TANKER RENTAL FOR DEVELOPMENT WATER (RRBB-20-7)NO WATER USED PER 2-9-00 CONVERSATION	Matl.	0.00		0.00	0	
		Labor	0		0.00	0	0
8 -A	OPERATING COST & DRIVER (RRBB-20-7)	Matl.	0.00		0.00	0	
		Labor	1,152	TD	22.60	26,035	26,035
9 -A	SAMPLE COLLECTION (27,000 GAL @ ONE/WELL)	Matl.	0.00		0.00	0	
		Labor	228	X	25.00	5,700	5,700

630816

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
10 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	0.00		0.00	0	
		Labor	0		0.00	0	0
****	SUBTOTAL ****	Matl.				0	
		Labor	1,380			31,735	31,735
	DISPOSAL OF SOLIDS						
	(4 DRUMS/WELL, 50 DRUMS/LOAD, 1 LOAD/DAY)						
11 -A	2 LABORERS TO LOAD & HAUL DRUMMED SOLIDS TO LANDFILL (NO TIPPING FEE)	Matl.	192.00	HRS	0.00	0	
		Labor	384	L	24.85	9,542	9,542
12 -A	55 GALLON DRUMS	Matl.	456.00	EA	55.00	25,080	
		Labor	0		0.00	0	25,080
13 -A	FORK TRUCK RENTAL (BCM-21)	Matl.	10.00	DAYS	175.00	1,750	
		Labor	0		0.00	0	1,750
14 -A	OPERATING COST & OPERATOR (BCM-21)	Matl.	80.00	HRS	9.20	736	
		Labor	80	OP	30.95	2,476	3,212
-A	FLATBED TRUCK RENTAL (BCM-20)	Matl.	10.00	DAYS	138.00	1,380	
		Labor	0		0.00	0	1,380
16 -A	OPERATING COST & DRIVER (BCM-20)	Matl.	80.00	HRS	11.13	890	
		Labor	80	TD	22.60	1,808	2,698
17 -A	SAMPLE COLLECTION (1/WELL)	Matl.	114.00	EA	25.00	2,850	
		Labor	228	X	25.00	5,700	8,550
18 -A	LEVEL MODIFIED D PPE (SAMPLING ONLY)	Matl.	228.00	HRS	8.00	1,824	
		Labor	0		0.00	0	1,824
****	SUBTOTAL ****	Matl.				34,510	
		Labor	772			19,526	54,036

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		12,426,230		51,261	12,477,491
SALES TAX		745,574			745,574
SUBTOTAL		13,171,804		51,261	13,223,065
TOTAL INDIRECT	20.00%	2,634,361	20.00%	10,252	2,644,613
TOTAL		15,806,165	(hrs. 2,152)	61,513	15,867,678
TOTAL (ESCALATED COST)		17,516,604		68,170	17,584,774

WBS .... 4.01.02.01 MONITORING WELLS (I/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
P ipant .... FP51 FIXED PRICE SUBCONT
Le of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... C CIVIL AND SITE
B/M Title .... MON WELLS (I/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	25 WELLS INSIDE FENCE						
	18 ADDITIONAL PZT MONITORING WELLS						
	(143 DAYS PER VENDOR)						
	(246 DAYS INCL. ADDITIONAL WELLS)						
	ACCESS ROAD (300'/WELL)						
1 -A	SITE PREP: CLEAR & GRUB LIGHT TREES,	Matl.	1.63	ACRE	1,975.00	3,219	
	GRUB & RMV STUMPS (HCM-41)	Labor	98	OP	30.95	3,033	6,252
2 -A	GRADER RENTAL (HCM-17)	Matl.	9.00	DAYS	670.00	6,030	
		Labor	0		0.00	0	6,030
3 -A	OPERATING COST & OPERATOR (HCM-17)	Matl.	72.00	HRS	16.92	1,218	
		Labor	72	OP	30.95	2,228	3,446
4 -A	FILTER FABRIC UNDERLAYMENT	Matl.	31,218.00	SY	1.03	32,155	
	(ECHOS-8-107)	Labor	390	L	24.85	9,692	41,847
5 -A	GRAVEL BASE - 6" DP, SPREAD & COMPACT	Matl.	31,218.00	SY	2.62	81,791	
	(HCM-58)	Labor	156	OP	30.95	4,828	86,619
****	SUBTOTAL ****	Matl.				124,413	
		Labor	716			19,781	144,194
	INSTALL MONITORING WELLS						
	(COST FROM VENDOR QUOTE)						
6 -A	MOBILIZATION (INCL. MOB. 1 RIG,	Matl.	1.00	LS	150,000.00	150,000	
	SET-UP, DECON PAD, PPE, ETC)	Labor	0		0.00	0	150,000

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
7 -A	MONITORING WELL W/ 2" SS TUBING, 6" OPEN HOLE, 10' SS SCREEN, 100' DP, 4 DRUMS/WELL SOLIDS, 1000 GAL/WELL PURGE WATER	Matl.	43.00	EA	14,500.00	623,500	
		Labor	0		0.00	0	623,500
****	SUBTOTAL ****	Matl.				773,500	
		Labor	0			0	773,500
	DISPOSAL OF WATER						
	(1000 GAL/WELL)						
8 -A	5000 GAL TANKER RENTAL FOR DEVELOPMENT WATER (RRBB-20-7)	Matl.	143.00	DAYS	320.00	45,760	
		Labor	0		0.00	0	45,760
9 -A	OPERATING COST & DRIVER (RRBB-20-7)	Matl.	1,144.00	HRS	20.70	23,681	
		Labor	1,144	TD	22.60	25,854	49,535
10 -A	SAMPLE COLLECTION (27,000 GAL @ ONE/WELL)	Matl.	25.00	EA	25.00	625	
		Labor	50	X	25.00	1,250	1,875
11 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	34.00	HRS	8.00	272	
		Labor	0		0.00	0	272
****	SUBTOTAL ****	Matl.				70,338	
		Labor	1,194			27,104	97,442
	DISPOSAL OF SOLIDS						
	(4 DRUMS/WELL, 50 DRUMS/LOAD, 1 LOAD/DAY)						
12 -A	2 LABORERS TO LOAD & HAUL DRUMMED SOLIDS TO LANDFILL (NO TIPPING FEE)	Matl.	24.00	HRS	0.00	0	
		Labor	48	L	24.85	1,193	1,193
13 -A	55 GALLON DRUMS	Matl.	172.00	EA	55.00	9,460	
		Labor	0		0.00	0	9,460
14 -A	FORK TRUCK RENTAL (BCM-21)	Matl.	4.00	DAYS	175.00	700	
		Labor	0		0.00	0	700
15 -A	OPERATING COST & OPERATOR (BCM-21)	Matl.	32.00	HRS	9.20	294	
		Labor	32	OP	30.95	990	1,284
16 -A	FLATBED TRUCK RENTAL (BCM-20)	Matl.	4.00	DAYS	138.00	552	
		Labor	0		0.00	0	552

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
17 -A	OPERATING COST & DRIVER (BCM-20)	Matl.	32.00	HRS	11.13	356	
		Labor	32	TD	22.60	723	1,079
18 -A	SAMPLE COLLECTION (1/WELL)	Matl.	34.00	EA	25.00	850	
		Labor	68	X	25.00	1,700	2,550
19 -A	LEVEL MODIFIED D PPE (SAMPLING ONLY)	Matl.	68.00	HRS	8.00	544	
		Labor	0		0.00	0	544
****	SUBTOTAL ****	Matl.				12,756	
		Labor	180			4,606	17,362

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		981,007		51,491	1,032,498
SALES TAX		58,860			58,860
SUBTOTAL		1,039,867		51,491	1,091,358
TOTAL INDIRECT	20.00%	207,973	20.00%	10,298	218,271
AL		1,247,840	(hrs. 2,090)	61,789	1,309,629
TOTAL (ESCALATED COST)		1,382,873		68,475	1,451,348

630821

630822

WBS .... 4.01.02.01 MONITORING WELLS (I/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
Participant .... SC01 OFFSITE SUB #1
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... C CIVIL AND SITE
B/M Title .... MON WELLS (I/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.4 0
Expiration Date: 09/15/1999

Item		Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1	-A	ANALYSIS OF SOLID WASTE SAMPLES	Matl.	34.00	EA	400.00	13,600	
		(ASSUME 1 PER WELL)	Labor	0		0.00	0	13,600
2	-A	ANALYSIS OF SOLID WASTE FOR INJECTION	Matl.	114.00	EA	400.00	45,600	
		WELLS	Labor	0		0.00	0	45,600
3	-A	ANALYSIS OF SOLID WASTE FOR	Matl.	190.00	EA	400.00	76,000	
		RESISTIVITY WELLS	Labor	0		0.00	0	76,000
4	-A	ANALYSIS OF LIQUID WASTE SAMPLES	Matl.	34.00	EA	400.00	13,600	
		(ASSUME 1 PER WELL)	Labor	0		0.00	0	13,600
5	-A	ANALYSIS OF LIQUID WASTE FOR	Matl.	114.00	EA	400.00	45,600	
		INJECTION WELLS	Labor	0		0.00	0	45,6
6	-A	ANALYSIS OF LIQUID WASTE FOR	Matl.	0.00		0.00	0	
		RESISTIVITY WELLS. NO WATER USED PER.	Labor	0		0.00	0	0
		2-9-00 CONVERSATION						
****		SUBTOTAL ****	Matl.				194,400	
			Labor	0			0	194,400
7	-A	SMO OVERSIGHT (16.4%)	Matl.	194.40	K$	164.00	31,882	
			Labor	0		0.00	0	31,882

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	226,282	0	226,282
SALES TAX	13,577		13,577
SUBTOTAL	239,859	0	239,859
TOTAL	239,859	(hrs. 0) 0	239,859
TOTAL (ESCALATED COST)	265,815	0	265,815

WBS .... 4.01.02.02 MONITORING WELLS (O/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... C CIVIL AND SITE
B/M Title .... MON WELLS (O/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.5 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	15 WELLS OUTSIDE FENCE						
	(38 DAYS PER VENDOR)						
	ACCESS ROAD (300'/WELL)						
1 -A	SITE PREP: CLEAR & GRUB LIGHT TREES,	Matl.	0.28	ACRE	1,975.00	553	
	GRUB & RMV STUMPS (HCM-41)	Labor	17	OP	30.95	526	1,079
2 -A	GRADER RENTAL (HCM-17)	Matl.	3.00	DAYS	670.00	2,010	
		Labor	0		0.00	0	2,010
3 -A	OPERATING COST & OPERATOR (HCM-17)	Matl.	24.00	HRS	16.92	406	
		Labor	24	OP	30.95	743	1,149
4 -A	FILTER FABRIC UNDERLAYMENT	Matl.	4,690.00	SY	1.03	4,831	
	(ECHOS-8-107)	Labor	59	L	24.85	1,466	6,297
5 -A	GRAVEL BASE - 6" DP, SPREAD & COMPACT	Matl.	4,690.00	SY	2.62	12,288	
	(HCM-58)	Labor	23	OP	30.95	712	13,000
****	SUBTOTAL ****	Matl.				20,088	
		Labor	123			3,447	23,535
	INSTALL MONITORING WELLS						
	(COST FROM VENDOR QUOTE)						
	(MOB. INCL. W/ WELLS I/S FENCE)						
6 -A	MONITORING WELL W/ 2" SS TUBING, 6"	Matl.	15.00	EA	14,500.00	217,500	
	OPEN HOLE, 10' SS SCREEN, 100' DP, 4	Labor	0		0.00	0	217,500
	DRUMS/WELL SOLIDS,						
	1000 GAL/WELL PURGE WATER						

630824

630823

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
****	SUBTOTAL ****	Matl.				217,500	
		Labor	0			0	217,500
	DISPOSAL OF WATER						
	(1000 GAL/WELL)						
7 -A	5000 GAL TANKER RENTAL FOR DEVELOPMENT WATER (RRBB-20-7)	Matl.	38.00	DAYS	320.00	12,160	
		Labor	0		0.00	0	12,160
8 -A	OPERATING COST & DRIVER (RRBB-20-7)	Matl.	304.00	HRS	20.70	6,293	
		Labor	304	TD	22.60	6,870	13,163
9 -A	SAMPLE COLLECTION (5,000 GAL @ ONE/WELL)	Matl.	7.00	EA	25.00	175	
		Labor	14	X	25.00	350	525
10 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	14.00	HRS	8.00	112	
		Labor	0		0.00	0	112
****	SUBTOTAL ****	Matl.				18,740	
		Labor	318			7,220	25,960
	DISPOSAL OF SOLIDS						
	(4 DRUMS/WELL, 50 DRUMS/LOAD, 1 LOAD/DAY)						
11 -A	2 LABORERS TO LOAD & HAUL DRUMMED SOLIDS TO LANDFILL (NO TIPPING FEE)	Matl.	8.00	HRS	0.00	0	
		Labor	16	L	24.85	398	398
12 -A	55 GALLON DRUMS	Matl.	28.00	EA	55.00	1,540	
		Labor	0		0.00	0	1,540
13 -A	FORK TRUCK RENTAL (BCM-21)	Matl.	1.00	DAYS	175.00	175	
		Labor	0		0.00	0	175
14 -A	OPERATING COST & OPERATOR (BCM-21)	Matl.	8.00	HRS	9.20	74	
		Labor	8	OP	30.95	248	322
15 -A	FLATBED TRUCK RENTAL (BCM-20)	Matl.	1.00	DAYS	138.00	138	
		Labor	0		0.00	0	138
16 -A	OPERATING COST & DRIVER (BCM-20)	Matl.	8.00	HRS	11.13	89	
		Labor	8	TD	22.60	181	270
17 -A	SAMPLE COLLECTION (1/WELL)	Matl.	7.00	EA	25.00	175	
		Labor	14	X	25.00	350	525

630825

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
18 -A	LEVEL MODIFIED D PPE (SAMPLING ONLY)	Matl.	14.00	HRS	8.00	112	
		Labor	0		0.00	0	112
****	SUBTOTAL ****	Matl.				2,303	
		Labor	46			1,177	3,480

BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		258,631		11,844	270,475
SALES TAX		15,518			15,518
SUBTOTAL		274,149		11,844	285,993
TOTAL INDIRECT	20.00%	54,830	20.00%	2,369	57,199
TOTAL		328,979	(hrs. 487)	14,213	343,192
TOTAL (ESCALATED COST)		364,579		15,751	380,330

630826

630825

WBS .... 4.01.02.02 MONITORING WELLS (O/S FENCE)
Cost Code .... 6100 REMEDIAL ACTION
P   cipant .... SC01 OFFSITE SUB #1
L   of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline C   CIVIL AND SITE
B/M Title .... MON WELLS (O/S FENCE)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... MONT WELLS
Quantity Take-Off By ...
Trace Number C.2.6 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	ANALYSIS OF SOLID WASTE SAMPLES	Matl.	7.00	EA	400.00	2,800	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	2,800
2 -A	ANALYSIS OF LIQUID WASTE SAMPLES	Matl.	7.00	EA	400.00	2,800	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	2,800
****	SUBTOTAL ****	Matl.				5,600	
		Labor	0			0	5,600
-A	SMO OVERSIGHT (16.4%)	Matl.	5.60	K$	164.00	918	
		Labor	0		0.00	0	918

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	6,518	0	6,518
SALES TAX	391		391
SUBTOTAL	6,909	0	6,909
TOTAL	6,909	(hrs. 0) 0	6,909
TOTAL (ESCALATED COST)	7,657	0	7,657

630827

630828

WBS .... 4.01.03 P&A WELLS
Cost Code .... 6100 REMEDIAL ACTION
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1Alt 4
Discipline .... C CIVIL AND SITE
B/M Title .... P&A WELLS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... GWOU
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... P&A EXIST WELLS
Quantity Take-Off By ...
Trace Number C.3.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	P&A WELLS (BASED ON VENDOR QUOTE)						
	(OVERHEAD & PROFIT INCLUDED BELOW AS INDIRECTS)						
	(USE 1 WELL/DAY = 15 DAYS)						
1 -A	P&A CEMENT-FILL AND SQUEEZE	Matl.	15.00	WELL	40,833.00	612,495	
		Labor	0		0.00	0	612,495
	DISPOSAL OF WATER						
	(USE 1000 GAL/WELL)						
2 -A	5000 GAL TANKER RENTAL FOR	Matl.	15.00	DAYS	320.00	4,800	
	DEVELOPMENT WATER (RRBB-20-7)	Labor	0		0.00	0	4,800
3 -A	OPERATING COST & DRIVER (RRBB-20-7)	Matl.	120.00	HRS	20.70	2,484	
		Labor	120	TD	22.60	2,712	5,196
4 -A	SAMPLE COLLECTION (15,000 GAL @	Matl.	15.00	EA	25.00	375	
	ONE/WELL)	Labor	30	X	25.00	750	1,125
5 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	30.00	HRS	8.00	240	
		Labor	0		0.00	0	240
****	SUBTOTAL ****	Matl.				620,394	
		Labor	150			3,462	623,856
	DISPOSAL OF SOLIDS						
	(USE 5 DRUMS/WELL, 50 DRUMS/LOAD, 1 LOAD/DAY = 2 DAYS)						
6 -A	2 LABORERS TO LOAD & HAUL DRUMMED	Matl.	16.00	HRS	0.00	0	
	SOLIDS TO LANDFILL (NO TIPPING FEE)	Labor	32	L	24.85	795	795

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Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
7 -A	55 GALLON DRUMS	Matl.	75.00	EA	55.00	4,125	
		Labor	0		0.00	0	4,125
8 -A	FORK TRUCK RENTAL (BCM-21)	Matl.	2.00	DAYS	175.00	350	
		Labor	0		0.00	0	350
9 -A	OPERATING COST & OPERATOR (BCM-21)	Matl.	16.00	HRS	9.20	147	
		Labor	16	OP	30.95	495	642
10 -A	FLATBED TRUCK RENTAL (BCM-20)	Matl.	2.00	DAYS	138.00	276	
		Labor	0		0.00	0	276
11 -A	OPERATING COST & DRIVER (BCM-20)	Matl.	16.00	HRS	11.13	178	
		Labor	16	TD	22.60	362	540
12 -A	SAMPLE COLLECTION (1/WELL)	Matl.	15.00	EA	25.00	375	
		Labor	30	X	25.00	750	1,125
13 -A	LEVEL MODIFIED D PPE (SAMPLE ONLY)	Matl.	30.00	HRS	8.00	240	
		Labor	0		0.00	0	240
****	SUBTOTAL ****	Matl.				5,691	
		Labor	94			2,402	8,093

BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		626,085		5,864	631,949
SALES TAX		37,565			37,565
SUBTOTAL		663,650		5,864	669,514
TOTAL INDIRECT	20.00%	132,730	20.00%	1,173	133,903
TOTAL		796,380	(hrs. 244)	7,037	803,417
TOTAL (ESCALATED COST)		882,559		7,798	890,357

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WBS	4.01.03 P&A WELLS	Building/Area	GWOU
Cost Code	6100 REMEDIAL ACTION	Plant Site	F
Participant	SC01 OFFSITE SUB #1	Contracting Type	G era
Level of Estimate .	P Planning/Feasibility Estimate	Funding Type	EXPENSE
B/M Attribute	1ALT 4	Source Site	PADUCAH
Discipline	C CIVIL AND SITE	Discipline Estimator ...	P&A EXIS
B/M Title	P&A WELLS	Quantity Take-Off By ...	
Receiving Site	PADUCAH	Trace Number	C.3.2 0
Cross-Cut Code			
Standard Value File	C:®ESTIMA™1®RRB2668A.val	Expiration Date: 09/15/1999	
Estimate File	C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a		

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total C M +
1 -A	ANALYSIS OF SOLID WASTE SAMPLES	Matl.	15.00	EA	400.00	6,000	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	
2 -A	ANALYSIS OF LIQUID WASTE SAMPLES	Matl.	15.00	EA	400.00	6,000	
	(ASSUME 1 PER WELL)	Labor	0		0.00	0	6
****	SUBTOTAL ****	Matl.				12,000	
		Labor	0			0	12
3 -A	SMO OVERSIGHT (16.4%)	Matl.	12.00	K$	164.00	1,968	
		Labor	0		0.00	0	1,

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	13,968	0	13,9
SALES TAX	838		8
SUBTOTAL	14,806	0	14,8
TOTAL	14,806 (hrs. 0)	0	14,8
TOTAL (ESCALATED COST)	16,408	0	16,.

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BILL OF MATERIAL SUMMARY		Material		Labor	Total Cost M + L
TOTAL DIRECT		91,776		31,982	123,758
SALES TAX		5,507			5,507
SUBTOTAL		97,283		31,982	129,265
TOTAL INDIRECT	20.00%	19,457	20.00%	6,396	25,853
TOTAL		116,740	(hrs. 1,162)	38,378	155,118
TOTAL (ESCALATED COST)		129,373		42,531	171,904

630831

WBS .... 4.02.01 DESIGN
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... AE01 A-E, ENVIRONMENTAL
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... X ENGINEERING
B/M Title .... AE RD REPORT
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... 1ALT 4 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number X.5.3 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	AE TITLE II DESIGN						
1 -A	RD REPORT (TITLE II) (1 FTE X 3 MOS)	Matl.	520.00	HOUR	0.00	0	
		Labor	520	T2	65.00	33,800	33,800

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	33,800	33,800
TOTAL	0	(hrs. 520) 33,800	33,8
TOTAL (ESCALATED COST)	0	36,905	36,905

630832 630831

WBS .... 4.02.01 DESIGN
Cost Code .... 9100 PROJECT MANAGEMENT
P[illegible]icipant .... AE01 A-E, ENVIRONMENTAL
of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... X ENGINEERING
B/M Title .... AE REVIEW RA WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... 1ALT 4 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number X.5.5 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -C	AE REVIEW RA WORK PLAN	Matl.	20.00	HOUR	0.00	0	
		Labor	20	T2	65.00	1,300	1,300

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	1,300	1,300
TOTAL	0	(hrs. 20) 1,300	1,300
'L (ESCALATED COST)	0	1,419	1,419

630833

WBS .... 4.02.01 DESIGN
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... AE01 A-E, ENVIRONMENTAL
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... X ENGINEERING
B/M Title .... AE RD WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... 1ALT 4 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number X.5.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -C	AE WRITE RD WORK PLAN	Matl.	40.00	HOUR	0.00	0	
		Labor	40	T2	65.00	2,600	2,600

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	2,600	2,600
TOTAL	0	(hrs. 40) 2,600	2,600
TOTAL (ESCALATED COST)	0	2,839	2,8

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630833

WBS .... 4.02.01 DESIGN
Cost Code .... 9100 PROJECT MANAGEMENT
P 'icipant .... R032 PAD ENG & TECH SVCS
. of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... X ENGINEERING
B/M Title .... CM RA WORK PLAN
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... 1ALT 4 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number X.5.6 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM WRITE RA WORK PLAN	Matl.	40.00	HOUR	0.00	0	
		Labor	40	MX	64.00	2,560	2,560

BILL OF MATERIAL SUMMARY	Material	Labor		Total Cost M + L
TOTAL DIRECT	0		2,560	2,560
TOTAL	0	(hrs. 40)	2,560	2,560
'AL (ESCALATED COST)	0		2,795	2,795

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WBS	4.02.01 DESIGN	Building/Area	1ALT 4 IND
Cost Code	9100 PROJECT MANAGEMENT	Plant Site	R
Participant	R032 PAD ENG & TECH SVCS	Contracting Type	G General
Level of Estimate .	P Planning/Feasibility Estimate	Funding Type	EXPENSE
B/M Attribute	1ALT 4	Source Site	PADUCAH
Discipline	X ENGINEERING	Discipline Estimator ...	INDIRECTS
B/M Title	CM REVIEW RD WORK PLAN	Quantity Take-Off By ...	
Receiving Site	PADUCAH	Trace Number	X.5.2 0
Cross-Cut Code			
Standard Value File	C:®ESTIMA™1®RRB2668A.val	Expiration Date:	09/15/1999
Estimate File	C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a		

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM REVIEW RD WORK PLAN	Matl.	20.00	HOUR	0.00	0	
		Labor	20	MX	64.00	1,280	1,280

BILL OF MATERIAL SUMMARY	Material	Labor		Total Cost M + L
TOTAL DIRECT	0		1,280	1,280
TOTAL	0	(hrs. 20)	1,280	1,280
TOTAL (ESCALATED COST)	0		1,398	1,[illegible]

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630835

WBS .... 4.02.01 DESIGN
Cost Code .... 9100 PROJECT MANAGEMENT
Pr ``ipant .... R032 PAD ENG & TECH SVCS
L. of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... X ENGINEERING
B/M Title .... CM REVIEW RD REPORT
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... 1ALT 4 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number X.5.4 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM REVIEW RD REPORT	Matl.	80.00	HOUR	0.00	0	
		Labor	80	MX	64.00	5,120	5,120

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	5,120	5,120
TOTAL	0	(hrs. 80) 5,120	5,120
`. (ESCALATED COST)	0	5,590	5,590

630837 030090

WBS .... 4.02.02 PROJECT INTEGRATION
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... AE01 A-E, ENVIRONMENTAL
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... U PROJECT ENGINEERING
B/M Title .... AE T-III ENGINEERING
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... 1ALT 4 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number U.6.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	AE TITLE III ENGINEERING (1/2 FTE X 9 MOS)	Matl.	780.00	HOUR	0.00	0	
		Labor	780	T3	55.00	42,900	42,900

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	0	42,900	42,900
TOTAL	0	(hrs. 780) 42,900	42,900
TOTAL (ESCALATED COST)	0	47,542	4[illegible]

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WBS .... 4.02.02 PROJECT INTEGRATION
Cost Code .... 9100 PROJECT MANAGEMENT
icipant .... R032 PAD ENG & TECH SVCS
of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... U PROJECT ENGINEERING
B/M Title .... CM FINAL REPORTS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... 1ALT 4 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number U.6.3 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM FINAL CONSTRUCTION REPORTS	Matl.	40.00	HOUR	0.00	0	
		Labor	40	MR	54.00	2,160	2,160

BILL OF MATERIAL SUMMARY	Material	Labor		Total Cost M + L
TOTAL DIRECT	0		2,160	2,160
TOTAL	0	(hrs. 40)	2,160	2,160
AL (ESCALATED COST)	0		2,394	2,394

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WBS .... 4.02.02 PROJECT INTEGRATION
Cost Code .... 9100 PROJECT MANAGEMENT
Participant .... R053 PAD FIELD SERVICES
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... U PROJECT ENGINEERING
B/M Title .... CM CONST OVERSIGHT
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... 1ALT 4 IND
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... INDIRECTS
Quantity Take-Off By ...
Trace Number U.6.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
1 -A	CM CONSTRUCTION OVERSIGHT (1 FTE X 9	Matl.	1,560.00	HOUR	0.00	0	
	MOS)	Labor	1,560	MR	54.00	84,240	84,240

BILL OF MATERIAL SUMMARY	Material	Labor		Total Cost M + L
TOTAL DIRECT	0		84,240	84,240
TOTAL	0	(hrs. 1,560)	84,240	84,240
TOTAL (ESCALATED COST)	0		93,356	93,3'

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WBS .... 4.03.01.01 MAINTENANCE (30 YRS)
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
 `icipant .... FP51 FIXED PRICE SUBCONT
 ι of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... 0 OTHER
B/M Title .... MAINTENANCE - 30 YEARS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... 1ALT 4 O&M
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.7.1 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	MAINTENANCE OF MONITORING WELLS INCLUDED AT 2% OF CAPITAL COST PER YEAR, EQUALS COMPLETE REPLACEMENT REPLACEMENT EVERY 50 YEARS						
	(90 EXISTING AND 32 NEW WELLS = 122 X $14,500/EA = $1,769,000X 2%=35386)						
1 -A	MAINTENANCE OF MONITORING WELLS (2% X 30 YRS)	Matl.	30.00	YRS	35,380.00	1,061,400	
		Labor	0		0.00	0	1,061,400

⌞L OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		1,061,400		0	1,061,400
SALES TAX		63,684			63,684
SUBTOTAL		1,125,084		0	1,125,084
TOTAL INDIRECT	20.00%	225,017	20.00%	0	225,017
TOTAL		1,350,101	(hrs. 0)	0	1,350,101
TOTAL (ESCALATED COST)		2,340,204		0	2,340,204

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WBS .... 4.03.01.02 SAMPLE COLLECTION (30 YRS)
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
Participant .... FP51 FIXED PRICE SUBCONT
Level of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... O OTHER
B/M Title .... MONITORING - 30 YEARS
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... 1ALT 4 O&M
Plant Site .... R
Contracting Type .... G General
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.7.2 0

Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	MONITORING - 30 YEARS						
	-SAMPLE COLLECTION-						
	(COST BY BECHTEL JACOBS)						
1 -A	QUARTERLY SAMPLING OF 122 WELLS =	Matl.	30.00	YRS	516,792.00	15,503,760	
	488/YR X $1,059/EA	Labor	0		0.00	0	15,503,760
****	SUBTOTAL ****	Matl.				15,503,760	
		Labor	0			0	15,503,760

BILL OF MATERIAL SUMMARY	Material		Labor		Total Cost M + L
TOTAL DIRECT		15,503,760		0	15,503,760
SALES TAX		930,226			930,226
SUBTOTAL		16,433,986		0	16,433,986
TOTAL INDIRECT	20.00%	3,286,797	20.00%	0	3,286,797
TOTAL		19,720,783	(hrs. 0)	0	19,720,783
TOTAL (ESCALATED COST)		34,183,110		0	34,183,110

WBS .... 4.03.01.03 SAMPLE ANALYSIS (30 YRS)
Cost Code .... 7300 OPERATIONS AND MAINTENANCE
' 'cipant .... SC01 OFFSITE SUB #1
ι . of Estimate . P Planning/Feasibility Estimate
B/M Attribute 1ALT 4
Discipline .... 0 OTHER
B/M Title .... MONIT- 30 YEARS (ANALYSIS)
Receiving Site .... PADUCAH
Cross-Cut Code ....
Standard Value File C:®ESTIMA™1®RRB2668A.val
Estimate File ..... C:®ESTIMA™1®ATL4®ALT4.Est 5-31-00 9:32a

Building/Area .... 1ALT 4 O&M
Plant Site .... R
Contracting Type .... S Subcontractor
Funding Type .... EXPENSE
Source Site .... PADUCAH
Discipline Estimator ... O&M
Quantity Take-Off By ...
Trace Number 0.7.3 0
Expiration Date: 09/15/1999

Item	Description	MATL. / LABOR	Quantity / Hours	Unit / Craft	Unit Price / Rate	Total Material / Total Labor	Total Cost M + L
	LAB ANALYSIS - 30 YEARS						
1 -A	QUARTERLY ANALYSIS OF 122 WELLS ▫	Matl.	30.00	YRS	195,200.00	5,856,000	
	488/YR X $400/EA	Labor	0		0.00	0	5,856,000
****	SUBTOTAL ****	Matl.				5,856,000	
		Labor	0			0	5,856,000
2 -A	SMO OVERSIGHT (16.4%)	Matl.	5,856.00	K$	164.00	960,384	
		Labor	0		0.00	0	960,384

BILL OF MATERIAL SUMMARY	Material	Labor	Total Cost M + L
TOTAL DIRECT	6,816,384	0	6,816,384
SALES TAX	408,983		408,983
SUBTOTAL	7,225,367	0	7,225,367
TOTAL	7,225,367	(hrs. 0) 0	7,225,367
TOTAL (ESCALATED COST)	12,524,123	0	12,524,123

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Disciplines
- C: CIVIL AND SITE
- O: OTHER
- U: PROJECT ENGINEERING
- X: ENGINEERING

Total Labor Hours: 13,294

COST SUMMARY

COST SUMMARY	Material	Labor	Total Cost M + L
Line Item Cost	42,034,863	456,804	42,491,667
Total Sales Tax	2,522,092		2,522,092
SUBTOTAL	44,556,955	456,804	45,013,759
Total Indirect	7,414,003	56,169	7,470,172
SUBTOTAL	51,970,958	512,973	52,483,931
Overhead	21,807,014	215,243	22,022,257
SUBTOTAL	73,777,972	728,216	74,506,188
Contingency	18,444,493	182,054	18,626,547
SUBTOTAL	92,222,465	910,270	93,132,7[illegible]
Market Adjustment			
TOTAL			93,132,735

TOTAL (ESCALATED DOLLARS) including overhead & contingency	133,591,574	1,007,419	134,598,993

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APPENDIX C8

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Summary of Previous Remedial Investigation Fate and Transport Modeling

The purposes of this task is to summarize all previous remedial investigation (RI) fate and transport models at the Paducah Gaseous Diffusion Plant (PGDP), to tabulate all available hydrogeologic and chemical-specific parameters, and to develop a consistent set of parameters and values, or methods for arriving at the appropriate parameters and values, to recommend for use in future fate and transport modeling tasks at PGDP. The parameters will be those reported in the feasibility study (FS) data summary report and the RI reports summarized therein. Specific values and parameters reported in modeling reports have been tabulated, along with ranges of values reported in standard references. Several RI reports did not list specific values. For example, it was common to report soil–water partition coefficient (K_d) values used in estimating the travel time in the regional gravel aquifer (RGA) from directly beneath the contaminant source to a receptor point without listing the K_d values used in modeling the vertical migration of the contaminant to the water table.

FATE AND TRANSPORT MODELING

Previous modeling efforts are briefly summarized below. They are organized according to the model used. A more detailed summary is available in the data summary report (DOE 2000), and the specific constituents modeled at each site are listed in the spreadsheets accompanying this report.

Summers Model: The Summers model was used to predict contaminant transport to receptor points for Waste Area Groupings (WAGs) 1 and 7, Solid Waste Management Units (SWMUs) 8, 38, 100, 131, 132, 133, 134, and 136. Model parameters are listed in the Summers portion of the database included on the accompanying CD. The Summers Transport sheet presents the values of the hydrogeologic parameters used in the modeling effort, along with the hydrologic unit modeled, the document and page number from which each value was extracted, the value of the parameter, the source of the parameter quoted in the document, and a source code as listed in the Notes sheet. This format is followed for presenting the data for each model used in fate and transport modeling. The Summers Const sheet lists the contaminants modeled, including many for which no distribution coefficients are available. The RI report (DOE 1996a) listed a value or a range of values of K_d for each constituent, but there was not a single value used at a particular location in a particular hydrologic unit, so a value could not be determined from the information in the RI. The only values listed are those for which it is clear that a specific value was used in a specific hydrologic unit at a known modeling site.

MEPAS Modeling: The Multimedia Environmental Pollutant Assessment System (MEPAS) model was the most widely used fate and transport model at PGDP and is expected to be used for any future modeling. The FS states that "Since 1997, such screening-level modeling has been consolidated to use of the MEPAS code at the site for consistency. It was selected as the best model to use (1) to simulate both partially saturated and saturated conditions; (2) to simulate degrading source terms; (3) to simulate several exposure pathways other than groundwater; (4) to perform risk calculations; and (5) for its ease of use" (DOE 2001). MEPAS has been applied at the following locations:

- WAG 27, SWMUs 1, 91, and 196 and area C-720
- WAG 28, SWMUs 99, 93, and 194 and Area of Concern 204
- WAG 3, SWMUs 4, 5, and 6
- WAG 6
- WAG 22, SWMU 2

Values and parameters used in the MEPAS modeling at PGDP are listed in the MEPAS portion of the database included on the accompanying CD in the same format described above for the Summers model.

SESOIL and AT123D Modeling: The Seasonal Soil Compartment (SESOIL) model was applied at

- WAG 22, SWMUs 7 and 30; and
- WAG 27, SWMU 91 as part of the Lasagna process assessment.

SESOIL is used in conjunction with the Analytical Transient 1-, 2-, 3-Dimensional (AT123D) model in a modeling system from RISKPRO®. SESOIL is used to simulate the migration of contaminants from the source(s) to the water table. An output file from SESOIL is then input into AT123D to predict the concentration of the contaminant in the groundwater directly beneath the source and to simulate the horizontal migration to receptor locations. The SESOIL portion of the database included on the accompanying CD contains the hydrogeologic parameters used in these modeling efforts, along with the K_d and the organic carbon – water partition coefficient (K_{oc}) values used in the WAG 22 modeling. The properties of the RGA used in the SWMU 91 modeling are presented in the AT123D portion of the database included on the accompanying CD, but the values used in the WAG 22 modeling were not included in the RI. K_d and K_{oc} values were also not available for either site

RESRAD Modeling: The RESRAD model is designed for radioisotopes and was used to model radioisotope migration at SWMU 2 in WAG 22. Hydrogeologic properties and distribution coefficients used in the modeling are presented in the RESRAD portion of the database included on the accompanying CD.

It should be noted that all available values of parameters used in fate and transport modeling have been included in this compilation. The result of this is that some modeling sites will be unequally represented in the statistical summary, particularly for K_d values. As an example the MEPAS modeling of SWMU 2 of WAG 22 included six layers in the model of vertical migration of contaminants to the water table with varying K_d values, whereas the model for WAG 6 included only topsoil, the Upper Continental Recharge System (UCRS), and the RGA.

MODFLOW Modeling: The regional ground-water flow model developed for the DOE in 1994 and revised in 1996 (DOE 1994, DOE 1996b) and 1997 (DOE 1997a, 1997b) and 1998 (DOE 1998a), covers nearly 100 km^2 (38.60mi^2) and simulates ground-water flow on a regional scale in the principal water-bearing units beneath the site. Previous revisions to the model (DOE 1997a) included refinements to better characterize geologic data, specifically the location of the Porters Creek Clay Terrace, the thickness of the Eocene Sands, and the extent of the finer grained material located in the vicinity of the C-746-K Sanitary Landfill. The regional model simulates ground water, sand, and gravel lenses within the UCRS (HU2), the RGA (HU 4/ HU 5), and the distribution of heterogeneous sediments comprising the Upper Continental Deposits (HU 2). MODFLOW, the United States Geological Survey's three-dimensional modular ground-water flow program, was used to perform the simulations with the regional model (McDonald and Harbaugh 1988).

The boundaries of the regional model coincide with natural boundaries, where possible, and minimize the influence of model boundaries on simulation results at the site. The model domain extends well beyond the PGDP to approximately 7.82 km (4.86 miles) from the east to the west boundaries and 11.00 km (6.86 miles) from the north to south boundaries. The finite-difference grid consists of 190 columns, 167 rows, and four layers for a total of 126,920 grid cells or nodes. The model grid uses a uniform 15.25 m (50 ft) areal grid spacing in the vicinity of the plant to provide increased computational detail in the area of interest and grades to larger grid spacing at greater distances from the site. A complete description of the conceptual model, overall model construction and calibrations can be found in the 1997 modeling report (DOE 1997a, DOE 1997b, and DOE 1998a). Final calibrated hydraulic parameters are presented in the MODFLOW portion of the database included on the accompanying CD.

In 1998 a transport model was constructed using the MODFLOW numerical model (DOE 1998a). Since that time, several refinements have been made. The refinements include changes in the transport code utilized, as well as transport parameters. Transport parameters for the primary contaminants that comprise the major offsite plumes were adjusted to approximate the current configurations of the plumes. The major transport parameters are the soil/water partitioning coefficient (K_d), and the decay constant (λ). In order to simulate sufficient transport of the plume to approximate the current observed migration of the TCE plume, TCE K_d values were used that ranged from 0.025 to 0.05 L/kg. Predictive transport simulations were conducted using TCE K_d-value of 0.05 L/kg. A TCE half-life of 26.6 years was used, and was based on the degradation rate for TCE that was presented in *Evaluation of Natural Attenuation Processes for Trichloroethylene and Technetium-99 in the Northeast and Northwest Plumes at the Paducah Gaseous Diffusion Plant Paducah, Kentucky* (LMES 1997). The regional model is being used and also, will be used in the future for supporting feasibility studies and various remedial designs.

Transport Parameters

The data from the spreadsheets were imported into ACCESS™ so that selected data sets could easily be created. From the ACCESS™ database, EXCEL™ spreadsheets were generated for all values of the following hydrogeologic parameters:

- bulk density;
- percent sand, silt, and clay;
- disconnectedness index;
- effective porosity;
- percent Fe + Al;
- field capacity;
- percent organic carbon;
- horizontal hydraulic conductivity in the RGA and terrace sand and gravel (TSG);
- intrinsic permeability;
- pH; and
- total porosity.

For each parameter the average, minimum, and maximum values were tabulated for all values, and for topsoil, the UCRS (HU1, HU2, HU3), the RGA, and the TSG. Average values were computed to best represent the particular parameter. For example, the percent organic carbon is an arithmetic average, while for the average of intrinsic permeability, the following formula was used:

$$k_{avg} = \frac{\sum H_i}{\sum (H_i * k_i)},$$

where k_i is the permeability and H_i is the thickness of the model layer to which that permeability was assigned. The results are summarized in the Table C8.1.

Partition Coefficients

K_d and K_{oc} values for 50 commonly modeled constituents at PGDP were exported from ACCESS™ database to spreadsheets. All modeled inorganics and several organic constituents were included. Included in these data are values of K_{oc} computed from the following equation:

$$K_d = foc * K_{oc}$$

when the fraction of organic carbon (foc) was known and K_d was given for an organic contaminant but K_{oc} was not.

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Table C8.1. Transport parameter tabulation results

Parameter	Hydrologic Unit	Average	Minimum	Maximum
Bulk Density (g/cc)	All	1.74	1.46	2.25
	UCRS	1.75	1.46	2.25
	RGA	1.71	1.67	2.16
Measured Values	UCRS	1.76	1.66	1.82
Measured Values	RGA	1.74	1.67	1.77
Recommended	*Site-specific measurements or use 1.75.*			
% Sand	HU1	20.5	8.0	33.0
	HU2	67.0	67.0	67.0
	HU3	8.7	8.0	10.0
	HU12	21.5	5.0	38.0
	HU123	41.3	17.0	72.0
	RGA	78.8	74.0	96.0
	UCRS	24.2	5.0	72.0
% Silt	HU1	44.5	37.0	52.0
	HU2	19.0	19.0	19.0
	HU3	35.3	30.0	38.0
	HU12	46.0	27.0	65.0
	HU123	40.3	16.0	63.0
	RGA	13.3	3.0	17.0
	UCRS	39.1	16.0	65.0
% Clay	HU1	35.0	30.0	40.0
	HU2	14.0	14.0	14.0
	HU3	56.0	54.0	60.0
	HU12	32.5	30.0	35.0
	HU123	18.5	12.0	21.0
	RGA	8.0	1.0	10.0
	UCRS	36.7	12.0	60.0
Recommended	*Site-specific measurements or use averages for HU1, HU2, HU3, RGA, and UCRS as needed.*			
Effective Porosity	UCRS	23.2	13.0	35.0
	RGA	28.9	25.0	30.0
Recommended	*All data were estimate. Consult reference on soil type or use 25 for UCRS and 30 for RGA.*			
%Fe+Al	Topsoil	3.88	2.40	4.00
	UCRS	3.75	2.00	4.20
	RGA	2.75	2.00	3.00
Recommended	*Values were all from a few reports. Make site-specific measurements or use the averages.*			
Field Capacity (%)	UCRS	23.8	9.0	42.0
	HU1	26.20	24	28
	HU2	14.67	9	35
	HU3	27.24	10	42
Recommended	*These are estimates. Use references on soil types or the averages.*			
Organic Carbon (%)	Topsoil	0.054	0.050	0.100
	UCRS	0.094	0.050	0.260
	RGA	0.034	0.020	0.200
	HU1	0.14	0.09	0.26
	HU2	0.10	0.07	0.20
	HU3	0.07	0.05	0.20
Recommended	*Site-specific measurements. Otherwise, use averages.*			
Horizontal Hyd	RGA	0.306	0.026	0.529
Cond (cm/s)	TSG	0.0010	0.0010	0.0010
0.53 was used in several MEPAS modeling efforts to estimate a "Darcy" velocity.				
Recommended	*Use sitewide groundwater model to estimate horizontal velocity for migration in RGA.*			

Table C8.1. Transport parameter tabulation results (continued)

Parameter	Hydrologic Unit	Average	Minimum	Maximum
Intrinsic	UCRS	8.54E-12	3.40E-13	3.10E-08
Permeability (cm^2)	RGA	8.90E-12	7.13E-12	1.25E-10
[Vertical]	TSG	5.39E-12	3.77E-12	6.04E-12
	HU1	3.51E-12	1.00E-12	1.30E-09
	HU2	6.08E-10	1.25E-10	3.10E-08
	HU3	3.35E-12	3.40E-13	3.78E-10
	Eight measurements consisted of permeameter, slug, and pump tests.			
Recommended	*Use averages for layers as needed.*			
pH	Topsoil	5.70	5.00	8.25
Measured Values	Topsoil	7.26	5.50	8.25
Measured Values	UCRS	6.14	5.80	6.76
Measured Values	RGA	6.39	6.20	6.60
Recommended	*Take site-specific measurements. If necessary, use 7.2 in topsoil and 6.2 elsewhere.*			
Porosity (%)	UCRS	38.8	15.0	48.0
	RGA	36.6	30.0	48.0
Measured Values	UCRS	33.5	30.0	37.2
Measured Values	RGA	37	37	37
Recommended	*Most values were estimated. Make site-specific measurements, infer from bulk density, or use 34 in UCRS and 37 in RGA.*			

It should be noted that values of K_{oc} computed from K_d and foc often do not agree with tabulated values of K_{oc}. The results of this summary are presented in Tables C8.2 and C8.3. In general, all modeling reports cited K_d and K_{oc} values from accepted references and the MEPAS database. Only specific values were included in this compilation. If a value was given for sand and another for loam or clay, those values were not included. If a range of values was given, that range was not included. Only specific values clearly linked to a specific modeling site and an identifiable model layer are included in this tabulation.

From this tabulation and several references on K_d values, a set of recommended K_d values to be used in the UCRS, RGA, and sand and loam, if several layers are used in the vertical model, are listed in Tables C8.4 and C8.5.

DISCUSSION

K_d Values for Inorganics

As can be seen from the tabulation of K_d values, a wide range of values has been used for specific contaminants. Examples are nickel, for which K_d values used at PGDP have ranged from 1.2 to 650; plutonium, for which values have ranged from 0 to 1200; and even technetium for which values have ranged from 0.1 to 20. While these values are found within the ranges of values in the literature (except for K_d = 0), the use of these K_d values can lead to widely varying results in the predictions of fate and transport modeling. This fact is well recognized by the regulatory community. The report *Understanding the Variation in Partition Coefficient, K_d Values* (EPA 1999) discusses this issue as follows:

"It is important to note that soil scientists and geochemists knowledgeable of sorption processes in natural environments have long known that generic or default partition coefficient values found in the literature can result in significant errors when used to predict the absolute impacts of contaminant migration or site-remediation options. Accordingly, one of the major recommendations of this report is

that for site-specific calculations, partition coefficient values measured at site-specific conditions are absolutely essential."

And as follows:

"Ideally, site-specific K_d values would be available for the range of aqueous and geological conditions in the system to be modeled. Values for K_d not only vary greatly between contaminants, but also vary as a function of aqueous and solid phase chemistry (Delegard and Barney 1983; Kaplan and Sern 1995; Kaplan et al. 1994c). For example, uranium K_d values can vary over 6 orders of magnitude depending on the composition of the aqueous and solid phase chemistry."

To compensate for the lack of knowledge on site-specific K_d values, modelers often adopt a "conservative" approach, using K_d values near the lower end of the literature values. While this approach has some merit in not ruling out contaminants that may cause off-site risk, it does not yield an accurate prediction of fate and transport and may underestimate the problem of cleanup of the site. The U.S. Environmental Protection Agency (EPA) recognizes this conundrum. It states that

"To address some of this concern when using generic or default K_d values for screening calculations, modelers often incorporate a degree of conservatism into their calculations by selecting limiting or bounding conservative K_d values. For example, the most conservative estimate from an off-site risk perspective of contaminant migration through the subsurface natural soil is to assume that the soil has little or no ability to slow (retard) contaminant movement (i.e., a minimum bounding K_d value). Consequently, the contaminant would migrate in the direction and, for a K_d value of 0.0, travel at the rate of water. Such an assumption may in fact be appropriate for certain contaminants such as tritium, but may be too conservative for other contaminants, such as thorium or plutonium, which react strongly with soils and may migrate 10^2 to 10^6 times more slowly than the water. On the other hand, to estimate the maximum risks (and costs) associated with on-site remediation options, the bounding K_d value for a contaminant will be a maximum value (i.e., maximize retardation)."

It is well recognized that K_d values for a single constituent may vary significantly depending on the aqueous- and solid-phase chemistry of the soil/aquifer through which the contaminant is migrating. EPA has created a series of lookup tables for selecting K_d values by correlating reported K_d values with a set of geochemical parameters measured at the site. (EPA 1990) The constituents for which lookup tables are currently available are cadmium, cesium, chromium, lead, plutonium, radon, strontium, thorium, tritium, and uranium. Even with these results, the lookup tables contain a wide range of K_d values for a single constituent.

Other approaches are geochemical modeling to estimate K_d values for a particular site and site-specific K_d measurements. While modeling does give insight into appropriate values, site-specific measurements implicitly take nearly all processes into account and should give the most reliable values. While the conservative approach (using low K_d values) is valid for the initial screening process, to keep under consideration constituents that might cause off-site risk, more accurate predictions of the fate and transport of the remaining candidate constituents are necessary to make decisions on appropriate remediation efforts.

Properties of Organics

To compute the K_d values appropriate for organic constituents, the normal approach is to multiply the foc in the soil by the K_{oc}. As reported by EPA (1996), this approach is appropriate for foc values of .001 or greater. EPA also recommends a ratio of 1.724 to convert measured organic material to organic carbon.

For organic acids and bases, the degree of ionization is a function of pH. Because the anion of an organic acid is less likely to sorp than the neutral species, the resultant K_{oc} is likely to be lower. For organic bases, the opposite is true. The variation of K_{oc} with pH may exceed an order of magnitude for a difference in pH between 6.8 and 4.9. While such extremes in pH are rare, the modeler should be aware of this phenomenon and adjust K_{oc} values where appropriate. K_{oc} values for ionizing organic acids as a function of pH in increments of 0.1 pH unit have been tabulated by EPA (2001).

Recommendations

The parameters needed for additional fate and transport modeling may be broadly divided into soil properties and constituent properties. Soil properties include soil and aquifer characteristics that determine the infiltration of water through the vadose zone to the water table and the subsequent horizontal flow to receptor locations as well as those properties that influence the leaching and migration of contaminants from the source areas to the receptor locations.

Constituent properties are those properties of contaminants that influence the rate at which they leach from the source and migrate as well as the concentration and time of arrival of the contaminants at receptor locations. The important parameters are listed below with recommendations for determining appropriate values for fate and transport modeling applications.

Soil properties

- Hydraulic

  — Horizontal hydraulic conductivity: The most reliable approach is to refer to the sitewide groundwater model and use the value for the zone or zones through which the contaminant must travel to reach receptor locations. When more than one hydraulic conductivity zone is encountered, they must be averaged to reproduce the correct travel time according to

  $$K_{avg} = \frac{\sum L_i}{\sum (L_i * K_i)},$$

  where K_i is the hydraulic conductivity in a zone of the sitewide groundwater model and L_i is the distance that the contaminant travels through that zone.

  — Vertical intrinsic permeabiltity: Use the recharge rate determined from the sitewide groundwater model and calibrate on the intrinsic permeability of the small-scale fate and transport model to match the recharge rate. In areas not representative of the general site surface, such as landfill covers, use a model such as the Hydrologic Evaluation of Landfill Performance (HELP) model to estimate the infiltration rate and then calibrate on the permeability to match that recharge rate.

  — Porosity: Use site-specific measurements or the average values in the transport parameter tabulation results table above.

  — Field capacity: This parameter is difficult to measure. Use reference values from the literature or model database or the average values in the transport parameter tabulation results table above.

  — Effective porosity: Usually this parameter is not measured or known. In that case the MEPAS guidance suggests using sand = 25%, silt = 15%, and clay = 10%.

  — Layer thickness: Site-specific measurement from boring logs.

- Chemical

  — pH: Site-specific measurement from geotechnical data.

  — % Sand, Silt, and Clay: Site-specific measurement from geotechnical data.

  — Total organic carbon: Site-specific measurement from geotechnical data.

  — % Fe and Al: Site-specific measurement from geotechnical data. If these data cannot be collected, use the average values from the transport parameter tabulation results table above.

  — Bulk density: Site-specific measurement from geotechnical data.

  — Freundlich exponent: If a site-specific value is not known, use 1.0.

Constituent Properties

- Organics: The most important properties of organic constituents that determine their leaching and migration rates and their concentrations at receptor locations are

  — K_{oc}, the water-carbon partitioning coefficient;
  — solubility;
  — Henry's Constant, which defines partitioning between air and water; and
  — biodegradation rate, which is the rate of contaminant loss through biochemical transformation.

  Each of these parameters is a property of the contaminant of interest. These values are tabulated and regularly updated. EPA maintains a database of these values, and values for most organic contaminants of interest are found in the Soil Screening Guidance User's Guide and Technical Background Document, both published by EPA in 1996. Other references should be used for the contaminants not included in EPA's soil screening guidance. These references include EPA's Treatability Database (EPA 1994), EPA's STF Database (EPA 1991), and Chemistry Handbooks. Extensive care must be taken for the selection of the biodegradation rate. The standard reference for biodegradation rates is the *Handbook of Environmental Degradation Rates* (Howard et al. 1991).

- Inorganics

  — Soil–water partition coefficient, K_d

As stated earlier, the values used in fate and transport modeling at Paducah were all chosen from the MEPAS database or from the standard references mentioned earlier, with the exception of uranium. K_d values for uranium were measured in soil from each of the hydrologic units and these values should be used in preference to literature values. For many contaminants there is a variation in measured K_d values of several orders of magnitude in the literature. The values used in the fate and transport modeling were often the geometric mean of a subset of the measured values, but these may not be the appropriate values to use for accurate modeling.

The soil–water partition coefficient strongly influences the predicted peak concentration and the time of the peak at receptor locations, the literature values are highly variable, and the values recommended by EPA in the soil screening guidance are very conservative in that they tend to lead to overpredictions of concentrations at receptor locations. To build reliable fate and transport models, it is necessary to have available more reliable and accurate site-specific partition coefficients. This can be accomplished by a combination of site-specific measurements and geochemical modeling.

Conceptually, this approach consists of measuring soil-water partition coefficients at several sites representative of the range of soil chemistry at PGDP. These values would then be used to *r*-calibrate a chemical reaction code such as MINTEQA2. The model would be used to estimate K_d values at contaminated sites with varying geochemistry.

There are several methods of measuring K_d values. Use of laboratory batch studies is the most common laboratory method for determining K_d values. A soil of known mass is added to a beaker. A known volume and concentration of an aqueous contaminant solution is added to the soil in the beaker. The beaker is sealed and mixed until sorption is estimated to be complete, typically 1 to 7 days. The solutions are centrifuged or filtered, and the remaining concentration of the contaminant in the supernatant is measured. The concentration of adsorbate sorbed on the solid phase and the soil–water partition coefficient are then computed from these results.

An alternative batch method is the in situ batch method developed to produce a K_d value for which the precise solution chemistry and solid-phase mineralogy is used for the modeling. A core sample containing a paired solid and aqueous phase is removed directly from an aquifer. The aqueous phase is separated from the solid phase by centrifugation or filtration, and then analyzed for the solute concentration. The solid is then analyzed for the concentration of the contaminant associated with the solid phase, and the K_d value is computed.

The second most common technique is the column method. A solution containing known amounts of a contaminant is introduced into a column of packed soil of known bulk density and porosity. The effluent concentration is monitored as a function of time. A known amount of a nonadsorbing tracer may also be introduced into the column, and its time-varying concentration provides information about the pore-water velocity. The resulting data are plotted as a breakthrough curve. The velocity of each constituent (i.e., tracer and contaminant) is calculated as the length of the column divided by the constituent's mean residence time. These data are used to compute a retardation factor and, hence, a partion coefficient.

Of these three techniques, the laboratory batch method is recommended because of its relatively low cost and the shorter time required for its application. The results will be reliable and greatly enhance the reliability of fate and transport modeling. Other approaches may be more appropriate for specific sites and contaminants.

Once a set of K_d values has been measured, these values can be used to calibrate and verify a geochemical model such as MINTEQA2. Such a model can predict K_d values given appropriate soil and geochemistry data. Once the model has been calibrated, it will be used to estimate K_d values at other contaminant sources.

Following the above recommendations will lead to consistent fate and transport modeling for the PGDP site that is more reliable and accurate than the screening level modeling done in the past.

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SUPPORTING DOCUMENTATION

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DESCRIPTION OF PGDP MODELING OF PARAMETER SUMMARY DATABASE

Eight tables imported from the spreadsheets MEPAS.xls, SESOIL.xls, RESRAD.xls, and SUMMERS.xls:

- MEPAS Const containing K_d and K_{oc} values used on MEPAS modeling,
- MEPAS Transport containing soil and aquifer properties used in MEPAS modeling,
- SESOIL Const containing K_d and K_{oc} values used on SESOIL modeling,
- SESOIL Transport containing soil and aquifer properties used in SESOIL modeling,
- RESRAD Const containing K_d and K_{oc} values used in RESRAD modeling,
- RESRAD Transport containing soil and aquifer properties used in RESRAD modeling,
- Summers Const containing K_d and K_{oc} values used in Summers modeling, and
- Summers Transport containing soil and aquifer properties used in Summers modeling.

The queries included are

- MEPAS transport variable,
- SESOIL transport variable,
- RESRAD transport variable, and
- SUMMERS transport variable,

which must be customized to extract the values of variables such as porosity, bulk density, fraction organic carbon (foc), etc. used in each of the models.

To extract the K_d and K_{oc} values used in all modeling efforts, use the queries

- MEPAS, SESOIL, RESRAD and SUMMERS K_d and K_{oc} ******

The one, two, and three chemical versions are designed to accommodate different spellings of the same modeled constituent. As an example, using the "two chemical" option and entering Tc*, and Tec* into the windows that appear will extract all the examples of K_d for ^{99}Tc listed as "Technetium and ^{99}Tc" but will not list thallium or thorium.

The source of K_d and K_{oc} values is often unclear. The original design was to denote by a letter code the source of these values. After going through the exercise, the conclusions below were reached.

- RI reports generally listed properties of organic chemicals including K_{oc}. These lists were often more extensive than the chemicals modeled in the investigation. Although the accepted practice is to use a K_d for organics computed from

$$K_d = foc * K_{oc},$$

where foc is the fraction of organic carbon in the soil, there were many cases in which a K_{oc}, a K_d, and an foc were listed and the above equation was not true. Calculated values of K_{oc} were computed from the above equation with K_d and foc known. The K_{oc} values listed were generally from

— the Risk Reduction Engineering Laboratory (RREL) Treatability Database (EPA 1994),
— EPA Soil Screening Guidance (EPA 1996),

— EPA's WATER 7 Database, and
— other standard references.

Many K_d values were from the MEPAS database, but the K_{oc} value was often not listed.

- K_d values for MEPAS modeling of inorganics were typically those in the MEPAS database. There is an algorithm available from the MEPAS distributors for adjusting the K_d values as a function of soil chemistry, but has not yet been made available.

- For other models the K_d values for inorganics were estimated from ranges listed in the following sources:

  — Shepard and Thibault 1990,
  — Baes and Sharp 1984,
  — Looney, Grant, and King 1987, and
  — EPA Soil Screening Guidance 1996

- The only site-specific values were those measured for uranium (DOE 1998c).

Table C8.2. Summary of transport parameters, inorganics

Contaminant	K_d Distribution (mL/g)		K_d Statistics (mL/g)	
Aluminum	Value	Frequency	Min	1500
	1500	9	Max	35300
All Values	3980	1	Number	20
	35300	10	Average	18524
Topsoil	Value	Frequency	Min	3980
	3980	1	Max	35300
	35300	2	Number	3
			Average	24860
UCRS	Value	Frequency	Min	1500
	1500	1	Max	35300
	35300	5	Number	6
			Average	29666.67
RGA	Value	Frequency	Min	1500
	1500	8	Max	35300
	35300	3	Number	11
			Average	10718.18
Americium	Value	Frequency	Min	82
All Values	82	7	Max	9600
	200	6	Number	20
	1000	4	Average	1343.7
	1900	1		
	9600	2		
Topsoil	Value	Frequency	Min	82
	82	1	Max	200
	200	1	Number	2
			Average	141
UCRS	Value	Frequency	Min	82
	82	4	Max	9600
	200	3	Number	13
	1000	4	Average	1856
	9600	2		
RGA	Value	Frequency	Min	82
	82	2	Max	1900
	200	1	Number	4
	1900	1	Average	566
Antimony	Value	Frequency	Min	2
All Values	2	1	Max	150
	6	2	Number	8
	45	4	Average	43
	150	1		
Topsoil	Value	Frequency	Min	2
	2	1	Max	2
			Number	1
			Average	2
UCRS	Value	Frequency	Min	6
	6	1	Max	150
	150	1	Number	2
			Average	78
RGA	Value	Frequency	Min	6
	6	1	Max	45
	45	4	Number	5
			Average	37.2

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Table C8.2. Summary of transport parameters, inorganics (continued)

Contaminant	K_d Distribution (mL/g)		K_d Statistics (mL/g)	
Arsenic	Value	Frequency	Min	5.86
All Values	5.86	4	Max	25
	19.4	8	Number	21
	25	9	Average	19.22095
Topsoil	Value	Frequency	Min	5.86
	5.86	1	Max	19.4
	19.4	1	Number	2
			Average	12.63
UCRS	Value	Frequency	Min	5.86
	5.86	2	Max	19.4
	19.4	6	Number	8
			Average	16.015
RGA	Value	Frequency	Min	5.86
	5.86	1	Max	25
	19.4	1	Number	11
	25	9	Average	22.75091
Barium	Value	Frequency	Min	0.5
All Values	0.5	8	Max	16000
	60	2	Number	17
	530	3	Average	2312.59
	2800	2		
	16000	2		
Topsoil	Value	Frequency	Min	2800
	2800	1	Max	2800
			Number	1
			Average	2800
UCRS	Value	Frequency	Min	60
	60	2	Max	16000
	530	2	Number	7
	2800	1	Average	5140
	16000	2		
RGA	Value	Frequency	Min	0.5
	0.5	8	Max	530
	530	1	Number	9
			Average	59.33333
Beryllium	Value	Frequency	Min	70
All Values	70	3	Max	8000
	650	9	Number	17
	800	1	Average	1509.41
	1400	2		
	8000	2		
Topsoil	Value	Frequency	Min	1400
	1400	1	Max	1400
			Number	1
			Average	1400
UCRS	Value	Frequency	Min	70
	70	2	Max	8000
	800	1	Number	6
	1400	1	Average	3056.667
	8000	2		
RGA	Value	Frequency	Min	70
	70	1	Max	650
	650	9	Number	10
			Average	592

Table C8.2. Summary of transport parameters, inorganics (continued)

Contaminant	K_d Distribution (mL/g)		K_d Statistics (mL/g)	
Cadmium	Value	Frequency	Min	14.9
All Values	14.9	3	Max	567
	40	2	Number	13
	80	4	Average	186.52
	423	2		
	567	2		
Topsoil	Value	Frequency	Min	423
	423	1	Max	423
			Number	1
			Average	423
UCRS	Value	Frequency	Min	14.9
	14.9	2	Max	567
	40	2	Number	7
	423	1	Average	238.1143
	567	2		
RGA	Value	Frequency	Min	14.9
	14.9	1	Max	80
	80	4	Number	5
			Average	66.98
Calcium	Value	Frequency	Min	25
All Values	25	4	Max	25
			Number	4
			Average	25
Topsoil				
UCRS				
RGA	Value	Frequency	Min	25
	25	4	Max	25
			Number	4
			Average	25
Cesium	Value	Frequency	Min	10
All Values	10	2	Max	4600.00
	249	4	Number	13
	280	5	Average	893.5385
	4600	2		
Topsoil	Value	Frequency	Min	10
	10	2	Max	10
			Number	2
			Average	10
UCRS	Value	Frequency	Min	249
	249	2	Max	4600
	4600	2	Number	4
			Average	2424.5
RGA	Value	Frequency	Min	249
	249	2	Max	280
	280	5	Number	7
			Average	271.1429
Chromium	Value	Frequency	Min	1
All Values	1	1	Max	3600
	10	1	Number	32
	16.8	3	Average	574.325
	30	2		
	35	9		
	56.5	4		
	168	2		
	360	2		

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Table C8.2. Summary of transport parameters, inorganics (continued)

Contaminant	K_d Distribution (mL/g)		K_d Statistics (mL/g)	
	565	4		
	3600	4		
Topsoil	Value	Frequency	Min	1
	1	1	Max	168
	10	1	Number	5
	56.5	1	Average	80.7
	168	2		
UCRS	Value	Frequency	Min	16.8
	16.8	2	Max	3600
	30	2	Number	13
	56.5	2	Average	1222.431
	360	2		
	565	1		
	3600	4		
RGA	Value	Frequency	Min	16.8
	16.8	1	Max	565
	35	9	Number	14
	56.5	1	Average	148.8071
	565	3		
Cobalt	Value	Frequency	Min	0.2
All Values	0.2	2	Max	1300
	1.94	2	Number	26
	8.81	6	Average	203.7362
	60	9		
	200	4		
	1300	3		
Topsoil	Value	Frequency	Min	0.2
	0.2	2	Max	1.94
	1.94	2	Number	4
			Average	1.07
UCRS	Value	Frequency	Min	8.81
	8.81	2	Max	1300
	200	4	Number	9
	1300	3	Average	524.18
RGA	Value	Frequency	Min	8.81
	8.81	4	Max	60
	60	9	Number	13
			Average	44.24923
Copper	Value	Frequency	Min	4.19
All Values	4.19	2	Max	336
	22	4	Number	20
	35	2	Average	107.369
	41.9	2		
	92.2	6		
	336	4		
Topsoil	Value	Frequency	Min	4.19
	4.19	2	Max	41.9
	41.9	2	Number	4
			Average	23.045
UCRS	Value	Frequency	Min	35
	35	2	Max	336
	92.2	2	Number	8
	336	4	Average	199.8

Table C8.2. Summary of transport parameters, inorganics (continued)

Contaminant	K_d Distribution (mL/g)		K_d Statistics (mL/g)	
RGA	Value	Frequency	Min	22
	22	4	Max	92.2
	92.2	4	Number	8
			Average	57.1
Iron	Value	Frequency	Min	10
All Values	10	2	Max	800
	15	12	Number	24
	220	9	Average	124.1667
	800	1		
Topsoil	Value	Frequency	Min	10
	10	2	Max	15
	15	2	Number	4
			Average	12.5
UCRS	Value	Frequency	Min	15
	15	6	Max	800
	800	1	Number	7
			Average	127.1429
RGA	Value	Frequency	Min	15
	15	4	Max	220
	220	9	Number	13
			Average	156.9231
Lead	Value	Frequency	Min	10
All Values	10	1	Max	16000
	234	5	Number	28.00
	270	9	Average	1220.429
	597	6		
	1830	6		
	16000	1		
Topsoil	Value	Frequency	Min	10
	10	1	Max	234
	234	2	Number	3
			Average	159.3333
UCRS	Value	Frequency	Min	234
	234	2	Max	16000
	597	2	Number	11
	1830	6	Average	2603.818
	16000	1		
RGA	Value	Frequency	Min	234
	234	1	Max	597
	270	9	Number	13
	597	3	Average	342.6923
Lithium	Value	Frequency	Min	0
All Values	0	1	Max	0.2
	0.2	2	Number	3
			Average	0.13
Topsoil	Value	Frequency	Min	0
	0	1	Max	0
			Number	1
			Average	0
UCRS	Value	Frequency	Min	0.2
	0.2	1	Max	0.2
			Number	1
			Average	0.2

Table C8.2. Summary of transport parameters, inorganics (continued)

Contaminant	K_d Distribution (mL/g)		K_d Statistics (mL/g)	
RGA	Value	Frequency	Min	0.2
	0.2	1	Max	0.2
			Number	1
			Average	0.2
Magnesium	Value	Frequency	Min	1.6
All values	1.6	4	Max	1.6
			Number	4
			Average	1.6
Topsoil				
UCRS				
RGA	Value	Frequency	Min	1.6
	1.6	4	Max	1.6
			Number	4
			Average	1.6
Manganese	Value	Frequency	Min	1.5
All Values	1.5	2	Max	750
	16.5	5	Number	32
	25.3	8	Average	76.85313
	36.9	6		
	50	9		
	750	2		
Topsoil	Value	Frequency	Min	1.5
	1.5	2	Max	25.3
	16.5	2	Number	5
	25.3	1	Average	12.26
UCRS	Value	Frequency	Min	16.5
	16.5	2	Max	750
	25.3	3	Number	13
	36.9	6	Average	140.7923
	750	2		
RGA	Value	Frequency	Min	16.5
	16.5	1	Max	50
	25.3	4	Number	14
	50	9	Average	40.55
Mercury	Value	Frequency	Min	10
All Values	10	2	Max	82
	82	8	Number	10
			Average	67.60
Topsoil				
UCRS	Value	Frequency	Min	10
	10	2	Max	10
			Number	2
			Average	10
RGA	Value	Frequency	Min	82
	82	8	Max	82
			Number	8
			Average	82
Molybdenum	Value	Frequency	Min	125
All Values	125	1	Max	125
			Number	1
			Average	125
Topsoil				
UCRS	Value	Frequency	Min	125
	125	1	Max	125
			Number	1

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Table C8.2. Summary of transport parameters, inorganics (continued)

Contaminant	K_d Distribution (mL/g)		K_d Statistics (mL/g)	
			Average	125
RGA				
Neptunium	Value	Frequency	Min	3
All Values	3	28	Max	25
	5	5	Number	37.00
	25	4	Average	5.648649
Topsoil	Value	Frequency	Min	3
	3	5	Max	3
			Number	5
			Average	3
UCRS	Value	Frequency	Min	3
	3	16	Max	25
	25	4	Number	20
			Average	7.4
RGA	Value	Frequency	Min	3
	3	6	Max	5
	5	5	Number	11
			Average	3.909091
Nickel	Value	Frequency	Min	1.2
All Values	1.2	2	Max	650
	12.2	3	Number	23.00
	58.6	6	Average	243.0696
	300	1		
	400	9		
	650	2		
Topsoil	Value	Frequency	Min	1.2
	1.2	2	Max	58.6
	58.6	1	Number	3
			Average	20.33333
UCRS	Value	Frequency	Min	12.2
	12.2	2	Max	650
	58.6	3	Number	8
	300	1	Average	225.025
	650	2		
RGA	Value	Frequency	Min	12.2
	12.2	1	Max	400
	58.6	2	Number	12
	400	9	Average	310.7833
Protactinium	Value	Frequency	Min	0
All Values	0	3	Max	500
	50	2	Number	7.00
	500	2	Average	157.1429
Topsoil				
UCRS	Value	Frequency	Min	0
	0	2	Max	500
	50	1	Number	5
	500	2	Average	210
RGA	Value	Frequency	Min	0
	0	1	Max	0
			Number	1
			Average	0
Plutonium	Value	Frequency	Min	0
All Values	0	3	Max	1200
	4	2	Number	33
	10	6	Average	196

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Table C8.2. Summary of transport parameters, inorganics (continued)

Contaminant	K_d Distribution (mL/g)		K_d Statistics (mL/g)	
	50	2		
	100	9		
	250	4		
	500.00	2		
	550	4		
	1200	1		
Topsoil	Value	Frequency	Min	4
	4	2	Max	100
	50	1	Number	4
	100	1	Average	39.5
UCRS	Value	Frequency	Min	0
	0	2	Max	1200
	10	4	Number	18
	50	1	Average	205
	100	4		
	250	4		
	500	2		
	1200	1		
RGA	Value	Frequency	Min	0
	0	1	Max	550
	10	2	Number	10
	100	3	Average	252
	550	4		
Potassium	Value	Frequency	Min	15
All Values	15	4	Max	15
			Number	4
			Average	15
Topsoil				
UCRS				
RGA	Value	Frequency	Min	15
	15	4	Max	15
			Number	4
			Average	15
Radium	Value	Frequency	Min	2.43
All Values	2.43	1	Max	36000
	24.3	5	Number	22.00
	100	6	Average	4998.542
	124	6		
	500	1		
	36000	3		
Topsoil	Value	Frequency	Min	2.43
	2.43	1	Max	24.3
	24.3	2	Number	3
			Average	17.01
UCRS	Value	Frequency	Min	24.3
	24.3	2	Max	36000
	100	2	Number	13
	124	6	Average	8384.046
	36000	3		
RGA	Value	Frequency	Min	24.3
	24.3	1	Max	500
	100	3	Number	5
	500	1	Average	164.86

Table C8.2. Summary of transport parameters, inorganics (continued)

Contaminant	K_d Distribution (mL/g)		K_d Statistics (mL/g)	
Radon	Value	Frequency	Min	0
All Values	0	8	Max	0
			Number	8
			Average	0
Topsoil	Value	Frequency	Min	0
	0	2	Max	0
			Number	2
			Average	0
UCRS	Value	Frequency	Min	0
	0	4	Max	0
			Number	4
			Average	0
RGA	Value	Frequency	Min	0
	0	2	Max	0
			Number	2
			Average	0
Selenium	Value	Frequency	Min	150
All values	150	4	Max	500
	500	2	Number	6
			Average	266.67
Topsoil				
UCRS	Value	Frequency	Min	500
	500	2	Max	500
			Number	2
			Average	500
RGA	Value	Frequency	Min	150
	150	4	Max	150
			Number	4
			Average	150
Silver	Value	Frequency	Min	0.4
All Values	0.4	4	Max	120
	4	4	Number	17
	40	2	Average	46.33
	90	5		
	120	2		
Topsoil	Value	Frequency	Min	0.4
	0.4	1	Max	4
	4	1	Number	2
			Average	2.2
UCRS	Value	Frequency	Min	0.4
	0.4	2	Max	120
	4	2	Number	8
	40	2	Average	41.1
	120	2		
RGA	Value	Frequency	Min	0.4
	0.4	1	Max	90
	4	1	Number	7
	90	5	Average	64.91428
Strontium	Value	Frequency	Min	2.34
All Values	2.34	1	Max	100
	100	2	Number	3
			Average	67.45
Topsoil	Value	Frequency	Min	2.34
	2.34	1	Max	2.34
			Number	1
			Average	2.34

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Table C8.2. Summary of transport parameters, inorganics (continued)

Contaminant	K_d Distribution (mL/g)		K_d Statistics (mL/g)	
UCRS	Value	Frequency	Min	100
	100	1	Max	100
			Number	1
			Average	100
RGA	Value	Frequency	Min	100
	100	1	Max	100
			Number	1
			Average	100
Tc-99	Value	Frequency	Min	0.1
All Values	0.1	14	Max	20
	1	8	Number	39
	3	7	Average	5.907692
	20	10		
Topsoil	Value	Frequency	Min	1
	1	3	Max	20
	3	1	Number	5
	20	1	Average	5.2
UCRS	Value	Frequency	Min	0.1
	0.1	2	Max	20
	1	5	Number	18
	3	4	Average	8.733334
	20	7		
RGA	Value	Frequency	Min	0.1
	0.1	12	Max	20
	3	2	Number	15
	20	1	Average	1.813333
Thallium	Value	Frequency	Min	0.00
All values	0	4	Max	1500
	0.2	4	Number	16
	0.8	2	Average	117.03
	74	5		
	1500	1		
Topsoil	Value	Frequency	Min	0
	0	1	Max	0.2
	0.2	1	Number	2
			Average	0.1
UCRS	Value	Frequency	Min	0
	0	2	Max	1500
	0.2	2	Number	7
	0.8	2	Average	214.5714
	1500	1		
RGA	Value	Frequency	Min	0
	0	1	Max	74
	0.2	1	Number	7
	74	5	Average	52.88572
Thorium	Value	Frequency	Min	40
All Values	40	3	Max	5800
	100	14	Number	54
	500	16	Average	1650.37
	2700	12		
	3300	2		
	5800	7		
Topsoil	Value	Frequency	Min	40
	40	3	Max	500
	100	2	Number	7
	500	2	Average	188.5714

Table C8.2. Summary of transport parameters, inorganics (continued)

Contaminant	K_d Distribution (mL/g)		K_d Statistics (mL/g)	
UCRS	Value	Frequency	Min	100
	100	8	Max	3300
	500	7	Number	29
	2700	12	Average	1493.103
	3300	2		
RGA	Value	Frequency	Min	100
	100	4	Max	5800
	500	5	Number	16
	5800	7	Average	2718.75
Tin	Value	Frequency	Min	450
All Values	450	2	Max	450
			Number	2
			Average	450
Topsoil				
UCRS	Value	Frequency	Min	450
	450	2	Max	450
			Number	2
			Average	450
RGA				
Uranium	Value	Frequency	Min	0
All Values	0	9	Max	3640
	35	26	Number	119
	50	16	Average	615.6381
	62.98	3		
	66.8	5		
	243	6		
	253	18		
	500	4		
	906	6		
	1170	10		
	1580	6		
	3640	10		
Topsoil	Value	Frequency	Min	0
	0	9	Max	253
	243	3	Number	13
	253	1	Average	75.53846
UCRS	Value	Frequency	Min	50
	50	7	Max	3640
	243	3	Number	59
	253	13	Average	1176
	500	4		
	906	6		
	1170	10		
	1580	6		
	3640	10		
RGA	Value	Frequency	Min	35
	35	26	Max	66.8
	50	9	Number	43
	62.98	3	Average	43.7893
	66.8	5		
Vanadium	Value	Frequency	Min	50
All Values	50	3	Max	1000
	100	4	Number	17.00
	1000	10	Average	620.5883

Table C8.2. Summary of transport parameters, inorganics (continued)

Contaminant	K_d Distribution (mL/g)		K_d Statistics (mL/g)	
Topsoil	Value	Frequency	Min	100
	100	1	Max	100
			Number	1
			Average	100
UCRS	Value	Frequency	Min	50
	50	2	Max	1000
	100	3	Number	7
	1000	2	Average	342.8571
RGA	Value	Frequency	Min	50
	50	1	Max	1000
	1000	8	Number	9
			Average	894.4445
Zinc	Value	Frequency	Min	3
All Values	3	1	Max	1300.00
	200	8	Number	13
	939	2	Average	467.7692
	1300	2		
Topsoil	Value	Frequency	Min	3
	3	1	Max	3
			Number	1
			Average	3
UCRS	Value	Frequency	Min	939
	939	1	Max	1300
	1300	2	Number	3
			Average	1179.667
RGA	Value	Frequency	Min	200
	200	8	Max	939
	939	1	Number	9
			Average	282.1111

Table C8.3. Summary of transport parameters, organics

Contaminant	K_d Distribution		K_d Statistics		K_{oc} Distribution		K_{oc} Statistics	
1,1-DCE	Value	Frequency	Min	0.1	Value	Frequency	Min	65
	0.1	8	Max	0.169	65	9	Max	65
All Values	0.169	1	Number	9			Number	9
			Average	0.11			Average	65
Topsoil								
UCRS	Value	Frequency	Min	0.169	Value	Frequency	Min	65
	0.169	1	Max	0.169	65	1	Max	65
			Number	1			Number	1
			Average	0.169			Average	65
RGA	Value	Frequency	Min	0.1	Value	Frequency	Min	65
	0.1	8	Max	0.1	65	8	Max	65
			Number	8			Number	8
			Average	0.1			Average	65
1,2-DCE	Value	Frequency	Min	0.02	Value	Frequency	Min	77.5
	0.016	1	Max	0.202	77.5	2	Max	126.5
All Values	0.0253	1	Number	6	80	1	Number	6
	0.0432	1	Average	0.09	86.4	1	Average	94.31667
	0.059	1			118	1		
	0.202	2			126.5	1		
Topsoil	Value	Frequency	Min	0.0432	Value	Frequency	Min	86.4
	0.0432	1	Max	0.0432	86.4	1	Max	86.4
			Number	1			Number	1
			Average	0.0432			Average	86.4
UCRS	Value	Frequency	Min	0.059	Value	Frequency	Min	77.5
	0.059	1	Max	0.202	77.5	2	Max	118
	0.202	2	Number	3	118	1	Number	3
			Average	0.15433			Average	91
RGA	Value	Frequency	Min	0.0253	Value	Frequency	Min	126.5
	0.0253	1	Max	0.0253	126.5	1	Max	126.5
			Number	1			Number	1
			Average	0.0253			Average	126.5
Aroclor-1254	Value	Frequency	Min	328	Value	Frequency	Min	395000
All Values	328	1	Max	26300	395000	2	Max	1.32E+08
	395	2	Number	9	1093333	1	Number	9
	4020	2	Average	8322	4020000	2	Average	42377593
	6360	1			8475000	1		
	6780	1			1.32E+08	1		
	26300	2			1.00E+08	1		
					1.32E+08	1		
Topsoil	Value	Frequency	Min	4020	Value	Frequency	Min	4020000
	4020	1	Max	4020	4020000	1	Max	4020000
			Number	1			Number	1
			Average	4020			Average	4020000
UCRS	Value	Frequency	Min	395	Value	Frequency	Min	395000
	395	2	Max	6780	395000	2	Max	9085714
	4020	1	Number	5	4020000	1	Number	5
	6360	1	Average	3590	8475000	1	Average	4474143
	6780	1			9085714	1		
RGA	Value	Frequency	Min	328	Value	Frequency	Min	1093333
	328	1	Max	26300	1093333	1	Max	1.32E+08
	26300	1	Number	2	1.32E+08	1	Number	2
			Average	13314			Average	66296667

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Table C8.3. Summary of transport parameters, organics (continued)

Contaminant	K_d Distribution		K_d Statistics		K_{oc} Distribution		K_{oc} Statistics	
Benzene	Value	Frequency	Min	0.161	Value	Frequency	Min	62
All Values	0.161	2	Max	0.161	62	2	Max	62
			Number	2			Number	2
			Average	0.161			Average	62
Topsoil								
UCRS	Value	Frequency	Min	0.161	Value	Frequency	Min	62
	0.161	2	Max	0.161	62	2	Max	62
			Number	2			Number	2
			Average	0.161			Average	62
RGA								
Carbon Tet	Value	Frequency	Min	0.1	Value	Frequency	Min	152
All Values	0.1	4	Max	3.09	152	4	Max	6600
	1.32	1	Number	7	4520	1	Number	7
	2.26	1	Average	1.01	6180	1	Average	2558.286
	3.09	1			6600	1		
Topsoil	Value	Frequency	Min	2.26	Value	Frequency	Min	4520
	2.26	1	Max	2.26	4520	1	Max	4520
			Number	1			Number	1
			Average	2.26			Average	4520
UCRS	Value	Frequency	Min	3.09	Value	Frequency	Min	6180
	3.09	1	Max	3.09	6180	1	Max	6180
			Number	1			Number	1
			Average	3.09			Average	6180
RGA	Value	Frequency	Min	0.1	Value	Frequency	Min	152
	0.1	4	Max	1.32	152	4	Max	6600
	1.32	1	Number	5	6600	1	Number	5
			Average	0.344			Average	1441.6
Chloroform	Value	Frequency	Min	0.04	Value	Frequency	Min	53
All Values	0.04	4	Max	0.04	53	4	Max	53
			Number	4			Number	4
			Average	0.04			Average	53
Topsoil								
UCRS								
RGA	Value	Frequency	Min	0.04	Value	Frequency	Min	53
	0.04	4	Max	0.04	53	4	Max	53
			Number	4			Number	4
			Average	0.04			Average	53
Cis-1,2-DCE	Value	Frequency	Min	0	Value	Frequency	Min	0
All Values	0	1	Max	0.092	0	1	Max	35.5
	0.03	8	Number	11	35.5	10	Number	11
	0.092	2	Average	0.03855			Average	32.27273
Topsoil								
UCRS	Value	Frequency	Min	0.092	Value	Frequency	Min	35.5
	0.092	2	Max	0.092	35.5	2	Max	35.5
			Number	2			Number	2
			Average	0.092			Average	35.5
RGA	Value	Frequency	Min	0	Value	Frequency	Min	0
	0	1	Max	0.03	0	1	Max	35.5
	0.03	8	Number	9	35.5	8	Number	9
			Average	0.02667			Average	31.55556
Naphthalene	Value	Frequency	Value	Frequency				
All Values	3.1	1	1190	1				
Topsoil								
UCRS	Value	Frequency	Value	Frequency				
	3.1	1	1190	1				
RGA								

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Table C8.3. Summary of transport parameters, organics (continued)

Contaminant	K_d Distribution		K_d Statistics		K_{oc} Distribution		K_{oc} Statistics	
Np237	Value	Frequency	Min	3				
All Values	3	28	Max	25				
	5	5	Number	37				
	25	4	Average	5.64865				
Topsoil	Value	Frequency	Min	3				
	3	5	Max	3				
			Number	5				
			Average	3				
UCRS	Value	Frequency	Min	3				
	3	16	Max	25				
	25	4	Number	20				
			Average	7.4				
RGA	Value	Frequency	Min	3				
	3	6	Max	5				
	5	5	Number	11				
			Average	3.90909				
Pentachlorophenol	Value	Frequency	Min	1.54	Value	Frequency	Min	592
All Values	1.54	1	Max	715	592	1	Max	1430000
	140	3	Number	12	476000	3	Number	12
	238	3	Average	315.128	652000	1	Average	735049.3
	326	1			700000	3		
	445	2			890000	2		
	715	2			1430000	2		
Topsoil	Value	Frequency	Min	238	Value	Frequency	Min	476000
	238	3	Max	238	476000	3	Max	476000
			Number	3			Number	3
			Average	238			Average	476000
UCRS	Value	Frequency	Min	1.54	Value	Frequency	Min	592
	1.54	1	Max	715	592	1	Max	1430000
	326	1	Number	6	652000	1	Number	6
	445	2	Average	441.257	890000	2	Average	882098.7
	715	2			1430000	2		
RGA	Value	Frequency	Min	140	Value	Frequency	Min	700000
	140	3	Max	140	700000	3	Max	700000
			Number	3			Number	3
			Average	140			Average	700000
TCE	Value	Frequency	Min	0	Value	Frequency	Min	0
All Values	0	1	Max	1.61	0	1	Max	2157.143
	0.0428	1	Number	25	94	12	Number	25
	0.0779	1	Average	0.399	214	1	Average	654.7724
	0.094	2			259.6667	1		
	0.1	8			955	2		
	0.244	1			1134	2		
	0.24	1			1550	2		
	0.332	2			1660	2		
	0.567	2			2012.5	1		
	0.77	2			2157.143	1		
	0.955	2						
	1.51	1						
	1.61	1						
Topsoil	Value	Frequency	Min	0.567	Value	Frequency	Min	955
	0.567	2	Max	0.955	955	1	Max	1134
	0.955	1	Number	3	1134	2	Number	3
			Average	0.69633			Average	1074.333

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Table C8.3. Summary of transport parameters, organics (continued)

Contaminant	K_d Distribution		K_d Statistics		K_{oc} Distribution		K_{oc} Statistics	
UCRS	Value	Frequency	Min	0.094	Value	Frequency	Min	94
	0.094	2	Max	1.61	94	4	Max	2157.143
	0.244	1	Number	9	955	1	Number	9
	0.2444	1	Average	0.70016	1550	2	Average	955.627
	0.775	2			2012.5	1		
	0.955	1			2157.143	1		
	1.51	1						
	1.61	1						
RGA	Value	Frequency	Min	0	Value	Frequency	Min	0
	0	1	Max	0.332	0	1	Max	1660
	0.0428	1	Number	13	94	8	Number	13
	0.0779	1	Average	0.1219	214	1	Average	349.6667
	0.1	8			259.6667	1		
	0.332	2			1660	2		
Trans-1,2-DCE	Value	Frequency	Min	0	Value	Frequency	Min	0
All Values	0	1	Max	0.115	0	1	Max	164.2857
	0.0059	1	Number	18	7	2	Number	18
	0.007	2	Average	0.03558	15	1	Average	36.03069
	0.012	1			19.66667	1		
	0.0278	2			27.8	2		
	0.03	8			38	10		
	0.1	2			164.2857	1		
	0.115	1						
Topsoil	Value	Frequency	Min	0.0278	Value	Frequency	Min	27.8
	0.0278	1	Max	0.0278	27.8	1	Max	27.8
			Number	1			Number	1
			Average	0.0278			Average	27.8
UCRS	Value	Frequency	Min	0.007	Value	Frequency	Min	7
	0.007	2	Max	0.115	7	2	Max	164.2857
	0.012	1	Number	7	15	1	Number	7
	0.0278	1	Average	0.0524	27.8	1	Average	42.44082
	0.099	2			38	2		
	0.115	1			164.2857	1		
RGA	Value	Frequency	Min	0	Value	Frequency	Min	0
	0	1	Max	0.03	0	1	Max	38
	0.0059	1	Number	10	19.66667	1	Number	10
	0.03	8	Average	0.02459	38	8	Average	32.36667
Vinyl Chloride	Value	Frequency	Min	0	Value	Frequency	Min	0
All Values	0	4	Max	0.729	0	1	Max	978.5714
	0.002	5	Number	21	2.51	8	Number	21
	0.0352	1	Average	0.15525	18.6	2	Average	236.9255
	0.0425	2			42.5	2		
	0.048	2			117.3333	1		
	0.15	1			432	2		
	0.256	1			512	1		
	0.35	1			700	1		
	0.432	2			750	1		
	0.685	1			911.25	1		
	0.729	1			978.5714	1		
Topsoil	Value	Frequency	Min	0.256	Value	Frequency	Min	432
	0.256	1	Max	0.432	432	1	Max	512
	0.432	1	Number	2	512	1	Number	2
			Average	0.344			Average	472

Table C8.3. Summary of transport parameters, organics (continued)

Contaminant	K_d Distribution		K_d Statistics		K_{oc} Distribution		K_{oc} Statistics	
UCRS	Value	Frequency	Min	0.0425	Value	Frequency	Min	18.6
	0.0425	2	Max	0.729	18.6	2	Max	978.5714
	0.048	2	Number	8	42.5	2	Number	8
	0.35	1	Average	0.29712	432	1	Average	393.0027
	0.432	1			700	1		
	0.685	1			911.25	1		
	0.729	1			978.5714	1		
RGA	Value	Frequency	Min	0	Value	Frequency	Min	0
	0	4	Max	0.15	0	1	Max	750
	0.002	5	Number	11	2.51	8	Number	11
	0.0352	1	Average	0.01775	117.3333	1	Average	80.67394
	0.15	1			750	1		

K_{oc} and K_d values are reported in mL/g.

Table C8.4. Recommended K_d values, inorganics

Analyte	Sand	Loam	UCRS	RGA	Comments
					Model Data[a]
Aluminum	1500	1500	1500.0	1500	
Antimony	6	45	25.5	6	
Arsenic	5.86	25	15.4	5.86	
Barium	60	16000	8030.0	60	
Beryllium	650	8000	4325.0	650	
Cadmium	40	567	303.5	40	
Calcium	25	25	25.0	25	
Chromium	35	360	197.5	35	
Copper	22	35	28.5	22	
Iron	15	220	117.5	15	
Lead	270	1830	1050.0	270	
Lithium	0.2	0.2	0.2	0.2	
Magnesium	1.6	1.6	1.6	1.6	
Manganese	16.5	50	33.3	16.5	
Mercury	10	82	46.0	10	
Molybdenum	125	125	125.0	125	
Nickel	12.2	400	206.1	12.2	
Potassium	15	15	15.0	15	
Selenium	150	500	325.0	150	
Silver	4	40	22.0	4	
Thallium	0.8	74	37.4	0.8	
Tin	450	450	450.0	450	
Vanadium	50	1000	525.0	50	
Zinc	200	1300	750.0	200	
Radioisotopes					
Americium	82	1000	541.0	82	
Cesium	249	4600	2424.5	249	
Cobalt	8.71	200	104.4	8.71	
Neptunium	3	25	14.0	3	
Protactinium	50	500	275.0	50	
Plutonium	10	250	130.0	10	
Radium	24.3	124	74.2	24.3	
Strontium	100	100	100.0	100	
Technetium	0.1	3	1.6	0.1	
Thorium	100	2700	1400.0	100	
Uranium	35	253	144.0	35	
					Rationale Source[b]
Aluminum	15.9	1500			Only 2 sources - took a low and a high value.
Antimony	45	150			Low value from S&T, B&S and SSG and Loam from S&T although MEPAS sometimes uses 2 and 6
Arsenic	5.86	27			5.86 from Batelle, 27 from SSG modeling.
Barium	30	60			SSG gives 30. 60 from B&S, could also use 530 from Batelle
Beryllium	82	800			82 from SSG. 800 in loam from S&T but number is based on CR in plants
Cadmium	37	40			37 from SSG. 40 from T&S loam
Calcium	5	30			Usually not modeled. From S&T
Chromium	16.8	30			16.8 common in modeling - 30 from S&T loam
Copper	22	35			22 from models - 35 from B&S
Iron	220	800			From S&T sand and loam
Lead	270	1830			270 from models and S&T - 1830 from models
Lithium	?	?			
Magnesium	1.6	4.5			1.6 from models - 4.5 from B&S

Table C8.4. Recommended K_d values, inorganics (continued)

Analyte	Sand	Loam	UCRS	RGA	Comments
Manganese	50	750			50 from modeling and S&T - 750 from S&T loam
Mercury	3.5	82			3.5 from SSG - 82 from modeling
Molybdenum	10	125			Both from S&T - 125 only number used in modeling
Nickel	38	300			38 from SSG - 300 from T&S loam
Potassium	15	55			Usually not modeled - Values from S&T using CR technique - 15 is ony number used in modeling
Selenium	8.6	150			8.6 from SSG - 150 from T&S and modeling
Silver	1.3	120			1.3 from SSG - 120 from S&T
Thallium	58	1500			58 from SSG - 1500 from B&S
Tin	100	450			100 from Looney - 450 from T&S with CR technique
Vanadium	50	1000			50 from modeling and Batelle - 1000 from SSG
Zinc	36	1300			36 from SSG - 1300 from T&S loam
					Radioisotopes
Americium	82	700			82 from modeling - 700 from B&S
Cesium	30	500			30 from SSG - 500 from S&T sand
Cobalt	60	550			60 from T&S sand - 550 from T&S clay
Neptunium	3	25			3 from modeling - 25 from T&S loam
Protactinium	50	500			both from modeling - S&T data from CR technique not used
Plutonium	80	250			80 from SSG - 250 from modeling
Radium	24.3	1262			24.3 from modeling - 1262 from min S&T loam value
Strontium	15	20			15 from SSG - 20 from S&T loam
Technetium	0.1	1			.1 from modeling and S&T - 1 from modeling
Thorium	1700	2700			1700 from SSG - 2700 from modeling
Uranium	253	1170			100 from SSG - 1170 from modeling

[a] Almost without exception K_d should be different in UCRS and RGA
Assume UCRS half sand half loam
So that K_d of UCRS = Average of Sand and Loam values
[b] In general a low value for sand and a medium to moderately high value for loam is suggested.

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Table C8.5. Recommended model parameters for organics

Constituents	Mol. wt. (g/mol)	Solubility S_w (mg/L)	S_w @ temp. (°C)	KOW (ml/ml)	Vapor pressure (tor @ °C)	Henry's constant (K_h) (atm.m^3/mol)	K_h @ temp. (°C)	Air Diff. coeff. (cm^2/s)		KOC (ml/g)		l (1/d)	Log (KOW)	
						pH=6 for Ionizing Organics				Biodegradation rate,				
					Volatile Organics[a]									
1,1-Dichloroethane	99	5.06E+03		6.17E+01	234 @25	5.62E-03	25	0.0742		5.34E+01	m	1.13E-03	1.79	
1,1 Dichloroethene	96.9	2.25E+03	25	1.35E+02	591@ 25	2.61E-02	25	0.090	s	6.50E+01	m	3.85E-03	2.13	
1,1,1 Trichloroethane	133.4	1.33E+03	20	3.02E+02	100 @ 20	1.72E-02	25	0.078	s	1.35E+02	m	6.35E-04	2.48	
1,1,2 Trichloroethane	133.4	4.42E+03	20	1.12E+02	30@25	9.13E-04	25#	0.078	#	7.50E+01	m	4.75E-04	2.05	
1,1,2-Trichloro-1,22,-trifluoroethene	187.4	1.70E+02		1.05E+03		3.96E-01	23*	0.078	t	6.57E+02		4.81E-04	3.02	*
1,2-Dichloroethane	99.0	8.52E+03		2.95E+01		9.79E-04		0.104		3.80E+01	m	9.63E-04	1.47	
1,2 Dichloroethene	96.9	8.00E+02	#	1.23E+02	200 #	6.60E-03	ssc	0.009		7.75E+01		2.41E-04	2.09	*
cis-1,2-Dichloroethene	96.9	3.50E+03		7.24E+01		4.08E-03		0.074		3.55E+01			1.86	
trans-1,2-Dichloroethene	96.9	6.30E+03		1.17E+02		9.38E-03		0.071		3.80E+01	m		2.07	
1,1,2-Trichloro-1,22,-trifluoroethene	187.4	1.70E+02	25#	1.04E+03		3.96E-01	25*	0.078	t	6.57E+02		4.81E-04	3.02	*
1,2-Dichlorobenzene	147.0	1.56E+02	25	2.69E+03		1.90E-03	25	0.069		3.79E+02	m	9.63E-04	3.43	
1,3-Dichlorobenzene	147.0	1.23E+02	25	2.40E+03		2.63E-03	25	0.069	t	1.51E+03		9.63E-04	3.38	
1,4-Dichlorobenzene	147.0	7.38E+01	25	2.63E+03	1.18 L	2.43E-03	25	0.069	t	6.16E+02	m	9.63E-04	3.42	
2-Butanone	72.1	2.75E+05		1.82E+00	100 @ 25	6.61E-07	25#	0.092	s	1.15E+00		2.48E-02	0.26	
2-Hexanone	100.2	3.50E+04	20	2.40E+01	2 @ 20	7.53E-06	20	0.078		1.51E+01			1.38	
4-Methyl-2-pentanone	100.2	1.91E+04		5.25E+00	10 @ 30	1.03E-06	25#	0.078		3.31E+00		2.48E-02	0.72	
Acetone	58.1	1.00E+06		5.75E-01	270 @ 30	3.88E-05	25#	0.124	s	5.75E-01		2.48E-02	-0.24	
Benzene	78.1	1.75E+03	20	1.35E+02	95 @ 25	5.55E-03	25	0.088	s	6.17E+01	m	9.63E-04	2.13	
Bromomethane	94.9	1.75E+04	20	1.26E+01	1420 @ 20	1.53E-04	25#	0.110	s	7.93E+00		6.19E-03	1.10	
Carbon disulfide	76.1	1.19E+03	20	1.00E+02	298 @ 20	3.03E-02	25#	0.104	s	4.57E+01			2.00	
Carbon Tetrachloride	153.8	7.93E+02	20	5.37E+02	113 @ 25	3.04E-02	25	0.078	s	1.52E+02	m	1.93E-03	2.73	
Chlorobenzene	112.6	4.72E+02	25	7.24E+02	11.8 @ 25	3.70E-03	25	0.073	s	2.24E+02	m	1.16E-03	2.86	
Chloroform	119.4	7.92E+03	25	8.32E+01	160 @ 20	3.67E-03	25	0.104	s	5.25E+01	m	3.85E-04	1.92	
Chloroethane	64.5	5.74E+03	20	2.69E+01	2660 @ 25	1.11E-02	24.8	0.107	s	1.70E+01		6.19E-03	1.43	
Chloromethane	50.5	6.36E+03	20	8.13E+00	3800 @ 20	8.82E-03	25	0.110	s	5.12E+00		6.19E-03	0.91	
Cyanide	27.0	1.00E+06		2.24E+00		2.98E-06	25#	0.173	#	1.41E+00		1.03E-03	0.35	
Dimethylbenzene	106.2	2.00E+02		5.89E+02	5 @ 20	5.25E-03	25	0.073	s	2.71E+02		1.93E-03	2.77	
Ethylbenzene	106.2	1.69E+02	20	1.38E+03	10 @ 25.9	7.88E-03	25	0.075	t	2.04E+02	m	3.04E-03	3.14	
Methylene chloride	84.9	1.30E+04	25	1.78E+01	429 @ 25	2.19E-03	25	0.101	s	1.00E+01	m	6.19E-03	1.25	
Styrene	104.1	3.10E+02	20	8.71E+02	5 @ 20	2.75E-03		0.071		9.12E+02	m	3.30E-03	2.94	
Tetrachloroethene	165.8	2.00E+02	25	4.68E+02	19 @ 25	1.84E-02	25	0.072	s	2.65E+02	m	4.19E-04	2.67	
Toluene	92.1	5.26E+02	20	5.62E+02	28 @ 25	6.64E-03	25	0.087	t	1.40E+02	m	3.30E-03	2.75	
Trans-1,3-Dichloropropene	111	2.80E+03		1.12E+02	34 @ -	1.80E-03		0.08		7.08E+01			2.05	
Trichloroethene	131.4	1.10E+03	25	5.13E+02	77 @ 25	1.03E-02	25	0.079	s	9.43E+01	m	4.19E-04	2.71	
Vinyl Acetate	86.1	2.00E+04		5.37E+00		5.11E-04		0.085	t	5.25E+00			0.73	*
Vinyl Chloride	62.5	2.76E+03	25	3.16E+01		2.70E-02	25	0.106	s	1.86E+01		2.41E-04	1.50	
Xylene	106.2	2.00E+02		5.89E+02	5 @ 20	5.25E-03	25	0.073	s	1.96E+02	m	1.93E-03	2.77	
					Semi-volatile Organics									
1,2,4-Trichlorobenzene	181.46	3.00E+02	22	1.02E+04		1.42E-03	25	0.03		1.66E+03	m	9.63E-04	4.01	
2-Chlorophenol	128.6	2.20E+04	20	1.41E+02	1.05E-5 L	3.91E-04	20	0.0501		3.96E+02			2.15	
2-Methylnaphthalene	142.2	2.60E+01	25	7.24E+03	10 @ 105	2.20E-02		0.056		4.56E+03			3.86	

Table C8.5. Recommended model parameters for organics (continued)

Constituents	Mol. wt. (g/mol)	Solubility S_w (mg/L)	S_w @ temp. (°C)	KOW (ml/ml)	Vapor pressure (tor @ °C)	pH=6 for Ionizing Organics: Henry's constant (K_h) ($atm.m^3/mol$)	K_h @ temp. (°C)	Air Diff. coeff. (cm^2/s)		Biodegradation rate, KOC (ml/g)		l (1/d)	Log (KOW)
2-methylphenol	108.1	2.60E+04	40	9.77E+01		1.20E-06	25*	0.074	t	9.12E+01		2.48E-02	1.99
2-methyl-1-propanoic acid	74.1	9.50E+04	18	6.76E+00	10 @ 25	2.44E-07				4.26E+00			0.83
2,4-Dichlorophenol	163.0	4.50E+03	25	1.20E+03		3.16E-06	20	0.035		1.57E+02		9.90E-03	3.08
2,4-Dinitrophenol	184.1	2.79E+03	18	3.55E+01	1.49E-5 L	4.43E-07	18	0.027		2.18E+01		1.30E-03	1.55
2,4-Dimethylphenol	122.2	7.87E+03	#	2.29E+02		2.00E-06	25	0.058		2.09E+02		2.48E-02	2.36
2,4,5-Trichlorophenol	197.5	1.20E+03	25	7.94E+03		4.43E-06	225*	0.029		2.21E+03		3.81E-04	3.90
2,4,6-Trichlorophenol	197.5	8.00E+02	25	5.01E+03		7.79E-06	25	0.032		7.96E+02		3.81E-04	3.70
3-Methylcholanthrene	268.3	3.00E-03	25	1.29E+07						8.12E+06			7.11
4-Chloro-3-methylphenol	142.6	3.85E+03	20	1.26E+03		2.50E-06	20	0.056		7.93E+02			3.10
4-Methylphenol	108.1	2.40E+04	40	8.51E+01		5.87E-09	25#	0.075	#	5.36E+01		2.48E-02	1.93
Acenaphthene	154.2	4.24E+00	25	8.32E+03		1.55E-04	25	0.042		4.90E+03	m	1.70E-03	3.92
Acenaphthylene	152.2	3.93E+00	25	1.17E+04		1.14E-04	25	0.062		7.40E+03		2.92E-03	4.07
Acetophenone	120.2	5.50E+03		3.80E+01	1 @15	7.80E-07				2.40E+01			1.58
Anthracene	178.2	4.34E-02	25	3.55E+04	1.95E-4 L	6.50E-05	25	0.032		2.35E+04	m	3.77E-04	4.55
Benzo (a) anthracene	228.3	9.40E-03	24	5.01E+05	5E-9 @ 20	3.35E-06	25#	0.051		3.58E+05	m	2.55E-04	5.70
Benzo (a) pyrene	252.3	1.62E-03	25	1.29E+06	5E-9 @ 21	1.13E-06	25	0.043		9.69E+05	m	3.27E-04	6.11
Benzo (b) fluoranthene	252.3	1.50E+03	#	1.58E+06	5E-7 L	1.11E-04	25#	0.023	#	1.23E+06		2.84E-04	6.20
Benzo(g,h,i)perylene	276.3	2.60E-04	25	1.70E+07	1E-10 @ 20	1.40E-07		0.042		1.07E+07		2.67E-04	7.23
Benzo (k) fluoranthene	252.3	8.00E-04	#	1.58E+06	1E-11 @ 20	8.29E-07	25#	0.023		1.23E+06		8.10E-05	6.20
Benzoic Acid	122.1	3.50E+03	20	7.24E+01	10 @ 132	1.54E-06		0.054		9.69E-01			1.86
Bis-(2-Ethylhexyl)phthalate	390.6	3.40E-01	25	2.00E+07	1.2 @ 200	1.02E-07	20	0.035	s	1.11E+05	m	1.78E-03	7.30
Butylbenzylphthalate	312.4	2.69E+00		6.92E+04	8.6E-6 @ 20	1.26E-06	25#	0.017	bb	1.37E+04	m	3.85E-03	4.84
Chrysene	228.3	1.60E-03	25	5.01E+05	6.3E-9 @25	9.46E-05	25	0.025		3.98E+05		1.73E-04	5.70
Dibenzo(a,h)anthracene	278.4	2.49E-03	25	4.90E+06	1E-10 L	1.47E-08	25	0.020	bb	1.79E+06	m	1.84E-04	6.69
Dibenzofuran	168.2	1.00E+01		1.32E+04				0.068		8.31E+03		6.19E-03	4.12
Diethylphthalate	222.2	1.08E+03		3.16E+02	0.05 @ 70	4.50E-07	25#	0.026	bb	8.22E+01	m	3.09E-03	2.50
Di-n-butylphthalate	278.4	4.00E+02	25	1.58E+05	0.1 @ 115	2.80E-07	25	0.042		1.57E+03	m	3.01E-02	5.20
Di-n-octylphthalate	390.6	2.00E-02	25	1.15E+08	0.2 @ 150	6.68E-05		0.015		9.98E+08		1.90E-03	8.06
Fluoranthene	202.3	2.06E-01	25	1.32E+05	5E-6 L	1.61E-05	25	0.030	s	4.91E+04	m	3.94E-04	5.12
Fluorene	166.2	1.98E+00	25	1.62E+04		6.36E-05	25	0.036	bb	7.71E+03	m	2.89E-03	4.21
Hexachlorobutadine	260.8	3.23E+00	20	6.46E+04	0.15 @20	8.15E-03	20	0.056		3.80E+04		9.63E-04	4.81
Hexachloroethane	236.7	5.00E+01		1.00E+04	0.40 @ 20	3.89E-03	25	0.003		8.70E+03		9.63E-04	4.00
Indeno(1,2,3-c,d)pyrene	276.3	2.20E-05		4.47E+06	1E-10 L	1.60E-06	25	0.019		3.47E+06		2.37E-04	6.65
Isophorone	138.2	1.20E+04		5.01E+01	0.38 @20	6.64E-06	20	0.062		4.68E+01		6.23E-02	1.70
Napthalene	128.2	3.10E+01	25	2.29E+03	0.082 @ 25	4.83E-04	25	0.059		1.19E+03	m	2.69E-03	3.36
N-nitroso-diphenylamine	198.2	3.51E+01		1.45E+03		5.00E-06	25w	0.031	bb	1.29E+03		5.10E-03	3.16
Pentachlorophenol	266.3	1.95E+03	20	1.23E+05		2.44E-08	20	0.056	t	1.56E+03		4.56E-04	5.09
Phenanthrene	178.2	8.16E-01	21	2.88E+04	1 @ 118	3.93E-05	25	0.054		1.82E+04		8.66E-04	4.46
Phenol	94.1	8.28E+04	25	3.02E+01		3.97E-07	25	0.082	s	2.88E+01		2.48E-02	1.48
Pyrene	202.3	1.35E-01	26	1.29E+05	2.5 @ 200	1.10E-05	25	0.027	bb	6.80E+04	m	9.12E-05	5.11
						Pesticides/PCBS							
Aroclor-1016	257.9	4.90E-02	24	2.40E+04		1.35E-02	25	0.046		1.51E+04			4.38
Aroclor-1248	299.5	5.40E-02		5.62E+05		4.40E-04	25	0.043		3.54E+05			5.75
Aroclor-1254	328.4	5.70E-02	24	1.07E+06		8.37E-03	25	0.041		6.75E+05		4.72E-03	6.03

Table C8.5. Recommended model parameters for organics (continued)

Constituents	Mol. wt. (g/mol)	Solubility S_w (mg/L)	S_w @ temp. (°C)	KOW (ml/ml)	Vapor pressure (tor @ °C)	pH=6 for Ionizing Organics Henry's constant (K_h) (atm.m^3/mol)	K_h @ temp. (°C)	Air Diff. coeff. (cm^2/s)	Biodegradation rate, KOC (ml/g)	l (1/d)	Log (KOW)
Aroclor-1260	375.7	8.00E-02	24	1.29E+06		3.36E-04	25	0.038	8.12E+05		6.11
Octachlorodibenzo-p-dioxin											

"Revised from Part 5 of 1996 SSG
Solubilities, Henry's Constant, and Log (K_{ow}) have been taken from RREL Treatability Data Base (EPA 1994) unless otherwise indicated.
Biodegradation half-lives are taken from Hand Book of Environmental Degradation Rates (Howard et al. 1991) unless otherwise indicated.
Air diffusion coefficients are obtained from EPA 1987 unless otherwise indicated.

| * | Represents calculated values
| ** | indicates the source of Lyman et al. 1990
| # | indicates STF Data Base (EPA 1991) as the source
| s | indicates Shen et. al 1993 as the source
|w|-EPA WATER7 database November 1990
m = measured Koc values
L = Source from EPA 1995
bb = Estimated using correlations in WATER8 Model.