



ORNL/GWPO-002

**OAK RIDGE  
NATIONAL  
LABORATORY**

**MARTIN MARIETTA**

**Paducah Gaseous Diffusion Plant  
Proposed Pilot Pump-and-Treat  
Project**

**Groundwater Corrective Actions  
Review Team**

G. W. Bodenstein  
R. R. Bonczek  
T. O. Early  
D. D. Huff  
K. J. Jones  
M. D. Nickelson  
C. T. Rightmire

**MANAGED BY  
MARTIN MARIETTA ENERGY SYSTEMS, INC.  
FOR THE UNITED STATES  
DEPARTMENT OF ENERGY**



**DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED**

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

**PADUCAH GASEOUS DIFFUSION PLANT PROPOSED  
PILOT PUMP-AND-TREAT PROJECT**

**Groundwater Corrective Actions Review Team**

**G. W. Bodenstein  
R. R. Bonczek  
T. O. Early  
D. D. Huff  
K. S. Jones  
M. D. Nickelson  
C. T. Rightmire**

**Final Report**

**Date Issued: November 1992  
Date Published: January 1994**

**Prepared by the  
OAK RIDGE NATIONAL LABORATORY  
Oak Ridge, Tennessee 37831-6285  
managed by  
MARTIN MARIETTA ENERGY SYSTEMS, INC.  
for the  
U.S. Department of Energy  
under contract DE-AC05-84OR21400**

**MASTER** *ds*

**DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED**

## CONTENTS

LIST OF FIGURES . . . . .	vi
LIST OF TABLES . . . . .	viii
ABSTRACT . . . . .	x
1. INTRODUCTION . . . . .	1
2. SUMMARY OF PREVIOUS CONCERNS AND TEAM RECOMMENDATIONS	1
3. SUMMARY OF RECENT FIELD AND MODELING STUDIES . . . . .	2
3.1 FIELD INVESTIGATIONS . . . . .	2
3.2 ANALYTICAL RESULTS . . . . .	5
3.3 DATA INTERPRETATION . . . . .	10
3.4 GROUNDWATER FLOW MODELING . . . . .	19
4. CONCLUSIONS AND RECOMMENDATIONS . . . . .	20
5. ACKNOWLEDGMENTS . . . . .	23
REFERENCES . . . . .	24
APPENDIX A . . . . .	25

## LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Location map of temporary driven well points and existing wells in the vicinity of the Northwest plume. . . . .	3
2	Schematic diagram illustrating components of system used to emplace well points. . . . .	5
3	TCE in groundwater from location J36 . . . . .	7
4	TCE in groundwater from well point locations in Transect A-A . . . . .	8
5	TCE in groundwater from well point locations in Transect B-B . . . . .	9
6	TCE in groundwater from well point locations in Transect C-C . . . . .	10
7	Tc-99 in groundwater from location J36. . . . .	11
8	Tc-99 in groundwater from well point locations in Transect A-A . . . . .	12
9	Tc-99 in groundwater from well point locations in Transect B-B . . . . .	13
10	Tc-99 in groundwater from well point locations in Transect C-C . . . . .	14

**LIST OF TABLES**

<u>Table</u>		<u>Page</u>
1	TCE AND <sup>99</sup> Tc Concentrations in groundwater From the Northwest Plume, PADUCAH Gaseous Diffusion Plant . . . . .	20

## ABSTRACT

On March 23, 1992, R.C. Sleeman of the Department of Energy, Oak Ridge Operations Office requested that a Groundwater Corrective Actions Team be assembled to evaluate the technical merit of and the need to implement a proposed groundwater pump-and-treat demonstration project for the Northwest contaminant plume at the Paducah Gaseous Diffusion Plant. In addition to other suggestions, the Team recommended that further characterization data be obtained for the plume. In the Fall of 1993 additional, temporary well points were installed so that groundwater samples from the shallow groundwater system and the Regional Gravel Aquifer (RGA) could be obtained to provide a three-dimensional view of groundwater contamination in the region of the plume. The results indicate that pure-phase DNAPL (trichloroethylene [TCE]) probably are present in the source area of the plume and extend in depth to the base of the RGA. Because the DNAPL likely will represent a source of a dissolved phase plume for decades it is essential that source containment take place. The Team recommends that although effective hydraulic containment can be achieved, other alternatives should be considered. For example, recent advances in emplacing low permeability barrier walls to depths of 100 to 150 ft make it possible to consider encirclement of the source of the Northwest plume.

## **1. INTRODUCTION**

On March 23, 1992, R. C. Sleeman of the Department of Energy, Oak Ridge Operations Office (DOE-ORO) requested that a Groundwater Corrective Actions Review Team (Team) be assembled to evaluate the technical merit of and the need to implement a proposed groundwater pump-and-treat demonstration project for the Northwest contaminant plume at the Paducah Gaseous Diffusion Plant (PGDP). The pilot project was proposed as an Interim Corrective Measure for the plume.

A Team composed of representatives from the DOE-ORO, several organizations within Martin Marietta Energy Systems, Inc. (Energy Systems), and three independent consultants from different universities was established to evaluate the most appropriate technologies for the Interim Corrective Measure. The Team reviewed documents associated with the proposed project and available hydrogeologic data that had been obtained by site investigation studies conducted in the vicinity of the Northwest plume. The Team approached this proposed pilot project from the perspective of an Interim Corrective Measure for source containment rather than for plume containment or remediation. This is an important distinction that helped guide the outcome of the evaluation. The Team prepared a report (Bodenstein et al. 1992) that evaluated the proposed project in the context of available technical data, identified key uncertainties, and made specific recommendations for obtaining the necessary data so that a final evaluation of the project could be completed.

The additional data have been obtained by a combination of field studies and numerical modeling investigations. This final report briefly reviews the results of these new data and presents the Team's final recommendations for the proposed pilot project.

## **2. SUMMARY OF PREVIOUS CONCERNS AND TEAM RECOMMENDATIONS**

The major conclusions and recommendations of the Team as a result of its initial evaluation can be summarized as follows:

- The project as proposed is intended to be a full-scale hydraulic containment of the source(s) of the Northwest plume, not plume remediation. More planning is needed to deal with plume remediation after source control.
- A pilot-scale demonstration of the pump-and-treat process is required before expansion to a full-scale project..
- The risk and hazard posed to residents by this plume with the current alternative municipal water supply has not been fully evaluated, and the reduction in risk and hazard through source containment vs the No Action Alternative has not been demonstrated. The potential for increased damage to ecological systems or

exacerbation of past damages to these systems through increased flow in creeks from discharge of pumped groundwater or through air emission of volatiles from an air stripper have not been evaluated. As a part of the pilot project and the investigations supporting it, attention should be given to these factors.

- An accurate determination of the nature and location of the source(s) is required.
- Further characterization of the lateral limits of the plume and the vertical distribution of contaminants within the plume should be completed before a decision is made on the preferred source-control option, which depends on whether or not pure-phase dense nonaqueous-phase liquids (DNAPLs) are present in the Regional Gravel Aquifer (RGA).
- The presence of both trichloroethylene (TCE) and technetium-99 (<sup>99</sup>Tc) in the Northwest plume may require groundwater extraction for treatment unless an in situ method for <sup>99</sup>Tc removal can be proven effective.

### **3. SUMMARY OF RECENT FIELD AND MODELING STUDIES**

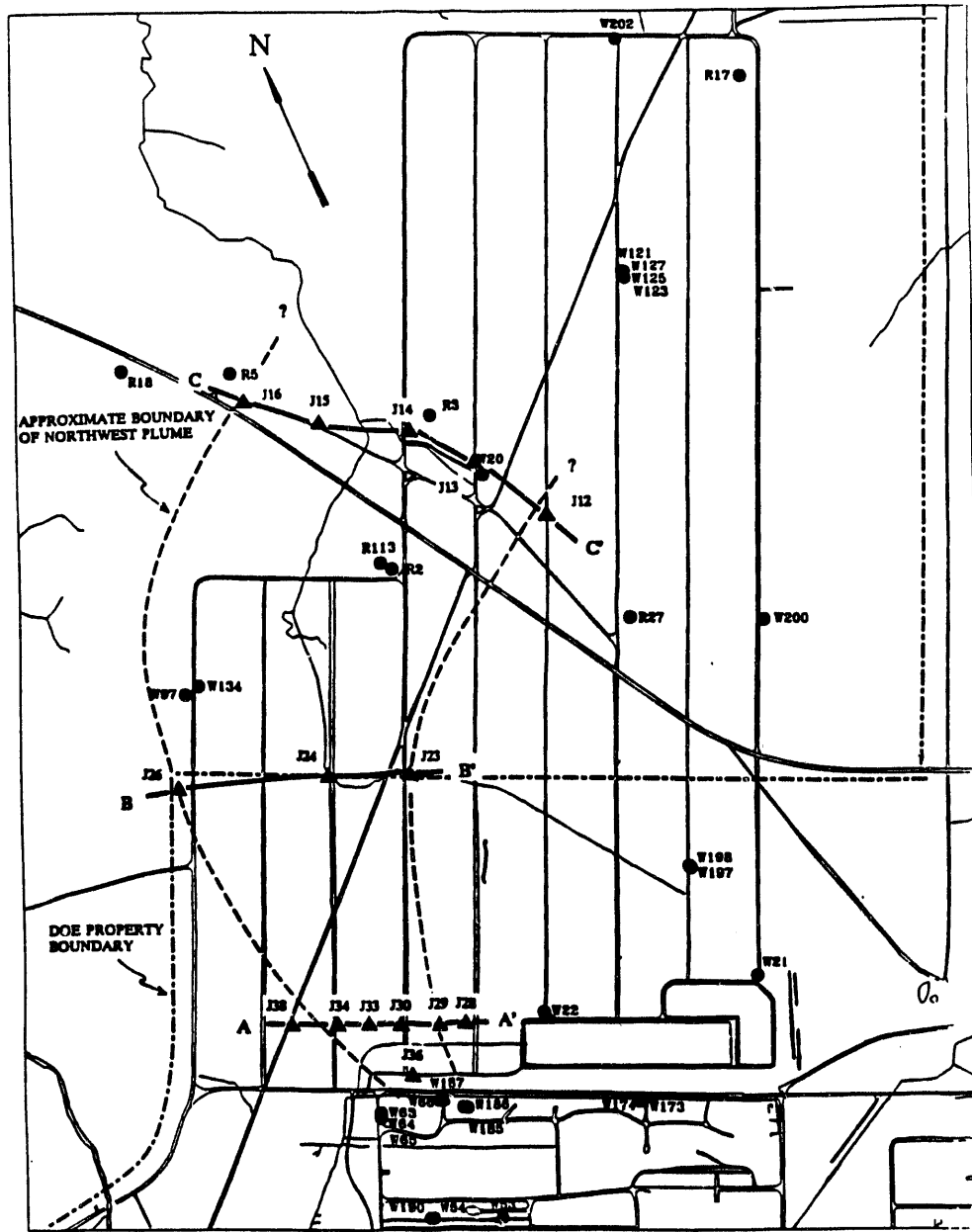
#### **3.1 FIELD INVESTIGATIONS**

Beginning in late August and concluding in early November, 1992, 15 new, temporary driven well points were emplaced for the purpose of defining the lateral boundaries of the Northwest plume and obtaining a vertical sequence of groundwater samples with which to better characterize the distribution of contaminants within the RGA. Groundwater samples were collected during emplacement, and each drive hole was plugged and abandoned following collection of the last sample from the hole by grouting through the drill rod as it was extracted. All but one of these well point locations were grouped into three primary transects through the plume. Figure 1 is a map of the vicinity around the Northwest plume showing the location of the temporary well point locations and existing monitoring and residential wells.

Each temporary well point was emplaced by using both hydraulic and hammer technology in association with an augered pilot hole. Field testing showed that the most efficient emplacement process involved the use of hollow-stem augers to drill to the top of the RGA. Then, a specially designed sampling section of drill rod with a detachable drive-point was driven into the RGA to a specified depth by using a combination of hydraulic force and hammering. At this point the screened section was exposed by retracting a movable sleeve and a sampling apparatus was inserted into the drill rod to collect the groundwater sample. Clogging of the screen prevented efficient collection of water in the

first stations emplaced. This problem was overcome by modifying the drilling method and using of the sleeve to protect the screen. These techniques evolved during the early stages of field activities and were employed for all subsequent driven well points.

During the early stages of this investigation, several techniques for groundwater sample collection were evaluated. The method employed for most samples involved placement of a one-way valve in the drill rod immediately above the screened section. The valve was configured to permit flow of water from the screened section through the valve and into the drill rod. A 0.5-in. (OD) polyethylene tube was inserted into the drill rod with the lower end placed just above the valve. The drill rod was pressurized with air, and groundwater was forced up the polyethylene tubing to the surface, where samples were collected.



- ▲ LOCATION OF TEMPORARY DRIVEN WELL POINTS
- EXISTING MONITORING WELLS (eg. W97) AND RESIDENTIAL WELLS (eg. R113)

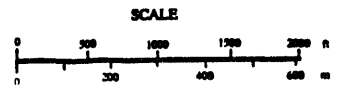


Fig. 1. Location map of temporary driven well points and existing wells in the vicinity of the Northwest plume.

Once a groundwater sample was collected, the drill rod and attached sampling section was driven to the next depth and the process was repeated. One to four samples were collected from the RGA by this method at each location. After the last sample was collected at each location, extraction of the drill rods from the hole began. The detachable drive point separated from the rod during extraction, thereby allowing the hole to be grouted to the ground surface as the rod was removed. Figure 2 is a schematic illustration of the system components process.

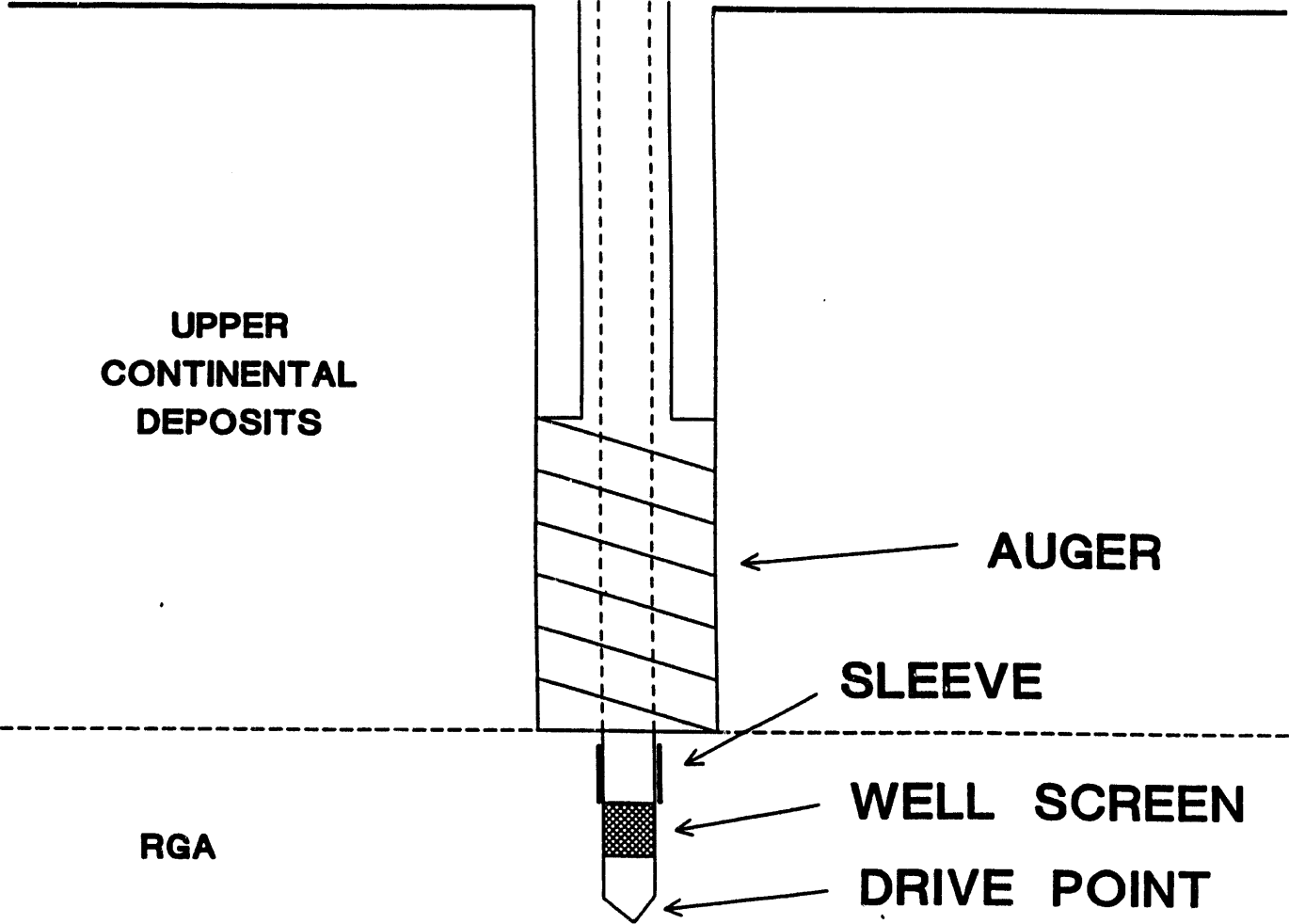
### 3.2 ANALYTICAL RESULTS

Groundwater samples were analyzed for volatile constituents by using a field gas chromatograph and a head space analysis technique. Many of the samples also were analyzed for volatiles at the PGDP or Oak Ridge K-25 laboratories for confirmation by means of a purge and trap method followed by gas chromatograph-mass spectrometer analysis. All samples were analyzed at the PGDP laboratory for  $^{99}\text{Tc}$  content. Analytical results for TCE and  $^{99}\text{Tc}$  in the groundwater samples are summarized in Table 1. The complete analyses, including results for blanks, are presented in a report prepared by PGDP technical staff (Clausen et al. 1993).

Frequent field and equipment blanks and duplicate analyses for the volatile constituents provide for quality assurance checks of the reliability of the data. In general, the following observations were made:

- With rare exceptions, no detectable TCE occurred in the blanks; the two exceptions had  $<1 \mu\text{g/L}$  each.
- Analysis of duplicate samples by gas chromatography generally compared favorably. (See Table 1.)
- Comparison of field gas chromatographic analyses and gas chromatographic analyses at either the PGDP or K-25 laboratories indicated reasonable agreement, except when the field gas chromatograph reported  $>1000 \mu\text{g/L}$  TCE. Concentrations of TCE  $>1000 \mu\text{g/L}$  are beyond the dynamic calibration range of the field instrument and are significantly underestimated.

During the course of the field investigations, analytical results from the field gas chromatograph indicated the possible presence of degradation products of TCE, such as vinyl chloride and cis-DCE, in many groundwater samples. These analytes could not be confirmed by the PGDP laboratory because of the analytical procedures used at that facility. Four samples from location J36 were analyzed at the K-25 laboratory by different methodology, and results from one of them suggest that the vinyl chloride and cis-DCE may have been misidentified in the field gas chromatographic analysis. This question must



**Fig. 2. Schematic diagram illustrating components of system used to emplace well points.**

**Table 1. TCE AND <sup>99</sup>TC Concentrations in Groundwater From The Northwest Plume Paducah Gaseous Diffusion Plant**

<b>SAMPLE/ ANALYTE</b>	<b>TCE(GJ) (ug/L)</b>	<b>TCE(K-25) (ug/L)</b>	<b>TCE(PAD) (ug/L)</b>	<b>TC-99 (pCI/L)</b>	<b>+/-ERROR (pCI/L)</b>
<b>J12-63</b>	5	N/A	N/A	69	25
<b>DUP.</b>	3	N/A	N/A	N/A	N/A
<b>J12-71</b>	2	N/A	N/A	60	23
<b>DUP.</b>	2	N/A	N/A	N/A	N/A
<b>J12-83</b>	3	N/A	2	78	23
<b>J13-64</b>	78	N/A	48	40	23
<b>DUP.</b>	73	N/A	N/A	N/A	N/A
<b>J13-74</b>	31	N/A	42	24	22
<b>J13-84</b>	4	N/A	4	0	0
<b>J14-80A</b>	2024	N/A	N/A	N/A	N/A
<b>DUP.</b>	1483	N/A	N/A	890	53
<b>J14-80B</b>	1044	N/A	N/A	N/A	N/A
<b>DUP.</b>	1757	N/A	N/A	N/A	N/A
<b>J14-95A</b>	19	N/A	N/A	2	19
<b>DUP.</b>	14	N/A	N/A	N/A	N/A
<b>J14-95B</b>	11	N/A	N/A	N/A	N/A
<b>DUP.</b>	10	N/A	N/A	N/A	N/A
<b>J15-62</b>	167	N/A	270	279	33
<b>J15-72</b>	158	N/A	200	160	28
<b>J16-59</b>	5	N/A	N/A	0	0
<b>DUP.</b>	5	N/A	N/A	N/A	N/A
<b>J16-68</b>	4	N/A	3	0	0
<b>J23-72</b>	64	N/A	N/A	N/A	N/A

<b>SAMPLE/ ANALYTE</b>	<b>TCE(GJ) (ug/L)</b>	<b>TCE(K-25) (ug/L)</b>	<b>TCE(PAD) (ug/L)</b>	<b>TC-99 (pCI/L)</b>	<b>+/-ERROR (pCI/L)</b>
<b>DUP.</b>	11	N/A	N/A	42	22
<b>J23-80</b>	17	N/A	N/A	15	25
<b>J24-66</b>	240	N/A	210	95	27
<b>J26-70A</b>	0.9	N/A	N/A	0	0
<b>DUP.</b>	0.5	N/A	N/A	N/A	N/A
<b>J26-70B</b>	8	N/A	N/A	N/A	N/A
<b>DUP.</b>	5	N/A	N/A	N/A	N/A
<b>J26-79</b>	0.7	N/A	N/A	0	0
<b>J26-89</b>	0.3	N/A	N/A	0	0
<b>DUP.</b>	1	N/A	N/A	N/A	N/A
<b>J26-99</b>	0.3	N/A	N/A	0	0
<b>DUP.</b>	0.9	N/A	N/A	N/A	N/A
<b>J28-33</b>	N/A	N/A	<1(J)	17	23
<b>J28-63</b>	5	N/A	11(J)	25	20
<b>J28-73</b>	36	N/A	110(J)	54	22
<b>J28-83</b>	48	N/A	330(J)	129	25
<b>J28-104</b>	2	N/A	2(J)	10	26
<b>J29-33</b>	N/A	N/A	<1	22	N/A
<b>J29-62</b>	3	N/A	<20	8	1
<b>DUP.</b>	4	N/A	N/A	N/A	N/A
<b>J29-72</b>	261	N/A	440	230	18
<b>DUP.</b>	27	N/A	390	225	18
<b>J29-82</b>	601	N/A	750	347	24
<b>J29-92</b>	300	N/A	360	253	19

<b>SAMPLE/ ANALYTE</b>	<b>TCE(GJ) (ug/L)</b>	<b>TCE(K-25) (ug/L)</b>	<b>TCE(PAD) (ug/L)</b>	<b>TC-99 (pCI/L)</b>	<b>+/-ERROR (pCI/L)</b>
<b>J30-30</b>	0.8	N/A	<1	6	18
<b>J30-66</b>	1495	N/A	1000	1454	63
<b>J30-73</b>	926	N/A	3400	248	32
<b>J30-87</b>	1662	N/A	3700	326	35
<b>J30-92</b>	17	N/A	37	77	8
<b>J33-63</b>	N/A	N/A	530	423	40
<b>J33-74A</b>	1706	N/A	8600(J)	3952	106
<b>J33-74B</b>	1572	N/A	N/A	N/A	N/A
<b>DUP.</b>	1807	N/A	N/A	N/A	N/A
<b>J33-83</b>	1889	N/A	7600(J)	231	33
<b>J33-91</b>	1376	N/A	4500(J)	666	48
<b>J34-61</b>	1398	N/A	2600	1504	68
<b>J34-71</b>	1852	N/A	5400	1884	75
<b>J34-81</b>	1628	N/A	8100	2134	79
<b>J36-67</b>	1564	4100	N/A	4616	115
<b>J36-77</b>	1862	8200	N/A	2625	119
<b>J36-86</b>	2048	16000	N/A	3714	141
<b>J36-92</b>	J36-92	16000	N/A	4800	117
<b>J36-92W</b>	2359	N/A	15000	2469	85
<b>J38-66</b>	6	N/A	3	26	23
<b>J38-76</b>	5	N/A	2	38	24
<b>DUP.</b>	3	N/A	2	32	23
<b>J38-83</b>	0.1	N/A	<1	2	7
<b>DUP.</b>	2	N/A	N/A	N/A	N/A

be resolved for future risk assessment evaluation but is not considered further in this report.

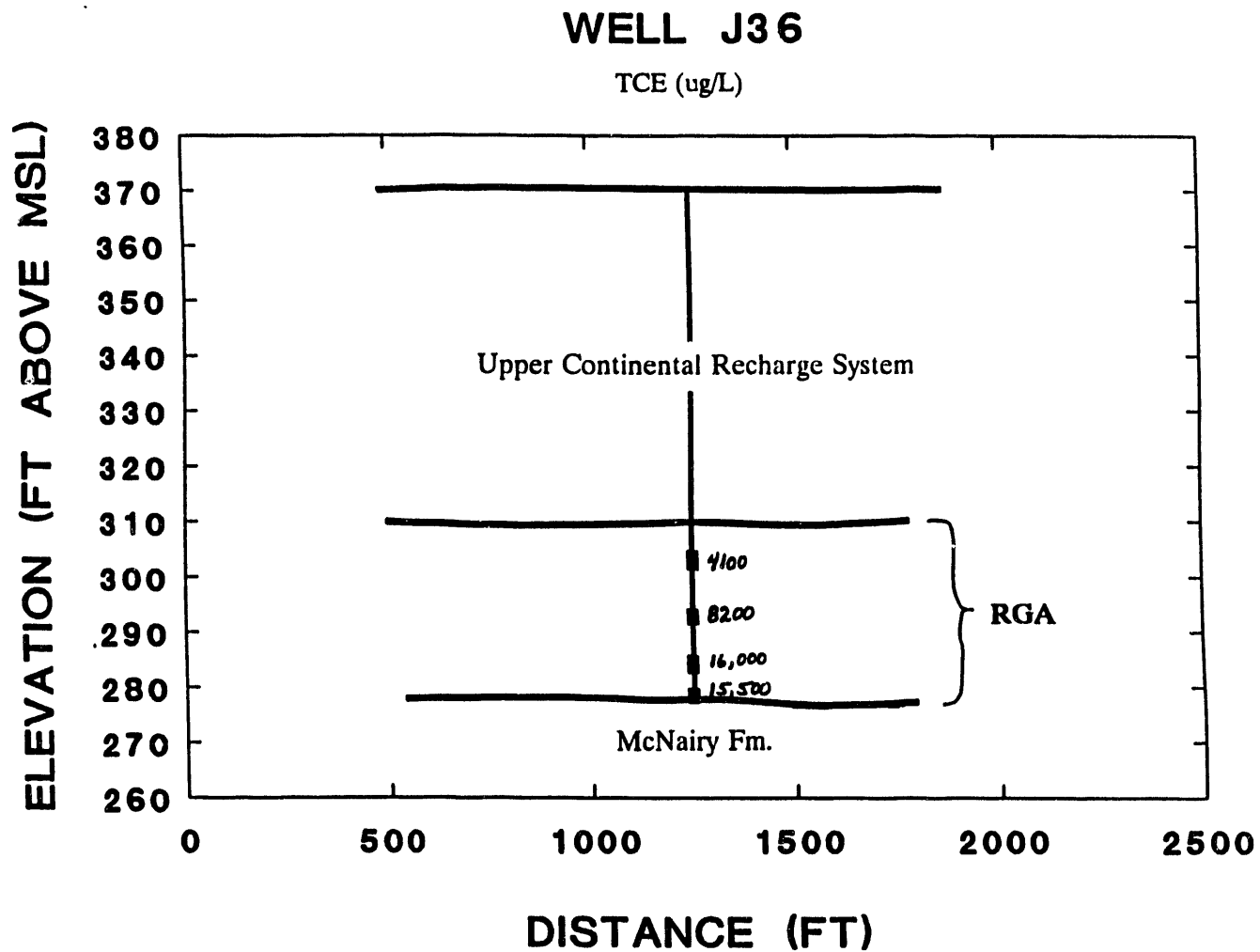
### **3.3 DATA INTERPRETATION**

A major purpose of these field studies was to explore how TCE is migrating to the RGA. One possibility is that TCE might be reaching the RGA dissolved in water that has passed through the source. Alternatively, TCE in the RGA could have resulted from migration of pure-phase DNAPL into the RGA. The Team reasoned that if the former had occurred, groundwater contamination in the RGA, especially near the source area, would be restricted to the upper portion of the RGA. If DNAPLs had migrated into the RGA and possibly pooled at the base of this formation, one would expect dissolved TCE to be spread vertically throughout the RGA, with possibly higher concentrations near the base of the RGA.

Data collected during this investigation are presented in Table 1. Figures 3 through 10 illustrate cross sections across the Northwest plume for the three transects and location J36. The TCE and  $^{99}\text{Tc}$  data for each sampling interval are provided, and these data are contoured where possible. The depth to the top of the RGA was determined by interpretation of augering results; the base of the RGA is assumed to be the depth of refusal for the drive point. Several key observations emerge:

- TCE and  $^{99}\text{Tc}$  are distributed throughout the vertical extent of the RGA along the centerline of the plume.
- Lateral boundaries to the plume are well defined for the three transects.
- The concentrations of TCE observed in groundwater at location J36 requires a presumption of DNAPLs in the RGA underlying Solid Waste Management Units (SWMUs) 7 and 30. This inference is supported by the vertical distribution of TCE observed in many of the well point locations.

The data from groundwater samples obtained in this field investigation, especially from well point location J36, support the interpretation that TCE has migrated to the RGA in the source region as a pure-phase DNAPL. Although at this time we cannot prove the presence of pure-phase DNAPL in the RGA under SWMUs 7 and 30, based on the evidence, we must assume that it is there and design the source containment technology accordingly.



**Fig. 3. TCE in groundwater from location J36. Where possible, concentrations reported are those obtained by the PGDP or K-25 laboratories. Results for samples where more than one analysis is available.**

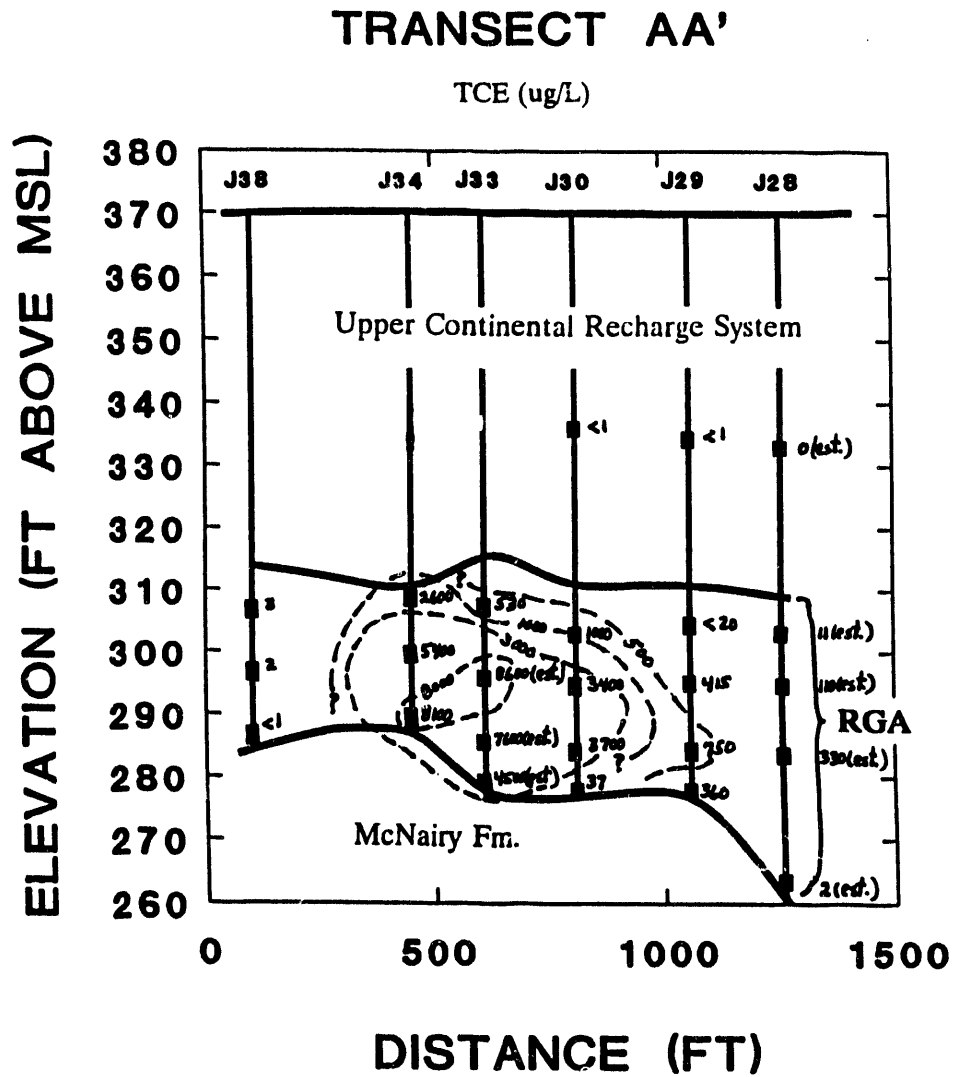
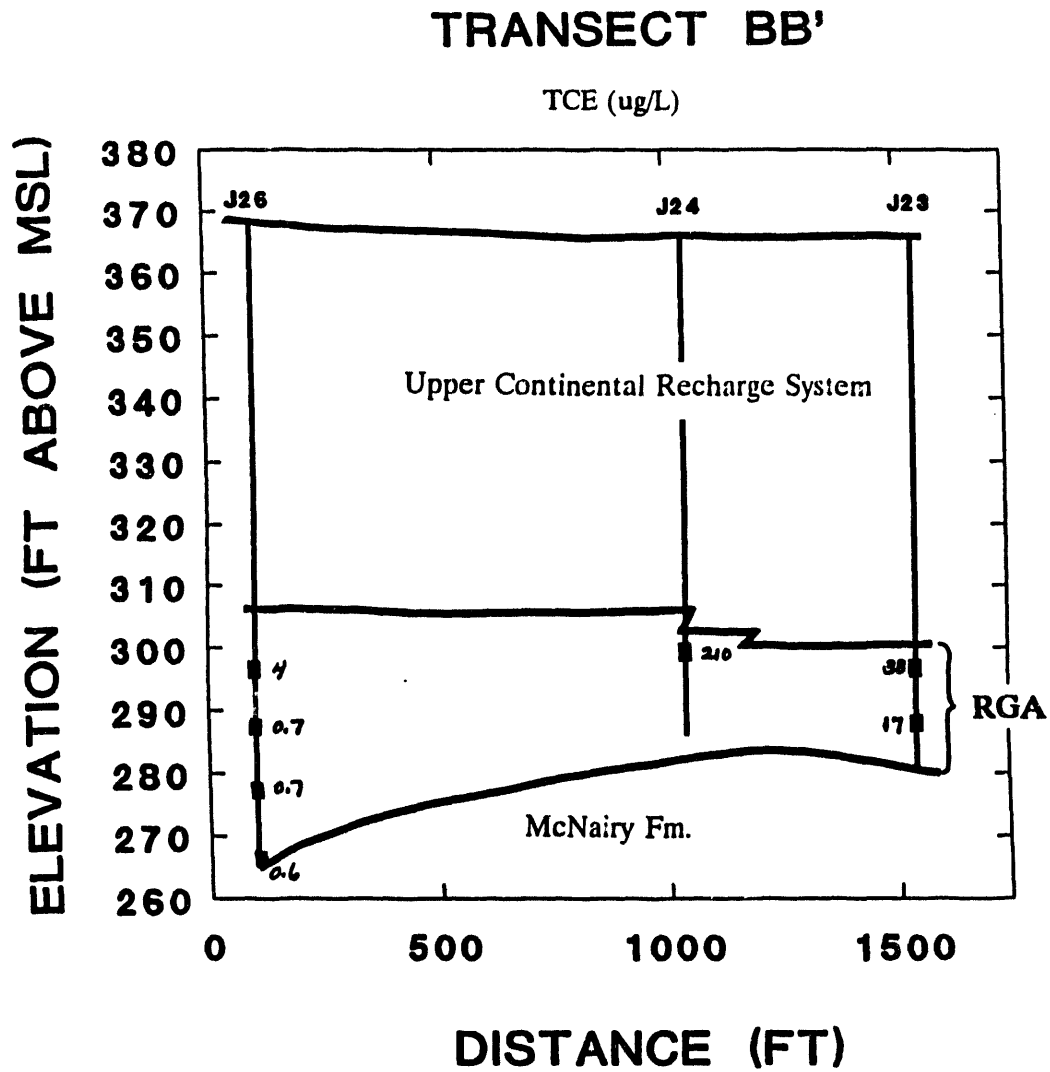


Fig. 4. TCE in groundwater from well point locations in Transect A-A. Where possible, concentrations reported are those obtained by the PGDP laboratory. Results for samples analyzed in duplicate are averaged.



**Fig. 5. TCE in groundwater from well point locations in Transect B-B. Where possible, concentrations reported are those obtained by the PGDP laboratory. Results for samples analyzed in duplicate are averaged.**

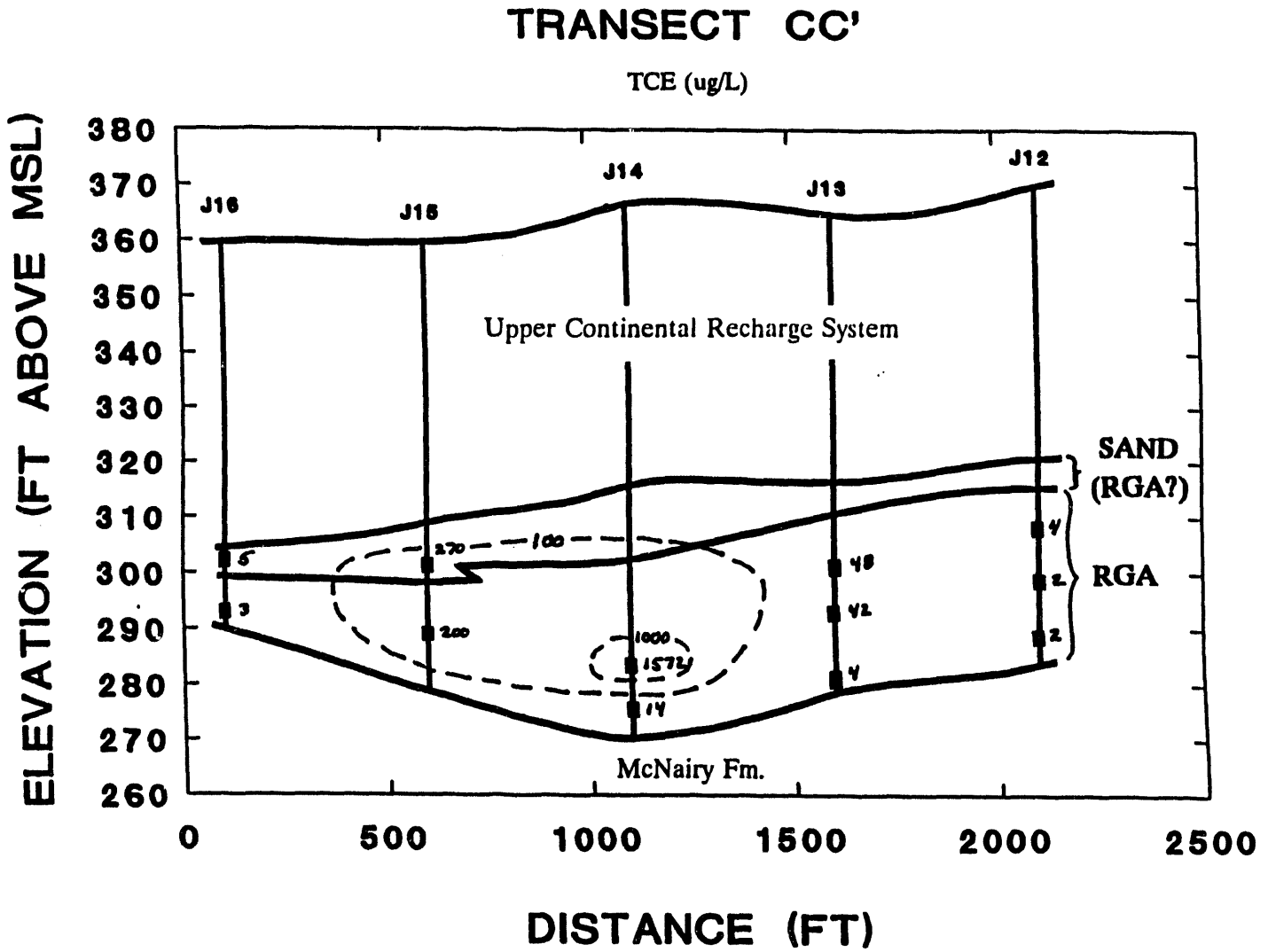
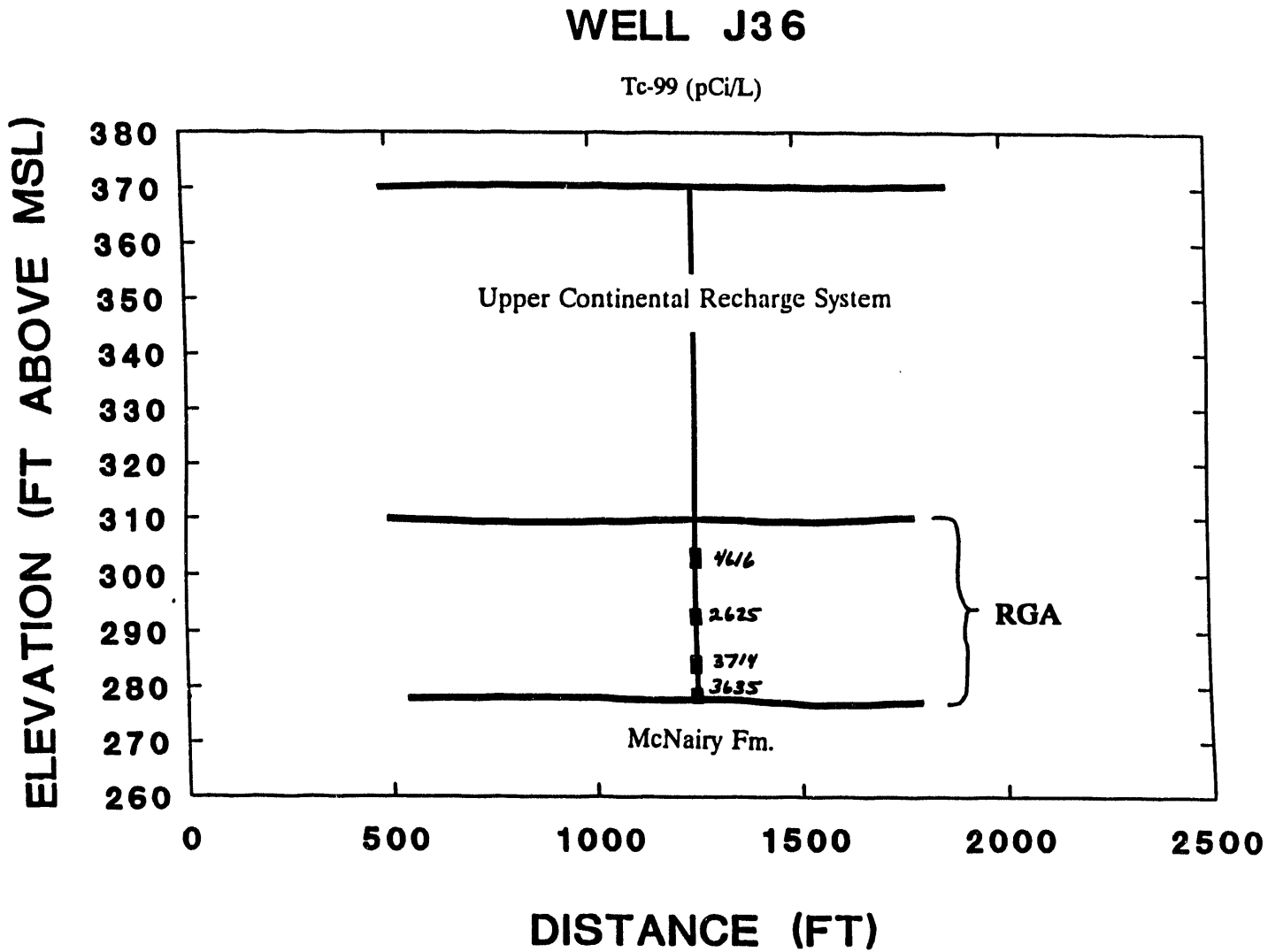


Fig. 6. TCE in groundwater from well point locations in Transect C-C. Where possible, concentrations reported are those obtained by the PGDP laboratory. Results for samples analyzed in duplicate are averaged.



**Fig. 7. <sup>99</sup>Tc in groundwater from location J36. Results for samples analyzed in duplicate are averaged.**

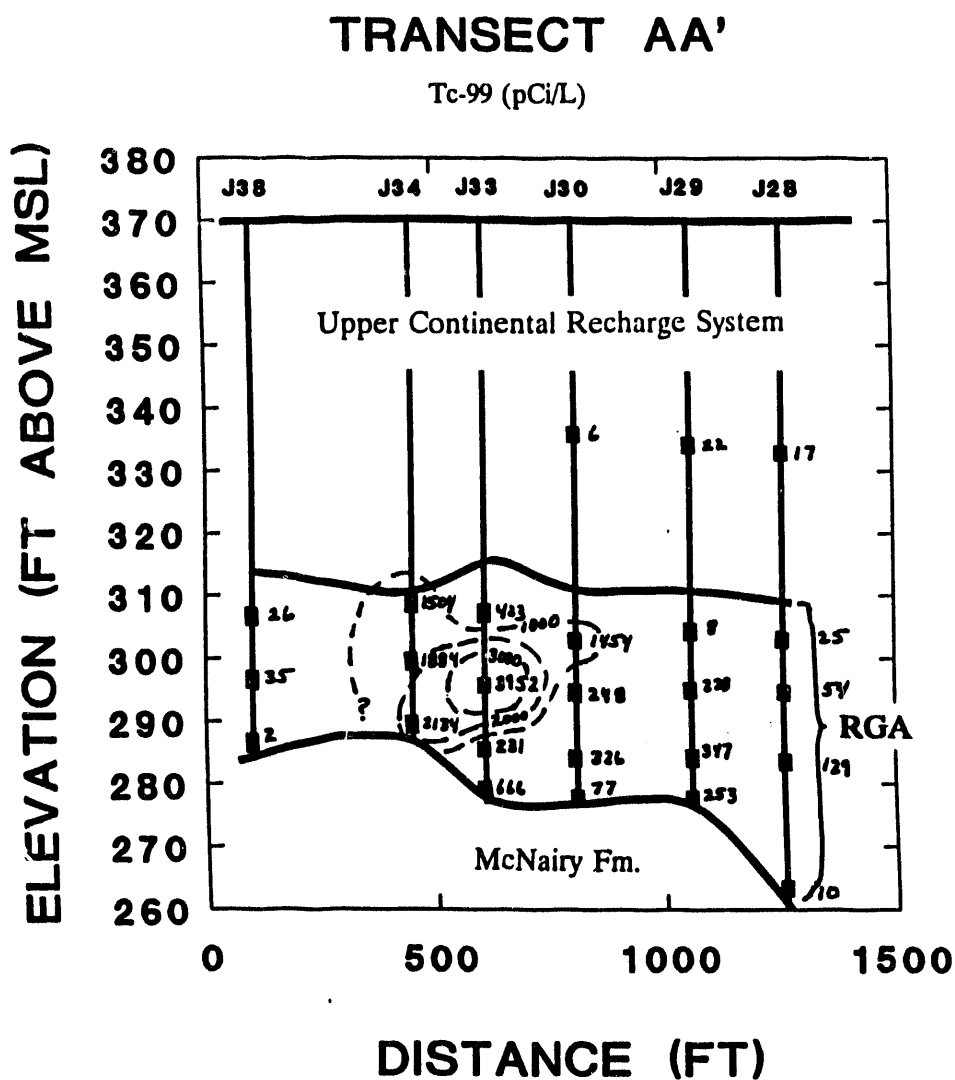


Fig. 8. <sup>99</sup>Tc in groundwater from well point locations in Transect A-A. Results for samples analyzed in duplicate are averaged.

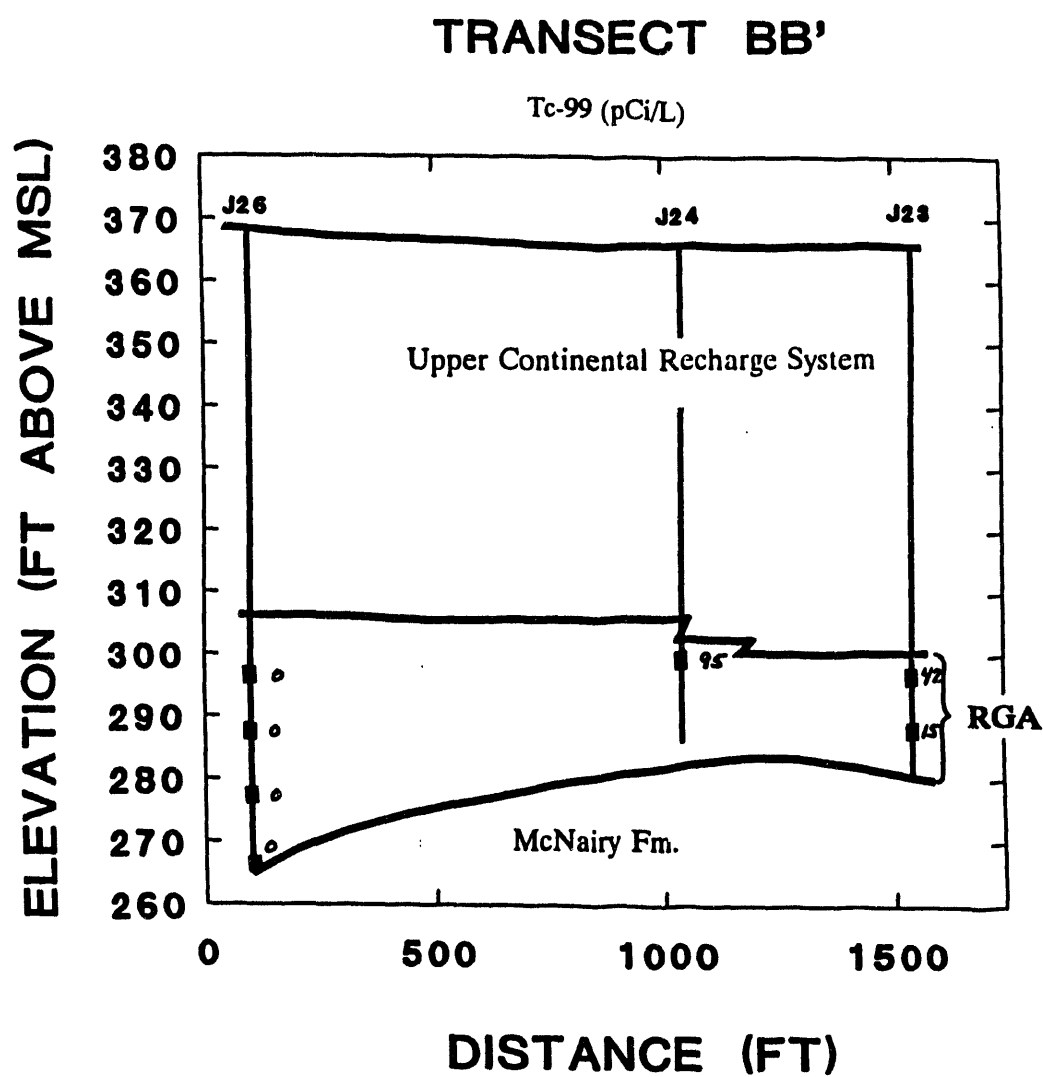


Fig. 9. <sup>99</sup>Tc in groundwater from well point locations in Transect B-B. Results for samples analyzed in duplicate are averaged.

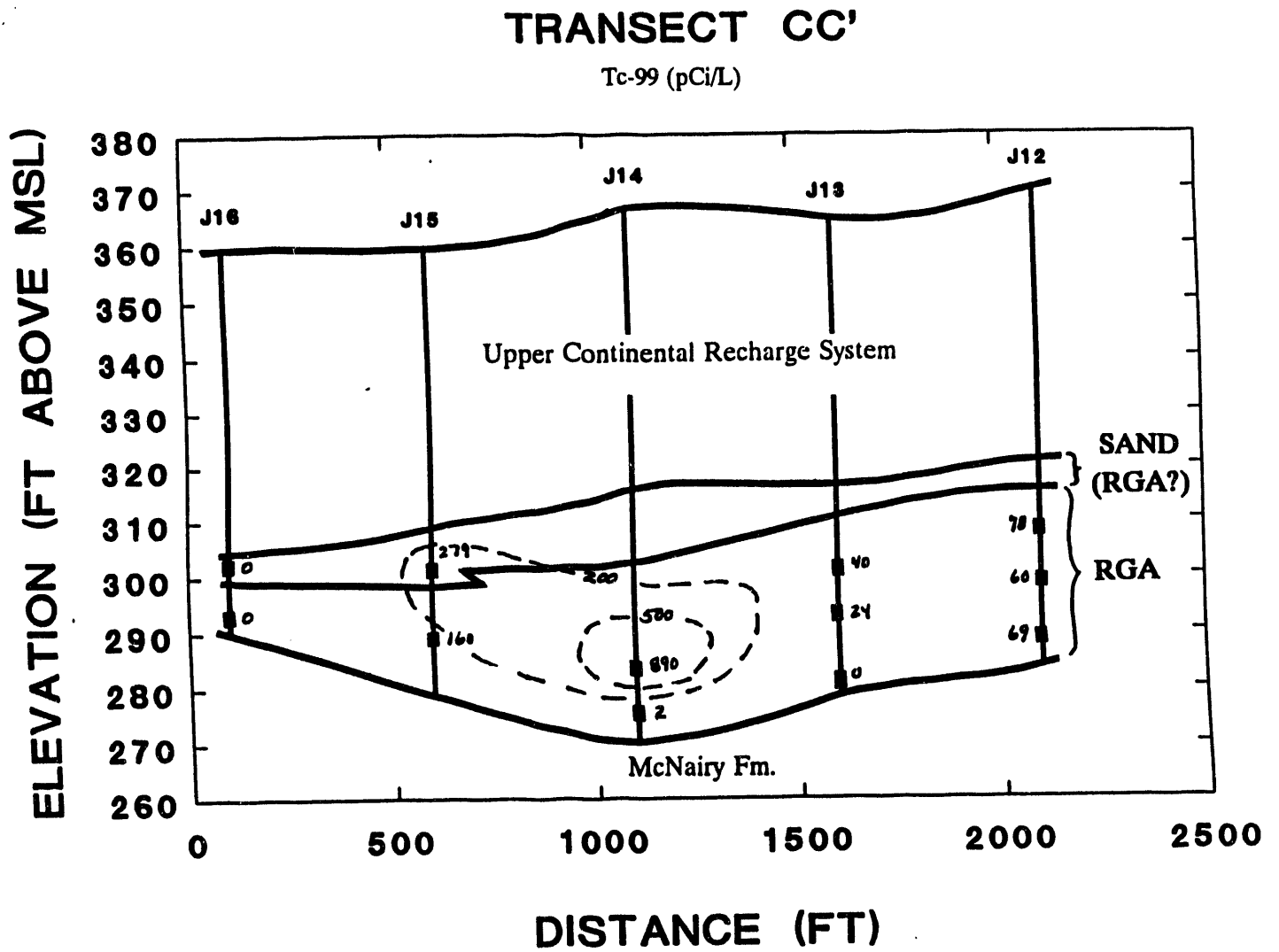


Fig. 10. <sup>99</sup>Tc in groundwater from well point locations Transect C-C. Results for samples analyzed in duplicate are averaged.

### **3.4 GROUNDWATER FLOW MODELING**

Recently, GeoTrans, a contractor to Energy Systems, completed a groundwater flow modeling study of the Northwest plume region so that it could recommend the most appropriate design of hydraulic source control for the plume. The results of this investigation are presented in a report (GeoTrans 1992) which explores two scenarios. The first option is for extraction wells to be located in the vicinity of Ogden Landing Road. The model indicates that nine wells, with a total pumping rate of 465 GPM, would be necessary to fully contain the source. The second option considered placing four wells closer to the source. With this configuration, a cumulative pumping rate of 183 GPM would be required for containment of the core ( $>100 \mu\text{g/L}$  TCE) of the plume.

#### **4. CONCLUSIONS AND RECOMMENDATIONS**

The Team evaluated the data obtained by the new field and modeling investigations and reached several conclusions:

- The groundwater chemistry data strongly suggest that pure-phase TCE has migrated into the RGA from a source region in the vicinity of SWMUs 7 and 30. Available data cannot determine the quantity and location of pure-phase TCE accumulations in the RGA, although it could occur either as residual droplets within the RGA or as a combination of droplets and discrete pools at the base of the RGA. In addition to TCE, evidence indicates that groundwater in the Northwest plume also is contaminated with <sup>99</sup>Tc.
- The pure-phase TCE will probably continue to be a source of a dissolved phase plume for decades.
- Currently, there is no effective method for remediating DNAPL sources in aquifers at the depth of the RGA; the only viable option is some form of source containment.
- Currently, the only proven technologies of source containment to address both TCE and <sup>99</sup>Tc contamination of groundwater is by using a pump-and-treat (hydraulic) methodology or by physical containment (i.e., walls).
- At least one emerging technology, the use of reactive gates, has promise for source containment of the Northwest plume but requires further development and evaluation.

The Team believes that for source containment in the near future, hydraulic containment by pump-and-treat is a technology proven to be effective. However, the Team supports the recommendation of the PGDP hydrology staff that refinements, such as addition of wall segments to funnel the flow of contaminated groundwater, be considered in concert with the basic design of the containment system. We believe that the pumping wells should be placed on DOE property south of Ogden Landing Road and designed to ensure that when the system becomes operational, contaminants released by the source in the future and incorporated into groundwater in the Northwest plume will no longer migrate across the DOE property boundary.

Although effective hydraulic containment can be achieved, the Team believes that several other alternatives for source containment should be considered. For example, recent advances in emplacing low-permeability barrier walls (slurry walls or sealable, interlocking sheet piling) to depths of 100 to 150 ft make it possible to consider complete

encirclement of the source of the Northwest plume. When coupled with an impermeable cap to prevent recharge, hydraulic isolation of the source can result in significant operation and maintenance savings.

Second, laboratory and field investigations currently in progress at the University of Waterloo (Ontario) that make use of in situ, permeable, reactive gates show great potential for removing TCE from groundwater and might also be effective in scavenging <sup>99</sup>Tc. Further development is required to evaluate this technology for implementation at PGDP or elsewhere. However, the Team is sufficiently encouraged by preliminary results of this work to recommend that Energy Systems/DOE actively seek a containment system that could incorporate this new technology, if merited, when the evaluation is complete.

The performance of both the pump-and-treat option and the reactive gate concept can be enhanced by incorporation of relatively short segments of in situ impermeable barriers, such as slurry walls or sealable sheet piling, to funnel the flow of contaminated groundwater to pumping wells or through the reactive gate, thereby reducing undesirable effects of simple pumping (e.g., treatment of excess water or mobilization of more-distant sources of contamination). We recommend that the planning and installation of impermeable walls occur in connection with design of the pump-and-treat option.

Currently, there are still some deficiencies in our understanding of the hydraulics of the RGA and the probable treatment technology that must be addressed. For example, additional hydraulic testing in the vicinity of the Northwest plume is required to refine design parameters for pumping wells and their placement and to optimize the design of the impermeable barriers. Furthermore, pilot-scale testing of the treatment technology is necessary to avoid potential costly mistakes prior to scale-up.

Based on these considerations, the Team recommends the following specific actions be undertaken by PGDP:

- Resolve the uncertainty concerning the possible existence of vinyl chloride and other halogenated hydrocarbon constituents in groundwater from the Northwest plume.
- Install a single well that is screened throughout the RGA to be used for limited hydraulic testing of the aquifer in the region where the hydraulic containment system is planned. Testing should include use of the borehole flowmeter developed by the Tennessee Valley Authority as well as standard pumping test methodologies. The purpose of this test is to obtain adequate characterization of aquifer hydraulic properties to facilitate design of pumping wells and to assist in future modeling activities.

- Utilize the test well to conduct a pilot plant performance demonstration (using a mobile system) for the purpose of evaluating the design of the treatment technology (air stripping for TCE and ion exchange for <sup>99</sup>Tc) under realistic conditions (a flow rate of about 10 GPM).
- As soon as appropriate hydraulic information for the RGA is available, commence modeling activities to optimize the design and placement of the pumping wells and the incorporation of an impermeable wall, injection well, or both, to direct contaminated groundwater flow.
- As a separate and concurrent activity, PGDP should support investigations to further evaluate the reactive gate technology and the feasibility of low-permeability walls for complete source isolation. Reactive gate investigations should elucidate reaction mechanisms between contaminants and the reactive components of the gate, model the hydraulic behavior of the wall, and optimize design features of the walls and gate to ensure its practicality in the hydrogeologic setting at PGDP. These investigations should include funding support for and close cooperation with the University of Waterloo or other research institutions. Evaluation of the wall technology should consider factors associated with methods of installation and performance assessment.
- If these concurrent investigations continue to support the reactive gate concept at PGDP, plans should be made to incorporate components of the system into the overall containment system. For example, once sufficient information is available concerning reaction mechanisms between contaminants and gate ingredients, reaction cells should be added in parallel to the groundwater treatment system to conduct a pilot-scale evaluation. If the entire concept proves to be feasible, then a reactive gate should be installed and tested. The pump-and-treat system should be retained as a backup system, if needed.
- If evaluation of low-permeability walls for source containment is favorable, use of this technology should be strongly considered. There are likely to be fewer uncertainties with these walls than with reactive gates, which should mean that they could be implemented more quickly. Furthermore, long-term operations costs are expected to be lower.
- Although the reactive-gate concept is the only currently emerging technology that might be applicable to containment of the Northwest Plume, Energy Systems should continue to explore and support evaluation of promising alternative technologies.
- Because data presented in this report suggest that pure-phase DNAPLs may be

present at the base of the RGA in the source area of the Northwest plume, plans should be made to investigate the McNairy Formation in this region to determine if significant contamination of groundwater by TCE and/or <sup>99</sup>Tc has occurred.

The Team strongly advocates the use of passive containment technologies such as barrier walls and reactive walls if they can be proven effective. In the case of PGDP, we believe that hydraulic and physical containment are the only viable near-term solutions to contaminant migration in the Northwest Plume. However, we recognize that pump-and-treat is an active form of containment for which there will be large initial capital expenses, as well as costly operation and maintenance considerations. If a passive containment concept can be made to work at PGDP, the savings in operation and maintenance costs will more than justify the redundancy of installing the passive system in addition to the pump-and-treat system. Obviously, we are unable to project the likely success of these technologies at PGDP or the final cost of such a system. Nevertheless, we believe that the investigations outlined here should be vigorously pursued to obtain the necessary technical, design, and financial data.

The Team consulted with Dr. Bernard Kueper (Queens University, Canada), an expert on DNAPL behavior in the subsurface, and his personal recommendations are provided in Appendix A. These recommendations are consistent with those discussed here. In his opinion, source control of the Northwest plume will be best accomplished by a pump-and-treat system, with the pumping wells located in the immediate vicinity of the DNAPL sources. Dr. Kueper believes that the new characterization data summarized in this report suggest that there is little risk of DNAPL short-circuiting within the RGA near the source of the Northwest plume, making it possible to place the interception wells close to the DNAPL source(s). Dr. Kueper further notes that a pilot-scale test should be undertaken before full-scale implementation of hydraulic containment and that additional effort should be taken to explore the potential usefulness of permeable reaction gates as a means of source control.

## **5. ACKNOWLEDGMENTS**

During the course of this evaluation the Team has worked closely and cooperatively with technical and management staff in the Environmental Restoration Program at PGDP. There have been significant contributions by PGDP staff to this final evaluation report for which the Team is grateful. The Team also would like to express its appreciation to the dedication of the Oak Ridge National Laboratory (ORNL)–Grand Junction and ORNL on-site staff who worked long hours to complete the required field work and to the PGDP and K-25 laboratories that provided analytical results with minimal delay.

## REFERENCES

- Bodenstein, G. W., R. R. Bonczek, T. O. Early, T. B. Hale, D. D. Huff, M. D. Nickelson, and C. T. Rightmire. 1992. Evaluation of the Pilot Groundwater Pump and Treat Demonstration for the Paducah Gaseous Diffusion Plant. KY-ER-15. Paducah Gaseous Diffusion Plant, Ky.
- Clausen, J. L., J. Zutman, N. Farrow. 1993. Characterization of the Northwest Plume Utilizing a Driven Discrete-Depth Sampling System. KY/ER-22. Paducah Gaseous Diffusion Plant, Paducah, Ky.
- GeoTrans. 1992. Groundwater modeling and offsite containment evaluation at the Paducah Gaseous Diffusion Plant. Prepared for Martin Marietta Energy Systems, Inc., by GeoTrans., Sterling, Va.

## INTERNAL DISTRIBUTION

1. L. V. Asplund
2. R. O. Barnett
3. L. D. Bates
4. F. P. Baxter
5. D. T. Bell
6. R. R. Bonczek
7. H. L. Boston
8. K. W. Cook
9. T. K. Cothron
10. D. G. Cope
11. J. H. Cushman
12. M. F. P. Delozier
13. J. W. Douthitt
14. R. B. Dreier
15. T. O. Early
16. J. M. Forstrom
17. D. E. Fowler
18. C. W. Gehrs
19. C. D. Goins
20. P. A. Gourieux
21. J. T. Grumski
22. T. B. Hale
23. S. G. Hildebrand
24. D. D. Huff
25. W. K. Jago
26. K. S. Jones
27. K. G. Kahl
28. P. Kanciruk
29. R. H. Ketelle
30. A. J. Kuhaida
31. D. M. Matteo
32. L. W. McMahon
33. J. R. Merriman
34. G. R. Miller
35. G. R. Moline
36. G. K. Moore
37. C. A. Motley
38. J. B. Murphy
39. M. D. Nickelson
40. M. J. Norris
41. F. S. Patton, Jr.
42. R. S. Poling
43. D. E. Reichle
44. C. T. Rightmire
45. T. H. Row
46. G. E. Rymer
47. F. E. Sharples
48. D. S. Shriner
49. E. D. Smith
50. S. H. Stow
51. H. A. Sydnor
52. L. E. Toran
53. L. O. Vaughan
54. D. B. Watson
55. S. H. Welch
56. R. K. White
57. S. L. Winters
58. T. F. Zondlo
59. Carol Young
60. Central Research Library
- 61-63. ER Document Management Center
- 64-66. ER Document Management Center at Paducah
- 67-82. ESD Library
- 83-84. Laboratory Records Dept.
85. Laboratory Records, ORNL-RC
86. ORNL Patent Section
- 87-88. Paducah Plant Library
89. ORNL Y-12 Technical Library

## EXTERNAL DISTRIBUTION

90. P. E. Barndt, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-SE 31
91. G. W. Bodenstein, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
92. Dr. S. N. Davis, 6540 W. Box Canyon Drive, Tucson, Arizona 85745
- 93-94. Robert Edwards, DOE Oak Ridge Field Office, Building C-100, Paducah, Kentucky 34220-1410
95. R. N. Farvolden, Professor, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario N2L 3G1 Canada
96. D. W. Freckman, Director, College of Natural Resources, 101 Natural Resources Building, Colorado State University, Fort Collins, CO 80523
97. C. S. Gist, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
98. R. C. Harriss, Institute for the Study of Earth, Oceans, and Space, Science and Engineering Research Building, University of New Hampshire, Durham, NH 03824
99. G. Y. Jordy, Director, Office of Program Analysis, Office of Energy Research, ER-30, G-266, U.S. Department of Energy, Washington, DC 20545
100. B. H. Kueper, Department of Civil Engineering Queen's University Kingston, Ontario Canada K7L 3N6
- 101-102. R. L. Nace, Branch Chief, Nonenrichment Facilities, Oak Ridge Program Division, Office of Eastern Area Programs, Office of Environmental Restoration, EM-423, Trevion 2, U.S. Department of Energy, Washington, DC 20585

103. A. Patrinos, Director, Environmental Sciences Division, Office of Health and Environmental Research, ER-74, U.S. Department of Energy, Washington, DC 20585
104. S. P. Riddle, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
- 105-124. R. C. Sleeman, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
125. D. K. Solomon, Department of Geology and Geophysics, 717 W. C. Browning Building, Salt Lake City, UT 84112-1183
- 126-127. H. M. Thron, Chief, Enrichment Facilities, Oak Ridge Program Division, Office of Eastern Area Programs, Office of Environmental Restoration, EM-423, Trevion, 2, U.S. Department of Energy, Washington, DC 20585
128. Don Wilkes, Science Applications International Corporation, Paducah, Kentucky 34220-1410
129. F. J. Wobber, Environmental Sciences Division, Office of Health and Environmental Research, ER-74, U.S. Department of Energy, Washington, DC 20585
130. Office of Assistant Manager for Energy Research and Development, U.S. Department of Energy Oak Ridge Operations, P.O. Box 2001, Oak Ridge, TN 37831-8600
- 131-132. Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831

**END**

**DATE  
FILMED**

**3 / 22 / 94**

