START 9613405.0156

0043004

BHI-00416
Rev. 2

Risk-Based Decision Analysis for the 200-BP-5 Groundwater Operable Unit

MAR 1996
RECEIVED
EDMC

Environmental Excellence
HANFORD

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Bechtel Hanford, Inc.
Richland, Washington

9613405.0157

TRADEMARK DISCLAIMER

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 or its contractors or subcontractors.

This report has been reproduced from the best available copy. Available in paper copy and microfiche.

Available to the U.S. Department of Energy
and its contractors from
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831
(615) 576-8401

Available to the public from the U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

Printed in the United States of America

DISCLM-5.CHP (8-91)

9613405.0158

BHI-00416
REV: 2
OU: 200-BP-5
TSD: N/A
ERA: N/A

APPROVAL PAGE

Title of Document: RISK-BASED DECISION ANALYSIS FOR THE 200-BP-5 GROUNDWATER OPERABLE UNIT

Author: G. R. Chiaramonte

Approval: G. C. Henckel, III, Manager, Groundwater Project

Signature

2/8/96
Date

The approval signature on this page indicates that this document has been authorized for information release to the public through appropriate channels. No other forms or signatures are required to document this information release.

BHI-DIS Cap 2-9-96

9613405.0159

BHI-00416
Rev. 2

Risk-Based Decision Analysis for the 200-BP-5 Groundwater Operable Unit

Author
G. R. Chiaramonte

Date Published
February 1996

Environmental Excellence
HANFORD

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Bechtel Hanford, Inc.
Richland, Washington

CONTENTS

1.0 INTRODUCTION 1

2.0 216-BY CRIBS PLUME 2
2.1 Existing Conditions 2
2.2 Future Conditions 2

3.0 216-B-5 REVERSE WELL PLUME 14
3.1 Existing Conditions 14
3.2 Future Conditions 16

4.0 GABLE MOUNTAIN POND PLUME 20
4.1 Existing Conditions 20
4.2 Future Conditions 20

5.0 REFERENCES 26

APPENDIX A - DISPERSIVITY DISCUSSION ..... A-i

FIGURES

1. 216-BY Cribs Plume Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Cobalt-60, Technetium-99 in Groundwater, Existing Conditions, Industrial Ingestion Scenario. 3
2. Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Future Conditions, Industrial Ingestion Scenario (longitudinal dispersivity = 200 ft) 6
3. Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Future Conditions, Residential Ingestion Scenario (longitudinal dispersivity = 200 ft) 7
4. Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Future Conditions, Industrial Ingestion Scenario (longitudinal dispersivity = 1,000 ft) 8
5. Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Future Conditions, Residential Ingestion Scenario (longitudinal dispersivity = 1,000 ft) 9
6. Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Estimated Conditions for 2018, Industrial Ingestion Scenario (longitudinal dispersivity = 1,000 ft) 11
7. Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Estimated Conditions for 2018, Residential Ingestion Scenario (longitudinal dispersivity = 1,000 ft.) 12

FIGURES (contd.)

8. 216-BY Cribs Plume Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Existing and Future Conditions 13
9. 216-B-5 Reverse Well Plume Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Cesium-137, Strontium-90, Plutonium-239/240 in Groundwater, Existing Conditions, Industrial Ingestion Scenario 15
10. 216-B-5 Reverse Plume Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Plutonium-239/240 in Groundwater, Existing and Future Conditions 19
11. Gable Mountain Pond Plume Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Strontium-90 in Groundwater, Existing Conditions, Industrial Ingestion Scenario 21
12. Gable Mountain Pond Polume Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Strontium-90 in Groundwater, Existing and Future Conditions . . . 24

TABLES

1. Transport Modeling Input Data for Technetium-99 in the 216-BY Cribs Plume 4
2. Results Predicted by Modeling in the 216-BY Cribs Plume 10
3. Modeling Case Results in the 216-BY Cribs Plume 10
4. Transport Modeling Input Data for Plutonium-239/240 in the 216-B-5 Reverse Well Plume 17
5. Transport Modeling Results 18
6. Travel-Time Analysis Results 20
7. Transport Modeling Input Data for Strontium-90 in the Gable Mountain Pond Plume 22
8. Gable Mountain Modeling Results 23

1.0 INTRODUCTION

A risk analysis was performed for the three groundwater contaminant plumes within the 200-BP-5 Operable Unit:

- 216-BY cribs plume
- 216-B-5 reverse well plume
- Gable Mountain pond plume.

The contaminants of potential concern (COPC) in the plumes include the following radionuclides: ^{99}Tc and ^{60}Co in the 216-BY cribs plume; ^{90}Sr, ^{137}Cs, and $^{239/240}$Pu in the 216-B-5 reverse well plume; and ^{90}Sr in Gable Mountain pond plume. The methodology used in the analysis is based on *Risk-Based Decision Analysis for Groundwater Operable Units* (BHI 1995). This methodology consists of three key elements:

- sample-specific risk characterization, which results in visual representations of human health risk associated with groundwater contamination

- estimation of natural attenuation (dispersion, retardation, and radioactive decay) as the contamination migrates from its present location to locations downgradient

- consideration of public health protection at key geographic locations along the natural migration pathway.

Risk assumptions and scenarios were based on *Hanford Site Risk Assessment Methodology* (HSRAM) (DOE-RL 1995). Hypothetical exposure scenarios were assessed based on current and future plume conditions. For current conditions, a hypothetical industrial groundwater ingestion scenario was evaluated; for future conditions, both industrial and residential ingestion scenarios were assumed. The industrial ingestion scenario, which is derived from HSRAM, was used in this risk analysis for illustrative purposes only. The 200 Area groundwater is currently not used for drinking water and it is not anticipated to be used for this purpose in the future; therefore, it should not be implied by this risk analysis that the U.S. Department of Energy (DOE) is advocating use of this groundwater for direct human ingestion.

Current conditions for the industrial scenario were based on the most recent (1994) validated groundwater concentration data. Future conditions for the industrial and residential scenarios were assessed using the recent groundwater concentration data, historical concentration data for ^{99}Tc in well 50-53A, and a combination of groundwater modeling and simple travel-time calculations, where appropriate. The residential scenario is more conservative (i.e., results in higher potential risks) than the industrial scenario. Uncertainties in this risk assessment are dominated by the use of conservative intake and toxicity values.

For current conditions, risk was calculated at each monitoring well using the observed radionuclide concentrations in groundwater from that well. The calculated values represent total radiological incremental lifetime cancer risk (ILCR). These values were plotted on base maps and risks were contoured.

For future conditions, the transport of ^{99}Tc and $^{239/240}Pu$ was modeled using a two-dimensional analytical flow and transport model called CONMIG (Walton 1989). The model simulated dispersion, adsorption, and radioactive decay of constituents during transport and assumes that the following statements are true: (1) steady-state groundwater flow is in a homogeneous, isotropic medium; (2) the groundwater flow velocity is uniform in one direction and dispersion is constant in time and space; and (3) the existing contaminant plumes can be represented as a group or cluster of point sources and there are no continuing sources of radionuclides (i.e., no contamination is currently being supplied to or produced in the aquifer).

The transport of ^{90}Sr and ^{137}Cs in the 216-B-5 reverse well plume was not modeled because these radionuclides exhibit a combination of moderate to high adsorption and relatively short half-lives. For these radionuclides, simple travel-time calculations and radioactive decay calculations indicated that these radionuclides will not migrate far before they decay to negligible levels. Therefore, modeling to assess the additional effects of dispersion is not necessary. For the radiological constituents modeled, the maximum ILCR in each plume is presented.

2.0 216-BY CRIBS PLUME

2.1 Existing Conditions

The maximum concentration of ^{99}Tc measured during the period between January 1993 and March 1995 was used as the input concentration for each well in the risk assessment model. At several wells, the highest concentration measured was not the product of the most recent sample event, which was the round 2 semi-annual groundwater monitoring activity that occurred during October and November 1994. Most results were from earlier semi-annual sampling events, except for the ^{99}Tc analysis for well 699-50-53A (8,640 pCi/L), which was determined from a Pacific Northwest National Laboratory (PNNL)-sponsored sampling of the well during February 1995.

The 216-BY cribs plume contains ^{60}Co and ^{99}Tc. The hypothetical risks based on current plume conditions are plotted in Figure 1 and represent the ILCRs for the industrial scenario assuming ingestion of both radionuclides through the consumption of drinking water (based on HSRAM [DOE-RL 1995]). Figure 1 shows a large area of risk greater than 1×10^{-5}; most of the risk is attributable to ^{99}Tc and not ^{60}Co. The maximum ILCR (6.9×10^{-5}) is calculated for groundwater at monitoring well 699-50-53A, which had a pretreatability test ^{99}Tc concentration of 8,640 pCi/L.

2.2 Future Conditions

Because ^{60}Co has a short half-life of 5.3 years, it was eliminated from consideration for calculating future risk and was not modeled. However, ^{99}Tc has a long half-life ($2.1 \times 10^{+5}$ years) and adsorption of ^{99}Tc on the aquifer matrix is negligible; therefore, the transport of ^{99}Tc in the 216-BY cribs plume was modeled. The input data used in the modeling are provided in Table 1.

Figure 1. 216-BY Cribs Plume Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Cobalt-60, Technetium-99 in Groundwater, Existing Conditions, Industrial Ingestion Scenario.

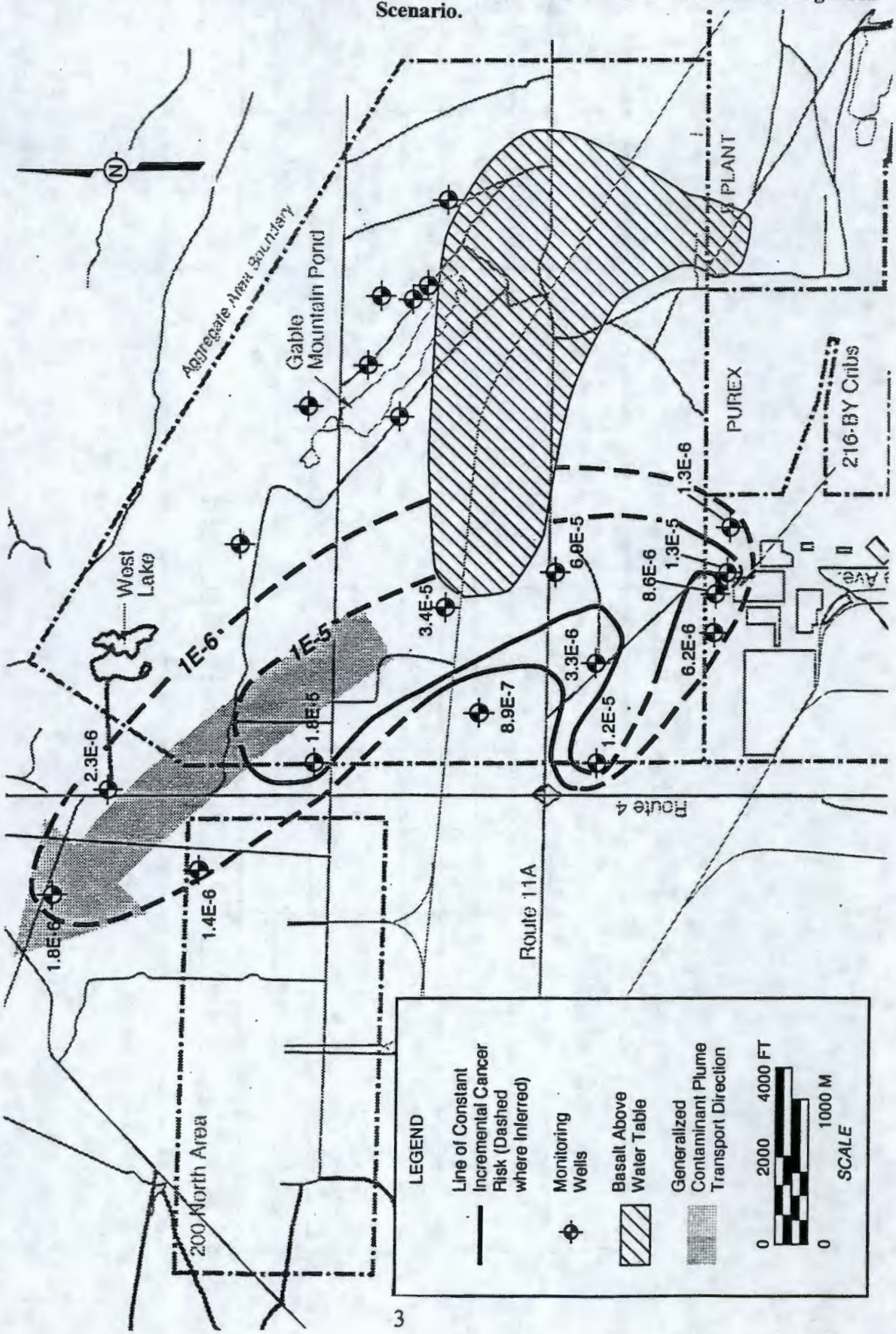


Table 1. Transport Modeling Input Data for Technetium-99 in the 216-BY Cribs Plume.

Model Run	Figure Numbers[a]	Total Porosity (%)	Effective Porosity (%)	Aquifer Thickness (ft)	Hydraulic Conductivity (ft/day)	Hydraulic Gradient (unitless)	Seepage Velocity (ft/day)
BYCRIB1	2 and 3	0.30	0.20	10	2,000	0.0001	1.0
BYCRIB2	4 and 5	0.30	0.20	10	2,000	0.0001	1.0
BYCRIB3	6 and 7	0.30	0.20	10	2,000	0.0001	1.0
BYCRIB5	8	0.30	0.20	10	2,000	0.0001	1.0
Model Run	**Figure Numbers**	**Longitudinal Dispersivity (ft)**	**Transverse Dispersivity (ft)**	**Aquifer Bulk Density (g/cm^3)**	**Distribution Coefficient (mL/g)**	**Distance from Source to Receptor (ft)**	**Travel Time (years)**
BYCRIB1	2 and 3	200	20	1.65	0	28,800	75
BYCRIB2	4 and 5	1,000	100	1.65	0	28,800	75
BYCRIB3	6 and 7	1,000	100	1.65	0	8,800	23
BYCRIB5	8	1,000	100	1.65	0	8,800	23

[a] Figure number refers to the figures presented in this report.

The objective of transport modeling was to determine the flow path length at which the maximum ILCR for ^{99}Tc at any location in the plume was no greater than 1×10^{-5} (this objective was requested by the U.S. Environmental Protection Agency [EPA]). Modeling results show that because of the large size of the ^{99}Tc plume, ILCRs will exceed 1×10^{-5} at the end of the flow path (the Columbia River). The modeled risk contours are shown graphically in Figures 2, 3, 4, and 5. (Note that the location of the Columbia River is approximately 2,000 ft beyond the edge of the model grid.)

The modeled transport of ^{99}Tc is essentially dependent upon dispersivity, as radioactive decay is negligible. There is uncertainty in the specification of values for dispersivity. Based on judgment of the modelers, a longitudinal dispersivity range of 200 ft to 1,000 ft was selected for the analysis to show sensitivity in the calculated risk results. Appendix A provides a more detailed discussion of dispersivity. Transverse dispersivities were assumed to be 0.1 times the longitudinal dispersivity. Based on these assumptions, the results predicted by the model are presented in Table 2.

At the request of EPA, additional modeling runs were performed to estimate the location and magnitude of risks posed by the ^{99}Tc plume in the year 2018. Three modeling cases were addressed as follows:

- Case 1: Concentration of ^{99}Tc was observed in well 699-50-53A that was 11,200 pCi/L during pump-and-treat operations (all other well concentrations were unchanged). One dispersivity scenario was modeled for this concentration (1,000 ft longitudinal/100 ft transverse).

- Cases 2a and 2b: The historical high concentration of ^{99}Tc in well 699-50-53A were represented by the 95% UCL of sample concentrations obtained during the period from June 26, 1987 to February 8, 1993. The following two dispersivity scenarios were addressed: Case 2a was 1,000 ft longitudinal/100 ft transverse; and Case 2b was 100 ft longitudinal/10 ft transverse. The 95% UCL was calculated to be 27,548 pCi/L of ^{99}Tc.

Results of these modeling cases are shown in the Table 3. Risk contours for Case 1 are plotted in Figures 6 and 7 for the industrial and residential scenarios, respectively. Figure 8 shows the risk contours for Case 2a based on a residential scenario. The existing plume (industrial scenario) is plotted on the same base map in Figure 8 for comparison.

The Case 2b dispersivity and travel-time conditions could not be modeled. An attempted run indicated that future ^{99}Tc concentrations were greater than the maximum source concentration. This does not imply that the dispersivity and travel-time conditions are physically impossible, only that the analytical model will not provide a correct solution under the constraints imposed.

A comparison of Cases 1 and 2a shows that future maximum concentrations and the corresponding risks are approximately proportional to current historical maximums assuming the same dispersivity. For example, if the source concentration is assumed to be doubled, then the maximum risk in the future plume is approximately doubled.

Figure 2. Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Future Conditions, Industrial Ingestion Scenario (longitudinal dispersivity = 200 ft).

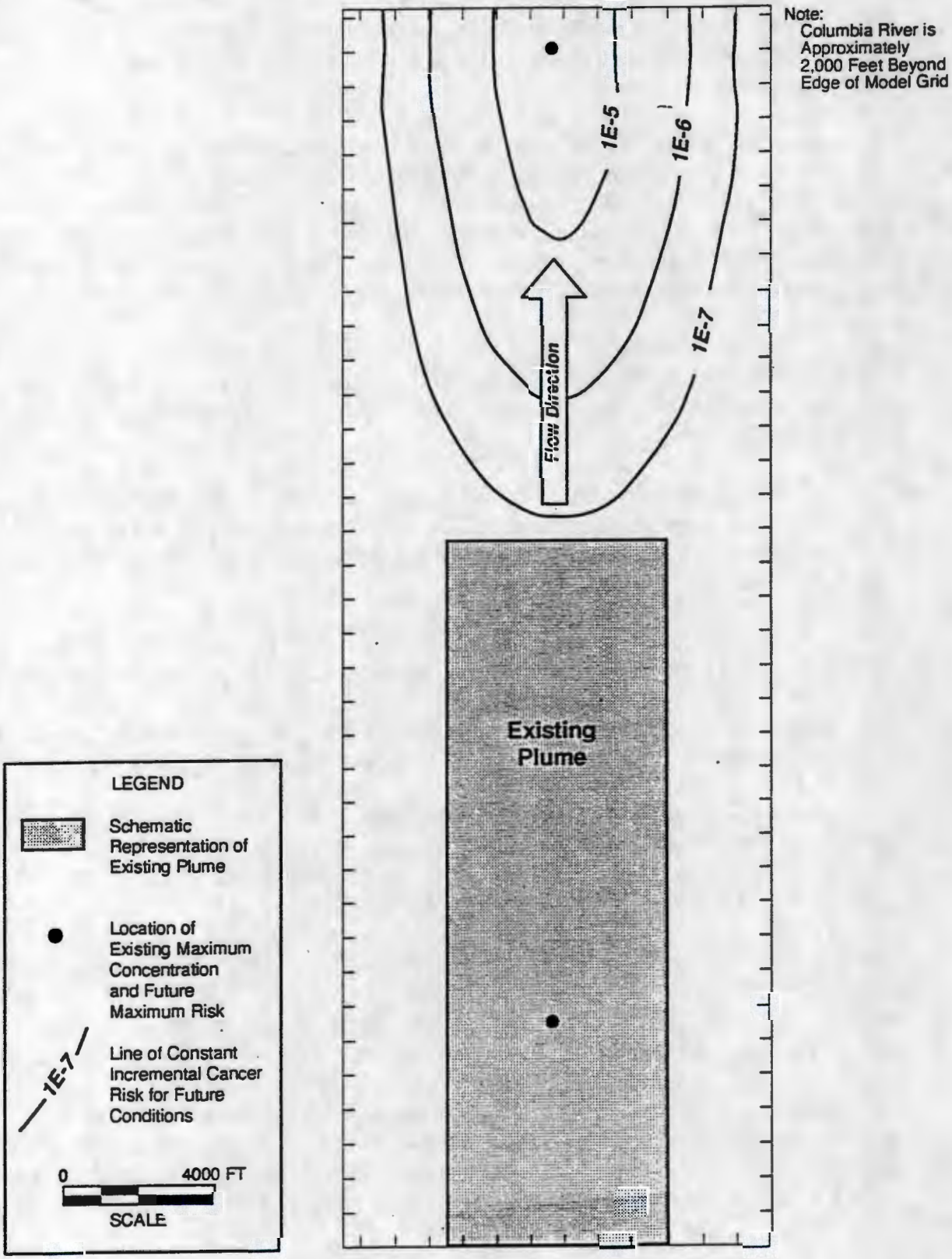


Figure 3. Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Future Conditions, Residential Ingestion Scenario (longitudinal dispersivity = 200 ft).

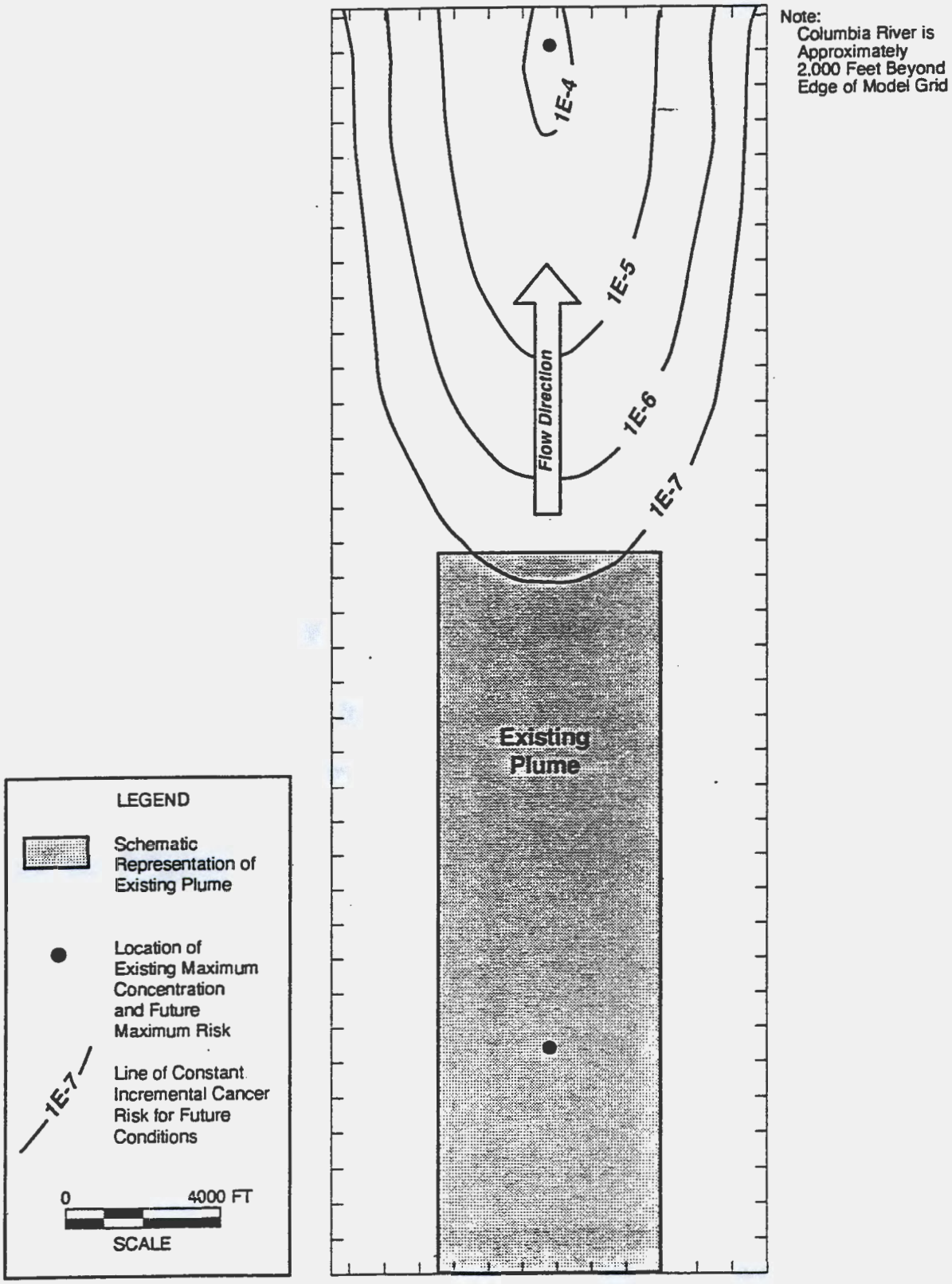


Figure 4. Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Future Conditions, Industrial Ingestion Scenario (longitudinal dispersivity = 1,000 ft).

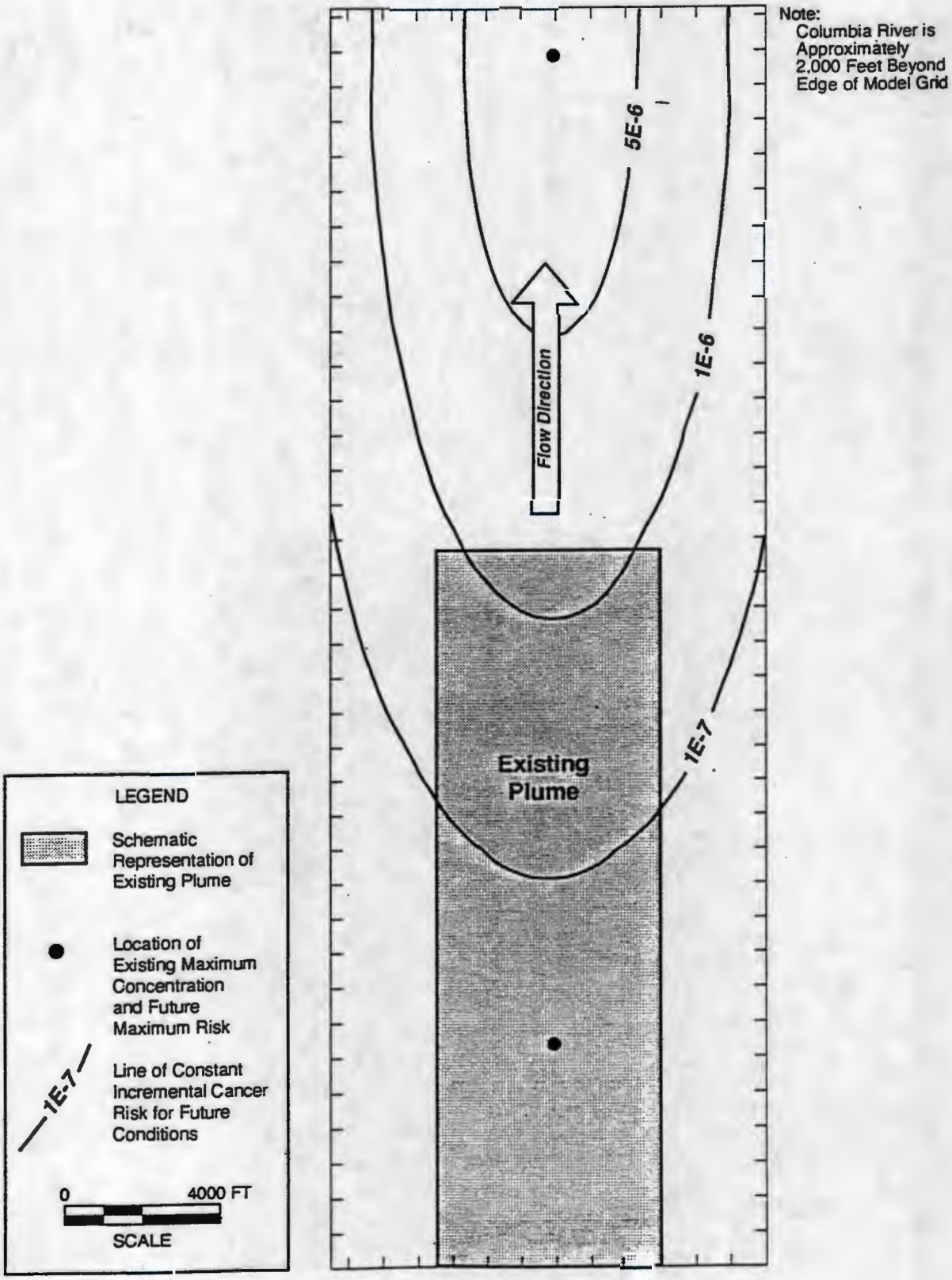


Figure 5. Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Future Conditions, Residential Ingestion Scenario (longitudinal dispersivity = 1,000 ft).

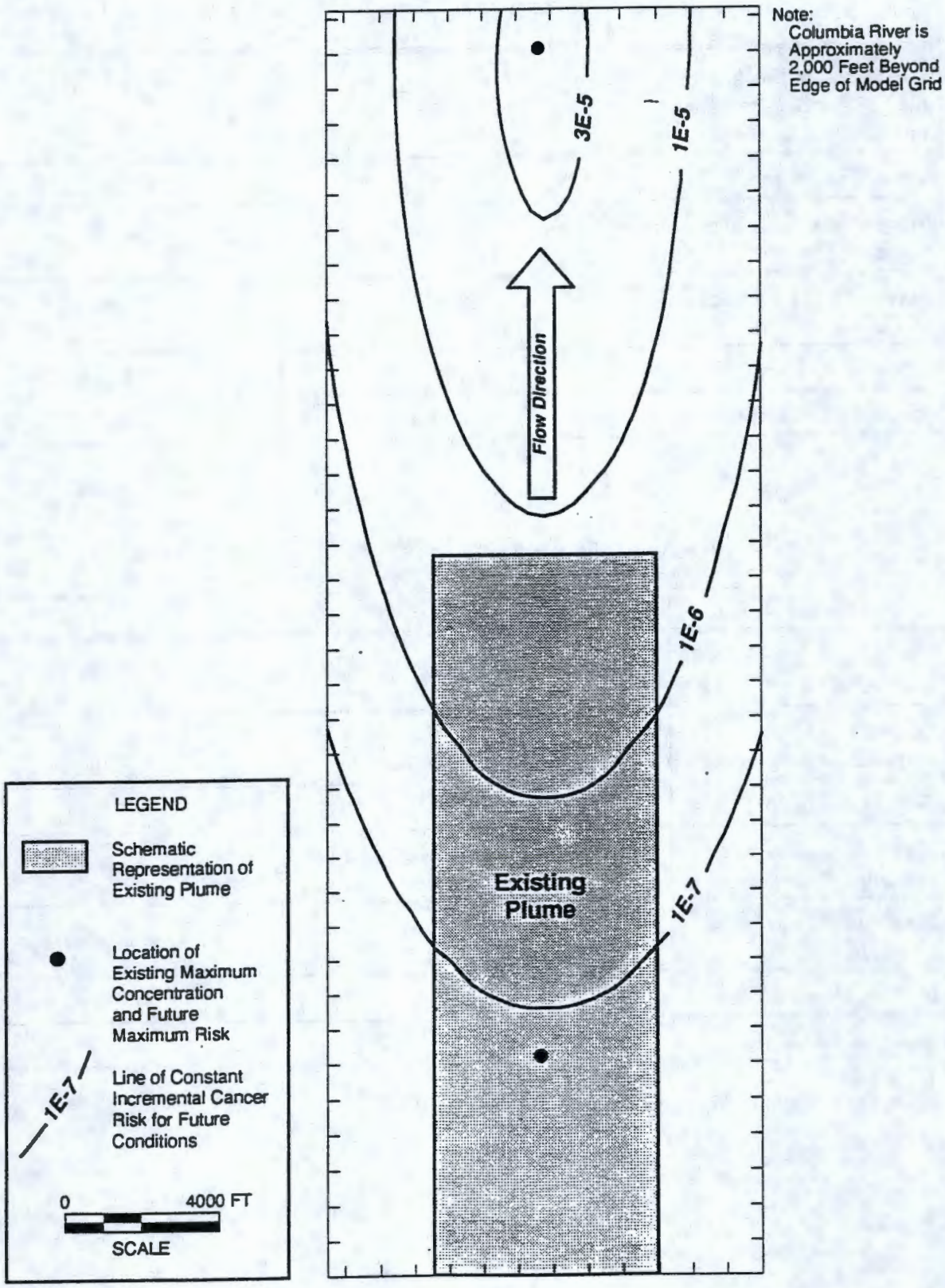


Table 2. Results Predicted by Modeling in the 216-BY Cribs Plume.

	Longitudinal Dispersivity = 200 ft	Longitudinal Dispersivity = 1,000 ft
^{99}Tc Concentration in Well 6-50-53A, pCi/L (existing plume)	8,640	8,640
Travel Time, Years	75	75
Travel Distance (to maximum risk point), ft	28,800	28,800
Maximum ^{99}Tc Concentration., pCi/L	4,190	1,270
Industrial Risk, ILCR	2.70E-5	8.30E-6
Residential Risk, ILCR	1.20E-4	3.60E-5

Table 3. Modeling Case Results in the 216-BY Cribs Plume.

Case	1	2a	2b
^{99}Tc concentration in well 50-53A, pCi/L	11,200	27,548	27,548
Dispersivity: longitudinal/transverse, ft	1,000/100	1,000/100	100/10
Travel time (to 2018), yrs	23	23	23
Travel distance to max. risk point, ft	8,800	8,800	*
Maximum ^{99}Tc in future plume, pCi/L	3,800	7,843	*
Industrial Risk, ILCR	2.5E-5	5.1E-5	*
Residential Risk, ILCR	1.1E-4	2.2E-4	*

*Unable to model this dispersivity and travel-time condition.

Figure 6. Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Estimated Conditions for 2018, Industrial Ingestion Scenario (longitudinal dispersivity = 1,000 ft).

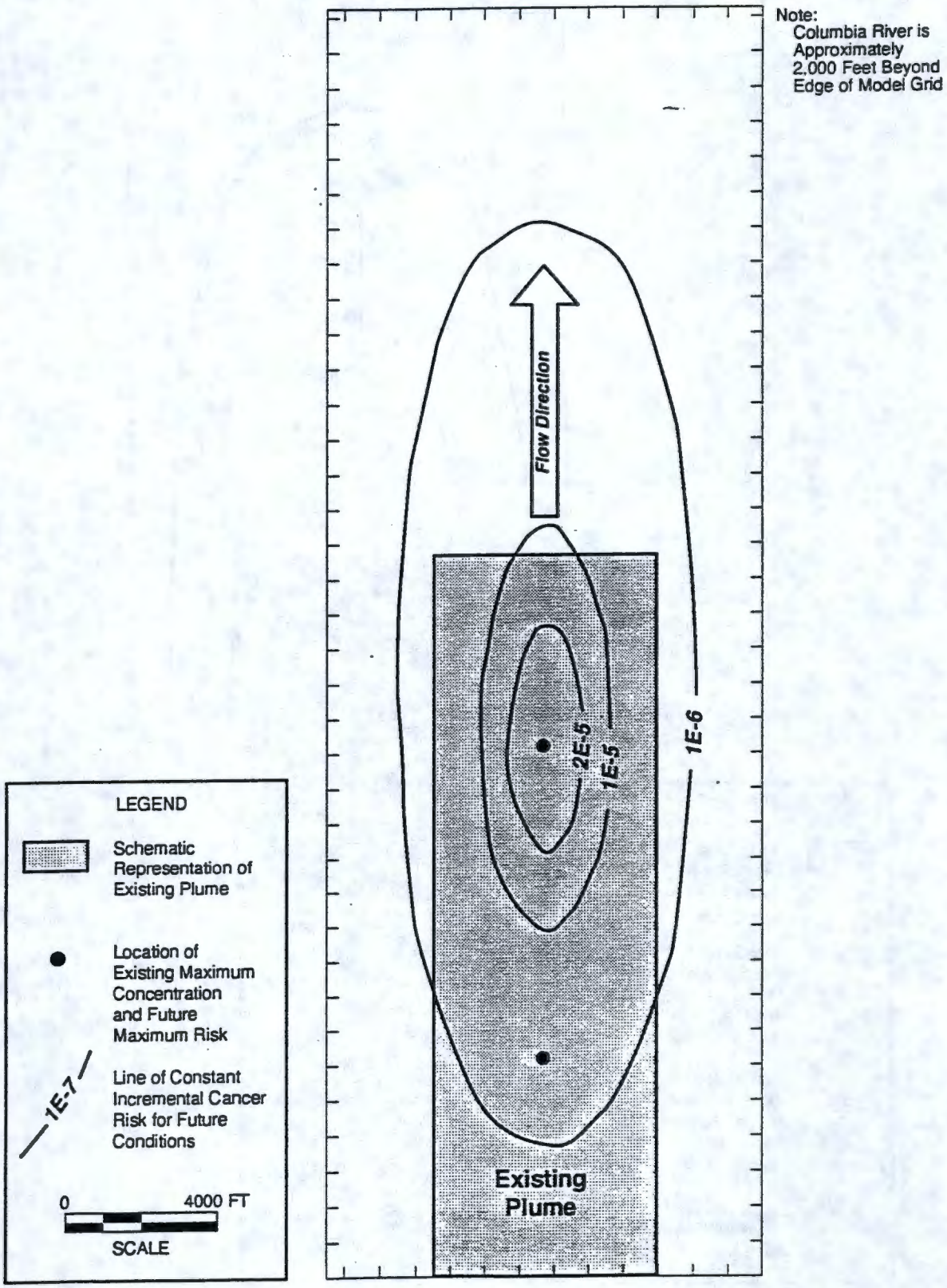


Figure 7. Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Estimated Conditions for 2018, Residential Ingestion Scenario (longitudinal dispersivity = 1,000 ft.)

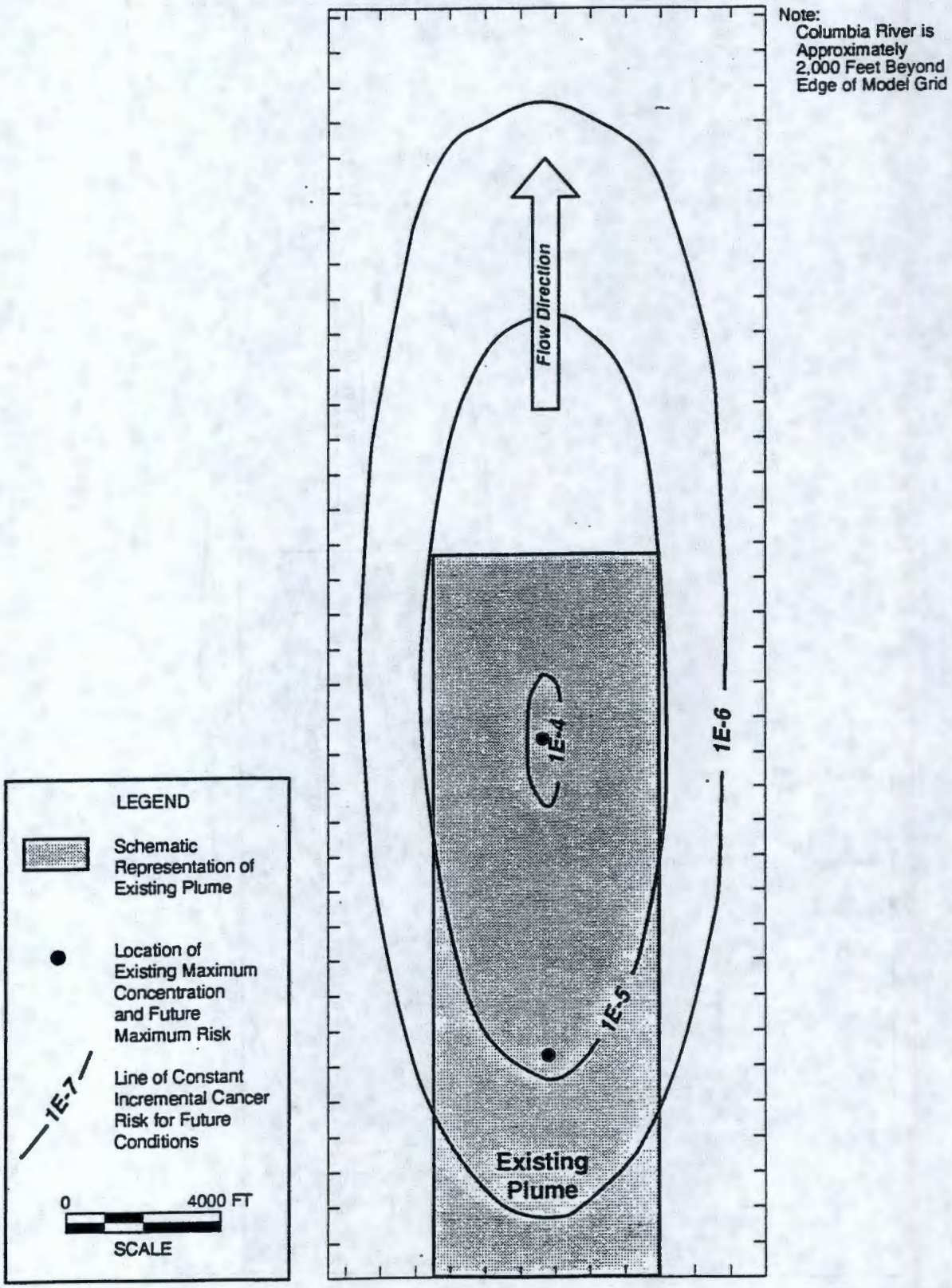
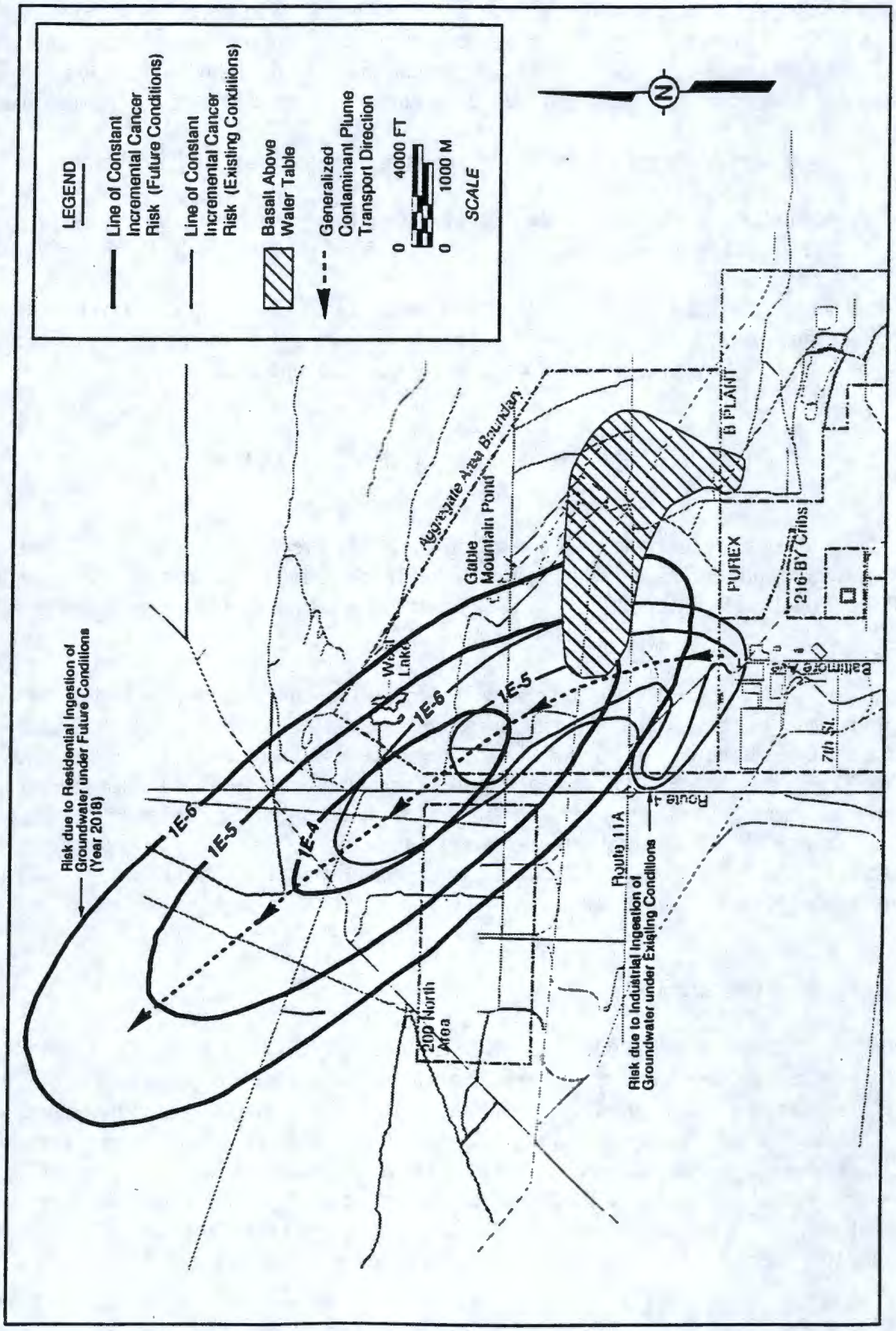


Figure 8. 216-BY Cribs Plume Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Technetium-99 in Groundwater, Existing and Future Conditions.



The source of the ^{99}Tc in groundwater is the 216-BY cribs. These cribs received waste from the mid-1950s to early 1970s (DOE-RL 1993). The current location of maximum concentrations of ^{99}Tc in the 216-BY cribs plume is approximately 4,000 to 6,000 ft north (or downgradient) of the suspected source area, and significant concentrations of ^{99}Tc are present in groundwater more than 10,000 ft further downgradient than the current location of maximum concentrations. Thus, ^{99}Tc is relatively mobile in the groundwater system to the north of the 200 East Area. Results of transport modeling of ^{99}Tc in the 216-BY cribs plume are uncertain for the following reasons:

- possible density-driven vertical migration of ^{99}Tc into the underlying basalt
- complexity of the hydrogeologic environment (i.e., exchange of groundwater between the basalt and the Hanford formation and channelized flow within the Hanford formation).

Observations presented in DOE-RL (1993) indicating that ^{99}Tc in the plume is relatively mobile provide support for the transport modeling results. However, the predicted future concentrations at the end of the flow path should be considered somewhat uncertain.

3.0 216-B-5 REVERSE WELL PLUME

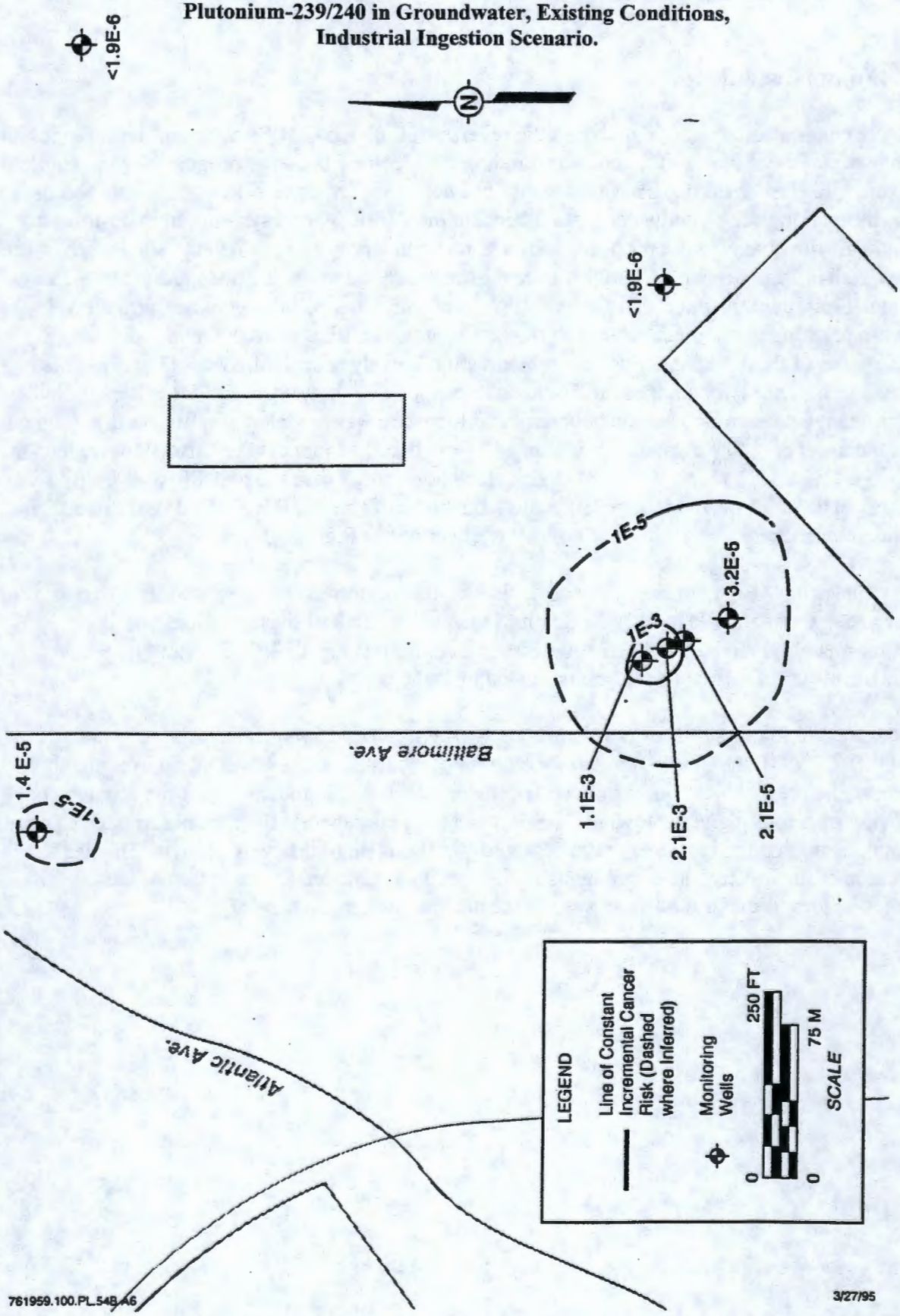
Calculation of risks from the ^{137}Cs and ^{90}Sr in the 216-B-5 reverse well plume are based on the highest concentration measured in each well during the period from January 1993 through March 1995. For all wells except 299-E28-25, the most recent sample collection provided the highest value.

Risk for $^{239/240}Pu$ in the 216-B-5 reverse well plume was calculated from the analysis of groundwater samples collected during the same January 1993 through March 1995 time period. Input to the risk model was provided by the most recent sampling event, except from wells 299-E28-23 and 299-E28-25, where the higher concentrations were found during earlier sampling events. The highest concentration and coincidentally the most recent $^{239/240}Pu$ sampling from well 299-E28-24 was rejected as suspect data because it was over 100 times greater than the average of the previous analyses from that well. The next highest concentration was used as input data for the risk calculation.

3.1 Existing Conditions

The 216-B-5 reverse well plume contains ^{90}Sr, ^{137}Cs, and $^{239/240}Pu$ as the principal COPCs. The risk profile based on current plume conditions (industrial-use scenario) is shown in Figure 9. Figure 9 shows a small area of risk greater than 1×10^{-5}. The analysis shows that no one radionuclide is consistently the major contributor to the ILCR but, rather, the major contributor differs from one monitoring well to the next. The maximum ILCR (2.1×10^{-3}) was calculated for groundwater at monitoring well 299-E28-23. In this well ^{90}Sr is the major contributor (86% of the ILCR), with a concentration of 2,310 pCi/L. The highest ILCR due to $^{239/240}Pu$ alone is 1.4×10^{-4}, due to 125 pCi/L of $^{239/240}Pu$ in groundwater at monitoring well 299-E28-25. Note that

Figure 9. 216-B-5 Reverse Well Plume Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Cesium-137, Strontium-90, Plutonium-239/240 in Groundwater, Existing Conditions, Industrial Ingestion Scenario.



a $^{239/240}Pu$ concentration of 2,670 pCi/L (well 299-E28-24) was not used in the risk assessment because it appears to be an incorrect result.

3.2 Future Conditions

Future conditions consider risk due to the reverse well plume COPCs at a point representing the boundary of the initial buffer zone surrounding the Central Plateau as proposed by the Hanford Future Site Uses Working Group. Because of uncertainty in future flow conditions (because of the dissipation of a groundwater mound beneath the 216-B-3 pond system), both northwest and southeast flow paths to the proposed buffer zone boundary were considered. The length of each flow path is approximately 20,000 ft. Travel-time calculations, along with radioactive decay calculations, demonstrated that ^{90}Sr and ^{137}Cs concentrations will decay to negligible levels before reaching the boundary for both flow paths; this is attributed to the moderate to high adsorption of these radionuclides combined with relatively short half-lives. Therefore, the transport of these two isotopes did not need to be modeled; however, $^{239/240}Pu$ still exhibited significant concentrations at the boundary and therefore was modeled. Input data used to model the transport of $^{239/240}Pu$ are given in Table 4. Note that the more conservative (longer) half-life of ^{239}Pu ($2.4 \times 10^{+4}$ years) was used in all calculations rather than the half-life of ^{240}Pu ($6.6 \times 10^{+3}$ years). The transport modeling results are tabulated in Table 5. The $^{239/240}Pu$ risk contours for the residential scenario are plotted for both flow directions in Figure 10.

As requested by EPA, a travel-time analysis was also performed to calculate travel distances of ^{90}Sr and ^{137}Cs at 50, 100, and 200 years into the future. Both of these isotopes will decay approximately three half-lives in 100 years and approximately six half-lives in 200 years. The travel-time analysis results are tabulated in Table 6.

As discussed in the *200 East Groundwater Aggregate Area Management Study Report* (DOE-RL 1993), the 216-B-5 reverse well has not received liquid waste for approximately 45 years. The present location of the 216-B-5 reverse well plume indicates that the plume is not moving or is moving very slowly (DOE-RL 1993). This supports the transport modeling results that indicate that the plume of ^{137}Cs, ^{90}Sr, and $^{239/240}Pu$ is migrating very slowly. This is likely because of the low hydraulic gradients in the area and/or moderate adsorption of the radionuclides in the groundwater system (or precipitation in the case of ^{90}Sr).

Table 4. Transport Modeling Input Data for Plutonium-239/240 in the 216-B-5 Reverse Well Plume.

Model Run	Flow Direction	Total Porosity (%)	Effective Porosity (%)	Aquifer Thickness (ft)	Hydraulic Conductivity (ft/day)	Hydraulic Gradient (unitless)	Seepage Velocity (ft/day)
RWNW5	northwest	0.30	0.20	40	2,000	0.0001	1.0
RWSE5	southeast	0.30	0.20	40	2,000	0.0004	4.0

Model Run	Flow Direction	Longitudinal Dispersivity (ft)	Transverse Dispersivity (ft)	Aquifer Bulk Density (gm/cm^3)	Distribution Coefficient (ml/gm)	Distance from Source to Receptor (ft)	Travel Time (years)
RWNW6	northwest	200	20	1.65	100	19,200	28,500
RWSE6	southeast	200	20	1.65	100	20,000	7,500

Table 5. Transport Modeling Results.

Risk Scenario	Flow Path Direction	$^{239/240}Pu$ Max. Concentration (pCi/L)	Travel Time (yrs)	ILCR
Industrial	Northwest	0.11	28,500	1.3E-7
Industrial	Southeast	0.20	7,500	2.3E-7
Residential	Northwest	0.11	28,500	5.7E-7
Residential	Southeast	0.20	7,500	1.0E-6

Figure 10. 216-B-5 Reverse Plume Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Plutonium-239/240 in Groundwater, Existing and Future Conditions.

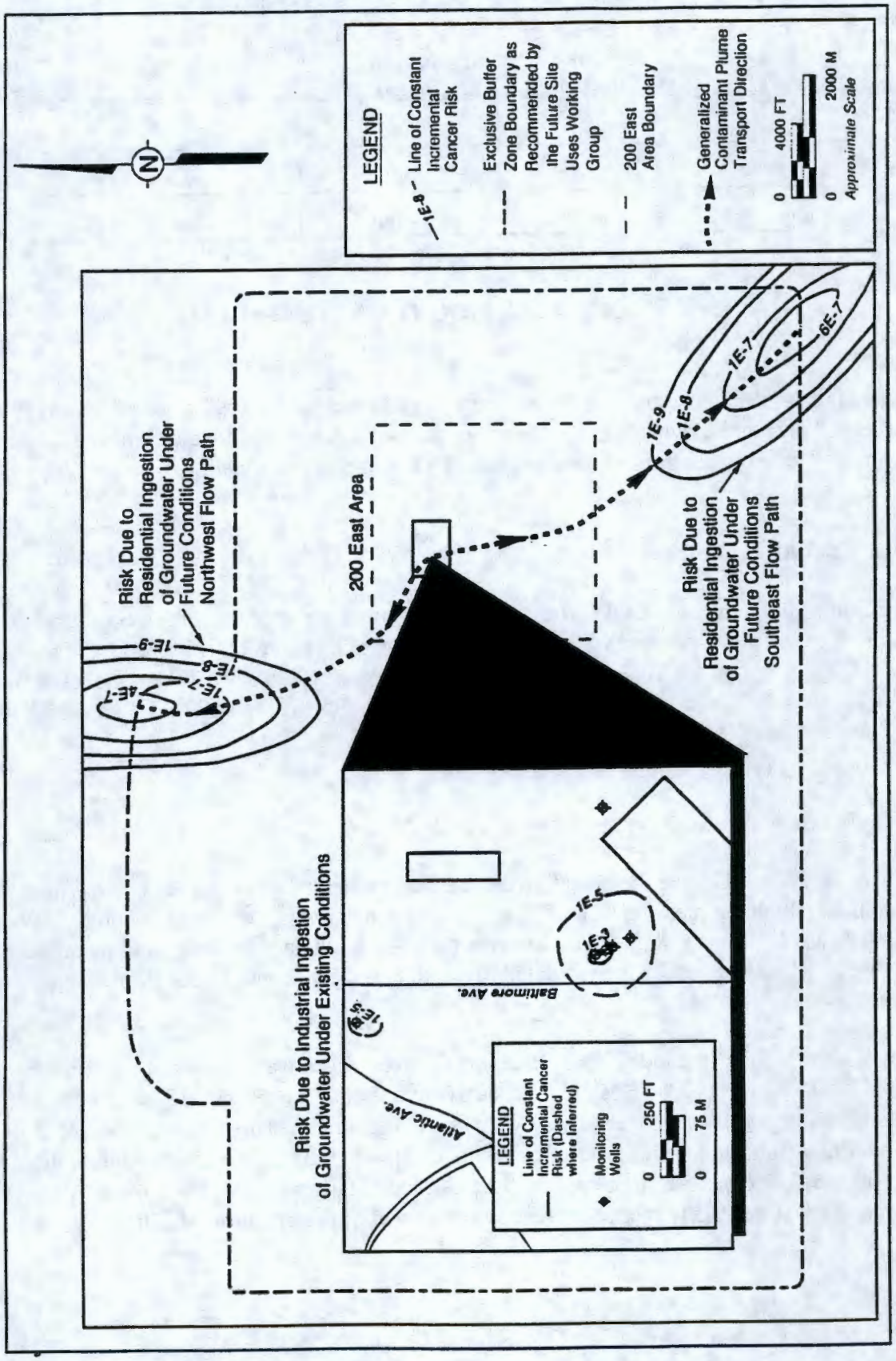


Table 6. Travel-Time Analysis Results.

Number of Years for Contaminant Migration to Occur	Distance (ft) ^{90}Sr Migrates in Southeast Direction	Distance (ft) ^{90}Sr Migrates in Northwest Direction	Distance (ft) ^{137}Cs Migrates in Southeast Direction	Distance (ft) ^{137}Cs Migrates in Northwest Direction
50	650	150	25	5
100	1,300	300	50	10
200	2,600	600	100	20

4.0 GABLE MOUNTAIN POND PLUME

The highest ^{90}Sr concentrations during the period from January 1993 through March 1995 were recorded during the most recent sampling of the wells that comprise the Gable Mountain Pond plume. These concentrations were used as input to the risk calculation.

4.1 Existing Conditions

Strontium-90 is the only COPC for the Gable Mountain pond plume. Risk contours based on current conditions (industrial-use scenario) are shown in Figure 11. Figure 11 shows a small area of risk greater than 1×10^{-5} in groundwater on the southeastern side of the pond. The maximum ILCR (1.8×10^{-4}) is calculated for groundwater at monitoring well 699-53-48B, which had a ^{90}Sr concentration of 994 pCi/L.

4.2 Future Conditions

Based on EPA's request, the objective of transport modeling was to determine the flow path length at which the maximum ILCR for ^{90}Sr at any location in the plume attenuates to below 1×10^{-5} as the plume migrates to the northwest. The input data for the modeling are shown in Table 7. Modeling results are tabulated in Table 8, and risk contours for the residential scenario are shown in Figure 12.

The Gable Mountain pond (216-A-25 pond) received waste water and cooling water from 1957 to 1987 (DOE-RL 1993). Despite first receiving this water more than 35 years ago, the ^{90}Sr groundwater plume has not advanced very far downgradient. This supports the transport modeling results and travel-time calculations that predict that ^{90}Sr will not migrate more than 4,400 ft before concentrations are less than risk-based target levels. The slow movement of ^{90}Sr in groundwater is likely related to the adsorption and/or precipitation of ^{90}Sr.

Figure 11. Gable Mountain Pond Plume Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Strontium-90 in Groundwater, Existing Conditions, Industrial Ingestion Scenario.

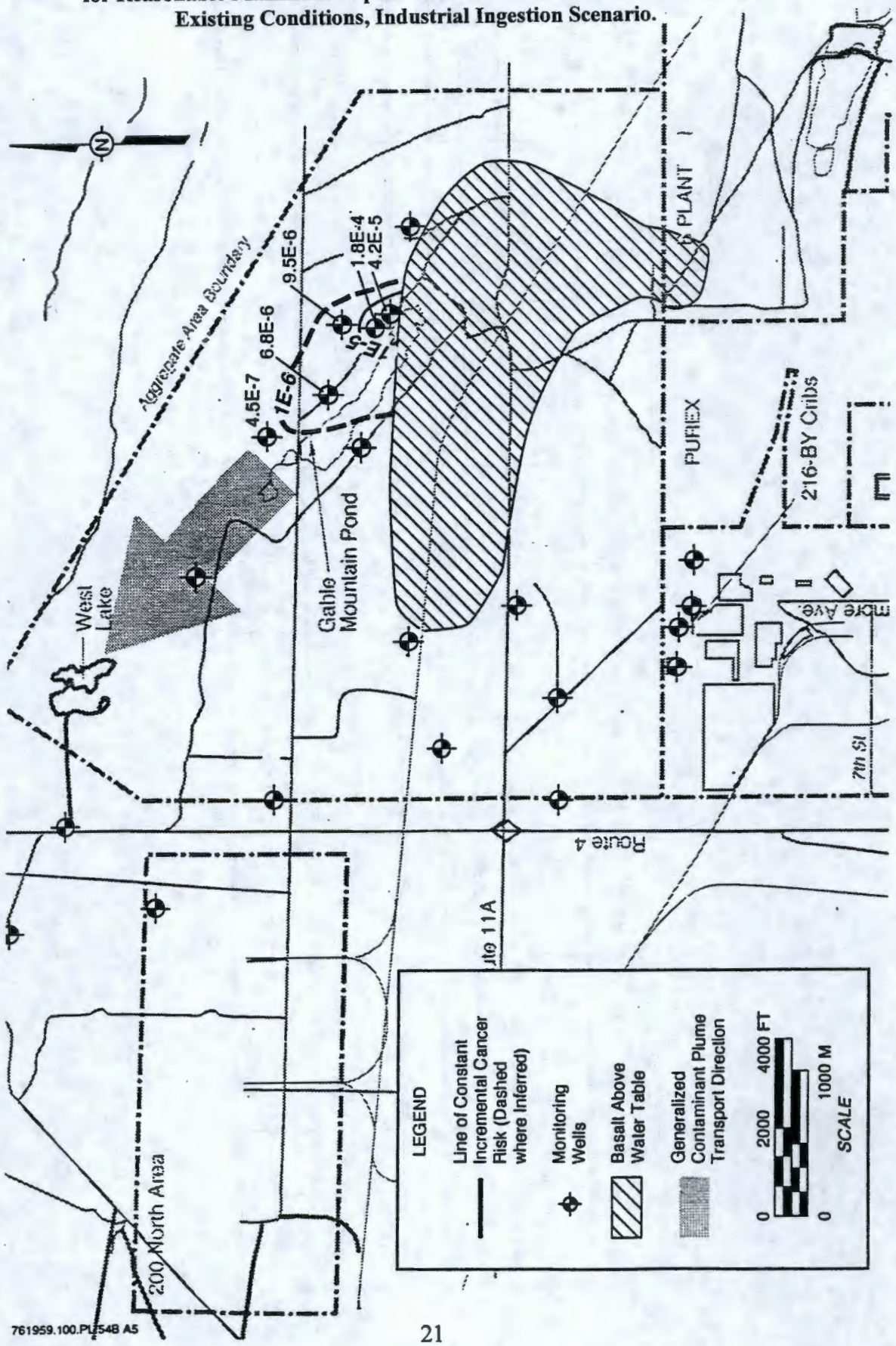


Table 7. Transport Modeling Input Data for Strontium-90 in the Gable Mountain Pond Plume.

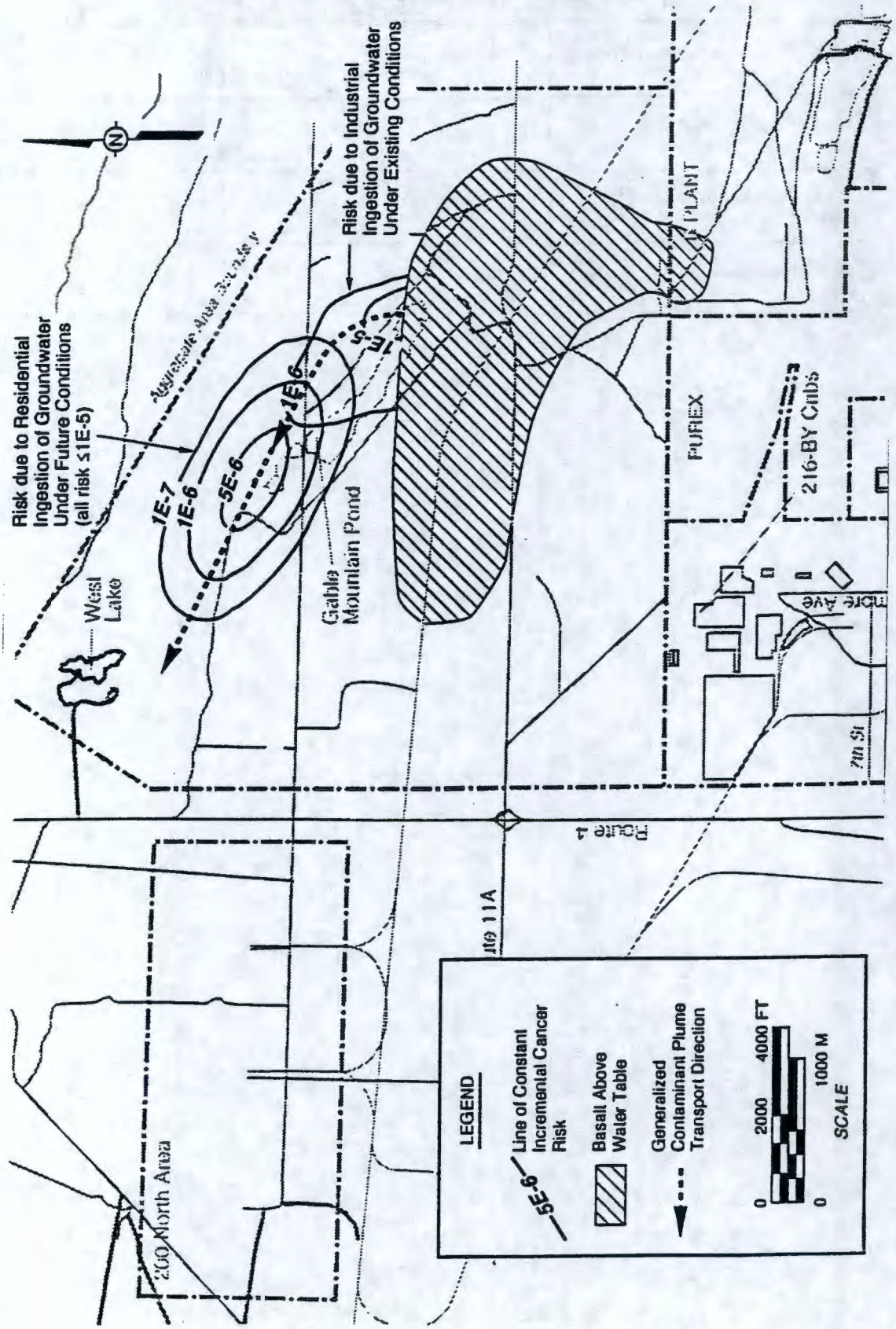
Model Run	Future-Use Exposure Scenario	Total Porosity (%)	Effective Porosity (%)	Aquifer Thickness (ft)	Hydraulic Conductivity (ft/day)	Hydraulic Gradient (unitless)	Seepage Velocity (ft/day)
GM3OUT	industrial	0.30	0.20	70	1,000	0.00015	7.5
GM4OUT	residential	0.30	0.20	70	1,000	0.00015	7.5

Model Run	Future-Use Exposure Scenario	Longitudinal Dispersivity (ft)	Transverse Dispersivity (ft)	Aquifer Bulk Density (gm/cm^3)	Distribution Coefficient (ml/gm)	Travel Distance (ft)	Travel Time (years)
GM3OUT	industrial	200	20	1.65	20	3,000	79
GM4OUT	residential	200	20	1.65	20	4,500	127

Table 8. Gable Mountain Modeling Results.

Risk Scenario	Industrial	Residential
Max. ^{90}Sr source conc. (existing plume), pCi/L	1,008	1,008
Travel time to reach 1E-5 ILCR, yrs	79	127
Travel distance to reach 1E-5 ILCR, ft	3,000	4,500
^{90}Sr concentration at 1E-5 ILCR, pCi/L	57	13

Figure 12. Gable Mountain Pond Plume Incremental Lifetime Cancer Risk for Reasonable Maximum Exposure to Strontium-90 in Groundwater, Existing and Future Conditions.



5.0 REFERENCES

BHI, 1995, *Risk-Based Decision Analysis for Groundwater Operable Units*, BHI-00161, Rev. 01, Bechtel Hanford, Inc., Richland, Washington.

DOE-RL, 1993, *200 East Groundwater Aggregate Area Management Study Report*, DOE/RL-92-19, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1995, *Hanford Site Risk Assessment Methodology*, DOE/RL-91-45, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Walton, W. C., 1989, *Analytical Groundwater Modeling, Flow and Contaminant Migration*, Lewis Publishers, Inc., Chelsea, Michigan.

APPENDIX A

DISPERSIVITY DISCUSSION

THIS PAGE INTENTIONALLY
LEFT BLANK

APPENDIX A
DISPERSIVITY

Dispersivity is defined as a characteristic length describing the ability of porous materials to disperse solutes (Walton 1985). In general, dispersivity is dependent on vertical and horizontal permeability and increases as the heterogeneity and anisotrophy of the geologic formations become greater (Mercado 1967). Dispersivity is influenced by the degree of and variations in stratification, typically varies from one layer to another, and depends on whether flow is principally through porous media or fractures.

Dispersion most often refers to spreading of the contaminant caused by the fact that not all of the contaminant actually moves at the same speed as the average linear groundwater velocity. In most groundwater flow systems, the effects of diffusion on contaminant dispersion is insignificant. The dispersion coefficient (D) is related to both hydrodynamic dispersion (D_h) and diffusion (D_f) by the following equation:

$$D = D_h + D_f$$

The units of dispersion are area/time (e.g., ft^2/sec).

Dispersivity (a), a constant value, is related to hydrodynamic dispersion by the equation:

$$D_h = aV,$$

where **V** is the directional groundwater velocity (vector) (units of distance/time).

Units of dispersivity are distance (e.g., ft).

There is much debate in the literature regarding dispersion (Anderson and Woessner 1992). Dispersivity is, in a sense, a constant correction factor used to account for the fact that it is not practical, and perhaps even impossible, to delineate the velocity distribution in detail. Some investigators advocate better resolution of the velocity distribution to minimize errors associated with estimating dispersivity values. Others propose that theoretically derived formulas involving parameters that describe the statistics of the hydraulic conductivity distribution be used to calculate dispersivities. Dispersivities have traditionally been estimated from trial-and-error model calibration and from tracer tests (Gelhar et al. 1985).

Dispersivity in porous media tends to increase and approach some maximum, asymptotic value with expansions in the volume of the aquifer system occupied by the solute. Large solute plumes encounter more permeability variations than do small solute plumes (Walton 1985). For mean travel distances less than 1,000 ft, longitudinal dispersivity (a_L) in uniformly porous aquifer systems may be estimated at one-tenth the flow path length (Pickens and Grisak 1981).

Dispersivity is scale-dependent. This estimate may not be valid for great distances because major geologic features may begin to dominate groundwater flow and influence contamination patterns.

Dispersivity can be treated as a mathematical correction factor (constant value) that is highly dependent on the judgment skills of the modeler.

REFERENCES

Anderson, M. P., and W. W. Woessner, 1992, *Applied Groundwater Modeling, Simulation of Flow and Advective Transport*, Academic Press, Inc., San Diego, California.

Gelhar, L. W., A. Mantoglou, C. Welter, and K. R. Rehfeldt, 1985, *A Review of Field-Scale Physical Solute Transport Processes in Saturated and Unsaturated Porous Media*, EPRI EA-4190, Electric Power Research Institute, Palo Alto, California.

Mercado, A., 1967, "The Spreading Pattern of Injection Water in a Permeability Stratified Aquifer," Symposium of Haifa, International Association of Scientific Hydrology, Publication No. 12.

Pickens, J. F., and G. E. Grisak, 1981, "Scale-Dependent Dispersion in a Stratified Granular Aquifer," *Water Resources Research*, Vol. 17, No. 6.

Walton, W. C., 1985, *Practical Aspects of Groundwater Modeling*, National Water Well Association, Worthington, Ohio.

DISTRIBUTION

Number of Copies		
ONSITE		
15	U. S. Department of Energy Richland Operations Office	
	DOE/RL Public Reading Room	H2-53
	ERC Team	
	G. R. Chiaramonte	H9-12
	D. B. Erb	H9-12
	G. C. Henckel, III	H4-80
	G. L. Kasza	H9-11
	D. A. Myers	H9-11
	R. W. Ovink	H4-92
	K. R. Porter	H9-12
	L. C. Swanson	H9-11
	R. Vinson	H9-12
	200-BP-5 Project File	H9-12
	BHI Document Control (3)	H0-09
	Hanford Technical Library	P8-55