WSRC-TR-2002-00117

Key Words:
Vadose Zone
Porflow

Retention:
Permanent

EFFECTS OF POINT SOURCES IN SLIT TRENCHES AT THE E-AREA LOW-LEVEL WASTE FACILITY ON GROUNDWATER CONCENTRATIONS

Prepared by:

Leonard B. Collard

February 28, 2002

Rev. 0

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

Prepared for the U.S. Department of Energy Under Contract Number DE-AC09-96SR18500

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

REVIEWS AND APPROVALS

Author

3/27/02

Leonard B. Collard, Waste Processing Technology **Date**

Design Check

3/27/02

J. R. Cook, Waste Processing Technology **Date**
(per Manual E7, Procedure 2.40)

SRTC Approvals/Review

3/27/02

B.T. Butcher, Level 4 Manager, Waste Processing Technology **Date**

3/27/02

W.E. Stevens, Level 3 Manager, Waste Processing Technology **Date**

Solid Waste Division Approval

3/27/02

W.T. Goldston, SW Technology and Integration **Date**

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

μCi	microcuries
Ci	curie
DOE	U.S. Department of Energy
E	exponential notation (e.g., 5E-10 = 5×10^{-10} = 0.0000000005)
ER	Environmental Restoration
ETF	Effluent Treatment Facility
ft	feet
g	gram
K_d	sorption coefficient
L	liters
Log	logarithm
m	meters
MCL	maximum contaminant level
ml	milliliters
PA	performance assessment
pCi	picocuries
SA	Special Analysis
U.S.	United States
WSRC	Westinghouse Savannah River Company
yr	year

1.0 EXECUTIVE SUMMARY

The analysis of point sources in a disposal unit is a new type of evaluation not previously considered in the SRS E-Area Low-Level Waste Facility (ELLWF) Performance Assessment (PA). The PA models radionuclide inventory as being uniformly distributed throughout the volume of the disposal unit. This PA simplifying assumption has been commonly employed to help streamline modeling waste sites. All major DOE sites with low-level waste disposal facilities have made this assumption in their PAs. However, recent advances in computer technology have provided the capability to perform rigorous analyses that account for more system heterogeneity on desktop computers. If adopted into PA practice, point source analyses would fundamentally change how PA modeling is performed and results are interpreted at the 100-m well.

This study examines the effects on groundwater concentrations from disposing point waste sources in slit trenches. The previous Performance Assessment and Special Analysis were based on the assumption that waste was uniformly spread throughout all trenches with no variation in concentration. Highly concentrated waste sources may occupy only a few boxes and thus only a small portion of the total volume of the slit trench. The placement location of the small waste volume may be important, thus various placement locations were examined in this study.

The Waste Acceptance Criteria (WAC; WSRC, 1997) allows the waste concentration in an individual package to exceed the nominal facility waste concentration by a factor of 10. If all waste in a slit trench exceeded the nominal facility waste concentration by the factor of 10, then the slit trench would be only one-tenth full on a volume basis. No previous analysis has been conducted for such a trench. The WAC also allows individual packages with concentrations that exceed this factor of 10 allowance to be accepted on an individual exception basis, but no quantitative analyses exist to support their acceptance.

In this study the entire waste inventory for a trench was assumed concentrated in 4 boxes, 20 boxes, 80 boxes, 160 boxes or one-half the trench (1000 boxes) representing concentrations that were about 500X, 100X, 25X, 12.5X and 2X the average concentration limit. Analyses were conducted for Basic I-129 (Kd of 0.6 ml/g) and H-Area CG-8 I-129 (Kd of 380 ml/g).

The meshes for the vadose zone and aquifer models were refined and reoriented to match the waste footprint to the size of the underlying aquifer cell footprint. The PA aquifer cell footprint of 200 ft by 200 ft was reduced to as small as 4 ft by 4 ft in some cases. These changes in implementing the PA model essentially doubled concentrations at the 100-m well.

Conclusions from this study are as follows:

1. The location of point sources across the trench width has minimal effect
2. Differences in results emerged from implementing the conceptual model differently than was done for the PA
3. A window with a variable footprint was used to calculate the average water concentrations over several aquifer cells beyond the 100 m buffer around the facility boundary. A window 20 ft square produced average concentrations about 30% to 70%

higher than a 200 ft square window. These differences were similar for both the low Kd and the high Kd contaminants. The 200 ft square window matched the aquifer cell size in the PA model used to calculate groundwater concentrations at the 100-m well.

4. Under some conditions concentrating waste may prove beneficial, however, it would require further investigation and careful management control.
5. Results for the 4-box and 20-box sets produced similar results when averaged over the selected window. Similar behavior was noted for 80-box and 160-box sets.
6. Analyses were conducted using nine uniformly loaded trenches and one trench with a point source load. This approach is useful if management can control the inventory in all 10 trenches. However, once a trench is closed that control is lost. A quasi-single trench approach was used in this report where the expected contribution from the nine uniformly loaded trenches was subtracted from all well concentrations. This provided information on managing each trench individually. The quasi-single trench model used an approximate method that assumes linearity and superposition of results that may not be completely accurate. An improved model would exclude initial waste in the nine trenches that in this report were simulated as being uniformly loaded.
7. As the elevation of the waste increased the well concentration decreased, i.e. concentrated waste placed at the top of the trench produces lower groundwater concentrations than does waste placed at the bottom of the trench.
8. Generally as the waste was moved farther away (horizontally) from the well, the groundwater concentrations decreased. Exceptions probably were caused by the peak from concentrated waste placed at the center of the point source trench arriving at the well at a time that reinforced the peak from the main body of waste. The peak from the concentrated waste closest to the well would have arrived at an earlier time. Another possibility is that the concentrated waste closest to the well followed a different path.
9. Concentrating the high Kd waste generally had a greater effect than concentrating the low Kd waste. For the full set of ten trenches and a 200 ft square window, the worst concentration case increased the groundwater concentration by 30% for the high Kd waste by only by 10% for the low Kd case.

The appropriate window size needs to be selected. Water from one trench typically passes beneath an adjacent trench before turning to better align with the long axis of the trench. It is recommended that a 20 ft wide window be used for groundwater protection because it approximates the width of a single trench, while a 150 ft wide window be used for residents located beyond a 100-m buffer.

The WAC limits could be reduced for all contaminants by dividing by a factor of 2 to 2.5 based on the differences discovered in this study on the method of implementing the aquifer conceptual model. After adjustments to the WAC are completed, each box that exceeds the average concentration limit could have its concentration amplified by the appropriate quasi-single trench factor for a 20 sq ft window in Table 4-2, which is reproduced below as Table ES- 1. The bolded original concentration factor and the Kd are used to select the appropriate row in the table. The table result for that row in the column titled Conc. Vs. 2000-box under the Quasi-Single Trench heading is selected. Alternatively, the table for a 200 ft square window could be used as shown in Table 4-3 that is reproduced below as Table ES- 2.

Table ES- 1. Group Worst Case Results by I-129 Kd with a 20 ft square window

			10 Trenches			Quasi-Single Trench		
Number of Boxes	**Conc.** Factor	Kd	Conc.	Conc. vs. 2000-box	Inv. Factor	Conc.	**Conc. vs. 2000-box**	Inv. Factor
1-40	**50-2000X**	**0.6**	1655	1.33	0.75	533	**4.26**	0.23
41-500	**4-50X**	**0.6**	1559	1.25	0.80	437	**3.50**	0.29
501-1800	**2-4X**	**0.6**	1377	1.10	0.91	255	**2.04**	0.49
1801-2000	**1X**	**0.6**	1247	1.00	1.00	125	**1.00**	1.00
1-40	**50-2000X**	**380**	93.6	1.75	0.57	45.4	**8.41**	0.12
41-500	**4-50X**	**380**	60.3	1.13	0.89	12.1	**2.24**	0.45
501-1800	**2-4X**	**380**	55.5	1.04	0.96	7.3	**1.35**	0.74
1801-2000	1X	**380**	53.5	1.00	1.00	5.4	1.00	1.00

Table ES- 2. Group Worst Case Results by I-129 Kd with a 200 ft square window

			10 Trenches			Quasi-Single Trench		
Number of Boxes	Conc. Factor	Kd	Conc.	Conc. vs. 2000-box	Inv. Factor	Conc.	Conc. vs. 2000-box	Inv. Factor
1-40	50-2000X	0.6	1013	1.14	0.88	209.2	2.35	0.43
41-500	4-50X	0.6	952	1.07	0.94	150.6	1.69	0.59
501-1800	2-4X	0.6	959	1.08	0.93	158.0	1.77	0.56
1801-2000	1X	0.6	890	1.00	1.00	89.0	1.00	1.00
1-40	50-2000X	380	56.2	1.30	0.77	17.3	4.00	0.25
41-500	4-50X	380	44.4	1.03	0.97	5.5	1.28	0.78
501-1800	2-4X	380	44.0	1.02	0.98	5.2	1.20	0.84
1901-2000	1X	380	43.2	1.00	1.00	4.3	1.00	1.00

The above results consider the full inventory of a trench as a single cluster generally closest to the water table and closest to the hypothetical well. Normal operations will tend to locate highly concentrated waste throughout a trench rather than at one location. This waste dispersal will produce a lower peak concentration than a single waste cluster. Some other factors that influence results are presented at the end of this report.

2.0 INTRODUCTION

This study examines the effects on groundwater concentrations from disposing point waste sources in slit trenches. The previous Performance Assessment (PA; McDowell-Boyer, et al., 2000) and Special Analysis (SA; Collard, 2000A) were based on the assumption that waste was uniformly spread throughout all trenches with no variation in concentration. Highly concentrated waste sources may occupy only a few boxes and thus only a small portion of the total volume of the slit trench. The placement location of the small waste volume may be important, thus various placement locations were examined in this study.

The Waste Acceptance Criteria (WAC; WSRC, 1997) allows the waste concentration in an individual package to exceed the nominal facility waste concentration by a factor of 10. If all waste in a slit trench exceeded the nominal facility waste concentration by the factor of 10, then the slit trench would be only one-tenth full on a volume basis. No previous analysis has been conducted for such a trench. The WAC also allows individual packages with concentrations that exceed this factor of 10 allowance to be accepted on an individual exception basis, but no quantitative analyses exist to support their acceptance.

In this study the entire waste inventory for a trench was assumed concentrated in 4 boxes, 20 boxes, 80 boxes, 160 boxes or one-half the trench (1000 boxes). The number of boxes and the concentration factor for that set of boxes are shown in Table 2-1.

Table 2-1. Modeled Box Sets Concentration Factors

Number of Boxes	Concentration Factor
4	500X
20	100X
80	25X
160	12.5X
1000	2X
2000	1X

The geometry for each box configuration is listed in Table 2-2. The configurations for 4 and 20 boxes are only one box in height. All other configurations match the waste cross-section of the PA and differ only in the number of boxes placed in the long direction of the trench.

Table 2-2. Nominal Point Source Configurations for B-25 Boxes

Number of Boxes	Width (Boxes/ft)	Length (Boxes/ft)	Height (Boxes/ft)
4	2 (8)	2 (12)	1 (4)
20	5 (20)	4 (24)	1 (4)
80	5 (20)	4 (24)	4 (16)
160	5 (20)	8 (48)	4 (16)
~1000	5 (20)	~50 (320)	4 (16)
~2000	5 (20)	~100 (640)	4 (16)

Point waste sources in the vadose zone model were initially analyzed by assuming a placement location in the center of a slit trench. Other placement locations to the right and left and up and down were considered to help determine the effects of the various locations on the groundwater concentrations. Table 2-3 lists the placement locations considered for one slit trench in the vadose zone model.

Table 2-3. Waste Locations in Vadose Zone Model for One Slit Trench

	HORIZONTAL LOCATION		
VERTICAL LOCATION	**Left**	**Center**	**Right**
Top	**X**	**X**	**X**
Center	**X**	**X**	**X**
Bottom	**X**	**X**	**X**

Figure 1 shows cross-sections of box placement locations for the single slit trench. In this figure, an orange line depicts the model boundary while black or colored blocks highlight the various placement locations for the point sources. The base of the model is the water table. The left edge of the model represent the point midway between a pair of trenches.

For the 4-box configuration cross-sections, colored boxes represent the cross-section of two B-25 boxes without stacking. The red boxes represent a left-side placement, the black boxes represent a center placement, and the green boxes represent a right-side placement. The black boxes overlap the other two colored boxes, because the trench is only 20 feet wide and can only accommodate 5 B-25 boxes, each with a width of 4 feet. A thick, gray dashed line depicts the outline of the PA waste area. Three sets of the red, black and green boxes are shown for the top, center and bottom elevation placements.

For the 20-box configuration cross-sections, the black boxes represent the cross-section of 5 B-25 boxes without stacking. Three sets of the black boxes represent the top, center and bottom elevation placements.

For all configurations with more boxes, the waste cross-section fully matches the waste cross-section of the PA. The difference in those configurations can only be seen in a plan view.

Various horizontal waste locations in the aquifer model were analyzed. For ease of discussion, the long axis of each trench is described as being in a North-South orientation with the north end being closest to a hypothetical 100-m well. The waste locations are listed in Table 2-4 and shown graphically in Figure 2. The full set of nine horizontal locations only applies to the 4-box configuration. All other configurations occupy the full width of the trench, thus they generally have three horizontal placement locations, South, Center, and North. The 1000-box configurations represent one-half the trench, thus they have only two horizontal placement locations, namely South and North. The 2000-box configuration represents the full trench and approximates the PA geometry.

Table 2-4. Waste Locations in Aquifer Model

	X-HORIZONTAL LOCATION		
Y-HORIZONTAL LOCATION	**West**	**Center**	**East**
North	**X**	**X**	**X**
Center	**X**	**X**	**X**
South	**X**	**X**	**X**

The contaminant flux at the water table from each waste placement cell in the vadose zone model was input as a source term to an underlying aquifer model cell that the water table intersected. (The aquifer model included both the vadose zone and the aquifers, hence the uppermost aquifer model cell extended to the ground surface.) The vertical location of the waste in the vadose zone did not affect the choice of location of the aquifer source cell, but it did affect the quantity and timing of contaminant flux reaching the water table.

Each point source configuration case was modeled for two I-129 waste streams. The first waste stream represented the original PA I-129, herein referred to as Basic I-129, with a Kd of 0.6 ml/g. The other waste stream selected was the H-Area CG-8 resin. The Special Analysis for high-concentration I-129 wastes in slit trenches (Collard, 2001) showed that the highest Kd waste streams with pronounced peaks within the 10,000 year period of interest were the H-Area CG-8 resin (380 ml/g) and the H-Area Filtercake (650 ml/g). Because the H-Area Filtercake does not pose a disposal problem it was not selected.

3.0 DISCUSSION

For comparison with Performance Assessments and Special Analyses and to help guide the selection of locations for point sources, the implementation of the conceptual model for slit trenches is discussed for both the vadose zone models and the aquifer models. Subsequently, the results of the point source analyses are presented.

Results from a refined 10-trench model with uniform waste distribution are first benchmarked with the PA or SA. Finally point source results are compared to a quasi-single trench model with a uniform waste distribution to isolate the effects of point sources. Results for the quasi-single trench model were calculated by subtracting the contributions from the nine uniformly loaded trenches from all well concentration results. For the benchmarked case, the remainder was assumed to be a single uniformly loaded trench that was used for ratio comparisons.

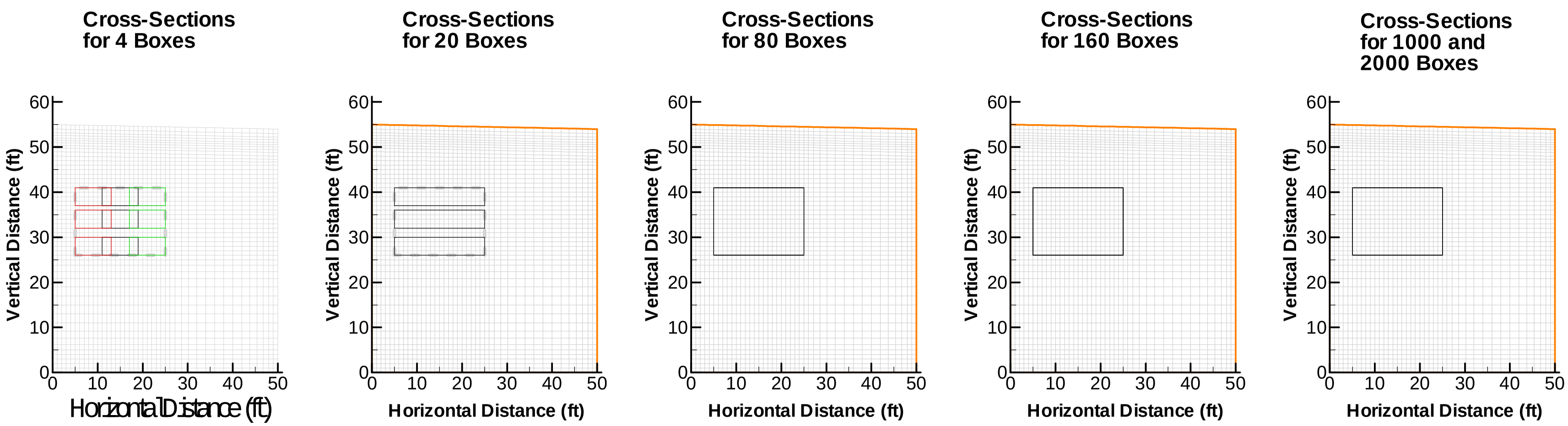


Figure 1. 2D Vadose Zone Model Showing Cross-Sections of Modeling Cases by Number of Boxes

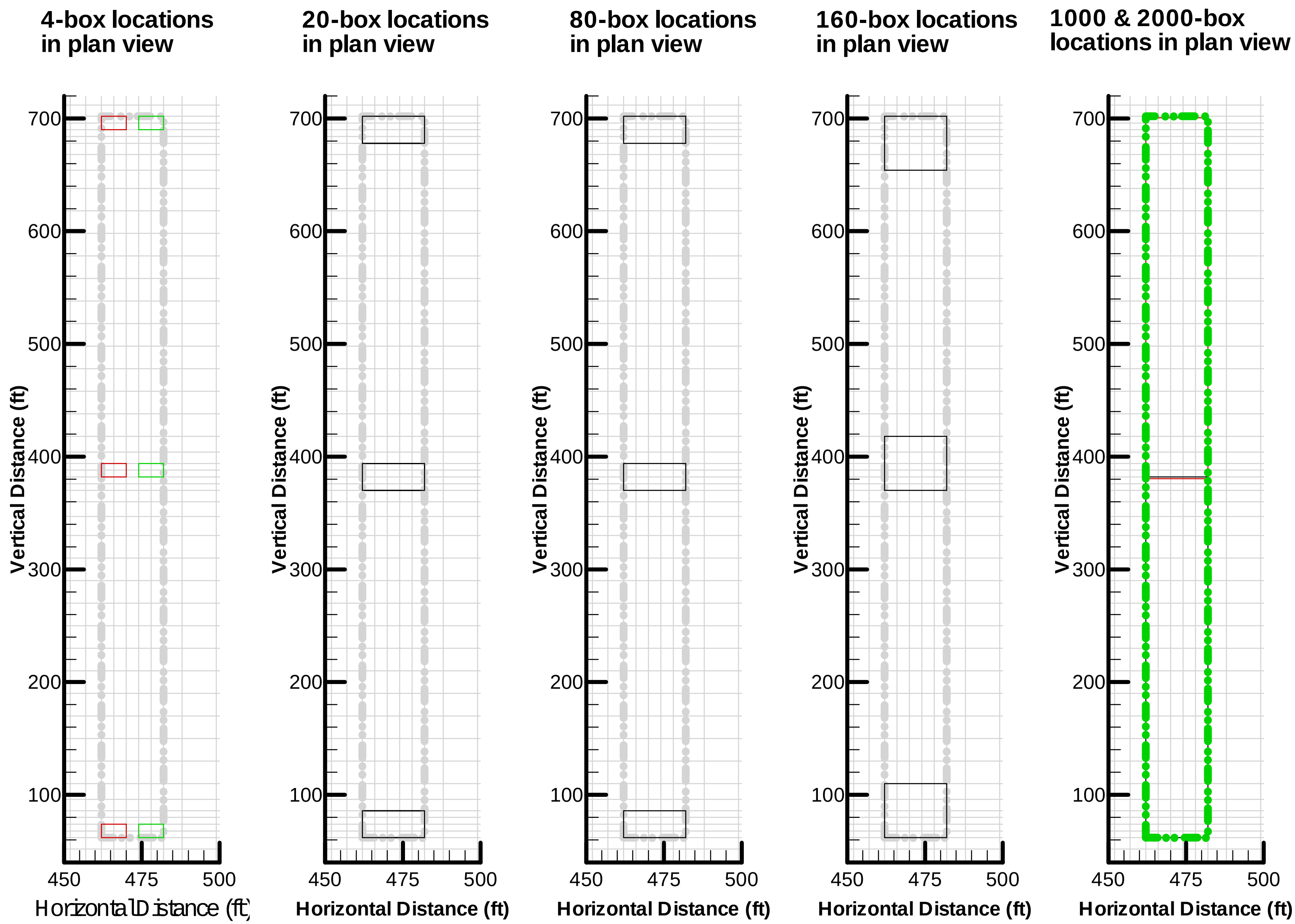


Figure 2. Plan View of Aquifer Model Showing Modeling Cases by Number of Boxes

3.1 CONCEPTUAL VADOSE ZONE MODELS

For vadose zone models, rather than simulating 10 slit trenches in one complex three-dimensional vadose zone model, only one slit trench was simulated in two dimensions. This approach was based on the fact that the rate at which the contaminant flux crosses the water table essentially is independent of the number of slit trenches, provided that they are identical. For advection-dominated cases, the fraction of the contaminant that crosses the water table over any specified amount of time is a function of the thickness of the waste, the speed of the contaminant carried by the water and the distance to the groundwater table. With all these components being equal for each trench, the same fraction of waste will cross the water table during the same time period.

Vadose zone models were based on a conceptual model of a slit trench with another slit trench to its left, but none to its right. The effect of the presence of slit trench to the left is apparent in Figure 3 for the failed stage of a trench. The gray-shaded region shows the full waste zone from the PA model. The blue squares show the paths that water molecules would travel if they were released at various locations along the top of the waste zone. The blue squares represent the location of those water particles at one-year intervals.

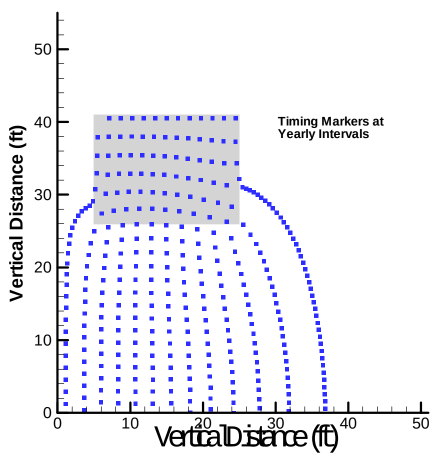


Figure 3. Streamtraces for the Failed Trench Stage with Water Particles Released from the Top of the Waste Zone

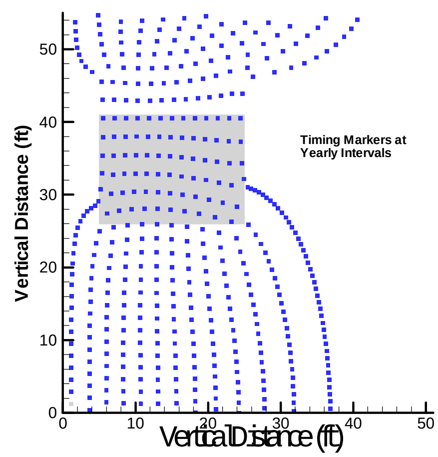


Figure 4. Streamtraces for the Failed Trench Stage with Water Particles Released from the Ground Surface

The left-most water particle at the top of the waste layer arrives at the water table at the base of the model in approximately 28 years. Water particles starting from the center of the top waste boundary arrive at the water table in approximately 21 years. Water particles starting from the right-hand side of the top waste boundary arrive at the water table in approximately 44 years. The presence of another slit trench to the left of the modeled trench constrains lateral spreading of water, resulting in higher speeds and shorter travel times.

The waste zone actually attracts water that penetrates the surface outside the footprint of the waste zone as shown in Figure 4. This attraction primarily is caused by the higher hydraulic conductivity in the waste zone, where the waste zone was assumed to transform into topsoil at the start of the trench's failed stage, versus the hydraulic conductivity of the surrounding native soil.

If a complex vadose zone model for 10 slit trenches were developed, all inside slit trenches would have other trenches on both sides and would show higher speeds and shorter travel times. The right-hand edge would show the greatest change, while the change would be less for water particles traveling through the center of the trench.

Based on the previous method of analysis and refined flow model results, point source locations were chosen across the width of the trench and vertically within the trench. The water speed (that determines the time to reach the water table) varies across the trench and may significantly affect the contaminant flux at the water table. The vertical locations primarily affect the distance to the water table and the arrival and peak times, with a smaller effect on the magnitude of the peak contaminant flux at the water table.

The geometry of the point source vadose zone model was refined to incorporate two basic requirements. First, one model was generated that could accommodate all the proposed geometrical configurations of point source wastes. Second, the geometry of the model was designed to match the footprints of proposed vadose zone waste cells with the footprints of underlying aquifer cells.

A general point source model for the vadose zone was developed and used as the base for all cases. The changes required for each specific placement case were reduced to identifying the point source waste area and specifying its Kd. This approach allowed application of the REPLACER computer program developed during the preliminary Uncertainty Study (Cook, et al., 2002) to help automate the process and reduce the potential for errors.

It appears that in photographs the waste boxes are oriented length-wise across the width of the trench producing an effective waste width of about 18 ft. However, for comparison with previous analyses, the waste width of 20 ft used in the PA model was retained for the point source study.

Minor corrections were made to the point source model where applicable. For example, the original model had a vertical thickness of the waste zone of 15 ft, while the actual box thickness was 16 ft.

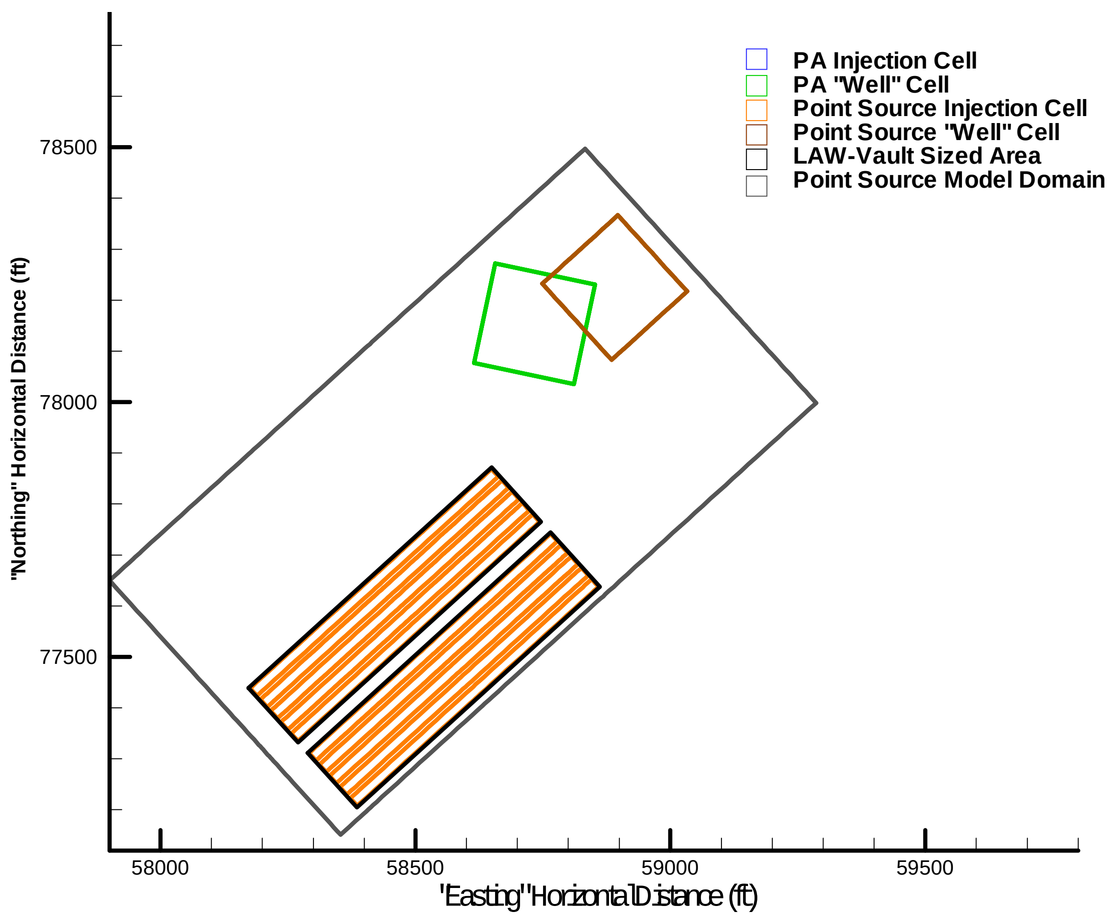
3.2 CONCEPTUAL AQUIFER MODELS

For the PA aquifer analysis, two sets of 5 slit trenches were anticipated for the time period that was simulated. This approach allowed plume interaction to occur among wastes from 10 slit trenches. The peak concentration at all theoretical 100-m wells were scanned and the largest value was used to establish the PA inventory limit by comparing it to the allowable water concentration limit (maximum contaminant level, MCL).

The PA aquifer model was developed to allow examination of results at distances as far away as the seeplines at Upper Three Runs and Four Mile Branch. With the large expanse of the modeling domain, the footprint of the aquifer cells was selected to be 200 feet by 200 feet for most of the modeling domain. The orientation of the plan view was selected based on regional considerations. On the other hand, the orientation of the point source model was selected based on the trench orientations and trying to match their footprints.

Each set of 5 slit trenches (see Figure 5) with empty space between and around them was assumed to occupy a LAW-vault sized footprint that was about 656 ft (200 m) long by 157 ft (48 m) wide with an area of 102,992 ft^2, or 205,984 ft^2 for both sets. Each LAW-vault sized footprint is shown as a black box surrounding 5 sets of orange boxes that represent slit trenches.

The six blue squares in Figure 5 represent the aquifer cells selected to receive the contaminant flux from the PA vadose zone model. Each PA aquifer cell occupied a footprint that was 200 ft long by 200 ft wide with an area of 40,000 ft^2, thus 6 aquifer cells occupied an area of 240,000 ft^2 that was 16.5 percent larger than the footprint of the two LAW-vault



sized footprints.

Figure 5. Aquifer Model Plan View Showing PA and Point Source Geometries

The point source model used the footprint only of the slit trenches sans the empty space between and around them. This approach was slightly conservative in that it neglected the lateral spreading beyond the footprint in the vadose zone model.

The footprint of each slit trench is 20 ft wide by 640 ft long or 12,800 ft^2. Ten slit trenches as used in the point source model would have a footprint of 128,000 ft^2, thus the PA model is higher by a factor of 1.88 (240,000 / 128,000). The volume of the six PA aquifer cells is 1,850,000 ft^3, while the volume of the source term point source aquifer cells is 765,000 ft^3, generating a PA model that is higher by a factor of 2.42 (1,850,000 / 765,000). The aquifer model cell oversizing results in dilution that lowers the well concentrations and increases the calculated allowable facility inventories.

For the PA aquifer model, the flux from one trench was evenly distributed over all the aquifer source cells. For the point source aquifer model, 9 trenches were assumed to have a uniform distribution equivalent to that of the PA or SA, and each set of aquifer cells underlying those nine trenches received the flux from one trench. Aquifer model cells underlying the point source received the flux from the vadose zone point source analysis. The final point source results were divided by 10 to reach a state equivalent to that of the PA analysis.

The selection of the location and size of the monitoring cell to report the concentration for the 100-m well varied from the PA analysis to the point source study. The PA aquifer model was simplified by selecting the closest aquifer cells that were about 100 m away and selecting those that exhibited the highest concentrations. The aquifer cell that was always the highest is shown as the green box in Figure 5.

For the point source models, a sliding window technique was developed. The footprint of the window and the region of aquifer cells that were at least 100 m away in the “northerly” direction were identified. At each requested time step, the window was slid from cell to cell horizontally, then vertically to find the window with the highest average concentration. For the full, uniform contaminant distribution case simulating the PA analysis, the brown box shown in Figure 5 shows the 200 ft by 200 ft window (that matches the PA aquifer cell footprint) with the highest average concentration at any recorded time over the period of analysis.

3.3 VADOSE ZONE RESULTS

3.3.1 Vadose Zone Flow Model Results

The steady-state flow models for the point source study were developed using the refined grid. Because the mesh refinement is the only change, there should be little difference between the vadose zone PA flow fields and the point source flow fields. Streamlines for the three trench stages are presented in Figure 6 with ten water particles started at equally spaced locations along the top of the modeling domain. For the uncapped trench stage all flow is essentially vertically downward. For the capped trench stage all surface infiltration is routed through the drain at the right side. The lone streamline that penetrates the waste zone is an artifact of the modeling/plotting system. However, it was retained to show the very slow speeds at which water would travel through the waste zone. For the failed cap trench stage, water moves through the waste zone faster than during the uncapped stage. Also, water is attracted from outside the waste zone footprint, so the water flow rate through the waste zone is higher than during the uncapped stage.

3.3.2 Vadose Zone Transport Model Results

Basic I-129 Case with a Kd of 0.6 ml/g

Fractional fluxes at the water table for basic I-129 waste (0.6 ml/g Kd) are compared with PA results in Figure 7 for all point source cases. This figure provides a macro look at these plots, while later figures provide more in-depth comparisons. The early part of the 80+ box (this case is applicable for 80, 160, 1000, and 2000 boxes) configuration essentially duplicates the PA results. Differences after the peak are an artifact of the PA retaining only 50 data points, while the point source analysis retained all recorded data points. The difference between the highest peak fractional flux for any box configuration and the PA peak fractional flux is a factor of 1.23 as shown in Table 3-1.

Table 3-1. Comparison of Peak Fractional Fluxes at Water Table

Peak Fractional Flux	Time (years)	Ratio of Flux to PA Flux	Number of Boxes	Elevation	Left-Right
8.91E-02	18.8	1.23	4	Down	Left
8.91E-02	18.8	1.23	4	Down	Center
8.91E-02	18.8	1.23	4	Down	Right
8.41E-02	22.7	1.16	4	Middle	Left
8.41E-02	22.7	1.16	4	Middle	Center
8.41E-02	22.7	1.16	4	Middle	Right
7.93E-02	25.0	1.09	4	Up	Left
7.93E-02	25.0	1.09	4	Up	Center
7.93E-02	25.0	1.09	4	Up	Right
8.91E-02	18.8	1.23	20	Down	N/A
8.41E-02	22.7	1.16	20	Middle	N/A
7.93E-02	25.0	1.09	20	Up	N/A
7.27E-02	22.3	1.00	80+	Full	N/A
7.27E-02	22.4	1.00	PA	N/A	N/A

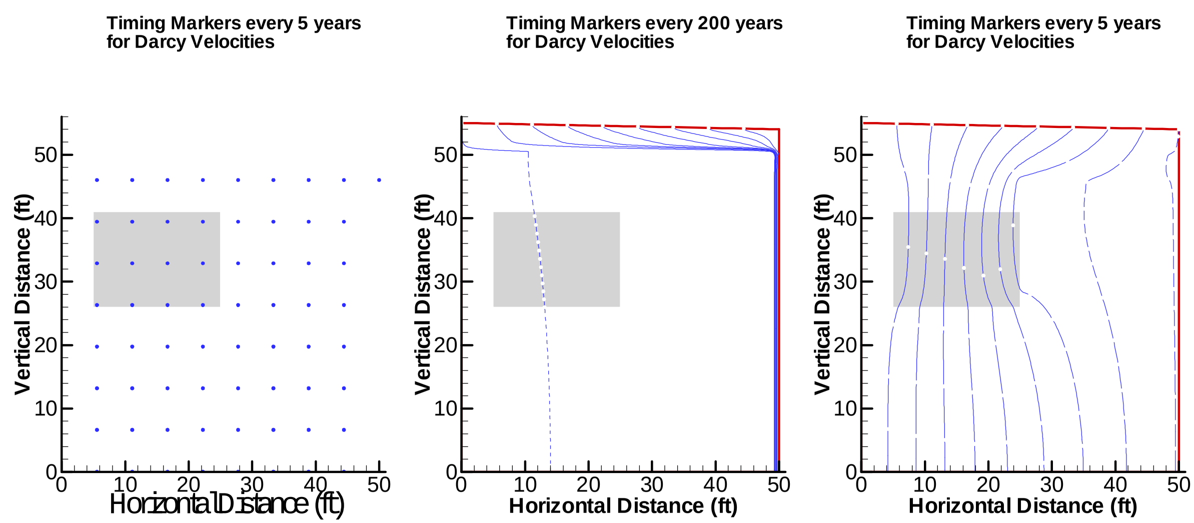


Figure 6. Streamlines for Uncapped, Capped, Failed Cap Trench Stages Shown Left to Right

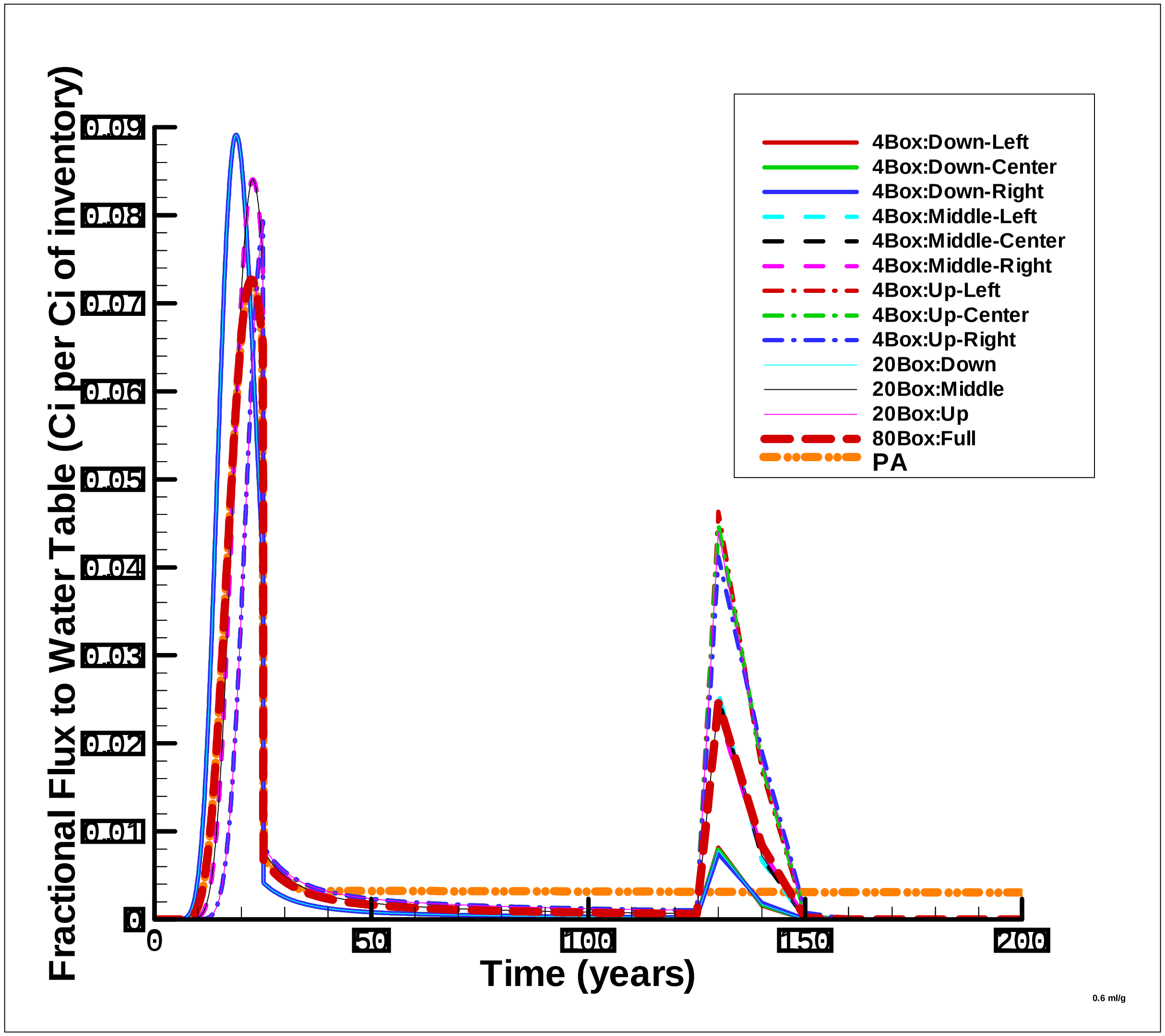


Figure 7. All Fractional Fluxes at Water Table for Basic I-129

No difference in the fractional flux for configurations of 4 boxes placed at various locations across the width of the trench can be discerned. Because the results in the table are identical, the output files were doublechecked, but the differences were very small. Figure 8 shows the similarities for the 4-box configurations placed across the bottom of the trench. Figure 9 shows the similarities for the 4-box configurations placed across the vertical center of the trench. Figure 10 shows the similarities for the 4-box configurations placed across the top of the trench. Because the fractional flux results are independent of the placement across the trench, further discussion of the fractional fluxes for Basic I-129 will be limited to 4-box configurations placed at the left side of the trench only.

Figure 11 shows the comparison of 4-box configurations at all three elevations. The boxes at the bottom of the trench show the highest concentrations at the earliest time because they have the least distance to travel to the water table. The secondary peak after 125 years (when the trench enters its failed cap stage) is the highest for the 4-box configuration at the top of the trench, because it had the most contamination still remaining in the vadose zone.

Figure 12 shows the comparison of 20-box configurations at all three elevations. These plots are identical to those for the 4-box configurations. This equality is another reflection of the lack of dependence of results on the location across the trench. The contaminant flux through the four boxes is at a higher concentration because it has a footprint that is one-fifth the size of the footprint for the 20 boxes, but the mass is identical.

Figure 13 shows the curves with the largest values for each box set along with the PA results. The 4-box and 20-box results are identical and are a factor of 1.23 higher than the PA results. Their peaks occur at 18.8 years versus the PA peak at 22.4 years. Peak contaminant fluxes for the 80+ boxes are identical to those for the PA, except that the peak occurs 0.1 years earlier at 22.3 years.

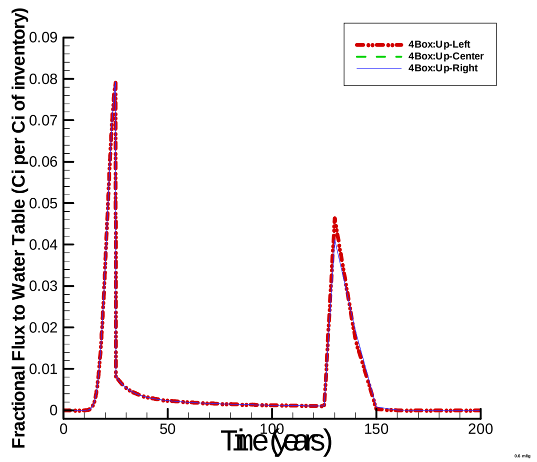
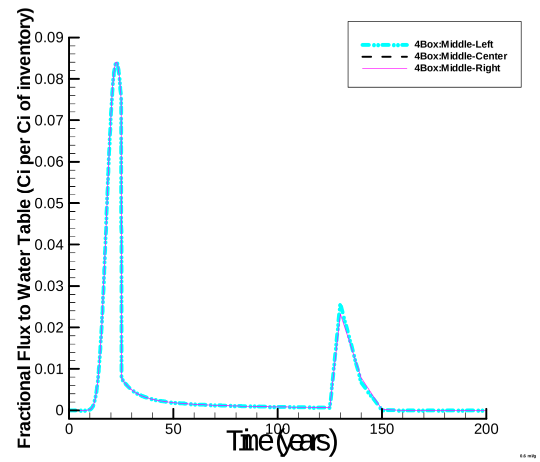
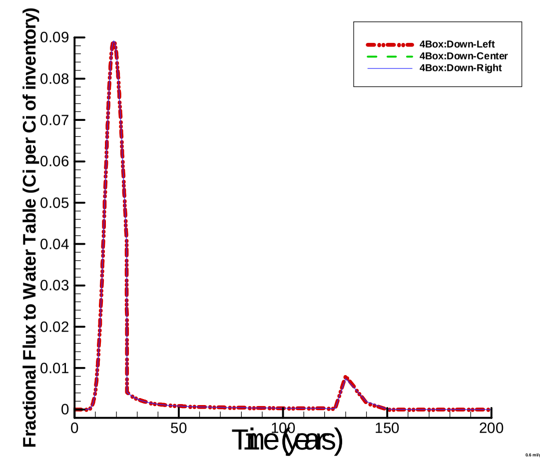
		

Figure 8. Basic I-129 Fractional Fluxes at Water Table for 4-Box Configurations at Trench Bottom	**Figure 9. Basic I-129 Fractional Fluxes at Water Table for 4-Box Configurations at Vertical Trench Center**	**Figure 10. Basic I-129 Fractional Fluxes at Water Table for 4-Box Configurations at Trench Top**

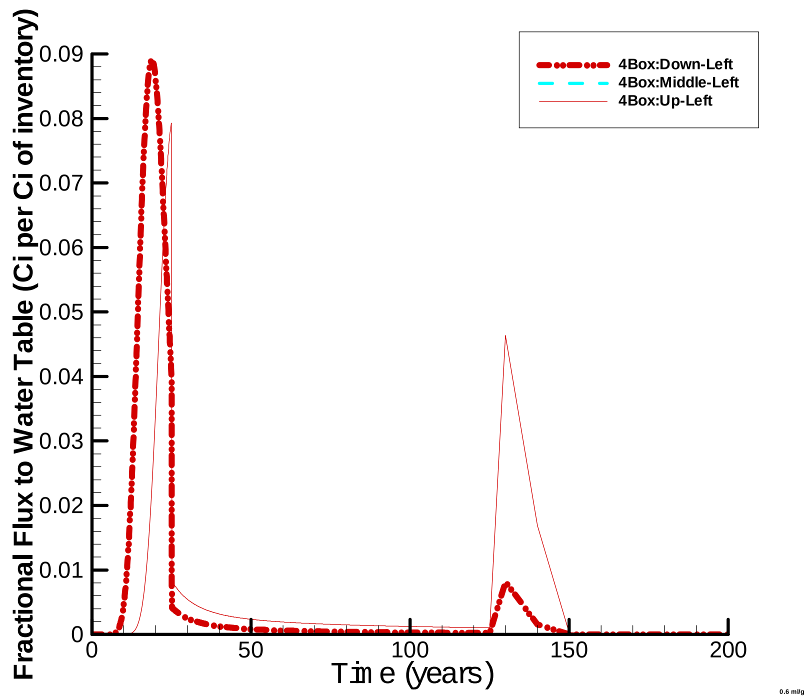


Figure 11. Basic I-129 Fractional Fluxes at Water Table for 4-Box Configurations at Trench Bottom, Middle and Top

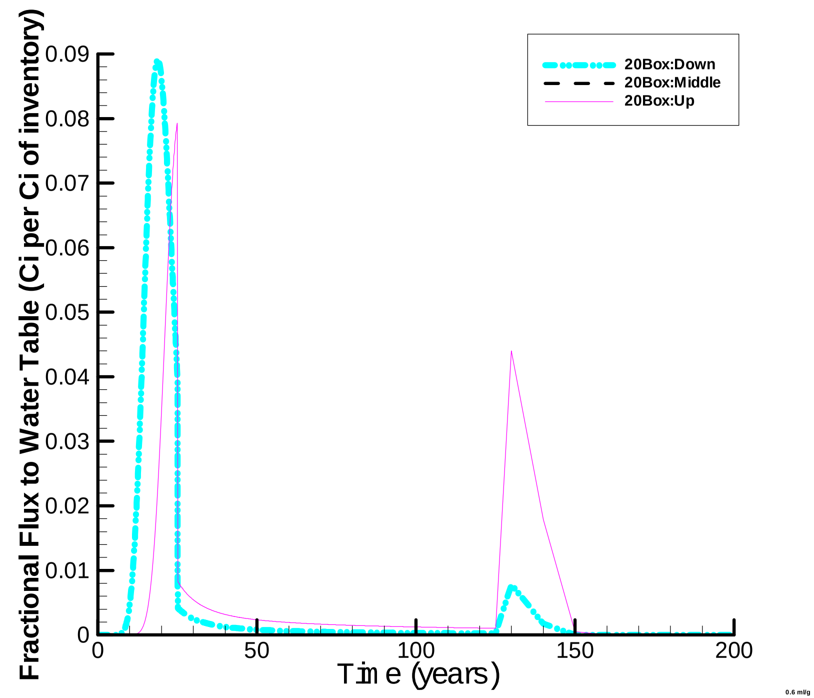


Figure 12. Basic I-129 Fractional Fluxes at Water Table for 20-Box Configurations at Trench Bottom, Middle and Top

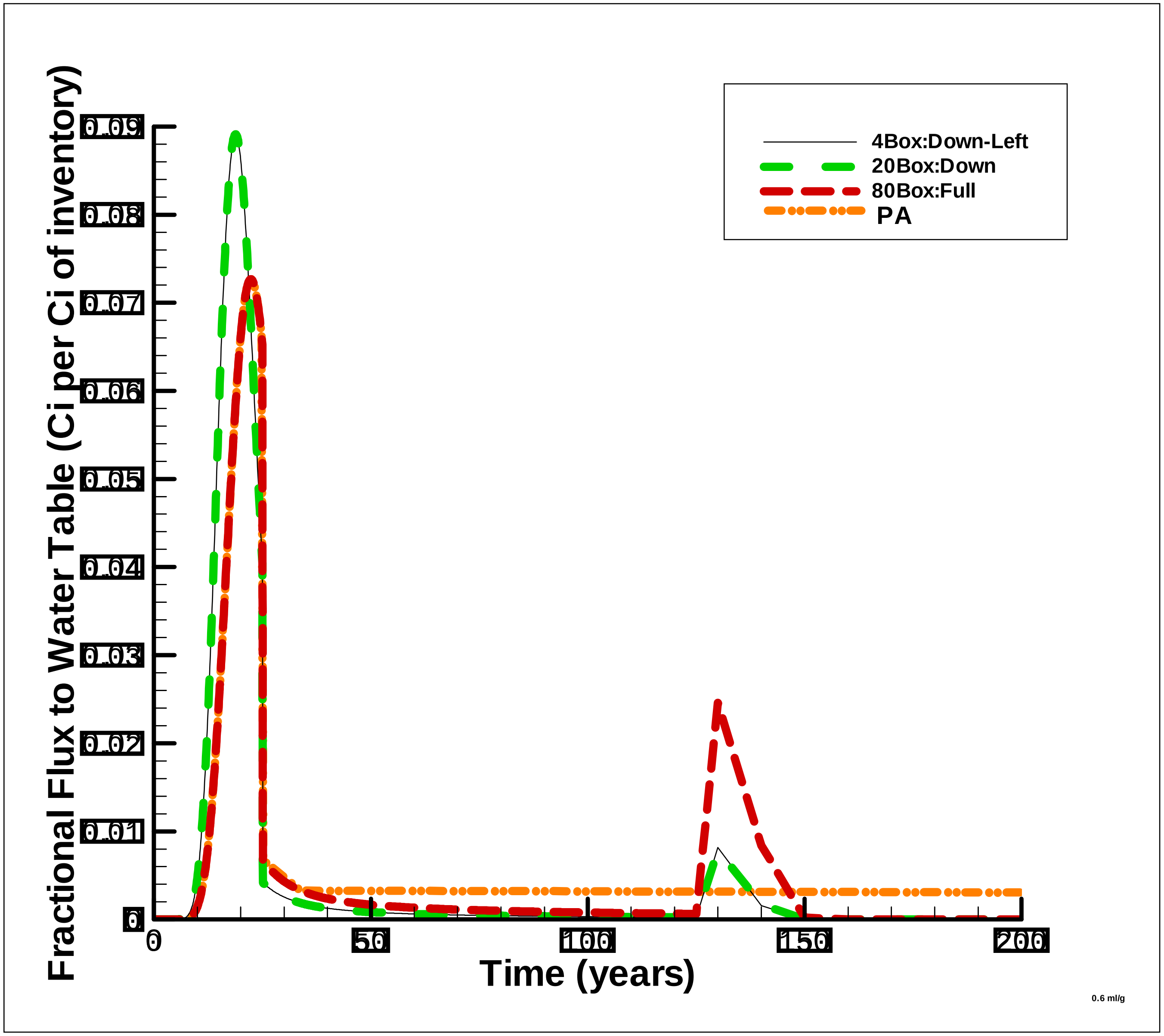


Figure 13. Basic I-129 Largest Fractional Fluxes at Water Table for Each Box Set (4 boxes, 20 boxes, 80+ boxes)

I-129 Case for H-Area CG-8 with a Kd of 380 ml/g

Fractional fluxes at the water table for H-Area CG-8 I-129 waste (380 ml/g Kd) are compared with PA results in Figure 14. This figure provides a macro look at these plots, while later figures provide more in-depth comparisons. The plot of the 80+ box (this case is applicable for 80, 160, 1000, and 2000 boxes) configuration is similar to but slightly exceeds PA results during the first 600 years. The difference between the highest peak fractional flux for any box configuration and the PA peak fractional flux is a factor of 3.60 as shown in Table 3-2.

Table 3-2. Comparison of Peak Fractional Fluxes at Water Table

Peak Fractional Flux	Time (years)	Ratio of Flux to PA Flux	Number of Boxes	Elevation	Left-Right
3.31E-03	170.1	3.20	4	Down	Left
2.74E-03	230.1	2.65	4	Down	Center
3.73E-03	180.1	3.60	4	Down	Right
1.86E-03	640.1	1.79	4	Middle	Left
1.83E-03	690.1	1.77	4	Middle	Center
1.94E-03	580.1	1.88	4	Middle	Right
1.56E-03	940.0	1.50	4	Up	Left
1.57E-03	990.1	1.52	4	Up	Center
1.59E-03	850.1	1.54	4	Up	Right
3.35E-03	180.1	3.23	20	Down	N/A
1.84E-03	620.1	1.78	20	Middle	N/A
1.53E-03	910.1	1.48	20	Up	N/A
1.08E-03	540.1	1.04	80+	Full	N/A
1.03E-03	575.0	1.00	PA	N/A	N/A

Some differences in results for placement across the width of the trench appear for the H-Area CG-8 I-129 waste, while none appeared for the Basic I-129. The lack of any differences for the basic I-129 was caused by its peak during the Uncapped Trench Stage that had essentially a uniform downward velocity field as shown in the left side of Figure 6. On the other hand, the H-Area CG-8 peaked during the Failed Cap Trench Stage that had a varied flow field. The right-hand boxes had the highest peaks while the center boxes had the lowest peaks.

Figure 15 shows the similarities for the 4-box configurations placed across the bottom of the trench. Figure 16 shows the similarities for the 4-box configurations placed across the vertical center of the trench. Figure 17 shows the similarities for the 4-box configurations placed across the top of the trench. The boxes at the right side of the trench create a peak flux that generally is only marginally higher than the flux for other box locations.

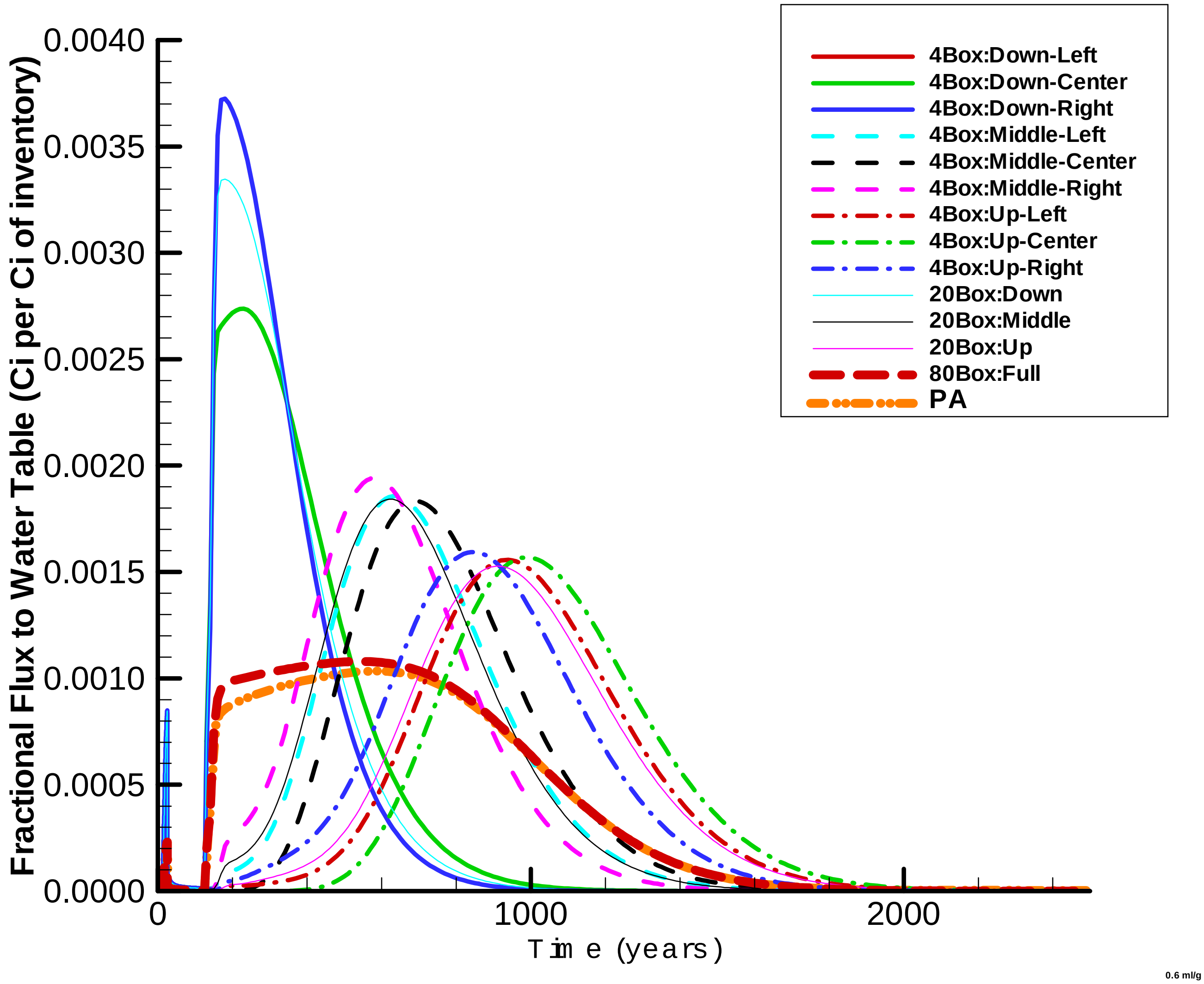


Figure 14. All Fractional Fluxes at Water Table for H-Area CG-8 I-129

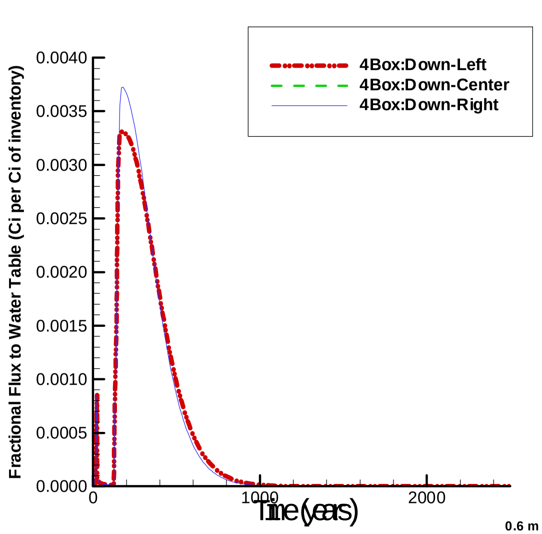


Figure 15. H-Area CG-8 I-129 Fractional Fluxes at Water Table for 4-Box Configurations at Trench Bottom

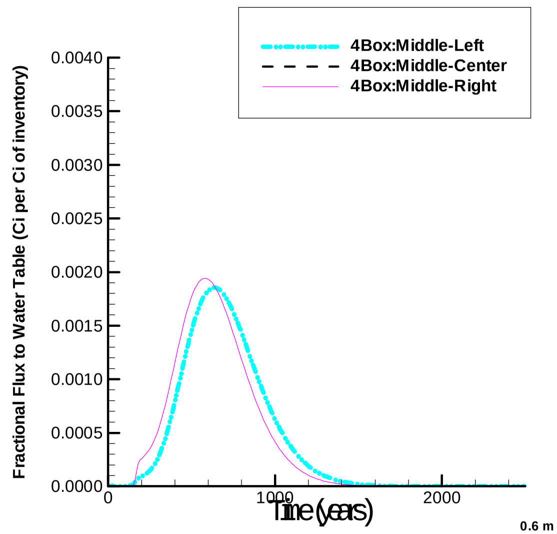


Figure 16. H-Area CG-8 I-129 Fractional Fluxes at Water Table for 4-Box Configurations at Vertical Trench Center

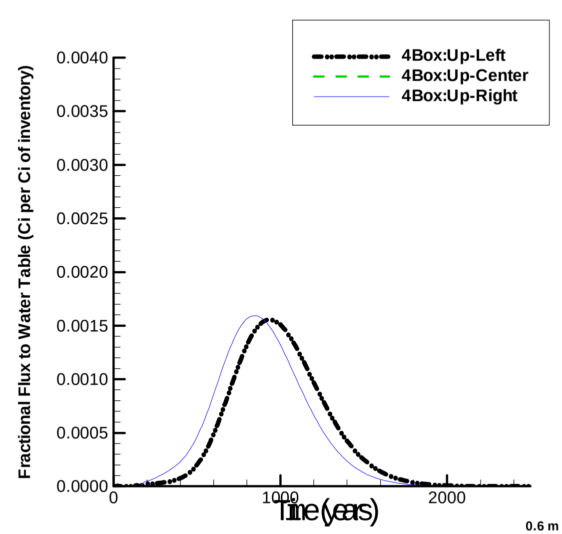


Figure 17. H-Area CG-8 I-129 Fractional Fluxes at Water Table for 4-Box Configurations at Trench Top

Figure 18 shows the comparison of left-side 4-box configurations at all three elevations. The boxes at the bottom of the trench show the highest concentrations at the earliest time because they have the least distance to travel to the water table

Figure 19 shows the comparison of 20-box configurations at all three elevations. These plots are very similar to those for the 4-box configurations. This relationship indicates that in the aggregate there is little effect of waste placement at various locations across the trench. The contaminant flux through the four boxes is at a higher concentration because it has a footprint that is one-fifth the size of the footprint for the 20 boxes, but the mass is identical.

Figure 20 shows the curves with the largest values for each box set along with the PA results. The 4-box and 20-box results are very similar. Their peaks occurred at 170 and 180 years, respectively, while the PA peak occurred at 575 years. The PA peak is very flat, such that the fractional flux at 200 years is about that at any period up to 700 years. Peak contaminant fluxes for the 80+ boxes are similar to those for the PA, but with a slightly higher peak.

3.4 AQUIFER RESULTS

3.4.1 Aquifer Flow Model Results

The aquifer model was refined to match the footprint of the overlying slit trenches and the point sources. A plan view of the aquifer model is shown in Figure 21. Water particles were released from the corners of the LAW-vault sized footprints to help define the model boundaries. The water particles initially traveled along the purple paths in a “northwesterly” direction (assuming that north is up in the figure), then turned and headed north. The particles released at the southeast and northwest corners follow essentially identical paths after the 100-m boundary was passed. Water particles released from the southwest and northeast corners moved in the same general directions but separated more laterally from the particles released from the other corners.

The water particle released from the southwest corner of the western LAW-vault sized footprint did not fit the general flow pattern. Instead it turned and headed southwest, likely an artifact of the nearby boundary condition, but it should have little effect because it occurs for only a minimal part of the modeling domain that is outside the point source trench.

The trench containing the point sources is the fourth one in from the left shown by a thick, dashed outline in Figure 21. The 100-m radius circles were drawn using centers at the northwest corners of the LAW-vault sized footprints. The 100-m buffer selected was an East-West line that excludes a minimal amount of territory that is beyond the 100-m radius.

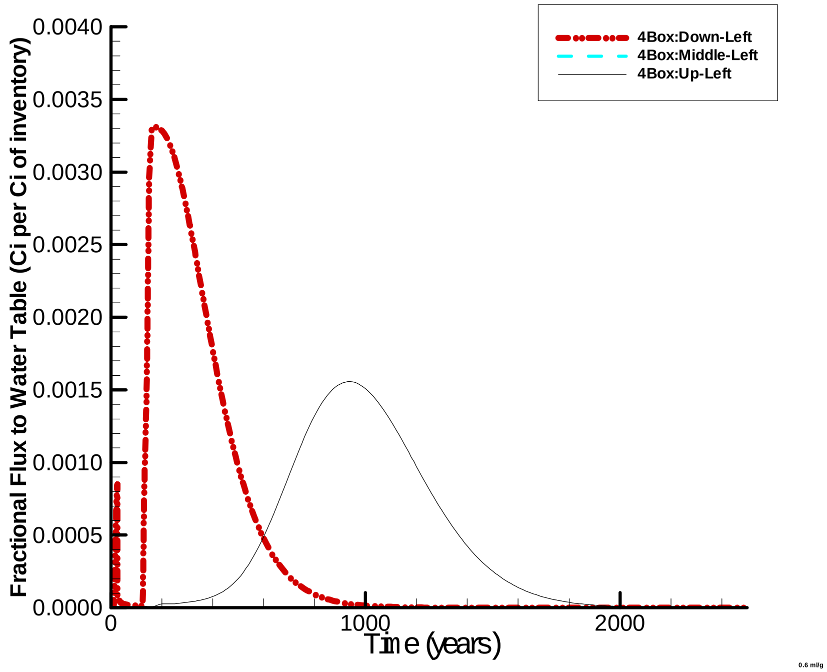


Figure 18. H-Area CG-8 I-129 Fractional Fluxes at Water Table for 4-Box Configurations at Trench Bottom, Middle and Top

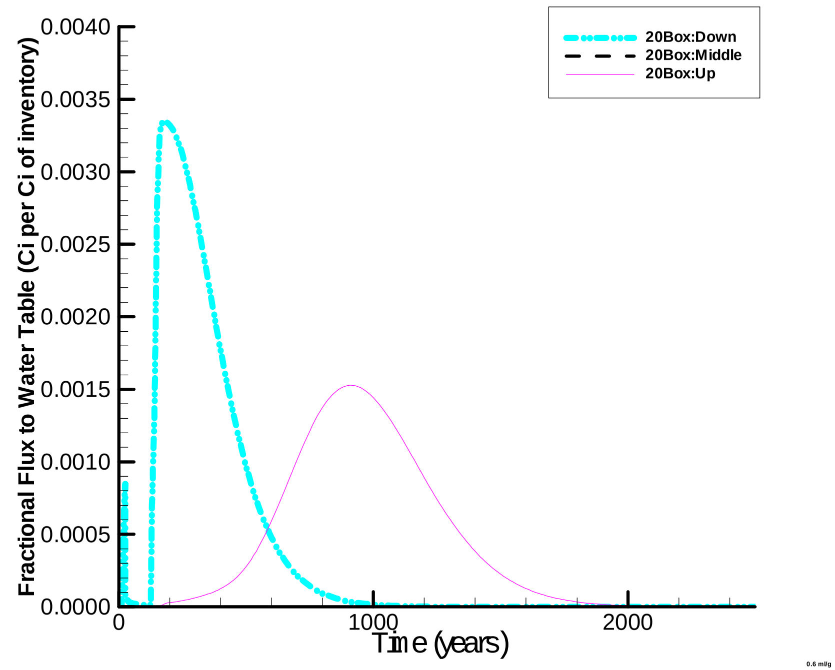


Figure 19. H-Area CG-8 I-129 Fractional Fluxes at Water Table for 20-Box Configurations at Trench Bottom, Middle and Top

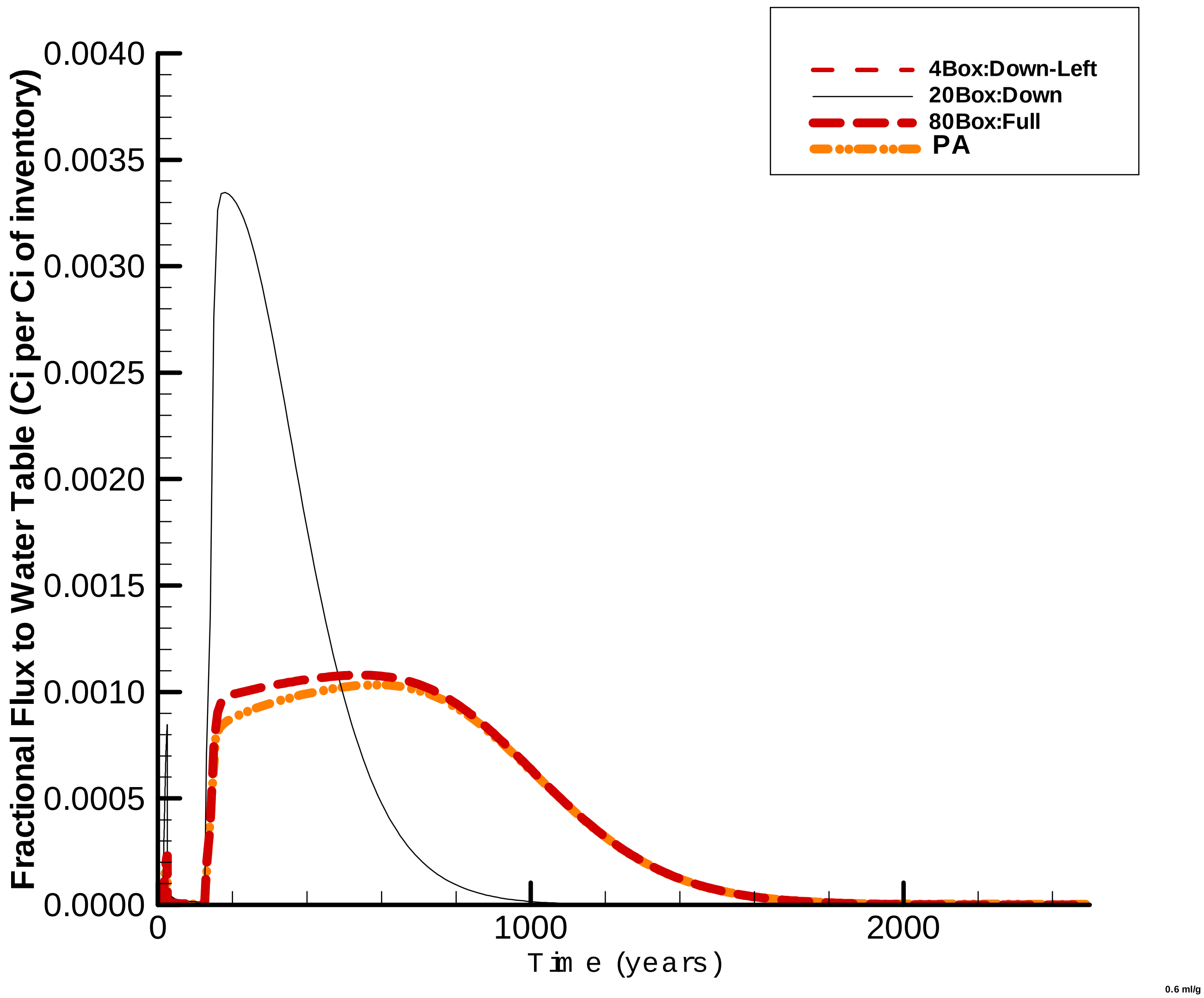


Figure 20. H-Area CG-8 I-129 Largest Fractional Fluxes at Water Table for Each Box Set (4 boxes, 20 boxes, 80+ boxes

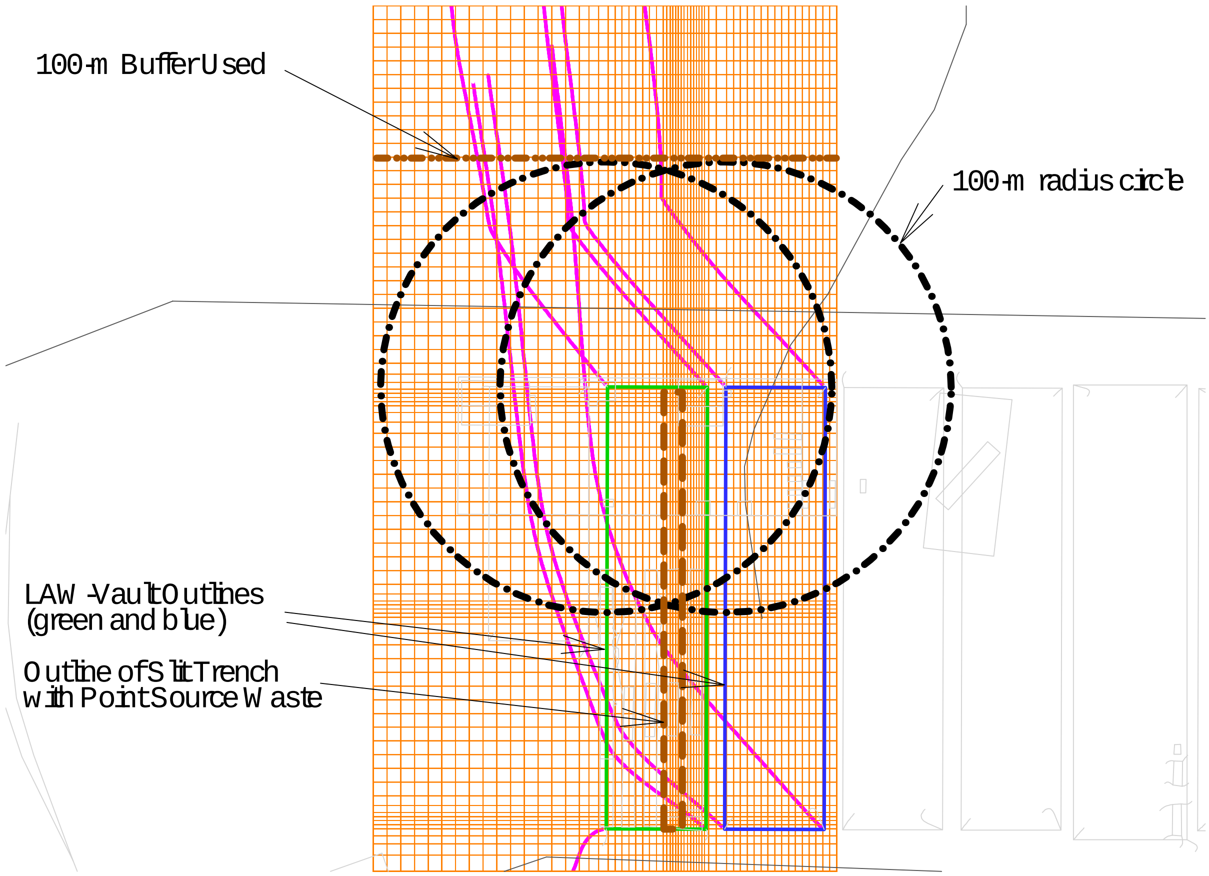


Figure 21. Point Source Aquifer Model with Particle Tracks

3.4.2 Aquifer Transport Model Results

The refined mesh provide the opportunity to calculate “well” concentrations over much smaller volumes than in the PA. However, the size and shape of that “well” volume can vary depending on the intended use of the results. For this study, the “well” volume was defined to be one cell thick. As discussed in Section 3.2, one choice for a footprint was a 200 ft square window for benchmarking against PA and SA results. Additionally a 20 ft square window was examined than matches the nominal width of a slit trench. Finally, the aquifer cell was considered as the minimal volume that could be used with the mesh developed for this study.

Basic I-129 Case with a Kd of 0.6 ml/g

The 2000-box case with a 200 ft square well window was benchmarked against PA results. The 2000-box case is a trench filled with uniform waste. Figure 22 shows that the 2000-box case and all other point source curves for Basic I-129 have peaks that are nearly twice as large as the PA results. Most of this is attributable to the dilution from oversizing the aquifer cells’ footprint (see Section 3.2) and selecting taller aquifer cells that resulted in a volume increase by a factor of 2.42. Figure 23 shows that the two rightmost blue PA aquifer cells are much deeper than all other source cells and are much thicker vertically creating a larger volume for the aquifer source cells.

A discontiguous source cell region in the PA model creates the rest of the difference. Figure 23 shows in a profile view that four of the blue PA source aquifer cells are at a high elevation while two are at a much lower elevation. This separation created two discontiguous plumes that reduced the plume interaction. Actually one of the blue PA source aquifer cells was below the green aquifer cell where the peak concentration was recorded, indicating that there likely was little interaction between that source cell and the aquifer well cell. The orange cells in the figure show the contiguous point source cell region.

The PA peak occurred at 29 years (see Table 3-3) while the uniform point source model peaked at 46 years. This could have been caused either by the lower blue PA source cells creating the peak and being much closer to the cell representing the well or by the sheer size of the aquifer cells with only one cell between the well and some of the source cells.

Figure 24 shows that the former caused the early peak. The figure shows the contaminant plume at the time of the peak in four horizontal slices. The horizontal slices represent the level of the well cell as the bottom figure, then three different levels above the well cell. The outline of source cells are shown in black in this figure and the well cell is shown in brown.

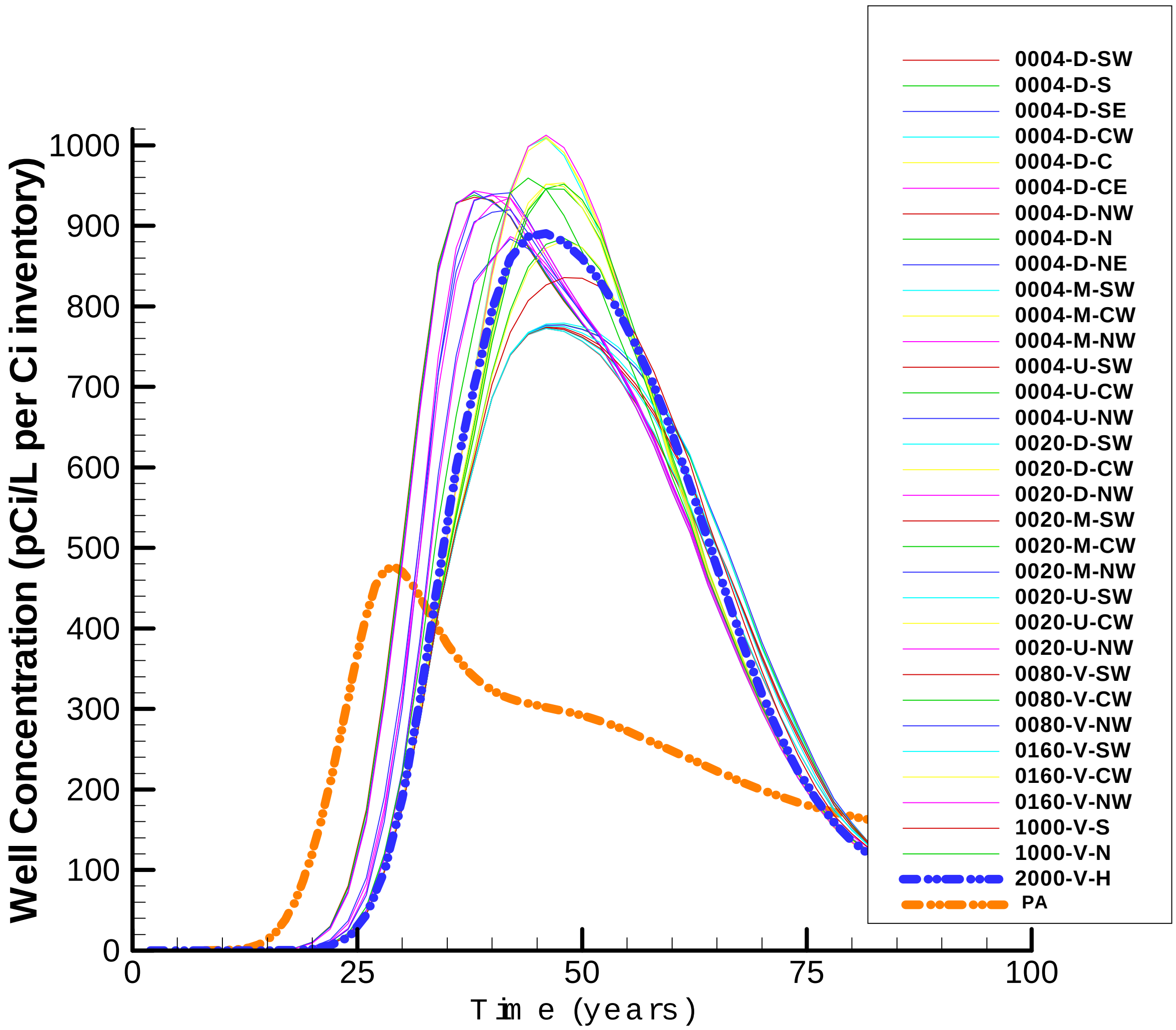


Figure 22. 100-m Well Concentrations for all Basic I-129 Point Source Cases and PA Results

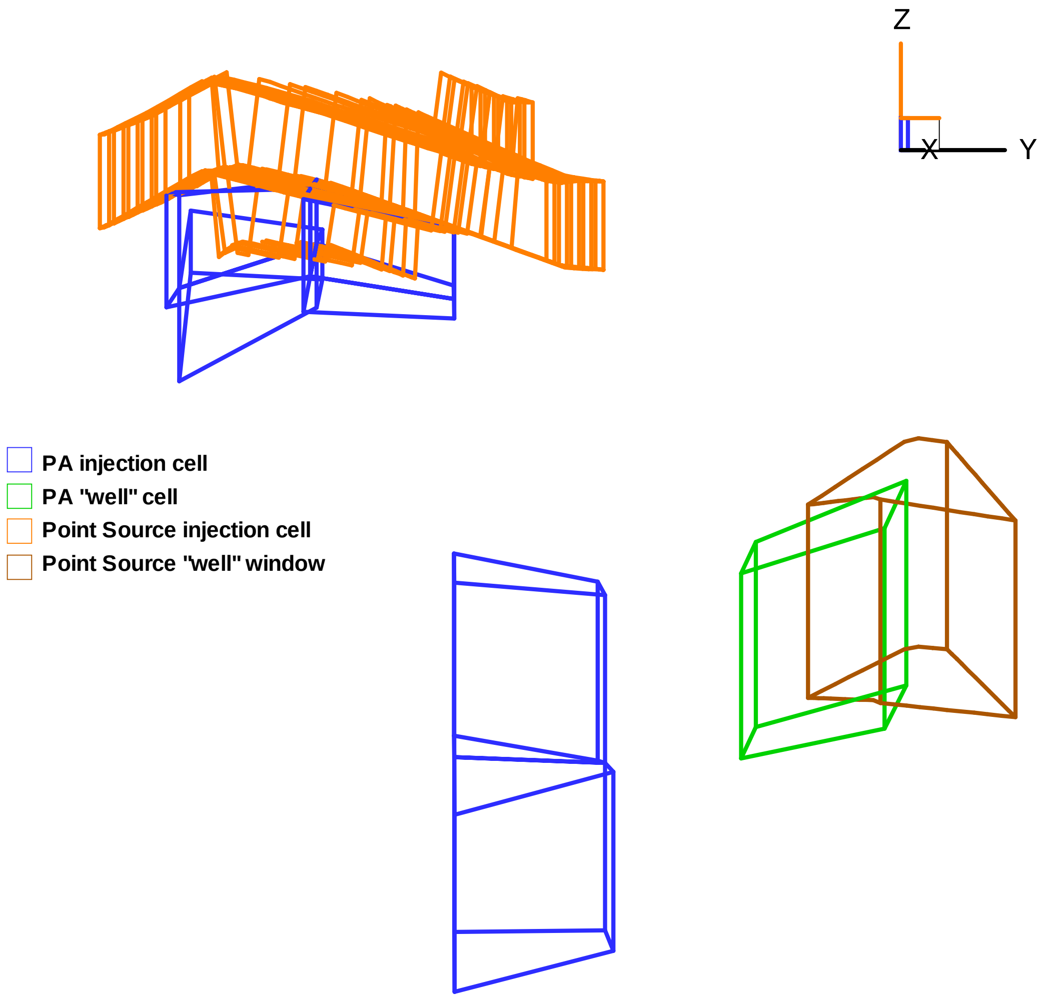


Figure 23. Profile of Aquifer Cell Boundaries Showing Size and Space Relationships between PA model and Point Source Models

The plume at the lowest level is further to the right than the other plumes. Also, the plume in the level immediately above the well level has lower concentrations than either the plumes above or below. The factors of the horizontal displacement in the lowest plume and the lower concentration above the well level indicate that a source other than from above created the plume at the well cell.

The difference between the well concentration peaks for the PA results and the 2000-box point source model is 1.87 for a 200 ft square window, 2.61 for a 20 ft square window and 2.61 for the maximum aquifer cell. Subsequent Basic I-129 comparisons in this report will be made versus the 2000-box case, to isolate the effects of the point sources from differences in implementing the conceptual models.

Results initially will be discussed for the cases with 10 trenches loaded with waste, nine uniformly and one with point source waste. In a second look, the results will be reduced by nine-tenths of the 2000-box case (simulating the PA case) to remove the effects of the nine uniform trenches. This quasi-single trench scenario will examine the effects of managing each trench individually, providing the greatest management flexibility.

The first sets of figures are for a 200 ft square window in plan view. That window duplicates the footprint of the PA well cell, hence it provides a useful starting point for comparison.

Figure 25 shows concentrations for 4-box configurations across the width of the trench at three north-south locations, namely at the south, center and north portions of the trench. In all cases, the boxes are assumed to be at the bottom of the trench. At each location, no discernible difference is evident for locations across the trench. The peaks for the boxes at the center portion of the trench are the highest among the three north-south locations, while the peaks for the boxes at the south portion of the trench are the lowest, lower than for the 2000-box case. Longer travel distance for the southerly waste may cause peaks that are lower than for the 2000-box case. The boxes at the northern edge of the trench may reach the well cells sooner than the rest of the waste, thus generating its own smaller peak that dissipates before the majority of the waste reaches the well cells.

Figure 26 shows concentrations for 4 boxes along the western edge of the trenches at south, central and north locations. The first figure (A) shows results for boxes at the bottom of the trench, while B shows results for boxes at the vertical center of the trench, and C shows results for boxes at the top of the trench. Peaks occurred at the earliest time for waste at the northern locations, but the peaks were not the highest. This could be caused by the point source waste arriving at the well cells before the other waste, or it could be caused by the model recording times missing the peak. In all cases, the peaks from the southern waste are less than the peak for the 2000-box case, indicating a likely offset in arrival times at the well cells versus most of the waste, or that under certain conditions concentrating the waste can decrease peaks.

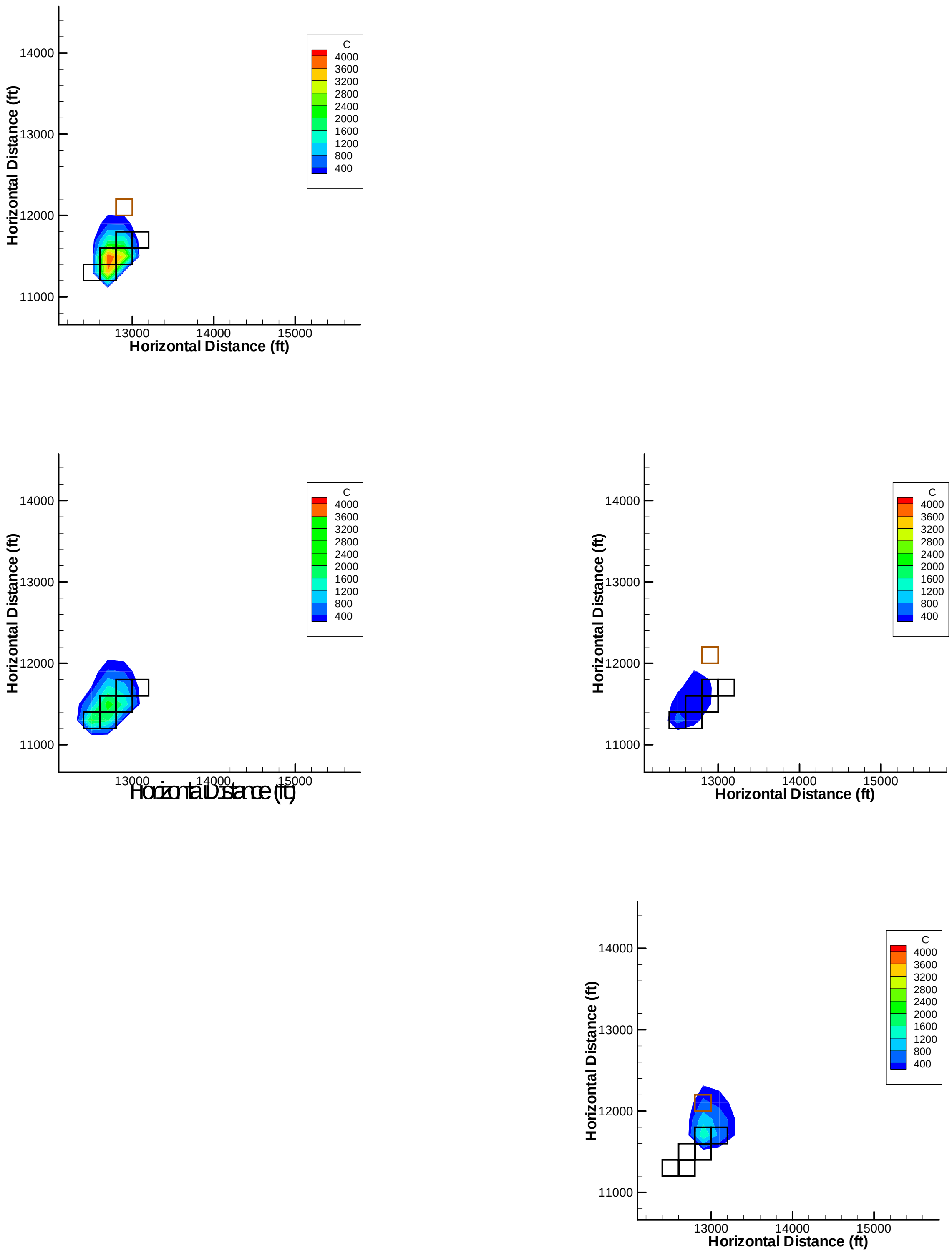


Figure 24. PA Concentration Plume at Peak Time at four different horizontal cell levels – topmost at upper left, moving downward to lowest at lower right that is at level of window with peak well concentration

Figure 27 shows concentrations at all three elevations for waste at the western edge of the trench in its north-south center. The peaks decreased as the elevation of the waste source increased. The peak for waste at the top of the trench essentially equaled that for the 2000-box case.

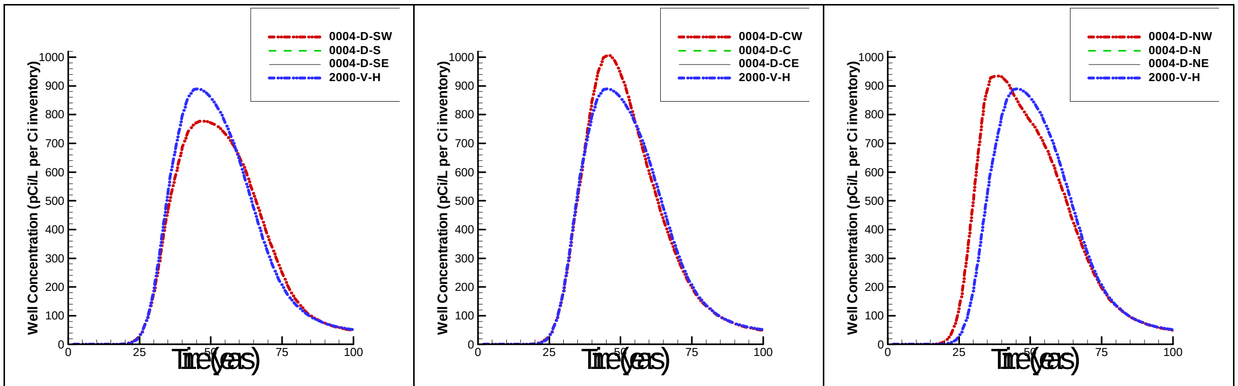
Figure 28 is the first of four figures for 20-box wastes. It shows concentrations for 20 boxes along the western edge of the trenches at south, central and north locations. The first figure (A) shows results for boxes at the bottom of the trench, while B shows results for boxes at the vertical center of the trench, and C shows results for boxes at the top of the trench. The results for the 20-box cases are essentially identical to those for the 4-box cases (Figure 26). Figure 29 shows results for three elevations of 20 boxes and the results are very similar to those for the 4-box cases (Figure 27).

Figure 30 shows results at different horizontal locations for 80 boxes, 160 boxes and 1000 boxes. The results for 80 boxes and 160 boxes are very similar. Once again waste at the northern edge achieved the earliest peaks, waste in the center achieved the highest peaks, and waste at the southern edge achieved the lowest peaks, which were lower than for the 2000-box case.

Figure 31 shows a comparison of selected results from different sizes of box sets generally located at the center of the trench in the north-south direction. Boxes at the bottom of the trench were selected where available. All peaks were higher than for the 2000-box case. Results from the 4-box case and the 20-box cases were essentially identical, as were those for the 80-box and 160-box cases. The 4-box and 20-box cases had the highest peaks, while the other cases had about the same magnitude for their peaks, although the 1000-boxes at the north end of the trench peaked slightly earlier than did 80-box and 160-box cases.

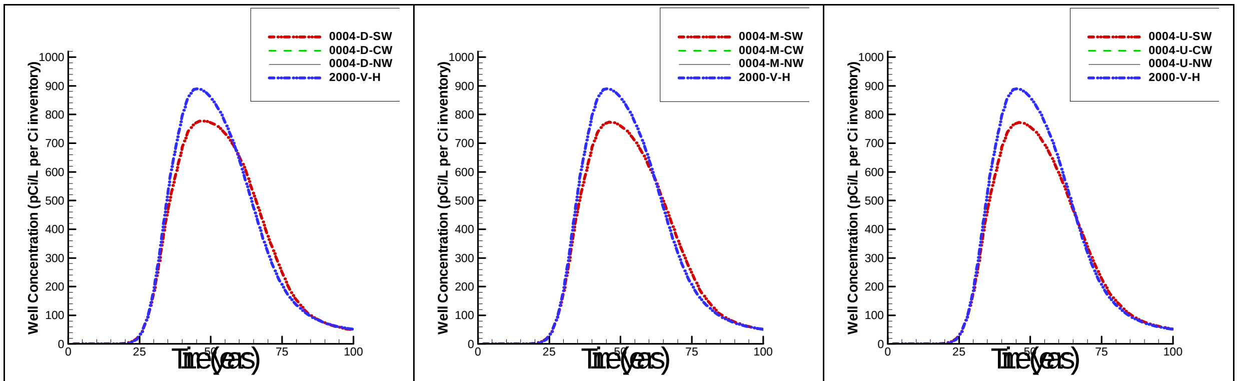
The next set of figures shows results if a 20 ft by 20 ft window is used. These results are very similar to those for the aquifer cell with the maximum concentration, because the size of the window and the cells are very close. Two figures are presented for the smaller window. Figure 32 shows all results on one plot. In general, comparison with the 200 ft by 200 ft window, the peaks occur at about the same times, but they are higher, ranging as high as about 1700 pCi/L/Ci of inventory versus about 1000 pCi/L/Ci for the larger window.

Figure 33 shows a comparison of selected results for the different sizes of box sets. Results from 4 boxes and 20 boxes are similar and results from 80 boxes and 160 boxes are similar. The 1000-box configuration created the highest peak followed by the 4- and 20-box configurations, then the 2000-box configuration and finally the 80- and 160-box configurations. The highest peak was about 1500 pCi/L/Ci of inventory indicating that the waste locations that generated the highest peaks were different than for the 200 ft square window.



(A)	(B)	(C)

Figure 25. Concentrations for Bottom 4-Box Configurations along South (A), Center (B) and North (C) Portions of Trench with a 200 ft square Window



(A)	(B)	(C)

Figure 26. Concentrations for 4 Boxes along West Edge at Bottom (A), Vertical Center (B) and Top (C) of Trench with a 200 ft square Window

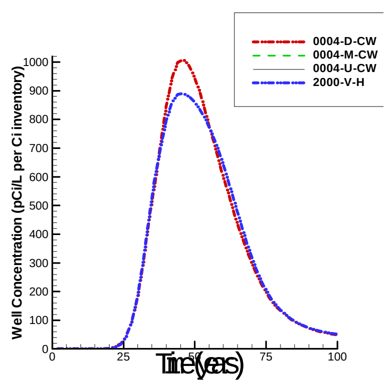


Figure 27. Concentrations for 3 Elevations of 4 Boxes at West Edge in Central Portion of Trench with a 200 ft square Window

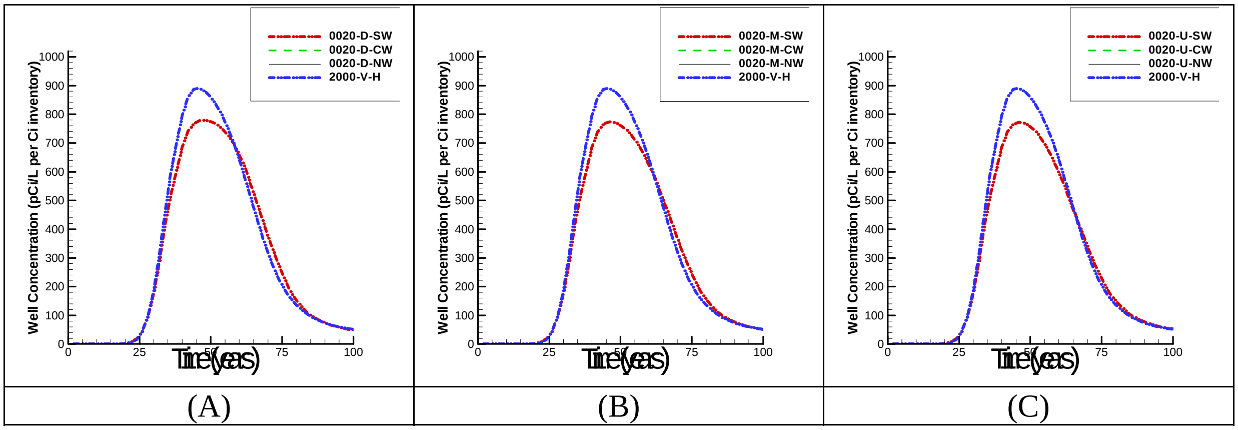


Figure 28. Well Concentrations for 20 Boxes along West Edge at Bottom (A), Vertical Center (B) and Top (C) of Trench with a 200 ft square Window

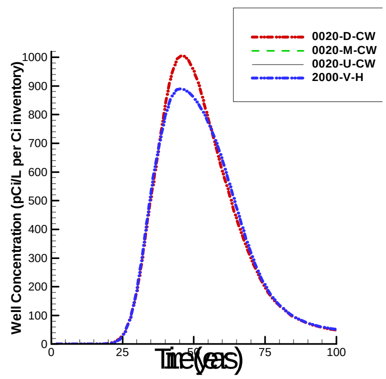


Figure 29. Well Concentrations for 3 Elevations of 20 Boxes at West Edge in Central Portion of Trench with a 200 ft square Window

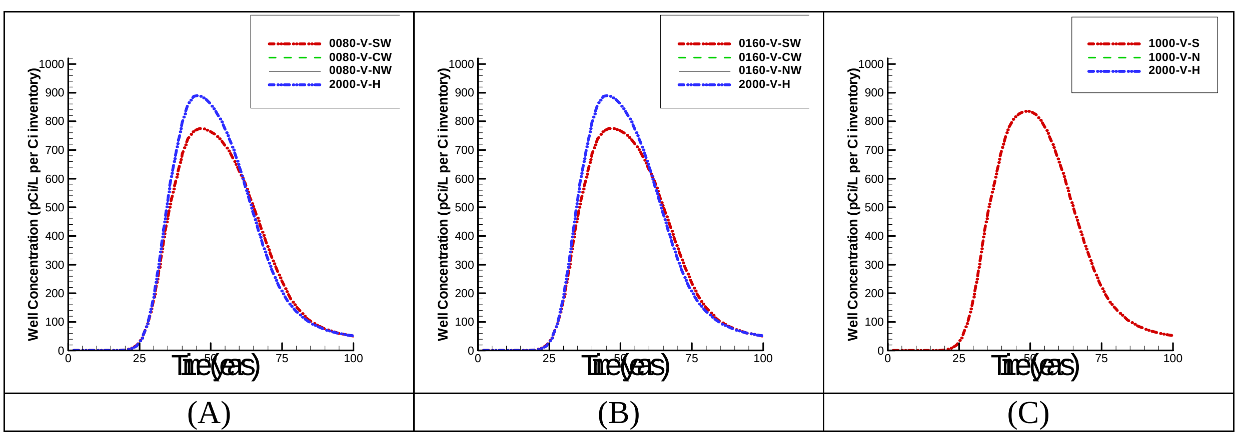


Figure 30. Well Concentrations for 3 Horizontal Locations of 80 Boxes (A) and 160 Boxes (B), and 2 Horizontal Locations of 1000 Boxes (C) with a 200 ft square Window

Key information from the plots is presented in tabular form by well window size and for the maximum aquifer cell. The tables identify the case and show the peak, year of occurrence, ratio versus the PA peak concentration and a multiplier for reducing the inventory. Then in the right-hand columns similar results are presented for a quasi-single trench.

Table 3-3 presents results for the 200 ft square window. Point source concentrations range from about 770 to 1010 pCi/L/Ci of inventory. Ratios versus the PA results of 477 pCi/L/Ci range from about 1.6 to 2.1. Inventory factors are the reciprocals of these ratios and they range from about 0.45 to about 0.6. The time of occurrences of the peaks ranges from 38 years to 48 years, significantly later than the PA peak of 29 years.

The quasi-single trench results produced many negative numbers indicating that concentrating wastes can be beneficial if it is done under the appropriate conditions. The conditions modeled were that waste in nine trenches is uniformly distributed and only one trench contains point sources. The worst cases for the quasi-single trench was an adjusted concentration of 211 pCi/L/Ci that produced a ratio of 2.37 when divided by the uniform quasi-single trench concentration of 89 pCi/L/Ci. Its inventory reduction factor was 0.42.

Table 3-4 presents results for the 20 by 20 ft window. Concentrations range from about 1100 to about 1650 pCi/L/Ci. Concentration ratios range from about 2.2 to 3.5 while inventory factors range from about 0.3 to 0.45. For the quasi-single trench positive results, the highest concentration is about 530 vs. the uniform concentration of 124. The ratio is 4.28 and the inventory factor is 0.23 (compared to 0.42 for a 200 ft square window).

Table 3-5 shows results for the maximum aquifer cell that are almost identical to those for the 20 ft square window. The peak concentration increased from 1650.6 to 1651.0, so no further discussion of these results will be pursued.

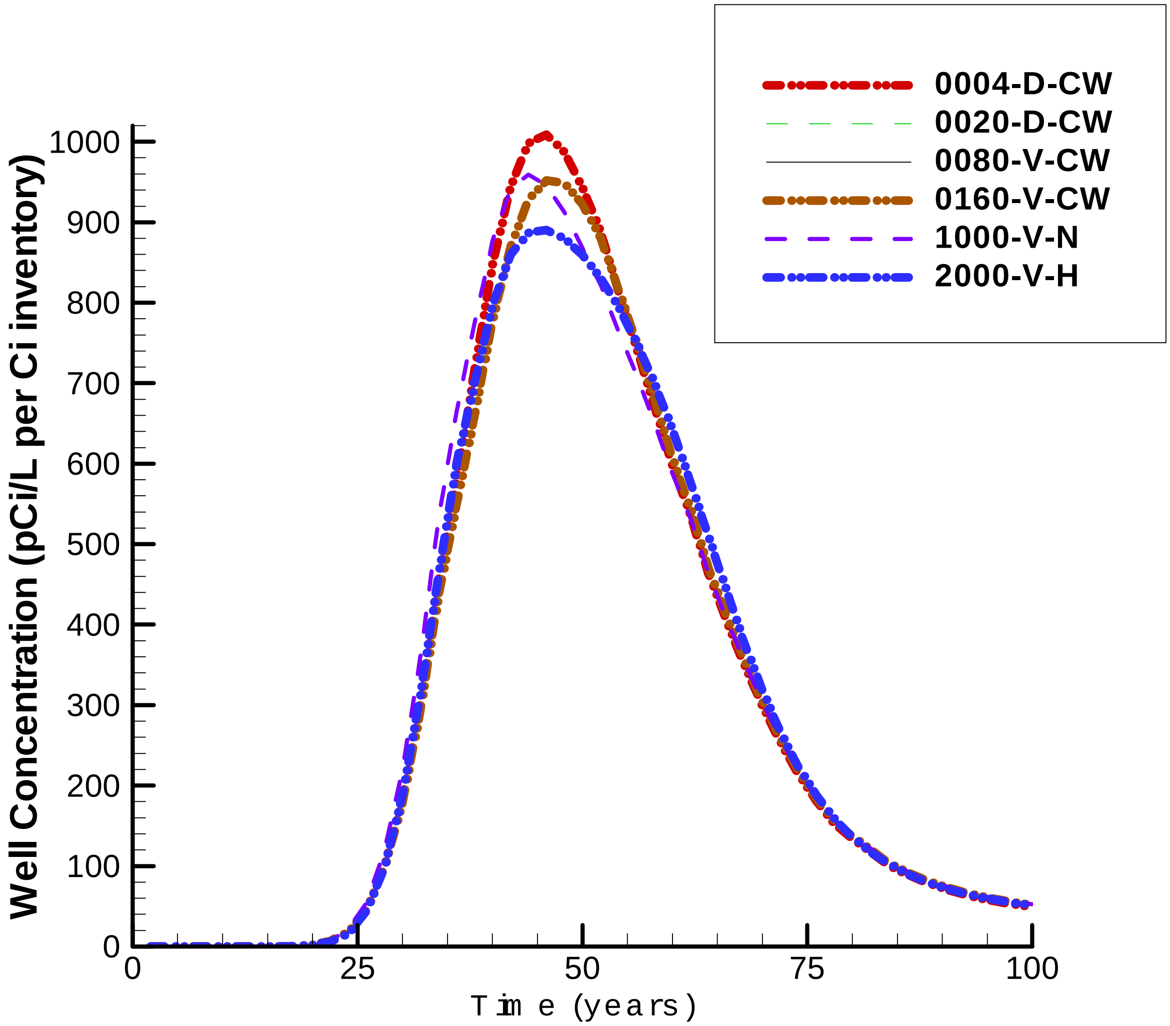


Figure 31. Comparison of Different Sizes of Box Sets with a 200 Square Foot Window

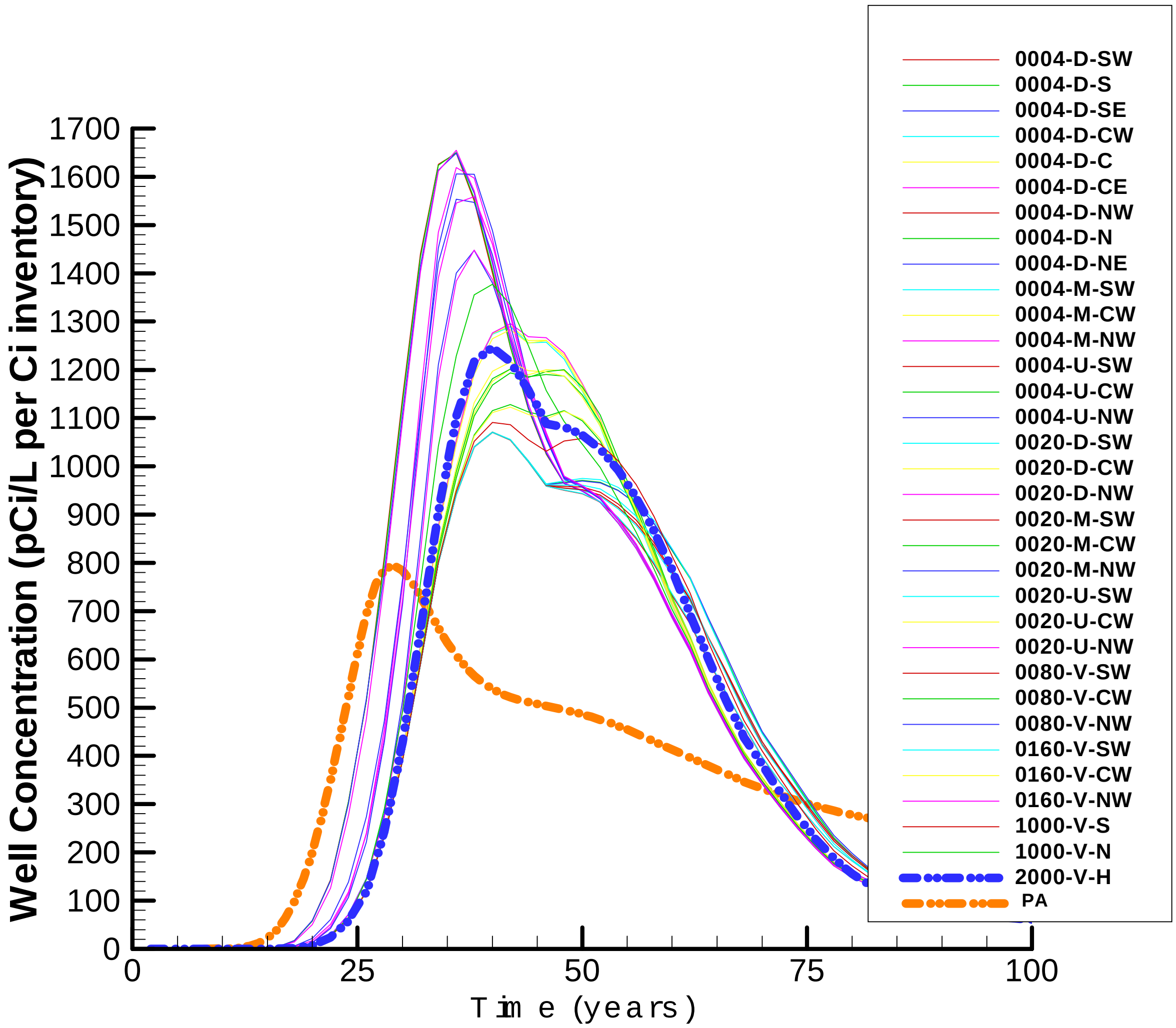


Figure 32. 100-m Well Concentrations for all Basic I-129 Point Source Cases and PA Results for a 20 ft square Window

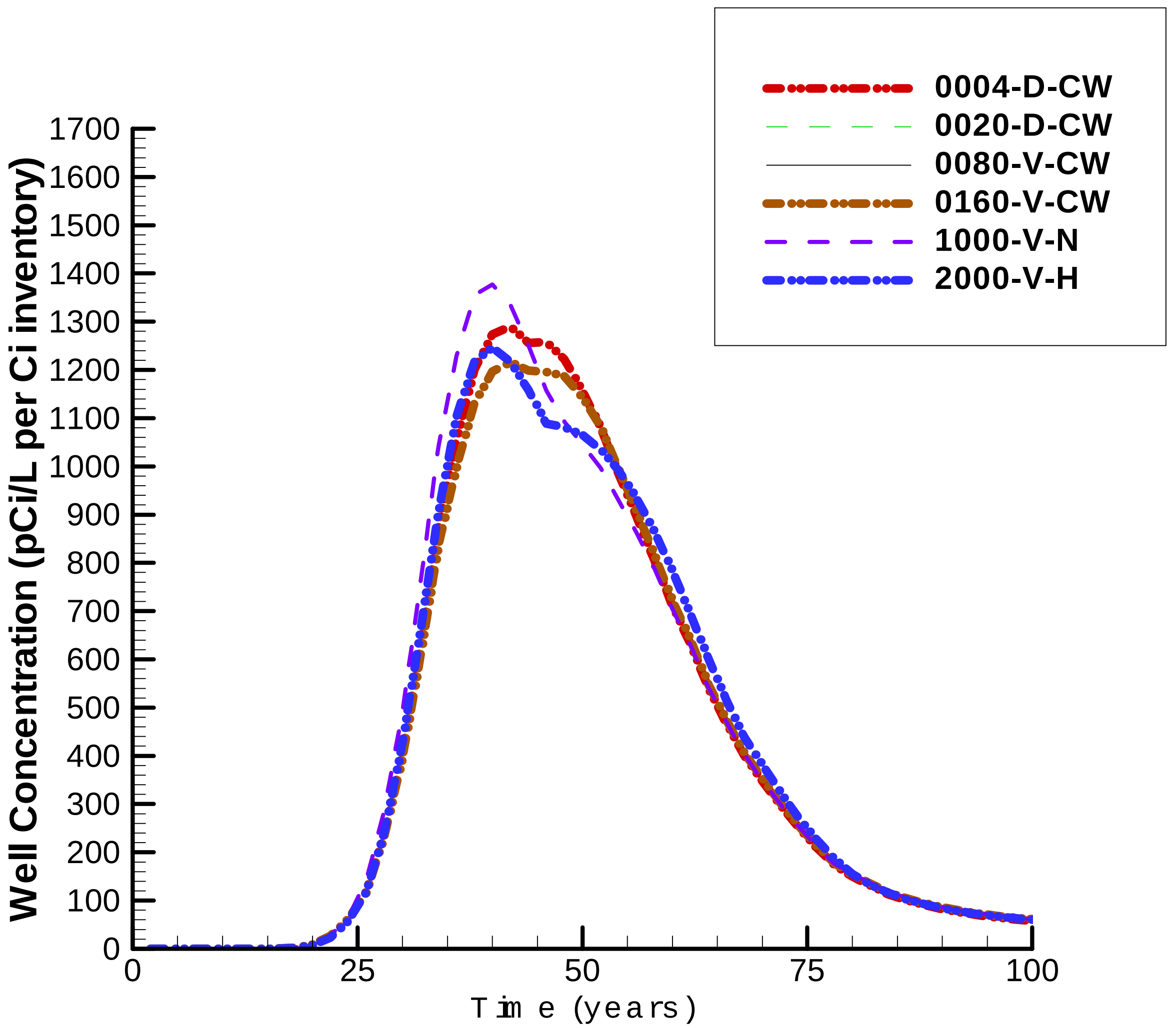


Figure 33. Comparison of Different Sizes of Box Sets for a 20 ft square Window

Table 3-3. Basic I-129 (Kd=0.6 ml/g), 200 ft by 200 ft Window

9 Uniform Trenches + 1 Point Source Trench							Minus 9 Uniform Trenches		
Time (yr)	Conc. (pCi/L/Ci))	Boxes	Elev.	Direction	Conc. Vs. PA	Inv. Reduce	Conc. (pCi/L/Ci)	Conc. Vs. 2000-box	Inv. Reduce
48	777.241	4	Down	SW	1.63	0.61	-24.10	-0.27	-3.69
48	777.168	4	Down	S	1.63	0.61	-24.18	-0.27	-3.68
48	776.979	4	Down	SE	1.63	0.61	-24.37	-0.27	-3.65
46	1008.936	4	Down	CW	2.12	0.47	207.59	2.33	0.43
46	1010.5	4	Down	C	2.12	0.47	209.16	2.35	0.43
46	1012.686	4	Down	CE	2.12	0.47	211.34	2.37	0.42
38	935.559	4	Down	NW	1.96	0.51	134.21	1.51	0.66
38	938.201	4	Down	N	1.97	0.51	136.86	1.54	0.65
38	941.732	4	Down	NE	1.97	0.51	140.39	1.58	0.63
46	773.109	4	Middle	SW	1.62	0.62	-28.24	-0.32	-3.15
48	953.314	4	Middle	CW	2.00	0.50	151.97	1.71	0.59
40	937.555	4	Middle	NW	1.97	0.51	136.21	1.53	0.65
46	772.251	4	Up	SW	1.62	0.62	-29.09	-0.33	-3.06
48	884.554	4	Up	CW	1.85	0.54	83.21	0.93	1.07
42	883.682	4	Up	NW	1.85	0.54	82.34	0.92	1.08
48	778.986	20	Down	SW	1.63	0.61	-22.36	-0.25	-3.98
46	1008.056	20	Down	CW	2.11	0.47	206.71	2.32	0.43
38	943.334	20	Down	NW	1.98	0.51	141.99	1.59	0.63
46	773.605	20	Middle	SW	1.62	0.62	-27.74	-0.31	-3.21
48	951.909	20	Middle	CW	2.00	0.50	150.56	1.69	0.59
42	940.756	20	Middle	NW	1.97	0.51	139.41	1.57	0.64
46	772.551	20	Up	SW	1.62	0.62	-28.79	-0.32	-3.09
48	881.87	20	Up	CW	1.85	0.54	80.53	0.90	1.11
42	886.532	20	Up	NW	1.86	0.54	85.19	0.96	1.05
46	774.371	80	N/A	SW	1.62	0.62	-26.97	-0.30	-3.30
46	945.641	80	N/A	CW	1.98	0.50	144.30	1.62	0.62
42	919.802	80	N/A	NW	1.93	0.52	118.46	1.33	0.75
46	775.367	160	N/A	SW	1.63	0.62	-25.98	-0.29	-3.43
46	951.94	160	N/A	CW	2.00	0.50	150.60	1.69	0.59
42	934.683	160	N/A	NW	1.96	0.51	133.34	1.50	0.67
48	835.471	1000	N/A	S	1.75	0.57	34.13	0.38	2.61
44	959.335	1000	N/A	N	2.01	0.50	157.99	1.77	0.56
46	890.383	2000	N/A	N/A	1.87	0.54	89.04	1.00	1.00
29	477	PA			1.00	1.00			

Table 3-4. Basic I-129 (Kd=0.6 ml/g), 20 ft by 20 ft Window

9 Uniform Trenches + 1 Point Source Trench							Minus 9 Uniform Trenches		
Time (yr)	Conc. (pCi/L/Ci))	Boxes	Elev.	Direction	Conc. Vs. PA	Inv. Reduce	Conc. (pCi/L/Ci)	Conc. Vs 2000-Box	Inv. Reduce
40	1070.641	4	Down	SW	2.24	0.45	-51.27	-0.41	-2.43
40	1070.632	4	Down	S	2.24	0.45	-51.28	-0.41	-2.43
40	1070.617	4	Down	SE	2.24	0.45	-51.30	-0.41	-2.43
42	1289.524	4	Down	CW	2.70	0.37	167.61	1.34	0.74
42	1291.898	4	Down	C	2.71	0.37	169.98	1.36	0.73
42	1295.887	4	Down	CE	2.72	0.37	173.97	1.40	0.72
36	1649.1	4	Down	NW	3.46	0.29	527.19	4.23	0.24
36	1650.595	4	Down	N	3.46	0.29	528.68	4.24	0.24
36	1648.791	4	Down	NE	3.46	0.29	526.88	4.23	0.24
40	1070.384	4	Middle	SW	2.24	0.45	-51.53	-0.41	-2.42
42	1201.719	4	Middle	CW	2.52	0.40	79.81	0.64	1.56
36	1619.346	4	Middle	NW	3.39	0.29	497.43	3.99	0.25
40	1070.349	4	Up	SW	2.24	0.45	-51.56	-0.41	-2.42
42	1127.787	4	Up	CW	2.36	0.42	5.87	0.05	21.23
38	1447.969	4	Up	NW	3.04	0.33	326.06	2.62	0.38
40	1071.332	20	Down	SW	2.25	0.45	-50.58	-0.41	-2.46
42	1283.357	20	Down	CW	2.69	0.37	161.44	1.30	0.77
36	1655.149	20	Down	NW	3.47	0.29	533.24	4.28	0.23
40	1071.008	20	Middle	SW	2.25	0.45	-50.91	-0.41	-2.45
48	1200.065	20	Middle	CW	2.52	0.40	78.15	0.63	1.60
36	1606.21	20	Middle	NW	3.37	0.30	484.30	3.89	0.26
40	1070.961	20	Up	SW	2.25	0.45	-50.95	-0.41	-2.45
42	1122.839	20	Up	CW	2.35	0.42	0.93	0.01	134.75
38	1448.005	20	Up	NW	3.04	0.33	326.09	2.62	0.38
40	1070.482	80	N/A	SW	2.24	0.45	-51.43	-0.41	-2.42
42	1201.37	80	N/A	CW	2.52	0.40	79.46	0.64	1.57
36	1553.898	80	N/A	NW	3.26	0.31	431.98	3.47	0.29
40	1070.571	160	N/A	SW	2.24	0.45	-51.34	-0.41	-2.43
42	1216.277	160	N/A	CW	2.55	0.39	94.36	0.76	1.32
38	1558.866	160	N/A	NW	3.27	0.31	436.95	3.51	0.29
40	1090.599	1000	N/A	S	2.29	0.44	-31.31	-0.25	-3.98
40	1377.033	1000	N/A	N	2.89	0.35	255.12	2.05	0.49
40	1246.571	2000	N/A	N/	2.61	0.38	124.66	1.00	1.00
29	477	PA			1.00	1.00			

Table 3-5. Basic I-129 (Kd=0.6 ml/g), by Aquifer Model Cell

9 Uniform Trenches + 1 Point Source Trench							Minus 9 Uniform Trenches		
Time (yr)	Conc. (pCi/L/Ci))	Boxes	Elev.	Direction	Conc. Vs. PA	Inv. Reduce	Conc. (pCi/L/Ci)	Conc. Vs 2000-Box	Inv. Reduce
40	1070.641	4	Down	SW	2.24	0.45	-51.27	-0.41	-2.43
40	1070.632	4	Down	S	2.24	0.45	-51.28	-0.41	-2.43
40	1070.617	4	Down	SE	2.24	0.45	-51.30	-0.41	-2.43
42	1289.524	4	Down	CW	2.70	0.37	167.61	1.34	0.74
42	1291.898	4	Down	C	2.71	0.37	169.98	1.36	0.73
42	1295.887	4	Down	CE	2.72	0.37	173.97	1.40	0.72
36	1650.887	4	Down	NW	3.46	0.29	528.97	4.24	0.24
36	1651.059	4	Down	N	3.46	0.29	529.15	4.24	0.24
36	1653.264	4	Down	NE	3.47	0.29	531.35	4.26	0.23
40	1070.384	4	Middle	SW	2.24	0.45	-51.53	-0.41	-2.42
42	1201.719	4	Middle	CW	2.52	0.40	79.81	0.64	1.56
36	1627.45	4	Middle	NW	3.41	0.29	505.54	4.06	0.25
40	1070.349	4	Up	SW	2.24	0.45	-51.56	-0.41	-2.42
42	1127.787	4	Up	CW	2.36	0.42	5.87	0.05	21.23
38	1447.969	4	Up	NW	3.04	0.33	326.06	2.62	0.38
40	1071.332	20	Down	SW	2.25	0.45	-50.58	-0.41	-2.46
42	1283.357	20	Down	CW	2.69	0.37	161.44	1.30	0.77
36	1656.644	20	Down	NW	3.47	0.29	534.73	4.29	0.23
40	1071.008	20	Middle	SW	2.25	0.45	-50.91	-0.41	-2.45
48	1200.065	20	Middle	CW	2.52	0.40	78.15	0.63	1.60
36	1614.458	20	Middle	NW	3.38	0.30	492.54	3.95	0.25
40	1070.961	20	Up	SW	2.25	0.45	-50.95	-0.41	-2.45
42	1122.839	20	Up	CW	2.35	0.42	0.93	0.01	134.75
38	1448.005	20	Up	NW	3.04	0.33	326.09	2.62	0.38
40	1070.482	80	N/A	SW	2.24	0.45	-51.43	-0.41	-2.42
42	1201.37	80	N/A	CW	2.52	0.40	79.46	0.64	1.57
36	1561.293	80	N/A	NW	3.27	0.31	439.38	3.52	0.28
40	1070.571	160	N/A	SW	2.24	0.45	-51.34	-0.41	-2.43
42	1216.277	160	N/A	CW	2.55	0.39	94.36	0.76	1.32
38	1558.866	160	N/A	NW	3.27	0.31	436.95	3.51	0.29
40	1090.599	1000	N/A	S	2.29	0.44	-31.31	-0.25	-3.98
40	1377.033	1000	N/A	N	2.89	0.35	255.12	2.05	0.49
40	1246.571	2000	N/A	N/	2.61	0.38	124.66	1.00	1.00
29	477	PA			1.00	1.00			

I-129 Case for H-Area CG-8 with a Kd of 380 ml/g

Figure 34 shows the SA results and well concentrations for all H-Area CG-8 I-129 cases using a 200 ft square window. Point source peaks range from about two times to four times the SA results.

The differences between the well concentration peaks for the SA results and the 2000-box point source model are 2.02 for a 200 ft square window, 2.50 for a 20 ft square window and 2.50 for the maximum aquifer cell. These results are very similar to those for Basic I-129 (1.87 for a 200 ft square window, 2.61 for a 20 ft square window and 2.61 for the maximum aquifer cell).

Figure 35 shows concentrations for 4-box configurations across the width of the trench at three north-south locations. The boxes were assumed to be at the bottom of the trench in all cases. In each case the results for box locations across the trench are very similar in shape and the peaks are close in magnitude, e.g., at the south end the peaks range from about 43 to 45 pCi/L/Ci. In all cases the peaks are highest for the eastern boxes, lowest for the central boxes, and they all match or exceed the 2000-box peak of about 43 pCi/L/Ci. The point source peaks occur earlier and are sharper than the 2000-box case. The peaks monotonically increase in magnitude toward the north end of the trench.

Figure 36 shows concentrations for 4 boxes along the western edge of the trenches at south, central and north locations. The first figure (A) shows results for boxes at the bottom of the trench, while B shows results for boxes at the vertical center of the trench and C shows results for boxes at the top of the trench. At each box depth, the times of occurrences of the peaks were quite similar, although the northern boxes had the highest peaks and the southern boxes had the lowest peaks. All peaks essentially matched or exceeded the 2000-box case, except for the boxes at the top of the trench.

Figure 37 shows concentrations at all three elevations for waste at the western edge of the trench in its north-south center. The peaks decreased as the elevation of the waste source increased. The peak for waste at the top of the trench was less than that for the 2000-box case.

Figure 38 is the first of four figures that present results for 20 boxes in a manner identical to the 4-box results. For Figure 38 and Figure 39, the results are very similar to the 4-box results and the discussion does not merit repeating.

Figure 40 shows results at different horizontal locations for 80 boxes, 160 boxes and 1000 boxes. The results for 80 boxes and 160 boxes are very similar. All peaks occurred at 580 years with the magnitude of the peak increasing in a northerly direction from about 41 to 44 pCi/L/Ci. The southern waste had a lower peak than the 2000-box case. The 1000 box cases were very similar to the 2000-box case with the northern half peak of 44 pCi/L/Ci exceeding the 2000-box peak of 43 pCi/L/Ci and the southern half peak of 42.5 pCi/L/Ci.

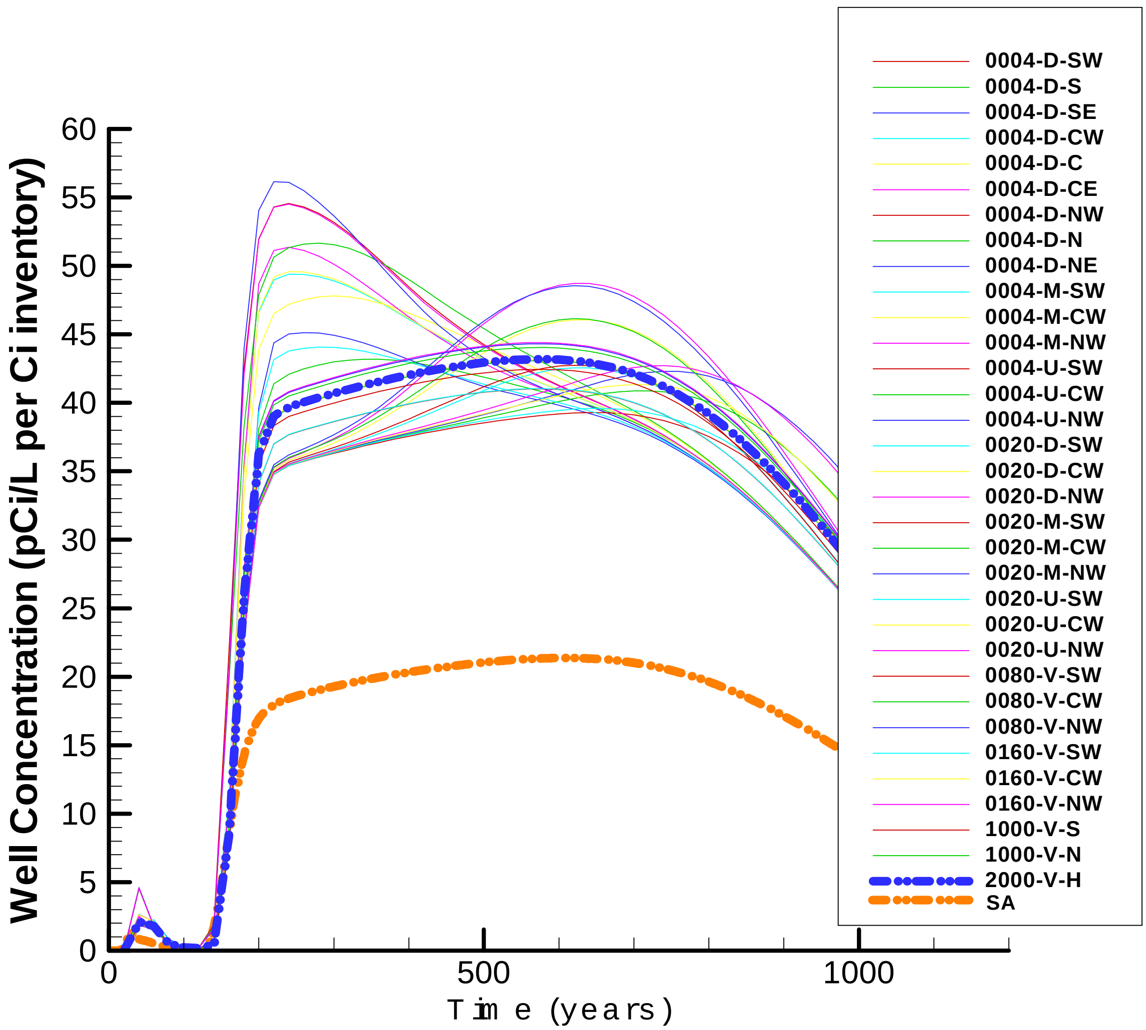
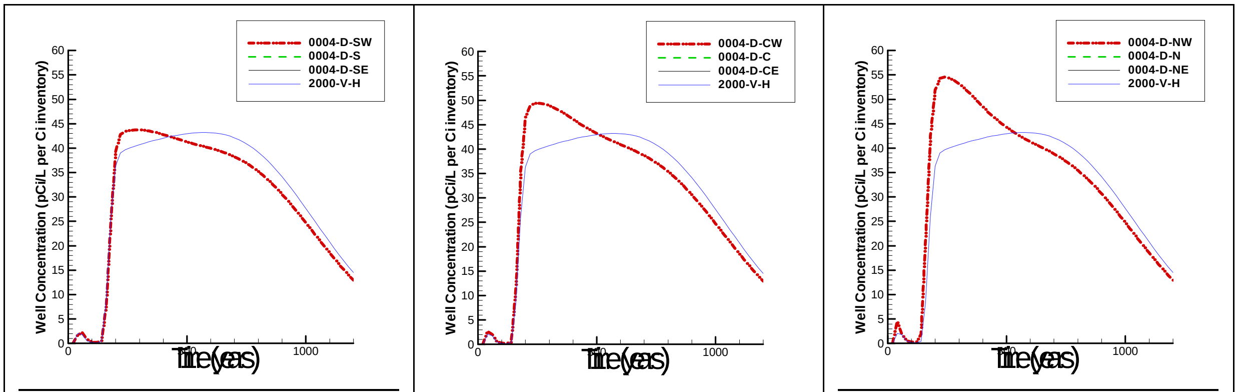
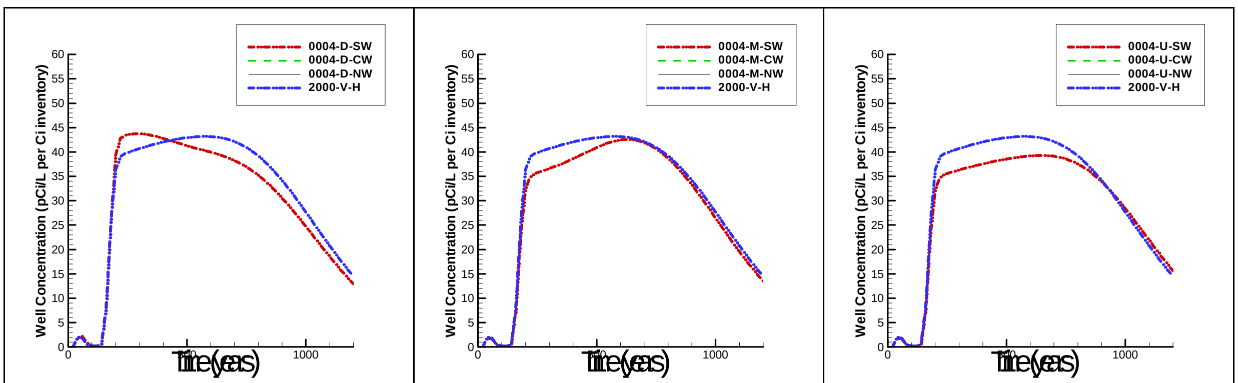


Figure 34. 100-m Well Concentrations for all H-Area CG-8 I-129 Point Source Cases and SA Results for a 200 ft square Window



(A)	(B)	(C)

Figure 35. Concentrations for 4-Box Configurations along South (A),Center (B) and North (C) Portions of Trench for a 200 ft square Window



(A)	(B)	(C)

Figure 36. Concentrations for 4 Boxes along West Edge at Bottom (A), Vertical Center (B) and Top (C) of Trench for a 200 ft square Window

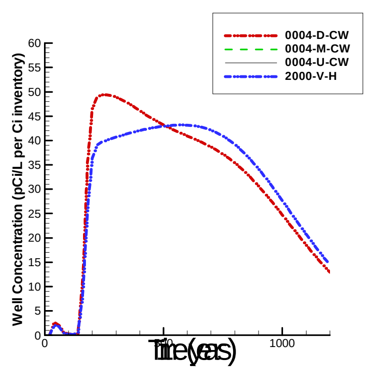
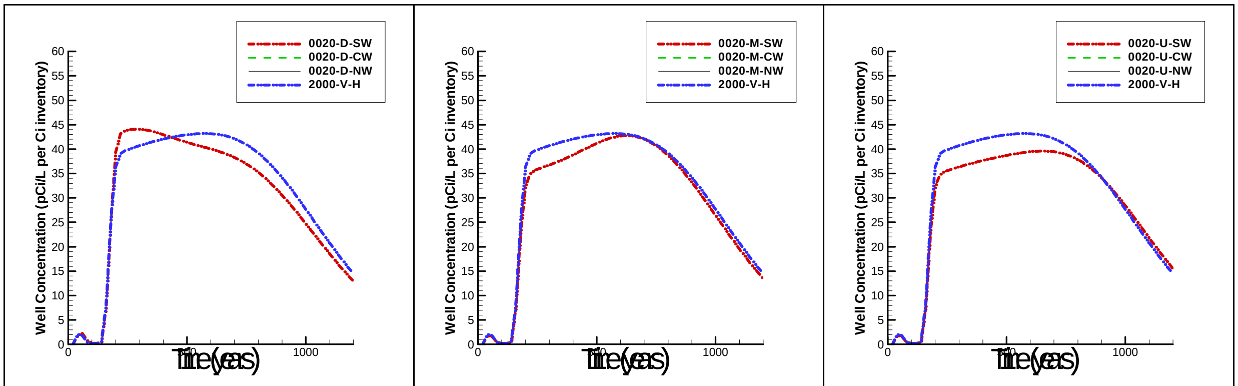


Figure 37. Concentrations for 3 Elevations of 4 Boxes at West Edge in Central Portion of Trench for a 200 ft square Window



(A)	(B)	(C)

Figure 38. Well Concentrations for 20 Boxes along West Edge at Bottom (A), Vertical Center (B) and Top (C) of Trench for a 200 ft square Window

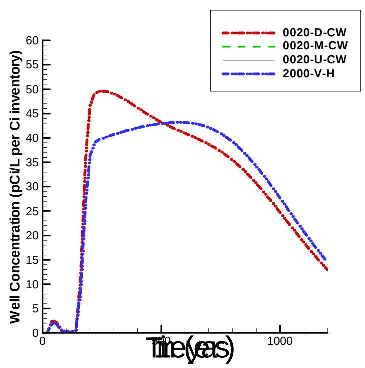
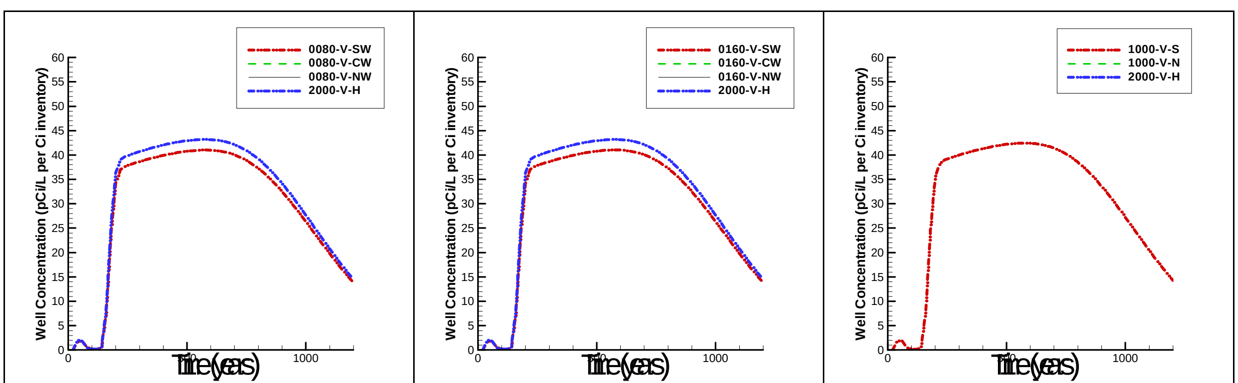


Figure 39. Well Concentrations for 3 Elevations of 20 Boxes at West Edge in Central Portion of Trench for a 200 ft square Window



(A)	(B)	(C)

Figure 40. Well Concentrations for 3 Horizontal Locations of 80 Boxes (A) and 160 Boxes (B), and 2 Horizontal Locations of 1000 Boxes (C) for a 200 ft square Window

Figure 41 shows a comparison of selected results for different sizes of box sets generally located at the center of the trench in the north-south direction. Boxes at the bottom of the trench were selected where available. All peaks were higher than for the 2000-box case, except for the 80- 160-box cases that matched the 2000-box case. The 4-Box and 20-Box cases matched and provided the highest peaks at 49 pCi/L/Ci versus the 2000-box case with a peak of 43 pCi/L/Ci. The 1000-Box case generated a peak of 44 pCi/L/Ci, only nominally higher than the 2000-box case.

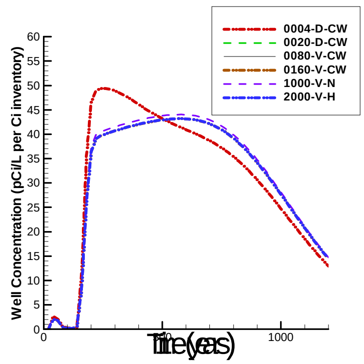


Figure 41. Comparison of Different Sizes of Box Sets for a 200 ft square Window

The next set of figures shows results for a 20 ft square window is used. These results are very similar to those for the aquifer cell with the maximum concentration because the window size and the cell sizes are close. Two figures are presented for the smaller window. Figure 42 shows all results on one plot. In general comparison with the 200 ft square window (Figure 34), the shapes of the curves are similar and the peaks occur at about the same times, but they are larger, ranging as high as about 94 pCi/L/Ci versus 56 pCi/L/Ci for the larger window.

Figure 43 shows a comparison of selected results for the different sizes of box sets. Plots are similar to the plots for the larger window (Figure 41), but the peaks are all higher by a factor of about 1.3 (e.g., for 4 boxes 62 versus 49 pCi/L/Ci).

Key information from the plots is presented in tabular form by well window size and for the maximum aquifer cell, exactly as was done for the Basic I-129. Table 3-6 presents results for the 200 ft square window. Point source concentrations range from about 39 to 56 pCi/L/Ci. Ratios versus the SA results of 21.4 pCi/L/Ci range from about 1.8 to 2.6. Inventory factors (the reciprocal of the ratios) range from about 0.4 to 0.55. The times of occurrence of the peaks range from about 220 to 740 years versus the SA time of 608 years. Waste placed at the bottom of the trench had peak times from 220 to 340 years. Waste placed at higher elevations peaked from 620 to 740 years. Waste placed throughout the entire cross-section of the SA waste all peaked at 580 years, slightly earlier than the SA.

The timing of the peak for the 2000-box case versus the SA is the exact opposite of that for Basic I-129. Examining the fractional fluxes to the water table (Figure 14), shows that the 2000-box case peaked slightly earlier at 540 years (Table 3-2) than did the SA case at 575 years. This indicates that the quicker travel time of contaminants through the vadose zone in the point source model had a greater impact than the slower travel time through the aquifer.

The worst case for the quasi-single trench was an adjusted concentration of 17.29 pCi/L/Ci that produced a ratio of 4.0 when divided by the uniform quasi-single trench concentration of 4.32 pCi/L/Ci. Its inventory reduction factor was 0.25. The differences in implementation of the conceptual model are reflected in the ratio of the 2000-box concentration to the SA results, i.e. 2.02 (43 pCi/L/Ci divided by 21 pCi/L/Ci) or an inventory factor of 0.50.

Table 3-7 presents results for the 20 ft square window. Concentrations range from about 49 to 93 pCi/L/Ci. Concentration ratios versus SA results range from about 2.3 to 4.4 while inventory factors range from about 0.25 to 0.45. The 2000-box concentration was higher than the SA concentration by 2.5 producing a conceptual modeling inventory difference factor of 0.4. For the quasi-single trench positive results, the highest concentration was about 45 pCi/L/Ci versus the uniform concentration of 5.4 pCi/L/Ci. The ratio was 8.5 and the inventory factor was 0.12 (compared to 0.25 for a 200 ft square window).

Table 3-8 shows results for the maximum aquifer cell that are almost identical to those for the 20 ft square window. The peak concentration only increased from 93.597 to 93.979 pCi/L/Ci, so no further discussion of these results will be presented.

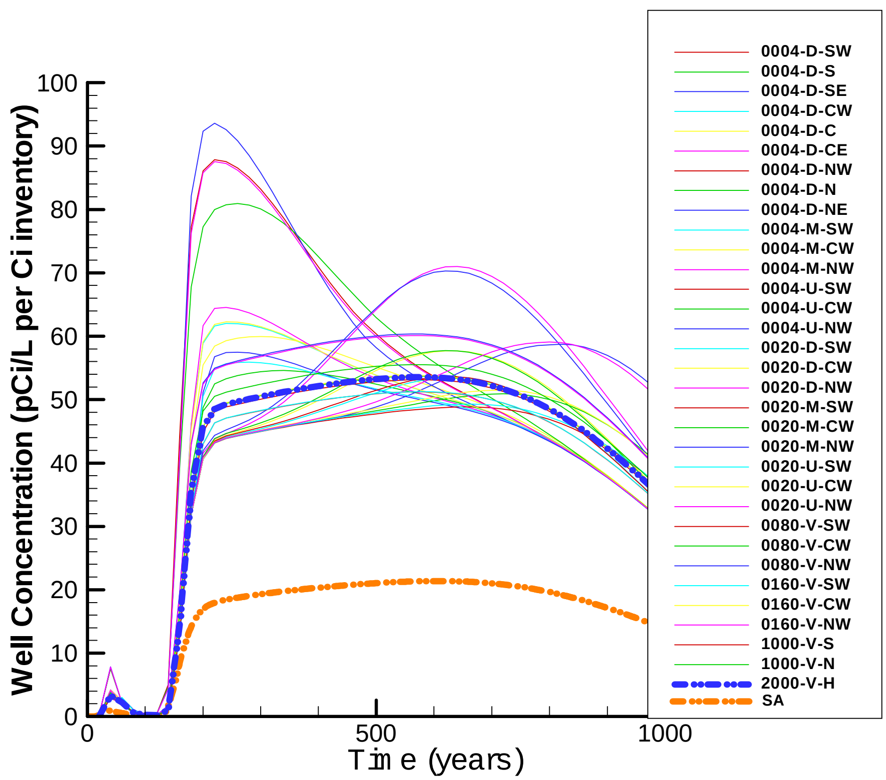


Figure 42. 100-m Well Concentrations for all H-Area CG-8 Point Source Cases and SA Results for 20 ft square Window

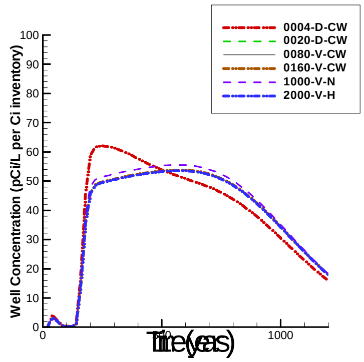


Figure 43. Comparison of Different Sizes of Box Sets for 20 ft square Window

Table 3-6. H-Area CG-8 I-129 (Kd=380 ml/g), 200 ft by 200 ft Window

9 Uniform Trenches + 1 Point Source Trench							Minus 9 Uniform Trenches		
Time (yr)	Conc. (pCi/L/Ci))	Boxes	Elev.	Direction	Conc. Vs. PA	Inv. Reduce	Conc. (pCi/L/Ci)	Conc. Vs 2000-Box	Inv. Reduce
300	43.733	4	Down	SW	2.04	0.49	4.86	1.13	0.89
340	43.187	4	Down	S	2.02	0.50	4.32	1.00	1.00
260	45.13	4	Down	SE	2.11	0.47	6.26	1.45	0.69
240	49.388	4	Down	CW	2.31	0.43	10.52	2.44	0.41
300	47.801	4	Down	C	2.23	0.45	8.93	2.07	0.48
240	51.345	4	Down	CE	2.40	0.42	12.47	2.89	0.35
240	54.554	4	Down	NW	2.55	0.39	15.68	3.63	0.28
280	51.662	4	Down	N	2.41	0.41	12.79	2.96	0.34
220	56.156	4	Down	NE	2.62	0.38	17.29	4.00	0.25
620	42.558	4	Middle	SW	1.99	0.50	3.69	0.85	1.17
640	46.065	4	Middle	CW	2.15	0.46	7.19	1.67	0.60
640	48.724	4	Middle	NW	2.28	0.44	9.85	2.28	0.44
640	39.294	4	Up	SW	1.84	0.54	0.42	0.10	10.21
720	40.872	4	Up	CW	1.91	0.52	2.00	0.46	2.16
740	42.305	4	Up	NW	1.98	0.51	3.43	0.80	1.26
280	44.063	20	Down	SW	2.06	0.49	5.19	1.20	0.83
240	49.572	20	Down	CW	2.32	0.43	10.70	2.48	0.40
240	54.501	20	Down	NW	2.55	0.39	15.63	3.62	0.28
620	42.751	20	Middle	SW	2.00	0.50	3.88	0.90	1.11
620	46.136	20	Middle	CW	2.16	0.46	7.27	1.68	0.59
620	48.565	20	Middle	NW	2.27	0.44	9.69	2.24	0.45
660	39.592	20	Up	SW	1.85	0.54	0.72	0.17	5.99
700	41.334	20	Up	CW	1.93	0.52	2.46	0.57	1.75
740	42.719	20	Up	NW	2.00	0.50	3.85	0.89	1.12
580	41.016	80	N/A	SW	1.92	0.52	2.15	0.50	2.01
580	43.081	80	N/A	CW	2.01	0.50	4.21	0.97	1.03
580	44.314	80	N/A	NW	2.07	0.48	5.44	1.26	0.79
580	41.038	160	N/A	SW	1.92	0.52	2.17	0.50	1.99
580	43.18	160	N/A	CW	2.02	0.50	4.31	1.00	1.00
580	44.395	160	N/A	NW	2.07	0.48	5.52	1.28	0.78
580	42.445	1000	N/A	S	1.98	0.50	3.57	0.83	1.21
580	44.037	1000	N/A	N	2.06	0.49	5.17	1.20	0.84
580	43.19	2000	N/A	N/	2.02	0.50	4.32	1.00	1.00
608	21.4	PA			1.00	1.00			

Table 3-7. H-Area CG-8 I-129 (Kd=380 ml/g), 20 ft by 20 ft Window

9 Uniform Trenches + 1 Point Source Trench							Minus 9 Uniform Trenches		
Time (yr)	Conc. (pCi/L/Ci))	Boxes	Elev.	Direction	Conc. Vs. PA	Inv. Reduce	Conc. (pCi/L/Ci)	Conc. Vs 2000-Box	Inv. Reduce
280	55.51	4	Down	SW	2.59	0.39	7.31	1.37	0.73
340	54.578	4	Down	S	2.55	0.39	6.38	1.19	0.84
260	57.483	4	Down	SE	2.69	0.37	9.28	1.73	0.58
240	62.026	4	Down	CW	2.90	0.35	13.83	2.58	0.39
300	59.975	4	Down	C	2.80	0.36	11.78	2.20	0.45
240	64.562	4	Down	CE	3.02	0.33	16.36	3.06	0.33
220	87.869	4	Down	NW	4.11	0.24	39.67	7.41	0.14
260	80.944	4	Down	N	3.78	0.26	32.74	6.11	0.16
220	93.597	4	Down	NE	4.37	0.23	45.40	8.48	0.12
640	53.411	4	Middle	SW	2.50	0.40	5.21	0.97	1.03
620	57.682	4	Middle	CW	2.70	0.37	9.48	1.77	0.56
640	71.019	4	Middle	NW	3.32	0.30	22.82	4.26	0.23
660	48.852	4	Up	SW	2.28	0.44	0.65	0.12	8.21
720	50.922	4	Up	CW	2.38	0.42	2.72	0.51	1.97
820	58.736	4	Up	NW	2.74	0.36	10.54	1.97	0.51
280	55.902	20	Down	SW	2.61	0.38	7.70	1.44	0.70
240	62.284	20	Down	CW	2.91	0.34	14.08	2.63	0.38
220	87.559	20	Down	NW	4.09	0.24	39.36	7.35	0.14
620	53.624	20	Middle	SW	2.51	0.40	5.42	1.01	0.99
620	57.737	20	Middle	CW	2.70	0.37	9.54	1.78	0.56
620	70.318	20	Middle	NW	3.29	0.30	22.12	4.13	0.24
660	49.289	20	Up	SW	2.30	0.43	1.09	0.20	4.92
720	51.498	20	Up	CW	2.41	0.42	3.30	0.62	1.62
800	59.091	20	Up	NW	2.76	0.36	10.89	2.03	0.49
580	51.231	80	N/A	SW	2.39	0.42	3.03	0.57	1.77
580	53.696	80	N/A	CW	2.51	0.40	5.50	1.03	0.97
560	60.336	80	N/A	NW	2.82	0.35	12.14	2.27	0.44
580	51.251	160	N/A	SW	2.39	0.42	3.05	0.57	1.76
580	53.803	160	N/A	CW	2.51	0.40	5.60	1.05	0.96
560	60.127	160	N/A	NW	2.81	0.36	11.93	2.23	0.45
580	53.133	1000	N/A	S	2.48	0.40	4.93	0.92	1.09
560	55.529	1000	N/A	N	2.59	0.39	7.33	1.37	0.73
580	53.555	2000	N/A	N/	2.50	0.40	5.36	1.00	1.00
608	21.4				1.00	1.00			

Table 3-8. H-Area CG-8 I-129 (Kd=380 ml/g), by Aquifer Model Cell

	9 Uniform Trenches + 1 Point Source Trench						Minus 9 Uniform Trenches		
Time (yr)	Conc. (pCi/L/Ci))	Boxes	Elev.	Direction	Conc. Vs. PA	Inv. Reduce	Conc. (pCi/L/Ci)	Conc. Vs 2000-Box	Inv. Reduce
280	55.51	4	Down	SW	2.59	0.39	7.31	1.37	0.73
340	54.578	4	Down	S	2.55	0.39	6.38	1.19	0.84
260	57.483	4	Down	SE	2.69	0.37	9.28	1.73	0.58
240	62.026	4	Down	CW	2.90	0.35	13.83	2.58	0.39
300	59.975	4	Down	C	2.80	0.36	11.78	2.20	0.45
240	64.562	4	Down	CE	3.02	0.33	16.36	3.06	0.33
220	88.104	4	Down	NW	4.12	0.24	39.90	7.45	0.13
260	81.108	4	Down	N	3.79	0.26	32.91	6.14	0.16
220	93.979	4	Down	NE	4.39	0.23	45.78	8.55	0.12
640	53.411	4	Middle	SW	2.50	0.40	5.21	0.97	1.03
620	57.682	4	Middle	CW	2.70	0.37	9.48	1.77	0.56
640	71.169	4	Middle	NW	3.33	0.30	22.97	4.29	0.23
660	48.852	4	Up	SW	2.28	0.44	0.65	0.12	8.21
720	50.922	4	Up	CW	2.38	0.42	2.72	0.51	1.97
820	58.775	4	Up	NW	2.75	0.36	10.58	1.97	0.51
280	55.902	20	Down	SW	2.61	0.38	7.70	1.44	0.70
240	62.284	20	Down	CW	2.91	0.34	14.08	2.63	0.38
220	87.713	20	Down	NW	4.10	0.24	39.51	7.38	0.14
620	53.624	20	Middle	SW	2.51	0.40	5.42	1.01	0.99
620	57.737	20	Middle	CW	2.70	0.37	9.54	1.78	0.56
620	70.526	20	Middle	NW	3.30	0.30	22.33	4.17	0.24
660	49.289	20	Up	SW	2.30	0.43	1.09	0.20	4.92
720	51.498	20	Up	CW	2.41	0.42	3.30	0.62	1.62
800	59.166	20	Up	NW	2.76	0.36	10.97	2.05	0.49
580	51.231	80	N/A	SW	2.39	0.42	3.03	0.57	1.77
580	53.696	80	N/A	CW	2.51	0.40	5.50	1.03	0.97
560	60.336	80	N/A	NW	2.82	0.35	12.14	2.27	0.44
580	51.251	160	N/A	SW	2.39	0.42	3.05	0.57	1.76
580	53.803	160	N/A	CW	2.51	0.40	5.60	1.05	0.96
560	60.127	160	N/A	NW	2.81	0.36	11.93	2.23	0.45
580	53.133	1000	N/A	S	2.48	0.40	4.93	0.92	1.09
560	55.529	1000	N/A	N	2.59	0.39	7.33	1.37	0.73
580	53.555	2000	N/A	N/	2.50	0.40	5.36	1.00	1.00
608	21.4	PA			1.00	1.00			

4.0 CONCLUSIONS

A suite of point source cases was analyzed to determine the effects on groundwater concentrations. The entire waste inventory for a trench was assumed concentrated in 4 boxes, 20 boxes, 80 boxes, 160 boxes or one-half the trench (1000 boxes). Each set of boxes was located at up to three different north-south locations. Additionally, smaller box sets were placed at different elevations and at different locations across the width of the trench. Analyses were conducted for Basic I-129 (Kd of 0.6 ml/g) and H-Area CG-8 I-129 (Kd of 380 ml/g).

Point source results were first benchmarked against PA or SA results by analyzing 10 uniformly loaded trenches. Subsequent analyses were conducted for 9 uniformly loaded trenches and one trench with a point source. Comparisons were made for a quasi-single trench by subtracting the estimated results for the 9 uniformly loaded trenches.

The first conclusion is that the location of point sources across the trench width has minimal effect. Fractional fluxes to the water table showed essentially no differences for the low Kd case and minor differences for the high Kd case, while the well concentrations for the 4-box and 20-box configurations were essentially identical, with both sets being only 1 box in height.

The second conclusion is that significant differences in results emerged from implementing the conceptual model differently from the PA. The point source model matched the footprint of the waste to the footprint of the underlying aquifer source cells. This required reducing cell sizes and reorienting the aquifer model to align with the long axis of the slit trenches. The PA introduced the flux at the water table to aquifer cells with a volume that was 2.4 times as large as the volume of the aquifer source cells used in the point source model. Additionally, the PA used two aquifer source cells that were vertically separated from the others, thus essentially generating two separate plumes that would not interact as strongly as a plume from a single, contiguous source region. The effects of the difference in implementing the conceptual model were segregated by first benchmarking the point source model, then by making comparisons of other point source models with the 2000-box point source case.

The third conclusion is that the window size has a significant impact, but that there is no significant difference between the small window and individual aquifer cells, because there was little size difference. The increase in concentrations from the big window to the small window was in the range of about 30% to 70%, for both the low Kd I-129 and the high Kd I-129.

The fourth conclusion is that under some conditions concentrating waste may prove beneficial. Small quantities of concentrated waste may generate its own peak that is smaller than the peak from the main waste and that may be sufficiently offset in time such that there is little or no peak interaction. A good example of this is placing the point source waste at the top of the trench.

The fifth conclusion is that within certain concentration ranges (portrayed by different sizes of box sets) there is no significant difference in results when averaging over the window sizes selected for this report. The 4- and 20-box sets produced similar results, as did the 80- and 160-box sets.

The sixth conclusion is that the quasi-single trench approach is problematic and represents a somewhat ideal case where nine trenches are uniformly loaded. It cannot truly capture the concentrations emanating from one point source trench as evidenced by negative reduced concentrations. This approach does shed some light on how plumes from various trenches interact and suggests that an integrated model may be needed to better understand the plume interactions. To manage a single trench it would be beneficial to analyze a single point source trench without the influence of uniformly loaded neighboring trenches. In this study the nine uniformly loaded trenches sometimes dominate and skew the results. Also, for some waste streams there are probably not enough boxes to fill even one trench, much less ten trenches.

The seventh conclusion is that as the elevation of the waste increased the well concentration decreased. The larger distance to the well caused this effect.

The eighth conclusion is that generally as the waste was moved farther away from the well (in a southerly direction) the concentrations decreased. Exceptions occurred when waste at some central locations generated the highest peaks, but this was likely caused by the timing of the peaks from the uniformly loaded trenches more closely matching the timing of the peaks from the point source trench.

The ninth conclusion is that concentrating the high Kd waste had a greater effect than concentrating the low Kd waste. For example, the highest concentration for the high Kd case with a 200 ft square window was about 56.2 pCi/L/Ci while the 2000-box case peak was 43.2 pCi/L/Ci generating a ratio of 1.3. The highest concentration for the low Kd case was about 1013 pCi/L/Ci while the 2000-box case peak was 890 pCi/L/Ci generating a ratio of 1.1. Placing waste with a high Kd nearer the water table was likely the cause, as seen in the fractional flux ratios. The ratio of the peak fractional flux to the water table versus the 2000-box case was as high as 3.6 (Table 3-2) for the high Kd case while the maximum ratio was only 1.23 for the low Kd case (Table 3-1).

The appropriate size window for averaging needs to be selected. A 20 ft wide window approximates the width of a single trench and is likely most appropriate for considering groundwater protection. The 200 ft wide window is wider than a set of 5 trenches with a 10 ft empty space between each pair of 20 ft wide trenches. Because flow is not parallel to the long trench axis, but rather passes under adjacent trenches, it would not be appropriate to use the full width of all 10 trenches when considering a resident 100 m away. A set of 5 trenches would be more realistic. Thus using a window about 140 to 150 ft wide could be used for residential applications. Interpolating between the 20 ft square window and the 200 ft square window would provide a suitable approximation. The formula would be based on the areas and the concentration (C_{150}) for a 150 ft square window would be

$C_{150} = C_{200} + 0.442 \times (C_{20} - C_{200})$

Where C_{200} is the concentration for a 200 ft square window and
C_{20} is the concentration for a 20 ft square window.

Adjustments for implementation of the general conceptual model should be separated from adjustments for point sources. The ratio of well concentrations for the 2000-box case to the PA or SA results was 2.61 for the low Kd case and 2.50 for the high Kd case. Therefore an adjustment of 2.5 seems appropriate for multiplying well concentrations and for dividing inventory limits.

Because results for certain groupings of box sets exhibited similar results it is appropriate to make recommendations by size of box sets. Each modeled box set represents a constant concentration increase relative to a uniform waste distribution as shown in Table 4-1.

Table 4-1. Modeled Box Sets Concentration Factors

Number of Boxes	Concentration Factor
4	500X
20	100X
80	25X
160	12.5X
1000	2X
2000	1X

It is recommended that a group size ranging from 1 box to 40 boxes be represented by the 4- and 20-box results. A group size ranging from 41 boxes to 500 boxes should be represented by the 80- and 160-box results. A group size ranging from 501 boxes to 1800 boxes should be represented by the 1000-box results. All larger box sets should be governed by the 2000-box results.

For each group the worst case results for the governing box set are provided in Table 4-2 for a 20 ft square window. Table 4.2 shows that the inventory factors are lower for the higher Kd case for the 1-40 box group. For the other size box groups, the reverse pattern is seen in that the inventory factors are higher for the higher Kd I-129 waste. The former relationship likely is caused by using the high Kd boxes that are placed at the bottom of the trench. The other groups have full waste cross-sections. This result means that stacking high Kd boxes would be a preferred configuration (versus a single layer on the bottom of the trench) for limiting increases in well concentrations.

Table 4-2. Group Worst Case Results by I-129 Kd with a 20 ft square window

			10 Trenches			Quasi-Single Trench		
Number of Boxes	Conc. Factor	Kd	Conc.	Conc. vs. 2000-box	Inv. Factor	Conc.	Conc. vs. 2000-box	Inv. Factor
1-40	50-2000X	0.6	1655	1.33	0.75	533	4.26	0.23
41-500	4-50X	0.6	1559	1.25	0.80	437	3.50	0.29
501-1800	2-4X	0.6	1377	1.10	0.91	255	2.04	0.49
1801-2000	1X	0.6	1247	1.00	1.00	125	1.00	1.00
1-40	50-2000X	380	93.6	1.75	0.57	45.4	8.41	0.12
41-500	4-50X	380	60.3	1.13	0.89	12.1	2.24	0.45
501-1800	2-4X	380	55.5	1.04	0.96	7.3	1.35	0.74
1801-2000	1X	380	53.5	1.00	1.00	5.4	1.00	1.00

The first column with an inventory factor relates to the inventory for all 10 trenches. If the inventory limit is reduced by that constant amount in all 10 trenches, then the MCL will still be met. However, if the inventory limit is reduced only for the point source trench, then the reduction must be greater. The second column of inventory factors listed under the quasi-single trench category attempts to provide this value. This second inventory factor is calculated by first subtracting the contribution from the nine uniformly loaded trenches, then determining the amount of reduction needed for the point source case to meet the MCL.

Similar to the above case, Table 4-3 provides worst case results for a 200 ft square window. The 200 sq ft window consistently produced smaller average concentrations.

The effects of concentrating the waste into point sources were reduced because the 200 sq ft window reduced the average concentrations more for the smaller box sets than for the 2000-box set (see Table 4-4). For example, the concentration for the 1-40 boxes for a Kd of 0.6 was reduced to 61% of its original value (1013 / 1655) while the concentration for 2000 boxes was reduced to 71% of its original value (890 / 1247). Thus, the concentration ratio was reduced by 86% (1.14 / 1.33). Changes in the Kd did not significantly change the window-size effects. The impact on quasi-single trench results was significantly greater than on the 10-trench results. For example, the concentration for 1-40 boxes of the low Kd material was reduced to 61% of its original value for 10 trenches, but it was reduced to 39% of its original value for the quasi-single trench results.

Table 4-3. Group Worst Case Results by I-129 Kd with a 200 ft square window

			10 Trenches			Quasi-Single Trench		
Number of Boxes	Conc. Factor	Kd	Conc.	Conc. vs. 2000-box	Inv. Factor	Conc.	Conc. vs. 2000-box	Inv. Factor
1-40	50-2000X	0.6	1013	1.14	0.88	209.2	2.35	0.43
41-500	4-50X	0.6	952	1.07	0.94	150.6	1.69	0.59
501-1800	2-4X	0.6	959	1.08	0.93	158.0	1.77	0.56
1801-2000	1X	0.6	890	1.00	1.00	89.0	1.00	1.00
1-40	50-2000X	380	56.2	1.30	0.77	17.3	4.00	0.25
41-500	4-50X	380	44.4	1.03	0.97	5.5	1.28	0.78
501-1800	2-4X	380	44.0	1.02	0.98	5.2	1.20	0.84
1801-2000	1X	380	43.2	1.00	1.00	4.3	1.00	1.00

Table 4-4. Ratios of Results for 200 Ft Square Window vs. 20 Ft Square Window

			10 Trenches			Quasi-Single Trench		
Number of Boxes	Conc. Factor	Kd	Conc.	Conc. vs. 2000-box	Inv. Factor	Conc.	Conc. vs. 2000-box	Inv. Factor
1-40	50-2000X	0.6	61%	86%	117%	39%	55%	187%
41-500	4-50X	0.6	61%	86%	118%	34%	48%	203%
501-1800	2-4X	0.6	70%	98%	102%	62%	87%	114%
1801-2000	1X	0.6	71%	100%	100%	71%	100%	100%
1-40	50-2000X	380	60%	74%	135%	38%	48%	208%
41-500	4-50X	380	74%	91%	109%	45%	57%	173%
501-1800	2-4X	380	79%	98%	102%	71%	89%	114%
1901-2000	1X	380	81%	100%	100%	80%	100%	100%

This study provides information for justifying or adjusting package limits that are 10 times the limit for the average box concentration and for providing guidance for accepting waste that exceeds the package limits. This study considers groups of boxes at a constant concentration higher than the average box limit. The increase in the well concentration for each group of boxes can be applied to each individual box to determine its specific contribution to the well concentration. That factor also is applicable for calculating the sum-of-fractions. Rather than trying to reduce the inventory limit, the individual contribution of each box could be amplified by multiplying its measured concentration by the well concentration ratio versus the 2000-box case.

This study indicates that a concentration factor from Table 4.2 could be applied to the measured concentration for waste that exceeds the average waste concentration limit. Additionally, a factor for differences in implementation of the conceptual modeling could be applied to the measured concentration for all waste, regardless of concentration. That factor is in the range of 1.9 to 2.0 based on the ratio of the 2000-box results to the PA or SA results as reported in Table 3-4 and Table 3-7 for a 200 ft square window, or about 2.5 for a 20 ft square window as reported in Table 3-4 and Table 3-7.

An example of applying this method would be to consider a box that has a concentration that is ten times the average waste concentration limit and has I-129 with a Kd of 0.6 ml/g. If the average waste concentration limit for a box is 0.1 Ci, then the example box has a concentration of 1 Ci. Using a factor of 2.25 for the difference in conceptual model implementation, the adjusted box concentration is calculated as 0.1 Ci x 2.25 = 0.225 Ci. Then Table 4.2 is entered with a concentration factor of 10X. Reading across the table for a quasi-single trench with a Kd=0.6 ml/g waste provides a factor of 3.50. The box concentration is adjusted a second time and is calculated as 0.225 Ci x 3.50 = 0.7875 Ci. This value of 0.7875 Ci is then used in the sum-of-fractions rather than the measured value of 0.1 Ci.

If the WAC is adjusted to include the effects of the differences in conceptual modeling implementation, then only the second step is required. The measured concentration of 0.1 Ci is multiplied by 3.50 to produce an adjusted concentration of 0.35 Ci. This indicates that in this example the concentrated waste is 3.5 times as potent as average waste. If operations wants to ensure that no more than 50% of the inventory is consumed by waste that is up to 10 times the average limit then they could develop a rule of thumb to limit the total number of such boxes. At 10 times the average concentration about 200 boxes would consume the trench's inventory based on a uniform distribution. Allowing no more than 50% of the inventory to be consumed by such boxes would limit the number to 100 boxes. Considering the potency, the number of such boxes would be reduced to 28. This example is based on all boxes being at 10 times the average concentration.

If the WAC is adjusted as discussed above and operations wants to consider the maximum number of boxes at 4 times the average concentration for I-129 at a Kd of 0.6 ml/g, then the analysis is as follows. The number of boxes without the potency considered would be 50% of 2000/4 or 250 boxes. The concentration factor is 2.04, so the total number of such boxes would be limited to about 125. This would then mean that all boxes over 4 times the average concentration would need to be approved on an exception basis.

5.0 FUTURE WORK

This study is part of an effort to improve modeling results. Other endeavors are foreseen that are expected to reduce conservatisms, increase predicted concentrations or be relatively neutral in results. These improvements can be categorized and the significance of expected outcomes can be qualitatively evaluated. It is recommended that future modeling improvements be examined on a pair-wise basis, selecting one improvement that is expected to reduce conservatisms and rapidly following with one that is expected to increase predicted concentrations. A partial listing of improvements that are currently expected to be significant follows.

Improvements expected to reduce conservatisms

1. Timing of doses to separate the effects of high Kd waste from low Kd waste
2. Activating mechanical dispersion in the refined model that will reduce arrival times but should diminish peaks
3. Incorporate both time and space variations for wastes to more accurately determine the plume interactions from wastes
4. Distributing the waste throughout the trench. Each case in this study considered a single waste cluster. Distributing the waste differently will reduce well concentrations.
5. Limiting the inventory of point source waste to the projected inventory. If the projected inventory is small, then the simulated waste cluster cannot be attained and well concentrations will be reduced.

Improvements expected to increase predicted concentrations

1. Recording results from the refined model at yearly intervals to increase the probability of recording the peak concentration
2. Incorporating subsidence reducing the thickness of the waste in addition to increasing surface infiltration. Collard (2000B) examined the effect of an increase in surface infiltration. Phifer and Wilhite (2001) reported a potential subsidence of seven to fifteen feet. Both effects have not been simultaneously simulated.

Improvements with unestimated outcomes

1. Using a refined model with only a single trench loaded with point sources rather than a quasi-single trench
2. Modifying the aquifer model to eliminate long, very thin elements that can force contaminant "smearing"
3. Determining whether the window should use a constant footprint over a single layer of aquifer cells or include consideration of water gradients. If the aquifer cell with the maximum concentration is used, then this improvement becomes moot.
4. Incorporating more and improved field data for the vadose zone model. Figures 3-2 through 3-4 in the annual report of the Vadose Zone Monitoring System Program show a high degree of heterogeneity in the sediments, but the model incorporates only a single native soil with properties determined from four "grab" samples that were highly disturbed (Yu, et al., 1993).

6.0 REFERENCES

Collard, L.B. 2000A. *Special analysis for Disposal of High-Concentration I-129 Waste in the Slit Trenches at the E-Area Low-Level Waste Facility*, WSRC-TR-2001-00021, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina.

Collard, L.B. 2000B. *Subsidence Sensitivity Study for Low-Level Waste in Slit Trenches*, WSRC-TR-2000-00524, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina.

Cook, J.R., L.B. Collard, G.P. Flach, and P.L. Lee. 2002. *Development of Probabilistic Uncertainty Analysis Methodology for SRS Performance Assessments Maintenance Plan Activities*, WSRC-TR-2002-00121, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina.

McDowell-Boyer, L., A.D. Yu, J.R. Cook, D.C. Kocher, E.L. Wilhite, H. Holmes-Burns, and K.E. Young. 2000. *Radiological Performance Assessment for the E-Area Low Level Waste Facility*, WSRC-TR-94-218, Revision 1, Westinghouse Savannah River Company, Aiken, South Carolina, 29808.

Phifer, M.A. and E.L. Wilhite. 2001. *Waste Subsidence Potential Versus Supercompaction*, WSRC-RP-2001-00613, Rev. 0, Westinghouse Savannah River Company, Aiken, South Carolina.

WSRC. 1997. *WSRC 1s Savannah River Site Waste Acceptance Criteria Manual, Procedure WAC 3.17 Low Level Radioactive Waste Acceptance Criteria*, Rev. 0, September.

Yu, A.D., C.A. Langton, and M.G. Serrato. 1993. *Physical Properties Measurement Program*., WSRC-RP-93-894, Westinghouse Savannah River Company, Aiken, South Carolina, 29808.

This page intentionally left