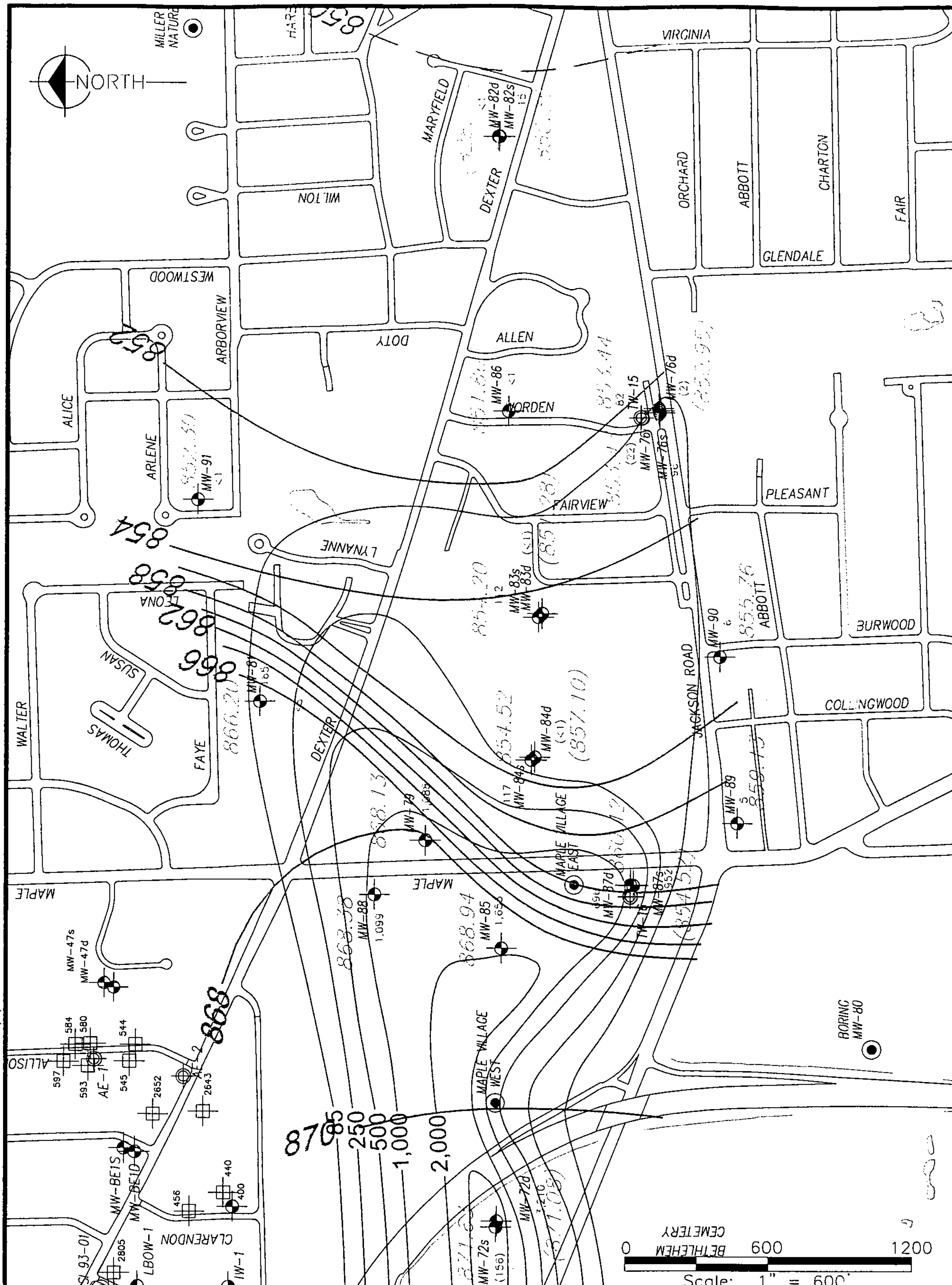
APPENDIX B

Unit E - Groundwater Flux Calculation - Maple Road Area

Input Parameters	Value	Comments			
Hydraulic Gradient (i)	0.0022605	Calcuated for the area between MW-72s and MW-85 (see supporting calculations below)			
Cross Sectional Area of Plume (A) in square feet	120000	This value was calculated by constructing a south-north cross section across the plume in the Maple Road area and using AUTOCAD to calculate the area of the aquifer.			
Hydraulic Conductivity (k) in gallons/day/foot2	2300	Value repesents aquifer transmissivity obtained from TW-16 aquifer test divided by aquifer thickness of 85 feet. This value is in the normal to high range for a sand/gravel type material.			
Groundwater Flux Calculation	**Q**	**K**	**i**	**A**	
Groundwater Flow Through Cross Sectional Area (Q) in gpd	623898	2300	0.0022605	120000	
Groundwater Flow Through Cross Sectional Area (Q) in gpm	433				
Where, Q = k x i x A					
Hydraulic Gradient Calculation (based on data collected September 30, 2003)	**Water Level (ft amsl)**	**Water Level (ft amsl)**	**Distance (feet)**	**Hydraulic Gradient**	
MW-72s to MW-85	871.63	868.94	1190	0.0022605	

Unit E - Groundwater Flux Calculation - Leading Edge of Plume Area

Input Parameters	Value	Comments		
Hydraulic Gradient (i)	0.0019041	Calcuated for the area between MW-83s and MW-82s (see supporting calculations below)		
Cross Sectional Area of Plume (A) in square feet	190000	This value was calculated by constructing a south-north cross section across the leading edge of the plume and using AUTOCAD to calculate the area of the aquifer.		
Hydraulic Conductivity (k) in gallons/day/foot2	2300	Value repesents aquifer transmissivity obtained from TW-15 aquifer test divided by aquifer thickness of 125 feet. This value is in the normal to high range for a sand/gravel type material.		
Groundwater Flux Calculation	**Q**	**K**	**i**	**A**
Groundwater Flow Through Cross Sectional Area (Q) in gpd	832072	2300	0.0019041	190000
Groundwater Flow Through Cross Sectional Area (Q) in gpm	578			
Where, Q = k x i x A				
Hydraulic Gradient Calculation (based on data collected September 30, 2003)	**Water Level (ft amsl)**	**Water Level (ft amsl)**	**Distance (feet)**	**Hydraulic Gradient**
MW-83s to MW-82s	854.2	850.35	2022	0.0019041



LEGEND

- MONITOR WELL
- RESIDENTIAL WELL
- PURGE WELL
- HYDROGEOLOGIC TEST BORING
- UV/OX. TREATMENT SYSTEM
- TEMPORARY PURGE WELL
- E_1 1,4-DIOXANE ISOCONCENTRATION CONTOUR (ug/L)
- E 1,4-DIOXANE ISOCONCENTRATION CONTOUR (ug/L)
- 1,4-DIOXANE CONCENTRATION (ug/L)
- DATA NOT USED

UNIT E AQUIFER
1,4-DIOXANE ISOCONCENTRATION MAP
JULY - AUGUST 2003
POTENTIOMETRIC SURFACE
SEPTEMBER 30, 2003

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Pall Life Sciences
Scio Twp., Washtenaw County, Michigan

Unit E
Groundwater Flux Calculation

PROJECT NO.
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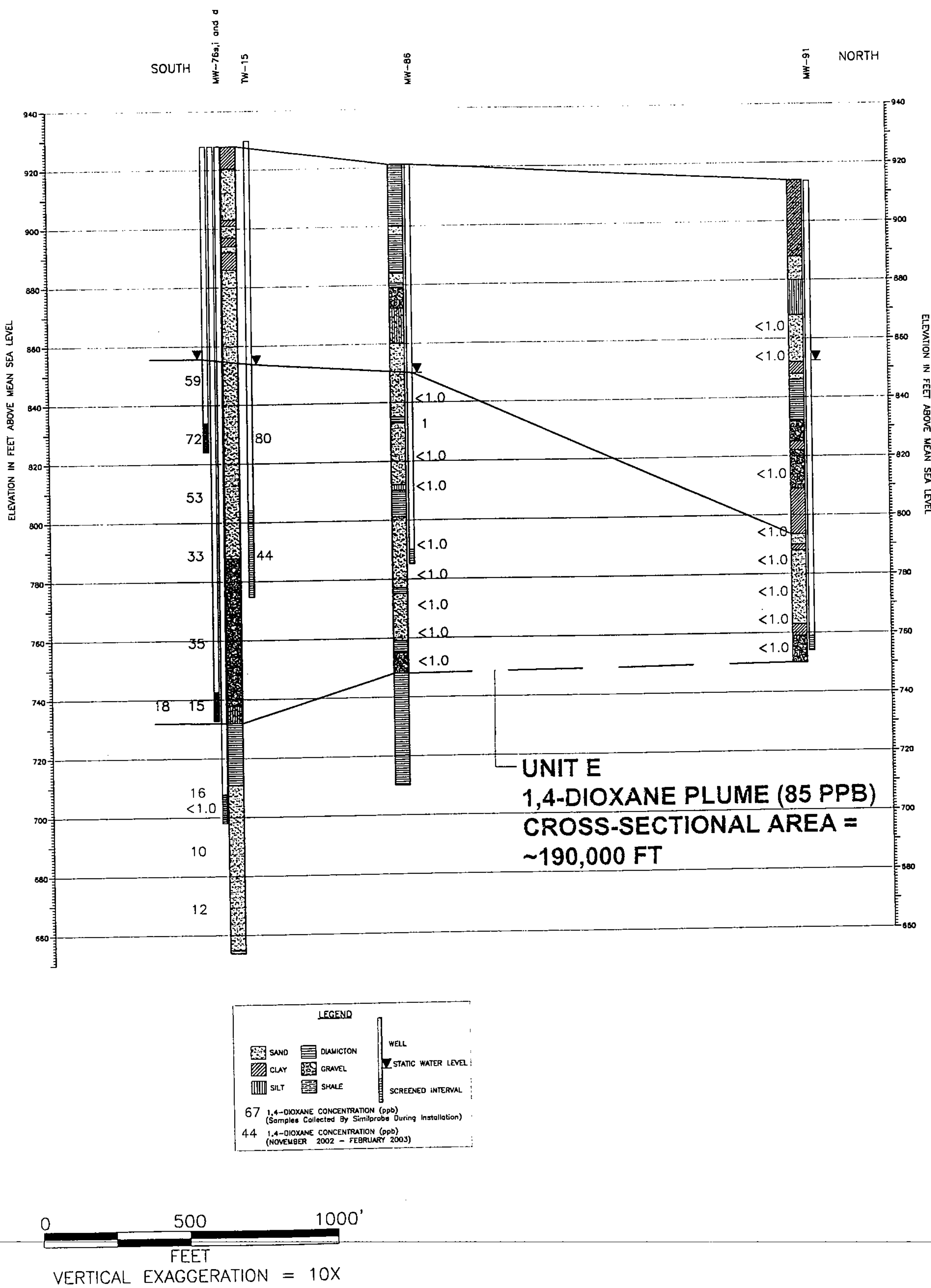

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Unit E
Groundwater Flux Calculation

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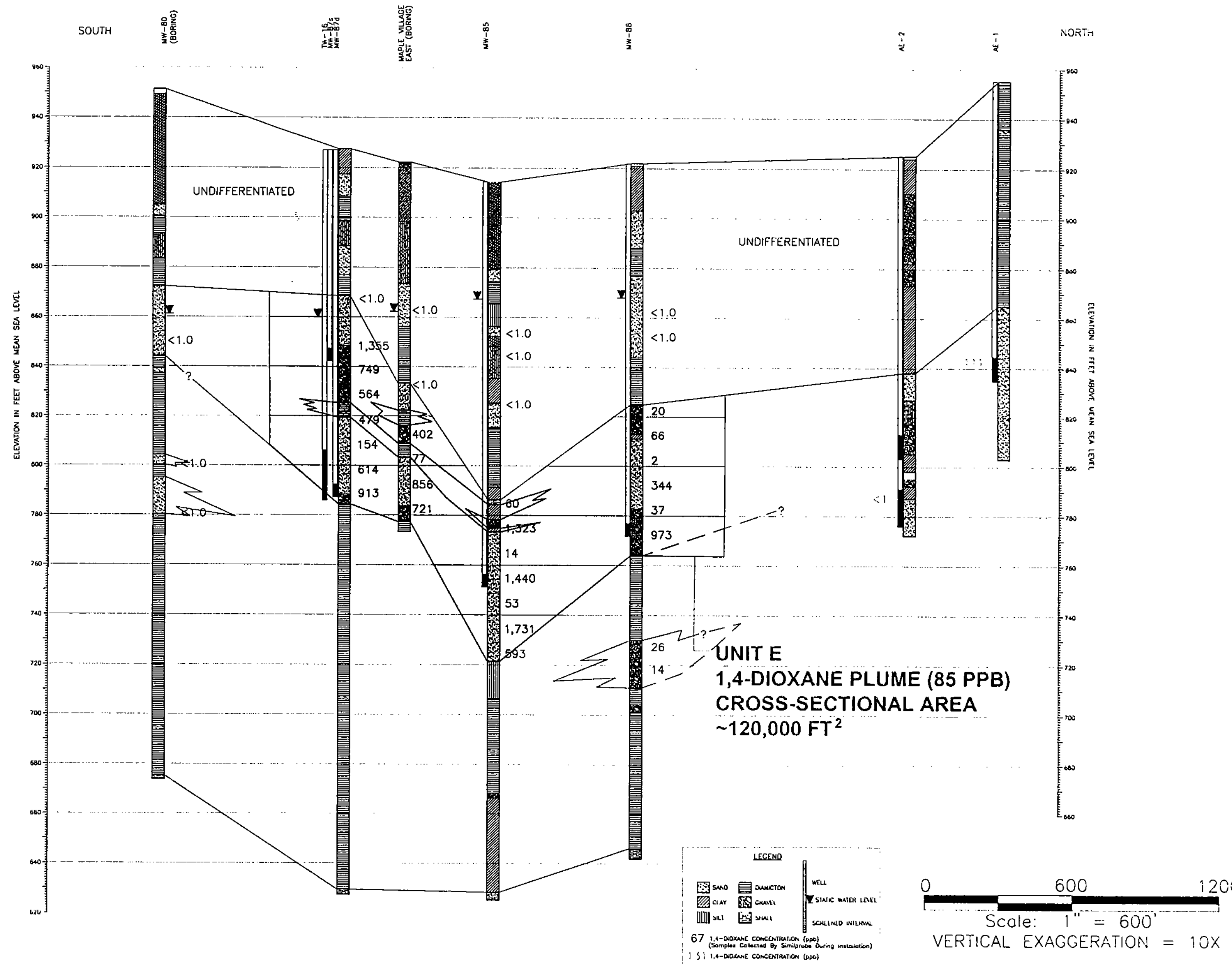

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APPENDIX C

Unit E Contaminant Transport Model
Pall Life Sciences, Ann Arbor, Michigan

INTRODUCTION

A contaminant transport model was constructed to evaluate the fate of the Unit E plume as it migrates hydraulically downgradient. This evaluation specifically focused on the predicting the 1,4-dioxane concentrations as the Unit E plume intersects the Huron River and the width of the plume as it migrates downgradient.

SELECTED MODEL CODE

The transport model was constructed using the WinTran 1995 software version 1.10 from Environmental Simulations, Inc. The WinTran software model is a two-dimensional groundwater flow and contaminant-transport model that allows the simulation of transient and/or steady-state flow and transport for both confined and unconfined aquifers.

The WinTran model makes the following assumptions:

- Ground-water flow is horizontal
- Contaminant concentrations are the same throughout the entire aquifer thickness
- Aquifer hydraulic conductivity is assumed to be isotropic and homogeneous.
- The reference head in the flow model is constant throughout all calculations
- All pumping rates, line-sink fluxes, pond recharge, and elliptical recharge rates are constant through time.
- All wells are assumed to fully penetrate the aquifer.
- Wells are assumed to be perfectly efficient and line-sinks are in perfect hydraulic communication with the aquifer.
- Particle traces and streamlines are two-dimensional.
- Chemical reactions are reduced to two types, (1) linear, fully-reversible sorption using a retardation coefficient, and (2) first-order decay.

APPROACH

The Unit E plume is oriented primarily, but not entirely, along an east-west axis. It was assumed that the plume would migrate downgradient along a flowpath similar to the plume axis. For this model simulation, however, the orientation of the flow path relative to the regional groundwater flow was irrelevant. 1,4-Dioxane concentrations and the Unit E plume width were determined at a distance equivalent to that of the Huron River as measured from the leading edge of the existing plume. Several Huron River simulated monitoring points were used to characterize the 1,4-dioxane concentrations across the plume width as the migrating Unit E plume intersected the river.

MODEL CONDITIONS AND INPUT DATA

Model Scenarios:

Two model scenarios are presented. The first involves the on-site (on PLS property) groundwater extraction and an extraction/treatment/re-injection near Maple Road (IRA). The second scenario is for comparison and simulates a no interim response action for the Unit E plume (No IRA). In the later case, the Unit E plume was allowed to migrate under natural groundwater flow conditions.

IRA Scenario

The model was run in a steady state mode under the following conditions:

Purge Wells
TW-11 = 100 gpm
TW-12 = 50 gpm
TW-17 (proposed) = 100 gpm
Maple Road Area = 200 gpm

Injection Wells
Maple Road Injection = 200 gpm (two wells each injecting at 100 gpm with 1,4-Dioxane concentrations at 20 ppb)

The following input data were used in the model:

- Concentration Data - Initial concentration data were input by importing a Surfer-grid file of the July-August 2003 1,4-Dioxane Isoconcentration Map for the Unit E-Plume.
- Aquifer thickness = 75 feet *(average thickness near Maple Village)*
- Hydraulic Conductivity = 100 ft/day *(estimate for sandy outwash material; reported range 2.84 – 284 ft/day for well sorted sandy outwash in Fetter, 2001)*
- Hydraulic Gradient = 0.00946 ft/ft *(based on the head gradient between Maple Village and the Huron River as represented on the City of Ann Arbor Groundwater Potentiometric Surface Map, Figure 4E, Fleis & Vandenbrink 2002)*
- Diffusion Coefficient = 0.000905 ft^2/day *(from Groundwater Chemical Desk Reference at http://www.dep.state.pa.us/physicalproperties/_cgi-bin?Diffusivity_water.idc)*
- Retardation Coefficient = 1.3 *(range 1 to 1.6, Priddle and Jackson, 1991)*
- Longitudinal Dispersivity (D_L) = 900 ft. Value was calculated using the 1/10th rule (Freeze and Cherry, 1979; Satkin and Bedient, 1988; Gelhar, Welty, and Rehfeldt, 1992) based on the distance from the plumes leading edge to the simulated Huron River receptors.
- Transverse Dispersivity (D_T) = 90 ft. DT value was calculated using the 1/10th rule as above.
- Half Life of 1,4-Dioxane = 0 days *(the model assumes no degradation of 1,4-Dioxane during transport. The half-life of 1,4-Dioxane ranges from 114 to 720 days (Sasaki, 1978; Kawasaki, 1990; Howard, 1990; Howard et. al., 1991). Using a zero value simulates the most conservative approach.*

RESULTS

The simulation results suggest that under IRA conditions the maximum 1,4-dioxane concentration at the simulated Huron River receptors would not exceed 150 ug/L. Under No IRA conditions the simulated maximum concentration at the Huron River receptors would not exceed 200 ug/L. These concentrations are well below the Part 201 Groundwater Surface Water Interface Criterion of 2800 ug/L. A plot of time versus 1,4-dioxane concentration for the simulated receptor with the highest 1,4-dioxane concentrations at the Huron River is provided for both IRA and No IRA conditions.

The maximum simulated width of the Unit E plume (defined by 85 ug/L) as it transects the Huron River is approximately 4200 feet under IRA conditions. The plume width is only marginally greater under No IRA conditions.

Water level data collected as part of the City of Ann Arbor Wellhead Protection Area Delineation Report for the Montgomery Wellfield by Fleis & Vandenbrink, 2002, indicates that groundwater flow downgradient of the Unit E plume is toward the northeast. If the plume follows this pathway, the plume width is not sufficient to impact other potential receptors. A map showing the predicted plume path and potential receptors is attached.

MODEL LIMITATIONS

The model presented is based on many assumptions. The model and the selected approach used for our analysis will provide a conservative estimate of the concentrations of 1,4-dioxane that will arrive at the Huron River. The model appears to be most sensitive to changes in longitudinal and transverse dispersivity (D_L & D_T). Additionally, geologic controls known to constrain the existing Unit E plume width (i.e. clay content and permeability barriers associated with aquifer geometry) were not simulated between the current leading edge of the Unit E plume and the Huron River. Consequently, the width of the simulated migration pathway is conservative and the ultimate plume width may be constrained by geologic and hydrogeologic conditions that are currently unknown.

The model also assumes that there are uniform concentrations of 1,4-dioxane vertically in the aquifer and the it does not account for vertical dispersion. The plume is generally mapped using the highest concentrations in a given well regardless of their specific depth within the aquifer. As such, on average, the vertical-concentration profile for a specific monitoring well may be less than the value used in the planar (2-D) model, which could further reduce 1,4-dioxane levels.

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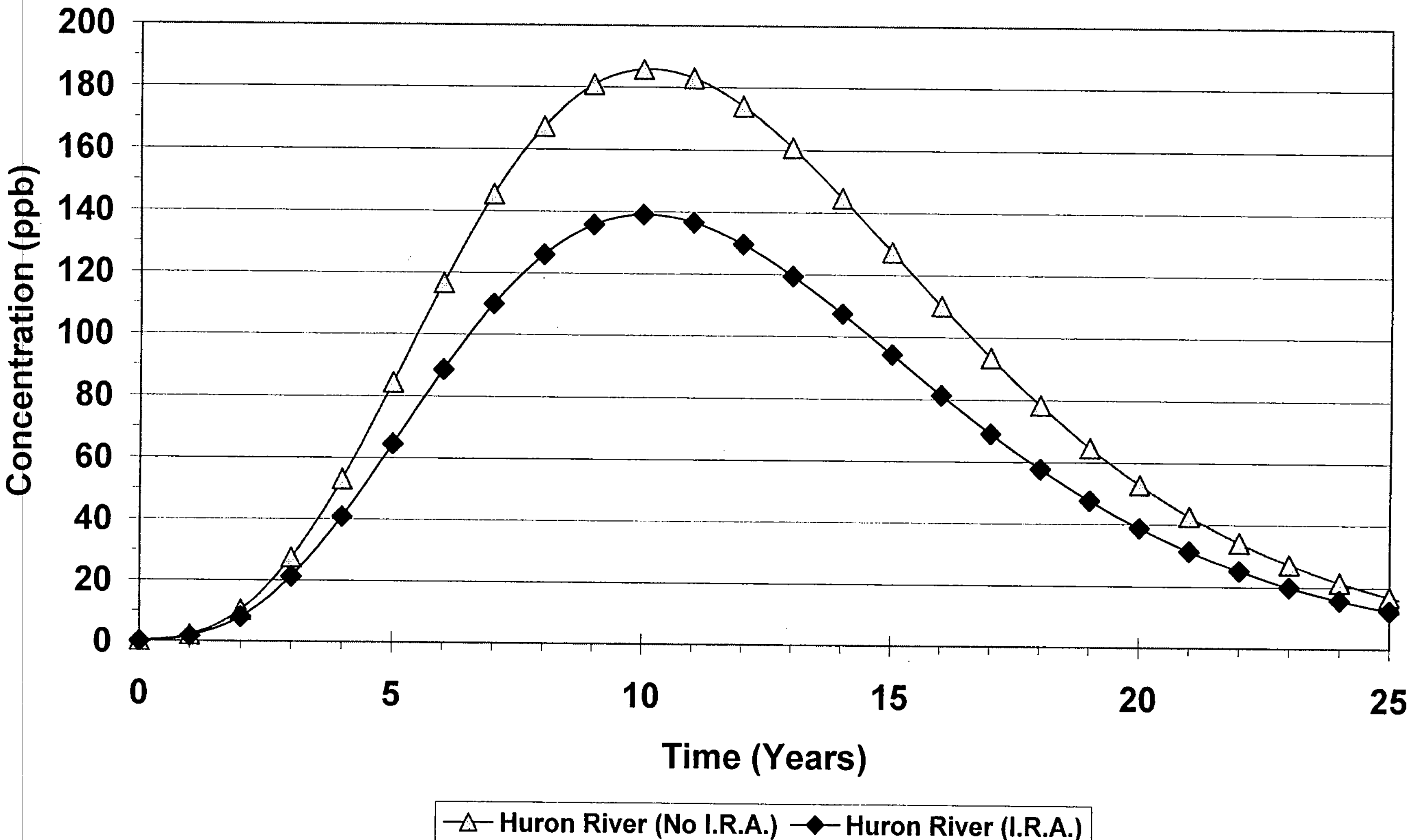
Simulated 1,4-Dioxane Concentration

WinTran -Transport Model (May 2004)



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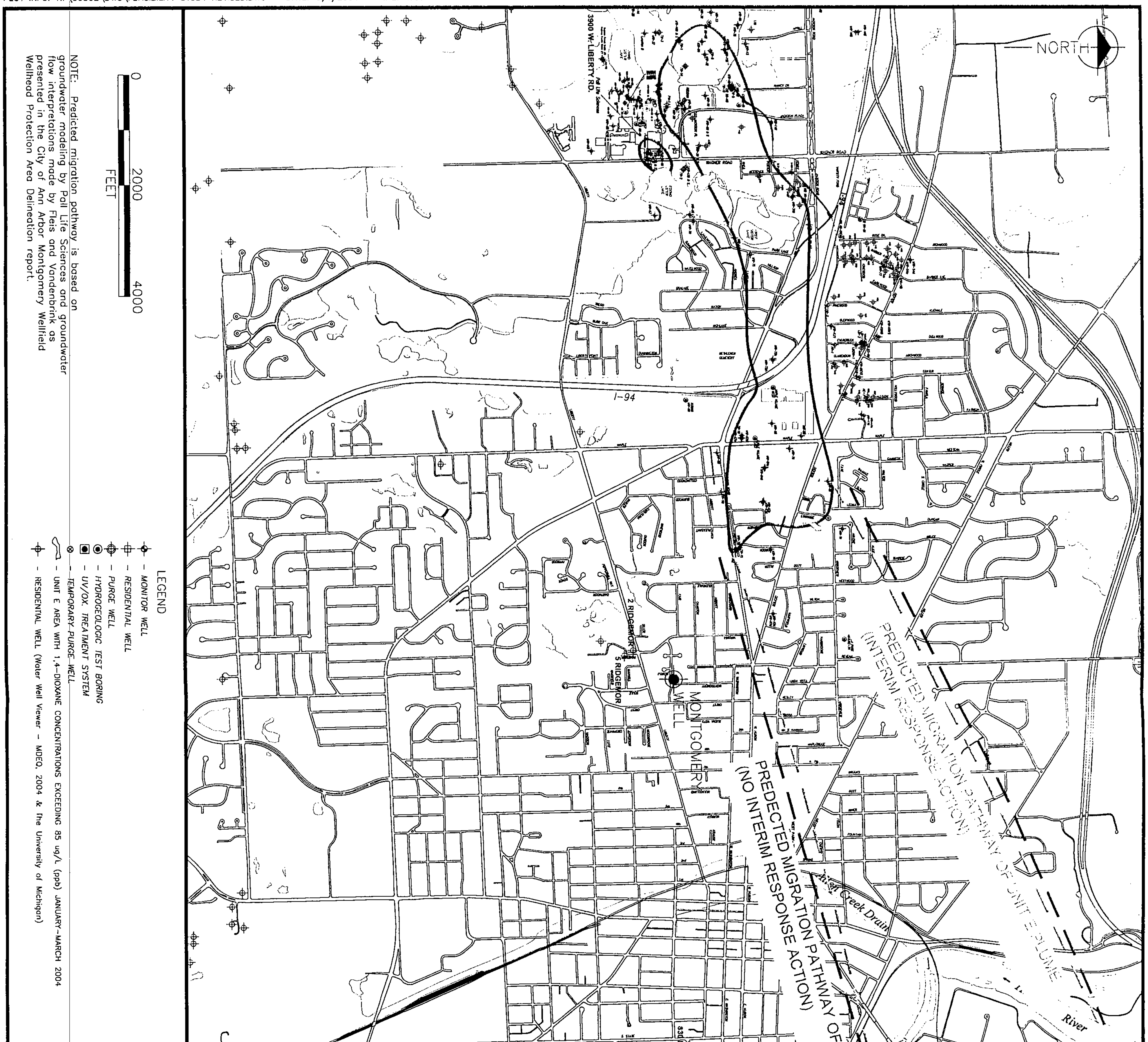

PROJECT NO. F9650	**Pall Life Sciences** Scio Twp., Washtenaw County, Michigan Unit E Contaminant Transport Model

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APPENDIX D

Appendix D
Alternative Technical Descriptions/Assumptions

The following descriptions/assumptions are provided as an appendix to the Pall Unit E Feasibility Study (FS) and supplement additional technical information provided in the alternative cost estimates (Tables 4 through 13). The infrastructure requirements for the alternatives were developed from a variety of sources including technology information developed by Pall and/or its consultants, vendor comments or information, literature reviews, common engineering principles, and prior experience with similar technologies. For the purposes of the FS, many assumptions were made regarding the infrastructure necessary for each alternative. If any of the alternatives were to be selected, additional site-specific information would be necessary to refine the alternative requirements.

Applicable to all Groundwater Pumping Strategies

The pumping rate necessary to capture the Unit E plume at the leading edge has been calculated to be approximately 578 gpm. This rate was determined by analyzing the amount of groundwater flowing through a cross section of the plume near the leading edge. Supporting calculations are provided in this Appendix B. If a treatment system were to be designed to halt the downgradient migration of the Unit E plume at the leading edge, the system would be designed with additional capacity to address uncertainties in this flux calculation. PLS would anticipate that a minimum system design capacity would be approximately 650 gpm. The need to operate the system at this capacity on a continuous basis is uncertain. As such, PLS has based its cost calculations for system operation and maintenance on an average 500 gpm flow rate. This number also reflects uncertainties in the actual flow needed to halt the plume, and represents a reasonable average that the system would likely be operated over time.

Groundwater extraction wells were positioned east of the known Unit E plume boundaries. The wells were installed ahead (downgradient) of the plume at reasonable distances. These locations would need to be adjusted based on the rate of plume advancement. Site-specific conditions such as utilities, trees, access, property boundaries etc. were not analyzed for well placement of the wells or pipelines and would need to be considered if an extraction alternative were implemented. Maps showing the layout of each alternative are generalized.

Applicable to all Groundwater Injection Strategies

It has been assumed that more wells would be needed for injection than extraction. As such, a minimum of 4 injection wells would need to be installed.

For alternative 4c, the injection wells would be located hydraulically downgradient of the plume and the area of influence of the extraction wells. Well locations would be determined based on the limits of the plume and additional hydrogeological studies. It has been assumed for the FS purposes that wells were installed ahead (downgradient) of the plume and extraction wells at distances seemed reasonable to minimize their hydraulic influence on the extraction wells. Like the extraction well locations, these locations would need to be adjusted based on the rate of plume advancement, hydrogeological conditions and other site conditions. Site-specific conditions such as utilities, trees, access, property boundaries etc. were not analyzed for well placement of the wells or pipelines and would need to be considered if an extraction alternative were implemented.

For alternative 3c, it has been assumed that injection wells would be located around the current boundaries of the plume near the PLS site. Management of this water would be more difficult than Alternative 4c because there would be more potential for interaction with the plume and potential for impacts on the capture of the extraction wells.

Injection well fouling is a known problem. It has been anticipated that such fouling would require routine well maintenance.

Alternative 2 – Technical components of this alternative are discussed in text of the FS.

Alternative 3a – A total of 3 extraction wells would be installed in this alternative. Ideally, the wells could be positioned in an area where less disruption would occur than if the wells were positioned in a residential setting. The location of the wells, and associated piping would be dictated by the location of the plume relative to receptors, hydrogeology, and an assessment of local infrastructure. Each of the extraction wells would be connected to a main extraction well pipeline via a connection line. The connection line would be an 8-inch HDPE pipe and would be trenched from each of the extraction wells approximately 100 feet to the main pipeline (It is assumed that each extraction well would be located approximately 100 feet from the main extraction well line). The main extraction well pipeline would consist of a double-cased pipe consisting of an outer piping consisting of 12-inch HDPE pipe and the inner piping consisting of 8-inch high density polyethylene (HDPE) pipe. The contaminated groundwater would be pumped through the 8-inch pipeline. The 12-inch pipeline acts as containment in the event of the failure of the 8-inch pipe. The pipeline would be installed by horizontal drilling which would minimize digging/trenching. The discharge pipeline would consist of 12-inch HDPE pipe. The pipeline would be installed by horizontal drilling which would minimize digging/trenching.

The extraction well pipeline would run from the three extraction wells to Jackson Road. The pipeline would then extend west along Jackson Road to Wagner Road. The pipeline would run south on Wagner Road to Pall, where the piping would terminate at the treatment building. The discharge line would start at Pall and would extend north along Wagner Road to the M14 junction. The discharge line would then run along M-14 where until it terminates at the Huron River. Manholes would be placed on 500-foot centers to allow for the monitoring of the pipelines.

Alternative 3c – A total of 3 extraction and 4 injection wells would be installed in this alternative. Ideally, the extraction and injection wells could be positioned in an area where less disruption would occur than if the wells were positioned in a residential setting. The location of the wells, and associated piping would be dictated by the location of the plume relative to receptors, hydrogeology, and an assessment of local infrastructure. Each of the extraction and injection wells would be connected to a main extraction well pipeline via a connection line. The connection line would be an 8-inch HDPE pipe and would be trenched from each of the extraction wells approximately 100 feet to the main pipeline (It is assumed that each extraction and injection well would be located approximately 100 feet from the main extraction or injection well line). The main extraction well pipeline would consist of a double-cased pipe consisting of an outer piping consisting of 12-inch HDPE pipe and the inner piping consisting of 8-inch HDPE pipe. The contaminated groundwater would be pumped through the 8-inch pipeline. The 12-inch pipeline acts as containment in the event of the failure of the 8-inch pipe. The pipeline would be installed by horizontal drilling which would minimize digging/trenching. The discharge pipeline would consist of 12-inch HDPE pipe and would be installed by trenching.

The extraction well pipeline would run from the three extraction wells to Jackson Road. The pipeline would then extend west along Jackson Road to Wagner Road. The pipeline would run south on Wagner Road to Pall, where the piping would terminate at the treatment building. The discharge line would start at Pall and would extend to the injection wells which would be located on Pall property. Manholes would be placed on 500-foot centers to allow for the monitoring of the pipelines.

Alternative 3e – A total of 3 extraction wells would be installed in this alternative. Ideally, the wells could be positioned in an area where less disruption would occur than if the wells were positioned in a residential setting. The location of the wells, and associated piping would be dictated by the location of the plume relative to receptors, hydrogeology, and an assessment of local infrastructure. Each of the extraction wells would be connected to a main extraction well pipeline via a connection line. The connection line would be an 8-inch HDPE pipe and would be trenched from each of the extraction wells approximately 100 feet to the main pipeline (It is assumed that each extraction well would be located approximately 100 feet from the main extraction well line). The main extraction well pipeline would consist of a double-cased pipe consisting of an outer piping consisting of 12-inch HDPE pipe and the inner piping consisting of 8-inch HDPE pipe. The contaminated groundwater would be pumped through the 8-inch pipeline. The 12-inch pipeline acts as containment in the event of the failure of the 8 inch pipe. The pipeline would be installed by horizontal drilling which would minimize digging/trenching. The discharge pipeline would consist of 12-inch HDPE pipe and would be installed by trenching.

The extraction well pipeline would run from the three extraction wells to Jackson Road. The pipeline would then extend west along Jackson Road to Wagner Road. The pipeline would run south on Wagner Road to Pall, where the piping would terminate at the treatment building. The discharge line would start at Pall and would extend to Honey Creek which bisects the Pall property. Manholes would be placed on 500-foot centers to allow for the monitoring of the pipelines.

Alternative 4a – A total of 3 extraction wells would be installed in this alternative. Ideally, the wells could be positioned in an area where less disruption would occur than if the wells were positioned in a residential setting. The location of the wells, and associated piping would be dictated by the location of the plume relative to receptors, hydrogeology, and an assessment of local infrastructure. Each of the extraction wells would be connected to a main extraction well pipeline via a connection line. The connection line would be an 8-inch HDPE pipe and would be trenched from each of the extraction wells approximately 100 feet to the main pipeline (It is assumed that each extraction well would be located approximately 100 feet from the main extraction well line). The main extraction well pipeline would consist of a double-cased pipe consisting of an outer piping consisting of 12-inch HDPE pipe and the inner piping consisting of 8-inch HDPE pipe. The contaminated groundwater would be pumped through the 8-inch pipeline. The 12-inch pipeline acts as containment in the event of the failure of the 8-inch pipe. The pipeline would be installed by horizontal drilling which would minimize digging/trenching. The discharge pipeline would consist of 12-inch HDPE pipe and would be installed by horizontal drilling.

The extraction well pipeline would run from the three extraction wells to Jackson Road. The pipeline would then extend north along Maple Road to an unknown location for treatment. For cost purposes, it is assumed that the treatment system would be located near the western portion of the Maple Village Shopping Center (Maple Village). At Maple Village, the pipeline would extend to the western portion of the property and would terminate at the treatment building. The discharge line would extend from Maple Village to Maple Road. At Maple Road, the discharge line would extend north to M14. At M14, the line would head east then north and terminate at the Huron River. The exact placement of the pipeline has not yet been determined; therefore, for general reference the pipelines (extraction well and discharge) have been shown to run down the middle of each road. Manholes would be placed on 500-foot centers to allow for the monitoring of the pipelines.

Alternative 4c – A total of 3 extraction wells would be installed in this alternative. Ideally, the wells could be positioned in an area where less disruption would occur than if the wells were positioned in a residential setting. The location of the wells, and associated piping would be dictated by the location of the plume relative to receptors, hydrogeology, and an assessment of local infrastructure. Each of the extraction wells would be connected to a main extraction well pipeline via a connection line. The connection line would be an 8-inch HDPE pipe and would be trenched from each of the extraction wells approximately 100 feet to the main pipeline. It is assumed that each extraction well would be located approximately 100 feet from the main extraction well line. The main extraction well pipeline would consist of a double-cased pipe consisting of an outer piping consisting of 12-inch HDPE pipe and the inner piping consisting of 8-inch HDPE pipe. The contaminated groundwater would be pumped through the 8-inch pipeline. The 12-inch pipeline acts as containment in the event of the failure of the 8-inch pipe. The pipeline would be installed by horizontal drilling which would minimize digging/trenching. The discharge pipeline would consist of 12-inch HDPE pipe and would be installed by horizontal drilling. The ~~injection well pipeline would be installed by horizontal drilling which would minimize digging/trenching.~~

The extraction well pipeline would run from the three extraction wells to Jackson Road. The pipeline would then extend north along Maple Road to an unknown location for treatment. For cost purposes, it is assumed that the treatment system would be located near the western portion of the Maple Village Shopping Center (Maple Village). At Maple Village, the pipeline would extend to the western portion of the property and would terminate at the treatment building. The discharge line would extend from Maple Village to Maple Road. The discharge line would extend from Maple Village to Maple Road. At Maple Road, the discharge line would extend south to Jackson Road (adjacent to the extraction well pipeline). The injection well line would then run east along Jackson Road. At Worden, the injection well line would branch off to the north along Worden to Dexter Avenue. A southern branch would head south along Glendale. The northern branch would then head east along Dexter Avenue to Pine Ridge Street where the line would head north to the injection well. The southern branch would head south along Glendale and would further branch off at Orchard and Fair Streets and would terminate at the injection wells. The last injection well with be located along Winewood Avenue. The exact placement of the pipeline has not yet been determined; therefore, for general reference the pipelines (extraction well and discharge) have been shown to run down the middle of each road. Manholes would be placed on 500-foot centers to allow for the monitoring of the pipelines.

Alternative 5 – A total of 3 extraction wells would be installed in this alternative. Ideally, the wells could be positioned in an area where less disruption would occur than if the wells were positioned in a residential setting. The location of the wells, and associated piping would be dictated by the location of the plume relative to receptors, hydrogeology, and an assessment of local infrastructure. Each of the extraction wells would be connected to a main extraction well pipeline via a connection line. The connection line would be an 8-inch HDPE pipe and would be trenched from each of the extraction wells approximately 100 feet to the main pipeline. It is assumed that each extraction well would be located approximately 100 feet from the main extraction well line. The main extraction well pipeline would consist of a double-cased pipe consisting of an outer piping consisting of 12-inch HDPE pipe and the inner piping consisting of 8-inch HDPE pipe. The contaminated groundwater would be pumped through the 8-inch pipeline. The 12-inch pipeline acts as containment in the event of the failure of the 8-inch pipe. The pipeline would be installed by horizontal drilling which would minimize digging/trenching. The discharge pipeline would consist of 12-inch HDPE pipe. The pipeline would be installed by digging/trenching.

The extraction well pipeline would run from the three extraction wells to Jackson Road. The pipeline would then extend west along Jackson Road to Wagner Road. The pipeline would run south on Wagner Road to Pall, where the piping would terminate at the treatment building. The exact placement of the extraction well pipeline has not yet been determined; therefore, for general reference the pipeline has been shown to run down the middle of each road. The discharge line would start at Pall and would extend to a deep injection well. The exact location of the deep injection well is not known; however, for cost purposes, it is assumed that the deep injection well would be installed on Pall property. The deep injection well would be installed in the Mt. Simon Formation. Manholes would be placed on 500-foot centers to allow for the monitoring of the pipelines.

Alternative 6 Groundwater Pumping with Active Remediation Proximate to the Huron River, if Necessary – A total of 5 extraction wells would be installed in this alternative. Ideally, the wells would be positioned in an area where less disruption would occur than if the wells were positioned in a residential setting. The location of the wells, and associated piping would be dictated by the location of the plume relative to receptors, hydrogeology, and an assessment of local infrastructure. Each of the extraction wells would be connected to a main extraction well pipeline via a connection line. The connection line would be an 8-inch HDPE pipe and would be trenched from each of the extraction wells approximately 100 feet to the main pipeline (It is assumed that each extraction well would be located approximately 100 feet from the main line). The main extraction well pipeline would consist of a double-cased pipe consisting of an outer piping consisting of 12-inch HDPE pipe and the inner piping consisting of 8-inch HDPE pipe. The contaminated groundwater would be pumped through the 8-inch pipeline. The

12-inch pipeline acts as containment in the event of the failure of the 8-inch pipe. The pipeline would be installed by horizontal drilling which would minimize digging/trenching.

The extraction well pipeline would be extended to a treatment site/building. A discharge line, consisting of a 12-inch HDPE pipe would be installed from the treatment building and extend to the Huron River. The exact placement of the pipeline has not yet been determined. Manholes would be placed on 500-foot centers to allow for the monitoring of the pipelines.

APPENDIX E

Supporting Calculations - A Analytical

Alternative 2

Sampling Table for 1,4-Dioxane	Units	Unit Cost	Events/Year	Units/Event	Samples/Year	Number of Years	Cost	Comments
Monitoring Wells	per sample	$250	1	30	30	40	$300,000	In plume
Monitoring Wells	per sample	$250	4	15	60	40	$600,000	Leading edge of plume
Total Analytical			**5**	**45**	**90**		**$900,000**	

Sampling Table for Natural Attenuation Parameters	Units	Unit Cost	Events/Year	Units/Event	Samples/Year	Number of Years	Cost	Comments
Monitoring Wells	per sample	$175	4	10	40	1	$7,000	10 wells per event, quarterly for the first year
Monitoring Wells	per sample	$175	2	10	20	39	$136,500	10 wells per event, semi-annual for 39 years
Total Analytical			**6**	**20**	**60**	**40**	**$143,500**	

Alternative 6

Sampling Table for 1,4-Dioxane	Units	Unit Cost	Events/Year	Units/Event	Samples/Year	Number of Years	Cost	Comments
Monitoring Wells (Pre-Contingency Implementation)	per sample	$250	1	30	30	20	$150,000	
Monitoring Wells (Pre-Contingency Implementation)	per sample	$250	4	15	60	20	$300,000	
Monitoring Wells (Post-Contingency Implementation)	per sample	$250	1	30	30	30	$225,000	
Total Analytical			**5**	**45**	**90**		**$675,000**	

Sampling Table for Natural Attenuation Parameters	Units	Unit Cost	Events/Year	Units/Event	Samples/Year	Number of Years	Cost	Comments
Monitoring Wells	per sample	$175	4	10	40	1	$7,000	10 wells per event, quarterly for the first year
Monitoring Wells	per sample	$175	2	10	20	19	$66,500	10 wells per event, semi-annual for 19 years
Total Analytical			**6**	**20**	**60**	**20**	**$73,500**	

Alternatives 3a, c, e, and 5 - Treatment at Pall

From Leading Edge (Near MW-86)

	Units	Estimated Quantity	Unit Price	Total
12-inch HDPE directional bored with 8-inch HDPE carrier pipe	LF	14,248.00	$214.50	$3,056,196.00
Steel casing pipe bored under main roads	Each	450.00	$325.00	$146,250.00
Precast man holes	Each	29.00	$2,600.00	$75,400.00
	Subtotal			$3,202,446.00
	Engineering and Inspection (12%)			$384,293.52
	Total Project Cost			**$3,586,739.52**

Assumptions:
Pipe from Wells to Pall with boring under 6 roads including steel casing pipe. All other road crossings would be open cut crossings.

From Pall to River Along M14

	Units	Estimated Quantity	Unit Price	Total
8-inch HDPE pipe trenched	LF	4,700.00	$28.00	$131,600.00
8-inch HDPE pipe bored	LF	6,000.00	$110.00	$660,000.00
8-inch HDPE pipe trenched (for gravity sewer)	LF	8,800.00	$30.00	$264,000.00
Steel casing pipe bored under main roads	LF	800.00	$250.00	$200,000.00
Precast man holes	Each	18.00	$2,000.00	$36,000.00
	Subtotal			$1,291,600.00
	Engineering and Inspection (12%)			$154,992.00
	Contingency (20%)			$258,320.00
	Total Project Cost			**$1,704,912.00**

Assumptions:
Pipe from Pall to River with boring under 8 roads including steel casing pipe All other road crossings would be open cut crossings.

Alternative 4a, c - Treatment at Maple Road

From Leading Edge of Plume to Maple Road

	Units	Estimated Quantity	Unit Price	Total
12-inch HDPE directional bored with 8-inch HDPE carrier pipe	LF	7,070.00	$214.50	$1,516,515.00
Steel casing pipe bored under main roads	LF	200.00	$325.00	$65,000.00
Precast man holes	Each	14.00	$2,600.00	$36,400.00
	Subtotal			$1,617,915.00
	Engineering and Inspection (12%)			$194,149.80
	Total Project Cost			**$1,812,064.80**

Assumptions:
Pipe from Leading Edge of Plume to Maple Road with boring under 3 intersections including steel casing pipe.

From Injection Wells to Maple Road

	Units	Estimated Quantity	Unit Price	Total
12-inch HDPE directional bored with 8-inch HDPE carrier pipe	LF	10,519.00	$214.50	$2,256,325.50
Steel casing pipe bored under main roads	LF	500.00	$325.00	$162,500.00
Precast man holes	Each	22.00	$2,600.00	$57,200.00
	Subtotal			$2,476,025.50
	Engineering and Inspection (12%)			$297,123.06
	Total Project Cost			**$2,773,148.56**

Assumptions:
Pipe from Injection Wells to Maple Road with boring under 7 intersections including steel casing pipe.

From Wells @ Maple Road to River Along M14

	Units	Estimated Quantity	Unit Price	Total
8-inch HDPE pipe bored	LF	7,500.00	$110.00	$825,000.00
8-inch HDPE pipe trenched (for gravity sewer)	LF	8,800.00	$30.00	$264,000.00
Steel casing pipe bored under main roads	LF	550.00	$250.00	$137,500.00
Precast man holes	Each	12.00	$2,000.00	$24,000.00
	Subtotal			$1,250,500.00
	Engineering and Inspection (12%)			$150,060.00
	Contingency (20%)			$250,100.00
	Total Project Cost			**$1,650,660.00**

Assumptions:
Pipe from Pall to River with boring under 6 roads including steel casing pipe. All other road crossings would be open cut crossings.

Alternative 6 - Treatment near River 1

From Leading Edge (Near River) to River 2

	Units	Estimated Quantity	Unit Price	Total
12-inch HDPE directional bored with 8-inch HDPE carrier pipe	LF	5,100.00	$214.50	$1,093,950.00
Steel casing pipe bored under main roads	Each	200.00	$325.00	$65,000.00
Precast man holes	Each	11.00	$2,600.00	$28,600.00
	Subtotal			$1,158,950.00
	Engineering and Inspection (12%)			$139,074.00
	Total Project Cost			**$1,298,024.00**

Assumptions:
Pipe from Wells to River with boring under 4 roads including steel casing pipe. All other road crossings would be open cut crossings.

Pumping Costs - 500 GPM

Theoretical H.P. = $\frac{Q(gpm) \times Head(ft)}{3960}$

Brake Horsepower = $\frac{Theoretical\ H.P.}{Pump\ Eff.}$

Cost for pumping per 1000 gallons = $\frac{189 \times Powercost\ per\ Kw/Hr \times Head\ (ft)}{Pump\ Eff. \times Motor\ Ef. \times 60}$

Assumptions

Cost per Kw/Hr. =	$0.08
Pump Eff. =	75%
Motor Efff. =	85%

500 GPM from Pall to High Point with 8" Pipe

Head Loss	42		
		Cost/Min =	$0.01
Theoretical H.P.	5.30	Cost/Day=	$11.95
Break Horse Power	7.07	**Cost/Year=**	**$4,363.10**
Cost for Pumping	$0.02		

500 GPM from Leading Edge to Pall with 8" Pipe

Head Loss (including pumping water level at 100')	434		
		Cost/Min =	$0.09
Theoretical H.P.	54.80	Cost/Day=	$123.52
Break Horse Power	73.06	**Cost/Year=**	**$45,085.35**
Cost for Pumping	$0.17		

500 GPM from Leading Edge to Maple Road with 8" Pipe

Head Loss	50		
		Cost/Min =	$0.01
Theoretical H.P	6.31	Cost/Day=	$14.23
Break Horse Power	8.42	**Cost/Year=**	**$5,194.16**
Cost for Pumping	$0.02		

500 GPM from Pall to Injection with 8" Pipe (to 12" Injection well)

Head Loss	10		
		Cost/Min =	$0.00
Theoretical H.P.	1.26	Cost/Day=	$2.85
Break Horse Power	1.68	**Cost/Year=**	**$1,038.83**
Cost for Pumping	$0.00		

500 GPM from Maple Road to High Point with 8" Pipe (towards Huron River)

Head Loss	440		
		Cost/Min =	$0.09
Theoretical H.P.	55.56	Cost/Day=	$125.23
Break Horse Power	74.07	**Cost/Year=**	**$45,708.65**
Cost for Pumping	$0.17		

500 GPM from Maple Road to Injection Wells with 8" Pipe - 500' Away

Head Loss	22		
		Cost/Min =	$0.00
Theoretical H.P.	2.78	Cost/Day=	$6.26
Break Horse Power	3.70	**Cost/Year=**	**$2,285.43**
Cost for Pumping	$0.01		

500 GPM from Maple Road to Injection Wells 8" Pipe - 2000' Away

Head Loss	28		
		Cost/Min =	$0.01
Theoretical H.P.	3.54	Cost/Day=	$7.97
Break Horse Power	4.71	**Cost/Year=**	**$2,908.73**
Cost for Pumping	$0.01		

500 GPM from Treatment to Honey Creek through 8" Pipe - 2351' Away

Head Loss	29		
		Cost/Min =	$0.01
Theoretical H.P.	3.66	Cost/Day=	$8.25
Break Horse Power	4.88	**Cost/Year=**	**$3,012.62**
Cost for Pumping	$0.01		

500 GPM from Maple Road to Injection Wells 8" Pipe (towards Huron River) - 10519' Away (Assume 20' elevation change)

Head Loss	61		
		Cost/Min =	$0.01
Theoretical H.P.	7.70	Cost/Day=	$17.36
Break Horse Power	10.27	**Cost/Year=**	**$6,336.88**
Cost for Pumping	$0.02		

500 GPM from Maple Road to Injection Wells with 8" Pipe - 3500' Away

Head Loss	34		
		Cost/Min =	$0.01
Theoretical H.P.	4.29	Cost/Day=	$9.68
Break Horse Power	5.72	**Cost/Year=**	**$3,532.03**
Cost for Pumping	$0.01		

Supporting Calculations - C Electrical

$$\text{Theoretical H.P.} = \frac{Q(gpm) \times Head(ft)}{3960}$$

$$\text{Brake Horsepower} = \frac{\text{Theoretical H.P.}}{\text{Pump Eff.}}$$

$$\text{Cost for Pumping per 1000 Gallons} = \frac{.189 \times \text{Powercost per Kw/Hr.} \times \text{Head (ft)}}{\text{Pump Eff. X Motor Eff. X 60}}$$

Assumptions

Cost per Kw/Hr. =	$0.08
Pump Eff. =	75%
Motor Eff. =	85%

500 GPM from Pall to High Point with 6" Pipe

Head Loss	168		
		Cost/Min=	$0.03
Theoretical H.P.	42.42424242	Cost/Day=	$47.81
Break Horse Power	56.56565657	Cost/Year=	$17,452.39
Cost for Pumping	$0.03		

500 GPM from Pall to High Point with 8" Pipe

Head Loss	42		
		Cost/Min=	$0.01
Theoretical H.P.	10.60606061	Cost/Day=	$11.95
Break Horse Power	14.14141414	Cost/Year=	$4,363.10
Cost for Pumping	$0.01		

500 GPM from Maple Rd to Pall with 6" Pipe

Head Loss	184		
		Cost/Min=	$0.04
Theoretical H.P.	46.46464646	Cost/Day=	$52.37
Break Horse Power	61.95286195	Cost/Year=	$19,114.53
Cost for Pumping	$0.04		

500 GPM from Maple Rd to Pall with 8" Pipe

Head Loss	45		
		Cost/Min=	$0.01
Theoretical H.P.	11.36363636	Cost/Day=	$12.81
Break Horse Power	15.15151515	Cost/Year=	$4,674.75
Cost for Pumping	$0.01		

500 GPM from Leading Edge to River with 8" Pipe

Head Loss	290		
		Cost/Min=	$0.06
Theoretical H.P.	73.23232323	Cost/Day=	$82.54
Break Horse Power	97.64309764	Cost/Year=	$30,126.16
Cost for Pumping	$0.06		

500 GPM from Leading Edge to Maple Road with 8" Pipe

Head Loss	375		
		Cost/Min=	$0.07
Theoretical H.P.	94.6969697	Cost/Day=	$106.73
Break Horse Power	126.2626263	Cost/Year=	$38,956.24
Cost for Pumping	$0.07		

Supporting Calculations - D UV/H2O2 System Cost (500-600 gpm)

Task #		Qty		COST
1	System Design			$ 15,000
2	O2 Regulator - Two Stage	2		$ 600
3	O_2 Evaporator	1		$ 200
4	O_2 Flow Meter - Manual	1		$ 250
5	O2 Flow Meter w/ Analog 4-20maDC	1		$ 3,500
6	O2 Pressure Gauge	1		$ 100
7	O_2 Pressure Transducer w/ Analog 4-20maDC			$ 300
8	O2 Check Valve	1		$ 100
9	O2 Diaphragm Valve	2		$ 600
10	O_2 Alarm w/ Dry Contact 24VDC	2		$ 5,000
11	O2 Pressure Relief Valve	1		$ 200
12	O2 Piping	1		$ 4,000
13	O_3 Generator w/ Analog 4-20maDC	1		$ 126,720
14	O_3 Analyzer w/ Analog 4-20maDC	1		$ 6,000
15	Dissolved O3 Analyzer w/ Analog 4-20maDC	1		$ 5,000
16	O_3 Alarm	2		$ 5,000
17	H_2O_2 Tank - Heated?	1		$ 1,600
18	H_2O_2 Pump	1		$ 500
19	H_2O_2 Flow Sensor	1		$ 300
20	H_2O_2 Injector	1		$ 270
21	H_2O_2 Piping			$ 200
22	O_3 Resistant Water Flow Meter	2		$ 8,500
23	O_3 Resistant Pressure Transducers	6		$ 1,320
24	O_3 Resistant Pressure Gauges	6		$ 200
25	O_3 Resistant Valves-Electric Actuated	4		$ 12,000
26	O_3 Resistant Valves-Electric Modulating	2		$ 7,500
27	O3 Regulator to Analyzer - Two Stage	1		$ 300
28	O3 Check Valve	1		$ 100
29	O3 Diaphragm Valve	16		$ 4,500
30	O3 Reaction Flow Meters - Manual & Auto	8		$ 25,000
31	O_3 Injector	8		$ 2,400
32	O_3 Purging System			$ 1,500
33	O_3 Destruct Unit	1		$ 4,000
34	O3 Piping / Tubing			$ 10,000
35	Chiller	1		$ 8,000
36	O_3 Resistant Recirc Tank (2,000 Gal)	1		$ 3,000
37	O_3 Resistant Recirc Pump	1		$ 10,000
38	Sample Ports	10		$ 250
39	Reactor Assembly & Piping			$ 25,000
40	Recirc & H2O2 Level Sensor	2		$ 3,600
41	Control System			$ 30,000
42	Power Wiring			$ 15,000
43	Control Wiring			$ 45,000
44	Booster Pumps	5		$ 35,000
45	Variable Speed Drives	5		$ 12,000
	Build Cost			**$ 439,610**
46	Permit Requirements			
47	Site Access			
48	Site Prep			$ 4,000
49	Pad for O_2 Tank			$ 2,000
50	Fencing			$ 3,500
51	Electrical Service			$ 5,000
52	Area Lighting			$ 4,000
53	Emergency Eyewash/Shower			$ 10,000
54	A/C Unit			$ 10,000
55	Heating Unit			$ 5,000
56	Exhaust Fans			$ 5,000
57	Building			$ 200,000
58				
59				
	Location Cost			**$ 248,500**
	Total Cost			**$ 688,110**

Supporting Calculations - E OZONE/H2O2 System O&M Cost (based on 600 gpm flow)

			Cost/Day		Cost/Year
ELECTRICAL	KW				
SP Pumps	25	$	2	$	730
Injector Booster Pumps	65	$	156	$	56,940
BP Pumps	25	$	60	$	21,900
Ozone	24	$	58	$	21,024
Chiller	10	$	24	$	8,760
Sub-Totals		**$**	**300**	**$**	**109,354**
CHEMICAL	Lbs/Day				
Peroxide	648	$	149	$	54,400
Liquid Oxygen (CF)	21,600	$	118	$	43,051
Sub-Totals		**$**	**267**	**$**	**97,450**
MAINTENANCE					
Ozone Parts		$	145	$	53,000
Misc.		$	71	$	26,000
Sub-Totals		**$**	**216**	**$**	**79,000**
TOTALS		**$**	**783**	**$**	**285,804**

Daily Gallons Treated		864,000
Cost/ 1,000 Gal	**$**	**0.91**

Supporting Calculations - F UV/H2O2 System Cost (500-600 gpm)

PLC	MATERIAL TOTAL	$12,618.76	1 2	$13,888.96	QUOTE TOTAL	$0.00
Components	MATERIAL TOTAL	$127,244.00	LABOR TOTAL	$37,829.46	QUOTE TOTAL	$0.00
Electrical	MATERIAL TOTAL	$33,935.83	LABOR TOTAL	$27,886.85	QUOTE TOTAL	$0.00
Plumbing	MATERIAL TOTAL	$24,500.00	LABOR TOTAL	$8,912.70	QUOTE TOTAL	$0.00
Design Costs	MATERIAL TOTAL	$0.00	LABOR TOTAL	$19,013.76	QUOTE TOTAL	$0.00
Chemical	MATERIAL TOTAL	$25,000.00	LABOR TOTAL	$15,000.00	QUOTE TOTAL	$0.00
Building	MATERIAL TOTAL	$92,000.00	LABOR TOTAL	$92,000.00	QUOTE TOTAL	$65,000.00
	MATERIAL TOTAL	**$315,298.59**	**LABOR TOTAL**	**$214,531.73**	**QUOTE TOTAL**	**$65,000.00**
TOTAL PRICE		**$594,830.32**				

Supporting Calculations - G UV/H2O2 System O&M Cost (based on 600 gpm flow)

			Cost/Day		Cost/Year
ELECTRICAL	KW				
SP Pumps	25	$	2	$	730
BP Pumps	25	$	60	$	21,900
UV	360	$	864	$	315,360
Sub-Totals		**$**	**926**	**$**	**337,990**
CHEMICAL	Lbs/Day				
Acid	2,556	$	204	$	74,635
Peroxide	1,076	$	344	$	125,677
Caustic	4,529	$	1,042	$	380,169
Bi-Sulfite					
Sub-Totals		**$**	**1,590**	**$**	**580,481**
MAINTENANCE	Per/Year				
Lamps	36	$	59.18	$	21,600
Quartz Tubes	24	$	6.58	$	2,400
Misc.		$	71	$	26,000
Sub-Totals		**$**	**137**	**$**	**50,000**
TOTALS		**$**	**2,653**	**$**	**968,471**

Daily Gallons Treated		864,000
Cost/ 1,000 Gal	**$**	**3.07**