APPENDIX D

MONITORED NATURAL ATTENUATION EVALUATION

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1.0 INTRODUCTION

An evaluation of Monitored Natural Attenuation (MNA) as a remedial alternative was conducted for the Old Erie Canal Site located in Clyde, New York (Site). The evaluation was conducted on behalf of Parker-Hannifin Corporation (P-H) and the General Electric Company (GE) in association with the performance of the Feasibility Study for the Site. The MNA evaluation was completed to determine the subsurface geochemical conditions and evaluate the significance of biodegradation of chlorinated volatile organic compounds (CVOCs) in groundwater at and in the vicinity of the Site as a result of naturally occurring biological activity. The findings were utilized to support the conclusions of the Feasibility Study (FS) and selection of remedial technologies.

The MNA evaluation was performed in accordance with the protocols outlined in the United States Environmental Protection Agency (USEPA) documents entitled *"Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites"* (USEPA OSWER Directive 9200.4-17P, April 1999) and "*Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water"*, (USEPA, September 1998).

This report presents the results of the MNA evaluation.

2.0 GEOLOGY AND HYDROGEOLOGY

Detailed descriptions of the Site geology and hydrogeology are presented in Section 3.1 of the FS. For ease of review, a summary of the key points pertaining to this MNA evaluation are presented in this section.

2.1 SITE GEOLOGY

The Site is located on the Lake Ontario plain within the Finger Lakes physiographic region of New York State. The soils at the Site consist of the following in descending order:

i) fill
ii) glaciofluvial deposits;
iii) glacial till; and
iv) bedrock.

Fill

Fill material is present across the majority of the Site, including on the property owned by the Village of Clyde located west of the P-H property. Fill thicknesses range up to 12 feet east of the manufacturing building. The fill on the P-H property is not contiguous with the fill on the Village of Clyde property.

The Site fill generally consists of sand, gravel, and silt mixed with cinders, ash, slag, brick, and glass. The volumes of fill are greatest in the Old Erie Canal along the southern Site boundary, along the eastern portion of the former Barge Turnaround, and in the vicinity of the manufacturing building.

Glaciofluvial Deposits

Glaciofluvial deposits consisting of channel silt, sand and gravel, sand, and gravel are present across the majority of the Site. Where the till is absent in the channel near the former Barge Turnaround, the glaciofluvial deposits directly overlie the bedrock. The maximum observed thickness of the glaciofluvial deposits is 23 feet at boring GP-36 located in the southern portion of the Site. The thickness of the glaciofluvial deposits is less east of the manufacturing building and in the southeast parking lot than it is in the center of the Site. Interbedded silt and clay, referred to in the Remedial Investigation (RI) report as "backswamp deposits," is present overlying the channel materials in the former Barge Turnaround area.

Glacial Till

The till beneath the Site is a Lodgment Till consisting of a poorly sorted mixture of red-brown clayey silt with some coarse to fine sand and little gravel. The till is present across the majority of the Site, ranging in thickness between 3.5 and 27.2 feet. The till is thickest at MW-7B, west of the former Barge Turnaround. As shown on the cross-sections, the till is thin or absent along an apparent channel in the vicinity of the former Barge Turnaround. Where present, the till acts as an aquitard separating the fill and glaciofluvial deposits from the bedrock unit.

Bedrock

The bedrock beneath the Site consists of shale and dolomitic limestone of the Late Silurian Syracuse-Camillus Formation. Based on the lithologic descriptions of the bedrock cores presented in the RI Report, the bedrock is gray to dark greenish-gray, fine-grained, moderately fractured shale and thinly bedded gray dolomitic limestone which is also moderately fractured.

During the Site investigations, the bedrock was encountered at depths ranging between 16.5 and 31 feet below grade. The bedrock surface generally slopes with a uniform gradient from the northeast to the southwest.

2.2 SITE HYDROGEOLOGY

The geologic units identified in the previous section were grouped into two major hydrogeologic units as follows:

- shallow unconsolidated unit; and
- shallow bedrock unit.

Each of these hydrogeologic units is described below.

Shallow Unconsolidated Unit

The shallow unconsolidated unit consists of the fill and glaciofluvial geologic units. This unit ranges in thickness from 1.0 to 29.2 feet, and is thickest within the glacial channel west of the facility. Based on testing conducted during the Site investigations, the hydraulic conductivity ranges from 0.33 feet per day (ft/day) (MW-9S) to 38.12 ft/day (TMW-2). The geometric mean hydraulic conductivity was determined to be 4.75 ft/day.

Water level measurements were collected during the Site investigations on five occasions. The general pattern of groundwater flow exhibited by the five sets of groundwater contours was consistent. The glacial channel acts as a local groundwater drainage point where groundwater flow from the east, north, and west converges. Groundwater flow from the east and central portions of the facility is westward towards the gravel-filled channel. Groundwater flow from the remainder of the facility is southward, directly to the Clyde River. The horizontal hydraulic gradients within the shallow unconsolidated unit are variable. In general, steeper gradients (i.e., on the order of 0.02 feet per feet [ft/ft]) occur at the limits of the glacial channel. Within the channel, the hydraulic gradients are much smaller, due to the fact that the unit here consists principally of glaciofluvial sand and gravel.

The groundwater flow volume that flows into the glacial channel was estimated using the units hydraulic conductivity and hydraulic gradient. The flow into the channel was divided into three components (east, north, and west) based on the August 3, 2004 groundwater contours. The calculations show that the total groundwater flow into the channel is on the order of 1500 ft^3/day (8 gpm).

Over most of the Site, the shallow unconsolidated unit is separated from the shallow bedrock unit by a low hydraulic conductivity, dense glacial till. The only area where the till is thin or absent occurs within the glacial channel. Within the facility property, vertical hydraulic gradients are downward from the shallow unconsolidated unit to the shallow bedrock unit. This indicates a potential from groundwater migration from the unconsolidated unit to the bedrock. The intervening till unit mitigates this potential groundwater flow is path. There is a potential connection between the unconsolidated unit and the bedrock along the axis of the glacial channel. This connection is manifested by the presence of Site-related chemicals in the bedrock monitoring well MW-6B.

The groundwater contours and surface water measurements collected confirm that the groundwater in the unconsolidated unit discharges to the Clyde River. There is also a small potential for shallow groundwater to migrate to the shallow bedrock, where the till is absent.

Shallow Bedrock Unit

The shallow bedrock unit is part of the Syracuse-Camillus Formation and consists of interbedded shale and limestone. Groundwater flow in this unit will occur principally through secondary porosity features (e.g., bedding plane fractures and joints). The hydraulic conductivity of the shallow bedrock is directly related to the frequency and degree of interconnection of the secondary porosity features. The geometric mean hydraulic conductivity of the shallow bedrock unit, based on testing conducted during the Site investigations, is 0.05 ft/day. The bedrock unit is much less permeable than the shallow unconsolidated unit.

Groundwater flow in the shallow bedrock beneath the Site is southwesterly. The data collected from the bedrock monitoring wells located south of the river suggests that flow from the south is to the northeast.

2.3 GROUNDWATER MIGRATION PATHWAYS AND RECEPTORS

An important aspect of the FS MNA evaluation is to include consideration of the current and future receptors of chemicals of concern in the groundwater. The details of the groundwater migration pathways and receptors are presented in Section 3.3 of the FS. For ease of review, the key findings of the groundwater migration pathways and receptors evaluation are repeated below.

- The Site and the Town of Clyde are serviced by a municipal water supply, the source of which is a well located more than a mile northwest of the Site. Thus, the Site cannot impact the source water.
- Given the availability of the municipal water supply system, there is little probability of the future use of groundwater for potable purpose at the Site. The future use of groundwater on the Site can be restricted through deed restrictions preventing future use of groundwater beneath the properties.
- An inventory of residential wells conducted during the RI noted that there were seven wells within a 1/2-mile radius of the Site. Four of these seven wells are not currently used for potable purposes, and the homes are supplied by the municipal system. The three wells used as potable water supply are located north and west of the Site. Thus, there are no current users of groundwater downgradient of the Site.
- There are currently no regional restrictions on the use of groundwater for potable or other water needs. Therefore, there is potential for future use of groundwater as a water supply in areas downgradient of the Site.
- The primary receptors of CVOCs in the shallow unconsolidated unit groundwater are:
  - the Clyde River;
  - the Shallow Bedrock; and
  - ambient and indoor air.

The flow of shallow groundwater toward the Clyde River in effect limits the migration of chemicals in groundwater (i.e., the extent of chemical presence is mature and cannot expand further). Also, chemical migration in the bedrock is limited. There are no current groundwater users at risk and the potential for future use of groundwater on the Site is limited.

3.0 OVERVIEW OF BIODEGRADATION

Important naturally occurring processes in groundwater are biologically mediated oxidation and reduction reactions. Naturally occurring reductive dechlorination (also called reductive biodegradation) is a biologically mediated degradation process that is effective for the destruction of CVOCs. Reductive dechlorination can result in the complete reduction of trichloroethene (TCE) through dichloroethene (DCE) and vinyl chloride (VC) to non-toxic end products such as ethane and ethene, provided sufficient primary substrate (organic carbon) is available.

Reductive biodegradation involves microbes that utilize carbon from an organic compound (the substrate) for microbial cell growth. As part of the biodegradation process, electrons are transferred from the organic substrate (electron donor) to an available electron acceptor. This transfer of electrons is defined as an oxidation-reduction (redox) reaction. Energy derived from this transfer of electrons is utilized by soil microorganisms for cellular respiration.

Reductive biodegradation will only occur if suitable quantities of the organic substrate and electron acceptors are available for the necessary redox reactions. Certain forms of organic matter; such as naturally existing organic matter, fuel hydrocarbons, and landfill leachate, are readily utilized as primary growth substrates during microbial biodegradation. The biodegradation of a primary substrate often will result in the cometabolic biodegradation of a secondary substrate, an organic compound that does not undergo direct biodegradation but is fortuitously degraded as a secondary reaction.

Typical electron acceptors available in groundwater, in the order of those that release the greatest energy to those that release the least energy, are dissolved oxygen, nitrate, manganese and iron coatings on soil, dissolved sulfate, and carbon dioxide. The sequential use of these electron acceptors occurs as groundwater redox potential becomes increasingly reducing during the biodegradation of organic compounds.

When groundwater becomes depleted of dissolved oxygen and nitrate, the conditions are conducive to the reduction and subsequent dissolution of iron and manganese oxides. Ferric iron (Fe3+) typically exists as an oxide coating on soil and is relatively insoluble in groundwater. Ferric iron is used as an electron acceptor during microbial biodegradation where it is reduced to Fe2+, which exists primarily in the dissolved phase. Manganese oxides are similarly utilized as electron acceptors under the appropriate redox conditions, and are reduced from the relatively insoluble Mn4+ form to dissolved manganese (Mn2+). The mobilization of manganese will begin prior to that of iron because Mn2+ is stable over a larger range of redox conditions than Fe2+. However, the concentration of dissolved iron in groundwater is often higher than that of manganese because soils typically consist of a higher iron content (Hem 1985). Increased concentrations of dissolved iron in groundwater are indicative of sufficiently reducing conditions for the reductive dechlorination of CVOCs. Reductive degradation of CVOCs can proceed under iron-reducing conditions, but is most effective under sulfate-reducing and methanogenic conditions. Under sulfate-reducing conditions, sulfate concentrations decrease as sulfate is transformed to sulfide. Under methanogenic conditions, carbon dioxide is used as the electron acceptor and methane is produced. Methanogenic conditions represent the most strongly reduced subsurface conditions and are most optimal for reductive dechlorination. Changes in the concentrations of the geochemical parameters listed above can be used as evidence of changes in biological activity in the groundwater.

Other processes that can control CVOC concentrations in groundwater include:

i) dispersion – lateral movement of compounds perpendicular to groundwater flow and the centerline of the source;

ii) diffusion – movement of dissolved compounds within the aquifer from a region of higher to regions of lower concentration;

iii) dilution - mixing of groundwater along the flow path;

iv) adsorption – binding of a compound to aquifer soil material; and

v) volatilization – mass transfer from the dissolved phase to the vapor phase in the vadose zone.

4.0 SITE-SPECIFIC BIODEGRADATION EVALUATION

4.1 DATA COLLECTED

Groundwater samples collected in June 2002, May 2003, August 2005, and November 2006 were analyzed for the following MNA parameters:

- volatile organic compounds (VOCs);
- dissolved gases (methane, ethane and ethene);
- total alkalinity;
- chloride;
- dissolved organic carbon (DOC);
- nitrate;
- sulfate; and
- sulfide.

Groundwater samples were collected by conventional purge and sample techniques or, for VOCs only, using Passive Diffusion Bags (PDBs). These groundwater chemistry results are useful in evaluating if groundwater conditions are favorable for biological activity and to determine if biodegradation indicators are present.

Each of the monitoring wells used in the MNA evaluation was purged of three well volumes and allowed to recover prior to collection of samples using conventional methods. Following purging, the following field parameters were measured using field instruments:

i) temperature;
ii) dissolved oxygen (DO);
iii) oxidation-reduction potential (ORP);
iv) hydrogen ion activity (pH);
v) dissolved iron; and
vi) turbidity.

Analytical results collected during the MNA evaluation are presented in the FS tables as follows:

i) Table 3.1 - VOC groundwater analytical results; and
ii) Table 3.6 - wet chemistry (i.e., geochemical parameters) groundwater analytical results (including geochemical, dissolved gas, and field parameters).

4.2 MNA EVALUATION METHODOLOGY

During the MNA evaluation groundwater samples were collected and analyzed and the results were evaluated for the following evidence or indicators of natural biological activity in groundwater:

i) CVOC concentrations over time and space;

ii) geochemical parameters that indicate strong reducing conditions;

iii) presence of CVOC daughter products; and

iv) microbial evidence of biodegradation potential.

CVOC Concentrations Over Time and Space

Evaluation of CVOC concentrations over time provides information regarding relative increases, steady state or decreases in CVOCs that result from both destructive and non-destructive natural attenuation processes over time. Four rounds of CVOC data were collected between June 2002 and November 2006 Most of the CVOC data was collected using low-flow sampling techniques. However, the 2003 round of CVOC data was collected using passive bag samplers. In general, there was not good correlation between the low flow and passive bag CVOC results, probably due to the discrete nature of the passive bag samples. Therefore the passive bag samples could not be used to evaluate CVOC concentrations over time.

CVOC concentrations over time are presented for six wells on Figures -17 through 22. These wells are MW-1S, MW-4S, MW-6S, MW-7S, EMW-2, and MW-4B. The graphs typically contain four points spread over 5 years, which is not sufficient to determine the statistical significance of any observed trends. However, the number of points and time period is sufficient to provide a general measure of the stability of the contaminant levels at the Site.

In cases where data such as these are lacking, microcosm studies are recommended to provide supplemental information for MNA evaluation (USEPA 1998). Microcosm studies were completed for the Site. The results of the microcosm studies are presented in Appendix B of the FS and are discussed further in this MNA evaluation.

The spatial distribution of samples collected between June 2002 and November 2006 includes background monitoring wells, source area wells, lateral wells and downgradient wells. This provides a general picture of the baseline CVOC distribution, which has resulted from the combined actions of the physical, chemical and biological factors that govern CVOC fate and transport in the subsurface.

Groundwater Geochemical Parameters that Indicate Reducing Conditions

The evaluation of redox indicators was conducted to determine whether conditions in the aquifer are conducive to biodegradation of TCE. This also involves evaluation of other geochemical parameters that are indicative of biodegradation processes, such as the presence of degradation and metabolic byproducts. In order for TCE to be used as an electron acceptor by the microorganisms in the subsurface, the concentrations of more energetically favorable electron acceptors (e.g., oxygen, nitrate) must be depleted. The optimal range for reductive degradation of CVOCs is sulfate-reducing and methanogenic, although, in general, "sufficiently reducing" means that conditions in the aquifer must be in the iron-reducing range.

The following conditions are indicative of iron-reducing conditions (after Wiedemeier et al., 1999):

i) DO concentrations below 0.5 milligrams per liter (mg/L);
ii) nitrate concentrations below 10 mg/L;
iii) dissolved iron and manganese concentrations above 1 mg/L;
iv) decreased sulfate and increased sulfide concentrations relative to background conditions; and
v) ORP values below 50 mV.

Under these conditions, iron and manganese oxide coatings on soil grains are reduced, releasing dissolved iron and dissolved manganese into the groundwater. Sulfate in the groundwater is likewise reduced, the concentrations of sulfate decrease, and the concentrations of sulfide increase.

Additionally, if significant biodegradation is occurring, the alkalinity and the concentrations of chloride, calcium, magnesium, and hardness could be higher in the source area relative to concentrations in upgradient wells. Chloride is produced from the degradation of TCE and its daughter products, and the increase in alkalinity is due to interactions of carbon dioxide with the aquifer material (Wiedemeier et al., 1999). The increases in calcium, magnesium, and hardness may indicate dissolution of carbonate minerals from the reaction with acids formed in the biodegradation of TCE.

Background wells are considered representative of conditions not affected by Site activities. Background conditions are represented by overburden monitoring well MW-2S and bedrock monitoring well MW-2B, which are located at the eastern boundary of the Site, adjacent to Elm Street. Groundwater samples collected from the background wells and from the wells within the source area were analyzed for DO, nitrate, dissolved iron, sulfate, methane, chloride, and total alkalinity. The results from each area were compared to determine if concentrations of each analyte within the source area are significantly greater than concentrations observed in the background wells.

Presence of CVOC Daughter Products

TCE is presumed to be the parent compound originally used at the site. The progress of reductive dechlorination can be readily assessed by comparing the prevalence of parent compound to daughter product (e.g. DCE, VC, ethene, and ethane) present in the subsurface at the site.

There are three DCE isomers: 1,1-DCE, cis-1,2-DCE (cDCE), and trans-1,2-DCE (tDCE). When DCE is produced through biodegradation of TCE, the production of the cDCE isomer is favored over tDCE and 1,1-DCE (Wiedemeier et al. 1999; and USEPA 1998). Therefore, if cDCE is the most abundant isomer (80 percent of total mass), then it can be assumed that the DCE was produced via anaerobic biodegradation.

Microbial Evidence of Biodegradation Potential

Additionally, a laboratory microcosm Study was conducted by GE (Microcosm Study Report GE, July 2004) to determine whether TCE and its degradation products could be completely degraded to ethene via natural reductive biodegradation at the Site. Microcosm experiments were conducted using soil from the Site and the ability of different organic carbon sources (i.e., lactate, ethanol, chitin and soybean oil) to support the reductive dechlorination of TCE was evaluated. Controls were also constructed to measure the natural (unamended) rate of biodegradation. Nutrients and/or supplemental bacterial culture were also added to several of the microcosm bottles to determine if their addition would be required to enhance natural reductive biodegradations.

Estimation of Mass Destroyed by Biodegradation

In some situations it is possible to do a mass balance to estimate the total amount of TCE destroyed due to biodegradation processes. To do the calculation, it is necessary to be able to measure a conservative end product of biodegradation and know the groundwater flux through the reactive zone. Both conditions are satisfied at this Site. In this case, chloride appears to be a reliable end product of the reductive dechlorination of TCE. In addition, the groundwater flow volume that flows into the glacial channel was estimated using the unit's hydraulic conductivity and hydraulic gradient. The calculations show that the total groundwater flow into the channel is on the order of 1500 ft^3/day (8 gpm).

5.0 MNA EVALUATION FINDINGS

5.1 CVOC CONCENTRATIONS OVER SPACE AND TIME

The spatial distribution of VOCs at the site is presented on Figures 1 to 5, inclusive. These Figures show the distribution of TCE, cDCE, VC, and benzene, toluene, ethylbenzene, and xylene (BTEX) across the site, utilizing 2002/2003 data from groundwater monitoring well and geoprobe sampling events and 2005 data from soil borings performed underneath the manufacturing building. The data were obtained from both overburden and bedrock locations. The spatial distribution of ethene and ethane are shown on Figure 5. These data were only collected in monitoring wells during the 2002/2003 sampling events, so the number of points is significantly fewer than for the VOCs.

Groundwater flow in the overburden aquifer ranges from a south-southwesterly to westerly direction. Figures 1 to 4 shows that VOCs were generally not detected in the overburden or bedrock wells upgradient or side-gradient from the Site. The concentrations of TCE, cDCE, VC, and ethane/ethene were highest in the barge turnaround area, with more isolated hotspots present underneath the building. Concentrations of BTEX compounds were roughly an order of magnitude lower than the chlorinated VOCs and were highest in the barge turnaround area. No VOCs were observed in the bedrock monitoring wells located across the Clyde River.

The spatial distribution of the CVOCs in the overburden and bedrock aquifer as shown on Figures 1 to 4 is consistent with the conclusion that the aquifer VOCs expansion is limited by ongoing natural attenuation and discharge to the Clyde River. This is evident by the absence of VOCs in the monitoring wells located across the Clyde River. There are no current groundwater users at risk.

CVOC concentrations over time are presented for six wells on Figures -17 through 22. These wells are MW-1S, MW-4S, MW-6S, MW-7S, EMW-2, and MW-4B. In general, CVOC concentrations in the wells are stable and in some cases appear to be declining over time. Concentrations are highest in MW-1S, MW-6S, and MW-4B. Of these, concentrations in MW-1S and MW-4B are stable, while concentrations in MW-6S exhibit some variability. MW-6S is located in the center of the barge turnaround area, where CVOC concentrations are highest. Wells MW-7S and EMW-2 are located on the sides of the barge turnaround in lower concentration areas. While the data are too sparse to infer statistical significance, the CVOC concentrations appear to be declining over time in these areas. A similar CVOC trend is observed in well MW-4S, located at the downgradient edge of the barge turnaround area.

5.2 GROUNDWATER GEOCHEMICAL PARAMETERS

The following sections describe the evaluation of the geochemical conditions in and downgradient of the Site for evidence of natural biodegradation. Groundwater samples were collected for geochemical indicator parameters from monitoring wells upgradient, within and downgradient of the Site during sampling events in both 2002 and 2003. The results were very comparable. These are presented on Figures 9 to 16 for DO, ORP, dissolved iron, sulfate, methane, alkalinity, and dissolved organic carbon, respectively. As was the case previously, data from overburden and bedrock wells are combined in these analyses.

5.2.1 REDOX INDICATOR PARAMETERS

The data for DO and ORP are shown on Figures 9 and 10 and indicate that most of the groundwater at the Site is reduced, as indicated by low (<0.5 mg/L) DO and neutral or negative ORP values. The reduction appears to be strongest in the barge turnaround area, but is generally consistent throughout the site. There are a few locations on the Site where the DO and ORP data do not agree. These include wells MW-1S, MW-7S, MW-12S, and MW-12B. These disagreements can occur due to sampling errors or equipment problems with the DO and ORP probes used to take the measurements. In these cases it can be helpful to consult the dissolved iron data. If dissolved iron is present, the groundwater must be anaerobic. Using this criterion, it is safe to say that the groundwater found in most of these wells is reduced.

Nitrate did not appear in any monitoring wells on the site and so was not included in the figures. Dissolved iron in shown on Figure 11 and is present in all on-Site monitoring wells except well MW-1S, indicating the iron reduction was occurring. Iron concentrations are highest in the barge turn-around area and along the former Erie Canal. The sulfate concentrations are shown on Figure 12 and are clearly higher in the bedrock wells than in the overburden wells. Sulfate appears to be reduced in the groundwater in the barge turnaround area and along the former canal relative to other overburden wells on the Site, suggesting that sulfate reduction is occurring. Sulfate levels in bedrock well MW-4B also appears to be reduced relative to other bedrock wells, but it is difficult to determine if these differences are significant. The methane data is shown on Figure 13 and indicate methanogenic conditions are prevalent in the overburden in the barge turnaround area and along the former canal, particularly in the vicinity of monitoring wells EMW-2, MW-6, EMW-4, EMW-3, and EMW-5. Methane production at bedrock well MW-4B is also substantial. The presence of methane indicates that groundwater conditions are strongly reduced and highly supportive of reductive dechlorination in those areas.

Chloride data is shown on Figure 14 and indicate there are elevated levels of chloride over background in the barge turnaround area, particularly at monitoring wells MW-6S and MW-4B. These concentrations range from 200-300 mg/L and are substantially higher than chloride concentrations in monitoring wells outside of this area, which range from 30-90 mg/L. Chloride is an end-product of reductive dechlorination. The correlation of high chloride concentrations with active biodegradation in the barge turnaround area suggests that reductive dechlorination of TCE and its daughter products is the source of the elevated chloride.

This correlation is strengthened when the chloride data is combined with sodium data. The most common non-biological source of free chloride is road salt. However, if this is the source of the chloride in the aquifer, the molar chloride to sodium ratio should be 1:1. The sodium and chloride balances were performed for all on-site monitoring wells with sodium and chloride concentrations greater than 10 mg/L. The results were tabulated using data from 2002 and 2003 in Table D.1 and using the November 2006 data in Table D.2. There is very good agreement between the two data sets.

The only monitoring wells on site that exhibit significant amounts of excess chloride are those in the bioactive area of the barge turnaround area. This includes MW-1S and MW-13S, which are upgradient of the bioactive zone, MW-6S, which is right in the center of the bioactive zone, MW-15S, which is downgradient in the bioactive zone, and MW-4B and MW-6B, which are in bedrock in the center and downgradient edge of the bioactive zone. The more limited excess chloride in MW-4B and MW-6B should be viewed in the context of the other on-site bedrock wells, which exhibit substantial deficits of chloride. This suggests there may be some natural source of sodium in the bedrock formation.

The sodium and chloride concentrations in well MW-8S is reflective of road salt, where the sodium and chloride concentrations are almost perfectly in balance. Given the high degree of transformation of TCE observed in the bioactive zone, the excess chloride observed there is most certainly derived from biological breakdown of TCE and its daughter products.

TABLE D.1

SODIUM AND CHLORIDE BALANCE AT OLD ERIE CANAL SITE (2002-2003 DATA)

Well ID	*Sodium (mg/L)*	*Chloride (mg/L)*	*Excess/Deficit Chloride*
MW-1S *	60.8	124.2	+ 30.4 %
MW-2S	43.3	26.3	- 40.5 %
MW-6S *	93.6	252.2	+108.0 %
MW-7S *	50.2	79.1	+ 1.6 %
MW-8S	215	329	- 2.8 %
MW-9S	56.3	87.7	+ 0.8 %
EMW-2	90.1	49.4	- 89.7 %
EMW-3	28.3	34	- 3.9 %
EMW-4	28.3	34	- 9.7 %
EMW-5	57.0	77.9	- 10.1 %
MW-2B	138.0	60.7	- 152.3 %
MW-4B *	126.0	205.5	+ 11.2 %
MW-7B	76.7	33.1	- 85.3 %

Note – Sodium and chloride data obtained for June 2002 sampling data. (*) indicates chloride data from June 2002 and May 2003 were averaged to obtain the values shown in the table.

TABLE D.2

SODIUM AND CHLORIDE BALANCE AT
OLD ERIE CANAL SITE (2006 DATA)

Well ID	*Sodium (mg/L)*	*Chloride (mg/L)*	*Excess/Deficit Chloride*
MW-1S	103	182	+14.5 %
MW-2S	61.8	21.5	- 54.5 %
MW-6S	67.8	236	+125.5 %
MW-7S	37.7	74.2	+ 27.5 %
MW-8S	158	248	+ 1.6 %
MW-9S	58.9	77.2	- 39.0 %
MW-13S	93.8	163	+12.5 %
MW-14S	90.4	141	+ 1.1 %
MW-15S	68.2	122	+ 15.9%
EMW-2	65.6	108	+ 6.7 %
EMW-3	30.9	38.3	- 19.7 %
EMW-4	59.2	70.9	- 22.5 %
EMW-5	55.0	77.2	- 9.1 %
MW-2B	70.6	57.4	-47.3 %
MW-3B	192	104	- 65.0 %
MW-4B	95.2	187	+ 27.3 %
MW-6B	73.6	144	+ 26.7 %
MW-5B	166	123	-52.0 %
MW-7B	90.6	40.6	- 71.0 %
MW-4C	244	253	- 32.9 %

Trends over time in chloride concentration for selected wells where data are available are also shown on Figure 23. These include wells MW-1S, MW-4S, MW-6S, MW-7S, EMW-2, and MW-4B. The concentrations of chloride in these wells appear to be stable over time, suggesting that the production of chloride is being sustained at the Site and providing another line of evidence that the biological processes continue to be active in reducing TCE and its daughter products.

Alkalinity data is shown on Figure 15 and indicate there are also elevated concentrations of alkalinity in the barge turnaround area and along the old Erie Canal. Alkalinity is derived from carbon dioxide, produced by the oxidation of organic material. Elevated levels of alkalinity in the barge turnaround area suggest the BTEX compounds are being biodegraded and supporting the reductive dechlorination observed. However, alkalinity is a non-specific indicator and could result from the biodegradation of other forms of organic carbon as well. This may be the case for the elevated levels of alkalinity observed in the wells located along the old Erie Canal and across the Clyde River in wells MW-12S and MW-12B.

Taken in total, these data strongly suggest that redox conditions and concomitant microbial activity are fully supportive of the reductive dechlorination of TCE and its daughter products to innocuous end products at the Site.

5.2.2 PRESENCE OF DEGRADATION/DAUGHTER PRODUCTS

As shown on Figures 1 to 3, the parent compound TCE is largely depleted across the site relative to its daughter products. This is illustrated for selected locations on Figures 6 to 8. These graphs show column plots of VOC concentrations from monitoring well, geoprobe, and soil boring data. With the exception of geoprobe point GP-25 and soil boring SSB-7, c-DCE and VC dominate in the groundwater and TCE is a minor component of the VOCs present at each location. In some cases TCE makes up less than 1 percent of the total VOCs in the groundwater. This indicates that reductive dechlorination is highly advanced in the most highly contaminated areas of the Site. This is supported by the presence of ethane and ethene at those locations, as shown on Figure 5, indicating that the dechlorination is proceeding all the way to non-hazardous end-products. The relative abundance of ethane and ethene in the graphs of Figures 6 to 8 may be misleading, because ethane and ethene are gases and are not readily retained in the groundwater in the subsurface.

Furthermore, the ratios of cDCE to tDCE and 1,1-DCE provide unequivocal evidence that the presence of cDCE is biogenic. The analytical data presented in Table 1 show that, where detected in both the overburden and bedrock aquifers, the concentrations of cDCE are greater than those of tDCE or 1,1-DCE, with the cDCE abundance ratio ranging from 0.93 to 1.00. Thus the DCE in the groundwater at the Site originates from the biodegradation of TCE.

Ethane and ethene concentrations are the ultimate end products of the reductive dechlorination of TCE. The presence of these innocuous end products is highly supportive of extensive reductive dechlorination of both TCE and its daughter products at the Site. Combined ethene + ethane concentrations of up to 6400 micrograms per liter (µg/L) and 1600 µg/L were measured in wells MW-6S and MW-4B, respectively. Ethane and ethene are gases and are highly subject to volatilization and biodegradation losses. As an example, molar balances of ethene in the aqueous phase of the microcosm study were typically only 10-20 percent of the starting TCE concentration. Therefore, it is reasonable to assume that the amount of ethane and ethene generated in the aquifer is substantially higher than the levels measured.

Trends over time in ethene and ethane concentrations are also shown on Figures -17 through 22 for wells MW-1S, MW-4S, MW-6S, MW-7S, EMW-2, and MW-4B. Concentrations of these end products of the reductive dechlorination process also appear to be stable over time, indicating that the biological processes active at the site continue to support dechlorination of TCE and its daughter products all the way to an innocuous end point.

The higher concentrations of BTEX in the groundwater are generally correlated to locations showing high concentrations of c-DCE and VC. This suggests that BTEX may be an important electron donor fueling the reductive dechlorination of TCE at those locations.

5.2.3 AVAILABILITY OF ORGANIC SUBSTRATE TO SUSTAIN MICROBIAL ACTIVITY

The spatial distribution of dissolved organic carbon (DOC) across the Site is shown on Figure 16. Concentrations of DOC ranged from 1.6 to 37.7 mg/L in the overburden aquifer and from not detected at 1 mg/L to 7.23 mg/L in the bedrock. The highest consistent concentrations of DOC are observed in the barge turnaround area, particularly at monitoring well MW-6S, where 37.7 mg/L DOC was measured. These DOC concentrations are providing electron donors for the reductive dechlorination observed at the Site. As previously mentioned, BTEX concentrations are also highest in the barge turnaround area, suggesting that BTEX may be an important component of this DOC. However, given the swampy nature of the barge turnaround area and the past use of that area by the Town of Clyde for sewage disposal, natural DOC in the form of humic materials will also be present and will likely also contribute to the support of reductive dechlorination. DOC at 33 mg/L is also measured in well MW-12S, located across the Clyde River. This is also most likely a naturally occurring form of DOC, because no contaminants have been measured in that well.

Trends over time in DOC for selected wells where data are available are also shown on Figure 24. These include wells MW-1S, MW-4S, MW-6S, MW-7S, EMW-2, and MW-4B. The concentrations of DOC in these wells appear to be stable over time, suggesting that the DOC at the site is being sustained and is continuing to provide a source of carbon and energy for the dechlorinating bacteria.

5.3 MICROCOSM STUDY RESULTS

A laboratory microcosm study was conducted by GE (Microcosm Study Report GE, July 2004) to determine whether TCE and its degradation products could be completely degraded via natural reductive biodegradation at the Site. Microcosm experiments were conducted using soil from the Site and different organic carbon sources were evaluated (i.e., lactate, ethanol, chitin and soybean oil). Controls were also constructed to measure the natural (unamended) rate of biodegradation. Nutrients and/or supplemental bacterial culture were also added to several of the microcosm bottles to determine if their addition would be required to enhance natural reductive biodegradations.

Complete reductive dechlorination of TCE to ethene was observed in both substrate-amended and unamended sample groups. Notably, the unamended controls were spiked with 5 and 50 mg/L TCE and in both cases completely reduced the TCE to ethene during the course of the study. It is unusual to observe this level of intrinsic activity at such high TCE concentrations. This supports the field data in demonstrating that robust intrinsic biological activity is currently operative at the Site. TCE in particular was dechlorinated very rapidly in the microcosm bottles. Rapid depletion of TCE is also observed in the field data.

All of the electron donors used in the study also supported complete reductive dechlorination of TCE to ethene. The addition of electron donors promoted a two to three fold increase in the overall biodegradation rate over the comparable unamended controls. TCE was biodegraded very rapidly in all the amended bottles. Lactate, chitin, and soybean oil promoted the fastest biodegradation of cDCE. Chitin and soybean oil promoted the fastest biodegradation of VC. In these cases, VC was biodegraded almost as fast as it was formed, so that very little was measured in the bottles.

Supplemental nutrient addition and bioaugmentation did not have a significant effect on the rate or extent of dechlorination. Therefore, neither supplemental nutrients nor bacteria are required to enhance biodegradation at the Site.

5.4 ESTIMATION OF MASS DESTROYED BY BIODEGRADATION

As discussed in Section 4.2, it is possible to estimate the amount of mass destroyed or transformed at the site by measuring the production of end products such as chloride, ethane, and ethene. As previously described, chloride concentrations are significantly elevated in the barge turnaround area relative to surrounding groundwater. Chloride concentrations in monitoring well MW-6S and MW-6B range from 200-300 mg/L, whereas chloride concentrations in the surrounding groundwater range from 30-90 mg/L. Chloride is a conservative end product of TCE reductive dechlorination, such that

$$\text{TCE} \rightarrow \text{Ethane/Ethene} + 3\ \text{Chloride}$$

Thus, every mole of TCE that is reduced to ethane or ethene produces three moles of chloride. The differential between chloride concentration inside and outside the bioactive area can be conservatively estimated to be 100 mg/L. In this case, 123.5 mg/L TCE need to destroyed (on a mass basis) to produce 100 mg/L chloride. The calculation is valid as long as there are no other sources of chloride unique to the bioactive area. The sodium balances performed in Section 5.2.1 provide conclusive proof the source of the excess chloride in the barge turnaround area is not road salt.

The total mass of TCE destroyed can be estimated if the groundwater flux through the reactive zone is known. In this case, calculations show that the total groundwater flow through the bioactive channel is on the order of 1500 ft^3/day (8 gpm). If the groundwater flux is multiplied by the chloride concentration, the amount of chloride produced and TCE destroyed can be calculated. By this method, it is estimated that 6 kg/day of chloride is produced at the Site from the destruction of 7.4 kg/day of TCE. This represents a TCE destruction rate of 5000 lbs/year.

The other significant end products of reductive dechlorination present at the site are ethene and ethane. Because these are unique products of the dechlorination process, these end products are even more conclusive than the chloride data. As previously stated, combined ethene + ethane concentrations of up to 6400 µg/L and 1600 µg/L were measured in wells MW-6S and MW-4B, respectively. These levels of ethene and ethane are subject to both biodegradation and volatilization losses. If we conservatively assume that 2500 µg/L ethane + ethene is generated in the subsurface due to reductive dechlorination of TCE, then the total TCE destroyed is equivalent to 550 lbs/year.

Thus the destruction and complete transformation of TCE at the site is strongly supported by both the chloride and ethane and ethene data. While there is uncertainty in the number, there is no question that substantial destruction of TCE and its daughter products is occurring. A destruction rate of 500-5000 lb/year is quite supportable using the available data. This number can be further refined if additional data is collected during subsequent sampling rounds.

6.0 CONCLUSIONS

- Analysis of CVOC concentrations over time on six monitoring wells indicate the CVOC concentrations are stable in the barge turnaround area and declining on the fringes. There is not yet sufficient data to infer statistical significance to these trends.
- Geochemical parameters collected from groundwater indicate that the overburden and bedrock aquifers at the Site are reducing. These geochemical conditions are favorable for the reductive biodegradation of TCE, cDCE and vinyl chloride and the production of ethene and ethane. Conditions become more oxidizing in both aquifers downgradient of the Site.
- With a few exceptions, the parent compound TCE is much diminished at the Site relative to its reductive chlorination daughter products cDCE, VC, and ethene/ethane. In some cases TCE made up less than 1% of the total VOCs in the groundwater. This indicates that reductive dechlorination is highly advanced in the most highly contaminated areas of the site. This is supported by the presence of ethane and ethene at those locations, indicating that the dechlorination is proceeding all the way to non-hazardous endproducts. Ethene and ethane concentrations appear to be stable over time.
- Chloride is highly elevated in the barge turnaround area. Molar balances performed using sodium data indicate an excess of chloride exists here, eliminating road salt as the source of the excess chloride. The excess chloride is most likely coming from the reductive dechlorination of TCE and its daughter products.
- BTEX compounds are also present in the barge turnaround area, suggesting that BTEX may be an important electron donor in supporting the reductive dechlorination of TCE and its daughter products. However, given the swampy nature of the area, natural DOC in the form of humic materials is also present and will likely contribute to the support of reductive dechlorination. Trend analysis over time indicate the levels of DOC in the groundwater are stable and sufficient to continue to support the ongoing reductive dechlorination of TCE and its daughter products.
- The results of microcosm studies show that the biodegradation capacity of Site soil is very strong, resulting in complete TCE degradation to ethene in both unamended and substrate-amended samples. In unamended controls spiked with 5 and 50 mg/L TCE, TCE was completely reduced to ethene during the course of the study. It is unusual to observe this level of intrinsic activity at such high TCE concentrations. This supports the field data in demonstrating that robust intrinsic biological activity is currently operative at the Site. The addition of electron donors promoted a two to three fold increase in the overall biodegradation rate over the comparable unamended controls. Neither nutrient supplements nor supplemental biocultures improved biodegradation rates.
- The results of the MNA evaluation show that substantial natural biodegradation by reductive dechlorination is occurring at Site. Calculations based on chloride and ethane and ethene concentrations and groundwater flux through the bioactive zone suggest that 500-5000 lbs/year of TCE are being destroyed due to ongoing biodegradation processes. This analysis, coupled with discharge of overburden aquifer groundwater to the Clyde River and the limited migration of CVOCs in the

bedrock aquifer indicate that the CVOCs are attenuating sufficiently such that there is no threat to groundwater users.

7.0 REFERENCES

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- Hem, J.D. 1985. Study and Interpretation of the Chemical Characteristics of Natural Water, U.S.G.S. Water-Supply paper 2254.
- USEPA, September 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents In Ground Water, EPA/600/R-98/128.
- USEPA, April 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites, USEPA OSWER Directive 9200.4-17P.
- Wiedemeier, T.H., H.S. Rifai, C.J. Newell, J.T. Wilson. 1999. Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface. John Wiley & Sons, Inc., New York.

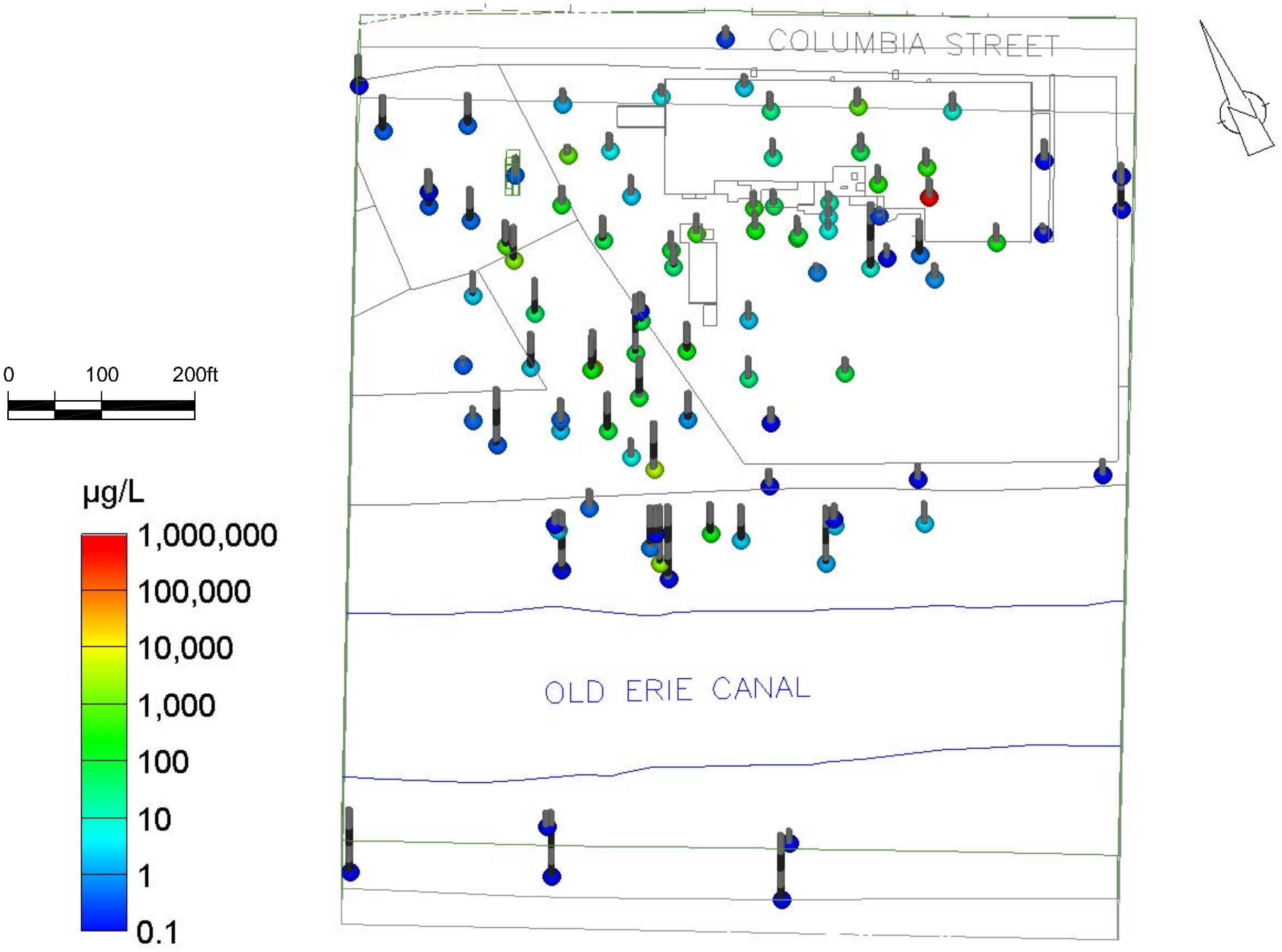

figure 1

TCE CONCENTRATIONS
IN GROUNDWATER
OLD ERIE CANAL SITE
Clyde, New York

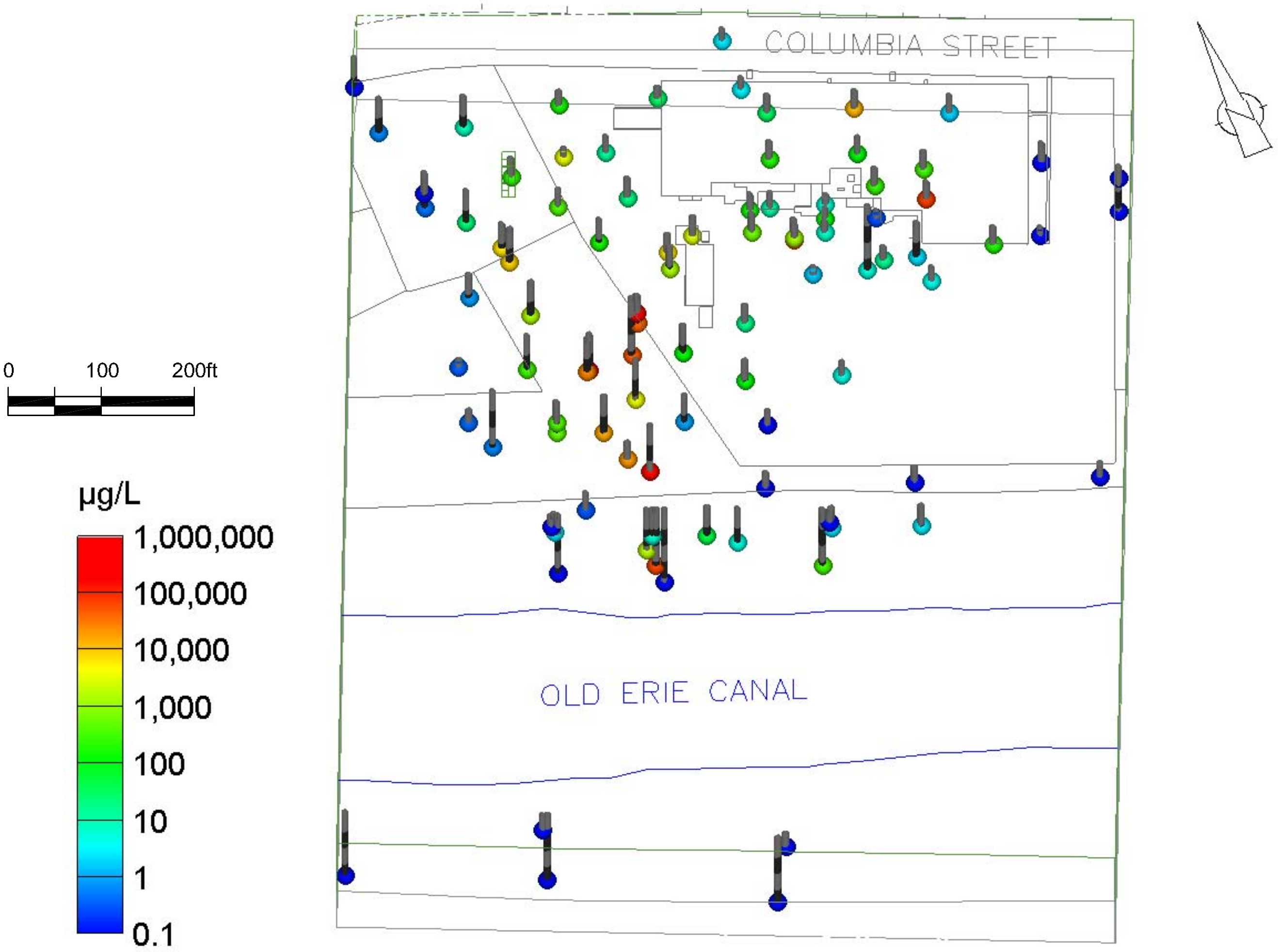

figure 2

CIS-DCE CONCENTRATIONS
IN GROUNDWATER
OLD ERIE CANAL SITE
Clyde, New York

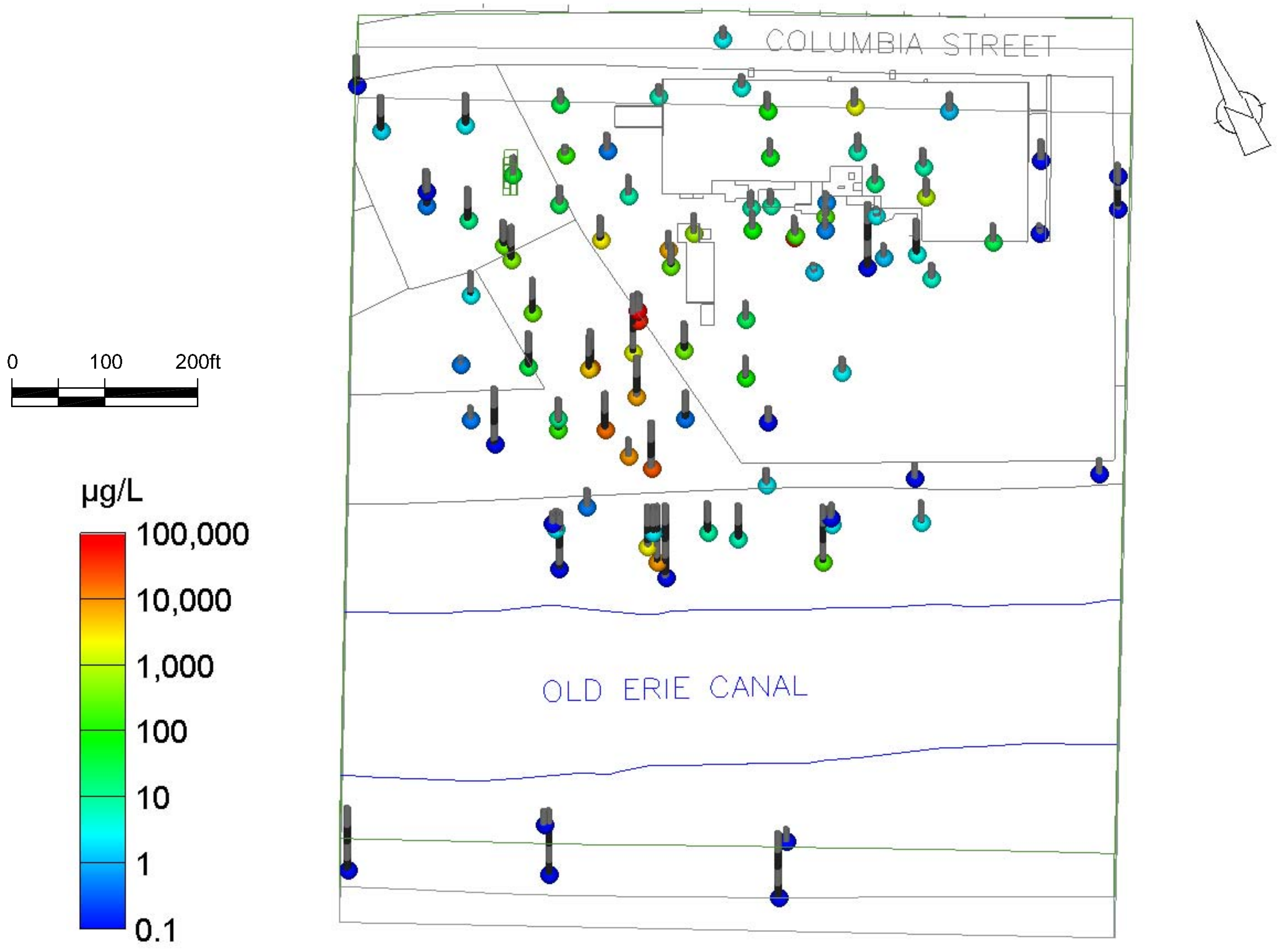

figure 3

VC CONCENTRATIONS
IN GROUNDWATER
OLD ERIE CANAL SITE

Clyde, New York

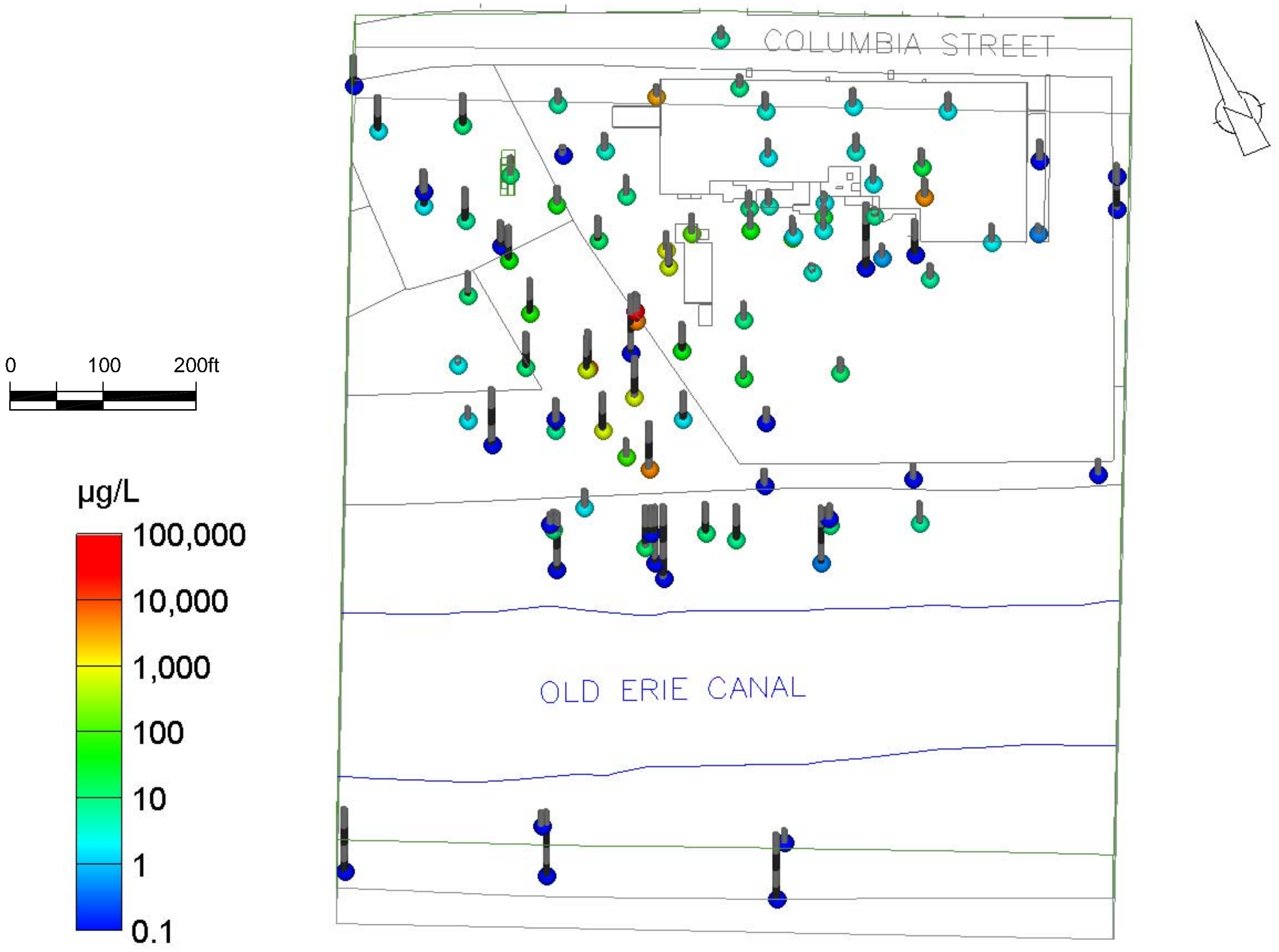

figure 4

BTEX CONCENTRATIONS
IN GROUNDWATER
OLD ERIE CANAL SITE
Clyde, New York

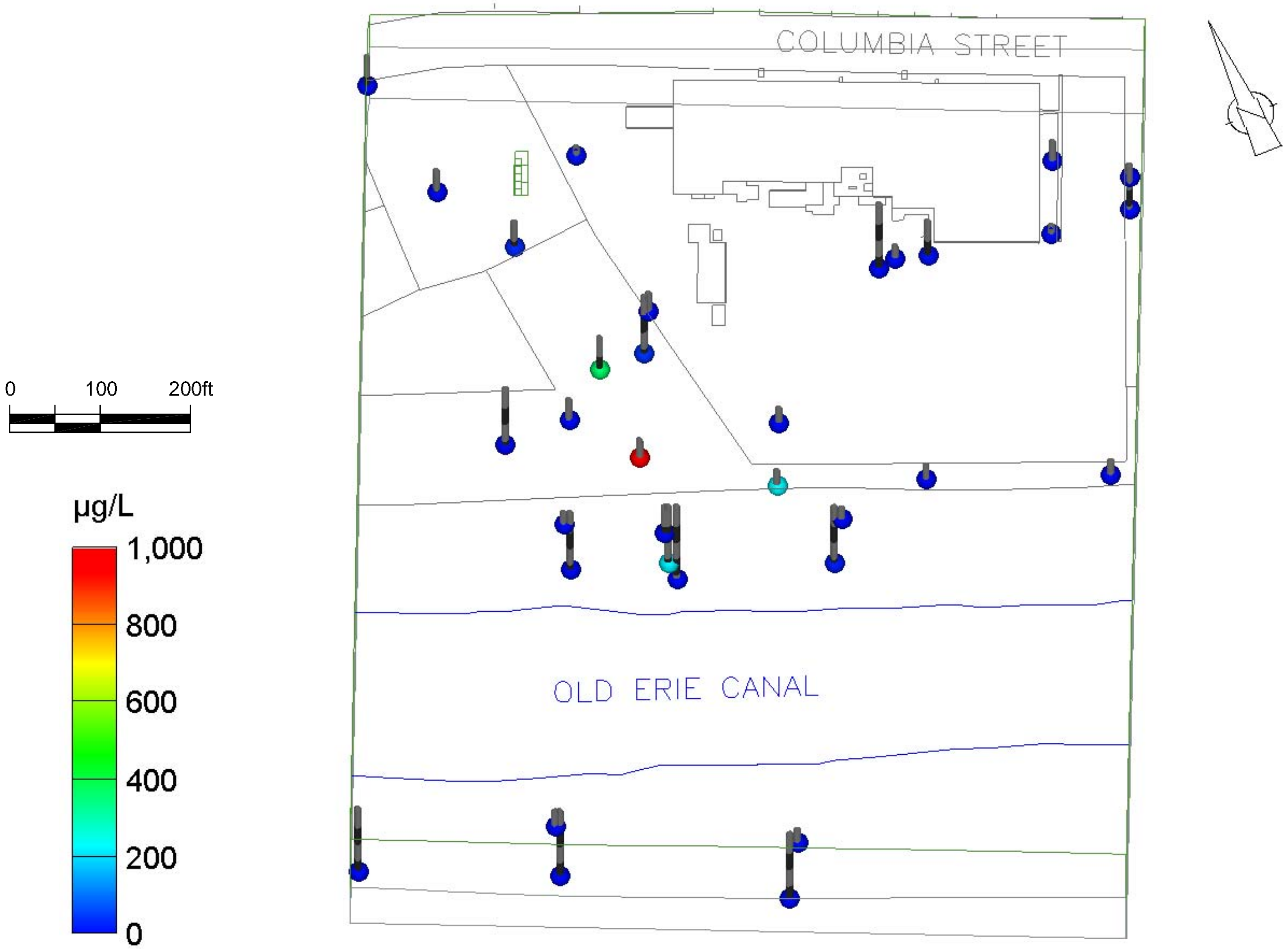

figure 5

ETHANE+ETHENE CONCENTRATIONS
IN GROUNDWATER
OLD ERIE CANAL SITE
Clyde, New York

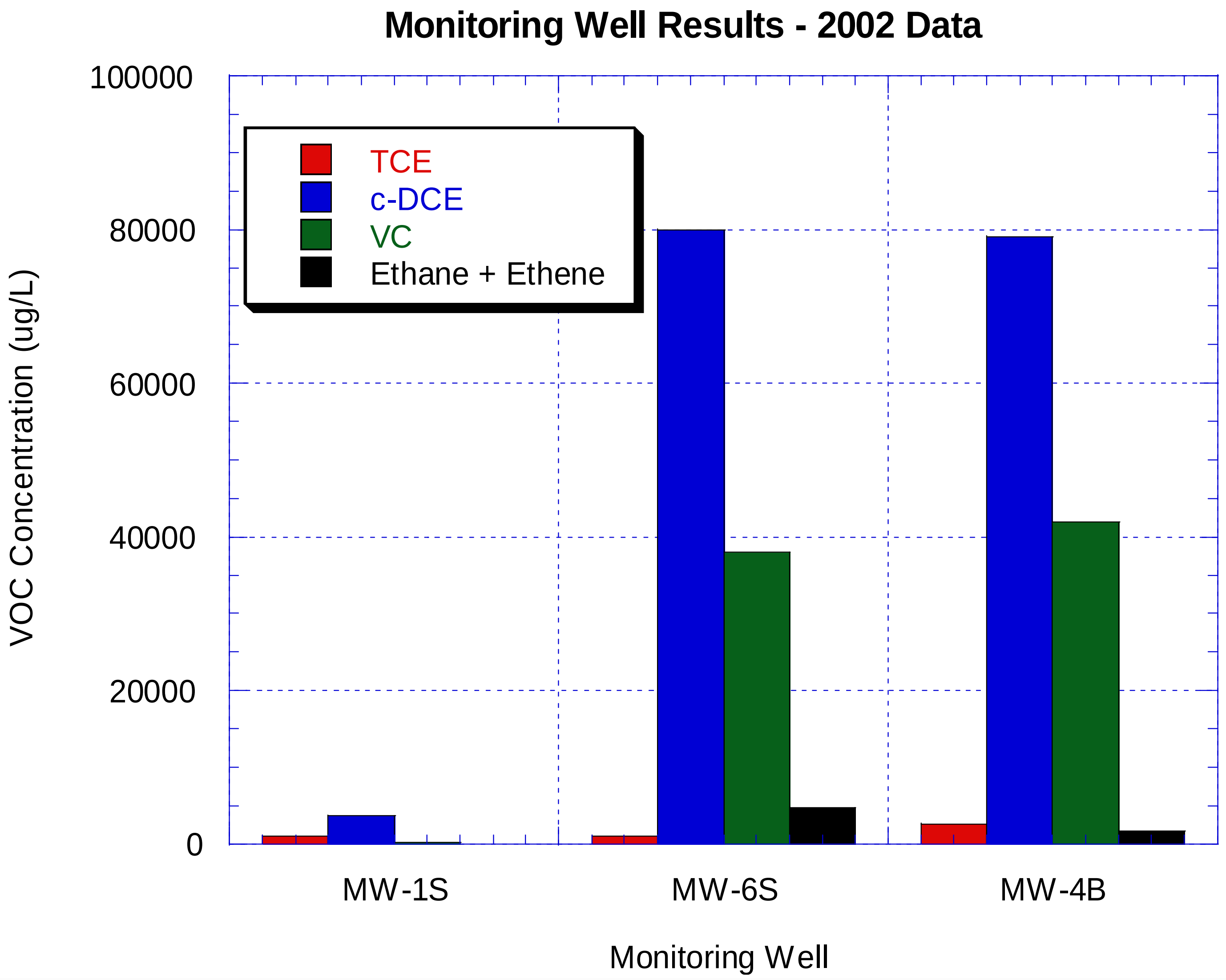

figure 6

VOCS IN GROUNDWATER FROM
SELECTED MONITORING WELLS
OLD ERIE CANAL SITE
Clyde, New York

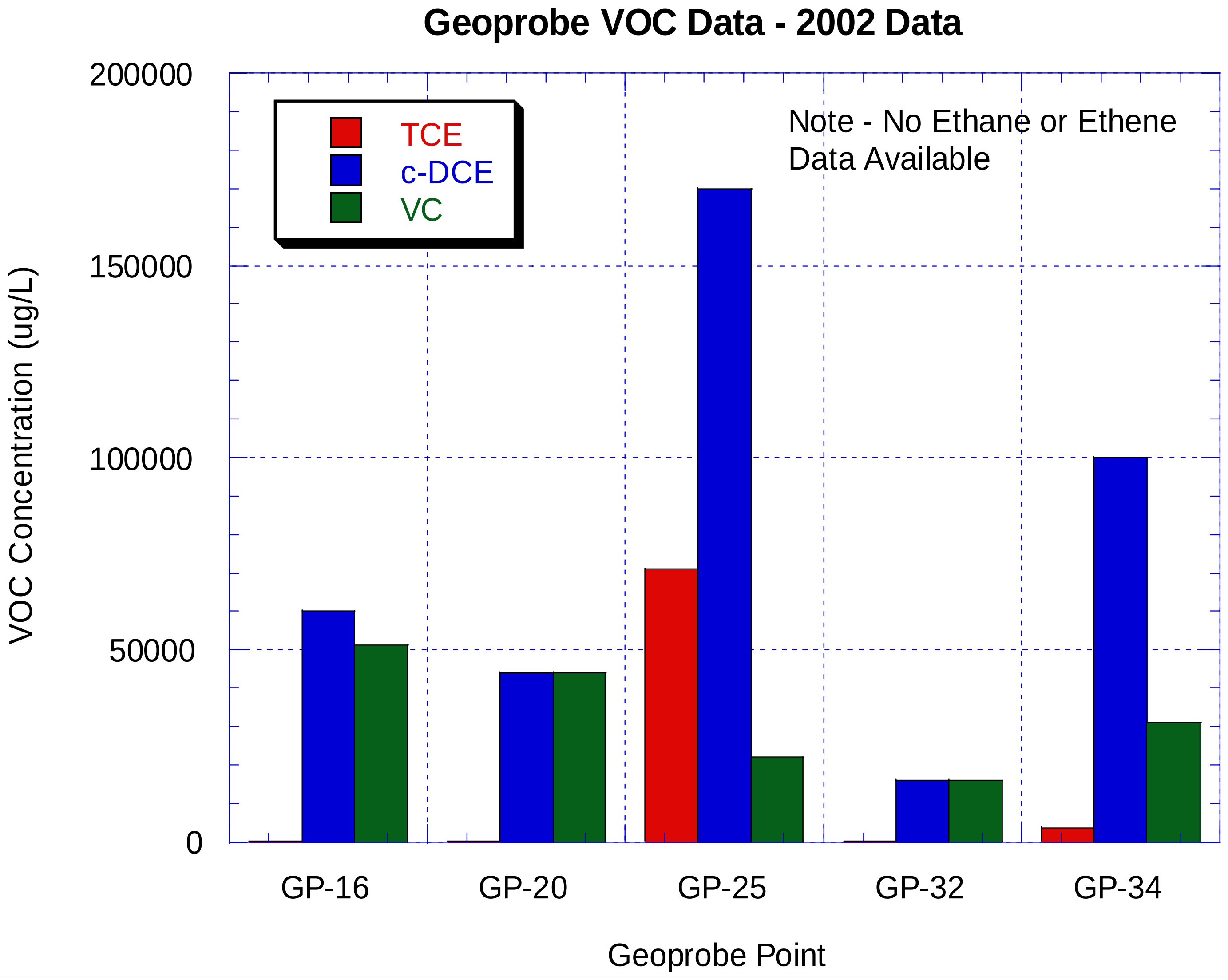

figure 7

VOCS IN GROUNDWATER FROM
SELECTED GEOPROBE POINTS
OLD ERIE CANAL SITE
Clyde, New York

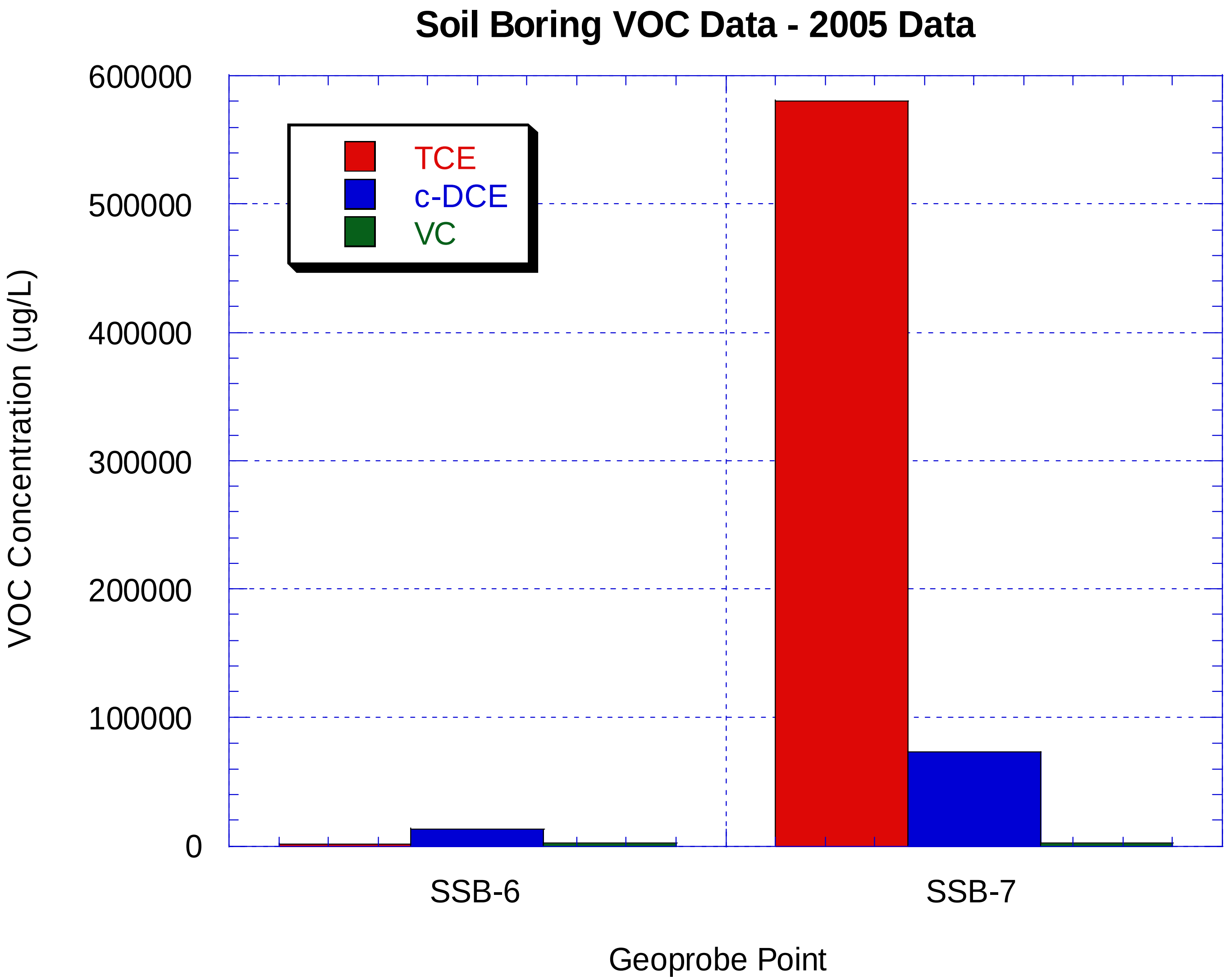

figure 8

VOCS IN GROUNDWATER FROM
SELECTED SOIL BORING LOCATIONS
OLD ERIE CANAL SITE
Clyde, New York

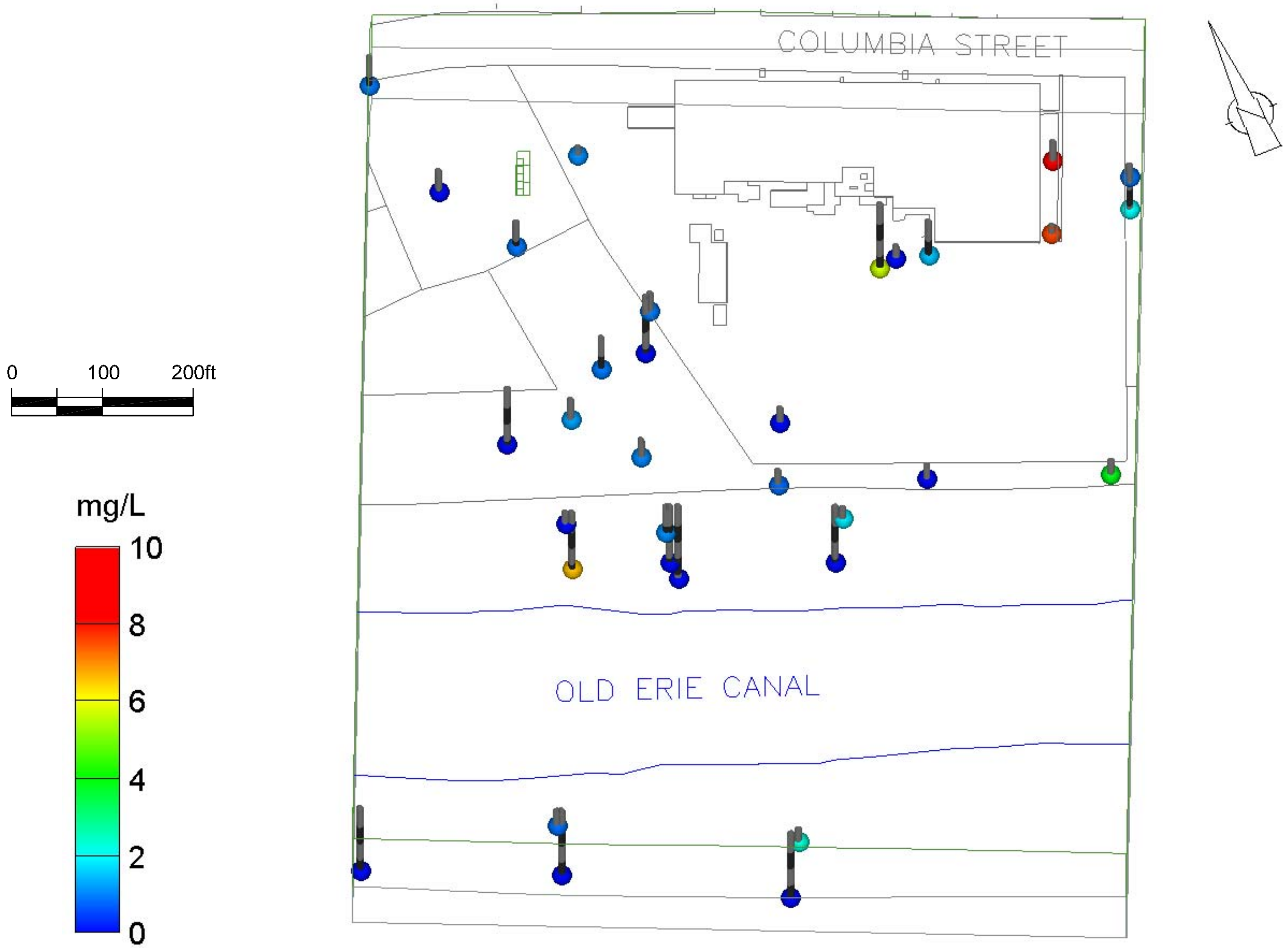

figure 9

DO CONCENTRATIONS
IN GROUNDWATER
OLD ERIE CANAL SITE
Clyde, New York

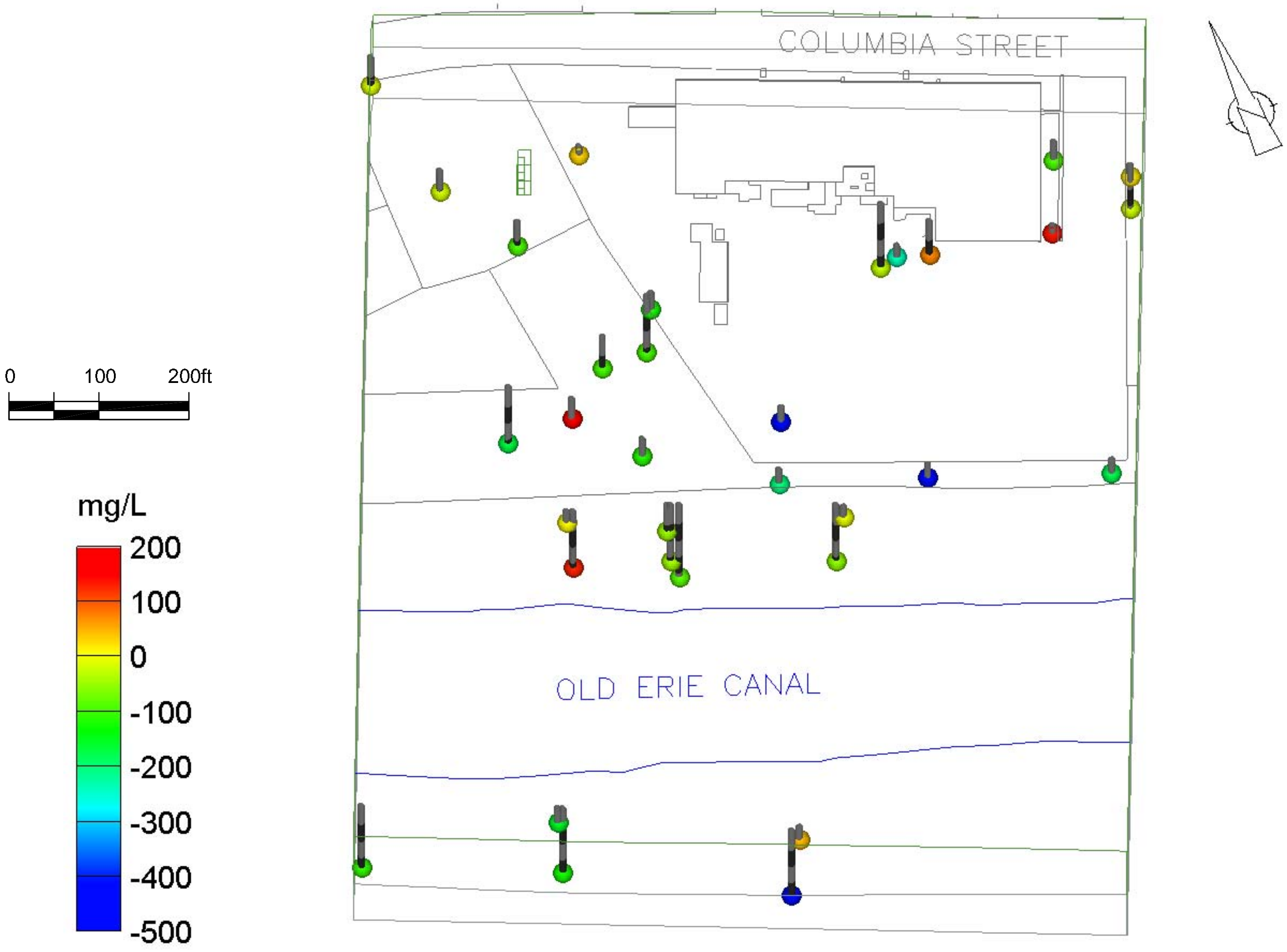

figure 10

ORP CONCENTRATIONS IN GROUNDWATER OLD ERIE CANAL SITE

Clyde, New York

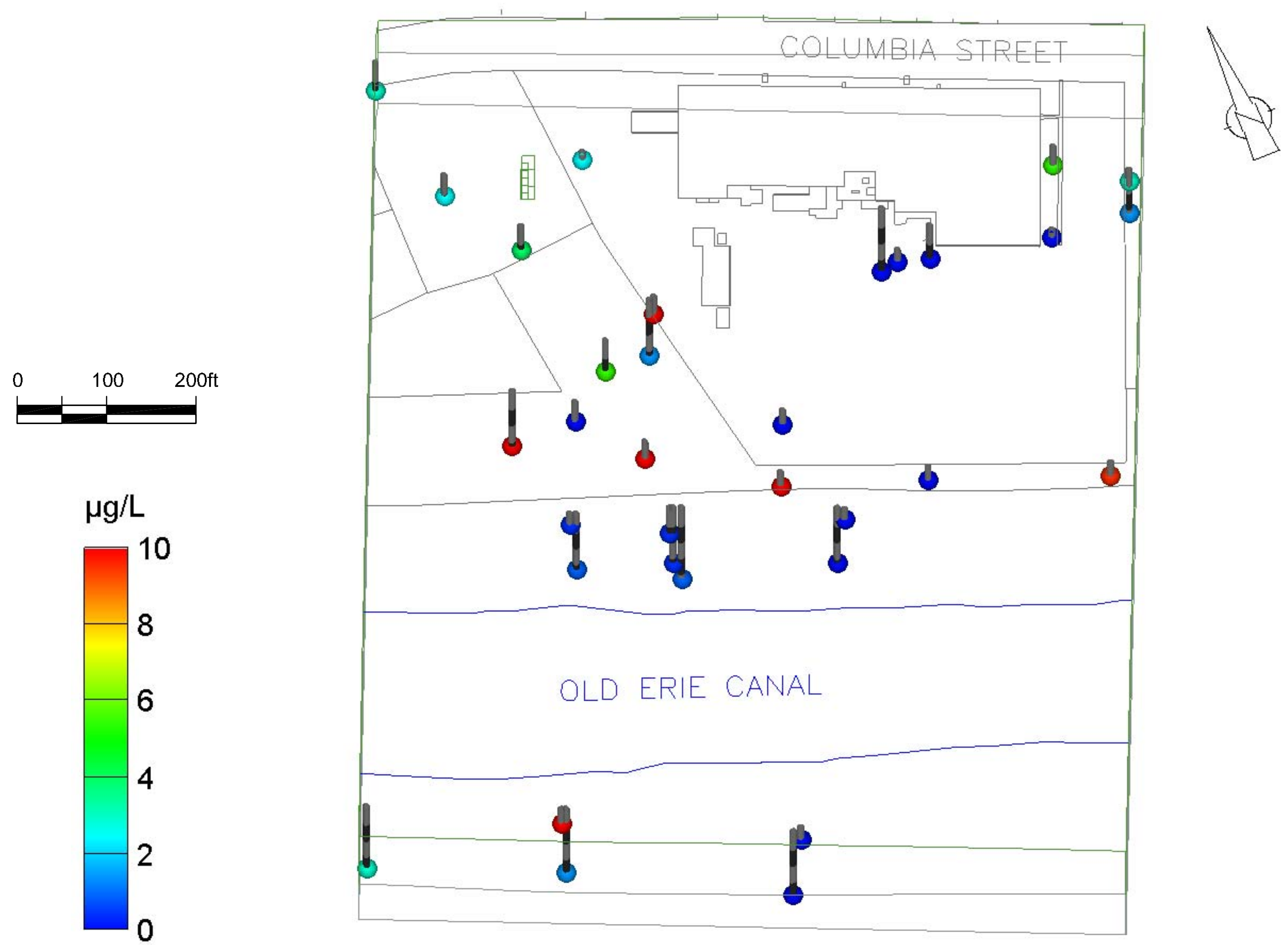

figure 11

DISSOLVED IRON CONCENTRATIONS IN GROUNDWATER OLD ERIE CANAL SITE

Clyde, New York

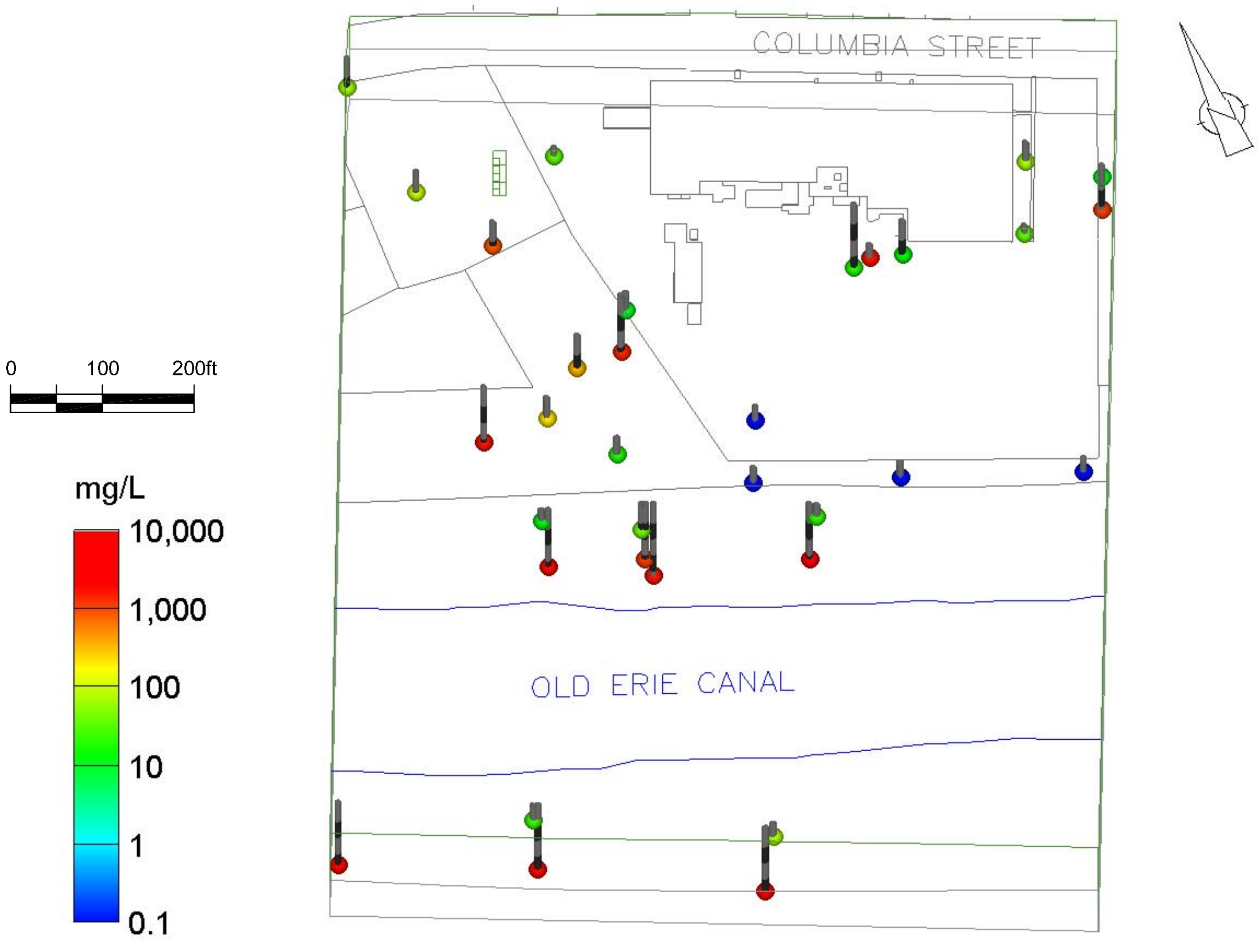

figure 12

SULFATE CONCENTRATIONS IN GROUNDWATER OLD ERIE CANAL SITE

Clyde, New York

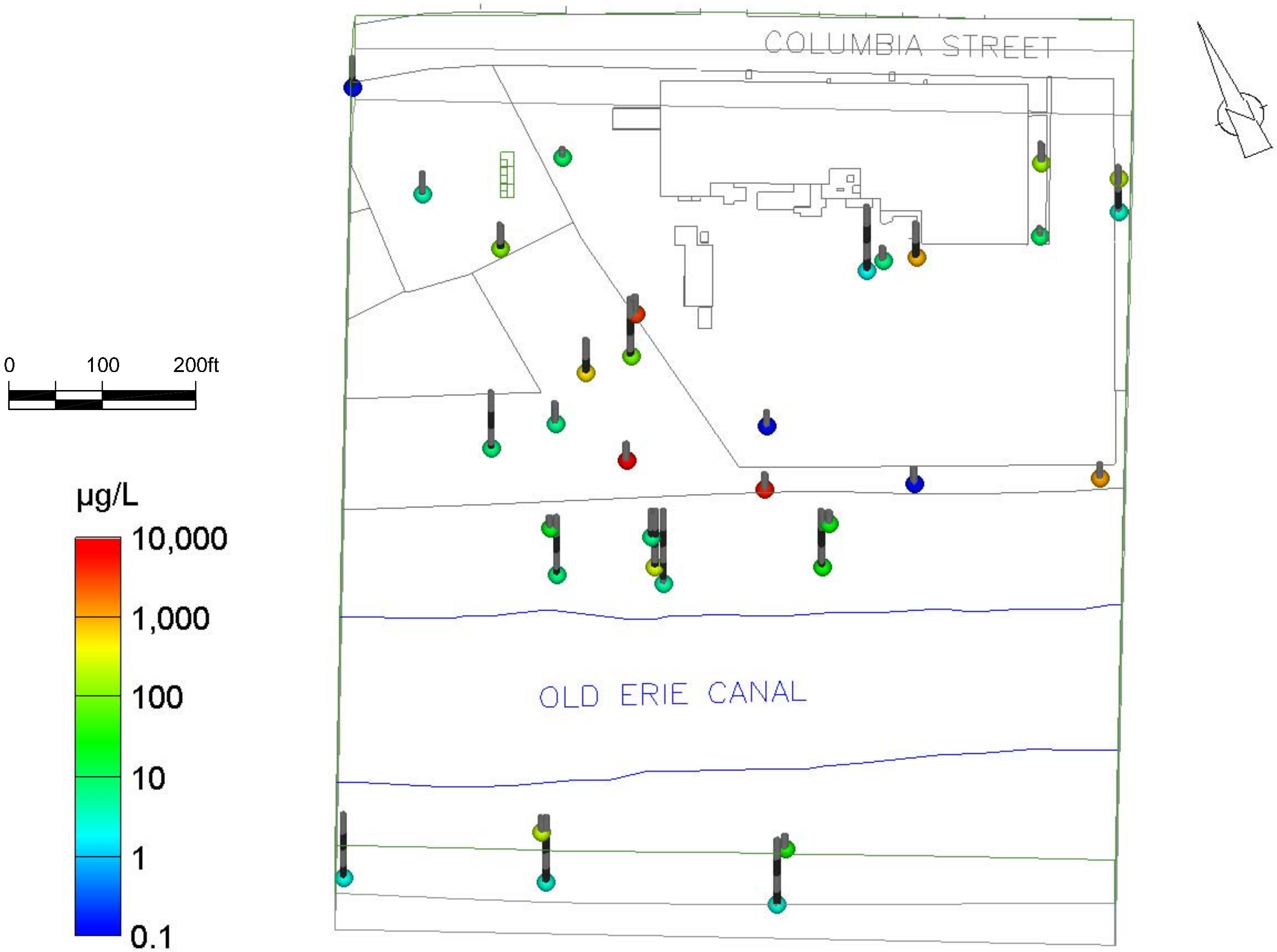

figure 13

METHANE CONCENTRATIONS IN GROUNDWATER OLD ERIE CANAL SITE

Clyde, New York

CRA

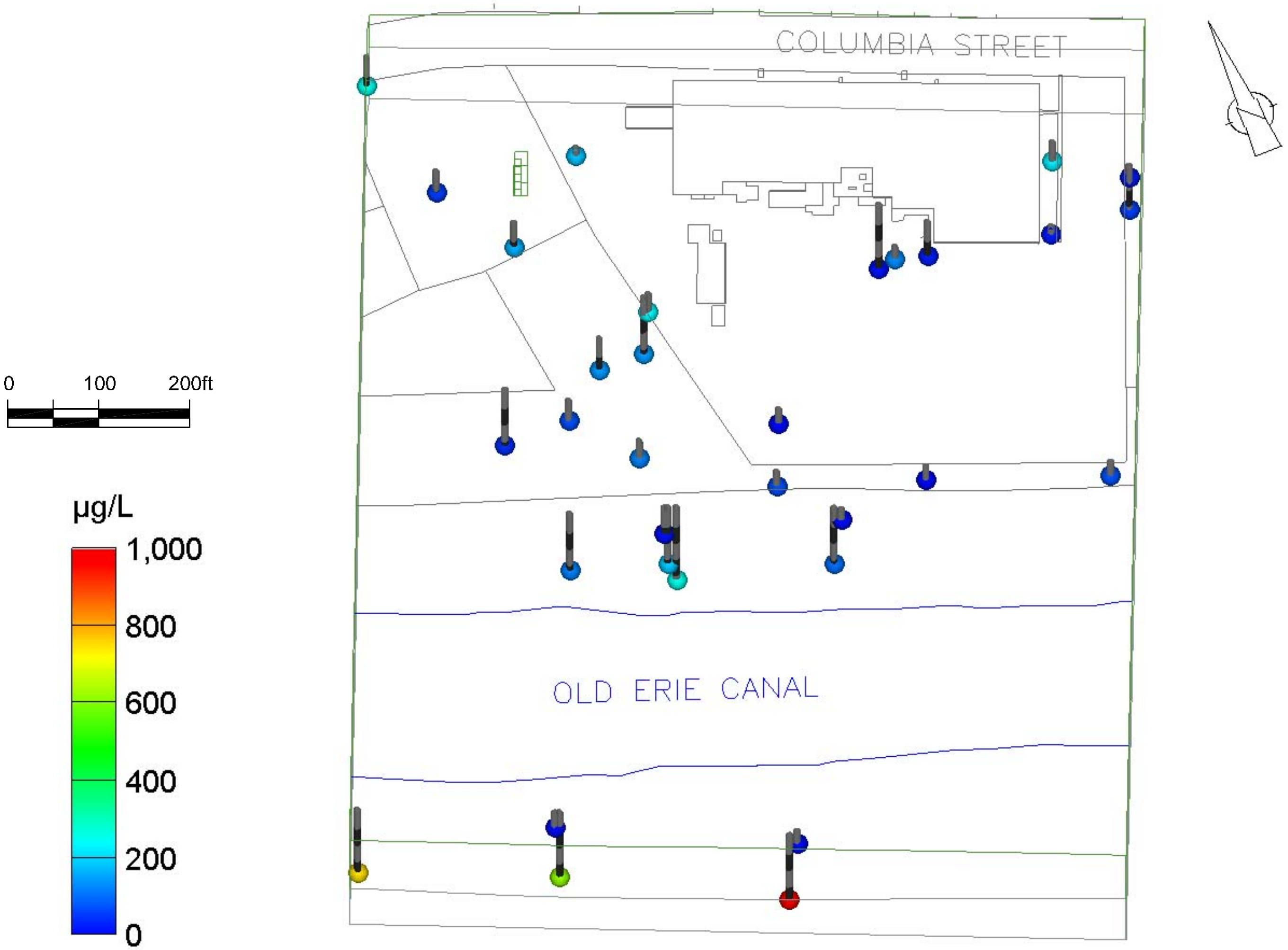

figure 14

CHLORIDE CONCENTRATIONS IN GROUNDWATER OLD ERIE CANAL SITE

Clyde, New York

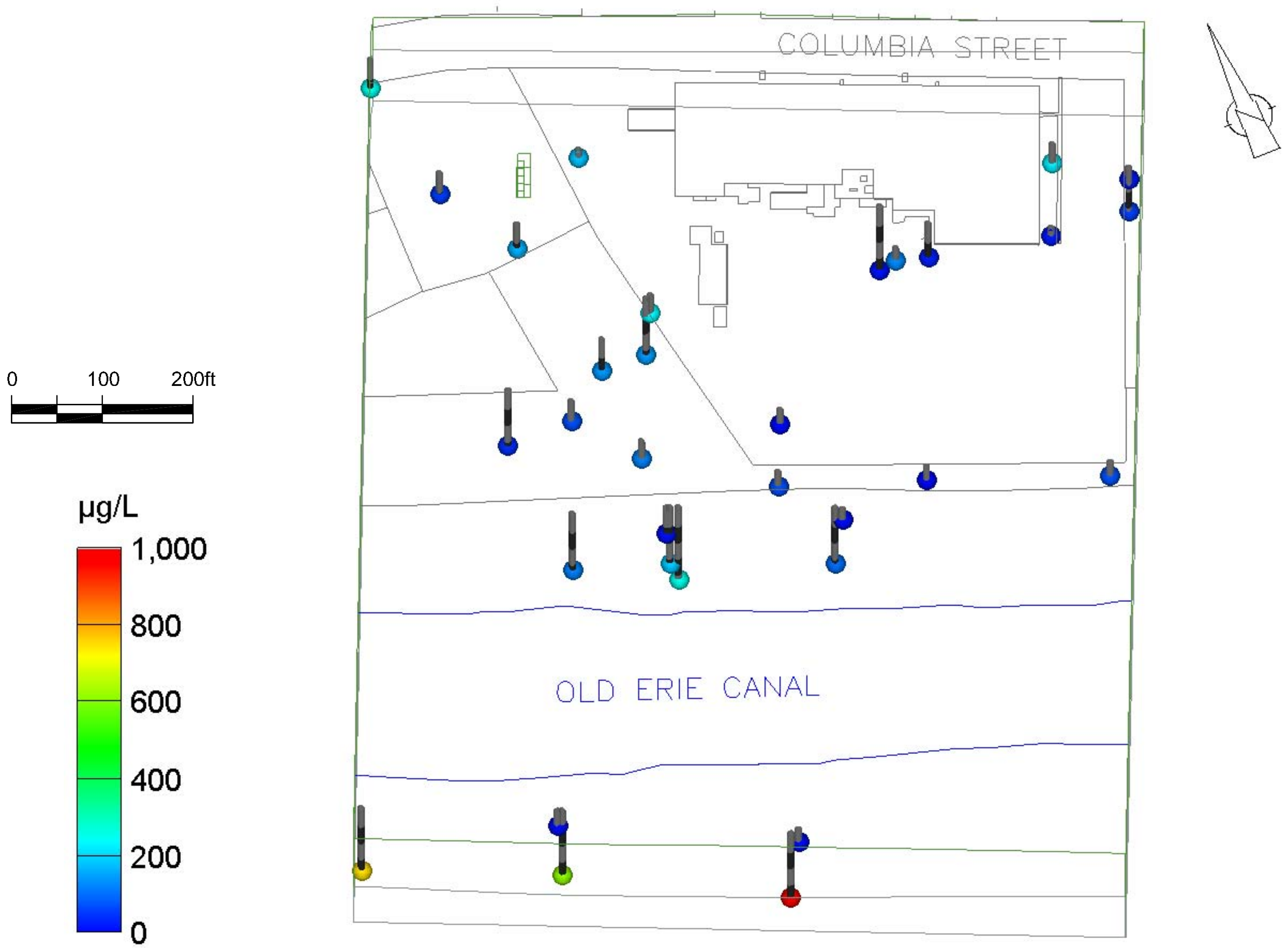

figure 15

ALKALINITY CONCENTRATIONS
IN GROUNDWATER
OLD ERIE CANAL SITE
Clyde, New York

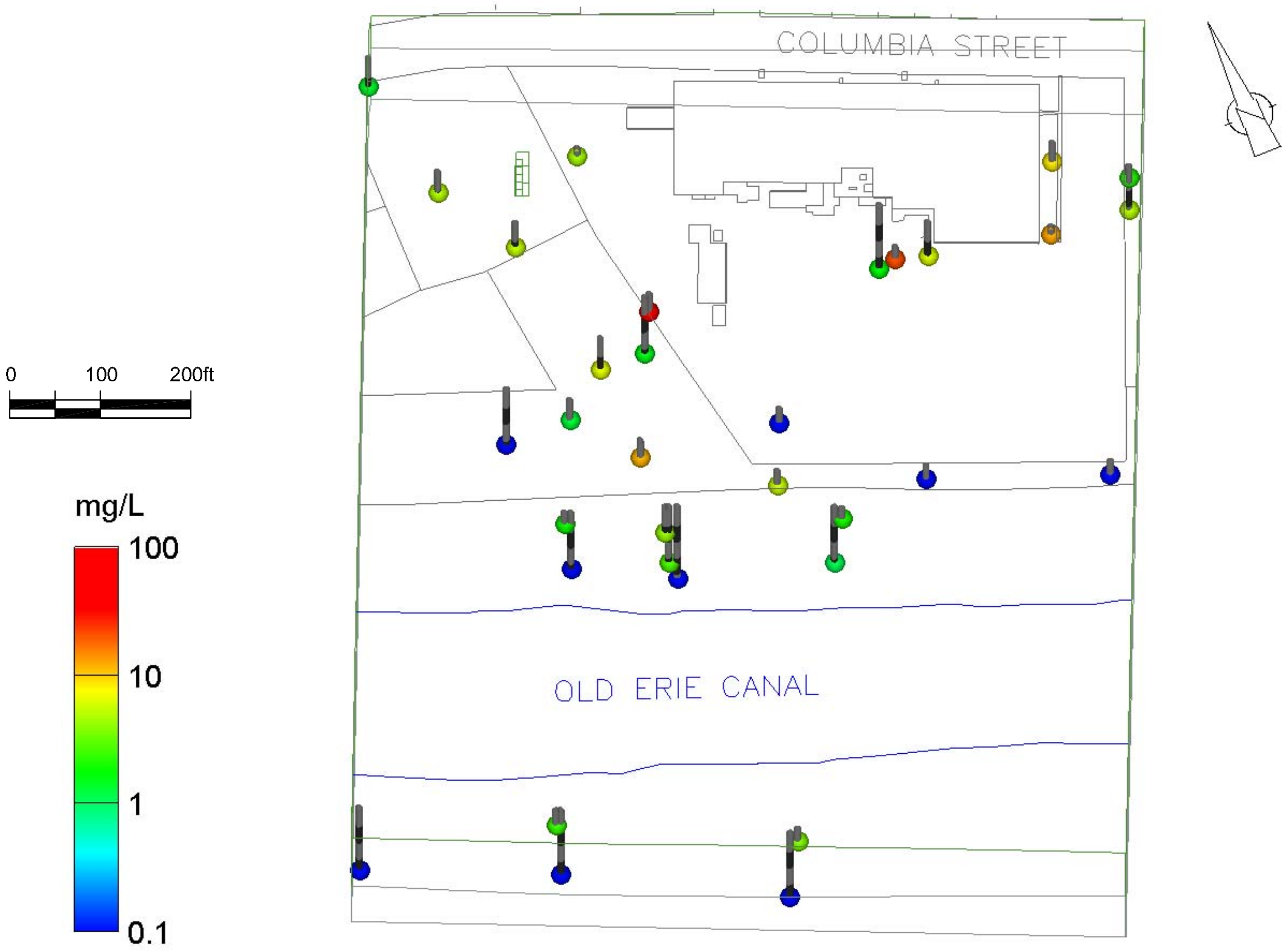

figure 16

DOC CONCENTRATIONS
IN GROUNDWATER
OLD ERIE CANAL SITE
Clyde, New York

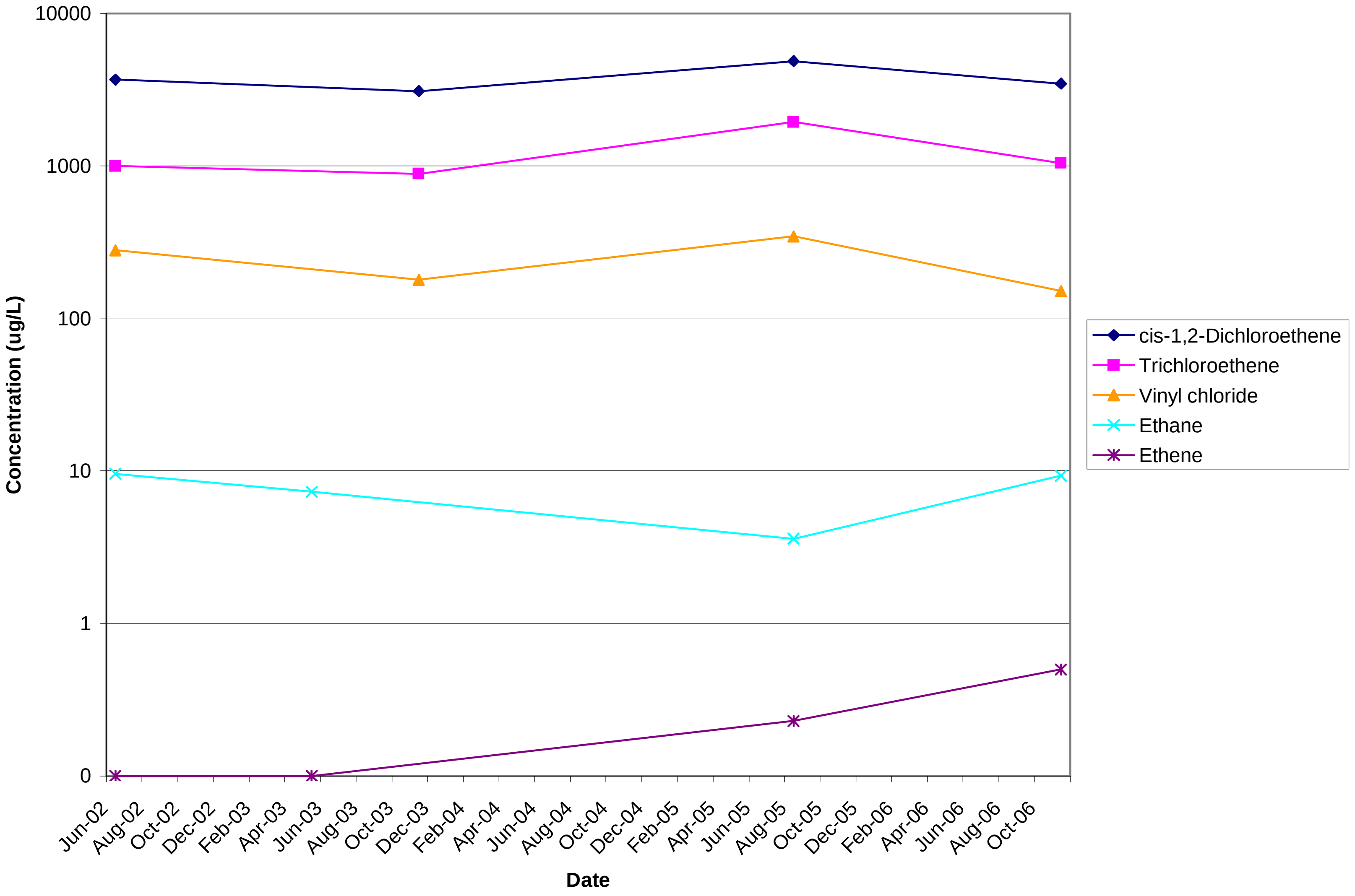

figure 17

MW-1S TCE & DEGRADATION PRODUCTS VS. TIME
OLD ERIE CANAL SITE
Clyde, New York

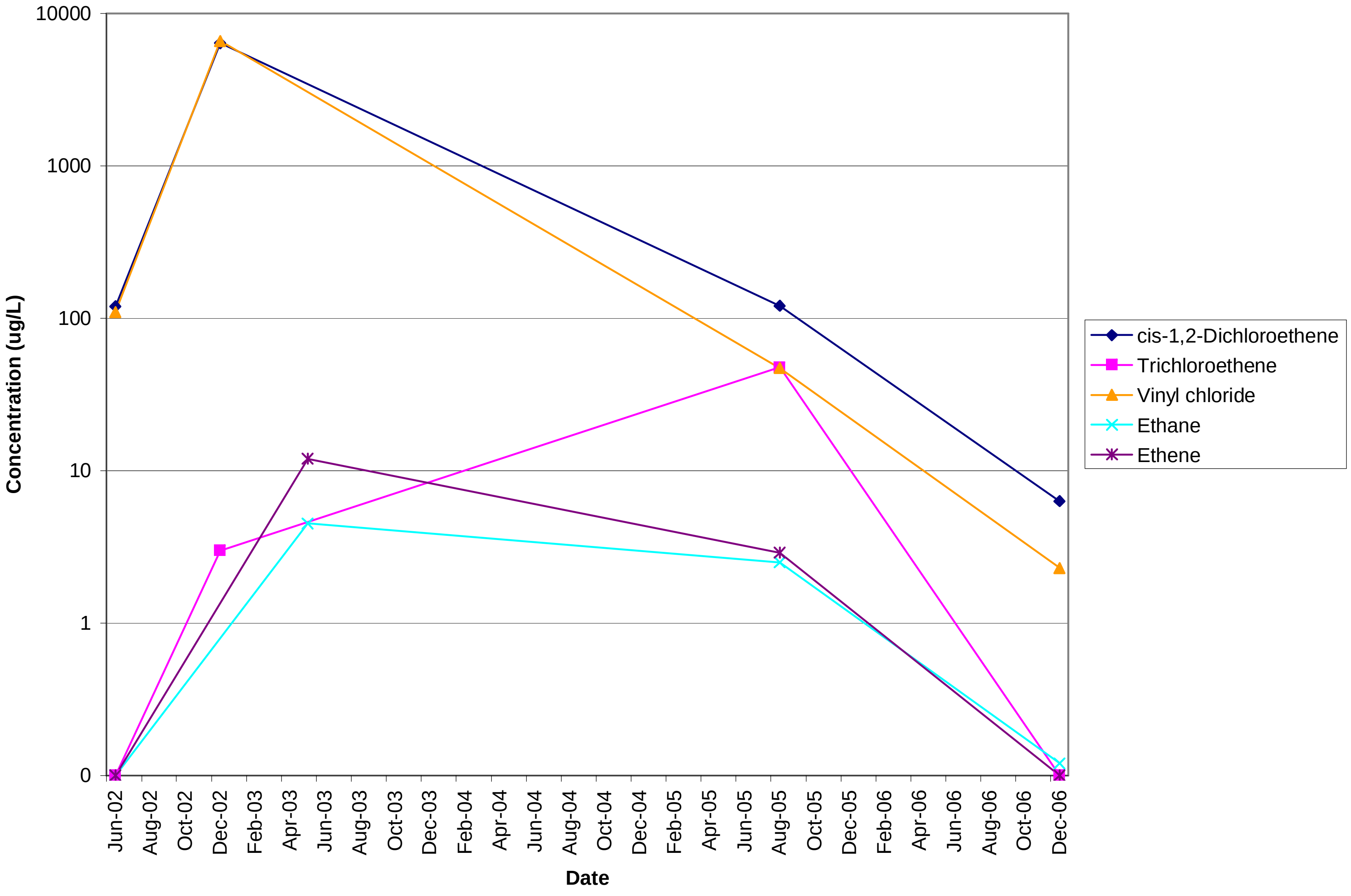

figure 18

MW-4S TCE & DEGRADATION PRODUCTS VS. TIME
OLD ERIE CANAL SITE
Clyde, New York

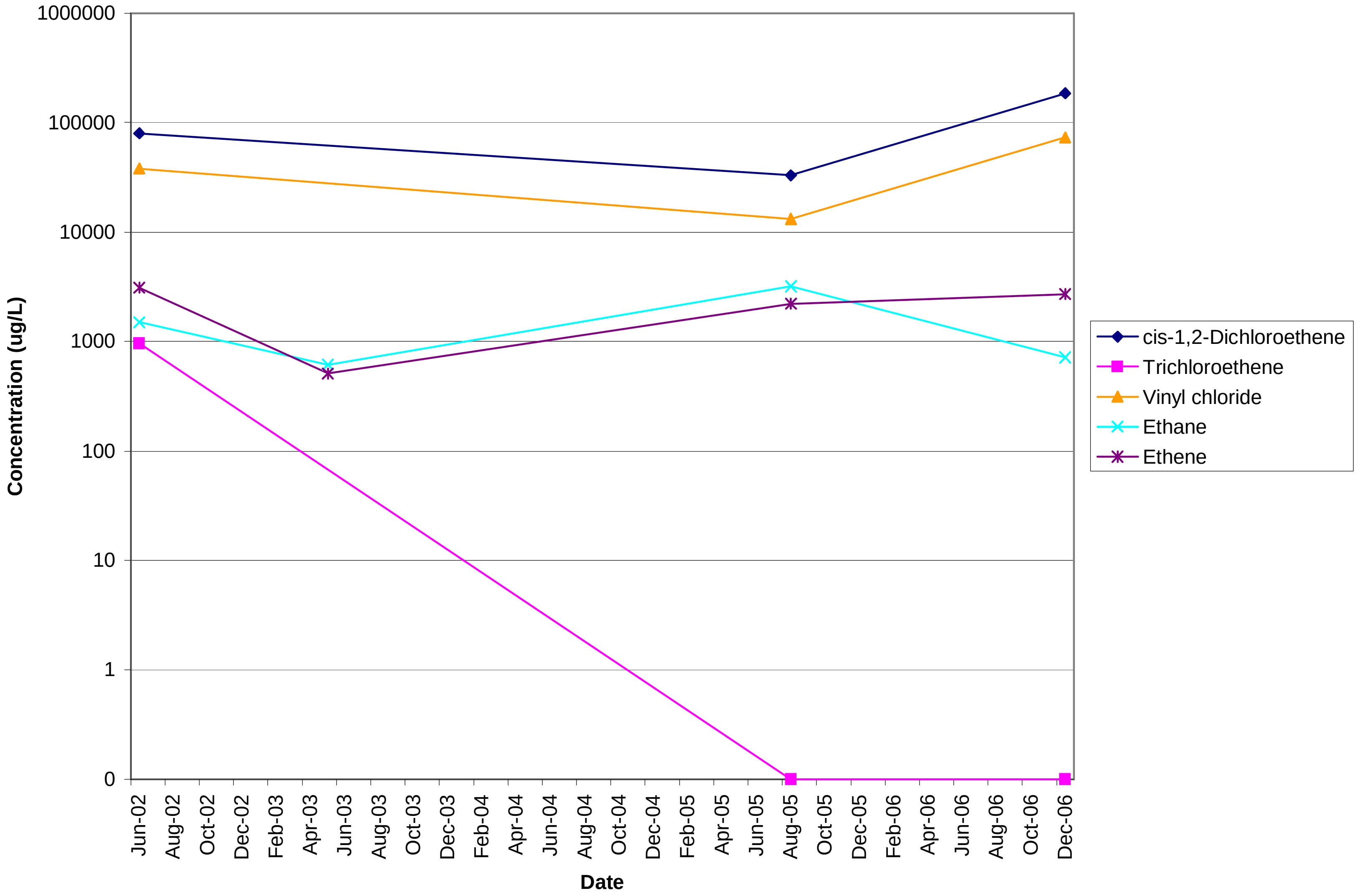

figure 19

MW-6S TCE & DEGRADATION PRODUCTS VS. TIME
OLD ERIE CANAL SITE
Clyde, New York

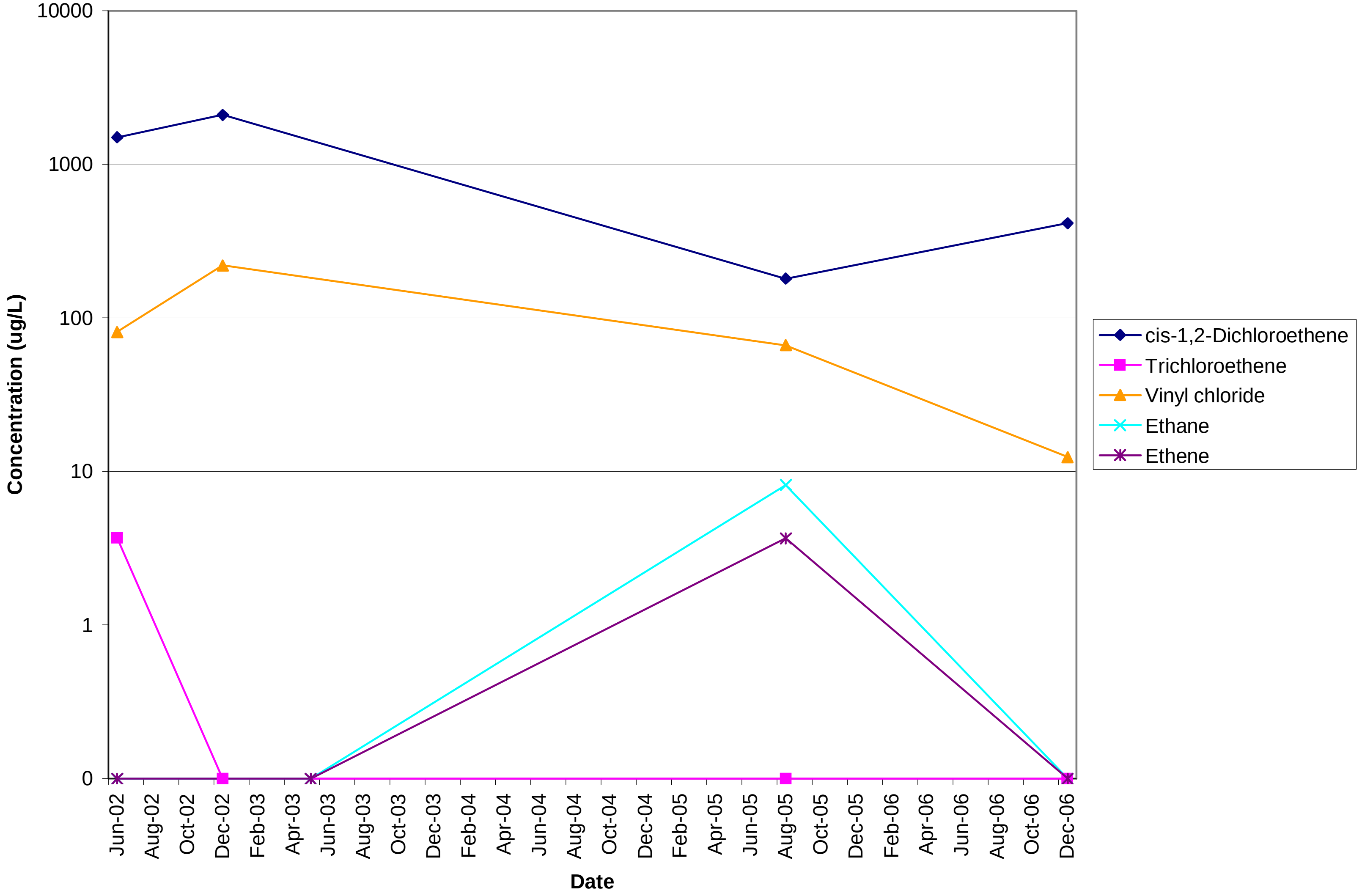

figure 20

MW-7S TCE & DEGRADATION PRODUCTS VS. TIME
OLD ERIE CANAL SITE
Clyde, New York

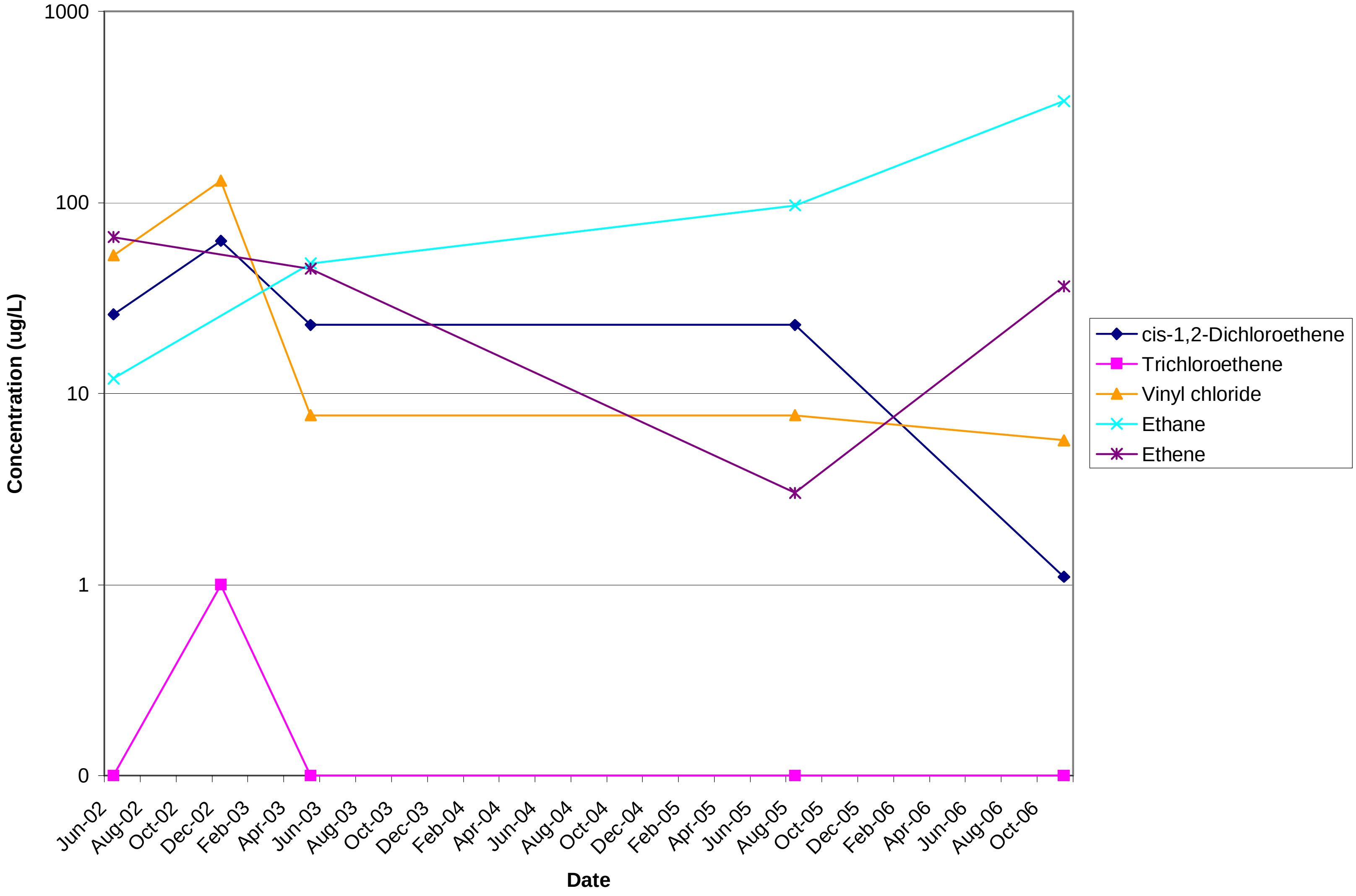

figure 21

EMW-2 TCE & DEGRADATION PRODUCTS VS. TIME
OLD ERIE CANAL SITE
Clyde, New York

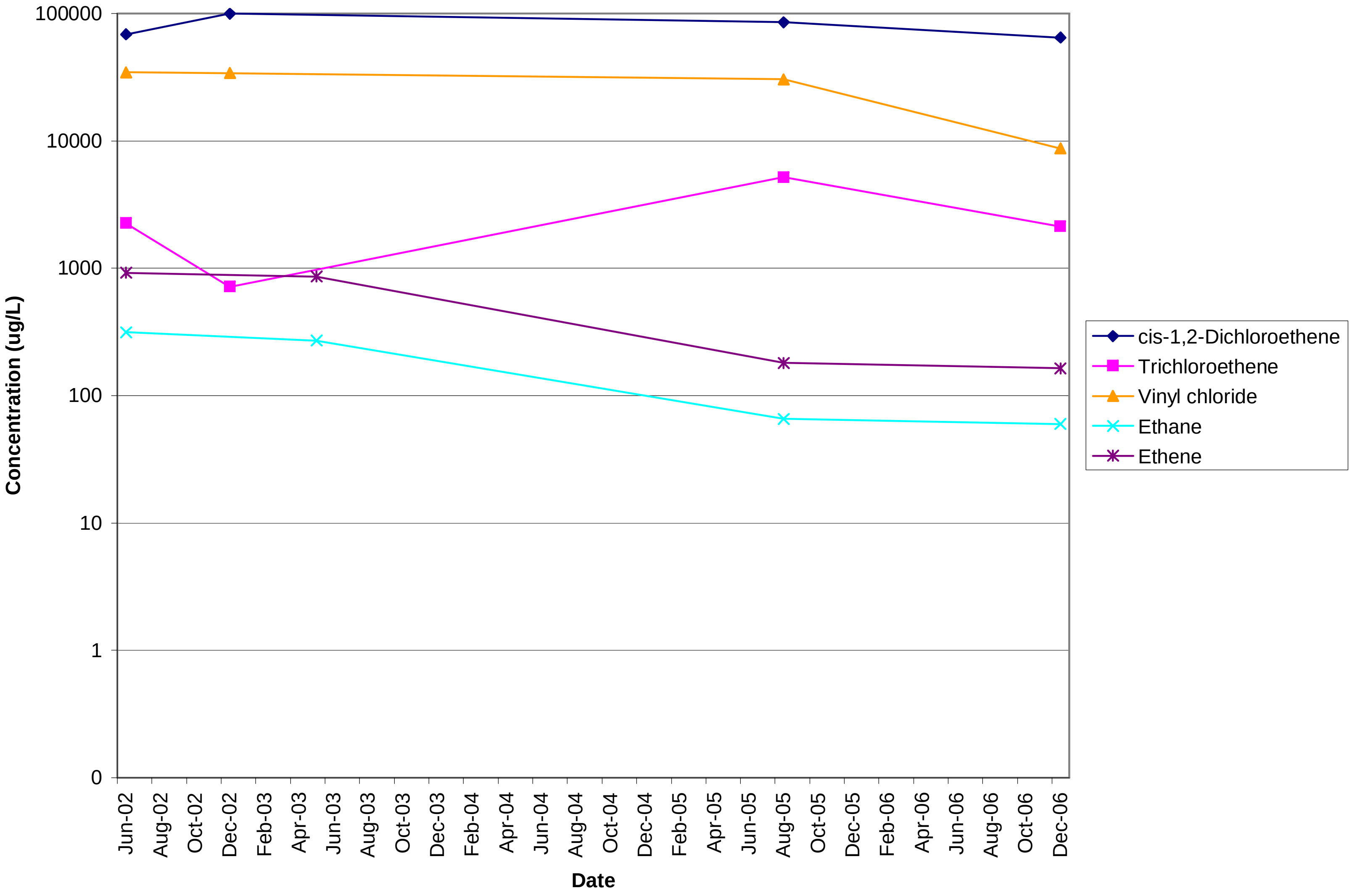

figure 22

MW-4B TCE & DEGRADATION PRODUCTS VS. TIME
OLD ERIE CANAL SITE
Clyde, New York

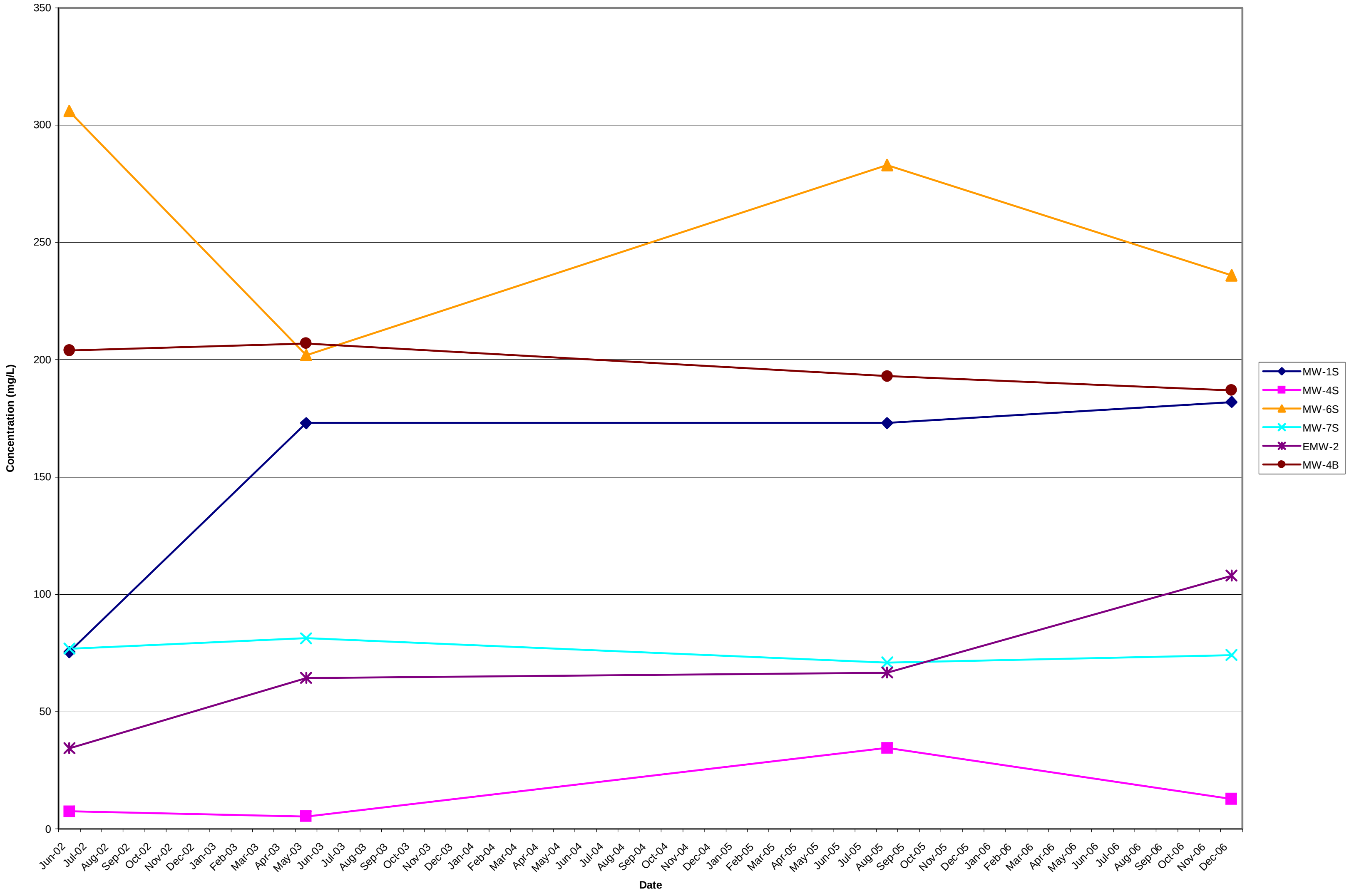

figure 23

CHLORIDE CONCENTRATION VS. TIME
OLD ERIE CANAL SITE
Clyde, New York

CRA

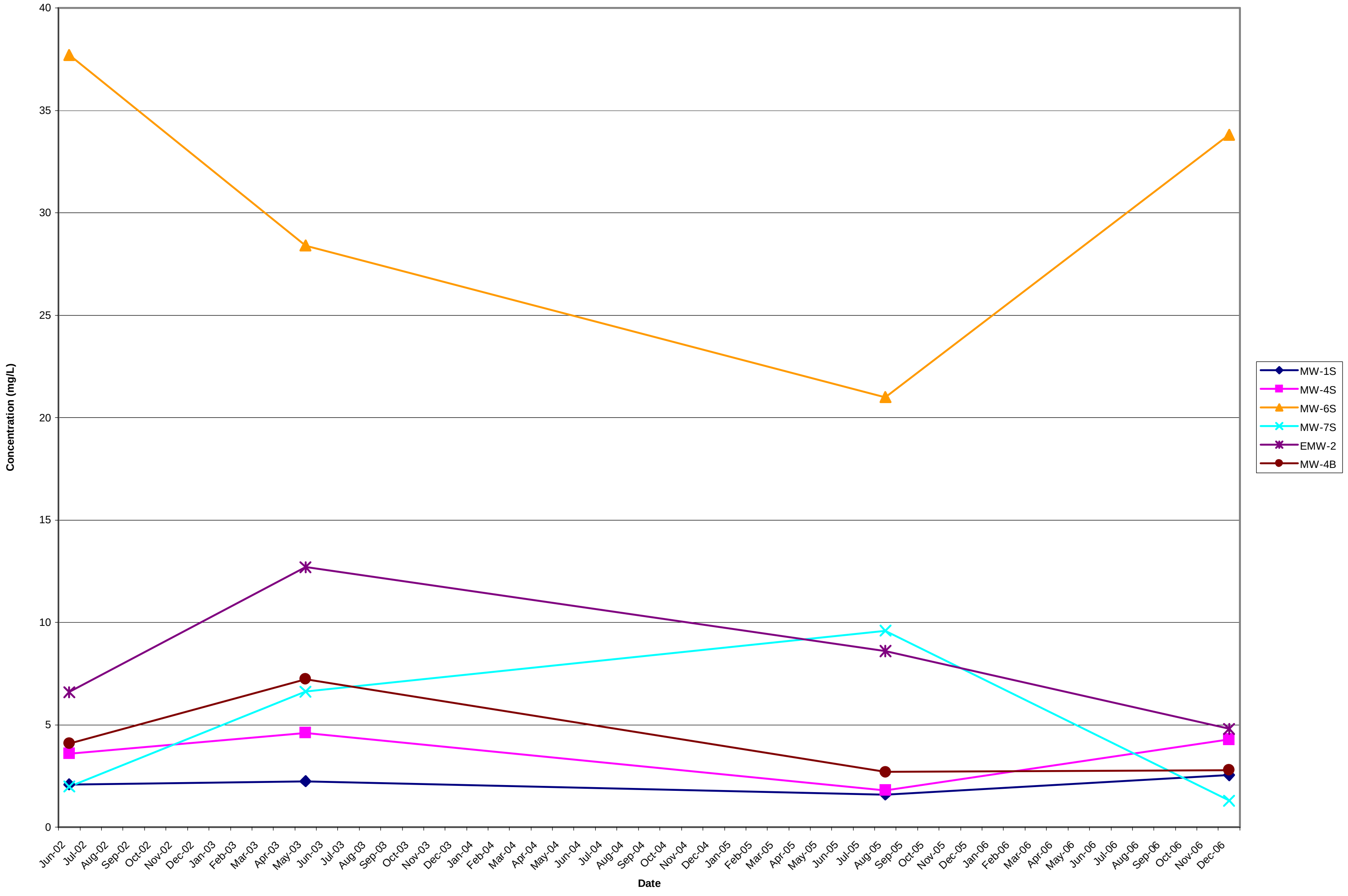

figure 24

DISSOLVED ORGANIC CARBON VS. TIME
OLD ERIE CANAL SITE
Clyde, New York

TABLE D.1

cis-1,2-DCE ABUNDANCE
MNA EVALUATION
OLD ERIE CANAL SITE
CLYDE, NEW YORK

Sample Location:		*EMW-2*	*EMW-2*	*EMW-2*	*EMW-2*	*EMW-2*	*EMW-2*	*EMW-2*	*EMW-2*	*EMW-2*	*EMW-3*	*EMW-4*	*EMW-4*
Sample Date:		*6/26/2002*	*12/19/2002*	*5/27/2003*	*5/27/2003*	*11/4/2003*	*11/4/2003*	*8/25/2005*	*8/25/2005*	*11/30/2006*	*6/26/2002*	*6/26/2002*	*12/19/2002*
				PB	*PB-Duplicate*	*PB*	*PB-Duplicate*		*Duplicate*				
1,1-Dichloroethene	μg/L	0	0	0	0	0	0	0	0	0	0	0	0
cis-1,2-Dichloroethene	μg/L	26	63	15	16	1.7	1.5	21.6	24.2	1.1	0.51	1.1	0.76
trans-1,2-Dichloroethene	μg/L	0.54	0	0	0	0	0	0	0	0	0	0	0
cis-DCE Abundance Ratio		**0.98**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Sample Location:		*EMW-4*	*MW-1*	*MW-1*	*MW-1*	*MW-1S*	*MW-1S*	*MW-1S*	*MW-1S*	*MW-1S*	*MW-3S*	*MW-3B*	*MW-4S*
Sample Date:		*8/25/2005*	*6/25/2002*	*5/28/2003*	*12/6/2006*	*6/26/2002*	*11/4/2003*	*8/24/2005*	*11/29/2006*	*11/29/2006*	*8/24/2005*	*12/5/2006*	*6/25/2002*
				PB						*Duplicate*			
1,1-Dichloroethene	μg/L	0	0	0	0	0	7.5	0	0	6.9	0	0	0
cis-1,2-Dichloroethene	μg/L	7.2	3.4	4.7	2.2	3700	3100	4880	3690	3240	57.1	351	120
trans-1,2-Dichloroethene	μg/L	0	0	0	0	32	35	50.6	32.4	34.2	0.68	5.9	0.76
cis-DCE Abundance Ratio		**1.00**	**1.00**	**1.00**	**1.00**	**0.99**	**0.99**	**0.99**	**0.99**	**0.99**	**0.99**	**0.98**	**0.99**

Sample Location:		*MW-4S*	*MW-4S*	*MW-4S*	*MW-4S*	*MW-4S*	*MW-4S*	*MW-4S*	*MW-4S*	*MW-4S*	*MW-4S*	*MW-4B*	*MW-4B*
Sample Date:		*12/19/2002*	*4/24/2003*	*4/24/2003*	*5/28/2003*	*5/28/2003*	*7/2/2003*	*7/2/2003*	*11/4/2003*	*8/24/2005*	*12/5/2006*	*6/25/2002*	*6/25/2002*
			PB-Top	*PB-Bottom*	*PB-Top*	*PB-Bottom*	*PB-Top*	*PB-Bottom*	*PB-Bottom*				*Duplicate*
1,1-Dichloroethene	μg/L	5.4	0	0	0	0	0	0	0	0	0	0	0
cis-1,2-Dichloroethene	μg/L	6400	8.7	3.9	1.6	3.2	2.9	2.3	7.9	121	6.3	58000	79000
trans-1,2-Dichloroethene	μg/L	37	0	0	0	0	0	0	0	1.2	0	0	0
cis-DCE Abundance Ratio		**0.99**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**0.99**	**1.00**	**1.00**	**1.00**

Sample Location:		*MW-4B*	*MW-4B*	*MW-4B*	*MW-4B*	*MW-4B*	*MW-4B*	*MW-5S*	*MW-6S*	*MW-6S*	*MW-6S*	*MW-6S*	*MW-6S*
Sample Date:		*12/19/2002*	*12/19/2002*	*5/28/2003*	*11/4/2003*	*8/24/2005*	*12/5/2006*	*8/25/2005*	*6/26/2002*	*5/28/2003*	*5/28/2003*	*11/4/2003*	*8/24/2005*
			Duplicate	*PB*	*PB*					*PB-Top*	*PB-Bottom*	*PB-Bottom*	
1,1-Dichloroethene	μg/L	0	0	0	20	105	0	0	0	0	0	0	0
cis-1,2-Dichloroethene	μg/L	100000	100000	32000	31000	84500	64800	15.1	80000	1500	9500	480	33100
trans-1,2-Dichloroethene	μg/L	0	0	0	20	345	130	0	0	0	0	0	65.5
cis-DCE Abundance Ratio		**1.00**	**1.00**	**1.00**	**1.00**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

TABLE D.1

cis-1,2-DCE ABUNDANCE
MNA EVALUATION
OLD ERIE CANAL SITE
CLYDE, NEW YORK

Sample Location:		*MW-6S*	*MW-6B*	*MW-7S*	*MW-7S*	*MW-7S*	*MW-7S*	*MW-7S*	*MW-7S*	*MW-7S*	*MW-7B*	*MW-7B*	*MW-7B*
Sample Date:		***12/6/2006***	***12/6/2006***	***6/24/2002***	***12/18/2002***	***5/27/2003***	***5/27/2003***	***11/4/2003***	***8/26/2005***	***12/4/2006***	***5/27/2003***	***11/4/2003***	***8/26/2005***
						PB	***PB-Duplicate***	***PB***			***PB***	***PB***	
1,1-Dichloroethene	µg/L	0	59.3	1.2	0	0	0	0	0	0.62	0	0	0
cis-1,2-Dichloroethene	µg/L	186000	50400	1500	2100	140	130	140	180	414	10	3	1.9
trans-1,2-Dichloroethene	µg/L	478	119	14	0	0	0	0	0.6	2.5	0	0	0
cis-DCE Abundance Ratio		**1.00**	**1.00**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**0.99**	**1.00**	**1.00**	**1.00**

Sample Location:		*MW-7B*	*MW-8S*	*MW-9S*	*MW-8S*	*MW-9S*	*MW-13S*	*MW-14S*	*MW-15S*	*MW-16S*	*MW-16B*	*GP-2*	*GP-4*
Sample Date:		***12/4/2006***	***6/24/2002***	***6/24/2002***	***8/24/2005***	***8/24/2005***	***11/30/2006***	***12/6/2006***	***12/7/2006***	***12/6/2006***	***12/6/2006***	***4/25/2002***	***4/24/2002***
1,1-Dichloroethene	µg/L	0	0	0	0	0	0	51.8	13.7	0	0	0	0
cis-1,2-Dichloroethene	µg/L	0.58	2.6	0.55	1.9	0.83	6870	28200	20800	5.7	16	2.9	8.7
trans-1,2-Dichloroethene	µg/L	0	0	0	0	0	0	80	30.8	0	0	0.23	0
cis-DCE Abundance Ratio		**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**0.93**	**1.00**

Sample Location:		*GP-5*	*GP-6*	*GP-8*	*GP-9*	*GP-10*	*GP-11*	*GP-12*	*GP-13*	*GP-14*	*GP-15*	*GP-16*	*GP-17*
Sample Date:		***4/25/2002***	***4/26/2002***	***4/24/2002***	***4/26/2002***	***4/24/2002***	***4/30/2002***	***4/26/2002***	***4/30/2002***	***4/26/2002***	***4/26/2002***	***4/25/2002***	***4/25/2002***
1,1-Dichloroethene	µg/L	0	0	0.37	0	0	0	0	22	0	0	70	0
cis-1,2-Dichloroethene	µg/L	170	30	230	14	22	420	21	9100	180	3200	60000	0.27
trans-1,2-Dichloroethene	µg/L	0.46	0	1	0	0	4.1	0	40	0	53	310	0
cis-DCE Abundance Ratio		**1.00**	**1.00**	**0.99**	**1.00**	**1.00**	**0.99**	**1.00**	**0.99**	**1.00**	**0.98**	**0.99**	**1.00**

Sample Location:		*GP-18*	*GP-19*	*GP-20*	*GP-22*	*GP-23*	*GP-24*	*GP-25*	*GP-25*	*GP-26*	*GP-27*	*GP-28*	*GP-29*
Sample Date:		***4/24/2002***	***5/1/2002***	***5/2/2002***	***4/25/2002***	***4/25/2002***	***4/24/2002***	***4/30/2002***	***4/30/2002***	***5/1/2002***	***4/26/2002***	***5/1/2002***	***4/26/2002***
									Duplicate				
1,1-Dichloroethene	µg/L	0	5.4	27	0	0	0.52	210	220	0	0.21	4.1	0
cis-1,2-Dichloroethene	µg/L	0.82	1500	44000	1.5	4.2	310	170000	180000	120	17	3700	110
trans-1,2-Dichloroethene	µg/L	0	9.9	170	0	0	0.68	0	0	0	0.43	15	0
cis-DCE Abundance Ratio		**1.00**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**0.96**	**0.99**	**1.00**

TABLE D.1

cis-1,2-DCE ABUNDANCE
MNA EVALUATION
OLD ERIE CANAL SITE
CLYDE, NEW YORK

Sample Location:		*GP-30*	*GP-31*	*GP-32*	*GP-33*	*GP-34*	*GP-34*	*GP-36*	*GP-37*	*GP-40*	*GP-41*	*GP-42*	*GP-43*
Sample Date:		*4/26/2002*	*4/24/2002*	*4/24/2002*	*5/1/2002*	*5/2/2002*	*5/2/2002*	*4/23/2002*	*4/23/2002*	*5/2/2002*	*5/2/2002*	*5/2/2002*	*5/2/2002*
							Duplicate						
1,1-Dichloroethene	µg/L	0	1.3	0	0	160	170	0.88	0	0	0	0	0
cis-1,2-Dichloroethene	µg/L	5	500	16000	0.98	100000	200000	1900	5.2	0.4	0.35	0.46	0.69
trans-1,2-Dichloroethene	µg/L	0	3.4	93	0	400	420	3.1	0	0	0	0	0
cis-DCE Abundance Ratio		**1.00**	**0.99**	**0.99**	**1.00**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Sample Location:		*GP-43*	*GP-45*	*GP-46*	*GP-47*	*GP-49*	*GP-50*	*GP-51*	*GP-53*	*GP-54*	*GP-56*	*GP-59*	*GP-60*
Sample Date:		*5/2/2002*	*11/21/2002*	*11/21/2002*	*11/21/2002*	*11/21/2002*	*11/21/2002*	*11/21/2002*	*11/21/2002*	*11/21/2002*	*11/21/2002*	*11/21/2002*	*11/21/2002*
		Duplicate											
1,1-Dichloroethene	µg/L	0	0	0	0	0	0	0	0	0	0	0	0
cis-1,2-Dichloroethene	µg/L	0.59	160	11	6	600	120	6000	1300	7.1	1400	0.31	46
trans-1,2-Dichloroethene	µg/L	0	4.6	0.83	0	6.4	0	0	0	0	11	0	0
cis-DCE Abundance Ratio		**1.00**	**0.97**	**0.93**	**1.00**	**0.99**	**1.00**	**1.00**	**1.00**	**1.00**	**0.99**	**1.00**	**1.00**

Sample Location:		*SSB-3*	*SSB-3*	*SSB-4*	*SSB-5*	*SSB-6*	*SSB-7*	*SSB-8*	*SSB-9*	*SSB-10*	*SSB-11*
Sample Date:		*1/14/2005*	*1/14/2005*	*1/14/2005*	*1/14/2005*	*1/14/2005*	*1/13/2005*	*1/13/2005*	*1/13/2005*	*1/14/2005*	*1/14/2005*
			Duplicate								
1,1-Dichloroethene	µg/L	0.62	0.67	0	0	34	0	2.5	0	3.6	0.96
cis-1,2-Dichloroethene	µg/L	200	210	31	110	13000	73000	320	1.8	210	260
trans-1,2-Dichloroethene	µg/L	5.1	5.6	0	5.6	35	0	3.7	0	2.6	3.9
cis-DCE Abundance Ratio		**0.97**	**0.97**	**1.00**	**0.95**	**0.99**	**1.00**	**0.98**	**1.00**	**0.97**	**0.98**