Department of Environmental Conservation

Division of Environmental Remediation

Special Report

Hydrogeologic and Geochemical Investigation of the Southwestern Portion of the Town of Tonawanda, Erie County, New York

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New York State Department of Environmental Conservation
Region 9
270 Michigan Avenue
Buffalo, New York 14203-2999

Special Report

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1.0 ABSTRACT

A detailed evaluation of the geology, hydrogeology and aqueous geochemistry of the southwestern portion of the Town of Tonawanda, Erie County, New York (Study Area) was completed to further evaluate significant (≈30 feet) groundwater elevation declines observed in deep overburden monitoring wells installed in the area. This phenomenon was subsequently attributed to groundwater extraction by the Dunlop Tire Corporation. A complete understanding of the temporal and spatial distribution of this phenomenon, along with the determination of the source of water supplying the well, is critical as groundwater extraction has the potential to increase contaminant migration from several inactive hazardous waste sites in the area.

Within the Study Area five distinct stratigraphic units were identified. These units, in order of increasing depth below ground surface, include fill materials, glaciolacustrine silty clay or recent alluvium, dense glacial till and shale bedrock of the Camillus Shale Formation. Most of the area is underlain by the glaciolacustrine deposit. In the western portion of the Study Area, however, the glaciolacustrine deposit grades abruptly into recent alluvium.

The hydrogeology of the Study Area was evaluated by examining hydrogeologic data obtained during this study. These data suggest that four hydrogeologic zones underlie the area: (1) a shallow water bearing zone consisting of miscellaneous fill and the upper portion of the glaciolacustrine deposit, (2) an intermediate zone consisting of the glaciolacustrine deposit and recent alluvium, (3) a deep water bearing zone consisting predominantly of glacial till, and (4) an upper bedrock water bearing zone. Groundwater in the shallow and intermediate hydrogeologic zones flows uniformly across the Study Area toward the Niagara River. In contrast, groundwater in the deep and upper bedrock zones is highly influenced by groundwater extraction at the Dunlop Tire Corporation. When the production well is being utilized (≈June to November), groundwater extraction dominates the flow regime and produces an elliptical flow pattern centered around the production well and the wells at the adjacent Polymer Applications Site.

A conceptual geochemical model based upon the hydrogeology of the Study Area was developed to provide the framework in which to evaluate the source of water supplying the Dunlop production well. Piper diagrams were generated to fingerprint water from the Niagara River and each of the hydrogeologic zones identified during this study. These diagrams indicate that Study Area waters are ionically very different; water from the Niagara River and shallow hydrogeologic zone is best classified as calcium-bicarbonate water, water from the intermediate hydrogeologic zone is best classified as magnesium-sulfate water, and water from the deep and upper bedrock hydrogeologic zones is best classified as calcium-sulfate water. The ionic composition of these waters is consistent with the conceptual geochemical model that was developed. The

Piper diagrams also indicate that the principle source of water supplying the Dunlop production well is from the Camillus Shale as extracted water is ionically similar to Camillus Shale groundwater.

2.0 INTRODUCTION

Several inactive hazardous waste sites, as defined by the New York State Department of Environmental Conservation (NYSDEC) in the Registry of Inactive Hazardous Waste Disposal Sites in New York State (Registry), are located in the southwestern portion of the Town of Tonawanda, Erie County, New York (Figure 2-1). These sites include the Dunlop Tire Corporation (Class 4), the E.I. DuPont Yerkes plant (now Delisted), the Polymer Applications Site (Class 2), the 3M O-Cel-O Sponge plant (now Class 4), and the FMC Corporation (now Delisted). These sites combined will be referred to as the Study Area. The NYSDEC classification scheme for Registry sites is summarized in Table 2-1.

During implementation of a State Superfund Remedial Investigation at the Polymer Applications Site in 1994, significant ($\approx$30 feet) groundwater elevation declines were observed in deep overburden monitoring wells during the summer months, a phenomenon believed to be attributable to groundwater extraction by the Dunlop Tire Corporation for non-contact cooling purposes. A complete understanding of the temporal and spatial distribution of this phenomenon, along with the determination of the source of water extracted by this well, is critical as groundwater extraction has the potential to increase contaminant migration from Polymer and the other inactive hazardous waste sites in the area. In addition, groundwater remediation strategies may have to be developed to account for this annual hydrogeologic phenomenon.

In April 1995, under the employ of the New York State Department of Environmental Conservation, I began a study to evaluate further the groundwater elevation declines in the Study Area. This study was completed in cooperation with the Dunlop Tire Corporation, the 3M O-Cel-O Sponge plant, the E.I. DuPont Yerkes plant, and the Niagara Mohawk Power Corporation. This report describes the field activities completed during this study, and discusses in detail the geology, hydrogeology, and geochemistry of groundwater and surface water within the Study Area.

2.1 Description of the Study Area

The Study Area encompasses approximately 1 mi^2 in the southwestern portion of the Town of Tonawanda, Erie County, New York, and is bordered on the west by the Niagara River, on the north by Sawyer Avenue, on the east by Two Mile Creek Road and Kenmore Avenue, and on the south by the General Motors Powertrain Division, Tonawanda Engine plant (Figure 2-1). Heavy industry is predominant throughout the area; however, a significant mix of light industrial, commercial, recreational, public, and residential land uses are found within and immediately adjacent to the Study Area. Light industrial and commercial properties are located along Sawyer and Kenmore Avenues, while residential areas are located

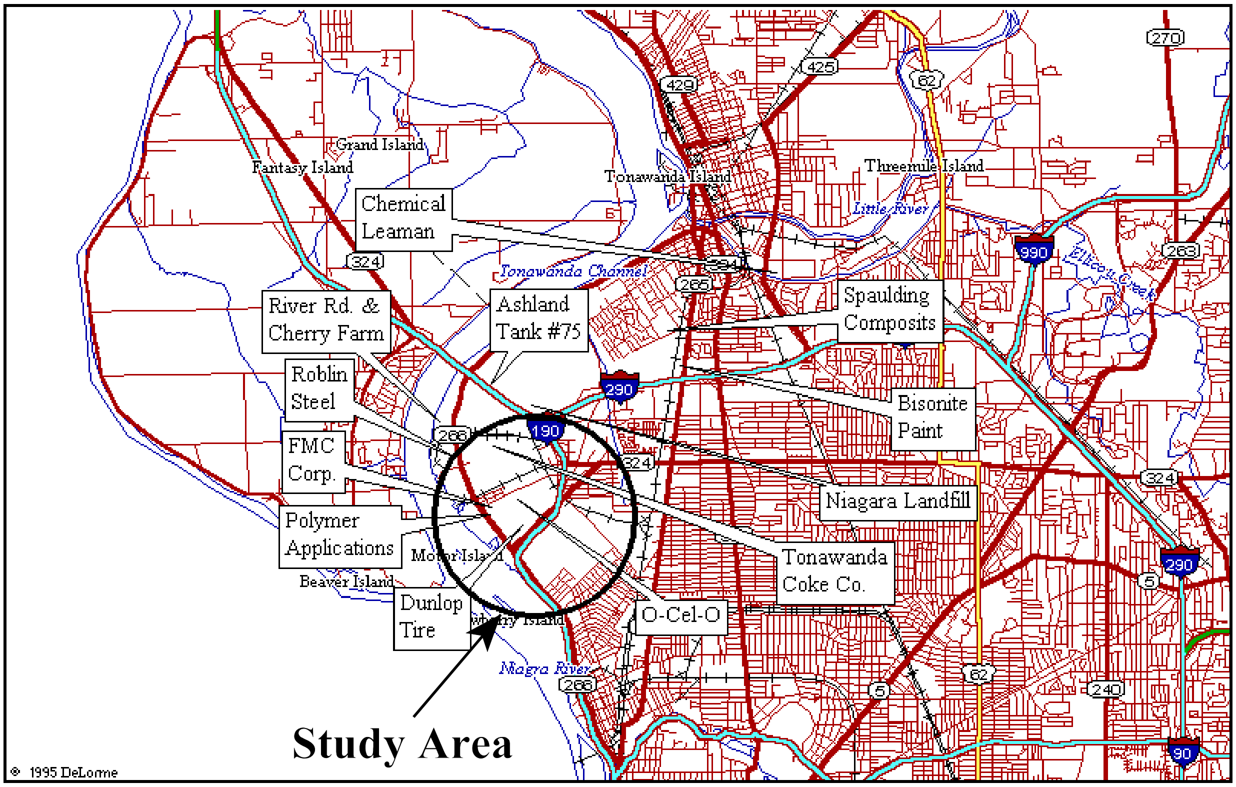


Figure 2-1. Study Area Location Map, Southwest Portion of the Town of Tonawanda, Erie County, New York.

Table 2-1.
Classification Codes for Sites Listed in the Registry of Inactive Hazardous Waste Disposal Sites in New York State.

Class	Description
1	Causing or presenting an imminent danger of causing irreversible damage to the public health or environment - immediate action required.
2	Significant threat to the public health or environment - action required.
2a	Temporary classification assigned to sites that have inadequate and/or insufficient data for inclusion in any of the other classifications.
3	Does not present a significant threat to the public health or environment - action may be deferred.
4	Site properly closed - requires continued management.
5	Site properly closed; no evidence of present or potential adverse impact - no further action required.
D	Site has been delisted from the Registry of Inactive Hazardous Waste Sites.

north of Sawyer Avenue, immediately east of the Study Area (Woodward Avenue West neighborhood), and approximately 1,200 feet southeast of the E.I. DuPont Yerkes plant (Edgar Avenue/Vulcan Street neighborhoods). The total population within a 1-mile radius of the Study Area is approximately 9,395, with approximately 110,843 residents within a 3-mile radius (General Sciences Corporation, 1986). Recreational activities that would take place within and adjacent to the Study Area include boating and other water related activities; Aqua Lane Park is located at the foot of Sheridan Drive along the Niagara River, while the Riverwalk, a paved hiking and bicycle path along River Road, connects this park with a series of parks to the north. Interstate 90 (New York State Thruway) transects the Study Area in a southwest to northeast direction (Figure 2-1).

The Study Area is located within the Erie-Niagara drainage basin of the Erie-Ontario Lowlands Physiographic Province of New York State. This province is characterized by a thick sequence of rock formations consisting predominantly of sandstones, shales, dolostones, and limestones from the Silurian and Devonian Periods (La Sala, 1968; Woodward-Clyde, 1993). The Erie-Ontario Lowlands are characterized also by low topographic relief, the result of erosion and deposition of sediments adjacent to lakes Erie and Ontario. Topography within the Study Area is relatively flat and slopes gently toward the Niagara River. Surface elevations range from 605 ft above mean sea level (amsl) in the eastern portion of the Study Area to approximately 570 ft amsl at the shore of the Niagara River. The average slope across the area is less than 1% (Woodward-Clyde, 1993).

Surface water discharge from the Study Area is either directly to the Niagara River via local drainage or to the Tonawanda Publicly Owned Treatment Works (POTW) via storm sewers. The Niagara River is a Class A-Special Waterway joining lakes Erie and Ontario. Class A-Special waters are utilized as a source of drinking water, for culinary or food processing purposes, or for primary contact recreation (NYSDEC, 1994). Flow in the river is controlled principally by the elevation of Lake Erie, which has a mean elevation of 571 feet amsl (Parsons Engineering Science, 1995). Surface water also collects in wetlands east and northeast of the Dunlop Tire Corporation plant (URS, 1992).

The climate of the Study Area is characterized as humid continental (Bechtel, 1993). While wide seasonal swings in temperature are characteristic of this climate, lakes Erie and Ontario moderate the temperature in western New York. The mean annual temperature of the Buffalo area is 48°F (9°C), with temperatures of 90°F (32°C) and above infrequent (Bechtel, 1993; NOAA, 1996). During the spring months, cold lake waters limit warming of the atmosphere over adjacent land masses, which delays typical spring conditions until late May or early June (NOAA, 1996). Summer comes suddenly in mid-June. During the autumn months, lake waters cool more slowly, thereby serving as a heat source that moderates cooling of the atmosphere at night (Bechtel, 1993). Snow flurries off the lake begin in mid-November or early December (NOAA, 1996), and typically last into March.

3.0 THE PROBLEM, STUDY OBJECTIVES AND SCOPE OF WORK

3.1 Statement of Problem

Figures 3-1 and 3-2 illustrate the groundwater flow pattern across the Study Area for the deep overburden/upper bedrock water bearing zones on May 4 and November 2, 1995, respectively. During May, when the production well is not being utilized, groundwater flows in a general southwest direction across the area toward the Niagara River (Figure 3-1). By November 2, active groundwater extraction had been ongoing for 5 months, 24 hours per day, at rates ranging from 1,200 to 1,800 gpm. Groundwater extraction dominates the flow regime and produces an elliptical flow pattern around the Dunlop production well and the wells at the Polymer Applications Site (Figure 3-2). Water level declines in November ranged from 4 to 31 feet throughout the Study Area.

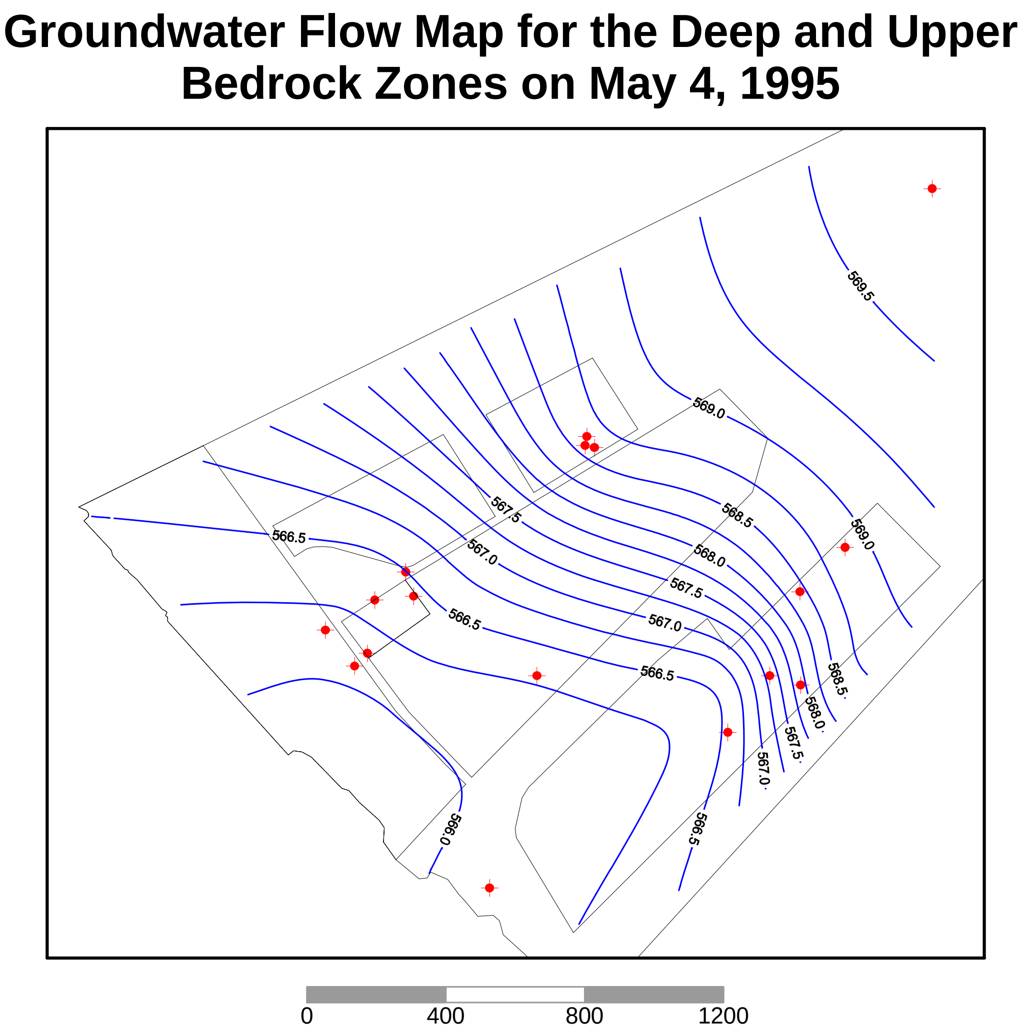


Figure 3-1. Deep and Upper Bedrock Zone Groundwater Flow Across the Study Area on May 4, 1995. Wells are Shown as Red Crossed Dots.

Groundwater Flow Map for the Deep and Upper Bedrock Zones on November 2, 1995

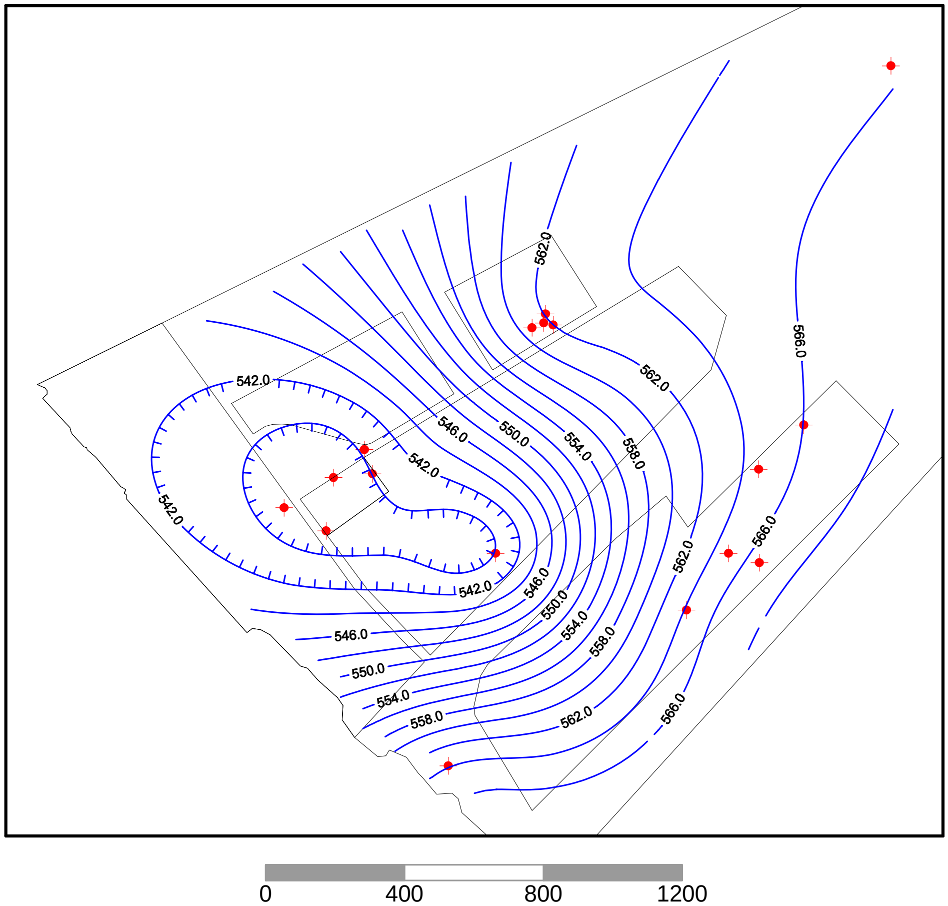


Figure 3-2. Deep and Upper Bedrock Zone Groundwater Flow Across the Study Area on November 2, 1995. Wells are Shown as Red Crossed Dots.

The groundwater elevation data and flow maps suggest that groundwater extraction by the Dunlop Tire Corporation has the potential to effect contaminant migration throughout the Study Area. This is particularly critical as deep overburden groundwater at the Polymer Applications Site was found to contain phenols at concentrations up to 75,200 µg/l. It is not known, however, whether this contaminant is actually migrating toward, and is being extracted by, the production well as the large quantities of water being extracted would dilute the contaminated groundwater to non-detect concentrations. In addition, the production well is not screened in the same hydrogeologic zone as the deep overburden Polymer wells; the production well is cased to a depth of 100 feet below ground surface (bgs), and extracts groundwater from a depth of 100 to 140 feet bgs. Since the depth to bedrock at the extraction well is ≈70 feet, groundwater is being extracted from a bedrock zone 30 to 70 feet below top of rock. As a result, groundwater from the upper 30 feet of bedrock cannot flow directly into the well, and could only reach the well if vertical fractures connect the upper bedrock with the zone of extraction. While the presence of solution-enlarged horizontal fractures, bedding-plane openings, and voids created by the dissolution of gypsum is well documented for the Camillus Shale, the frequency and extent of vertical fractures are less well documented. For the Study Area, the only information available regarding fractures in the Camillus Shale is the description of cores obtained during individual site studies. While horizontal fractures are prevalent, the identification of vertical fractures from vertical cores is difficult, with the results often inconclusive.

As a further complication, it is possible that groundwater extraction induces infiltration of Niagara River water into the Camillus Shale. Such a phenomenon was described by La Sala (1968) using temperature measurements of extracted groundwater at the E.I. DuPont Yerkes Plant. During the period in which these measurements were collected, the pumping rate was ≈700 gpm from a well located about 1,000 feet from the river. La Sala (1968) reports that groundwater temperature from the Camillus Shale is approximately 50°F (10°C), with an annual range of only about 1 or 2°F (0.6 to 1.1°C). The temperature range of extracted groundwater, however, was observed to be about 12°F (6.7°C), and mirrored the temporal distribution of temperatures in the Niagara River, but at a lower amplitude (Figure 3-3). These temperature fluctuations were also observed to be about two months out of phase with the river, a relationship attributed by La Sala (1968) to the travel time of water from the river to the well. It is more likely, however, that river water reached the DuPont well more quickly than this given the large extraction rates, and that this water was cooled by the colder rock mass as it flowed to the well. The phase shift, therefore, represents the time required to heat the rock conductively by the warmer river water, thereby allowing warmer water to reach the well. Such a phenomenon has been observed in the City of Niagara Falls along the Niagara River (Bill Kappel, personal communication).

To summarize the problem, the source of water supplying the Dunlop production well is unknown. Such identification is critical, however, as groundwater extraction could exacerbate the migration of contaminants from the nearby inactive hazardous waste sites within the Study Area. The potential sources of water supplying the well include: (1) Camillus Shale groundwater from the screened zone of the production well, (2) upper bedrock and deep overburden groundwater infiltrating to the screened zone through vertical fractures in the bedrock, and (3) water from the Niagara River that recharges the Camillus Shale during active groundwater extraction. In order to determine which source(s) is(are) supplying the Dunlop production well, a complete understanding of the geology and hydrogeology of the Study Area is required.

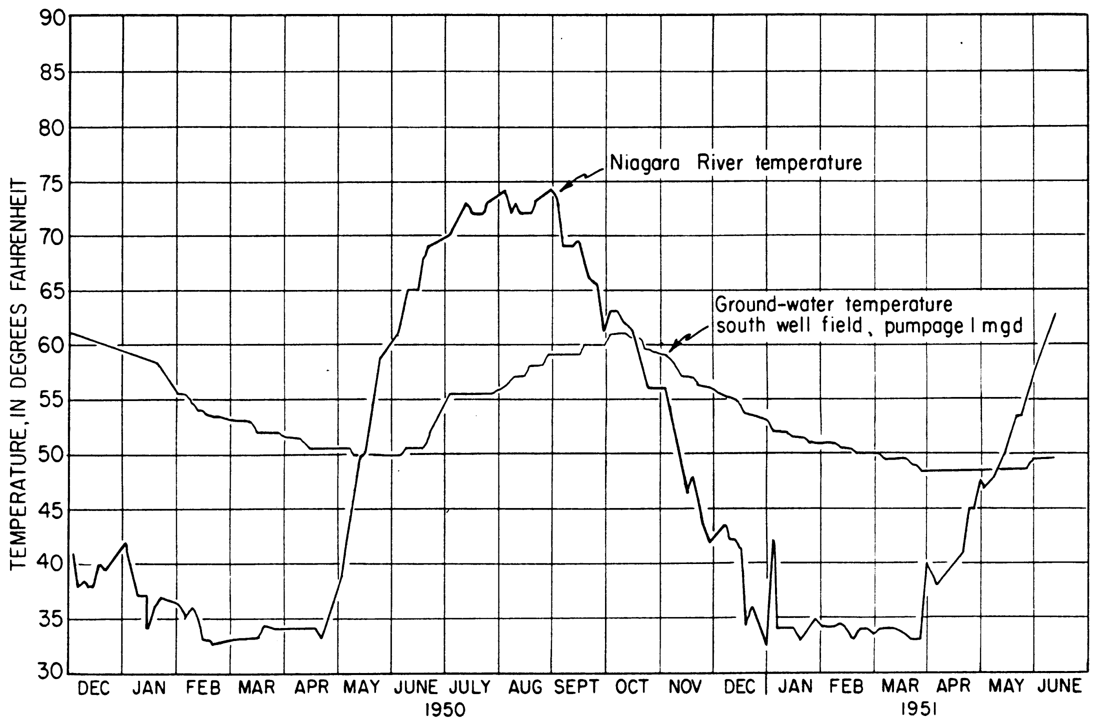


Figure 3-3. Temperatures of Niagara River Water and Groundwater Extracted by the E.I. DuPont Yerkes Plant. From La Sala (1968).

3.2 Objectives

The purpose of this study was to obtain information sufficient to further evaluate the effect of groundwater extraction by the Dunlop Tire Corporation. The specific objectives of the study are summarized as follows:

- confirm that groundwater extraction by the Dunlop Tire Corporation produces the observed groundwater elevation declines observed at the Polymer Applications Site, and if confirmed, to determine the source of water being extracted by the well;

- determine the characteristics, areal extent and hydrogeologic properties of strata underlying the Study Area;

- describe the hydrogeologic conditions of the area, including groundwater elevations and groundwater flow patterns; and

- delineate the temporal and spatial distribution of groundwater elevation declines throughout the

Study Area.

The geology and hydrogeology of the area are evaluated in detail, with the information utilized to develop a conceptual geochemical model. Geochemical data were obtained during this study and evaluated within the framework of this model and utilized to determine the source of water being extracted by the Dunlop production well.

3.3 Investigative Approach

To meet the study objectives, the geology and hydrogeology of the area were evaluated in detail during Phase I of this study, which included the following activities: (1) a boring and test pit inventory, (2) a well inventory, (3) water level measurements, (4) completion and compilation of recharge and pump test data, and (5) compilation of precipitation and evapotranspiration data. These activities are briefly described in the following sections.

3.3.1 *Boring and Test Pit Inventory*

Information concerning borings and test pits, such as location, owner, elevation, total depth, date completed and stratigraphy was compiled from site investigation reports. More than 400 boring and test pit logs were compiled, the locations of which are shown on Plate 1. The stratigraphic information obtained from these logs was utilized to evaluate the geology of the Study Area.

3.3.2 *Well Inventory*

Information concerning monitoring wells, such as location, owner, elevation, total depth, date drilled, and screened geologic unit was compiled from several sources including well logs provided by the United States Geological Survey, site investigation reports, and La Sala (1968). Plate 2 shows the locations of wells utilized in this study. Abandoned wells, or wells not utilized in this study, are shown on Plate 1. To resolve uncertainties in previous well surveys, four deep overburden monitoring wells were resurveyed by 3M O-Cel-O during the week of July 17, 1995 and nine deep overburden and upper bedrock monitoring wells were resurveyed by the NYSDEC during the week of August 13, 1995.

3.3.3 *Water Level Measurements*

To evaluate the hydrogeology of the shallow and intermediate depth overburden soils, water levels were measured monthly in 22 shallow overburden and 15 intermediate overburden wells beginning in August 1995. Historical water level measurements from monitoring wells within the Study Area were also obtained from site investigation reports and evaluated as part of this study. Water level measurements for the Niagara

River were obtained from water resources data compiled by the United States Geological Survey (Hornlein et al., 1995).

To evaluate the hydrogeology of the deep overburden soils and upper bedrock, water levels were measured weekly in 17 deep overburden and upper bedrock monitoring wells from April 1995 through January 1996, and in one newly installed deep overburden monitoring well at the 3M O-Cel-O Sponge plant from July 1995 through January 1996.

The water level data obtained during this study were utilized to construct hydrographs and groundwater contour maps for shallow overburden, intermediate overburden, deep overburden and upper bedrock water bearing zones.

3.3.4 *Recharge and Pump Tests*

To evaluate the hydrogeologic properties (i.e., hydraulic conductivity) of the strata underlying the Study Area, hydraulic conductivity values determined from slug, packer and laboratory tests were compiled from site investigation reports, while several bail down tests were conducted on the Dunlop Tire Corporation shallow and intermediate overburden wells. Aquifer transmissivity and storativity were also compiled when available.

3.3.5 *Precipitation and Evapotranspiration Measurements*

Monthly, annual, and long-term average precipitation values were compiled from data collected by the U.S. Weather Service station at the Buffalo International Airport located 10 miles east of the Study Area. These data are summarized in Table 3-1 and shown graphically in Figure 3-1. Potential evapotranspiration estimates were taken from Staubitz and Miller (1987) and are also summarized in Table 3-1. The data from Table 3-1 were compared to the groundwater elevation data from the shallow and intermediate overburden wells to evaluate the effect of precipitation and evapotranspiration on water levels in these wells.

The data obtained during Phase I of this study were evaluated to develop a complete understanding of the geology and hydrogeology of the Study Area, which forms the framework for the geochemical evaluations that were completed as Phase II of this study. Activities completed during Phase II included the following: (1) measurement of field parameters, (2) collection of water samples for chemical analysis, (3) development of a conceptual geochemical model, and (4) geochemical evaluation of the data. These activities are briefly described in the following sections.

Table 3-1. Monthly Precipitation Data as Measured at the U.S. Weather Service Station at the Buffalo International Airport.				
Month	**Long Term Mean Monthly Precipitation (inches)**	**Mean Monthly Precipitation, 1990-1994 (inches)**	**1995 Monthly Precipitation (inches)**	**Potential Evapotranspiration (Staubitz and Miller, 1987)**
January	2.70	2.80	4.89	0.46
February	2.31	2.75	2.62	0.43
March	2.68	3.21	1.33	0.89
April	2.87	4.46	1.41	1.69
May	3.14	3.60	2.40	3.13
June	3.55	3.18	1.33	4.26
July	3.08	3.85	3.53	5.31
August	4.17	3.57	2.07	4.32
September	3.49	4.22	1.32	2.55
October	3.09	3.21	6.07	1.51
November	3.83	3.84	4.14	0.71
December	3.67	4.52	2.88	0.48
Totals	**38.58**	**43.21**	**33.99**	**25.74**

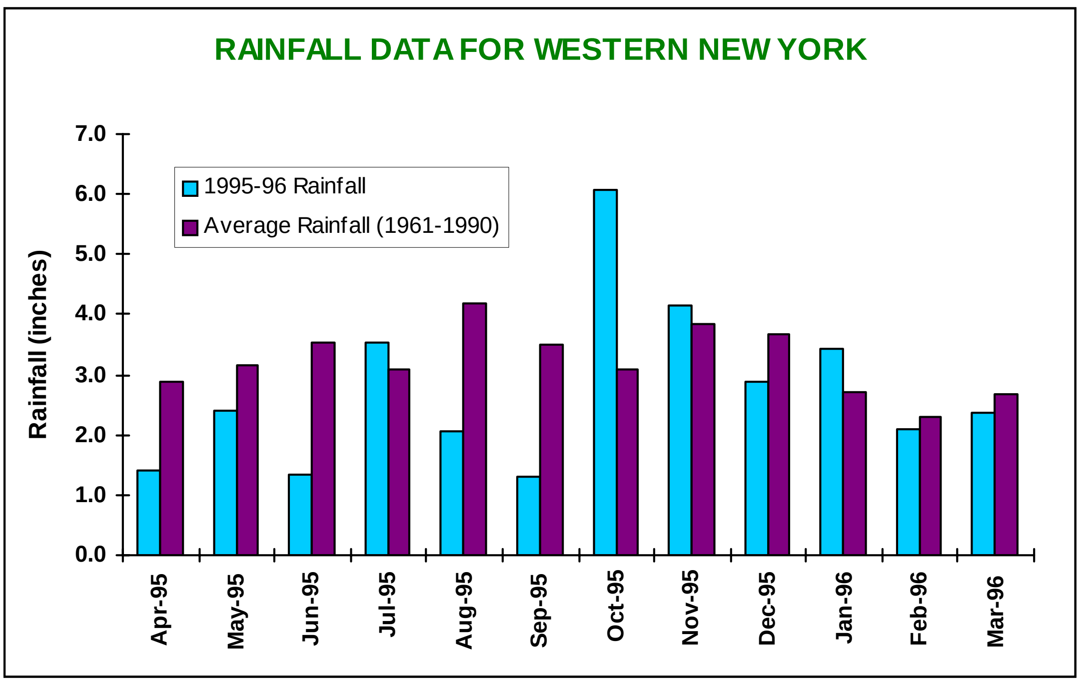


Figure 3-4. Rainfall Data for Western New York (NOAA, 1996).

3.3.6 *Chemical Analyses and Measurement of Field Parameters*

Historical chemical analyses of groundwater samples for organic and inorganic contaminants were compiled and evaluated. Groundwater samples were also collected for chemical analyses by several companies during this study and were also compiled and evaluated. Since the existing water quality database for the Study Area was not extensive enough for evaluation with geochemical methods, 70 samples were collected from area wells and analyzed by Recra Environmental, Inc. in Amherst, New York for major cations and anions (calcium, magnesium, sodium, potassium, sulfate, chloride and alkalinity). Specific conductance, pH, Eh, temperature and turbidity were measured in the field at the time of sample collection.

Historical water quality data (1985 through 2003) for the Niagara River were also compiled and evaluated. In addition, one sample of Niagara River water at Aqua Lane Park was collected during this study for chemical analysis of the major cations and anions. Since the Dunlop production well obtains water from the Camillus Shale, and because only two wells within the Study Area totally screen this unit, water quality data from bedrock wells at a site north of the Study Area were also compiled and evaluated.

3.3.7 *Development of a Conceptual Geochemical Model*

As groundwater flows through the subsurface environment, it evolves geochemically based upon the minerals present in the aquifer and the solubility of those minerals. As a general rule, the concentration of major ions will increase naturally. This generalization suggests that shallow groundwater in recharge areas will be lower in major ion concentrations than shallow groundwater in discharge areas, and further, will also be lower in major ion concentrations than groundwater deeper in the system (Freeze and Cherry, 1979). Combining this general principle with the known hydrogeology of the Study Area, a conceptual geochemical model for the area was developed to provide the framework in which to conduct detailed geochemical evaluations.

3.3.8 *Geochemical Evaluation*

Once the water quality database was obtained and the conceptual geochemical model developed, detailed geochemical evaluation was conducted. This evaluation included the construction of scatter and piper plots. The results of the geochemical evaluation were then evaluated within the framework of the conceptual geochemical model.

3.4 Benefits of the Study

This study was initially conducted to evaluate further the effect of groundwater extraction by the Dunlop Tire Corporation, to determine the source(s) of water being extracted by the well, and to delineate the temporal and spatial distribution of groundwater elevation declines throughout the Study Area. Prior to this study, the source of water supplying the Dunlop production well was unknown. Such identification is critical as groundwater extraction could exacerbate the migration of contaminants from the nearby inactive hazardous waste sites, and particularly the Polymer Applications Site, where deep overburden groundwater is significantly contaminated with phenols. The results of this study, however, can be extended to other portions of Tonawanda and nearby locales where the geology and hydrogeology are similar. Since a large number of inactive hazardous waste sites and landfills are located in these areas, the findings of this study, especially the detailed evaluation of the geology and hydrogeology, have far reaching applications.

4.0 SURFACE WATER HYDROLOGY

Due to the large number of inactive hazardous waste sites within the Study Area, surface water runoff is a potential pathway for the migration of contaminants to the Niagara River. In addition, infiltration of surface water and precipitation recharges shallow groundwater, and in the process, leaches contaminants from the waste material through which it passes. Surface water hydrology, therefore, is an important aspect of this study as the leaching of contaminants has the potential to impact deeper water bearing zones; water from these zones has the potential to migrate to the Dunlop production well. This section describes the surface water hydrology of the Study Area, which includes precipitation, evapotranspiration, and site drainage and infiltration characteristics.

4.1 Precipitation

Infiltration, and hence groundwater recharge, depends upon the amount of precipitation falling on an area and the amount of water lost through evapotranspiration (discussed below) and runoff. The long term mean annual precipitation in the western New York area as measured at the Buffalo International Airport is 38.58 inches (Table 3-1), which equates to a mean monthly precipitation of 3.22 inches. This precipitation is fairly evenly distributed throughout the year (Table 3-1; Figure 3-4), although slightly larger amounts fall in June, August, September, November, and December. Severe droughts are rare, but periods of low precipitation and relatively high temperatures are common, sometimes causing at least temporary concern over declining water supplies and moisture stress in crops and other vegetation. Precipitation generally falls as rain from April through November, and as snow from December through March. The mean annual snowfall in the area is 93 inches, with two-thirds of this total falling between December and February (Bechtel, 1993). The snowpack generally reaches its maximum depth in February, and decreases in March and early April (Dethier, 1966). During this snowmelt period, there is a significant increase in both surface water runoff and groundwater recharge.

In contrast to the long term mean annual precipitation, the mean annual precipitation in western New York from 1990 through 1994 was 43.21 inches (Table 3-1), a 12% increase over the long term mean annual precipitation. The largest increase during this period occurred in the late winter and spring months, with April exhibiting the largest increase in precipitation (+1.59"). The total precipitation measured at the Buffalo International Airport during 1995, however, was only 33.99 inches (Table 3-1), a decrease of ≈12% over the long term mean annual precipitation and a decrease of ≈21% over the mean annual precipitation between 1990 and 1994. While the monthly precipitation for January and October 1995 was substantially higher than the long term means for these months (+2.19" and +2.98", respectively), the monthly precipitation for March, April, May, June, August and September was substantially lower (-1.35", -1.46", -0.74", -2.22", -2.10" and

-2.17", respectively) than the long term means for these months.

4.2 Evapotranspiration

Evapotranspiration is defined as the sum of the water loss attributable to evaporation from soil and surface water bodies (e.g., lakes, rivers, wetlands) and to transpiration by plants (Staubitz and Miller, 1987). Since quantifying the contribution to water loss by each mechanism is generally not possible, the term potential evapotranspiration was introduced and is defined as the maximum evapotranspiration that would occur if the quantity of water available in soil was unlimited (Freeze and Cherry, 1979). Under actual field conditions where soil moisture is limited, evapotranspiration will always be less than the potential evapotranspiration.

Specific estimates of potential evapotranspiration rates for the Study Area were not made as part of this study; however, annual evapotranspiration rates for the nearby Ashland 1 and 2 sites (near the Ashland Tank No. 75 Site on Figure 2-1) have been estimated. In addition, Staubitz and Miller (1987) report monthly potential evapotranspiration rates for the Clarence-Newstead area of northeastern Erie County (Table 3-1). The annual evapotranspiration rates for the Ashland 1 and 2 sites were estimated at 29.4 inches, 28.2 inches and 29.2 inches for the years 1987, 1988 and 1989, respectively (Bechtel, 1993). These rates are similar to the 25.74 inch annual estimate for the Clarence-Newstead area (Staubitz and Miller, 1987). Because of this similarity, the monthly evapotranspiration rates reported by Staubitz and Miller (1987) are believed to accurately represent potential evapotranspiration rates for the Study Area.

4.3 Site Drainage Characteristics

In order to develop a complete understanding of surface water runoff and infiltration within the Study Area, drainage characteristics will be described by site. In general, however, surface water runoff from the area drains predominantly through ditches and storm sewers that ultimately discharge to either the Niagara River or the Tonawanda Publicly Owned Treatment Works (POTW). Infiltration is highly localized, occurring primarily through the bottom of ditches, wetlands, and surface water impoundments/ponds at the various industrial properties within the Study Area.

4.3.1 *Polymer Applications Site*

Surface water runoff from the Polymer Applications Site is controlled largely by perimeter ditches and a containment wall constructed around the rear portion of the Polymer property (Figure 4-1). Runoff from the front of the property collects in ditches along the northern and southern property lines. Drainage from these ditches is directed through two corrugated pipes to a ditch west of River Road, flows south to a slag pond on the Niagara Mohawk Huntley Plant property (Plate 1), and discharges directly into the Niagara River. On-site drainage confined by the containment wall exits the site through sewers to the Town of Tonawanda sanitary sewer system or by infiltration into the fill material and subsurface native soil. Water entering the Town of Tonawanda sanitary sewer system is directed to the Tonawanda POTW for treatment.

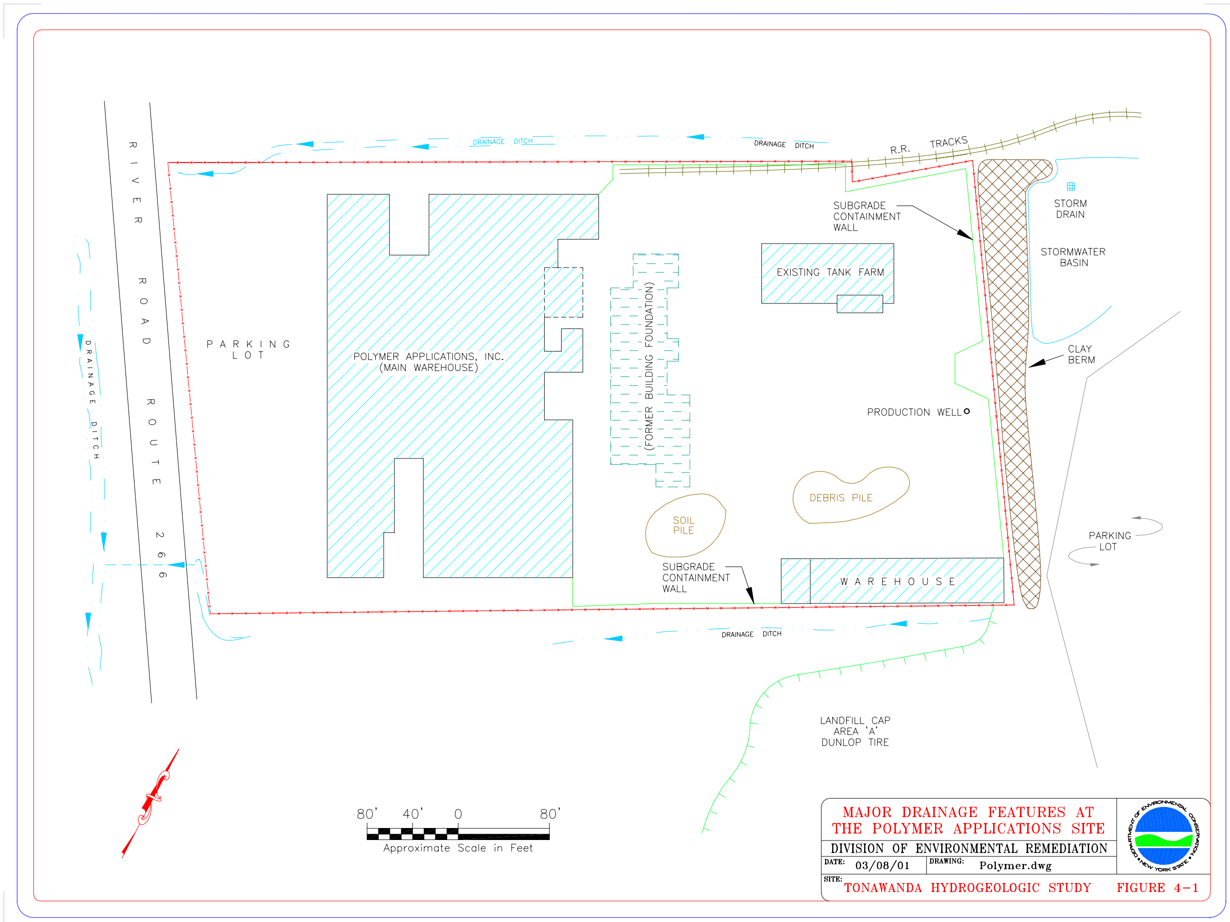


Figure 4-1. Major Drainage Features at the Polymer Applications Site.

4.3.2 *Dunlop Tire Corporation*

Surface water runoff from the Dunlop property is controlled by an extensive storm sewer system and a series of ditches. Surface water from the area immediately surrounding plant buildings drains into a storm sewer system that discharges to an on-site settling pond (Plate 1) permitted under the State Pollution Discharge and Elimination System (SPDES) program. Non-contact cooling water utilized during manufacturing operations also discharges to this pond. Discharge from the settling pond flows under River

Road, enters a 4-foot diameter corrugated steel pipe, and discharges directly into the Niagara River. Total discharge from this outfall is approximately 6 million gallons per day (mgd) (Parshall, personal communication). Runoff from the eastern portion of the Dunlop property collects in a series of ditches and a wetland area surrounding the capped landfills. The ditches drain into a single ditch west of the landfills before discharging into a storm sewer along Sheridan Drive. This discharge is also permitted under the SPDES program.

Runoff from the northern portion of the Dunlop property collects in a ditch along the northern property line and flows westward toward the stormwater basin behind the Polymer Applications Site (Figure 4-1). This basin drains into the storm sewer system that discharges into the settling pond. Most runoff from the western portion of the Dunlop property is directed to either the settling pond or the borrow pit excavated during site remediation activities (Plate 1). Some runoff from the Area A cap (Figure 4-1), however, also collects in the ditch along the southern property line of the Polymer Applications Site. This discharge is permitted under the SPDES program.

In addition to receiving surface water runoff, the settling pond, borrow pit and wetland also capture precipitation directly. Water collecting in the borrow pit is allowed to evaporate and infiltrate into the subsurface soil unless reaching a predetermined height, at which point it is pumped into the settling pond. Water from this pond also infiltrates into the subsurface soil, locally recharging shallow groundwater in this area of the property. Water collecting in the wetland can also recharge shallow groundwater, but is largely lost to evapotranspiration during the hot summer months when the wetland is typically dry.

4.3.3 *E.I. DuPont Yerkes Plant*

The E.I. DuPont Yerkes Plant is permitted under the SPDES program to discharge storm water, non-contact cooling water, backwash wastewater from an on-site water treatment plant and boiler blowdown water into the Niagara River. Approximately 3.1 mgd of pretreated water is discharged to the river through the facility’s SPDES outfall (Smythe, personal communication). Surface water runoff from the plant collects in a series of storm sewers that connect to a single storm sewer along River Road. This storm sewer also discharges directly into the Niagara River through the SPDES outfall.

All process wastewater generated at the plant is discharged to the Town of Tonawanda sanitary sewer system where it is directed to the Tonawanda POTW for treatment. These discharges are regulated in accordance with the town sewer use ordinance and industrial pretreatment program, which is overseen by the Department's Division of Water.

4.3.4 *Niagara Mohawk Huntley Plant*

The Niagara Mohawk Huntley Plant (now owned by NRG Thermal, LLC) is permitted under the SPDES program to discharge cooling water, storm water and treated process wastewater via eight outfalls into the Niagara River. While some of this water can be discharged directly into the river, other process water is first sent to a series of slag ponds (Plate 1) for solids settling prior to discharge. Within the facility, water is utilized for condenser cooling, boiler make-up, ash removal, metals cleaning and sanitary purposes. Water for sanitary use is obtained from municipal supplies, while all other water is obtained directly from the Niagara River.

Runoff from the coal pile and wastewater from the metals treatment plant is pumped directly into one of two concrete equalization lagoons. Each lagoon has a capacity of approximately one million gallons. The wastewater treatment process consists of hydroxide metals precipitation using lime (for manganese and iron removal), polymer enhanced sedimentation and pH adjustment. Metal sludge is gravity thickened, dewatered and incinerated with coal in the facility boilers. Treated water in the equalization lagoons is discharged directly into the Niagara River through one of the SPDES outfalls. Shallow groundwater is locally recharged by infiltration through the bottom of the slag ponds.

4.3.5 *3M O-Cel-O Sponge Plant*

Most surface water runoff from the 3M O-Cel-O Sponge plant collects in an on-site storm sewer system that discharges to a ditch along Sawyer Avenue. Water in this ditch flows westward along Sawyer Avenue before discharging directly into the Niagara River through one of the SPDES outfalls on the Niagara Mohawk Huntley Plant property. Runoff from the rear portion of the O-Cel-O property is directed toward either catch basins that connect with the on-site storm sewer system, a wetland area located east of the property, or a ditch along the railroad right-of-way. Water collecting in the wetland locally recharges shallow groundwater, but is largely lost to evapotranspiration during the hot summer months when the wetland is typically dry.

All process wastewater generated at the plant is discharged to the Town of Tonawanda sanitary sewer system where it is directed to the Tonawanda POTW for treatment. These discharges are regulated in accordance with the town sewer use ordinance and industrial pretreatment program.

4.3.6 *FMC Tonawanda Plant*

The FMC Tonawanda Plant is permitted under the SPDES program to discharge storm water, treated process wastewater, deionizer recharge water and boiler blowdown water into the Niagara River through one of the SPDES outfalls on the Niagara Mohawk Huntley Plant property. Surface water runoff from the western portion of the FMC property is directed to ditches along Sawyer Avenue and River Road, which discharge directly into the Niagara River. Some runoff also occurs from the southern portion of the property along the Niagara Mohawk rail spur. This drainage, however, ultimately collects in the ditch along River Road and is discharged directly into the Niagara River.

4.4 Niagara River

The Niagara River forms the western boundary of the Study Area (Figure 2-1), and as described above, receives discharges from several industries in the area. The river is designated as a Class A-Special waterway by the NYSDEC, indicating that it can be utilized for consumption and recreational purposes. The Niagara River is a source of municipal drinking water for a population of more than 600,000 people (NYSDEC, 1994). The Erie County Water Authority VanDeWater Intake and the Tonawanda Water District No. 1 Intake are located within the Study Area, while the Erie County Water Authority treatment plant is located a short distance to the north along River Road. Numerous industries throughout western New York also withdraw water directly from the river for process and cooling purposes.

Within the Study Area, the principal industrial users of Niagara River water are the Dunlop Tire Corporation, the E.I. DuPont Yerkes Plant, and the Niagara Mohawk Huntley Plant. At all three facilities, non-contact cooling and/or process water is pumped directly from the river. At the Dunlop facility, however, non-contact cooling water is pumped directly from the Camillus Shale bedrock from approximately June through November when river temperatures are sufficiently high to prohibit proper cooling. Historically, the E.I. DuPont Yerkes Plant also utilized water extracted from the Camillus Shale, but this practice has been discontinued.

5.0 GEOLOGY

One objective of this study was to establish the characteristics, areal extent and hydrogeologic properties of strata underlying the Study Area. This is important as these attributes govern the occurrence and flow of groundwater across the area. These attributes also govern the potential for contaminant migration from the area, and determine the rate and extent of this migration. As a result, a detailed evaluation of the Study Area geology is essential. Before completing such a detailed evaluation, however, it is important to first describe the regional geologic history of the western New York area as a general knowledge of this history is critical to a complete understanding of the complex interrelationships between the various geologic strata and their hydrogeologic properties.

5.1 Regional Geology

Much of western New York, and all of Tonawanda, is located within the Erie-Niagara Drainage Basin of the Erie-Ontario Lowlands Physiographic Province of New York State. This basin borders Lake Erie and the Niagara River to the west, and includes all of Erie County, the southern portion of Niagara County, the western portions of Genesee and Wyoming Counties, the northern portion of Cattaraugus County and small portions of Alleghany and Chautauqua Counties (Figure 5-1). The stratigraphic sequence of the Erie-Niagara Basin generally consists of glacially-derived lacustrine, fluvial and till deposits of Pleistocene age overlying Silurian and Devonian age bedrock (La Sala, 1968; Koszalka et al., 1985).

5.1.1 *Surficial Geology*

Geologic evidence suggests that at least four major glacial episodes covered parts of North America during the Pleistocene Epoch (Buehler and Tesmer, 1963). In western New York, however, there is evidence of only two such episodes. The last glacial event in the area, the Wisconsin, eroded and modified the earlier glacial deposits to such an extent that little evidence of their existence remains. These glacial events also resulted in the widening of preexisting valleys and basins, and led to the development of the present day drainage system of the western New York area (La Sala, 1968).

A complex sequence of proglacial lakes that formed during the final retreat of the Wisconsin ice sheet inundated an extensive area of western New York. This succession originated in the Erie-Huron Basin prior to 14,000 years ago as the ice sheet retreated from the basin. Further retreat produced Lake Arkona about 13,600 years ago (Hough, 1958). A readvance of the ice sheet followed about 13,000 years ago and resulted in a water level increase to the Lake Whittlesey stage. A series of advances and retreats over the next 300 years produced, from latest to earliest, lakes Warren, Wayne, Lowest Warren, Grassmere, Lundy and Tonawanda, the last forming about 9,800 years ago (Calkins and Brett, 1978). To the north, Lake Iroquois occupied the Ontario Basin at this time. This lake sequence was responsible for the deposition of stratified lacustrine clays, silts, sands and gravels that now cover much of western New York.

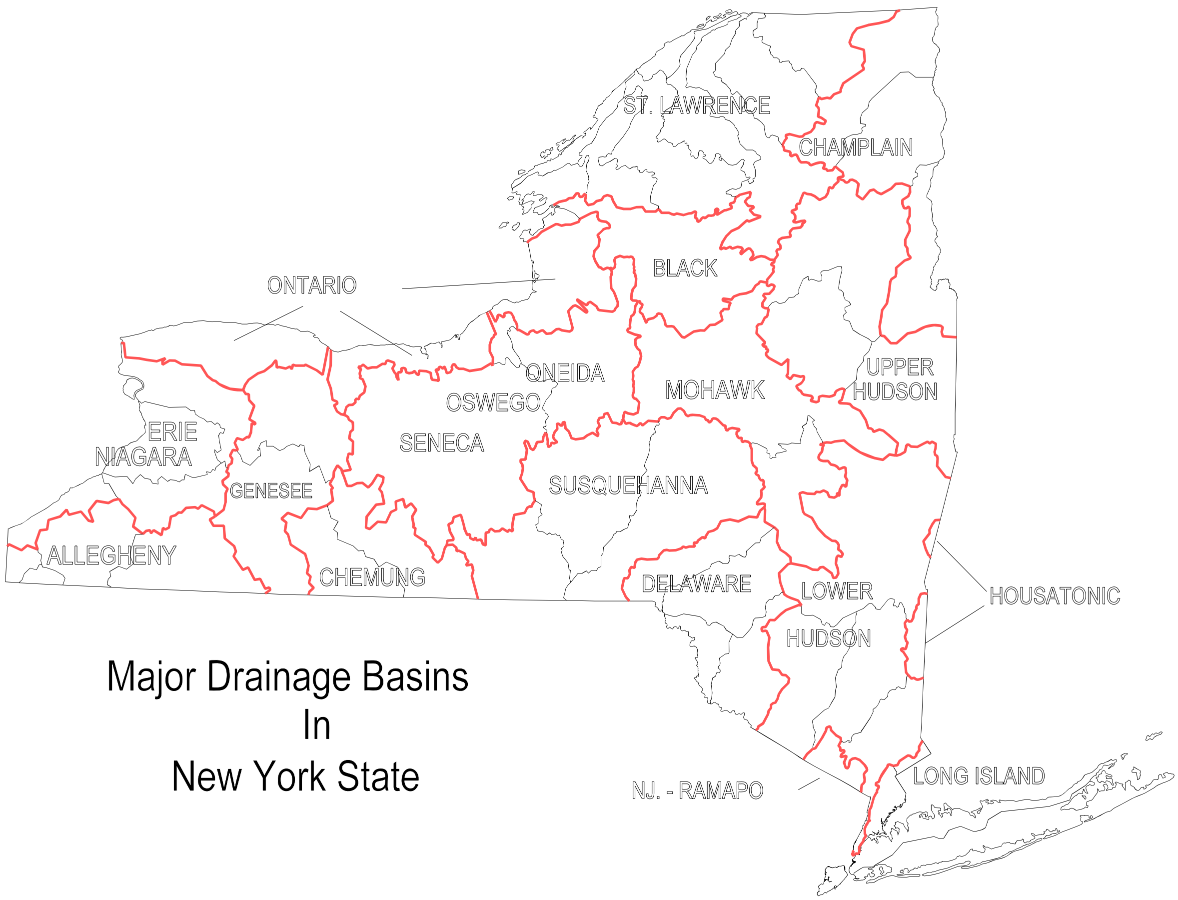


Figure 5-1. Location Map of the Erie-Niagara Basin.

The Pleistocene Epoch presented a variety of environments that resulted in the deposition of several types of unconsolidated deposits. In the Tonawanda area these deposits include the following (Malcolm Pirnie, 1987; Recra Environmental, 1990; URS, 1992; Woodward-Clyde, 1993; Conestoga Rovers & Associates, 1997; Weston, 1998):

- Glacial till consisting of a non-sorted, non-stratified mixture of sand, silt, clay, gravel and rock fragments deposited directly from glacial ice;

- Glaciolacustrine deposits consisting primarily of silt, sand and clay deposited in lakes that formed during melting and retreat of the ice sheets;

- Glaciofluvial deposits consisting of sand and gravel deposited either by glacial meltwater streams or by the reworking of till and other glacial deposits along the shore of former glacial lakes; and

- Alluvial deposits consisting of silt, sand and gravel deposited by streams during comparatively recent geologic time.

La Sala (1968) reports that glacial till is the most widespread deposit in the Erie-Niagara Basin, ranging in thickness from 2 to 200 feet. Lacustrine clay is also widespread, reaching thicknesses of 300 feet in some valleys within the basin (La Sala, 1968). In the Tonawanda area, the combined thickness of glacial till and lacustrine clay ranges from approximately 65 feet at the Study Area to more than 95 feet at the Town of Tonawanda Landfill located approximately 1.25 miles to the northeast (Malcolm Pirnie, 1995).

5.1.2 *Bedrock Geology*

The bedrock underlying western New York is characterized as a thick sequence of shales, sandstones, limestones and dolostones deposited in ancient seas during the Silurian and Devonian Periods (Buehler and Tesmer, 1963). This stratigraphic sequence is summarized in Table 5-1. Bedrock bedding generally strikes in an east-west direction, approximately paralleling the Niagara and Onondaga escarpments, and dips to the south at approximately 30 to 40 feet per mile (Johnson, 1964; La Sala, 1968; Yager and Kappel, 1987). Erosion and weathering, however, have produced local differences in the bedrock surface configuration (Snyder Engineering, 1987).

The uppermost bedrock formation underlying the Study Area is the Camillus Shale Formation of the Salina Group, which was deposited in a shallow sea environment during the Late Silurian Period (Rickard and Fisher, 1970). This formation extends across northern Erie County in an east-west trending belt approximately 6 to 8 miles wide (Conestoga-Rovers & Associates, 1997). Exposures of this formation are rare because of the low relief of the outcrop area and the mantle of glacial deposits. Buehler and Tesmer (1963, page 30) describe the Camillus Shale as a "thin bedded shale to massive mudstone. Color is gray or brownish gray with some beds showing a red or green tinge. Gypsum and anhydrite are present throughout the formation in Erie County," and occur in beds and lenses up to 5 feet in thickness (La Sala, 1968). Subsurface data indicate, however, that a considerable quantity of grey limestone and dolostone is

Table 5-1.
Stratigraphic Sequence of the Western New York Area. Compiled from Buehler and Tesmer (1963) and Brett et al. (1995).

Epoch	Group	Formation	Member
Middle Devonian	Hamilton	Moscow Shale	Windom Shale Kashong Shale
		Ludlowville Formation	Tichenor Limestone Wanakah Shale Ledyard Shale Centerfield Limestone
		Skaneateles Formation	Levanna Shale Stafford Limestone
		Marcellus Shale	Oatka Creek Shale
		Onondaga Limestone	Seneca Limestone Morehouse Limestone Nedrow Limestone Clarence Limestone Edgecliff Limestone
Late Silurian	Salina	Akron Dolostone	
		Bertie Dolostone	Williamsville Dolostone Scajaquada Dolostone Falkirk Dolostone Oatka Dolostone
		Camillus Shale Syracuse Formation Vernon Shale	
Middle Silurian	Lockport	Guelph Dolostone Eramosa Dolostone	
		Goat Island Dolostone	Vinemount Dolostone Ancaster Dolostone Niagara Falls Dolostone
		Gasport Limestone	Pekin Dolostone Gothic Hill Limestone
	Clinton	Decew Dolostone	
		Rochester Shale	Burleigh Hill Shale Lewiston Shale
		Irondequoit Limestone Rockway Dolostone Williamson Shale Merritton Limestone	
		Reynales Limestone	Hickory Corners Limestone
		Neahga Shale	
Early Silurian	Medina	Kodak Sandstone Cambria Shale Thorold Sandstone Grimsby Formation Devils Hole Shale Power Glen Shale Whirlpool Sandstone	
Late Ordivician	Richmond	Queenston Shale Oswego Sandstone	

interbedded within the shale (Stanley Consultants, 1981; GZA, 1983; URS, 1992; Woodward-Clyde, 1993; Parsons Engineering Science, 1995). The upper 10 to 25 feet of this formation can be heavily weathered and often contains abundant bedding planes and vertical fractures enlarged by dissolution and glacial scour (La Sala, 1968). Buehler and Tesmer (1963) report that the maximum thickness of the Camillus Shale is 400 feet. Within the Erie-Niagara Basin, however, the thickness of this formation ranges from approximately 80 to 100 feet (Rickard, 1966).

5.2 Study Area Geology

The stratigraphy of the Study Area has been evaluated by examining approximately 460 stratigraphic logs obtained from borings, monitoring wells, and test pits completed at the various sites within the area (Table A-1 in Appendix A). The locations of all borings and test pits evaluated during this study are shown on Plate 1, while the locations of all monitoring wells are shown on Plate 2. These stratigraphic logs indicate that most intrusive activities have been confined to the fill material and the upper 25± feet of the underlying native deposits. Numerous borings, however, have completely penetrated these deposits, while several borings have been advanced into the underlying Camillus Shale bedrock. Figure 5-2 is a geologic cross section constructed from these logs, and is referenced in the following discussion where appropriate.

5.2.1 *Fill*

Fill material overlies the native deposits throughout most of the Study Area (Figure 5-2), but is largely discontinuous from site to site (Figure 5-3). Where fill material is absent, native deposits are encountered immediately below a thin topsoil layer. The fill material encountered consists predominantly of production wastes, off-specification products, miscellaneous plant wastes, flyash, slag and coal. These materials were typically disposed directly on plant property, either in natural low lying areas or within pits excavated into the native deposits for disposal purposes. Where encountered, fill ranges from trace thicknesses to 34.5 feet, with the thickest fill areas at the E.I. DuPont Yerkes and the Niagara Mohawk Huntley plants (Figure 5-3; Table A-1). At the E.I. DuPont Yerkes Plant these areas are associated with disposal pits excavated into the native deposits, while at the Niagara Mohawk Huntley Plant these areas are associated with disposal in low lying areas along the Niagara River. Excluding these two sites, the thickness of fill throughout the Study Area is generally less than 4 feet (Figure 5-3; Table A-1).

5.2.2 *Glaciolacustrine Deposits*

Throughout most of the Study Area a thick, continuous, glaciolacustrine deposit either underlies the fill material or is encountered immediately below the thin topsoil layer. This deposit represents the largest

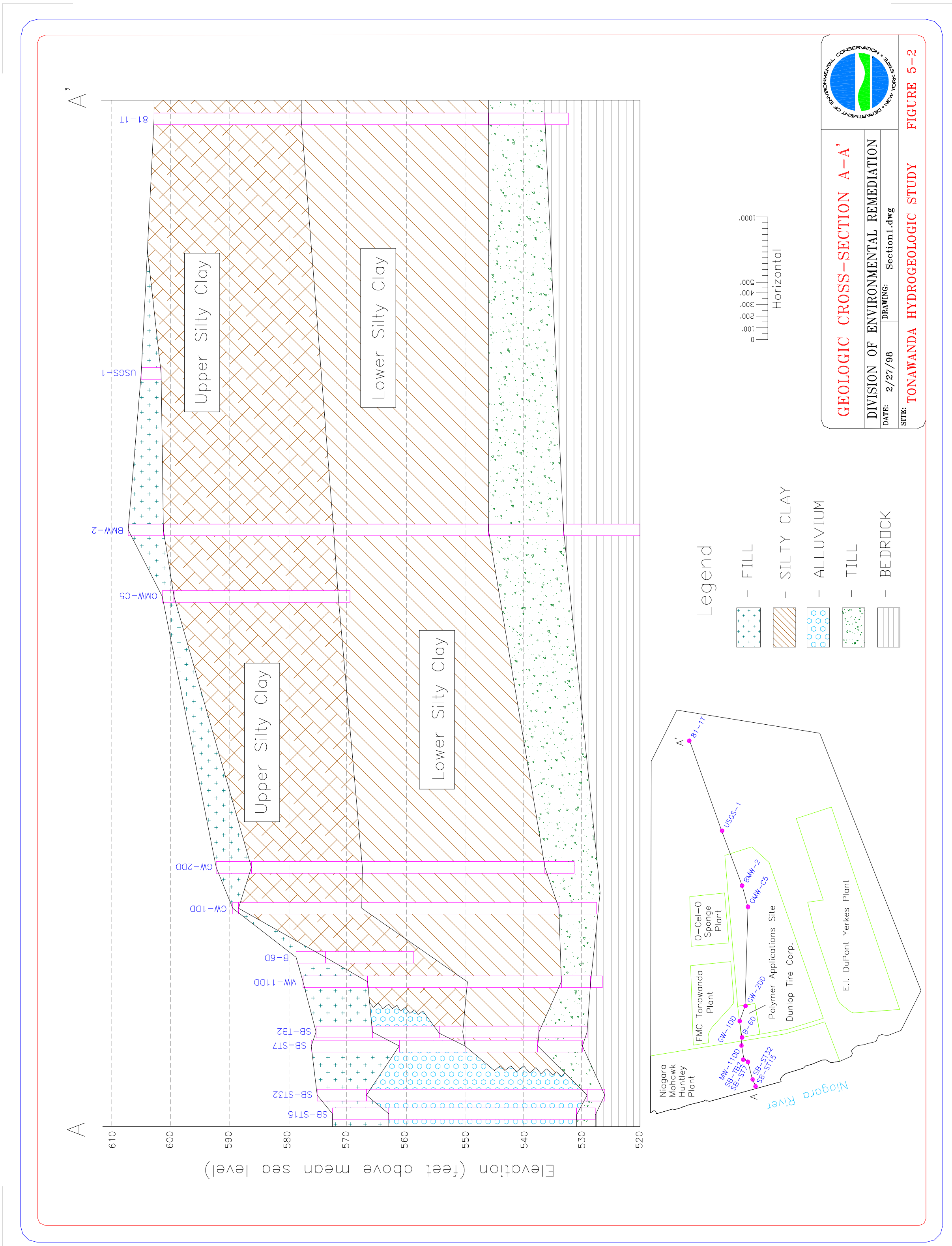


Figure 5-2. Geologic Cross-Section A-A'.

Fill Thickness Map

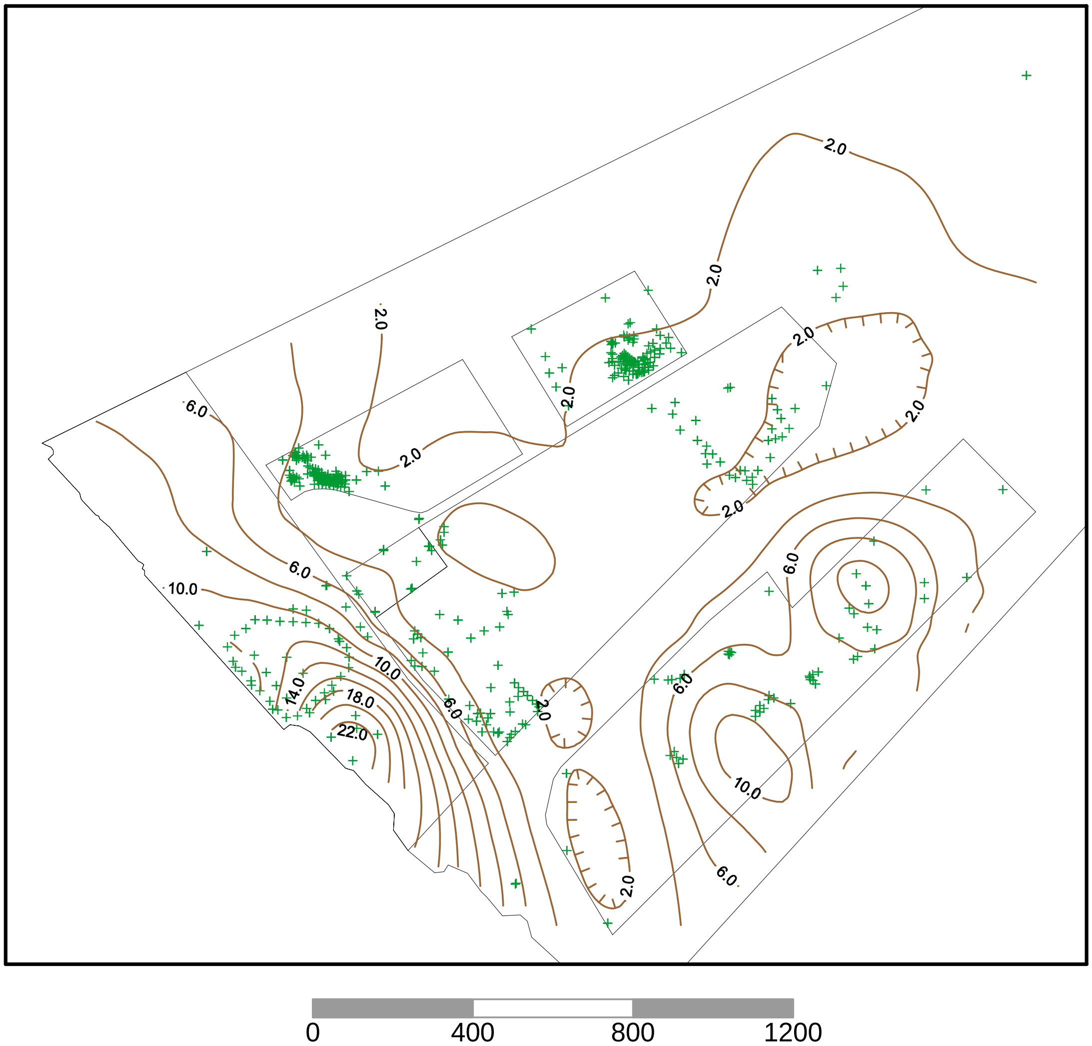


Figure 5-3. Fill Thickness Contour of the Study Area. Boring, Monitoring Well and Test Pit Locations are Shown as Crosses. Scale in Meters.

percentage of native soils underlying the area, and was encountered at every site. The glaciolacustrine deposit consists of two subunits distinguished primarily by moisture content and relative permeability, which are described as follows:

- **Upper Silty Clay:** This subunit is typically 25 to 30 feet thick (Figure 5-2), and consists predominantly of reddish brown to brown, very firm to stiff, dry to moist, low to medium plasticity, silty clay. The upper silty clay typically contains 15 to 30% silt and 5 to 15% gravel

(Weston, 1998). The upper several feet of this subunit are commonly mottled, with yellow, brown, orange and gray being the most predominant colors. Vertical desiccation cracks are pervasive throughout the upper silty clay, which results in a higher permeability in this subunit relative to the lower silty clay.

- **Lower Silty Clay:** This subunit is also typically 25 to 30 feet thick (Figure 5-2), and consists predominantly of reddish brown to brown, soft to very soft, saturated, highly plastic, silty clay. The lower silty clay typically contains 5 to 15% silt and 0 to 5% gravel (Weston, 1998). Vertical desiccation cracks are not present in the lower silty clay due to its high moisture content. A lower permeability in this subunit relative to the upper silty clay is inferred from the lack of desiccation cracks and the higher percentage of clay.

Laminations (varves) are common throughout the glaciolacustrine deposit, indicating that it was deposited in a glacial lake environment. Silt lenses, fine sand lenses, and distinct layers of subangular to subrounded gravel and pebbles (drop stones) are also observed within this deposit. Boring logs suggest sharp transitions between these lenses and the silty clay; however, observations made by the author during investigations at individual sites within the Study Area indicate that these transitions are much more gradational. Borings that have completely penetrated the glaciolacustrine deposit reveal that it directly overlies glacial till, and ranges in thickness from 2.2 to 76.0 feet (Table A-1).

5.2.3 *Recent Alluvium*

Stratigraphic logs indicate that a lateral facies change in the glaciolacustrine deposit occurs in the western portion of the Study Area near the Niagara River (Figure 5-2). This deposit grades abruptly into recent alluvium, which consists predominantly of interbedded layers of brown to gray, fine to coarse grained, sandy silt, sand and gravel. Recent alluvium directly underlies fill material in this portion of the Study Area (Figure 5-2). This deposit was encountered in one boring (well MW-10DD) completed at the Polymer Applications Site, in most borings completed at the Niagara Mohawk Huntley Plant, and in the USGS boring (well 81-2TA) completed in Aqua Lane Park (Plate 1; Table A-1). The thickness of this deposit is greatest along the Niagara River (27 to 40 feet) and thins to the east where it grades into the glaciolacustrine deposit (Figure 5-2; Table A-1). Individual layers within the recent alluvium deposit typically range in thickness from 1.0 to 15.0 feet (Stanley Consultants, 1981; GZA, 1983). In many instances, however, sampling was not continuous, or boring logs were not descriptive enough to quantify precisely the thickness of these layers.

A surface contour map of the native deposits (glaciolacustrine deposit and recent alluvium) is shown as Figure 5-4. To represent the surface configuration prior to excavation of the disposal pits at the E.I. DuPont Yerkes Plant, some data from this site have been excluded. Figure 5-4 reveals that the native deposits in the eastern portion of the Study Area are relatively flat lying with typical elevations around 600 feet above mean sea level (amsl). A sharp decrease in elevation (≈25 feet over a distance of≈400 feet), however, is observed in the western portion of the area, and is roughly centered over River Road. The surface topography of the Study Area (Figure 5-5) also shows decreasing elevations in this area, but not to the extent of Figure 5-4 due to the extensive filling that has occurred along the Niagara River. A rapid decrease in surface topography is also observed north of the Study Area at Niawanda and Isleview parks in

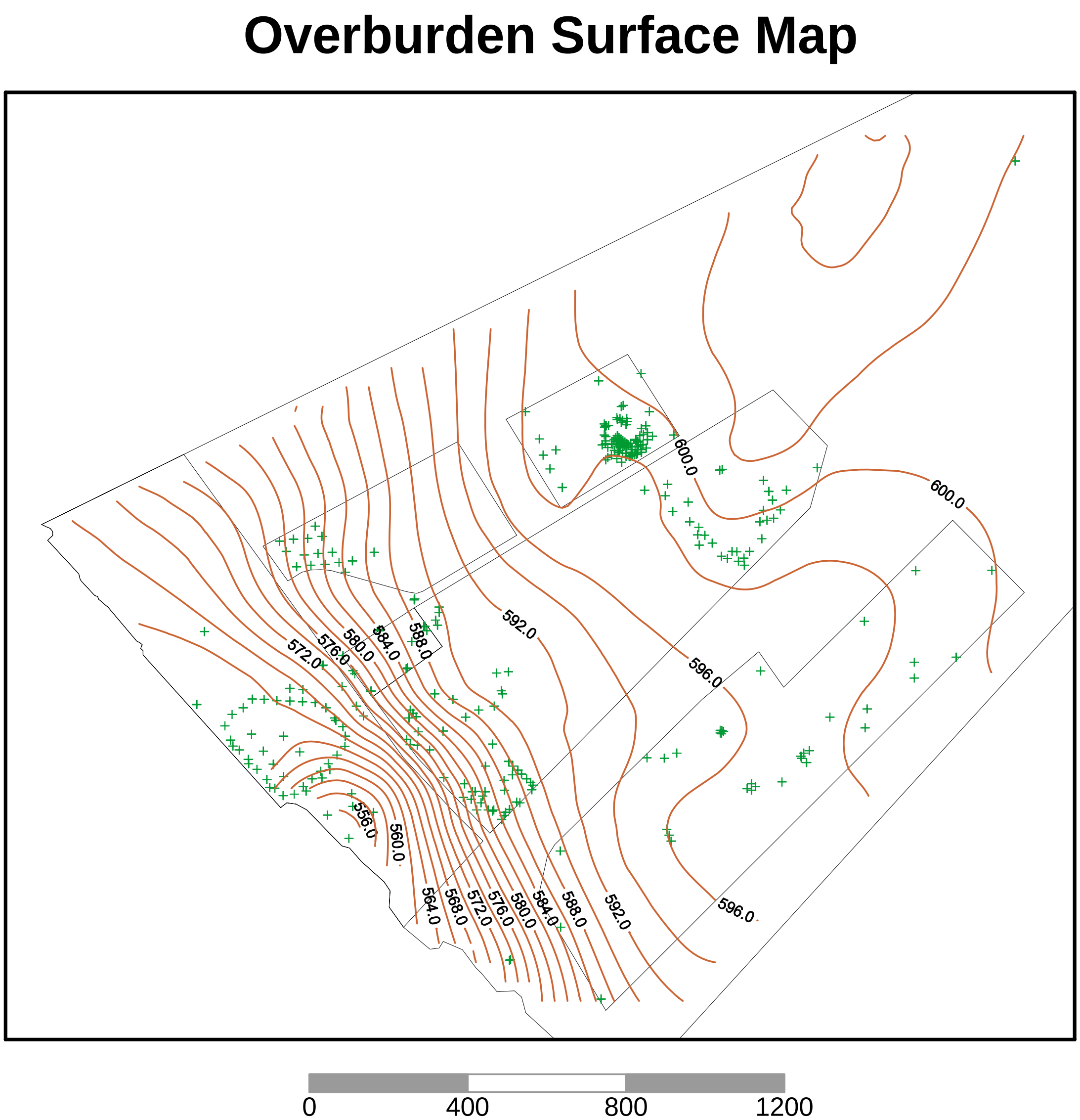


Figure 5-4. Native Soil Surface Contour of the Study Area. Boring, Monitoring Well and Test Pit Locations are Shown as Crosses. Scale in Meters.

the Town of Tonawanda. These features likely delineate the former extent of the Niagara River shoreline during recession of the ice sheets approximately 10,000 years ago. The presence of sand and gravel in this portion of the Study Area is consistent with a fluvial environment.

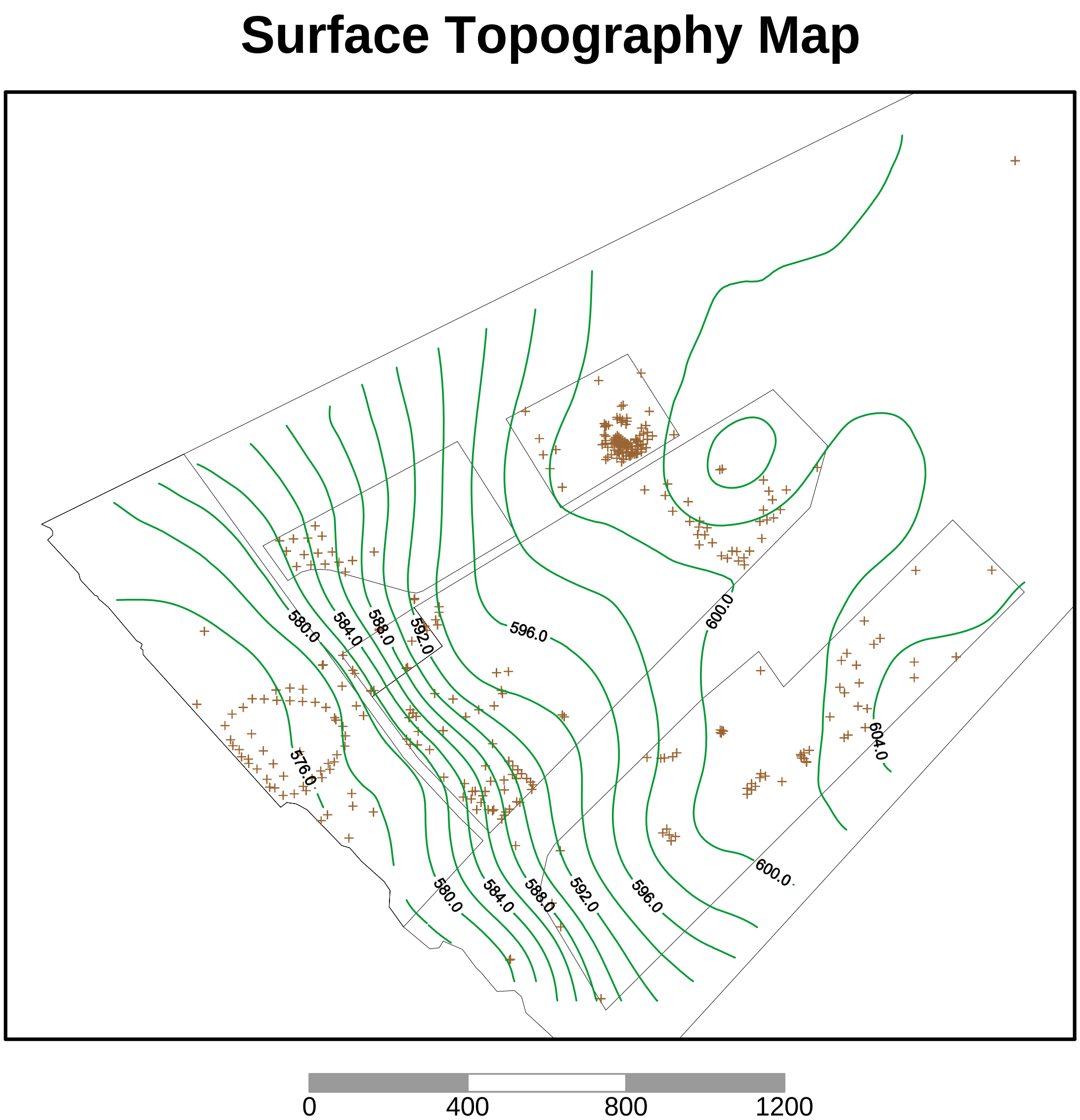


Figure 5-5. Surface Topography Contour of the Study Area. Boring, Monitoring Well and Test Pit Locations are Shown as Crosses. Scale in Meters.

5.2.4 *Glacial Till*

A relatively thin, continuous layer of glacial till underlies either the glaciolacustrine deposit or recent alluvium, and mantles the underlying Camillus Shale bedrock (Figure 5-2). The term "till" is used for a variety of non-sorted, non-stratified glacial deposits; however, because a till is so variable, caution must be exercised when describing its character and hydrogeologic properties. The till underlying the Study Area is characterized as a very dense, heterogeneous mixture of gray clay, silt, sand, gravel and shale bedrock fragments, with silt and clay occurring at the greatest percentage. The thickness of this deposit is quite variable across the area, ranging from 0.4 to 19 feet (Figure 5-6; Table A-1). At 34 of 63 locations, however, the thickness of this deposit is 6 feet or less. A surface contour map of the glacial till is shown as Figure 5-7 and suggests that the till surface is hummocky in nature, with shallow depressions separating low relief

Glacial Till Thickness Map

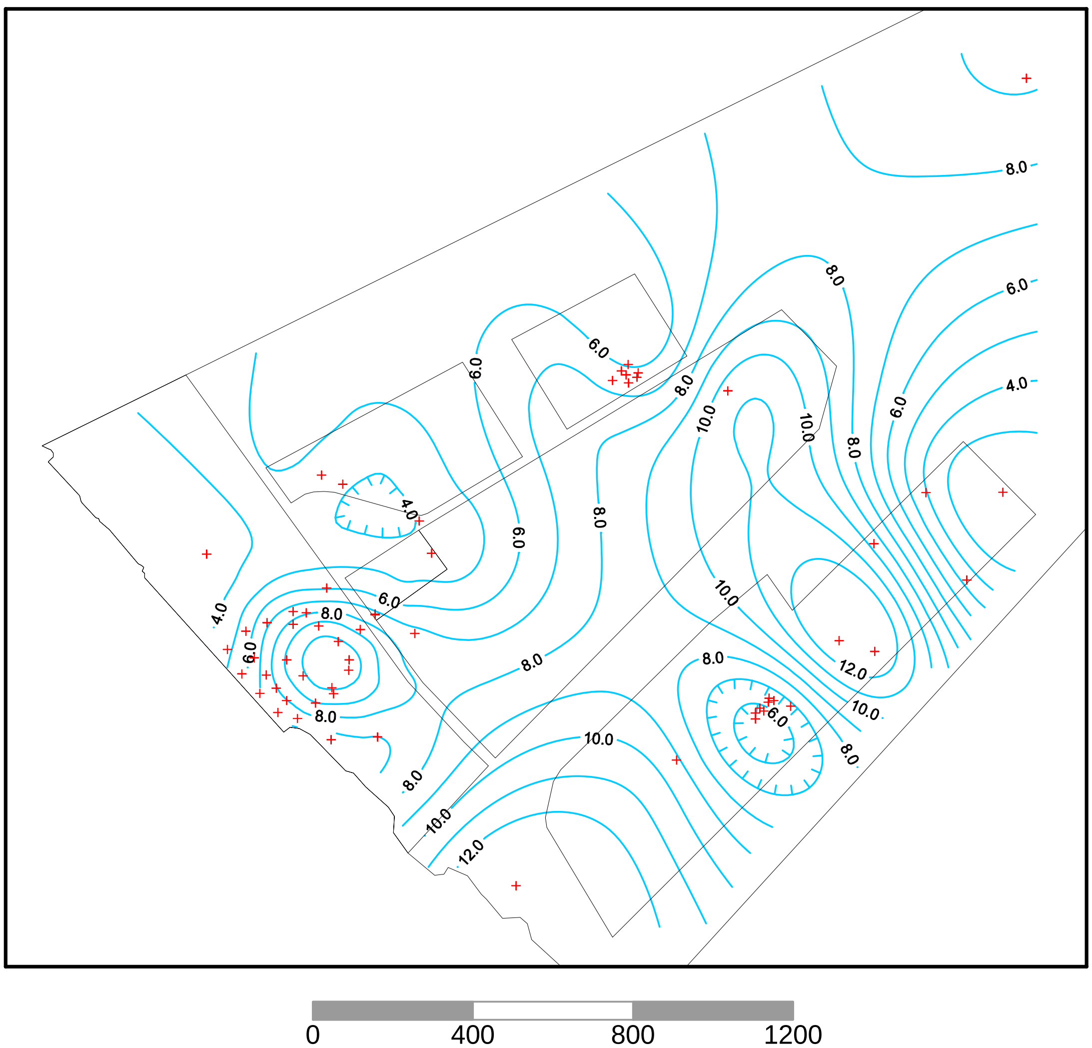


Figure 5-6. Glacial Till Thickness Contour of the Study Area. Boring and Monitoring Well Locations are Shown as Crosses. Scale in Meters.

mounds. Comparison of Figures 5-6 and 5-7 indicates that areas of greater till thickness correlate well with the low relief mounds, while areas of lower till thickness correlate well with the shallow depressions.

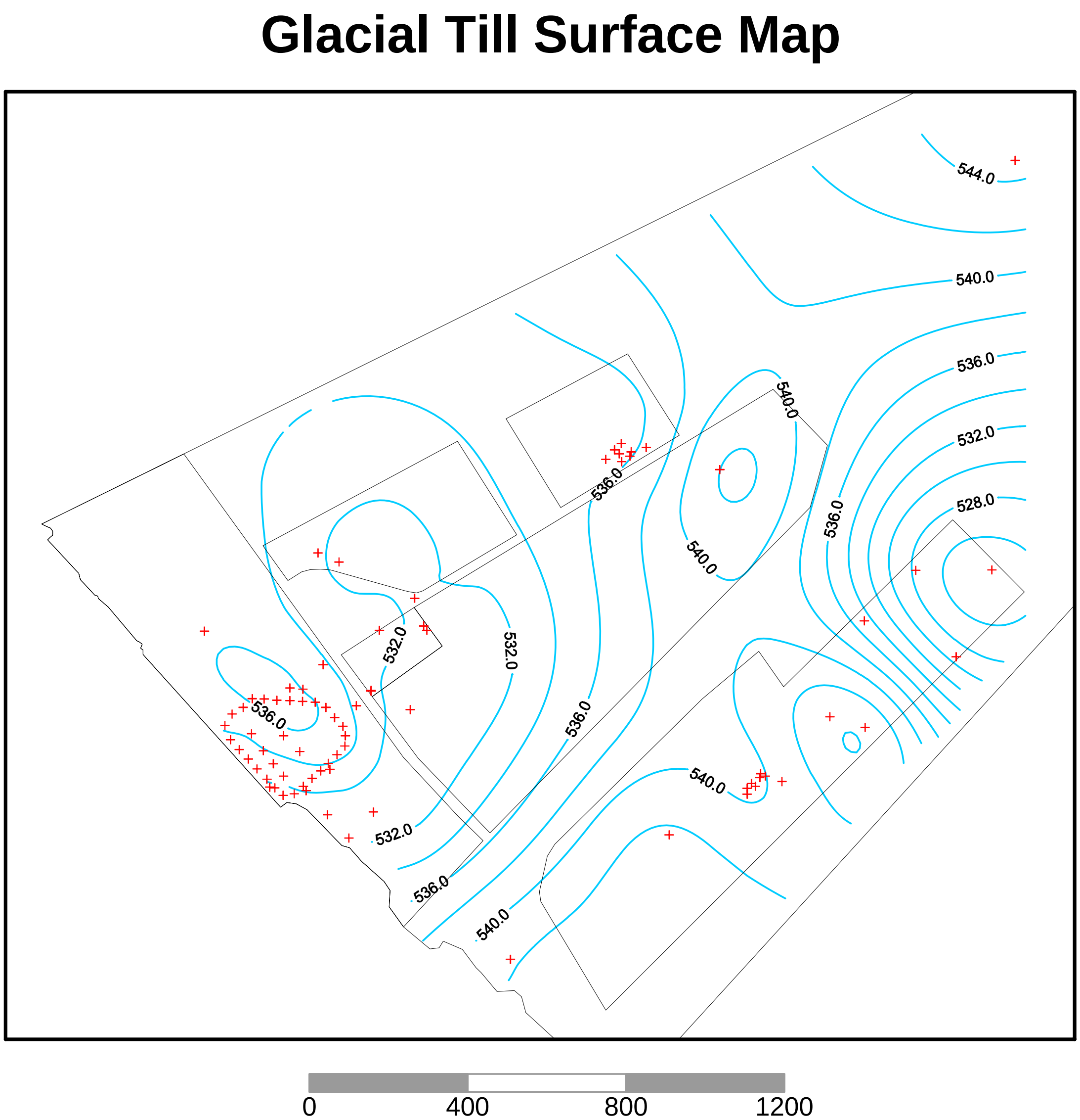


Figure 5-7. Glacial Till Surface Contour of the Study Area. Boring and Monitoring Well Locations are Shown as Crosses. Scale in Meters.

5.2.5 *Camillus Shale*

The uppermost bedrock unit underlying the Study Area is the Camillus Shale Formation of the Salina Group. Bedrock was encountered in 72 borings completed in the area (Table A-1), with 35 borings having penetrated this formation to various depths. The only boring in the Study Area that completely penetrated the Camillus Shale is a former gas well on the Dunlop Tire Corporation property. The boring log for this well, however, is not descriptive enough to distinguish the Camillus Shale from the other formations of the Salina Group, but indicates that the Salina Group is approximately 230 feet thick in this portion of the Tonawanda area. The deepest borings in the Study Area for which detailed stratigraphic logs are available were completed to a depth of 20 feet below top of rock. These borings did not penetrate the bottom of the Camillus Shale.

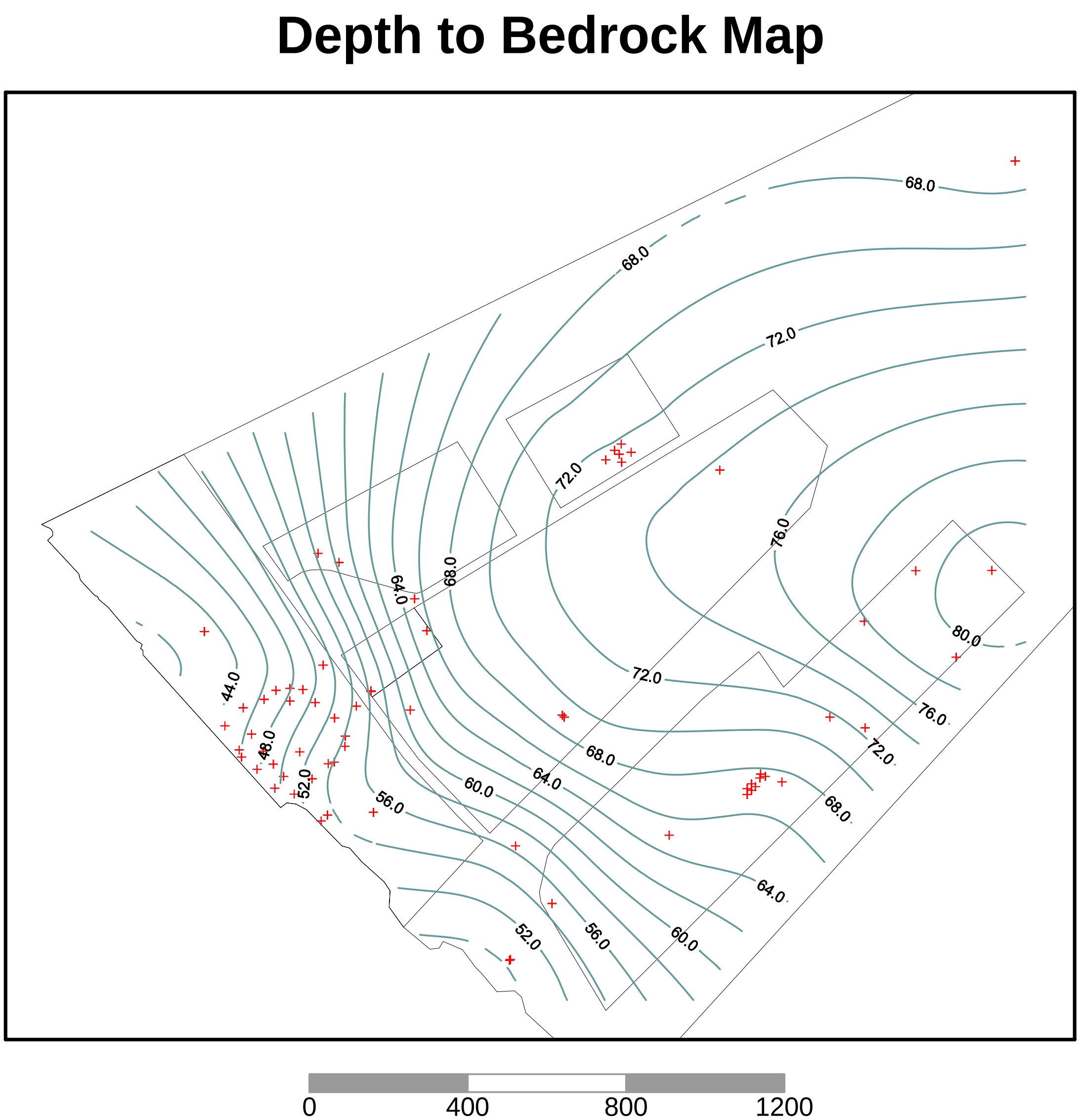


Figure 5-8. Depth to Bedrock Contour of the Study Area. Boring and Monitoring Well Locations are Shown as Crosses. Scale in Meters.

The Camillus Shale underlying the Study Area is characterized as a light to dark gray, fine to medium grained, slightly to moderately weathered, thin to massively bedded, shale containing layers of limestone and dolostone. This formation also contains numerous shale and gypsum partings, gypsum filled vugs, and gypsum masses and lenses. All borings with significant core recovery showed moderate to extensive fracturing in the upper 20 feet of bedrock. Detailed stratigraphic logs, however, are not available for borings completed below this depth, so it is unknown how deep this zone of fracturing extends. These fractures are slightly to moderately weathered, while some rubble zones and weathered vertical fractures were observed during logging of the cores. Bedrock core recovery was often high (85 to 100% being typical), but the rock quality designation (RQD), a measure of fracture density, was often very low (typically less than 60%). Vertical fractures were also observed but are rare.

Depth to bedrock beneath the Study Area is quite variable, ranging from 42.2 to 82.0 feet (Figure 5-8; Table A-1). Bedrock is deepest in the eastern portion of the area where the surface topography is highest, and shallows uniformly to the west as the surface topography decreases (compare Figures 5-5 and 5-8). A surface contour map of the Camillus Shale is shown as Figure 5-9 and suggests that a shallow ($\approx$10 feet in relief) east-west trending bedrock trough underlies the central portion of the Study Area. To the south, the bedrock surface rises abruptly to the crest of what appears to be an elongated bedrock ridge. To the north, however, the bedrock surface rises more gently to a bedrock high. The trend of this trough is consistent with a suspected regional bedrock lineament in the area (Bechtel, 1993).

Bedrock Surface Map

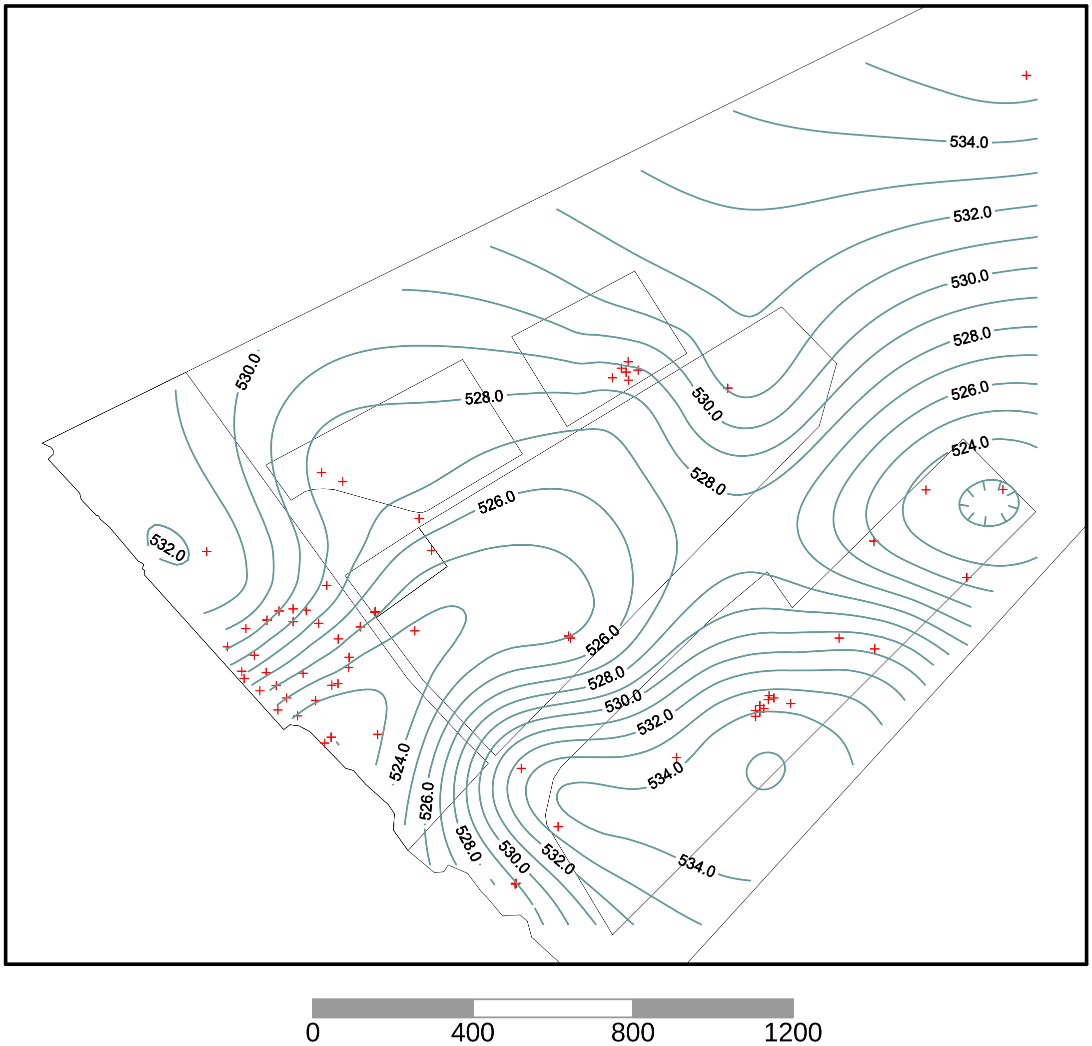


Figure 5-9. Bedrock Surface Contour of the Study Area. Boring and Monitoring Well Locations are Shown as Crosses. Scale in Meters.

6.0 GROUNDWATER HYDROGEOLOGY

In Section 5.0 the geology of the Study Area was described in detail. In this section the hydrogeologic properties of these strata are evaluated. As part of this evaluation hydrographs and groundwater flow maps of the area are examined along with the temporal and spatial distribution of groundwater elevation declines attributed to groundwater extraction by the Dunlop Tire Corporation. Before completing such a detailed evaluation, however, it is important to first describe the regional hydrogeologic setting of the Tonawanda area.

6.1 Regional Hydrogeology

Many site investigations and hydrogeologic studies have been completed in the Tonawanda area. These studies indicate that there are three principal hydrogeologic zones in the area described as follows:

- The upper Camillus Shale bedrock, which can be characterized as a confined aquifer;

- The glaciolacustrine silty clay deposit, which can be characterized as an aquitard, confining groundwater from the underlying Camillus Shale; and

- Shallow alluvium, glaciofluvial and fill deposits, which can be characterized as either unconfined (water table) or perched aquifers.

Of these zones, the principal aquifers include the sands and gravels of the recent alluvium and glaciofluvial deposits, and the upper bedrock of the Camillus Shale Formation. In the Tonawanda area, unconfined groundwater is encountered largely within the glaciofluvial, alluvium and fill deposits. Where these deposits overlie the glaciolacustrine silty clay deposit, perched groundwater conditions occur. Well yields from these deposits in the Tonawanda area are generally unknown, although wells installed in highly permeable outwash deposits in the Tonawanda Creek valley have yields ranging from 1,000 to 1,400 gallons per minute (gpm) (La Sala, 1968).

The glaciolacustrine deposit separates the water table and/or perched aquifer from the confined upper bedrock aquifer. The hydraulic conductivity of this deposit is extremely low, typically ranging from 10^{-6} to 10^{-8} cm/s. The glaciolacustrine deposit, therefore, can be considered an aquitard, preventing the vertical movement of shallow groundwater to the underlying Camillus Shale. Some vertical movement, however, can occur through the dessication cracks in the upper silty clay unit of this deposit. Horizontal groundwater flow within this deposit is also severely limited. In fact, the glaciolacustrine deposit is generally not water bearing, yielding only small quantities of water, which is primarily interstitial pore water that is tightly bound to the soil particles. This deposit, however, often contains thin seams and stringers of silt and sand that can allow limited horizontal groundwater flow. If areally extensive, these seams and stringers can be utilized as a source of water (La Sala, 1968).

La Sala (1968) reports that the Camillus Shale is "by far the most productive bedrock aquifer" in the Erie-Niagara Basin, with individual well yields ranging from 300 to 1,200 gpm. The production well at the Dunlop Tire Corporation yields 600 to 900 gpm (Pyanowski, 1990), although yields of 1,800 gpm were observed during this study.

Groundwater within the Camillus Shale occurs primarily in the following types of openings: (1) weathered surface fractures, (2) horizontal beds widened by dissolution, (3) vertical joints, and (4) small cavities and vugs. The availability of groundwater within the Camillus Shale results largely from the dissolution of thin (up to 5 feet in thickness; La Sala, 1968) gypsum seams and layers interbedded throughout the formation. Since the solubility of gypsum is high compared to the shales, limestones and dolostones that constitute the Camillus Shale, circulating groundwater will more readily dissolve the gypsum, producing migration pathways that can transmit large quantities of groundwater. The most prolific water-bearing zones, therefore, are generally horizontal because gypsum typically occurs in horizontal beds and thin zones of gypsiferous shale and dolostone (La Sala, 1968). These water bearing zones have been encountered at varying depths and stratigraphic horizons within the Camillus Shale in Erie County, with individual dissolution zones ranging up to several miles in lateral extent (La Sala, 1968). The larger solution openings most likely occur in discharge areas near Tonawanda Creek and the Niagara River, where groundwater flow is greatest. Some horizontal groundwater flow, however, may also occur through small cavities and vugs. Thus, while the hydraulic conductivity of the Camillus Shale is typically very low, the dissolution of gypsum produces zones of high transmissivity within the formation. Reported transmissivity values for the Camillus Shale based upon specific-capacity tests range from 7,000 to 70,000 gallons per day per feet (gpd/ft) (La Sala, 1968). Because of these yields, groundwater from the Camillus Shale is commonly utilized for industrial purposes (i.e., non-contact cooling). This water, however, is not utilized as a source of drinking water in the Tonawanda area because of naturally occurring high mineral content and the close proximity of the Niagara River, an important source of municipal drinking water throughout the Western New York area.

Vertical movement of groundwater also occurs within the Camillus Shale, especially in the upper several feet of bedrock where vertical fractures, created by stress relief from tectonic events and glacial rebound (Gross and Engelder, 1991), have been enlarged by glacial scour, dissolution and other weathering processes. In general, however, vertical movement of groundwater within the Camillus Shale is limited. La Sala (1968) reports that this weathered and fractured zone is in hydraulic communication with the overlying glacial till throughout the Tonawanda area. Collectively, these zones are capable of yielding small quantities of water to wells, but are generally not used for domestic or industrial purposes.

Most recharge to the Camillus Shale results from infiltration of rainfall, snowmelt, and surface water through the overburden deposits (Johnson, 1964; La Sala, 1968). The low permeability of the glacial deposits within the Tonawanda area, however, only permit limited recharge to the upper bedrock aquifer. Subsurface flow of groundwater from areas of higher elevation (e.g., the Niagara Escarpment) also recharges the upper bedrock aquifer (Johnson, 1964; La Sala, 1968). Recharge of deeper unconsolidated deposits and the upper bedrock aquifer may also result from infiltration of Niagara River and Tonawanda Creek water through the recent alluvium and glaciofluvial deposits. In general, however, these water bodies are typically discharge zones, so recharge in these areas would be restricted to the small stagnant zone underlying these water bodies.

6.1.1 *Regional Groundwater Flow*

Detailed information regarding regional groundwater flow in the upper Camillus Shale bedrock of the Tonawanda area is not available. Based upon water level data from several sites in the Town of Tonawanda, groundwater in the upper Camillus Shale flows toward Tonawanda Creek and the Niagara River, the principal discharge zones in the Tonawanda area. Localized perturbations in this flow pattern, however, would occur at any facility that extracts large quantities of groundwater from the Camillus Shale for industrial purposes (e.g., the Dunlop Tire Corporation).

6.2 Study Area Hydrogeology

The hydrogeology of the Study Area has been evaluated by examining hydrogeologic data obtained during this study. These data suggest that four hydrogeologic zones underlie the area: (1) a shallow water bearing zone consisting of miscellaneous fill and the upper portion of the glaciolacustrine deposit, (2) an intermediate zone consisting of the glaciolacustrine deposit and recent alluvium, (3) a deep water bearing zone consisting predominantly of glacial till, and (4) an upper bedrock water bearing zone. The designation of the intermediate zone as a single hydrogeologic unit is highly generalized as the hydrogeologic properties of the glaciolacustrine deposit and recent alluvium are significantly different. As described in Section 6.1, the glaciolacustrine deposit is more accurately characterized as an aquitard, restricting the downward movement of groundwater from the shallow to the deeper hydrogeologic zones, while the sands and gravels of the recent alluvium deposit can transmit large quantities of groundwater. In addition, the designation of the deep water bearing zone as a separate hydrogeologic unit is also highly generalized as this zone is in hydraulic communication with the upper bedrock hydrogeologic zone (La Sala, 1968).

6.2.1 *Shallow Hydrogeologic Zone*

Twenty-two shallow hydrogeologic zone wells were monitored during this study (Plate 2; Table B-1 in Appendix B). Wells were assigned to this zone if they screened either the fill material or upper portion of the glaciolacustrine deposit. For the latter wells, an arbitrary depth of 10 feet was selected, with any well having a portion of the screen less than this depth assigned to the shallow hydrogeologic zone. Historically, water level measurements from these and other shallow zone wells have been collected on numerous occasions: eleven times at the Polymer Applications Site between October 3, 1983 and July 13, 1994; six times at the E.I. DuPont Yerkes Plant between October 2, 1979 and June 1993; nine times at the Niagara Mohawk Huntley Plant between April 24, 1981 and March 21, 1995; and twenty-one times at the Dunlop Tire Corporation between December 21, 1982 and September 27, 1991 (see Table C-1 in Appendix C). In order to obtain a more temporal data set, however, water level measurements were collected monthly between August 1995 and January 1996 from 22 shallow zone wells within the Study Area (see Table C-2 in Appendix C).

The water level data obtained during this study were utilized to construct hydrographs for the shallow zone wells (Figures 6-1 thru 6-3). These hydrographs reveal that water levels fluctuated throughout the year. For wells that screen the fill materials (dashed lines on Figures 6-1 thru 6-3), water levels were lowest in the relatively dry summer and early fall months, and increased in the relatively wet late fall and winter months. Some exceptions to this pattern, however, were observed. For example, Polymer well B-5S exhibited almost no fluctuations (Figure 6-1). Water levels in this well ranged from 587.51 feet amsl to 587.74 feet amsl (Table C-2 in Appendix C). While the exact nature of this response is unknown, it is likely related to the containment wall constructed around the rear portion of the Polymer Application's property. In addition, although the hydrographs for wells GW-3S and GW-4S followed the general trend, both wells experienced significant water level decreases in January 1996 (Figure 6-1).

The hydrographs for wells that screen the upper portion of the glaciolacustrine deposit (solid lines on Figures 6-1 thru 6-3) generally follow the pattern observed for the fill wells. Some significant exceptions to this pattern, however, were observed. For example, water levels in DuPont well DYF-2 decreased substantially throughout the summer and fall months before going dry in November 1995 (Figure 6-2).

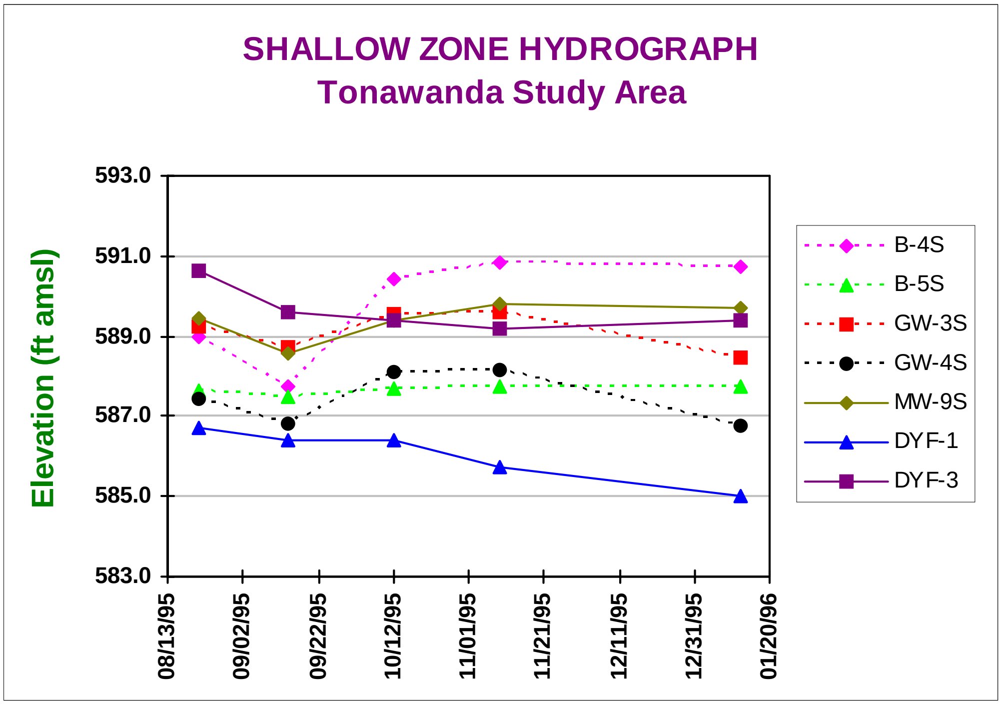


Figure 6-1. Shallow Zone Hydrograph for the Tonawanda Study Area. Dashed Lines Denote Fill Wells. Solid Lines Denote Glaciolacustrine Wells.

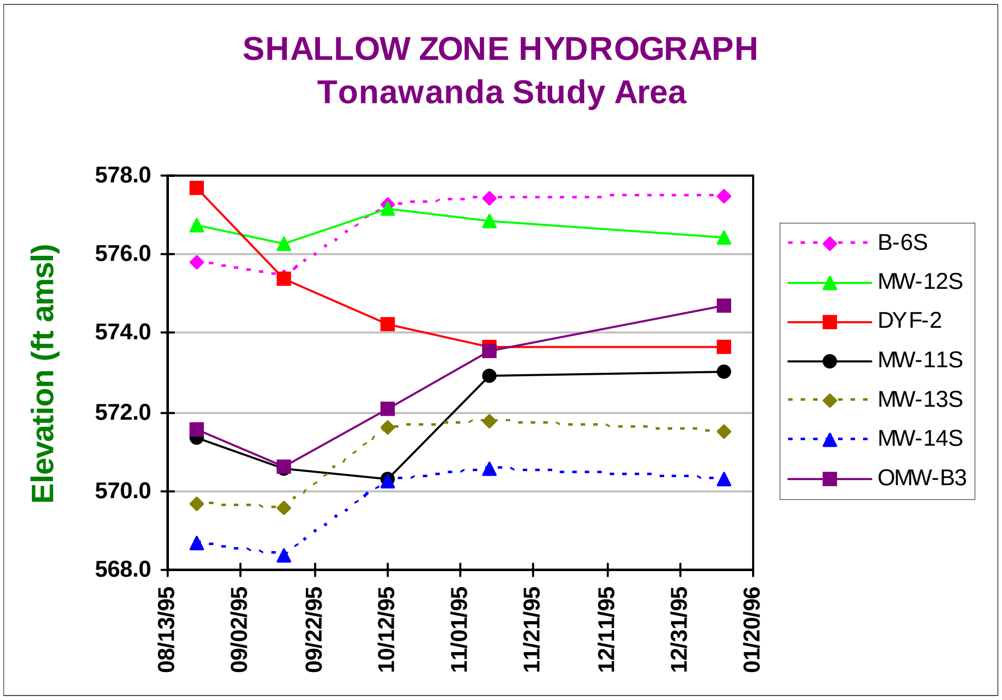


Figure 6-2. Shallow Zone Hydrograph for the Tonawanda Study Area. Dashed Lines Denote Fill Wells. Solid Lines Denote Glaciolacustrine Wells.

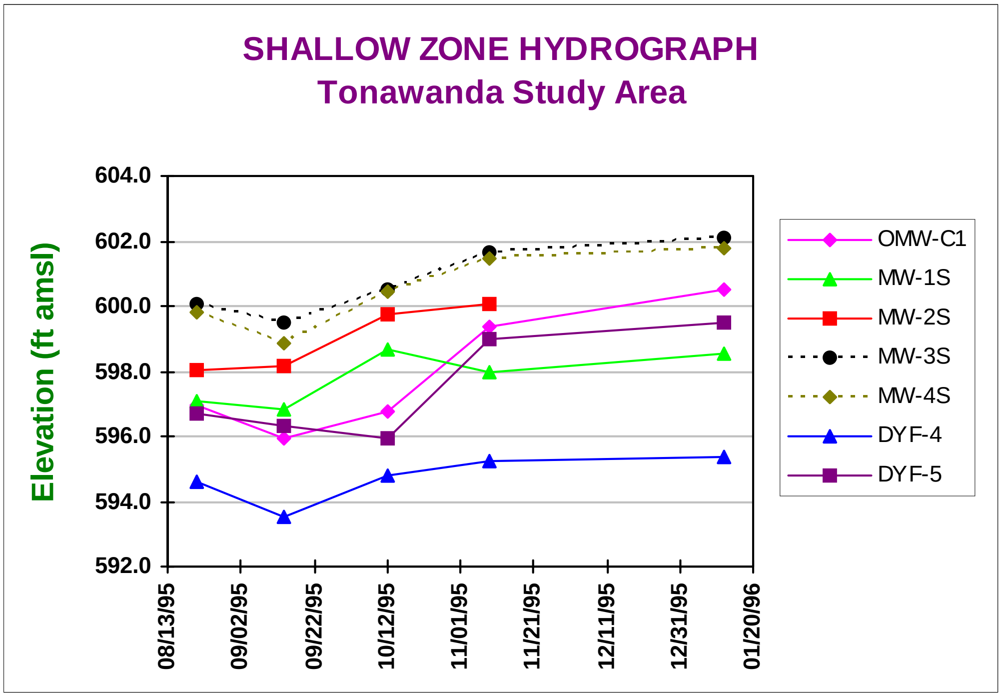


Figure 6-3. Shallow Zone Hydrograph for the Tonawanda Study Area. Dashed Lines Denote Fill Wells. Solid Lines Denote Glaciolacustrine Wells.

Water levels in wells DYF-1 and DYF-3 also decreased continuously during the study, but not as dramatically as well DYF-2 (Figure 6-1). In addition, although wells MW-11S and DYF-5 followed the general trend, water levels in both wells did not respond to the higher than normal rainfall in October 1995 (Figure 3-4) until November of that year (Figures 6-2 and 6-3).

Figures 6-4 and 6-5 illustrate the shallow zone groundwater flow pattern across the Study Area on September 14, 1995 and November 9, 1995, respectively. These dates were selected as they represent the lowest and highest water levels observed during the study. Water level data from wells DYF-2 and B-5S were not included in these contours because their hydrographs were so anomalous compared to the other shallow zone wells. In addition, water levels from Polymer well GW-3S were also omitted as this well is located within the containment wall and likely monitors groundwater that is isolated from the regional groundwater in this zone.

Figures 6-4 and 6-5 reveal that shallow zone groundwater flows toward the Niagara River and is relatively uniform across the Study Area. There is evidence of groundwater mounding in the southeastern portion of the area, but additional wells would be required to fully delineate the extent of this mound. These figures also reveal that the groundwater flow patterns for September and November 1995 are nearly identical, differing only in the groundwater elevations between dry and wet weather conditions. The groundwater contour maps for the remaining months (not shown) are similar to those of Figures 6-4 and 6-5.

Groundwater Flow Map for the Shallow Zone on September 14, 1995

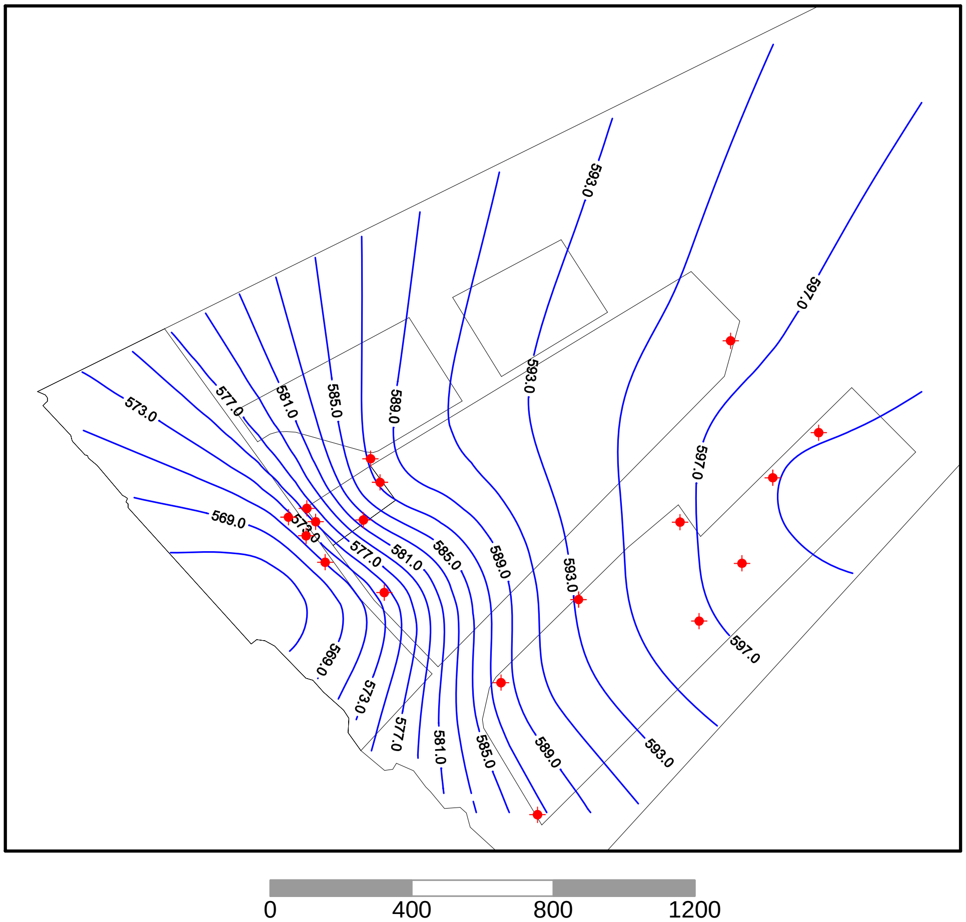


Figure 6-4. Shallow Zone Groundwater Flow Across the Study Area on September 14, 1995. Wells are Shown as Red Crossed Dots. Scale in Meters.

Although groundwater flow is relatively uniform across the Study Area, slightly steeper gradients are observed near River Road that correlate well with the rapid decline in surface elevation of the native deposits (compare Figure 5-4 with Figures 6-4 and 6-5). Gradients are also slightly steeper across the Dunlop Tire Corporation and Polymer Applications Sites than across the E.I. DuPont Yerkes facility (see Table D-1 in Appendix D). Table D-1 indicates, however, that the mean hydraulic gradient is relatively constant throughout the year, being only slightly higher in November and January. The arithmetic and geometric mean hydraulic gradients were found to range from 0.0052 m/m to 0.0061 m/m, and from 0.0052 m/m to 0.0060 m/m, respectively. Both the arithmetic and geometric means were calculated because hydrogeologic data often exhibit wide ranges of values (i.e., greater than one order of magnitude). The arithmetic mean, therefore, can be overly influenced by the largest or smallest values in the data set. To account for this limitation, the geometric mean is often utilized to provide a more appropriate measure of the typical value of the data set.

In situ permeability tests have been conducted on six wells that screen the fill material and seven wells that screen the upper portion of the glaciolacustrine deposit. In addition, three permeameter tests have been completed on shallow zone soils from the Study Area. The Shelby tube samples collected for these tests

Groundwater Flow Map for the Shallow Zone on November 9, 1995

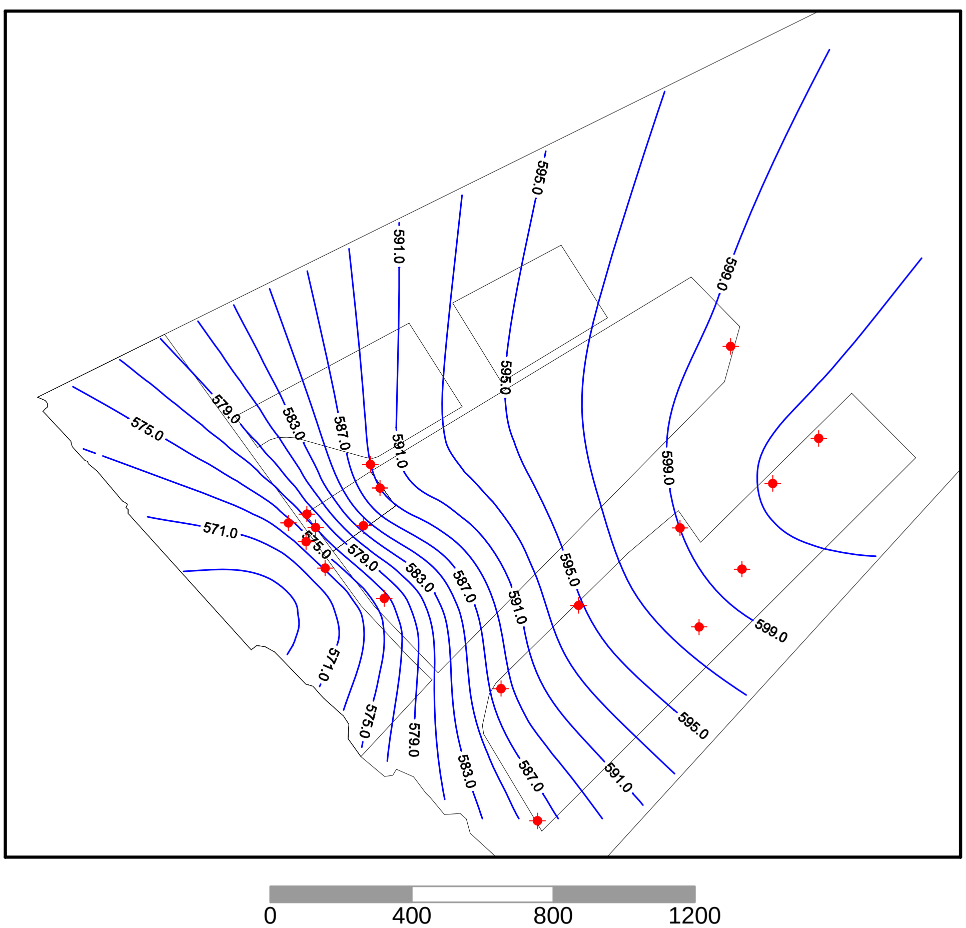


Figure 6-5. Shallow Zone Groundwater Flow Across the Study Area on November 9, 1995. Wells are Shown as Red Crossed Dots. Scale in Meters.

came from the reddish brown silty clay unit of the glaciolacustrine deposit. The permeability test results for the fill material are summarized in Table 6-1, while the results for the upper portion of the reddish brown silty clay are summarized in Table 6-2.

Table 6-1.
Hydraulic Conductivity Test Data for the Fill Material of the Shallow Hydrogeologic Zone.

Well Number	Site Name	Hydraulic Conductivity (cm/sec)	Screened Unit	Test Method
Vertical Hydraulic Conductivity				
No Laboratory Conductivity Tests Have Been Conducted on the Fill Material from Within the Study Area.				
Geometric Mean		**N/A**		
Arithmetic Mean		**N/A**		
Horizontal Hydraulic Conductivity				
B-4S	PAS	8.60e-04	Miscellaneous Fill	Slug
"	"	2.46e-06	" " "	"
B-6S	PAS	4.94e-06	Miscellaneous Fill	Slug
B-7S	PAS	6.40e-04	Miscellaneous Fill	Slug
MW-13S	PAS	8.97e-05	Misc. Fill; Reddish Brown Silty Clay	Slug
MW-14S	PAS	1.18e-05	Misc. Fill; Reddish Brown Silty Clay	Slug
Geometric Mean		**4.38e-05**		
Arithmetic Mean		**2.68e-04**		

PAS Polymer Applications Site.
N/A Not Applicable.

Hydraulic conductivity of the fill material within the Study Area is variable, ranging from 8.60 x 10^{-4} to 2.46 x 10^{-6} cm/sec (Table 6-1). The arithmetic and geometric means for these data are 2.68 x 10^{-4} and 4.38 x 10^{-5} cm/sec, respectively. These results, however, only come from wells installed at the Polymer Applications Site. Since these data may not be representative of the fill material throughout the Study Area they are only considered a first order approximation. Vertical hydraulic conductivities are not available for the fill material.

Vertical hydraulic conductivities for the upper portion of the glaciolacustrine deposit range from 1.1 x 10^{-6} to 2.0 x 10^{-7} cm/sec, with arithmetic and geometric means of 5.43 x 10^{-7} and 4.17 x 10^{-7} cm/sec, respectively (Table 6-2). Horizontal hydraulic conductivities of the reddish brown silty clay (bulk matrix) are on the same order of magnitude, ranging from 3.31 x 10^{-6} to 5.75 x 10^{-8} cm/sec. The arithmetic and geometric means for these data are 1.17 x 10^{-6} and 5.25 x 10^{-7} cm/sec, respectively (Table 6-2). Based upon these hydraulic conductivity results (vertical and horizontal), and the fact that the upper silty clay soils are

Table 6-2.
Hydraulic Conductivity Test Data for the Glaciolacustrine Deposit of the Shallow Hydrogeologic Zone.

Well or Boring Number	Site Name	Hydraulic Conductivity (cm/sec)	Screened Unit	Test Method
Vertical Hydraulic Conductivity				
C-7	FMC	3.30e-07	Reddish Brown Silty Clay	Shelby
F-8	FMC	1.10e-06	Reddish Brown Silty Clay	Shelby
"	"	2.00e-07	" " " "	"
Geometric Mean		**4.17e-07**		
Arithmetic Mean		**5.43e-07**		
Horizontal Hydraulic Conductivity (Bulk Matrix)				
OMW-1 *	DTC	5.75e-08	Reddish Brown Silty Clay	Slug
OMW-B3 *	DTC	1.70e-06	Peat; Reddish Brown Silty Clay	Bail Down
OMW-C1 *	DTC	1.31e-07	Reddish Brown Silty Clay	Slug
"	"	2.80e-07	" " " "	Bail Down
MW-9S	PAS	2.33e-06	Reddish Brown Silty Clay	Slug
MW-11S	PAS	3.31e-06	Reddish Brown Silty Clay	Slug
MW-12S	PAS	3.99e-07	Black Silt & Fine Sand; Reddish Brown Silty Clay	Slug
Geometric Mean		**5.25e-07**		
Arithmetic Mean		**1.17e-06**		
Horizontal Hydraulic Conductivity (Desiccation Cracks)				
OMW-1 **	DTC	1.97e-05	Reddish Brown Silty Clay	Slug
OMW-B3 **	DTC	2.40e-05	Peat; Reddish Brown Silty Clay	Bail Down
OMW-C1 **	DTC	2.40e-06	Reddish Brown Silty Clay	Slug
"	"	6.70e-06	" " " "	Bail Down
Geometric Mean		**9.34e-06**		
Arithmetic Mean		**1.32e-05**		

PAS Polymer Applications Site. **DTC** Dunlop Tire Corporation.
***** Late response data. ****** Early response data.

typically unsaturated, the glaciolacustrine deposit is best characterized as a confining layer, restricting the downward movement of groundwater from the fill material to the deeper water bearing zones.

Wells installed entirely within the upper portion of the glaciolacustrine deposit, however, contain some groundwater. This water is believed to be a combination of soil pore water (where the soils are moist) and groundwater from the fill material that enters the wells through vertical dessication cracks. Early response data from slug tests, believed to represent the permeability of this fractured soil (URS, 1992), yield hydraulic conductivities about an order of magnitude higher than the bulk matrix permeabilities. Hydraulic conductivities of the early response data range from 2.4×10^{-5} to 2.4×10^{-6} cm/sec, with arithmetic and geometric means of 1.32×10^{-5} and 9.34×10^{-6} cm/sec, respectively (Table 6-2).

6.2.2 *Intermediate Hydrogeologic Zone*

Fifteen intermediate hydrogeologic zone wells were monitored during this study (Plate 2; Table B-2 in Appendix B). Wells were assigned to this zone if they screened either the glaciolacustrine or alluvium deposits. An exception was made for Niagara Mohawk wells NM-A and NM-B as well construction diagrams were not available. These wells were assigned to the intermediate zone based upon their total depth. Historically, water level measurements from these and other intermediate zone wells have been collected on numerous occasions: eleven times at the Polymer Applications Site between August 30, 1983 and July 13, 1994; twenty times at the Niagara Mohawk Huntley Plant between April 24, 1981 and March 21, 1995; and eleven times at the Dunlop Tire Corporation between April 29, 1991 and September 27, 1991 (see Table C-3 in Appendix C). In order to obtain a more temporal data set, however, water level measurements were collected monthly between August 1995 and January 1996 from 15 intermediate zone wells within the Study Area (see Table C-4 in Appendix C).

The water level data obtained during this study were utilized to construct hydrographs for the intermediate zone wells (Figures 6-6 thru 6-9). These hydrographs reveal that water levels fluctuated throughout the year. For wells B-3D, B-4D, B-5D (Figure 6-6) and NM-B (Figure 6-7), the hydrographs were similar to those from the shallow zone wells: water levels were lowest in the relatively dry summer and early fall months, and increased in the relatively wet late fall and winter months. This pattern of water level fluctuations, however, may not be typical for this zone as other patterns are evident from the hydrographs. For example, wells OMW-A4, OMW-C5, OMW-C7, MW-3I and OMW-B4 exhibited a slightly different pattern of water level fluctuations (Figure 6-7 thru 6-9). Water levels in these wells followed the trend just discussed, but did not respond immediately to the higher than normal rainfall in October 1995 (Figure 3-4). In fact, water levels in wells OMW-A4, OMW-C7 and OMW-B4 dropped drastically in November 1995 before rebounding by January 1996. A third pattern was observed for wells OMW-A6, NM-A, 81-2TB, B-2D and B-6D, which exhibited almost no fluctuations (Figures 6-6, 6-7, and 6-9). The exact nature of this response is unknown for wells OMW-A6, B-2D and B-6D, although it is suspected that well OMW-A6 may be influenced by underground utilities and building foundations at the Dunlop Tire Corporation facility. Well 81-2TB, installed in Aqua Lane Park near the Niagara River (Plate 2), monitors the alluvium deposit. The hydrographs for this well and the Niagara River (Figure 6-7) are similar, suggesting that the water levels in this well are influenced by the river. This response was not unexpected, however, as the alluvium deposit is in direct hydraulic communication with the Niagara River (Figure 5-2). The hydrographs for wells 81-2TB and NM-A are nearly identical, suggesting that well NM-A also monitors the alluvium deposit and is influenced by the river.

Figures 6-10 and 6-11 illustrate the intermediate zone groundwater flow pattern across the Study Area on September 14, 1995 and January 12, 1996, respectively. These dates were selected as they represent the lowest and highest water levels observed during the study. Water level data from well OMW-A6 was not included in these contours because this well may be influenced by underground utilities and building foundations, and may not be representative of regional intermediate zone groundwater flow.

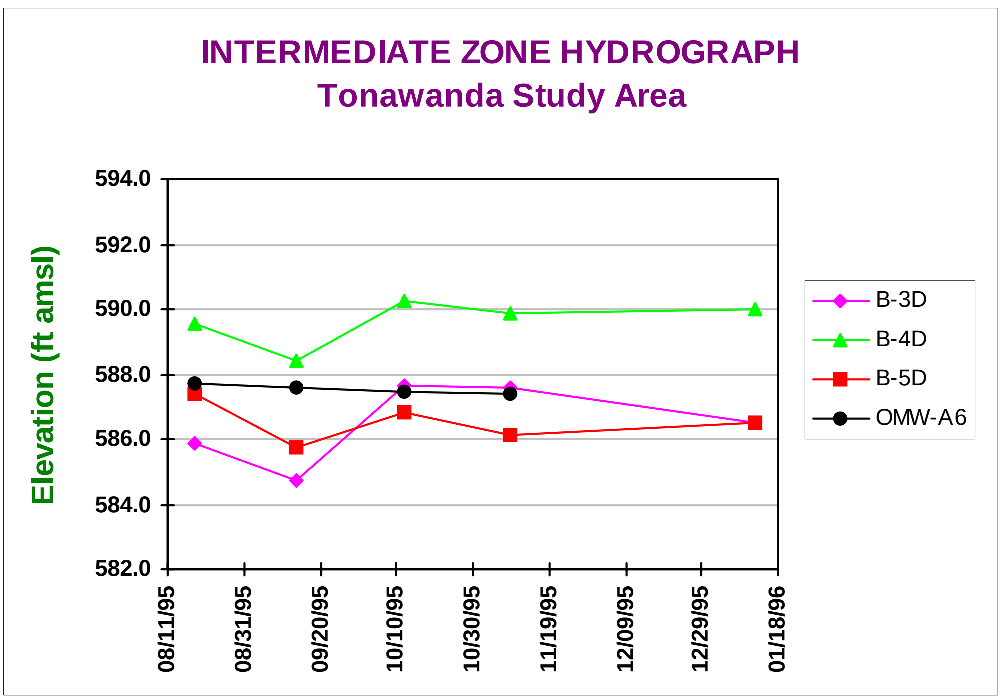


Figure 6-6. Intermediate Zone Hydrograph for the Tonawanda Study Area. Solid Lines Denote Glaciolacustrine Wells.

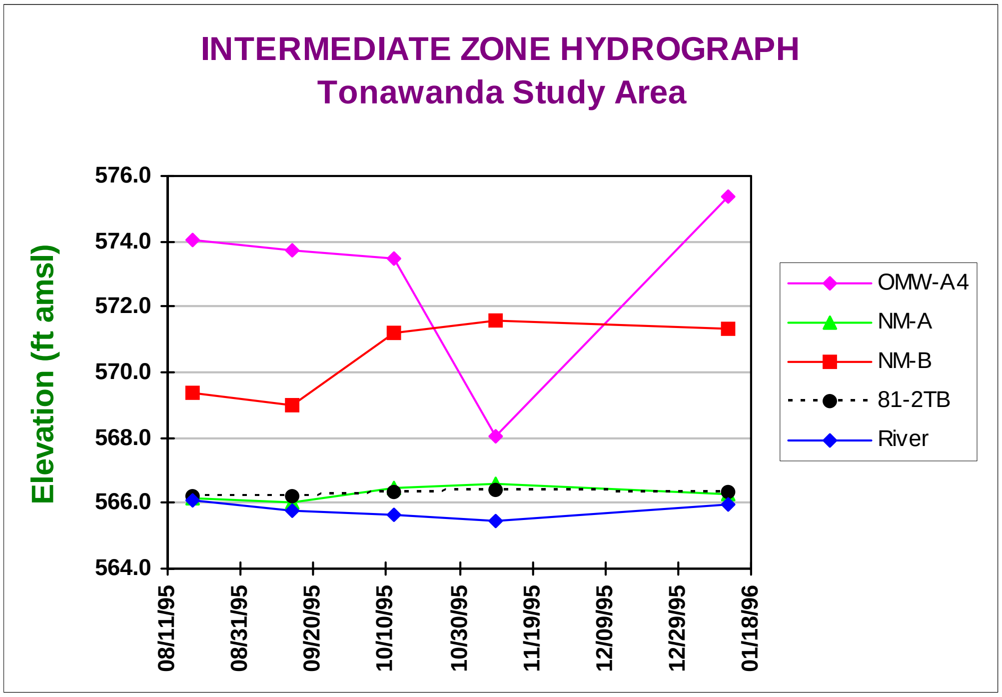


Figure 6-7. Intermediate Zone Hydrograph for the Tonawanda Study Area. Dashed Lines Denote Alluvium Wells. Solid Lines Denote Glaciolacustrine Wells.

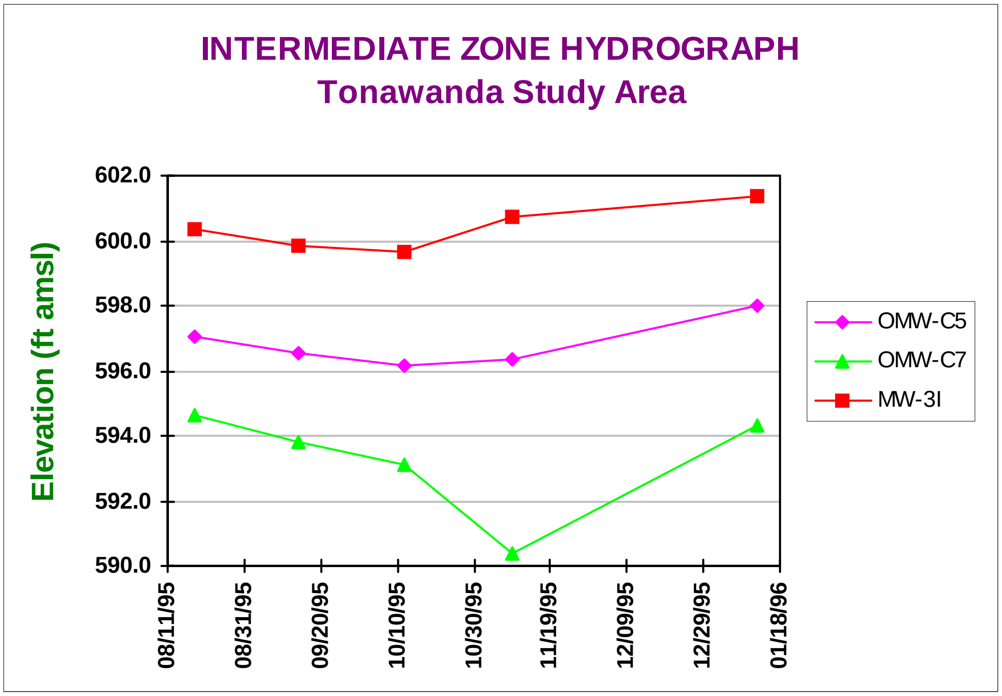


Figure 6-8. Intermediate Zone Hydrograph for the Tonawanda Study Area. Solid Lines Denote Glaciolacustrine Wells.

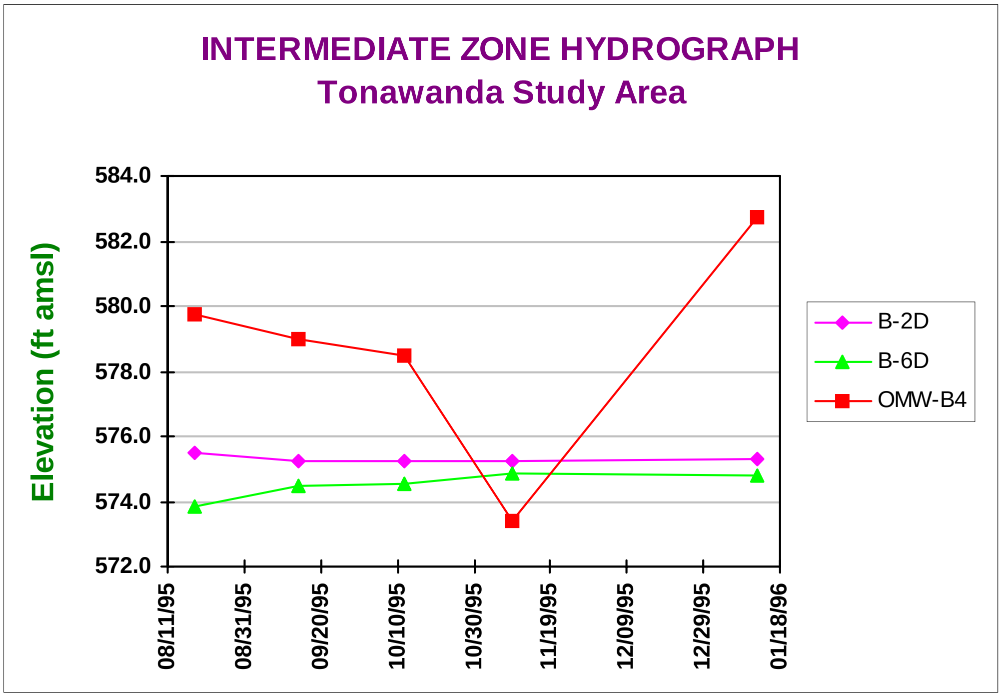


Figure 6-9. Intermediate Zone Hydrograph for the Tonawanda Study Area. Solid Lines Denote Glaciolacustrine Wells.

Figures 6-10 and 6-11 reveal that intermediate zone groundwater flows toward the Niagara River and is relatively uniform across the Study Area. The flow pattern and water levels are similar to those from the shallow hydrogeologic zone (compare Figures 6-10 and 6-11 with Figures 6-4 and 6-5), suggesting that the upper portion of the glaciolacustrine deposit is a water table aquifer. The groundwater contour maps also reveal that the groundwater flow patterns for September 1995 and January 1996 are nearly identical, differing only in the groundwater elevations between dry and wet weather conditions. The groundwater contour maps for the remaining months (not shown) are similar to those of Figures 6-10 and 6-11.

Although groundwater flow is relatively uniform across the Study Area, slightly steeper gradients are observed near River Road that correlate well with the rapid decline in surface elevation of the native deposits (compare Figure 5-4 with Figures 6-10 and 6-11). The mean hydraulic gradient is relatively constant throughout the year, being only slightly higher in November (Table D-2 in Appendix D). The arithmetic and geometric mean hydraulic gradients were found to range from 0.0077 m/m to 0.0085 m/m, and from 0.0077 m/m to 0.0084 m/m, respectively. These gradients are slightly larger than those calculated for the shallow hydrogeologic zone (compare Table D-2 with Table D-1).

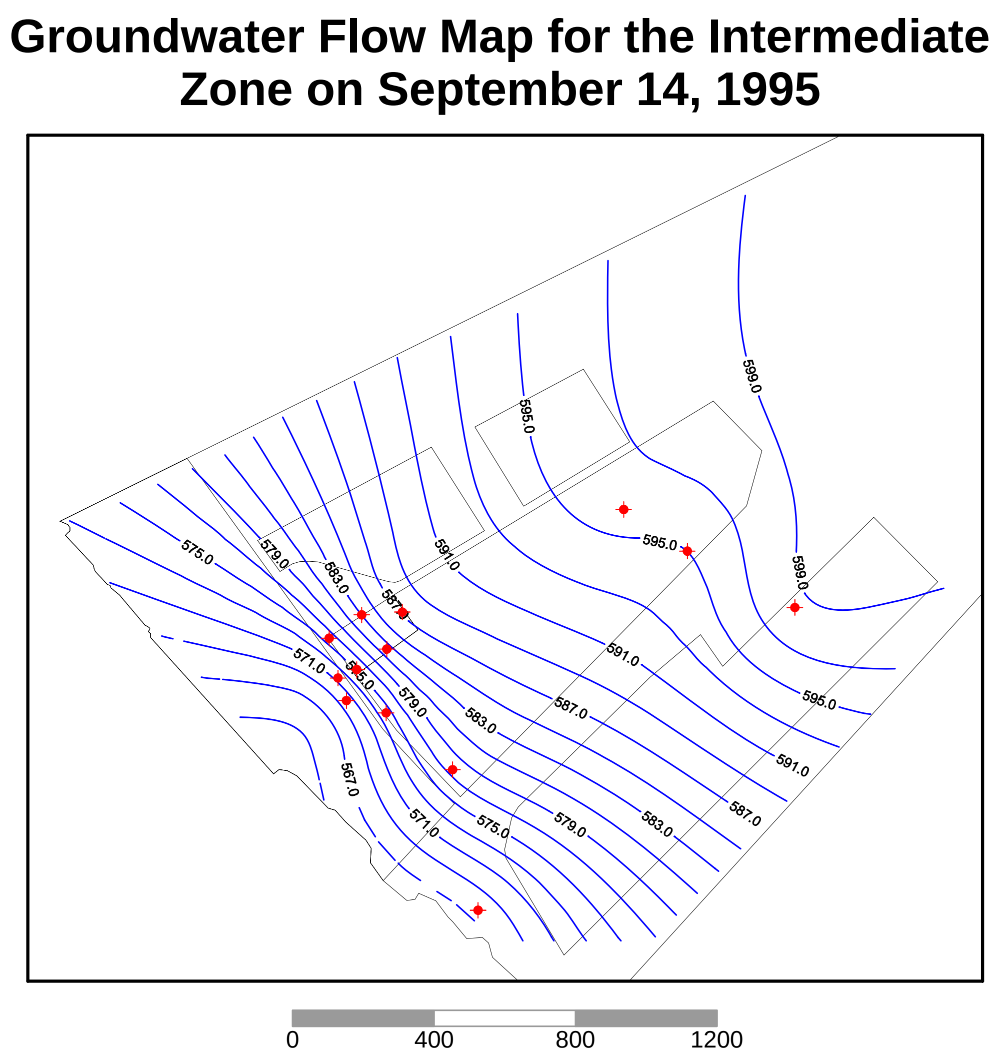


Figure 6-10. Intermediate Zone Groundwater Flow Across the Study Area on September 14, 1995. Wells are Shown as Red Crossed Dots. Scale in Meters.

In situ permeability tests have been conducted on six wells that screen the glaciolacustrine deposit. In addition, fourteen permeameter tests have been completed on soils from this deposit within the Study Area. These results are summarized in Table 6-3. In situ permeability tests have not been conducted on any wells within the Study Area that screen the alluvium deposit. Such tests, however, have been conducted on wells that screen this deposit at the nearby Niagara Mohawk Cherry Farm and Roblin Steel sites (Figure 2-1). These results are summarized in Table 6-4.

Vertical hydraulic conductivities for the glaciolacustrine deposit range from 1.08×10^{-8} to 5.83×10^{-8} cm/sec, with arithmetic and geometric means of 1.96×10^{-8} and 1.68×10^{-8} cm/sec, respectively (Table 6-3). Horizontal hydraulic conductivities of the reddish brown silty clay (bulk matrix) are an order of magnitude

Groundwater Flow Map for the Intermediate Zone on January 12, 1996

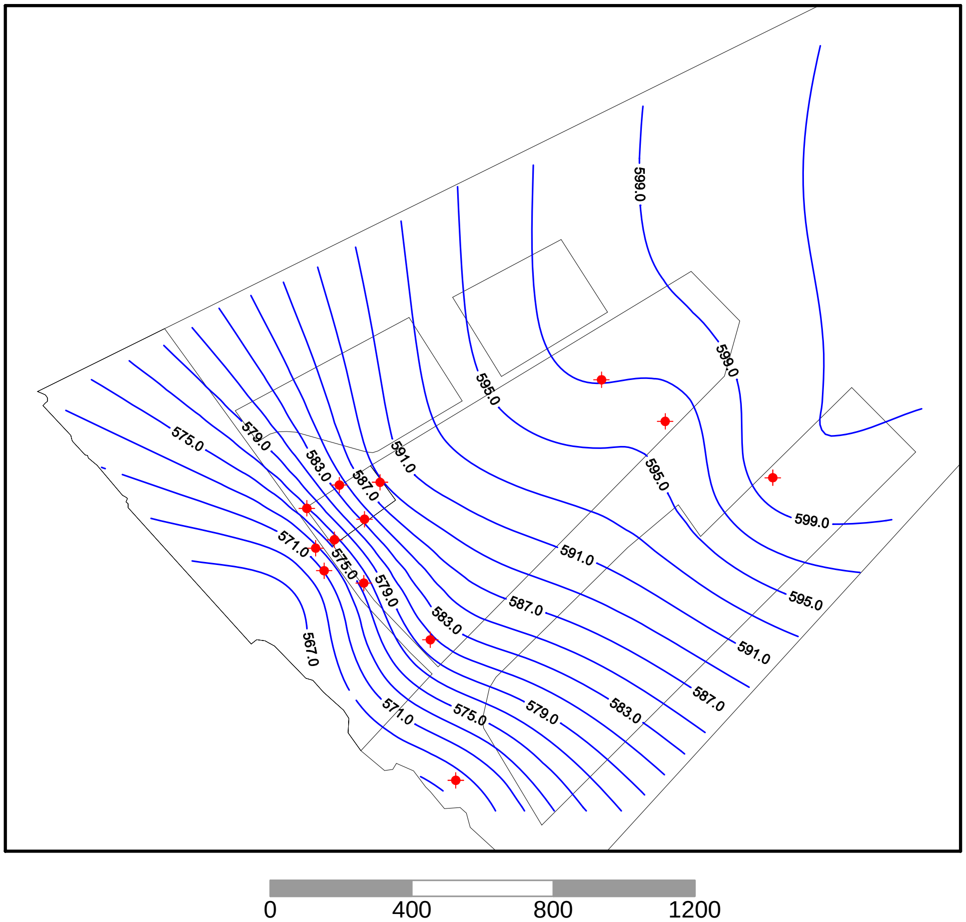


Figure 6-11. Intermediate Zone Groundwater Flow Across the Study Area on January 12, 1996. Wells are Shown as Red Crossed Dots. Scale in Meters.

greater, ranging from 7.48 x 10^{-6} to 5.50 x 10^{-8} cm/sec. The arithmetic and geometric means for these data are 2.00 x 10^{-6} and 9.70 x 10^{-7} cm/sec, respectively (Table 6-3). These results (vertical and horizontal) confirm that the glaciolacustrine deposit is best characterized as a confining layer, restricting the downward movement of groundwater from the shallow hydrogeologic zone to the deeper water bearing zones.

Intermediate zone wells installed entirely within the glaciolacustrine deposit, however, contain some groundwater. This water is believed to be a combination of soil pore water (where the soils are moist) and groundwater from the fill material that enters the wells through vertical dessication cracks. Early response data from slug tests, believed to represent the permeability of this fractured soil (URS, 1992), yield hydraulic conductivities slightly greater than the bulk matrix permeabilities. Hydraulic conductivities of the early response data range from 1.9 x 10^{-5} to 1.1 x 10^{-6} cm/sec, with arithmetic and geometric means of 8.77 x 10^{-6} and 4.99 x 10^{-6} cm/sec, respectively (Table 6-3).

Table 6-3.
Hydraulic Conductivity Test Data for the Glaciolacustrine Deposit of the Intermediate Hydrogeologic Zone.

Well or Boring Number	Site Name	Hydraulic Conductivity (cm/sec)	Screened Unit	Test Method
Vertical Hydraulic Conductivity				
B-3D	DYF	1.56e-08	Reddish Brown Silty Clay	Shelby
"	"	1.60e-08	" " " "	"
B-4D	DYF	1.59e-08	Reddish Brown Silty Clay	Shelby
"	"	1.54e-08	" " " "	"
B-7D	DYF	1.16e-08	Reddish Brown Silty Clay	Shelby
"	"	1.08e-08	" " " "	"
MW-8DD	PAS	1.19e-08	Reddish Brown Silty Clay	Shelby
"	"	1.27e-08	" " " "	"
MW-9DD	PAS	1.66e-08	Reddish Brown Silty Clay	Shelby
"	"	1.72e-08	" " " "	"
MW-10DD	PAS	5.83e-08	Reddish Brown Silty Clay	Shelby
"	"	4.71e-08	" " " "	"
MW-11DD	PAS	1.24e-08	Reddish Brown Silty Clay	Shelby
"	"	1.31e-08	" " " "	"
Geometric Mean		**1.68e-08**		
Arithmetic Mean		**1.96e-08**		
Horizontal Hydraulic Conductivity (Bulk Matrix)				
OMW-A4 *	DTC	1.80e-06	Reddish Brown Silty Clay	Bail Down
OMW-B4 *	DTC	9.20e-07	Reddish Brown Silty Clay	Bail Down
OMW-C5 *	DTC	7.48e-06	Reddish Brown Silty Clay	Slug
"	"	5.50e-08	" " " "	Bail Down
OMW-C7 *	DTC	5.40e-07	Reddish Brown Silty Clay	Bail Down
B-2D	PAS	1.00e-06	Reddish Brown Silty Clay	Slug
B-4D	PAS	2.20e-06	Reddish Brown Silty Clay	Slug
Geometric Mean		**9.70e-07**		
Arithmetic Mean		**2.00e-06**		

Table 6-3 (continued). Hydraulic Conductivity Test Data for the Glaciolacustrine Deposit of the Intermediate Hydrogeologic Zone.				
Well or Boring Number	**Site Name**	**Hydraulic Conductivity (cm/sec)**	**Screened Unit**	**Test Method**
Horizontal Hydraulic Conductivity (Desiccation Cracks)				
OMW-A4 **	DTC	1.70e-05	Reddish Brown Silty Clay	Bail Down
OMW-B4 **	DTC	1.90e-05	Reddish Brown Silty Clay	Bail Down
OMW-C5 **	DTC	1.75e-06	Reddish Brown Silty Clay	Slug
"	"	1.10e-06	" " " "	Bail Down
OMW-C7 **	DTC	5.00e-06	Reddish Brown Silty Clay	Bail Down
Geometric Mean		**4.99e-06**		
Arithmetic Mean		**8.77e-06**		

DYF DuPont Yerkes Plant.
DTC Dunlop Tire Corporation.
****** Early response data.
PAS Polymer Applications Site.
***** Late response data.

Hydraulic conductivity of the alluvium deposit is relatively uniform, with most wells having conductivities in the 10^{-3} cm/sec range (Table 6-4). The arithmetic and geometric means for these data are 6.31×10^{-3} and 1.59×10^{-3} cm/sec, respectively. These results indicate that the alluvium deposit is best characterized as an aquifer that could produce relatively high yields of water. Vertical hydraulic conductivities are not available for the alluvium deposit.

Several well clusters that screen the shallow and intermediate hydrogeologic zones exist within the Study Area. Water level data collected during this study indicate a downward flow potential between the shallow and intermediate zones (Figures 6-12 thru 6-14). The extremely low hydraulic conductivity of the glaciolacustrine deposit, however, suggests that the downward movement of groundwater would be limited, but could occur through the vertical desiccation cracks. Stratigraphic logs of borings completed in the Study Area indicate that the glaciolacustrine deposit is unsaturated to depths of approximately 25 to 30 feet (URS, 1992; Woodward-Clyde, 1993; Parsons Engineering Science, 1995; Weston, 1998). Such findings confirm that the downward movement of groundwater into the glaciolacustrine deposit is minimal.

Table 6-4. Hydraulic Conductivity Test Data for the for the Recent Alluvium Deposit of the Intermediate Hydrogeologic Zone.				
Well or Boring Number	**Site Name**	**Hydraulic Conductivity (cm/sec)**	**Screened Unit**	**Test Method**
Vertical Hydraulic Conductivity				
No Laboratory Conductivity Tests Have Been Conducted on the Recent Alluvium from Within or Near the Study Area.				
Geometric Mean		**N/A**		
Arithmetic Mean		**N/A**		
Horizontal Hydraulic Conductivity				
MW-1D	CFS	1.40e-04	Grey Fine Sand; Grey Gravel	Slug
MW-2I	CFS	9.14e-04	Grey Fine Sand	Slug
"	"	7.00e-04	" " "	"
MW-3I	CFS	2.74e-04	Grey Fine to Medium Sand and Silt	Slug
"	"	2.60e-04	" " " " "	"
MW-4I	CFS	3.05e-03	Grey Fine Sand; Grey Silt	Slug
"	"	3.40e-03	" " " "	"
MW-4D	CFS	3.20e-04	Grey Fine to Medium Sand and Silt; Till	Slug
MW-5I	CFS	1.52e-04	Grey Fine to Medium Sand	Slug
"	"	2.40e-04	" " " "	"
MW-5D	CFS	6.10e-03	Grey Fine to Medium Sand; Glacial Till	Slug
MW-6I	CFS	6.10e-03	Grey Fine to Medium Sand	Slug
"	"	6.00e-03	" " " "	"
MW-6D	CFS	3.20e-03	Brown Silt; Brown Fine Sand	Slug
MW-71	CFS	3.05e-03	Grey Fine to Medium Sand and Silt	Slug
"	"	4.60e-03	" " " " "	"
MW-8I	CFS	6.00e-03	Brown Fine to Medium Sand	Slug
MW-9I	CFS	2.50e-03	Grey Fine to Coarse Sand	Slug
MW-10I	CFS	1.80e-03	Grey Fine to Coarse Sand; Brown Silt	Slug
MW-11I	CFS	3.00e-04	Light to Medium Brown Silt	Slug
GW-1	RSS	2.00e-03	Brown Silt; Fine to Medium Sand	Slug
GW-2	RSS	9.00e-02	Grey Fine Sand; Grey Silt; Grey Clay	Slug
GW-5	RSS	4.00e-03	Brown Fine to Medium Sand	Slug
Geometric Mean		**1.59e-03**		
Arithmetic Mean		**6.31e-03**		
CFS Niagara Mohawk Cherry Farm Site.			**RSS Roblin Steel Site.**	

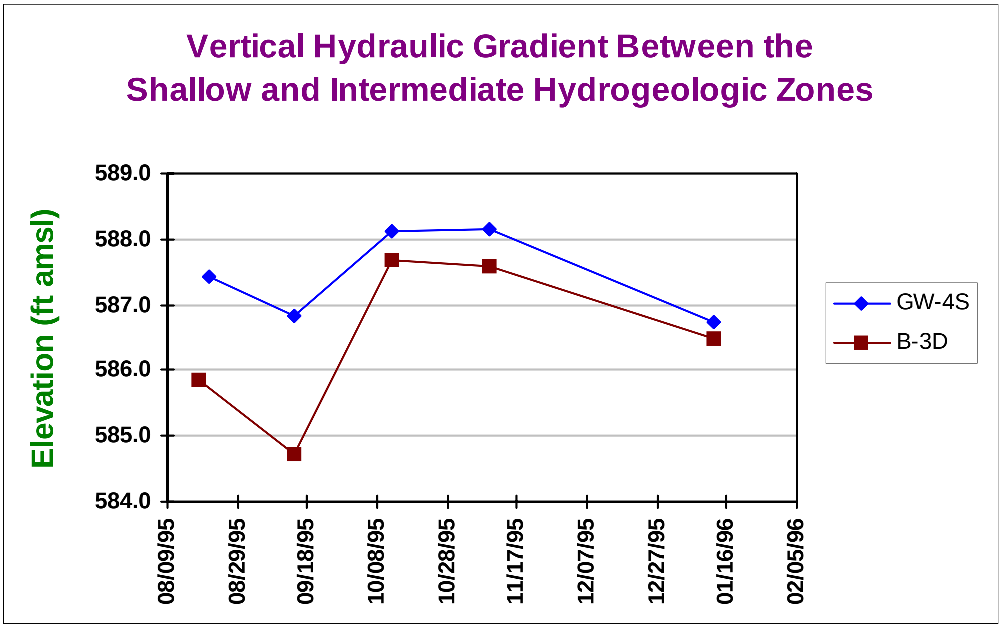


Figure 6-12. Vertical Hydraulic Gradient Between the Shallow and Intermediate Zones Within the Tonawanda Study Area. The Shallow Zone Well Is Denoted by Blue Diamonds, While the Intermediate Zone Well Is Denoted by Brown Squares.

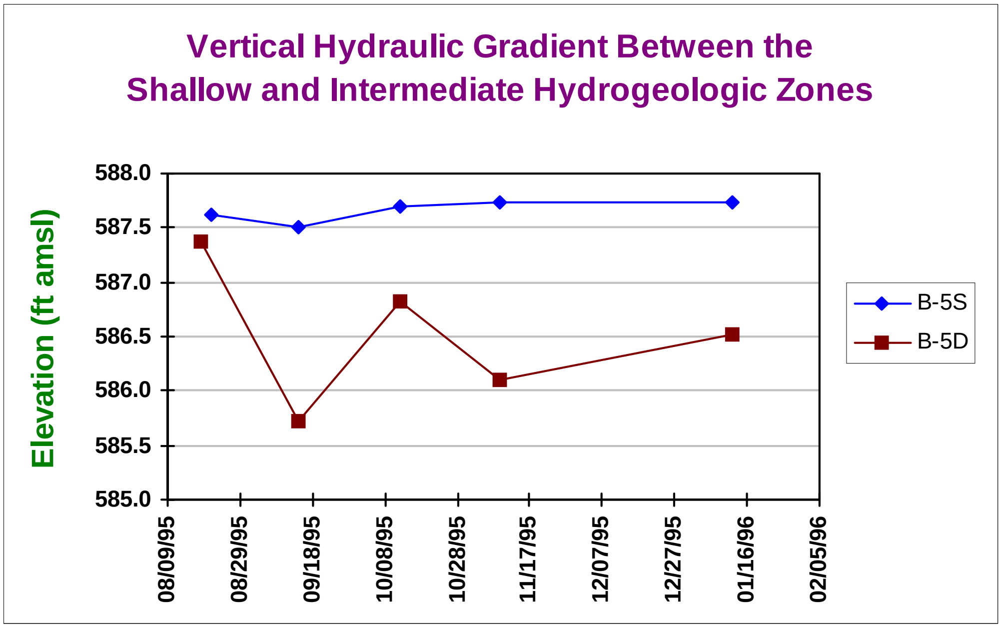


Figure 6-13. Vertical Hydraulic Gradient Between the Shallow and Intermediate Zones Within the Tonawanda Study Area. The Shallow Zone Well Is Denoted by Blue Diamonds, While the Intermediate Zone Well Is Denoted by Brown Squares.

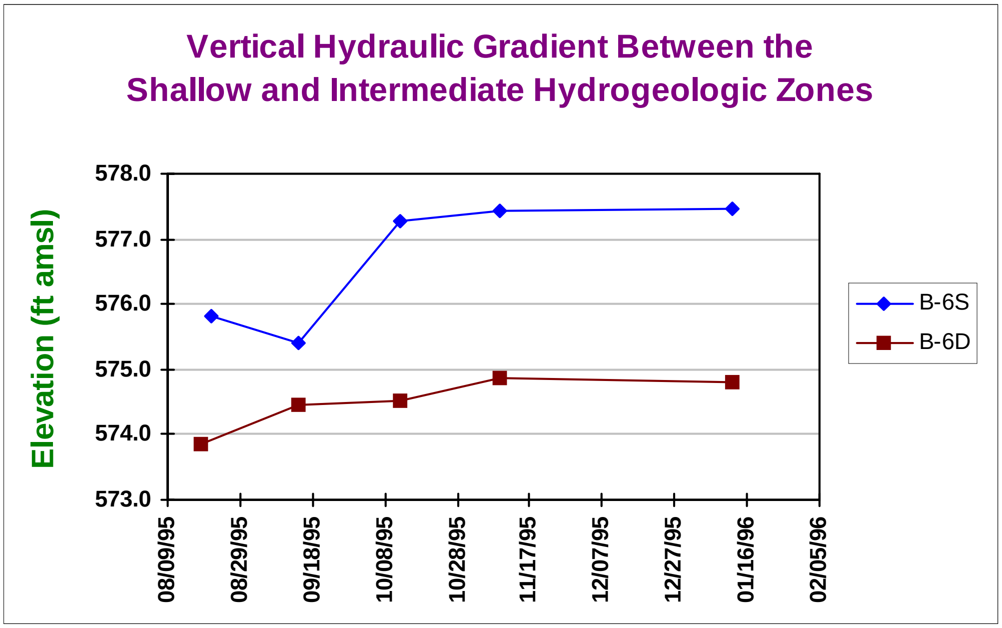


Figure 6-14. Vertical Hydraulic Gradient Between the Shallow and Intermediate Zones Within the Tonawanda Study Area. The Shallow Zone Well Is Denoted by Blue Diamonds, While the Intermediate Zone Well Is Denoted by Brown Squares.

6.2.3 *Deep Hydrogeologic Zone*

Fifteen deep hydrogeologic zone wells were monitored during this study (Plate 2; Table B-3 in Appendix B). Eight of these wells screen the unconsolidated deposits directly overlying bedrock, while the remaining wells screen both the unconsolidated deposits and upper Camillus Shale. Historically, water level measurements from these and other deep zone wells have been collected on numerous occasions: fourteen times at the Polymer Applications Site between August 30, 1983 and July 13, 1994; six times at the E.I. DuPont Yerkes Plant between October 2, 1979 and June 1993; and once at the 3M O-Cel-O Sponge Plant on May 8, 1992 (see Table C-5 in Appendix C). In order to obtain a more temporal data set, however, water level measurements were collected weekly between April 1995 to January 1996 from 15 deep zone wells within the Study Area (see Table C-6 in Appendix C).

The water level data obtained during this study were utilized to construct hydrographs for the deep zone wells (Figures 6-15 thru 6-17). These hydrographs reveal that prior to the initiation of groundwater extraction by the Dunlop Tire Corporation, water levels ranged from 566 to 570 feet above mean sea level with small fluctuations that appear to mirror fluctuations in the Niagara River (Figure 6-16). Following the initiation of groundwater extraction on June 5, 1995, water level declines were observed in all wells. The greatest water level declines were observed in wells at the Polymer Applications Site except well MW-10DD

(Figure 6-15). While drilling this well, artesian conditions were encountered in a basal sand deposit so the well was plugged with bentonite to a shallower depth prior to well installation. The isolation of this well from the deep hydrogeologic zone appears to have been effective but incomplete. With the exception of well MW-10DD, water level fluctuations in the Polymer Application wells ranged from 24 to 28 feet (Table C-6 in Appendix C). The lowest water level declines (< 2 feet) were observed in wells MW-1D and MW-2D at the E.I. DuPont Yerkes Plant (Figures 6-16; Table C-6 in Appendix C). Figures 6-15 thru 6-17 also indicate that during the period of active groundwater extraction water levels in most deep zone wells fall below water levels in the Niagara River. This suggests that water from the river could be recharging the deep zone during this time.

The response of the deep zone wells to groundwater extraction by the Dunlop Tire Corporation indicates that this zone is in direct hydraulic communication with the upper bedrock hydrogeologic zone. As a result, water level data from both zones (deep and upper bedrock) have been combined and contoured to determine the groundwater flow pattern of these zones across the Study Area. These contours are discussed in Section 6.2.4 - Upper Bedrock Hydrogeologic Zone.

In situ permeability tests have been conducted on six wells that monitor the deep hydrogeologic zone. In addition, fifteen permeameter tests have been completed on the glacial till from the Study Area. The results of these tests are summarized in Table 6-5, and indicate that the hydraulic conductivity of the deep zone within the Study Area is extremely variable, ranging from 6.91×10^{-3} to 9.10×10^{-9} cm/sec. The arithmetic and geometric means for these data are 6.32×10^{-4} and 5.84×10^{-6} cm/sec, respectively. Four of the conductivity values, however, come from wells that screen both the glacial till and upper Camillus Shale. Eliminating these values from the data set, the hydraulic conductivity of the glacial till is found to range from 1.00×10^{-3} to 9.10×10^{-9} cm/sec. This range in conductivity attests to the heterogeneous nature of the glacial till underlying the area, which, as described in Section 5.2.4, is characterized as a very dense, heterogeneous mixture of gray clay, silt, sand, gravel and shale bedrock fragments, with silt and clay occurring at the greatest percentage. The arithmetic and geometric means for the glacial till are 1.20×10^{-4} and 2.56×10^{-6} cm/sec, respectively. The vertical hydraulic conductivity of the glacial till was calculated from one reconstituted sample and determined to be 1.50×10^{-6} cm/sec (Table 6-5).

Three well clusters at the Polymer Applications Site screen the intermediate and deep hydrogeologic zones within the Study Area. Water level data collected during this study indicate a downward flow potential between the intermediate and deep zones (Figures 6-18 thru 6-20). The range in hydraulic conductivity values of the glacial till suggests that downward movement of groundwater could occur in areas where conductivity is relatively high, but would be limited in areas where conductivity is relatively low.

Table 6-5. Hydraulic Conductivity Test Data for the Deep Hydrogeologic Zone.				
Well or Boring Number	**Site Name**	**Hydraulic Conductivity (cm/sec)**	**Screened Unit**	**Test Method**
Vertical Hydraulic Conductivity				
SB-ST1	NMH	1.50e-06	Glacial Till	Laboratory **
Geometric Mean		**1.50e-06**		
Arithmetic Mean		**1.50e-06**		
Horizontal Hydraulic Conductivity				
SB-ST1	NMH	3.60e-08	Glacial Till	Geotechnical *
"	"	1.60e-08	" "	"
SB-ST5	NMH	2.40e-07	Glacial Till	Geotechnical *
SB-ST7	NMH	8.90e-08	Glacial Till	Geotechnical *
SB-ST9	NMH	9.10e-07	Glacial Till	Geotechnical *
SB-ST11	NMH	5.50e-07	Glacial Till	Geotechnical *
SB-ST13	NMH	6.00e-05	Glacial Till	Geotechnical *
SB-ST15	NMH	1.00e-03	Glacial Till	Geotechnical *
SB-ST17	NMH	1.50e-06	Glacial Till	Geotechnical *
SB-ST19	NMH	7.90e-06	Glacial Till	Geotechnical *
SB-ST21	NMH	7.90e-06	Glacial Till	Geotechnical *
SB-ST21	NMH	9.40e-04	Glacial Till	Slug
"	"	3.40e-06	" "	"
SB-ST23	NMH	2.00e-06	Glacial Till	Geotechnical *
SB-ST25	NMH	9.10e-09	Glacial Till	Geotechnical *
SB-ST30	NMH	6.00e-05	Glacial Till	Geotechnical *
B-1DD	PAS	7.20e-05	Glacial Till	Slug
MW-8DD	PAS	6.91e-03	Glacial Till; Camillus Shale	Slug
MW-9DD	PAS	2.56e-06	Glacial Till	Slug
MW-10DD	PAS	1.90e-05	Grey Clay; Grey Silt	Slug
MW-11DD	PAS	4.19e-03	Glacial Till; Camillus Shale	Slug
Geometric Mean		**5.84e-06**		
Arithmetic Mean		**6.32e-04**		

NMH Niagara Mohawk Huntley Plant.
PAS Polymer Applications Site.
***** Conductivity estimated from the Kozeny-Carman equation (GZA, 1983).
****** Falling head permeability test on reconstituted sample.

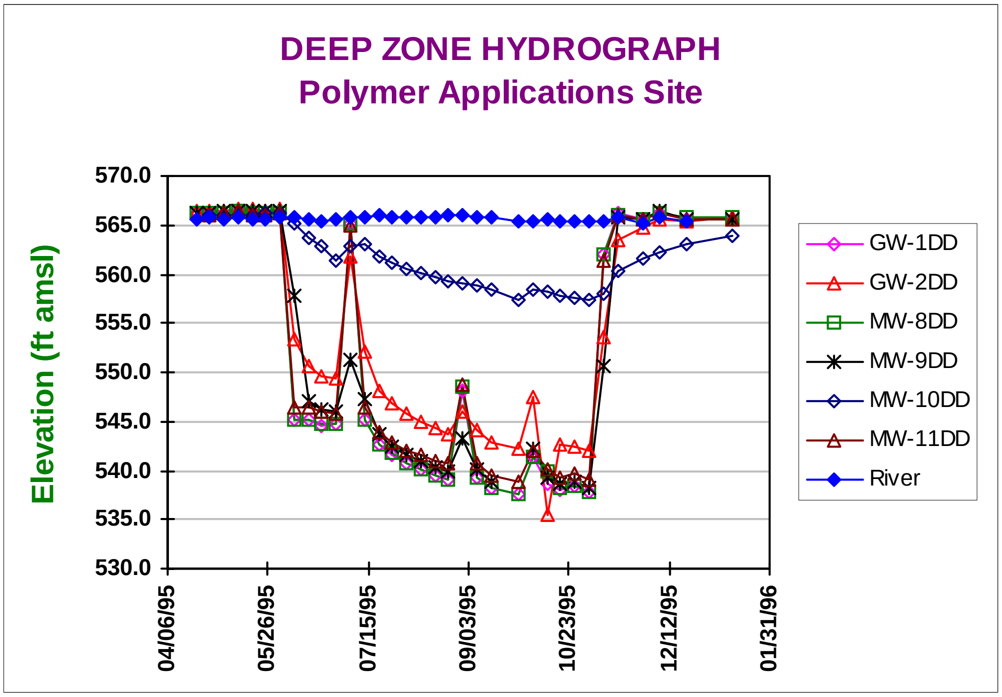


Figure 6-15. Deep Zone Hydrograph for the Tonawanda Study Area.

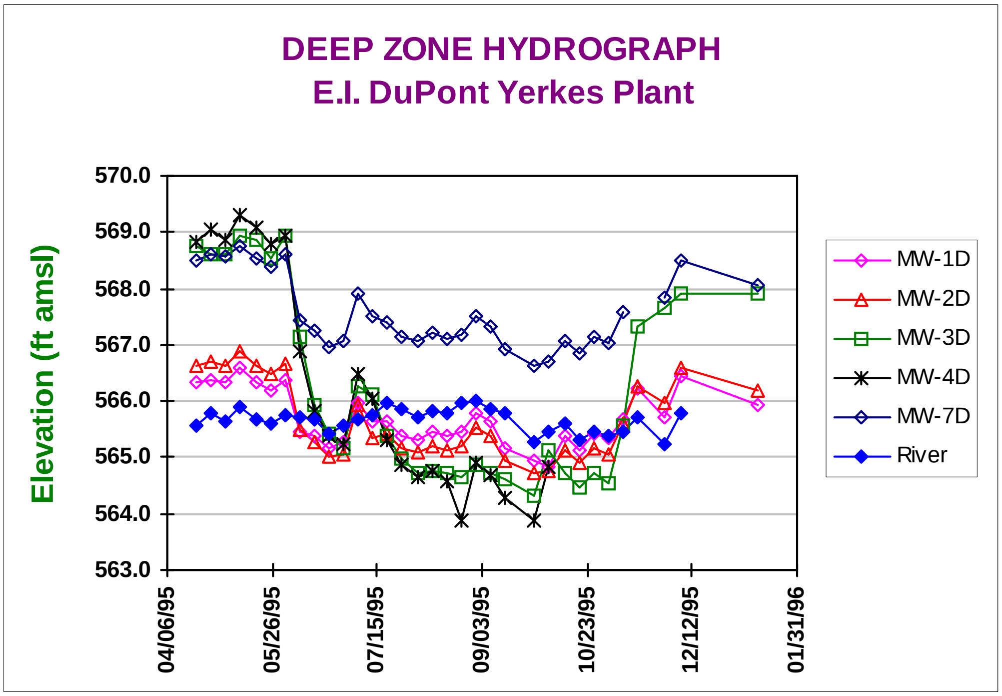


Figure 6-16. Deep Zone Hydrograph for the Tonawanda Study Area.

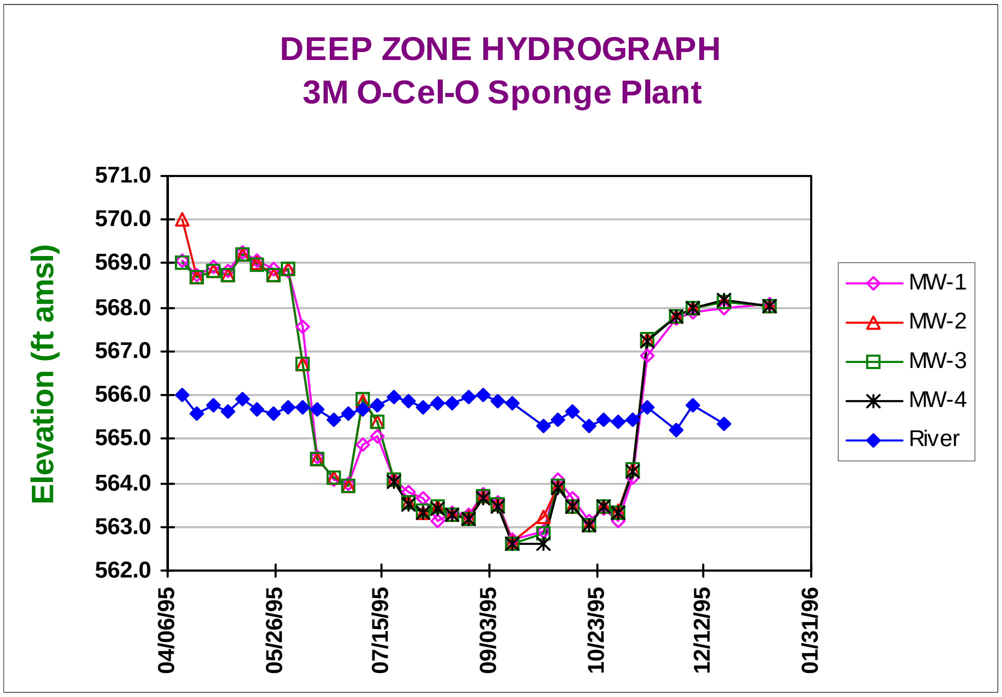


Figure 6-17. Deep Zone Hydrograph for the Tonawanda Study Area.

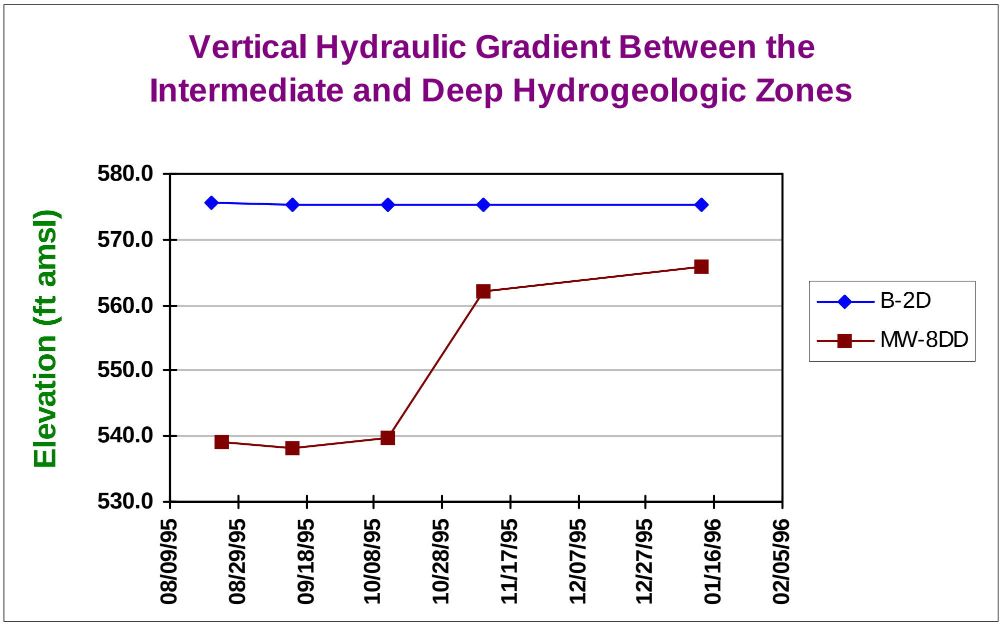


Figure 6-18. Vertical Hydraulic Gradient Between the Intermediate and Deep Zones Within the Tonawanda Study Area. The Intermediate Zone Well Is Denoted by Blue Diamonds, While the Deep Zone Well Is Denoted by Brown Squares.

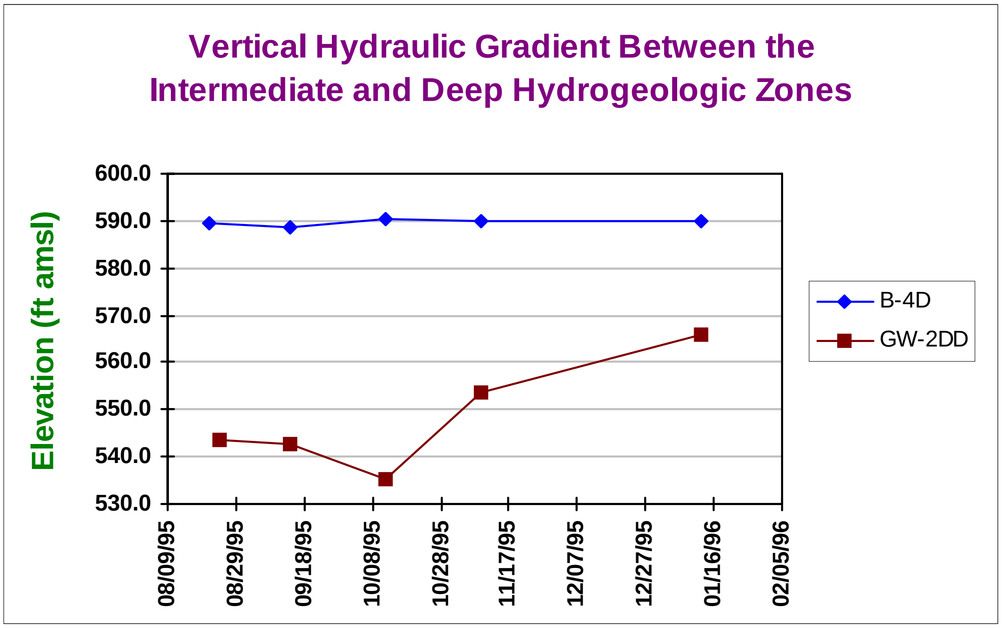


Figure 6-19. Vertical Hydraulic Gradient Between the Intermediate and Deep Zones Within the Tonawanda Study Area. The Intermediate Zone Well Is Denoted by Blue Diamonds, While the Deep Zone Well Is Denoted by Brown Squares.

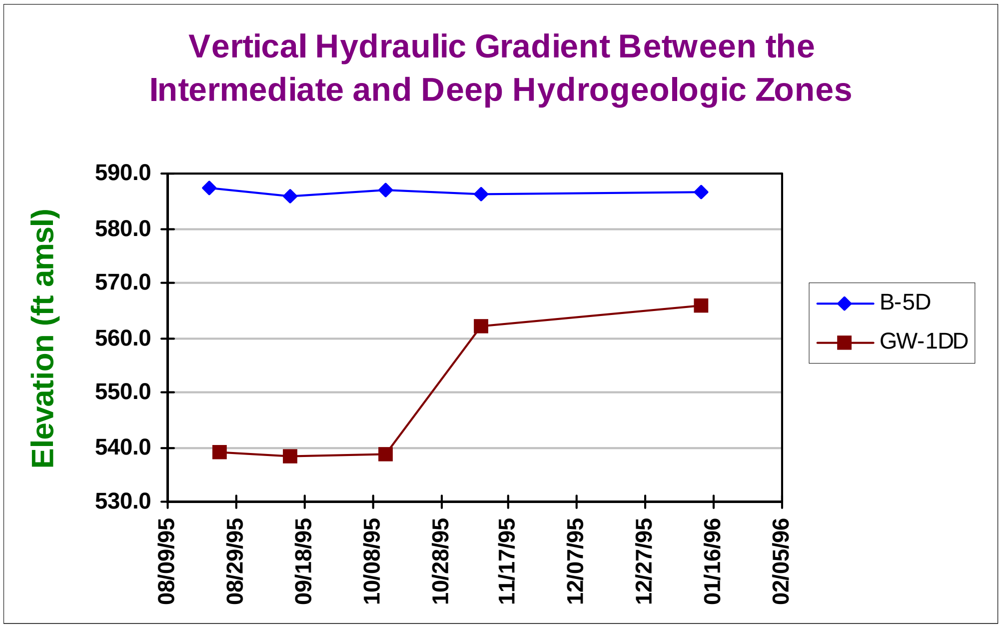


Figure 6-20. Vertical Hydraulic Gradient Between the Intermediate and Deep Zones Within the Tonawanda Study Area. The Intermediate Zone Well Is Denoted by Blue Diamonds, While the Deep Zone Well Is Denoted by Brown Squares.

6.2.4 *Upper Bedrock Hydrogeologic Zone*

Three upper bedrock hydrogeologic zone wells were monitored during this study (Plate 2; Table B-4 in Appendix B). Historically, water level measurements from these and other upper bedrock zone wells in the Study Area have been collected on numerous occasions: seventeen times at the Dunlop Tire Corporation between December 21, 1982 and September 27, 1991; and fourteen times at the Niagara Mohawk Huntley Plant between May 27, 1983 and March 21, 1995 (see Table C-7 in Appendix C). In order to obtain a more temporal data set, however, water level measurements were collected weekly between April 1995 to January 1996 from 3 upper bedrock zone wells within the Study Area (see Table C-8 in Appendix C).

The water level data obtained during this study were utilized to construct hydrographs for the upper bedrock zone wells (Figure 6-21). This figure reveals that prior to the initiation of groundwater extraction by the Dunlop Tire Corporation, water levels ranged from 566 to 570 feet above mean sea level with minor fluctuations. Following the initiation of groundwater extraction on June 5, 1995, however, water level declines were observed in two of the three upper bedrock wells. Water level declines were not observed in well 81-2TA, which due to its location near the Niagara River may be insensitive to groundwater extraction by the Dunlop Tire Corporation. The rapid water level decrease in well 81-1T during September 1995 (Figure 6-21) occurred when the well was purged prior to collecting a sample for geochemical analysis. Figure 6-21 indicates that it took several weeks for the water level in this well to return to “normal” levels, indicating that the hydraulic conductivity of the upper Camillus Shale is very low in this region of the Study Area.

Figures 3-1 and 3-2 illustrate the groundwater flow pattern across the Study Area for the deep and upper bedrock hydrogeologic zones on May 4, 1995 and November 2, 1995, respectively. These dates were selected as they represent the lowest and highest water levels observed during the study. During May, when the Dunlop production well is not being utilized, groundwater flows in a general southwest direction across the Study Area toward the Niagara River (Figure 3-1). A similar pattern of groundwater flow is observed in December 1995 (not shown) and January 1996 (not shown) after groundwater extraction has ceased and water levels have returned to their pre-pumping levels. During times of steady-state groundwater flow the mean hydraulic gradient across the area is relatively constant, with both the arithmetic and geometric mean hydraulic gradients ranging from 0.0005 m/m to 0.0006 m/m (Table D-3 in Appendix D).

By November 2, 1995, groundwater extraction had been ongoing for 5 months, 24 hours per day, at rates ranging from 1,200 to 1,800 gpm. Figure 3-2 reveals that groundwater extraction by the Dunlop Tire Corporation dominates the flow regime and produces an elliptical flow pattern centered around the production well and the wells at the Polymer Applications Site. Water level declines at this time ranged from 4 to 31 feet throughout the Study Area.

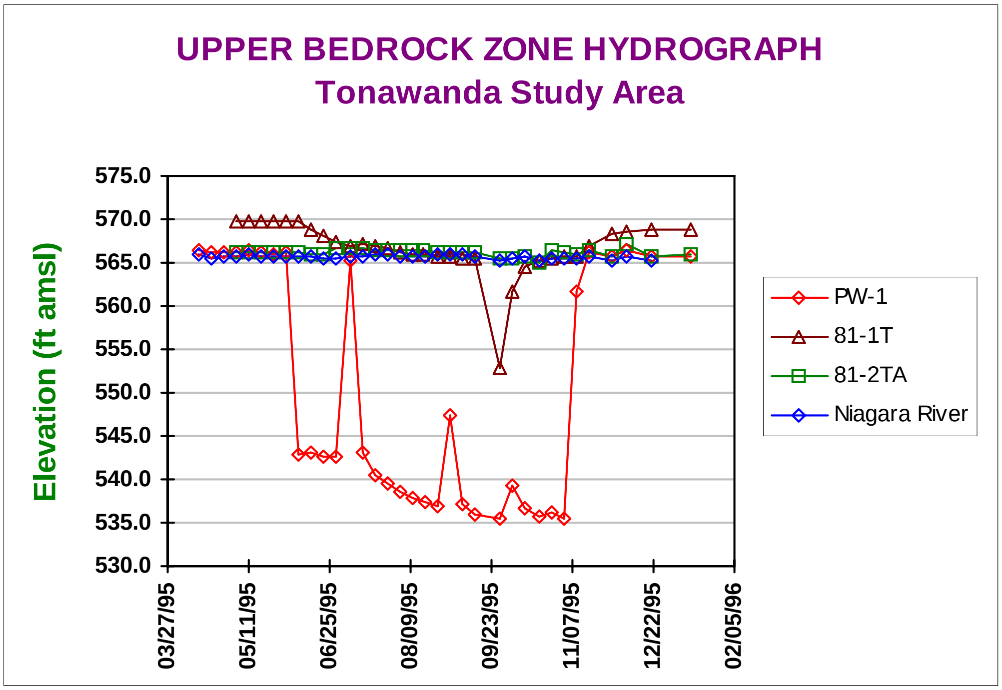


Figure 6-21. Upper Bedrock Zone Hydrograph for the Tonawanda Study Area.

The groundwater elevation data and flow maps suggest that groundwater extraction by the Dunlop Tire Corporation has the potential to effect contaminant migration throughout the Study Area. This is particularly critical as deep zone groundwater at the Polymer Applications Site was found to contain phenols at concentrations up to 75,200 µg/l. The Dunlop production well, however, is cased to a depth of 100 feet below ground surface (bgs), and extracts groundwater from a depth of 100 to 140 feet bgs. Since the depth to bedrock at the extraction well is ≈70 feet, groundwater is being extracted from a zone 30 to 70 feet below top of rock. As a result, groundwater from the upper 30 feet of bedrock cannot flow directly into the well, and could only reach the well if vertical fractures connect the upper bedrock hydrogeologic zone with the zone of extraction. While the presence of solution-enlarged horizontal fractures, bedding-plane openings, and voids created by the dissolution of gypsum is well documented for the Camillus Shale, the frequency and extent of vertical fractures are less well documented. In fact, there is no information available regarding vertical fractures in the Camillus Shale within the Study Area.

In situ permeability tests have been conducted on four wells that monitor the upper bedrock hydrogeologic zone within the Study Area. The results of these tests are summarized in Table 6-6, and indicate that the hydraulic conductivity of the upper bedrock zone is quite variable, ranging from 5.68 x 10^{-4} to 7.60 x 10^{-7} cm/sec. The arithmetic and geometric means for these data are 4.86 x 10^{-5} and 1.05 x 10^{-5} cm/sec, respectively. The hydraulic conductivity results for the upper portion of the Camillus Shale bedrock suggest that groundwater flow would be variable throughout the formation, but on average would be relatively slow.

There are no well clusters within the Study Area that monitor the deep and upper bedrock hydrogeologic zones. There is one well cluster, however, that screens the intermediate and upper bedrock zones. Water level data collected during this study indicate a downward flow potential between these zones, although a slight upward flow potential was observed during August 1995 (Figure 6-22). As stated in Section 6.2.3, the range in hydraulic conductivity values of the glacial till (Table 6-5) suggests that downward movement of groundwater could occur in some areas, but would be limited in others.

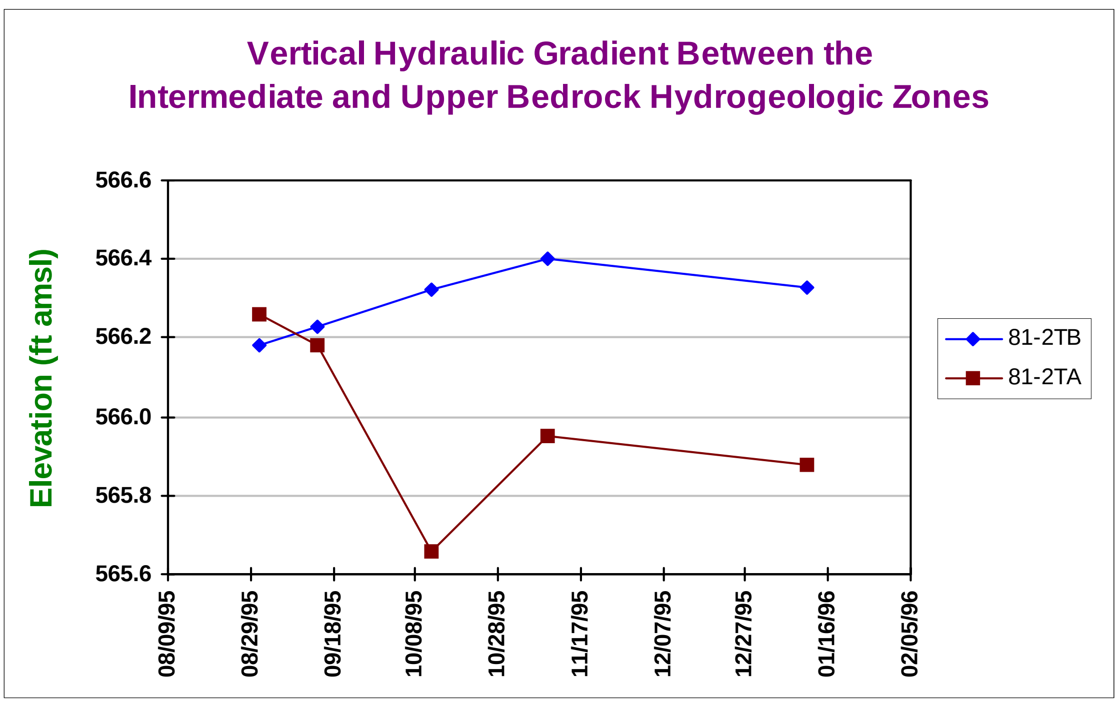


Figure 6-22. Vertical Hydraulic Gradient Between the Intermediate and Upper Bedrock Zones Within the Tonawanda Study Area. The Intermediate Zone Well Is Denoted by Blue Diamonds, While the Upper Bedrock Zone Well Is Denoted by Brown Squares.

Table 6-6. Hydraulic Conductivity Test Data for the Upper Bedrock Hydrogeologic Zone.				
Well or Boring Number	**Site Name**	**Hydraulic Conductivity (cm/sec)**	**Screened Unit**	**Test Method**
Vertical Hydraulic Conductivity				
No Laboratory Conductivity Tests Have Been Conducted on Rock Core Obtained from Within the Study Area.				
Geometric Mean		**N/A**		
Arithmetic Mean		**N/A**		
Horizontal Hydraulic Conductivity				
SB-ST13	NMH	7.16e-06	Camillus Shale	Packer
"	"	1.70e-06	"	"
"	"	9.49e-06	"	"
SB-ST17	NMH	5.68e-04	Camillus Shale	Packer
"	"	2.60e-05	"	"
"	"	2.50e-05	"	"
"	"	2.30e-05	"	"
"	"	2.03e-05	"	"
"	"	2.36e-05	"	"
SB-ST21	NMH	1.54e-06	Camillus Shale	Packer
"	"	3.00e-06	"	"
"	"	4.37e-06	"	"
"	"	1.12e-05	"	"
SB-ST25A	NMH	6.40e-05	Camillus Shale	Packer
"	"	8.15e-05	"	"
"	"	2.67e-06	"	"
"	"	2.02e-06	"	"
"	"	7.60e-07	"	"
Geometric Mean		**1.05e-05**		
Arithmetic Mean		**4.86e-05**		

N/A Not applicable.
NMH Niagara Mohawk Huntley Plant.

7.0 GROUNDWATER GEOCHEMISTRY

7.1 General

One objective of this study was to evaluate the potential effect of groundwater extraction by the Dunlop Tire Corporation on contaminant migration from individual inactive hazardous waste sites within the Study Area. The direct approach in making this evaluation would be to collect a sample of the extracted water for chemical analysis. Such a sample was collected in August 1995 and analyzed for total phenols, the major contaminant detected in deep zone groundwater at the Polymer Applications Site. Phenols were not detected in this sample. It is suspected, however, that the large pumping rates diluted this sample to such an extent that phenols were not detected. An alternative method, therefore, is to determine the source of groundwater supplying the production well. If this source is contaminated within the radius of influence, there would be a potential for contaminants to migrate toward the well. Such an evaluation can be accomplished through the use of geochemical evaluation methods.

Geochemical evaluation methods are based upon the principle that dissolved constituents in groundwater occur in predictable proportions, which are based upon the minerals present in the aquifer. In addition, the way in which dissolved constituents behave is known and predictable. As a result, if the minerals present are known, it is possible to predict the water quality resulting from the dissolution of these minerals. Geochemical evaluation methods, therefore, can be utilized to fingerprint different water types by the proportions of dissolved constituents present in the water.

7.2 Water Quality Database

The existing water quality database for the Study Area was not complete enough to use these geochemical evaluation methods. As a result, 57 samples were collected for chemical analyses during this study from the four hydrogeologic zones identified, the Niagara River and the wetland adjacent to the Dunlop Tire Corporation Site. These data are summarized in Appendix E. All samples were analyzed by Recra Environmental, Inc. in Amherst, New York for calcium, magnesium, sodium, potassium, sulfate, chloride, and alkalinity. Temperature, pH and turbidity were measured in the field at the time of sample collection.

In addition, historical water quality data from various locations along the Niagara River in the Tonawanda area are available. These data cover the years 1985 through 2003, and are summarized in Table E-1 in Appendix E. One sample from the river was also collected during this study for chemical analysis. These results are also summarized in Table E-1. Since the Dunlop production well is screened within the Camillus Shale, and owing to the fact that only three wells within the Study Area are totally screened within this formation, water quality data from nearby upper bedrock wells in the Tonawanda area were also compiled. These data are summarized in Table E-6 of Appendix E.

Prior to conducting geochemical evaluations, the general reliability of the data set must first be determined by completing charge balance calculations. These calculations consider the major dissolved species that account for most of the charge contribution to the solution. These species include calcium, magnesium, sodium, potassium, bicarbonate, chloride, and sulfate. Because most natural waters are electrically neutral, the sum of the positive charges should be approximately equal to the sum of the negative charges, with respect to the above seven ions. If there is a significant departure from neutrality (greater than 20 percent), there might be a problem with the analytical results and hence data reliability.

To calculate charge balance error, the concentration of each of the above seven ions is converted to their respective charge contributions. Each of the ions has a positive or negative charge, as follows:

CATIONS (POSITIVE CHARGE)	**ANIONS (NEGATIVE CHARGE)**
Calcium (+2)	Alkalinity (or bicarbonate) (-1)
Magnesium (+2)	
Sodium (+1)	Sulfate (-2)
Potassium (+1)	Chloride (-1)

The amount of charge contributed by each ion is determined by taking the reported concentration of each ion (in parts per million), dividing by its molecular weight, and multiplying by the ionic charge. For example, the amount of charge due to 100 ppm calcium is:

$$\underset{\text{(concentration)}}{100\text{ ppm}} \div \underset{\text{(molecular weight)}}{40\text{ mg/mmol}} \times \underset{\text{(ionic charge)}}{2} = \underset{\text{(total charge)}}{5\text{ meq/L.}}$$

The total charge is expressed in milliequivalents per liter (meq/L). This value is calculated for each of the seven ions, with the calculated meq/L values added separately for the positive and negative ions as follows:

$\sum$meg/L cations = meq/L calcium + meq/L magnesium + meq/L sodium + meq/L potassium,
$\sum$meq/L anions = meq/L bicarbonate + meq/L sulfate + meq/L chloride.

The percent error is then calculated as follows:

$$(\sum \text{meq/L cations} - \sum \text{meq/L anions}) \div (\sum \text{meq/L cations} + \sum \text{meq/L anions}) \times 100 = \% \text{ error.}$$

There may be circumstances that will produce excessive charge balance errors even with good analytical data. For example, if there is a significant concentration of trace constituents in the water sample, the result will be an apparent imbalance. For typical natural water samples, however, trace constituents are rarely concentrated enough to result in an error exceeding 20 percent.

In general, the error of the water quality database utilized in this study is less than 20 percent (Tables E-1 thru E-7 in Appendix E), indicating that the data are reliable for evaluation with geochemical evaluation methods. There were only nine samples that had errors greater than 20%, with eight of these samples associated with Polymer Application wells. Since all of the unacceptable Polymer errors are associated with samples collected in March 1994 (Tables E-2 thru E-4), and since acceptable errors were obtained from the same wells in subsequent sampling events completed during this study, the large charge balance errors are likely attributable to laboratory error. The results with unacceptable error were not utilized in the geochemical evaluation.

7.3 Geochemical Evaluation Methods

The geochemical evaluation method utilized in this study relied extensively on ion ratios, rather than comparisons of reported concentrations of individual constituents. This technique minimizes the effects of seasonal and random variability in reported concentrations between sampling events, while changes in water quality over time can be more reliably determined. The graphical method utilized was the Piper diagram. These plots were interpreted within the context of the known hydrogeology of the Study Area, such that water quality patterns could be related to the water bearing zone materials.

7.3.1 *Piper Diagrams*

A water's chemical character is determined by seven major ions (calcium, magnesium, sodium, potassium, chloride, sulfate, and bicarbonate); therefore, evaluating the relative abundance of these ions can be utilized to identify mineral or waste sources for these ions. As a result, Piper diagrams are an effective means of evaluating a large quantity of water quality data as numerous samples can be included on a single plot. Major ion groupings and mixing trends are clearly differentiated, while water quality changes for a given well over time can also be determined.

Piper diagrams are prepared by first calculating the relative proportion of each cation (calcium, magnesium, sodium, potassium) to the total cation concentration, and the relative proportion of each anion (chloride, sulfate, bicarbonate) to the total anion concentration. The cation chemistry for each sample is plotted on the lower left triangle of the Piper diagram, while the anion chemistry is plotted on the lower right triangle (Figure 7-1). The corresponding data points in each triangle are then extrapolated up into the central diamond and plotted at the intersection of the extrapolations (Figure 7-1). Waters originating from different geologic materials will plot within distinct regions that will be characteristic of the associated aquifer. Waters that are mixtures will plot between these distinct regions. Thus, the origin of a given water chemistry can be determined, along with mixing reactions between different water types.

7.4 Conceptual Geochemical Model of the Study Area

As groundwater flows through the subsurface environment, it evolves geochemically based upon the minerals present in the aquifer and the solubility of those minerals. As a general rule, the concentration of total dissolved solids (TDS) and most of the major ions will increase naturally. This generalization suggests that shallow groundwater in recharge areas will be lower in TDS and major ion concentration than shallow groundwater in discharge areas, and further, will also be lower in TDS and major ion concentration than groundwater deeper in the system (Freeze and Cherry, 1979). Combining this general principle with the known hydrogeology of the Study Area, a conceptual geochemical model for the area was developed. The Piper diagrams generated during this study are then interpreted within the framework of this model.

As discussed in Section 5.0, the general stratigraphy of the Study Area with increasing depth consists of miscellaneous fill, glaciolacustrine silty clays, glacial till, and Camillus Shale bedrock. While the hydraulic conductivity of the glaciolacustrine deposit is extremely low, the presence of vertical desiccation cracks increases the potential for precipitation to infiltrate to deeper hydrogeologic zones. As infiltration proceeds, this water will evolve by increasing in TDS and major ion concentrations. Since limestone, dolostone, and shale are the dominant rock types in the area, the overburden soils will be composed predominantly of the minerals present in these rocks. As a result, the shallow hydrogeologic zone, which is characterized by active flushing during infiltration, will be dominated by bicarbonate resulting from the interaction of soil CO_2 with carbonate derived from the dissolution of limestone and dolostone in the soils. Water from the Niagara River would also be dominated by bicarbonate due to the interaction of carbonate ions in the water with atmospheric CO_2. For wells screened within the fill materials, however, groundwater quality would likely exhibit a wide range of characteristics relating to the chemistry of the fill.

Niagara River in Tonawanda - 1985 thru 2003

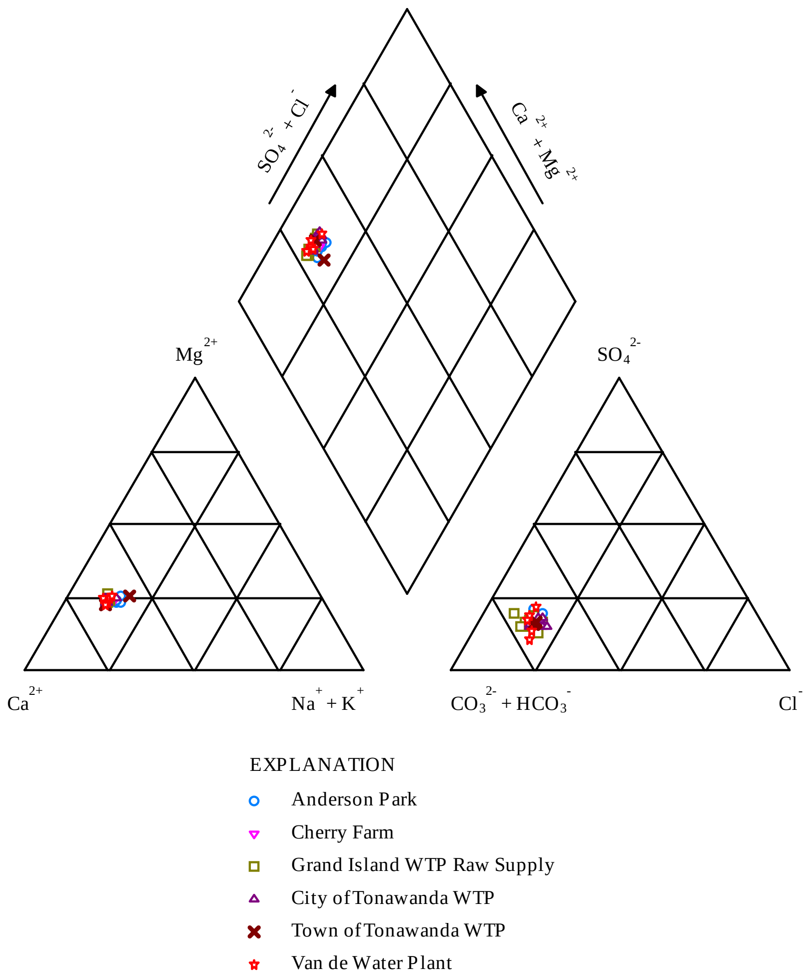


Figure 7-1. Piper Diagram Showing the Ionic Composition of Water from the Niagara River in the Tonawanda Area.

As water continues to infiltrate through the unsaturated zone (the intermediate hydrogeologic zone), the concentrations of calcium, magnesium and bicarbonate will continue to increase. In addition, the presence of shale minerals begins to play a significant role in the evolution of the infiltrating water. Since sodium and sulfate are common ions in shale, water in the intermediate zone will also exhibit increasing concentrations of these ions. Once this water reaches the saturated zone, it will continue to evolve but under closed-system conditions as atmospheric CO_2 is no longer available to the system. The carbonate minerals are less soluble under closed-system conditions, giving rise to increased dissolution of other minerals in the soils.

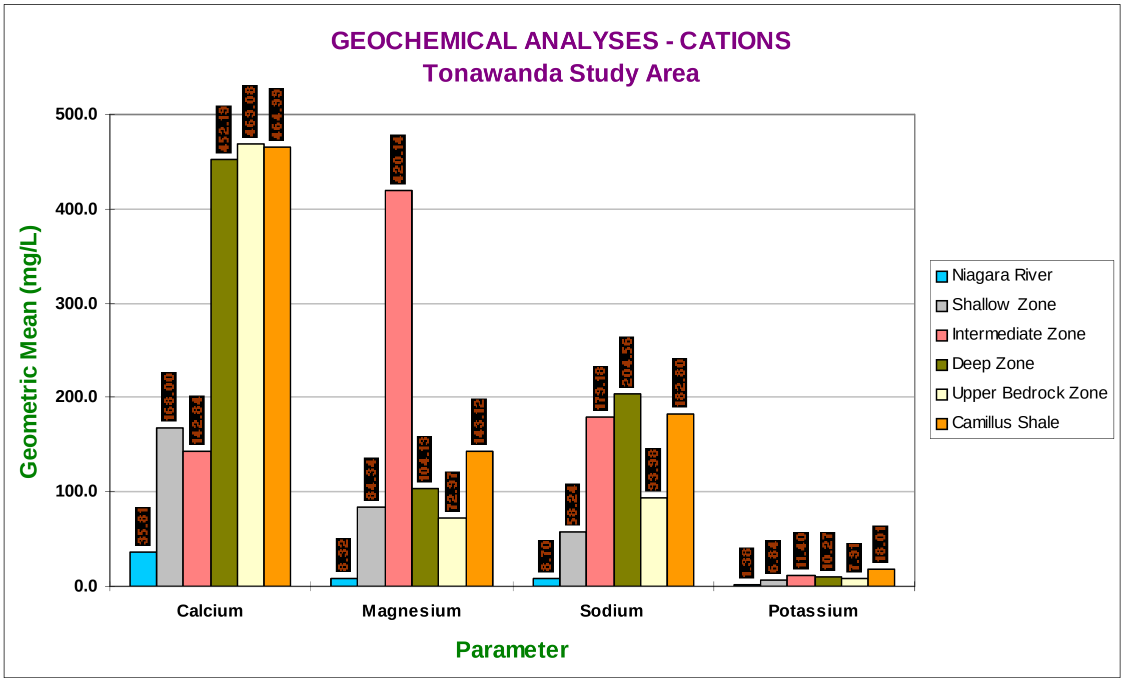
Groundwater within the deep and upper bedrock hydrogeologic zone evolves differently than water within the unsaturated zone. While water in the unsaturated zone evolves during infiltration, groundwater in the deep and upper bedrock zones evolves as it flows through the saturated media. The recharge zone, which is located well away from the Study Area, would have characteristics similar to those in the shallow hydrogeologic zone; active flushing during recharge would be dominated by bicarbonate resulting from the interaction of soil CO_2 with carbonate derived from the dissolution of limestone and dolostone in the recharge zone. As groundwater flows through the deep and upper bedrock zones, the concentrations of the major ions would continue to increase, as would the concentration of TDS. Since the Camillus Shale contains abundant quantities of gypsum ($CaSO_4 \cdot H_2O$), groundwater within this formation will become concentrated in calcium and sulfate, while bicarbonate concentrations will decrease as limestone ($CaCO_3$), which is also found in abundant quantities within the Camillus Shale, is less soluble under close-system (saturated) conditions.

There are three possible sources of water supplying the Dunlop production well: (1) groundwater from the Camillus Shale bedrock, (2) water from the Niagara River infiltrating into the Camillus Shale bedrock, or (3) water from both the Camillus Shale and river (source mixing). The conceptual geochemical model described above provides a framework in which to evaluate these possibilities. If groundwater from the Camillus Shale is the source, extracted groundwater will be ionically similar to Camillus Shale groundwater. On the other hand, if the Niagara River is the source, extracted groundwater will be ionically similar to water from the river. If both sources are supplying water to the production well, extracted groundwater will be ionically distinct, plotting between Camillus Shale groundwater and Niagara River water on a Piper diagram.

7.5 Geochemical Results

7.5.1 *Niagara River*

Water from the Niagara River contains higher concentrations of calcium (28.5 to 40.1 mg/l) and bicarbonate (100.0 to 124.5 mg/l) compared to the other major anions and cations (Table E-1 in Appendix E). The geometric means for calcium and bicarbonate are 35.81 mg/l and 115.63 mg/l, respectively (Figure 7-2). The other major anions and cations are detected at much lower concentrations (Table E-1): magnesium (7.1 to 10.0 mg/l), potassium (1.2 to 1.6 mg/l), sodium (7.1 to 11.6 mg/l), chloride (7.5 to 22.5 mg/l) and sulfate (14.0 to 30.7 mg/l). The geometric means for these constituents are also shown on Figure 7-2. Based upon the Piper diagram for these data (Figure 7-1), water from the Niagara River is classified as a calcium-bicarbonate water that has remained relatively constant geochemically over at least an 18 year period. Turbidity of the Niagara River is extremely low, ranging from 0.5 to 9.5 NTU's, while the pH is slightly basic, ranging from 7.6 to 8.4 standard pH units (Table E-1).



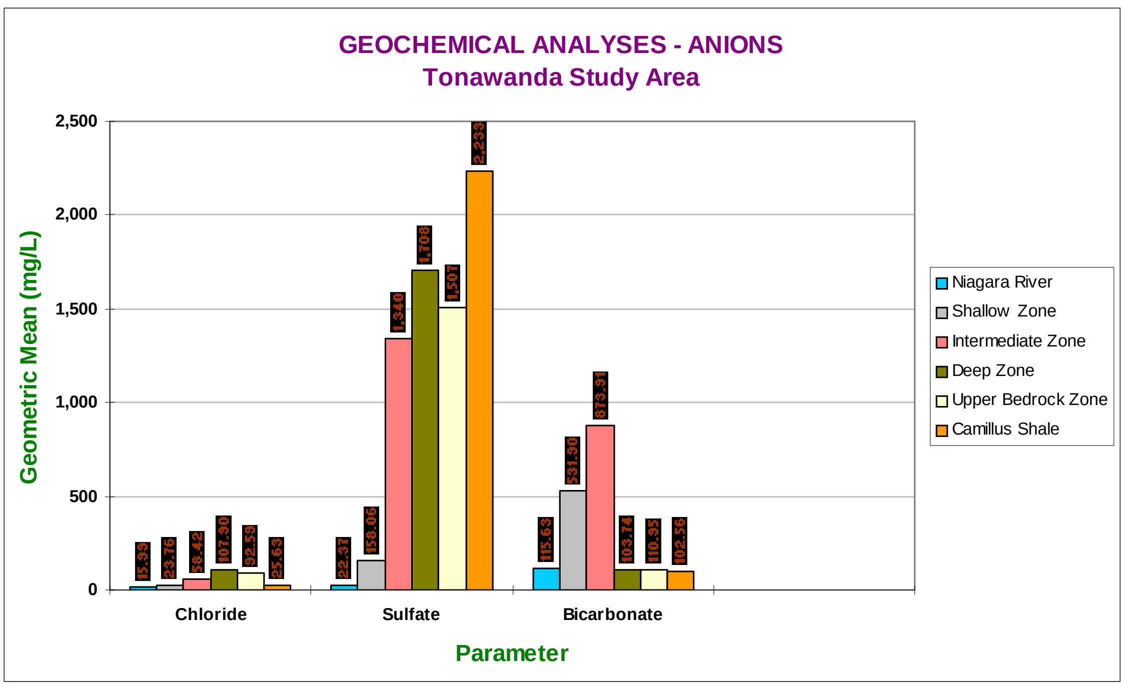


Figure 7-2. Major Cation and Anion Data from the Study Area Showing Variations in Geometric Means for the Hydrogeologic Zones Evaluated in this Study.

7.5.2 *Wetlands*

Water from the wetland adjacent to the Dunlop Tire Corporation Site is extremely variable, although only two samples of this water were analyzed during the study (Table E-7 in Appendix E). Concentrations of the major anions and cations range as follows: calcium (51.6 to 167.0 mg/l), magnesium (13.1 to 49.3 mg/l), sodium (32.3 to 504.0 mg/l), potassium (4.6 to 8.6 mg/l), chloride (71.4 to 1,060 mg/l), sulfate (89.8 to 96.8 mg/l) and bicarbonate (58.3 to 293.8 mg/l). The Piper diagram for these data (Figure 7-3) indicates that wetland water near Sawyer Avenue is a calcium-sulfate water, while the wetland water near Dunlop well OMW-C1 is a sodium-chloride water. The turbidity of the wetland water is relatively low, ranging from 6.9 to 13.8 NTUs (Table E-7). The pH of this water is relatively constant, ranging from 6.5 to 7.2 standard pH units (Table E-7).

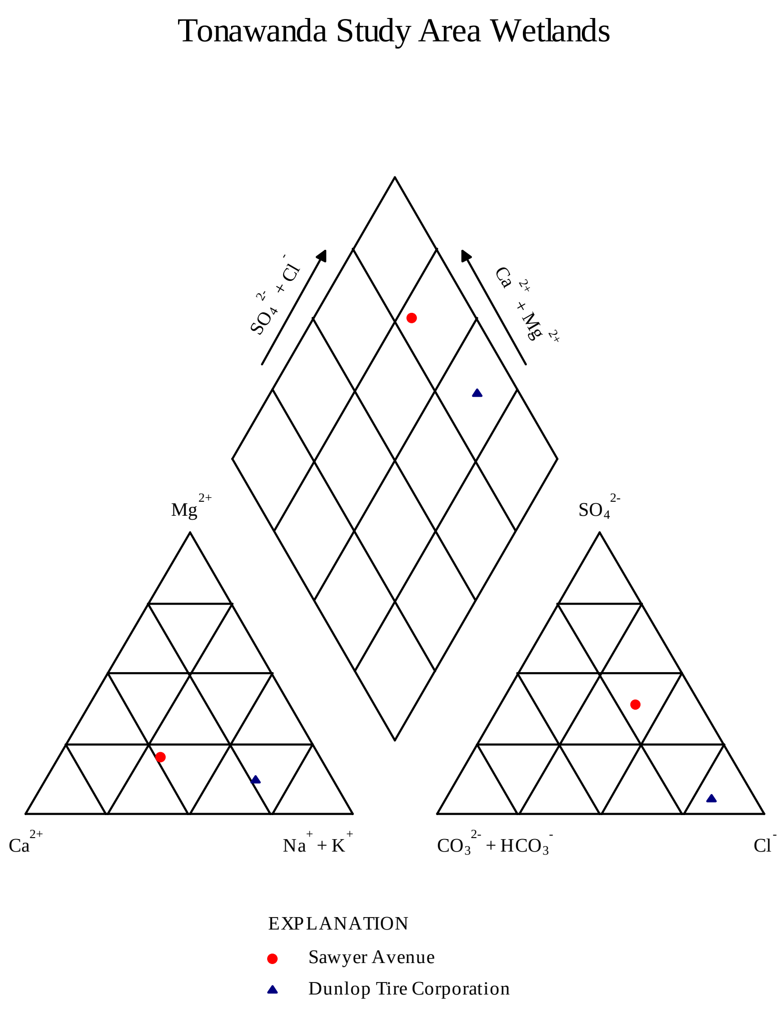


Figure 7-3. Piper Diagram Showing the Ionic Composition of Water from the Wetlands Within the Tonawanda Study Area.

7.5.3 *Shallow Hydrogeologic Zone*

Water from the shallow hydrogeologic zone is highly variable, most likely affected by precipitation, seasonal fluctuations in water levels and the fill materials through which shallow groundwater flows (Table E-2 in Appendix E). In general, water in this zone contains higher concentrations of calcium (74.7 to 551.0 mg/l) and bicarbonate (43.6 to 1,353 mg/l) compared to the other major anions and cations. The geometric means for calcium and bicarbonate are 168.00 mg/l and 531.90 mg/l, respectively (Figure 7-2). Concentrations of the other major anions and cations range as follows: magnesium (16.3 to 571.0 mg/l), sodium (21.0 to 206.0 mg/l), potassium (2.9 to 13.6 mg/l), chloride (7.0 to 70.9 mg/l) and sulfate (3.4 to 2,260 mg/l). The geometric means for these constituents are also shown on Figure 7-2, while the Piper diagram for the shallow zone is given as Figure 7-4. The Piper diagram indicates that shallow zone groundwater is best classified as a calcium-bicarbonate water, although well OMW-C1 at the Dunlop Tire Corporation contains magnesium-sulfate water (Figure 7-4), and Polymer Application wells MW-13S and MW-14S contain calcium-sulfate water (Figure 7-4).

The turbidity of shallow zone groundwater is extremely variable, ranging from 28.0 to over 1,000 NTUs (Table E-2). The pH of this water is highly variable, ranging from 4.6 to 8.6 standard pH units (Table E-2).

7.5.4 *Intermediate Hydrogeologic Zone*

Water from the intermediate hydrogeologic zone is highly variable, but in general contains higher concentrations of magnesium (112.0 to 1,380 mg/l) and sulfate (78.5 to 7,560 mg/l) compared to the other major anions and cations (Table E-3 in Appendix E). The geometric means for magnesium and sulfate are 420.14 mg/l and 1,340 mg/l, respectively (Figure 7-2). Concentrations of the other major anions and cations range as follows: calcium (55.1 to 539.0 mg/l), sodium (30.5 to 659.0 mg/l), potassium (4.1 to 31.9 mg/l), chloride (22.9 to 169.0 mg/l) and bicarbonate (601.1 to 1,164 mg/l). The geometric means for these constituents are also shown on Figure 7-2, while the Piper diagram for the intermediate zone is given as Figure 7-5. The Piper diagram indicates that intermediate zone groundwater is best classified as a magnesium-sulfate water, although well OMW-A6 at the Dunlop Tire Corporation and well MW-3D at the Polymer Applications Site contain magnesium-bicarbonate water (Figure 7-5). Figure 7-5 also indicates that the proportion of magnesium in intermediate zone water is relatively constant, while the proportions of sulfate and bicarbonate very considerably.

The turbidity of intermediate zone groundwater is extremely variable, ranging from 4.5 to 1,030

NTUs (Table E-3). The pH of this water is highly variable, ranging from 5.9 to 8.1 standard pH units (Table E-3).

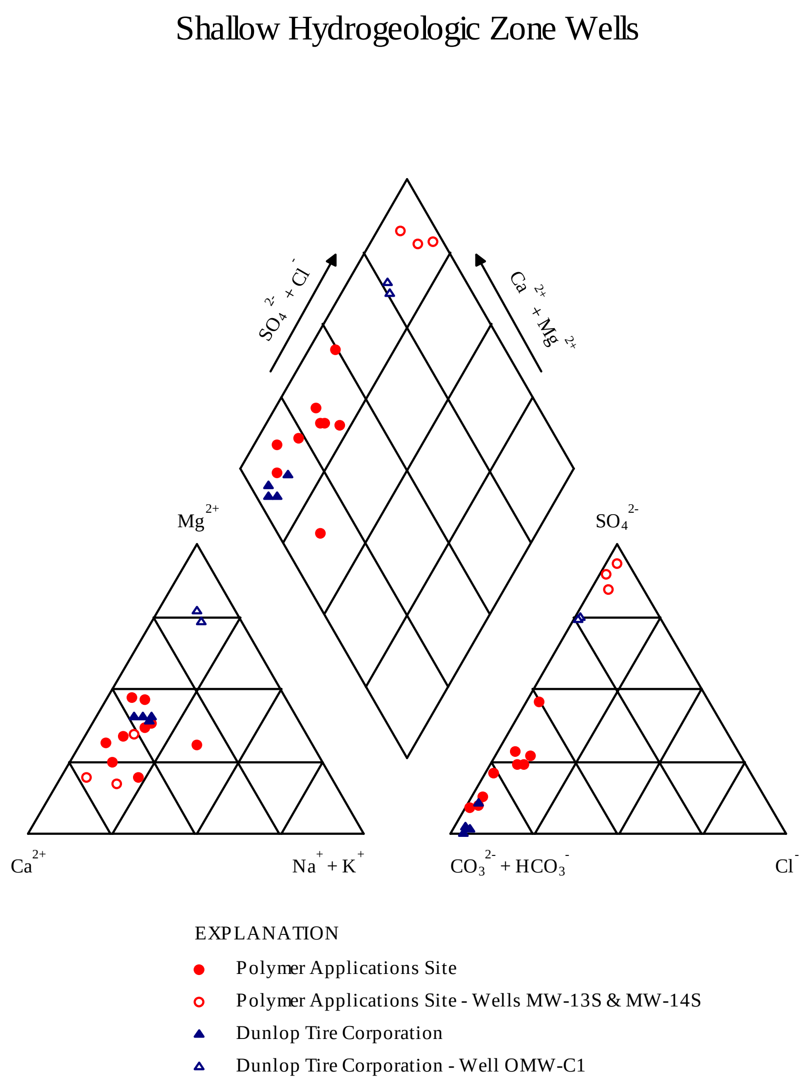


Figure 7-4. Piper Diagram Showing the Ionic Composition of Water from the Shallow Hydrogeologic Zone Within the Tonawanda Study Area.

7.5.5 *Deep Hydrogeologic Zone*

Water from the deep hydrogeologic zone contains higher concentrations of calcium (35.3 to 935.0 mg/l) and sulfate (74.9 to 4,210 mg/l) compared to the other major anions and cations (Table E-4 in Appendix E). The geometric means for calcium and sulfate are 452.19 mg/l and 1,708 mg/l, respectively (Figure 7-2). Concentrations of the other major anions and cations range as follows: magnesium (2.2 to 331.0 mg/l), sodium (14.5 to 384.0 mg/l), potassium (4.5 to 37.4 mg/l), chloride (18.0 to 296.0 mg/l) and bicarbonate (32.3 to 848.6 mg/l). The geometric means for these constituents are also shown on Figure 7-2, while the Piper diagram for the deep zone is given as Figure 7-6. The Piper diagram indicates that deep zone groundwater is best classified as a calcium-sulfate water, although Polymer Application wells GW-1DD and MW-8DD contain higher proportions of bicarbonate.

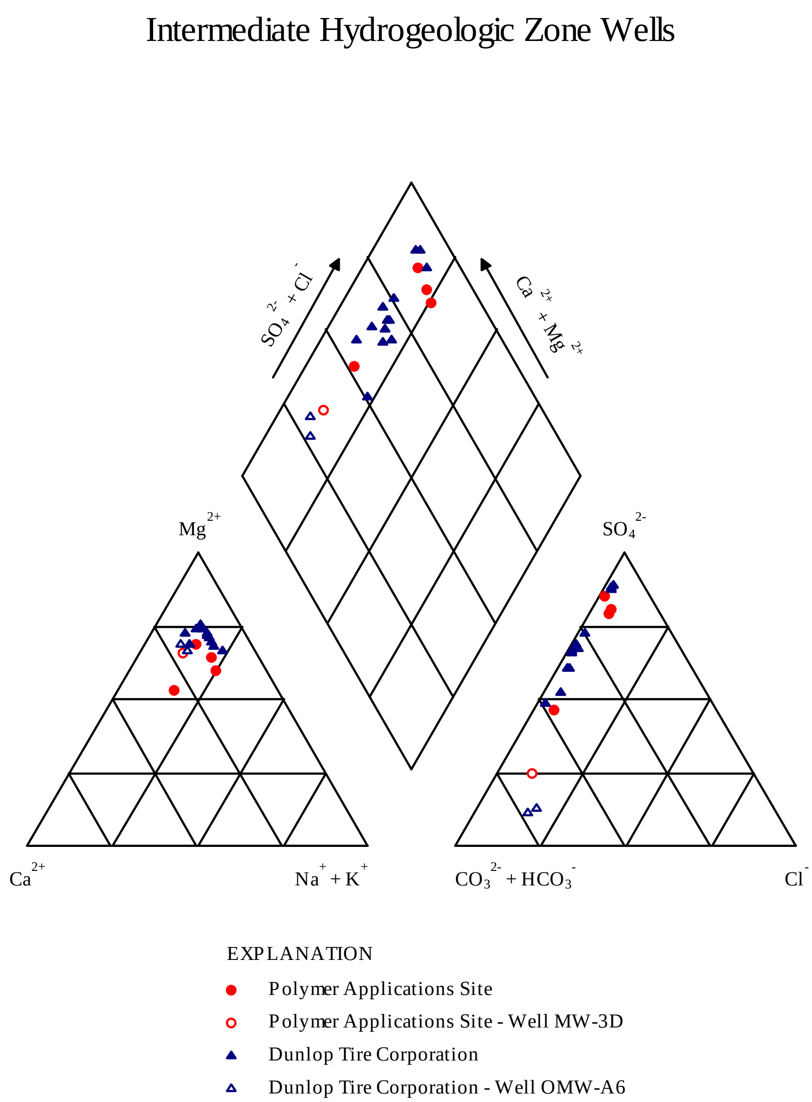


Figure 7-5. Piper Diagram Showing the Ionic Composition of Water from the Intermediate Hydrogeologic Zone Within the Tonawanda Study Area.

The turbidity of deep zone groundwater is highly variable, ranging from 2.9 to over 200 NTUs (Table E-4). In general, the pH of this water ranges from slightly acidic to slightly basic, with typical values ranging from 6.6 to 8.7 standard pH units (Table E-4). Some pH values, however, were as low as 5.2 standard pH units (Polymer Application well MW-10DD), while Polymer Application well GW-1DD had a pH of 12.2 standard pH units (Table E-4).

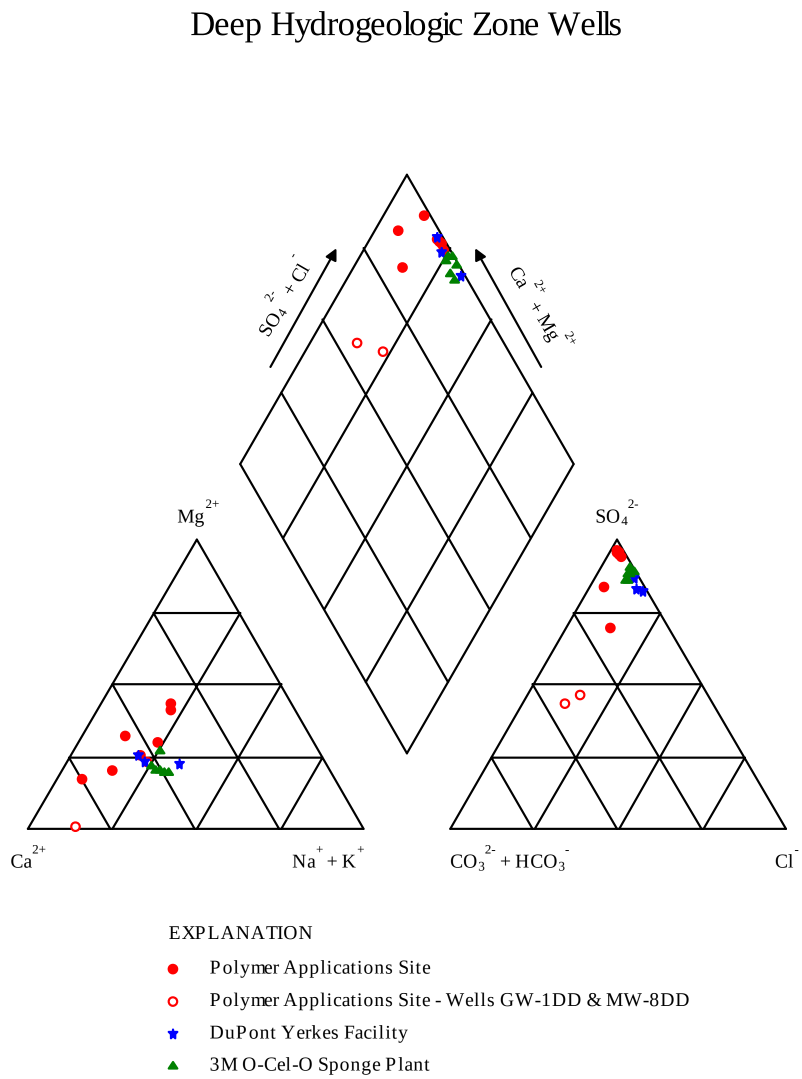


Figure 7-6. Piper Diagram Showing the Ionic Composition of Water from the Deep Hydrogeologic Zone Within the Tonawanda Study Area.

7.5.6 *Upper Bedrock Hydrogeologic Zone*

Water from the upper bedrock hydrogeologic zone contains higher concentrations of calcium (373.0 to 601.0 mg/l) and sulfate (960.0 to 2,290 mg/l) compared to the other major anions and cations (Table E-5 in Appendix E). The geometric means for calcium and sulfate are 469.08 mg/l and 1,507 mg/l, respectively (Figure 7-2). Concentrations of the other major anions and cations range as follows: magnesium (35.8 to

154.0 mg/l), sodium (29.9 to 271.0 mg/l), potassium (2.8 to 28.6 mg/l), chloride (29.2 to 188.0 mg/l) and bicarbonate (43.0 to 240.2 mg/l). The geometric means for these constituents are also shown on Figure 7-2, while the Piper diagram for the upper bedrock zone is given as Figure 7-7. The Piper diagram indicates that upper bedrock zone groundwater is best classified as a calcium-sulfate water.

The turbidity of upper bedrock zone groundwater is variable, ranging from 2.3 to 137.4 NTUs (Table E-5). The pH of this water is relatively constant, ranging from 7.0 to 7.6 standard pH units (Table E-5).

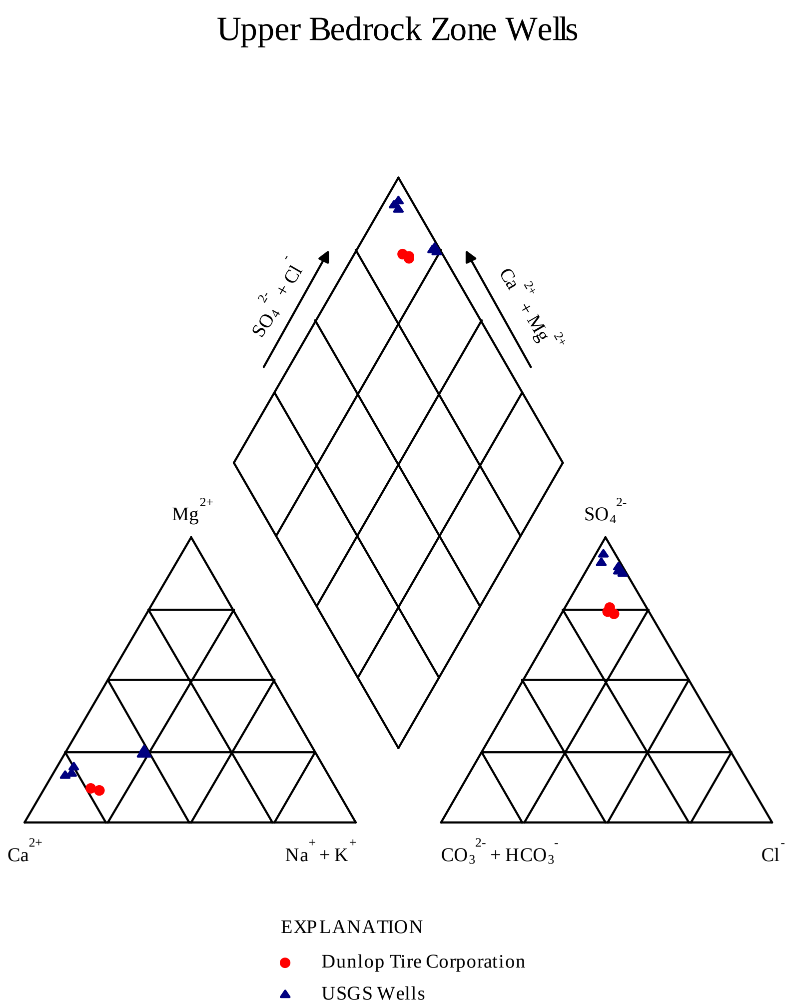


Figure 7-7. Piper Diagram Showing the Ionic Composition of Water from the Upper Bedrock Hydrogeologic Zone Within the Tonawanda Study Area.

As discussed in Section 6.0, only three upper bedrock zone wells are located within the Study Area. Because water levels in this zone are highly influenced by groundwater extraction at the Dunlop Tire Corporation, we cannot be certain that the Piper diagram for the upper bedrock zone is representative of Camillus Shale groundwater. As a result, water quality data from nearby upper bedrock wells in the Tonawanda area were compiled during this study. These data are summarized in Table E-6 of Appendix E. Water from these wells contain higher concentrations of calcium (389.0 to 612.0 mg/l) and sulfate (1,700 to 2,970 mg/l) compared to the other major anions and cations (Table E-6). The geometric means for calcium and sulfate are 464.99 mg/l and 2,233 mg/l, respectively (Figure 7-2). Concentrations of the other major anions and cations range as follows: magnesium (35.7 to 232.0 mg/l), sodium (60.5 to 476.0 mg/l), potassium (3.8 to 64.7 mg/l), chloride (3.6 to 385.0 mg/l) and bicarbonate (21.7 to 458.4 mg/l). The geometric means for these constituents are also shown on Figure 7-2, while the Piper diagram for the Camillus Shale bedrock is given as Figure 7-8. The Piper diagram indicates that upper bedrock zone groundwater is best classified as a calcium-sulfate water. This data, however, plots in two distinct groups within the calcium-sulfate quadrant. The first group contains proportions of calcium and magnesium above 75%, while the second group contains proportions of these cations below 75%. The second group contains slightly higher proportions of sodium and chloride than the first group, which may be related to the presence of salt within the Camillus Shale.

A comparison of Figures 7-7 and 7-8 indicate that the upper bedrock groundwater collected from the Study Area is representative of Camillus Shale groundwater, although the Dunlop production well contains slightly lower proportions of sulfate.

7.6 Geochemical Evaluation

The Piper diagrams presented in Section 7.5 reveal that distinct water types are present within the Study Area. For example, water in the Niagara River is best classified as a calcium-bicarbonate water (Figure 7-1), while water in the Camillus Shale bedrock is best classified as a calcium-sulfate water (Figure 7-8). In this section, the water types identified during this study will be discussed in relation to the conceptual geochemical model described in Section 7.4.

Water in the Niagara River is best classified as a calcium-bicarbonate water that has remained relatively constant geochemically over time (Figure 7-1). This type of water results from the interaction of atmospheric CO_2 with carbonate derived from the dissolution of limestones and dolostones through which the river flows. The presence of calcium-bicarbonate water in the river is consistent with the conceptual geochemical model for the Study Area.

Upper Camillus Shale Bedrock in the Tonawanda Area

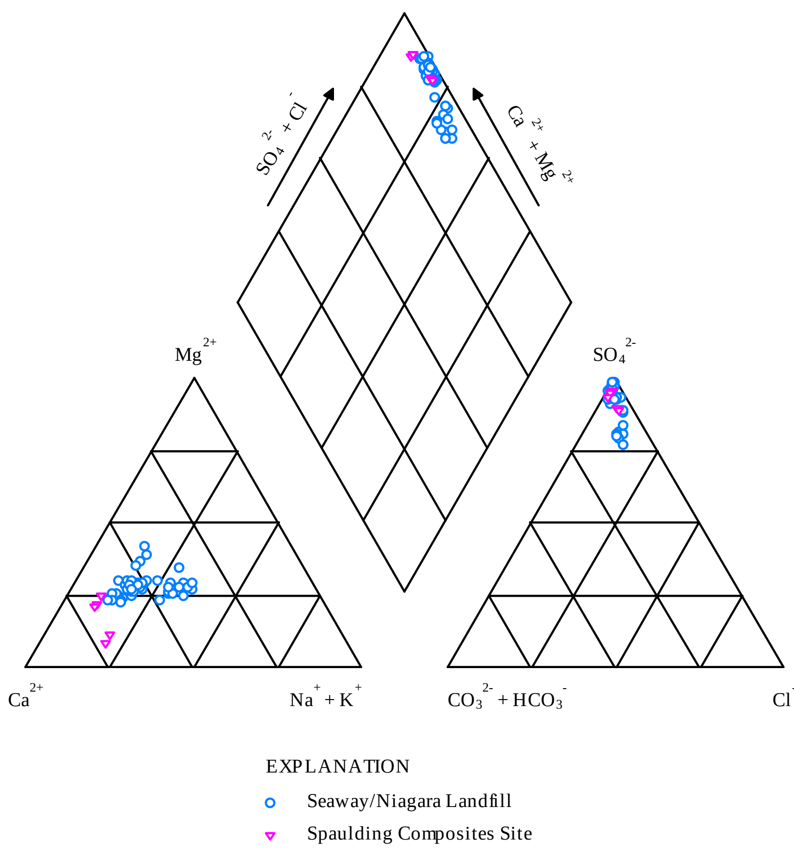


Figure 7-8. Piper Diagram Showing the Ionic Composition of Water from the Upper Camillus Shale Bedrock in the Tonawanda Area.

Water in the wetlands adjacent to the Dunlop Tire Corporation is classified as both a calcium-sulfate water and a sodium-chloride water (Figure 7-3). The conceptual geochemical model for the Study Area suggests, however, that this water should be bicarbonate rich due to its interaction with atmospheric CO_2. The presence of relatively high sulfate in the Sawyer Avenue sample may be indicative of acid rain deposition, while the sodium-chloride water near Dunlop well OMW-C1 is likely attributed to road salt spread on the adjacent thruway during the winter months. As a result, the true nature of this water cannot be determined without the collection and analysis of additional samples.

Water in the shallow hydrogeologic zone is also best classified as a calcium-bicarbonate water, although Dunlop well OMW-C1 contains magnesium-sulfate water (Figure 7-4), and Polymer Application wells MW-13S and MW-14S contain calcium-sulfate water (Figure 7-4). The calcium-bicarbonate water of this zone results from the interaction of soil CO_2 with carbonate dissolved from fill materials and shallow zone soils, and is consistent with the conceptual geochemical model for the Study Area. The presence of high sulfate in the two Polymer wells is likely related to the presence of coal in the fill materials screened by these wells; sulfur is a common component of coal that contributes to acid rain. This would also explain the low pH water in these wells (4.6 to 6.1 standard pH units) compared to the other shallow zone wells. Dunlop well OMW-C1 is discussed below.

Water in the intermediate hydrogeologic zone is best classified as a magnesium-sulfate water (Figure 7-5), which makes it geochemically distinct from shallow zone water (Figure 7-4). Dunlop well OMW-A6 and Polymer Application well MW-3D, however, contain magnesium-bicarbonate water (Figure 7-5). The Piper diagrams for the shallow and intermediate zones also suggest that Dunlop well OMW-C1 is best classified as an intermediate zone well. In addition, Figure 7-5 indicates that the proportion of magnesium in intermediate zone water is relatively constant, while the proportions of sulfate and bicarbonate very significantly. The presence of bicarbonate is some wells (OMW-A6 and MW-3D) is likely due to the more rapid infiltration of bicarbonate-rich water into intermediate zone soils through vertical dessication cracks.

The conceptual geochemical model for the Study Area predicts increasing concentrations of calcium, magnesium and bicarbonate in intermediate zone water, and suggests that concentrations of sodium and sulfate would also increase due to the presence of shale minerals in intermediate zone soils. Figure 7-2 shows that, with the exception of calcium, concentrations of magnesium, sodium, bicarbonate and sulfate in the intermediate zone are substantially higher than those detected in the shallow zone. This results from the greater dissolution of minerals in the intermediate zone soils as water moves slowly through the relatively impermeable glaciolacustrine deposit.

Water in the deep hydrogeologic zone is best classified as a calcium-sulfate water, although Polymer Application wells GW-1DD and MW-8DD contain higher proportions of bicarbonate (Figure 7-6). Wells in this zone also have a slightly higher proportion of sodium than shallow and intermediate zone water (Figure 7-2), which is likely due to the increased presence of shale minerals in deep zone soils. It is suggested here that the ionic composition of the two Polymer Application wells is attributed to the mixing of shallow and deep zone water due to the improper installation of well GW-1DD. Two lines of evidence support this conclusion. First, Polymer Application well GW-1DD contains significant concentrations of phenol. The shallow zone well at this location (B-5S) also contains significant phenol contamination, while the intermediate zone well at this location (B-5D) does not. The absence of phenol in well B-5D, combined with the extremely low hydraulic conductivity of intermediate zone soils, suggest that the migration of phenol contaminated water from the shallow to the deep zone is not occurring through the glaciolacustrine deposit. Second, the water in well GW-1DD has a pH of 12.2 standard pH units (Table E-4 in Appendix E), which is significantly higher than any other well installed in the Study Area and much higher than would be produced by the simple dissolution of carbonate minerals in deep zone soils. The dissolution of grout in an improperly constructed well, however, could produce a pH this high. The higher proportion of calcium and bicarbonate in well GW-1DD is consistent with this scenario; the higher proportion of calcium results from the dissolution of lime in the grout while the higher proportion of bicarbonate results from the introduction of calcium-bicarbonate water from the shallow zone. Polymer Application well MW-8DD also contains higher proportions of bicarbonate because it is located immediately downgradient of well GW-1DD (Figure 3-1).

Water in the upper bedrock hydrogeologic zone is best classified as a calcium-sulfate water, which is consistent with the conceptual geochemical model for the Study Area. USGS well 81-2TA, however, contains slightly higher proportions of calcium, while the Dunlop production well contains slightly lower proportions of sulfate (Figure 7-7) than nearby upper bedrock zone wells in the Tonawanda area (Figure 7-8). The calcium-sulfate water of this zone evolves as it flows through the saturated media from the recharge to the discharge zone, and becomes concentrated in calcium and sulfate due to the abundant quantities of gypsum ($CaSO_4 \bullet H_2O$) in the Camillus Shale. Bicarbonate concentrations will concomitantly decrease as limestone ($CaCO_3$), which is also found in abundant quantities within the Camillus Shale, is less soluble under closed-system (saturated) conditions. Figure 7-7 also indicates that the principle source of water supplying the Dunlop production well is from the Camillus Shale as extracted water is ionically similar to Camillus Shale groundwater (compare Figure 7-7 with Figure 7-8).

8.0 SUMMARY

During implementation of a Remedial Investigation at the Polymer Applications Site, significant (≈30 feet) groundwater elevation declines were observed in deep overburden monitoring wells during the summer months. This phenomenon was subsequently attributed to groundwater extraction by the Dunlop Tire Corporation. A complete understanding of the temporal and spatial distribution of this phenomenon, along with the determination of the source of water extracted by this well, is critical as groundwater extraction has the potential to increase contaminant migration from Polymer and the other inactive hazardous waste sites in the area. To further evaluate this potential, a detailed study of the geology and hydrogeology of the area was completed, with the information utilized to develop a conceptual geochemical model for the Study Area. Geochemical data were obtained during this study and evaluated within the framework of this model to determine the source of water being extracted by the Dunlop production well.

8.1 Geology

The stratigraphy of the Study Area was evaluated by examining approximately 460 stratigraphic logs obtained from borings, monitoring wells, and test pits completed at the various sites within the area. These data reveal that fill material overlies the native deposits throughout most of the Study Area, but is largely discontinuous from site to site. The thickness of fill is generally less than 4 feet, although thicker areas of fill are associated with disposal pits excavated into the native deposits at the E.I. DuPont Yerkes Plant, and former low lying areas along the Niagara River at the Niagara Mohawk Huntley Plant.

Throughout most of the Study Area a thick, continuous, glaciolacustrine deposit either underlies the fill material or is encountered immediately below a thin topsoil layer. This deposit represents the largest percentage of native soils underlying the area, and ranges in thickness from 2.2 to 76.0 feet. In the western portion of the Study Area near the Niagara River, the glaciolacustrine deposit grades abruptly into recent alluvium, which consists predominantly of interbedded layers of sandy silt, sand and gravel. Recent alluvium directly underlies fill material in this portion of the Study Area. The thickness of the alluvium deposit is greatest along the Niagara River (27 to 40 feet) and thins to the east where it grades into the glaciolacustrine deposit.

A relatively thin, continuous layer of glacial till underlies either the glaciolacustrine deposit or recent alluvium, and mantles the underlying Camillus Shale bedrock. The till underlying the Study Area is characterized as a very dense, heterogeneous mixture of clay, silt, sand, gravel and shale bedrock fragments, with silt and clay occurring at the greatest percentage. The thickness of this deposit is quite variable across the area, ranging from 0.4 to 19 feet. The Camillus Shale bedrock is characterized as a slightly to moderately weathered, thin to massively bedded, shale containing layers of limestone and dolostone. This formation also contains numerous shale and gypsum partings, gypsum filled vugs, and gypsum masses and lenses. Depth to bedrock beneath the Study Area is quite variable, ranging from 42.2 to 82.0 feet.

8.2 Hydrogeology

The hydrogeology of the Study Area was evaluated by examining hydrogeologic data obtained during this study. These data suggest that four hydrogeologic zones underlie the area: (1) a shallow water bearing zone consisting of miscellaneous fill and the upper portion of the glaciolacustrine deposit, (2) an intermediate zone consisting of the glaciolacustrine deposit and recent alluvium, (3) a deep water bearing zone consisting predominantly of glacial till, and (4) an upper bedrock water bearing zone.

Groundwater in the shallow and intermediate hydrogeologic zones flows uniformly across the Study Area toward the Niagara River. Hydraulic conductivity data from intermediate zone soils indicate that the glaciolacustrine deposit is best characterized as a confining layer, restricting the downward movement of groundwater from the shallow hydrogeologic zone to the deeper water bearing zones. The alluvium deposit, however, is a relatively high yielding water bearing zone within the Study Area.

Groundwater in the deep and upper bedrock hydrogeologic zones is highly influenced by groundwater extraction at the Dunlop Tire Corporation. When the Dunlop production well is not being utilized (≈November to June), groundwater in these zones flows in a general southwest direction across the Study Area toward the Niagara River. When the production well is operating (≈June to November), however, groundwater extraction dominates the flow regime and produces an elliptical flow pattern centered around the production well and the wells at the Polymer Applications Site. Water level declines at this time ranged from 4 to 31 feet throughout the Study Area.

8.3 Geochemistry

A conceptual geochemical model based upon the hydrogeology of the Study Area was developed to provide the framework in which to evaluate the source of water supplying the Dunlop production well. In this model, infiltrating water will evolve by increasing in TDS and major ion concentrations. Groundwater in the shallow hydrogeologic zone, which is characterized by active flushing during infiltration, will be dominated by bicarbonate resulting from the interaction of soil CO_2 with carbonate derived from the dissolution of limestone and dolostone in the soils. Water from the Niagara River will also be dominated by bicarbonate due to the interaction of carbonate ions in the water with atmospheric CO_2.

As water continues to infiltrate through the unsaturated zone (the intermediate hydrogeologic zone), the concentrations of calcium, magnesium, and bicarbonate will continue to increase. Since sodium and sulfate are also common ions in Study Area soils, water in the intermediate zone will also exhibit increasing concentrations of these ions. Once this water reaches the saturated zone, it will continue to evolve but under closed-system (saturated) conditions as atmospheric CO_2 is no longer available to the system.

Groundwater within the deep and upper bedrock hydrogeologic zones evolves as it flows through the saturated media; the concentrations of the major ions would continue to increase, as would the concentration of TDS. Since the Camillus Shale contains abundant quantities of gypsum ($CaSO_4 \bullet H_2O$), groundwater within this formation will become concentrated in calcium and sulfate, while bicarbonate concentrations will decrease as limestone ($CaCO_3$), which is also found in abundant quantities within the Camillus Shale, is less soluble under closed-system conditions.

Piper diagrams were generated to fingerprint water from the Niagara River and each of the hydrogeologic zones identified during this study. These diagrams indicate that Study Area waters are ionically very different; water from the Niagara River and shallow hydrogeologic zone is best classified as calcium-bicarbonate water, water from the intermediate hydrogeologic zone is best classified as magnesium-sulfate water, and water from the deep and upper bedrock hydrogeologic zones is best classified as calcium-sulfate water. The ionic composition of these waters is consistent with the conceptual geochemical model developed for the Study Area. The Piper diagrams also indicate that the principle source of water supplying the Dunlop production well is from the Camillus Shale as extracted water is ionically similar to Camillus Shale groundwater. This suggests that groundwater extraction has the potential to increase contaminant migration from the Polymer Applications Site and the other inactive hazardous waste sites in the area if those sites adversely impact deep and upper bedrock zone groundwater. Fortunately, the extremely low hydraulic conductivity of the glaciolacustrine deposit prevents the downward migration of shallow zone groundwater to the deeper zones.

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APPENDIX A

SOIL BORING, TEST PIT AND MONITORING WELL STRATIGRAPHIC SUMMARY TABLES

Table A-1.
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
Dunlop Tire Corporation (915018)																	
USGS-1	670172*	4759792*	601.3*	4.0+	597.30												
USGS-2	669872*	4759807*	601.8*	2.0+	599.80												
USGS-3	669453*	4758958*	588.0*	3.0	585.00												
USGS-4	669307*	4759064*	578.0*	1.5+	576.50												
PW-1	669606	4759222	593.3*	Stratigraphic Log for the Overburden Is Not Available												69.0	524.30
PW-2	669611	4759217	593.3*	Stratigraphic Log for the Overburden Is Not Available												71.0	522.30
BH-3	669881*	4759458*	N/A	Stratigraphic Log for the Overburden Is Not Available												67.0	N/A
OMW-1	669532	4759045	590.81	2.0	588.81												
OMW-2	669229	4759227	585.64	4.0	581.64												
OMW-3	670140	4759721	600.76	1.0+	599.76												
OMW-4	670010	4759845	607.49	6.0	601.49												
OMW-A3	669452	4759284	595.43	2.0	593.43												
OMW-A4	669213	4759161	582.0*	0.5+	581.50												
OMW-A5	669455	4759276	595.4*	2.0	593.40												
OMW-A6	669470	4759332	594.28	6.5	587.78												
OMW-B2	669356	4759014	583.78	0.5+	583.28												
OMW-B3	669271	4759134	577.85	12.0	565.85												
OMW-B4	669401	4759000	586.0*	0.5+	585.50												
OMW-C1	670250	4759849	601.04	0.5	600.54												
OMW-C5	669885	4759738	601.39	2.0	599.39												
OMW-C6	669948	4759679	600.45	2.0	598.45												
OMW-C7	670065	4759620	599.3*	0.8+	598.50												
BMW-1	669222	4759235	585.19	4.0	581.19	51.0							55.0	530.19	7.5	62.5	522.69
BMW-2	670004	4759843	607.16	6.0	601.16	55.4							61.4	545.76	12.8	74.2	532.96
TH-1	669526	4759052	590.9*	2.0	588.90												
TH-2	669516	4759061	591.0*	3.5	587.50												
TH-3	669503	4759073	591.1*	3.2	587.90												
TH-4	669494	4759083	591.1*	1.5	589.60												
TH-5	669481	4759093	591.2*	1.6	589.60												

Table A-1 (continued).
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
Dunlop Tire Corporation (continued)																	
TH-6	669471	4759105	591.1*	2.5	588.60												
TH-7	669490	4759061	590.5*	>2.8	N/A												
TH-8	669480	4759071	591.0*	2.2	588.80												
TH-9	669491	4759002	589.7*	2.0	587.70												
TH-10	669460	4759032	589.3*	0.0	589.30												
TH-11	Location Unknown		N/A	1.5	N/A												
TH-12	669412	4759093	587.8*	10.0	577.80												
TH-13	669463	4758976	589.2*	2.0	587.20												
TH-14	669419	4758982	586.6*	0.8	585.80												
TH-15	669405	4759017	586.2*	1.4	584.80												
TH-16	669376	4759009	585.4*	0.5+	584.90												
TH-17	669379	4759028	586.3*	2.1	584.20												
TH-18	Location Unknown		N/A	2.5	N/A												
TH-19	669330	4759262	592.7*	3.4	589.30												
TH-20	669284	4759276	594.2*	0.7+	593.50												
TH-21	669219	4759215	584.2*	1.0+	583.20												
TH-22	670105	4759712	600.5*	1.2	599.30												
TH-23	670114	4759741	601.5*	1.1	600.40												
TH-24	670157	4759742	600.4*	1.1	599.30												
TH-25	670128	4759789	604.2*	1.2	603.00												
TH-26	670114	4759817	606.7*	0.7+	606.00												
TP-A1	669242	4759180	584.0*	2.0	582.00												
TP-A2	669237	4759218	586.4*	3.4	583.00												
TT-A2	669440	4759329	594.6*	3.5	591.10												
TT-A3	669434	4759245	594.8*	3.0	591.80												
TT-A4	669395	4759235	592.3*	2.4	589.90												
TT-A5	669362	4759217	592.0*	2.4	589.60												
TT-A6	669305	4759182	587.8*	2.5	585.30												
TT-A7	669240	4759146	582.7*	1.0	581.70												

Table A-1 (continued). Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.																		
Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
Dunlop Tire Corporation (continued)																	
TT-A8	669222	4759147	582.0*	1.0	581.00												
TP-B1	669473	4758983	588.6*	1.5	587.10												
TP-B2	669459	4758968	588.3*	1.3	587.00												
TP-B3	669430	4758979	586.8*	1.5	585.30												
TP-B4	669411	4759028	586.5*	1.5	585.00												
TP-B5	669425	4759054	587.8*	>2.5	N/A												
TT-B1	669359	4759048	584.7*	5.0	579.70												
TT-B2W	669390	4758982	584.8*	3.5	581.30												
TT-B2E	669459	4759057	590.9*	2.5	588.40												
TT-B3	669433	4758982	587.2*	0.6	586.60												
TT-B4	669499	4759000	590.2*	1.5	588.70												
TT-B5	669529	4759033	590.5*	1.5	589.00												
TT-B6	669430	4759149	591.4*	1.0	590.40												
TT-B7	669386	4759029	586.6*	1.0	585.60												
TP-C1	670066	4759602	598.6*	0.3+	598.30												
TP-C2	670051	4759612	599.8*	0.5+	599.30												
TP-C3	670047	4759636	600.2*	0.5+	599.70												
TP-C4	670023	4759619	599.0*	0.5+	598.50												
TP-C5	669972	4759696	603.9*	>3.0	N/A												
TP-C6	669953	4759713	604.0*	>3.0	N/A												
TT-C1	670137	4759767	601.1*	2.0	599.10												
TT-C2	670123	4759716	600.4*	2.5	597.90												
TT-C3	670110	4759669	600.4*	1.5	598.90												
TT-C4	670079	4759637	599.7*	0.8	598.95												
TT-C5	670035	4759637	600.0*	1.0	599.00												
TT-C6	670008	4759625	600.8*	1.5	599.30												
TP-NEA1	669295	4759482	596.8*	5.7	591.10												
TP-NEA2	669295	4759496	594.7*	5.0	589.70												
TP-NEA3	669286	4759463	596.2*	4.5	591.70												

Table A-1 (continued).
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
Dunlop Tire Corporation (continued)																	
TP-NEA4	669291	4759450	596.2*	4.2	592.00												
TP-OC1	669814	4759792	599.8*	2.0	597.80												
TP-OC2	669952	4759653	601.7*	2.0	599.70												
TP-OC3	669985	4759658	599.8*	3.0	596.80												
TP-OC4	669928	4759712	602.2*	6.0	596.20												
TP-OC5	669924	4759762	602.7*	1.0	601.70												
TP-OC6	669966	4759678	604.7*	6.0	598.70												
TP-OC7	669951	4759698	604.2*	6.0	598.20												
TP-OC8	669866	4759778	604.4*	8.0	596.40												
E.I. DuPont Yerkes Plant (915019)																	
WW-1	669488	4758891	590.00	Stratigraphic Log Is Not Available												55.0	535.00
WW-2	669580	4758745	590.00	Stratigraphic Log Is Not Available												55.0	535.00
MW-1D	670161	4759053	600.88	3.0	597.88	59.0							62.0	538.88	4.7	66.7	534.18
MW-2D	670282	4759217	600.33	2.0	598.33	53.0							55.0	545.33	15.5	70.5	529.83
MW-3D	670369	4759460	603.10	7.0	596.10	61.0							68.0	535.10	11.0	79.0	524.10
MW-4D	670499	4759588	602.17	3.6	598.57	73.4							77.0	525.17	2.0	79.0	523.17
MW-5D	670691	4759589	604.0*	4.0	600.00	76.0							80.0	524.00	2.0	82.0	522.00
MW-6	670601	4759369	604.0*	4.0	600.00	73.0							77.0	527.00	3.0	80.0	524.00
MW-7D	670371	4759190	605.00	6.0	599.00	51.0							57.0	548.00	15.5	72.5	532.50
DYF-1	669704	4758503	589.43	0.9	588.53												
DYF-2	669602	4758685	587.83	0.5+	587.33												
DYF-3	669601	4758878	592.20	2.0	590.20												
DYF-4	669820	4759114	597.29	2.0	595.29												
DYF-5	670107	4759334	602.36	4.8	597.56												
B-T1	670073	4759036	601.35	3.5	597.85	59.5							63.0	538.35	3.4	66.4	534.95
B-T2	670073	4759021	601.55	19.5	582.05	43.5							63.0	538.55	2.7	65.7	535.85
B-T3	670084	4759048	601.45	5.0	596.45	58.0							63.0	538.45	3.4	66.4	535.05
B-T4	670094	4759041	600.85	3.0	597.85	60.0							63.0	537.85	3.7	66.7	534.15

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
E.I. DuPont Yerkes Plant (continued)																	
B-T5	670119	4759067	601.25	8.5	592.75	54.5							63.0	538.25	4.9	67.9	533.35
B-T6	670107	4759073	601.15	13.0	588.15	50.0							63.0	538.15	5.4	68.4	532.75
B-T7	670105	4759063	601.45	6.0	595.45	56.5							62.5	538.95	5.0	67.5	533.95
B-T8	670084	4759032	600.95	4.0	596.95	52.5							56.5	544.45	10.0	66.5	534.45
B-C1	669881	4758903	600.05	4.0	596.05												
B-C2	669892	4758914	600.05	8.0	592.05	52.0							60.0	540.05	13.2	73.2	526.85
B-C3	669870	4758933	600.15	2.5	597.65												
B-C4	669860	4758923	600.05	5.0	595.05												
B-C5	669876	4758918	599.85	2.0	597.85	54.0							56.0	543.85	10.2	66.2	533.65
SB-1A	670353	4759244	604.7*	16.5	588.20												
SB-1B	670376	4759238	604.7*	7.0	597.70												
SB-2A1	669895	4759126	598.2*	4.0	594.20												
SB-2A2	669864	4759113	598.2*	6.0	592.20												
SB-2A3	669855	4759112	598.2*	12.2	586.00												
SB-2B1	669885	4759116	598.2*	12.0	586.20												
SB-3A	670356	4759303	604.1*	20.0	584.10												
SB-3B	670349	4759348	604.1*	18.5	585.60												
SB-4A	670318	4759164	604.2*	18.2	586.00												
SB-4B	670328	4759171	604.2*	18.0	586.20												
SB-5A	670307	4759292	601.1*	10.0	591.10												
SB-5B	670319	4759278	601.1*	10.0	591.10												
SB-6A	670393	4759401	603.5*	>13.6	N/A												
SB-6B	670409	4759416	603.5*	>24.0	N/A												
SB-7A	670311	4759360	601.9*	>13.3	N/A												
SB-7B	670325	4759378	601.9*	18.5	583.40												
SB-8A	670495	4759316	605.0*	6.2	598.80												
SB-8B	670495	4759356	605.0*	5.5	599.50												
SB-9A	670013	4759181	601.0*	6.5	594.50												
SB-9B	670005	4759184	601.0*	6.5	594.50												

Table A-1 (continued).
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
E.I. DuPont Yerkes Plant (continued)																	
SB-9C	670005	4759177	601.0*	5.5	595.50												
SB-9D	670008	4759175	601.0*	6.5	594.50												
SB-9E	670009	4759183	601.0*	6.5	594.50												
SB-10A	670210	4759113	600.7*	4.0	596.70												
SB-10B	670209	4759118	600.7*	4.0	596.70												
SB-10C	670208	4759122	600.7*	6.0	594.70												
SB-10D	670223	4759104	600.7*	>0.6	N/A												
SB-10E	670223	4759102	600.7*	4.0	596.70												
SB-10F	670216	4759126	600.7*	4.0	596.70												
SB-10G	670230	4759132	600.7*	4.0	596.70												
SB-10H	670217	4759111	600.7*	12.9	587.80												
Polymer Applications Site (915044)																	
B-1D	669123	4759284	580.97	7.8	573.17	39.2							47.0	533.97	9.0	56.0	524.97
B-2D	669130	4759284	581.44	Detailed Stratigraphic Log Is Not Available													
B-3D	669215	4759342	589.21	3.5	585.71												
B-4D	669259	4759447	591.93	5.8	586.13												
B-5S	669144	4759439	589.23	3.0	586.23												
B-6D	669052	4759373	578.66	5.0	573.66												
B-7D	669082	4759327	578.42	5.8	572.62												
GW-1DD	669144	4759436	589.38	1.0	588.38	54.5							55.5	533.88			
GW-2DD	669256	4759447	592.25	6.0	586.25	50.0							56.0	536.25			
GW-3S	669226	4759409	591.69	5.0	586.69												
GW-4S	669212	4759340	589.43	2.0	587.43												
MW-8DD	669123	4759282	580.89	6.0	574.89	41.0							47.0	533.89	6.9	53.9	526.99
MW-9S	669232	4759514	592.11	3.3	588.81												
MW-9DD	669233	4759517	593.47	4.0	589.47	57.1							61.1	532.37	4.9	66.0	527.47
MW-10DD	669086	4759245	575.88	6.9	568.98	38.1				45.0	530.88	3.1	48.1	527.78	1.9	50.0	525.88
MW-11S	669000	4759348	577.27	2.6	574.67												

Table A-1 (continued).
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
Polymer Applications Site (continued)																	
MW-11DD	669002	4759349	577.40	11.0	566.40	33.0							44.0	533.40	5.0	49.0	528.40
MW-12S	669077	4759335	578.91	3.1	575.81												
MW-13S	669050	4759295	575.54	5.7	569.84												
MW-14S	669104	4759220	575.68	4.8	570.88												
WW-1	669264	4759436	591.99	5.7	586.29	59.3							65.0	526.99	2.0	67.0	524.99
SB01	669071	4759387	NS	Stratigraphic Log Is Not Available													
SB02	669159	4759411	NS	Stratigraphic Log Is Not Available													
SB03	669235	4759361	NS	Stratigraphic Log Is Not Available													
SB04	669287	4759405	NS	Stratigraphic Log Is Not Available													
SB05	669265	4759425	NS	Stratigraphic Log Is Not Available													
SB06	669205	4759411	NS	Stratigraphic Log Is Not Available													
SB07	669227	4759483	NS	Stratigraphic Log Is Not Available													
SB08	669195	4759454	NS	Stratigraphic Log Is Not Available													
SB09	669191	4759465	NS	Stratigraphic Log Is Not Available													
SB10	669159	4759442	NS	Stratigraphic Log Is Not Available													
SB11	669260	4759519	NS	Stratigraphic Log Is Not Available													
Niagara Mohawk Huntley Plant																	
B-7	669077	4758991	575.10							20.8	554.35						
B-8	668683	4759249	575.10							12.5	562.60						
B-9	Location Unknown		N/A														
B-10	Location Unknown		N/A														
B-11	Location Unknown		N/A														
B-12	Location Unknown		N/A														
B-13	Location Unknown		N/A														
B-14	668774	4759144	572.88							1.0	571.88						
B-15	668867	4759039	573.41				5.0	568.41	11.5	16.5	556.91	26.5	43.0	530.41			
B-16	668999	4759063	580.69				15.0	565.69									
B-17	669034	4759209	578.27	7.5	570.77												

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
Niagara Mohawk Huntley Plant (continued)																	
B-18	668814	4759099	573.43							3.0	570.43						
SB-EB1	669129	4758976	576.87	34.0	542.87	15.5				28.0	548.87	6.0	49.5	527.37	5.5	55.0	521.87
SB-EB2	669074	4759023	578.67	31.5	547.17	17.5				30.0	548.67	1.5	49.0	529.67	2.5	51.5	527.17
SB-EB3	669019	4759084	580.85	39.0	541.85	6.0				34.5	546.35	4.5	45.0	535.85	7.2	52.2	528.65
SB-EB4	668959	4759030	574.43							28.0	546.43	15.0	43.0	531.43			
SB-EB5	669013	4758969	577.70	44.0	533.70	5.0				30.0	547.70	14.0	49.0	528.70	6.0	55.0	522.70
SB-EB6	669067	4758910	577.50	40.0	537.50	3.5				25.0	552.50	15.0	43.5	534.00			
SB-TB1	668951	4759287	575.38	20.5	554.88	23.5	9.5	565.88	34.5				44.0	531.38	5.0	49.0	526.38
SB-TB2	668918	4759290	575.18	21.0	554.18	17.0	9.5	565.68	10.5	20.0	555.18	1.0	38.0	537.18	8.2	46.2	528.98
SB-AC1	668702	4759434	574.79				8.0	566.79	12.0	20.0	554.79	19.5	39.5	535.29	2.7	42.2	532.59
SB-ST1	669058	4759169	578.53	20.0	558.53	17.0	15.0	563.53	22.0				37.0	541.53	19.0	56.0	522.53
SB-ST2	669052	4759193	577.80	15.0	562.80	28.5	10.0	567.80	33.5				43.5	534.30			
SB-ST3	669031	4759215	576.75	16.5	560.25	23.5	15.0	561.75	25.0				40.0	536.75	10.2	50.2	526.55
SB-ST4	669009	4759241	577.15	16.5	560.65	24.0	10.0	567.15	30.5				40.5	536.65			
SB-ST5	668982	4759254	577.96	21.0	556.96	16.0	11.1	566.86	25.9				37.0	540.96	15.5	52.5	525.46
SB-ST6	668950	4759256	577.20	23.0	554.20	15.0	14.0	563.20	24.0				38.0	539.20			
SB-ST7	668918	4759258	575.93	26.0	549.93	12.5	15.0	560.93	6.5	21.5	554.43	4.5	38.5	537.43	7.7	46.2	529.73
SB-ST8	668885	4759259	576.48	26.5	549.98	8.5	10.0	566.48	10.0	20.0	556.48	6.5	35.0	541.48			
SB-ST9	668853	4759262	576.13	28.5	547.63	9.0	11.5	564.63	3.5	15.0	561.13	13.5	37.5	538.63	8.2	45.7	530.43
SB-ST10	668823	4759263	574.25				12.0	562.25	7.0	19.0	555.25	14.0	33.0	541.25			
SB-ST11	668800	4759241	574.36				10.5	563.86	9.5	20.0	554.36	21.0	41.0	533.36	2.4	43.4	530.96
SB-ST12	668772	4759224	574.23				10.0	564.23	5.0	15.0	559.23	26.5	41.5	532.73			
SB-ST13	668754	4759195	574.60				10.0	564.60	5.0	15.0	559.60	25.0	40.0	534.60	5.1	45.1	529.50
SB-ST14	668768	4759159	573.42				10.5	562.92	4.5	15.0	558.42						
SB-ST15	668790	4759134	572.32				9.5	562.82	10.5	20.0	552.32	21.5	41.5	530.82	3.3	44.8	527.52
SB-ST16	668813	4759110	571.22				9.5	561.72	5.5	15.0	556.22						
SB-ST17	668835	4759085	570.12				10.0	560.12	4.0	14.0	556.12	23.0	37.0	533.12	7.4	44.4	525.72
SB-ST18	668860	4759059	570.30				13.5	556.80	1.5	15.0	555.30	26.0	41.0	529.30			
SB-ST19	668880	4759037	571.06				10.0	561.06	5.0	15.0	556.06	26.0	41.0	530.06	7.2	48.2	522.86

Table A-1 (continued).
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
Niagara Mohawk Huntley Plant (continued)																	
SB-ST20	668901	4759018	572.26							15.0	557.26	27.0	42.0	530.26			
SB-ST21	668929	4759022	573.83							10.0	563.83	36.0	46.0	527.83	6.0	52.0	521.83
SB-ST22	668952	4759041	577.42				15.0	562.42	5.0	20.0	557.42	22.0	42.0	535.42			
SB-ST23	668974	4759061	577.42	33.0	544.42	9.0	14.0	563.42	6.5	20.5	556.92	12.5	42.0	535.42	12.0	54.0	523.42
SB-ST24	668996	4759080	577.01	30.0	547.01	9.5	11.0	566.01	10.0	21.0	556.01	9.0	39.5	537.51			
SB-ST25	669015	4759099	577.11	29.0	548.11	12.2				22.5	554.61	6.5	41.2	535.91	12.4	53.6	523.51
SB-ST26	669037	4759121	576.58	28.0	548.58	12.0	14.5	562.08	13.5				40.0	536.58			
SB-ST27	669057	4759143	577.46	19.0	558.46	21.5	15.0	562.46	4.0				40.5	536.96	14.2	54.7	522.76
SB-ST28	668902	4759067	575.10							6.5	568.60	40.0	46.5	528.60	4.3	50.8	524.30
SB-ST29	668876	4759098	573.90							7.5	566.40	37.5	45.0	528.90	5.4	50.4	523.50
SB-ST30	668851	4759131	574.90				7.2	567.70	10.1	17.3	557.60	28.2	45.5	529.40	3.9	49.4	525.50
SB-ST31	668943	4759129	577.66	30.0	547.66	10.5				13.0	564.66	17.0	40.5	537.16	12.5	53.0	524.66
SB-ST32	668821	4759174	575.00				8.5	566.50	6.5	15.0	560.00	31.0	46.0	529.00	3.0	49.0	526.00
SB-ST33	668902	4759169	589.76	47.3	542.46	2.2	23.0	566.76	7.5	30.5	559.26	16.8	49.5	540.26	16.5	66.0	523.76
A-1	669030	4759103	577.91	Stratigraphic Log for the Overburden Is Not Available												55.3	522.61
A-2	668997	4758954	575.59	Stratigraphic Log for the Overburden Is Not Available												55.5	520.09
A-3	668796	4759116	573.04	Stratigraphic Log for the Overburden Is Not Available												46.2	526.84
A-4	668883	4759285	575.44	Stratigraphic Log for the Overburden Is Not Available												45.6	529.84
United States Geological Survey Wells																	
81-1T	670750	4760626	602.50	0.5+	602.00	56.5							57.0	545.50	9.5	66.5	536.00
81-2TA	669475	4758603	576.58							8.0	568.58	26.0	34.0	542.58	15.0	49.0	527.58
81-2TB	669473	4758601	576.66							8.0	568.66						
Shanco Plastics (915048)																	
USGS-1	670286*	4760143*	NS	3.5													
USGS-2	670292*	4760098*	NS	2.0													
USGS-3	670274*	4760070*	NS	3.0													
USGS-4	670228*	4760138*	NS	4.0													

Table A-1 (continued).
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
3M O-Cel-O Sponge Plant (915148)																	
B-1	669856	4759970	NS	2.0													
B-2	669835	4759975	NS	0.0													
B-3	669835	4759942	NS	0.4+													
B-4	669861	4759943	NS	0.5+													
B-5	669850	4759956	NS	0.0													
BH-1	669758	4759969	601.9*	4.0	597.90												
BH-2	669755	4759963	601.8*	2.0	599.80												
BH-3	669769	4759974	601.7*	1.5	600.20												
BH-4	669770	4759966	601.5*	4.0	597.50												
BH-5	669767	4759958	601.2*	3.0	598.20												
BH-6	669744	4759976	601.5*	6.7	594.80												
BH-7	669745	4759971	601.5*	2.0	599.50												
BH-8	669752	4759974	601.6*	1.2	600.40												
BH-9	669760	4760007	601.6*	3.6	598.00												
BH-10	669755	4760004	601.6*	1.7	599.90												
BH-11	669713	4759933	601.1*	0.0	601.10												
BH-12	669715	4759928	601.1*	1.0	600.10												
BH-16	669590	4759894	600.7*	2.0	598.70												
BH-18	669698	4760069	600.4*	0.5+	599.90												
BH-19	669804	4759907	601.6*	0.8+	600.80												
BH-20	669821	4759920	602.3*	3.1	599.20												
BH-21	669834	4759929	602.5*	3.0	599.50												
BH-22	669821	4759939	601.9*	2.0	599.90												
BH-23	669811	4759934	601.7*	2.0	599.70												
BH-24	669802	4759930	601.8*	2.0	599.80												
BH-25	669817	4759955	599.3*	0.6+	598.70												
BH-26	669806	4759949	601.5*	1.5	600.00												
TB-1	669826	4759991	601.7*	0.0	601.70												
TB-2	669805	4760088	601.2*	0.0	601.20												

Table A-1 (continued).
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
3M O-Cel-O Sponge Plant (continued)																	
TB-3	669513	4759991	598.5*	0.0	598.50												
TB-4	669548	4759922	600.0*	0.0	600.00												
TB-5	669606	4759799	601.3*	0.0	601.30												
MW-1	669888	4759932	600.4*	1.5	598.90												
MW-2	669558	4759881	600.3*	2.0	598.30												
MW-3	669575	4759846	600.2*	2.0	598.20												
CST-3	669792	4759918	601.8*	5.1	596.70												
CST-4	669796	4759914	601.9*	0.2	601.70												
CST-5	669795	4759902	601.6*	2.0	599.60												
CST-103	669792	4759921	601.6*	3.2	598.40												
I-0	669745	4759930	601.2*	2.0	599.20												
K-0	669749	4759926	601.5*	6.0	595.50												
M-0	669754	4759922	601.6*	4.0	597.60												
O-0	669759	4759918	601.6*	4.0	597.60												
Q-0	669764	4759914	601.3*	4.0	597.30												
S-0	669768	4759910	601.2*	4.0	597.20												
T-0	669773	4759907	601.2*	4.0	597.20												
I-20	669741	4759925	601.2*	2.0	599.20												
K-20	669746	4759921	601.6*	2.0	599.60												
M-20	669750	4759918	601.8*	2.0	599.80												
O-20	669755	4759913	601.9*	4.0	597.90												
Q-20	669760	4759910	601.5*	4.0	597.50												
S-20	669764	4759906	601.2*	4.0	597.20												
T-20	669769	4759902	601.1*	2.0	599.10												
S-34	669762	4759903	601.2*	4.0	597.20												
O-51	669747	4759904	602.3*	2.0	600.30												
Q-34	669754	4759905	601.8*	>4.0	N/A												
I-40	669737	4759921	601.3*	3.0	598.30												
K-40	669742	4759916	601.7*	3.7	598.00												

Table A-1 (continued).
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
3M O-Cel-O Sponge Plant (continued)																	
M-40	669746	4759913	602.0*	>4.0	N/A												
O-40	669751	4759909	602.2*	2.0	600.20												
M-60	669743	4759909	601.9*	4.0	597.90												
K-60	669738	4759912	601.5*	>4.0	N/A												
K-68	669734	4759908	601.4*	2.0	599.40												
SB-1	Location Unknown		N/A	Stratigraphic Log Is Not Available													
SB-2	Location Unknown		N/A	Stratigraphic Log Is Not Available													
SB-3	669810	4759908	601.1*	0.0	601.10												
SB-4	669804	4759917	N/A	Stratigraphic Log Is Not Available													
SB-5	669798	4759904	601.5*	0.0	601.50												
SB-6	669797	4759916	601.9*	4.0	597.90												
SB-7	669798	4759904	601.5*	0.0	601.50												
SB-8	669798	4759904	601.5*	0.0	601.50												
SB-9	669790	4759894	599.6*	5.0	594.60												
SB-10	669805	4759895	600.4*	4.0	596.40												
SB-11	669797	4759895	598.8*	4.0	594.80												
SB-12	669796	4759884	599.5*	3.8	595.70												
SB-13	669789	4759882	599.5*	6.0	593.50												
SB-14	669818	4759899	600.3*	4.0	596.30	63.0							67.0	533.30			
SB-15	669793	4759883	599.3*	2.0	597.30												
SB-16	669782	4759895	600.0*	4.0	596.00												
SB-17	669784	4759883	599.1*	2.0	597.10												
SB-18	669767	4759885	599.1*	0.0	599.10												
SB-19	669780	4759888	599.0*	7.0	592.00	62.0							69.0	530.00	4.0	73.0	526.00
SB-20	669717	4759956	601.2*	6.5	594.70												
SB-21	669713	4759952	601.2*	6.0	595.20												
SB-22	669716	4759953	601.2*	2.0	599.20												
SB-23	669712	4759960	601.0*	2.0	599.00												
SB-24	669723	4759956	601.1*	2.0	599.10												

Table A-1 (continued).
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
3M O-Cel-O Sponge Plant (continued)																	
SB-25	669779	4759911	601.3*	2.0	599.30												
SB-26	669750	4759893	600.3*	8.0	592.30												
SB-27	669715	4759910	600.7*	5.0	595.70												
SB-28	669749	4759887	599.5*	2.0	597.50												
SB-29	669707	4759907	600.8*	0.0	600.80												
SB-30	669806	4759888	600.3*	6.0	594.30												
SB-31	669767	4759878	599.4*	0.0	599.40												
SB-32	669780	4759880	599.5*	2.0	597.50												
SB-33	669775	4759878	599.5*	4.0	595.50												
SB-34	669716	4759917	600.7*	4.0	596.70												
SB-35	669753	4759902	601.7*	0.0	601.70												
SB-36	669768	4759899	601.0*	2.0	599.00												
SB-37	669761	4759870	599.5*	Shallow Overburden Was Not Sampled													
SB-38	669771	4759909	601.2*	2.0	599.20												
SB-39	669754	4759911	602.0*	4.0	598.00												
SB-40	669715	4759956	601.2*	3.5	597.70												
SB-41	669730	4759909	601.4*	4.0	597.40												
SB-42	669721	4759875	600.0*	3.0	597.00												
SB-43	669730	4759881	599.9*	6.0	593.90												
SB-44	669738	4759893	599.8*	4.0	595.80	59.0							63.0	536.80	7.5	70.5	529.30
SB-45	669756	4759863	599.9*	6.0	593.90	60.0							66.0	533.90	6.0	72.0	527.90
SB-46	669721	4759900	600.0*	4.0	596.00												
SB-47	669744	4759872	600.1*	6.0	594.10												
SB-48	669758	4759886	598.6*	4.0	594.60												
SB-49	669747	4759889	600.1*	4.0	596.10												
MW-1	669777	4759877	602.41	4.0	598.41	64.1							68.1	534.31	0.4	68.5	533.91
MW-2	669755	4759909	602.62	4.0	598.62	66.0							70.0	532.62	1.4	71.4	531.22
MW-3	669750	4759883	602.14	Shallow Overburden Was Not Sampled									68.0	534.14	4.0	72.0	530.14
MW-4	669716	4759869	602.04	7.5	594.54	57.5							65.0	537.04	9.0	74.0	528.04

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
3M O-Cel-O Sponge Plant (continued)																	
LY-1	669784	4759888	602.76	Stratigraphic Log Is Not Available													
LY-2	669772	4759889	602.71	Stratigraphic Log Is Not Available													
FMC Tonawanda Plant (915025)																	
B-1	669131	4759635	589.00	1.6	587.40												
B-2	669148	4759598	NS	1.5													
B-3	669102	4759634	NS	0.6													
B-4	669076	4759613	588.06	2.3	585.76												
B-5	668982	4759701	583.08	3.5	579.58												
B-6	668999	4759675	583.58	3.3	580.28												
B-7	669025	4759635	585.38	1.7	583.68												
B-8	669042	4759609	586.73	1.7	585.03	56.50							58.2	528.53	1.8	60.0	526.73
B-9	669058	4759584	588.26	1.4	586.86												
B-10	668963	4759670	582.10	2.6	579.50												
B-11	668989	4759632	582.68	1.5	581.18	48.00							49.5	533.18	6.5	56.0	526.68
B-12	669007	4759604	585.41	2.5	582.91												
B-13	668927	4759668	585.45	4.6	580.85												
B-14	668954	4759628	583.78	1.8+	581.98												
B-15	668971	4759602	583.84	2.2+	581.64												
B-16	668892	4759663	581.65	6.3	575.35												
B-17	668909	4759637	581.80	2.4	579.40												
B-18	668935	4759598	583.04	1.5+	581.54												
USGS-1	669049	4759624	NS	0.5+													
USGS-2	668979	4759611	NS	3.0													
USGS-3	668970	4759623	NS	3.5													
USGS-4	668966	4759632	NS	3.0													
TP-A1	668985	4759616	NS	4.0													
TP-A2	668986	4759612	NS	4.0													
TP-A3	668980	4759618	NS	3.8													
TP-A4	668991	4759616	NS	3.5													

Table A-1 (continued). Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.																	
Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
FMC Tonawanda Plant (continued)																	
TP-A5	668991	4759612	NS	5.0													
TP-A6	668996	4759609	NS	5.0													
TP-A7	668989	4759612	NS	4.8													
TP-A8	668995	4759613	NS	4.5													
TP-A9	669001	4759609	NS	5.0													
TP-A10	668993	4759610	NS	5.0													
TP-B1	669004	4759616	NS	4.5													
TP-B2	669005	4759621	NS	5.0													
TP-B3	668996	4759618	NS	4.5													
TP-B4	668998	4759623	NS	3.5													
TP-B5	669005	4759627	NS	4.0													
TP-B6	669011	4759618	NS	3.0													
TP-B7	668991	4759623	NS	3.5													
TP-C1	669035	4759620	NS	2.5													
TP-C2	669039	4759623	NS	2.0													
TP-C3	669032	4759618	NS	3.5													
TP-C4	669028	4759616	NS	3.5													
TP-C5	669031	4759626	NS	3.0													
TP-C6	669027	4759623	NS	4.0													
TP-C7	669023	4759617	NS	4.0													
TP-C8	669039	4759614	NS	3.0													
TP-C9	669026	4759627	NS	2.0													
TP-D1	669026	4759611	NS	4.5													
TP-D2	669025	4759608	NS	5.5													
TP-D3	669024	4759604	NS	6.0													
TP-D4	669017	4759607	NS	7.0													
TP-D5	669018	4759611	NS	6.0													
TP-D6	669019	4759618	NS	4.5													
TP-D7	669011	4759609	NS	5.0													

Table A-1 (continued).
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
FMC Tonawanda Plant (continued)																	
TP-D8	669012	4759614	NS	5.0													
TP-D9	669031	4759603	NS	4.5													
TP-D10	669032	4759607	NS	4.5													
TP-E1	668928	4759675	NS	4.0													
TP-E2	668925	4759673	NS	4.0													
TP-E3	668921	4759671	NS	5.5													
TP-E4	668924	4759682	NS	2.5													
TP-E5	668921	4759679	NS	7.5													
TP-E6	668917	4759674	NS	7.0													
TP-E7	668932	4759666	NS	2.0													
TP-E8	668926	4759662	NS	6.0													
TP-F1	668949	4759665	NS	1.5													
TP-F2	668954	4759661	NS	1.5													
TP-F3	668946	4759666	NS	1.5													
TP-F4	668941	4759672	NS	1.0													
TP-F5	668946	4759670	NS	1.5													
TP-F6	668943	4759675	NS	1.0													
TP-F7	668955	4759670	NS	1.0													
TP-F8	668952	4759675	NS	1.0													
TP-F9	668932	4759693	NS	3.5													
TP-G1	668967	4759642	NS	3.0													
TP-G2	668960	4759644	NS	2.0													
TP-G3	668955	4759648	NS	1.5													
TP-G4	668974	4759641	NS	3.0													
TP-H1	668977	4759625	NS	3.0													
TP-H2	668983	4759628	NS	3.0													
TP-H3	668976	4759628	NS	3.5													
TP-H4	668972	4759630	NS	3.5													
TP-H5	668969	4759633	NS	4.5													

Table A-1 (continued).
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
FMC Tonawanda Plant (continued)																	
TP-H6	668974	4759633	NS	5.0													
TP-H7	668981	4759638	NS	2.5													
TP-H8	668970	4759627	NS	2.5													
TP-H9	668973	4759623	NS	2.5													
TP-I1	668920	4759615	NS	2.5													
TP-I2	668916	4759613	NS	2.5													
TP-I3	668913	4759610	NS	2.0													
TP-I4	668922	4759617	NS	4.0													
TP-I5	668927	4759620	NS	3.5													
TP-I6	668918	4759623	NS	4.0													
TP-I7	668913	4759619	NS	3.0													
TP-I8	668909	4759625	NS	3.0													
TP-I9	668921	4759607	NS	2.0													
B-X1	669049	4759613	NS	2.0													
B-X2	669039	4759614	NS	2.4													
B-X3	669030	4759615	NS	5.6													
B-X4	669021	4759616	NS	2.3													
B-X5	669012	4759617	NS	5.0													
B-X6	669003	4759619	NS	4.3													
B-X7	668993	4759620	NS	6.0													
B-X8	668984	4759622	NS	2.4													
B-Y1	669048	4759603	NS	2.3													
B-Y2	669039	4759605	NS	2.7													
B-Y3	669029	4759606	NS	8.4													
B-Y4	669020	4759607	NS	4.3													
B-Y4C	Location Unknown		NS	5.3													
B-Y5	669011	4759608	NS	4.3													
B-Y6	669001	4759610	NS	4.6													
B-Y7	668992	4759612	NS	4.2													

Table A-1 (continued).
Stratigraphic Summary of Borings, Test Pits, and Monitoring Wells Installed in the Tonawanda Study Area, Erie County, New York.

Well, Test Pit or Boring Number	UTM Coordinates		Ground Surface Elevation	Reddish Brown Silty Clay			Sandy Silt			Sand, Silt & Gravel			Glacial Till			Camillus Shale	
	Easting	Northing		Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation	Thickness	Depth	Surface Elevation
FMC Tonawanda Plant (continued)																	
B-Y8	668983	4759613	NS	8.0													
B-Z1	669047	4759594	NS	3.5													
B-Z2	669037	4759595	NS	5.0													
B-Z3	669028	4759597	NS	4.2													
B-Z4	669019	4759598	NS	4.5													
B-Z5	669010	4759600	NS	4.2													
B-Z6	669000	4759601	NS	4.4													
B-Z7	668991	4759602	NS	4.2													
B-Z8	668982	4759603	NS	2.8													
B-D4	Location Unknown		NS	7.3													
B-EB	Location Unknown		NS	6.5													
B-HB	668973	4759628	NS	3.5													
B-IB	Location Unknown		NS	3.6													
B-A5W	668992	4759607	NS	2.7													
B-A5N	668988	4759612	NS	6.6													
B-A5S	668997	4759611	NS	4.7													
B-A5E	668993	4759617	NS	4.4													
B-A5SE	668997	4759614	NS	4.3													

*** Estimated Elevation or Location. Estimated Elevations Were Obtained from Individual Site Surveys.** **N/A Not Applicable.**
+ Fill Material Not Present. Depth to Reddish Brown Silty Clay Represents Thickness of Topsoil Layer. **NS Not Surveyed.**

APPENDIX B

MONITORING WELL INSTRUMENTATION SUMMARY TABLES

Table B-1.
Monitoring Well Instrumentation Summary for Shallow Zone Wells Installed in the Study Area.

Well Designation	Ground Surface Elevation (ft. AMSL)	Top of Riser Elevation (ft. AMSL)	Total Boring Depth (ft. BGS)	Sandpack Interval (ft. BGS)	Sandpack Interval (ft. AMSL)	Well Screen Interval (ft. BGS)	Well Screen Interval (ft. AMSL)	Screened Unit
Polymer Applications Site (Registry Number 915044)								
B-4S	592.46	594.26	6.0	2.50 to 6.00	589.96 to 586.46	4.00 to 6.00	588.46 to 586.46	Miscellaneous Fill
B-5S	589.23	591.14	5.0	3.00 to 5.00	586.23 to 584.23	2.50 to 5.00	586.73 to 584.23	Miscellaneous Fill; Reddish Brown Silty Clay
B-6S	579.84	582.13	5.0	3.00 to 5.00	576.84 to 574.84	3.50 to 5.00	576.34 to 574.84	Miscellaneous Fill
B-7S	578.26	578.12	6.0	3.00 to 6.00	575.26 to 572.26	4.50 to 6.00	573.76 to 572.26	Miscellaneous Fill
GW-3S	591.69	594.53	10.0	1.50 to 10.00	590.19 to 581.69	2.00 to 10.00	589.69 to 581.69	Miscellaneous Fill; Reddish Brown Silty Clay
GW-4S	589.43	592.40	10.0	1.50 to 10.00	587.93 to 579.43	2.00 to 10.00	587.43 to 579.43	Miscellaneous Fill; Reddish Brown Silty Clay
MW-9S	592.11	593.82	10.2	3.50 to 10.00	588.61 to 582.11	4.00 to 10.00	588.11 to 582.11	Reddish Brown Silty Clay
MW-11S	577.27	579.22	14.2	3.00 to 14.00	574.27 to 563.27	4.00 to 14.00	573.27 to 563.27	Reddish Brown Silty Clay
MW-12S	578.91	580.77	12.0	3.00 to 12.00	575.91 to 566.91	4.00 to 12.00	574.91 to 566.91	Brown/Black Silt & Fine Sand; Reddish Brown Silty Clay
MW-13S	575.54	577.58	10.0	3.50 to 10.00	572.04 to 565.54	4.00 to 10.00	571.54 to 565.54	Miscellaneous Fill; Reddish Brown Silty Clay
MW-14S	575.68	577.99	12.0	3.00 to 12.00	572.68 to 563.68	4.00 to 12.00	571.68 to 563.68	Miscellaneous Fill; Reddish Brown Silty Clay
Dunlop Tire Corporation Site (Registry Number 915018)								
OMW-B3	577.85	580.58	16.0	6.00 to 15.00	571.85 to 562.85	9.50 to 14.50	568.35 to 563.35	Peat; Reddish Brown Silty Clay
OMW-C1	601.04	603.84	18.0	5.00 to 17.50	596.04 to 583.54	7.00 to 17.00	594.04 to 584.04	Reddish Brown Silty Clay
E.I. DuPont Yerkes Plant Site (Registry Number 915019)								
MW-1S	600.88	602.74	5.5	?? to ??	?? to ??	3.50 to 5.50	597.38 to 595.38	Grey Organic Silt & Clay
MW-2S	600.33	602.85	5.5	?? to ??	?? to ??	2.50 to 4.50	597.83 to 595.83	Reddish Brown Silty Clay
MW-3S	603.10	604.88	7.5	?? to ??	?? to ??	5.50 to 7.50	597.60 to 595.60	Miscellaneous Fill

Table B-1 (continued). Monitoring Well Instrumentation Summary for Shallow Zone Wells Installed in the Study Area.								
Well Designation	**Ground Surface Elevation (ft. AMSL)**	**Top of Riser Elevation (ft. AMSL)**	**Total Boring Depth (ft. BGS)**	**Sandpack Interval (ft. BGS)**	**Sandpack Interval (ft. AMSL)**	**Well Screen Interval (ft. BGS)**	**Well Screen Interval (ft. AMSL)**	**Screened Unit**
E.I. DuPont Yerkes Plant Site (continued)								
MW-4S	602.17	604.26	5.0	?? to ??	?? to ??	3.00 to 5.00	599.17 to 597.17	Miscellaneous Fill; Reddish Brown Silty Clay
DYF-1	589.43	592.24	14.0	3.00 to 14.00	586.43 to 575.43	4.00 to 14.00	585.43 to 575.43	Reddish Brown Silty Clay
DYF-2	587.83	591.35	14.0	3.00 to 14.00	584.83 to 573.83	4.00 to 14.00	583.83 to 573.83	Reddish Brown Silty Clay
DYF-3	592.20	595.27	14.0	3.00 to 14.00	589.20 to 578.20	4.00 to 14.00	588.20 to 578.20	Reddish Brown Silty Clay
DYF-4	597.29	600.12	14.0	3.00 to 14.00	594.29 to 583.29	4.00 to 14.00	593.29 to 583.29	Reddish Brown Silty Clay
DYF-5	602.36	605.24	14.0	3.00 to 14.00	599.36 to 588.36	4.00 to 14.00	598.36 to 588.36	Reddish Brown Silty Clay

Ft. AMSL Feet Above Mean Sea Level.
Ft. BGS Feet Below Ground Surface.

Table B-2.
Monitoring Well Instrumentation Summary for Intermediate Zone Wells Installed in the Study Area.

Well Designation	Ground Surface Elevation (ft. AMSL)	Top of Riser Elevation (ft. AMSL)	Total Boring Depth (ft. BGS)	Sandpack Interval (ft. BGS)	Sandpack Interval (ft. AMSL)	Well Screen Interval (ft. BGS)	Well Screen Interval (ft. AMSL)	Screened Unit
Polymer Applications Site (Registry Number 915044)								
B-2D	581.44	583.71	23.7	12.40 to 23.70	569.04 to 557.74	13.70 to 23.70	567.74 to 557.74	Reddish Brown Silty Clay
B-3D	589.21	591.14	21.0	10.00 to 21.00	579.21 to 568.21	11.00 to 21.00	578.21 to 568.21	Reddish Brown Silty Clay
B-4D	591.93	594.13	20.0	9.00 to 20.00	582.93 to 571.93	10.00 to 20.00	581.93 to 571.93	Reddish Brown Silty Clay
B-5D	589.16	591.24	20.0	9.00 to 20.00	580.16 to 569.16	10.00 to 20.00	579.16 to 569.16	Reddish Brown Silty Clay
B-6D	578.66	580.89	20.0	9.00 to 20.00	569.66 to 558.66	10.00 to 20.00	568.66 to 558.66	Reddish Brown Silty Clay
B-7D	578.42	578.15	20.0	9.00 to 20.00	569.42 to 558.42	10.00 to 20.00	568.42 to 558.42	Reddish Brown Silty Clay
Dunlop Tire Corporation Site (Registry Number 915018)								
OMW-A4	582.0*	584.18	24.0	5.50 to 24.00	576.50 to 558.00	13.00 to 23.00	569.00 to 559.00	Reddish Brown Silty Clay
OMW-A6	594.28	593.74	24.5	11.00 to 24.50	583.28 to 569.78	13.50 to 23.50	580.78 to 570.78	Reddish Brown Silty Clay
OMW-B4	586.0*	587.73	22.0	9.00 to 22.50	577.00 to 563.50	10.50 to 20.50	575.50 to 565.50	Reddish Brown Silty Clay
OMW-C5	601.39	604.37	32.0	12.50 to 30.00	588.89 to 571.39	16.00 to 26.00	585.39 to 575.39	Reddish Brown Silty Clay
OMW-C7	599.3*	601.40	22.0	6.00 to 22.00	593.30 to 577.30	11.00 to 21.00	588.30 to 578.30	Reddish Brown Silty Clay
E.I. DuPont Yerkes Plant Site (Registry Number 915019)								
MW-3I	603.10	605.01	??	?? to ??	?? to ??	?? to 21.50	?? to 581.60	Reddish Brown Silty Clay
Niagara Mohawk Power Corporation - Huntley Plant								
NM-A	575.5*	577.84	??	?? to ??	?? to ??	?? to 19.60	?? to 555.90	No Construction Diagram Available
NM-B	575.75*	578.58	??	?? to ??	?? to ??	?? to 18.00	?? to 557.75	No Construction Diagram Available
USGS Monitoring Wells								
81-2TB	576.66	580.73	18.5	16.50 to 18.50	560.16 to 558.16	16.50 to 18.50	560.16 to 558.16	Grey Sand

Ft. AMSL **Feet Above Mean Sea Level.**
Ft. BGS **Feet Below Ground Surface.**
***** **Estimated Elevation.**

Table B-3.
Monitoring Well Instrumentation Summary for Deep Zone Wells Installed in the Study Area.

Well Designation	Ground Surface Elevation (ft. AMSL)	Top of Riser Elevation (ft. AMSL)	Total Boring Depth (ft. BGS)	Sandpack Interval (ft. BGS)	Sandpack Interval (ft. AMSL)	Well Screen Interval (ft. BGS)	Well Screen Interval (ft. AMSL)	Screened Unit
Polymer Applications Site (Registry Number 915044)								
GW-1DD	589.38	591.61	60.0	52.50 to 60.00	536.88 to 529.38	55.00 to 60.00	534.38 to 529.38	Grey Silt, Sand & Gravel
GW-2DD	592.25	594.36	61.0	52.50 to 61.00	539.75 to 531.25	55.00 to 61.00	537.25 to 531.25	Reddish Brown Silty Clay; Grey Silt, Sand & Gravel
MW-8DD	580.89	582.11	55.0	48.00 to 55.00	532.89 to 525.89	50.00 to 55.00	530.89 to 525.89	Grey Silt, Sand & Gravel; Camillus Shale
MW-9DD	593.47	595.07	66.0	59.00 to 66.00	534.47 to 527.47	61.00 to 66.00	532.47 to 527.47	Grey Silt, Sand & Gravel
MW-10DD	575.88	577.59	50.0	36.00 to 43.00	539.88 to 532.88	37.00 to 42.00	538.88 to 533.88	Grey Clay; Grey Silt
MW-11DD	577.40	579.24	51.0	44.00 to 51.00	533.40 to 526.40	46.00 to 51.00	531.40 to 526.40	Grey Silt, Sand & Gravel; Camillus Shale
E.I. DuPont Yerkes Plant Site (Registry Number 915019)								
MW-1D	600.88	602.80	72.0	?? to ??	?? to ??	62.00 to 72.00	538.88 to 528.88	Grey Sand & Silt; Camillus Shale
MW-2D	600.33	602.59	76.0	?? to ??	?? to ??	66.00 to 76.00	534.33 to 524.33	Grey Till; Camillus Shale
MW-3D	603.10	604.57	84.0	?? to ??	?? to ??	74.00 to 84.00	529.10 to 519.10	Grey Sand & Silt; Camillus Shale
MW-4D	602.17	604.54	84.0	?? to ??	?? to ??	74.00 to 84.00	528.17 to 518.17	Grey Clay; Grey Sand & Gravel; Camillus Shale
MW-7D	605.00	605.79	77.5	?? to ??	?? to ??	67.50 to 77.50	537.50 to 527.50	Grey Silt, Sand & Gravel; Camillus Shale
3M O-Cel-O Sponge Site (Registry Number 915148)								
MW-1	602.41	602.06	69.0	62.00 to 69.00	540.41 to 533.41	63.00 to 68.00	539.41 to 534.41	Reddish Brown Silty Clay
MW-2	602.62	602.21	71.4	65.00 to 70.00	537.62 to 532.62	66.00 to 70.00	536.62 to 532.62	Grey Sandy Gravel & Clay
MW-3	602.14	603.88	72.5	64.00 to 72.00	538.14 to 530.14	66.00 to 72.00	536.14 to 530.14	Reddish Brown Silty Clay; Grey Gravelly Sand & Clay
MW-4	602.04	601.84	77.0	67.20 to 77.20	534.84 to 524.84	69.20 to 74.20	532.84 to 527.84	Grey Silt, Sand & Gravel

Ft. AMSL **Feet Above Mean Sea Level.**
Ft. BGS **Feet Below Ground Surface.**

Table B-4. Monitoring Well Instrumentation Summary for Upper Bedrock Zone Wells Installed in the Study Area.								
Well Designation	**Ground Surface Elevation (ft. AMSL)**	**Top of Riser Elevation (ft. AMSL)**	**Total Boring Depth (ft. BGS)**	**Sandpack Interval (ft. BGS)**	**Sandpack Interval (ft. AMSL)**	**Well Screen Interval (ft. BGS)**	**Well Screen Interval (ft. AMSL)**	**Screened Unit**
Dunlop Tire Corporation Site (Registry Number 915018)								
PW-1	593.3*	588.71	140.0	?? to ??	?? to ??	100.0 to 140.0	493.30 to 453.30	Camillus Shale
USGS Monitoring Wells								
81-1T	602.50	605.18	70.0	68.00 to 70.00	534.50 to 532.50	68.00 to 70.00	534.50 to 532.50	Camillus Shale
81-2TA	576.58	579.40	50.0	48.00 to 50.00	528.58 to 526.58	49.00 to 50.00	527.58 to 526.58	Camillus Shale

Ft. AMSL Feet Above Mean Sea Level.
Ft. BGS Feet Below Ground Surface.
***** Estimated Elevation.

APPENDIX C

WATER LEVEL DATA

Well Designation	Top of Riser Elevation	October 3, 1983		October 17, 1983		June 25, 1990		August 8, 1990		June 14, 1993		January 4, 1994	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Polymer Applications Site (Registry Number 915044)													
B-4S	594.26	4.25	590.01	4.08	590.18	4.12	590.14	4.72	589.54	4.01	590.25	3.24	591.02
B-5S	591.14	4.17	586.97	3.83	587.31	3.48	587.66	3.52	587.62	3.36	587.78	3.40	587.74
B-6S	582.13									4.78	577.35		
B-7S	578.12			5.17	572.95								
GW-3S	594.53					4.97	589.56	5.22	589.31	4.80	589.73	7.70	586.83
GW-4S	592.40					5.20	587.20	5.92	586.48			4.54	587.86
MW-9S	593.82												
MW-11S	579.22												
MW-12S	580.77												
MW-13S	577.58												
MW-14S	577.99												

Table C-1. Historical Groundwater Elevations in Shallow Hydrogeologic Zone Wells Installed in the Study Area. (All water levels and elevations measured in feet)

Table C-1 (continued).
Historical Groundwater Elevations in Shallow Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	March 11, 1994		March 15, 1994		May 31, 1994		June 28, 1994		July 13, 1994			
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation		
Polymer Applications Site (Registry Number 915044)													
B-4S	594.26			2.22	592.04	4.83	589.43	2.90	591.36	4.35	589.91		
B-5S	591.14			3.24	587.90			3.42	587.72	3.65	587.49		
B-6S	582.13			5.54	576.59	5.86	576.27	5.96	576.17	6.04	576.09		
B-7S	578.12					1.07	577.05	0.92	577.20	1.06	577.06		
GW-3S	594.53			4.32	590.21			4.59	589.94	5.32	589.21		
GW-4S	592.40			2.64	589.76			4.40	588.00	5.50	586.90		
MW-9S	593.82	9.10	584.72	8.74	585.08	3.72	590.10	3.65	590.17	4.05	589.77		
MW-11S	579.22	5.96	573.26	4.70	574.52	5.55	573.67	6.18	573.04	6.51	572.71		
MW-12S	580.77	3.15	577.62	11.72	569.05	4.06	576.71	3.50	577.27	4.16	576.61		
MW-13S	577.58	5.68	571.90	5.50	572.08	6.12	571.46	5.90	571.68	6.54	571.04		
MW-14S	577.99	7.42	570.57	7.02	570.97	7.73	570.26	7.54	570.45	8.02	569.97		

Table C-1 (continued).
Historical Groundwater Elevations in Shallow Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	December 21, 1982		December 22, 1982		January 6, 1983		January 10, 1983		March 7, 1983		March 22, 1983	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Dunlop Tire Corporation Site (Registry Number 915018)													
OMW-1	593.66	14.30	579.36	14.20	579.46	14.20	579.46	14.20	579.46	7.40	586.26	6.40	587.26
OMW-2	589.22	13.30	575.92	13.20	576.02	13.20	576.02	13.20	576.02	10.25	578.97	10.00	579.22
OMW-3	604.27	15.20	589.07	15.10	589.17	15.20	589.07	15.20	589.07	10.75	593.52	9.00	595.27
OMW-4	610.36	11.30	599.06	11.30	599.06	11.20	599.16	11.20	599.16	11.30	599.06	11.30	599.06
OMW-B2	586.73												
OMW-B3	580.58												
OMW-C1	603.84												
OMW-C6	603.00												

Well Designation	Top of Riser Elevation	April 5, 1983		April 19, 1983		May 2, 1983		May 16, 1983		May 31, 1983		September 21, 1983	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Dunlop Tire Corporation Site (Registry Number 915018)													
OMW-1	593.66	5.80	587.86	5.40	588.26	5.50	588.16	5.15	588.51	5.95	587.71	8.17	585.49
OMW-2	589.22	8.55	580.67	7.40	581.82	6.95	582.27	6.55	582.67	6.95	582.27	5.63	583.59
OMW-3	604.27	7.50	596.77	6.30	597.97	5.60	598.67	5.25	599.02	4.90	599.37	9.96	594.31
OMW-4	610.36	11.30	599.06	11.30	599.06	11.30	599.06	11.30	599.06	11.30	599.06	8.94	601.42
OMW-B2	586.73												
OMW-B3	580.58												
OMW-C1	603.84												
OMW-C6	603.00												

Table C-1 (continued).
Historical Groundwater Elevations in Shallow Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	May 1, 1991		May 2, 1991		May 3, 1991		May 6, 1991		May 7, 1991		May 8, 1991	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Dunlop Tire Corporation Site (Registry Number 915018)													
OMW-1	592.87*									4.39	588.48		
OMW-2	588.45*									5.06	583.39		
OMW-3	603.44*	2.93	600.51							3.20	600.24		
OMW-4	609.50*	7.94	601.56							8.12	601.38		
OMW-B2	586.73	18.42	568.31	18.34	568.39	18.28	568.45	18.00	568.73	17.94	568.79	17.90	568.83
OMW-B3	580.58	NA	Dry	15.50	565.08	14.20	566.38	9.46	571.12	8.87	571.71	8.80	571.78
OMW-C1	603.84					17.74	586.10	10.80	593.04	9.08	594.76	7.58	596.26
OMW-C6	603.00					19.05	583.95	18.58	584.42	18.44	584.56	18.38	584.62

Well Designation	Top of Riser Elevation	May 17, 1991		July 3, 1991		September 27, 1991							
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation						
Dunlop Tire Corporation Site (Registry Number 915018)													
OMW-1	592.87*	11.72	581.15	11.30	581.57	8.07	584.80						
OMW-2	588.45*	11.43	577.02	12.10	576.35	7.85	580.60						
OMW-3	603.44*	12.02	591.42	12.46	590.98	10.01	593.43						
OMW-4	609.50*	8.23	601.27	8.57	600.93	NA	Dry						
OMW-B2	586.73	18.46	568.27	16.96	569.77	8.55	578.18						
OMW-B3	580.58	14.03	566.55	7.38	573.20	9.45	571.13						
OMW-C1	603.84	9.96	593.88	6.85	596.99	9.75	594.09						
OMW-C6	603.00	18.18	584.82										

Table C-1 (continued).
Historical Groundwater Elevations in Shallow Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	October 2, 1979		December 28, 1990		September 1992		December 1992		March 1993		June 1993	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
E.I. DuPont Yerkes Plant Site (Registry Number 915019)													
MW-1S	602.74	4.17	598.57	3.03	599.71	3.57	599.17	3.10	599.64	2.20	600.54	3.62	599.12
MW-2S	602.85	4.17	598.68	2.48	600.37	3.21	599.64	2.43	600.42	2.15	600.70	2.80	600.05
MW-3S	604.88	3.63	601.25	2.81	602.07	3.02	601.86	2.82	602.06	2.48	602.40	3.06	601.82
MW-4S	604.26	3.42	600.84	2.57	601.69	2.54	601.72	2.58	601.68	2.38	601.88	2.61	601.65
DYF-1	592.24					15.08	577.16	9.82	582.42	7.50	584.74	10.09	582.15
DYF-2	591.35					17.15	574.20	14.93	576.42	11.27	580.08	12.21	579.14
DYF-3	595.27					5.53	589.74	4.98	590.29	4.61	590.66	4.38	590.89
DYF-4	600.12					4.73	595.39	4.37	595.75	3.98	596.14	4.42	595.70
DYF-5	605.24					5.43	599.81	4.50	600.74	3.80	601.44	5.32	599.92

Table C-1 (continued).
Historical Groundwater Elevations in Shallow Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	April 24, 1981		May 1, 1981		May 7, 1981		May 15, 1981		May 22, 1981		May 28, 1981	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Niagara Mohawk Huntley Plant													
B-7	575.10**	8.78	566.32	8.78	566.32	8.87	566.23	9.03	566.07	8.70	566.40	9.03	566.07
B-14	572.88**	3.90	568.98	3.86	569.02	3.90	568.98	4.03	568.85	3.90	568.98	3.78	569.10
B-16	580.69**	11.44	569.25	11.60	569.09	11.60	569.09	11.65	569.04	11.60	569.09	11.65	569.04
B-17	578.27**	8.63	569.64	7.88	570.39	8.29	569.98	8.88	569.39	8.71	569.56	9.29	568.98
B-18	573.43**	6.17	567.26	5.09	568.34	5.09	568.34	5.13	568.30	5.17	568.26	5.42	568.01

Well Designation	Top of Riser Elevation	June 5, 1981		June 12, 1981		March 21, 1995							
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation						
Niagara Mohawk Huntley Plant													
B-7	575.10**	8.66	566.44	8.95	566.15								
B-14	572.88**	3.90	568.98	3.94	568.94	9.60	563.28						
B-16	580.69**	11.60	569.09	11.69	569.00								
B-17	578.27**	9.29	568.98	8.38	569.89								
B-18	573.43**	5.05	568.38	5.34	568.09	9.85	563.58						

***   Top of Riser Resurveyed During URS Investigation.**
NA   Not Applicable.
****   Top of Riser Elevation Unknown. Referenced Elevation is Ground Surface.**

Table C-2.
Groundwater Elevations in Shallow Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	August 21, 1995		September 14, 1995		October 12, 1995		November 9, 1995		January 12, 1996	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Polymer Applications Site (Registry Number 915044)											
B-4S	594.26	5.30	588.96	6.50	587.76	3.84	590.42	3.44	590.82	3.55	590.71
B-5S	591.14	3.52	587.62	3.63	587.51	3.44	587.70	3.40	587.74	3.40	587.74
B-6S	582.13	6.32	575.81	6.71	575.42	4.85	577.28	4.70	577.43	4.66	577.47
B-7S	578.12	NM	----------	NM	----------	NM	----------	NM	----------	NM	----------
GW-3S	594.53	5.29	589.24	5.80	588.73	5.00	589.53	4.92	589.61	6.08	588.45
GW-4S	592.40	4.96	587.44	5.56	586.84	4.28	588.12	4.26	588.14	5.65	586.75
MW-9S	593.82	4.39	589.43	5.25	588.57	4.42	589.40	4.00	589.82	4.10	589.72
MW-11S	579.22	7.89	571.33	8.68	570.54	8.94	570.28	6.30	572.92	6.21 ++	573.01
MW-12S	580.77	4.02	576.75	4.51	576.26	3.60	577.17	3.91	576.86	4.32	576.45
MW-13S	577.58	7.90	569.68	8.02	569.56	5.98	571.60	5.82	571.76	6.07 ++	571.51
MW-14S	577.99	9.33	568.66	9.62	568.37	7.76	570.23	7.42	570.57	7.67 ++	570.32
Dunlop Tire Corporation Site (Registry Number 915018)											
OMW-B3	580.58	9.04	571.54	9.94	570.64	8.52	572.06	7.04	573.54	5.89	574.69
OMW-C1	603.84	6.86	596.98	7.92	595.92	7.08	596.76	4.46	599.38	3.32	600.52

Table C-2 (Continued).
Groundwater Elevations in Shallow Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	August 21, 1995		September 14, 1995		October 12, 1995		November 9, 1995		January 12, 1996	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
E.I. DuPont Yerkes Plant Site (Registry Number 915019)											
MW-1S	602.74	5.68 +	597.06	5.92	596.82	4.08	598.66	4.78 **	597.96	4.18	598.56
MW-2S	602.85	4.80 +	598.05	4.71	598.14	3.13	599.72	2.78 **	600.07	Frozen	----------
MW-3S	604.88	4.82 +	600.06	5.38	599.50	4.36	600.52	3.20 **	601.68	2.81	602.07
MW-4S	604.26	4.46 *	599.80	5.38	598.88	3.82	600.44	2.78 **	601.48	2.50	601.76
DYF-1	592.24	5.54 *	586.70	5.83	586.41	5.83	586.41	6.51 **	585.73	7.24	585.00
DYF-2	591.35	13.68 *	577.67	15.98	575.37	17.13	574.22	Dry	<573.65	Dry	<573.65
DYF-3	595.27	4.64 *	590.63	5.67	589.60	5.86	589.41	6.06 **	589.21	5.87	589.40
DYF-4	600.12	5.50 *	594.62	6.60	593.52	5.31	594.81	4.86 **	595.26	4.74	595.38
DYF-5	605.24	8.52 +	596.72	8.94	596.30	9.31	595.93	6.26 **	598.98	5.73	599.51

NM **Not Measured.**
***** **Water Level Measured on August 16, 1995.**
+ **Water Level Measured on August 24, 1995.**
****** **Water Level Measured on November 10, 1995.**
++ **Water Level Measured on January 11, 1996.**

Table C-3.
Historical Groundwater Elevations in Intermediate Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	August 30, 1983		September 15, 1983		October 3, 1983		October 17, 1983		September 21, 1990		June 14, 1993	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Polymer Applications Site (Registry Number 915044)													
B-2D	583.71	7.47	576.24	11.37	572.34	14.00	569.71	14.25	569.46	10.57	573.14	8.66	575.05
B-3D	591.14							4.58	586.56			3.75	587.39
B-4D	594.13					13.08	581.05	5.67	588.46			3.40	590.73
B-5D	591.24					20.00	571.24	19.00	572.24			4.01	587.23
B-6D	580.89					20.58	560.31	19.58	561.31			6.02	574.87
B-7D	578.15					16.17	561.98						

Well Designation	Top of Riser Elevation	January 4, 1994		March 15, 1994		May 31, 1994		June 28, 1994		July 13, 1994			
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Polymer Applications Site (Registry Number 915044)													
B-2D	583.71	8.60	575.11	7.65	576.06			8.03	575.68	8.00	575.71		
B-3D	591.14	3.53	587.61	3.00	588.14			3.61	587.53	4.45	586.69		
B-4D	594.13	3.88	590.25	2.57	591.56			3.03	591.10	3.90	590.23		
B-5D	591.24	4.30	586.94	11.04	580.20			4.18	587.06	4.90	586.34		
B-6D	580.89	5.80	575.09	14.00	566.89			7.20	573.69	6.72	574.17		
B-7D	578.15					1.96	576.19	0.74	577.41	1.57	576.58		

Table C-3 (continued).
Historical Groundwater Elevations in Intermediate Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	April 29, 1991		April 30, 1991		May 1, 1991		May 2, 1991		May 3, 1991		May 6, 1991	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Dunlop Tire Corporation Site (Registry Number 915018)													
OMW-A3	598.22	11.20	587.02	9.80	588.42	7.38	590.84	6.37	591.85	5.76	592.46	5.39	592.83
OMW-C5	604.37							NA	Dry	NA	Dry	NA	Dry

Well Designation	Top of Riser Elevation	May 7, 1991		May 8, 1991		May 17, 1991		July 3, 1991		September 27, 1991			
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Dunlop Tire Corporation Site (Registry Number 915018)													
OMW-A3	598.22	5.50	592.72	5.63	592.59	5.45	592.77	10.98	587.24	16.75	581.47		
OMW-C5	604.37	29.34	575.03	29.38	574.99	27.70	576.67	22.41	581.96	21.15	583.22		

Table C-3 (continued).
Historical Groundwater Elevations in Intermediate Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	April 24, 1981		May 1, 1981		May 7, 1981		May 15, 1981		May 22, 1981		May 28, 1981	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Niagara Mohawk Huntley Plant													
B-8	575.10**	8.43	566.67	9.02	566.08	8.77	566.33	8.85	566.25	8.52	566.58	8.68	566.42
B-15	573.41**	6.01	567.40	7.59	565.82	7.59	565.82	7.68	565.73	7.26	566.15	7.34	566.07
B-17A	578.27**												
SB-ST-25A	577.11**												

Well Designation	Top of Riser Elevation	June 5, 1981		June 12, 1981		May 27, 1983		May 31, 1983		June 1, 1983		June 13, 1983	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Niagara Mohawk Huntley Plant													
B-8	575.10**	8.52	566.58	8.77	566.33								
B-15	573.41**	7.30	566.11	7.51	565.90								
B-17A	578.27**												
SB-ST-25A	577.11**					8.20	568.91	8.25	568.86	8.25	568.86	8.40	568.71

Well Designation	Top of Riser Elevation	June 15, 1983		June 17, 1983		June 21, 1983		June 22, 1983		September 26, 1983		September 27, 1983	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Niagara Mohawk Huntley Plant													
B-8	575.10**												
B-15	573.41**												
B-17A	578.27**												
SB-ST-25A	577.11**	8.30	568.81	8.40	568.71	8.45	568.66	8.38	568.73	8.50	568.61	8.60	568.51

Table C-3 (continued).
Historical Groundwater Elevations in Intermediate Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	September 29, 1983		March 21, 1995									
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Niagara Mohawk Huntley Plant													
B-8	575.10**												
B-15	573.41**			10.50	562.91								
B-17A	578.27**			6.80	571.47								
SB-ST-25A	577.11**	8.79	568.32										

****** **Top of Riser Elevation Unknown. Referenced Elevation is Ground Surface.**
NA **Not Applicable.**

Table C-4. Groundwater Elevations in Intermediate Hydrogeologic Zone Wells Installed in the Study Area. (All water levels and elevations measured in feet)											
Well Designation	**Top of Riser Elevation**	**August 18, 1995**		**September 14, 1995**		**October 12, 1995**		**November 9, 1995**		**January 12, 1996**	
		Depth to Water	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**
Polymer Applications Site (Registry Number 915044)											
B-2D	583.71	8.21 *	575.50	8.46	575.25	8.46	575.25	8.47	575.24	8.40	575.31
B-3D	591.14	5.28 *	585.86	6.42	584.72	3.47	587.67	3.54	587.60	4.64	586.50
B-4D	594.13	4.58 *	589.55	5.70	588.43	3.88	590.25	4.24	589.89	4.10	590.03
B-5D	591.24	3.86 *	587.38	5.51	585.73	4.42	586.82	5.14	586.10	4.72	586.52
B-6D	580.89	7.04 *	573.85	6.43	574.46	6.36	574.53	6.03	574.86	6.10	574.79
B-7D	578.15	NM	----------	NM	----------	NM	----------	NM	----------	NM	----------
Dunlop Tire Corporation Site (Registry Number 915018)											
OMW-A4	584.18	10.14	574.04	10.44	573.74	10.68 **	573.50	16.15	568.03	8.80	575.38
OMW-A6	593.74	6.00	587.74	6.17	587.57	6.30 **	587.44	6.35	587.39	NM	----------
OMW-B4	587.73	7.97	579.76	8.72	579.01	9.25 **	578.48	14.31	573.42	5.02	582.71
OMW-C5	604.37	7.32	597.05	7.83	596.54	8.22 **	596.15	8.02	596.35	6.39	597.98
OMW-C7	601.40	6.74	594.66	7.60	593.80	8.26 **	593.14	11.03	590.37	7.08	594.32
E.I. DuPont Yerkes Plant Site (Registry Number 915019)											
MW-3I	605.01	4.64 +	600.37	5.18	599.83	5.34	599.67	4.26 #	600.75	3.66	601.35
Niagara Mohawk Huntley Plant											
NM-A	577.84	11.68 *	566.16	11.81	566.03	11.35	566.49	11.27	566.57	11.54 #*	566.30
NM-B	578.58	9.20 *	569.38	9.57	569.01	7.36	571.22	7.02	571.56	7.23 #*	571.35
USGS Monitoring Wells											
81-2TB	580.73	14.55 ++	566.18	14.50	566.23	14.41	566.32	14.33	566.40	14.40 #*	566.33

Table C-4 (continued).
Groundwater Elevations in Intermediate Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

NM	**Not Measured.**
*****	**Water Level Measured on August 21, 1995.**
+	**Water Level Measured on August 24, 1995.**
++	**Water Level Measured on August 31, 1995.**
******	**Water Level Measured on October 3, 1995.**
#	**Water Level Measured on November 10, 1995.**
#*	**Water Level Measured on January 11, 1996.**

Table C-5.
Historical Groundwater Elevations in Deep Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	August 30, 1983		September 15, 1983		September 21, 1983		October 3, 1983		October 17, 1983		June 25, 1990	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Polymer Applications Site (Registry Number 915044)													
B-1DD	582.15	40.30	541.85	40.10	542.05	39.70	542.45	42.67	539.48	45.92	536.23	15.75	566.40
GW-1DD	591.61											25.07	566.54
GW-2DD	594.36											27.41	566.95
MW-8DD	582.11												
MW-9DD	595.07												
MW-10DD	577.59												
MW-11DD	579.24												

Well Designation	Top of Riser Elevation	August 8, 1990		June 14, 1993		January 4, 1994		March 11, 1994		March 15, 1994		May 31, 1994	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Polymer Applications Site (Registry Number 915044)													
B-1DD*	582.15	38.02	544.13			16.36	565.79						
GW-1DD	591.61	38.03	553.58			25.80	565.81			35.09	556.52		
GW-2DD	594.36	37.33	557.03	26.96	567.40	27.78	566.58			27.47	566.89		
MW-8DD	582.11							16.14	565.97	15.82	566.29	15.27	566.84
MW-9DD	595.07							10.93	584.14	15.12	579.95	27.06	568.01
MW-10DD	577.59							7.15	570.44	8.91	568.68	10.05	567.54
MW-11DD	579.24							13.27	565.97	13.02	566.22	12.35	566.89

Table C-5 (continued).
Historical Groundwater Elevations in Deep Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	June 28, 1994		July 13, 1994									
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Polymer Applications Site (Registry Number 915044)													
B-1DD*	582.15												
GW-1DD	591.61	45.39	546.22	46.08	545.53								
GW-2DD	594.36	42.40	551.96	42.80	551.56								
MW-8DD	582.11	45.90	536.21	36.50	545.61								
MW-9DD	595.07	31.21	563.86	34.21	560.86								
MW-10DD	577.59	12.50	565.09	13.43	564.16								
MW-11DD	579.24	31.85	547.39	32.47	546.77								

Table C-5 (continued). Historical Groundwater Elevations in Deep Hydrogeologic Zone Wells Installed in the Study Area. (All water levels and elevations measured in feet)													
Well Designation	**Top of Riser Elevation**	**October 2, 1979**		**December 28, 1990**		**September 1992**		**December 1992**		**March 1993**		**June 1993**	
		Depth to Water	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**
E.I. DuPont Yerkes Plant Site (Registry Number 915019)													
MW-1D	602.80	37.58	565.22	36.61	566.19	36.53	566.27	36.08	566.72	36.22	566.58	35.65	567.15
MW-2D	602.59	38.00	564.59	36.12	566.47	36.57	566.02	35.65	566.94	35.68	566.91	35.22	567.37
MW-3D	604.57	42.00	562.57	36.00	568.57	38.75	565.82	35.80	568.77	35.66	568.91	35.39	569.18
MW-4D	604.54	42.00	562.54	35.67	568.87	38.87	565.67	35.37	569.17	35.09	569.45	34.89	569.65
MW-7D	605.79	39.42	566.37	37.34	568.45	37.83	567.96	36.92	568.87	36.98	568.81	36.47	569.32
Well Designation	**Top of Riser Elevation**	**May 8, 1992**											
		Depth to Water	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**
3M O-Cel-O Sponge Site (Registry Number 915148)													
MW-1	604.03	34.88	569.15										
MW-2	605.56	36.43	569.13										
MW-3	604.09	34.98	569.11										
*** Well Damaged; Replaced by Well MW-8DD.**													

Table C-6. Groundwater Elevations in Deep Hydrogeologic Zone Wells Installed in the Study Area. (All water levels and elevations measured in feet)													
Well Designation	**Top of Riser Elevation**	**April 13, 1995**		**April 20, 1995**		**April 27, 1995**		**May 4, 1995**		**May 11, 1995**		**May 18, 1995**	
		Depth to Water	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**
Polymer Applications Site (Registry Number 915044)													
GW-1DD	591.61	NM	---------	25.38	566.23	25.36	566.25	25.38	566.23	25.26	566.35	25.38	566.23
GW-2DD	594.36	NM	---------	27.92	566.44	27.85	566.51	27.84	566.52	27.74	566.62	27.82	566.54
MW-8DD	582.11	NM	---------	15.87	566.24	15.84	566.27	15.88	566.23	15.76	566.35	15.90	566.21
MW-9DD	595.07	NM	---------	28.78	566.29	28.78	566.29	28.73	566.34	28.75	566.32	28.69	566.38
MW-10DD	577.59	NM	---------	NM	---------	11.67	565.92	11.66	565.93	11.53	566.06	11.52	566.07
MW-11DD	579.24	NM	---------	NM	---------	13.20	566.04	13.04	566.20	12.86	566.38	13.20	566.04
E.I. DuPont Yerkes Plant Site (Registry Number 915019)													
MW-1D	602.80	NM	---------	36.46	566.34	36.42	566.38	36.46	566.34	36.22	566.58	36.46	566.34
MW-2D	602.59	NM	---------	35.98	566.61	35.88	566.71	35.96	566.63	35.72	566.87	35.96	566.63
MW-3D	604.57	NM	---------	35.82	568.75	35.98	568.59	35.98	568.59	35.64	568.93	35.72	568.85
MW-4D	604.54	NM	---------	35.70	568.84	35.49	569.05	35.66	568.88	35.22	569.32	35.44	569.10
MW-7D	605.79	NM	---------	37.28	568.51	37.18	568.61	37.23	568.56	37.02	568.77	37.25	568.54
3M O-Cel-O Sponge Site (Registry Number 915148)													
MW-1	604.03	34.94	569.09	35.27	568.76	35.11	568.92	35.22	568.81	34.75	569.28	34.97	569.06
MW-2	605.56	35.56	570.00	36.86	568.70	36.71	568.85	36.82	568.74	36.34	569.22	36.56	569.00
MW-3	604.09	35.09	569.00	35.41	568.68	35.25	568.84	35.35	568.74	34.87	569.22	35.11	568.98
NM Not Measured.													

Table C-6 (continued).
Groundwater Elevations in Deep Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	May 25, 1995		June 1, 1995		June 8, 1995		June 15, 1995		June 22, 1995		June 29, 1995	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Polymer Applications Site (Registry Number 915044)													
GW-1DD	591.61	25.50	566.11	25.35	566.26	46.54	545.07	46.53	545.08	46.98	544.63	47.00	544.61
GW-2DD	594.36	27.86	566.50	27.72	566.64	40.98	553.38	43.63	550.73	44.72	549.64	45.06	549.30
MW-8DD	582.11	16.00	566.11	15.84	566.27	36.98	545.13	36.99	545.12	37.40	544.71	37.42	544.69
MW-9DD	595.07	28.70	566.37	28.59	566.48	37.19	557.88	47.92	547.15	48.96	546.11	49.05	546.02
MW-10DD	577.59	11.45	566.14	11.42	566.17	12.43	565.16	13.90	563.69	14.66	562.93	16.30	561.29
MW-11DD	579.24	13.16	566.08	13.01	566.23	32.75	546.49	32.82	546.42	33.30	545.94	33.38	545.86
E.I. DuPont Yerkes Plant Site (Registry Number 915019)													
MW-1D	602.80	36.60	566.20	36.41	566.39	37.34*	565.46	37.41	565.39	37.62	565.18	37.53	565.27
MW-2D	602.59	36.10	566.49	35.93	566.66	37.10*	565.49	37.32	565.27	37.58	565.01	37.54	565.05
MW-3D	604.57	36.04	568.53	35.64	568.93	37.44*	567.13	38.63	565.94	39.16	565.41	39.42	565.15
MW-4D	604.54	35.75	568.79	35.60	568.94	37.64*	566.90	38.73	565.81	39.14	565.40	39.32	565.22
MW-7D	605.79	37.40	568.39	37.19	568.60	38.36*	567.43	38.55	567.24	38.82	566.97	38.72	567.07
3M O-Cel-O Sponge Site (Registry Number 915148)													
MW-1	602.06**	33.20	568.86	33.21	568.85	34.50	567.56	37.47	564.59	38.00	564.06	38.08	563.98
MW-2	602.21**	33.47	568.74	33.32	568.89	35.50	566.71	37.65	564.56	38.10	564.11	38.26	563.95
MW-3	603.88**	35.15	568.73	35.00	568.88	37.18	566.70	39.35	564.53	39.76	564.12	39.94	563.94

*** Water Level Measured on June 9, 1995.**
**** Well Casings and Risers Cut Shorter Between May 18 & 25, 1995.**

Table C-6 (continued).
Groundwater Elevations in Deep Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	July 6, 1995		July 13, 1995		July 20, 1995		July 27, 1995		August 3, 1995		August 10, 1995	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Polymer Applications Site (Registry Number 915044)													
GW-1DD	591.61	26.42	565.19	46.50	545.11	48.96	542.65	49.97	541.64	50.88	540.73	51.50	540.11
GW-2DD	594.36	32.67	561.69	42.28	552.08	46.31	548.05	47.59	546.77	48.64	545.72	49.36	545.00
MW-8DD	582.11	16.93	565.18	36.95	545.16	39.41	542.70	40.39	541.72	41.34	540.77	41.95	540.16
MW-9DD	595.07	43.80	551.27	47.78	547.29	51.46	543.61	52.57	542.50	53.48	541.59	54.11	540.96
MW-10DD	577.59	14.70	562.89	14.60	562.99	15.77	561.82	16.40	561.19	16.98	560.61	17.41	560.18
MW-11DD	579.24	14.06	565.18	32.88	546.36	35.28	543.96	36.30	542.94	37.15	542.09	37.76	541.48
E.I. DuPont Yerkes Plant Site (Registry Number 915019)													
MW-1D	602.80	36.84	565.96	37.15*	565.65	37.16	565.64	37.41	565.39	37.48	565.32	37.33	565.47
MW-2D	602.59	36.67	565.92	37.26*	565.33	37.18	565.41	37.43	565.16	37.50	565.09	37.38	565.21
MW-3D	604.57	38.30	566.27	38.44*	566.13	39.20	565.37	39.59	564.98	39.86	564.71	39.82	564.75
MW-4D	604.54	38.06	566.48	38.48*	566.06	39.24	565.30	39.68	564.86	39.88	564.66	39.79	564.75
MW-7D	605.79	37.88	567.91	38.29*	567.50	38.38	567.41	38.66	567.13	38.71	567.08	38.56	567.23
3M O-Cel-O Sponge Site (Registry Number 915148)													
MW-1	602.06	37.20	564.86	37.00	565.06	37.98	564.08	38.26	563.80	38.43	563.63	38.95	563.11
MW-2	602.21	36.35	565.86	36.80	565.41	38.14	564.07	38.64	563.57	38.88	563.33	38.76	563.45
MW-3	603.88	37.95	565.93	38.48	565.40	39.83	564.05	40.32	563.56	40.52	563.36	40.43	563.45
MW-4+	601.84	NM	---------	NM	---------	37.81	564.03	38.32	563.52	38.54	563.30	38.41	563.43

NM **Not Measured.**
***** **Water Level Measured on July 14, 1995.**
+ **Well Constructed on July 18, 1995.**

Table C-6 (continued).
Groundwater Elevations in Deep Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	August 16, 1995		August 24, 1995		August 31, 1995		September 7, 1995		September 14, 1995		September 28, 1995	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Polymer Applications Site (Registry Number 915044)													
GW-1DD	591.61	52.09	539.52	52.51	539.10	43.41	548.20	52.36	539.25	53.47	538.14	54.02	537.59
GW-2DD	594.36	49.96	544.40	50.65	543.71	48.28	546.08	50.35	544.01	51.54	542.82	52.22	542.14
MW-8DD	582.11	42.58	539.53	43.00	539.11	33.50	548.61	42.80	539.31	43.90	538.21	44.44	537.67
MW-9DD	595.07	54.66	540.41	55.21	539.86	51.90	543.17	55.05	540.02	56.19	538.88	64.54	530.53
MW-10DD	577.59	17.84	559.75	18.30	559.29	18.47	559.12	18.76	558.83	19.24	558.35	20.25	557.34
MW-11DD	579.24	38.37	540.87	38.60	540.64	30.48	548.76	38.56	540.68	39.71	539.53	40.39	538.85
E.I. DuPont Yerkes Plant Site (Registry Number 915019)													
MW-1D	602.80	37.42	565.38	37.34	565.46	37.01	565.79	37.16	565.64	37.64	565.16	37.84	564.96
MW-2D	602.59	37.48	565.11	37.38	565.21	37.07	565.52	37.22	565.37	37.63	564.96	37.88	564.71
MW-3D	604.57	39.86	564.71	39.92	564.65	39.71	564.86	39.84	564.73	39.94	564.63	40.24	564.33
MW-4D	604.54	39.96	564.58	40.65	563.89	39.65	564.89	39.84	564.70	40.24	564.30	40.66	563.88
MW-7D	605.79	38.68	567.11	38.60	567.19	38.30	567.49	38.45	567.34	38.87	566.92	39.16	566.63
3M O-Cel-O Sponge Site (Registry Number 915148)													
MW-1	602.06	38.72*	563.34	38.78	563.28	38.31	563.75	38.50	563.56	39.34**	562.72	39.15	562.91
MW-2	602.21	38.94*	563.27	39.00	563.21	38.51	563.70	38.72	563.49	39.56**	562.65	38.98	563.23
MW-3	603.88	40.60*	563.28	40.68	563.20	40.19	563.69	40.38	563.50	41.25**	562.63	41.02	562.86
MW-4	601.84	38.58*	563.26	38.64	563.20	38.17	563.67	38.37	563.47	39.22**	562.62	39.25	562.59

***	Water Level Measured on August 17, 1995.**
****	Water Level Measured on September 15, 1995.**

Table C-6 (continued).
Groundwater Elevations in Deep Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	October 5, 1995		October 12, 1995		October 19, 1995		October 26, 1995		November 2, 1995		November 9, 1995	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Polymer Applications Site (Registry Number 915044)													
GW-1DD	591.61	50.26	541.35	52.90	538.71	53.58	538.03	53.24	538.37	53.82	537.79	29.54	562.07
GW-2DD	594.36	46.94	547.42	58.92	535.44	51.68	542.68	51.93	542.43	52.27	542.09	40.83	553.53
MW-8DD	582.11	40.84	541.27	42.32	539.79	44.00	538.11	43.68	538.43	44.28	537.83	20.04	562.07
MW-9DD	595.07	52.76	542.31	55.78	539.29	56.46	538.61	56.31	538.76	56.82	538.25	44.44	550.63
MW-10DD	577.59	19.10	558.49	19.47	558.12	19.80	557.79	19.96	557.63	20.16	557.43	19.62	557.97
MW-11DD	579.24	37.20	542.04	39.23	540.01	39.97	539.27	39.64	539.60	40.19	539.05	17.81	561.43
E.I. DuPont Yerkes Plant Site (Registry Number 915019)													
MW-1D	602.80	37.98	564.82	37.40	565.40	37.66	565.14	37.38	565.42	37.44	565.36	37.14*	565.66
MW-2D	602.59	37.84	564.75	37.48	565.11	37.68	564.91	37.42	565.17	37.52	565.07	37.00*	565.59
MW-3D	604.57	39.44	565.13	39.83	564.74	40.10	564.47	39.86	564.71	40.02	564.55	39.00*	565.57
MW-4D	604.54	39.72	564.82	NM	---------	NM	---------	NM	---------	NM	---------	NM	---------
MW-7D	605.79	39.10	566.69	38.72	567.07	38.94	566.85	38.66	567.13	38.76	567.03	38.22*	567.57
3M O-Cel-O Sponge Site (Registry Number 915148)													
MW-1	602.06	38.00	564.06	38.43	563.63	38.92	563.14	38.64	563.42	38.94	563.12	37.95	564.11
MW-2	602.21	38.28	563.93	38.74	563.47	39.16	563.05	38.76	563.45	38.86	563.35	37.92	564.29
MW-3	603.88	39.96	563.92	40.42	563.46	40.84	563.04	40.44	563.44	40.54	563.34	39.59	564.29
MW-4	601.84	37.94	563.90	38.40	563.44	38.82	563.02	38.40	563.44	38.52	563.32	37.56	564.28

NM Not Measured.
***** Water Level Measured on November 10, 1995.

Table C-6 (continued).
Groundwater Elevations in Deep Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	November 16, 1995		November 29, 1995		December 7, 1995		December 21, 1995		January 12, 1996			
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Polymer Applications Site (Registry Number 915044)													
GW-1DD	591.61	25.46	566.15	26.00	565.61	25.31	566.30	26.02	565.59	25.94	565.67		
GW-2DD	594.36	30.86	563.50	29.61	564.75	28.70	565.66	29.02	565.34	28.63	565.73		
MW-8DD	582.11	16.02	566.09	16.48	565.63	15.80	566.31	16.40	565.71	16.41	565.70		
MW-9DD	595.07	29.18	565.89	29.41	565.66	28.57	566.50	29.39	565.68	29.44	565.63		
MW-10DD	577.59	17.37	560.22	15.91	561.68	15.32	562.27	14.51	563.08	13.62**	563.97		
MW-11DD	579.24	13.17	566.07	13.64	565.60	12.94	566.30	13.56	565.68	13.59**	565.65		
E.I. DuPont Yerkes Plant Site (Registry Number 915019)													
MW-1D	602.80	36.56	566.24	37.07	565.73	36.35	566.45	NM	---------	36.88	565.92		
MW-2D	602.59	36.34	566.25	36.63	565.96	36.00	566.59	NM	---------	36.40	566.19		
MW-3D	604.57	37.26	567.31	36.92	567.65	36.67	567.90	NM	---------	36.66	567.91		
MW-4D	604.54	NM	---------	NM	---------	36.48	568.06	NM	---------	NM	---------		
MW-7D	605.79	37.64	568.15	37.94	567.85	37.29	568.50	NM	---------	37.72	568.07		
3M O-Cel-O Sponge Site (Registry Number 915148)													
MW-1	602.06	35.16	566.90	34.29*	567.77	34.18	567.88	34.07	567.99	33.96**	568.10		
MW-2	602.21	34.94	567.27	34.41*	567.80	34.22	567.99	34.08	568.13	34.17**	568.04		
MW-3	603.88	36.62	567.26	36.09*	567.79	35.88	568.00	35.74	568.14	35.84**	568.04		
MW-4	601.84	34.60	567.24	34.06*	567.78	33.84	568.00	33.69	568.15	33.80**	568.04		

NM Not Measured.
***** Water Level Measured on November 28, 1995.
****** Water Level Measured on January 11, 1996.

Table C-7.
Historical Groundwater Elevations in Upper Bedrock Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	December 21, 1982		December 22, 1982		January 6, 1983		January 10, 1983		March 7, 1983		March 22, 1983	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Dunlop Tire Corporation Site (Registry Number 915018)													
BMW-1	588.62	54.00	534.62	54.30	534.32	60.00	528.62	50.80	537.82	55.45	533.17	51.75	536.87
BMW-2	610.62	61.50	549.12	61.30	549.32	54.70	555.92	57.90	552.72	62.45	548.17	61.70	548.92

Well Designation	Top of Riser Elevation	April 5, 1983		April 19, 1983		May 2, 1983		May 16, 1983		May 31, 1983		September 21, 1983	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Dunlop Tire Corporation Site (Registry Number 915018)													
BMW-1	588.62	46.50	542.12	50.10	538.52	50.70	537.92	53.30	535.32	45.80	542.82	45.98	542.64
BMW-2	610.62	58.10	552.52	59.30	551.32	59.90	550.72	60.75	549.87	56.55	554.07	55.45	555.17

Well Designation	Top of Riser Elevation	May 1, 1991		May 7, 1991		May 17, 1991		July 3, 1991		September 27, 1991			
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Dunlop Tire Corporation Site (Registry Number 915018)													
BMW-1	587.74*			21.74	566.00	21.18	566.56	40.24	547.50	49.48	538.26		
BMW-2	609.79*	41.86	567.93	41.80	567.99	41.71	568.08	53.36	556.43	59.25	550.54		

Table C-7 (continued).
Historical Groundwater Elevations in Upper Bedrock Hydrogeologic Zone Wells Installed in the Study Area.
(All water levels and elevations measured in feet)

Well Designation	Top of Riser Elevation	May 27, 1983		May 31, 1983		June 1, 1983		June 13, 1983		June 15, 1983		June 17, 1983	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Niagara Mohawk Huntley Plant													
SB-ST-21	573.83**							14.12	559.71	13.90	559.93	14.05	559.78
SB-ST-25A	577.11**	38.05	539.06	29.80	547.31	32.75	544.36	32.15	544.96	34.25	542.86	36.15	540.96
A1	577.91**												
A2	575.59**												
A3	573.04**												
A4	575.44**												

Well Designation	Top of Riser Elevation	June 21, 1983		June 22, 1983		September 26, 1983		September 27, 1983		September 29, 1983		September 30, 1983	
		Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation	Depth to Water	Elevation
Niagara Mohawk Huntley Plant													
SB-ST-21	573.83**	12.90	560.93	13.00	560.83	9.40	564.43	9.80	564.03	10.05	563.78		
SB-ST-25A	577.11**	33.20	543.91	34.10	543.01	26.73	550.38	29.50	547.61	31.96	545.15		
A1	577.91**											38.80	539.11
A2	575.59**											10.46	565.13
A3	573.04**											8.13	564.91
A4	575.44**											34.98	540.46

Table C-7 (continued). Historical Groundwater Elevations in Upper Bedrock Hydrogeologic Zone Wells Installed in the Study Area. (All water levels and elevations measured in feet)														
Well Designation	**Top of Riser Elevation**	**October 3, 1983**		**March 21, 1995**									
		Depth to Water	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**
Niagara Mohawk Huntley Plant													
SB-ST-21	573.83**	9.81	564.02										
SB-ST-25A	577.11**	28.69	548.42										
A1	577.91**	31.99	545.92	15.00	562.91								
A2	575.59**	9.87	565.72	10.30	565.29								
A3	573.04**	7.32	565.72	9.50	563.54								
A4	575.44**	26.89	548.55	9.97	565.47								

***** **Top of Riser Resurveyed During URS Investigation.**
****** **Top of Riser Elevation Unknown. Referenced Elevation is Ground Surface.**

Table C-8. Groundwater Elevations in Upper Bedrock Hydrogeologic Zone Wells Installed in the Study Area. (All water levels and elevations measured in feet)													
Well Designation	**Top of Riser Elevation**	**April 13, 1995**		**April 20, 1995**		**April 27, 1995**		**May 4, 1995**		**May 11, 1995**		**May 18, 1995**	
		Depth to Water	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**
Dunlop Tire Corporation Site (Registry Number 915018)													
PW-1	588.71	22.20	566.51	22.57	566.14	22.54	566.17	22.48	566.23	22.34	566.37	22.56	566.15
USGS Monitoring Wells													
81-1T	605.18	NM	---------	NM	---------	NM	---------	35.48*	569.70	35.49	569.69	35.41	569.77
81-2TA	579.70	NM	---------	NM	---------	NM	---------	13.59*	566.11	13.61	566.09	13.59	566.11

NM **Not Measured.**
***** **Water Level Measured on May 5, 1995.**

Table C-8 (continued). Groundwater Elevations in Upper Bedrock Hydrogeologic Zone Wells Installed in the Study Area. (All water levels and elevations measured in feet)													
Well Designation	**Top of Riser Elevation**	**May 25, 1995**		**June 1, 1995**		**June 8, 1995**		**June 15, 1995**		**June 22, 1995**		**June 29, 1995**	
		Depth to Water	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**
Dunlop Tire Corporation Site (Registry Number 915018)													
PW-1	588.71	22.65	566.06	22.48	566.23	45.82	542.89	45.54	543.17	46.12	542.59	46.11	542.60
USGS Monitoring Wells													
81-1T	605.18	35.43	569.75	35.46	569.72	35.50	569.68	36.31	568.87	37.20	567.98	37.85	567.33
81-2TA	579.70	13.59	566.11	13.60	566.10	13.62	566.08	13.70	566.00	13.78	565.92	12.76*	566.64

***** **Riser Repaired on June 30, 1995. New Elevation is 579.40.**

Table C-8 (continued). Groundwater Elevations in Upper Bedrock Hydrogeologic Zone Wells Installed in the Study Area. (All water levels and elevations measured in feet)													
Well Designation	**Top of Riser Elevation**	**July 6, 1995**		**July 13, 1995**		**July 20, 1995**		**July 27, 1995**		**August 3, 1995**		**August 10, 1995**	
		Depth to Water	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**
Dunlop Tire Corporation Site (Registry Number 915018)													
PW-1	588.71	23.44	565.27	45.64	543.07	48.25	540.46	49.14	539.57	50.16	538.55	50.79	537.92
USGS Monitoring Wells													
81-1T	605.18	38.26	566.92	37.96	567.22	38.17	567.01	38.51	566.67	38.88	566.30	39.12	566.06
81-2TA	579.40	12.80	566.60	12.83	566.57	12.87	566.53	12.93	566.47	12.97	566.43	13.05	566.35

Table C-8 (continued). Groundwater Elevations in Upper Bedrock Hydrogeologic Zone Wells Installed in the Study Area. (All water levels and elevations measured in feet)													
Well Designation	**Top of Riser Elevation**	**August 16, 1995**		**August 24, 1995**		**August 31, 1995**		**September 7, 1995**		**September 14, 1995**		**September 28, 1995**	
		Depth to Water	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**
Dunlop Tire Corporation Site (Registry Number 915018)													
PW-1	588.71	51.40+	537.31	51.73	536.98	41.23	547.48	51.56	537.15	52.86	535.85	53.30	535.41
USGS Monitoring Wells													
81-1T	605.18	39.26*	565.92	39.42	565.76	39.56	565.62	39.60	565.58	39.68	565.50	52.28	552.90
81-2TA	579.40	13.06*	566.34	13.10	566.30	13.14	566.26	13.16	566.24	13.22	566.18	13.86	565.54

***** **Water Level Measured on August 17, 1995.**
+ **Water Level Measured on August 18, 1995.**

Table C-8 (continued). Groundwater Elevations in Upper Bedrock Hydrogeologic Zone Wells Installed in the Study Area. (All water levels and elevations measured in feet)													
Well Designation	**Top of Riser Elevation**	**October 5, 1995**		**October 12, 1995**		**October 19, 1995**		**October 26, 1995**		**November 2, 1995**		**November 9, 1995**	
		Depth to Water	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**
Dunlop Tire Corporation Site (Registry Number 915018)													
PW-1	588.71	49.47	539.24	52.16	536.55	52.90	535.81	52.56	536.15	53.14	535.57	27.01	561.70
USGS Monitoring Wells													
81-1T	605.18	43.42	561.76	40.65	564.53	40.00	565.18	39.74	565.44	39.44	565.74	39.57	565.61
81-2TA	579.40	13.90	565.50	13.74	565.66	14.45	564.95	12.88	566.52	13.28	566.12	13.45	565.95

Table C-8 (continued). Groundwater Elevations in Upper Bedrock Hydrogeologic Zone Wells Installed in the Study Area. (All water levels and elevations measured in feet)													
Well Designation	**Top of Riser Elevation**	**November 16, 1995**		**November 29, 1995**		**December 7, 1995**		**December 21, 1995**		**January 12, 1996**			
		Depth to Water	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**	**Depth to Water**	**Elevation**
Dunlop Tire Corporation Site (Registry Number 915018)													
PW-1	588.71	22.62	566.09	23.03	565.68	22.40	566.31	23.00	565.71	23.04	565.67		
USGS Monitoring Wells													
81-1T	605.18	38.36	566.82	36.86	568.32	36.57	568.61	36.27	568.91	36.27*	568.91		
81-2TA	579.40	13.02	566.38	13.67	565.73	12.33	567.07	13.74	565.66	13.52*	565.88		
*** Water Level Measured on January 11, 1996.**													

APPENDIX D

HYDRAULIC GRADIENT CALCULATIONS

Table D-1.
Hydraulic Gradient Calculations for the Shallow Hydrogeologic Zone.

Upgradient Well					Downgradient Well					Distance (Meters)	Hydraulic Gradient
Well Number	UTM Easting	UTM Northing	Groundwater Elev.		Well Number	UTM Easting	UTM Northing	Groundwater Elev.			
			Feet	Meters				Feet	Meters		
August 21, 1995											
MW-2S	670282	4759217	598.05	182.29	DYF-1	669704	4758503	586.70	178.83	918.63	0.0038
MW-3S	670369	4759460	600.06	182.90	DYF-1	669704	4758503	586.70	178.83	1165.36	0.0035
OMW-C1	670250	4759849	596.98	181.96	OMW-B3	669271	4759134	571.54	174.21	1212.30	0.0064
OMW-C1	670250	4759849	596.98	181.96	MW-11S	669000	4759348	571.33	174.14	1346.66	0.0058
OMW-C1	670250	4759849	596.98	181.96	MW-14S	669104	4759220	568.66	173.33	1307.27	0.0066
										Arithmetic Mean =	**0.0052**
										Geometric Mean =	**0.0050**

Upgradient Well					Downgradient Well					Distance (Meters)	Hydraulic Gradient
Well Number	UTM Easting	UTM Northing	Groundwater Elev.		Well Number	UTM Easting	UTM Northing	Groundwater Elev.			
			Feet	Meters				Feet	Meters		
September 14, 1995											
MW-2S	670282	4759217	598.14	182.31	DYF-1	669704	4758503	586.41	178.74	918.63	0.0039
MW-3S	670369	4759460	599.50	182.73	DYF-1	669704	4758503	586.41	178.74	1165.36	0.0034
OMW-C1	670250	4759849	595.92	181.64	OMW-B3	669271	4759134	570.64	173.93	1212.30	0.0064
OMW-C1	670250	4759849	595.92	181.64	MW-11S	669000	4759348	570.54	173.90	1346.66	0.0057
OMW-C1	670250	4759849	595.92	181.64	MW-14S	669104	4759220	568.37	173.24	1307.27	0.0064
										Arithmetic Mean =	**0.0052**
										Geometric Mean =	**0.0050**

Table D-1 (continued).
Hydraulic Gradient Calculations for the Shallow Hydrogeologic Zone.

Upgradient Well					Downgradient Well					Distance (Meters)	Hydraulic Gradient
Well Number	UTM Easting	UTM Northing	Groundwater Elev.		Well Number	UTM Easting	UTM Northing	Groundwater Elev.			
			Feet	Meters				Feet	Meters		
October 12, 1995											
MW-2S	670282	4759217	599.72	182.79	DYF-1	669704	4758503	586.41	178.74	918.63	0.0044
MW-3S	670369	4759460	600.52	183.04	DYF-1	669704	4758503	586.41	178.74	1165.36	0.0037
OMW-C1	670250	4759849	596.76	181.89	OMW-B3	669271	4759134	572.06	174.36	1212.30	0.0062
OMW-C1	670250	4759849	596.76	181.89	MW-11S	669000	4759348	570.28	173.82	1346.66	0.0060
OMW-C1	670250	4759849	596.76	181.89	MW-14S	669104	4759220	570.23	173.81	1307.27	0.0062
										Arithmetic Mean =	**0.0053**
										Geometric Mean =	**0.0052**

Upgradient Well					Downgradient Well					Distance (Meters)	Hydraulic Gradient
Well Number	UTM Easting	UTM Northing	Groundwater Elev.		Well Number	UTM Easting	UTM Northing	Groundwater Elev.			
			Feet	Meters				Feet	Meters		
November 9, 1995											
MW-2S	670282	4759217	600.07	182.90	DYF-1	669704	4758503	585.73	178.53	918.63	0.0048
MW-3S	670369	4759460	601.68	183.39	DYF-1	669704	4758503	585.73	178.53	1165.36	0.0042
OMW-C1	670250	4759849	599.38	182.69	OMW-B3	669271	4759134	573.54	174.82	1212.30	0.0065
OMW-C1	670250	4759849	599.38	182.69	MW-11S	669000	4759348	572.92	174.63	1346.66	0.0060
OMW-C1	670250	4759849	599.38	182.69	MW-14S	669104	4759220	570.57	173.91	1307.27	0.0067
										Arithmetic Mean =	**0.0056**
										Geometric Mean =	**0.0055**

Table D-1 (continued).
Hydraulic Gradient Calculations for the Shallow Hydrogeologic Zone.

Upgradient Well					Downgradient Well					Distance (Meters)	Hydraulic Gradient
Well Number	UTM Easting	UTM Northing	Groundwater Elev.		Well Number	UTM Easting	UTM Northing	Groundwater Elev.			
			Feet	Meters				Feet	Meters		
January 12, 1996											
MW-2S	670282	4759217			DYF-1	669704	4758503			918.63	
MW-3S	670369	4759460	602.07	183.51	DYF-1	669704	4758503	585.00	178.31	1165.36	0.0045
OMW-C1	670250	4759849	600.52	183.04	OMW-B3	669271	4759134	574.69	175.17	1212.30	0.0065
OMW-C1	670250	4759849	600.52	183.04	MW-11S	669000	4759348	573.01	174.65	1346.66	0.0062
OMW-C1	670250	4759849	600.52	183.04	MW-14S	669104	4759220	570.32	173.83	1307.27	0.0070
										Arithmetic Mean =	**0.0061**
										Geometric Mean =	**0.0060**

Arithmetic mean for all data = 0.0054.
Geometric mean for all data = 0.0053.

Table D-2.
Hydraulic Gradient Calculations for the Intermediate Hydrogeologic Zone.

Upgradient Well					Downgradient Well					Distance (Meters)	Hydraulic Gradient
Well Number	UTM Easting	UTM Northing	Groundwater Elev.		Well Number	UTM Easting	UTM Northing	Groundwater Elev.			
			Feet	Meters				Feet	Meters		
August 18, 1995											
MW-3I	670369	4759460	600.37	182.99	81-2TB	669473	4758601	566.18	172.57	1241.25	0.0084
OMW-C5	669885	4759738	597.05	181.98	OMW-A4	669213	4759161	574.04	174.97	885.73	0.0079
OMW-C5	669885	4759738	597.05	181.98	B-6D	669052	4759373	573.85	174.91	909.46	0.0078
										Arithmetic Mean =	**0.0080**
										Geometric Mean =	**0.0080**

Upgradient Well					Downgradient Well					Distance (Meters)	Hydraulic Gradient
Well Number	UTM Easting	UTM Northing	Groundwater Elev.		Well Number	UTM Easting	UTM Northing	Groundwater Elev.			
			Feet	Meters				Feet	Meters		
September 14, 1995											
MW-3I	670369	4759460	599.83	182.83	81-2TB	669473	4758601	566.23	172.59	1241.25	0.0083
OMW-C5	669885	4759738	596.54	181.83	OMW-A4	669213	4759161	573.74	174.88	885.73	0.0078
OMW-C5	669885	4759738	596.54	181.83	B-6D	669052	4759373	574.46	175.10	909.46	0.0074
										Arithmetic Mean =	**0.0078**
										Geometric Mean =	**0.0078**

Table D-2 (continued).
Hydraulic Gradient Calculations for the Intermediate Hydrogeologic Zone.

Upgradient Well					Downgradient Well					Distance (Meters)	Hydraulic Gradient
Well Number	UTM Easting	UTM Northing	Groundwater Elev.		Well Number	UTM Easting	UTM Northing	Groundwater Elev.			
			Feet	Meters				Feet	Meters		
October 12, 1995											
MW-3I	670369	4759460	599.67	182.78	81-2TB	669473	4758601	566.32	172.61	1241.25	0.0082
OMW-C5	669885	4759738	596.15	181.71	OMW-A4	669213	4759161	573.50	174.80	885.73	0.0078
OMW-C5	669885	4759738	596.15	181.71	B-6D	669052	4759373	574.53	175.12	909.46	0.0072
										Arithmetic Mean =	**0.0077**
										Geometric Mean =	**0.0077**

Upgradient Well					Downgradient Well					Distance (Meters)	Hydraulic Gradient
Well Number	UTM Easting	UTM Northing	Groundwater Elev.		Well Number	UTM Easting	UTM Northing	Groundwater Elev.			
			Feet	Meters				Feet	Meters		
November 9, 1995											
MW-3I	670369	4759460	600.75	183.11	81-2TB	669473	4758601	566.40	172.64	1241.25	0.0084
OMW-C5	669885	4759738	596.35	181.77	OMW-A4	669213	4759161	568.03	173.14	885.73	0.0097
OMW-C5	669885	4759738	596.35	181.77	B-6D	669052	4759373	574.86	175.22	909.46	0.0072
										Arithmetic Mean =	**0.0085**
										Geometric Mean =	**0.0084**

Table D-2 (continued). Hydraulic Gradient Calculations for the Intermediate Hydrogeologic Zone.											
Upgradient Well					Downgradient Well					Distance (Meters)	Hydraulic Gradient
Well Number	UTM Easting	UTM Northing	Groundwater Elev.		Well Number	UTM Easting	UTM Northing	Groundwater Elev.			
			Feet	Meters				Feet	Meters		
January 12, 1996											
MW-3I	670369	4759460	601.35	183.29	81-2TB	669473	4758601	566.33	172.62	1241.25	0.0086
OMW-C5	669885	4759738	597.98	182.26	OMW-A4	669213	4759161	575.38	175.38	885.73	0.0078
OMW-C5	669885	4759738	597.98	182.26	B-6D	669052	4759373	574.79	175.20	909.46	0.0078
										Arithmetic Mean =	0.0081
										Geometric Mean =	0.0080

Arithmetic Mean for All Data = 0.0080.
Geometric Mean for All Data = 0.0080.

Table D-3.
Hydraulic Gradient Calculations for the Deep and Upper Bedrock Hydrogeologic Zones.

Upgradient Well					Downgradient Well					Distance (Meters)	Hydraulic Gradient
Well Number	UTM Easting	UTM Northing	Groundwater Elev.		Well Number	UTM Easting	UTM Northing	Groundwater Elev.			
			Feet	Meters				Feet	Meters		
May 4, 1995											
81-1T	670750	4760626	569.70	173.64	MW-10DD	669086	4759245	565.93	172.50	2162.42	0.0005
81-1T	670750	4760626	569.70	173.64	MW-11DD	669002	4759349	566.20	172.58	2164.77	0.0005
MW-4D	670499	4759588	568.88	173.39	81-2TA	669475	4758603	566.11	172.55	1420.85	0.0006
										Arithmetic Mean =	**0.0005**
										Geometric Mean =	**0.0005**

Upgradient Well					Downgradient Well					Distance (Meters)	Hydraulic Gradient
Well Number	UTM Easting	UTM Northing	Groundwater Elev.		Well Number	UTM Easting	UTM Northing	Groundwater Elev.			
			Feet	Meters				Feet	Meters		
June 1, 1995											
81-1T	670750	4760626	569.72	173.65	MW-10DD	669086	4759245	566.17	172.57	2162.42	0.0005
81-1T	670750	4760626	569.72	173.65	MW-11DD	669002	4759349	566.23	172.59	2164.77	0.0005
MW-4D	670499	4759588	568.94	173.41	81-2TA	669475	4758603	566.10	172.55	1420.85	0.0006
										Arithmetic Mean =	**0.0005**
										Geometric Mean =	**0.0005**

Table D-3 (continued). Hydraulic Gradient Calculations for the Deep and Upper Bedrock Hydrogeologic Zones.											
Upgradient Well					**Downgradient Well**					**Distance (Meters)**	**Hydraulic Gradient**
Well Number	**UTM Easting**	**UTM Northing**	**Groundwater Elev.**		**Well Number**	**UTM Easting**	**UTM Northing**	**Groundwater Elev.**			
			Feet	**Meters**				**Feet**	**Meters**		
December 21, 1995											
81-1T	670750	4760626	568.91	173.40	MW-10DD	669086	4759245	563.08	171.63	2162.42	0.0008
81-1T	670750	4760626	568.91	173.40	MW-11DD	669002	4759349	565.68	172.42	2164.77	0.0005
MW-3D	670369	4759460			81-2TA	669475	4758603			1238.42	
								Arithmetic Mean =			**0.0006**
								Geometric Mean =			**0.0006**
Upgradient Well					**Downgradient Well**					**Distance (Meters)**	**Hydraulic Gradient**
Well Number	**UTM Easting**	**UTM Northing**	**Groundwater Elev.**		**Well Number**	**UTM Easting**	**UTM Northing**	**Groundwater Elev.**			
			Feet	**Meters**				**Feet**	**Meters**		
January 12, 1996											
81-1T	670750	4760626	568.91	173.40	MW-10DD	669086	4759245	563.97	171.90	2162.42	0.0007
81-1T	670750	4760626	568.91	173.40	MW-11DD	669002	4759349	565.65	172.41	2164.77	0.0005
MW-3D	670369	4759460	567.91	173.10	81-2TA	669475	4758603	565.88	172.48	1238.42	0.0005
								Arithmetic Mean =			**0.0006**
								Geometric Mean =			**0.0005**
Arithmetic Mean for All Data = 0.0006. **Geometric Mean for All Data = 0.0005.**											

APPENDIX E

GEOCHEMICAL DATA

Table E-1.
General Water Quality Analyses of the Niagara River in the Tonawanda Area.
(All results in mg/l except for pH and turbidity)

Date of Collection	pH	Turbidity (NTU's)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Total Alkalinity	Bicarbonate (HCO_3)	% Error
Anderson Park											
03/21/88	NR	NR	35.0	8.0	9.8	1.4	17.0	25.0	97.0	118.3	-1.86
04/18/88	NR	NR	32.0	7.3	9.4	1.2	16.0	24.0	82.0	100.0	0.32
05/16/88	NR	NR	37.0	8.7	10.0	1.4	15.0	21.0	97.0	118.3	3.42
06/29/88	NR	NR	36.0	8.5	9.5	1.4	15.0	25.0	100.0	121.9	-0.57
09/07/88	NR	NR	33.0	8.6	9.0	1.2	15.0	25.0	95.0	115.8	-1.73
10/03/88	NR	NR	38.0	9.0	9.8	1.4	15.0	30.0	96.0	117.0	1.60
11/14/88	NR	NR	38.0	9.1	10.0	1.6	15.0	30.0	98.0	119.5	1.21
Niagara Mohawk Cherry Farm Site											
06/23/03	NR	NR	40.1	9.6	11.1	NA	18.0	21.2	93.1	113.5	7.60
Grand Island Water Treatment Plant Raw Water Supply											
02/19/86	7.7	2.2	36.0	7.8	7.9	NA	15.0	24.0	99.8	121.7	-2.38
11/12/86	8.3	1.0	34.8	8.0	8.5	NA	20.0	17.2	97.7	119.1	-1.95
02/03/87	8.1	0.5	36.9	8.2	8.5	NA	20.0	22.5	95.5	116.4	-0.94
09/08/87	8.4	0.5	35.4	8.1	8.5	NA	7.5	23.0	89.0	108.5	6.33
02/08/88	8.0	4.8	39.5	10.0	8.7	NA	13.4	21.0	95.5	116.4	7.62
11/16/88	8.3	3.0	36.6	7.9	8.2	NA	12.5	19.1	94.6	115.3	3.52
02/08/89	8.1	9.5	36.0	8.3	7.9	NA	15.0	24.0	92.4	112.7	0.94
12/04/89	8.3	9.2	35.5	8.9	7.7	NA	20.0	22.9	95.6	116.6	-1.96
01/16/90	8.1	1.4	37.2	8.6	8.3	NA	15.0	24.5	91.3	111.3	2.94
11/19/90	8.1	1.8	35.7	8.7	8.6	NA	15.0	18.7	93.1	113.5	3.58

Table E-1 (continued). General Water Quality Analyses of the Niagara River in the Tonawanda Area. (All results in mg/l except for pH and turbidity)											
Date of Collection	**pH**	**Turbidity (NTU's)**	**Calcium (Ca)**	**Magnesium (Mg)**	**Sodium (Na)**	**Potassium (K)**	**Chloride (Cl)**	**Sulfate (SO_4)**	**Total Alkalinity**	**Bicarbonate (HCO_3)**	**% Error**
Town of Tonawanda Water Treatment Plant Raw Water Supply											
03/12/86	7.6	0.9	37.3	7.8	8.2	NA	17.5	22.7	97.4	118.8	-0.93
09/19/95	8.3	2.4	33.0	9.0	11.6	1.5	15.4	20.0	87.7	106.9	5.25
City of Tonawanda Water Treatment Plant Raw Water Supply											
04/08/86	7.8	3.8	28.5	7.1	7.8	NA	17.5	24.0	92.8	113.1	-9.66
06/04/87	8.3	1.4	39.3	8.2	8.6	NA	17.5	22.5	91.1	111.1	3.91
12/08/87	8.0	0.9	37.8	8.8	8.2	NA	20.0	20.5	93.3	113.8	1.90
03/15/88	8.0	0.8	34.8	8.3	8.4	NA	18.2	20.5	98.8	120.5	-2.29
11/15/88	8.2	5.1	34.9	7.8	8.5	NA	15.0	19.6	94.6	115.3	0.58
03/13/89	8.1	0.7	36.5	8.6	8.8	NA	15.0	20.6	96.8	118.0	2.20
11/20/89	8.0	2.0	37.9	8.1	8.5	NA	22.5	21.5	95.6	116.6	-1.12
01/31/90	8.0	4.2	34.8	8.2	8.5	NA	17.5	23.3	87.1	106.2	1.12
Erie County Water Authority Van de Water Plant Raw Water Supply											
12/09/85	8.0	8.2	36.0	8.2	7.1	NA	15.0	26.5	102.1	124.5	-4.07
02/25/86	7.7	1.7	35.2	7.6	8.0	NA	15.0	24.9	102.1	124.5	-4.42
03/21/88	8.2	0.9	36.9	7.7	8.1	NA	17.5	14.0	97.6	119.0	1.64
01/24/90	8.1	3.0	34.2	8.1	8.3	NA	17.5	18.0	99.8	121.7	-2.31
09/24/90	8.1	7.7	34.4	8.6	8.6	NA	15.3	30.7	93.6	114.1	-2.49

NA Not Analyzed.
NR Not reported.
Shaded values have unacceptable errors.

Table E-2.
General Water Quality Analyses of Groundwater from the Shallow Hydrogeologic Zone Underlying the Study Area.
(All results in parts per million except for specific conductance, pH, temperature, turbidity, and Eh)

Well Designation	Date of Collection	Temp. (ºC)	pH	Turbidity (NTU's)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Total Alkalinity	Bicarbonate (HCO_3)	% Error
Polymer Applications Site (Registry Number 915044)													
B-4S	03/16/94	4.2	6.8	NM	131.0	49.3	26.1	12.0	7.0	43.9	471.0	574.3	6.70
B-5S	03/17/94	4.3	8.6	NM	80.4	16.3	32.5	6.7	23.0	85.8	207.0	252.4	2.71
B-6S	07/31/96	15.6	7.3	NM	184.0	95.1	82.9	5.5	70.9	229.0		662.0	807.11.85
"	12/18/97	7.3	7.2	≈100	203.0	94.7	79.9	3.1	60.0	242.0	711.0	866.9	1.26
GW-3S	03/17/94	3.4	6.4	NM	74.7	39.9	82.5	10.1	12.0	45.2	440.0	536.5	3.75
GW-4S	03/16/94	7.1	7.1	NM	214.0	85.6	140.0	9.1	19.0	112.0	652.0	794.9	**20.40**
MW-9S	03/18/94	6.7	6.2	NM	114.0	77.6	36.5	3.6	21.0	177.0	434.0	529.1	3.00
"	07/31/96	15.0	7.1	NM	125.0	78.8	21.0	4.2	14.1	71.6	498.0	607.2	7.43
MW-11S	03/17/94	6.8	7.6	NM	200.0	62.4	29.1	2.9	27.0	417.0	488.0	595.0	-7.69
"	12/19/97	6.3	6.7	103.8	197.0	47.5	44.9	3.1	12.6	152.0	578.0	704.7	2.27
MW-12S	03/17/94	5.4	7.8	NM	577.0	339.0	122.0	33.9	100.0	678.0	335.0	408.4	**45.35**
MW-13S	03/18/94	9.7	5.2	NM	232.0	37.9	22.9	7.3	32.0	712.0	92.0	112.2	-5.05
"	12/19/97	8.8	5.6	>200	231.0	36.8	66.4	13.6	18.2	849.0	35.8	43.6	-3.04
MW-14S	03/18/94	5.9	4.6	NM	493.0	79.5	31.8	8.2	7.0	3,630	<5.0	6.1	**-39.72**
"	12/19/97	9.7	6.1	>1000	551.0	225.0	168.0	13.2	27.3	2,240	225.0	274.3	1.65
Dunlop Tire Corporation Site (Registry Number 915018)													
OMW-B3	04/25/97	9.4	6.7	62.5	213.0	109.0	56.1	7.4	27.2	21.2	1,020	1,244	1.45
"	10/30/97	NM	6.5	140.0	208.0	110.0	66.0	9.8	27.0	3.4	1,110	1,353	-1.02
"	05/05/99	15.0	6.6	70.3	162.0	90.5	64.6	7.3	23.3	98.7	881.0	1,074	-4.61
"	05/08/01	NM	NM	NM	160.0	84.6	63.1	5.6	24.5	11.0	652.0	794.9	12.22
OMW-C1	04/25/97	8.0	7.0	45.5	142.0	571.0	161.0	11.1	33.2	2,090	697.0	849.8	2.48
"	10/30/97	NM	6.9	28.0	143.0	542.0	206.0	13.2	31.8	2,260	793.0	966.8	-2.22

NM Not Measured.
Shaded values have unacceptable errors.

Table E-3. General Water Quality Analyses of Groundwater from the Intermediate Hydrogeologic Zone Underlying the Study Area. (All results in parts per million except for specific conductance, pH, temperature, turbidity, and Eh)													
Well Designation	**Date of Collection**	**Temp. (ºC)**	**pH**	**Turbidity (NTU's)**	**Calcium (Ca)**	**Magnesium (Mg)**	**Sodium (Na)**	**Potassium (K)**	**Chloride (Cl)**	**Sulfate (SO_4)**	**Total Alkalinity**	**Bicarbonate (HCO_3)**	**% Error**
Polymer Applications Site (Registry Number 915044)													
B-2D	03/16/94	7.3	6.7	NM	539.0	566.0	330.0	23.5	57.0	3,403	540.0	658.4	3.01
B-3D	03/16/94	7.2	7.2	NM	95.1	180.0	65.6	4.2	71.0	234.0	632.0	770.5	7.16
B-4D	03/17/94	4.4	5.9	NM	109.0	286.0	116.0	4.2	73.0	743.0	803.0	979.0	0.80
B-5D	03/17/94	6.0	8.1	NM	330.0	621.0	262.0	14.9	81.0	5,410	579.0	705.9	**-22.91**
B-6D	03/17/94	8.2	7.4	NM	331.0	606.0	479.0	17.3	204.0	5,540	484.0	590.1	**-19.74**
"	07/31/96	11.1	7.3	NM	219.0	636.0	404.0	18.2	153.0	3,060	553.0	674.2	1.38
"	12/18/97	9.2	6.6	77.8	249.0	618.0	495.0	22.1	169.0	3,250	644.0	785.2	0.03
Dunlop Tire Corporation Site (Registry Number 915018)													
OMW-A4	04/25/97	10.9	7.1	8.1	356.0	1,380	489.0	24.3	128.0	7,560	802.0	977.8	-7.23
"	10/30/97	NM	6.8	25.0	352.0	1,280	659.0	31.9	118.0	7,525	882.0	1,075	-7.66
"	05/05/99	13.9	7.1	1,030	307.0	1,050	335.0	28.4	122.0	6,860	855.0	1,042	-16.54
OMW-A6	04/25/97	14.6	7.3	13.3	55.1	112.0	30.5	4.1	88.1	85.2	493.0	601.1	-2.61
"	10/30/97	NM	7.2	29.0	64.6	130.0	48.0	5.9	84.7	78.5	551.0	671.8	3.60
OMW-B4	04/25/97	10.3	7.3	4.5	106.0	419.0	183.0	9.6	28.1	1,590	718.0	875.4	-0.29
"	10/30/97	NM	7.0	25.0	108.0	392.0	225.0	12.0	26.9	1,500	785.0	957.1	0.06
"	05/05/99	12.8	7.4	411.0	98.4	367.0	169.0	10.8	22.9	1,500	760.0	926.6	-4.83
"	05/08/01	NM	NM	NM	92.7	379.0	256.0	8.9	27.2	900.0	955.0	1,164	10.00
OMW-C5	04/25/97	11.8	7.2	12.2	116.0	299.0	79.8	8.5	52.0	810.0	693.0	844.9	2.86
"	10/30/97	NM	7.0	27.0	128.0	300.0	102.0	11.4	44.5	1,220	777.0	947.3	-8.19
"	05/05/99	14.4	7.3	228.0	60.5	144.0	46.0	4.2	47.5	822.0	735.0	896.1	**-32.26**
OMW-C7	04/25/97	10.0	7.3	8.5	134.0	528.0	165.0	11.0	33.8	1,860	858.0	1,046	0.66
"	10/30/97	NM	7.1	28.0	132.0	508.0	209.0	13.9	35.9	1,670	802.0	977.8	5.49
"	05/05/99	13.3	7.2	369.0	104.0	399.0	141.0	10.5	31.0	1,770	655.0	798.6	-6.72
"	05/08/01	NM	NM	NM	105.0	433.0	208.0	9.0	49.8	1,300	805.0	981.5	5.89

Table E-3. General Water Quality Analyses of Groundwater from the Intermediate Hydrogeologic Zone Underlying the Study Area. (All results in parts per million except for specific conductance, pH, temperature, turbidity, and Eh)	
NM	**Not Measured.**
	Shaded values have unacceptable errors.

Table E-4.
General Water Quality Analyses of Groundwater from the Deep Hydrogeologic Zone Underlying the Study Area.
(All results in parts per million except for specific conductance, pH, temperature, turbidity, and Eh)

Well Designation	Date of Collection	Temp. (ºC)	pH	Turbidity (NTU's)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Total Alkalinity	Bicarbonate (HCO_3)	% Error
Polymer Applications Site (Registry Number 915044)													
GW-1DD	03/17/94	13.7	12.2	NM	564.0	2.2	97.7	17.6	146.0	655.0	696.0	848.6	2.10
GW-2DD	03/17/94	7.8	5.8	NM	365.0	171.0	303.0	15.6	21.0	268.0	24.0	29.3	**74.66**
MW-8DD	03/15/94	7.2	5.4	NM	35.3	9.5	14.5	6.1	18.0	74.9	64.0	78.0	-0.23
MW-9DD	03/18/94	11.8	6.1	NM	1,759	719.0	88.8	39.0	22.0	889.0	72.0	87.8	**76.13**
"	09/26/95	NM	7.8	NM	588.0	169.0	249.0	10.3	36.1	3,313	86.6	105.6	-13.79
"	07/31/96	13.9	7.5	NM	483.0	190.0	278.0	12.8	68.6	2,320	55.0	67.1	0.79
MW-10DD	03/18/94	7.5	5.2	NM	361.0	243.0	246.0	5.3	55.0	2,780	59.0	71.9	-10.75
"	09/25/95	NM	7.6	NM	935.0	331.0	236.0	4.5	61.1	4,210	115.0	140.2	-4.21
"	12/19/97	10.3	7.4	51.2	403.0	300.0	273.0	5.4	58.7	2,360	61.7	75.2	4.39
MW-11DD	03/17/94	16.1	7.4	NM	41.8	12.2	16.4	9.7	24.0	60.4	335.0	408.4	**-36.10**
"	09/25/95	NM	6.9	NM	596.0	81.3	62.2	5.6	61.0	1,628	250.0	304.8	-1.67
"	12/19/97	10.6	6.6	32.6	491.0	91.3	127.0	10.0	147.0	1,060	271.0	330.4	8.87
E.I. DuPont Yerkes Plant (Registry Number 915019)													
MW-3D	09/19/95	NM	8.2	>200	862.0	241.0	363.0	6.8	282.0	2,930	65.3	79.6	5.73
MW-4D	09/19/95	NM	8.4	12.1	437.0	134.0	384.0	6.8	296.0	1,970	33.2	40.5	-0.32
MW-7D	09/19/95	NM	7.5	12.1	496.0	129.0	245.0	4.6	214.0	1,750	81.3	99.1	2.26
3M O-Cel-O Sponge Site (Registry Number 915148)													
MW-1	11/28/95	10.0	8.7	108.0	446.0	105.0	302.0	16.3	168.0	1,950	26.5	32.3	-1.57
MW-2	11/28/95	10.7	8.7	50.0	506.0	117.0	297.0	21.7	150.0	2,220	30.6	37.3	-2.73
MW-3	08/08/95	13.3	8.5	2.9	488.0	117.0	324.0	10.7	167.0	2,070	110.0	134.1	-1.69
"	11/29/95	9.4	8.6	93.0	507.0	126.0	281.0	14.1	151.0	2,130	91.8	111.9	-2.22
MW-4	08/08/95	15.7	8.7	10.0	476.0	119.0	348.0	37.0	169.0	1,940	103.0	125.6	2.49
"	11/28/95	10.3	8.0	100.0	559.0	192.0	330.0	37.4	178.0	2,270	61.2	74.6	4.88

Table E-4. General Water Quality Analyses of Groundwater from the Deep Hydrogeologic Zone Underlying the Study Area. (All results in parts per million except for specific conductance, pH, temperature, turbidity, and Eh)	
NM	Not Measured.
	Shaded values have unacceptable errors.

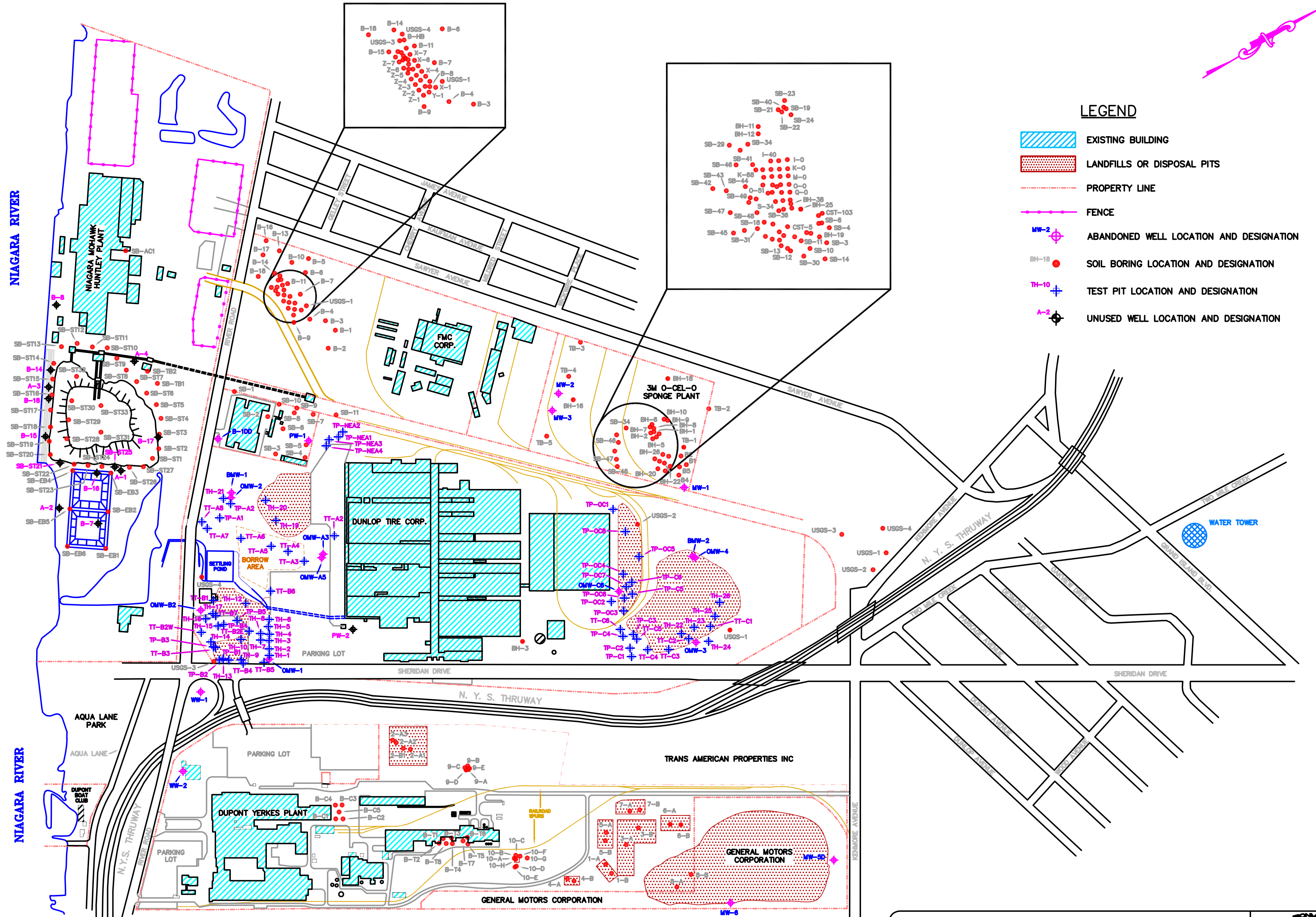
Table E-5. General Water Quality Analyses of Groundwater from the Upper Bedrock Hydrogeologic Zone Underlying the Study Area. (All results in parts per million except for specific conductance, pH, temperature, turbidity, and Eh)													
Well Designation	**Date of Collection**	**Temp. (ºC)**	**pH**	**Turbidity (NTU's)**	**Calcium (Ca)**	**Magnesium (Mg)**	**Sodium (Na)**	**Potassium (K)**	**Chloride (Cl)**	**Sulfate (SO_4)**	**Total Alkalinity**	**Bicarbonate (HCO_3)**	**% Error**
Dunlop Tire Corporation Site (Registry Number 915018)													
PW-1	09/21/95	NM	7.0	NM	392.0	36.2	102.0	5.4	188.0	1,190	197.0	240.2	-11.29
"	07/30/96	15.0	7.2	2.3	389.0	37.5	84.7	7.0	127.0	960.0	174.0	212.1	-1.29
"	08/29/97	13.2	7.3	NM	373.0	35.8	98.7	7.9	138.0	1,040	164.0	200.0	-5.05
USGS Monitoring Wells													
81-1T	09/25/95	NM	7.6	NM	476.0	133.0	231.0	15.7	177.0	2,203	62.5	76.2	-7.16
"	07/30/96	14.4	7.6	81.6	507.0	154.0	249.0	28.6	176.0	2,290	35.3	43.0	-3.71
"	12/18/97	7.8	7.3	137.4	504.0	141.0	271.0	20.6	169.0	1,790	39.8	48.5	6.78
81-2TA	09/20/95	NM	7.1	NM	570.0	72.6	29.9	2.8	29.2	1,420	101.0	123.1	4.96
"	07/30/96	12.2	7.3	NM	464.0	70.5	31.9	3.6	30.0	1,920	88.2	107.5	-16.64
"	12/18/97	8.8	7.3	>100	601.0	81.7	45.1	4.3	32.9	1,370	97.5	118.9	10.52
NM Not Measured.													

Table E-6. General Water Quality Analyses of Groundwater from the Upper Camillus Shale Bedrock in the Tonawanda Area. (All results in parts per million except for specific conductance, pH, temperature, turbidity, and Eh)													
Well Designation	**Date of Collection**	**Temp. (ºC)**	**pH**	**Turbidity (NTU's)**	**Calcium (Ca)**	**Magnesium (Mg)**	**Sodium (Na)**	**Potassium (K)**	**Chloride (Cl)**	**Sulfate (SO_4)**	**Total Alkalinity**	**Bicarbonate (HCO_3)**	**% Error**
Seaway/Niagara Landfill (Registry Number 915074)													
W-1	11/21/89	9.1	8.0	60.0	470.0	110.0	140.0	13.0	5.8	2,000	53.0	64.6	-5.24
"	05/31/90	NR	NR	69.4	401.0	131.0	136.0	11.0	5.8	2,000	44.6	54.4	-7.55
"	05/29/96	13.0	7.1	5.0	474.0	118.0	149.0	11.6	5.1	1,980	45.3	55.2	-2.96
"	08/13/97	13.1	7.5	4.5	439.0	116.0	167.0	18.2	5.9	2,460	34.6	42.2	-14.72
W-2	11/21/89	7.9	8.3	55.0	480.0	150.0	220.0	13.0	78.0	2,200	68.0	82.9	-3.68
"	05/31/90	NR	NR	30.0	409.0	216.0	172.0	11.0	83.6	2,350	62.4	76.1	-7.00
"	11/21/94	NR	NR	14.0	439.0	158.0	210.0	11.4	88.2	2,400	59.9	73.0	-9.84
"	05/30/96	13.2	7.3	26.0	425.0	158.0	200.0	15.7	75.9	2,240	68.0	82.9	-7.77
W-3	11/21/89	9.8	7.8	38.0	440.0	110.0	120.0	8.7	9.0	1,900	74.0	90.2	-6.54
"	05/31/90	NR	NR	30.2	424.0	135.0	104.0	7.2	10.6	2,000	74.7	91.1	-8.28
"	02/21/95	NR	NR	22.0	583.0	146.0	155.0	7.3	9.1	1,900	57.0	69.5	7.76
"	02/21/95	NR	NR	24.0	612.0	151.0	145.0	8.2	9.1	1,770	66.5	81.1	12.35
"	05/29/96	12.8	7.3	16.0	487.0	111.0	128.0	8.0	9.1	1,970	78.3	95.5	-4.69
W-6	11/22/89	7.9	9.0	48.0	440.0	130.0	160.0	10.0	3.6	2,200	44.0	53.6	-8.30
"	05/31/90	NR	NR	231.0	491.0	148.0	175.0	8.3	7.7	2,180	49.9	60.8	-2.55
"	05/29/96	13.3	7.5	16.0	466.0	148.0	172.0	9.4	7.5	2,570	47.4	57.8	-12.05
"	08/12/97	14.1	7.9	24.0	516.0	150.0	192.0	13.7	6.9	2,320	44.2	53.9	-3.07
W-7	11/21/89	5.4	8.4	48.0	480.0	150.0	180.0	20.0	23.0	2,200	77.0	93.9	-4.20
"	05/31/90	NR	NR	21.9	409.0	192.0	148.0	17.0	9.1	2,100	93.7	114.2	-3.63
"	05/29/96	14.1	7.5	25.0	474.0	152.0	171.0	17.3	13.9	2,240	92.7	113.0	-5.72
"	08/13/97	14.2	7.8	23.0	424.0	137.0	175.0	23.1	11.9	2,610	86.4	105.3	-16.97
W-8	11/22/89	8.2	7.9	14.0	460.0	160.0	330.0	27.0	170.0	2,500	110.0	134.1	-7.83
"	05/31/90	NR	NR	79.5	410.0	232.0	348.0	20.0	141.0	2,260	96.6	117.8	1.60
"	05/30/96	13.0	7.1	20.0	444.0	209.0	410.0	52.3	242.0	2,590	288.0	351.1	-7.54

Table E-6 (continued). General Water Quality Analyses of Groundwater from the Upper Camillus Shale Bedrock in the Tonawanda Area. (All results in parts per million except for specific conductance, pH, temperature, turbidity, and Eh)													
Well Designation	**Date of Collection**	**Temp. (ºC)**	**pH**	**Turbidity (NTU's)**	**Calcium (Ca)**	**Magnesium (Mg)**	**Sodium (Na)**	**Potassium (K)**	**Chloride (Cl)**	**Sulfate (SO_4)**	**Total Alkalinity**	**Bicarbonate (HCO_3)**	**% Error**
Seaway/Niagara Landfill (continued)													
W-8	08/13/97	14.2	7.4	20.0	436.0	194.0	456.0	56.8	285.0	2,750	273.0	332.8	-10.29
W-10	05/31/90	NR	NR	58.0	395.0	232.0	130.0	34.0	8.1	2,300	17.8	21.7	-4.33
"	05/29/96	13.9	8.1	2.1	475.0	148.0	147.0	10.8	6.1	2,230	45.3	55.2	-5.83
"	08/13/97	14.5	7.6	4.0	424.0	139.0	156.0	15.6	6.9	2,590	44.2	53.9	-16.55
W-11	11/21/89	7.5	7.9	250.0	470.0	140.0	300.0	43.0	33.0	2,300	100.0	121.9	-2.83
"	05/31/90	NR	NR	18.5	427.0	166.0	233.0	38.0	43.8	2,440	156.0	190.2	-10.03
"	05/30/96	13.6	7.4	31.0	460.0	165.0	313.0	54.8	50.1	2,310	169.0	206.0	-2.66
"	08/13/97	13.8	7.3	4.3	402.0	141.0	302.0	53.1	39.0	2,590	154.0	187.8	-12.93
W-12	11/22/89	5.0	8.1	1.4	490.0	180.0	440.0	51.0	380.0	2,800	350.0	426.7	-13.10
"	05/31/90	NR	NR	7.4	411.0	186.0	410.0	41.0	252.0	2,860	220.0	268.2	-13.96
"	05/30/96	13.5	7.0	7.0	464.0	228.0	476.0	64.7	322.0	2,970	371.0	452.3	-11.15
"	08/12/97	13.7	6.9	3.2	543.0	229.0	457.0	59.6	385.0	2,930	376.0	458.4	-9.34
W-13	12/04/89	10.6	8.4	340.0	520.0	150.0	200.0	15.0	34.0	2,300	80.0	97.5	-3.55
"	05/31/90	NR	NR	59.0	503.0	214.0	179.0	9.5	29.1	2,110	85.6	104.4	4.15
"	05/29/96	12.5	7.6	25.0	469.0	159.0	187.0	12.1	31.8	2,110	105.0	128.0	-2.52
"	08/13/97	13.3	7.1	4.4	422.0	146.0	183.0	15.4	29.9	2,350	82.6	100.7	-11.24
W-14D	05/29/96	12.7	7.2	2.6	473.0	196.0	352.0	27.7	236.0	2,670	321.0	391.4	-11.01
"	08/12/97	14.1	6.9	4.0	529.0	201.0	375.0	39.8	224.0	2,360	303.0	369.4	-1.88
W-15	12/04/89	7.7	8.2	290.0	460.0	143.0	160.0	26.0	16.0	2,000	73.0	89.0	-2.20
"	05/31/90	NR	NR	52.4	474.0	155.0	142.0	19.0	16.9	2,430	82.7	100.8	-10.64
"	05/29/96	12.1	7.8	21.0	491.0	166.0	171.0	21.9	27.1	2,290	109.0	132.9	-5.22
"	08/12/97	14.9	7.3	1.8	499.0	162.0	190.0	28.8	51.5	1,940	97.9	119.4	2.98
W-16	05/31/90	NR	NR	58.0	389.0	115.0	130.0	11.0	9.1	2,270	60.7	74.0	-17.06
"	05/29/96	12.0	8.0	1.3	471.0	150.0	161.0	11.8	13.5	2,250	53.6	65.4	-5.98

Table E-6 (continued). General Water Quality Analyses of Groundwater from the Upper Camillus Shale Bedrock in the Tonawanda Area. (All results in parts per million except for specific conductance, pH, temperature, turbidity, and Eh)													
Well Designation	**Date of Collection**	**Temp. (ºC)**	**pH**	**Turbidity (NTU's)**	**Calcium (Ca)**	**Magnesium (Mg)**	**Sodium (Na)**	**Potassium (K)**	**Chloride (Cl)**	**Sulfate (SO_4)**	**Total Alkalinity**	**Bicarbonate (HCO_3)**	**% Error**
Seaway/Niagara Landfill (continued)													
W-16	08/12/97	14.5	7.6	1.6	543.0	161.0	192.0	18.2	16.5	2,220	63.4	77.3	0.76
W-17	05/31/90	NR	NR	59.0	468.0	105.0	110.0	3.8	5.3	2,140	32.6	39.7	-10.45
"	05/29/96	12.9	6.8	1.8	479.0	112.0	146.0	4.2	4.4	2,180	30.9	37.7	-7.78
"	08/12/97	13.7	7.9	1.8	526.0	116.0	169.0	7.0	5.2	1,820	26.9	32.8	5.59
Spaulding Composites Site (Registry Number 915050)													
BW-9	07/25/96	13.4	10.4	50.0	486.0	48.2	128.0	41.2	12.6	1,800	71.7	87.4	-7.50
"	11/26/96	11.6	8.5	183.0	497.0	35.7	136.0	37.7	11.6	1,840	76.7	93.5	-8.83
BW-10	07/24/96	12.2	6.7	79.0	439.0	101.0	68.8	13.7	18.2	2,020	96.1	117.2	-14.52
"	11/25/96	10.5	7.5	66.0	474.0	108.0	76.1	13.1	17.3	1,850	111.0	135.3	-6.97
BW-12	07/24/96	12.4	7.0	62.0	474.0	92.7	60.5	29.6	89.8	1,950	105.0	128.0	-14.30
"	11/26/96	8.5	7.0	15.0	510.0	92.3	66.0	28.0	88.9	1,700	94.9	115.7	-5.13
NR Not reported.													

Table E-7. General Water Quality Analyses of Surface Water from Wetlands Within the Study Area. (All results in parts per million except for specific conductance, pH, temperature, turbidity, and Eh)													
Sample Location	**Date of Collection**	**Temp. (ºC)**	**pH**	**Turbidity (NTU's)**	**Calcium (Ca)**	**Magnesium (Mg)**	**Sodium (Na)**	**Potassium (K)**	**Chloride (Cl)**	**Sulfate (SO_4)**	**Total Alkalinity**	**Bicarbonate (HCO_3)**	**% Error**
Wetland Areas													
Sawyer Ave.	12/18/97	0.9	6.5	6.9	51.6	13.1	32.3	8.6	71.4	89.8	47.8	58.3	2.20
Dunlop	12/18/97	0.8	7.2	13.8	167.0	49.3	504.0	4.6	1,060	96.8	241.0	293.8	-3.41



NOTES:

1. BASE MAP PREPARED FROM VARIOUS SITE INVESTIGATION REPORTS COMPILED AND EVALUATED DURING THIS STUDY.

2. TEST PITS FROM THE FMC CORPORATION HAVE NOT BEEN INCLUDED ON THIS PLATE DUE TO SPATIAL CONSTRAINTS. A LARGE NUMBER OF SOIL BORINGS HAVE ALSO BEEN COMPLETED AT THE SITE AND ARE SHOWN.

SOIL BORING, TEST PIT AND MONITORING WELL LOCATION MAP

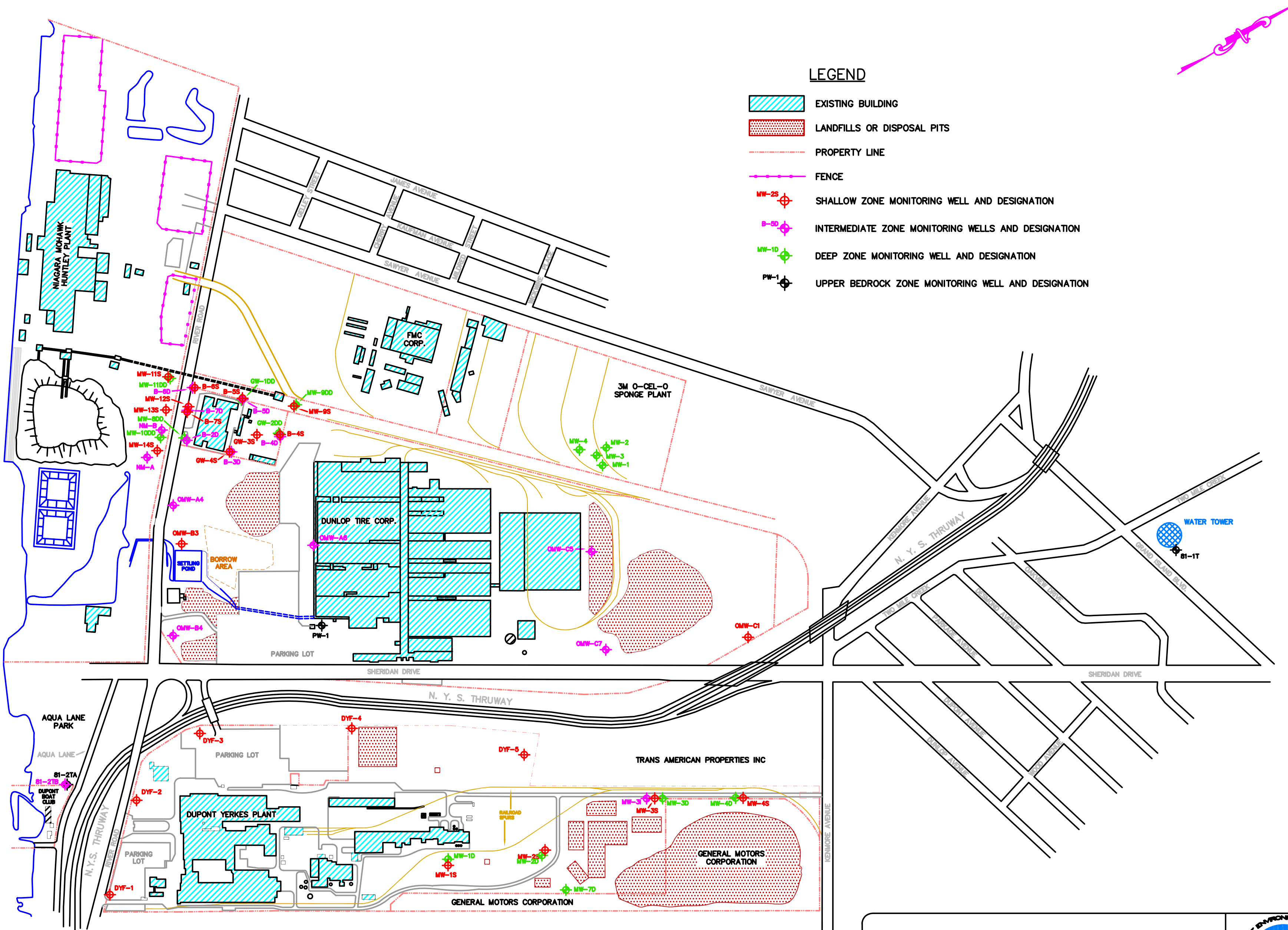
DIVISION OF ENVIRONMENTAL REMEDIATION

DATE: 04/12/05

DRAWING: Study Area Map

SITE: TONAWANDA HYDROGEOLOGIC STUDY

PLATE 1



NOTES:

1. BASE MAP PREPARED FROM VARIOUS SITE INVESTIGATION REPORTS COMPILED AND EVALUATED DURING THIS STUDY.

MONITORING WELL LOCATION MAP

DIVISION OF ENVIRONMENTAL REMEDIATION

DATE: 04/12/05 DRAWING: Study Area Map

SITE: TONAWANDA HYDROGEOLOGIC STUDY PLATE 2