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DU PONT

Volume 1

Geohydrologic Investigations
Niagara Plant
Niagara Falls, New York

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December 23, 1983
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E. I. duPont de Nemours & Co., Inc.
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Attention: Mr. Timothy D. Van Domelen

GEOHYDROLOGIC INVESTIGATIONS
NIAGARA PLANT
NIAGARA FALLS, NEW YORK
VOLUME I

Gentlemen:

We are pleased to present herein our Report of Geohydrologic Investigations conducted for the Niagara Plant site, Niagara Falls, New York. This study was conducted in accordance with your request and our Proposal dated October 10, 1983. The objectives of the study and an outline of the scope of work were defined in the "DuPont Niagara Site Groundwater Study" submitted to the New York State Department of Environmental Conservation during May 1983. Woodward-Clyde Consultants was retained by DuPont to serve as the independent technical reviewer for this plan under DuPont Contract Order LN-7827-5R. Subsequently, Woodward-Clyde Consultants was retained by DuPont to serve as the geohydrologic consultant to complete the work defined in the Groundwater Study Plan.

This report was prepared utilizing the presently available data in order to comply with the established schedule of submittals to New York State Department of Environmental Conservation. It is recognized that additional work is planned, including additional sampling and analysis of groundwater and completion of the tasks defined in the Manmade Passageways Investigation Plan. As additional information becomes available, findings and conclusions presented herein will be reassessed in light of the continually developing data base. The data utilized during the preparation of this report is presented in the Appendices, included as Volume II of this submittal.

This report was prepared by and under the direction of Mr. Frank S. Waller, P.E., Principal-in-Charge and Mr. Jeffrey C. Evans, P.E., Project Manager. Major contributors to this study were the Task Leaders for geology, Mr. Raymond S. Lambert, P.G.; Geohydrology, Mr. Mark N. Gallagher; and Contaminant Transport, Mr. Vydas Brizgys, P.G.

The rock samples obtained during the field investigation phase of the project are presently being stored at our facilities in Plymouth Meeting, Pennsylvania. The rock core will be stored and available for inspection for a period of one year from this date. At the completion of that time period, ultimate disposition of the cores will be determined in consultation with DuPont.

We sincerely appreciate the opportunity of providing these services to you on this project. If you have any questions, please contact us.

Very truly yours,

WOODWARD-CLYDE CONSULTANTS

Jeffrey C. Evans, P.E.
Project Manager

Frank S. Waller, P.E.
Principal

JCE/FSW/gmb

Attachment

cc: Mr. Raymond G. Schaefer, DuPont
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GEOHYDROLOGIC INVESTIGATIONS
NIAGARA PLANT
NIAGARA FALLS, NEW YORK
VOLUME I

Prepared for:

E. I. DUPONT DE NEMOURS & CO., INC.

Niagara Falls, New York

Prepared by:

WOODWARD-CLYDE CONSULTANTS

Plymouth Meeting, Pennsylvania

EXECUTIVE SUMMARY

An investigation was undertaken at the DuPont Niagara Plant Site to evaluate the presence and movement of suspect chemical contaminants in the overburden and bedrock groundwater flow regimes. This report presents our findings and conclusions regarding groundwater flow rate and direction within the Lockport Formation and overlying unconsolidated soils, groundwater quality, and contaminant flow into and out of plant boundaries. The report also presents the results of our investigations of the site geologic and geohydrologic conditions, monitoring well installations, groundwater sampling and chemical analysis. The base of information developed during this study can be used to formulate design recommendations for any potential remedial actions.

The DuPont Niagara Plant site is underlain by unconsolidated overburden deposits consisting of fill, glacial till and glacial lake deposits. Beneath the overburden soils the site is underlain by the fractured dolomite of the Lockport Formation. Beneath the Lockport Formation, and extending beyond the limit of these investigations, is the Rochester Shale.

Groundwater in the area of the DuPont Niagara Plant site is encountered in both the unconsolidated overburden soils and the underlying rock. To investigate the hydrologic regime in the vicinity of the plant site, a total of 52 monitoring wells were installed. Specifically, the wells provided a means to sample groundwater for chemical analysis and to determine elevations of the groundwater. The information collected during this investigation was used to prepare groundwater contour maps for each of the underlying groundwater flow zones (fracture zones), and ultimately to estimate the direction and quantity of groundwater flow at the plant site area within the overburden soils and the Lockport Formation. The source of groundwater recharge for the overburden in the vicinity of the Niagara Plant Site is from direct infiltration of precipitation. The source of groundwater recharge in the underlying Lockport Formation is from induced infiltration of water from the Niagara River and to a lesser extent, from leakage downward from the overlying overburden groundwater flow regime. Groundwater flow in the overlying overburden zone in the west site area (west of Gill Creek) discharges toward Gill Creek and the Niagara River and in the east site (east of Gill Creek) toward the northeast. By contrast, flow in the underlying fractured rock is from the Niagara River toward the Olin production wells, northwest of the site, and toward an unidentified groundwater discharge area to the northeast of the site.

During the period January through May, 1983, chemical analyses were performed on groundwater samples obtained from monitoring wells installed along the north side of the Niagara Parkway by the USGS for the New York State Department of Environmental Conservation. Sampling and analysis of groundwater from monitoring wells DuPont installed began in June, 1983, and is continuing. Based upon the results of the chemical analyses for DuPont-related volatile organic compounds of samples within the general plant area, concentration values for any given parameter have been found to vary from below detectable limits up to thousands of parts per million. DuPont-related compounds refer to those compounds relating to previous manufacturing activities by DuPont. At any given monitoring well, similar, but less dramatic variations over time were observed. The presence of second-phase fluid may account for the wide range of analytical results that have been reported. The solubility limits as measured under laboratory conditions ranged from a low of 150 ppm to a high of 20,000 ppm. Based upon field reports during well installation and groundwater sampling, as well as the specific analytical results compared with solubility limits, it is concluded that second-phase fluid does exist at selected locations throughout the plant site. Further, the relative distribution of volatile compounds was compared with the locations of previous processes and events on the plant site. A correlation between the process/event areas and concentrations of the individual compounds, monitoring well locations appears to be evident. Analyses were also conducted for two non-DuPont related volatile organic compounds, and these were detected at a limited number of monitoring wells primarily in the eastern portion of the site. It is likely, however, that these compounds are not present as second-phase organics. Analyses were conducted for other DuPont-related organic compounds as well. Again, a correlation appears to be established between former site processes and concentrations detected at selected wells. Analyses for DuPont inorganic compounds were also conducted and former processes were identified as likely sources of detected inorganic compounds.

Potential migration of contaminants at the DuPont Niagara Plant site was evaluated during this study. Because of the presence of two liquid phases, the transport process is complex, and is governed by a number of factors. Whereas, movement of solubilized compounds is governed primarily by groundwater flow, the movement of second-phase organics results more from a geologic structure control than from groundwater flow. Based upon the available data, it cannot be ascertained with any certainty that lateral migration of second-phase flow is occurring at the overburden bedrock interface.

Because of vertical fracturing in the bedrock, pathways exist for downward migration of second-phase fluid into the deeper portions of the rock. This downward migration pattern of second-phase organics resembles a three-dimensional maze. Based upon a review of the available analytical data, it appears that second-phase organic exists in the B zone, C zone, and CD zone monitoring intervals, but not below these intervals.

The migration of contaminants that are dissolved in the water would be controlled primarily by the groundwater flow regime. In the shallow groundwater regime, the general lateral flow pattern appears to be radial, with groundwater discharging into Gill Creek and into the Niagara River. There is also a downward component of flow to the deeper bedrock zones. In the deeper bedrock zones, horizontal flow patterns are primarily away from the Niagara River towards the northwest, reflecting the influence of the Olin Pumping Well, and to the northeast, probably reflecting the influence of the Niagara Power Project intakes.

Based upon the data available regarding contamination concentrations and groundwater flow direction and quantity, the total organic (i.e. volatile organic chlorocarbons) loading directly to the Niagara River through the shallow overburden is estimated to be on the order of nine pounds per day. Along Gill Creek, the total organic loading is estimated to be on the order of three pounds per day. Note that the Gill Creek loadings would be expected to contribute to the Niagara River loadings. The effect on the Niagara River flowing at the minimum rate of 50,000 cu.ft./second is expected to be negligible. The total loading to the Olin production wells from flow in the underlying bedrock, may be on the order of as much as 50 pounds/day. The percentage of this derived from the DuPont Niagara Plant site cannot be determined. Contaminant loadings to the northeast from the DuPont Niagara Plant site through the bedrock groundwater system are estimated to be on the order of 25 pounds/day. Note that contaminant loadings are considered "order of magnitude" numbers and are based upon the data generated for this study. Additional limitations regarding the data are described in detail in the report.

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INTRODUCTION

The U.S. Geological Survey, under the direction of the New York State Department of Environmental Conservation (DEC), drilled and sampled six wells in late 1982 and early 1983. These wells were located along the southern boundary of the DuPont Niagara Plant site. Samples of the groundwater from these wells, which intercepted the water table at approximately the overburden/bedrock interface, were found to contain varying concentrations of contaminants, consisting primarily of chlorocarbons. These data prompted DuPont to undertake a geohydrologic investigation to determine if the DuPont Plant site is a contributing source of these contaminants. A Groundwater Investigation Plan, dated May 1983, was prepared and submitted by DuPont to New York State DEC. This plan described in detail the steps to be taken to evaluate the potential presence and movement of suspect chemical contaminants at the DuPont Niagara Plant site in both the overburden and groundwater system. The following report presents the findings and conclusions resulting from the geohydrologic investigation conducted at the Niagara Plant site.

PROJECT DESCRIPTION

The DuPont Niagara Plant site, which encompasses 95 acres, is bordered on the south side by the Robert Moses Parkway (formerly known as the Niagara Parkway) and on the north side by Buffalo Avenue, as shown on Plate 1. Gill Creek divides the site into two approximately equal sections east and west of the present-day stream channel. DuPont's Niagara Plant has been in continuous operation since 1898 when the Niagara Electrochemical Company began the manufacture of sodium. DuPont acquired the site in 1930 and continued site development with new products and processes, including producing both organic and inorganic chemicals.

The drilling and sampling of six shallow monitoring wells by the U.S. Geological Survey revealed the presence of contaminants in the groundwater approximately at the interface between the overburden and the bedrock. As a result of these findings, a groundwater investigation plan was developed to evaluate the groundwater contamination conditions at the DuPont Niagara Plant site. This plan included the following objectives:

- o Determine groundwater flow rate and direction within the Lockport Formation and the overlying unconsolidated soils.
- o Determine groundwater quality.
- o Assess contaminant flow into and out of plant boundaries.
- o Develop a base of information to analyze, recommend and begin design of any potential remedial action.

In order to accomplish the objectives of the plan, certain major elements of the program were identified. These major elements included:

- o Locate, design and install monitoring wells.
- o Obtain and analyze groundwater samples to characterize groundwater chemistry.
- o Conduct aquifer tests to determine groundwater velocity and direction, aquifer characteristics and hydrogeologic boundary conditions.
- o Determine contaminant transport within and from the DuPont Plant site.

Described below is a summary of the major elements of the groundwater investigation plan.

MONITORING WELL INSTALLATIONS

Monitoring wells were designed by DuPont and installed at a total of 21 locations. The monitoring well locations are shown on Plate 2. At each of these locations, anywhere from one to seven monitoring wells were installed to sample groundwater from various depths. Also, one soil boring was advanced at each location. In total, 52 individual monitoring wells were installed. These wells provide the capability to sample groundwater and monitor groundwater levels at elevations varying from the top of rock to the interface between the Lockport Formation and the underlying Rochester Shale. The logs for the borings and well installations are included herein as Appendix A.

AQUIFER TESTING

Pump tests were conducted in both August and October, 1983 utilizing the Olin production wells. Further, individual aquifer well tests (slug tests) were conducted at selected wells during the same time period. These data were utilized in our interpretation and development of the groundwater flow model and geohydrologic conditions. The pump and slug test data utilized are presented as Appendix B.

GROUNDWATER CHEMISTRY AND CONTAMINANT TRANSPORT

In order to assess the contaminant migration into and out of the plant boundaries, representative groundwater samples were obtained from the available wells and analyzed. These data, combined with the site specific geologic and groundwater flow data, were utilized to develop our conceptual model of contaminant transport. The analytical chemistry data utilized in this study are presented as Appendix C.

MANMADE PASSAGEWAYS INVESTIGATION

In order to augment the data from well installations, pump tests and groundwater sampling, an investigation of the potential for contaminant migration through manmade passageways was undertaken. This investigation is in progress and results are not presently available. A separate report will be prepared describing monitoring well installations, water and soil sampling, and analytical chemical data resulting from the manmade passageways investigation program.

PREVIOUS REPORTS

The information utilized to prepare this report was derived from the site specific studies and analyses described herein and from previously prepared reports and/or documents. All data not available prior to this study and generated specifically for this study are presented herein. Data already available in the form of reports, letters and/or other available documents are identified as presented in Appendix D, References. Also included in Appendix D is a list of engineering drawings utilized for this study. Where such data are utilized directly, an author reference is given in the text in parenthesis. The reader is thereby referred to Appendix D for a complete citation of the reference, including author, organization, report title, and date. As shown, the previously available information can range from regional geologic studies to plant site specific studies conducted in the past, such as for the Gill Creek Restoration (Northan, 1982).

SITE OPERATIONAL HISTORY

The DuPont Niagara Plant has been in continuous operation since 1898 when the Niagara Electrochemical Company began the manufacture of sodium. DuPont acquired the site in 1930 and site development continued as new processes and products, both organic and inorganic, were developed. The site manufacturing peaked in both size and diversity in the 1950's and, since that time, several processes/products have been eliminated. The DuPont Company has prepared a listing of products manufactured at the Niagara Plant site over the last 80 plus years. Presented on Table 1 is a bar graph showing the primary product and the time at which manufacture occurred. Additional detail regarding site operation history is provided in the report generated as a result of the Interagency Task Force program (Roberson, 1978). In 1978, DuPont searched its records to determine possible waste disposal areas within the plant site. A report was prepared detailing production areas, time of use, process chemistry and waste disposal practices (Roberson, 1978). In response to the survey findings, DuPont conducted an analytical investigation and, where required, remedial action was taken to remove sources of contamination. Site history prior to DuPont's acquisition in approximately 1930 is sketchy at best, with no documented record available.

The impact and influence of geological events and the characteristics of overburden deposits and bedrock in the region of the plant are discussed primarily in the context of groundwater flow and contaminant migration. Consistent with this approach, certain details of geologic history, stratigraphy and overburden and bedrock properties are discussed to emphasize their bearing upon the Niagara Plant hydrogeologic regime. Conversely, geologic information having no relationship to groundwater flow and contaminant migration is not discussed. Proper characterization and understanding of the plant site geology establish the framework on which to evaluate and integrate plant site hydrogeologic data.

GEOLOGIC HISTORY

The glacial history of the area is briefly discussed below as detailed by Kindle and Taylor, 1913. The natural soil overburden encountered at the DuPont Niagara Plant site and much of that which occurs in this region of New York is of glacial origin and of Pleistocene age. Most, if not all, of the glacial deposits in the plant area is from the Wisconsin glaciation, with older Pleistocene deposits having been removed or significantly reworked by subsequent glaciations. The glacial ice, which moved from the northeast across the region, scoured the bedrock surface, plucking out large blocks and removing the upper relatively weak and weathered portion of bedrock. Till (sediments, which were deposited directly from glacial ice) is often highly variable in grain size and are rarely stratified (layered). The till deposits have been locally reworked and redeposited as a result of submergence by glacial meltwaters. Periglacial deposits consisting of silt and clay from glacial lakes and sand and gravel from streams also occur. These types of deposits commonly show better sorting and stratification. As a result, the soils beneath the plant site may exhibit a wide range in hydraulic conductivity (permeability). The silt-clay mixture soils would tend to restrict the movement of groundwater or contaminants downward into the fractured bedrock. Conversely, the granular soils would tend to accumulate contaminants and transmit them readily into the bedrock.

During the withdrawal of glacial ice, a series of ancestral glacial lakes formed and dissipated. Two of these lakes had particular influence on the site vicinity. These lakes were Lake Lundy and Lake Tonawanda. Lake Lundy, as it decreased in aerial extent, became known as Lake Tonawanda. Glacial Lake Tonawanda extended from Niagara Falls to Holley, New York, being about 50 miles in length and from less than one to nine miles in width. The Niagara Plant site and the adjacent Niagara River are located within the lake's western limit in the Niagara Falls area.

These glacial events affect the site in that much, if not all, of the decomposed bedrock has been removed; thus, resulting in a relatively hard and regular top of bedrock surface. Also, as a result of these glacial events, the overburden soils can be expected to vary widely in material type, density, thickness and aerial extent.

SUBSURFACE CONDITIONS

The subsurface data and interpretation presented in this report are based upon 74 soil borings and core holes drilled from April to November 1, 1983 under the direction of DuPont/Conoco. These logs are presented in Appendix A. The 52 monitoring wells installed at the 21 well cluster locations are summarized in Table 2. Through the utilization of this subsurface information, the logging of bedrock cores (see Appendix A) by WCC personnel and the availability of related data from WCC in-house files, the following descriptions of the overburden soils and bedrock have been prepared.

The subsurface materials encountered at the plant site are summarized in the Site Stratigraphic Column presented as Table 3. Of significance to any discussion of the Dupont plant site stratigraphy is that, since 1895, the plant site has encroached approximately 900 feet upon the Niagara River through filling along the shoreline. Therefore, a significant amount of miscellaneous fill debris is present under the plant site. The Niagara River shoreline locations for the years 1893, between 1893 and 1907, 1907, 1955 and 1983 and the former location of Gill Creek are shown on Plate 3.

OVERBURDEN SOILS

The overburden soils beneath the plant site have been classified into the four basic material types as follows: (1) fill, (2) alluvium, (3) glaciolacustrine and (4) till. These groups are referred to as Stratum 1 through 4, respectively.

FILL: Stratum 1 consists of large boulders; shot rock; cinders in a mixture of sand, silt and clay; and lesser amounts of brick, stone and slag. If all of the overburden materials encountered are assumed to be fill, the thickness of fill varies widely, from 6 to 23 feet. An isopach (thickness) map of the fill/overburden is shown on Plate 4. A Geologic Section Location Plan is shown on Plate 5. Geologic Sections A-A', B-B', C-C', D-D' and E-E', presented as Plates 6 to 8, illustrate how the fill extends as a continuous deposit varying in thickness across the plant site. As stated previously, much of the existing plant site is located in an area once occupied by the Niagara River and a significant amount of fill has been placed to achieve the existing site grades. However, some naturally occurring glacial soil deposits most likely did exist prior to fill placement.

It is highly possible that granular fill materials have been placed in direct contact with till deposits. In WCC's 1979 Gill Creek report (Waller and Coad, 1979), fill was encountered in all of the 27 test borings and probes. The fill in the Gill Creek area included crushed stone, cinders, brick, silt, sand, gravel and, in the Niagara Mohawk right-of-way, shot rock. The density of the fill materials ranged from loose to very dense. Much of this material was classified as contaminated and was removed by DuPont in 1981 during the Gill Creek restoration work (Northan, 1981).

ALLUVIAL/GLACIAL DEPOSITS: Overburden soils consisting of naturally occurring glacial drift are expected to be present beneath the plant site. However, their thickness, lateral extent and continuity across the site are expected to be limited and often nonexistent. Due to the presence of shot rock and boulders in the fill, split spoon sampling of the underlying soils was often precluded. Consequently, the soil boring data does not permit preparation of isopach maps for these strata. Test boring information obtained from the area of the Niagara Power Project intake structure, located about 6,000 feet east (upstream) of the plant site, indicate the presence of 13 to 20 feet of soil consisting of glacial till (silt, clay and gravel) overlying the rock in this area of the Niagara River bed. To the west (downstream) of the DuPont Plant and progressing toward the area of rapids, the thickness and aerial extent of these deposits are expected to diminish due to river scour processes. The DuPont Plant is located between the intake structure and rapids areas. It would be reasonable, therefore, to expect similar overburden deposits to be present to some extent in the plant site area. Cultural influences, such as dredging, may have removed these deposits in selected areas. Soil boring data obtained during recent and previous monitoring well installations and from plant site excavations, such as B-107 landfill, have been used to prepare the following descriptions of glacial/alluvial deposits.

Alluvial Deposits: Based upon the available soil logs, Stratum 2, when encountered, is estimated to consist of from two to three feet of alluvium composed of brown silt and clay locally containing fine sand and gravel. Alluvial deposits were encountered in soil borings at well cluster locations 16, 17 and 21. These deposits unconformably overlie both the glaciolacustrine and till deposits. Standard Penetration Resistance (SPR) values indicate these soils to be classified as stiff.

Glacial Deposits: Two types of glacial deposits have been encountered at the plant site. The most recent being glaciolacustrine (glacial lake) and the older being till.

The glaciolacustrine deposit of Stratum 3, when encountered, is estimated to consist of about four feet of brown silt and red clay. This deposit also includes red-brown clay and silt, with mixtures containing sand and gravel locally. SPR values characterize these soils as being from firm to stiff. Glaciolacustrine deposits were encountered in the soil boring at well cluster location 17.

In the 1979 Gill Creek study (Waller and Coad, 1979), test borings drilled adjacent to Gill Creek encountered a thin layer of firm to stiff silty clay. This or similar material is also described in DuPont's Gill Creek Restoration report of December 29, 1981. The deposit consists of a layer of reddish brown clay thickening from less than one foot to about four feet to the south. Within the clay are angular 2- to 6-inch fragments of bedrock. Underlying this material is a thin (0 to 9-inch) discontinuous layer of plastic bluish to dark gray clay in contact with bedrock. Therefore, at least in a limited extent, there are relatively impermeable soil deposits present in contact with the bedrock. This type of soil deposit would tend to impede the downward migration of groundwater and/or contaminants.

The glacial till of Stratum 4, the lowermost overburden deposit, when encountered, is estimated to consists of two to eight feet of material composed of brown to gray silty clay/silt containing rock fragments and sand. The till may also consists of red-brown silt, sand, gravel and clay having occasional boulders. The till is unconformably overlain by the alluvial and the glaciolacustrine clay deposits. Where the glaciolacustrine clay is absent, the alluvial or fill deposits are in contact with the till.

Till was encountered in the soil borings at well cluster locations 4, 7, 10, 13, 15, 17, 18, 19, 20, and 21. In the January 26, 1981 DuPont report, relating to the B-107 area, till consisting of clay with cobbles and boulders and red clay on top of bedrock was encountered in excavations. SPR values indicate these soils range from a firm to hard condition.

BEDROCK

As shown on Plates 9 and 10, the DuPont Niagara Plant is underlain by the Lockport Formation of middle Silurian age (320-350 million years old). As described by Zenger 1965, the Lockport Formation is principally a dolomite (calcium-magnesium carbonate). As a formation, it is characterized by a brown-gray color, medium granularity, medium to thick bedding, carbonaceous partings (laminae), vugs and stylolites (thin, irregular suture-like structure). The approximately 200-foot section of the Lockport Formation in the Niagara Falls vicinity is divided into five members as described below. Regionally, the bedrock bedding planes in the Niagara Falls area strike near east-west and dip at approximately 30 feet per mile. Test boring results indicate the depth to bedrock in the DuPont Plant site area ranges from approximately 6 to 23 feet. Approximately 157 feet of Lockport Formation was penetrated to reach the Rochester Shale during monitoring well installations. A structure contour map of the top of bedrock is shown on Plate 11.

The top of the bedrock surface is variable in attitude across much of the plant site. However, certain generalities can be made. In the area west of Alundum Road, the bedrock surface slopes to the southwest from an elevation of about 564 to an elevation of 557 feet. In the central area of the plant site, in the vicinity of Gill Creek, the bedrock surface generally slopes to the south having localized slope reversals. Here top of rock elevations are generally between 560 and 557 feet. An erosional surface or swale is suggested in this area which possibly reflects a combination of ancestral paths of Gill Creek and the presence of Gill Creek and Stony Islands (see Plate 3). In the eastern area of the plant site the bedrock surface slopes to the northeast from an elevation of 559 to an elevation of 546. Plant-wide, shallowest bedrock occurs in the northwestern extreme of the site in the vicinity of well cluster 20 (elevation 564). Deepest bedrock occurs in the northeastern extreme of the site in the vicinity of well cluster 17 (elevation 546).

Elevations of utility inverts located along Adams Avenue and DuPont Road identified on site engineering prints (see Appendix D) provided by DuPont are shown on Plate 12. Based upon the top of bedrock contours, also shown on Plate 12, it can be established that up to about 10 feet of bedrock was locally excavated during utility installation. These local irregularities in the top of bedrock surface have not been incorporated into the overall plant structure contour map.

STRATIGRAPHY: The stratigraphy of the Lockport Formation has direct bearing upon the potential for groundwater bearing zones and potential pathways of contaminant migration. For example, subtle or distinct variations in lithology (rock type), grain size, bedding thickness and the nature of rock unit (members) contacts within the Lockport Formation can either individually or jointly impact the overall groundwater regime. A particular contact between members can provide an interface through which a significant amount of groundwater flow can occur. Also, thinner bedded intervals of rock which are overlain by thicker bedded intervals are potential water-bearing zones.

As shown on Plate 13, the Lockport Formation is divided into five members. They are described in the order in which they are encountered: (1) Oak Orchard, (2) Eramosa, (3) Goat Island, (4) Gasport, and (5) DeCew. Over half the thickness of the Lockport consists of the Oak Orchard member. The portion of the Lockport Formation which immediately underlies the DuPont Plant site is the Oak Orchard member.

During previous geologic studies performed by WCC in the Niagara Falls area, excellent exposures of the lower members of the Lockport Formation and underlying Rochester Shale were examined along the south haul road of the Niagara Power Plant. The DeCew, Gasport, and Goat Island Eramosa members of the Lockport are exposed in a 70-foot vertical section in excavated rock along the east bank of the Niagara Gorge. Although not located in the immediate plant vicinity, opportunity to directly investigate lithology, bedding and fracturing at such a scale provided useful information which, coupled with the site specific rock cores, has been incorporated into this report.

Oak Orchard Member: The Oak Orchard member is described as a brown-gray to dark gray, fine to medium grained, thin to mostly thick bedded, saccaroidal (well developed, uniform size crystals), bituminous (containing carbonaceous matter) dolomite.

As with the underlying Eramosa member, the Oak Orchard has carbonaceous partings, vugs and stylolites. The exact thickness of the Oak Orchard in the Niagara Falls area is not known, but is estimated to be at least 120 feet. Where detailed geologic logs were available (well cluster 1, 4 and 8), approximately 90 feet of Oak Orchard was encountered.

The contact between the Oak Orchard and Eramosa members is conformable (no erosional discontinuities) and is described as sharp. Further discussion of this contact by Zenger is as follows: ". . .the light-weathering, thin to medium bedded Eramosa is overlain by brown, massive, bituminous, very vuggy dolomite that is the basal Oak Orchard. Limonitic stains at this contact are attributed to groundwater having dissolved iron bearing minerals (pyrite) as it migrated downward through the overlying vuggy stratum, subsequently deposited them on issuing forth at the contact with the less permeable Eramosa." Core holes that were advanced in excess of 100 feet penetrated this interface and the underlying Eramosa at the plant site; namely, at well clusters 1, 4, 8, 10 and 15.

Eramosa Member: The Eramosa is typically a medium to dark gray, fine-grained, thin to medium bedded, argillaceous (containing clay) and bituminous dolomite. This member is characterized by carbonaceous shale partings and locally having mineralized vugs containing calcite, gypsum, sphalerite and galena while also being pyritic in part. The thickness of the Eramosa in the Niagara Falls area is reported from 16 to 18 feet. At the site, the Eramosa is about 20 feet thick. The contact between the Eramosa and Goat Island members is conformable and marked by shaly, limonitic partings having chert nodules above and below the contact. Groundwater was observed emitting from this contact as reported by Zenger.

Goat Island Member: The Goat Island is light olive-gray to brownish gray, medium-grained, thick bedded, saccharoidal dolomite. Chert nodules occur in the upper part and stylolites and carbonaceous partings are abundant. Vugs typically contain gypsum, calcite and sphalerite. The thickness of the Goat Island member in the Niagara Falls area is usually from 19 to 25 feet. Rock conforming to the Goat Island member was encountered in well clusters 1, 4, 8 and 15. The contact between the Goat Island and Gasport members is conformable being both gradational and abrupt in lithologic change.

Gasport Member: The Gasport is predominately olive-gray to brownish-gray, coarse-grained, medium to thick bedded, fossil fragmented, crinoidal limestone or dolomite. The thickness of the Gasport in the Niagara Falls area is reportedly from 15 to 23 feet. Rock conforming to the Gasport member was encountered in well clusters 1, 4, 8 and 15. At well cluster 1, the Gasport is about 23 feet thick. The contact between the Gasport and DeCew members is sharp and marked by an oxidized surface. The DeCew is fine-grained, has a greenish hue due to the weathering of pyrite. The contact is an irregular, dark, argillaceous seam indicating a break in sedimentation.

DeCew Member: The DeCew member is typically medium to dark gray, fine grained, thin to thick bedded and massive, argillaceous dolomite. The lower part has intercalated shale and dolomitic shale. The thickness of the DeCew is about eight feet. The contact between the DeCew member of the Lockport Formation and the Rochester Shale is abrupt and undulating. The lower DeCew consists of intercalated shale and argillaceous dolomite that grade upward from the Rochester Shale. Rock conforming to the DeCew member was encountered at well clusters 1, 4, 8 and 15.

BEDROCK FRACTURES AND JOINTS: Particular attention has been directed towards the identification and description of the fractures and joints encountered in bedrock core obtained during plant monitoring well installations and their description in the literature and WCC's prior regional experience. In the context of this report, the term fracture refers to low angle breaks and the term joint refers to high angle breaks as measured from the horizontal. The widespread presence of bedrock fractures and joints both laterally and vertically in the Lockport Formation is perhaps the single-most important geologic feature existing beneath the plant site and surrounding areas influencing groundwater movement and potential contaminant migration. Geologic Sections A-A', B-B', C-C', D-D' and E-E', presented as Plates 6 to 8 illustrate in part this complex and selective migration pathway system. Also shown on Plates 6 to 8 are the various monitoring well types and the fractures they intercept. These well types and fractures are designated as either A, B, C, CD, D, E, F or J. Note that Geologic Sections A-A' and B-B' are projected to a common elevation in order to compensate for the southerly bedrock dip, thus, permitting relatively straight lines of correlation among equivalent fractures.

A basic and brief discussion of the origin of bedrock fractures and joints is appropriate in order to provide an understanding of their occurrence and impact on the plant site region hydrogeology. The presence of high angle joints or those which crosscut bedding planes can be attributed to large scale regional forces induced as a result of tectonic deformation in the Appalachian Mountains in the geologic past. These stresses have resulted in the occurrence of widespread rupture surfaces or joints in the bedrock. Comparatively, the relatively low angle bedding plane fractures can be attributed to tensional forces acting upon the bedrock as a result of removal of significant amounts of overlying bedrock by erosional processes and by isostatic rebound resulting from the removal of glacial ice. Bedding planes provide preferential surfaces along which separation can occur. Both high angle joint planes and low angle bedding fractures have been enlarged due to groundwater migration and solutioning of the carbonate Lockport Formation. Subsequently, a complex network of groundwater flow passageways in the bedrock has resulted.

Bedding Plane Fractures: The most common bedrock fractures encountered in core holes at the plant site approximate bedding planes. Plate 14 is a composite plot of the dips of fracture encountered in core holes. From this plot, it can be seen that 90 percent of the fractures dip between 0 and 10 degrees from the horizontal. It should be kept in mind, however, that a vertical core hole would not be expected to encounter a high number of steeply dipping joints. Therefore, the presence of vertical joints cannot be ignored. This topic will be discussed separately. Plots of the fracture frequency (the number of fractures or joints per foot) for the well cluster localities are presented in Plates 15 to 18. A perspective for the degree of bedrock fracturing can be gained through examination of these plots.

The greatest fracture frequency (3 or more fractures per foot) is generally confined to the upper 25 to 30 feet of bedrock. Intervals of comparable fracture frequencies do occur at depth, but are generally less extensive. Well clusters having the highest number of fractures in the upper 25 to 30 feet of bedrock are 1, 10 and 16, with 4 being highly fractured from 31 to 45 feet. Unfractured intervals of bedrock varying from 1 to 11 feet are present. No generalization can be made as to a particular depth where bedrock fractures are absent or significantly diminish.

Water Bearing Bedding Plane Fractures: Groundwater occurs in the Lockport Formation in bedding plane fractures, vertical joints and solution cavities. Of these three, bedding plane fractures are the major source of groundwater movement.

Johnston (1964) indicates that there are at least seven distinct water-bearing fracture zones within the Lockport Formation in the vicinity of the Power Authority of the State of New York. These seven zones can be traced laterally one to four miles and are associated with high frequencies of bedding plane fractures. Bedding plane fractures similar to Johnston's seven major zones and vertical joint exist at the plant site. For example, F type monitoring wells probably represent the number 5 water-bearing zone of Johnston. However, detailed correlation with Johnston's seven zones was not possible due to the multiplicity of fractures present.

Bedding plane fractures have been enhanced by groundwater solutioning resulting in enlargement of fracture widths. Water-bearing zones can consist of a single open bedding fracture of approximately 1 to 3 millimeters in width or a one-foot interval of rock containing several openings of which any single fracture can pinch out laterally. Bedding plane fractures can correspond to lithologic contacts and variability in bedding thicknesses. Little is known about the aerial extent of water bearing zones. They can pinch out laterally and be replaced by adjacent fractures. They may persist for miles or for only a few feet. Therefore, the number of water-bearing zones parallel to the bedding encountered in plant site core holes are not necessarily equivalent or precisely correlative to all of the seven zones described by Johnston. Further, several fractured zones above the uppermost water-bearing zone described by Johnston are believed to exist at the plant site.

Vertical Joints: The presence of vertical joints in the Niagara Falls area within the Lockport Formation has been described by previous workers (Johnston and Zenger). Plate 19 shows the strike (direction with respect to north) of joints in the Niagara Falls area. The data upon which these plots are based was obtained from bedrock outcrops and exposures located at Necco Park (approximately 1.5 miles northeast of the DuPont Plant site) and at Niagara Power Project haul road (approximately 3.75 miles north of the site). Upon comparison of these two sites, bedrock jointing generally strikes northeast, north-northwest and northwest. The presence of vertical joints at the

American Falls has also been described in the literature. The presence of vertical jointing in the Lockport Formation is significant, since these joints provide pathways for vertical migration of contaminants and cross-communication among water-bearing zones. The exceptional well yields described in the plant vicinity have been postulated as being a result of an east-northeasterly set of vertical joints (Johnston). The presence of contaminants at depth in the bedrock beneath the plant site supports the role of vertical joints in providing pathways for downward migration of contaminants.

GEOHYDROLOGY

Groundwater in the area of the DuPont Niagara Plant site is encountered in both the unconsolidated overburden and consolidated rock. To investigate the hydrologic regime in the vicinity of the plant site, a total of 52 monitoring wells were installed to sample groundwater from various elevations in the overburden and bedrock. The bedrock monitoring wells were completed as "open hole" wells in the water bearing zone (fracture) of interest. Overburden wells were screened into the top of rock. The monitoring wells were used to measure the elevation of groundwater heads at selected fracture zones, monitor change in hydraulic head with time in response to local pumping changes, determine vertical flow potential, perform single well permeability tests (slug tests), monitor the response of groundwater heads to river stage changes, and obtain samples for chemical analysis.

The information collected during this investigation was used to prepare groundwater contour maps for each of the fracture zones, contour maps showing the change in hydraulic head due to changes in pumping rate, time-drawdown, time-recovery and distance-recovery curves for the water level response to pumping changes, and curves showing well river stage ratio versus distance from the Niagara River. This compiled information was then used to estimate the direction and volume of groundwater flow in the plant site area within the Lockport Formation and unconsolidated overburden material.

The sources of groundwater in the vicinity of the DuPont Niagara Plant site are direct infiltration of precipitation and induced infiltration of water from the Niagara River. The mode of occurrence of groundwater in the bedrock and overburden materials differs due to the composition of the water-bearing units. The overburden materials, which primarily consist of fill deposits, are characterized as a granular porous media. Groundwater occurs in the pore space among the grains and flow occurs predominantly in the zone of saturation. The quantity of groundwater and flow rate are dependent on the hydraulic conductivity which in turn is related to volume of pore space between the grains (porosity) and the interconnection of the pore spaces. The primary source of groundwater recharge to the overburden groundwater regime is direct infiltration of precipitation.

The volume of recharge is dependent upon several factors including the vertical permeability of the surficial soils, the soil moisture content, and evapotransporation rates. Precipitation which percolates through the unsaturated zone to the zone of saturation will flow to natural and man-made groundwater discharge areas. The degree of heterogeneity of the overburden materials will influence the volume and direction of groundwater flow in the plant site area. Groundwater flow to the bedrock groundwater regime from the overburden flow regime will depend on the degree to which the two regimes are hydraulically connected.

The Lockport Formation is a fractured rock media as has been previously discussed. Groundwater occurs primarily in the open area of fractures and cavities. The quantity of groundwater and flow rate is dependent on the size of the fractures and cavities and the degree to which fractures and cavities are interconnected. The source of groundwater within the Lockport Formation is primarily from induced infiltration of Niagara River water and secondarily from vertical leakage from overlying water-bearing zones. The volume of recharge is dependent on the degree of hydraulic connection with the Niagara River and the degree to which water-bearing zones are hydraulically interconnected by vertical fractures. The direction of groundwater flow in the bedrock is from areas of higher hydraulic heads to areas of lower hydraulic heads. Historically, the flow of groundwater in the bedrock has been in the direction of the Niagara Gorge from the Niagara River (Johnston). The gorge is at a lower hydraulic head than the Niagara River above the Niagara River waterfall; thus, the gorge is a regional discharge area. Superimposed on the regional pattern of groundwater are local effects due to the artificial removal of water from the bedrock by pumping. The effect of pumping is to create an area of lower hydraulic head and an artifical discharge point. This results in groundwater flow toward the pumping well. At present, Olin Corporation is essentially continuously pumping from production wells located to the northwest of the plant site as shown on Plate 2. The result of this pumpage has been to locally alter the direction of groundwater flow in the vicinity of the pumping well. Historically, both the DuPont Niagara Plant and Olin Corporation have pumped groundwater from the Lockport Formation starting about 1934. The DuPont production well has been out-of-service for many years. It is expected that the configuration of the groundwater table during the early years of pumping is similar to that present today, although the location and number of pumping wells has changed. During the period of operation of both production wells, the groundwater flow contours would be expected to be skewed toward the DuPont production well. The DuPont production well would be expected to have induced groundwater flow from a larger portion of the Niagara Plant site than the present Olin production well.

Described in subsequent sections of the report are the field investigations and analyses conducted as part of our site assessment studies. Our findings and conclusions regarding the geohydrology are also presented. The basic data are presented in Appendix B.

FIELD INVESTIGATIONS

PUMP TESTS: Woodward-Clyde Consultants personnel monitored water levels in selected wells during the August/September and October, 1983 pump tests. The pumping wells were those utilized by Olin Corporation for non-contact cooling water. The Olin production wells are 20 to 24-inch diameter pumping wells constructed as "open hole" from approximately 30 to 125 feet below ground surface. The upper 30 feet of the wells are cased with steel pipe. Review of drillers logs for the Olin production well suggests that the wells are open from the C through D zones. The E and F zones are not specifically reported on the logs, but Olin reports that a minor amount of water is supplied to the wells from below the D zone, suggesting the presence of the E and F zones. In addition, comparison of fracture elevations would indicate that the Olin production wells penetrate the E and F zones.

Woodward-Clyde Consultants personnel monitored the water level in selected wells using tape measures and/or Stevens Recorders. Water levels were recorded at close intervals during the start of each test and at larger time intervals during the latter part of the test. Water levels were recorded on field data sheets and then entered into the WCC data base management system.

The August/September pump test consisted of both a step-up test (increased pumpage rate and a step-down test (decreased pumpage rate). The increased pumpage of 1374 gpm was from the second Olin production well approximately thirty feet from the primary pumping well. Both wells have similar well construction geometries. The step-up test started on August 25 at 9:00 a.m. and the step-down test started on August 30 at 2:00 p.m.

The October pump test consisted of a recovery and drawdown test using the primary Olin production well. The Olin production wells were shut down at 9:00 a.m. on October 17, 1983. The pump rate prior to being shut down was reported to be 1972 gallons per minute (gpm). The drawdown test started at approximately 11:00 a.m. on October 19, 1983. The pump rate reportedly stabilized approximately 15 minutes after being started at a rate of 1722 gpm. Drawdown was monitored until approximately 12:00 p.m. on October 21, 1983. Because of scheduling problems during the Olin Plant turnaround, some of the early time data is not available.

The results of the pumping test were used to estimate the zone of influence of the Olin production wells, the magnitude of pumping effects and the computations of formational transmissivities. With respect to contaminant transport in the Plant site area, the zone of influence of the Olin production well, is the most important factor obtained from the two pumping test. The areal extent of the zone of influence describes that area in which solubilized contaminants will migrate to the Olin production well.

The results of the pump tests are included in Appendix B. The computer output presenting the data include the time at which the measurement was taken, the measured depth, the water table elevation and the elevation change with time. The water levels are not corrected for river fluctuations.

SINGLE WELL PERMEABILITY TESTS (SLUG TESTS)

Single well permeability tests (slug tests) were performed on the Regolth wells (A wells) and selected bedrock wells. The purpose of these tests was to estimate the permeability of the overburden soils and bedrock in the near well vicinity. The tests were performed using the slug test method outlined by Cooper, et al (1967) and Bouwer and Rice (1976).

Woodward-Clyde Consultants personnel performed the slug test using a Data Instruments 25psia or Druck 10psig pressure transducer coupled to an Esterline Angus portable strip chart recorder. The change in water level measured by the pressure transducer was initiated using a sealed iron pipe (the slug) lowered below the water table. The slug volume is 0.15 cubic feet. This slug results in a head change of approximately 1.8 feet in the DuPont monitoring wells.

Test results were examined first assuming the water-bearing zone to be "confined." Wells that did not respond as "confined" were considered "unconfined." This distinction is only for the area of the water-bearing zone immediately near the well. This does not imply a regional unconfined hydraulic condition in the water-bearing zone. Several of the wells responded as confined during the initial part of the test and unconfined for the remainder of the test. Results from these wells are presented for both confined and unconfined conditions. The actual permeability of the water-bearing zone in the vicinity of these wells is probably within the reported range. The test results are valid only for the water-bearing zone in the near vicinity of the well.

The data from the tests were reduced using the methods outlined by Cooper et al (1967) for a confined aquifer and Bouwer and Rice (1976) for an unconfined aquifer. The test results for the A well, listed in Table 4, show permeability values ranging from $3x10^{-1}$ centimeters per second (cm/sec) to $8x10^{-3}$ cm/sec. The wells north of DuPont Road generally have permeabilities lower than those south of DuPont Road. The difference in permeabilities between these two areas is approximately an order of magnitude.

The bedrock monitoring well test results are reported for both confined and unconfined cases where applicable. In addition, permeabilities are reported using the total open hole length and/or an estimate of the total open fracture length of one foot. The permeability is a function of that part of the well that responds to water level changes. The slug test results for the bedrock wells are listed in Table 5. These permeability values are reported to show the possible range in values using different lengths of open hole that respond to water level changes. The total well length permeability is typically an order of magnitude lower than the fracture length permeability and represents a macro-permeability over the open section of the well. The fracture length permeability represents an estimated permeability of the fractures open to the well. Because the sum of the fracture length is unknown, a value of one foot was applied as a constant for all wells. The actual total fracture width is probably less than one foot. In several cases, the wells responded very rapidly to the induced change in head, that is, a sine-type wave was generated in the well. The absolute permeability values from these tests are less reliable, though useful for comparison with other data.

Slug test results are reported for all fracture zones, except CD. Zones B and F exhibited the smallest range in values suggesting relatively consistent physical hydraulic properties in each zone. The average permeability in the F zone was computed to be 0.05 cm/sec and the average in the B zone was computed to be 0.4 cm/sec. The C and D zone test results exhibit similar results, but exhibit a larger range than the B and F zone results. The results of the slug tests for the C and D zones suggest a greater degree of heterogeneity and anisotopy, with respect to the hydraulic physical properties in these zones, than for the B and F zones. The test results for the C zone ranged from 0.8 cm/sec to $1x10^{-4}$ cm/sec and for the D zone ranged from 0.5 cm/sec to $9x10^{-4}$ cm/sec.

GROUNDWATER ANALYSIS

The response to pumping of the groundwater regime in the DuPont Plant site area is a function of several factors. These factors include the quantity of pumpage, the zones from which pumping is occurring, the areal extent of horizontal fracture zones and the degree to which horizontal fractures are interconnected with vertical fractures. Two pump tests were monitored to quantify the effect of pumping on the groundwater regime. The August pump test monitored principally the B zone wells; only a limited number of A zone wells and the few C through J wells were available at that time. The pumping effects for the August drawdown test are listed in Table 6. The effect of pumping was measured by comparing the water level prior to the test and at concurrent times after the test began.

To identify pumping effects, it is necessary to assume that the effects of river stage changes are zeroed when comparing concurrent times and that a difference in water level is due to pumpage. Inherent imprecision in using this technique probably limits the detection of water level changes to greater than 0.3 feet. Water level changes due to pumping were observed primarily in the C through J fracture zones. The largest change in water levels was observed in monitoring wells 1J and 1D. The A and B zone wells typically exhibit water level changes of less than 0.3 feet, or a positive value, suggesting no or small pumping effects. Positive values could be the result of river fluctuations or precipitation influences.

The second pump test was conducted during the week of October 17, 1983. The test was monitored for both a recovery and drawdown test period. The recovery test was initiated by the shutdown of the Olin production wells and drawdown by the start-up of the Olin production wells. Significantly more bedrock monitoring wells were available for observation during this test period. The maximum water level recoveries observed during the recovery test are listed in Table 7.

The water levels in the CD and D zone monitoring wells exhibited the most significant response to the release of pumping stress. The recovery of the water levels in the CD zone were contoured (See Plate 20) to depict the radius of influence of the Olin production wells. The contours exhibit a radial configuration which decreases in gradient with increasing distance from the pumping well. The radius of influence of the pumping well extends to a minimum distance of at least 1980 feet, to the southeast, at monitoring well 1C. Well 1C exhibited a recovery of 0.33 feet. The radius of influence would be expected to extend some distance further to the southeast of 1C. Monitoring wells 4C and 1C were used as CD zone wells because their fracture elevations are consistent with the CD zone. (See Plates 6 and 8).

The recovery in the D zone was similar to that in the CD zone. The D zone water level recovery contour map exhibits the same radial pattern around the pumping well (See Plate 21). The radius of influence of the pumping well extends to the east, at a minimum, to monitoring well 10D. Monitoring well 10D had an observed recovery of 2.26 feet. The D zone does show recoveries similar to that of the CD zone of wells located closer to the pumping well, but much larger recoveries at further distances. This observation suggests a much larger zone of influence in the D zone than that found in the CD zone. Monitoring well 15D was not used to generate contour maps because water was heard running into the monitoring well. Monitoring well 15D was repaired subsequent to the October pump test. The recovery in 15D was similar to that expected, but the results were considered less reliable. The F zone showed less recovery near the pumping well (See Plate 22) than CD or D, but recoveries similar to that of the CD zone at distance. The shallower recovery gradient in the F zone suggest a larger radius of influence than in the CD zone.

Insufficient data was available from the C zone to document the area of pumping influence. Monitoring well 10C did not show detectable recovery during the time frame of the test. This observation limits the pumping influence in the C zone, during the time frame of the test, to some distance less than that of 10C. Pumping influence was detected in 15C during the August pump test and would have been expected to respond to recovery during the October test. Monitoring well 15C was cross-grouted during installation of well 15D and has subsequently been repaired. This assumption would place the zone of influence some distance east of 15C. Monitoring well 15C was not available for observation during the October test. The elevation of the water bearing fracture in monitoring well 2C is similar to that of a CD zone fracture elevation. Both water level and recovery data exhibit characteristics different from either the C, CD or D zones. Water levels were much lower than expected and recovery greater than expected. These observations suggest a somewhat more direct hydraulic connection with the pumping well than found in monitoring wells in the same zone at similar distances. Monitoring well 14C was originally drilled to the D zone depth, but subsequently grouted back to the C zone depth. As no major water bearing zones were observed, this well was not utilized.

Monitoring wells 5B and 16B exhibited recoveries during the October testing suggesting some pumping influence in this zone. Monitoring well 16B did not show any response to pumping during the August test. Monitoring well 16B has a water-bearing fracture elevation consistent with that of the C zone (See Plates 7 and 8), although the water levels are representative of the B zone. This data suggests that 16B may have a poor hydraulic connection with the pumping well and be in hydraulic connection with both B and C zones.

Monitoring well 5A was dry prior to the recovery test. Monitoring well 5A did recover 2.4 feet during the test, suggesting some influence in the A zone at this locality due to pumping. No observable recoveries were documented in the other monitored A zone monitoring wells.

Monitoring well 1J did respond to pumping. This well response is discussed in detail in subsequent sections.

Water level measurements at concurrent times were insufficient to adequately describe the response of the groundwater regime to pumping during the October drawdown test. The response of the groundwater regime to the October drawdown test would be expected to be similar to that of the recovery test at similar pump rates. At similar pump rates, drawdown would equal the amount of recovery and the cone of recovery depicted on the recovery contour maps would be inverted to represent drawdown.

The radius of influence of a pumping well can be graphically estimated using the recovery in a monitoring well versus its distance from the pumping well. The recovery versus distance values are plotted on semi-logarithmic graphs. The data plots represent the trace of the recovery cone along a straight line. This line represents the flow path of groundwater in which a radial cone of influence develops due to pumping. The line can be extended to the zero recovery intercept to obtain a radius of influence. The distance obtained at the zero recovery intercept is an approximation because at some distance from the pumping well the recovery no longer can be represented as a straight line on a semi-logarithmic graph. The actual radius of influence in a porous media is typically somewhat less than that obtained using this method. In the fractured rock present at the site, the actual groundwater flow paths would be expected to follow a circuitous route in the heterogenous, anisotropic media. Therefore, the distance at which pumping effects are observed may vary significantly in the same fracture zone.

Sufficient recovery data were obtained during the October recovery test to construct recovery versus distance data plots for the C, CD, D and F zones. Data plots for monitoring wells 1, 5 and 10 for the D and F zones describe a straight line trace of the recovery cone of influence (Plate 23 and Plate 24, respectively). In both data plots, monitoring well group 15 data exhibited less recovery than expected. Interpretation of the data suggests that D and F zone monitoring wells at well cluster locations 1, 5 and 10 react to the release of pumping stress in a similar manner and, therefore, have a similar hydraulic connection with the pumping well. The slope of the line for both zones is similar suggesting that the hydraulic properties of the zones are also similar. Data from monitoring wells 15D and 15F do not fit the relationship indicating a different hydraulic connection with the pump well and possibly different hydraulic properties of the zones in the vicinity of this well cluster. The recovery in monitoring wells 15, zones D and F, may represent the pumping effect at some greater distance due to a circuitous flow path.

The recovery/distance data plot for the C and CD zone monitoring wells shows a much greater scatter (see Plate 25) than the data for the D and F zones. A straight line cannot reasonably be drawn through the set of data points. The data plot does show a trend that has a much larger slope than that observed in the D and F zones. The scatter in the data likely represents the variance in flow directions due to the heterogenous, anisotropic nature of the fractured rock. The data indicate that groundwater flow in C and CD zones has a higher degree of complexity than that found in the D or F zones. In addition, the steep slope of the trend suggests the hydraulic properties of the the C and CD zones are different than that of the D or F zones.

The zero recovery intercept for each data plot was used to estimate the radius of influence of the pumping well in each zone. The largest radius of influence of approximately 4400 feet was found in the D zone. The radius of influence in the F zone was found to be approximately 2800 feet. The minimum radius of influence was found in the C and CD zone of approximately 1800 feet.

VERTICAL GRADIENTS

The groundwater flow paths in the DuPont Niagara Plant site area are primarily the horizontal and vertical fractures present in the bedrock. Based upon the regional flow patterns previously discussed, the hydraulic head would be expected to decrease with increasing depth. At the DuPont plant site, the effect of local pumping is superimposed on the regional groundwater trends, resulting in a modified local groundwater flow regime. Pumpage from the Olin production wells is not equally distributed among all of the fracture zones. In the zones that are the principal water sources, the heads have been reduced significantly compared to the other zones. The principal water-bearing zones from which pumpage is occurring appear to be the CD and D zones. The effect of pumpage from these zones causes a change from the regional vertical groundwater gradients. The gradient is the head difference (or flow potential) divided by the length of the flow path. During both the August and October pump tests, the general pattern was a downward flow potential to either the CD or D zones and an upward flow potential to the CD or D zone from the E and F zones. The one J zone well, at well cluster 1, exhibited a consistent upward flow potential. The potential for flow exists as seen in the difference in measured water levels for the various fracture zones. If vertical flow paths are present flow would be downward to the CD or D zone from above in the section, upward from the E and F zones to the CD or D zones and downward from the F zone to J zone.

Water levels at various monitoring wells were measured to document the vertical groundwater flow potential between zones at well cluster locations. These observations were taken:

- Prior to the start of the August 25, 1983 pump test (Table 8)
- On August 29, 1983 at high (Table 9) and low (Table 10) river stage
- On October 17, 1983 after the start of the recovery test (Table 11),
- On October 19, 1983 after the start of the drawdown test (Table 12).

The basic vertical flow potential trends did not change for the time periods observed. Increased pumpage tends to increase the downward and upward gradients. Decreased pumpage tends to decrease the downward and upward gradients. The October 17, 1983 recovery test data exhibits the general gradient trend noted during pumping.

This observation suggests that either the wells had not fully recovered, so that a constant downward flow potential was found to exist through the section or, that at static equilibrium conditions, there exists an upward gradient to the CD or D zone from the E and F zones. This condition could exist naturally in the CD and D zones only if groundwater is being discharged at a much greater rate than the E or F zones. The most probable reason the trend did not reverse is that the CD and D zones had not fully recovered at the time of observation.

The change in Niagara River stage effects groundwater levels, as observed in many of the monitoring wells. The efficiency at which the monitoring wells respond varies vertically between fracture zones, horizontally between the same fracture zones and with time. The effect of the river stage changes is to increase or decrease, on a small scale, the observed vertical gradient. The river stage changed approximately two feet from low to high water stage during the August and October pump tests. This results in a daily fluctuation in the vertical gradient of a maximum value of less than one foot in one direction, at a well efficiency of 100 percent. After November 1, 1983, the river level is maintained at a constant flow rate with minor adjustments. During the constant flow rate period the vertical gradients will not be influenced to any large degree by the Niagara River.

TRANSMISSIVITIES

Transmissivity is the rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient. The hydraulic conductivity of an aquifer is equal to the transmissivity divided by the saturated thickness. The transmissivity of an aquifer can be computed using measured drawdowns in observations wells collected during a pump test. In porous media, the transmissivity of a formation is inversely related to drawdown. That is the higher the transmissivity of a formation, the smaller the drawdown at some distance from the pumping well. In fracture rock media, this relationship also holds true but may not be evident in the observed drawdowns. That is, two monitoring wells at equal plan distance from the pumping well may exhibit different drawdowns. This is because one of the wells may have a more direct hydraulic connection with the pumping, and thus exhibit a greater drawdown. The second well may have a less direct hydraulic connection with the pumping well and thus exhibit a smaller drawdown.

Calculation of transmissivity would result in a higher value for the monitoring well with the less direct hydraulic connection and lower value for the monitoring well with a more direct hydraulic connection. In actuality the inverse may be true for the comparative magnitude of transmissivity for the two cases. As noted, drawdown is related to the distance from the pumping well for a given transmissivity. In a fractured rock media, the actual flow path distance may not be equal to the plan distance from the pumping well. That is, two wells equi-distant from the pumping well may exhibit different drawdown because the flow path for one may described as a circuitous path while the other a more direct flow path. Hence, the transmissivity of a fracture rock media can vary several orders of magnitude.

Water level changes in selected monitoring wells were obtained during the August 25, and October 17, 1983 pump tests. These data were used to generate time versus drawdown or recovery curves as presented in Appendix B. These curves were used to compute formational transmissivities by matching published type curves for "water table fractured rock" conditions (Boulten and Streltslova, 1978) and "leaky confined" conditions (Hantush, 1956). The water level observations were corrected for Niagara River fluctuation using well hydrographs and water level data collected during the test. The well hydrographs were recorded using Stevens Recorder. The hydrographs described the change in monitoring well water level due to Niagara River stage changes. The pumping influence was estimated by subtracting out the effect of the Niagara River, at unique times, during the test.

The majority of the time drawdown curves matched the early part of the "water table fractured rock" type curves. Several of the data plots also match the later parts of the "water table fractured rock" type curves. The latter type curves describe the change in water level due to a reduction in vertical leakage. The data curves were also compared to the "leaky confined" type curves and several of the data plots also matched these type curves. Monitoring well 15C was the only well that matched only the "leaky confined" type curves. The estimated transmissivity calculated using the type curve match method are only first-cut approximations, as the Lockport Formation does not conform to all of the assumptions for which the governing equations are valid.

The data curves, in general, define a curve that exhibits a steep slope during the early time segment of the test. As shown on Plate 26, the time/drawdown curve plot for monitoring well 4C is a typical example of the data curve. During the early time, the principal source of water is from the fractures. With time, the curves flatten out. During this time, sufficient water is being supplied either by leakage or a recharge boundary, so that the water level is essentially constant. With time, if the effects of leakage are reduced due to dewatering of vertical fractures or reduction of vertical gradients, the water levels would be expected to start to decline. Water level declines were noted at later time segments in monitoring wells 5F and 10F. The time-recovery curve for well 10F is presented as Plate 27.

The calculation of the transmissivity of a water-bearing fracture requires quantification of the flow (pumpage) resulting in a measured drawdown. The total pumpage from the Olin production wells is a composite flow of the sum of flows from each water bearing zone intercepted by the well. Olin has estimated the volume of flow from three sections of the production well (verbal communication) using chemical loadings from water samples collected using packers. Olin personnel estimated that approximately 78 percent of the total pumpage is from the fractures identified as C and CD zones, 12 percent from the fractures identified as the D zone and 10 percent from the fractures identified as the E and F zones. WCC subdivided Olin's estimate for the C and CD zones to estimate transmissivities. WCC assumed 20 percent of the flow to be in the C zone and 58 percent of the flow to be in CD zone.

WCC estimated the fracture flow quantities using the hydraulic relationship which establishes that drawdown at any point is proportional to the pump rate. Thus, the drawdown in a specific fracture zone is proportional to the quantity of groundwater being pumped from that fracture and the sum of head changes at a monitoring well cluster is proportional to the total pump rate. Using this relationship, WCC estimated specific fracture zone flow quantities by (1) summing the head changes in each fracture zone for a monitoring well cluster, (2) computing the percentage that a change in head for a fracture zone was with respect to the sum of the head change for the monitoring well cluster (3) assigning fracture flow rates based on computed percentages and the total pump rate and (4) assigning weighted average flow quantities for each fracture zone using the results for the monitoring well clusters.

WCC used this same method to come to an approximation of the total pumpage from zones C through F. For this approximation, the heads in each zone were compared with the total head change for each well cluster. The results were averaged and weighted on the basis of the results from distance drawdown plots, slug test, and vertical gradients. This technique results in the estimation that the pumpage from the D zone is greater than that estimated by Olin and a similar volume for the E and F zones. Table 13 presents the range of flow volumes assigned to each fracture zone to calculate the transmissivities.

The transmissivities calculated using both Olin's estimate and WCC's estimate are presented in Table 14. Table 14 also presents the additional data used to calculate these values. The disparity in transmissivity using the WCC and Olin estimated flow rates is on the order of one to three times for the C, CD, and D zones. The F zone flow estimates are equal. The range of transmissivities reported is computed to be from 450,000 gallons per day feet (gal/dyft) in monitoring well 10D to 2000 gal/dyft in monitoring well 5F. The following discussion of transmissivities, estimated for specific fracture zones, uses the values generated applying the WCC estimated flow rates and the "water table fractured rock" type curves when available.

C-ZONE TRANSMISSIVITY: Limited time/drawdown data was available for the C-zone. The time/drawdown results for monitoring well 15C were available from the August 25, 1983 pump test. The estimated transmissivity for 15C, using the "leaky artesian (confined)" type curves, is 56,000 gal/dyft.

CD-ZONE TRANSMISSIVITY: Sufficient time-drawdown/recovery data was available for monitoring wells 2C, 4C and 15CD to describe the transmissivity in the CD zone. Monitoring wells 2C and 4C are identified as CD wells with respect to their fracture elevation as shown on Plates 6, 7 and 8. Time-drawdown data for 4C were collected during the August pump test while 2C and 15CD data were collected during the October 17, 1983 pump test. The range in transmissivities for the CD zone is computed to be from 21,000 gal/dyft in monitoring well 15CD to 4,000 gal/dyft in 2C. The average transmissivity for the CD zone is estimated to be 12,000 gal/dyft.

D-ZONE TRANSMISSIVITY: Sufficient time-drawdown/recovery data was available from monitoring wells 1D, 5D and 10D to estimate the transmissivity of the D zone. The time-drawdown data for 1D was from the August 25, 1983 pump test and for 5D and 10D from the October 17, 1983 pump test. The transmissivity in the D zone was computed to range from 450,000 gal/dyft in 10D to 6,000 gal/dyft in 5D. The high transmissivity estimated for the D zone using monitoring well 10D seems to be anomalous when compared to the other transmissivity values. Therefore, the results for 10D were not used in developing the transmissivity results for the D zone. The average transmissivity for the D zone is estimated at 19,000 gal/dyft.

TRANSMISSIVITY OF OTHER ZONES: Limited time-drawdown data are available for the E zone. Monitoring well 1E time-drawdown observations from the August 25, 1983 pump test were used to estimate the transmissivity. The transmissivity at monitoring well 1E was estimated at 9000 gal/dyft.

Time-drawdown/recovery data from monitoring wells 5F and 10F were available to estimate the transmissivity of the F zone. The estimated transmissivity at 5F is 2400 gal/dyft and at 10F is 14,000 gal/dyft. The average transmissivity for the F zone is estimated at 8,000 gal/dyft.

Monitoring well 1J responded to pumping during both the August and October pump tests. Because 1J is open hole, from an elevation immediately below that of 1F (Plate 6) to the top of the Rochester shale, the monitoring well responded to pumping as a composite well. The exposed zones of the Lockport Dolomite in the open hole that responded to pumping are unknown. It is believed more likely that minor fracures in the upper section of the open hole are responsible for the change in water level due to pumping. The actual component of flow causing the observed change in water level was not estimated. Review of the rock log of monitoring well 1J does not report any major fractures. Minor fractures were observed by WCC in their review of the rock core (Appendix A). The hydraulic head loss in monitoring well 1J is probably related to water loss by upward flow in the fractures near the base of the F zone to the F zone, a reduction in vertical leakage from the F zone and/or horizontal flow to the pumping well. Groundwater flow in the vicinity of monitoring well 1J would be expected to be along flow paths with low transmissivities. Based on these assumptions, the section of the Lockport Formation that responded to pumping in monitoring well 1J probably has a transmissivity of less than 1000 gal/dyft.

TRANSMISSIVITY BY OTHER METHODS: Additional methods of estimating the transmissivity of the Lockport Formation were applied to the available data. These methods were used to further refine the transmissivity estimates made using the time-drawdown/recovery data for the August and October pump tests. The methods used are (1) distance versus recovery (Walton, 1970), (2) Theim steady state (Walton, 1970), and (3) well/river stage ratios (Ferris, 1963). Each of these methods were derived for porous media and requires homogenous, isotropic conditions to be present in the flow media. The Lockport Formation does not conform to all of the assumptions for which these methods are valid but these procedures are useful to make an estimate of transmissivity.

The graphical plots of distance versus recovery data for the CD, D and F zones, were presented earlier in this report (Plates 23, 24 and 25). The estimates of transmissivity using distance versus recovery methods are listed in Table 15. The results are presented using both Olin and WCC estimated flow rates. The transmissivities estimated using this method are similar to those estimated using the time drawdown method. The transmissivity estimated for the CD zone is 15,000 gal/dyft, for the D zone, 44,000 gal/dyft and for the F zone, 16,000 gal/dyft.

The estimates of transmissivity using the Theim steady state equations are listed in Table 16. The steady state equations were solved using the drawdown observation for each monitoring well in a specific zone. The resultant transmissivities are reported as an average for each zone. The estimated transmissivities for the D and F zones using the Thiem method are on the order of 2 to 3 times higher than those of the time-drawdown/recovery method. By contrast, the C zone estimate was three times lower and the CD zone 10 times lower. The estimated transmissivities using the Thiem method are 18,000 gal/dyft in the C zone, 800 gal/dyft in the CD zone, 73,000 gal/dyft in the D zone and 29,000 gal/dyft in the F zone.

The stage ratio method assumes that a regulated river, fluctuating in simple harmonic motion, will generate a train of sinusoidal waves which propogate through the groundwater regime. The decrease in wave amplitude and increase in lag time with distance from the river are functions of the transmissivity of the formation. For the stage ratio method, the ratio of the groundwater stage in a monitoring well to the river stage is plotted against the distance from the river boundary to the monitoring well on semi-logarithmic paper. The stage ratios used to generate the data plots are listed in Table 17. The stage ratios are based on monitoring well and Niagara River hydrographs collected during the course of this study.

Stage ratios were available for fracture zones B, CD, D and F. The graphical presentation of the data is included in Plates 28 through 30. The data plots were not useful in estimating transmissivity because the data exhibit either scatter in the stage ratios or near vertical trends. The stage ratio plot for the B zone exhibits a wide scatter in the ratios. An estimate of transmissivity was made using monitoring wells 1B, 3B and 5B. The estimated transmissivity, applying an estimated storage coefficient of 0.1, is 500,000 gal/dy ft. This value can vary significantly depending on the actual storage coefficient of the B zone, hence the reliability of this figure cannot be assessed.

The stage ratio plot for the CD zone also exhibits wide scatter in the ratios. An estimate of transmissivity using monitoring wells 1C, 4C and 7C and a storage coefficient of 0.1 is 460,000 gal/ftdy. This value is greater than that calculated using the other methods.

The stage ratio plots for the D and F zones exhibit near vertical trends. Transmissivities cannot be calculated using these data. It is generally accepted that the stage ratio method is not useful in estimating transmissivities, but is useful in describing river stage effects on the groundwater regime. Therefore, transmissivities computed utilizing this method must be considered less reliable than transmissivities computed utilizing the other methods described above.

In fractured rock media, it is possible to have the transmissivities vary several orders of magnitude from point to point. This is due to the variance in continuity and size of the fracture. The results of the transmissivity calculations show a range in values that would be expected for a fractured rock media. The actual transmissivity of a specific water bearing fracture is probably within the reported range.

RIVER LEVEL RESPONSE

The Niagara River fluctuates several feet on a daily cycle during part of the year in response to the removal of water by the New York Power Authority. The cycle varies depending on the time of year. After November 1st, a minimum river flow is maintained and only small adjustments in the river stage are made to maintain this flow. The response due to changes in the river stage of the groundwater regime in the DuPont Plant site area, was measured in the monitoring wells using a Stevens Recorder. The hydrographs reflect the response of the groundwater regime to river stage changes for selected wells. The change in river stage was recorded concurrently with groundwater stage changes. The ratio of groundwater stage to river stage, at concurrent times, represents the efficiency at which the groundwater responds to river stage changes. The efficiency at a specific monitoring well relates to the ease at which the river stage change is transmitted through the groundwater regime. The degree to which the river stage change is transmitted through the groundwater regime is related to several factors including the hydraulic connection between the two environments and the transmissivity of the specific fracture zone.

The stage ratios for selected monitoring wells (Table 17) and the corresponding stage ratio versus distance from the river plots (Plates 28 through 30) were presented in the previous section. As discussed earlier, under ideal conditions the amplitude of the change in stage would be expected to decease with increasing distance from the river and the lag time at which a river induced groundwater stage change reaches a point in the fracture zone should increase with increasing distance from the river. The graphical plot of the stage ratios versus distance from the Niagara River for the B and CD zones (Plates 28 and 29) exhibit a wide scatter in the ratios. In several cases, monitoring wells at greater distances from the river have larger stage ratios than monitoring wells closer to the river. The disparity in the B and CD zone stage ratios suggest that the influence of the river is not consistent across the plant site. This is likely due to differences in hydraulic connection and transmissivity of the fracture zone.

The stage ratio plots for the D and F zone exhibit near vertical trends. In these zones, there is essentially no attenuation of the wave form as it propogates through the fracture zone. The monitoring well efficiencies for this zone exceed 50 percent.

In summary, the influence of the Niagara River on the groundwater regime in the DuPont Niagara plant site varies within fracture zones as well as between fracture zones. The responses of the B and CD zones suggest that the hydraulic connection between the two environments varies and/or that the hydraulic properties of the fracture zones vary horizontally. The response of the D and F zones suggest good hydraulic connection between the two zones as well as in the horizontal direction within the fracture zone.

GROUNDWATER CONDITIONS

As previoiusly discussed, groundwater levels were measured at selected wells at concurrent times during the August and October pump tests. The water levels were measured typically within 1.5 hours to minimize river stage influences. During the August pump test, water level measurements were collected prior to the beginning of the step-up pump test and at the conclusion of the step-up pump. During the October pump test, water level measurements were collected prior to the start of the recovery test and at the conclusion of the recovery test. The water level measurements were utilized to construct groundwater contour maps as presented on Plates 31 through 44. The data utilized are listed in Tables 18 and 19.

Note that the groundwater contour maps are constructed for water levels from the same fracture zone. The monitoring well boring logs were reviewed (Appendix B) and fracture elevations cross-checked. In addition, selection of water levels in fracture zones with the same elevation was based on comparison with slug test data, pumping influence data and well geometry. The following discussion describes in detail the analyses required to formulate our conclusions as to when and how to utilize groundwater data from any given monitoring well.

The monitoring wells were designated by fracture zones (A, B, C, etc.) and were generally screened or completed at about the same elevation. However, detailed review of the several factors influencing the geohydrologic conditions altered some of these zones, monitoring well 17B is identified as a CD zone monitoring well based on fracture elevation. Monitoring well 16B has a major water-bearing fracture elevation consistent with the C zone, but the water levels in 16B fit the B zone. Geologic section B-B' (Plate 7), which included well 16B, shows several minor fractures. Based on this information, 16B is used as a B-zone monitoring well with the understanding that it may be influenced by the C zone.

Monitoring wells 10C and 15C were the only two wells that had fracture elevations consistent with and uniquely related to the C zone. Thus, no groundwater contour maps were generated for the C zone.

Monitoring wells 1C, 4C, 7C, 18C, 5CD and 15CD have fracture elevations consistent with that of the CD zone. Monitoring well 2C has a fracture elevation consistent with the CD zone, but was not used in the construction of groundwater contour maps because the water levels measured were inconsistent and pumping influence generally greater than that found in the zones in the vicinity of 2C. Monitoring well 2C appears to have more direct hydraulic connection with the pumping well than the other monitoring wells in the CD zone.

The D zone monitoring wells are generally consistent with the D zone elevation. Monitoring well 15D was not used because of leakage noted during the October pump test. Monitoring well 14C has a major water bearing fracture consistent with that of the D zone. The response to pumping and slug test results were less than that expected for the D zone. This information suggests that monitoring well 14C has a poor hydraulic connection with the surrounding D zone fracture. Therefore, monitoring well 14C was not used in the groundwater contours for the D zone. The F zone monitoring wells are consistent with the F zone fracture elevations.

GROUNDWATER FLOW DIRECTIONS

Groundwater elevation contour maps shown on Plates 31 through 44 were constructed using the previously discussed data. The elevation contours represent the approximate configuration of the groundwater potentiometric surface for that fracture zone. The elevation contours for the A zone represent the configuration of the unconfined water table surface in contact with the overburden soils and the atmosphere. Horizontal groundwater flow is normal to the elevation contours from areas of higher to lower hydraulic head.

A zone groundwater contour maps were constructed for October 17, 1983 (Plate 31) and October 19, 1983 (Plate 32). Water levels measured in the DEC monitoring wells along the Niagara Parkway were used in the construction of the October 19, 1983 A zone contour map. The configuration of the groundwater surface in the A zone for both data sets exhibit similar trends (see Plates 33 through 36). The groundwater flow direction in the west plant area (west of Gill Creek) is in a radial pattern outward from the central west plant area. Both Gill Creek and the Niagara River probably represent discharge boundaries. Groundwater flow direction in the east plant area exhibits a general northeastward trend, except in the area of monitoring well 8A and DEC well No. 1. In this area a groundwater divide exists. Groundwater flow south of this divide is in a southwest direction. The northeasterly flow of groundwater in the east plant area is possibly being controlled by a groundwater sink to the northeast of the DuPont plant site. The effect of sewers, in the plant site area, on the direction of groundwater flow is not well established. Sewers that act as line sinks to the normal groundwater trends distort the direction of groundwater flow toward the sink. Additional information will be provided after completion of the manmade passageways investigation.

Groundwater elevation contour maps were constructed for the B zone using August, 1983 (Plates 33 and 34) and October, 1983 (Plates 35 and 36) water level data. The configuration of the groundwater levels, in the B zone, exhibited the same general trend for each measuring time. The general direction of groundwater flow in the west plant area is toward the west-northwest. The elevation contours tend to form a radial pattern in the direction of the Niagara River skewed to the east. The configuration of the contour elevations and direction of groundwater flow in the B zone suggests that the Niagara River is a recharge boundary, i.e. flow is from the Niagara River toward the plant site.

Groundwater elevation contour maps for the CD zone were constructed using the August, 1983 (Plates 37 and 38) and October, 1983 (Plates 39 and 40) water level data. The configuration of the groundwater surface for the four data sets is similar. The configuration of the groundwater surface describes a radial pattern north from the Niagara River. The area near Gill Creek defines a flow divide. Groundwater flow direction west of Gill Creek is northwesterly while the flow direction east of Gill Creek is toward the northeast. The groundwater contours exhibit a relatively uniform hydraulic gradient away from the Niagara River. The flow direction suggests that the Niagara River is a recharge boundary. The direction of groundwater flow is being controlled by two hydrologic discharge boundaries. These boundaries are located to the northwest and northeast. The component of groundwater flow to the northwest is being controlled by the Olin production well and to the northeast probably by the Power Authority tunnel excavation.

Groundwater elevation contour maps were constructed for the D zone using the October water level measurements (Plates 41 and 42). Limited data was available for the D zone. The data that was available exhibits the general groundwater flow direction trends noted for the B and CD zone. The general direction of flow is to the northwest and northeast. The monitoring well 15D water levels were not used as has been previously discussed.

Groundwater contour maps for the F zone were constructed using the October, 1983 (Plates 43 and 44) water level measurements. The direction of groundwater flow for the October 17, 1983 data is in a westerly direction east of monitoring wells 15F and 1F and in a northeasterly direction northeast of these monitoring wells. This observation is based on data taken after the Olin production wells were shut down. The direction of flow for October 19, 1983 data is in a northwesterly direction. This observation is based on data taken after the Olin production wells were restarted. This is the general flow direction trend noted in the B, CD and D zones. The flow direction trend for the October 17, 1983 data may represent the F zone before equilibrium was reached with respect to the recovery test.

Subsequent to the October groundwater elevation data presented earlier in the report, groundwater elevation data has been collected on a monthly basis during November and December 1983. Several hydrologic factors influencing groundwater levels in the plant site area have changed after the October measurements and are discussed below. During the November and December measuring period, the river fluctuations were at a minimum. In addition precipitation recharge has also increased. The influence of these hydrologic factors has had a minimal effect on the groundwater levels measured during November and December. The groundwater elevations during this time frame are similar to that observed during August and October. In addition, the configuration of the groundwater table in the A zone and potentiometric surface in the other monitored zones is similar to that presented in this report.

Subsequent to the October pump test monitoring wells were installed in the J zone. The J zone monitoring wells were installed at monitoring well clusters 4, 8 and 15. These wells have open hole lengths that span the contact of the Lockport Formation and Rochester Shale. After well installation, the monitoring wells were developed (between December 1 and 7, 1983). Static water levels for these wells are not available because the water levels have not recovered as of December 21, 1983. The recovery rate of these J wells is slow. Monitoring wells 4J and 15J are recovering at a rate of between one and three feet per day while monitoring well 8J is recovering at a rate of approximately 0.2 feet per day. The slow recovery rates in the J zone indicates that minimal groundwater flow would be expected to occur in the zone of monitoring.

GROUNDWATER FLOW REGIME SUMMARY

The groundwater regime in the vicinity of the DuPont plant site can be described as an unconfined water table regime in the overburden materials and as a leaky confined or "water table fractured rock" regime in the bedrock. The principal source of recharge to the overburden water table regime is the direct infiltration of precipitation recharge migrating vertically to the zone of saturation. Groundwater flow in the zone of saturation is down gradient to discharge points as summarized herein.

Groundwater in the southwest plant area discharges to Gill Creek and the Niagara River. In the east plant area groundwater flow is toward the northeast. The Niagara River does induce water level changes in the monitoring wells along the south side of the plant area and may be a recharge boundary in part of this limited area.

Groundwater flow quantities and velocities across the site were calculated by applying Darcy's law. The flow quantities were calculated using the area halfway between two monitoring wells, the average saturated thickness in this area, the hydraulic gradient determined from the water level elevation contours and the permeability from the slug test results from the monitoring wells. The sections used to estimate the flow volumes are shown on Plate 45. The resultant flows are estimated based on the known conditions at the site. The estimated flow quantities for the overburden water table are listed in Table 20. The estimated flow quantity to Gill Creek between Adams Avenue and monitoring well 1A is 9,300 gpd. The estimated flow quantity to the Niagara River between monitoring wells 1A and 4A is 102,000 gpd. The estimated flow quantity to the southwest, between monitoring wells 4A and 19A is 9,300 gpd. The quantity of flow to the northeast between monitoring wells 7A and 18A is 5,000 gpd. The estimated groundwater velocities in the overburden flow sections are provided in Table 20.

The principal hydrologic controls on groundwater flow in the Lockport Dolomite are (1) the Niagara River, (2) the Olin production wells, (3) an unidentified groundwater sink to the northeast and (4) the regional groundwater flow. The Niagara River is a recharge boundary for the bedrock groundwater regime in the plant site area. Leakage occurs through the river bed and is transmitted to the groundwater regime through vertical fractures. The quantity of leakage from the Niagara River is a function of the hydraulic connection between the two environments and the hydraulic gradient of the groundwater regime. The artificial removal of water by pumping causes an increase in hydraulic gradient in the groundwater flow regime. Theoretically, the increase in gradient will increase the flow rate. Correspondingly, the leakage rate will increase dependent upon the hydraulic connection between the river and bedrock.

The radial zone of influence of the pumping well would be expected to be less in directions other than that toward the river, due to the influence of the recharge boundary. If the Niagara River were not present as a recharge boundary, the Olin production wells would be expected to have a much larger radius of influence. Based on distance recovery data, the zone of pumping influence may extend to distances of 1800 feet in the CD zone, 4400 feet in the D zone and 2800 feet in the F zone. The quantity of groundwater flow in the plant site area influenced by pumping is, therefore, some component of the Olin pump rate. In an isotropic, homogeneous porous media, with no recharge boundary, approximately 25 percent of the Olin pumpage would flow from the DuPont plant site. Because groundwater flow is in a fractured media and a recharge boundary is present, the quantity of groundwater flow from the DuPont Plant site is probably in the range of 25 to 50 percent of the Olin pump rate.

Groundwater flow quantities and flow velocities were estimated for the bedrock flow regime using Darcy's law. The results of the computations are estimates using the available transmissivities and hydraulic gradient data collected during this study. Average transmissivities, calculated using the time-recovery and distance-recovery methods, discussed in a previous section of the report were used in the computation of flow for the CD, D and F zones. The results from the slug tests were used in the computation for the B zone. Insufficient hydraulic gradient data were available for the C, E and J zones to perform the computations. The hydraulic gradients used in the calculations is that from the October 19, 1983 contour maps. These maps represent the configuration of the groundwater potentiometric surface during pumping. Groundwater flow volumes and velocities were computed for flow toward the northwest in the direction of the Olin production wells and toward the northeast. Sufficient data were available to compute the groundwater flow quantities and velocities in the B, CD, D and F zones to the northwest. The width of the flow zone, parallel to the groundwater contours, used in the computation was 1700 feet. The width described a distance from approximately Gill Creek to monitoring well cluster 5. Calculated flow quantities for the component of groundwater flow, in the bedrock, to the northwest using the distance-recovery transmissivities are (1) 15 gpm in the B Zone (2) 177 gpm in the CD zone, (3) 115 gpm in the D zone and (4) 95 gpm in the F zone. The total calculated flow for these zones is 402 gpm (Table 21). The total calculated flow using the time-recovery transmissivities is 253 gpm.

Sufficient data were available for the CD zone to compute groundwater flow quantities and velocities to the northeast. The width of the flow zone is 800 feet from approximately monitoring well cluster 7 to 17. The calculated flow quantity to the northeast in the CD zone is: 72 gpm using the distance-recovery transmissivities and 58 gpm using the time-recovery transmissivities (Table 21).

Calculated groundwater velocities to the northwest ranged from 40 ft/dy in the CD zone to 2 ft/dy in the B zone (Table 21). Calculated groundwater velocities to the northeast in the CD zone were in the range of 35 ft/dy (Table 21). The hydraulic sink to the northeast of the plant site results in bedrock groundwater flow toward a northeasterly direction. The groundwater contours on the east and west sides of the plant describe the same general pattern. This suggests that the quantity of groundwater flow to the northeast is similar to that to the northwest.

The potential for downward vertical groundwater flow exists from the A, B and C zones to the CD or D zones. Conversely, an upward flow potential exist from the E and F zones to the CD or D zones. The potential for flow also exists from the F zone to the J zone as observed at well cluster 1.

The A and B zones did not, to a measurable degree, respond to the pumping tests. The C, CD, D, E and F zones responded to pumping to a varying degree. The CD and D zones exhibited the largest response. These observations suggest that the hydraulic connection between zones A and B and the deeper water-bearing zones is poor. Zones C through F are hydraulically connected as seen in water level fluctuations due to river stage changes, changes in water level due to well development and in the time-drawdown/recovery curves. The quality of the hydraulic connection between these zones will vary due to the heterogenous geologic fabric of fractured rock as previously discussed.

The hydrologic properties and flow quantities described in this section of the report are estimated based on observations made during the course of this study. The heterogenous, anisotropic nature of the fractured rock imparts a degree of uncertainty in describing the groundwater regime. The estimate of groundwater flow quantities, flow direction and transmissivity are probably within the range of values expected for fractured rock media. As additional information becomes available, it may be necessary to refine these estimates.

CONTAMINANT TRANSPORT

ANALYTICAL RESULTS

During the period of January through May 1983, chemical analyses were performed on groundwater samples obtained from monitoring wells installed by the USGS for NYSDEC along the north side of the Niagara Parkway. The locations of these wells are shown on Plate 2. DEC monitoring wells were installed, sampled, and analyzed with the intention of providing water quality data for groundwater at the overburden/bedrock interface. The results of the analyses, for specific compounds, are presented in Table 22. No data for the DEC wells were available beyond the May of 1983 sampling.

DuPont initiated a study of the Niagara Plant site geology and groundwater. Sampling and analyses at the associated monitoring wells began in June 1983. Sampling and analyses were conducted periodically as the monitoring wells were installed and developed. Initial sampling was, therefore, limited to two areas, well cluster locations 1 and 21 as shown on Plate 2. Well cluster location 1 contained seven wells at that time and these had been installed to monitor different depth intervals. These fracture zones were A, B, C, D, E, F and G as described in previous sections of this report. Well cluster location 21 contained only one well, a shallow (A-type) well.

In September and October 1983, groundwater samples were obtained from a total of 38 monitoring wells that had been installed and developed in the general plant area. Although initial analyses were performed for all priority pollutants, subsequent analyses have been made for specific indicator parameters, which include both DuPont-related and non-DuPont-related compounds. The results of the indicator parameter chemical analyses, which have been provided to date, have been grouped with respect to volatile organic compounds (Table 23) and pesticides/PCB's, phenolics and inorganic compounds (Table 24). Of the total 15 indicator parameters, four are considered to be non-DuPont related. These four non-DuPont related compounds are: benzene, chlorobenzene, BHC's, and phenolics.

ASSESSMENT OF ANALYTICAL RESULTS

DUPONT VOLATILE ORGANIC COMPOUNDS: Based on the results of the chemical analyses for the DuPont-related volatile organic compounds (Table 24, excluding benzene and chlorobenzene), concentration values for any given parameter can be seen to range from below detectable limits up to thousands of parts per million (ppm) within the general plant area. At a given monitoring well, similar, but less dramatic, variations over time can be observed. The presence of second phase fluid would account for the wide range of analytical results that have been reported. The solubilities of the compounds, as measured under laboratory conditions, range from a low of 150 ppm for tetrachloroethylene to a high of 20,000 ppm for methylene chloride (Table 25). Although the concentration of any specific compound at the DuPont site has not exceeded its specific solubility, it is generally considered that if the concentration of a volatile organic compound in a field sample is about 10 percent of the laboratory solubility, the compound could very likely be present as a second phase fluid. Based on field reports during monitoring well installation and during groundwater sampling operations, second phase fluid was observed to exist in the groundwater at a number of monitoring locations within the plant area. Consequently, the analytical data from those areas and wells that contain second phase fluid cannot be used directly to assess the specific quality of the groundwater. This is not to say that contaminants do not exist, rather, that the data represent at least a partial assay of the chemical composition of the second phase fluid.

To illustrate the relative distribution of the volatile compounds, the chemical analytical data for the October sampling were plotted for each compound at each sampling point. The results are shown on Plates 46 through 52. A comparison of these plots suggests a non-uniform distribution of chemical compounds. Trans-1,2-dichloroethylene (Plate 47) appears to be the most pervasive throughout the site; 1,1,2,2-tetrachloroethane (Plate 50) the least. Such a distribution would not be unexpected based on the locations of previous processes and events at the plant site. Based on available historical information, the locations of various processes and events are shown on Plate 53. Compared with the plots of the individual compounds, correlations between process/event areas and monitoring well locations appear to be evident. The major trichloroethylene and tetrachloroethylene processes were located in the vicinity of well clusters 8 and 9, and 13 and 14. The relatively high levels of volatile organic compounds at well cluster 1 are likely attributable to materials that had been disposed in a pit (commonly referred to as 107 tank farm pit or B-107 landfill) in the immediate vicinity of well cluster 1. Removal of contaminated materials from this area was performed in 1980/1981 and, according to the report issued by DuPont, the major organic compounds in the waste material consisted of tetrachloroethane, tetrachloroethylene and trichloroethylene.

To provide a conceptual plan view of the relative degree of contamination, the data from the October sampling of the A wells were plotted for total C-2 and total C-1 compound concentrations using a concentration contour format. The C-2 compounds were organic compounds that contain two carbon atoms in the molecular structure and are considered to be tetrachloroethylene, trans-1,2-dichloroethylene, trichloroethylene, vinyl chloride, and 1,1,2,2-tetrachloroethane. The C-1 compounds contain one carbon atom and were considerd to be chloroform and methylene chloride. The apparent concentration contours that were developed for the C-2 compounds are shown on Plate 54, and the C-1 compounds are shown on Plate 55. Because of the presence of second phase organics fluid, the contours do not represent actual groundwater quality conditions, as has been previously discussed, nor do they necessarily represent any actual distribution pattern of second phase fluid. Based on a review of the available analytical data and the characteristics of the organic compounds, it is believed that, for the C-2 compounds in the A zone, second phase fluid likely exist at wells 1A, 13A, 14A, 15A and 21A in the western portion of the site, and at wells 8A and 10A in the eastern portion of the site. At the other locations, it is believed that the compounds are dissolved in water and, therefore, the analytical results could be considered to be representative of the quality of the groundwater.

The C-1 compounds appear to be limited primarily to the western part of the site. Because of the high solubilities of methylene chloride and chloroform (Table 25), it is likely that the C-1 compounds are not present as a second phase fluid. However, it is possible that the C-1 compounds are dissolved in the second phase C-2 compounds, where they exist, as well as in the groundwater. Consequently, representative groundwater quality conditions for C-1 compounds contamination would likely be limited to the same wells as those for the C-2 compounds.

Somewhat different conditions exist at depth as shown on Plate 56. However, because the conditions are more inherently related to contaminant transport conditions, the discussion is presented below in the contaminant transport section of this report.

DUPONT ORGANIC COMPOUNDS: Analyses for indicator parameters included PCB compounds which were considered to be DuPont-related. Based upon the analytical results, only three PCB compounds (1248, 1254 and 1260) were detected in any of the wells at any time (see Table 24). PCB-1248 was detected in monitoring wells 12A and 12B, with the highest concentration (0.025 ppm) being detected in 12B during the October, 1983 sampling. Well cluster 12 is located to the south of the former Building (Bldg) 310 site, where voluntary restoration activities had been performed by DuPont for removal of PCB-contaminated materials (DuPont report - 29 December 1981). PCB-1248 was associated with the process at this site. Observations made during the course of the restoration work indicated that a portion of the building foundation was situated directly on top of fractured rock and that contamination could have migrated into the fractured rock. Based on this information, the PCB-1248 found in 12A and 12B may be associated with the former Bldg 310 site. No other possible DuPont-related source of PCB-1248 has been identified. PCB's that were not necessarily DuPont-related were reportedly previously detected in the sediment in Gill Creek. The sediment was removed as part of the Gill Creek Restoration project, but may also represent a contributing source of PCB's.

PCB-1254 was detected in the well cluster 1 area, but only in well 1C. The concentration of PCB-1254 was reported to be 0.110 ppm and 0.044 ppm for September and October, 1983 samplings, respectively. There is no information to specifically link PCB-1254 with any DuPont-related operations. As previously discussed, Gill Creek may have been a contributing source. However, it is not possible to establish the source of the PCB-1254 with any degree of confidence.

PCB-1260 was reported to have been detected in well 8B. However, the concentration was 0.00016 ppm in September, 1983 and below the detection limit of 0.00010 ppm in October, 1983. Because the September value was close to the detection limit, the available data do not provide statistically significant evidence that PCB-1260 is, in fact, present.

DUPONT INORGANIC COMPOUNDS: Soluble barium was detected in virtually all the wells sampled to date (Table 24). The concentrations of soluble barium have ranged from 0.03 ppm to 0.68 ppm.

Soluble copper was detected at wells 15A (ranging from 0.06 to 19 ppm) and 15C (2.4 ppm). This well cluster is in the immediate vicinity of former Bldg 57, which produced copper cyanide and zinc cyanide, and, consequently, was the likely source of the copper detected in the monitoring wells.

Cyanide has been detected at eight well cluster areas, with concentrations ranging from 1.1 ppm to 61 ppm. The highest concentrations have been reported at well cluster 8 and well cluster 16. Apparent concentration contours were constructed using the October, 1983 sampling data for the A and B wells, and are presented in Plates 59 and 60, respectively. The apparent contour patterns suggest the presence of discrete "hot spots" in the area. Well cluster 16 is located in the immediate vicinity of Bldg 44 (see

Plate 53), which formally produced sodium cyanide, and, therefore, could be considered to be the likely source of the cyanide that has been detected in the western portion of the plant site. In addition, some of the cyanide may also be attributable to previous metallic cyanide processes in the vicinity of well cluster 15. Although a cyanide wash area and a cyanide sludge weathering area have been reported to have existed in the area of well clusters 4 and 6, no apparent impact of significance is evident in the analytical results from these wells. In the eastern portion of the site, processes involving cyanide were used, in the past, in and around Bldg 403S, which is in the immediate vicinity of well cluster 8. It has also been reported that this general area had been subject to brine and organics leaks due to pipe failures. The former processes, and associated problems, were the likely sources of cyanide detected in the A and B wells in this area.

NON-DUPONT VOLATILE ORGANIC COMPOUNDS: Of the nine volatile organic indicator parameters, benzene and chlorobenzene are considered to be unrelated to any DuPont processes. Benzene and chlorobenzene have been detected at a limited number of monitoring wells, primarily in the eastern portion of the site, as depicted on Plates 57 and 58, prepared using October, 1983 sampling data. The highest concentrations of benzene have been consistently found in well cluster 8 (Table 23). Relatively elevated concentrations of benzene and chlorobenzene have also been reported, on occasion, at well clusters 10 and 18. Chlorobenzene has also been reported at well clusters 10 and 18. Because benzene and chlorobenzene are often associated, it is possible that a source of these two compounds exists in the vicinity of well clusters 10 and 18. However, chlorobenzene has not been detected at well cluster 8. This would suggest that either the benzene and chlorobenzene are not related, or there is an alternate source of only benzene in the vicinity of well cluster 8.

Based on the solubilities of the two compounds and the reported concentrations from the well samples, it is likely that the benzene and chlorobenzene are not present as second phase fluids.

NON-DUPONT ORGANIC COMPOUNDS: The groundwater monitoring indicator parameters have also included hexachlorocyclohexane isomers (BHC's) and total recoverable phenolics, neither of which has been reported to be associated with any DuPont processes to date. BHC's have been detected in almost every monitoring well, although concentrations have generally been less than 1 part per billion (ppb), as shown in Table 24. However, relatively high total BHC concentrations have been detected in certain areas with the higher concentrations being found in the deeper B, C and D wells. The highest total concentration (499 ppb) was found in well 1C. As shown in Plate 61, these areas are around Well Clusters 1, 10, 12, 14, 15, 16, 18 and 19, which are located along the northern site boundary (along Adams Avenue) and along Gill Creek. The anomalously high concentrations in these different areas would tend to suggest that, in addition to the general presence of BHC's in the overall area, there may have been some specific source or sources. For example, because of a downward hydraulic gradient, Gill Creek may be a contributing recharge to the bedrock groundwater and any BHC's in Gill Creek could be transported into the bedrock. However, it is not possible to establish the source of BHC's with any certainty from the available data.

Total recoverable phenolics have been detected in approximately half of the well cluster locations. With the exception of one measurement, the concentrations of the phenolics, where detected, have been consistently below 1 ppm, and generally below 0.1 ppm. As shown in Plate 62 for the October, 1983 sampling, there is no readily apparent pattern to the presence or absence of the phenolics. However, phenol can be associated with benzene and chlorobenzene, which have been detected in the ppm range in the eastern part of the plant site. Although some such correlation may exist in the eastern part, the same possible association does not appear to exist in the western part.

ASSESSMENT OF CONTAMINANT TRANSPORT CONDITIONS

Transport of contaminants at the DuPont site, because of the presence of two liquid phases, is a complex process that is governed by a number of factors. The movement of chemical compounds that are dissolved in water is governed primarily by the groundwater flow regime. The movement of second phase organics, which, at this site, are denser (heavier) than water (Table 25), results from more geologic structure control than control by the groundwater flow regime.

SECOND PHASE FLUID TRANSPORT

The primary driving force of the second phase organic fluid is gravitational. Because the compounds are heavier than water, the movement can be opposite the groundwater flow direction, both vertically and laterally, if the force of groundwater flow (velocity) is insufficient to offset the force of gravity upon the second phase fluid. The path of least resistance would be defined by the size and degree of interconnection of the interstices in the subsurface materials. As interstitial space decreases, resistance to movement due to capillary forces increases. Although a highly circuitous pathway can readily be dictated, the net direction of movement would be downward. However, because of the net downward movement and because of the degree of control that can be exerted by the geologic fabric, the second phase fluid can also become trapped.

A ZONE CONTAMINANT TRANSPORT CONDITIONS: As discussed in a previous section, second phase fluid exists in areas in the A monitoring zone, which is intended to monitor the upper part of the bedrock. Assuming that sources have been from above the top of the bedrock, migration patterns to the bedrock would be controlled by the physical characteristics of the overburden. Depending on the degree of vertical fracturing of the bedrock and the size of the fractures, migration at the bedrock/overburden interface could be vertically downward, along the top of the rock (if an adequate slope exists), stopped, say in a depression, or any combination of the above. Assuming that the process/event areas depicted in Plate 53 represent the only sources of DuPont-related compounds that are present in second phase, an assessment of possible migration pathways can be made. Well 14A is located in the immediate vicinity of a former C-2 solvent process area. Wells 13A, 15A and 21A have also exhibited second phase C-2 compounds. Referring to Plate 11 (top of bedrock structure map), the slope of the top of rock appears to be towards wells 13A and 21A, which would be a potential migration pathway and could account for the presence of the second phase C-2 compounds at these monitoring locations. Although well 15A appears to be up-slope of 14A, with respect to top of bedrock, lateral migration to the west could have occurred due to the characteristics of the overburden. The second phase compounds that have been noted at well 1A may be related to the former 107 landfill, as previouisly described, although a potential pathway along the top of the rock appears to exist between well 1A and wells 13A and 21A, and could be a contributing source.

Based on the available data, it cannot be ascertained with any certainty if lateral migration of second phase fluid is occurring at the overburden/bedrock interface. Because of the scatter in analytical results that can occur when water samples containing second phase organics are analyzed, apparent temporal variations in analytical results cannot be assumed to represent changes in contaminant flux. The apparent absence of second phase fluid in wells 2A, 3A and 16A, which are located along a potential migration pathway (with respect to the slope of the top of bedrock) from wells 13A and 15A, would tend to suggest that migration would be occurring at a relatively slow rate, if at all. A similar situation would appear to exist in the eastern portion of the site, with respect to wells 7A, 8A and 18A. However, because there are other controlling factors, such as variations in the physical characteristics of the overburden or man-made passageways, a resultant pathway could by-pass the existing monitoring points.

DEEPER BEDROCK CONTAMINANT TRANSPORT CONDITIONS: Because of vertical fracturing in the bedrock, pathways exist for downward migration of second phase fluid into deeper portions of the bedrock. However, the degree and amount of vertical fracturing is variable, as is the distribution of second phase organics. In addition, horizontally-oriented joints and fractures can intersect vertical fractures and can provide an easier pathway in a more lateral direction. Consequently, the downward migration pattern of the second phase fluids resembles a three-dimensional maze.

Based on a review of the available analytical data, it appears that second phase fluid exists in the B zone monitoring interval at well cluster locations 1, 3, 8, 12 and 16. However, as previously discussed, second phase fluid in the overlying monitoring zone appears to exist at well cluster locations 1, 8, 13, 14, 15 and 21. Consequently, at well cluster locations 3, 12 and 16, it would appear that either an overlying source existed in the past, but has since dissipated, or second phase fluid migrated down and away from the existing, shallow second phase areas. Because the regional dip of the bedrock is to the south, as explained in a previous section, a migration component to the south along horizontally-oriented fractures would be expected to exist. However, the regional dip is relatively small and the resulting gravitation component is also small. Further, the groundwater flow pattern is to the north, which would provide a resultant resisting force to migration. Based on the existing data, there is no evidence to indicate that migration is occurring to the south at present. Based on the period of record, wells that did not exhibit second phase fluid during the initial sampling have not exhibited second phase fluid during the most recent sampling event. Assuming that migration did occur in the past, which produced the results observed at present, one additional driving force could likely have been periodic releases of organics into the subsurface, which could have increased the pressure head on the existing organics, thereby resulting in migration. Without additional input, migration could have ceased. Another driving force could have been a result of previous pumping at DuPont's production wells, located in the southwestern part of the site, near existing monitoring well cluster location 4. During pumping, induced changes in hydraulic gradient and increases in groundwater flow velocities towards the pumping well could have had an effect on the movement of the organics. Alternately, the existing period of analytical record may not be adequate, with respect to the time interval, to assess the potential for slow migration.

Based on the existing data, it appears that second phase organics have migrated downward to the C and CD monitoring interval, but not beyond. Initial analytical data for a complete vertical profile at one location was limited to well location 1. A plot of the October, 1983 sampling data versus depth is presented on Plate 56, which illustrates the significant decrease in apparent concentrations below the C fracture monitoring zone, which suggests that vertical fracturing is inadequate for downward migration of second phase in this area.

Additional data, which was recently received, provided November analytical results for deeper bedrock intervals at well cluster locations 2, 5, 10, 14 and 15. However, at location 2 there are no wells below the CD zone. The November analytical results are presented in Table 26 for the indicator parameters. Because the shallower wells at these locations were not sampled at the same time as the new deeper wells, data from previous sampling periods were included to provide some basis for comparison. The results of the analyses suggest the presence of second phase organics at 2C and 15C/D. The results from well cluster 15 also suggest that second phase organics exist at the D and F zones. However, the data from well cluster 15 may reflect the effects of potential cross-contamination during sampling. It has been reported that a J well was being installed and that, at the time of sampling, drilling operations were suspended to allow samples to be obtained from the other wells. During this time, an open hole existed through the bedrock sequence at the J well site and contaminants could have migrated into the borehole. When adjacent wells were purged, the resultant head differential would have provided a driving force for the contaminated water to move from the J hole to the other wells. The data from the D and F wells appear similar to the data for the CD well with respect to the C-1 and C-2 compounds.

Well 15CD, 15D and 15F were subsequently resampled. In addition, well 15J was sampled for the first time. The results of the analyses are presented in Table 27. Well 15J appears to indicate the presence of second phase organics fluid. The apparent concentrations of organic compounds in wells 15D and 15F appear to indicate a general decrease with respect to the initial sampling. These data appear to confirm that cross-contamination during drilling did occur as discussed. Additional purging of these wells is recommended to try and remove this non-representative contamination.

SOLUBILIZED CONTAMINANT TRANSPORT

The migration of contaminants that are dissolved in the groundwater would be controlled primarily by the groundwater flow regime. As has been explained in more detail in a previous section of this report, both lateral and vertical components of groundwater flow exist beneath the plant site. In the shallow groundwater regime, the general lateral flow pattern appears to be radial with groundwater discharging to Gill Creek from either side of the plant site, to the Niagara River, and to areas to the west and northeast for the western and eastern portions, respectively. There is also a downward component of flow to the deeper bedrock zones.

In the deeper bedrock zones, the horizontal flow patterns are primarily towards the northwest, reflecting the influence of the Olin production wells. However, in the northeastern part of the site, the flow pattern appears to be to the northeast. Major recharge to the bedrock aquifer appears to be from the Niagara River. However, some recharge is also being contributed through vertical components of groundwater flow. The hydraulic gradients derived from measurements at the wells indicate the potential for downward flow from the upper zones to the D zone, which appears to be the major water-bearing zone. Conversely, the hydraulic gradients from the zones below the D zone indicate a potential for upward flow to the D zone.

The downward components provide the means for contaminants to penetrate to deeper zones, as is reflected in the analytical data. In addition, groundwater flowing in the areas of second phase fluids can promote dissolution of the second phase fluid, which would increase the concentration of the contaminants in the groundwater. Consequently, the second phase organics can constitute a source of groundwater contamination.

Although the mechanism for solubilized contaminant transport of the DuPont-related compounds is apparently evident downward to the D zone, contaminants exist in the water-bearing zones below the D zone. Because there exists an upward flow gradient from the deeper zones into the D zone, the presence of contaminants below the D zone would appear to be contradictory to the upward flow. However, there is evidence that cross-contamination is known to have occurred at well cluster location 1. The original cluster included a well designated as 1G. The results of the initial sampling indicated high levels of contamination and the presence of second phase fluid (see Table 23). It was discovered that the upper casing was leaking from an area in the vicinity of the C zone. The well was subsequently grouted and abandoned. Because of the cross-contamination that occurred, including the inflow of second phase fluid, the existing deep wells 1E, 1F and 1J are believed to be still reflecting the impact of the cross-contamination, based on the apparent trend of decreasing concentrations with time for the parameters associated with the 1C monitoring zone.

Contaminants have also been detected in the deeper zones at well cluster locations 10 and 15. Although wells 15D and 15F may have been cross-contaminated, as previously described, the concentrations of some compounds at depth do not appear to be consistent with concentrations in the shallower monitoring zones. In addition, wells 10D and 10F also appear to exhibit some inconsistent contaminant concentrations with respect to direct cross-contamination. It is possible that these wells are exhibiting the effects of the cross-contamination that occurred at well cluster location 1. That is, contaminants introduced into 1G may be migrating laterally in the deeper bedrock zones and are being detected in the other deep wells. Because of the random pattern of interconnected horizontal and vertical fractures, the pathway of groundwater flow cannot be expected to be direct. Rather, the actual flow path would describe a tortuous route, both vertically and laterally. The apparent concentrations of C-2 compounds and the concentrations of BHC's (total 407 ppm - see Table 24) that were detected in well 1G would tend to give support to this concept. There are likely other sources, such as the Niagara River, which recharges the deeper zones, that may be contributing contaminants.

CONTAMINANT LOADING

Because it cannot be ascertained with any certainty if the second phase fluid is actively migrating, no estimate of contaminant loading due to second phase movement can be made. Consequently, contaminant loading estimates were limited to the solubilized contaminants.

SHALLOW FLOW REGIME: For the shallow groundwater regime, estimates were made of contaminant loadings to the Niagara River and to Gill Creek along a section described by wells 21, 1, 2, 4 and 5 (see Plate 45). A section described by wells 7 and 18 was used to estimate contaminant loadings to the northeast. The loadings are based on groundwater conditions on 19 October 1983 and using the analytical data for October, 1983 sampling, except for well 5A, where it was necessary to use September, 1983 data. Because groundwater flow conditions and chemical concentrations are subject to variations, these estimates are provided only as a general assessment of contaminant loadings. Loadings were calculated using estimated groundwater discharges, as described in a previous section of this report, and assuming that the concentration of a specific parameter was constant to a point halfway between the given monitoring well and the next monitoring well on the section line. For example, the concentration of chloroform at well 2A was assumed to be constant in the shallow aquifer to the mid-point between wells 2A and 4A, and 2A and 1A, at which point the concentration of chloroform was assumed to be that of either 4A or 1A.

Based on the above method, the total loading of organic compounds directly to the Niagara River was estimated to be on the order of 4 pounds per day (lbs/d), of which C-2 compounds contributed on the order of 1 lb/d, and the C-1 compounds contributed on the order of 3 lbs/d. The individual compound loadings are presented in Table 28. The estimates for the C-2 compounds are on the low side because of the presence of second phase fluid at 1A. However, assuming that the concentrations represented actual water quality conditions, the resultant C-2 compound loading was estimated to be on the order of 4-1/2 lbs/d, yielding a total organic loading estimate on the order of 8 lbs/d. The total BHC loading was estimated to be on the order of 10^{-4} lbs/d; phenolics, 10^{-2} lbs/d; and cyanide, on the order of 1/2 lb/d.

Along Gill Creek, the total organic loading was estimated to be on the order of 3 lbs/d, excluding second phase fluid. Using the second phase concentrations, the total loading estimate becomes on the order of 9-1/2 lbs/d; approximately 7 lbs/d for C-2 compounds and 2-1/2 lbs/d for C-1 compounds. Total BHC loadings were estimated to be on the order of 10^{-5} lbs/d; phenolics, 10^{-2} lbs/d; and cyanide, 10^{-2} lbs/d. Note that the Gill Creek loadings would be expected to contribute to the total Niagara River loadings.

Based upon the limited geohydrologic data along the southern boundary of the eastern part of the site, a concept of the order of magnitude of the total direct loading to the Niagara River was made by assuming the groundwater discharge to be 85,000 gpd (the highest value on the western side) and assuming the concentration of contaminants to be the same as reported for DEC well 2 for the May sampling (Table 22). Based on these assumptions, total volatile organic compound loading was estimated to be 0.2 lbs/d. Loadings for BHC's were estimated to be 0.002 lbs/d; for cyanide, 0.23 lbs/d.

For the plant site, the estimated total direct loading to the Niagara River would be on the order of 7 lbs/d for C-1 and C-2 compounds, excluding second phase, and on the order of 17 lbs/d for C-1 and C-2 compounds, including second phase data. Because of a lack of groundwater data along the southern boundary of the eastern part of the site, loading estimates could not be made.

Total loadings to the northeast quadrant of the plant site were estimated to be on the order of 10^{-3} lbs/d for organics; 10^{-5} lbs/d for total BHC's; 10^{-3} lbs/d for phenolics; and 10^{-2} lbs/d for cyanide.

BEDROCK FLOW REGIME: Based on the groundwater flow estimates in the bedrock zones, which were described in a previous part of this report, the contributions to the Olin production wells from beneath the DuPont plant site were estimated to range from about 140 to 175 gpm for the CD zones, 50 to 115 gpm for the D zone, and 50 to 95 gpm for the F zone. To estimate the loading to the northwest, the analytical data for the deep wells at well cluster location 15 is necessary. However, because of apparent cross-contamination and the presence of second-phase fluid, the available data from well cluster location 15 were not used for estimating loadings. To provide a concept of the loading that could be occurring, it was assumed that the concentrations of compounds observed at wells 5CD and 5F are representtive of the concentrations in the groundwater moving to the northwest. Assuming a discharge of 175 gpm for the CD zone, the estimated total loading of volatile organics would be about 3 lbs/d. Similarly for the F zone, the estimated loading would be about 1/2 lbs/d. Because a number of compounds were not detected at well location 5 but would be expected at well location 15, the total volatile organic loading may be higher than the estimate of about 4 lbs/d.

Groundwater discharge to the west-northwest was estimated to be about 15 gpm in the B zone. Loadings to the northwest were estimated based on October sampling results for well 19B. The loading of C-2 compounds was estimated to be about 1-1/2 lbs/d, and the C-1 compounds to be about 5-1/2 lbs/d. For an estimate of loadings toward the west, well 5B was used. These loadings were estimated to be about 1 lb/d for C-2 compounds and 10^{-4} lbs/d for C-1 compounds. The total volatile chlorocarbon loading in the western part of the site, then, may be on the order of 8 lbs/d.

To provide another concept of the loading that could be occurring, it was first assumed that all the organic compounds at the Olin well were attributable solely to the DuPont site. Based on information in the Olin report, the total organic concentration in the well water in February 1983 was approximately 2.4 ppm. Assuming the concentration to be the same and assuming a pumping rate of 2,000 gallons per minute, the total loading to the Olin production wells from DuPont would be on the order of 50 lbs/d. Based upon the geohydrologic conditions previously discussed, the estimated flow from the DuPont site to the Olin production wells is approximately 50 percent of the total pumpage. Utilizing this estimate, the resulting loading to the Olin production wells from the DuPont Plant site could be on the order of 25 lbs/d.

The radius of influence of the Olin production wells does not affect the entire DuPont plant site. The component of flow to the northeast from the northeast portion of the DuPont site would be expected to be at a similar discharge rate as that to the northwest because of similar hydraulic gradients. However, because total compound concentrations are lower, total loading would be expected to be lower. Because the monitoring wells in the northeast section only extend to the CD zone, which is estimated to have a discharge in the range of 60 to 75 gpm, loading estimates could only be performed for the CD zone, using analytical data from well 17B, which is actually a CD-type well. The resultant estimated total volatile organic loading would be about 0.08 lb/d. Because there are no wells in the B zone, no estimate of the contribution from this zone could be made. Nonetheless, the total loading through the bedrock regime would be expected to be less than the loadings estimated for the northwest part of the site.

SUMMARY AND CONCLUSIONS

An investigation was undertaken on the DuPont Niagara Plant site to evaluate the presence and movement of suspect chemical contaminants in the overburden and groundwater flow regimes. The DuPont Niagara Plant site is underlain by unconsolidated overburden deposits consisting of fill, alluvium, glacial till and glacial lake deposits. Beneath the overburden soils the site is underlain by the fractured dolomite of the Lockport Formation. Beneath the Lockport Formation extending beyond the limit of these investigations is the Rochester Shale.

Groundwater in the area of the DuPont Niagara Plant site is encountered in both the unconsolidated overburden soils and the underlying bedrock. The source of groundwater for flow in the overburden in the vicinity of the Niagara Plant Site is from direct infiltration of precipitation. The source of groundwater for flow in the underlying Lockport Formation is from induced infiltration of water from the Niagara River and, to a lesser extent, leakage downward from the overlying overburden groundwater flow regime. Groundwater flow in the overlying overburden zone discharges toward Gill Creek and the Niagara River. In contrast, flow in the underlying fractured bedrock is from the Niagara River towards the Olin production wells northwest of the site and towards an unidentified groundwater discharge area to the northeast of the site, probably the power intake tunnels.

Based upon the data available regarding contamination concentrations and groundwater flow direction and quantity, the total organic loading directly to the Niagara River through the shallow overburden zone is estimated to be on the order of nine pounds per day. Along Gill Creek, the total organic loading is estimated to be on the order of three pounds per day. Note that the Gill Creek loadings would be expected to contribute to the Niagara River loadings. The effect on the Niagara River, which flows at the minimum rate of 50,000 cu.ft./second, is expected to be negligible. The total loading to the Olin production wells from flow in the underlying bedrock may be on the order of as much as 50 pounds/day. The percentage of this derived from the DuPont Niagara Plant site cannot be determined. Since the Olin production wells are receiving water radially, the amount of loading coming from the DuPont Niagara Plant site in relationship to other off-site sources is not defined. Contaminant loadings to the northeast from the DuPont

Niagara Plant site through the bedrock groundwater system are estimated to be on the order of 25 pounds/day. It can be conservatively assumed that, based upon regional groundwater flow patterns, contaminants leaving the DuPont Niagara Plant site are expected to eventually contribute to the Niagara River loadings. Note that contaminant loadings are considered "order of magnitude" numbers and are based upon the data generated for this study. Additional limitations regarding the data are described in detail in the report.

In summary, the study described herein has satisfied the original groundwater study plan objectives to:

- Determine groundwater flow rate and direction within the Lockport Formation and the overlying unconsolidated soils.
- Determine groundwater quality.
- Assess contaminant flow into and out of plant boundaries.
- Develop a base of information to analyze, recommend and begin design of any potential remedial action.

LIMITATIONS

The findings and conclusions presented in this report are based upon the interpretations developed from the available geologic, subsurface and groundwater chemistry data. These findings and conclusions are subject to confirmation and/or revision as additional information becomes available. Factors which influence the utilization of the data have been discussed in this report and local anamolies should be expected. Note that estimates of groundwater flow and contaminant loading should be considered "order of magnitude" and could be expected to vary from the estimates provided.

SUMMARY GLOSSARY OF GEOLOGIC TERMS

ARGILLACEOUS: Pertaining to, largely composed of, or containing clay-size particles or clay minerals such as "argillaceous ore" in which the gangue is mainly clay.

CONFORMABLE: Said of strata or stratification characterized by an unbroken sequence in which the layers are formed one above the other in parallel order by regular, uninterrupted deposition under the same general conditions; also said of the contracts (abrupt, gradational, or intercalated) between such strata.

CRINOIDAL LIMESTONE: A limestone consisting almost entirely of the fossil skeletal parts of crinoids.

GLACIAL DRIFT: A general term for material transported by glaciers and deposited directly on land.

GLACIOLACUSTRINE: Pertaining to, derived from, or deposited in glacial lakes.

INTERCALATED: Said of layered material that exists or is introduced between layers of a different character.

ISOPACH MAP: A map that shows the varying true thickness of a designated stratigraphic unit.

ISOSTATIC REBOUND: The adjustment of the crust of the Earth to maintain equilibrium among units of varying mass and density.

LITHOLOGY: The physical character of a rock.

PERIGLACIAL: Said of the processes, conditions, areas, climates, and topographic features at the immediate margins of former and existing glaciers and ice sheets, and influenced by the cold temperature of the ice.

SACCAROIDAL: Said of the crystalline granular texture seen in some dolomites in which the constituent crystals are well-developed and of approximately uniform size.

SOLUTIONING: A process of chemical weathering by which rock material passes into solution; e.g. the dissolution and removal of the calcium carbonate in limestone by carbonic acid derived from rainwater containing carbon dioxide acquired during its passage through the atmosphere.

STRATIGRAPHY: The arrangement of strata, esp. as to geographic position and chronologic order of sequence.

STRUCTURE CONTOUR MAP: A map that portrays subsurface configuration by means of structure contour lines.

STYLOLITE: A thin seam or a surface or contact usually occurring in "pure" or homogeneous carbonate rocks (certain limestones, and dolomites), marked by an irregular and interlocking or mutual interpenetration of the two sides, the columns, pits, and teeth-like projections on one side fitting into their counterparts on the other.

TECTONIC DEFORMATION: Movement of the crust produced by Earth forces, including the formation of ocean basins, continents, plateus, and mountain ranges.

TILL: Unsorted and unstratified drift, generally unconsolidated, deposited directly by and underneath a glacier without subsequent reworking by water from the glacier, and consisting of a heterogeneous mixture of clay, sand, gravel, and boulders varying widely in size and shape.

UNCONFORMITY: A substantial break or gap in the geologic record where a rock unit is overlain by another that is not next in stratigraphic succession.

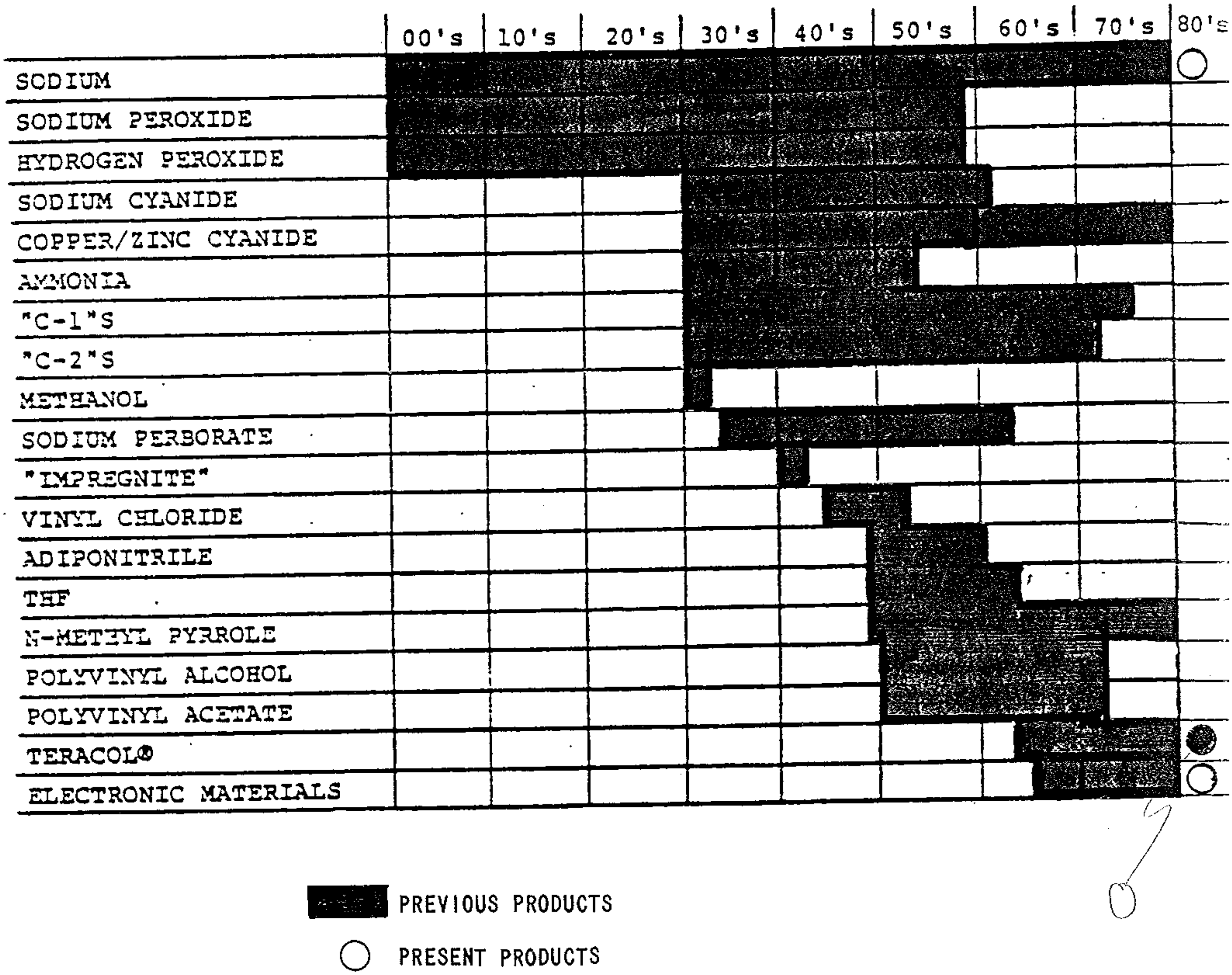
VUG: A small cavity in a vein or in rock, usually lined with crystals of a different mineral composition from the enclosing rock.

TABLES

TABLE I

DU PONT NIAGARA FALLS

PRODUCTS



MONITORING WELL SUMMARY
DUPONT NIAGARA PLANT
E.I. DUPONT DE NEMOURS & CO.
TABLE 2

Well	Elevation (feet)	Thickness of Overburden/Depth To Bedrock (feet)	Elevation of Top of Bedrock (feet)	Depth (feet)	Well Screen/ Open Hole Interval(feet)
1A	569.0	16.0	553.0	19.0	16.0-19.0
1B	568.2	12.3	556.0	29.0	16.0-29.0
1C	569.7	14.0	555.7	42.5	31.0-42.5
1D	568.8	15.5	553.4	74.5	42.5-74.5
1E	567.6	15.0	552.6	88.3	74.0-88.3
1F	569.4	15.0	554.4	97.0	90.0-97.0
1G	568.6	15.0	553.6	170.0	Grouted
1J	569.7	15.0	554.7	170.0	97.0-170.0
2A	570.1	14.0	556.1	17.0	14.0-17.0
2C	(570.1)	14.0	556.1	45.5	31.0-45.5
3A	569.0	11.5	557.5	12.5	11.5-12.5
3B	569.0	11.5	557.5	26.1	15.0-26.1
4A	570.0	13.5	556.5	16.5	13.5-16.5
4C	(570.0)	13.5	556.5	46.0	30.0-46.0
4J	(570.0)	13.0	557.0	173.0	150.0-173.0
5A	569.4	13.0	556.5	16.0	13.0-16.0
5B	569.4	13.0	556.5	26.0	17.0-26.0
5CD	(569.4)	13.0	556.5	50.0	42.0-50.0
5D	(569.4)	13.0	556.5	60.0	50.0-60.0
5F	(569.4)	13.0	556.5	96.0	88.0-96.0
6A	571.3	14.0	557.3	17.0	14.0-17.0
7A	567.9	16.0	551.9	19.0	16.0-19.0
7C	567.9	16.0	551.9	45.0	30.0-45.0
8A	568.2	12.0	556.2	15.0	12.0-15.0
8B	568.0	12.0	556.2	28.6	17.0-28.6
8J	568.2	12.0	556.2	170.5	150.0-170.5
9A	568.3	10.0	558.3	13.0	10.0-13.0
10A	567.1	7.5	559.6	10.5	7.5-10.5
10C	567.1	7.5	559.6	28.8	19.8-28.8
10D	(567.1)	7.0	559.6	70.0	38.0-70.0
10F	(567.1)	7.0	559.6	105.0	84.0-105.0
11A	567.9	8.0	559.9	11.0	8.0-11.0
12A	568.9	11.0	557.9	14.0	11.0-14.0
12B	568.9	11.0	557.9	27.0	14.0-27.0
13A	569.5	10.0	559.5	13.0	10.0-13.0
14A	568.9	8.0	560.9	11.0	8.0-11.0
14C	(568.9)	8.0	560.9	70.0	25.0-70.0
15A	568.0	6.0	562.0	9.0	6.0- 9.0
15C	568.2	6.0	562.0	31.0	22.5-31.0
15CD	(568.2)	6.0	562.0	47.0	35.0-47.0
15D	(568.2)	6.0	562.0	73.0	50.0-73.0
15F	(568.2)	6.0	562.0	105.0	83.0-105.0
15J	(568.2)	6.0	562.0	169.5	150.0-169.5
16A	569.5	11.5	558.0	14.5	11.5-14.5
16B	569.3	11.5	557.8	36.3	14.5-36.3
17A	568.9	23.0	545.9	25.0	23.0-25.0
17B	568.9	21.0	547.9	51.8	24.5-51.8
18A	567.3	13.0	554.3	16.0	13.0-16.0
18C	567.6	13.0	554.6	35.9	16.0-21.3
19A	570.2	8.5	561.7	11.0	8.5-11.0
19B	569.8	10.5	559.3	23.1	13.5-23.1
20A	570.9	6.0	56.49	9.0	6.0- 9.0
21A	569.5	11.0	558.5	14.0	11.0-14.0

( ) Elevation based on ground elevation of nearest well in group

TABLE 3
GENERALIZED STRATIGRAPHIC COLUMN
NIAGARA PLANT
E.I. DUPONT DE NEMOURS & CO.

GEOLOGIC AGE: PERIOD	EPOCH	STAGE	FORMATION	APPROX. THICK-NESS (feet)	STRATUM NO.		DESCRIPTION
QUATERNARY	RECENT		FILL unconformity	6 - 23	1	OVERBURDEN	Brown to gray sand and silt with clay and gravel, having brick, cinders and rock locally
			ALLUVIUM unconformity	0 - 3	2		Brown to gray silt and fine sand with gravel locally
	PLEISTOCENE	WISCONSIN	GLACIO - LACUSTRINE	0 - 4	3		Red-brown clay, silt, silty clay and clayey silt with sand and gravel laminated
			TILL unconformity	0 - 8	4		Red-brown silt, sand, gravel and clay, with rock fragments having occasional boulders
SILURIAN	UPPER		LOCKPORT FORMATION	156.5 (Maximum Penetrated)	5	BEDROCK	Dark gray to brown, massive to thin-bedded dolomite locally containing algal and gypsum deposits
	LOWER		ROCHESTER SHALE	7 (Maximum Penetrated)			Gray, thin to shaly-bedded shale

TABLE 4

SOIL PERMEABILITIES, REGOLITH WELLS[1]
DUPONT NIAGARA PLANT
NIAGARA FALLS, NEW YORK

Well No.	COEFFICIENT OF PERMEABILITY[2] Confined	Unconfined
1A	—	$8x10^{-3}$
2A	—	$3x10^{-2}$
3A	—	$1x10^{-2}$
4A	—	$3x10^{-1}$
5A	$4x10^{-2}$	$2x10^{-2}$
6A	$6x10^{-2}$	$4x10^{-2}$
7A	$1x10^{-3}$	—
8A	$1x10^{-3}$	—
9A	—	$2x10^{-2}$
10A	—	$4x10^{-2}$
13A	$1x10^{-2}$	—
14A	$3x10^{-3}$	—
15A	—	$1x10^{-3}$
16A	$1x10^{-2}$	$3x10^{-3}$
18A	$6x10^{-3}$ (early)[3]	$6x10^{-3}$ (late)[4]
19A	$4x10^{-3}$	—
21A	$4x10^{-2}$ (early)	$1x10^{-3}$ (late)

(1) Permeability test performed using the slug test method

(2) Test results in centimeters per second

(3) Permeability calculated using data from early part of test

(4) Permeability calculated using data from late part of test

TABLE 5

ROCK PERMEABILITIES, BEDROCK WELLS[(1)]
DUPONT NIAGARA PLANT

Well No.	Coefficient of Permeability[(2)] Confined		Unconfined		Comments
	L=L[(3)]	L=1.0 ft	L=L	L=1.0 ft	
1B	—	—	$5x10^{-2}$	$3x10^{-1}$	
3B	$8x10^{-2}$	$8x10^{-1}$	$4x10^{-2}$	$2x10^{-1}$	
5B	—	—	$3x10^{-2}$	$2x10^{-1}$	Shallow response[(5)]
12B	$2x10^{-1}$	$1x10^{0}$	—	—	Shallow response[(5)]
1C	—	—	$2x10^{-5}$	$1x10^{-4}$	
2C	—	—	—	—	Estimated at $1x10^{-2}$
4C	—	—	$5x10^{-3}$	$4x10^{-2}$	
10C	$5x10^{-2}$	$5x10^{-1}$	$3x10^{-2}$	$1x10^{-1}$	
14C	—	—	—	—	Estimated at $1x10^{-4}$
15C	—	—	$2x10^{-1}$	$8x10^{-1}$	Very fast, sloshing[(5)]
1D	$2x10^{-4}$	$7x10^{-3}$	$2x10^{-4}$	$9x10^{-4}$	
5D	—	—	—	$5x10^{-1}$	Very fast, sloshing[(5)]
10D	$1x10^{-4}$	$3x10^{-3}$	$8x10^{-5}$	$1x10^{-3}$	
15D	—	—	—	$3x10^{-1}$	Very fast, sloshing[(5)]
1E	—	—	$2x10^{-4}$	$1x10^{-3}$	
1F	$4x10^{-2}$	$2x10^{-1}$	$2x10^{-2}$	$8x10^{-2}$	
5F	—	—	$2x10^{-2}$	$7x10^{-2}$	Sine wave generated[(5)]
15F	$4x10^{-4}$	$5x10^{-3}$	$3x10^{-4}$	$2x10^{-3}$	
1J	—	—	$4x10^{-4}$	$1x10^{-2}$	Shallow response[(5)]

(1) Permeability test performed using the slug test method
(2) Test results in centimeters per second
(3) L = open length of well
(4) Conversion, cm/sec = 21,203 gpd/ft^2
(5) Questionable test results

TABLE 6

PUMPING INFLUENCE[1]
AUGUST DRAWDOWN TEST
DUPONT NIAGARA PLANT

Well No.	Pre-Drawdown August 25, 1983		Post-Drawdown August 30, 1983		
	Time	Depth	Time	Depth	Drawdown
1A	0911	9.31	0858	9.27	0.04
1B	0851	10.13	0858	10.24	-0.11
1C	0853	12.43	0904	12.98	-0.55
1D	0852	17.31	0901	19.74	-2.43
1E	0855	12.20	0900	13.1	-0.9
1F	0848	13.32	0837	14.00	-0.68
1J	0850	21.89	0902	27.4	-5.51
3A	1403	10.58	1339	9.38	1.20
3B	0911	9.66	0833	9.78	-0.12
4C	0906	11.41	0842	12.53	-1.14
7A	1358	15.37	1333	15.44	-0.07
7C	0900	16.87	0847	17.44	-0.57
8A	1140	5.88	11.54	5.51	-0.37
8B	0854	5.83	0843	5.80	0.03
10A	1345	6.27	13.47	5.75	0.52
10C	0850	12.71	0836	12.72	-0.01
12A	1339	11.40	1353	11.34	0.06
12B	0845	12.14	0832	12.15	0.01
15C	0900	13.04	0825	13.36	-0.32
16B	0907	14.20	0903	14.32	-0.12
17B	0927	21.04	0854	21.65	-0.61
19A	0930	7.83	0849	6.99	0.84
19B	0905	15.56	0900	15.60	-0.04

(1) Drawdown due to Olin production well start-up, all measurements are in feet.

TABLE 7

PUMPING INFLUENCE[1]
OCTOBER RECOVERY TEST
DUPONT NIAGARA PLANT

Well No.	Pre-Recovery October 17, 1983 Time	Depth	Post-Recovery October 19, 1983 Time	Depth	Recovery
1A	0827	9.31	0938	9.73	-0.42
1B	0827	10.28	0935	10.63	-0.35
1C	0825	12.53	0939	12.20	0.33
1D	0825	16.88	0941	14.40	2.48
1E	0826	12.15	0940	11.22	0.93
1F	0824	13.31	0938	12.77	0.54
1J	0823	21.24	0937	15.74	5.50
2A	0832	7.19	0917[2]	7.33	-0.14
2C	0832	17.5	0917[2]	13.31	4.2
4A	0855	7.22	0907	7.6	-0.4
4C	0854	11.24	0907	9.80	1.44
5A	0730	Dry	0905	14.81	>2.38
5B	0900	17.79	0905	15.03	2.76
5CD	0744	16.95	0856	12.33	4.62
5D	0903	16.19	0856	11.75	4.44
5F	0901	14.43	0902	12.07	2.36
10A	0834	7.94	0926	8.10	-0.16
10C	0823	13.00	0926	13.05	-0.05
10D	0825	16.12	0927	13.86	2.26
10F	0829	9.55	0930	9.08	0.47

(1) Recovery due to Olin production well shutdown, all measurements in feet.

(2) October 18, 1983

TABLE 7 (CONTINUED)

Well No.	Pre-Recovery October 17, 1983 Time	Pre-Recovery October 17, 1983 Depth	Post-Recovery October 19, 1983 Time	Post-Recovery October 19, 1983 Depth	Recovery
14A	0837	7.55	0840	7.78	-0.23
14C	0837	17.60	0839	16.80	0.80
15A	0835	2.9	0847	2.97	-0.1
15C	0833	21.02	0846	Dry	Indeterm.
15CD	0831	21.62	0845	13.82	7.80
15D	0834	14.18	0846	10.92	3.26
10F	0830	10.79	0845	9.77	1.02
16A	0837	7.65	0849	7.74	-0.09
16B	0838	14.47	0849	13.94	0.53

TABLE 8

VERTICAL GROUNDWATER FLOW POTENTIALS(1) BETWEEN MONITORED WELLS DUPONT NIAGARA PLANT AUGUST 25, 1983 PRIOR TO START OF PUMP TEST

Well	Time	Groundwater Elevation	Vertical ΔH(2) A	B	C	D	E	F
1A	0911	562.92	0					
1B	0851	561.28	-1.64	0				
1C	0853	560.44	-2.48	-0.84	0			
1D	0852	554.61	-8.31	-6.67	-5.83	0		
1E	0855	558.58	-4.34	-2.70	-1.86	+3.97	0	
1F	0848	559.17	-3.75	-2.11	-1.27	+4.56	+0.59	0
1J	0850	549.99	-12.93	-11.29	-10.45	-4.62	-8.59	-9.18
3A	1004	564.75	0					
3B	1003	559.00	-5.75					
4A	1651	562.02	0					
4C	1652	556.86	-5.16					
5A	1129	561.91	0					
5B	1123	561.72	-0.19					
7A	1146	555.46	0					
7C	1144	554.18	-1.28					
8A	1140	562.13	0					
8B	1138	561.89	-0.24					

(1) - = downward flow potential in feet
+ = upward slow potential in feet

(2) Read flow potentials from vertical ΔH column to well column.

TABLE 8 (CONTINUED)

Well	Time	Groundwater Elevation	Vertical ΔH A	B	C	D	E	F
10A	1130	563.01	0					
10C	1128	557.64	-5.37					
12A	1125	560.96	0					
12B	1123	559.76	-1.20					
16A	0953	564.16	0					
16B	0952	558.38	-5.78					
17A	1156	550.37	0					
17B	1152	547.88	-2.49					
19A	0930	565.64	0					
19B	0929	557.40	-8.24					

TABLE 9

VERTICAL GROUNDWATER FLOW POTENTIALS[1]
BETWEEN MONITORED WELLS
DUPONT NIAGARA PLANT
AUGUST 29, 1983[2]
HIGH RIVER STAGE[2]

Well	Time	Groundwater Elevation	Vertical ΔH[3]					
			A	B	C	D	E	F
1A	0908	562.93	0					
1B	0907	561.12	-1.81	0				
1C	0904	559.89	-3.04	-1.23	0			
1D	0906	552.25	-10.78	-8.97	-7.74	0		
1E	0906	557.65	-5.28	-3.47	-2.24	+5.50	0	
1F	0928	558.42	-4.51	-2.70	-1.47	+6.27	+0.77	0
1J	0909	544.50	-18.43	-16.62	-15.39	-7.65	-13.15	-13.92
3A	0833[4]	565.64	0					
3B	0848[4]	559.00	-6.64					
4A	0825	562.51	0					
4C	0825	557.06	-5.45					
8A	0816	562.38	0					
8B	0816	561.94	-0.44					
19A	0917	565.63	0					
19B	0917	557.43	-8.20					

(1) - = downard flow potential in feet
+ = upward flow potential in feet

(2) Measurements taken at approximately high river stage

(3) Read flow pontentials from vertical ΔH column to well column.

(4) August 30, 1983

TABLE 10

VERTICAL GROUNDWATER FLOW POTENTIALS(1)
BETWEEN MONITORED WELLS
DUPONT NIAGARA PLANT
AUGUST 29, 1983
LOW RIVER STAGE(2)

Well	Time	Groundwater Elevation	Vertical ΔH(3)					
			A	B	C	D	E	F
1A	2131	561.92	0					
1B	2132	560.11	-1.81	0				
1C	2128	559.27	-2.65	-0.84	0			
1D	2129	551.36	-10.56	-8.75	-7.91	0		
1E	2130	557.01	-4.91	-3.10	-2.26	+5.65	0	
1F	2158	557.09	-4.83	-3.02	-2.18	+5.73	+0.08	0
1J	2133	544.18	-17.74	-15.93	-15.09	-7.18	-12.83	-12.91

(1) - = downward flow potential in feet

+ = upward flow potential in feet

(2) Measurements taken at approximately low river stage

(3) Read flow potential from vertical ΔH column to well column

TABLE 11

VERTICAL GROUNDWATER FLOW POTENTIALS(1)
BETWEEN MONITORED WELLS
DUPONT NIAGARA PLANT
OCTOBER 17, 1983
START OF RECOVERY TEST

Well	Time	Groundwater Elevation	Vertical ΔH(2)						
			A	B	C	CD	D	E	F
1A	1236	562.59	0						
1B	1235	560.84	-1.75	0					
1C	1232	560.43	-2.16	-0.41	0				
D	1233	557.23	-5.36	-3.61	-3.20		0		
1E	1234	559.17	-3.42	-1.67	-1.26		+1.94	0	
1F	1231	559.69	-2.90	-1.15	-0.74		+2.46	+0.52	0
1J	1231	553.35	-9.24	-7.49	-7.08		-3.88	-5.82	-6.34
2A	1220	562.25	0						
2C	1220	553.7(3)	-8.6						
3A	1215	565.28	0						
3B	1216	559.27	-6.01						
4A	1222	562.18	0						
4C	1221	559.75	-2.43						
5A	1240	557.27	0						
5B	1230	557.33	+0.06	0					
5CD	1237	556.4(3)	-0.9	-0.9		0			
5D	1228	556.6(3)	-0.6	-0.7		+0.2	0		
5F	1229	553.6(3)	-3.6	-3.7		-2.8	-3.0		
7A	1234	555.92	0						
7C	1235	553.24	-2.68						

(1) - = downward flow potential in feet

+ = upward flow potential in feet

(2) Read flow potential from vertical ΔH column to well column

(3) Elevation based on ground elevation of nearest well in group

TABLE 11 (CONTINUED)

Well	Time	Groundwater Elevation	Vertical ΔH A	B	C	CD	D	E	F
8A	1231	562.60	0						
8B	1232	561.51	-1.09						
10A	1215	561.15	0						
10C	1218	557.36	-3.79		0				
10D	1216	552.6(3)	-8.6		-4.7		0		
10F	1219	558.4(3)	-2.8		+1.0		+5.8		
12A	1211	560.75	0						
12B	1212	559.11	-1.64						
14A	1205	564.18	0						
14C	1207	552.6(3)	-11.6						
15A	1214	565.34	0						
15C		Dry	—		—				
15CD	1211	556.2(3)	-9.1		—	0			
15D	1213	556.9(3)	-8.4		—	+0.7	0		
15F	1212	559.1(3)	-6.2		—	+2.9	+2.2		
16A	1220	564.44	0						
16B	1220	558.61	-5.83						
17A	1345	551.31	0						
17B	1345	548.58	-2.73						
19A	1215	566.47	0						
19B	1215	557.82	-8.65						

TABLE 12

VERTICAL GROUNDWATER FLOW POTENTIALS[1] BETWEEN MONITORED WELLS DUPONT NIAGARA PLANT OCTOBER 19, 1983 START OF DRAWDOWN TEST

Well	Time	Groundwater Elevation	Vertical ΔH[2] A	B	C	CD	D	E	F
1A	1603	562.13	0						
1B	1604	560.38	-1.75	0					
1C	1601	560.16	-1.97	-0.22	0				
1D	1666	555.07	-7.06	-5.31	-5.09		0		
1E	1605	558.52	-3.56	-1.81	-1.59		+3.50	0	
1F	1602	558.51	-3.62	-1.87	-1.65		+3.44	-0.06	0
1J	1603	553.46	-8.67	-6.92	-6.70		-1.61	-5.11	-5.05
2A	1609	561.73	0						
2C	1609	551.7[3]	-10.0						
3A	1546	565.23	0						
3B	1548	558.48	-6.75						
4A	1554	561.37	0						
4C	1556	558.08	-3.29						
5A		Dry	—						
5B	1625	554.70	—	0					
5CD	1625	556.6[3]	—	+1.9		0			
5D	1969	553.7[3]	—	-1.0		-2.9	0		
5F	1820	554.5[3]	—	-0.2		-2.1	+0.8		
7A	1608	556.01	0						
7C	1608	553.26	-2.75						

(1) - = downward flow potential in feet
    + = upward flow potential in feet

(2) Read flow potentials from vertical ΔH column to well column

(3) Elevation based on ground elevation of nearest well in group

TABLE 12 (CONTINUED)

Well	Time	Groundwater Elevation	Vertical ΔH A	B	C	CD	D	E	F
8A	1605	562.20	0						
8B	1605	561.11	-1.09						
10A	1557	560.96	0						
10C	1556	557.32	-3.64		0				
10D	1535	554.7(3)	-6.3		-2.6		0		
10F	1554	557.3(3)	-3.7		-0.0		+2.6		
12A	1606	560.49	0						
12B	1605	558.87	-1.62						
14A	1620	563.90	0						
14C	1619	553.3(3)	-10.6						
15A	1620	565.31	0						
15C		Dry	—		—				
15CD	1618	549.9(3)	-15.4		—	0			
15D	1618	553.8(3)	-11.5		—	+3.9	0		
15F	1616	557.7(3)	-7.6		—	+7.8	+3.9		
16A	1616	564.34	0						
16B	1615	557.82	-6.52						
17A	1625	551.58	0						
17B	1625	548.90	-2.68						
18A	1620	559.24	0						
18C	1620	560.17	+0.93						
19A	1625	566.13	0						
19B	1625	556.93	-9.2						

TABLE 13

OLIN PRODUCTION WELL PUMP RATES
PERCENT OF PUMPAGE ASSIGNED TO FRACTURE ZONES
AUGUST AND OCTOBER, 1983 PUMP TESTS
DUPONT NIAGARA PLANT

Fracture[1] Zones	Estimated Percent of Pumpage		Flow Per Fracture[4]			
			August Test		October Test	
	WCC[2]	Olin[3]	WCC	Olin	WCC	Olin
C	10	20	137	275	197	394
CD	40	58	550	797	789	1144
D	40	12	550	165	789	237
E/F	10	10	137	137	197	197
			QT=1374 gpm		QT=1972 gpm	

(1) Based on Olin well logs and WCC correlations

(2) Estimate based on percent change in head due to pumping changes for an individual well compared to the well group.

(3) Estimate reported by Olin.

(4) Flows in gallons per minute

TABLE 14

TIME-DRAWDOWN PLOT RESULTS
AUGUST 25, 1983 PUMP TEST
DUPONT NIAGARA PLANT

Well No.	Match Point(1)								Transmissivity(2)			
	Water Table Fractured Rock				Leaky Artesian				Water Table Fractured Rock		Leaky Artesian	
	$W_{FWp}(U_{AF}, U_b, BF, b, c)$	$(1/U_{AF})$	Time	Drawdown	w(1/u,r/B)	1/u,r/B	Time	Drawdown	Q (WCC)	Q (Olin)	Q (WCC)	Q (Olin)
1D	1	1	2.6	2.7	—	—	—	—	23000	7000	—	—
1E	0.1	1	22.5	0.18	—	—	—	—	8700	8700		
1J	1	1	31	2.25	1	1	915	5	—	—	—	—
4C	1	1	2.7	1.5	1	1	100	0.98	10000	21000	16000	32000
15C	—	—	—	—	1	2	320	0.28	—	—	56000	112000

TIME-RECOVERY PLOT RESULTS
OCTOBER 17, 1983 RECOVERY TEST
DUPONT NIAGARA PLANT

Well No.	$W_{FWp}(U_{AF}, U_b, BF, b, c)$	$(1/U_{AF})$	Time	Drawdown	w(1/u,r/B)	1/u,r/B	Time	Drawdown	Q (WCC)	Q (Olin)	Q (WCC)	Q (Olin)
2C	1	1	18	6	1	1	208	10	3700	7500	2300	4500
5D	1	1	1.8	16	—	—	—	—	5600	1700	—	—
5F	1	1	1.7	9.4	—	—	—	—	2400	2400	—	—
10D	1	1	3.5	0.2	1	1	740	0.15	450000	135000	602000	181000
10F	1	1	5.6	1.69	—	—	—	—	13000	13000	—	—
10F(3)	1	1	780	1.6	—	—	—	—	14000	14000	—	—
14C early	1	1	120	.12	—	—	—	—	188000	376000	—	—
14C late	1	1	750	0.8	—	—	—	—	28000	56000		
15CD	1	10	9.8	4.3	1	1	245	23.5	21000	30000	3800	5600

(1) Time in minutes, drawdown in feet
(2) Transmissivity (gal/ft-day), based on pump rate distribution to specific fracture zones as estimated by WCC/Olin.
(3) Late Time data, $1/U_{BF}$

TABLE 15

TRANSMISSIVITY ESTIMATE USING THE DISTANCE-RECOVERY METHOD OCTOBER 17, 1983 RECOVERY TEST DUPONT NIAGARA PLANT

Fracture Zone	Δs(2)	Pumpage Olin Estimate(3)	Transmissivity(1)	Pumpage WCC Estimate(3)	Transmissivity(1)
CD	27.0	1144	22000	789	15000
D	9.5	237	13000	789	44000
F	6.7	197	16000	197	16000

(1) Transmissivity in gpd/ft
(2) Δs = change in head over one log cycle, in feet
(3) Pumpage in gpm, see Table 13.

TABLE 16

TRANSMISSIVITY ESTIMATED USING THEIM STEADY STATE EQUATIONS APPLYING WCC AND OLIN ESTIMATED PUMP RATE DISTRIBUTIONS DUPONT NIAGARA PLANT

		Transmissivity[1]			
		WCC Pump Rate			Olin Pump Rate[3]
Well Group	N[2]	Minimum	Maximum	Mean	Mean
C	5	3705	37335	18034	36068
CD	1	—	—	847	1695
D	5	49978	109219	73139	21944
F	5	15044	58496	29263	29263

(1) Transmissivity (gal/ft. day)

(2) Number of elements used to compute mean

(3) Pumpage in gpm

TABLE 17

WELL/RIVER STAGE RATIOS[1]
DUPONT NIAGARA PLANT

Well Number	Number Of Measurements	Average[2] ΔH Well/ΔH River	Distance From[3] River (feet)	Lag Time (min)
1B	4	0.60	292	0
1C	5	0.39	292	135
1D	1	.56	292	0
1E	4	0.40	292	30
1F	29	0.80	292	0
1J	2	0.16	292	180
2C	3	0.48	276	Large
3B	3	0.38	427	25
4C	1	0.86	232	10
5B	15	0.15	551	15
5CD	1	0.38	551	0
5D	1	0.80	551	0
5F	2	0.59	551	0
7C	3	0.19	754	720
8B	2	0.70	472	0
10C	1	0.09	758	0
10D	1	0.81	758	NA[4]
10F	9	0.60	758	NA[4]
12B	3	0.34	532	0
15C	13	0.30	938	15
15CD	3	0.51	938	0
15D	3	0.58	938	NA[4]
15F	3	0.67	938	0
16B	3	0.33	780	0
17C	2	0.53	1511	0
19B	3	0.22	1226	15

(1) Ratios = maximum change in head in well divided by maximum change in river level, from high to low water, at concurrent times.
(2) Average based on data collected from August through October, 1983.
(3) Distance approximate to center of well group
(4) Not available

TABLE 18

GROUNDWATER ELEVATIONS[(1)]
DUPONT NIAGARA SITE

Well No.	August 25, 1983 Time	August 25, 1983 Water Table Elevation	August 30, 1983 Time	August 30, 1983 Water Table Elevation
1B	0851	562.10	1353	560.96
1C	0853	560.44	1350	559.90
3B	0911	559.12	1329	558.95
4C	0906	557.37	1324	557.07
5B	0850	558.35	1400	557.91
7C	0900	554.10	1333	553.65
8B	0854	561.99	1327	561.79
12B	0845	559.80	1359	559.64
15C	0900	558.19	N/A	—
16B	0907	558.50	1343	558.32
17CD	0927	547.69	1339	547.52
18C	0900	556.2	1400	556.8
19B	0905	557.50	1352	557.39

(1) Elevation in feet, Datum = Edward Dean Adams Station

TABLE 19

GROUNDWATER ELEVATIONS[(1)]
DUPONT NIAGARA PLANT

	October 17, 1983		October 19, 1983	
Well	Time	Elevation[(2)]	Time	Elevation[(3)]
1A	1236	562.59	1603	562.13
1B	1235	560.84	1604	560.38
1C	1232	560.43	1601	560.16
1D	1233	557.23	1606	555.07
1E	1234	559.17	1605	558.57
1F	1231	559.69	1602	558.51
1J	1231	553.35	1603	553.46
2A	1220	562.25	1609	561.73
2C	1220	553.7	1609	551.7
3A	1215	565.28	1546	565.23
3B	1216	559.27	1548	558.48
4A	1222	562.18	1554	561.60
4C	1221	559.75	1556	558.08
5A	1240	557.38	1626	<552.5
5B	1230	557.35	1625	554.72
5CD	1237	556.5	1630	556.6
5D	1228	556.6	1628	553.7
5F	1229	553.6	1627	554.5
6A	1226	559.34	1643	557.94
7A	1234	555.92	1608	556.01
7C	1235	553.24	1608	553.26

(1) Elevation in feet, Datum = Edward Dean Adams Station

(2) Measured after start of recovery test

(3) Measured after start of drawdown test

TABLE 19 (CONTINUED)

Well	Time	Elevation	Time	Elevation
8A	1231	562.60	1605	562.20
8B	1232	561.51	1605	561.11
9A	1227	562.30	1601	561.77
10A	1215	561.30	1557	561.11
10C	1218	557.37	1556	557.33
10D	1216	552.6	1535	554.7
10F	1219	558.4	1554	557.3
11A	1214	562.34	1601	561.98
12A	1211	560.75	1602	560.49
12B	1212	559.11	1605	558.87
13A	1248	564.16	1615	564.02
14A	1205	564.48	1620	564.20
14C	1207	552.6	1619	553.4
15A	1214	565.3	1620	565.3
15C	1204	<547.2	1620	<547.2
15CD	1211	556.2	1618	549.9
15D	1213	556.9	1618	553.9
15F	1212	559.2	1616	557.7
16A	1220	564.45	1616	564.35
16B	1220	558.66	1615	557.87

TABLE 19 (CONTINUED)

Well	Time	Elevation	Time	Elevation
17A	1345	551.31	1625	551.58
17B	1345	548.58	1625	548.90
18A			1620	559.24
18C			1620	560.17
19A	1215	566.47	1625	566.13
19B	1215	557.82	1625	556.93
20A				<561.85
21A	1250	562.51	1611	562.23
Dec Wells				
1			1625	564.0
2			1639	561.86
3			1643	561.57
4			1646	561.42
5			1644	561.23

TABLE 20

A ZONE ESTIMATED FLOW QUANTITIES(1)

Section No.(2)	Length (ft)	Average Saturated Thickness (ft)	Gradient (Ft/Ft)	Permeability (cm/sec)	Flow (gpd)	Velocity (ft/day)
1	500	2	0.02	2.2×10^{-2}	9,300	1.24
2	575	3.5	0.008	2.5×10^{-1}	85,000	5.67
3	525	4	0.008	3.0×10^{-2}	10,700	0.68
4	200	4.5	0.006	5.5×10^{-2}	6,800	0.94
5	175	4.5	0.007	5.0×10^{-2}	5,600	0.99
6	350	2.5	0.01	2×10^{-2}	3,700	0.57
7	600	4.0	0.013	1.4×10^{-3}	950	0.05
8	600	4.0	0.013	6×10^{-3}	4,070	0.22

(1) Flow quantities estimated using October 17, 1983 water level data

(2) See Plate 45

TABLE 21

SUMMARY OF FLOWS AND VELOCITIES[1] IN THE BEDROCK GROUNDWATER REGIME ACROSS DUPONT SITE

Zone	Width (ft)	Gradient (ft/ft)	Average Permeability (ft/min)	Transmissivity Distance-Recovery (gpm/ft)	Transmissivity Type Curve (gpm/ft)	Flow (gpm)	Velocity[3] (ft/day)
			FOR FLOW IN THE NORTHWEST DIRECTION				
B[2]	1700	0.0029	0.40	—	—	15	2
CD	1700	0.010	—	10.4	—	177	40
D	1700	0.0022	—	30.6	—	115	26
F	1700	0.0050	—	11.1	—	95	22
CD	1700	0.010	—	—	8.3	141	32
D	1700	0.0022	—	—	13.2	49	12
F	1700	0.0050	—	—	5.6	48	10
			FOR FLOW IN THE NORTHEAST DIRECTION				
CD	800	0.0087	—	10.4	—	72	35
CD	800	0.0087	—	—	8.3	58	27

(1) Flows calculated using Q = TiW
Velocities calculated Using V = T i/b

(2) Flow calculated using Q = KiA
Velocity calculated using q = Ki

(3) Thickness, b, chosen at L = 0.5 feet

TABLE 22
ANALYTICAL RESULTS FOR DEC WELLS
DUPONT - NIAGARA FALLS PLANT

	DEC-1	DEC-2				DEC-3				DEC-4			
	May	Jan	Mar	Apr	May	Jan	Mar	Apr	May	Jan	Mar	Apr	May
Tetrachloroethylene	<0.004	0.006	0.011	—	0.018	48.0	48.0	71.0	87.0	2.20	0.130	—	—
Trans-1,2-dichloroethylene	—	0.160	0.750	0.210	0.140	20.0	36.0	44.0	32.0	9.10	22.0	20.0	15.0
Trichloroethylene	—	0.110	0.017	0.016	0.026	470.0	630.0	700.0	880.0	52.0	14.0	15.0	11.0
Vinyl Chloride	—	—	0.900	0.450	0.100	—	3.60	—	—	—	9.20	26.0	<10.0
1,1,2,2-Tetrachloroethane	—	0.039	<0.006	0.006	<0.006	310.0	220.0	260.0	260.0	11.0	0.091	—	—
Chloroform	—	0.100	—	—	—	11.0	25.0	35.0	38.0	150.0	340.0	220.0	150.0
Methylene Chloride	—	—	—	—	—	2200.0	4000.0	2900.0	3000.0	120.0	140.0	91.0	62.0
Benzene	<0.004	—	0.033	0.017	0.005	2.50	0.015	—	—	—	0.110	—	—
Chlorobenzene	<0.006	0.001	0.012	0.014	<0.006	0.510	0.029	—	—	0.460	<0.060	—	—
α - BHC (ppb)		—	0.46	0.64	0.59	35.0	360.0	1200.0	1000.0	—	2.1	8.1	4.9
β - BHC (ppb)		—	0.23	2.2	2.3	20.0	34.0	140.0	95.0	—	0.32	<1.0	0.93
δ - BHC (ppb)		—	<0.8	19.0	<2.0	8.5	18.0	140.0	63.0	—	0.33	0.57	0.19
γ - BHC (ppb)		—	<0.3	<0.5	0.46	110.0	55.0	190.0	150.0	—	0.12	0.60	0.24
Phenolics			<0.010	<0.010	<0.010		0.147	0.145	0.120		0.014	0.019	<0.010
Cyanide	<0.010	0.130	1.30	0.790	0.330	<0.010	0.051	0.070	0.120	3.00	0.033	0.025	0.054
Copper	0.412	0.007	0.030	0.014	0.112	0.005	0.034	0.070	0.110	0.001	0.124	0.038	<0.003

Notes: Results in mg/l (ppm) except where noted.

— = not detected

Blank space = no data/no sample

TABLE 23

VOLATILE COMPOUND ANALYTICAL RESULTS
DUPONT - NIAGARA PLANT SITE

	Tetrachloroethylene				Trans-1,2-dichloroethylene				Trichloroethylene				Vinyl Chloride			
	June	July/ Aug.**	Sept	Oct	June	July/ Aug.**	Sept	Oct	June	July/ Aug.**	Sept	Oct	June	July/ Aug.**	Sept	Oct
1A	42.0	17.0	16.0	14.0	23.0	32.0	32.0	27.0	140.0	62.0	35.0	26.0	2.40	2.60	—	—
1B	72.0	80.0	6.5	17.0	20.0	37.0	280	23.0	42.0	320.0	380.0	240.0	2.20	3.90	—	—
1C	79.0	120.0	81.0	99.0	14.0	12.0	12.0	21.0	480.0	590.0	450.0	660.0	1.40	1.60	1.7	—
1D	0.360	0.300	—	—	9.0	6.80	7.30	5.30	2.60	3.80	2.80	5.70	0.790	0.150	—	—
1E	1.10	0.057	0.027	—	0.340	0.120	0.200	0.460	4.60	0.220	0.025	0.015*	0.050	0.025	—	0.053
1F	2.90		0.780	0.300	0.100		1.50	1.70	4.00		1.50	0.190*	0.050		—	—
1G	99.0				8.60				310.0				0.050			
1J		3.40	3.30	1.10		0.880	0.520	0.410		2.30	2.80	0.120*		—	—	—
2A		—	0.780	—		19.0	19.0	6.4		4.00	11.0	1.30*		4.40	4.50	2.1
2C																
3A		—	—	—		3.90	1.80	4.90		—	—	0.065*		0.680	1.40	0.710
3B		4.10	8.00	4.40		18.0	52.0	42.0		78.0	140.0	94.0		2.80	6.10	—
4A		—	—	—		0.290	0.031	0.094		0.014	—	0.034*		0.430	0.047	0.180
4C			0.034	—			0.069	0.021			0.330	0.340*			—	—
5A		0.032	0.062			0.760	1.40			0.052	0.210			0.690	0.360	
5B		—	—	—		0.240	0.430	0.230		—	—	0.023*		—	—	5.8
5CD																
5D																
5F																
6A		—	—	—		0.002	0.002	0.014		—	—	0.068*		0.220	0.220	0.081
7A		—	—	—		0.002	0.003	0.007		—	—	0.019*			—	—
7C		—	0.006	0.013		0.019	0.014	0.018		0.046	0.029	0.035*		—	—	—
8A		—	—	—		12.0	17.0	28.0		0.150	0.150	0.350*		0.730	1.20	1.30
8B		0.870	—	—		7.10	85.0	77.0		11.0	5.70	8.90		1.30	—	—
9A		—	—	—		1.20	0.960	1.00		0.160	0.047	0.110		0.430	1.40	1.10
10A		—	—	0.130		0.180	8.80	12.0		—	—	2.80		0.120	1.40	1.00
10C		2.30	—	—		0.630	1.40	2.50		14.0	0.051	1.30*		0.130	0.360	0.660
10D																
10F																
11A		—	—	—		0.960	0.640	0.480		—	—	0.023*		0.600	1.00	0.90
12A		—	—	—		0.014	0.120	0.250		0.004	0.003	0.098*		0.028	0.076	0.130
12B		2.80	5.50	7.10		5.30	7.40	15.0		7.40	12.0	17.0		1.10	1.50	1.70
13A		17.0	20.0	54.0		14.0	29.0	52.0		30.0	55.0	150.0		2.60	2.00	2.10
14A		56.0	72.0	56.0		4.20	—	—		140.0	57.0	45.0		—	—	—
14C																
15A		1.10	0.400	13.0		—	0.032	1.4		2.00	0.450	25.0		—	—	—
15C		76.0	57.0			14.0	14.0			230.0	170.0			2.10	0.970	
15CD																
15D																
15F																
16A		—	—	—		0.610	0.780	1.40		6.40	6.80	4.20		—	—	—
16B		4.30	3.70	38.0		5.80	7.90	20.0		13.0	16.0	93.0		3.40	3.20	6.00
17A		0.014	0.009	0.011		0.002	0.002	0.003		0.002	0.003	0.18*		—	—	—
17B		0.007	0.008	0.024		0.014	0.014	0.019		0.007	0.003	0.048*		—	—	—
18A		—	—	—		0.045	0.025	0.039		0.002	—	0.011*		0.032	0.020	0.040
18C		—	—	—		5.80	5.50	4.10		0.140	—	0.060*		2.70	2.20	2.00
19A		0.082	—	0.078		0.140	0.120	0.150		0.180	0.120	0.150*		—	—	—
19B		0.026	0.012	1.50		0.140	0.110	3.10		0.025	0.016	2.00		0.760	0.980	2.80
21A	4.70	2.20	1.00	4.10	390.0	39.0	28.0	58.0	360.0	24.0	16.0	40.0	5.80	4.00	3.00	4.90

	1,1,2,2-tetrachloroethane				Chloroform				Methylene Chloride				Benzene				Chlorobenzene			
	June	July/ Aug.**	Sept	Oct	June	July/ Aug.**	Sept	Oct	June	July/ Aug.**	Sept	Oct	June	July/ Aug.**	Sept	Oct	June	July/ Aug.**	Sept	Oct
1A	13.0	2.90	—	1.4	18.0	11.0	11.0	9.3	140.0	46.0	72.0	44.0	—	—	—	—	—	—	—	—
1B	34.0	47.0	96.0	32.0	2.10	2.80	4.20	2.90	60.0		200.0	260.0	6.70	4.40	—	—	0.600	0.470	—	—
1C	—	87.0	130.0	190.0	2.00	1.50	0.880	—	5.10		—	—	1.30	1.50	2.7	—	—	—	0.190	—
1D	—	0.720	—	1.1	—	0.035	—	—	0.550		—	—	—	0.170	—	—	—	—	—	—
1E	—	0.068	—	—	0.009	—	0.016	—	—		—	—	0.034	—	—	—	—	—	—	—
1F	—		0.280	—	0.014		0.230	—	—		0.530	—	0.045		—	—	—		—	—
1G	—				0.970				7.60				0.860				—			
1J		0.069	—	—		0.022	0.025	—			—	—		—	0.046	—		—	—	—
2A		—	—	—		1.60	1.50	0.55		9.60	8.10	0.95		—	—	—		—	—	—
2C																				
3A		—	—	—		0.021	—	0.009		—	—	—		—	—	—		—	—	—
3B		1.10	—	—		4200	130.0	480.0		1800	72.0	740.0		—	—	—			—	—
4A		—	—	—		—	0.019	0.010		—	0.054	—		—	—	—		—	—	—
4C			—	—			0.007	0.010			—	0.028			—	—		—	—	—
5A		—	—				0.008				—			—	0.004			—	—	
5B		—	—	—		—	—	0.002		50.0	—	—		—	—	—		—	—	—
5CD																				
5D																				
5F																				
6A		—	—	—		0.004	0.003	0.490		0.014	—	0.200		—	—	0.017		—	—	0.015
7A		—	—	—		—	—	—		—	—	—		—	—	—		0.008	0.014	0.016
7C		—	—	—		0.970	0.058	0.010		—	0.012	—		0.009	0.007	0.017		—	—	—
8A		—	—	—		—	—	—		0.020	—	—		4.0	6.0	4.6		—	—	—
8B		—	—	—		—	—	—		—	—	—		3.5	3.2	2.4		—	—	—
9A		—	—	—		—	0.035	0.098		—	—	—		0.024	—	—		—	—	—
10A		—	—	—		—	—	—		—	—	0.027			—	1.40			0.043	2.20
10C		4.30	—	—		0.026	—	—		—	—	—		0.059	0.031	0.180		—	—	0.280
10D																				
10F																				
11A		—	—	—		—	—	—		—	—	—		—	0.024	0.024		—	0.045	0.036
12A		—	—	—		—	—	—		—	—	—		—	—	0.010		—	—	—
12B		0.910	3.30	2.30		—	0.055	—		—	0.330	—		—	—	—		—	—	—
13A		0.510	0.840	1.10		270.0	50.0	68.0		6.80	3.00	3.20		—	—	—		—	—	—
14A		92.0	39.0	23.0		0.460	—	—		—	—	—		—	—	—		—	—	—
14C																				
15A		—	—	1.20		14.0	2.50	610.0		2.50	0.210	59.0		—	—	—		—	—	—
15C		50.0	50.0	Dry		170.0	27.0			83.0	100.0			0.940	0.640			0.370	0.300	
15CD																				
15D																				
15F																				
16A		—	—	—		0.220	3.20	2.50		—	0.200	—		—	—	—		—	—	—
16B		—	—	5.20		39.0	460.0	2000.0		53.0	74.0	200.0		—	—	—		—	—	—
17A		—	—	—		—	0.004	—		—	—	—		—	—	—		—	—	—
17B		—	—	—		0.002	0.003	0.002		—	—	—		—	—	—		—	—	—
18A		—	—	—		—	0.002	—		—	—	—		0.082	0.130	0.019		0.017	0.010	0.009
18C		—	—	—		0.088	—	0.016		—	—	—		0.340	0.490	1.00		4.90	2.60	9.20
19A		—	—	—		0.120	0.100	0.070		—	—	—		—	—	—		—	—	—
19B		—	—	0.260		0.030	0.160	27.0		—	0.030	2.70		—	—	—		—	—	0.008
21A	1.70	1.60	0.630	13.0	—	0.026	—	0.130	—	—	—	—	—	—	—	—	—	—	—	—

Notes:
(1) All results in mg/l (PPM)
(2) ** = July sampling data for A wells only; other data from August sampling
(3) — = less than detection limit; refer to Appendix C
(4) Blank space indicates no data/no sample
(5) * laboratory cross-contamination in range of .015 to .042 ppm.

TABLE 24

ANALYTICAL RESULTS FOR PESTICIDES/PCB's, PHENOLICS AND INORGANICS
DUPONT - NIAGARA PLANT SITE

Well	BHC α June	BHC α July/ Aug.**	BHC α Sept	BHC α Oct	BHC β June	BHC β July/ Aug.**	BHC β Sept	BHC β Oct	BHC δ June	BHC δ July/ Aug.**	BHC δ Sept	BHC δ Oct	BHC γ June	BHC γ July/ Aug.**	BHC γ Sept	BHC γ Oct
1A	*	*	0.16	0.34	*	*	*	*	*	*	0.03	0.047	*	*	0.03	0.031
1B	130.0	50.0	42.0	22.0	12.0	7.9	*	6.6	74.0	26.0	38.0	1.7	150.0	53.0	52.0	33.0
1C	80.0	770.0	310.0	150.0	21.0	90.0	37.0	19.0	8.4	440.0	0.96	130.0	100.0	1100.0	480.0	200.0
1D	0.89	*	0.08	0.42	0.19	*	0.07	0.077	0.12	*	1.3	0.40	1.1	*	0.52	0.51
1E	0.54	0.06	0.07	0.50	0.45	0.03	0.02	0.046	0.27	*	0.05	0.32	0.43	0.06	0.08	0.50
1F	9.8		1.7	0.73	1.3		0.15	0.14	2.1		0.11	*	4.0		0.79	0.17
1G	160.0				22.0				55.0				170.0			
1J		3.4	0.82	1.3		0.10	0.06	0.10		0.61	0.20	0.10		0.85	0.33	0.17
2A		0.05	0.07	0.09		*	0.07	*		*	*	0.015		*	*	*
2C																
3A		0.05	*	0.051		*	0.05	*		*	0.04	*			*	*
3B		5.1	0.16	*		*	*	*		0.70	0.24	*		0.22	0.34	*
4A		0.03	0.02	0.075		0.03	*	*		*	*	*		0.02	*	*
4C		0.28	0.03	0.12		0.06	*	*		0.11	*	*		0.32	*	*
5A		0.02	*			*	*			*	*			*	*	
5B		*	*	0.20		*	*	0.023		*	*	0.046		*	*	0.038
5CD																
5D																
5F																
6A		*	*	0.10		*	*	0.17		*	*	0.14		*	*	*
7A		0.03	0.03	0.064		*	0.02	0.024		*	*	0.032		*	*	0.080
7C		0.02	*	0.062		*	0.05	0.039		*	0.05	0.078		*	*	0.10
8A		*	0.17	0.16		*	*	*		*	*	*		*	0.11	0.33
8B		*	*	0.11		*	*	*		*	*	*		*	0.02	0.093
9A		*	*	*		*	*	*		*	*	*		*	0.01	0.16
10A		*	*	0.18		*	0.02	0.039		*	*	*		*	*	0.20
10C		5.1	0.10	0.31		0.04	0.07	0.078		1.6	0.24	0.23		4.8	0.05	0.23
10D																
10F																
11A		*	*	0.20		*	0.02	*		*	*	*		*	*	0.01
12A		0.05	8.9	7.3		*	*	*		*	*	*		*	0.04	*
12B		1.9	8.9	7.3		0.45	0.21	*		0.30	*	*		1.1	2.8	1.2
13A		*	*	0.043		*	*	*		*	*	*		*	*	*
14A		*	*	0.52		*	*	0.20		*	*	*		*	*	*
14C																
15A		*	0.06	0.23		0.20	0.09	0.20		*	*	0.031		*	*	0.039
15C		64.0	3.4			12.0	2.1			22.0	12.0			69.0	17.0	
15CD																
15D																
15F																
16A		0.39	*	*		*	0.04	*		*	*	0.023		0.13	*	*
16B		14.0	15.0	47.0		1.6	1.9	1.4		0.75	*	8.9		1.1	2.1	8.2
17A		0.32	0.05	0.15		*	0.03	*		*	*	*		0.31	0.07	0.14
17B		0.28	0.08	0.15		*	*	*		*	0.08	*		0.18	0.10	0.11
18A		*	*	0.069		24.0	*	0.038		*	*	0.009		*	*	0.046
18C		5.2	6.1	9.2		1.2	0.80	1.5		*	1.1	1.7		1.6	1.8	3.0
19A		0.05	0.04	0.17		0.24	0.06	0.12		*	*	0.12		0.01	*	0.086
19B		0.48	0.40	3.0		*	0.06	0.18		0.03	0.06	0.10		0.01	0.04	0095
21A	6.9	*	*	0.10	0.30	*	*	*	25.0	*	*	*	*	*	*	*

Well	PCB - 1248 June	PCB - 1248 July/ Aug.**	PCB - 1248 Sept	PCB - 1248 Oct	PCB - 1254 June	PCB - 1254 July/ Aug.**	PCB - 1254 Sept	PCB - 1254 Oct	PCB - 1260 June	PCB - 1260 July/ Aug.**	PCB - 1260 Sept	PCB - 1260 Oct	Phenolics June	Phenolics July/ Aug.**	Phenolics Sept	Phenolics Oct
1A		*	*	*		*	*	*		*	*	*	—		*0.01	0.035
1B		*	*	*		*	*	*		*	*	*	0.024	0.03	0.053	0.052
1C		*	*	*		*	110.0	44.0		*	*	*	0.019	*	*	0.013
1D		*	*	*		*	*	*		*	*	*	—	*	*	*
1E		*	*	*		*	*	*		*	*	*	0.013	*	*	*
1F			*	*			*	*			*	*	0.023		*	*
1G													0.027			
1J		*	*	*		*	*	*		*	*	*		*	*	*
2A		*	*	*		*	*	*		*	*	*			*	*
2C																
3A		*	*	*		*	*	*		*	*	*			*	0.015
3B		*	*	*		*	*	*		*	*	*		0.081	0.053	0.063
4A		*	*	*		*	*	*		*	*	*			*	*
4C		*	*	*		*	*	*		*	*	*		0.017	*	*
5A		*	*			*	*			*	*				*	
5B		*	*	*		*	*	*		*	*	*		*	0.02	*
5CD																
5D																
5F																
6A		*	*	*		*	*	*		*	*	*			*	*
7A		*	*	*		*	*	*		*	*	*			*	0.013
7C		*	*	*		*	*	*		*	*	*		0.038	0.05	0.072
8A		*	*	*		*	*	*		*	*	*			0.15	2.4
8B		*	*	*		*	*	*		*	0.16	*		1.2	0.10	0.35
9A		*	*	*		*	*	*		*	*	*			*	0.03
10A		*	*	*		*	*	*		*	*	*			*	0.065
10C		*	*	*		*	*	*		*	*	*		*	*	0.029
10D																
10F																
11A		*	*	*		*	*	*		*	*	*			*	0.025
12A		*	2.6	*		*	*	*		*	*	*			*	*
12B		*	2.6	25.0		*	*	*		*	*	*		*	*	*
13A		*	*	*		*	*	*		*	*	*			0.012	0.012
14A		*	*	*		*	*	*		*	*	*			*	*
14C																
15A		*	*	*		*	*	*		*	*	*			*	*
15C		*	*			*	*			*	*			*	0.01	
15CD																
15D																
15F																
16A		*	*	*		*	*	*		*	*	*			0.32	0.39
16B		*	*	*		*	*	*		*	*	*		0.12	0.076	0.071
17A		*	*	*		*	*	*		*	*	*			*	0.014
17B		*	*	*		*	*	*			*	*		*	*	*
18A		*	*	*		*	*	*		*	*	*			0.014	0.018
18C		*	*	*		*	*	*		*	*	*		0.012	0.012	*
19A		*	*	*		*	*	*		*	*	*			*	*
19B		*	*	*		*	*	*		*	*	*		*	*	*
21A		*	*			*	*	*		*	*	*	0.051		0.028	0.044

Well	Total Cyanide June	Total Cyanide July/ Aug.**	Total Cyanide Sept	Total Cyanide Oct	Soluble Barium June	Soluble Barium July/ Aug.**	Soluble Barium Sept	Soluble Barium Oct	Soluble Copper June	Soluble Copper July/ Aug.**+	Soluble Copper Sept	Soluble Copper Oct
1A	0.060	0.059	0.06	0.12	0.25	*	0.05	0.16		0.010	*	*
1B	0.54	0.074	0.08	0.11	0.30	0.48	0.14	0.41		0.016	*	*
1C	1.50	1.7	0.07	0.23	0.27	0.38	0.04	0.20		0.246	*	*
1D	0.125	*	0.10	0.025	0.35	0.24	0.12	0.35		0.018	*	*
1E	—	*	*	*	0.31	0.50	0.05	0.18		0.016	*	*
1F	—		0.06	*	0.23		0.12	0.27			*	*
1G	0.012				0.32							
1J		0.018	0.065	*		1.0	0.22	0.60		0.756	*	*
2A		0.024	0.15	3.3		*	0.30	0.33		0.008	0.004	*
2C												
3A		3.3	2.2	1.4		0.08	0.06	0.16		0.008	*	*
3B		200	0.48	5.0		0.09	0.25	0.45		0.050	0.016	0.008
4A		0.016	1.0	*		0.74	0.05	0.06		0.008	*	*
4C		*	1.0	*		0.09	0.05	0.06		0.004	*	*
5A		0.088 -	2.0			0.19	0.58			0.052	*	
5B		0.26	0.54	*		0.36	0.70	0.16		0.010	0.01	*
5CD												
5D												
5F												
6A		0.024	0.36	0.049		*	0.13	0.31		*	0.01	*
7A		1.3	6.0	1.3		*	0.16	0.20		*	*	*
7C		0.35	0.56	0.052		*	0.24	0.37		0.024	*	*
8A		37.0	36.0	61.0		0.10	0.07	0.07		0.458	*	*
8B		17.0	23.0	9.9		*	0.03	0.07		0.012	*	*
9A		0.62	8.2	3.5		*	0.10	0.36		0.014	*	0.006
10A		0.021	0.31	0.062		0.17	0.09	0.34		0.008	*	*
10C		0.11	0.28	*		*	0.07	0.11		0.010	*	*
10D												
10F												
11A		0.044	0.017	0.10		*	0.07	0.24		0.022	0.004	*
12A		0.010	*	0.011		*	0.06	0.15		0.007	*	0.010
12B		0.070	0.024	0.10		0.08	0.14	0.27		0.004	*	0.008
13A		0.044	0.02	0.038		*	0.15	0.29		0.006	*	*
14A		0.036	0.045	0.059		*	0.09	0.11		0.032	0.014	0.022
14C												
15A		9.6	0.17	3.5		0.019	0.12	0.43		6.6	0.060	19.0
15C		0.94	0.12			*	0.10			0.746	2.4	
15CD												
15D												
15F												
16A		40.0	0.04	36.0		0.05	0.08	0.11		0.024	*	0.024
16B		89.0	0.013	7.1		*	0.05	0.32		0.018	*	0.01
17A		*	0.013	*		0.06	0.07	0.07		0.014	*	0.014
17B				*		*	0.04	0.13		0.016	*	*
18A		0.041	0.08	0.060		0.07	0.18	0.13		0.198	*	*
18C		0.89	0.14	0.72		*	0.05	0.13		0.012	0.006	0.006
19A		0.081	0.152	0.063		*	0.05	0.08		0.076	0.02	0.010
19B		0.33	0.17	1.1		*	0.06	0.13		0.016	*	*
21A	0.98	0.56	0.10	0.033	0.33	*	0.19	0.28		0.021	*	0.008

NOTES:

(1) BHC's and PCB's concentrations in μg/l (PPB)
Other parameters in mg/l (PPM)
(2) Concentrations of PCB -1016, -1221, -1232, -1242 below detection limits at all wells.
(3) * = less than detection limit; refer to Appendix C.
(4) Blank space indicates no data/no sample
(5) + = analyses for Total copper.
(6) ** = July sampling data for A wells only; other data from August sampling

TABLE 25
LABORATORY SOLUBILITIES AND SPECIFIC GRAVITIES
OF VOLATILE ORGANIC COMPOUNDS
DUPONT - NIAGARA FALLS PLANT SITE

Compound	Laboratory Solubility	Specific Gravity
Tetrachloroethylene	150 mg/l	1.626
Trans-1,2-Dichloroethylene	600 mg/l	1.26
Trichloroethylene	1100 mg/l	1.46
Vinyl Chloride	1100 mg/l	0.912
1,1,2,2-Tetrachloroethane	2900 mg/l	1.60
Chloroform	8000 mg/l	1.49
Methylene Chloride	20,000 mg/l	1.326
Benzene	1780 mg/l	0.879
Chlorobenzene	500 mg/l	1.107

Source: Verschueren, Karel, 1977, Handbook of environmental data on organic chemicals.

TABLE 26

ANALYTICAL RESULTS FROM NOVEMBER SAMPLING
OF RECENTLY-INSTALLED DEEPER WELLS
DUPONT – NIAGARA FALLS PLANT SITE

	Tetrachloroethylene	Trans-1,2-dichloroethylene	Trichloroethylene	Vinyl Chloride	1,1,2,2-tetrachloroethane	Chloroform	Methylene Chloride	Benzene	Chlorobenzene	BHC α	BHC β	BHC δ	BHC γ	Phenolics	Total Cyanide	Soluble Barium	Soluble Copper
2A*	—	6.40	1.30	2.10	—	0.55	0.95	—	—	0.09	—	0.015	—	—	3.3	0.33	—
2C	41.0	5.50	190.0	0.340	40.0	1.60	57.0	0.170	—	26.0	3.4	1.3	19.0	—	0.19	-.31	—++
5A**	0.062	1.40	0.210	0.360	—	0.008	—	0.004	—	—	—	—	—	—	2.0	0.58	—
5B	—	0.300	0.140	0.250	—	—	—	—	—	0.04	0.04	—	—	—	0.091	0.43	—++
5CD	—	0.530	0.320	0.470	—	—	—	—	—	0.09	0.03	0.06	—	0.016	0.14	0.31	—++
5F	0.027	0.038	0.050	—	—	0.270	0.090	—	—	—	—	—	—	0.015	—	—	—++
10A*	0.130	12.0	2.80	1.00	—	—	0.027	1.40	2.20	0.18	0.039	—	0.20	0.065	0.062	0.34	—
10C*	—	2.50	1.30	0.660	—	—	—	0.180	0.280	0.31	0.078	0.23	0.23	0.029	—	0.11	—
10D	5.20	2.80	32.0	—	15.0	0.180	0.041	0.560	—	2.3	3.8	0.41	2.7	0.016	0.012	0.41	—
10F	0.250	3.50	0.066	0.310	—	—	—	—	—	1.4	0.22	0.03	0.03	0.014	—	0.34	—
14A*	56.0	—	45.0	—	23.0	0.460	—	—	—	0.52	0.20	—	—	—	0.059	0.11	0.022
14C	8.10	2.60	18.0	—	—	—	0.160	—	—	32.0	4.4	4.7	37.0			0.31	0.008
15A*	13.0	1.40	25.0	—	1.20	610.0	59.0	—	—	0.23	0.20	0.031	0.039	—	3.5	0.43	19.0
15CD	52.0	2.90	160.0	—	42.0	42.0	24.0	—	—	—	—	—	—	—	2.1	0.29	2.5++
15D+	18.0	3.20	48.0	—	11.0	93.0	18.0	—	—	17.0	3.2	4.9	16.0	0.012	23.0	0.34	18.0++
15F+	30.0	4.10	78.0	—	—	47.0	7.40	0.800	7.30	—	2.0	—	—	—	0.056	—	—

NOTES:

(1) no PCB's detected
(2) * = October data used; no November data
(3) ** = September data used; no November data
(4) — = not detected/below detection limit
(5) Blank space = no data/no sample
(6) + = possible cross-contamination; refer to text
(7) ++ = analysis for Total copper.
(8) concentrations in μg/l

TABLE 27

ANALYTICAL RESULTS FROM

RESAMPLING OF WELL CLUSTER 15

DUPONT - NIAGARA FALLS PLANT SITE

Parameter	15C/D		15D		15F		15J*
	Initial	Resample	Initial	Resample	Initial	Resample	
Tetrachloroethylene	52.0	30.2	18.0	24.6	30.0	7.42	13.0
Trans-1,2-dichloroethylene	2.90	2.17	3.20	—	4.10	1.38	0.349
Trichloroethylene	160.0	55.9	48.0	3.18	78.0	5.35	18.9
Vinyl Chloride	—	—	—	—	—	—	—
1,1,2,2-tetrachloroethane	42.0	—	11.0	—	—	—	—
Chloroform	42.0	21.0	93.0	1.79	47.0	6.06	33.8
Methylene Chloride	24.0	26.0	18.0	5.59	7.40	2.75	5.40
Benzene	—	—	—	—	0.800	—	—
Chlorobenzene	—	—	—	—	7.30	—	—
BHC α (ppb)	—	—	17.0	—	—	—	0.03
BHC β (ppb)	—	—	3.2	—	2.0	—	0.35
BHC δ (ppb)	—	—	4.9	—	—	—	0.11
BHC γ (ppb)	—	—	16.0	—	—	—	0.03
Phenolics	—	—	0.012	—	—	—	—
Total Cyanide	2.1	0.055	23.0	23.5	0.056	0.052	0.18
Soluble Barium	0.29	0.22	0.34	0.23	—	0.18	0.76
Total Copper	2.5	0.055	18.0	0.256	—	0.052	0.196

Notes:
1) All results in mg/l (ppm) except as noted
2) * = 15J first sampled during resampling of other wells
3) – = Below detection limit; refer to Appendix C

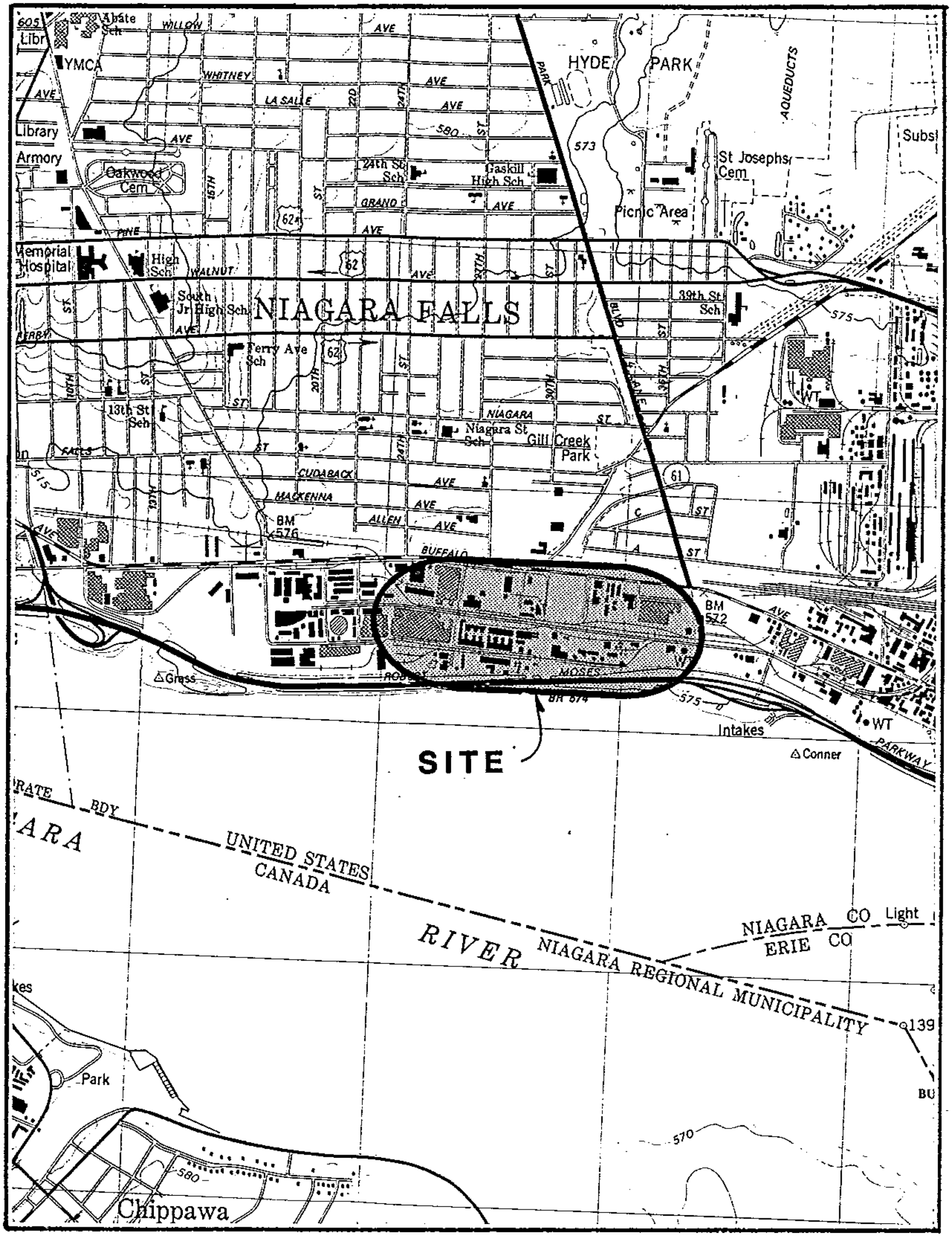
TABLE 28
LOADING ESTIMATES FOR
INDICATOR PARAMETERS - "A" ZONE
DUPONT - NIAGARA FALLS PLANT SITE

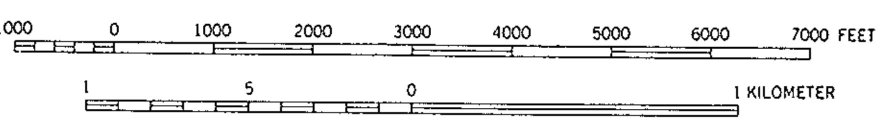
Parameter	Direct Niagara River Loading Estimates (lbs/d) From Control Well Sections										NE Quadrant Loading Estimate (lbs/d)		
	5A	4A	2A	1A	Sub Total	1A	21A	Sub Total	S-E*	Total	7A	18A	Total
Tetrachloroethylene	0.005	–	–	(0.70)	(0.7)	(0.65)	(0.13)	(0.78)	0.01	(1.5)	–	–	–
Trans-1,2-dichloroethylene	0.109	0.067	0.572	(1.35)	(2.1)	(1.26)	(1.79)	(3.0)	0.10	(5.2)	10^{-4}	0.001	0.001
Trichloroethylene	0.016	–	0.116	(1.30)	(1.4)	(1.22)	(1.24)	(2.5)	0.02	(3.9)	–	–	–
Vinyl Chloride	0.028	0.128	0.188	–	0.34	–	0.151	0.15	0.07	0.5	–	0.001	0.001
1,1,2,2-tetrachloroethane	–	–	–	0.070	0.07	0.065	0.401	0.47	–	0.5	–	–	–
Chloroform	0.001	0.007	0.049	0.466	0.52	0.435	0.004	0.44	–	1.0	–	–	–
Methylene Chloride	–	–	0.085	2.2	2.3	2.1	–	2.1	–	4.4	–	–	–
Benzene	10^{-4}	–	–	–	10^{-4}	–	–	–	0.004	0.004	–	0.001	0.001
Chlorobenzene	–	–	–	–	–	–	–	–	–	–	10^{-4}	10^{-4}	10^{-4}
Total BHC's	–	10^{-4}	10^{-5}	10^{-5}	10^{-4}	10^{-5}	–	10^{-5}	0.002	0.002	10^{-6}	10^{-5}	10^{-5}
Phenolics	–	0.009	–	0.002	0.01	0.002	0.001	0.003	–	0.01	10^{-4}	0.001	0.001
Cyanide	0.155	0.037	0.295	0.006	0.49	0.006	0.001	0.007	0.23	0.7	0.01	0.002	0.01

Total C-1 compound loading estimate = 5 lbs/d
Total C-2 compound loading estimate = 2 lbs/d (12 lbs/d)

Notes: 1) ( ) = loading using second-phase influence as actual water quality conditions; actual loading likely less than indicated
2) * = loading estimate at southern plant boundary, eastern part of site; refer to text
3) - = not detected

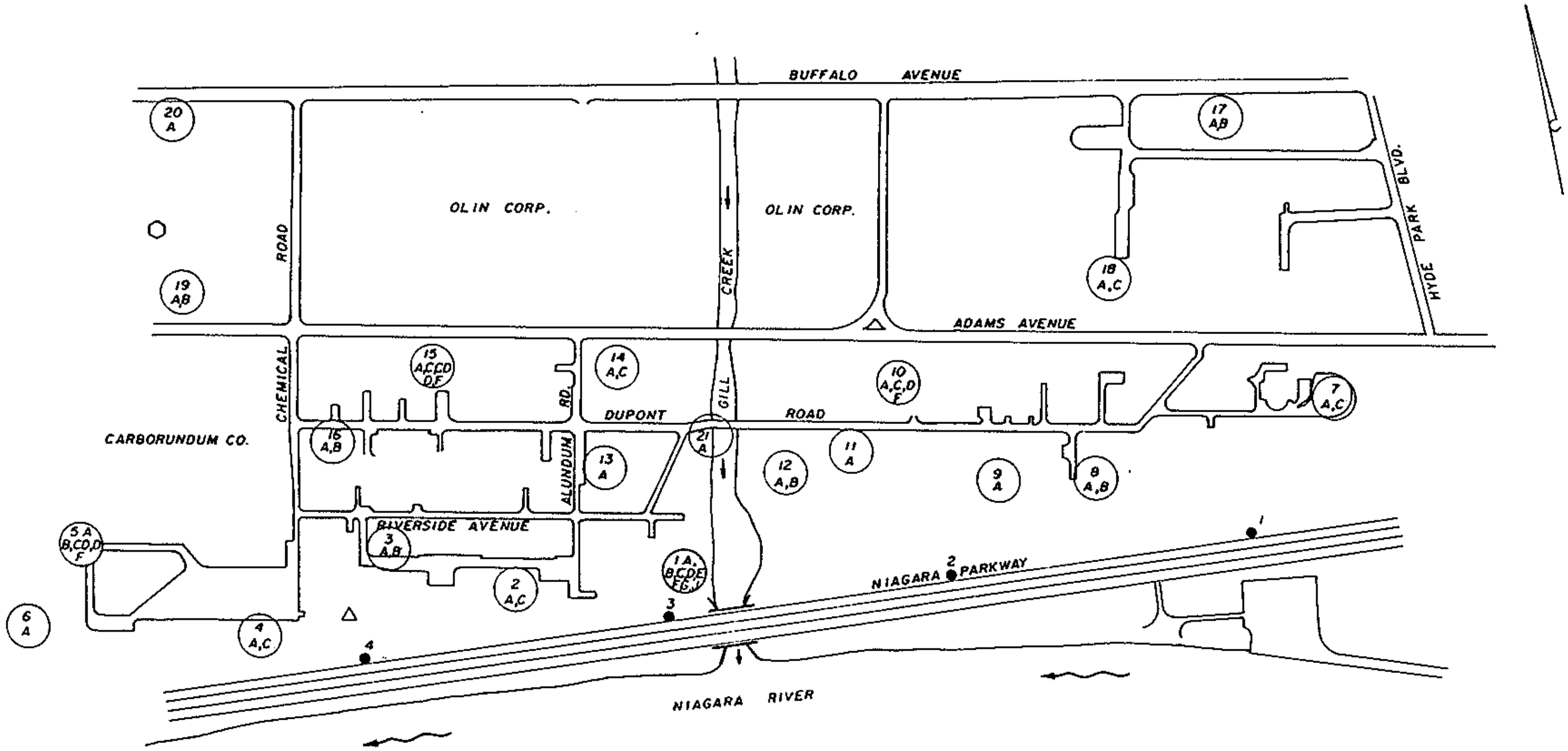
PLATES





REGIONAL LOCATION PLAN

PLATE 1



LEGEND:

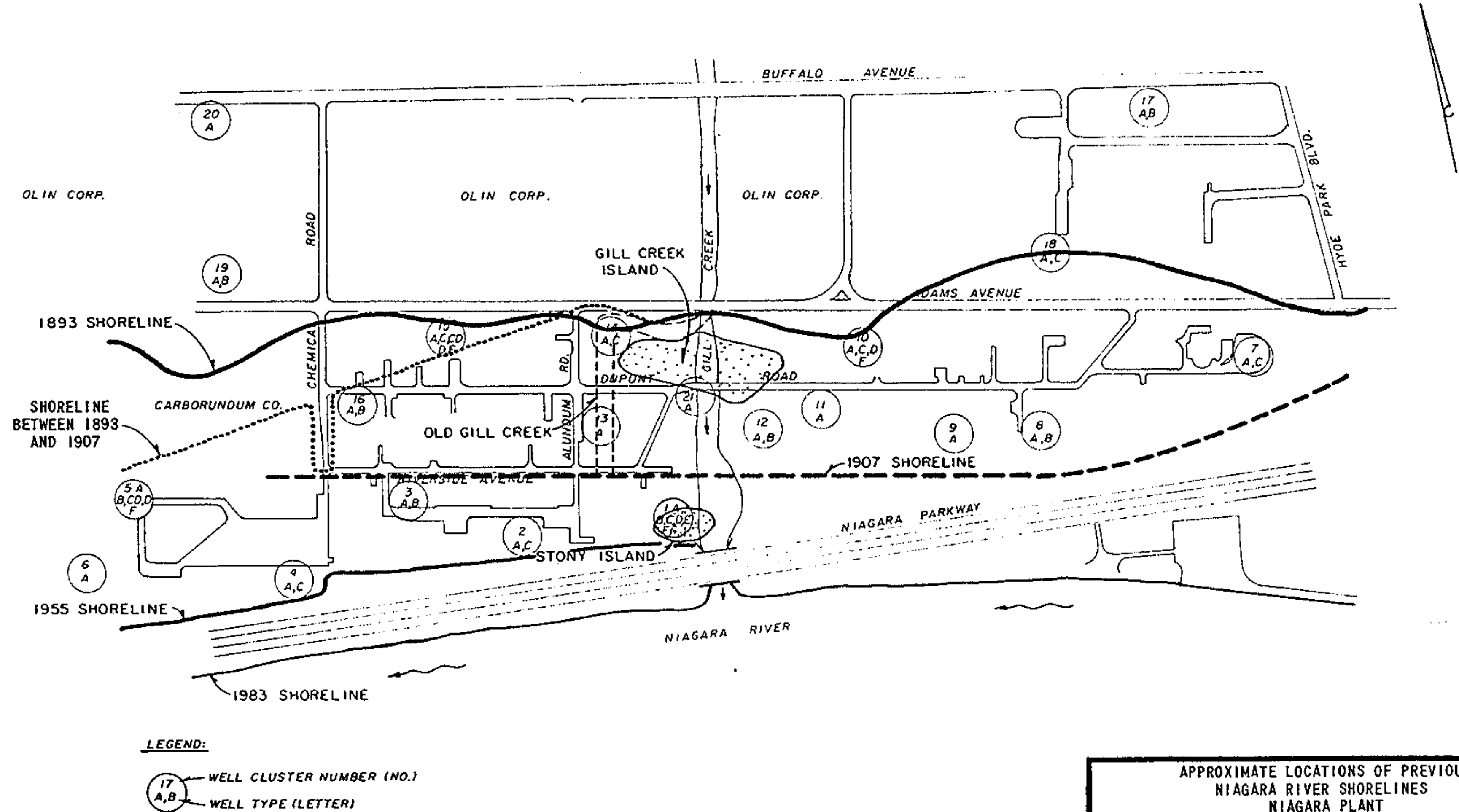
- (17 A,B) — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)
- ● DEC WELLS
- △ DUPONT PRODUCTION WELL
- ⬡ OLIN PRODUCTION WELLS

SITE PLAN
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 2

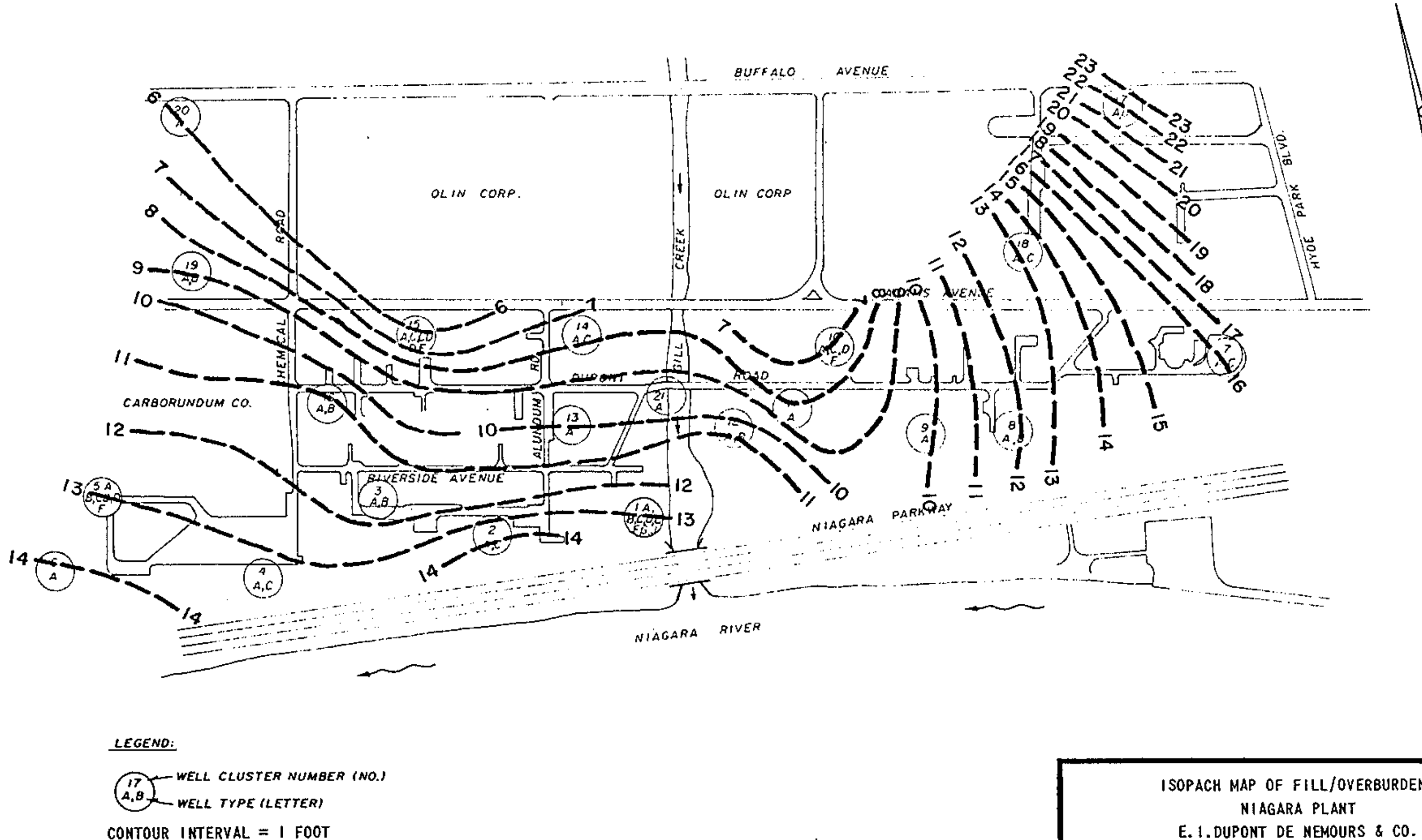


APPROXIMATE LOCATIONS OF PREVIOUS
NIAGARA RIVER SHORELINES
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 3

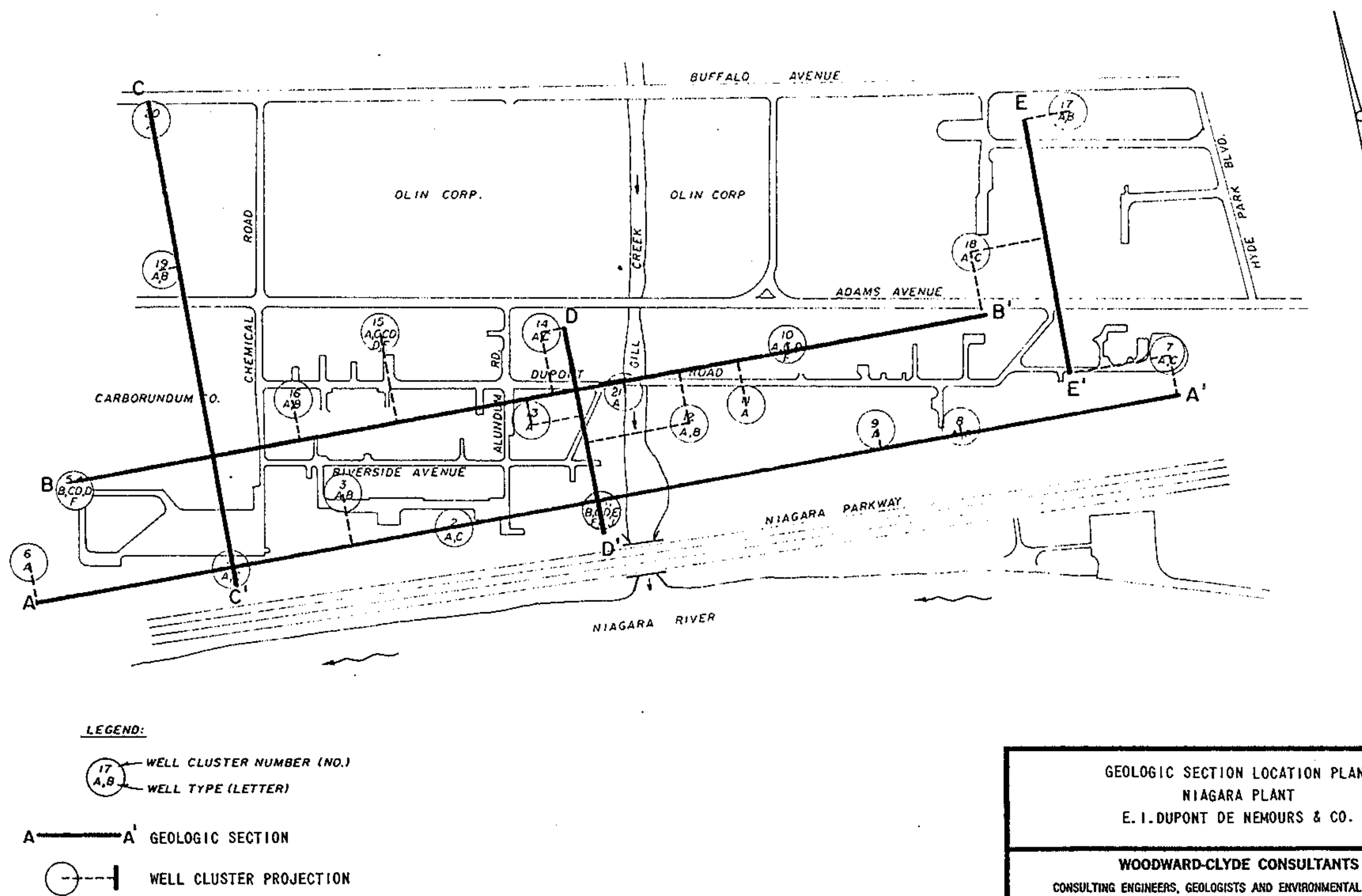


ISOPACH MAP OF FILL/OVERBURDEN
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 — 300	DATE: 11/15/83	
CHECKED: J.C.E.		JOB: 83C2236	

PLATE 4

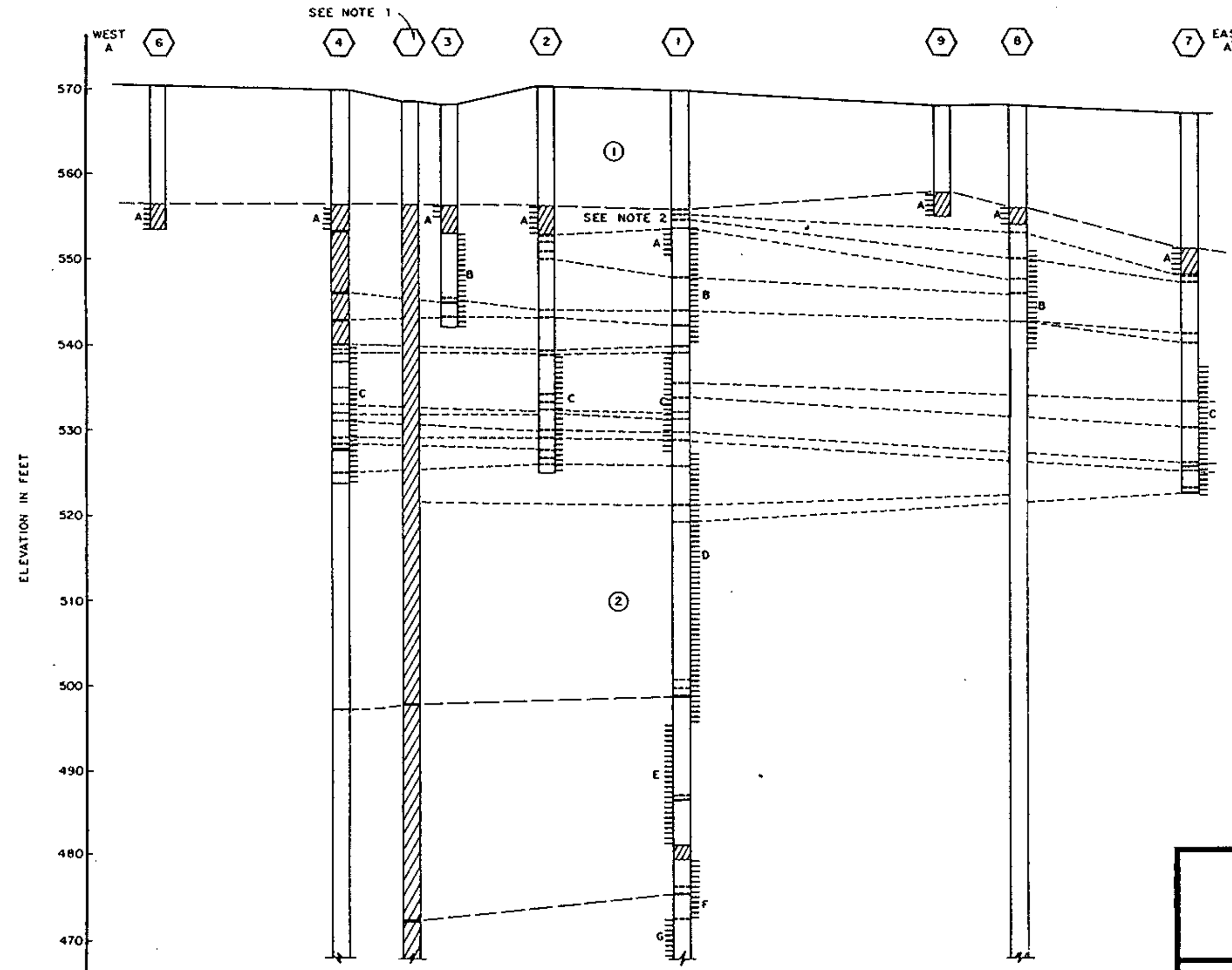


GEOLOGIC SECTION LOCATION PLAN
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T. P.	SCALE in FEET 0 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236-5

PLATE 5



EXPLANATION

12 WELL CLUSTER NUMBER

NO CORE AVAILABLE

MAJOR FRACTURE CAUSING DRILL WATER LOSS

FRACTURE / FRACTURES LOGGED FROM CORES

A UNCASED INTERVAL OF WELL AND SPECIFIC WELL DESIGNATION

① OVERBURDEN MATERIALS

② BEDROCK-LOCKPORT FORMATION

------ INTERPRETIVE CORRELATION OF FRACTURES

NOTES: 1) DUPONT PLANT WELL

2) ELEVATION OF TOP OF ROCK SHOWN IS AT WELL 1C

GEOLOGIC SECTION A-A'
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 — 400	DATE: 11/21/83	
CHECKED : J.C.E.		JOB : 83C2236	

PLATE 6

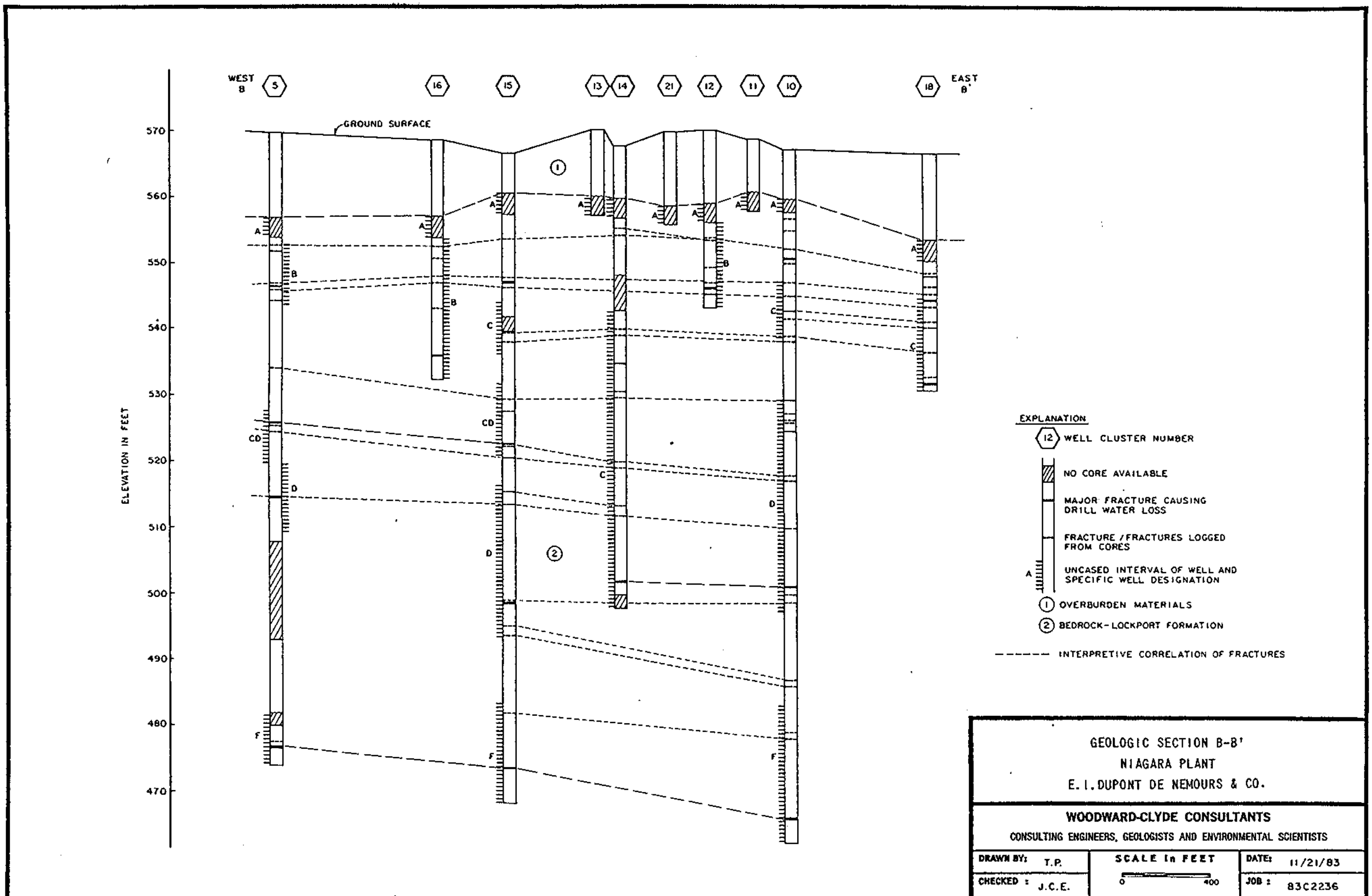
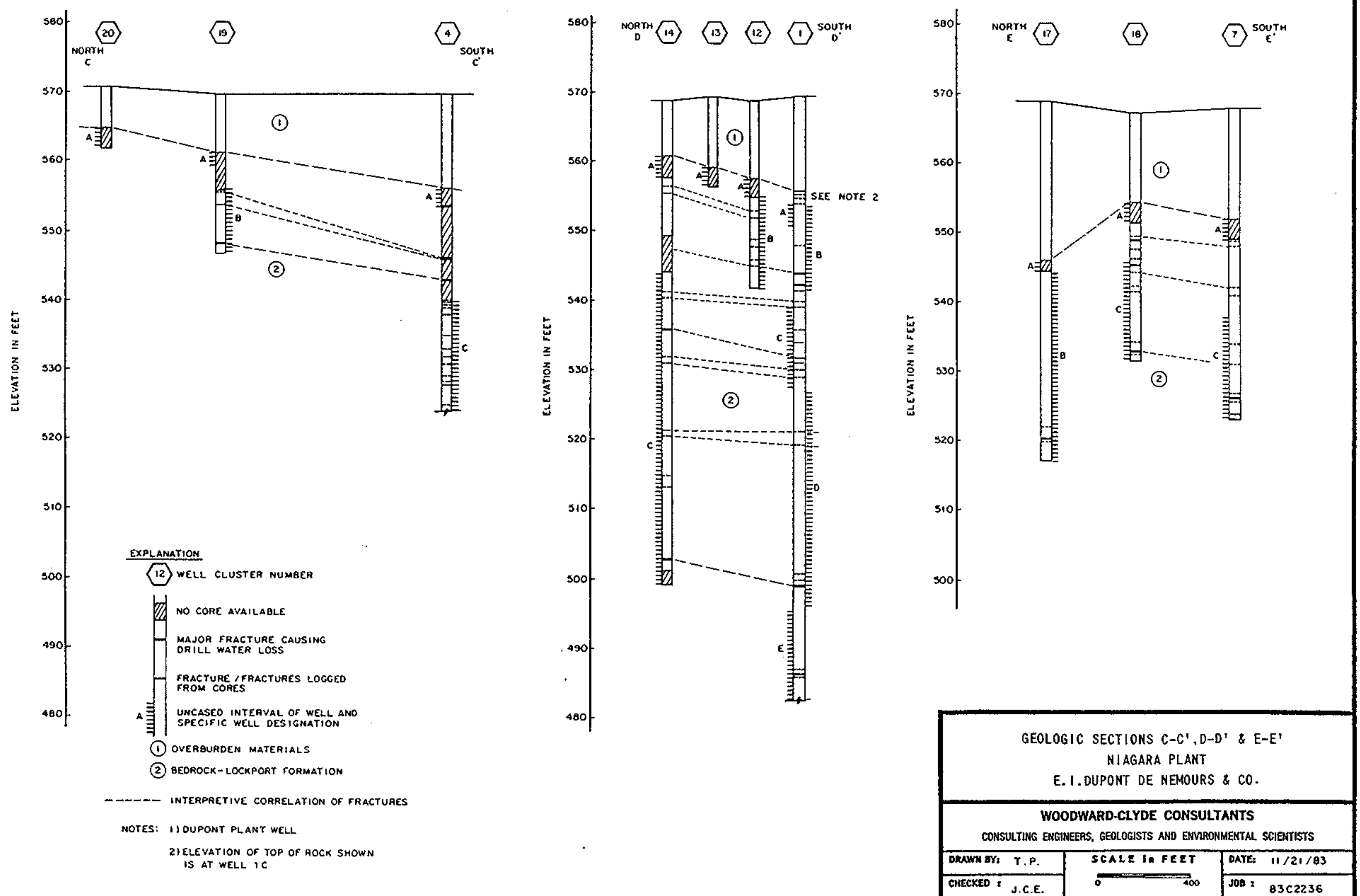

WEST B
EAST B'
5
16
15
13
14
21
12
11
10
18
GROUND SURFACE
ELEVATION IN FEET
570
560
550
540
530
520
510
500
490
480
470
A
B
C
CD
D
F
1
2
EXPLANATION
12 WELL CLUSTER NUMBER
NO CORE AVAILABLE
MAJOR FRACTURE CAUSING DRILL WATER LOSS
FRACTURE / FRACTURES LOGGED FROM CORES
UNCASED INTERVAL OF WELL AND SPECIFIC WELL DESIGNATION
1 OVERBURDEN MATERIALS
2 BEDROCK-LOCKPORT FORMATION
INTERPRETIVE CORRELATION OF FRACTURES
GEOLOGIC SECTION B-B'
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS
DRAWN BY: T.P.
CHECKED : J.C.E.
SCALE In FEET
0
400
DATE: 11/21/83
JOB : 83C2236

PLATE 7

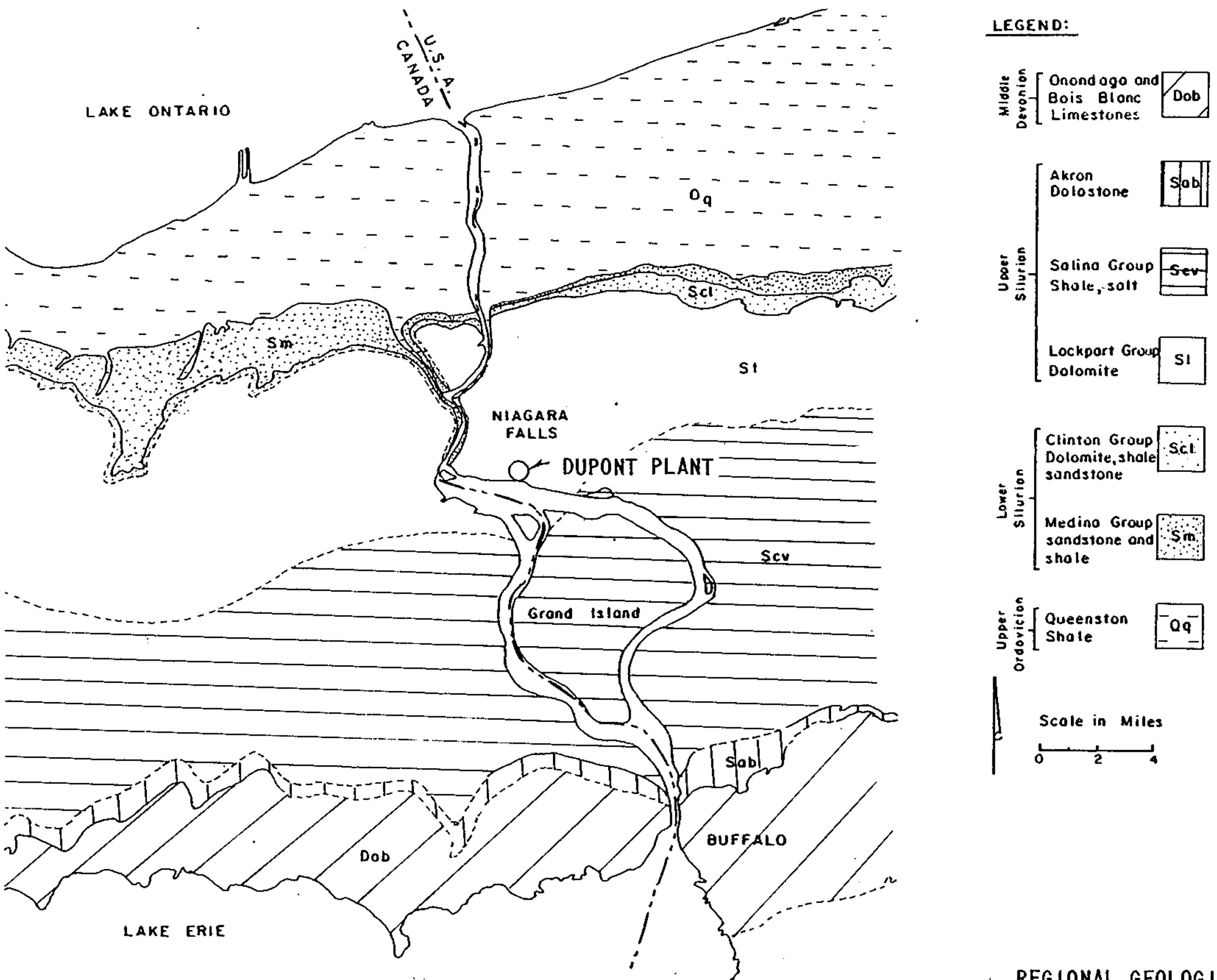


GEOLOGIC SECTIONS C-C', D-D' & E-E'
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

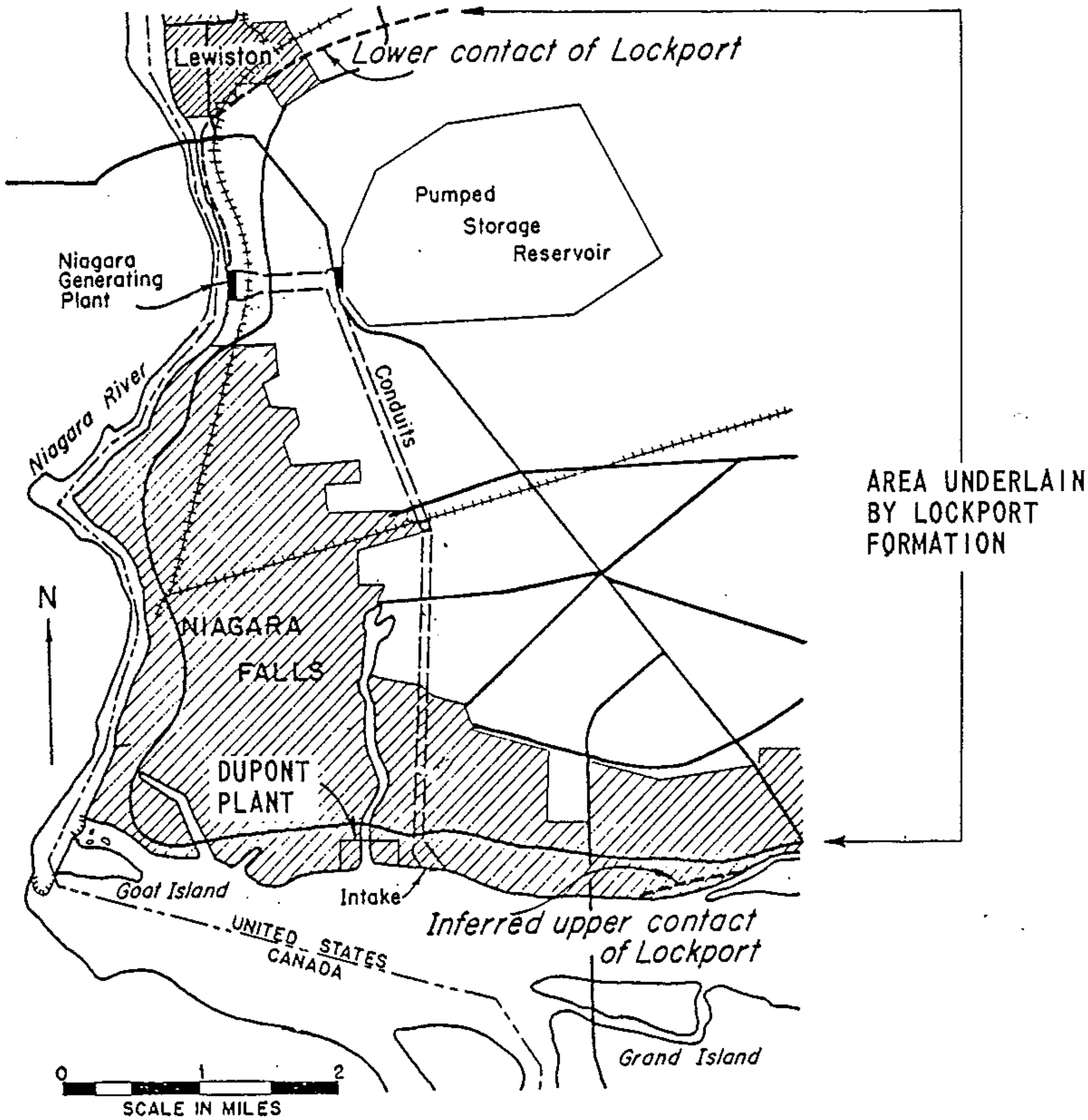
DRAWN BY: T.P.	SCALE In FEET	DATE: 11/21/83	
CHECKED: J.C.E.		JOB: 83C2236	

PLATE 8



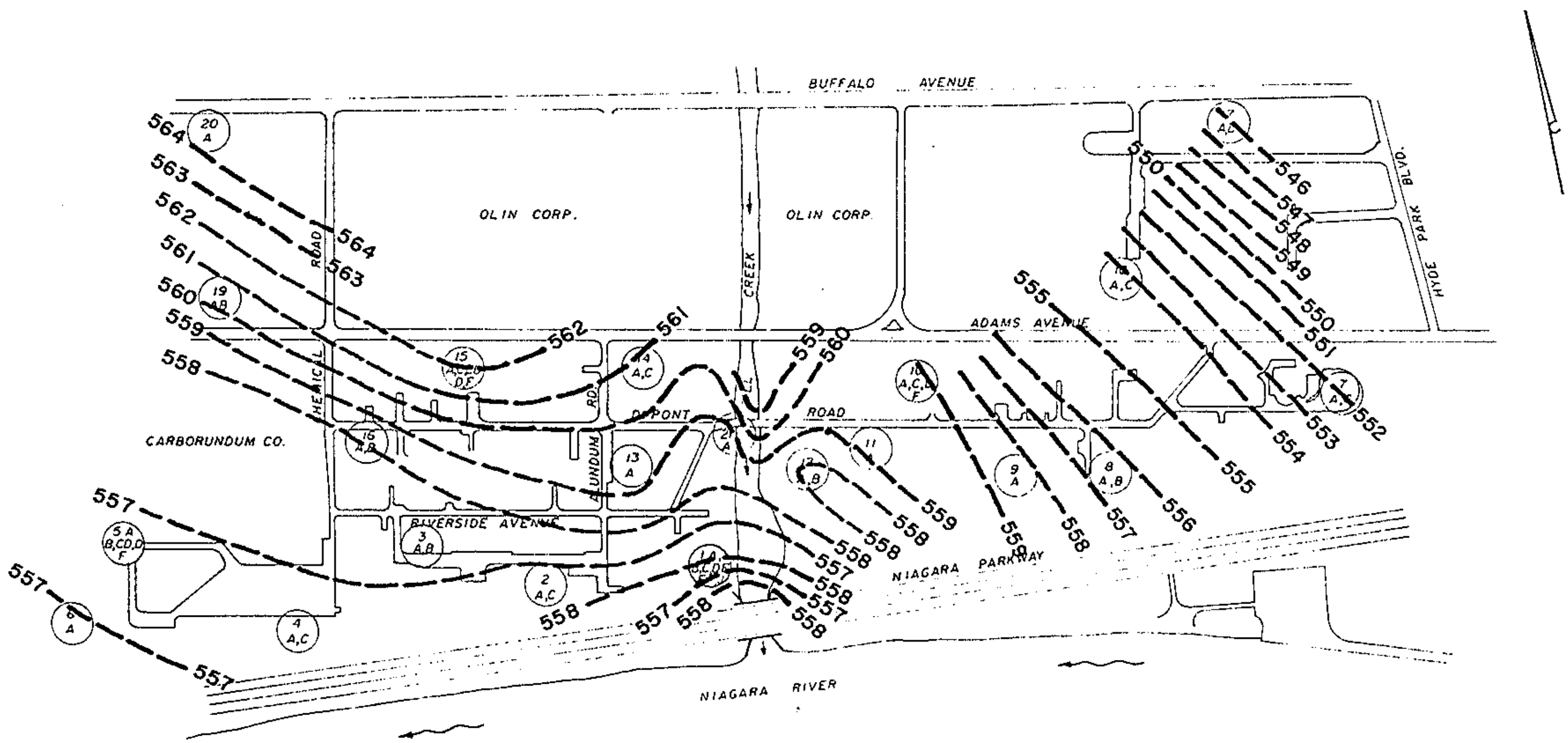
REGIONAL GEOLOGIC MAP
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.

PLATE 9



SITE LOCATION AND GEOLOGY MAP
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.
after N.Y.State Museum and Science
service bulletin no. 404

PLATE 10



LEGEND:

WELL CLUSTER NUMBER (NO.)
WELL TYPE (LETTER)

CONTOUR INTERVAL = 1 FOOT

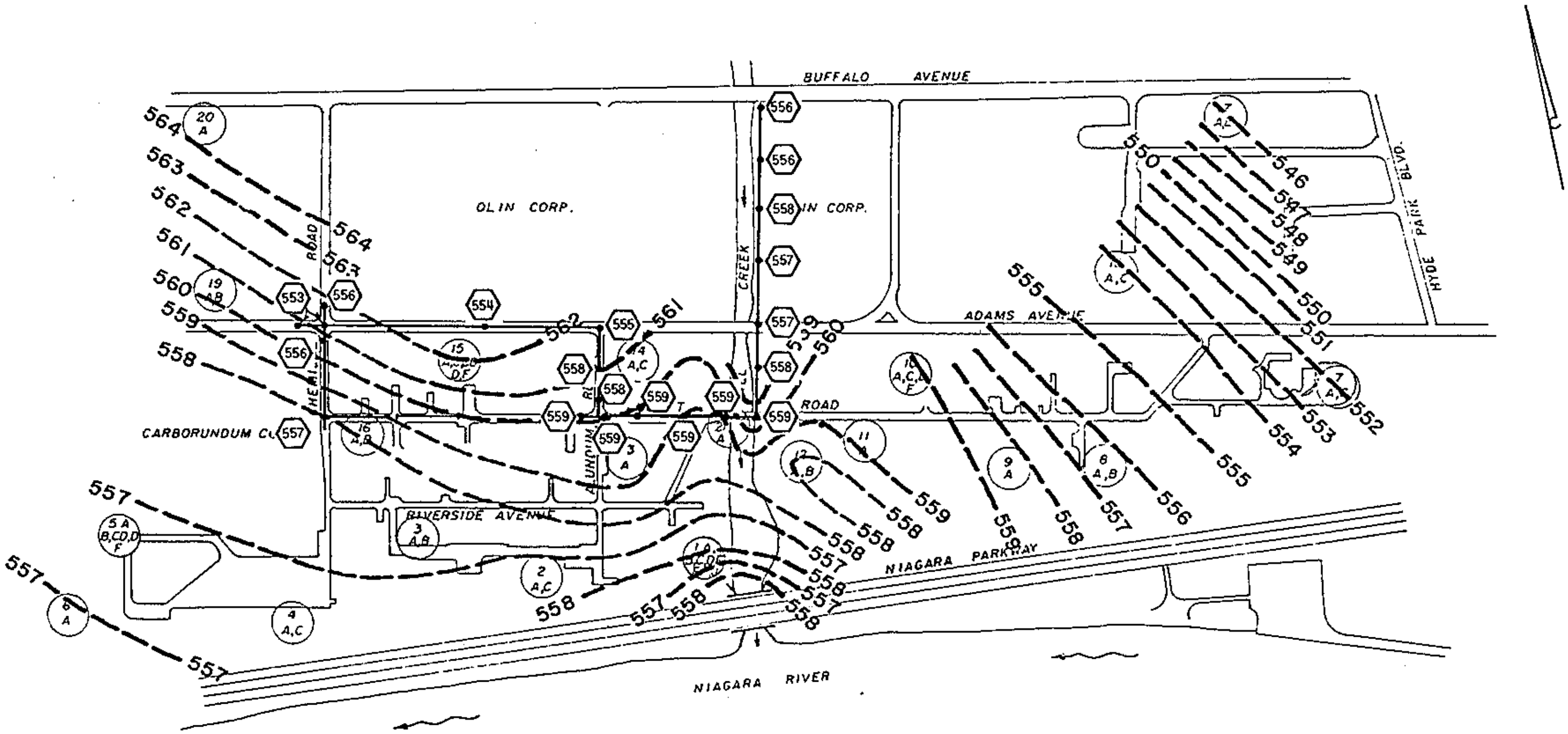
557 ELEVATION OF TOP OF BEDROCK

TOP OF BEDROCK STRUCTURE CONTOUR MAP
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET	DATE: 11/15/83	
CHECKED: J.C.E.	0 300	JOB: 83C2236	

PLATE 11



LEGEND:

WELL CLUSTER NUMBER (NO.)
WELL TYPE (LETTER)

CONTOUR INTERVAL = 1 FOOT

(554) UTILITY LOCATION SHOWING INVERT ELEVATION

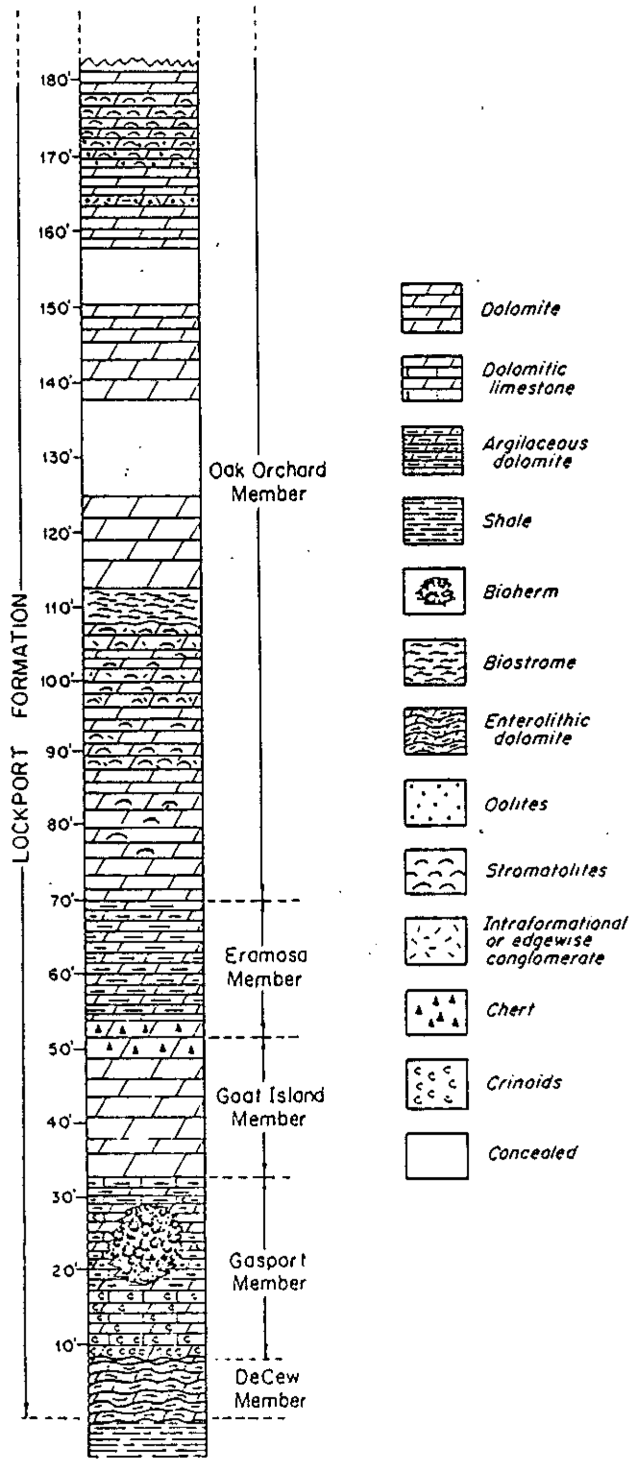
— — 557 ELEVATION OF TOP OF BEDROCK

ULITITY INVERT AND TOP OF BEDROCK MAP
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

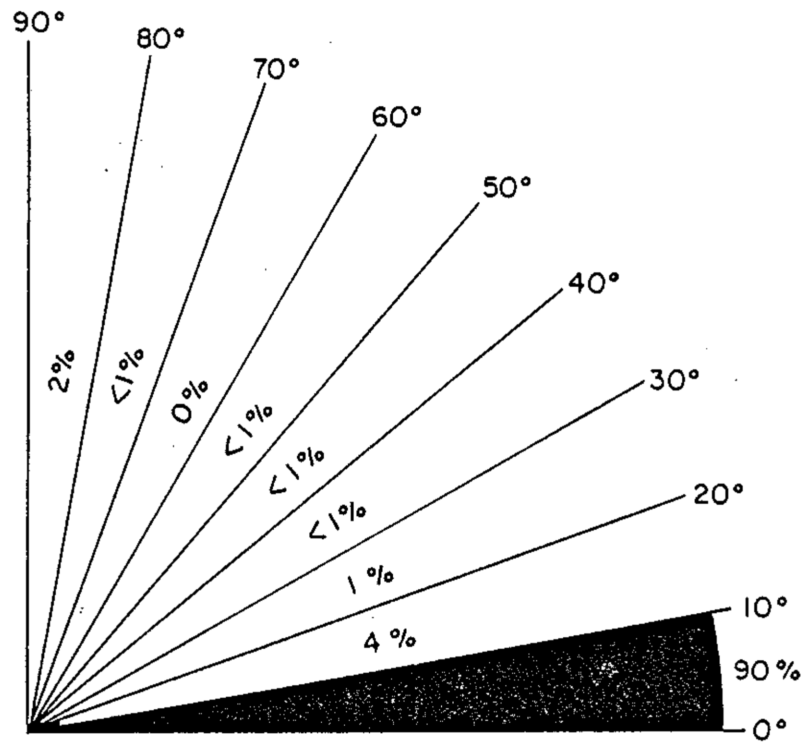
PLATE 12



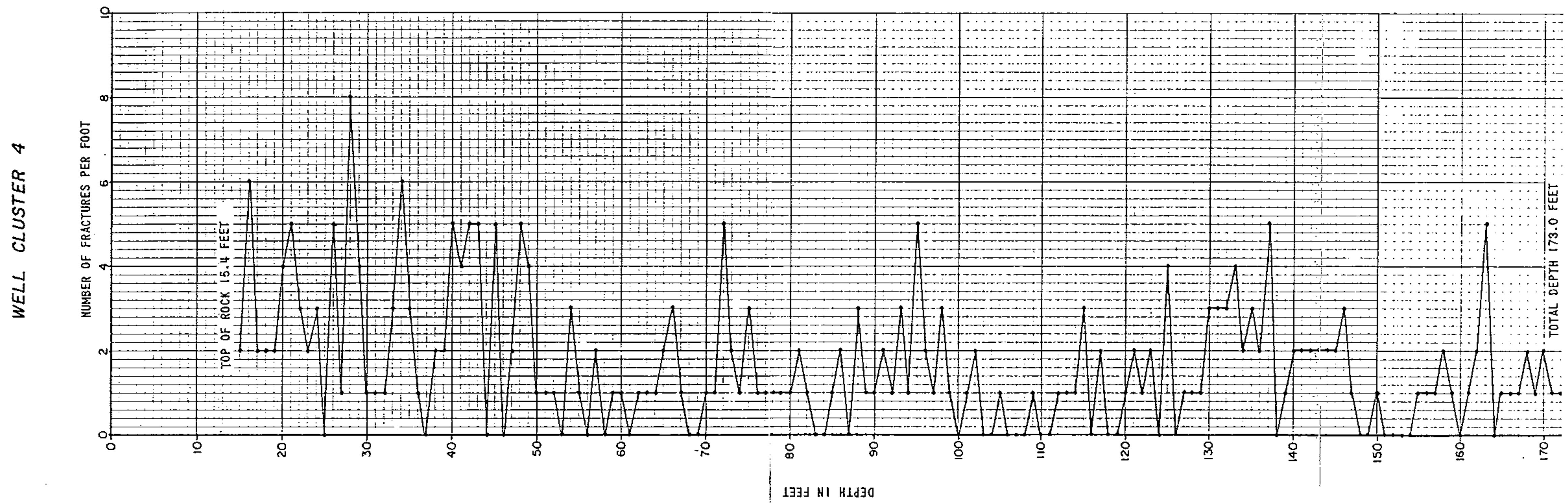
COLUMNAR SECTION OF LOCKPORT FORMATION
IN NIAGARA FALLS AREA
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.

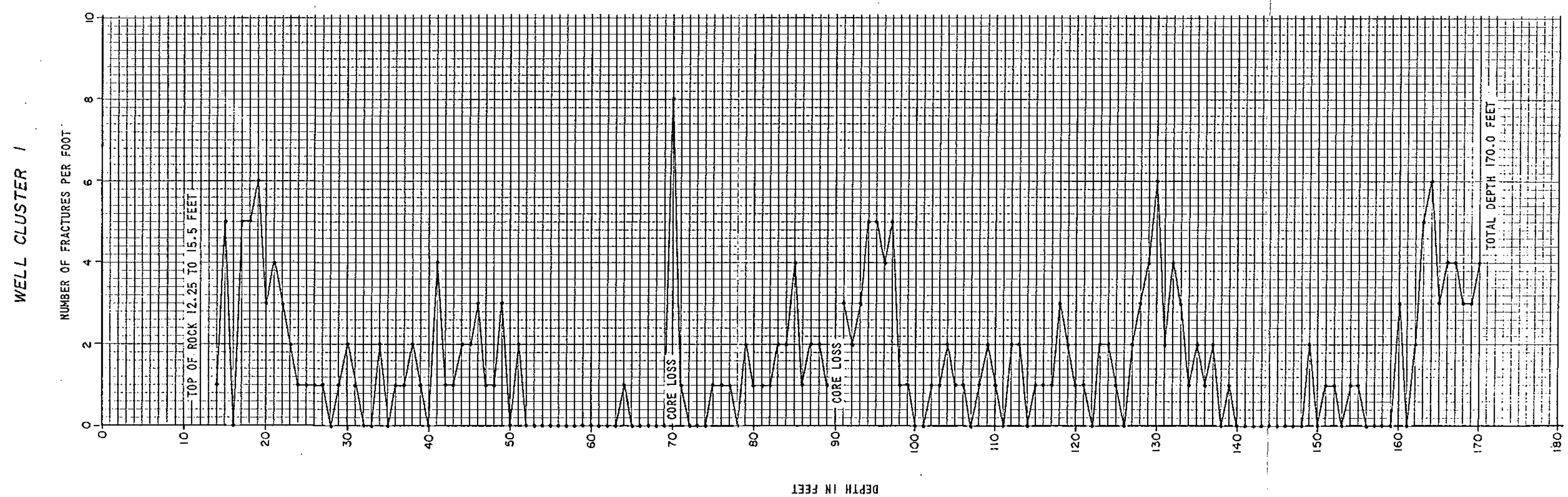
after N.Y.State Museum and Science
service bulletin no. 404

PLATE 13



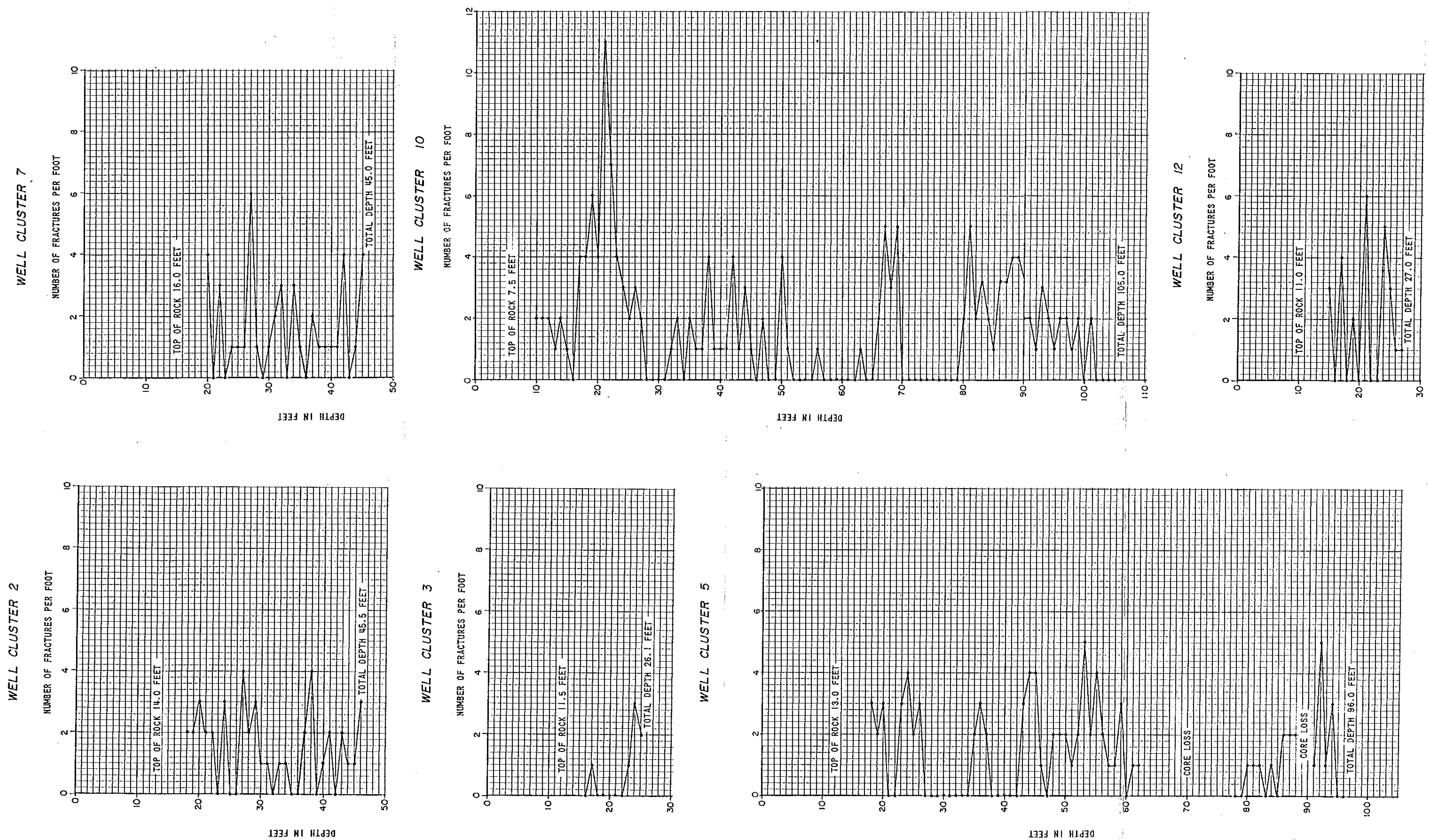
COMPOSITE PLOT OF DIP OF FRACTURES
ENCOUNTERED IN CORE HOLES
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.





FRACTURE FREQUENCY PLOTS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

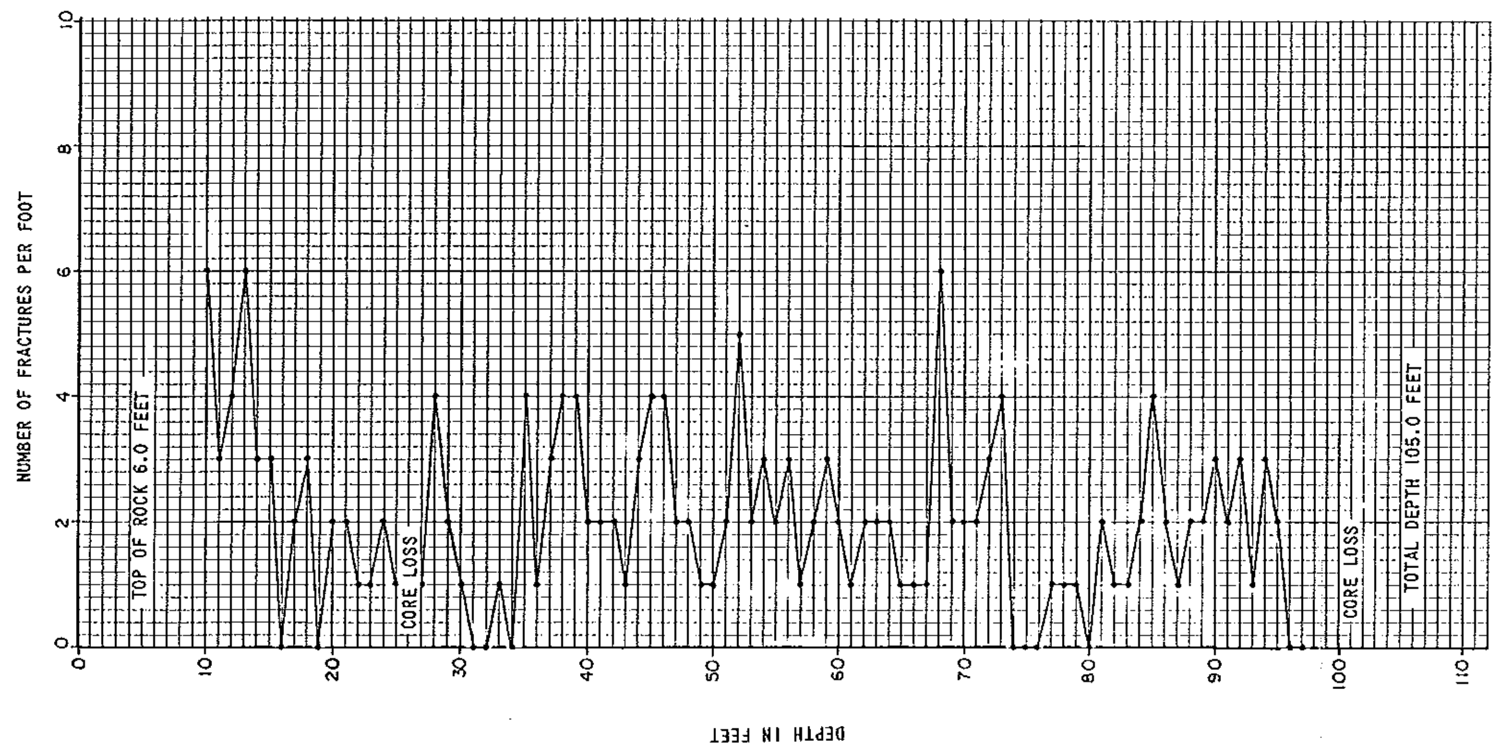
PLATE 15



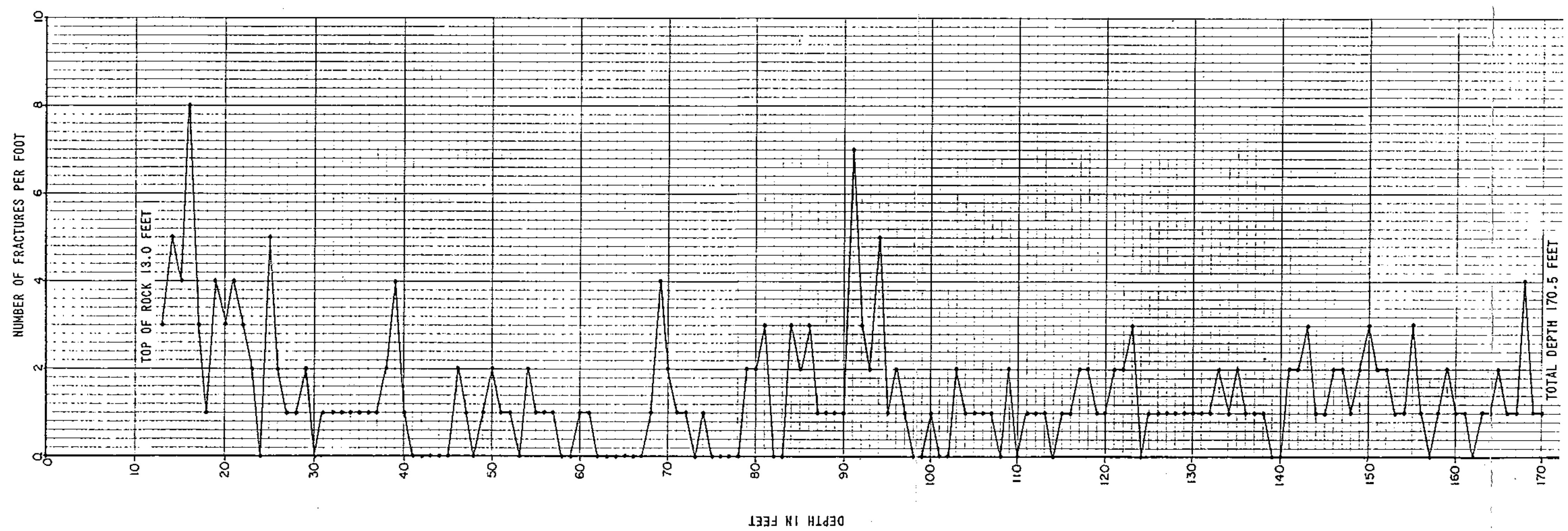
FRACTURE FREQUENCY PLOTS
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.

PLATE 16

WELL CLUSTER 15

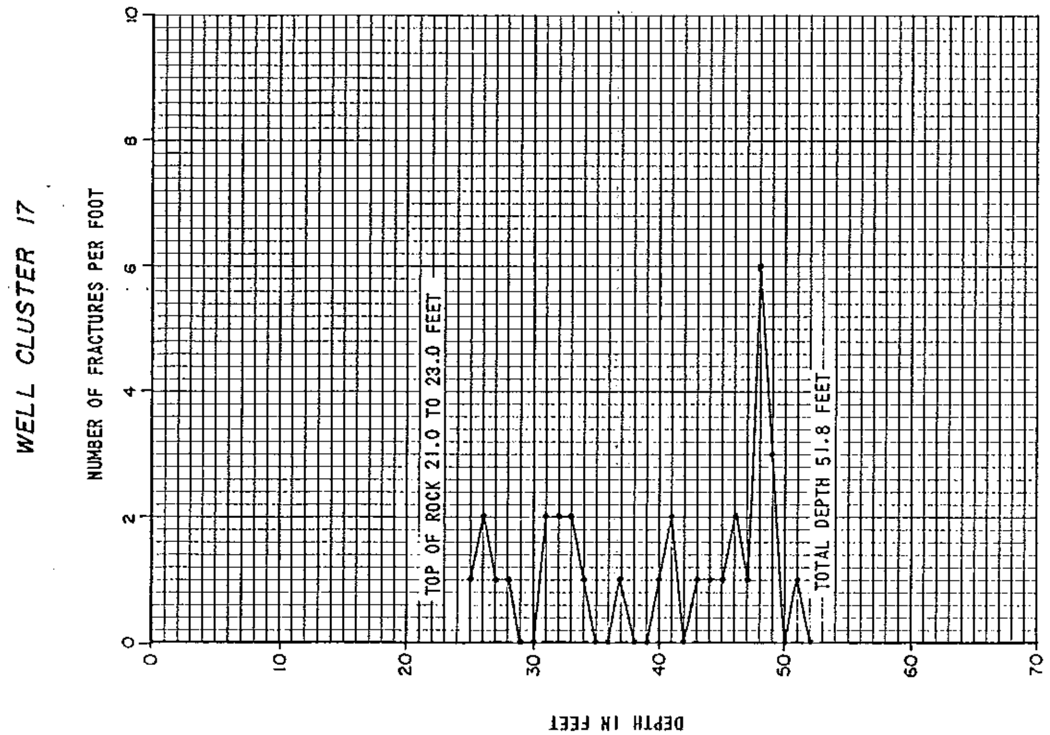


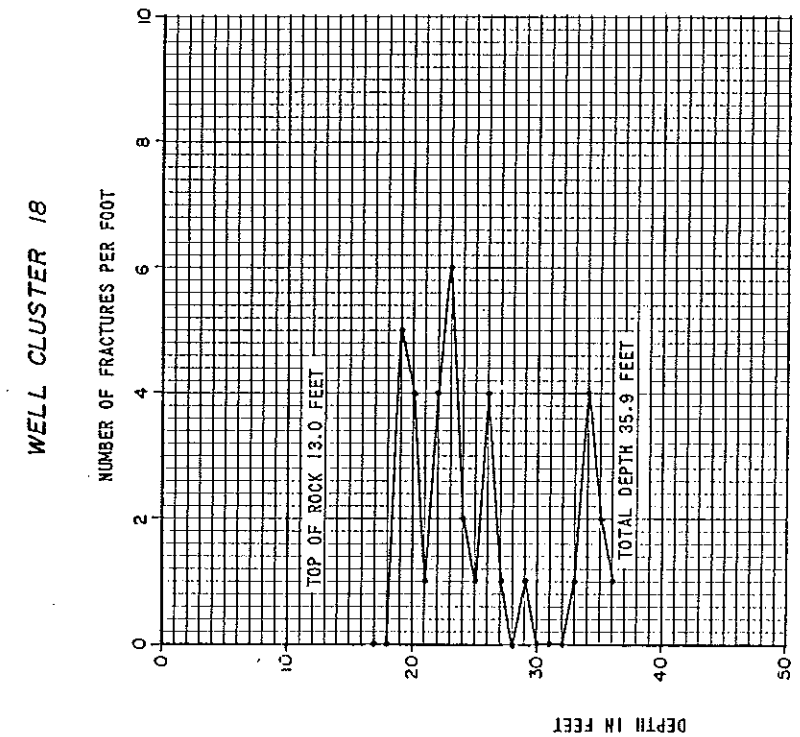
WELL CLUSTER 8

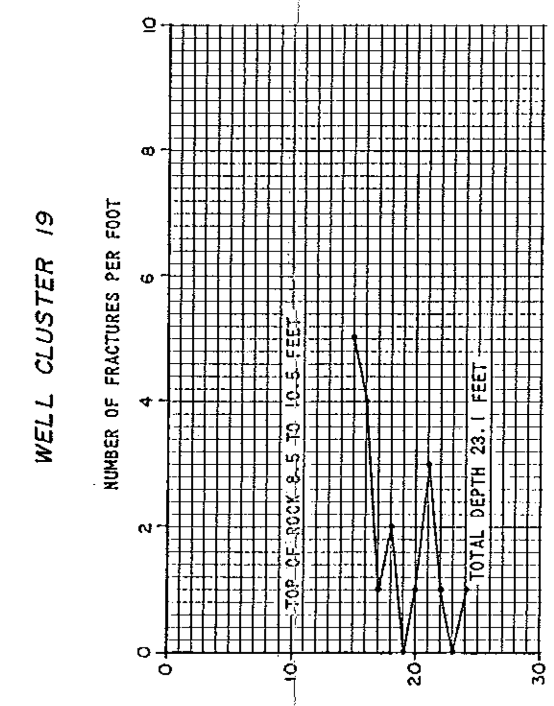


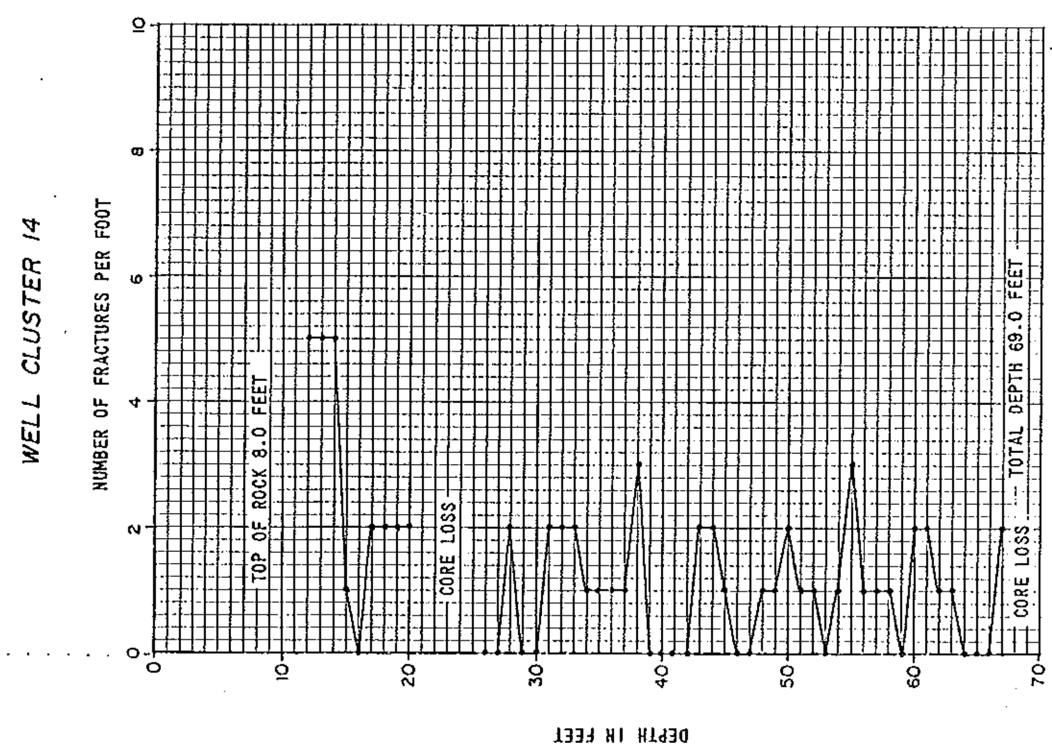
FRACTURE FREQUENCY PLOTS
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.

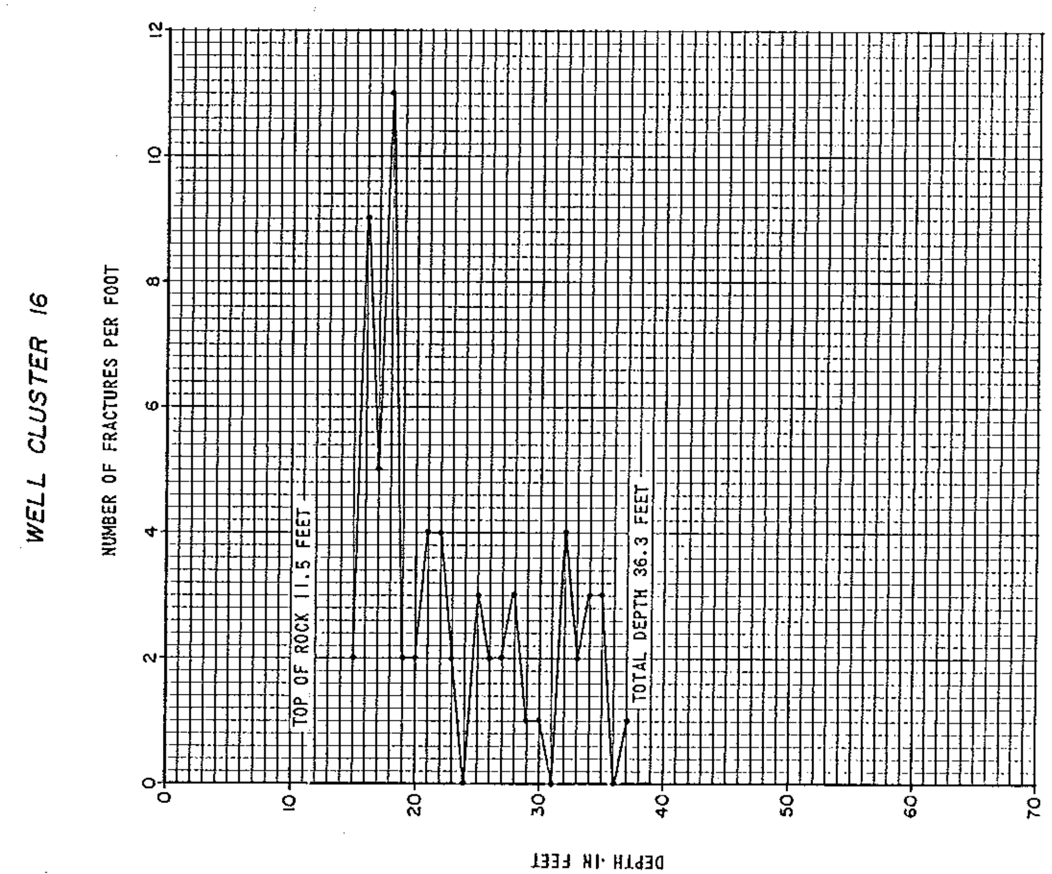
PLATE 17





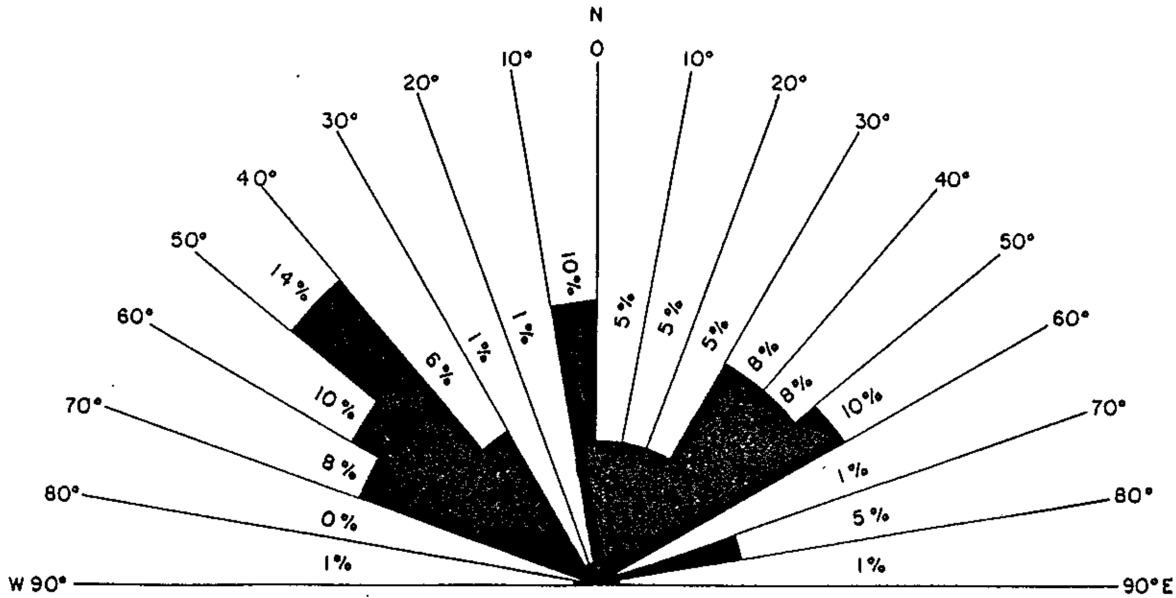




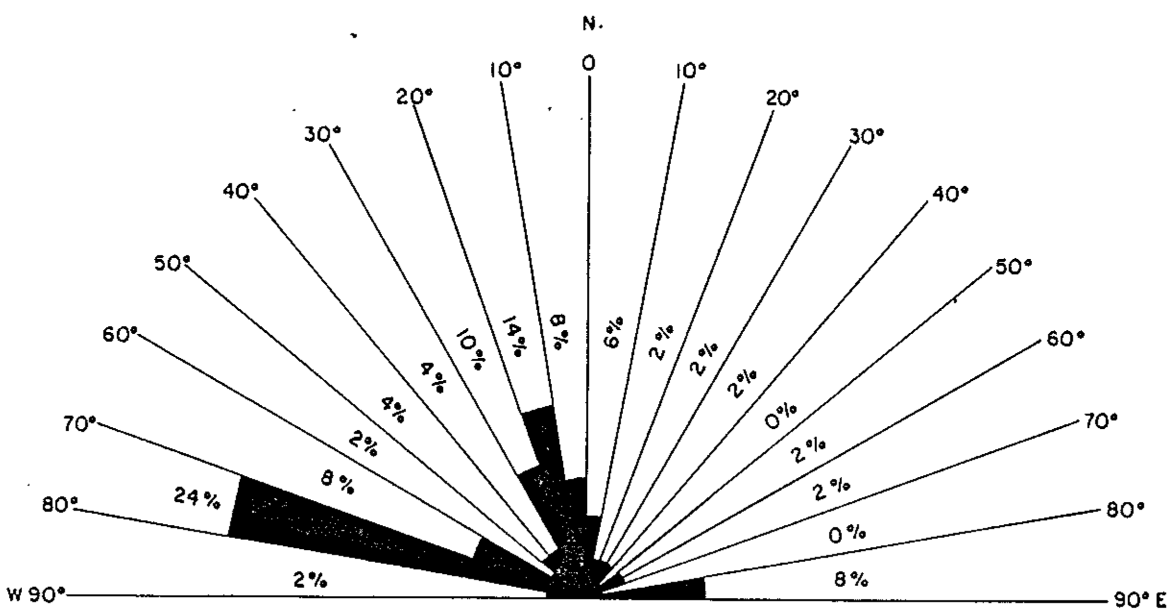


FRACTURE FREQUENCY PLOTS
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.

PLATE 18

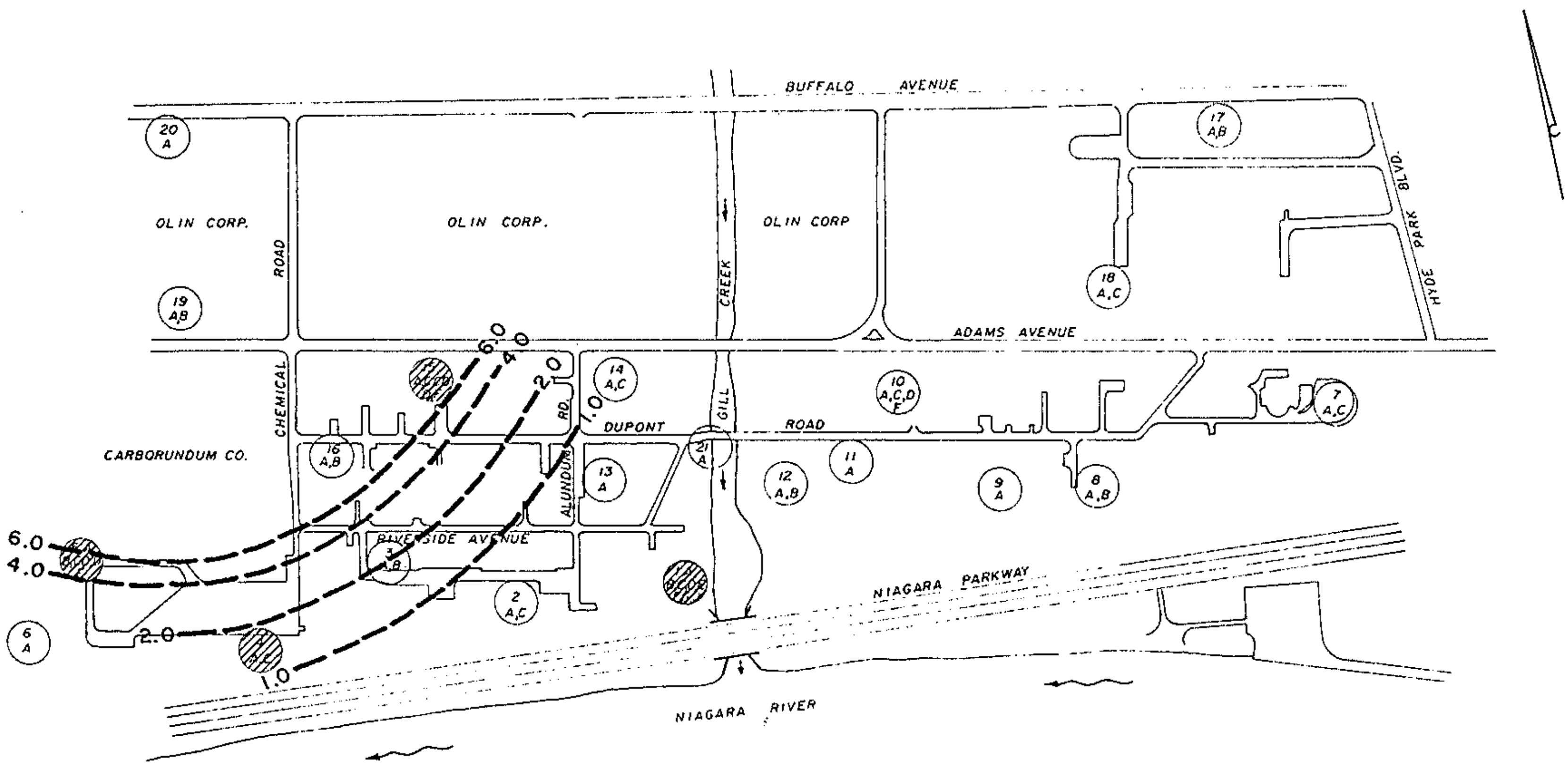


STRIKE OF VERTICAL JOINTS IN UPPER LOCKPORT FORMATION
NORTH OF NECCO PARK - DATA FROM 1979 R.F.WESTON REPORT



STRIKE OF JOINTS IN LOWER LOCKPORT FORMATION AND UPPER
ROCHESTER SHALE ALONG NIAGARA POWER PROJECT HAUL ROAD
DATA FROM WCC INHOUSE FILES

STRIKE OF JOINTS IN NIAGARA FALLS AREA
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.



LEGEND:

(17 A,B) — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)

WELL USED TO GENERATE CONTOUR MAP

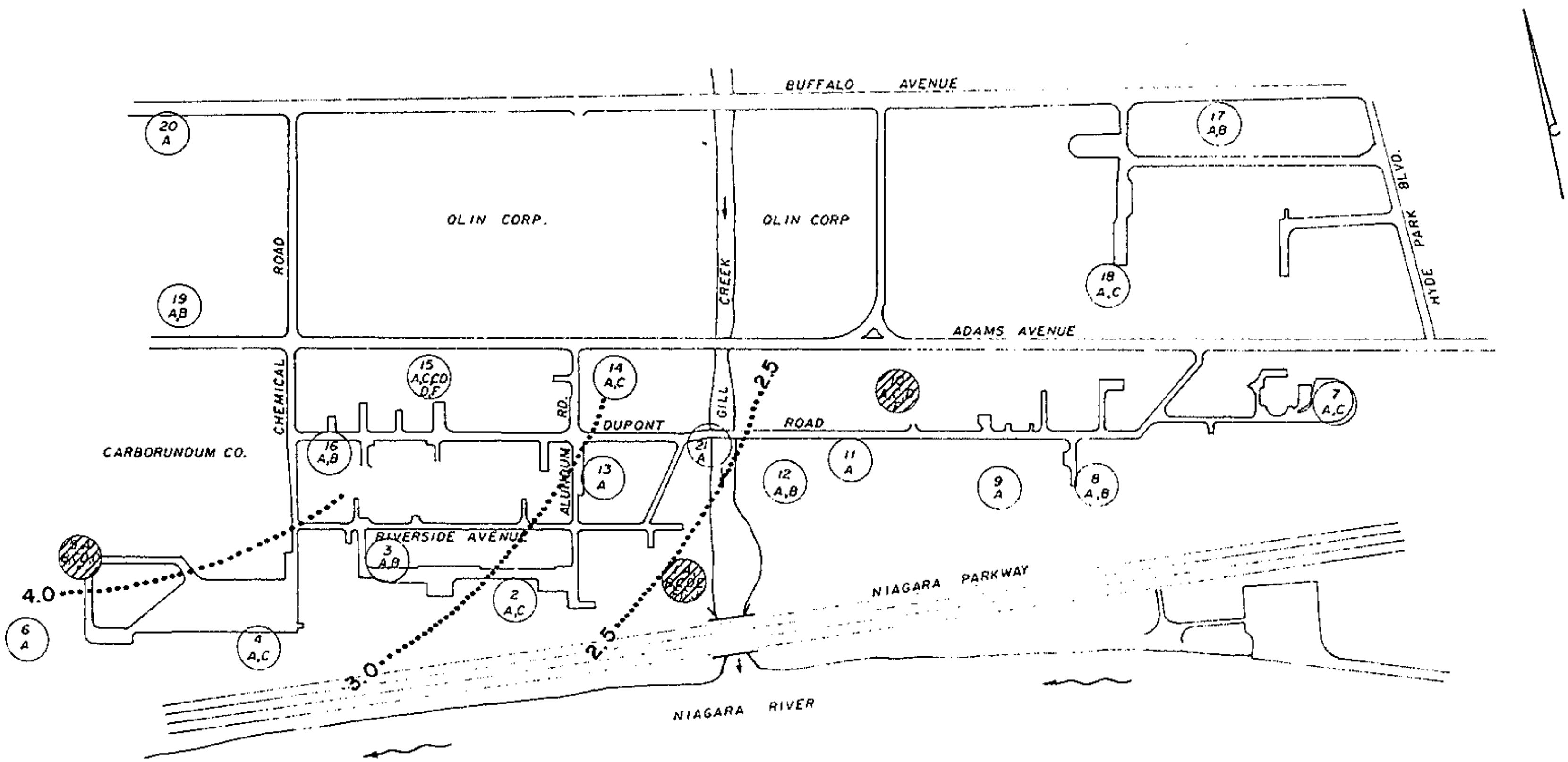
2.0 GROUNDWATER LEVEL RECOVERY IN FEET, VALUE EQUALS DIFFERENCE IN WATER LEVEL, AT CONCURRENT TIMES, BEFORE AND AFTER RECOVERY TEST BEGAN

RECOVERY IN THE CD-ZONE, OCTOBER 17, 1983
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236-5

PLATE 20



LEGEND:

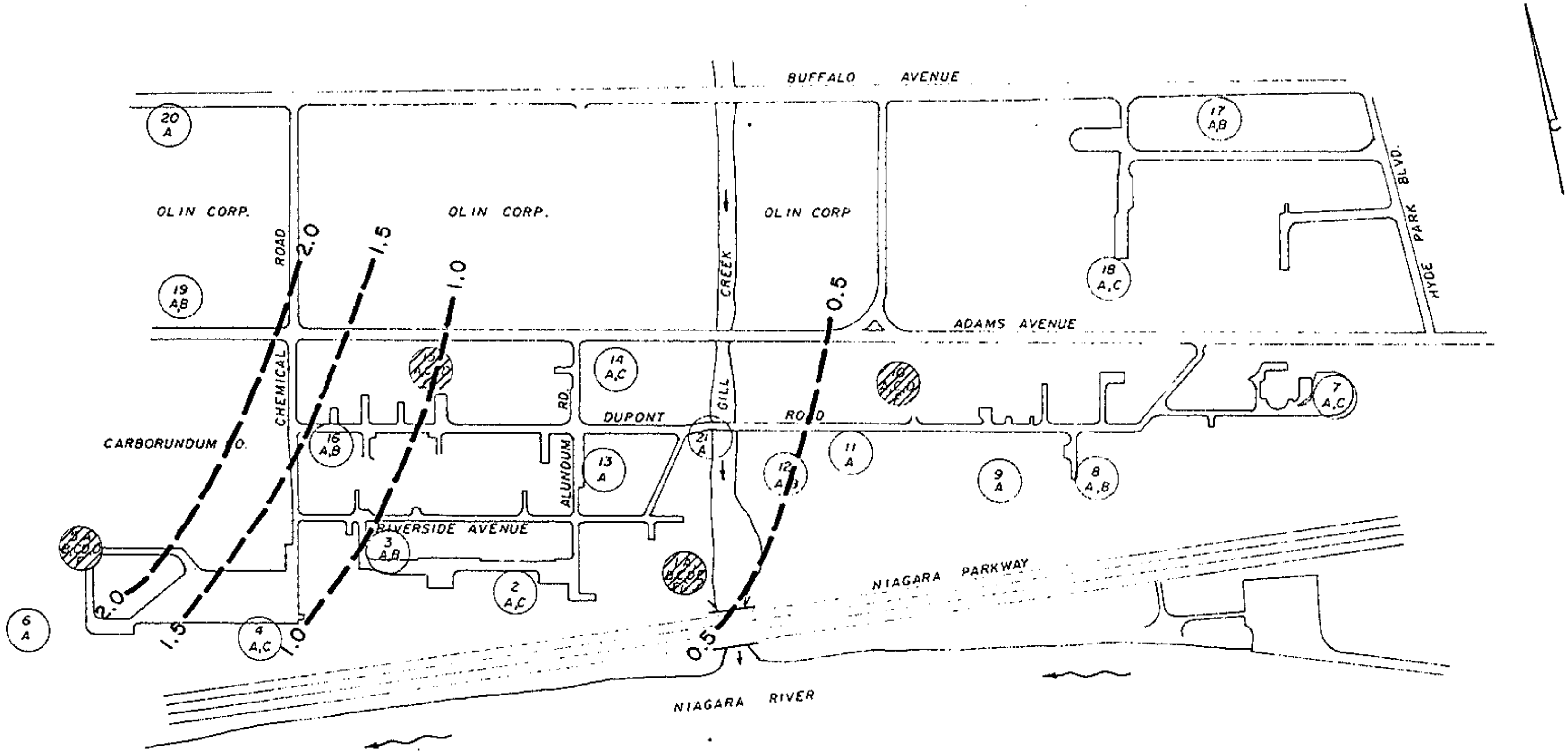
- 17 A,B — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)
- WELL USED TO GENERATE CONTOUR MAP
- 3.0 GROUNDWATER LEVEL RECOVERY IN FEET, VALUE EQUALS DIFFERENCE IN WATER LEVEL, AT CONCURRENT TIMES, BEFORE AND AFTER RECOVERY TEST BEGAN

RECOVERY IN THE D-ZONE, OCTOBER 17, 1983
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET	DATE: 11/15/83
CHECKED: J.C.E.	0 300	JOB: 83C2236

PLATE 21



LEGEND:

17 A,B — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)

WELL USED TO GENERATE CONTOUR MAP

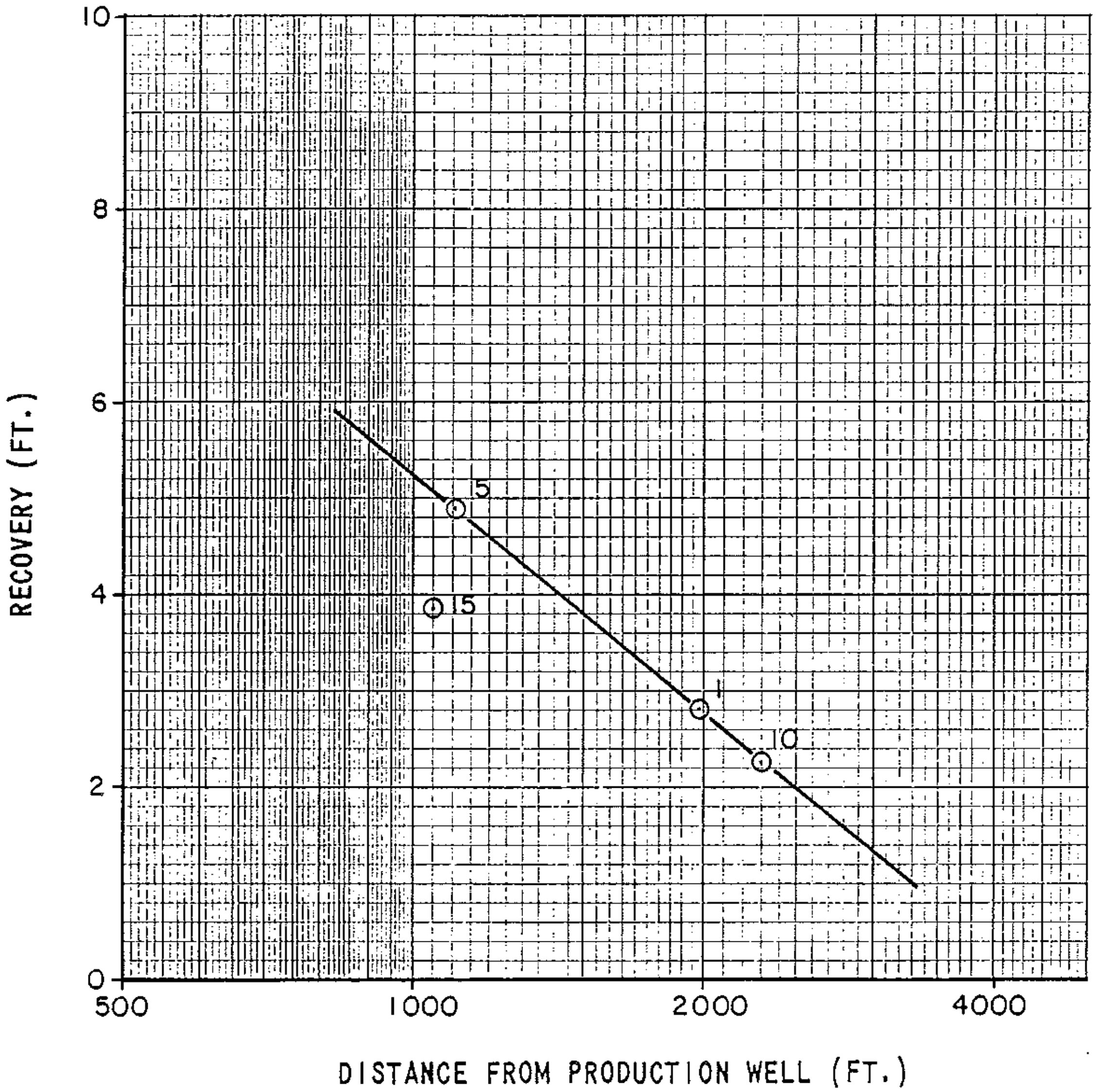
2.0 GROUNDWATER LEVEL RECOVERY IN FEET, VALUE EQUALS DIFFERENCE IN WATER LEVEL, AT CONCURRENT TIMES, BEFORE AND AFTER RECOVERY TEST BEGAN

RECOVERY IN THE F-ZONE, OCTOBER 17, 1983
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T. P.	SCALE In FEET	DATE: 11/15/83
CHECKED: J.C.E.	0 300	JOB: 83C2236

PLATE 22



D-ZONE

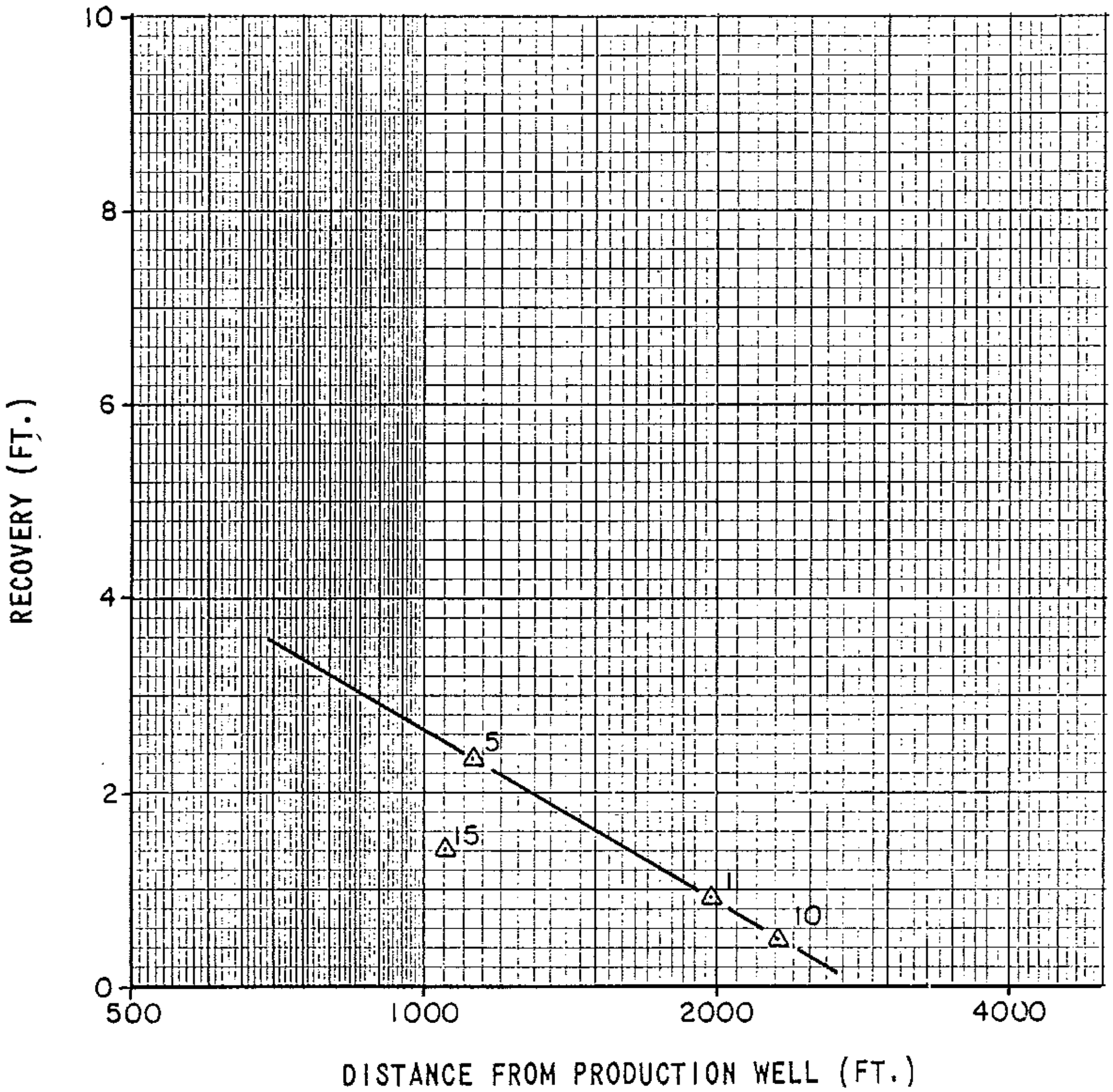
DISTANCE-RECOVERY PLOT

OCTOBER 17, 1983 RECOVERY TEST

NIAGARA PLANT

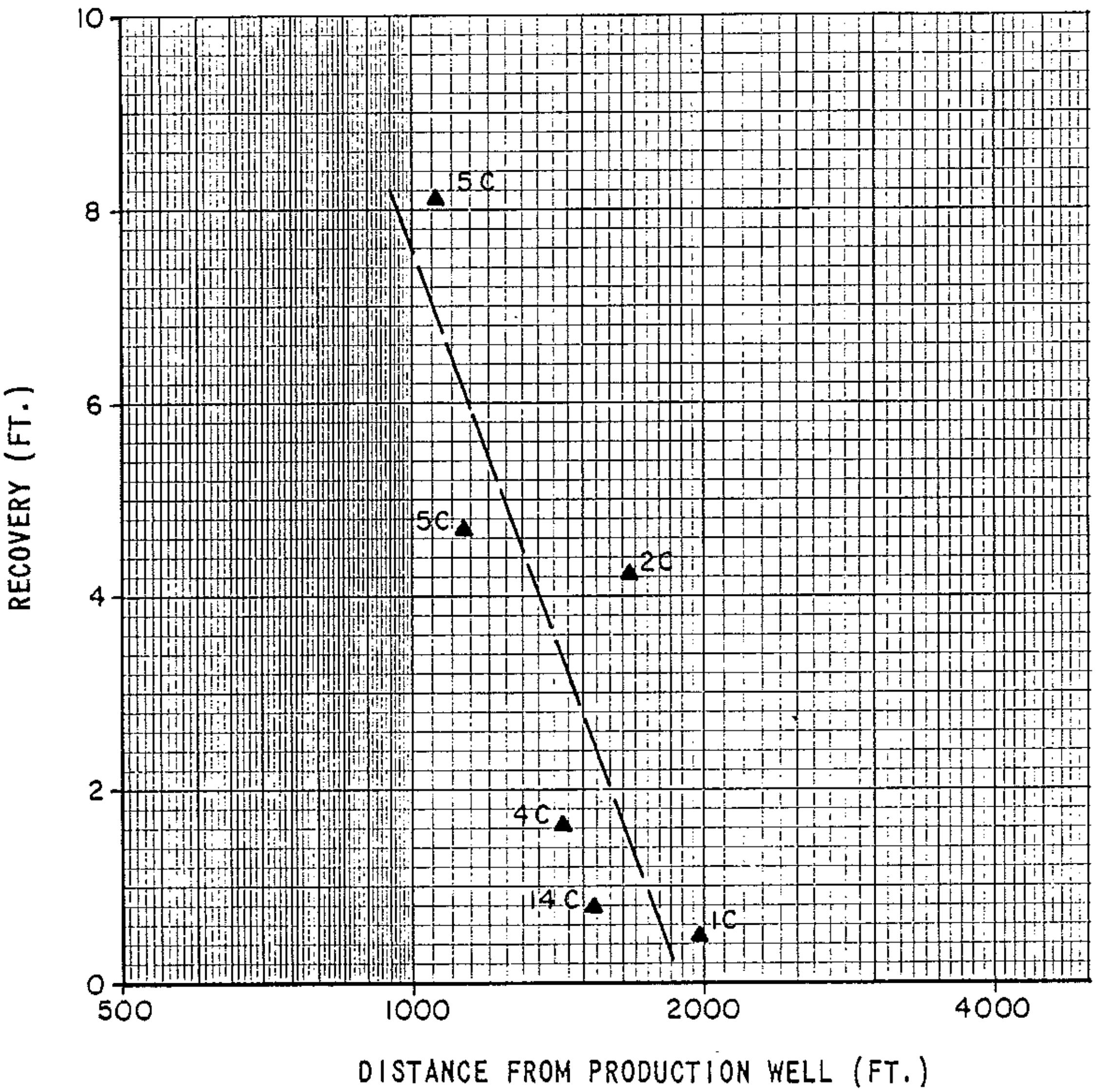
E. I. DUPONT DE NEMOURS & CO.

PLATE 23



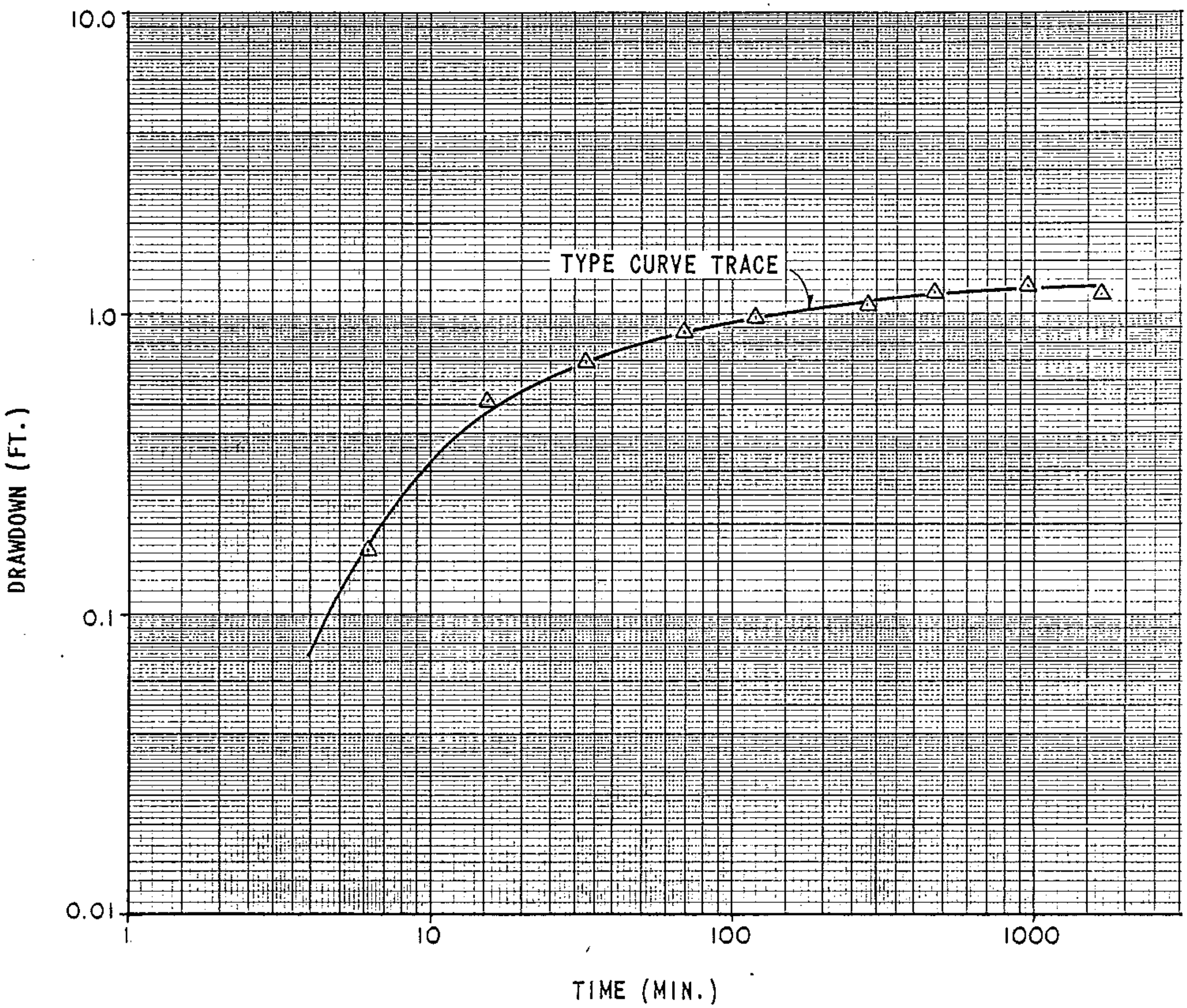
F-ZONE
DISTANCE-RECOVERY PLOT
OCTOBER 17, 1983 RECOVERY TEST
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

PLATE 24



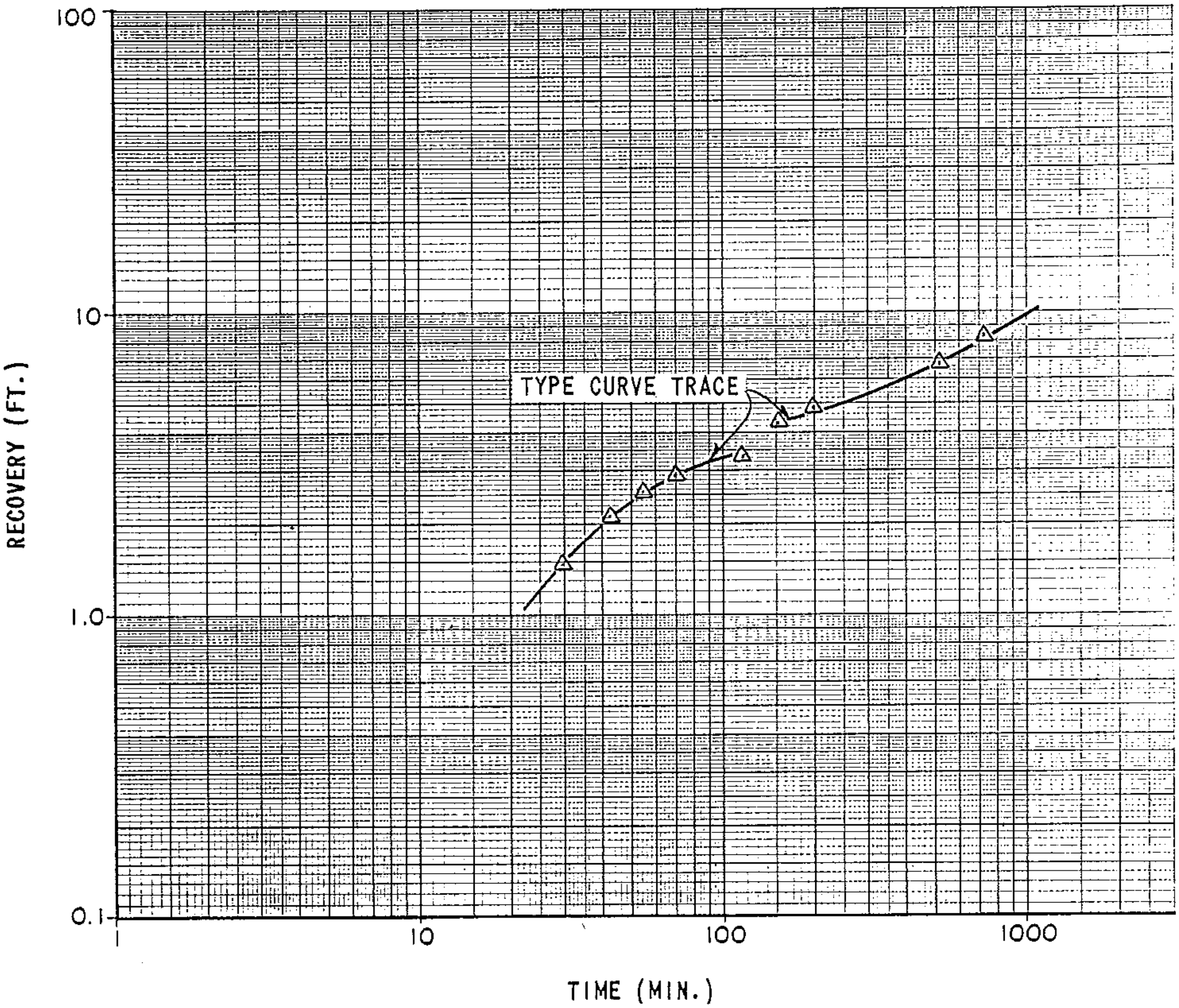
C-CD ZONE
DISTANCE-RECOVERY PLOT
OCTOBER 17, 1983 RECOVERY TEST
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

PLATE 25



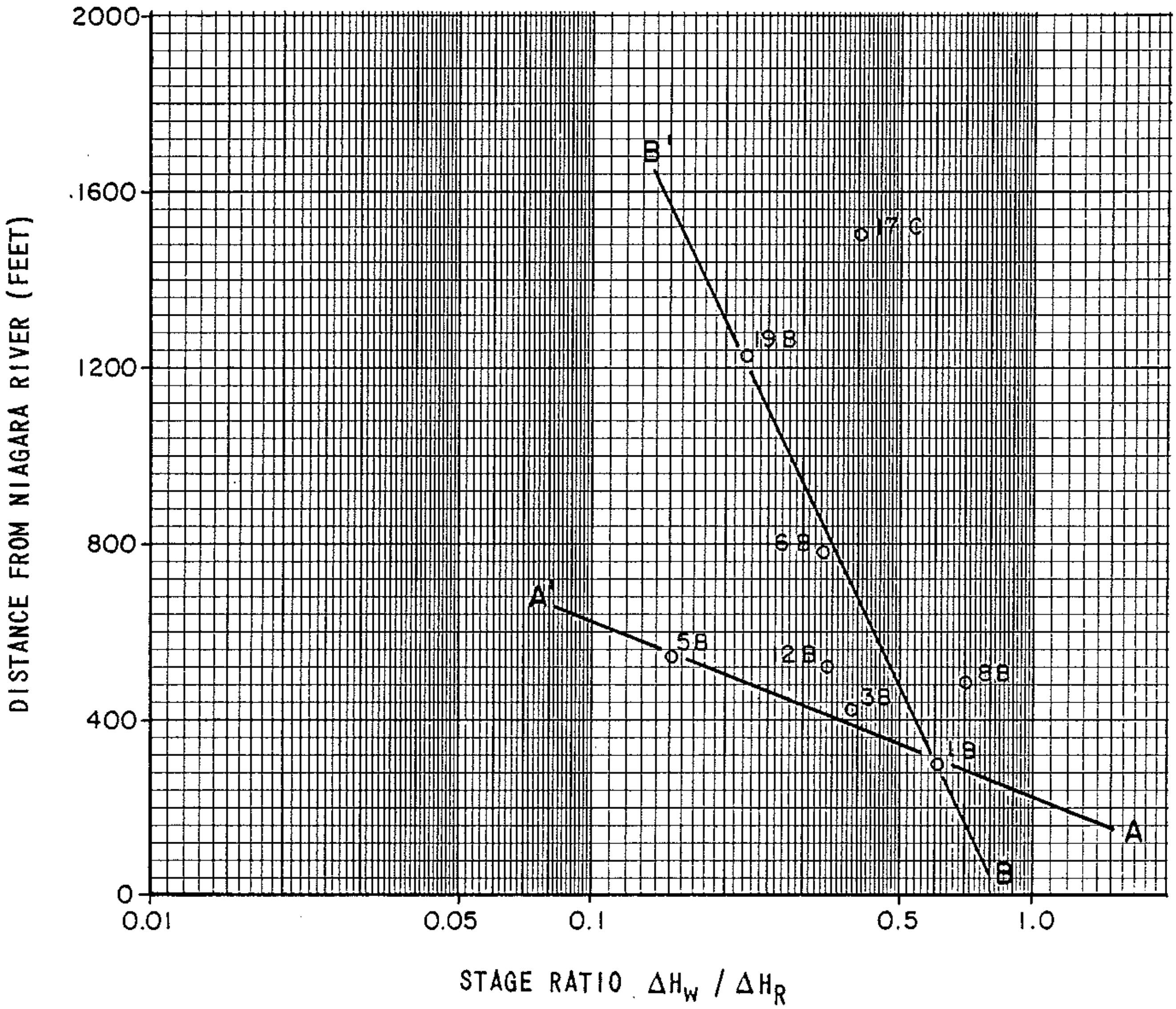
WELL 4C
TIME-DRAWDOWN CURVE
AUGUST 25, 1983 - RECOVERY TEST
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.

PLATE 26



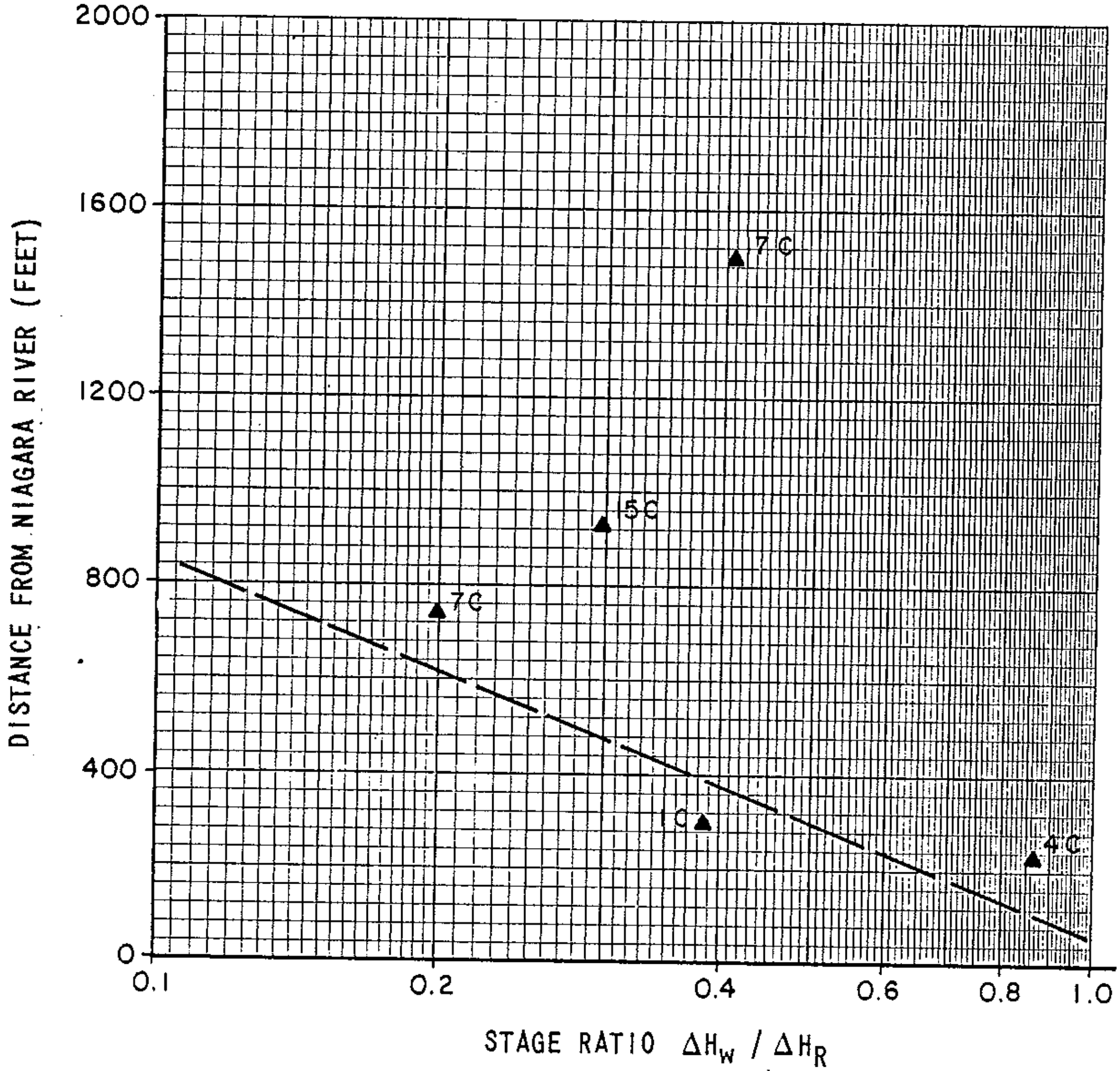
WELL 10F
TIME-RECOVERY CURVE
OCTOBER 17, 1983 - RECOVERY TEST
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

PLATE 27



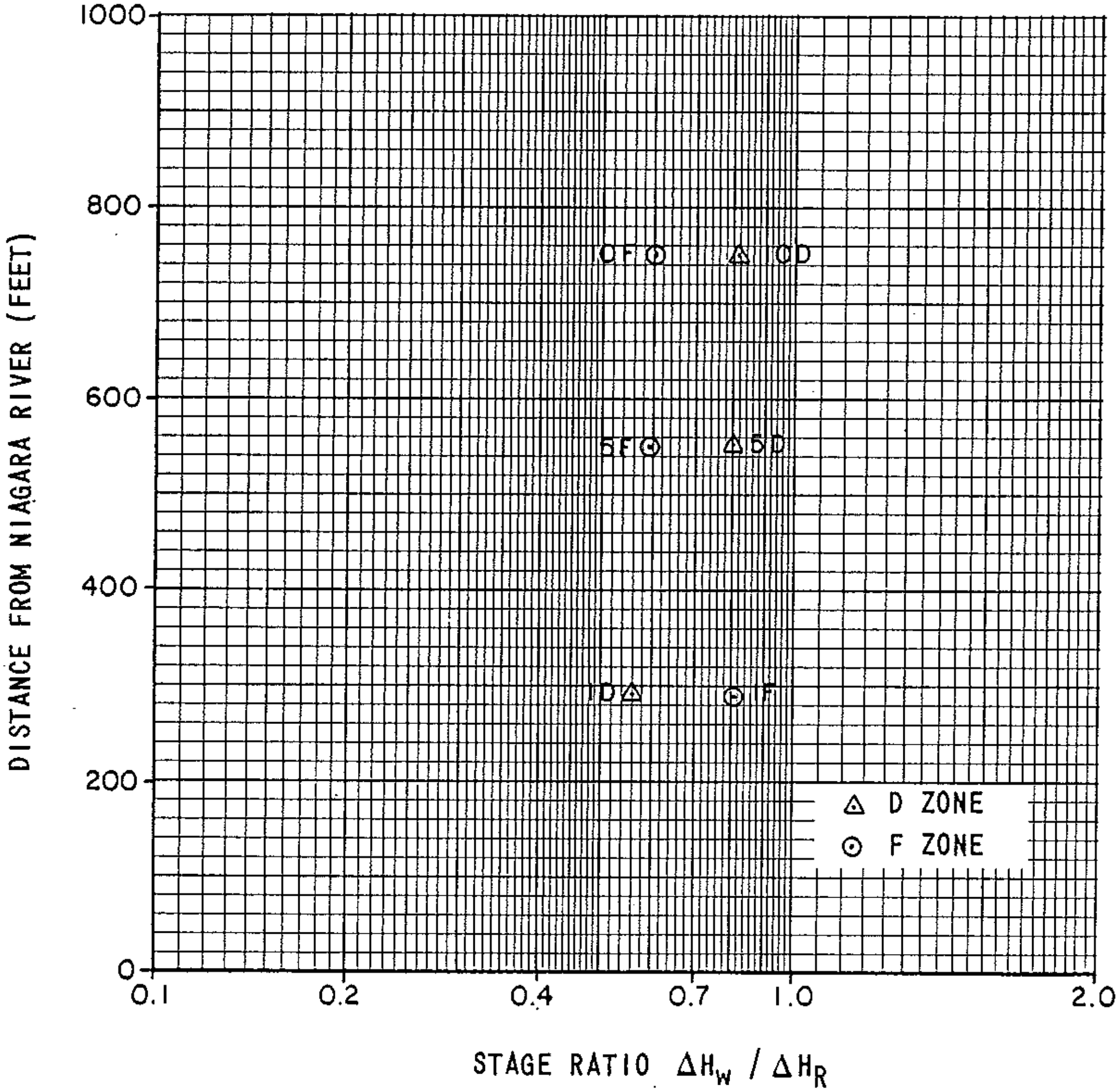
B-ZONE
STAGE RATIO PLOT
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.

PLATE 28



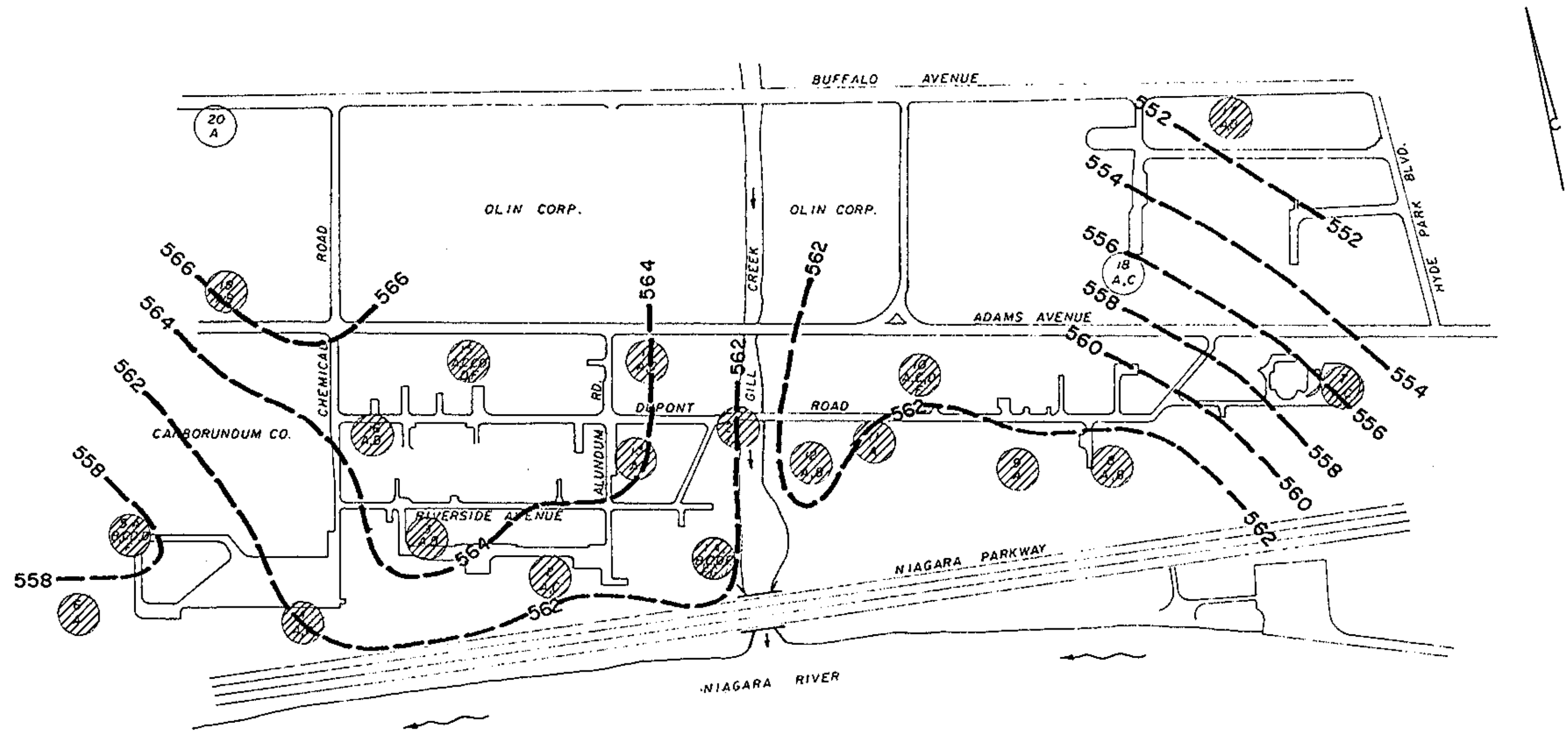
CD-ZONE
STAGE RATIO PLOT
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.

PLATE 29



D & F ZONES
STAGE RATIO PLOT
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.

PLATE 30



DURING RECOVERY TEST

OCTOBER 17, 1983, TIME ~ 1200

LEGEND:

17 A,B — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)

WELL USED TO GENERATE CONTOUR MAP

561 GROUNDWATER ELEVATION

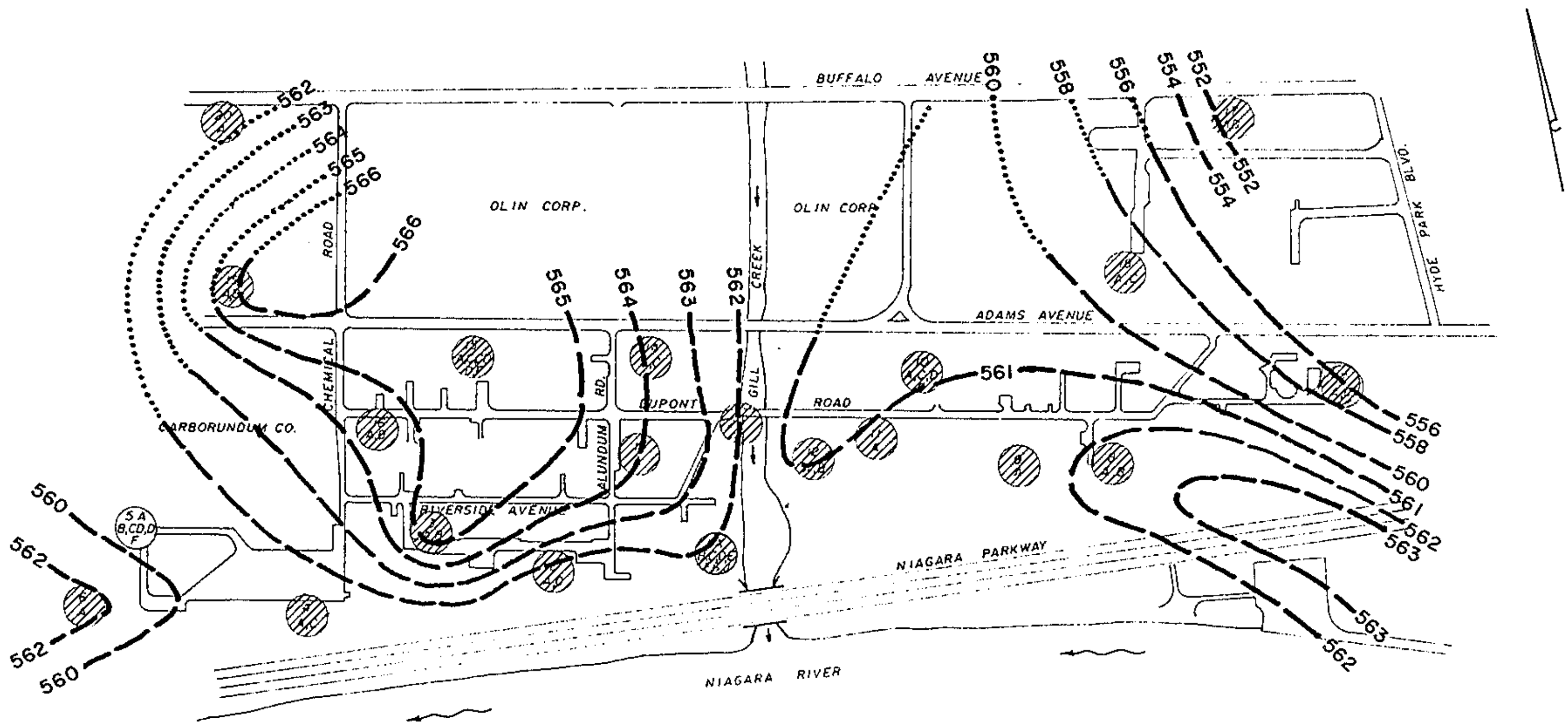
NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

A-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET	DATE: 11/15/83	
CHECKED: J.C.E.	0 — 300	JOB: 83C2236	

PLATE 31



DURING PUMPING TEST

OCTOBER 19, 1983, TIME ~ 1600

LEGEND:

17 A,B — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)

WELL USED TO GENERATE CONTOUR MAP

561 GROUNDWATER ELEVATION

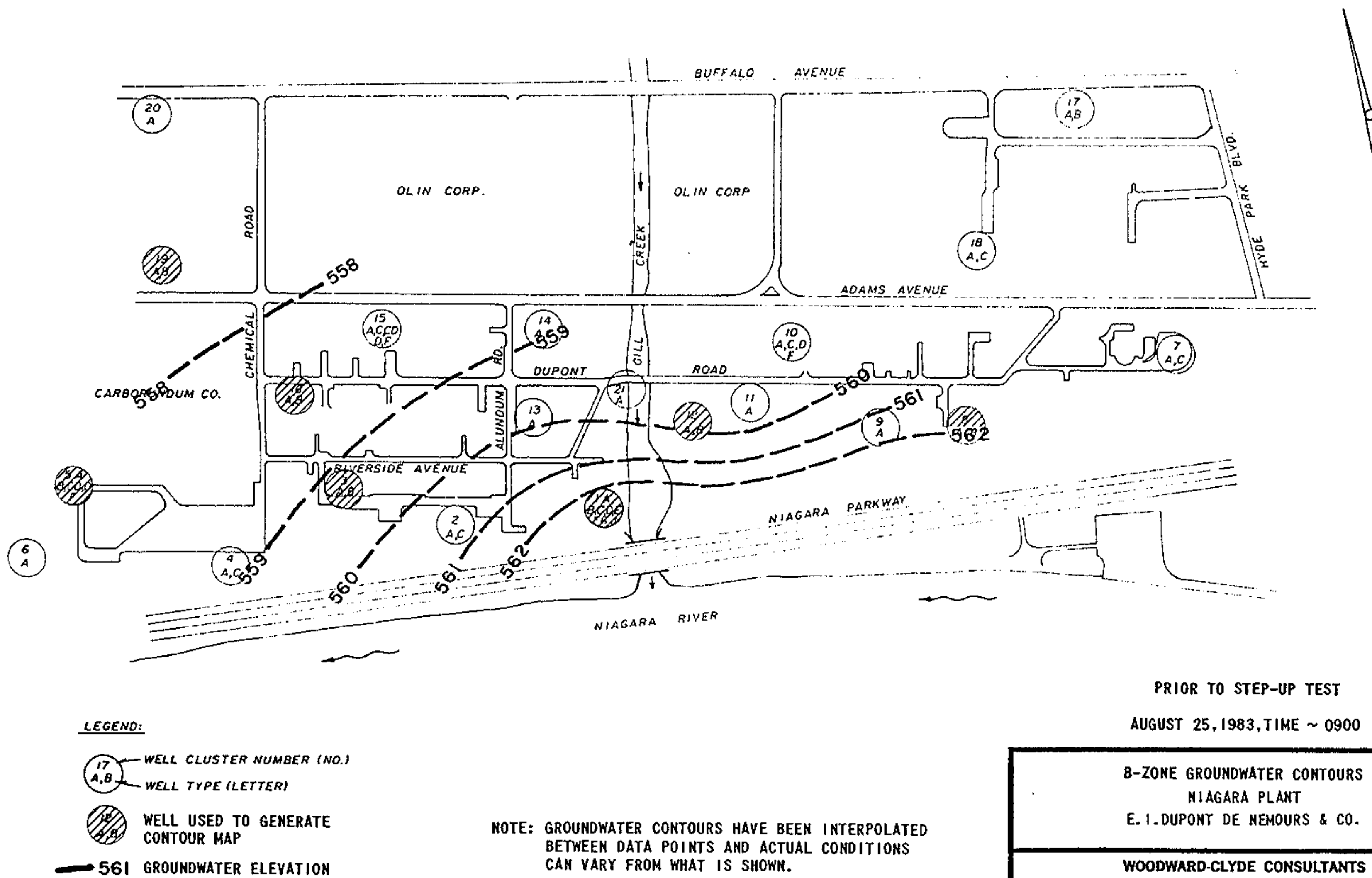
NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

A-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 32



PRIOR TO STEP-UP TEST

AUGUST 25, 1983, TIME ~ 0900

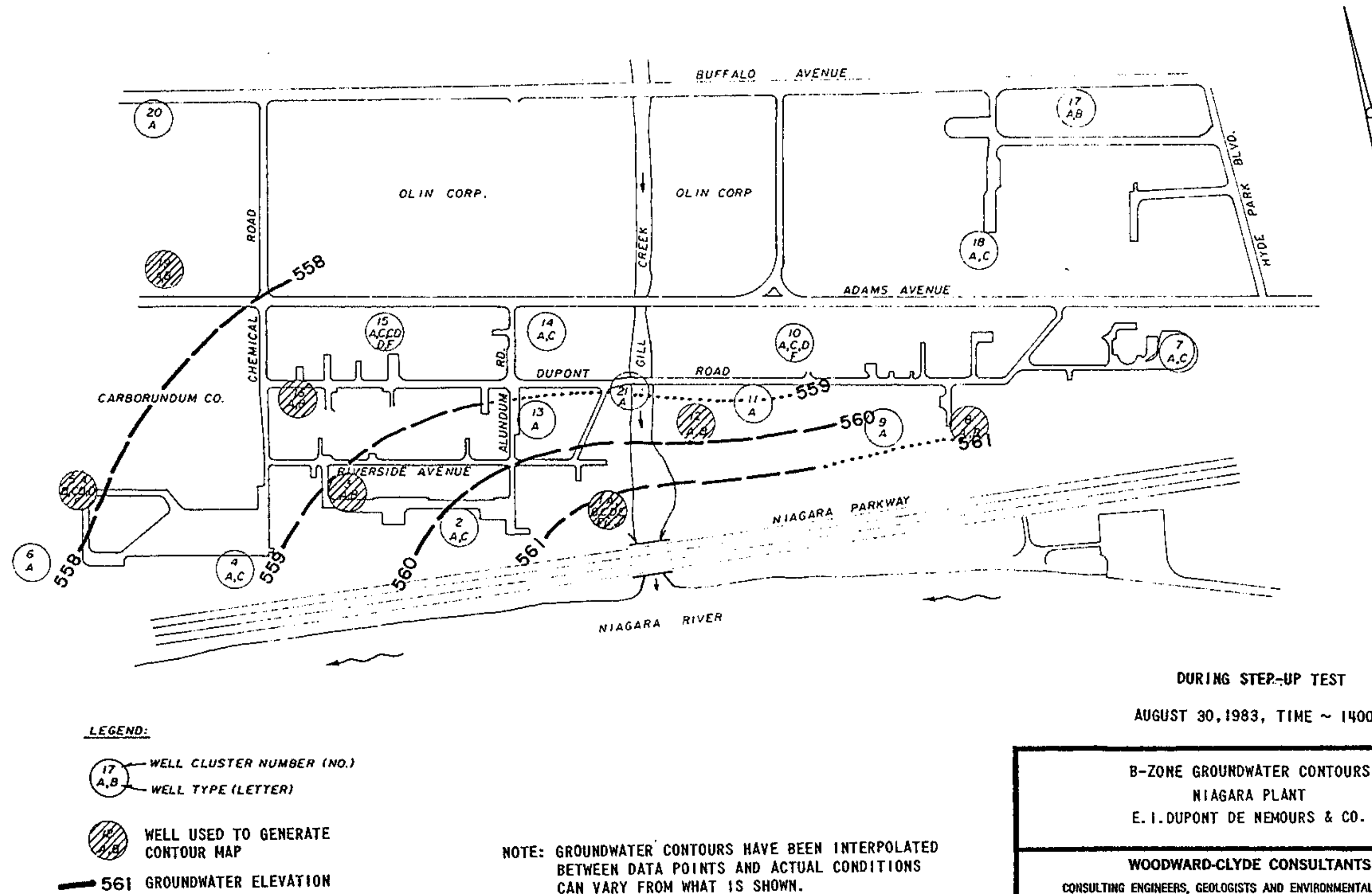
NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

B-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 33



NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

DURING STEP-UP TEST

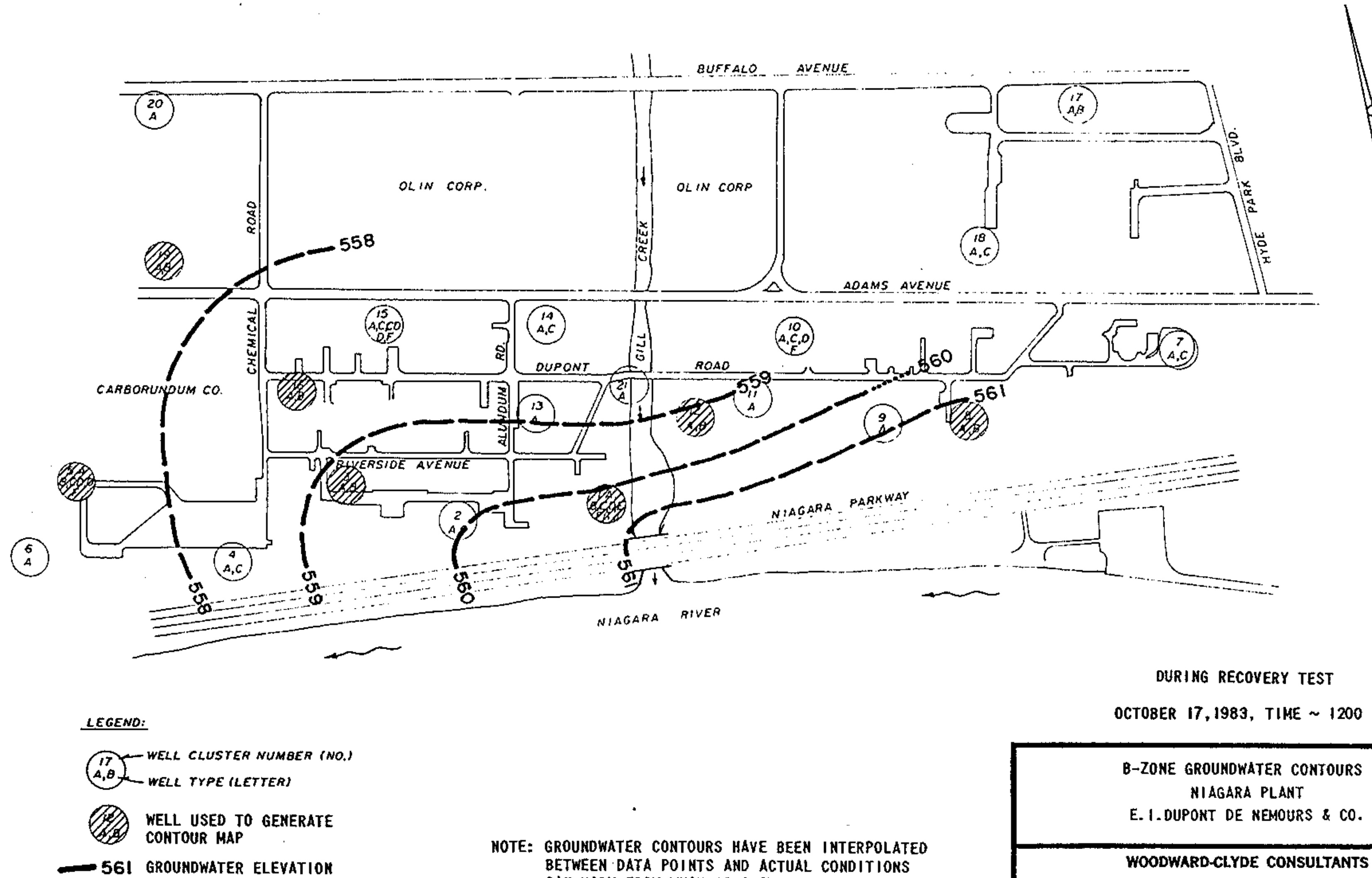
AUGUST 30, 1983, TIME ~ 1400

B-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 34



DURING RECOVERY TEST

OCTOBER 17, 1983, TIME ~ 1200

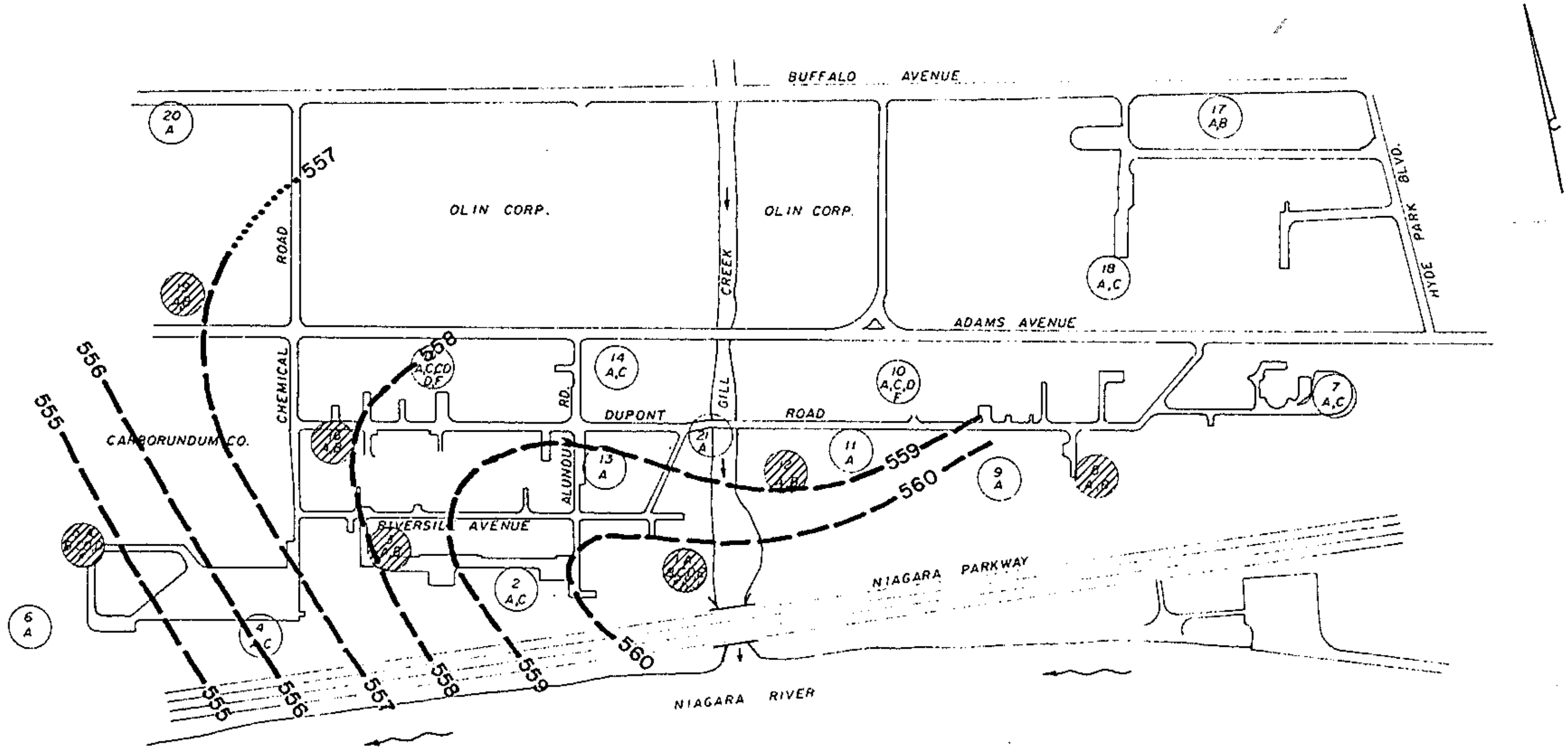
NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

B-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 35



DURING PUMPING TEST

OCTOBER 19, 1983, TIME ~ 1600

LEGEND:

17 A,B — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)

WELL USED TO GENERATE CONTOUR MAP

561 GROUNDWATER ELEVATION

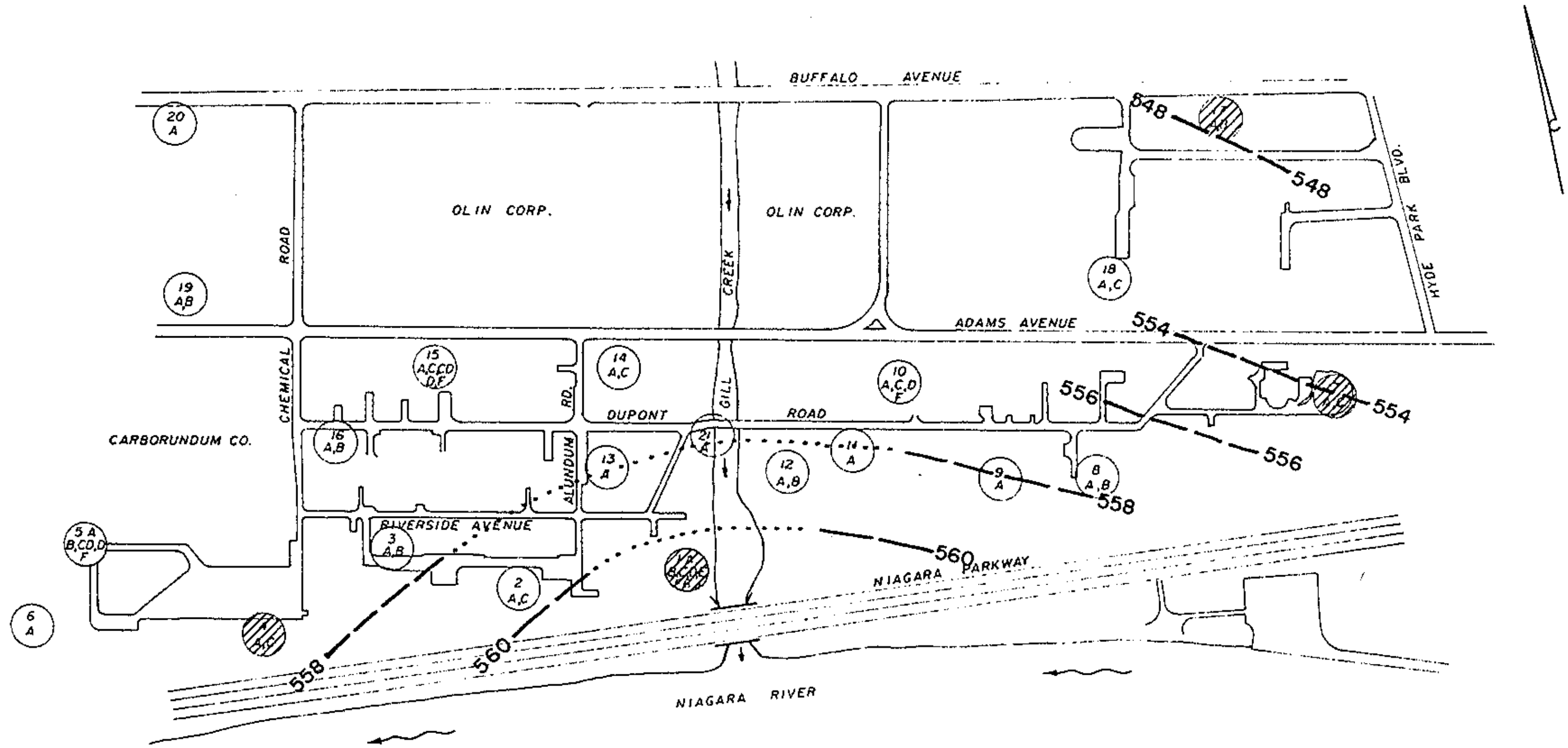
NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

B-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 36



PRIOR TO STEP-UP TEST

AUGUST 25, 1983, TIME ~ 0900

LEGEND:

WELL CLUSTER NUMBER (NO.)

WELL TYPE (LETTER)

WELL USED TO GENERATE CONTOUR MAP

561 GROUNDWATER ELEVATION

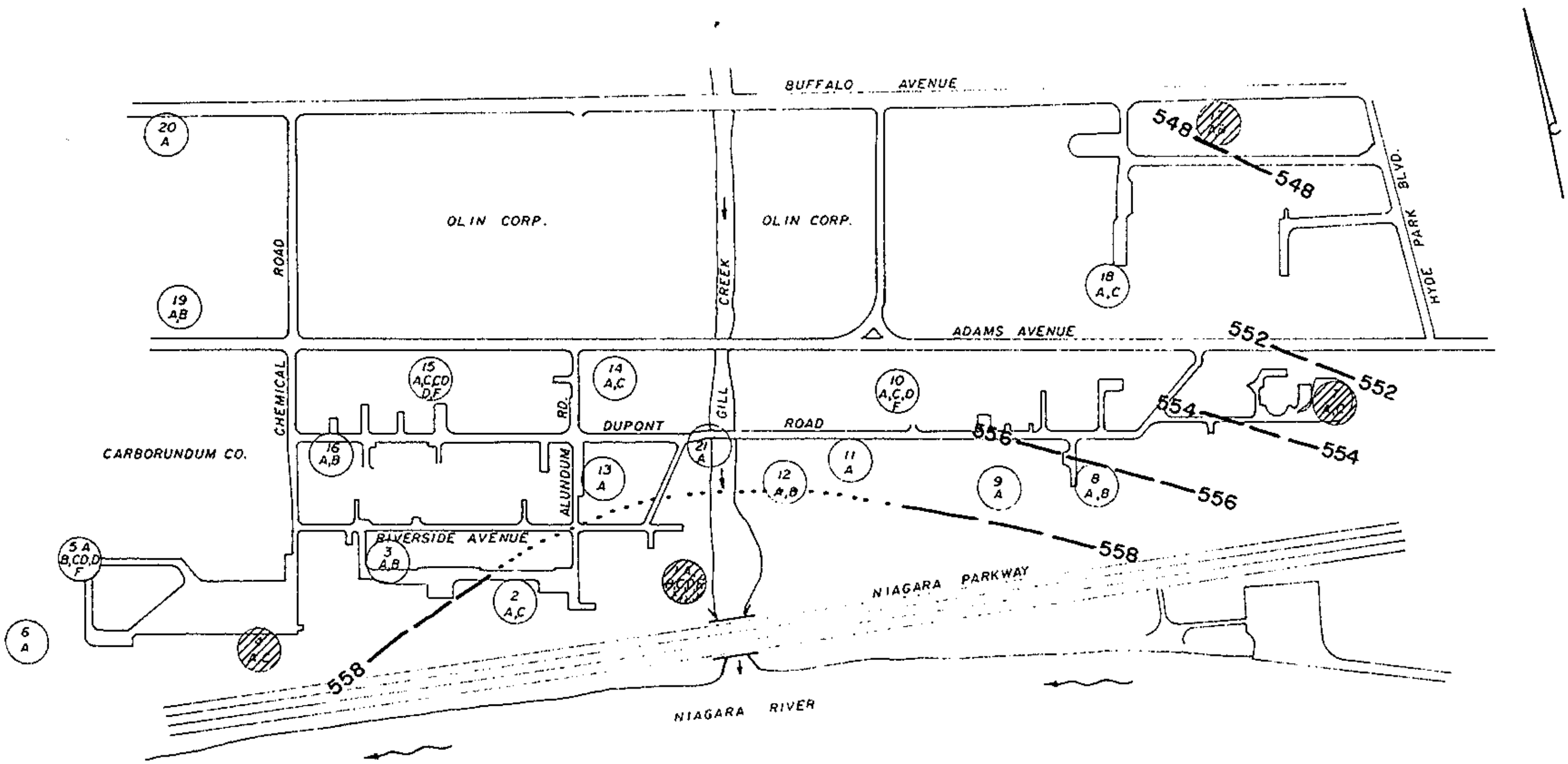
NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

CD-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 37



DURING STEP-UP TEST

AUGUST 30, 1983, TIME ~ 1400

LEGEND:

WELL CLUSTER NUMBER (NO.)

WELL TYPE (LETTER)

WELL USED TO GENERATE CONTOUR MAP

561 GROUNDWATER ELEVATION

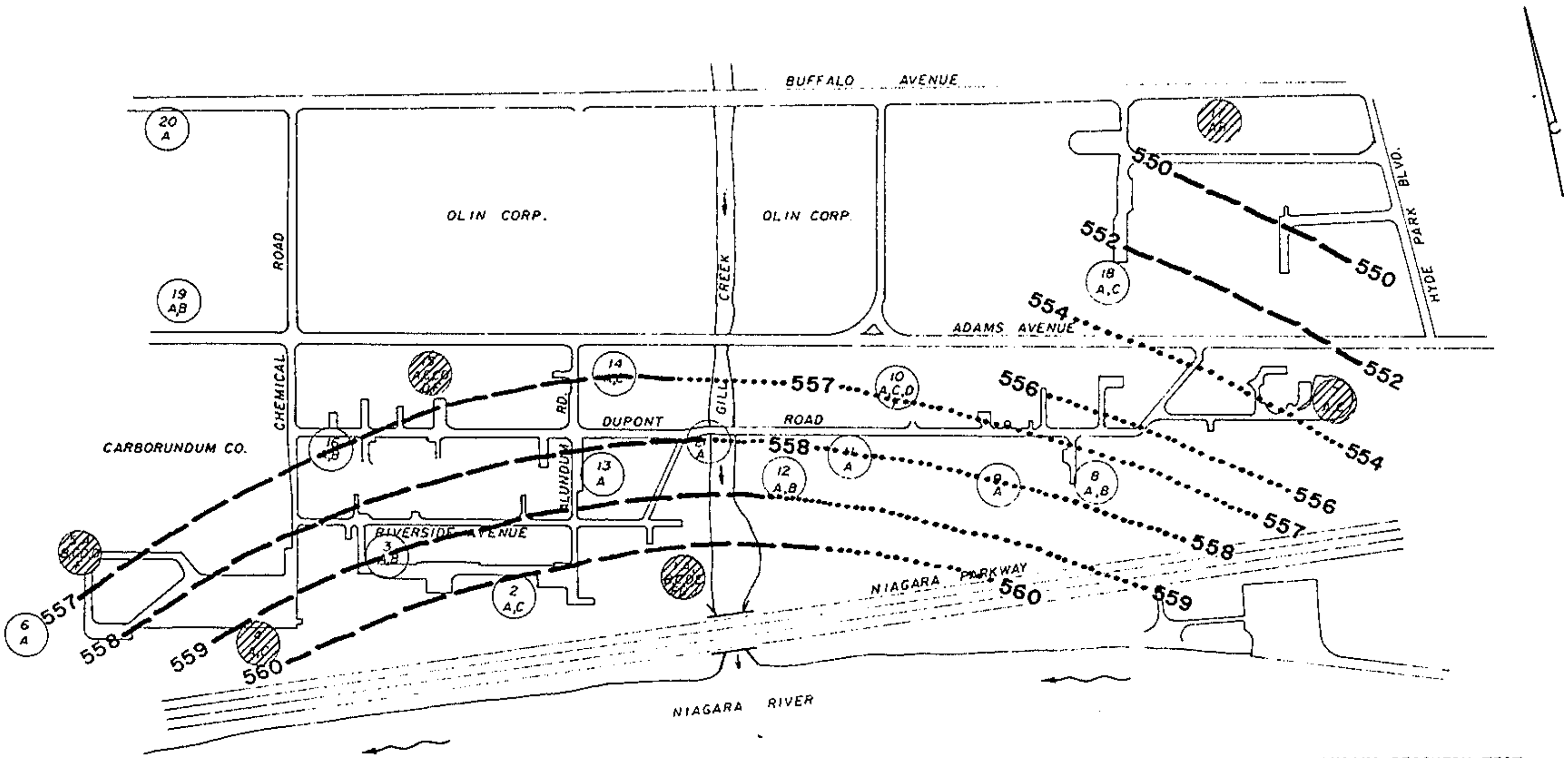
NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

CD-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 38



DURING RECOVERY TEST

OCTOBER 17, 1983, TIME ~ 1200

LEGEND:

- WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER) — 17 A,B
- WELL USED TO GENERATE CONTOUR MAP
- 561 GROUNDWATER ELEVATION

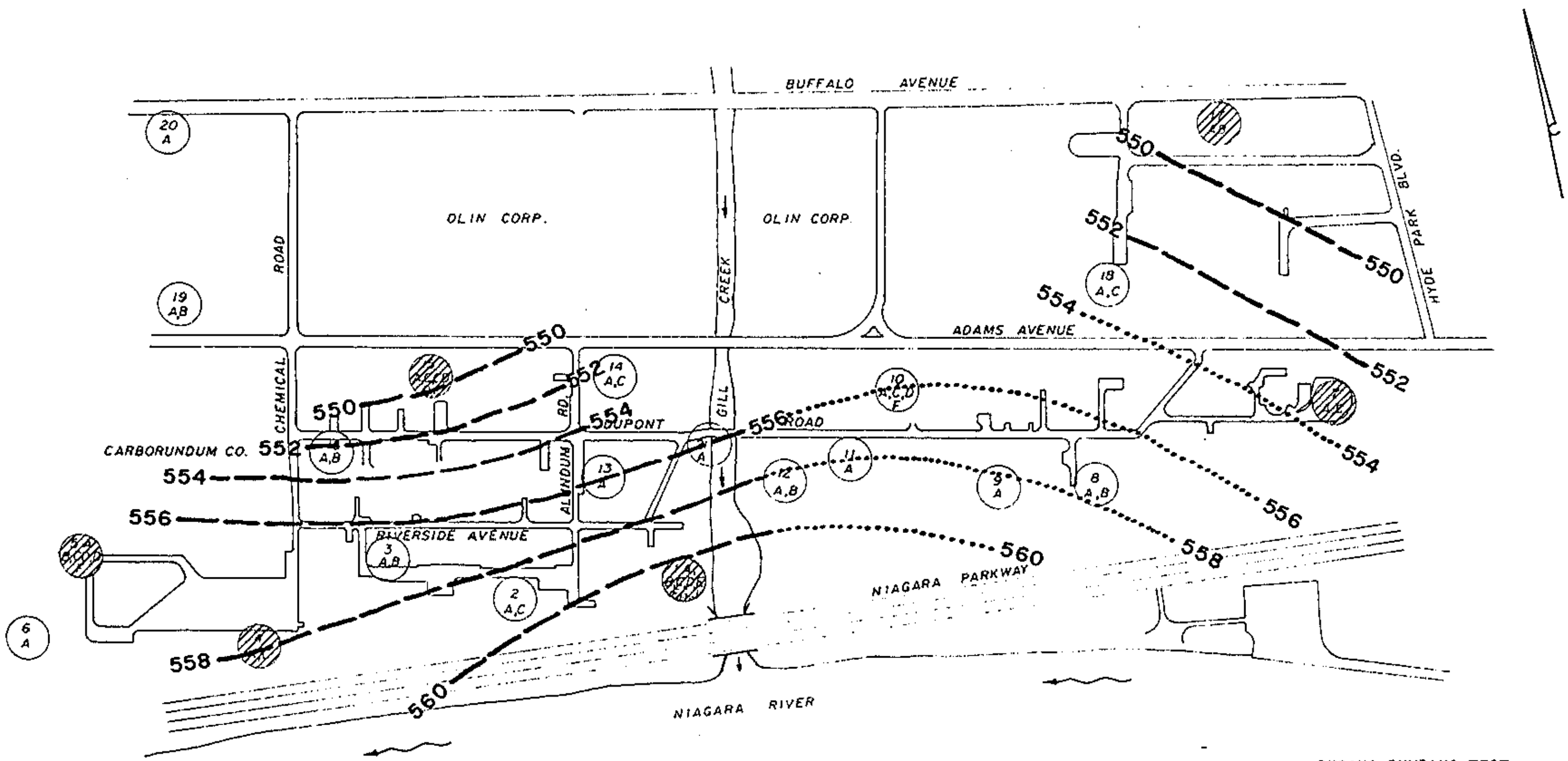
NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

CD-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 39



DURING PUMPING TEST

OCTOBER 19, 1983, TIME ~ 1600

LEGEND:

17 A,B — WELL CLUSTER NUMBER (NO.) — WELL TYPE (LETTER)

WELL USED TO GENERATE CONTOUR MAP

561 GROUNDWATER ELEVATION

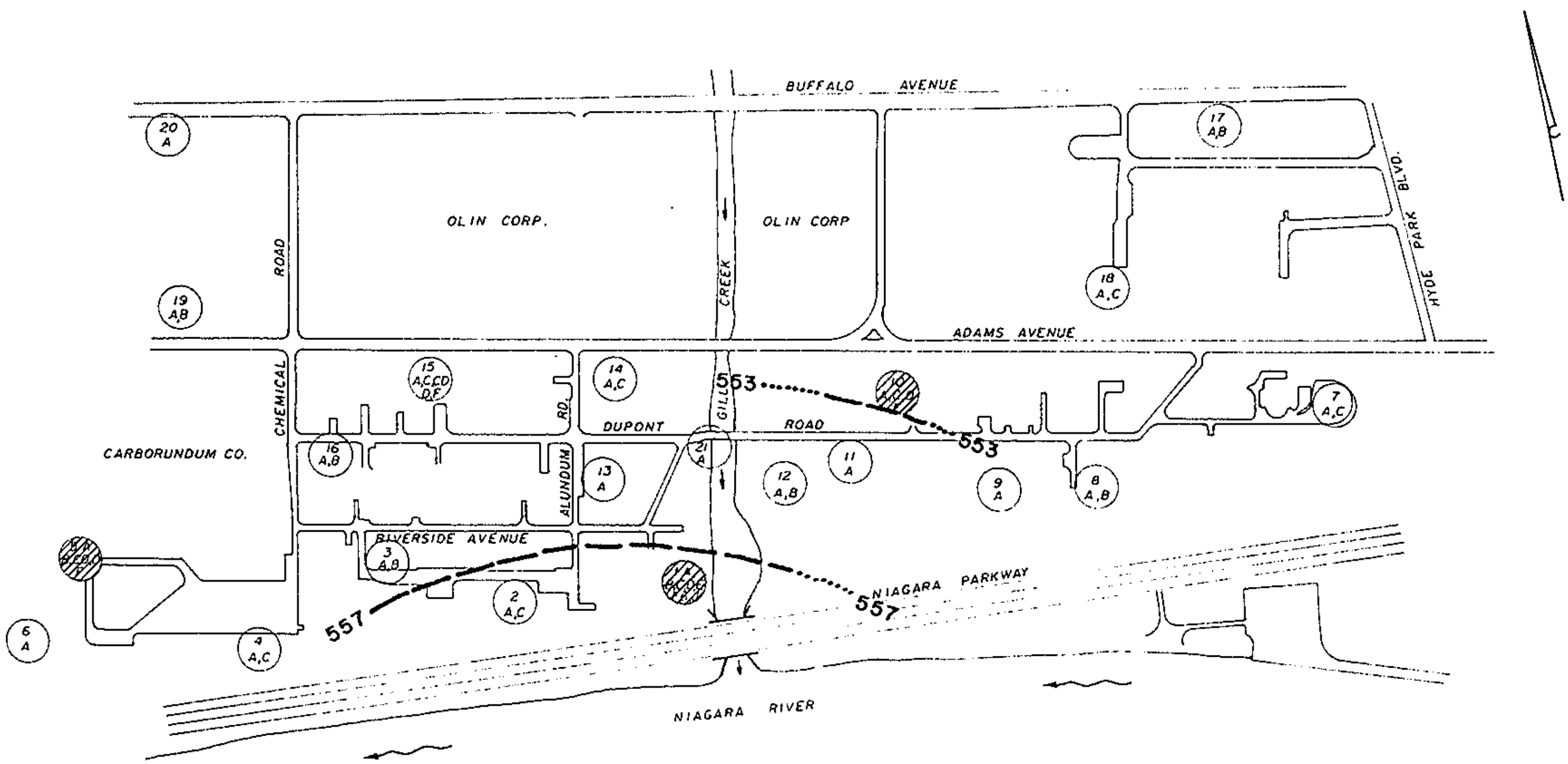
NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

CD-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 40



LEGEND:

17 A,B — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)

WELL USED TO GENERATE CONTOUR MAP

561 GROUNDWATER ELEVATION

NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

DURING RECOVERY TEST

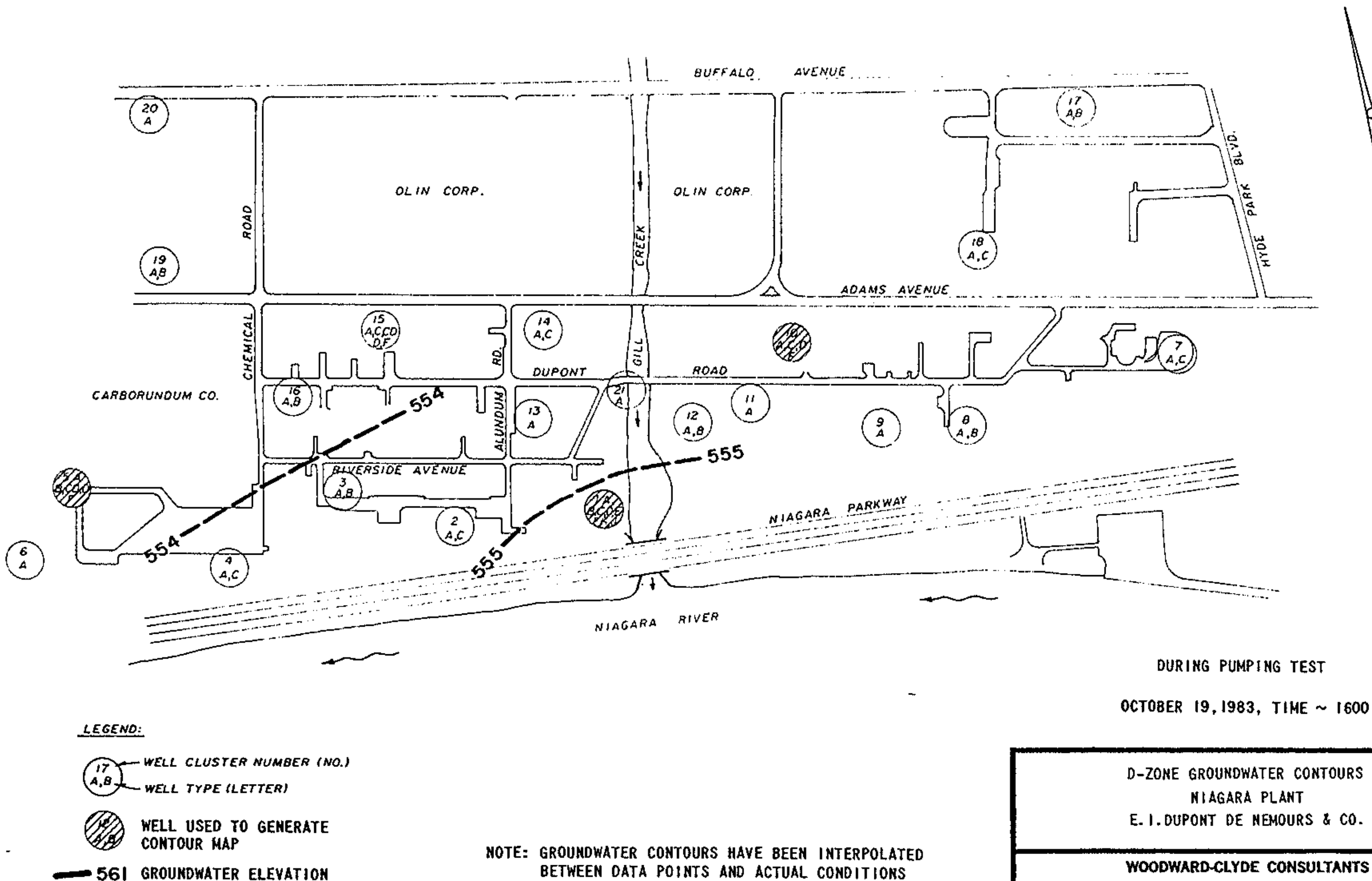
OCTOBER 17, 1983, TIME ~ 1200

D-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 41



DURING PUMPING TEST

OCTOBER 19, 1983, TIME ~ 1600

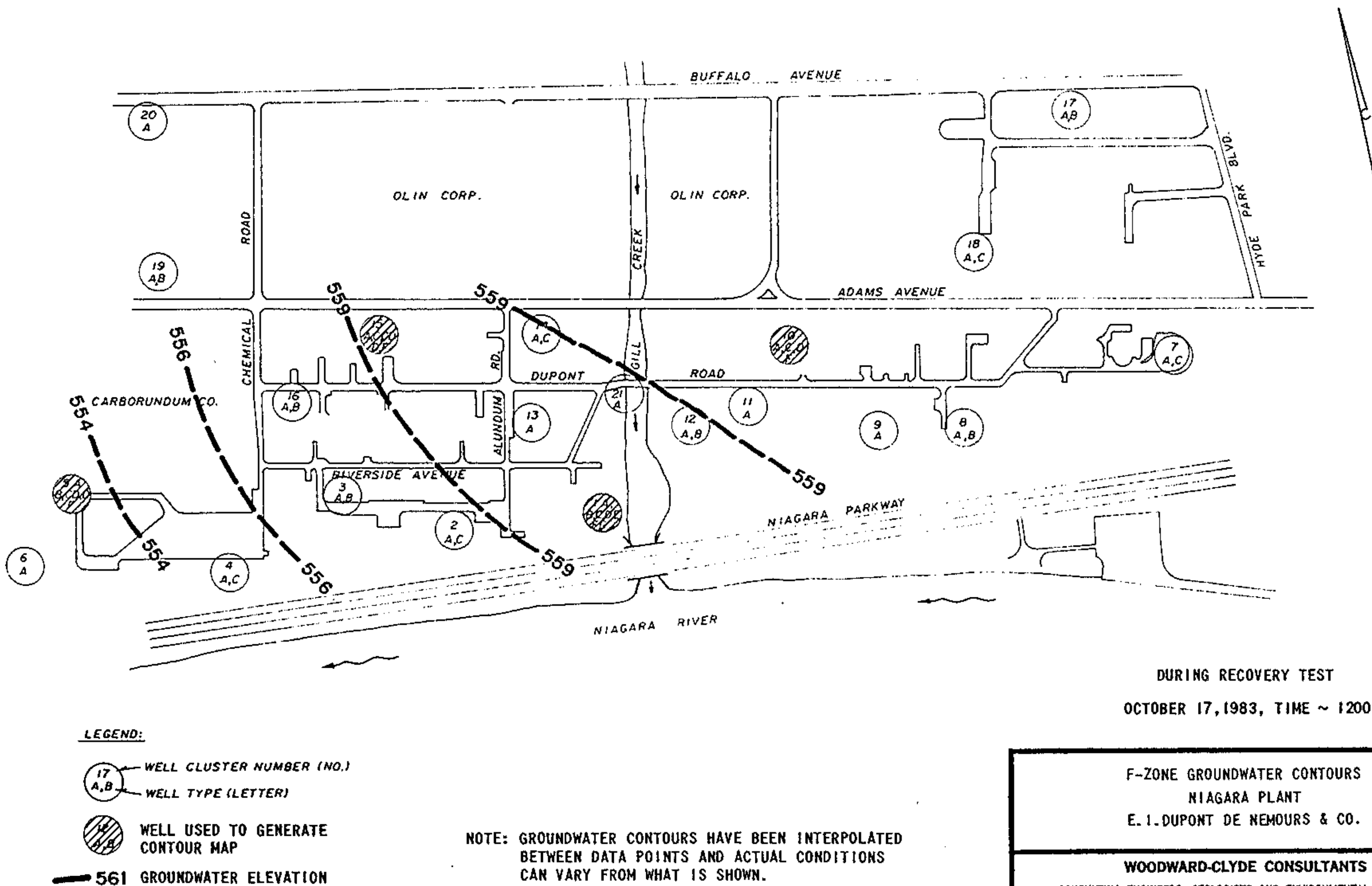
NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

D-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET	DATE: 11/15/83
CHECKED: J.C.E.	0 300	JOB: 83C2236

PLATE 42



NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

DURING RECOVERY TEST

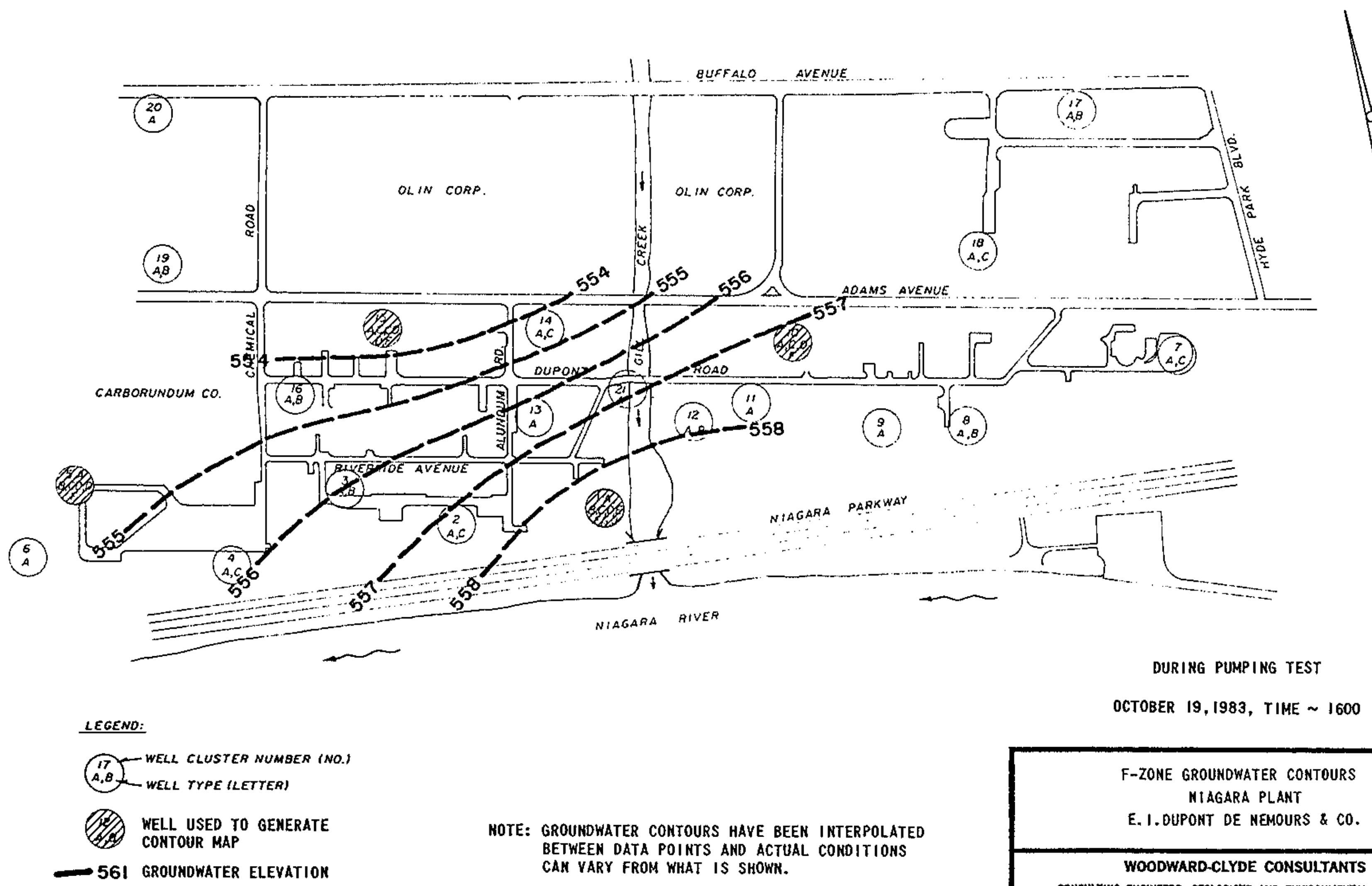
OCTOBER 17, 1983, TIME ~ 1200

F-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 43



NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

DURING PUMPING TEST

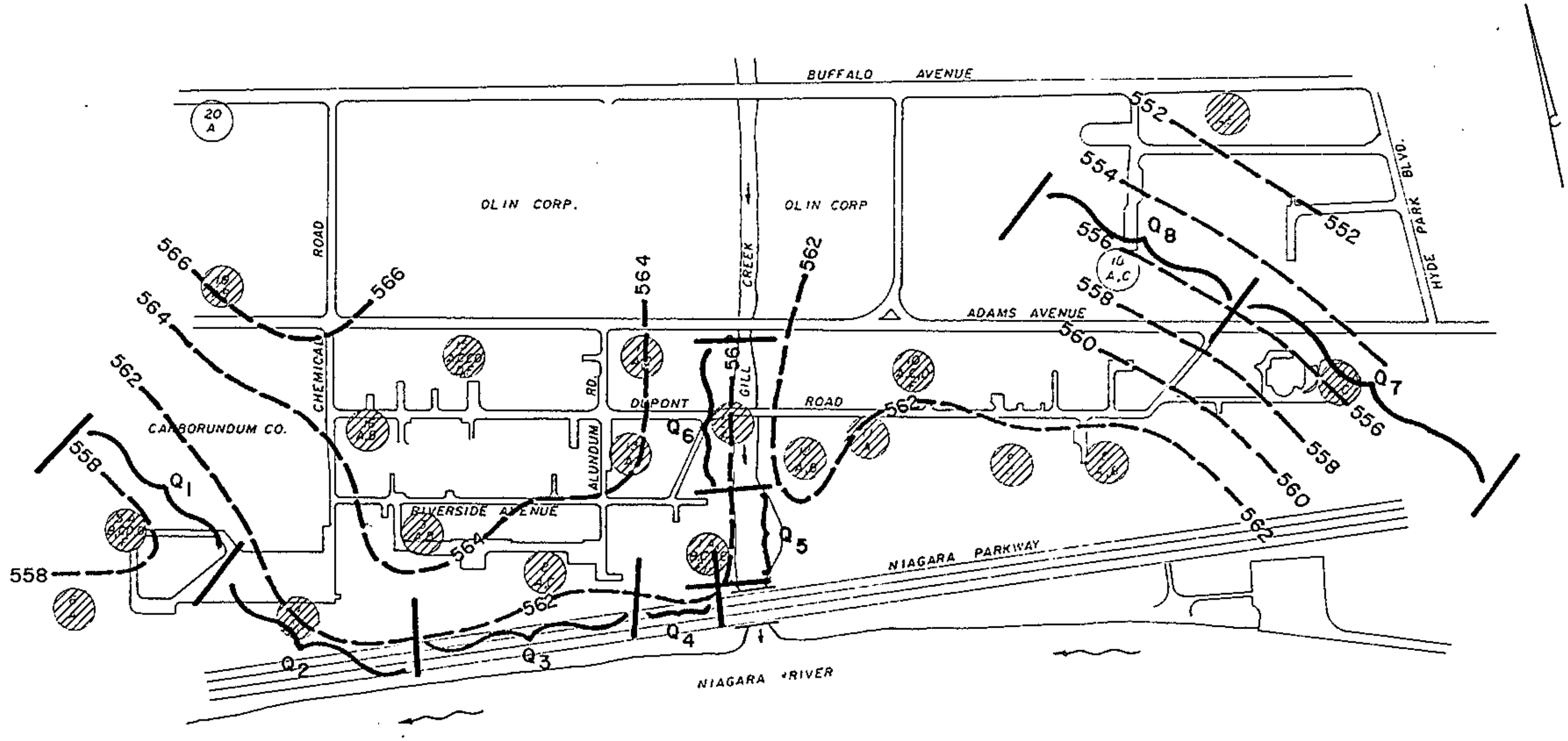
OCTOBER 19, 1983, TIME ~ 1600

F-ZONE GROUNDWATER CONTOURS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 — 300	DATE: 11/15/83	
CHECKED: J.C.E.		JOB: 83C2236	

PLATE 44



LEGEND:

- (17 A,B) — WELL CLUSTER NUMBER (NO.); WELL TYPE (LETTER)
- WELL USED TO GENERATE CONTOUR MAP
- 561 GROUNDWATER ELEVATION
- Q1 FLOW SECTION

NOTE: GROUNDWATER CONTOURS HAVE BEEN INTERPOLATED BETWEEN DATA POINTS AND ACTUAL CONDITIONS CAN VARY FROM WHAT IS SHOWN.

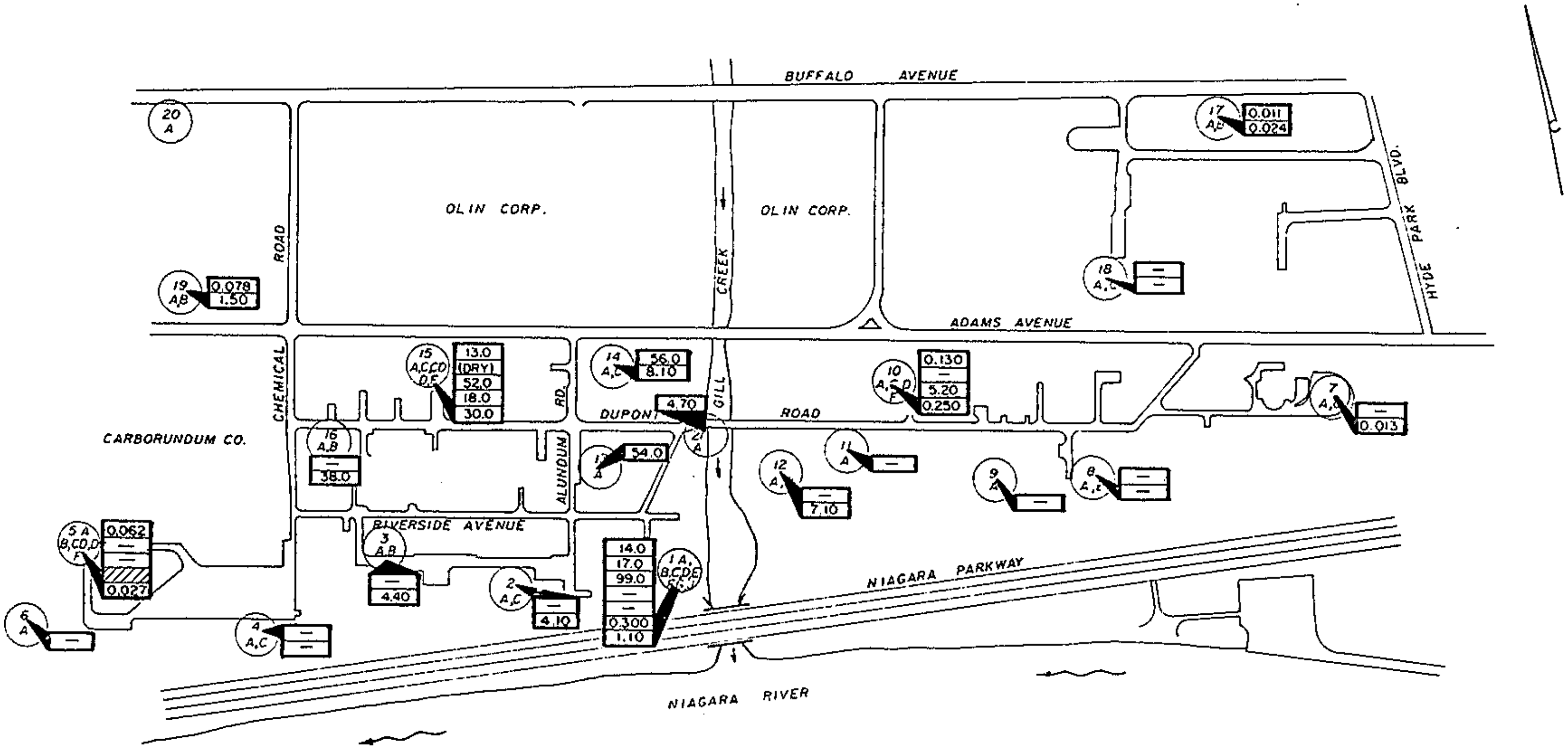
OCTOBER 17, 1983, TIME ~ 1200

FLOW SECTIONS IN THE A ZONE
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET	DATE: 11/15/83	
CHECKED: J.C.E.	0 300	JOB: 83C2236	

PLATE 45



LEGEND:

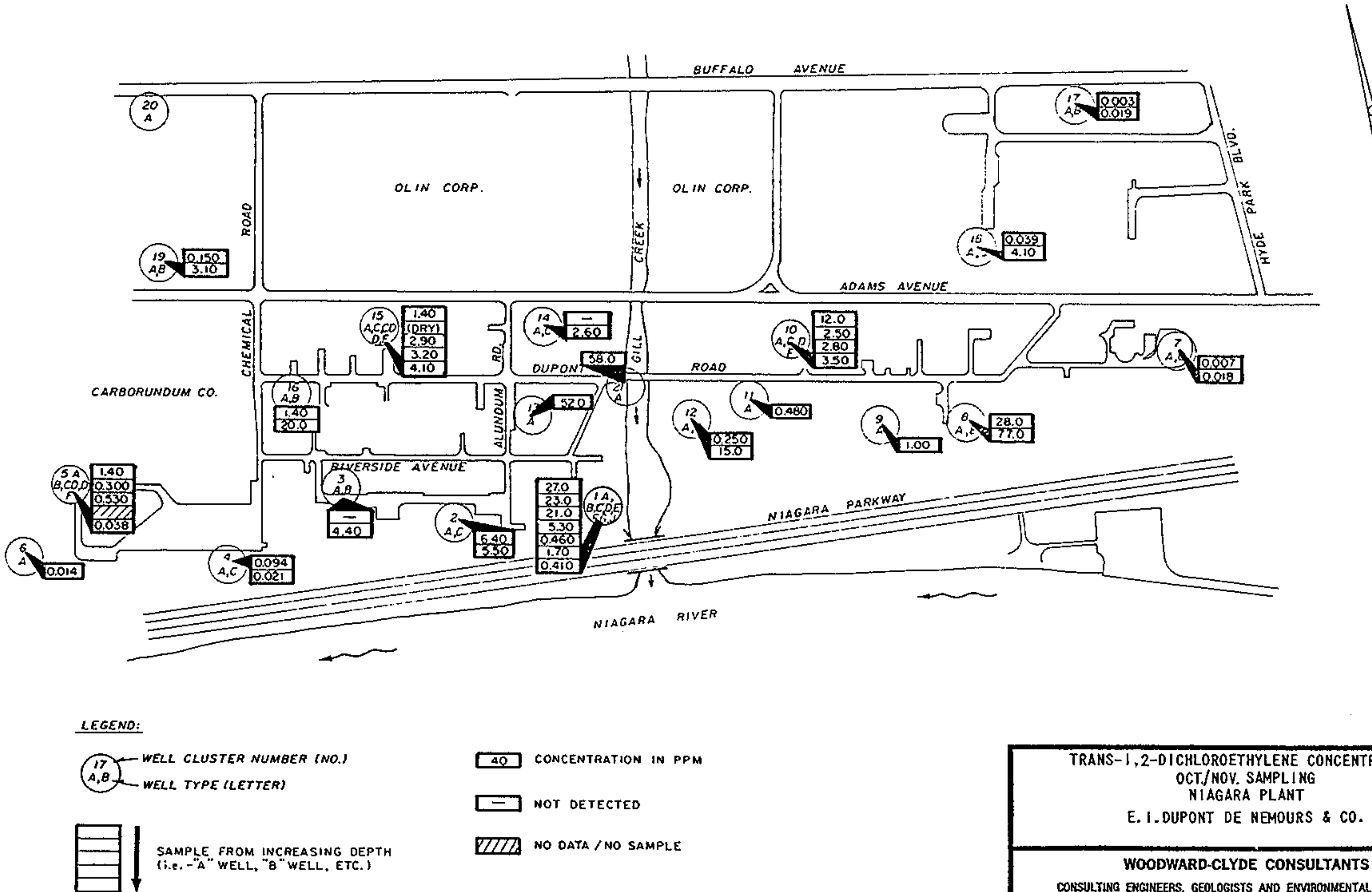
- (17 / A,B) — WELL CLUSTER NUMBER (NO.); WELL TYPE (LETTER)
- SAMPLE FROM INCREASING DEPTH (i.e. "A" WELL, "B" WELL, ETC.)
- [40] CONCENTRATION IN PPM
- [—] NOT DETECTED
- [////] NO DATA / NO SAMPLE

TETRACHLOROETHYLENE CONCENTRATIONS, OCT./NOV. SAMPLING
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 — 300	DATE: 11/15/83	
CHECKED: J.C.E.		JOB: 83C2236	

PLATE 46

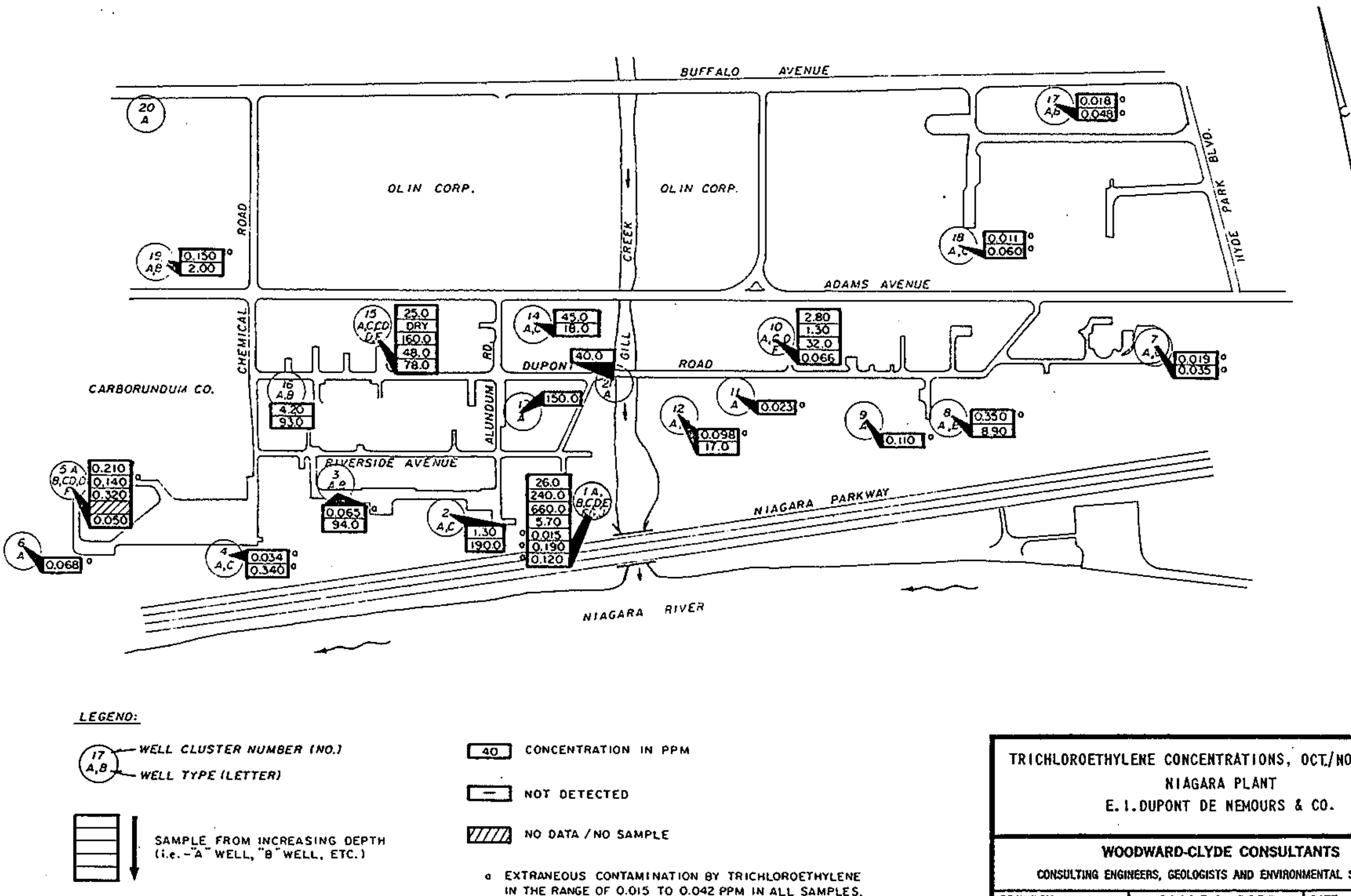


TRANS-1,2-DICHLOROETHYLENE CONCENTRATIONS,
OCT./NOV. SAMPLING
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 — 300	DATE: 11/15/83
CHECKED : J.C.E.		JOB : 83C2236

PLATE 47

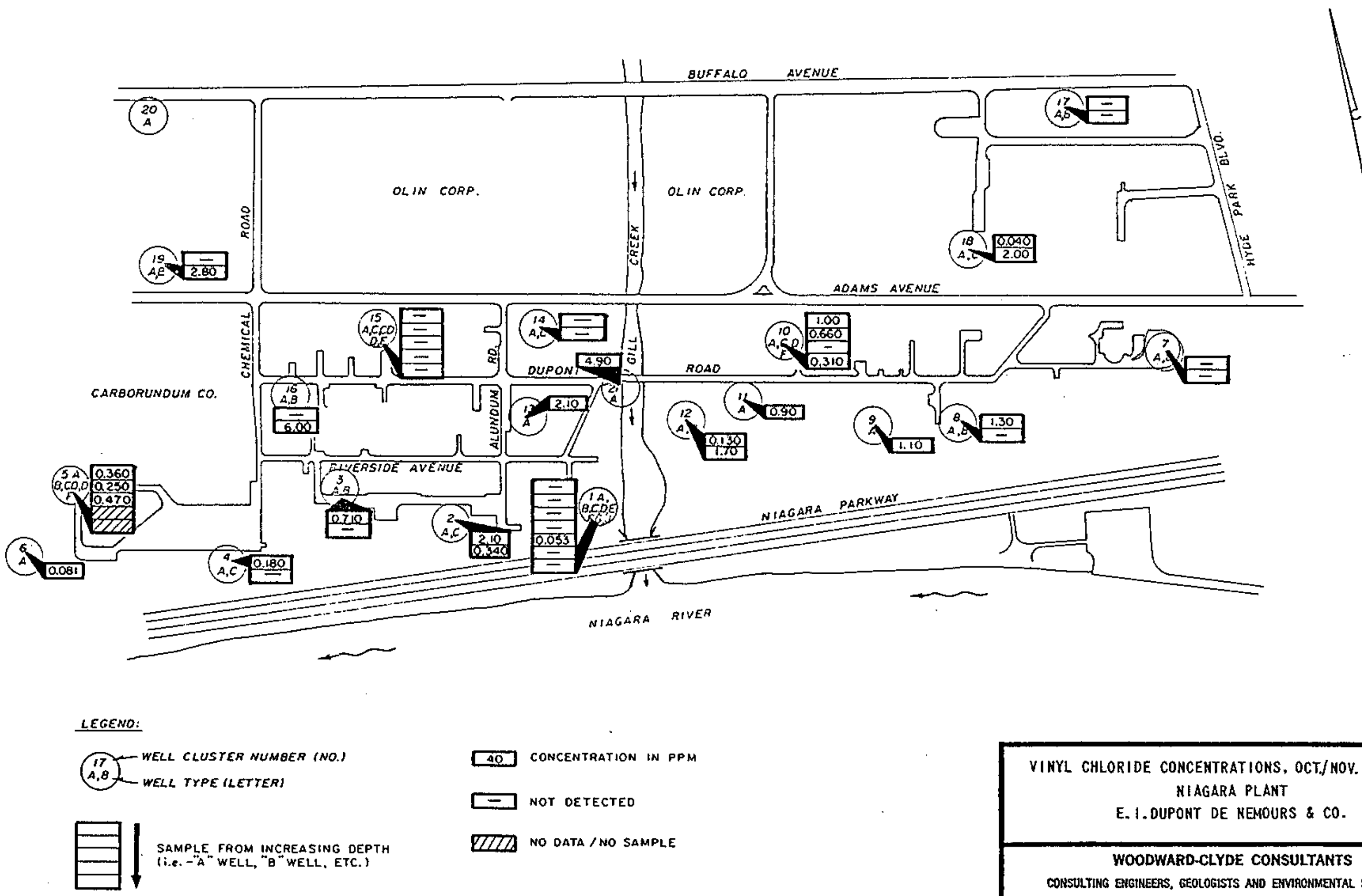


TRICHLOROETHYLENE CONCENTRATIONS, OCT./NOV. SAMPLING
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236-

PLATE 48

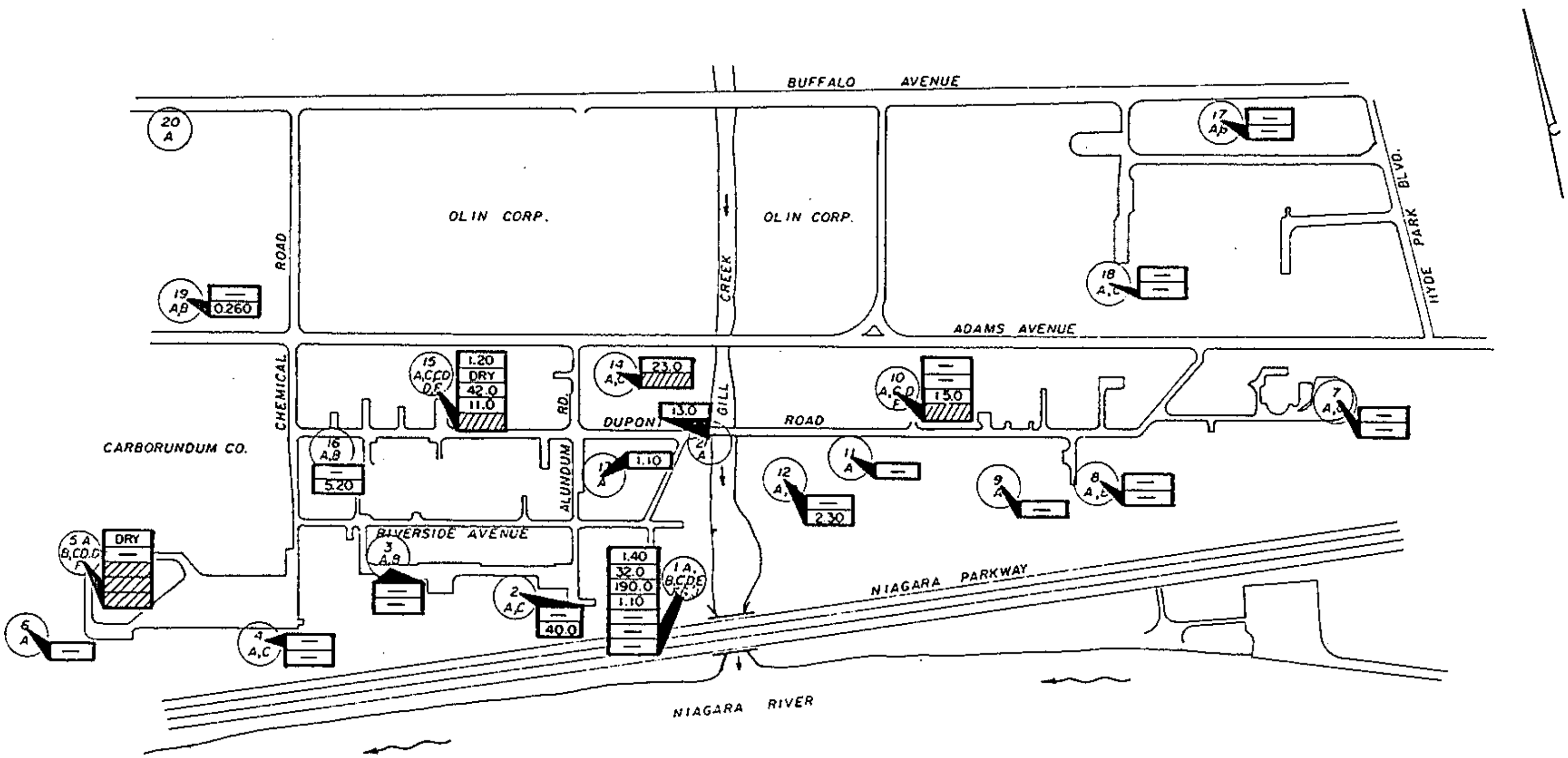


VINYL CHLORIDE CONCENTRATIONS, OCT./NOV. SAMPLING
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET	DATE: 11/15/83	
CHECKED: J.C.E.	0 — 300	JOB: 83C2236	

PLATE 49



LEGEND:

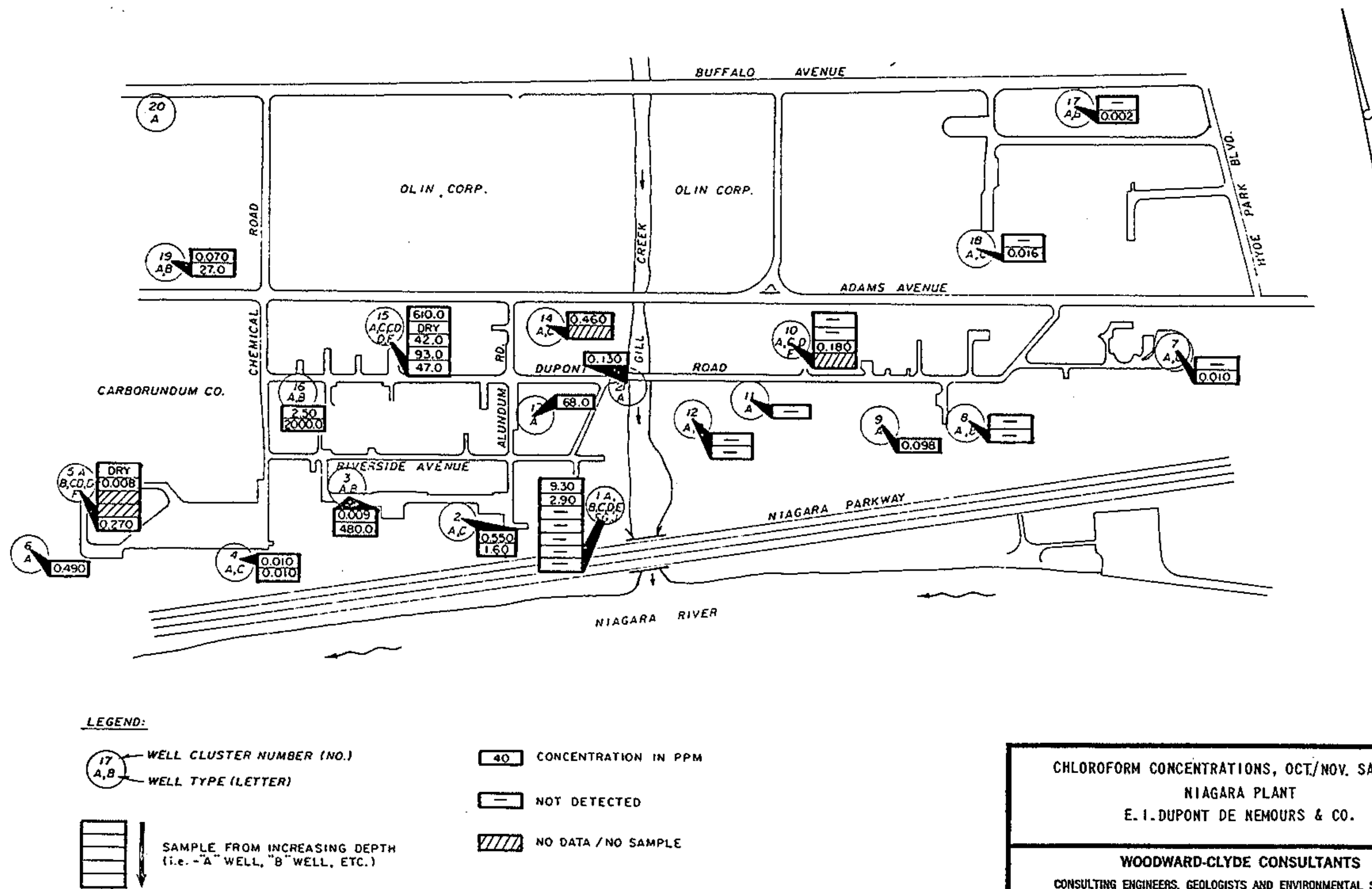
- 17 A,B — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)
- SAMPLE FROM INCREASING DEPTH (i.e.-"A" WELL, "B" WELL, ETC.)
- 40 — CONCENTRATION IN PPM
- — — NOT DETECTED
- (hatched) — NO DATA / NO SAMPLE

1,1,2,2-TETRACHLOROETHANE CONCENTRATIONS,
OCT./NOV. SAMPLING
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 50

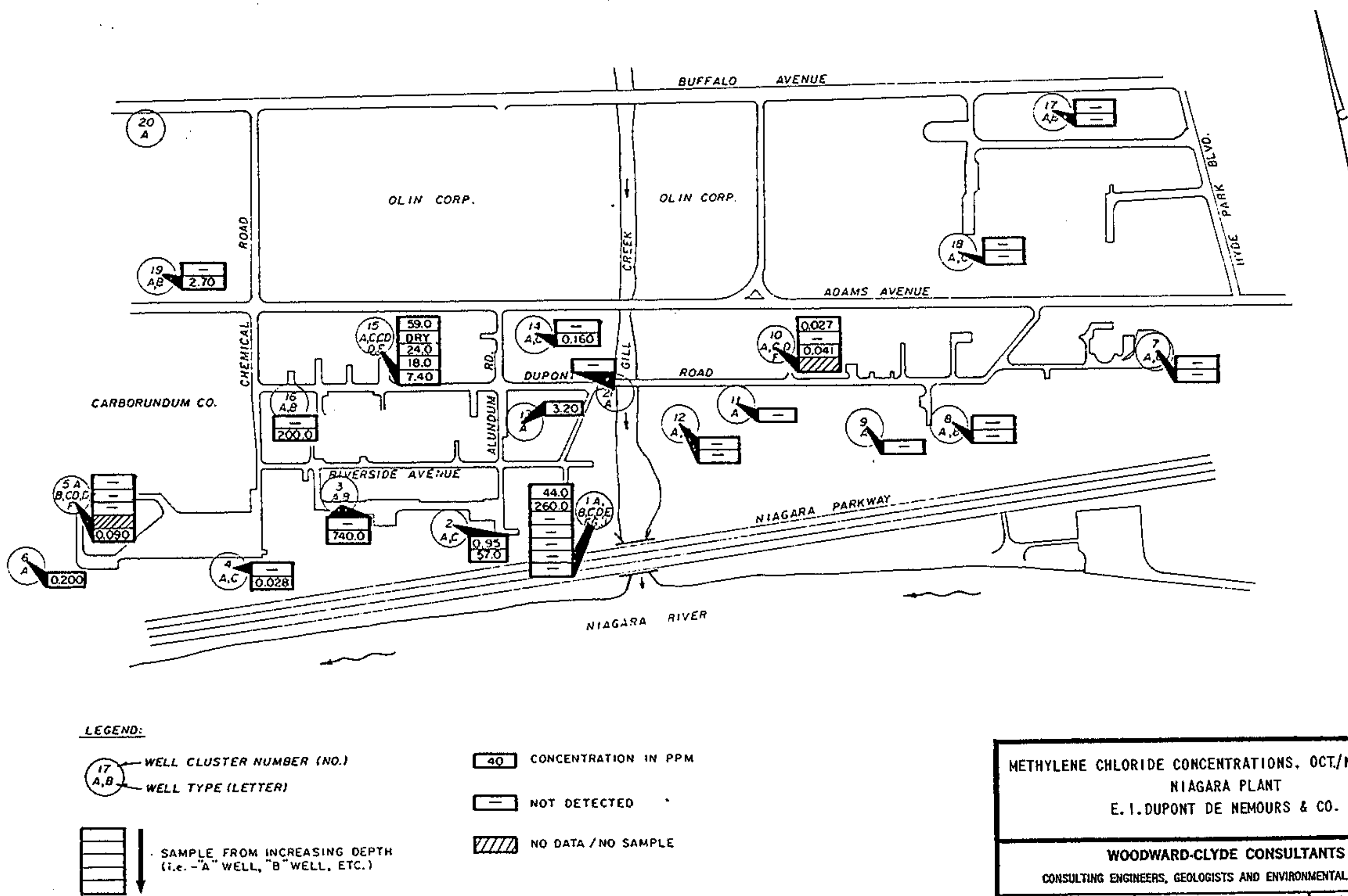


CHLOROFORM CONCENTRATIONS, OCT/NOV. SAMPLING
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 51

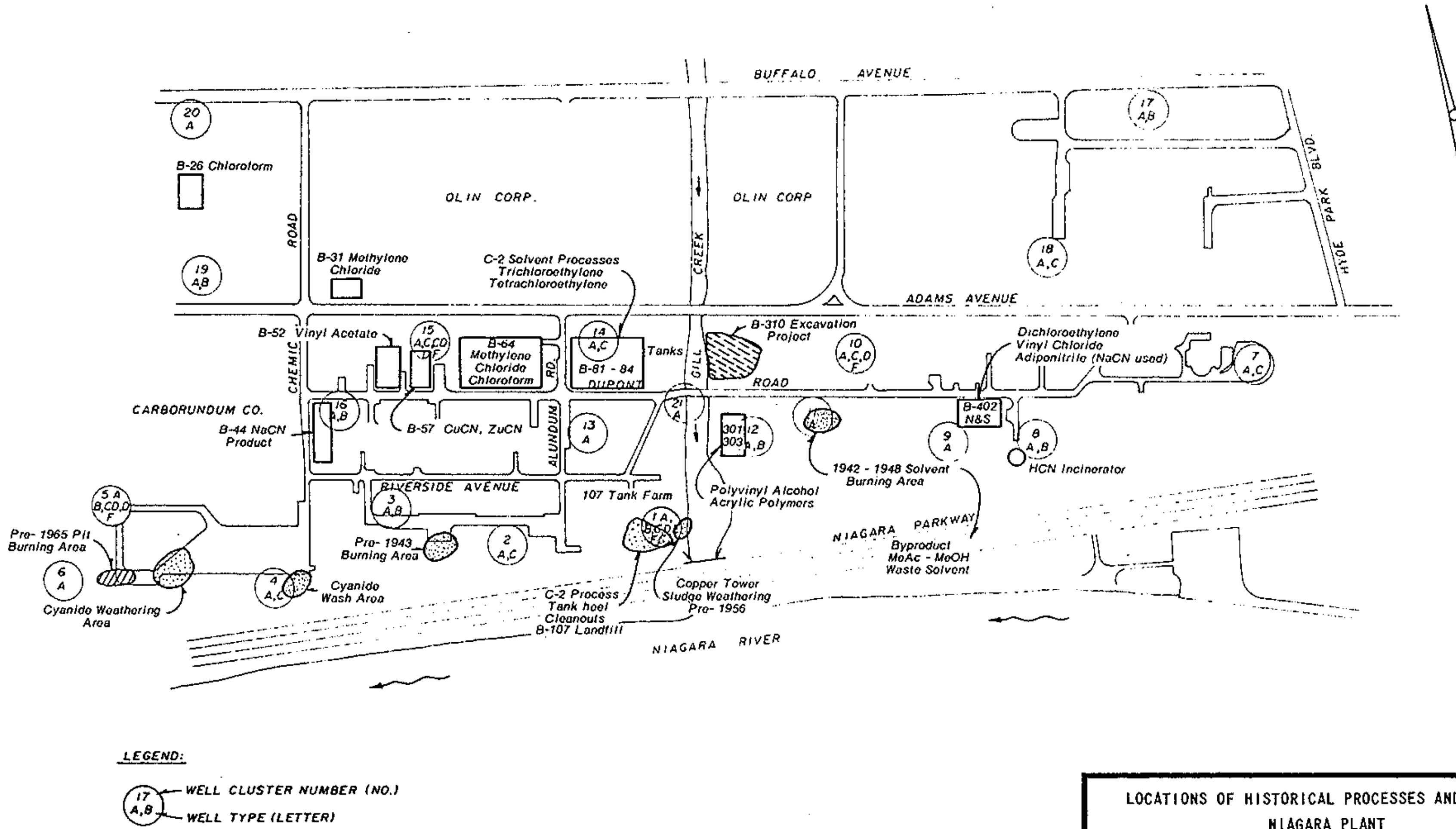


METHYLENE CHLORIDE CONCENTRATIONS, OCT./NOV. SAMPLING
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET		DATE: 11/15/83
CHECKED: J.C.E.	0 — 300		JOB: 83C2236

PLATE 52

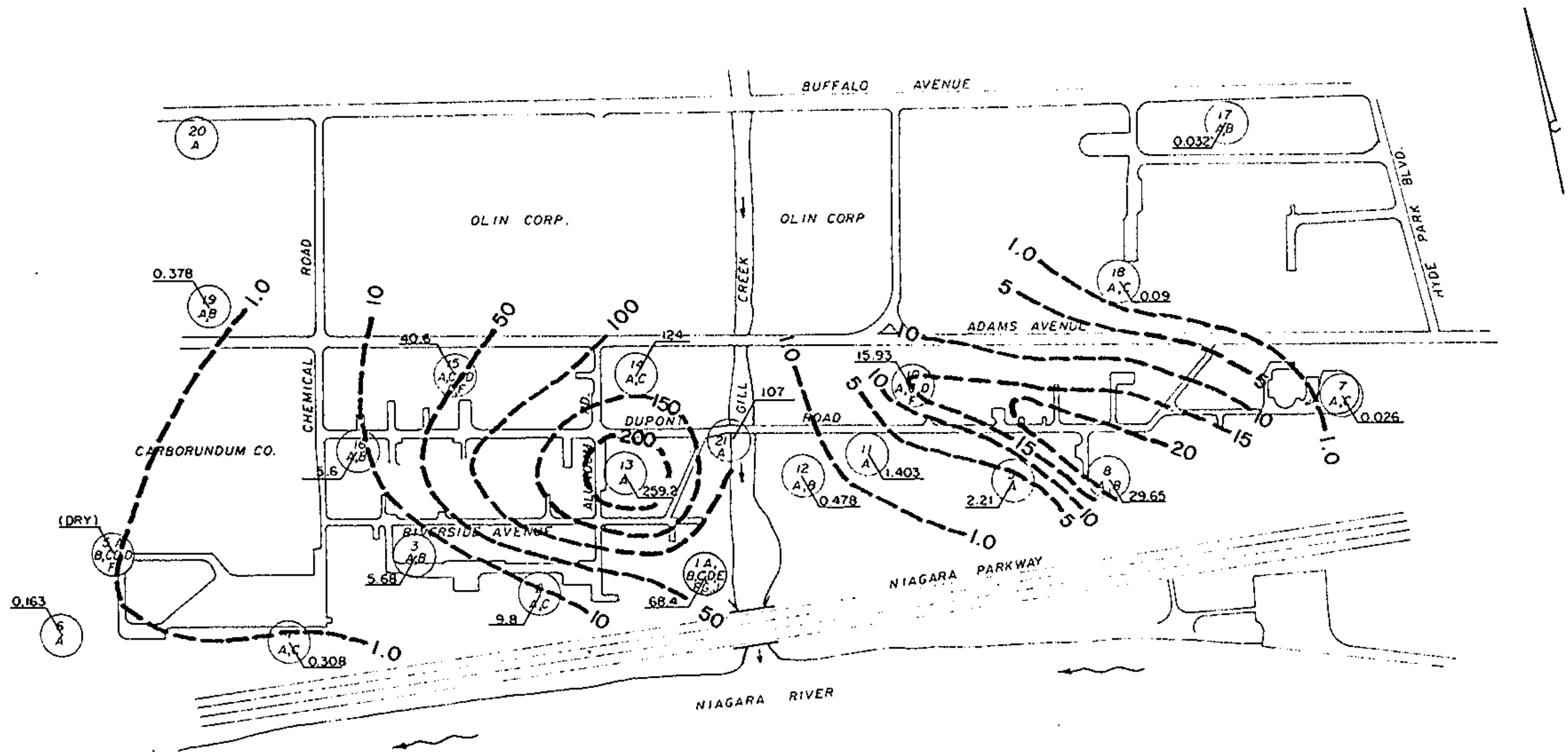


LOCATIONS OF HISTORICAL PROCESSES AND EVENTS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 53



LEGEND:

WELL CLUSTER NUMBER (NO.)
WELL TYPE (LETTER)

CONTOUR INTERVAL AS NOTED
CONCENTRATIONS IN PPM (mg/l)

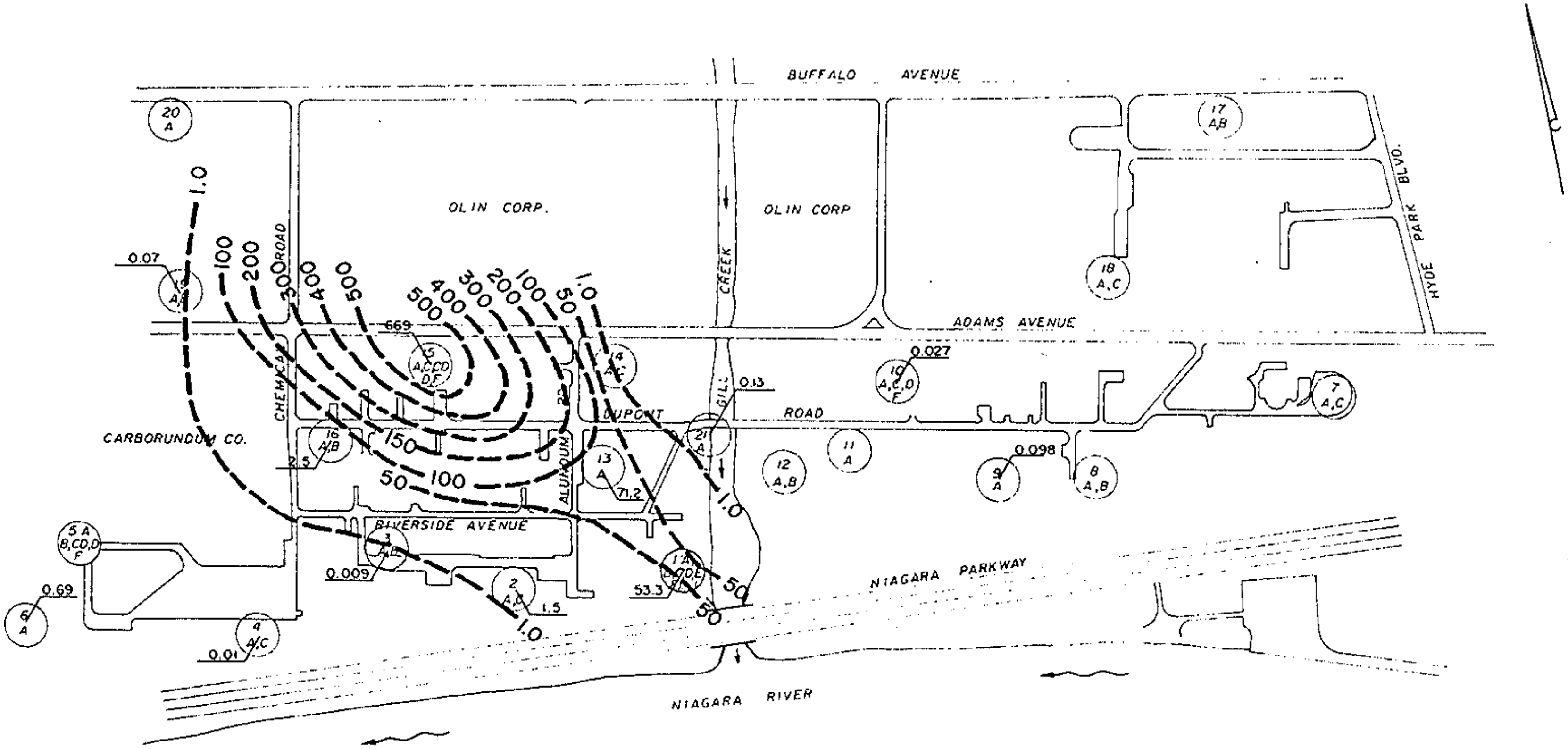
NOTE: CONCENTRATION CONTOURS HAVE BEEN INTERPOLATED TO ILLUSTRATE AREAS OF RELATIVE CONTAMINATION AND ARE NOT INTENDED TO REPRESENT ACTUAL GROUNDWATER QUALITY CONDITIONS.

APPARENT CONCENTRATION CONTOURS FOR
C-2 COMPOUNDS - OCTOBER SAMPLING -"A" WELLS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 54



LEGEND:

17 A,B — WELL CLUSTER NUMBER (NO.) / WELL TYPE (LETTER)

CONTOUR INTERVAL AS NOTED

CONCENTRATIONS IN PPM (mg/l)

NOTE: CONCENTRATION CONTOURS HAVE BEEN INTERPOLATED TO ILLUSTRATE AREAS OF RELATIVE CONTAMINATION AND ARE NOT INTENDED TO REPRESENT ACTUAL GROUNDWATER QUALITY CONDITIONS.

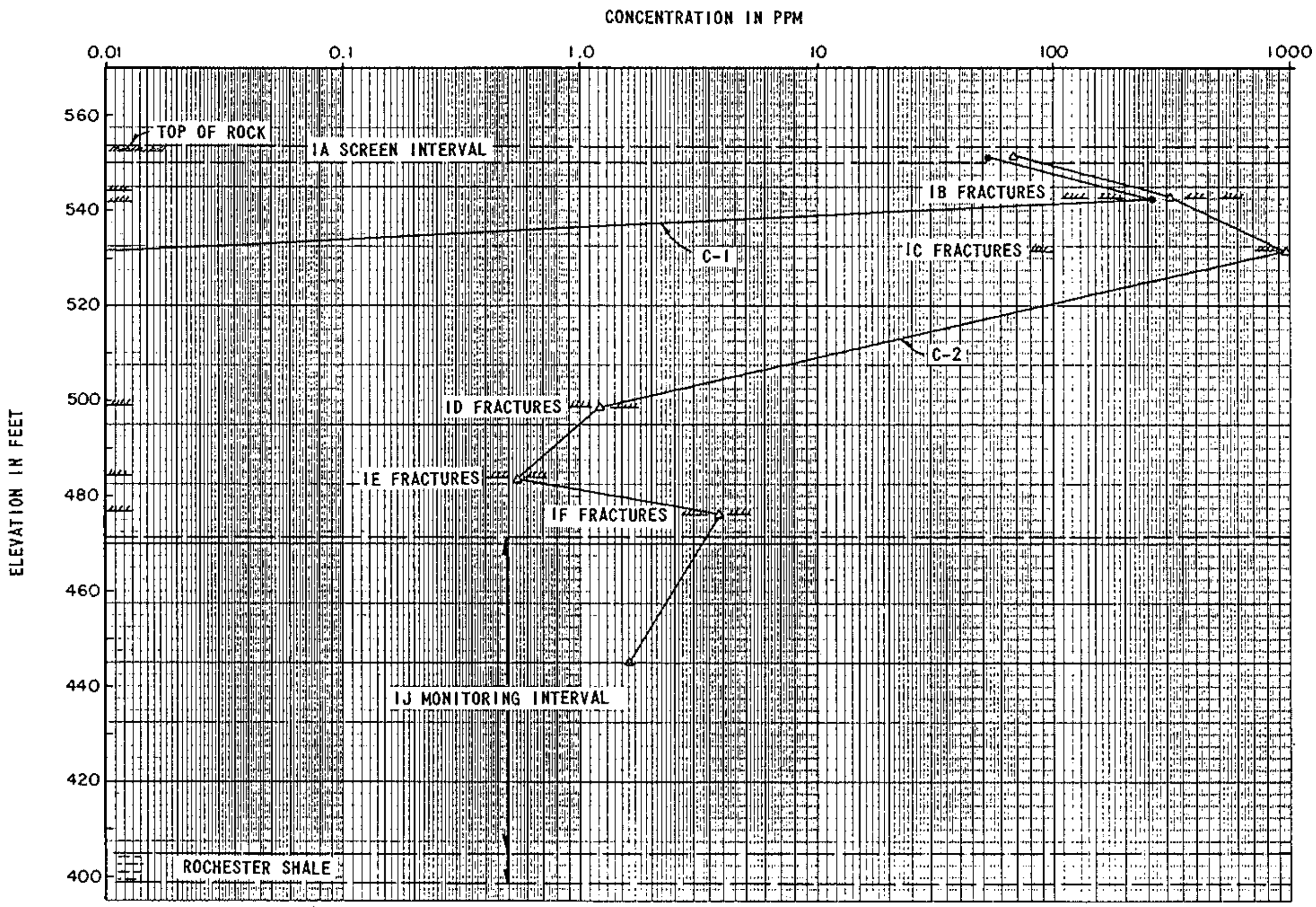
APPARENT CONCENTRATION CONTOURS FOR
C-1 COMPOUNDS - OCTOBER SAMPLING -"A" WELLS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS

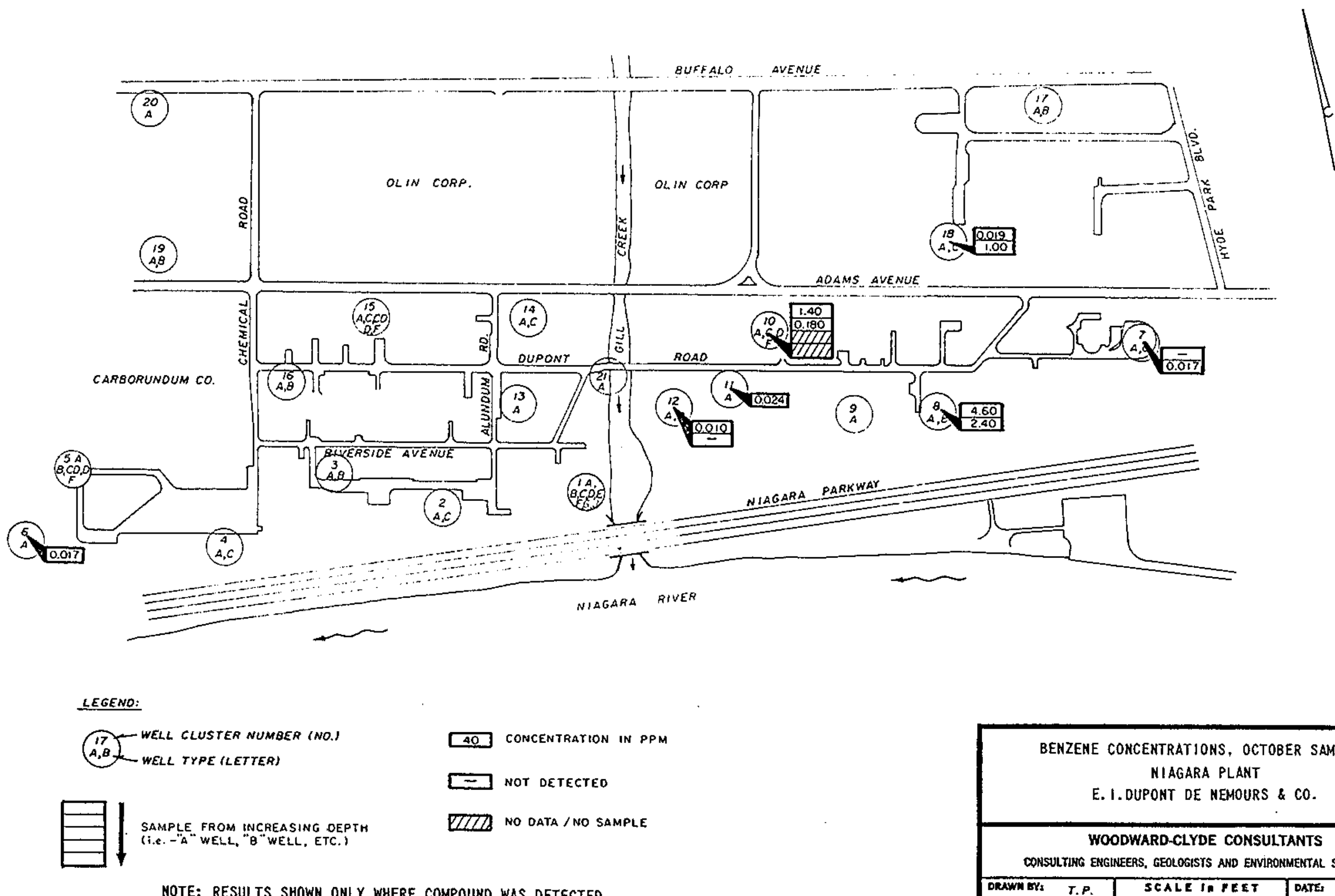
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET	0 — 300	DATE: 11/15/83
CHECKED: J.C.E.			JOB: 83C2236-5

PLATE 55



CONCENTRATIONS OF C-1 AND C-2 COMPOUNDS WITH DEPTH
NO.1 WELL CLUSTER - OCTOBER SAMPLING
NIAGARA PLANT
E.I.DUPONT DE NEMOURS & CO.

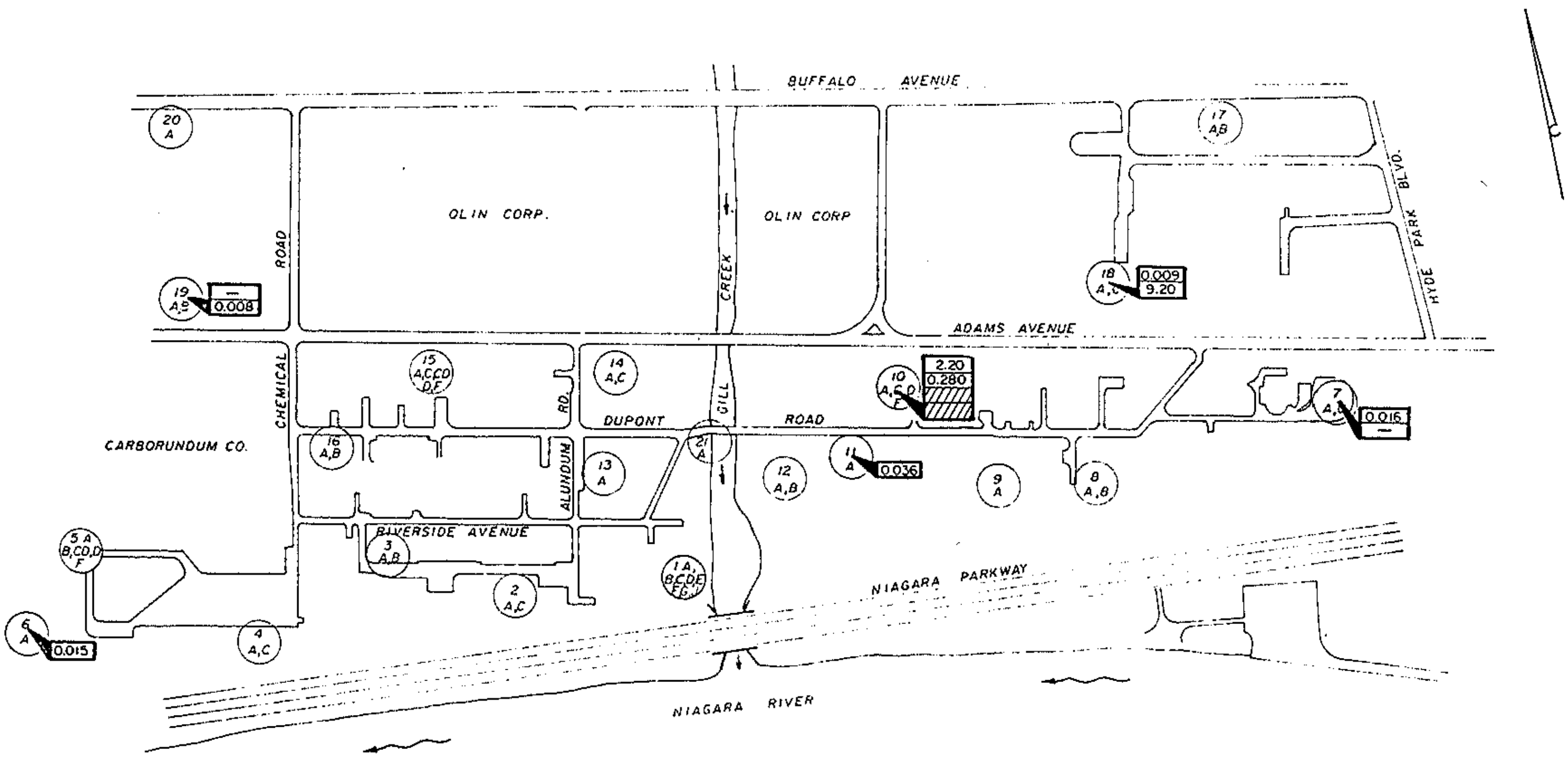


BENZENE CONCENTRATIONS, OCTOBER SAMPLING
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 57



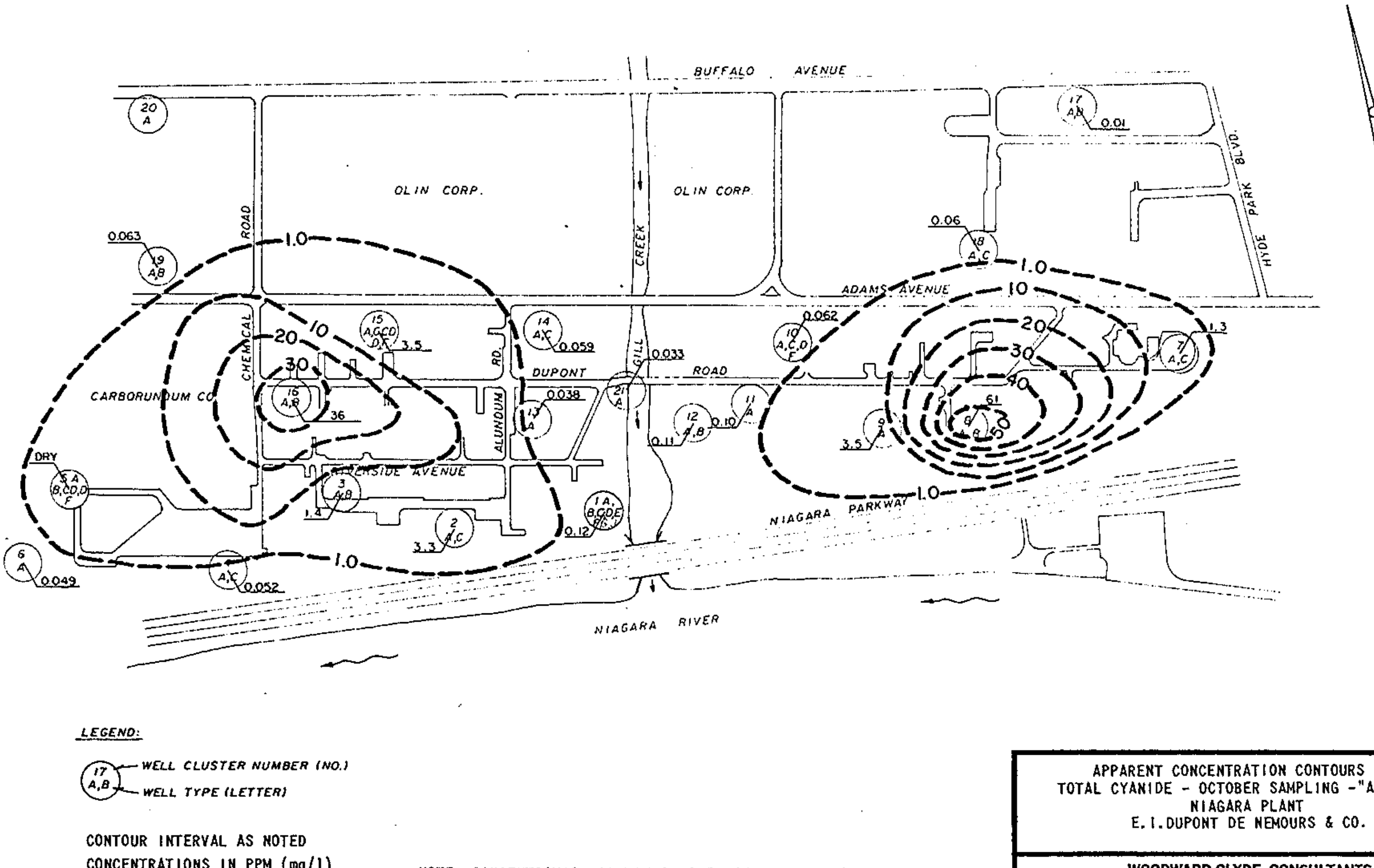
LEGEND:

- [40] CONCENTRATION IN PPM
- [—] NOT DETECTED
- [////] NO DATA / NO SAMPLE

NOTE: RESULTS SHOWN ONLY WHERE COMPOUND WAS DETECTED

CHLOROBENZENE CONCENTRATIONS, OCTOBER SAMPLING NIAGARA PLANT E.I. DUPONT DE NEMOURS & CO.		
WOODWARD-CLYDE CONSULTANTS CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS		
DRAWN BY: T.P.	SCALE in FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 58



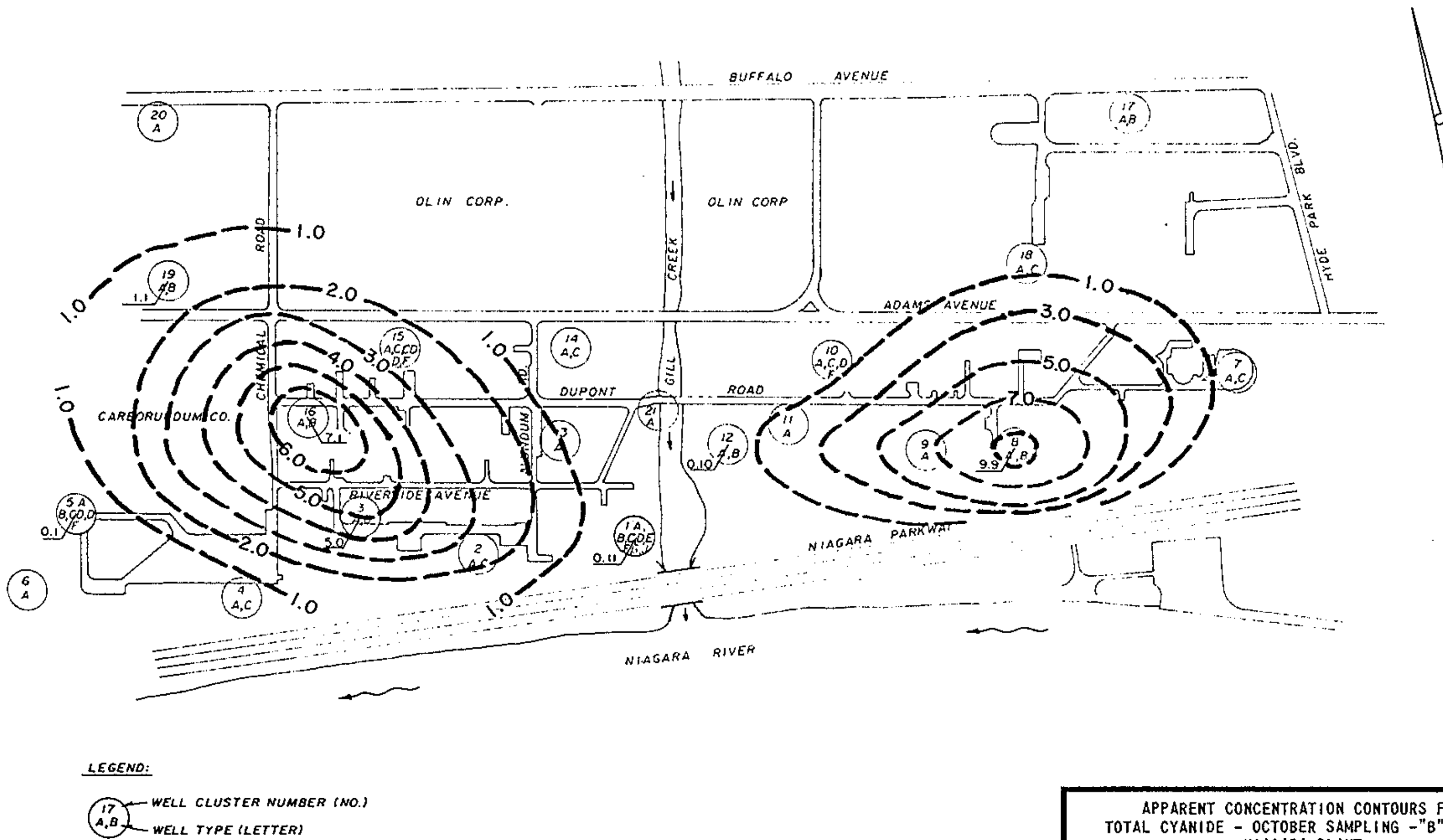
NOTE: CONCENTRATION CONTOURS HAVE BEEN INTERPOLATED TO ILLUSTRATE AREAS OF RELATIVE CONTAMINATION AND ARE NOT INTENDED TO REPRESENT ACTUAL GROUNDWATER QUALITY CONDITIONS.

APPARENT CONCENTRATION CONTOURS FOR
TOTAL CYANIDE - OCTOBER SAMPLING -"A" WELLS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 59



CONTOUR INTERVAL AS NOTED
CONCENTRATIONS IN PPM (mg/l)

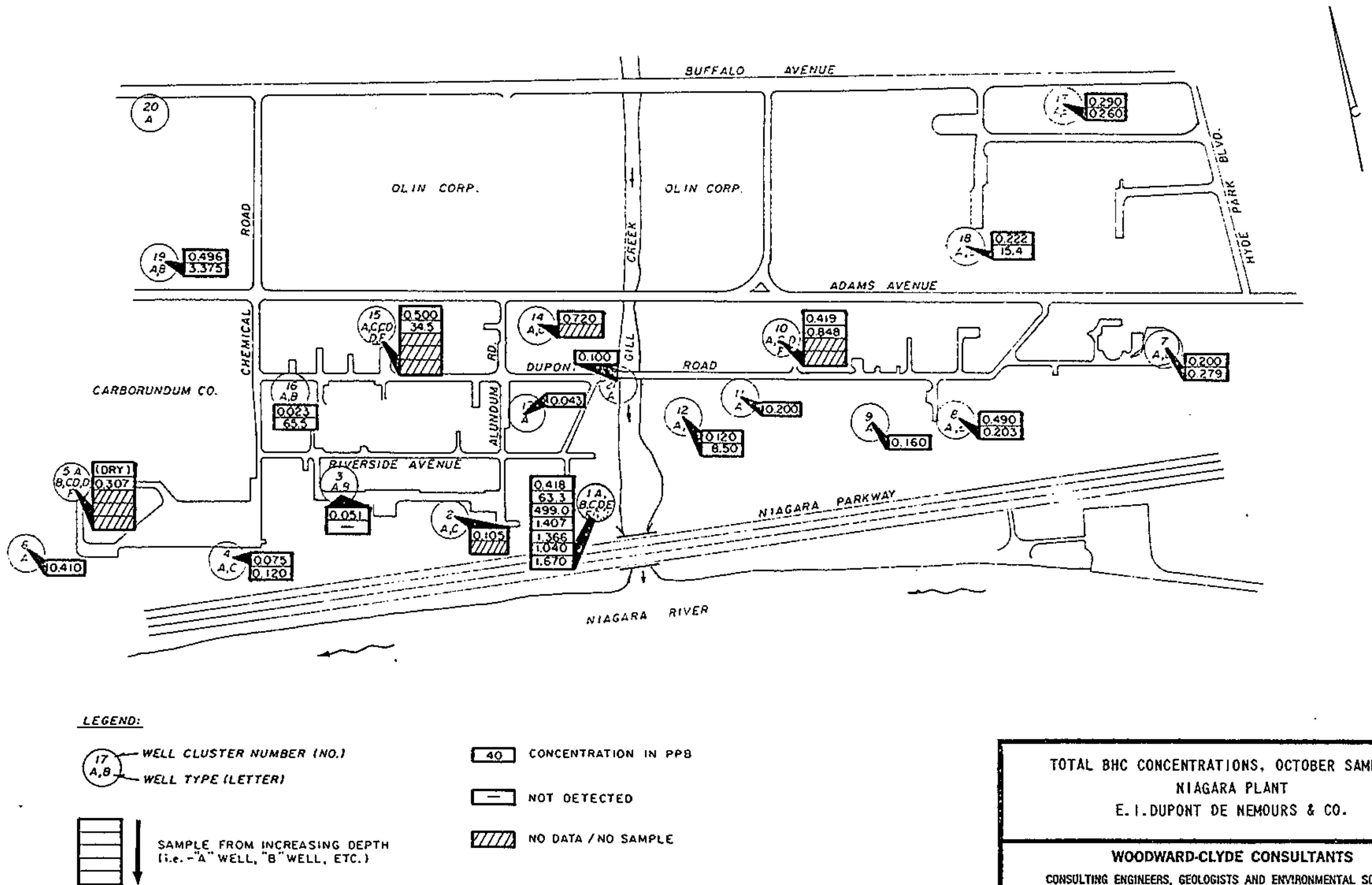
NOTE: CONCENTRATION CONTOURS HAVE BEEN INTERPOLATED TO ILLUSTRATE AREAS OF RELATIVE CONTAMINATION AND ARE NOT INTENDED TO REPRESENT ACTUAL GROUNDWATER QUALITY CONDITIONS.

APPARENT CONCENTRATION CONTOURS FOR
TOTAL CYANIDE - OCTOBER SAMPLING -"B" WELLS
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE in FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 60

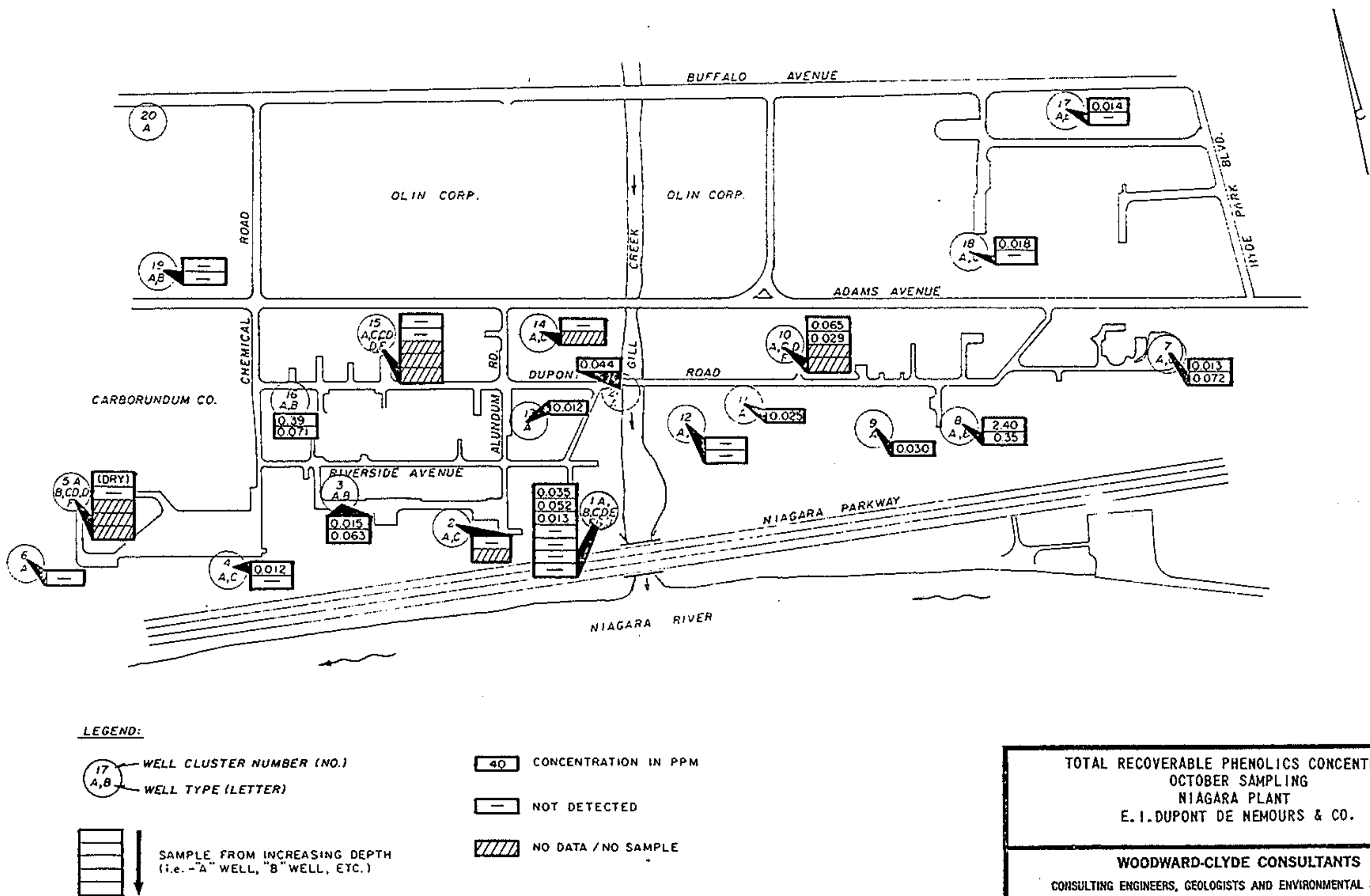


TOTAL BHC CONCENTRATIONS, OCTOBER SAMPLING
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 61



TOTAL RECOVERABLE PHENOLICS CONCENTRATIONS
OCTOBER SAMPLING
NIAGARA PLANT
E. I. DUPONT DE NEMOURS & CO.

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

DRAWN BY: T.P.	SCALE IN FEET 0 — 300	DATE: 11/15/83
CHECKED: J.C.E.		JOB: 83C2236

PLATE 62