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February 27, 1984

Mr. P. Crabtree
Ministry of the Environment
Niagara Steering Committee
119 King Street West
12th Floor
Box 2112
Hamilton, Ontario
L8N 3Z9

Dear Mr. Crabtree:

We are pleased to submit our final report on the review and interpretation of the Hooker Niagara Plant Site. In the report we have addressed in Section 6 the remedial measures which have been proposed in the Hooker (1981) Best Available Technology/Best Management Practices document listed in the references to our report. The conclusions and recommendations presented in our report are related to those proposed measures. It is our understanding that several of these remedial measures are currently in abeyance pending the resolution of State litigation on this site.

If we can provide anything further concerning the Niagara Plant Site please contact myself or the Project Engineer, Brian Whiffin. Thank you for the opportunity to be of service to the Ministry.

Yours truly,

G.E. Grisak
President

GEG/gr

Encl.

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HYDROGEOLOGIC EVALUATION

OF THE

HOOKER NIAGARA PLANT SITE

REPORT TO
NIAGARA RIVER STEERING COMMITTEE
ONTARIO MINISTRY OF THE ENVIRONMENT

PREPARED BY
GTC GEOLOGIC TESTING CONSULTANTS LTD.
785 CARLING AVENUE, 4TH FLOOR
OTTAWA, ONTARIO

FINAL REPORT

February 23, 1984

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FOREWORD

This report has been prepared for the Niagara River Steering Committee of the Ontario Ministry of the Environment. The purpose of this report is to provide the Ministry with an independent technical review and interpretation, from a hydrogeological standpoint, of the potential impact to the Niagara River from waste disposal operations at the Hooker Niagara Plant Site. The S-Area disposal site, located at the Hooker Niagara Plant, was evaluated in detail in a previous report (GTC, 1982b). It is hoped that this report can be used to assist in the understanding of past and present hydrogeologic conditions and the development of satisfactory remedial measures.

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1.0 BACKGROUND

The Hooker Niagara Plant (HNP), operated by Hooker Chemical and Plastics Corporation, contains a number of waste disposal areas located within the plant boundaries. The HNP Site, also referred to as the Buffalo Avenue Plant, covers an area of approximately 130 acres (State of New York, 1982) in the southeast portion of the City of Niagara Falls, New York (Figure 1). The HNP Site is bounded on the south by the Robert Moses Parkway, on the east by 53rd Street, on the west by Iroquois Street and on the north by the former New York Central Railroad (NYCRR) and Energy Boulevard (see Figure 2 and air photo in Appendix I). The present Niagara River shoreline is located approximately 100 yards south of the Hooker plant property (State of New York, 1982).

The HNP has been the site of manufacture of various chemicals since the early 1900's, the wastes and byproducts of which have been disposed at a number of locations throughout the plant site. According to the State of New York (1982), "... Hooker dumped chemical wastes at various plant property disposal areas by various means, including but not limited to, discharging liquids and other wastes directly into the disposal areas from trailers and punctured drums and depositing wastes in bulk or drummed quantities directly into the ground." "During the course of manufacturing process, spillage of raw materials and chemicals onto the soil has occurred and continues to occur. These chemicals have percolated through the soil and into the ground water."

This report presents a compilation of available data for the HNP hydrogeologic system, including an assessment of the relationships between ground water contamination, wastewater loadings and infiltration/exfiltration, and watermain leakages. The site contains some relatively permeable geologic units which readily convey water and dissolved contaminants in the subsurface. In addition, numerous wastewater sewers, sanitary sewers and storm sewers as well as watermains are present at the HNP site. Many of the sewers and watermains are leaky, adding considerable complexity to the evaluation of ground water contamination in the plant area. Wastewater sewers discharge process water and waste products directly to the Niagara River under Hooker's State Pollutant Discharge Elimination System (SPDES) permit. However, approximately 7.0% of the final discharge to the Niagara River is unidentified (Hooker, 1980b) and 74.0% of the chemical loading is unidentified (Hooker, 1979a). Unidentified flows and loadings are attributed to ground water infiltration and/or unidentified connections to the sewer system (stubs).

The HNP disposal sites are distributed within the HNP property boundaries and take their designations from the various plant area designations (Figure 2). Wastes deposited at each site and the methods of disposal are not well documented. A waste inventory was prepared by Hooker (1978) which presents estimates of the waste type and quantities at some of the HNP disposal sites (Table 1). A detailed assessment of the S-Area disposal site in the context of the HNP site has been presented previously by GTC (1982b). Historical chemical loadings to the Niagara River from the wastewater sewer system (Table 2) also provide an indication of the type of contaminants present at the HNP site and their distribution by wastewater sewer outfall (see Figure 9 for wastewater sewer system outfall designations and locations). The eleven chemicals listed below comprise 94% of the total organic loading in the wastewater outfalls (Hooker, 1980a):

Trichloroethylene
Tetrachloroethylene
Toluene

Chlorobenzotrifluorides
Monochlorobenzene
Dichlorobenzenes
Chlorotoluenes
Dichlorotoluenes
Trichlorobenzenes
Tetrachlorobenzenes
Hexachlorocyclopentadiene

2.0 LOCAL GEOLOGY

The geology of the Hooker Niagara Plant (HNP) site is presented in this section based primarily on interpretation of borehole logs initially logged by Leggette, Brashears and Graham, Inc. (1980a). The regional scale geology is discussed in Appendix II as adapted from GTC (1982b).

The borehole logging varied somewhat between geologists and companies providing some uncertainty in borehole log interpretation. This necessitated the utilization of some subjectivity in conjunction with interpretive judgement in order to form a practical interpretation of the actual stratigraphy.

2.1 Glacial Deposits

The following stratigraphic interpretation involved assimilation of borehole data compiled by Leggette, Brashears and Graham (1980a) as well as by Conestoga-Rovers and Assoc., as presented in Leggette, Brashears and Graham (1980a). The results of the geologic interpretation are presented in an isometric projection (30°) commonly referred to as a fence diagram. The fence diagram (Figure 3; Appendix III) shows a 3-dimensional view of the entire HNP site as seen from the west/southwest. Stratigraphic units are shown with relevant surface features (for example, streets and Niagara River shoreline) indicated for reference locations.

From the fence diagram, it is evident that the stratigraphic sequence at HNP site is typical, for the most part, of the stratigraphy encountered on a regional scale (see Appendix II). A deposit of glacial till overlies bedrock at virtually all locations, varying in thickness from 0 to 16 feet and averaging about 6 feet. There is a notable absence of till or clay on the southwest side of S-Area at borehole 14. The sandy fill appears to directly overlie the bedrock in this area. The combined thickness of the till and clay averages approximately 15 feet north of Adams Avenue (Figure 4), thinning to close to zero at the Niagara River Shoreline. (It should be noted that Figure 4 is from GTC, (1982b)). Reinterpretation of borehole logs resulted in some changes in the combined thickness of clay and till. The reinterpreted values are denoted by the bracketed numbers in Figure 4.) A thin silt deposit (average depth 4 feet) overlies the clay at many locations north of the southern plant boundary although this unit appears to have been disturbed by surface activities and often contains fill material. Thick silt deposits up to 13 feet are present at boreholes 7 and 8. A layer of highly variable material overlies the silt at all locations and has been designated as fill, although it may consist only of native deposits exhibiting anthropogenetic effects. Portions of the HNP site have been reclaimed from the Niagara River using fill materials. Consequently, the thickness of the fill material overlying the native silt, clay and till generally increases from the vicinity of Adams Avenue south to the River.

Although the material above the silt layer is designated generally as fill, individual units of sand, silt and shot rock can be distinguished. A deposit of sand in the southern plant area can be delineated commencing near the western plant boundary and increasing in thickness to the east. The sand reaches a maximum thickness of 24 feet at borehole 14 in S-Area where the sand is in direct contact with the Lockport Dolomite bedrock.

Additional fill was placed along the shoreline of the Niagara River in the early 1960's to facilitate construction of the Robert Moses Parkway. Leggette, Brashears and Graham (1979e) describe the present shoreline geology as follows: "The sediments in the Parkway area consist generally of a few feet of fine-grained fill at the surface, underlain by about 20 feet of 'shot-rock' fill. Natural sediments underly the fill and consist of about 1 to 9 feet of till which overlies the dolomite bedrock". The rock fill is shown on the fence diagram (Figure 3; Appendix III), and has been extended to the Niagara River shoreline. 'Shot rock' fill beneath the Parkway is believed to originate from the conduit excavations for the Power Authority of the State of New York (PASNY). The material excavated was the Lockport Dolomite.

In logging interpretation, boreholes were interpreted so as to identify the individual stratigraphic units where possible, attributing as little as possible of the stratigraphy to the relatively undefinable fill zone. For instance, a borehole interval which is clearly silt with a small amount of brick fragments detected, has been designated as silt. Whereas a logging interval consisting of material of no fixed description is designated as fill. Borehole logs through the fill material describe it as highly heterogeneous. It is noted to contain sand, silt, clay, gravel, bricks, cinders, slag, ash, wood, friable material, rock fragments, root material, glass, mud, concrete, rubber, and shot rock (Leggette, Brashears and Graham, 1980a). Silt, sand and sandy silt zones are often present in the interpreted sand, silt and fill layers and boundaries between the units are often indistinct. However, in general, the stratigraphic interpretation in Figure 3 is considered representative of the HNP site.

Topography in the HNP vicinity generally slopes gently southward to the Niagara River (Figure 5) with the exception of a localized high point at S-Area. This mound rises about 8 feet above the surrounding landscape and is due to the placement of fill upon which two clay-lined calcium fluoride sedimentation-clarification lagoons are located. The land surface is also built up between the Hooker plant area and the Niagara River to form the Robert Moses Parkway.

2.2 Bedrock Geology

Underlying the glacial and fill deposits of the HNP site is the Lockport Dolomite, the uppermost bedrock formation in the immediate Niagara area. The thickness of the Lockport Dolomite beneath the HNP is about 125 feet (PASNY, 1963; Niagara Power Project, Drawing 11G-106, Rev. 2, 1958). The Lockport is described as principally dolomite with thin beds of limestone and shaley dolomite. Most of the beds in the Lockport formation are described as "thick" (1 foot to 3 feet), or "thin", (1 inch to 1 foot); however, massive beds up to eight feet thick, as well as very thin beds (1/4 to 1 inch) occassionally occur (Johnston, 1964). Several extensive and open bedding joints permeate the Lockport, however vertical hydraulic communication throughout the entire thickness of the Lockport appears limited (op. cit.). Beneath the Lockport Dolomite lies the Rochester Shale, with a thickness of approximately 60 feet (inferred from observations at the Niagara Gorge).

Bedrock conditions at the HNP site are generally representative of conditions on a regional scale (Appendix II). The upper surface of the Lockport Formation is relatively smooth as is evident in Figure 6. Local lows in the topography of the bedrock surface appear to occur beneath approximately the center of U-Area and on the northeast corner of S-Area. The Lockport Dolomite immediately underlies the till, and the upper 10 to 15 feet are believed to be relatively highly fractured as compared to greater depths.

3.0 LOCAL HYDROGEOLOGY

Ground water flow in the Niagara area occurs through both the unconsolidated deposits and the bedrock. In the unconsolidated native deposits and fill materials, water is able to flow through the pores or interstices between the individual grains. In the bedrock, compaction and cementation have reduced the size of the intergranular pore spaces, restricting the flow. Ground water flow in the sedimentary rock is essentially confined to fractures, joints and interconnected solution cavities in the rock. There has been no indication in reports reviewed that the glacial till or lacustrine clay at HNP site exhibit any fractures. However, some fracturing in these deposits is expected and has been detected at the Love Canal disposal site.

The Niagara Gorge is a major ground water discharge zone in the Niagara Falls area. The gorge, roughly 300 feet deep, cuts through the glacial deposits, the Lockport Dolomite, Clinton and Albion Groups and into the Queenston Shale. Determination of the areal extent of influence of the gorge on the ground water system is problematic. However, previous interpretations (Johnston, 1964) suggest that the gorge has a significant effect on ground water flow beneath the entire city of Niagara Falls. There are insufficient recent data available to attempt a large scale ground water flow contour map in either the bedrock or the glacial deposits. Further discussion of the regional hydrogeology in the Niagara Falls area is included in Appendix IV.

3.1 Unconsolidated Deposits

Most significant ground water flow in the unconsolidated deposits occurs in the units overlying the clay and till. A sand unit is present in varying depths in the portion of the area paralleling the Niagara River between Adams Avenue and the River. The sand is stratigraphically between the clay/till and the silt units. The silt above the sand in this area is attributed to filling operations and is not considered to be a native deposit.

Hydraulic conductivities for a number of overburden wells were calculated from slug and pump test results by Leggette, Brashears and Graham and presented in Hooker (1980a). Slug and pump tests, for which test conditions were not provided, resulted in the determination of a wide range of hydraulic conductivities varying from 0.02 gpd/ft^2 (9.0 x 10^{-7} cm/s) to 187.6 gpd/ft^2 (8.9 x 10^{-3} cm/s).

Water table elevations were monitored at the Hooker Niagara Plant Site and surrounding property during the period October 1979 to August 1981 (Conestoga-Rovers and Assoc., 1981a). Attempts were made (GTC, 1982b) to prepare water table contour maps, based on linear interpolation techniques, for specific dates corresponding to periods of low and high ground water levels during the year 1981 (Figures 7 and 8). There does not appear to be sufficient data to confidently develop a water table map for either of these periods without utilizing some subjectivity. This is likely due to a combination of factors, including the fact that the overburden wells are screened over various lengths, and that watermain exfiltration and sewer infiltration tend to considerably complicate the shallow subsurface flow regime.

In general, the plan view direction of ground water flow in the overburden is southerly towards the Niagara River. However significant downward vertical gradients from the overburden into the bedrock also exist and there are several anomalous areas, such as the ground water lows found along Buffalo Avenue between 47th and 53rd Streets. These lows, in addition to the low at the north end of 47th Street, are likely due to sewer infiltration, while the anomalously high areas are related, in some instances, to watermain leakages. Leakage from the S-Area sedimentation-clarification lagoons and Water Treatment Plant finished water reservoir cause the relative high in the southeast portion of the HNP (GTC, 1982b). The water levels in individual wells for the periods of high and low ground water levels vary, on an absolute scale, by 1 to 2 feet, however the general flow direction appears similar for both periods (i.e., towards the Niagara River.) .

The PASNY conduits intake structure also appears to have a significant influence on ground water flow in the overburden in the southwest portion of the study area. The intake area is a major ground water low in the overburden with ground water movement from the overburden (predominantly shot rock fill overlying a very thin till layer) into the bedrock, suggesting that the permeable shot rock fill may be in close hydraulic connection with the bedrock. The bedrock water levels are apparently controlled by the exterior drainage system around the conduits as well as by the berms and grout curtains installed during the construction phase of the conduits (see Figures 14 and 15). The intake structures impact overburden water levels from slightly north of the southern plant boundary, south to the River (Figures 7 and 8).

3.1.1 Sewer Infiltration/Exfiltration

The wastewater sewer system at the HNP site consists of 5 separate systems referred to as Outfalls 001 to 005. Wastewater Outfalls 001, 002, 003 and 005 discharge directly to the Niagara River (Figure 9) while Outfall 004 discharges to the Falls Street Tunnel at 47th Street, which eventually discharges to the Niagara River below the American Falls. The wastewater sewer system is shown as an isometric projection in

Figure 10 and at full scale in Appendix III as based on data from Hooker (1980a).

A comprehensive study of the wastewater sewer flow rates and chemical loadings was conducted by Conestoga-Rovers and Assoc. (referenced as Hooker 1980a and b) and Arthur D. Little (1980a) in order to identify the source of contaminants detected at the wastewater outfalls. The unidentified flows identified in these studies are discussed in this section of the report in conjunction with site hydrogeology while the unidentified loadings are discussed in Section 4.2.

Measurement of mainline sewer flows and stub flows by Conestoga-Rovers and Assoc. (Hooker, 1980a) found that approximately 7% of the combined outfall flow was not accounted for by known discharges to the sewer system. The unidentified flow is attributed to either ground water infiltration or unidentified sewer connections (stub flows). The unidentified flow was calculated over each particular sewer leg for which data were available in Hooker (1980a) in order to delineate areas of inflow or outflow along the sewer. Data on unidentified flow for June and July 1980 were available (Hooker, 1980a) and are presented in Figures 11 and 12 (positive values are infiltration and negative values are exfiltration). Considerable variation is seen in the magnitude and direction of the unidentified flows. However, some inferences may be drawn from the data. Outfall 001 sewer system appears to be accepting moderate amounts (0.37 cfs) of infiltration which is an average infiltration received over the entire outfall system. No data were presented for the Outfall 002 sewers in Hooker (1980a). Infiltration seems to dominate in the northern portion of the sewer system which discharges at Outfall 003 while exfiltration clearly dominates in the southern portion. No clear pattern is present for sewers discharging at Outfalls 004 or 005. Unidentified flows for the Outfall 005 sewer system are very large on a relative scale suggesting that major sources and sinks of sewer water exist in this area. Little change is noted between the months of June and July 1980 except between manholes 5-29 and 5-17, where relatively large changes were observed. The reason for these large variations is unknown.

The sewer systems' effect on the ground water regime was re-examined in part by attempting correlation with the geology. An isometric projection of the sewer system can be overlain on the isometric projection (fence diagram) of the HNP site stratigraphy. (These drawings are presented in large scale in Appendix III and at reduced scale in Figures 3 and 10 for the stratigraphic and sewer projections respectively. Overlays of the sewer system at large scale size are available in Appendix V.) Virtually all the wastewater sewers are located below the water table. The wastewater sewers in the upper reaches of the Outfall 001 system are located within the more permeable upper silt and fill zones. This is also true of the northern portion of the Outfall 003 sewer system, the upper reaches of Outfall 004 and extreme upper reaches of Outfall 005. As the sewers progress to the south they are more deeply incised into the underlying clay and till. Higher rates of ground water flow are possible in the upper more permeable stratigraphic zones, possibly correlating with the moderate infiltration rates contributing to the Outfalls 001 and 003 north wastewater sewers.

Some correlation may also be drawn between the overburden water table contours and the unidentified flows. Although these drawings consist of data for different time periods, some observed anomalies may be useful in explaining the unidentified flows. For instance, ground water levels fluctuate along Buffalo Avenue between Iroquois Street and 47th Street, corresponding to large inflows and outflows to the sewer in this location. Also the ground water low at monitoring well 95 (see Figure 2 for well numbers and location) occurs at the same location as a relatively large inflow to the sewers suggesting that infiltration is perhaps occurring here. However, it is clear in Figure 8 and to a lesser extent in Figure 7 that a ground water high exists in the vicinity of Outfall 003 north wastewater sewer, an area which has been inferred to have moderate wastewater sewer infiltration rates. If inflow is to be attributed to infiltration in this area, then it is apparent that some significant source of ground water exists in this area. A similar case exists for Outfall 001 where ground water levels are somewhat higher than the surrounding area, yet inflow to the sewer was calculated.

The apparent ground water highs in Outfall 003 north and in the upper reaches of Outfall 001 can likely be partially attributed to leakage of watermains (Figure 13) identified in Hooker (1981). Leakages from watermains were measured between 1 and 15 gpm (0.002 and 0.033 cfs) (Hooker, 1981) and form a relatively consistent contribution to ground water recharge in the HNP area.

Additional anomalies in the water table, such as the water table low along Buffalo Avenue between 47th and 53rd Streets, are possibly attributable to sewer infiltration. Sanitary sewers are also present at the HNP and may be impacting the ground water system.

3.2 Lockport Dolomite

The Lockport Dolomite bedrock hydrogeologic system under discussion in this section is essentially that which exists in the upper 10 to 15 feet of the bedrock. Specific mention is made when this is not the case. Hydraulic conductivity data and estimates for various portions of the Lockport Dolomite are listed in Table 3.

Ground water levels in the upper Lockport beneath the HNP site are controlled by recharge from the Niagara River. Piezometric levels in the Lockport in the vicinity of the plant site are generally lower than the water levels in the river or the overburden, resulting in flow into the bedrock from both the overburden and the river. Piezometric levels in the upper Lockport range from 562 feet (Hooker Datum)* along the river to approximately 550 feet along the NYCRR tracks (Figures 14 and 15). The Niagara River is maintained at a long term average level of 561.65 feet (Hooker Datum) in the Grassy Island pond slightly downstream of S-Area (D. Manion, Ontario Hydro, personal communication, 1982) and at 561.85 feet (Hooker Datum) at the PASNY intakes (J. Fitzgerald, PASNY, personal communication, 1982). This river level variation is restricted, by international agreement, to maximum daily fluctuations of 1.5 feet.

There is a reasonably good hydraulic connection between the Niagara River and the Lockport Dolomite at the HNP site. River bottom sediments and/or native deposits were noted in the range of 3.0 to 3.5 feet in the river bed just south of Iroquois Street (PASNY, 1963). Further upstream along the Water Treatment Plant intake tunnel, river bottom sediments vary between 10 and 20 feet (City of Niagara Falls, 1980). (The Water Treatment Plant intake tunnel extends 5,125 feet to approximately the center of the Niagara River.) Reports by Leggette, Brashears and Graham (1979f) indicate that the response of wells in the upper Lockport along the river to

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*Several datums are in effect in the Niagara Falls area. (i.e. USLS, IGLD, Hooker). The datum used in this report is the Hooker datum, as most data available use this reference. The relationship between datums is provided in Appendix VI.

fluctuations in the level of the Niagara River is approximately 100% over a period of 1 to 1.5 hours. Piezometric levels measured in a well located deeper in the Lockport (SS-2, completion zone 24 to 39 ft below top of rock) responded with a water level change about one-third the change in the level of the Niagara River, suggesting that the lower sections of the Lockport are less well connected hydraulically to the Niagara River, although there is some degree of interconnectivity (the drillers log indicates that "grout from the shore shaft pilot hole appears to have partially plugged the fracture").

Piezometric contour drawings (Figures 14 and 15) for the upper Lockport Dolomite (10 to 15 feet) have been prepared using available data for periods corresponding to periods of low and high ground water levels (GTC 1982b). The data used are from the study conducted between October 1979 and August 1981 (Conestoga-Rovers and Associates, 1981a). The river levels are from Ontario Hydro (1982) records. The figures show that although absolute water levels in the upper Lockport changed on different dates, virtually the same ground water flow patterns in the HNP site vicinity are observed. It should be noted that the piezometric contours (as well as chemical data) are prepared using some wells or piezometers which straddle the lower overburden and upper Lockport Dolomite (Table 4). These data are assumed to be applicable to the upper Lockport.

The ground water flow patterns for the upper Lockport indicate that, in the vicinity of the HNP site, water flows from the Niagara River into the bedrock in a north-northwesterly direction. The PASNY conduit intake structure has a considerable effect on the ground water flow pattern. There is a grout curtain (indicated on Figures 14 and 15) completely surrounding the intakes which extends approximately 90 feet into the Lockport Dolomite (to elevation 454.7, Hooker datum (PASNY, 1963)). Although not shown on these Figures, the grout curtain extends into the river and parallels the shoreline at a distance of about 630 feet from shore. The portion of the grout curtain which is located along the river shoreline appears to substantially restrict south-north water flow from the Niagara River across the intake structure area. Since the grout curtain restricts south-north flow from the river into the Lockport Dolomite, most of the ground water moving in an east-west direction near the intake structure has entered in the upstream river reaches.

The Niagara River Gorge to the west has a strong influence on the general bedrock ground water flow directions throughout the Niagara Falls area see Appendix IV. The majority of ground water flow beneath the City of Niagara Falls has been interpreted as being directed towards the gorge (Johnston, 1964). However, the external drain system of the PASNY conduits must also be an important factor in the area to the immediate west of Iroquois Street. The drain system extends to an elevation of 488 ft, which represents approximately one-third the thickness of the Lockport Dolomite. The hydraulic heads in the lower bedding plane joints are substantially lower than those in the upper portions of the Lockport (Johnston, 1964).

Given these circumstances, there is the strong likelihood that a good vertical hydraulic connection exists at the PASNY conduits over at least the upper 50 feet of the Lockport, with vertical ground water movement occurring from the upper to the lower zones.

The open drain system also allows lateral continuity across the conduits, although water must follow a circuitous path within the drainage system to cross the sealed conduits. The drain system slopes north to the open canal near the reservoir, and water can also move in that direction with relative ease.

From the available information it is uncertain whether the effect of the heavy industrial pumping at the Olin plant (about one mile downstream of S-Area) is noticeable on the upper Lockport Dolomite piezometric levels. The bedrock is apparently in relatively direct contact with the River at the pumping site, therefore the extent of the pumping influence in the bedrock may be quite limited.

4.0 OVERBURDEN CONTAMINATION

4.1 Contamination Levels in Overburden Monitoring Wells

Several ground water quality monitoring programs have been conducted to date at the Hooker Niagara Falls Plant site which characterize the contaminant distribution in the overburden ground water regime (Arthur D. Little, 1980a, 1981a). Various parameters have been measured at different times, with the result that more extensive data exists for some constituents than for others. The constituents measured most extensively are pH, chloride, conductivity, alkalinity, total organic carbon (TOC) and total organic halogens (TOH). The TOC, TOH, conductivity and chloride data are presented in Figures 16 to 19 and are tabulated in GTC (1982b). As noted in the report by Arthur D. Little (1981a), many of the wells had not chemically stabilized prior to the last sampling, i.e. there appeared to be significant cement contamination in at least 18 of the wells (Table 5) on the last date sampled. In addition, procedures and analytical methods varied between laboratories, and complete documentation (i.e. chain of custody documents and protocol) have not been assessed for the preparation of this report. The chemical data should, therefore, be considered to be extremely approximate, indicative only of general patterns.

Some studies were concerned with individual toxic organic chemicals within the overburden (Arthur D. Little, 1980a). The samples were analysed by six different laboratories: EPA, Hydroscience, Radian, New York State, Raltech and Hooker. The wells and piezometers sampled were limited in number and the constituents analysed were not consistent between samples. However, these data are presented for completeness in diagrammatic form as overlays in Appendix VII and in table and diagramatic form in GTC (1982b). The contaminants which were analyzed for in the overburden wells* consisted primarily of the 11 contaminants identified in the wastewater sewer outfalls which comprise 94% of the loading to the Niagara River (Hooker, 1980b). These include trichloroethylene, tetrachloroethylene, toluene, chlorobenzotrifluorides, monochlorobenzene, dichlorobenzenes, chlorotoluenes, dichlorotoluenes, trichlorobenzenes, tetrachlorobenzenes and hexachlorocyclopentadiene. The resulting concentrations and number of samples on which these are based are given in GTC (1982b).

The data used to develop the ground water contamination figures are selected from the aforementioned studies using the following procedure:

- Samples with reported sampling dates prior to well installation are not utilized
- Samples taken within approximately 3 to 4 weeks of well installation are not utilized
- Averages of the remaining samples are taken where several values exist
- Single values are used where there are not several samples
- It is assumed that samples from wells SP8 and SP8A dated 1978 are actually 1979 (i.e. typographical or labelling error)

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*Some installations have a shallow and a deep piezometer installed in the overburden. In the immediate S-Area vicinity average concentrations for the shallow and deep overburden piezometers are taken to be representative of the overburden because the overall fill is relatively permeable (CW1A and 1B; CW6A and 6B; CW14A and 14B). At well 40 the shallowest piezometer (40A) is utilized as it is located in the silt layer as are other wells in the surrounding area. Well 40B is located in the till zone at a depth of 15 to 20 feet.

In considering the parameters TOH, TOC, conductivity and chloride, several areas of ground water contamination including S-Area (see GTC 1982b) become evident. TOH concentrations (Figure 16) in monitoring wells show significant areas of overburden ground water contamination at F-Area, D-Area and S-Area and to a lesser extent at U-Area and N-Area. TOC concentrations also show significant contamination generally in the D-Area vicinity and somewhat lower concentrations distributed around the southeast portion of U-Area. Chloride and conductivity measurements show little elevation outside S-Area with the exception of above-background conductivity in H-Area and southeast U-Area.

Evaluation of the concentration data for the 11 organic contaminants cited previously suggest that, although each contaminant has a unique distribution in the overburden ground water regime at the HNP site, the four corners of the HNP site (S-Area, U-Area, F-Area and C-D Areas) show localized high concentrations for the majority of the contaminants. Table 6 has been compiled to illustrate the presence of high concentrations of individual contaminants in the shallow ground water system by plant area designation. (The reader is referred to Appendix VII for absolute concentrations.) In studying this table in conjunction with data in Appendix VII, the following summary is possible.

- Significant concentrations of 8 or more of the 11 contaminants are measured in the ground water at D-area

- Significant concentrations of 4 to 7 of the 11 contaminants are measured in the ground water at B, F-east, G-south, and U-south areas

- Significant concentrations of 1 to 3 of the 11 contaminants are measured in the ground water at F, H, M, W and N-south areas

4.2 Unidentified Loading in Wastewater Sewers

Volumetric flows and mass loadings to the wastewater sewer system were measured both within the mainline sewers and the individual connections (stubs) from various plant processes. This study was conducted by Conestoga-Rovers and Associates (referenced as Hooker, 1980a) and Arthur D. Little (1980a). The chemical data were collected over a period of several months commencing in May 1980 and terminating in August 1980. Mainline sewer samples were collected on different dates from stub flow samples and volumetric flow rates were also measured at a different time. Mass loadings were calculated using concentrations and flows from all of these sampling and measurement times.

To evaluate the unidentified loading component to the wastewater sewers, the incremental change in loading was calculated across each sewer leg for which data was available. The following equation was used within each sewer section:

$$\text{UNIDENTIFIED LOADING} = \text{OUTFLOW} - \text{INFLOW} - \Sigma \text{ STUB FLOWS}$$

The source of data used for these calculations was Arthur D. Little (1980a) which tabulates the results of all loading and flow measurements made during the four month study period. The incremental loadings are presented in Figures 20 to 30 for the same 11 organic contaminants measured in the overburden wells. In these figures, a positive value indicates increased loading to the sewer and a negative value indicates decreased loading. Discrepancies were found between the relative directions (i.e. infiltration or exfiltration) of unidentified loading and unidentified flow. For instance, some zones of increased loading, which suggest infiltration of contaminated ground water, show a decrease in flow rate, suggesting exfiltration.

The relative directions are indicated in the figures. The discrepancies can be partially attributed to sampling and measuring over a relatively long time period, as concentrations and flow rates likely vary on a temporal basis. The relative inaccuracies associated with both sewer flow rate measurements and/or organic chemical analyses could not be quantitatively incorporated into the assessment. Consequently, Figures 20 to 30 should be regarded as indicative of general patterns only. The discrepancies also suggest that the data collected to date are not completely consistent, either within a single data set (eg. flow rates) or between data sets (eg. chemical loading and flow rates).

Plant areas with apparently high influxes of contaminants into the wastewater sewers are listed in Table 7. Unidentified influxes are identified as "apparent" due to the discrepancies between directions of incremental loading and flow. From Table 7 and Figures 20 to 30 the following can be qualitatively derived

- Significant amounts of 8 to 11 of the 11 contaminants measured appear to be infiltrating in D and U-south areas.

- Significant amounts of 4 to 7 of the 11 contaminants measured appear to be infiltrating in B, M, W, G-south, N-south, U-north and V-east areas.

- Significant amounts of 1 to 3 of the 11 contaminants measured appear to be infiltrating at C,F,H,J,T,V, F-east and U-west areas.

These areas of unidentified loading agree fairly well with the areas of high chemical concentrations in the ground water identified in the previous section.

The incremental sewer loadings (Figures 20 to 30) can also be correlated with the overburden ground water concentrations by overlaying the ground water concentrations on the incremental loading figures (overlays available in Appendix VII). (Note: sewer loadings are in units of lbs/day while ground water concentrations are in µg/L).

Some correlation may also be drawn between areas of the sewer undergoing infiltration (Section 3.1.1) and areas of significant "apparent" unidentified influx. Infiltration was identified as contributing to Outfall 001 (U-Area) and Outfall 003-north (D-Area, M-Area and W-Area) sewer systems of which D-Area and U-Area south have significant unidentified mass loadings of most of the contaminants measured while M-Area and W-Area have significant levels of influx for only some of the contaminants. Sewers at all 4 of these plant areas are situated for the most part within the more permeable silt and fill layers. The large but highly variable infiltrations and exfiltrations along Buffalo Avenue contributing to Outfall 005 are in the same area of highly variable positive and negative chemical loadings, although there does not appear to be a direct correlation.

In summary it is apparent that, although there is some inconsistency within and between data sets, infiltration of contaminated ground water into the wastewater sewer contributes significantly to the organic chemical loading of the Niagara River. The wastewater sewers at the HNP site discharged to the Niagara River an average load of 154.5 lbs/day during 1979 (Hooker, 1981). Hooker (1979) estimates that 74% of the loading is due to infiltration of contaminated ground water (or unidentified sewer stub flow).

5.0 BEDROCK CONTAMINATION

Contaminant monitoring programs have been conducted within the upper 10 to 15 feet of the Lockport Dolomite bedrock, the uppermost bedrock unit below the Niagara Plant. (Some monitoring wells are located across the interface between the Lockport and the overlying till (see Table 4)). The bedrock monitoring programs consist of less extensive specific monitoring data than were obtained in the overburden monitoring wells and include measurements of total organic halogens(TOH), total organic carbon (TOC), chlorides, conductivity, pH and alkalinity (Arthur D. Little, 1981a). As noted previously, some of these wells appeared to exhibit significant cement contamination on the last date sampled. These wells are listed in Table 5. The only specific organic chemical concentrations available for the bedrock wells consist of measurements at the S-Area disposal site which are discussed in detail in GTC (1982b).

Contour diagrams have been prepared (GTC, 1982b) for measurements of TOH, TOC, chlorides and conductivity (Figures 31 to 34) based on linear interpolation techniques. Limited subjectivity was invoked where necessary to facilitate contour construction. The data used in developing these figures were subjected to the same criteria utilized for data selection as outlined in Section 4.1.

It is apparent from Figure 31 that relatively high concentrations of halogenated organics are present in the upper Lockport ground water below U-Area south of Adams Avenue. High TOH concentrations were detected in wells 5, 6 and 7 while moderate concentrations were detected at surrounding wells. U-Area is a former production area for trichloroethylene and was also used for dewatering of sludges at the ground surface (Hooker, 1979). Presently, a residue reactor located in U-Area incinerates organic wastes from plant processes. Relatively high TOH concentrations were also detected below F-Area, N-Area, S-Area and between C-Area and J-Area.

High TOC concentrations (Figure 32) were measured beneath N-Area (well 10) and relatively high concentrations were present at U-Area (well 6) and H-Area (well 40). Conductivity and chloride measurements also indicate areas of contamination in the southern portions of U-Area and in N-Area (Figures 33 and 34).

Generally high contamination levels below N-Area and U-Area south are attributed to a combination of the thin till and clay (Figure 4) over the bedrock and the effect of the grout curtain, installed during construction of the PASNY power conduit intakes (Figures 7 and 8). The stratigraphy to the south of U-Area and N-Area can be readily visualized using the full-size isometric projection in Appendix III. The stratigraphy consists of a thin layer of till overlain by permeable rock fill. The overburden and bedrock water levels (Figures 7 and 8; 14 and 15, respectively) are essentially the same south of U-Area, suggesting a relatively good hydraulic connection.

The grout curtain installed by PASNY (1963) to prevent ground water infiltration to the conduit excavations appears to have remained partially effective. This is evident in Figures 14 and 15. Normally, river water from the Niagara River recharges the upper bedrock in the stretch of river upstream of the falls (Johnston, 1964). Such is the case in the vicinity of S-Area (Figures 14 and 15) where flow directions (perpendicular to the potentiometric contours) are directed away from the river to the north/northwest. However, the grout curtain, paralleling the Niagara River shoreline south of U-Area and a portion of N-Area, appears to cut off river water recharge as indicated by the water levels which are significantly below river level, and the flow direction which is parallel to the shoreline (Figures 14 and 15).

Inflow of river water to the upper Lockport is substantiated by conductivity data for the wells in the upper Lockport. Three (Figure 33) of the 4 wells nearest the Niagara River reflect the inflow of water from the river into the bedrock (Niagara River conductivity is approximately 0.2 mmho/cm; Ontario Ministry of Environment, 1968-1982 Niagara River records). The exception is well SP-8, which shows a conductivity of 1.5 mmho/cm as well as TOH concentration of 17,000 ug/L. It is possible that this reflects an interconnection between the overburden and bedrock provided by the drilled borehole ("black, oily" liquid was encountered through the lower overburden portion of the hole; Leggette, Brashears and Graham, 1980a). This may also be the case in other bedrock installations, although those in S-Area have the "oily" liquid notation in the overburden portion of the holes more frequently than others (i.e. no oily liquid was noted in boreholes 5, 6, 7 or 8, although chemical odors are indicated).

As a consequence of the grout curtain, contaminated ground water migrating towards the Niagara River in the overburden through U-Area and N-Area sites flows readily downwards through the highly permeable fill and thin till covering, entering the upper bedrock aquifer. The migration pathway from this point onwards is uncertain. It is likely, however, that the miscible contaminants in the bedrock beneath U-Area and N-Area are advected with the ground water flow to the north/northwest.

On a larger scale, the transport of ground water and concomitantly dissolved contaminants in the bedrock, is generally in a north-northwest direction, towards the PASNY conduits and the Niagara Gorge. The drainage system around the conduits provides for good vertical hydraulic connection between the upper Lockport and the deeper bedding joints. As discussed in Appendix II, the base of the conduits' excavation at the intakes is within 75 feet of the base of the Lockport Dolomite, and at Royal Avenue, (approximately 1 mile north of the intakes) where drainage pump station A is located, the base of the excavation extends to within about 40 feet of the base of the Lockport. Most of the contaminants migrating off the HNP site in the upper Lockport ground water system will be intercepted by the drainage system around the PASNY conduits. This drainage system will allow vertical communication throughout the greater portion of the Lockport Dolomite. The route that contaminants will take after reaching the conduit drainage system is uncertain. Gate valves in pump station B at the Northern end of the conduits (Figure 1) maintain the hydraulic head in the northern sections of the drainage system at elevation 550.65 ft (Hooker Datum) or less, while similar valves at Royal Avenue maintain the head 10 feet higher, at 560.65 ft or less. However, the head control in the drainage system may be supplemented by the natural vertical variation in hydraulic head within the Lockport Dolomite. The conduits' drainage system allows good vertical connection, and the lower water bearing bedding joints are believed to have substantially lower hydraulic head than the upper Lockport. In fact, during drilling, Johnston (1964) found that often, once the lower zones were penetrated by drilling, they drained the upper zones. Some portion of the water in the drainage system will undoubtedly enter these lower water bearing zones.

The PASNY conduit drainage system raises several points with regard to bedrock contamination and potential contaminant transport to the Niagara River:

- In the HNP vicinity, approximately the upper 1/2 of the Lockport Dolomite may be accessed by contaminated water (or even the upper 2/3 if pump station A at Royal Avenue is considered);

- The full thickness of the Lockport is breached by the drainage system in the northern section of the conduits, as well as the open canal leading from the power reservoir to the gorge;

- Pump station A may represent a fairly good bedrock ground water sampling station (if pumped) and, in conjunction with the drainage system, may also represent a relatively effective interceptor capability for contaminated ground water;

- Contaminated water collected in the drainage system may migrate northerly along the conduits to emerge at the reservoir canal or, depending on the relative gradients, westerly to the gorge by migrating around the conduits through the drainage system and out bedding joints on the west side of the conduits.

The drainage system around the PASNY conduits can be regarded, in any case, as a major factor in the assessment of the bedrock ground water flow system and potential contaminant transport pathways.

6.0 EVALUATION OF PROPOSED REMEDIAL MEASURES

6.1 Proposed Remedial Measures

A comprehensive plan for remedial action at the HNP site is presented in Hooker (1981). The scope of Hooker's report covers remedial actions for the entire plant site with the exception of the S-Area remedial program. The S-Area remedial program will involve identification of the extent and nature of the remedial work required at S-Area as well as in the bedrock beneath the entire HNP site (Hooker, 1981).

The remedial program proposed in Hooker (1981) is multifaceted - addressing many aspects of contamination at the HNP site. The Hooker (1981) report should be consulted for a detailed discussion of the proposed remedial program. A summary of the program is presented below:

- The remedial programs proposed fall under several different categories as follows:

  1. Process Improvements;
  2. Best Management Practices;
  3. Outfall Chlorocarbon Loading Reductions.

- Process improvements incorporate consolidation of off-gas scrubbing operations in the N-Area which will result in a reduction in flow of 0.086 MGD to the S-Area lagoons and implementation of BAT for fluoride removal resulting in a reduction in fluoride concentration in lagoon effluent (Hooker, 1981).

- Best management practices include remedial work addressing 9 main topics listed in Hooker (1981) as follows:

  1. Reduce watermain exfiltration;
  2. Close and plug abandoned sewer laterals;

3. Annually inspect existing wastewater sewer catchbasin sumps to determine the need for cleaning;
4. Eliminate identified floor drain and sump pump connections from the Outfall sewer system.
5. Spill control program;
6. Niagara Plant demolition work;
7. Niagara Plant paving;
8. Training Program;
9. Visual Improvement Plan (VIP).

- Practices 1 and 4 are expected to reduce the halogenated organic chemical loading by 8 lbs/day (Hooker, 1981).

- The planned outfall chlorocarbon loading reductions (from Hooker, 1981) for all 3 remedial action categories are presented in Table 8. It should be noted that calculation of reductions in loadings from the assumptions and data presented in this table suggest that a 51% loading reduction (75 lbs/day) for the outfalls will result from implementation of the proposed remedial measures. The estimated outfall loading (66.8 lbs/day) (Table 8) resulting from implementation of the proposed remedial measures is believed to be representative based on data provided. The remedial measures are summarized below and given in diagramatic form in Figure 35.

1. "Divert Outfall 001 flows to Outfall 005, collect and treat groundwater from the U-Area south of Adams Ave., pave U-Area south with controlled storm runoff discharge to Outfall 001 and existing catchbasins adjacent to the Robert Moses Parkway, and reduce watermain exfiltration.".

2. "Close Outfall 002, divert approximately 1.5 gpm existing outfall flows to the sanitary sewer via the API separator. Separate cooling water and condensate

flow for direct discharge to Outfall 003 and divert storm runoff to existing catchbasins adjacent to the Robert Moses Parkway."

3. "Reroute sedimentation - clarification lagoon discharge in S-Area from Outfall 003 to the V-Area sanitary sewer."

4. "Divert Outfall 005-East flows around the F-Area to the K-28 pump station at Iroquois Street, collect and treat groundwater from the F-Area, pave the F-Area, direct storm runoff to Outfall 005 and reduce watermain exfiltration."

- Excavated soil resulting from implementation of the proposed remedial measures will be disposed of beneath a cap where capping is proposed or in the S-Area landfill.

- No remedial measures are planned for D-Area, V-64, and W-107 (Hooker, 1981). Plant area V-80 will be included in the S-Area remedial program. Remedial actions are planned for F-Area, N-Area and U-Area with further study suggested for U-Area and V-56.

- The flow rates estimated for the leachate collection system (Figure 35) are 3500 gpm for Outfall 001 and 5500 gpm for Outfall 005 based on "stabilized groundwater flow regime conditions" (Hooker, 1981). The leachate will be treated in an on-site activated carbon treatment plant and the effluent discharged to the city sanitary sewer system.

- Sanitary sewer discharges (Figure 35) will consist of average discharges of (Hooker, 1981):

    1. 0.10 MGD (0.85 MGD maximum) from N-Area wastewater sewers

2. 0.41 MGD (0.45 MGD maximum) from S-Area lagoon discharge

3. 0.01 MGD (0.02 MGD maximum) from treated ground water collected in 005-west and 001-south tile drain systems.

6.2 Evaluation of Proposed Remedial Measures

Implementation of proposed remedial measures will significantly reduce contaminant loading to the Niagara River from a number of contaminated areas. For instance, the construction of a tile drain collection system in F-Area, in conjunction with the use of the former wastewater sewer along Buffalo Avenue (contributing to Outfall 005) (Figure 35) will serve to intercept contaminated ground water flow from the north which originated in F-Area and part of G-Area and A-Area. The wastewater sewer in this area is known to display fairly good hydraulic connection with the overburden ground water regime. The question which arises regarding this leachate collection scheme is the effectiveness of the old wastewater sewer system as a collection system. Infiltration occurs only at highly localized areas of leaky sewer pipe connections or other breaches. However, the hydraulic gradient imposed by pumping will likely be transmitted along the utility trench in which the sewer pipe is located, effectively intercepting ground water flow from the north.

The effectiveness of intercepting ground water from the north in the U-Area south leachate collection system is likely similar to that of the 005 system. However, the extent to which contaminants and ground water will be affected south of U-Area is questionable. The zone of influence from pumping the sewer and proposed tile drain is not known and it is likely that contaminants much to the south of the proposed leachate collection system will continue to migrate south and/or downward through the highly permeable fill material.

Abandonment of the Outfall 002 sewer system will reduce direct discharges to the Niagara River, but does not address the removal of contaminants from N-Area or the prevention of contaminant migration from the site. The water table contours shown in Figures 7 and 8 indicate ground water flow towards the river for the easterly half of N-Area. Therefore, without remedial actions in this region there will likely be contaminant migration along the sand unit beneath N-Area and into the adjacent fill material allowing direct discharge to the river.

Reduction in watermain exfiltration will reduce the chemical load to the sewer system contributing to Outfall 003 north (D-Area and M-Area) and 001 (U-Area) where water table mounding and infiltration were linked to watermain leakage.

Plant improvements programs, such as paving and spill control, will also affect loading rates. Paving will reduce the movement of contaminants downward to the water table by limiting the recharge of precipitation. However, it does not affect horizontal movement due to flow induced by up-gradient recharge.

6.3 Alternative Remedial Measures

Modifications to remedial measures proposed in Hooker (1981) include:

- Utilization of the proposed abandoned 002 Outfall system to intercept southward migration of contaminated ground water. This should be incorporated subsequent to a more detailed study of the contaminants present and their distribution at N-Area. Reported inventories for N-Area (Table 1) indicate possibly large quantities of organics. N-Area has also been identified as a disposal area for inorganic waste, as well as construction debris (Hooker, 1981). Analyses of water samples for inorganic constituents are recommended since these have not been reported in previous monitoring programs.

- Movement of the U-Area leachate collection system farther to the south to a position where the majority of contaminants, whose distribution should be determined from further ground water monitoring, can be more effectively collected. This may also involve moving the proposed collection system farther to the west and also extending the collection system farther to the east to intercept all southward movement of contaminants between Outfall 001 and 002 collection systems.

Alternate remedial measures and areas of concern include:

- Implementation of remedial measures at D-Area which was found to be contributing significant amounts of most organic contaminants measured to the sewer system. No remedial meaures have been proposed for this area to date which will eliminate loading to the Niagara River. Infiltration to the sewer system contributing to Outfall 003 will continue to occur although reductions in watermain leakage will somewhat reduce the differential gradients and the amount of ground water available.

- Remedial programs which deal with ground water contamination in the bedrock do not appear to exist. Contamination does exist in the bedrock and should be addressed, as a potential exists for widespread distribution of contaminants areally and vertically within the bedrock. Monitoring programs for both organic and inorganic contaminants should be initiated as no inorganic concentration data are available for these parameters. The plant areas (U and N) nearest the zone of bedrock contamination are both known to have been former disposal areas for inorganic chemicals including heavy metals at U-Area (Hooker, 1981).

7.0 CONCLUSIONS

Evaluation of previous studies and the proposed remedial measures for the Hooker Niagara Plant property have resulted in the following conclusions which are considered pertinent to Niagara River water quality. Specific evaluations and conclusions regarding S-Area are not included in this report (the reader is referred to GTC 1982b).

- Significant contaminant loading to the Niagara River occurs as a consequence of infiltration of contaminated ground water from the overburden hydrogeologic system to the HNP wastewater sewer system. The wastewater sewers are effectively acting as drains within the ground water system in many of the plant areas. The entire plant site appears characterized by elevated organic chemical concentrations (Total Organic Halogens, TOH) in the overburden ground water.

  Of a total chemical loading of 154.6 lbs/day from wastewater sewer discharge in 1979, approximately 74% has been attributed to infiltration of contaminated ground water to the wastewater sewer sytem (or due to unidentified sewer stubs from process areas) (Hooker, 1979a; Hooker, 1980b). The remainder is due to direct process water discharge to the wastewater sewers.

- Direct discharge of contaminated ground water to the Niagara River from the overburden occurs for approximately 1500 feet of shoreline from 53rd Street west. The chemical loading to the river is derived principally from S-Area and to a lesser extent from N-Area. The TOH loading to the river from direct ground water discharge is estimated at about 2 lbs/day, with 1.75 lbs/day derived from S-Area (GTC, 1982b). The chemical loading from direct ground water discharge to the Niagara River is about 1.75% of the chemical load to the river derived from infiltration of contaminated ground water into the wastewater sewers.

- Contaminants in the overburden ground water system are also transported downward into the upper Lockport Dolomite, although in most areas the till and clay which overlie the Lockport serve to restrict the rate of transport. Notwithstanding, significant contamination is present in the upper Lockport Dolomite beneath V-Area, N-Area, S-Area and F-Area. Although other areas possess bedrock wells with significant contamination, the data are insufficient to establish the full extent of contamination.

  Ground water flow in the upper Lockport Dolomite is generally in a north-northwest direction, away from the Niagara River. Some contaminated ground water from V-Area appears to enter the PASNY conduit drainage system in the vicinity of the intake structures. The remainder of the ground water flow in the bedrock which originates from the HNP site will likely be intercepted by the PASNY conduits' drainage system. The conduits' external drainage system also allows contaminated ground water in the upper Lockport Dolomite access to lower bedding joints and water bearing zones. In any case, the contaminated ground water in the Lockport Dolomite eventually discharges to the Niagara River, either directly to the Gorge after flowing around the conduits, or to the open canal at the north end of the conduits.

  Although quantitative estimates of the chemical loading to the river from the contaminated bedrock ground water are not possible, qualitatively it is likely of the same order of magnitude as the loading from the overburden ground water discharge. Flow paths in the bedrock and/or PASNY drainage system are uncertain, as are the potential dispersion and dilution processes.

- Proposed remedial measures in the overburden emphasize the reduction of loading to the Niagara River through reduction of infiltration to the wastewater sewers. Some collection and treatment of contaminated ground water were proposed, where significant infiltration to the existing wastewater sewers has been detected, by using the leaking sewers as drains and augmenting these in some instances. Planned remedial measures are estimated by Hooker (1981) to reduce the wastewater sewers loading to the Niagara River by 74.2% or 114.6 lbs/day. However, based on the assumptions and data provided in Hooker (1981), calculations indicate that the loading will be reduced by 51% or 74.8 lbs/day. The remaining loading to the Niagara River after implementation of the remedial meaures and best management practices is reported to be 67 lbs/day (Hooker, 1981). The collection and removal of contaminants is generally addressed at only localized areas, leaving many contaminated areas untouched. The potential remains for migration in the ground water system and/or infiltration to other sewers within or external to the HNP boundaries.

- No bedrock monitoring programs for organic and inorganic contaminants are known to be planned and remedial measures do not address the bedrock contamination.

- Sanitary sewers at the HNP site may be the source of unexplained anomalies in the water table at some locations and may transport infiltrating contaminants away from the HNP site. The impact of the sanitary sewers has not been addressed in this report.

- The sources of ground water contamination (other than S-Area) have not been addressed in the proposed remedial plans. Consequently, the extent and nature of continued contamination cannot be assessed.

8.0 RECOMMENDATIONS

The following recommendations are made for the purpose of assisting the ongoing studies and remediation assessments on the Hooker Niagara Plant property.

- The remedial measures proposed by Hooker (1981) should be implemented with emphasis on replacing or repairing all leaky sewers, reducing watermain exfiltration and intercepting, collecting and treating overburden ground water passing through the HNP site and flowing towards the Niagara River.

- The sources of ground water contamination within the HNP site should be directly addressed with alternative remedial measures derived to reduce the source loading where possible.

- The proposed abandoned wastewater sewer in Outfall 002 sewer system could be utilized as a collection drain to intercept contaminated ground water from the north. Further monitoring in the overburden is recommended in the adjacent N-Area vicinity to complete the data base and to define the organic and inorganic wastes present and their distribution.

- Further studies should be conducted at D-Area, for which data suggest the presence of high concentrations of many organics in the ground water, as well as significant infiltration to the wastewater sewers, yet no remedial measures are presently planned.

- Overburden monitoring in the corridor between the HNP site and the Niagara River should be increased to obtain a complete set of water level and contaminant concentration data for all monitoring wells for the purpose of establishing the southern limit to which remedial measures need be effective.

- Individual organic and inorganic contaminants including heavy metals should be monitored in the bedrock. No data presently exist for these parameters and such data would serve to define the extent of contamination which appears to originate principally in U-Area, N-Area and F-Area. This should include a monitoring effort to the south of the existing contamination zones to determine if down-dip migration of a high density fraction of contaminants is occurring (i.e. transport of non-aqueous phase organic liquids).

- Bedrock monitoring wells should be installed down-gradient of the HNP site, that is, to the northwest, to define the extent of contamination in the bedrock. This may also include monitoring of the water present in the exterior drain system of the PASNY conduits at the pump stations located at Royal Avenue and at the reservoir end of the conduits.

- Reduced discharge from the wastewater outfalls to the Niagara River is desirable since the sewer systems will likely continue to derive contaminants from the shallow ground water regime on the HNP property. On-site treatment of all water collected in the wastewater sewer system would be an alternative.

REFERENCES

American Falls International Board, 1974. Preservation and Enhancement of American Falls at Niagara. Final report to the International Joint Commission including Appendix C - Geology and Rock Mechanics.

Arthur D. Little, Inc., 1980a. Niagara Plant Comprehensive Water Management Study, Chemical Loadings and Groundwater Quality, Volume IV, September 19, 1980.

Arthur D. Little, Inc., 1981a. Niagara Plant/Water Treatment Plant, Survey Wells, Monitoring Parameter Data. Prepared for S-Area Settlement Discussions. April, 1981.

City of Niagara Falls, 1980. New York, Water Treatment Plant, Investigatory Team, Summary Report. May 7, 1980.

Conestoga-Rovers and Assoc. Ltd., 1980a-b. See Hooker (1980a-b)

Conestoga-Rovers and Assoc. Ltd, 1980c. Hydraulic Containment, Hyde Park, February, 1980.

Conestoga-Rovers and Assoc. Ltd., 1981a. Monitoring Well Installation Details and Monitoring Well Water Elevations, Hooker Buffalo Avenue Plant and Drinking Water Treatment Plant. November 20, 1981.

Experimental Farms Service, 1935. Soil Survey Map of County of Welland, Province of Ontario.

Fitzgerald, J.E., 1982. PASNY, written correspondence with B. Whiffin, GTC. June 25, 1982.

Gartner Lee Assoc. Ltd., 1982. Hyde Park Landfill, Hydrogeological Review, Final Report, April, 1982.

GTC Geologic Testing Consultants Ltd., 1982a. Recommended drilling and borehole testing program for evaluation of the Rochester Shale near the Hyde Park Landfill. Report submitted to Ontario Ministry of Environment, July, 1982.

GTC Geologic Testing Consultants Ltd., 1982b. S-Area Hydrogeologic Evaluation, Final Report. Report to Niagara River Steering Committee, Ontario Ministry of the Environment, August 24, 1982

Hooker Chemical and Plastics Corporation, 1978. Correspondence between J.A. Cull, Program Manager, Special Environmental Situations, Hooker Chemical and Plastics Corporation (HCPC) and John Iannotti, Interagency Task Force, in Hooker Chemical and Plastics Corporation, 1979a.

Hooker Chemical and Plastics Corporation, 1979a. Chlorocarbon Source Investigation Program, Niagara Plant, Hooker Specialty Chemicals Division, March, 1979.

Hooker Chemicals and Plastics Corporation (HCPC, Hooker), 1980a. Volume II - Field Investigation, Report on Wastewater Outfall Sewers, Niagara Plant Comprehensive Water Management Study, compiled by Conestoga-Rovers and Assoc., September 22, 1980.

Hooker Chemicals and Plastics Corporation (HCPC, Hooker), 1980b. Volume I - Executive Summary, Report on Wastewater Outfall Sewers, Niagara Plant Comprehensive Water Management Study, compiled by Conestoga-Rovers and Assoc., September 22, 1980.

Hooker Chemical and Plastics Corporation, 1981. Plan of Best Available Technology and Best Management Practice, Niagara Plant. SPDES No. 0003336. November 1981.

Johnston, R.H., 1964. Groundwater in the Niagara Falls Area, New York. State of New York, Conservation Dept., Water Resources Commission, Bulletin GW-53.

Leggette, Brashears & Graham, Inc. 1979a - f, 1980c - e. Progress Report (1 to 9) Shallow Groundwater Quality Investigation, Hooker Chemicals and Plastics Corporation, Niagara Falls, New York Plant.

Leggette, Brashears & Graham, Inc., 1980a. Hooker Chemical and Plastics Corp., Niagara Falls Plant, New York. Geologic Logs.

Manion, D., 1982. Ontario Hydro, telephone conversation with B. Whiffin, GTC. June 15, 1982.

Maslia, M.L. and R.H. Johnston, 1982, Simulation of Groundwater Flow in the Vicinity of Niagara Falls, New York, United States Geologic Survey, Open File Report 82-159.

Ontario Hydro, 1982. Niagara River Levels at Slater's Point, Ontario. January 1981 - June 1982.

Pietraszek, G., 1982. NYSDEC, telephone conversation with B. Whiffin, GTC. June 9, 1982.

Power Authority of the State of New York (PASNY), 1963a. Drawings showing PASNY Conduit and Intake Details and Geologic Information.

State of New York, 1982. Complaint filed in the Supreme Court of the State of New York by Department of Environmental Conservation against Hooker Chemicals and Plastics Corporation regarding chemical dumping and/or spilling at the Buffalo Avenue Plant.

TABLE 1. Inventory of Wastes Disposed at the Hooker Niagara Plant Site (after Hooker, 1978)

Waste Category	Physical State	Total Estimated Quantity - Tons	Container
D-Area (1930-1942)			
Miscellaneous acid chlorides other than benzoyl - includes acetyl, caprylyl, butyryl, nitro benzoyls	L,S	200	D,B
Thionyl chloride and miscellaneous sulfur/chlorine compounds (1930-1975)*	L,S	400	D,B
Miscellaneous chlorination - includes waxes, oils, naphthalenes, aniline	L,S	500	D,B
Benzoyl chlorides (1930-1975) and benzotrichlorides (1930-1967)	L,S	800	D,B
Liquid disulfides (LDS/LDSN/BDS) and chlorotoluenes (1930-1967)	L	800	D,B
Metal chlorides (1930-1967)	S	100	D
Benzyl chlorides - includes benzal chloride, benzyl alcohol, benzyl thiocyanate (1930-1967)	L,S	800	D,B
Sodium sulfides/sulfhydrates (1939-1975)	S	200	D
Miscellaneous - 10% of above		600	
		4,400	

GTC

Waste Category	Physical State	Total Estimated Quantity - Tons	Container
/-Area (1930-1975) (2 sites)			
Phosphorous and inorganic phosphorous derivatives other than sodium hypophosphite - includes chlorides, sulfides	L,S	200	D
		200	
?-Area (1930-1946)			
Dodecyl (Laurel, Lorol) mercaptans (DDM), chlorides and miscellaneous organic sulphur compounds (1940-1974)	L,S	100	D,B
Chlorobenzenes (1930-1974)	L,S	1,400	D,B
		1,500 **	
S- and N- Areas (1947-1975) (major dispoal use phased out about 1961)			
Organic phosphorous compounds - includes phosphites, phosphonates, acid phosphates, thiophosphates	L,S	200	D,B
Miscellaneous acid chlorides other than benzoyl - includes acetyl, caprylyl, butyryl, nitro benzoyls	L,S	400	D,B
Phenol Tars (from Durez)	L	800	B
Thionyl chloride and miscellaneous sulphur/chlorine compounds (1930-1975)	L	4,200	D

GTC

Waste Category	Physical State	Total Estimated Quantity - Tons	Container
HET acid, anhydride and HETRONS (1953-1975)	L,S	500	D,B
Miscellaneous chlorination - includes waxes, oils, naphthalenes, aniline	L,S	400	D,B
Dodecyl (Lauryl, Loröl) mercaptans (DDM), chlorides and miscellaneous organic sulphur compounds (1940-1975)	L,S	8,100	D
Trichlorophenol (TCP) (1949-1972)	L,S	200	D
Benzoyl chlorides (1968-1975) and benzotrichlorides (1930-1967)	L,S	3,300	D,B
Liquid disulfides (LDS/LDSN/BDS) and chlorotoluenes (1930-1967)	L,S	2,200	D,B
Metal chlorides (1930-1967)	S	900	D
Hexachlorocyclopentadiene (C-56) (1949-1975)	L,S	17,400	D,B
Chlorobenzenes (1930-1974)	L,S	18,900	D,B
Benzyl chlorides - includes benzal chlorides, benzyl alcohol, benzyl thiocyanate (1930-1967)	L,S	1,600	D
Thiodan (Endosulfan) (1958-1975)	L,S	700	D,B
Sodium sulfides/sulfhydrates (1939-1975)	S	4,200	D
Miscellaneous -10% of above		6,400	
		70,400	

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Waste Category	Physical State	Total Estimated Quantity - Tons	Container
<u>Residue Reactor or Incinerator* - Plant Area 3 (U-Area)</u>** (1961-1975)			
Benzotrichlorides (1968-1975)	L	9,300	B
HCl purification and chlorotoluenes (1967-1975)	L	25,200	B
HET acid, anhydride and HETRONS (1953-1975)	L	3,400	B
Benzoyl chlorides (1930-1975) and benzotrichlorides (1930-1967)	L	23,400	B
Hexachlorocyclopentadiene (C-56) (1949-1975)	L	28,100	B
Chlorobenzenes (1930-1974)	L	43,400	B
Thiodan (Endosulfan) (1958-1975)	L	23,100	B
Miscellaneous - 10% of above		15,600	
		171,500	

L - Liquid waste under normal conditions
S - Solid waste under normal conditions
L,S - Sludge or combination of liquid and solid wastes

B - Bulk shipment of residues
D - Drum shipment of residues
C - non-metal containers of residues

* Thionyl includes an estimated 300 tons which was incinerated in the boiler house area.
** Some of this material was excavated and moved to S- and N- areas.
*** Wastes delivered to the Residue Reactor were incinerated.

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TABLE 2. Historical Outfall Chemical Loadings to the Niagara River

Outfall	Total Average Loading (lbs/day) July 1978 - Dec. 1978*	1979**	1980***
001	16	40.3	39.86
002	34	20.43	11.73
003	22	48.78	51.79
004	8.3	4.23	4.63
005	77	40.74	151.21[1]
	157.3	154.48	259.22[1]

1 In December, 1980, the failure of a heat exchanger resulted in an increased loading to Outfall 005.

* Hooker (1979a)
** Hooker (1980b)
*** Hooker (1981)

Table 3. Hydraulic Conductivity Data for Bedrock

SOIL/ROCK TYPE	PERMEABILITY	ANISOTROPY Kx/Kz	LOCATION	COMMENTS	SOURCE
Lockport Dolomite	10^{-3} cm/s		PASNY conduits Niagara Falls, N.Y.	from measured seepage flows into conduit excavation	Calculated from transmissibilities and saturated thickness in "Groundwater in the Niagara Falls Area, N.Y." R.H. Johnston, 1964, pp. 33
	2.4×10^{-2} cm/s		Niagara Falls N.Y.	measured from well hydraulically connected to Niagara River at E.I. du Pont de Nemours & Co.	" " "
	3.7×10^{-4} cm/s		Niagara Falls N.Y.	measured from well located in lower 40 ft of formation	" " "
	5.1×10^{-3} cm/s (3.7×10^{-4} cm/s - 2.4×10^{-2} cm/s)		Niagara Falls N.Y.	average and range of values obtained by Johnston (1964)	" " "
	10^{-3} cm/s			upper 15 ft of formation. method of measurement unknown	"Hydraulic Containment, Hyde Park", Conestoga-povers and Assoc., 1980c p. 5
	5.3×10^{-4} - 7.1×10^{-4} cm/s	1000:1	Hyde Park	lower part of Lockport formation. Result of numerical model calibration.	"Simulation of Groundwater Flow in the Vicinity of Hyde Park Landfill, Niagara Falls, N.Y." R.H. Johnston & M.L. Maslia, 1982, pg 13

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SOIL/ROCK TYPE	PERMEABILITY	ANISOTROPY Kx/Kz	LOCATION	COMMENTS	SOURCE
	$1.7 \times 10^{-3} - 2.3 \times 10^{-3}$ cm/s	100:1	Hyde Park	upper part of the Lockport formation. Result of numerical model calibration	"Simulation of Ground-water Flow in the Vicinity Hyde Park Landfill, Niagara Falls, N.Y." R.H. Johnston M.L. Maslia, 1982 pg 13
Rochester Shale	7.1×10^{-6} cm/s	1000:1	Hyde Park	from numerical model calibration	" " "
					" " "
					" " "
					" " "
	3.4×10^{-5} cm/s		East of Welland Canal	average of 13 pressure packer tests by Gartner Lee near Welland Canal, Ont.	"Hyde Park Landfill, Hydrogeological Review Final Report" Grant Anderson, Gartner Lee Assoc. Ltd. 1982 pg 2, Appendix A
Irondequoit Limestone	1.1×10^{-4} cm/s 7.2×10^{-5} cm/s - 1.5×10^{-4} cm/s		East of Welland Canal	average of 2 pressure packer tests by Gartner Lee near Welland Canal, Ont.	"Hyde Park Landfill Hydrogeological Review, Final Report" Grant Anderso Gartner Lee & Assoc.,1982 pp 2-3, Appendix A

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TABLE 4. Bedrock Wells Screened Across the Upper Lockport Dolomite and the Lower Overburden

Well	Screened Interval (depth - ft)	Bedrock Depth (ft)
1	14-24	22.5
2	18-28	22.5
3	14.1-24.1	21.5
4	16-26	20.3
5	21-31	24.5
6	21-31	27.0
10	20.5-30.5	25.5
13	25-30	27
23	22-27	24
28	21.5-26.5	22.5
32	19-29	24.5
CW6	34-37	36
CW13	35.5-40.5	36

TABLE 5. Wells Exhibiting High pH (Apparent Cement Contamination) on Last Sampling

Well	pH
5A	11.7
6A	12.3
7	12
7A	12.1
8	10.9
8A	12
9A	12.7
10	10.7
10A	10.7
19	9.2
20	12
26	10.3
28	12.3
28A	10.3
30 (? Erratic)	12.2
40B	11.3
SP1A	11.3

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TABLE 6. Plant Areas (excluding S-Area) Exhibiting High Concentrations of Organic Contaminants in Overburden Wells

Contaminant	Plant Areas Exhibiting Significant Concentration
Trichloroethylene	D, U-south
Tetrachloroethylene	B, D, M, U-south
Toluene	B, D, F, U-south
Chlorobenzotrifluorides	D, N-south
Monochlorobenzene	B, D, F, H, W, F-east, G-south, U-south
Dichlorobenzene	B, D, F, F-east, G-south, U-south
Chlorotoluenes	B, D, F, N-south, U-south
Dichlorotoluenes	D
Trichlorobenzenes	D, H, F-east, G-south
Tetrachlorobenzenes	H, F-east, G-south, U-south
Hexachlorocyclopentadiene	D

TABLE 7. Plant Areas (excluding S-Area) Exhibiting "Apparent" Influx of Contaminants to Wastewater Sewers

Contaminant	Plant Areas Exhibiting "Apparent" Significant Influx of Contaminants
Trichloroethylene	B, C, D, M, W, N-south, U-south
Tetrachloroethylene	B, D, M, W, U-north, U-south, V-south, V-east
Toluene	C, D, T, G-south, U-north, U-south, U-west
Chlorobenzotrifluorides	B, C, D, F, H, M, V, W, G-south, N-south, U-north, U-south
Monochlorobenzene	H, T, U-south U-west
Dichlorobenzene	B, D, V, F-east, N-south, U-south, V-east
Chlorotoluenes	B, C, D, H, J, M, T, W, G-south, N-south U-south, U-west, V-east
Dichlorotoluenes	D, F, G-south, N-south, U-north, U-south
Trichlorobenzenes	B, D, M, W, G-south, U-north, U-south
Tetrachlorobenzenes	G-south, U-north, V-east (no data for Outfall 001)
Hexachlorocyclopentadiene	D, M, W, V-east

TABLE 8. Estimated Halogenated Organic Loading Reductions following Implementation of Proposed Remedial Measures (from Hooker, 1981)

Outfall	1980 Average Loading (lbs/day)	Estimated Loading Reduction (lbs/day)	Estimated Load Under Plan ** (lbs/day)
001	39.86	34.1	5.8
002	11.73	10.6	1.1
003	51.79	10.4	41.3
004	4.63	-	4.6
005	151.21*	129.3*	21.9
TOTAL	259.15*	184.4*	74.7
BMP's	-	7.9	7.9
TOTAL RECOMMENDED WORK PLAN	259.15*	192.3*	66.8

Note: *In December, 1980, the failure of a heat exchanger resulted in an increased loading to Outfall 005. In 1979, the loading for Outfall 005 was 40.7 lbs/day and the average total loading for all Outfalls was 154.5 lbs/day. Therefore assuming proportionate loading via the Outfalls in 1979 and 1980 the reduction in loading for the recommended work plan based on the 1979 average total loading is estimated to be 74.2% of 154.5 lbs/day or 114.6 lbs/day.

**It should be recognized that this is an estimated load based on calculations which might yield results plus or minus 20% from the final number.

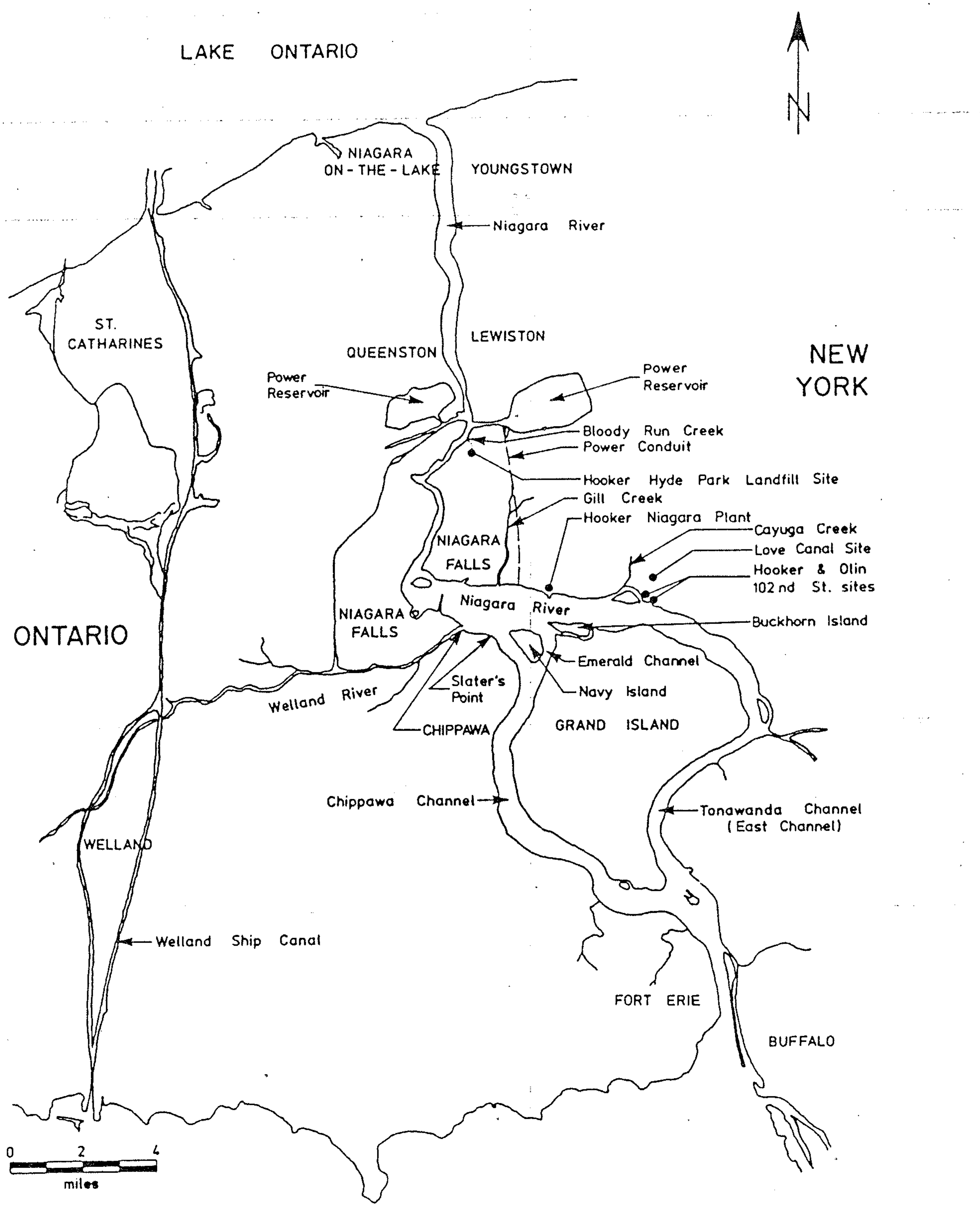

Figure 1. Plan of Niagara Falls and surrounding area

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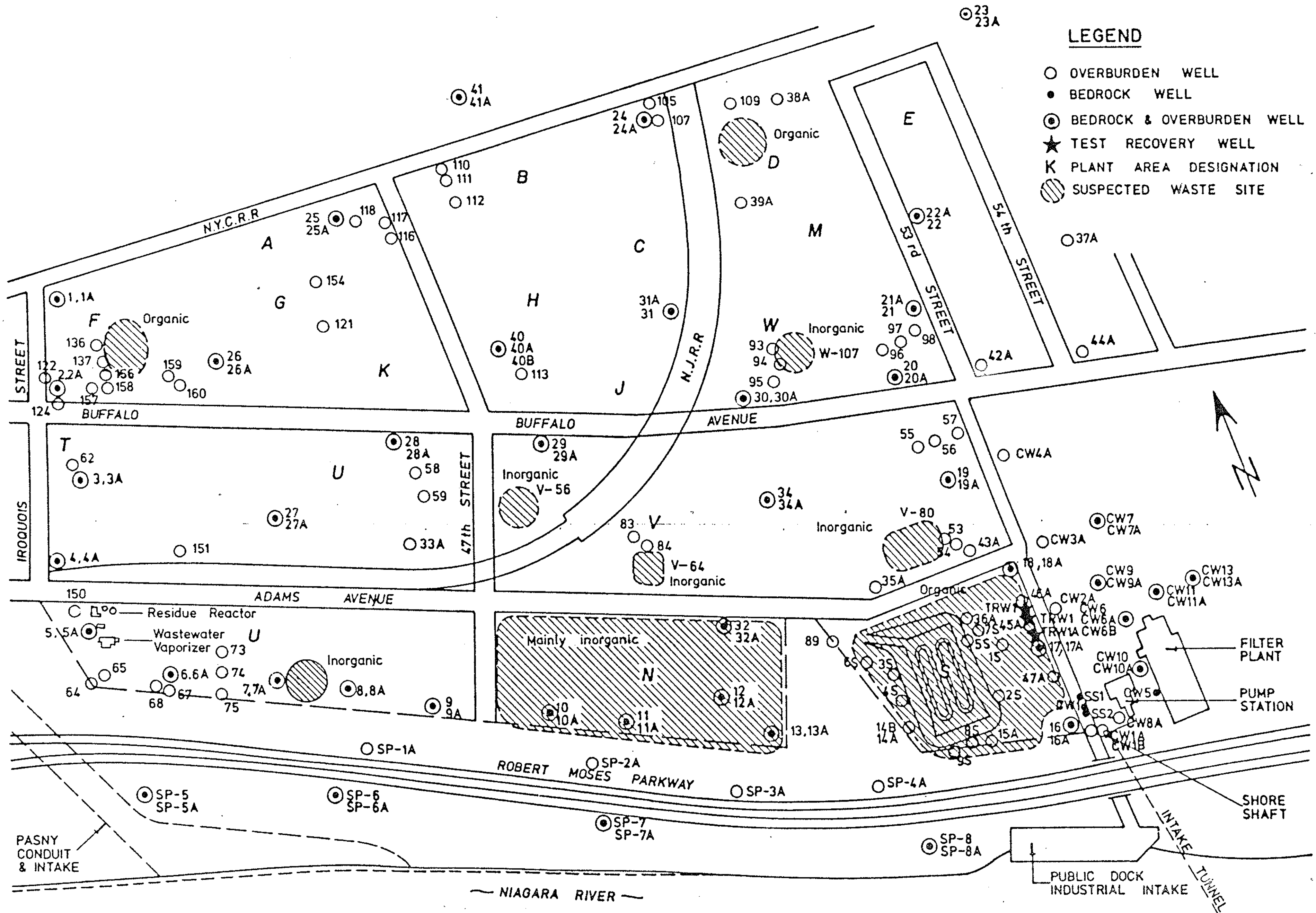

Figure 2. Plan of Hooker Niagara Plant Site

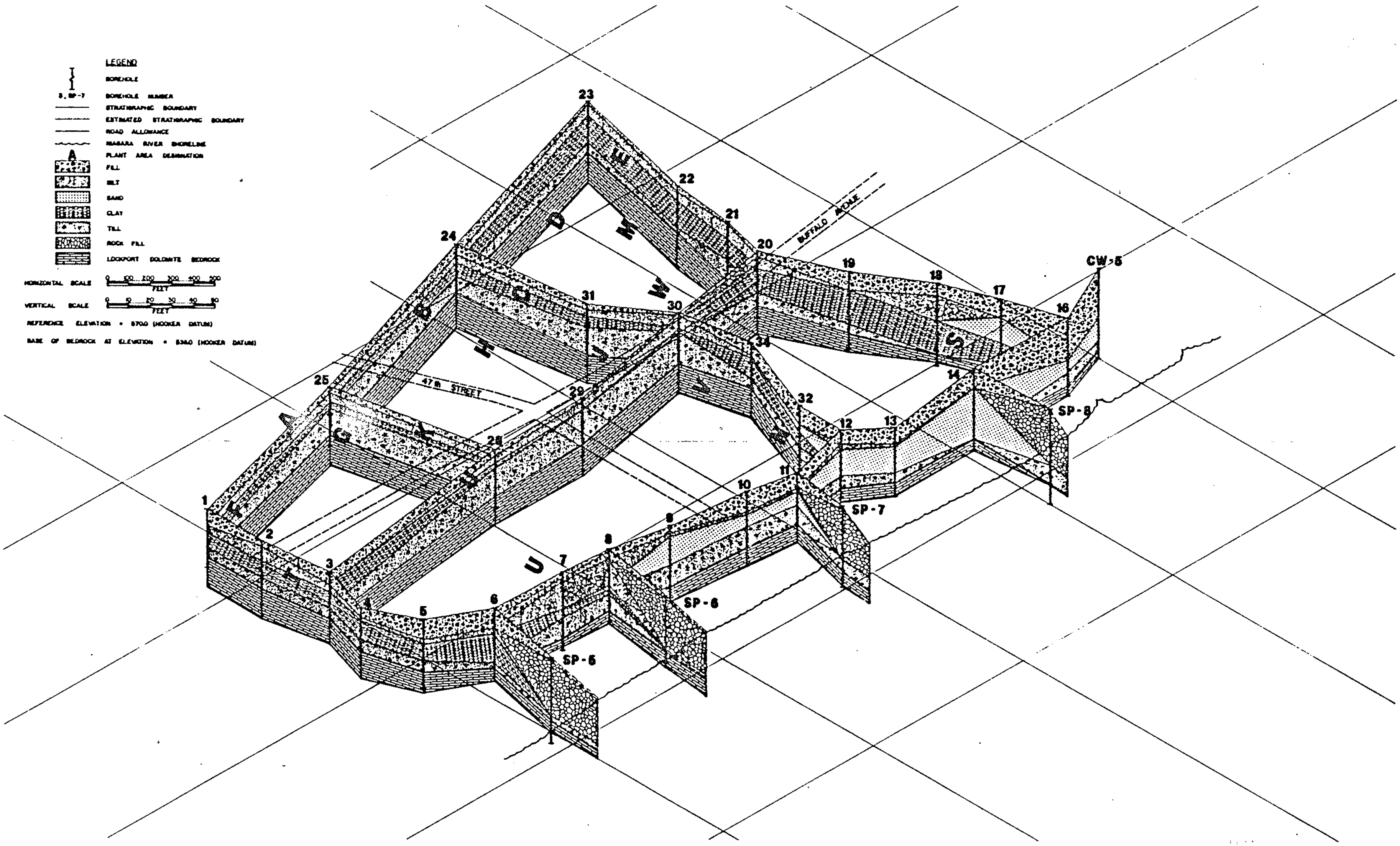

Figure 3. Isometric (30°) projection of the Hooker Niagara Plant stratigraphy

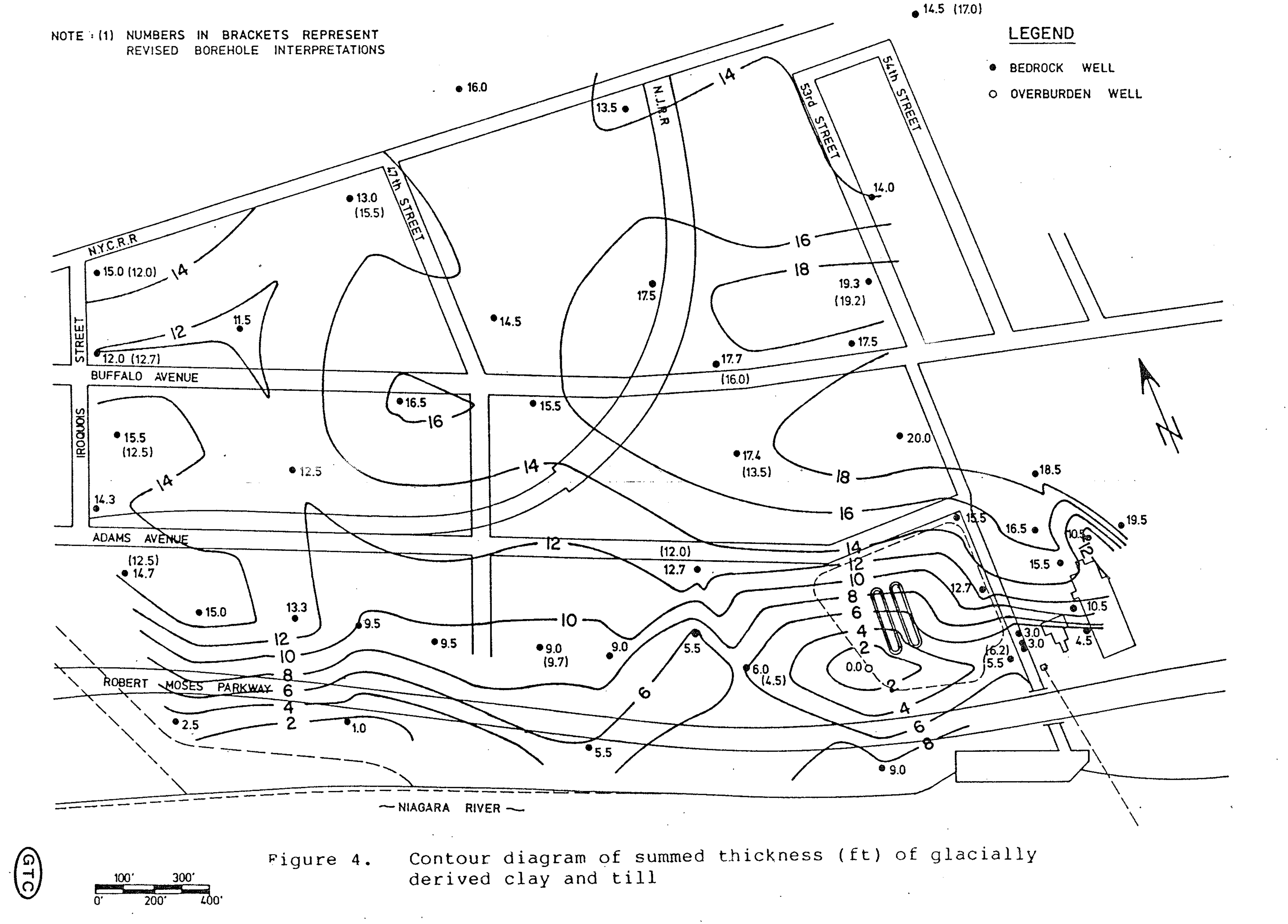

Figure 4. Contour diagram of summed thickness (ft) of glacially derived clay and till

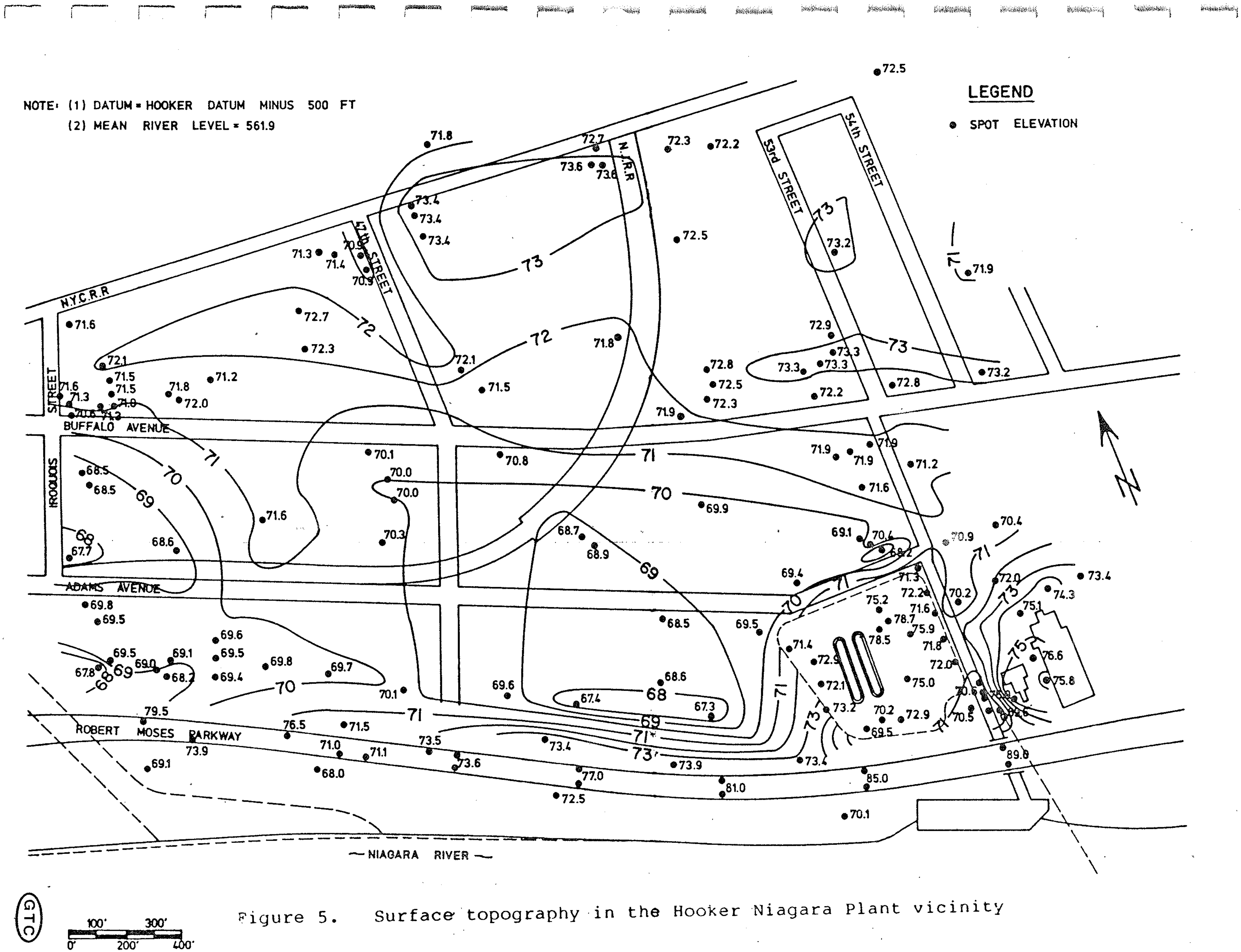

Figure 5. Surface topography in the Hooker Niagara Plant vicinity

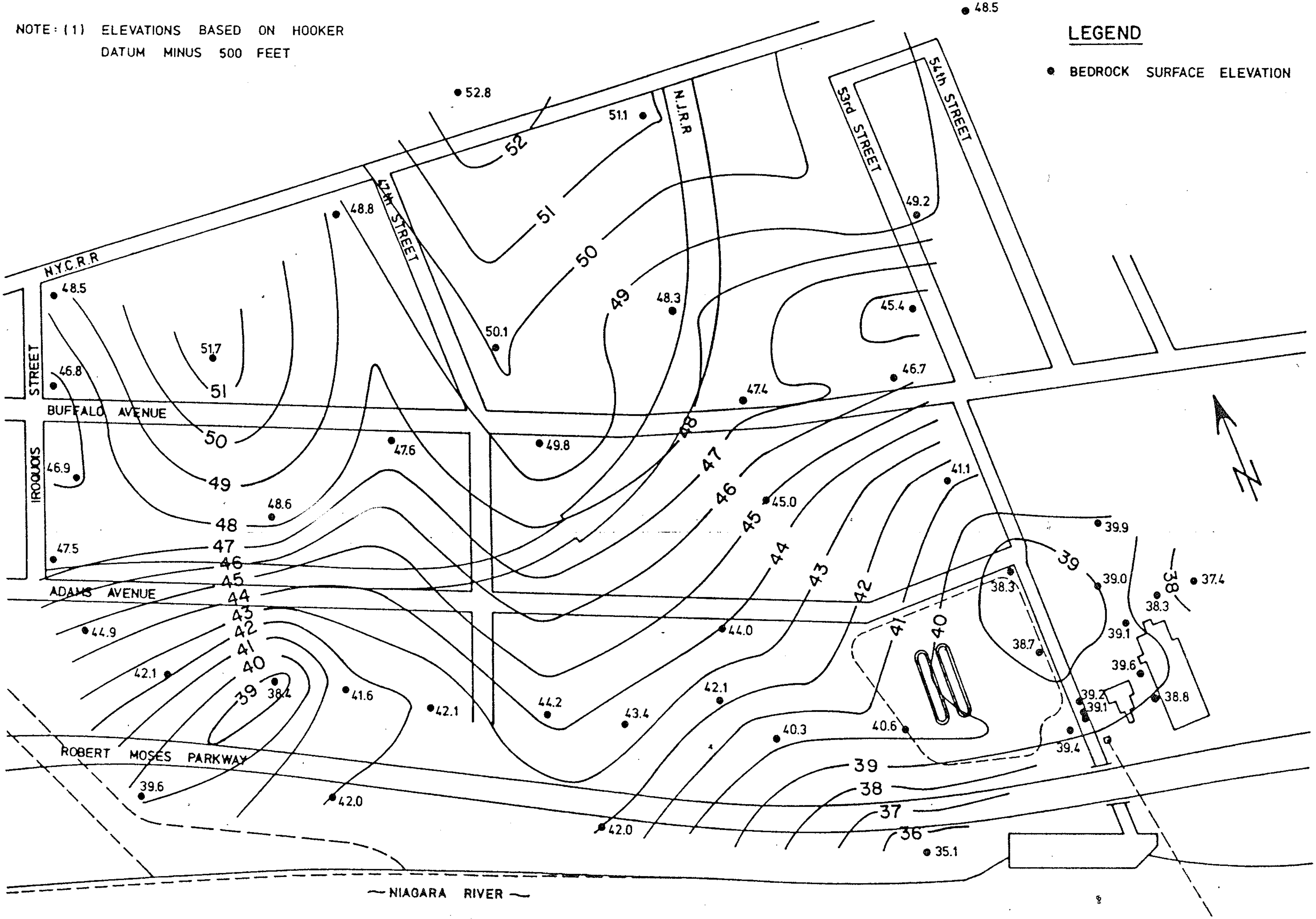

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Figure 6. Topography of the upper surface of the Lockport Dolomite in the vicinity of the Hooker Niagara Plant

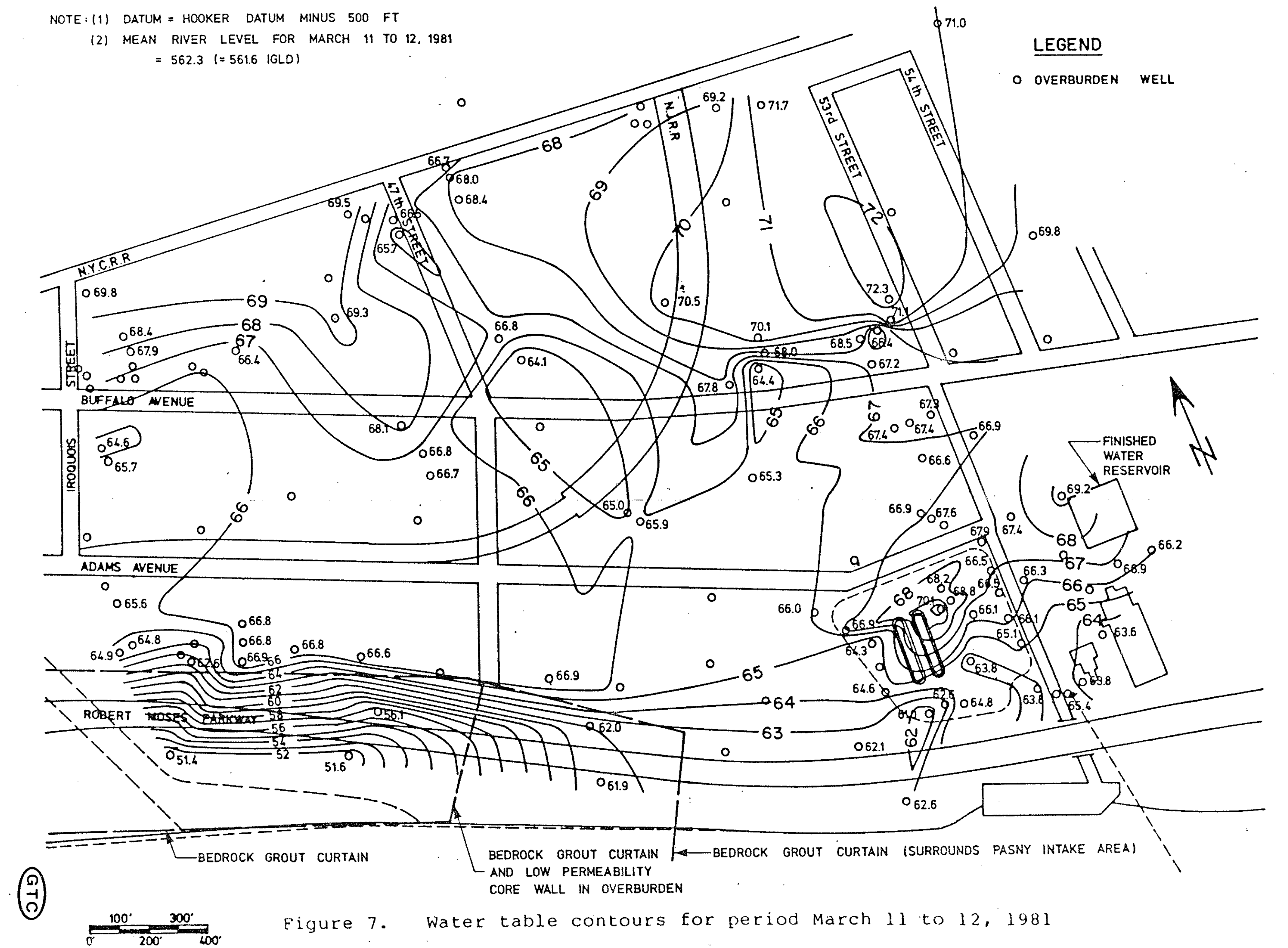

Figure 7. Water table contours for period March 11 to 12, 1981

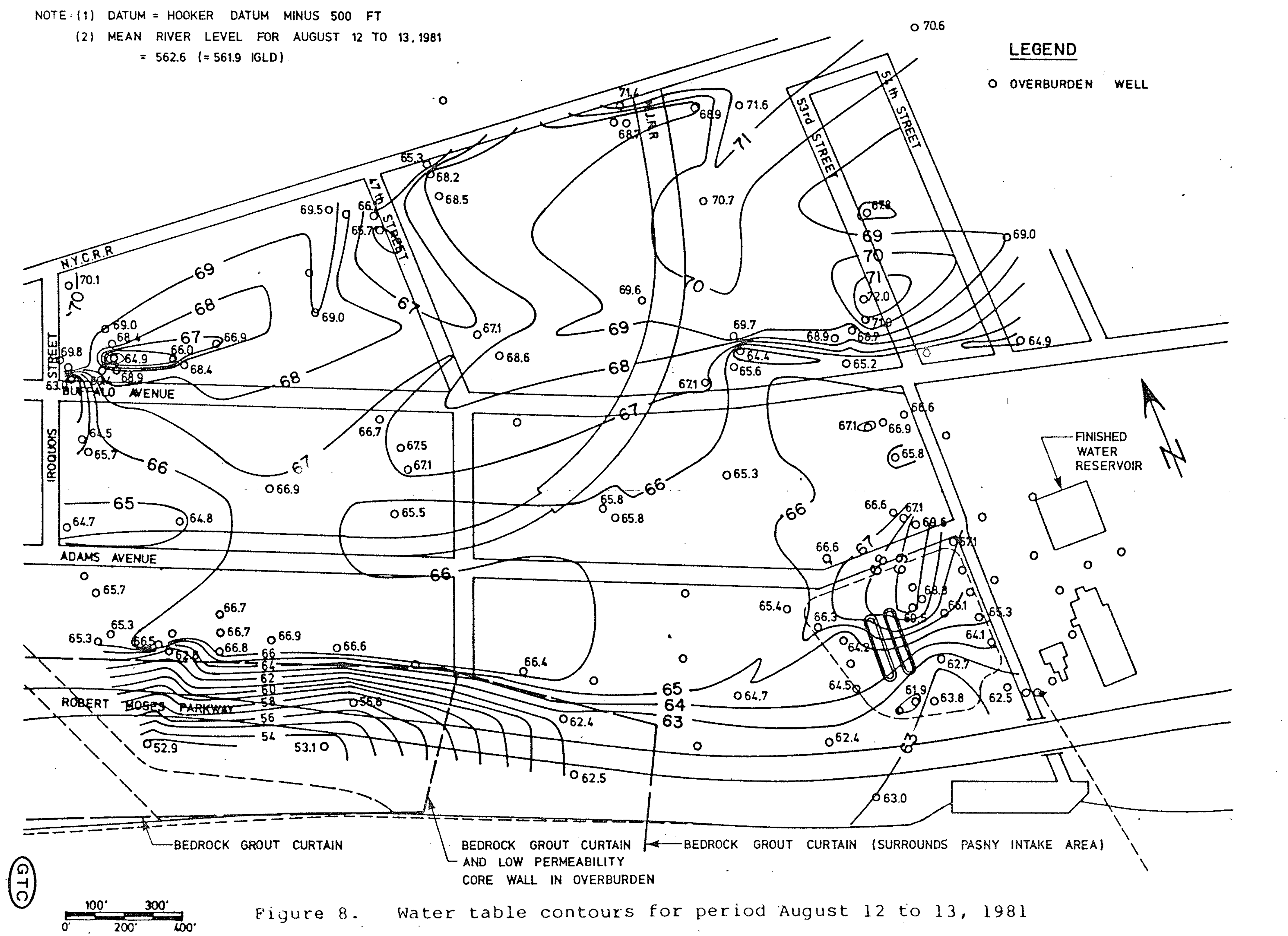

Figure 8. Water table contours for period August 12 to 13, 1981

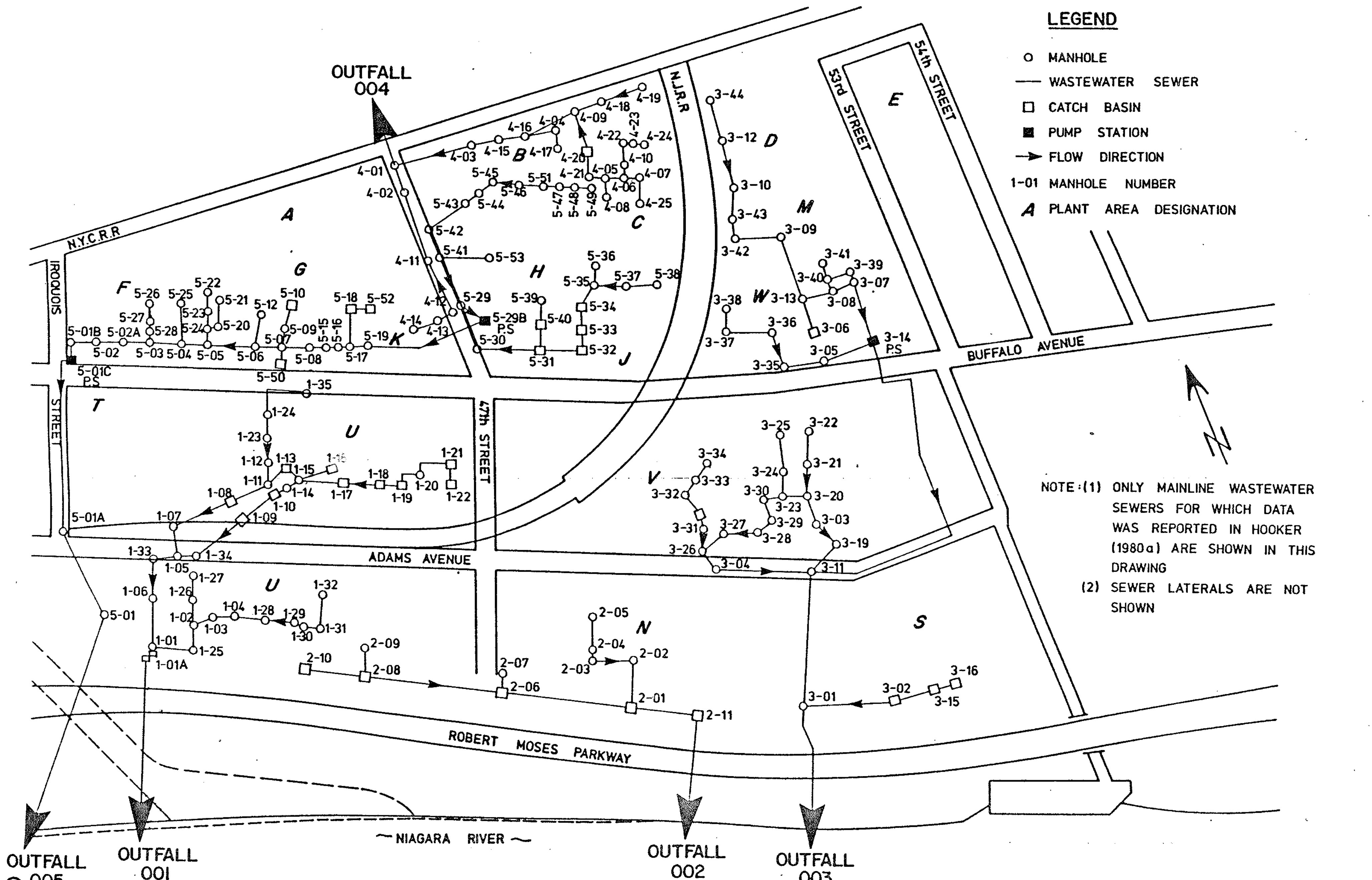

Figure 9. Location and designation of the wastewater sewer system at the Hooker Niagara Plant Site (after Hooker, 1980a)

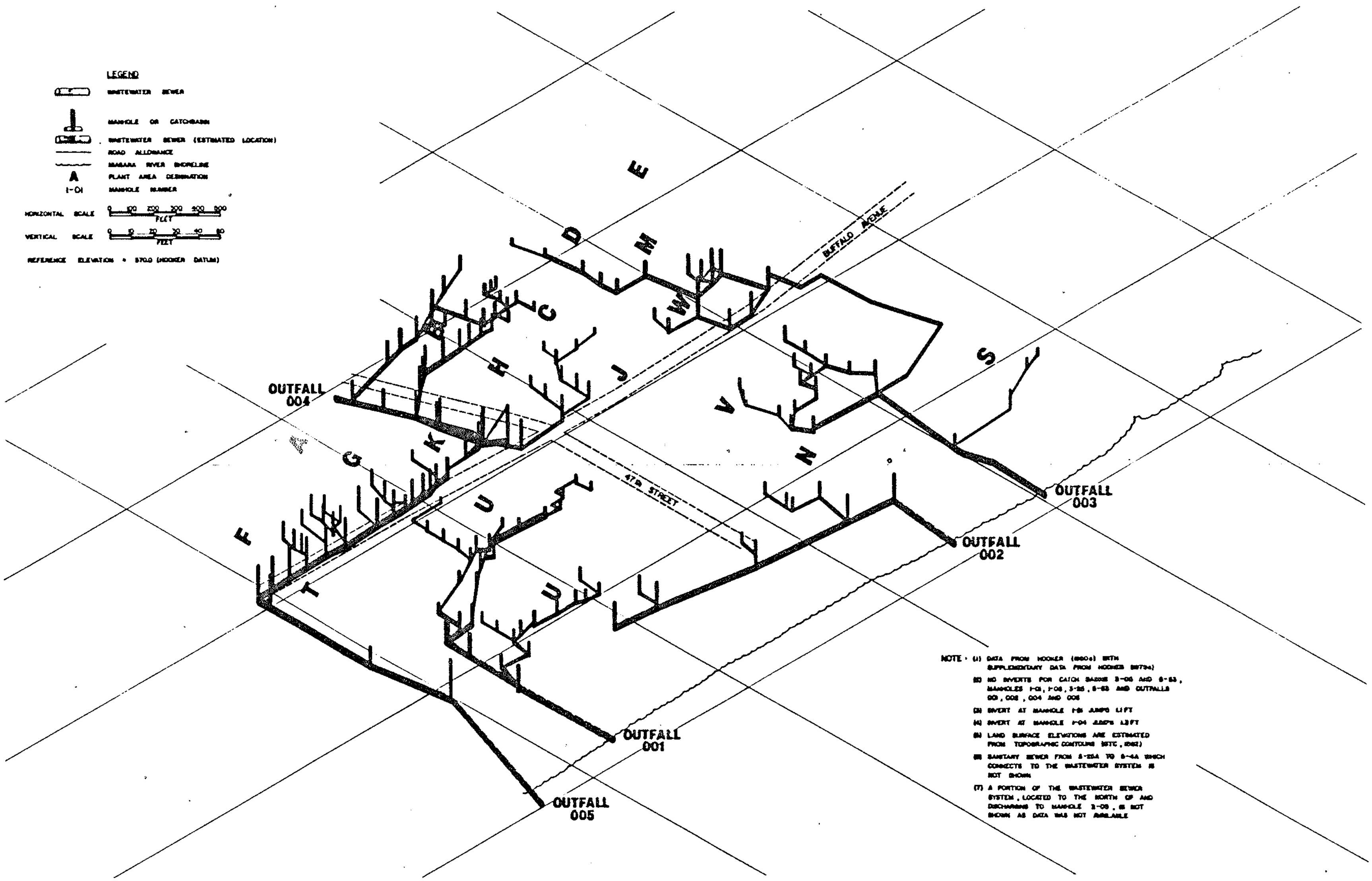

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Figure 10. Isometric (30°) projection of the Hooker Niagara Plant wastewater sewer system (after Hooker, 1980a)

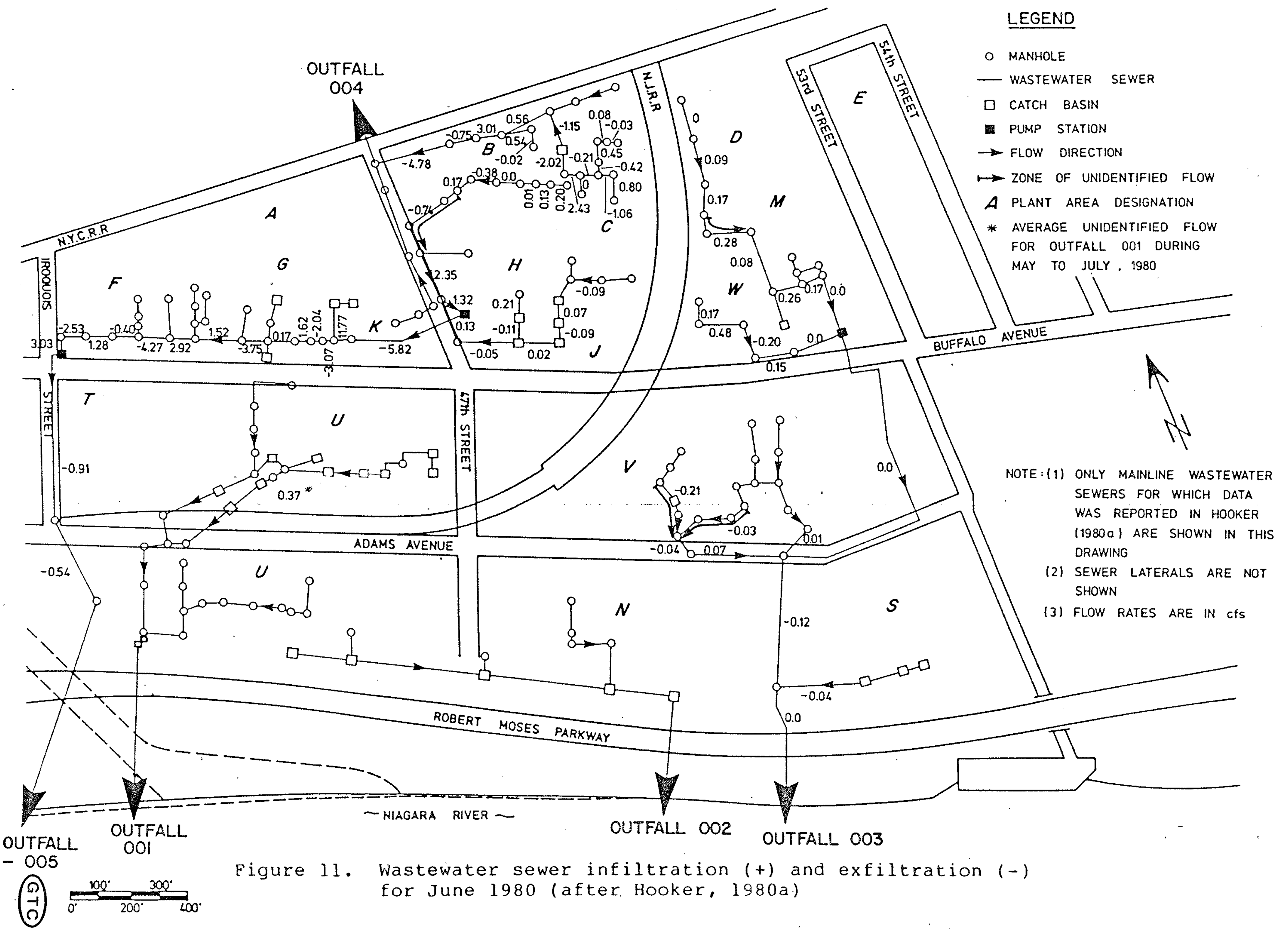

Figure 11. Wastewater sewer infiltration (+) and exfiltration (-) for June 1980 (after Hooker, 1980a)

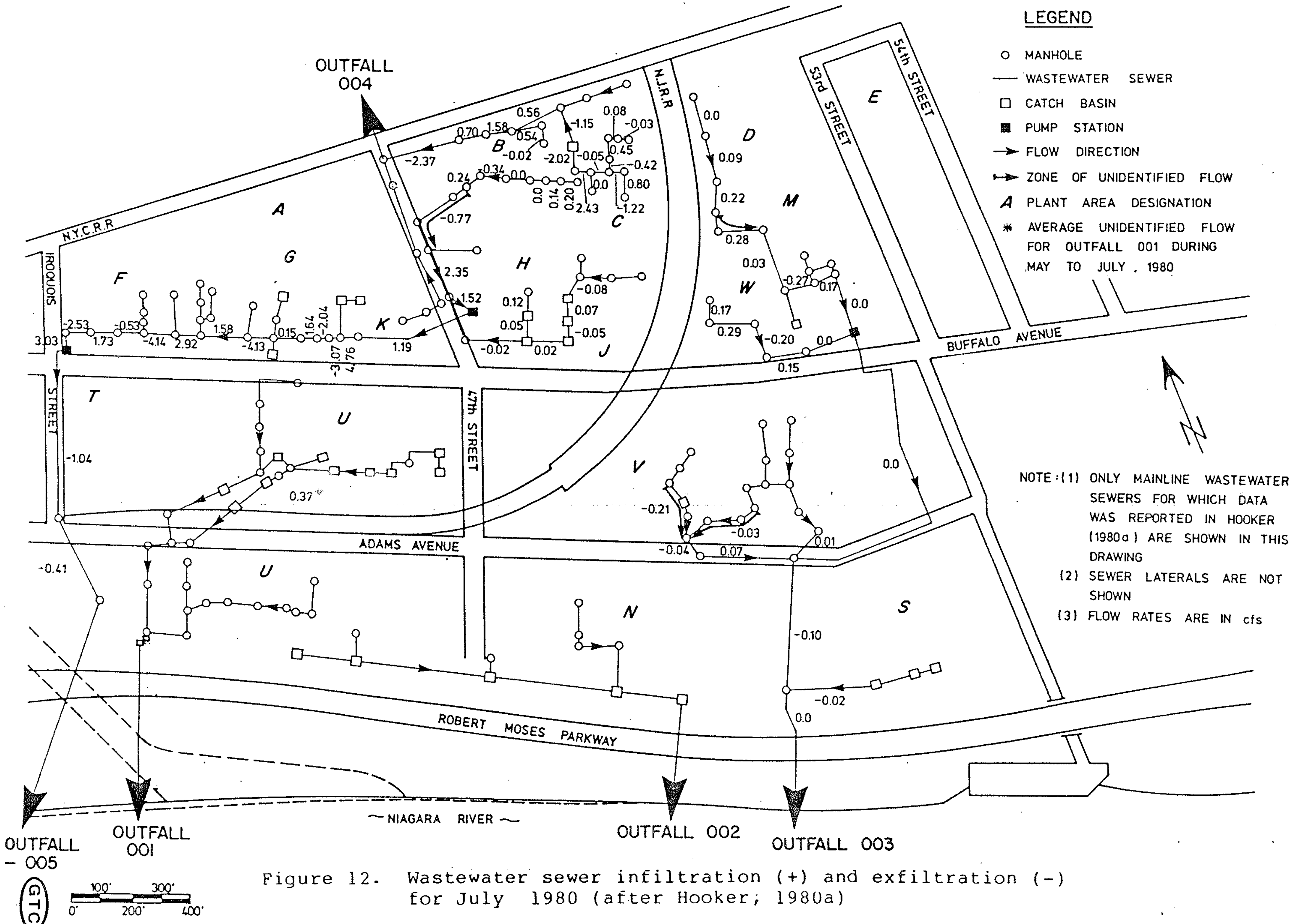

Figure 12. Wastewater sewer infiltration (+) and exfiltration (-) for July 1980 (after Hooker, 1980a)

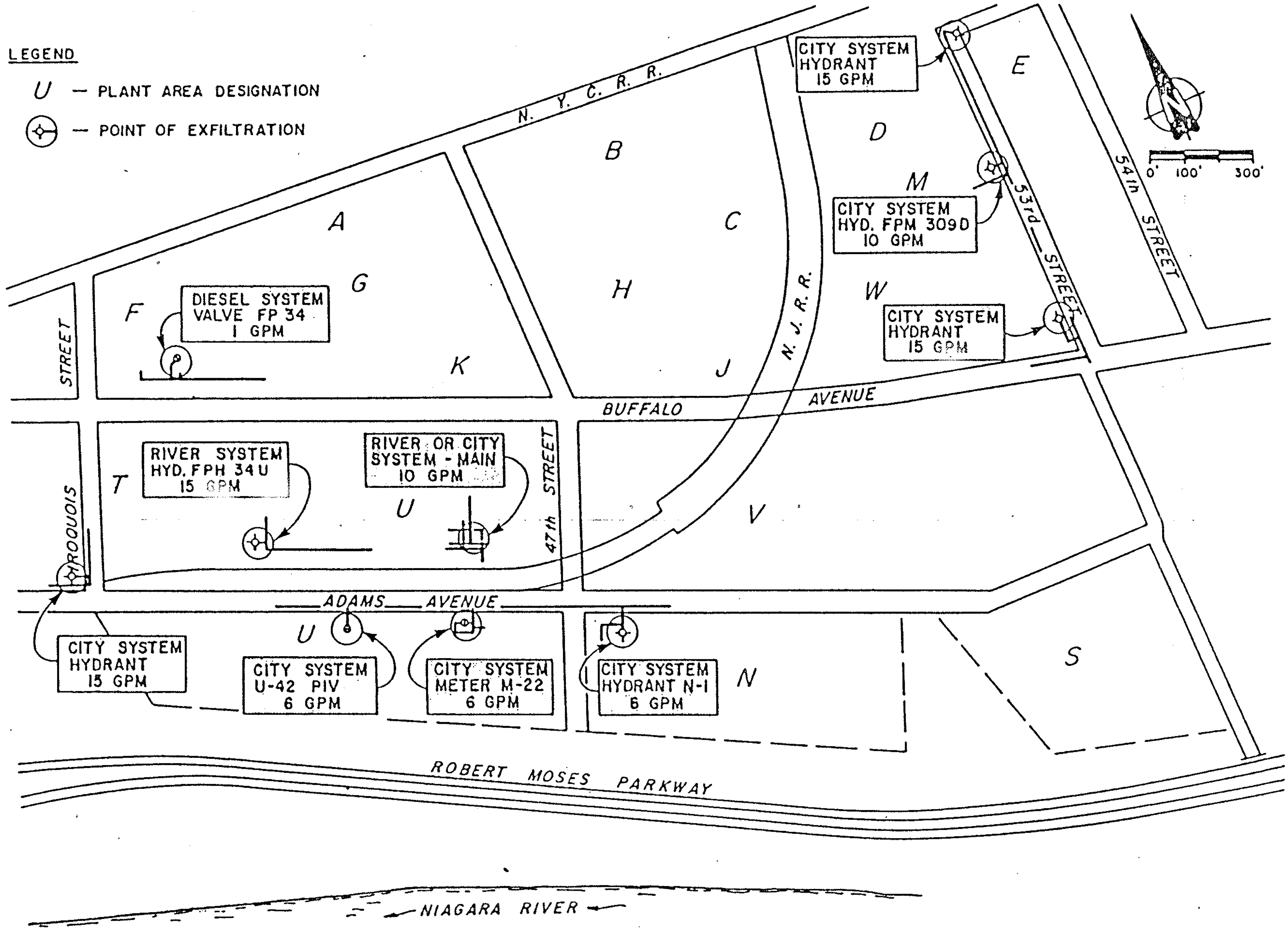

Figure 13. Watermain exfiltration identified on the Hooker Niagara Plant Site (Hooker, 1981)

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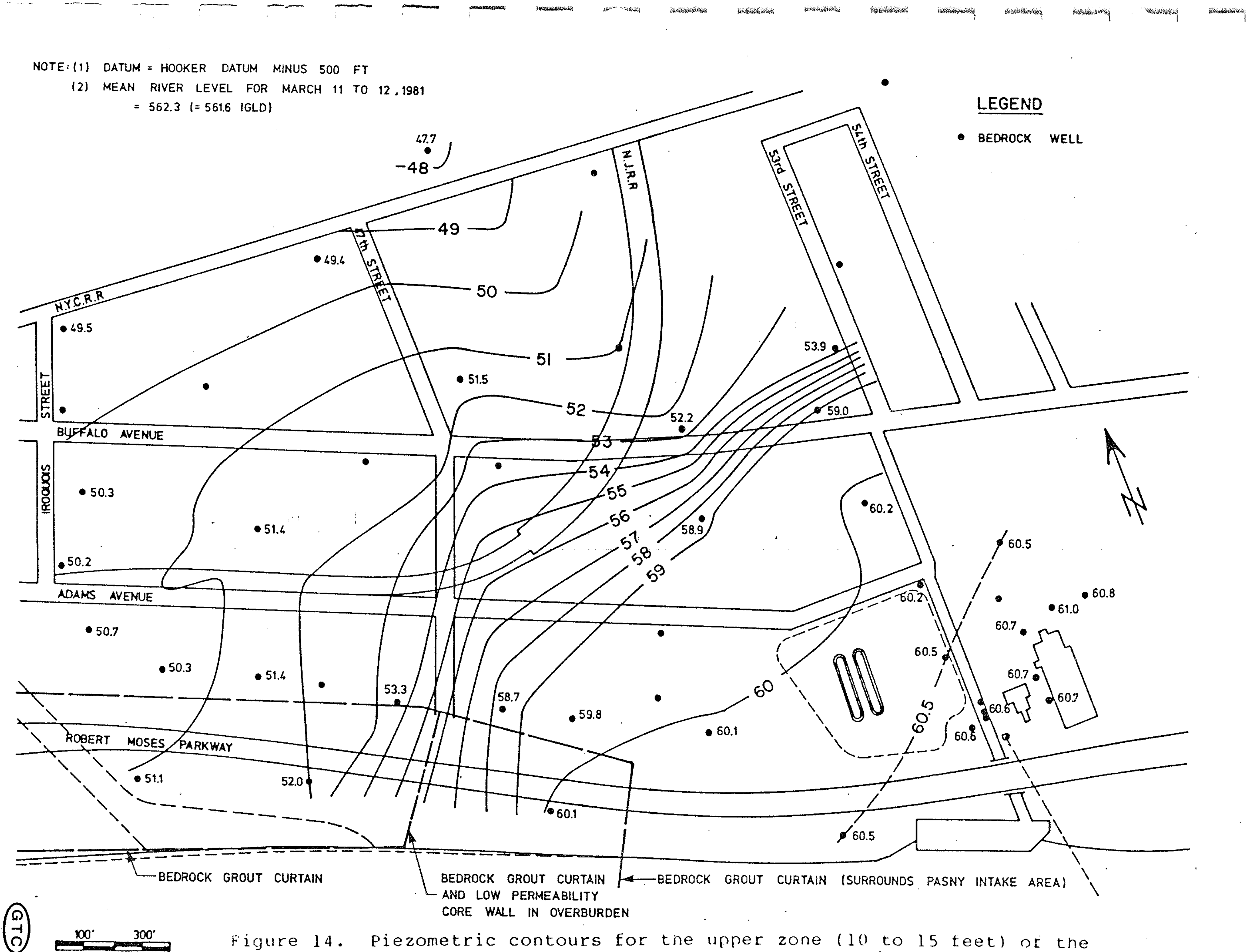

Figure 14. Piezometric contours for the upper zone (10 to 15 feet) of the Lockport Dolomite for period March 11 to 12, 1981

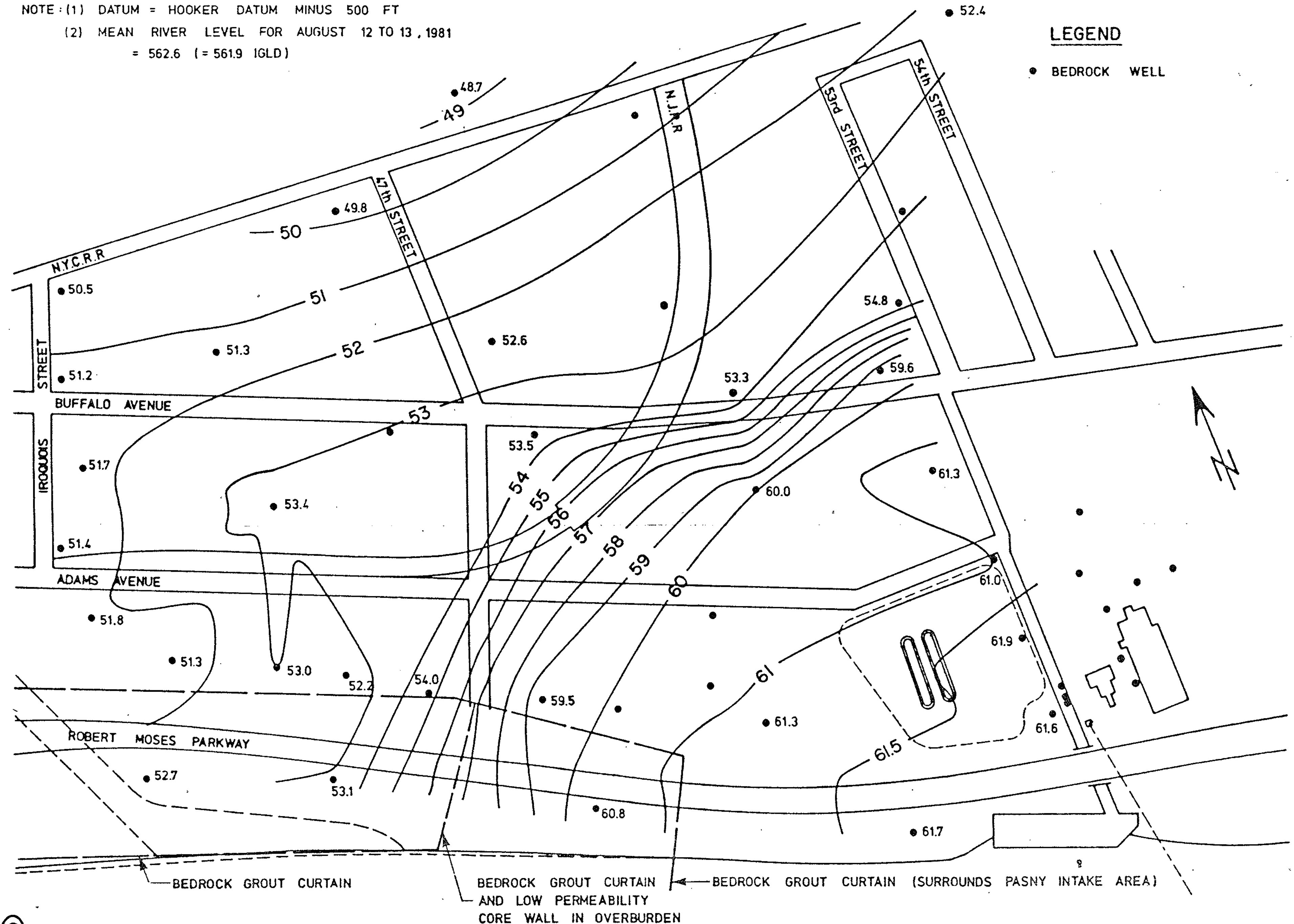

Figure 15. Piezometric contours for the upper zone (10 to 15 feet) of the Lockport Dolomite for period August 12 to 13, 1981

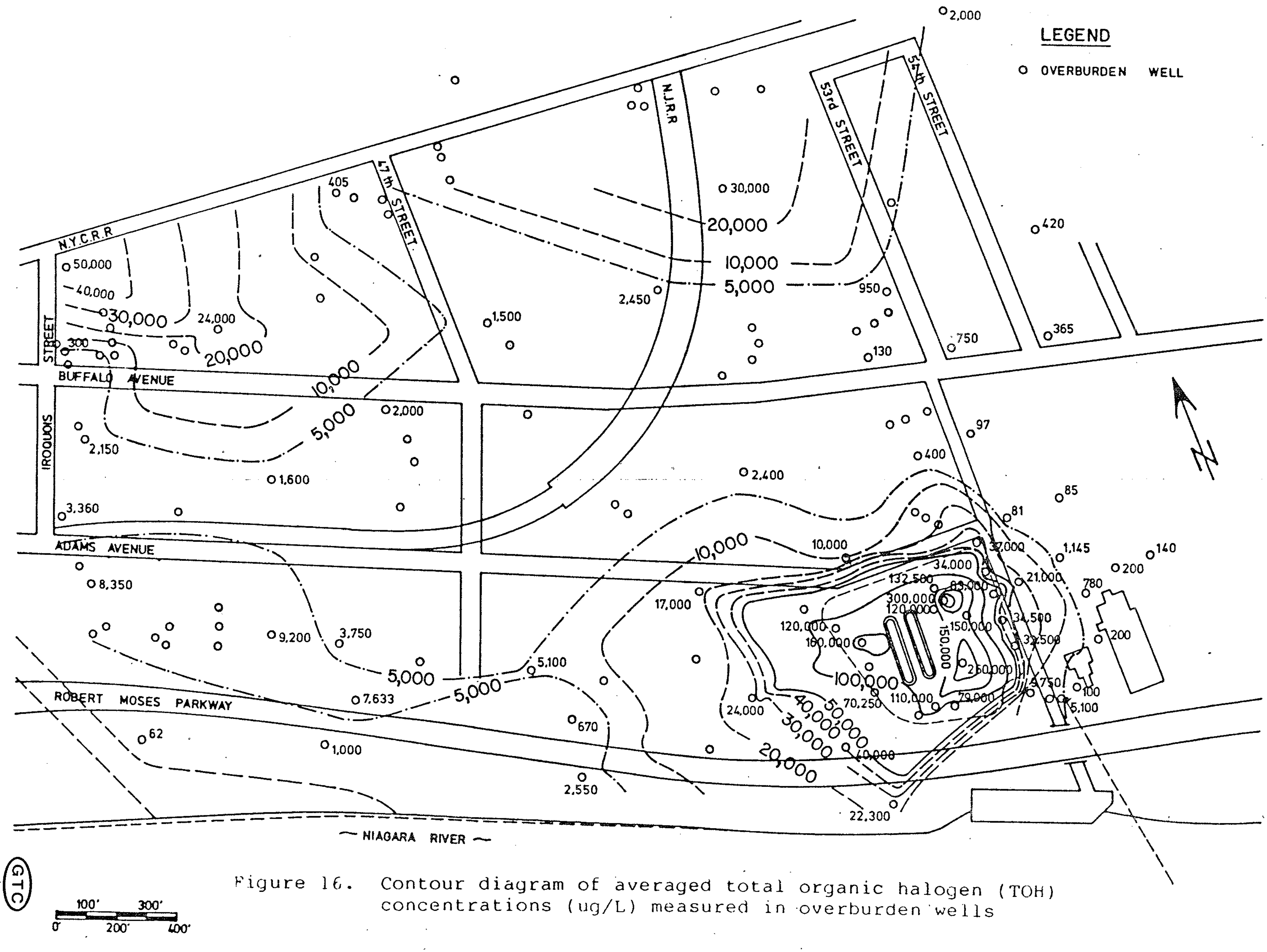

Figure 16. Contour diagram of averaged total organic halogen (TOH) concentrations (ug/L) measured in overburden wells

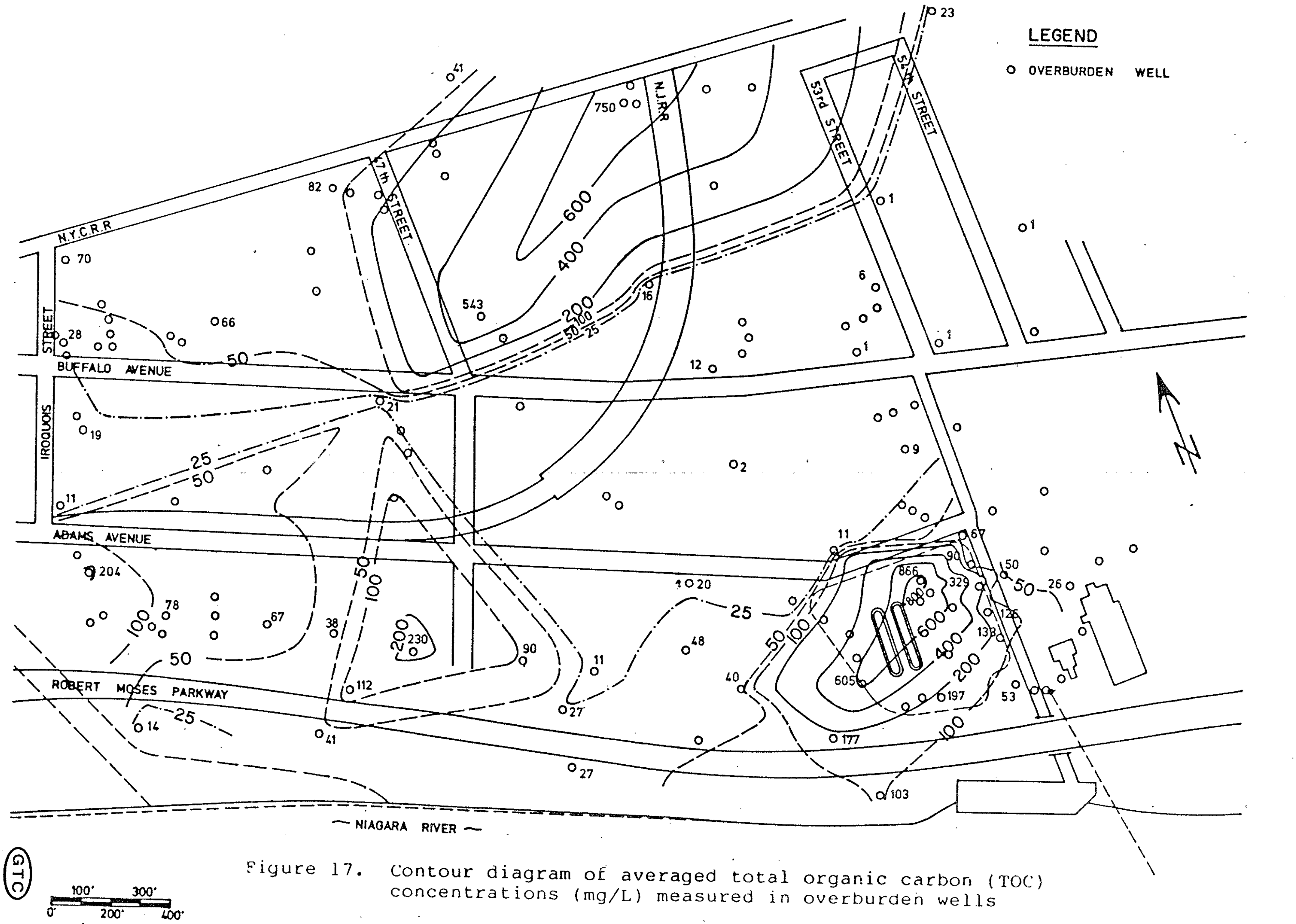

Figure 17. Contour diagram of averaged total organic carbon (TOC) concentrations (mg/L) measured in overburden wells

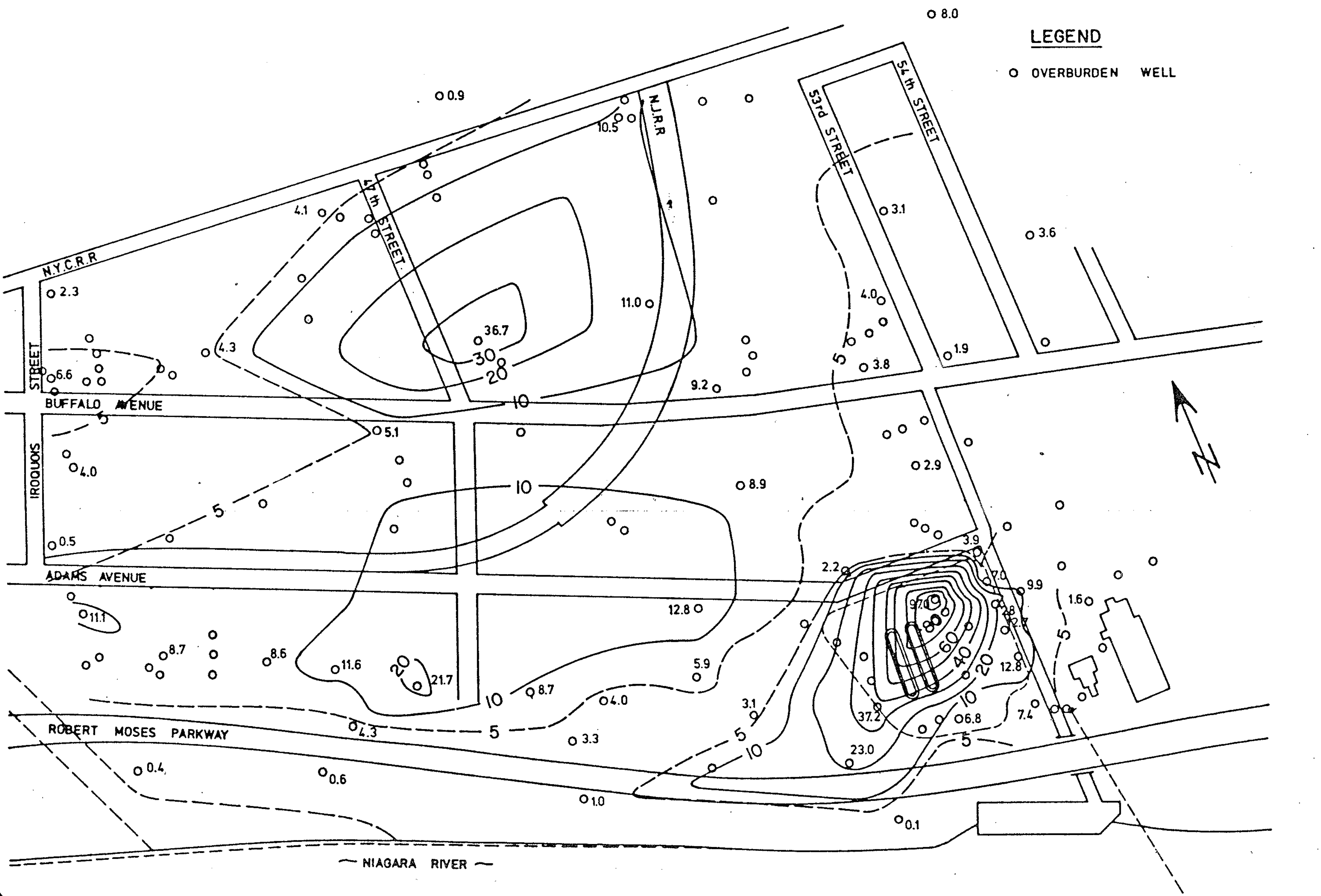

Figure 18. Contour diagram of averaged conductivity (mmho/cm) measured in overburden wells

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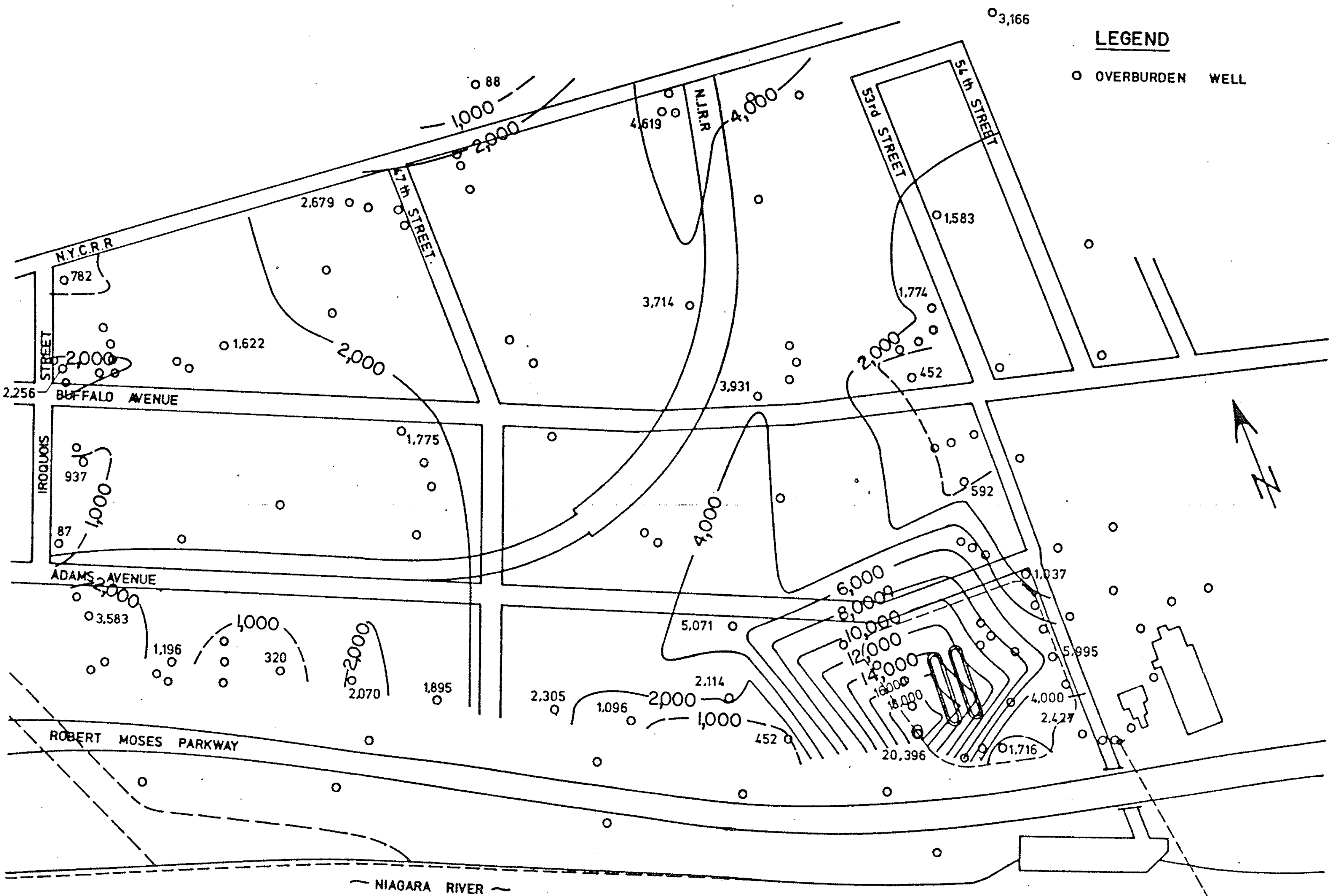

Figure 19. Contour diagram of averaged chloride (Cl) concentrations (mg/L) measured in overburden wells

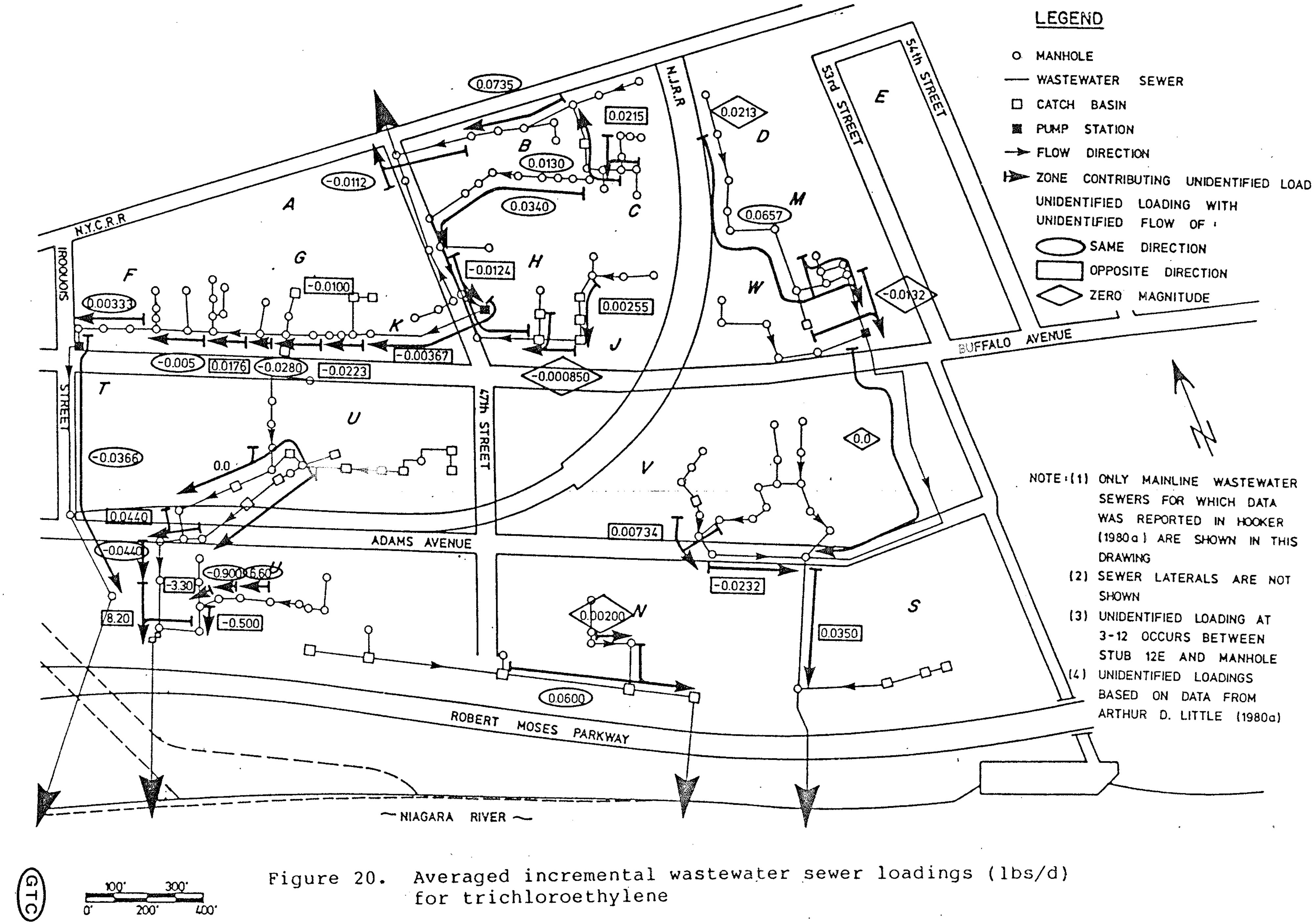

Figure 20. Averaged incremental wastewater sewer loadings (lbs/d) for trichloroethylene

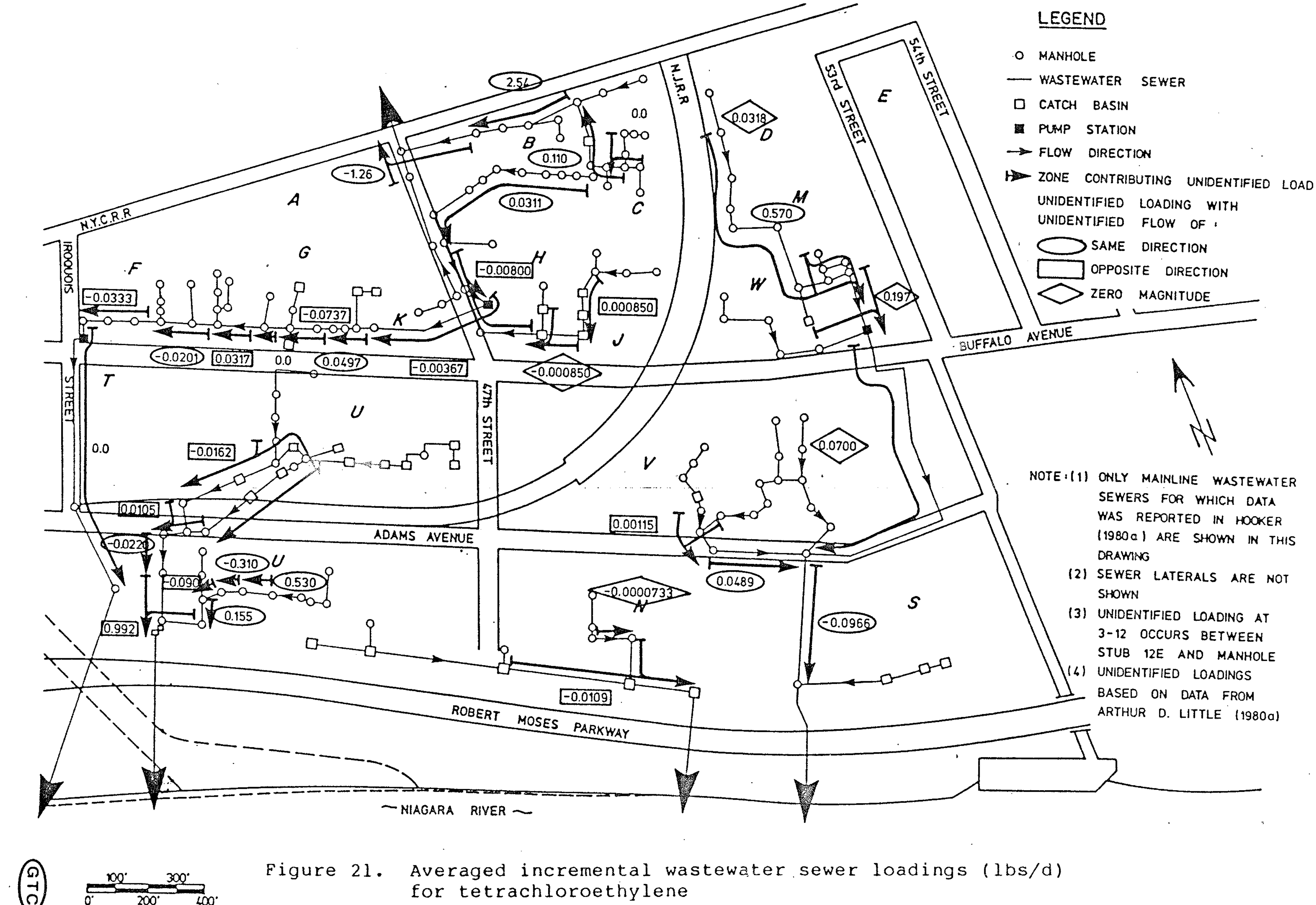

Figure 21. Averaged incremental wastewater sewer loadings (lbs/d) for tetrachloroethylene

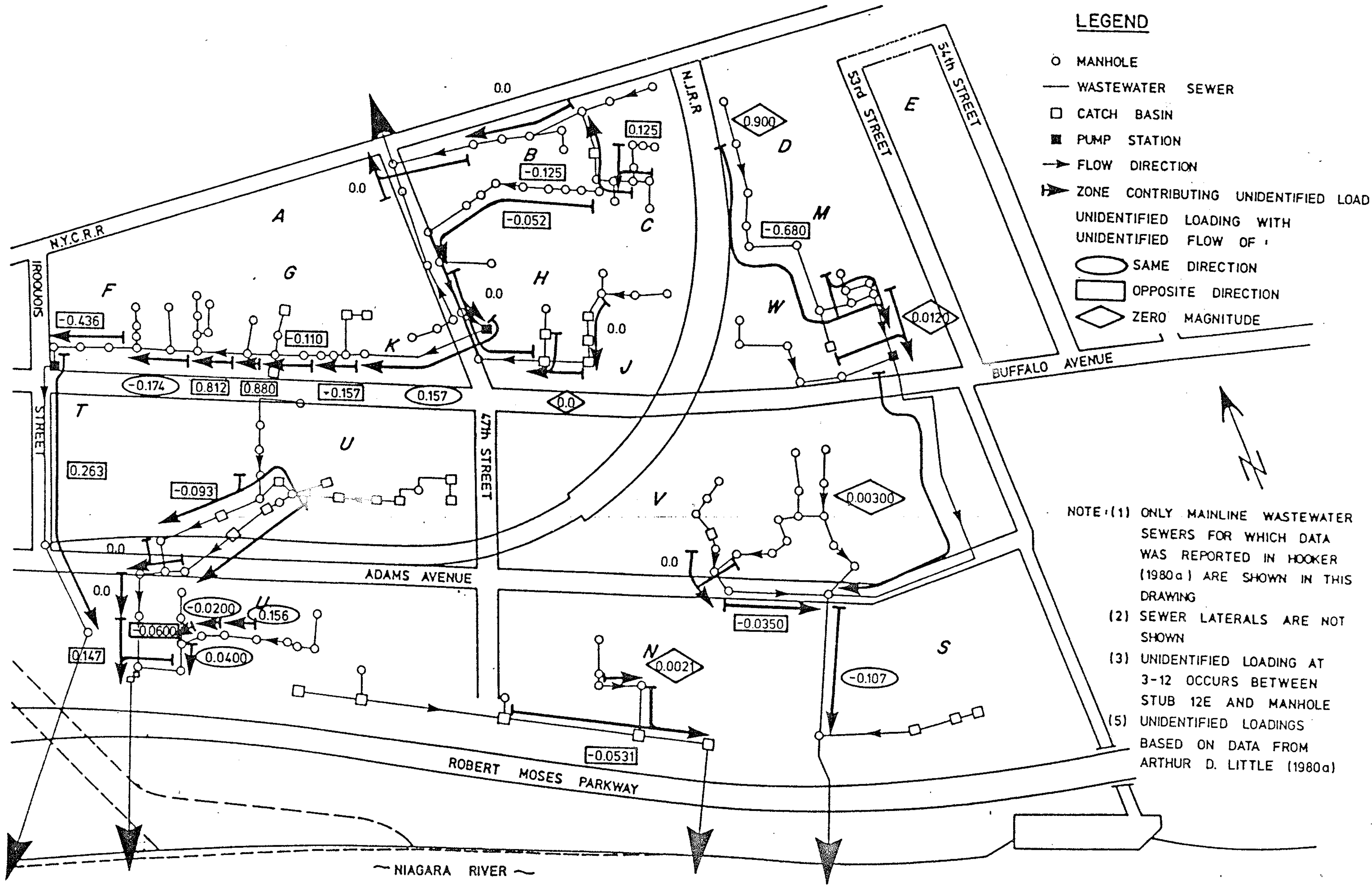

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Figure 22. Averaged incremental wastewater sewer loadings (lbs/d) for toluene

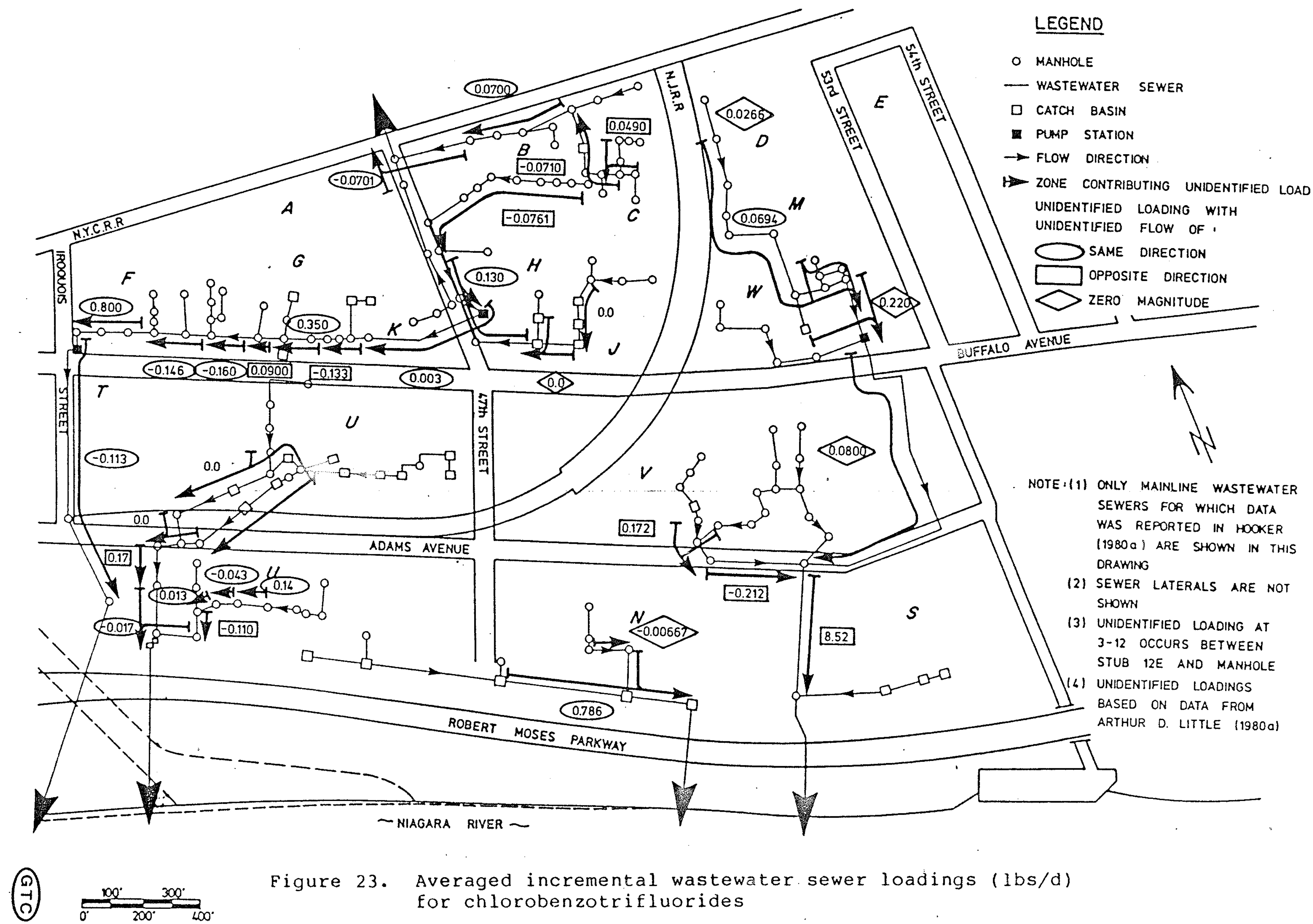

Figure 23. Averaged incremental wastewater sewer loadings (lbs/d) for chlorobenzotrifluorides

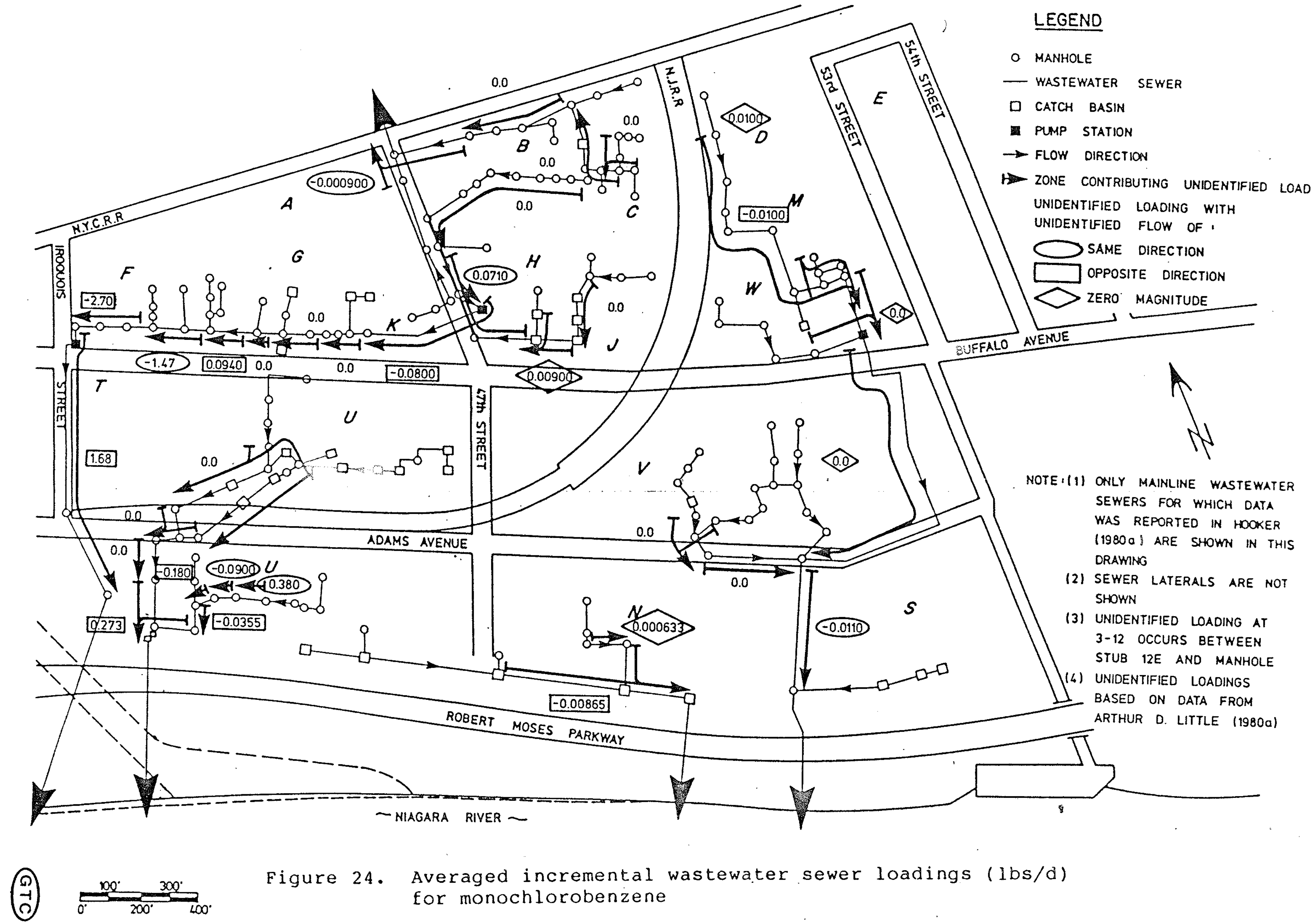

Figure 24. Averaged incremental wastewater sewer loadings (lbs/d) for monochlorobenzene

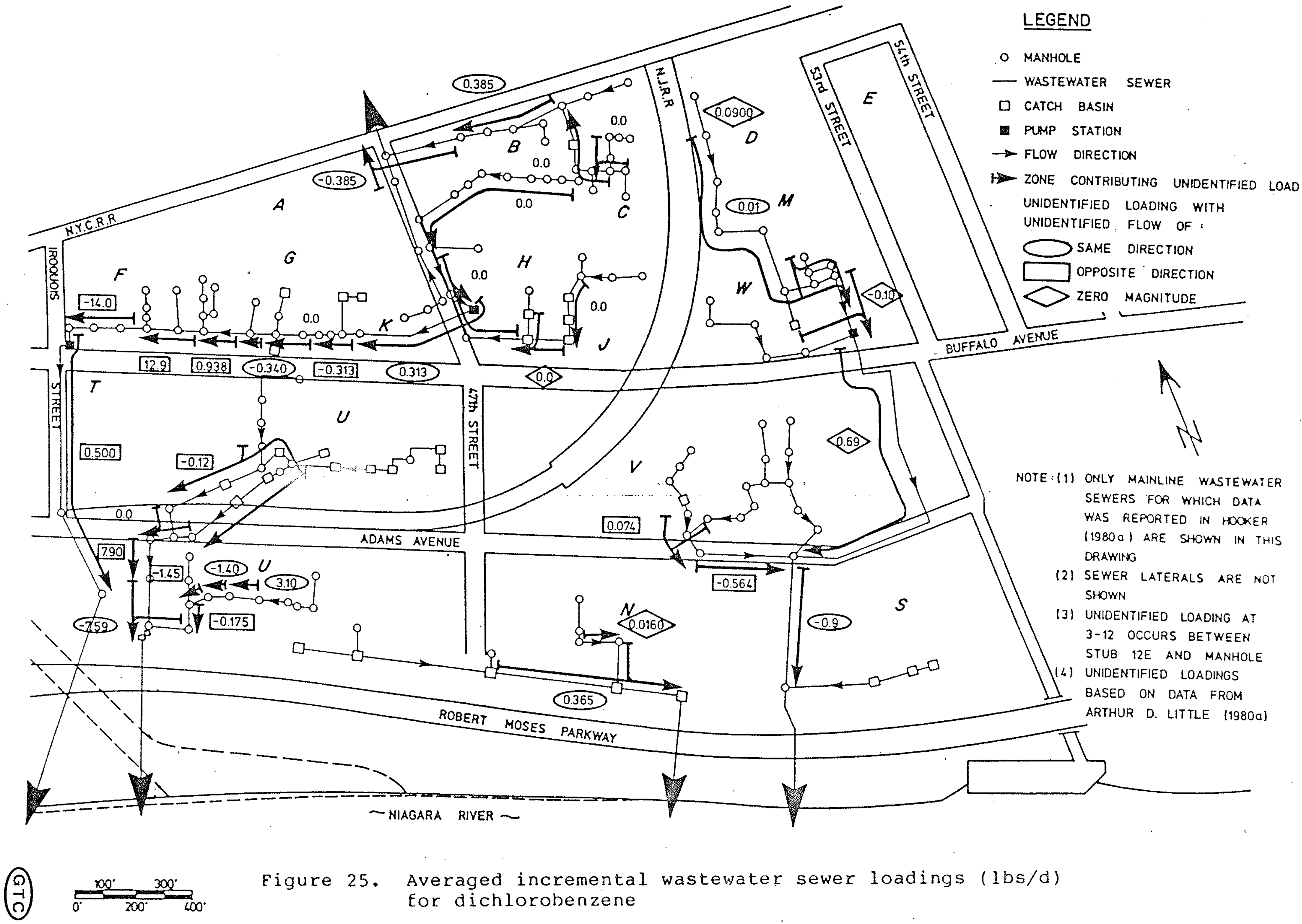

Figure 25. Averaged incremental wastewater sewer loadings (lbs/d) for dichlorobenzene

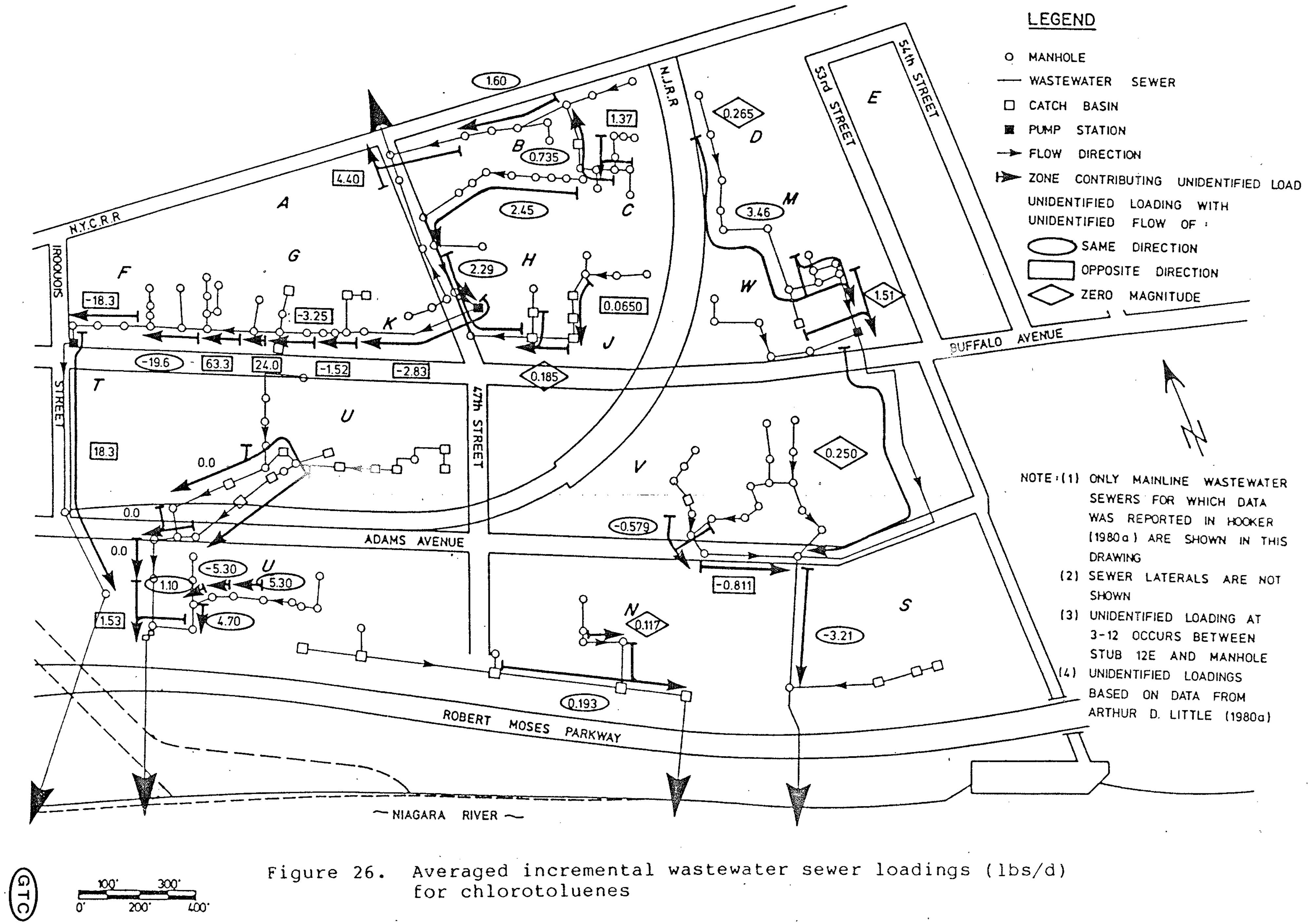

Figure 26. Averaged incremental wastewater sewer loadings (lbs/d) for chlorotoluenes

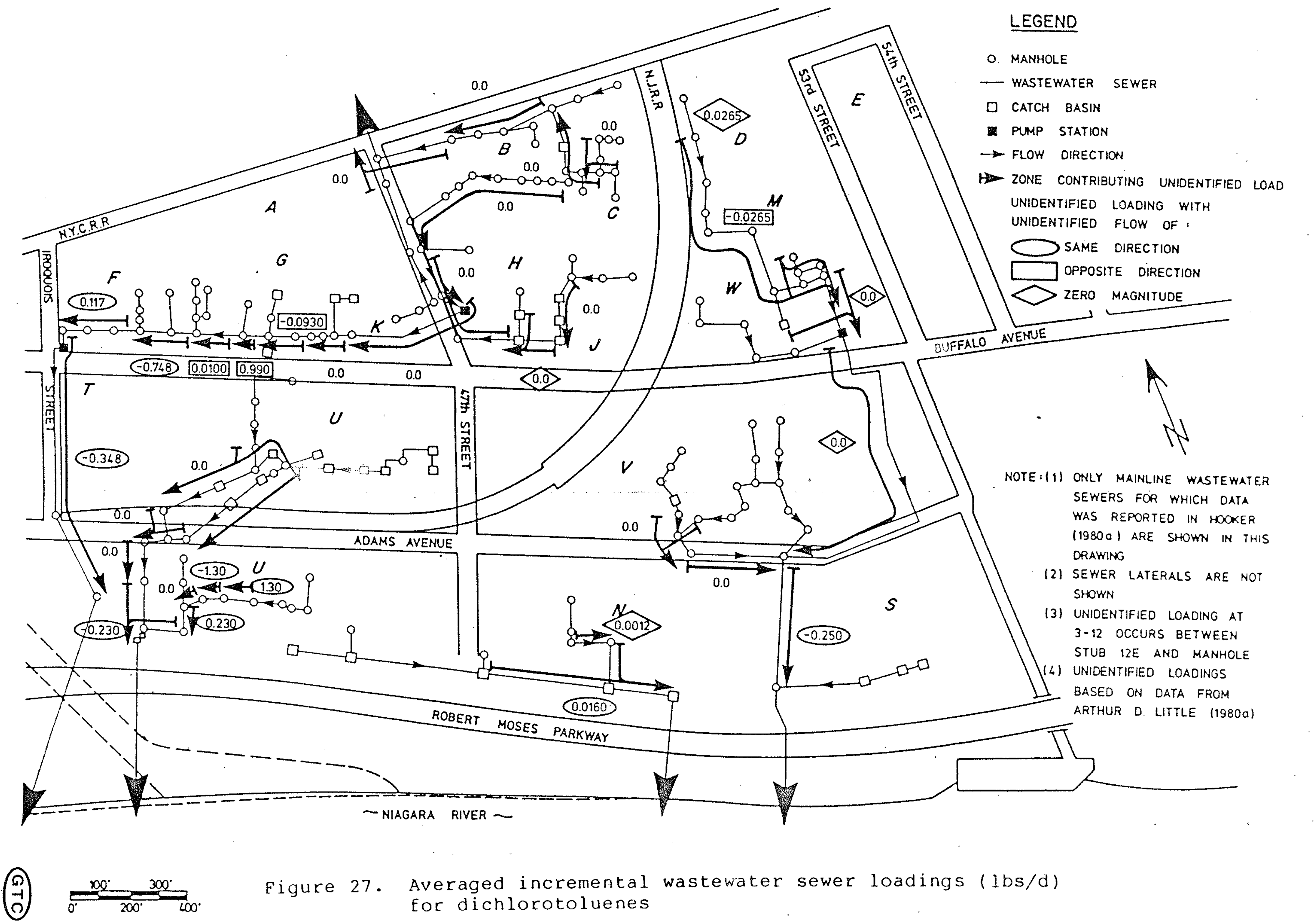

Figure 27. Averaged incremental wastewater sewer loadings (lbs/d) for dichlorotoluenes

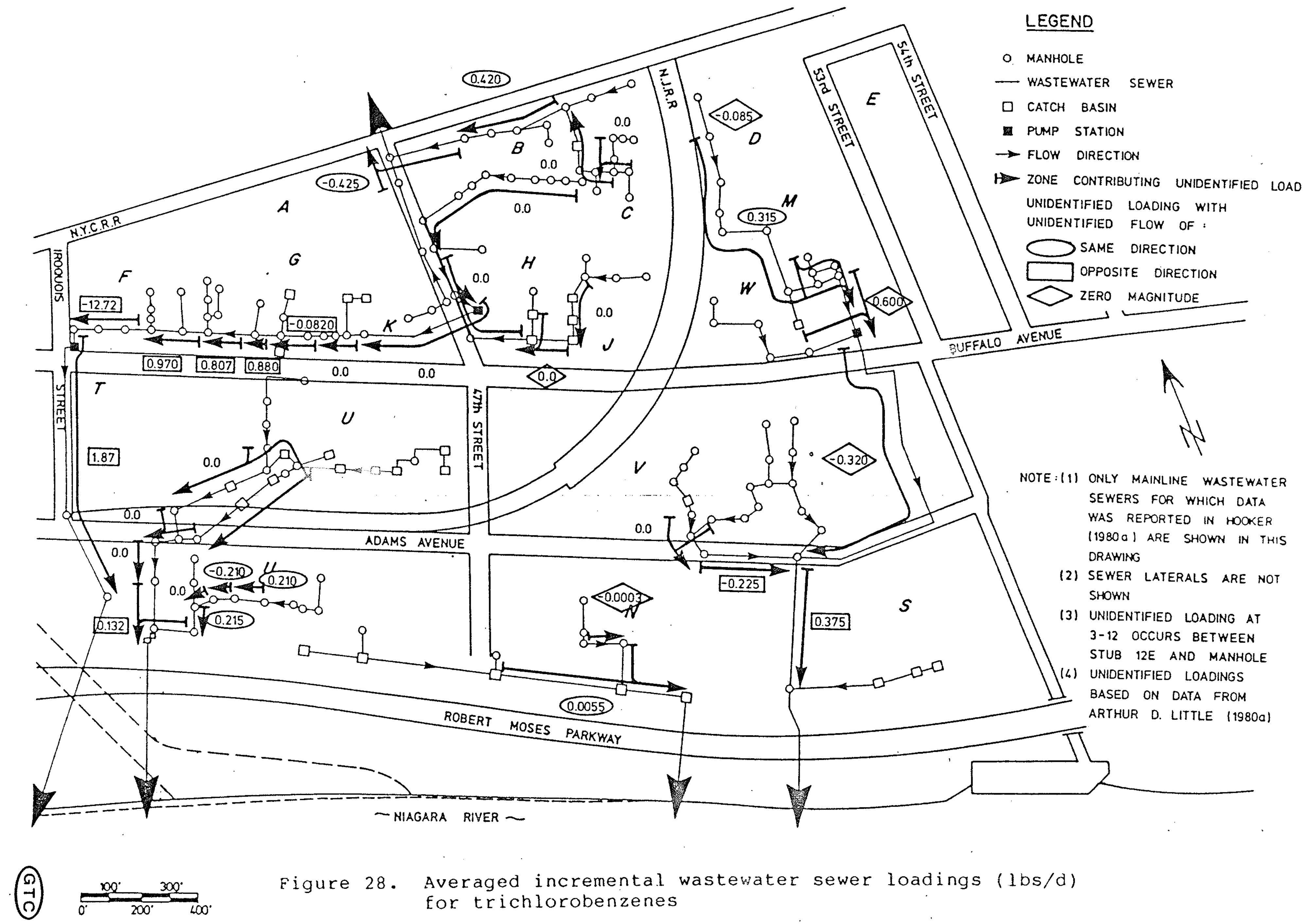

Figure 28. Averaged incremental wastewater sewer loadings (lbs/d) for trichlorobenzenes

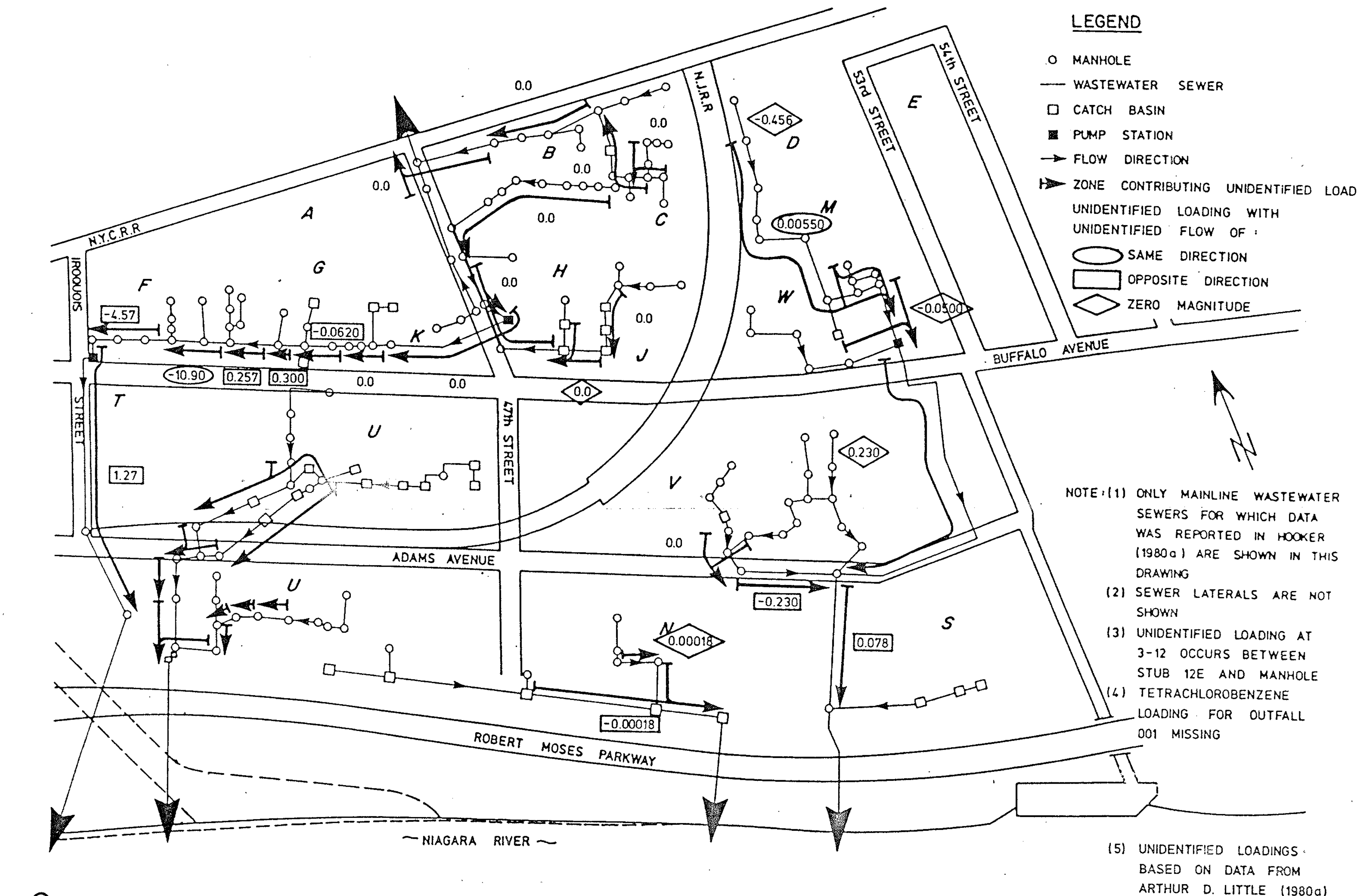

Figure 29. Averaged incremental wastewater sewer loadings (lbs/d) for tetrachlorobenzenes

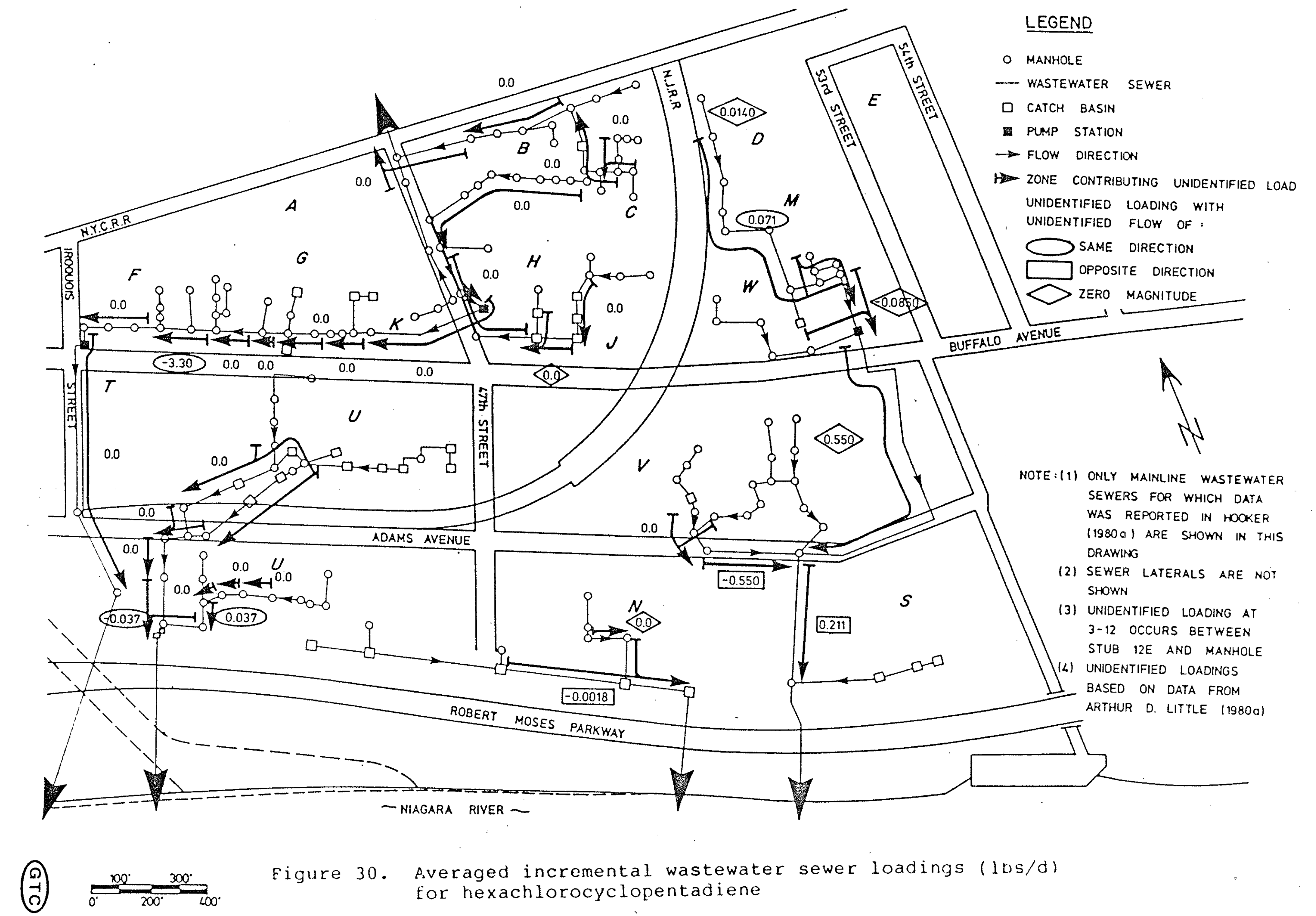

Figure 30. Averaged incremental wastewater sewer loadings (lbs/d) for hexachlorocyclopentadiene

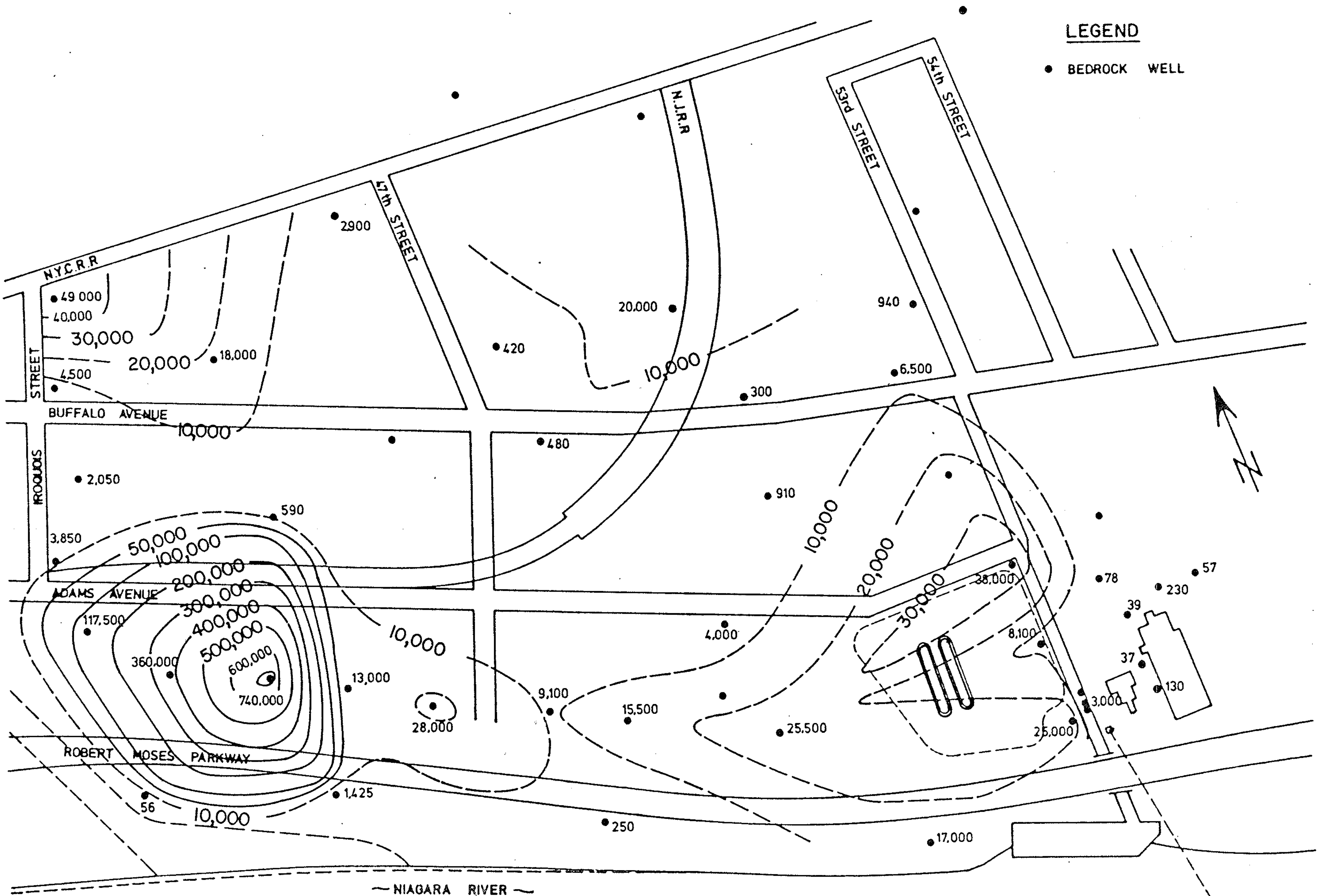

Figure 31. Contour diagram of averaged total organic halogen (TOH) concentrations (ug/L) measured in wells screened in the upper portion of the Lockport Dolomite (or across the upper Lockport and lowermost overburden; see Table 4).

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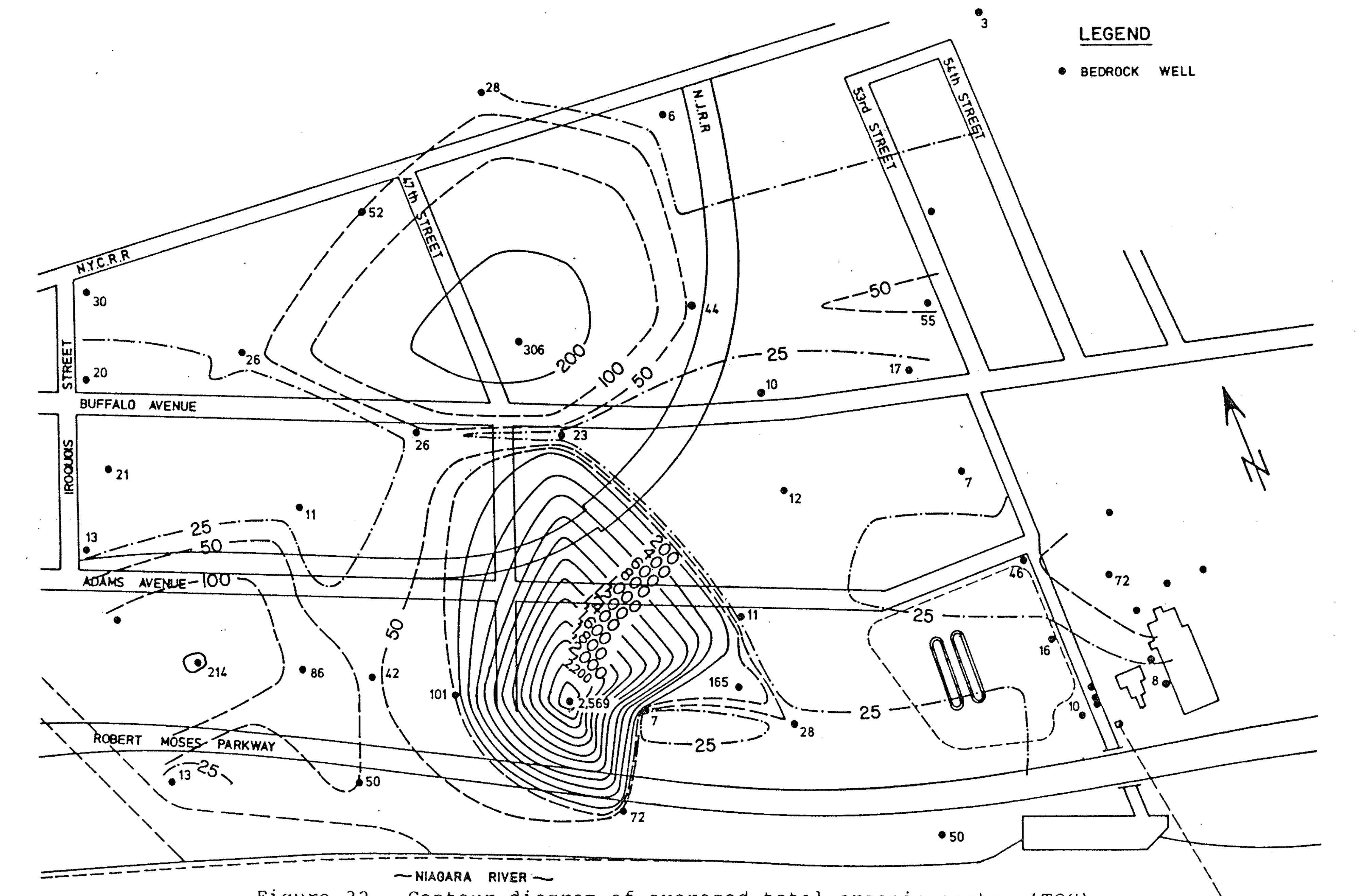

Figure 32. Contour diagram of averaged total organic carbon (TOC) concentrations (mg/L) measured in wells screened in the upper portion of the Lockport Dolomite (or across the upper Lockport and lowermost overburden; see Table 4)

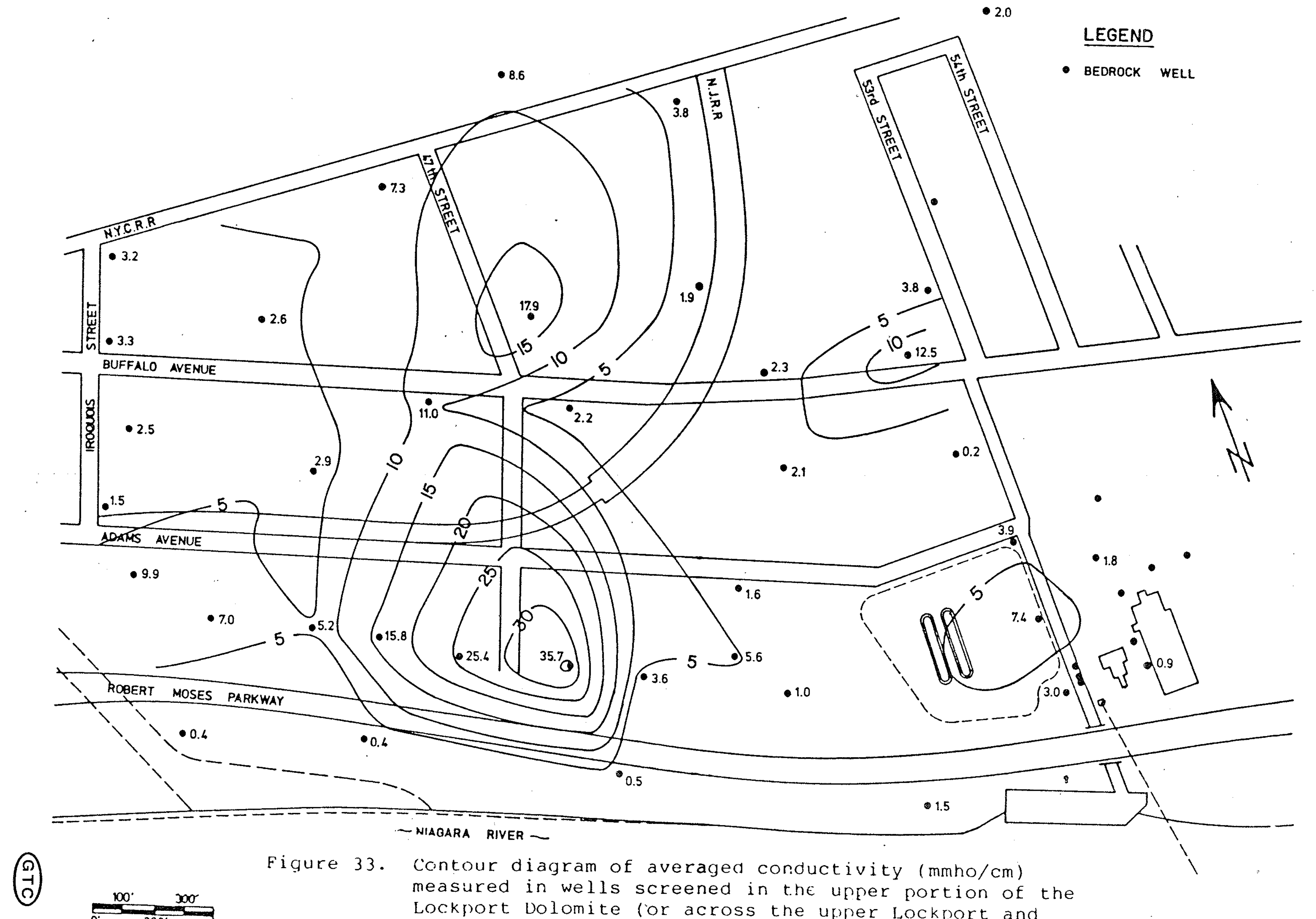

Figure 33. Contour diagram of averaged conductivity (mmho/cm) measured in wells screened in the upper portion of the Lockport Dolomite (or across the upper Lockport and lowermost overburden; see Table 4)

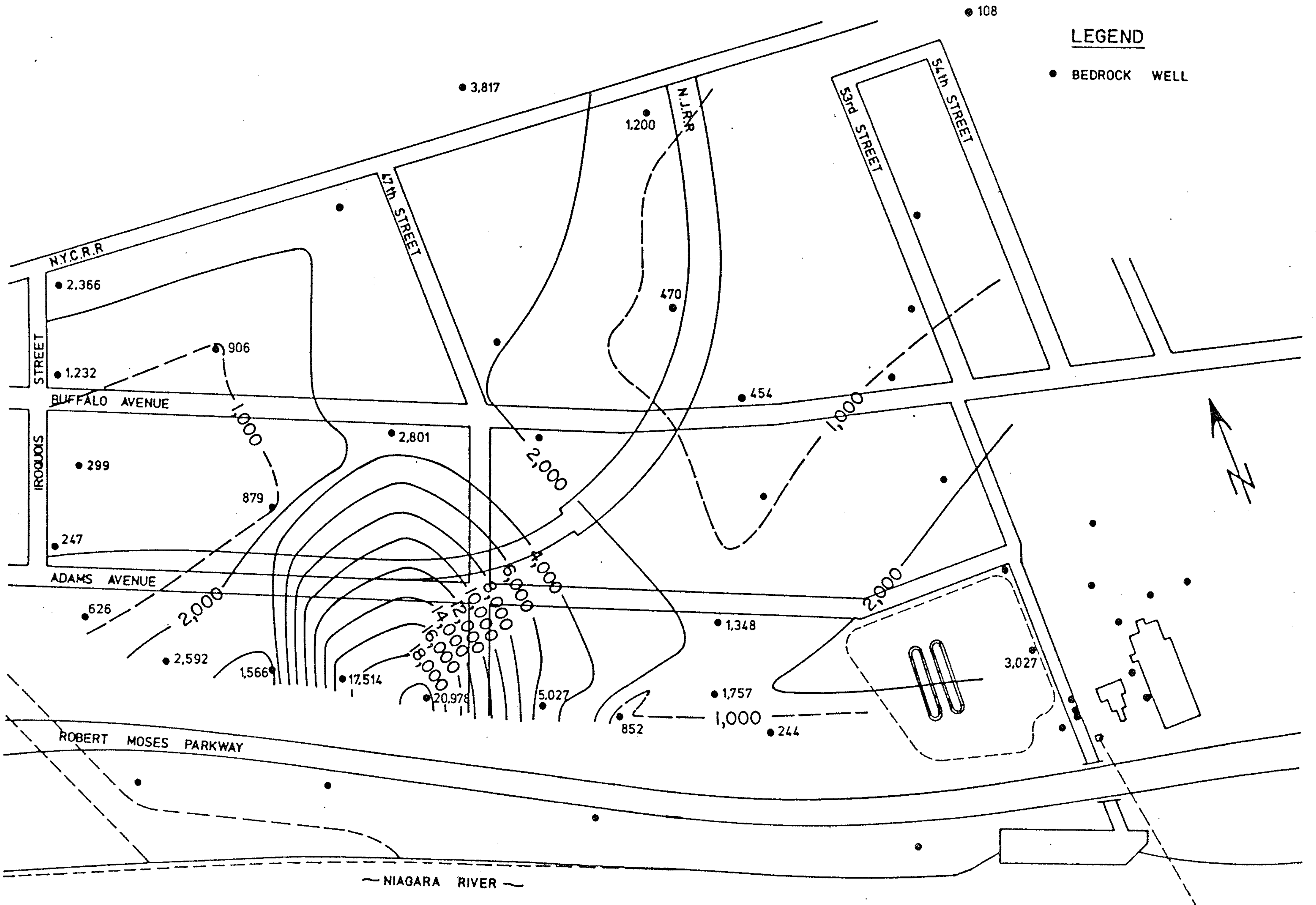

Figure 34. Contour diagram of averaged chloride (Cl) concentrations (mg/L) measured in wells screened in the upper portion of the Lockport Dolomite (or across the upper Lockport and lowermost overburden; see Table 4)

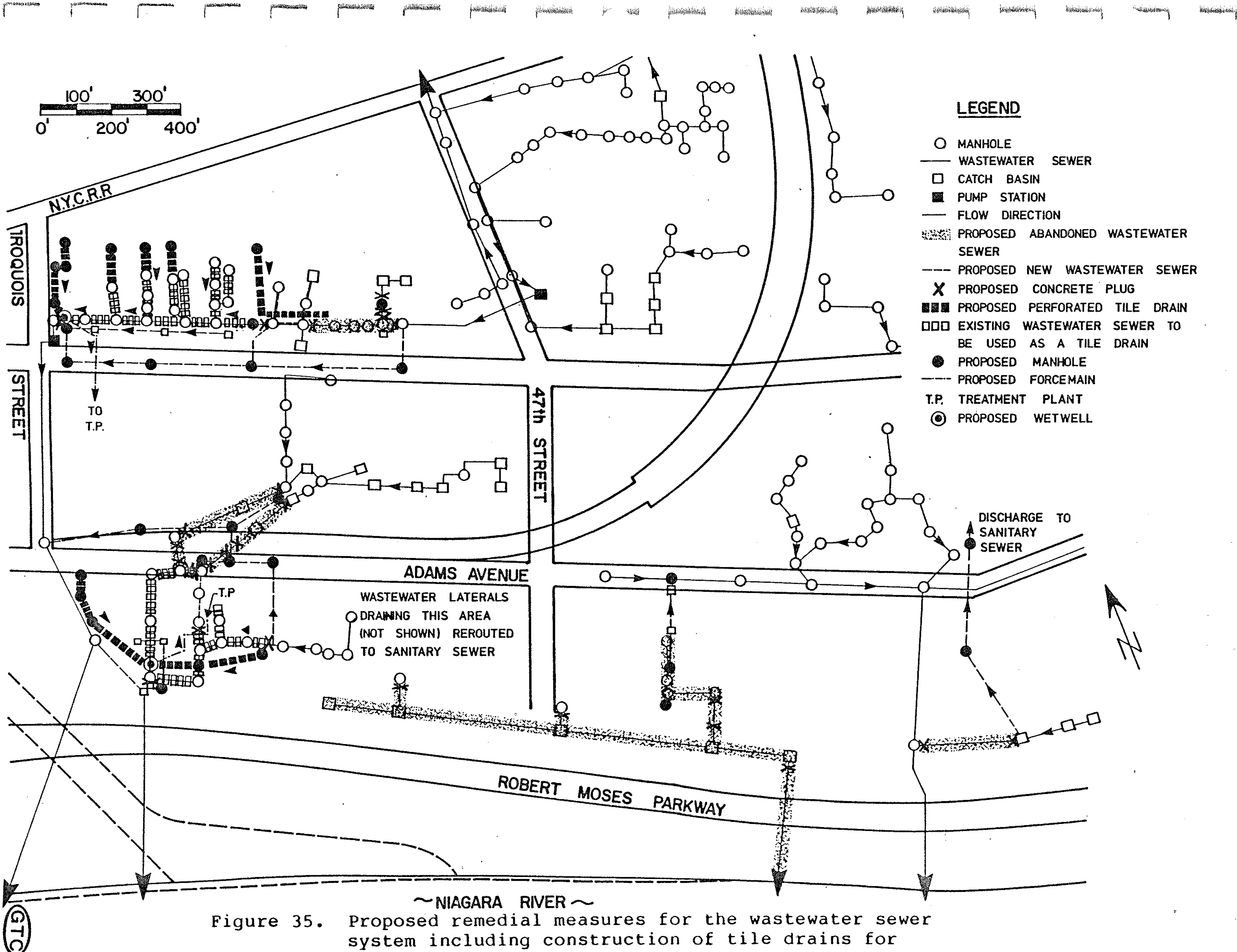

Figure 35. Proposed remedial measures for the wastewater sewer system including construction of tile drains for ground water collection (after Hooker, 1981)

APPENDIX I

Air Photo of the Hooker Niagara Plant Site (1959)

NOTE

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APPENDIX II

Regional Geology

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Regional Geology

The geology in the Niagara Falls area consists of a thin layer of unconsolidated glacial deposits overlying Paleozoic sedimentary bedrock. The unconsolidated deposits consist of glacial till overlain by glaciolacustrine clay, silt and some fine sand. The till is relatively unstratified glacial drift consisting of clay, sand and boulders. The till directly overlies the bedrock throughout the Niagara Region.

The depth of the glacial deposits varies significantly between the north and south sides of the Niagara escarpment. The Hooker Niagara Plant (HNP) is located south of the escarpment where glacial deposits are generally 5 to 15 feet thick. Thicknesses of glacially derived materials north of the escarpment range up to 90 feet thick (Johnston, 1964).

The bedrock in the Niagara area consists of relatively flat lying beds of dolomite, shale, limestone and sandstone. Formations dip to the south at about 30 feet per mile, or 0.3° (Johnston, 1964). Cross-sections through the bedrock formations are shown in Figures II.1 and II.2.

The uppermost bedrock formation in the immediate Niagara Falls area is the Lockport Dolomite, which is up to 150 feet thick throughout the Niagara area (Johnston, 1964). The thickness of the Lockport beneath the City of Niagara Falls, N.Y. varies from about 140 feet just north of the Hooker Plant site to about 100 feet beneath the power storage reservoir (see Figure 1) at the north end of the city. The Lockport formation consists mainly of dolomite along with thin beds of limestone and shaly dolomite. Five distinct zones within the Lockport were identified by Johnston (1964). From uppermost to lowermost these zones are:

a) brownish-grey, coarse-to medium-grained dolomite, locally saccharoidal (finely textured) with thin intervals of curved bedding (algal structures)

b) grey to dark grey, fine-grained dolomite, containing abundant carbonaceous partings

c) tannish-grey, fine-grained dolomite

d) light grey, coarse-grained limestone containing abundant crinoid fragments (Gasport Limestone Member)

e) light grey, shaly dolomite, laminated in part (Decew Member).

Most of the beds in the Lockport formation are described as "thick" (1 foot to 3 feet), or "thin" (1 inch to 1 foot); however, massive beds up to eight feet thick and very thin beds (1/4 to 1 inch) occassionally occur within the formation (Johnston, 1964). The bedding is normally straight, but some curved bedding exists. Several extensive and open bedding joints exist throughout the Lockport Dolomite.

The Rochester Shale formation, part of the Clinton Group, immediately underlies the Lockport Dolomite. Johnston (1964) also provides a discussion of the geology of the Clinton and underlying Albion Groups and the Queenston Shale (Figure II.2). "The Clinton and Albion Groups are a series of shales, sandstones, and limestones which crop out along a narrow belt parallel to the Niagara escarpment. The Clinton rocks are composed principally of the dark-grey Rochester Shale at the top, but also contain two thin limestones (Irondequoit and Reynales) and a thin shale (Neahga) at the base. The Albion Group underlying the Clinton consists of two thin sandstones which are separated by a sequence of alternating shale and sandstone".

"The Queenston Shale, beneath the Albion Group, consists mostly of brick-red, sandy shale and thin beds of greenish-grey shale and greenish-grey sandstone. The thickness of the Queenston is 1,200 feet. However, only 200 feet are exposed in the area; the remainder of the formation crops out under Lake Ontario".

Laboratory tests conducted on the Lockport have indicated that the formation is structurally sound and durable when subjected to many cycles of freezing and thawing, or wetting and drying (American Falls International Board, 1974). The Rochester shale, which underlies the Lockport, and the shale beds in the Neahga, Grimsby and Queenston Formations are, on the other hand, weaker and less durable; breaking down when subjected to similar tests (American Falls International Board, 1974).

Soils in the Niagara area are slightly acidic, dark greyish to reddish-brown silty clay loam overlying slightly acidic compact, mottled reddish-brown silty clay with few stones (Experimental Farms Service, 1935).

Topography can be described as smooth and undulating with very little relief except for the Niagara Escarpment and the Niagara River Gorge.

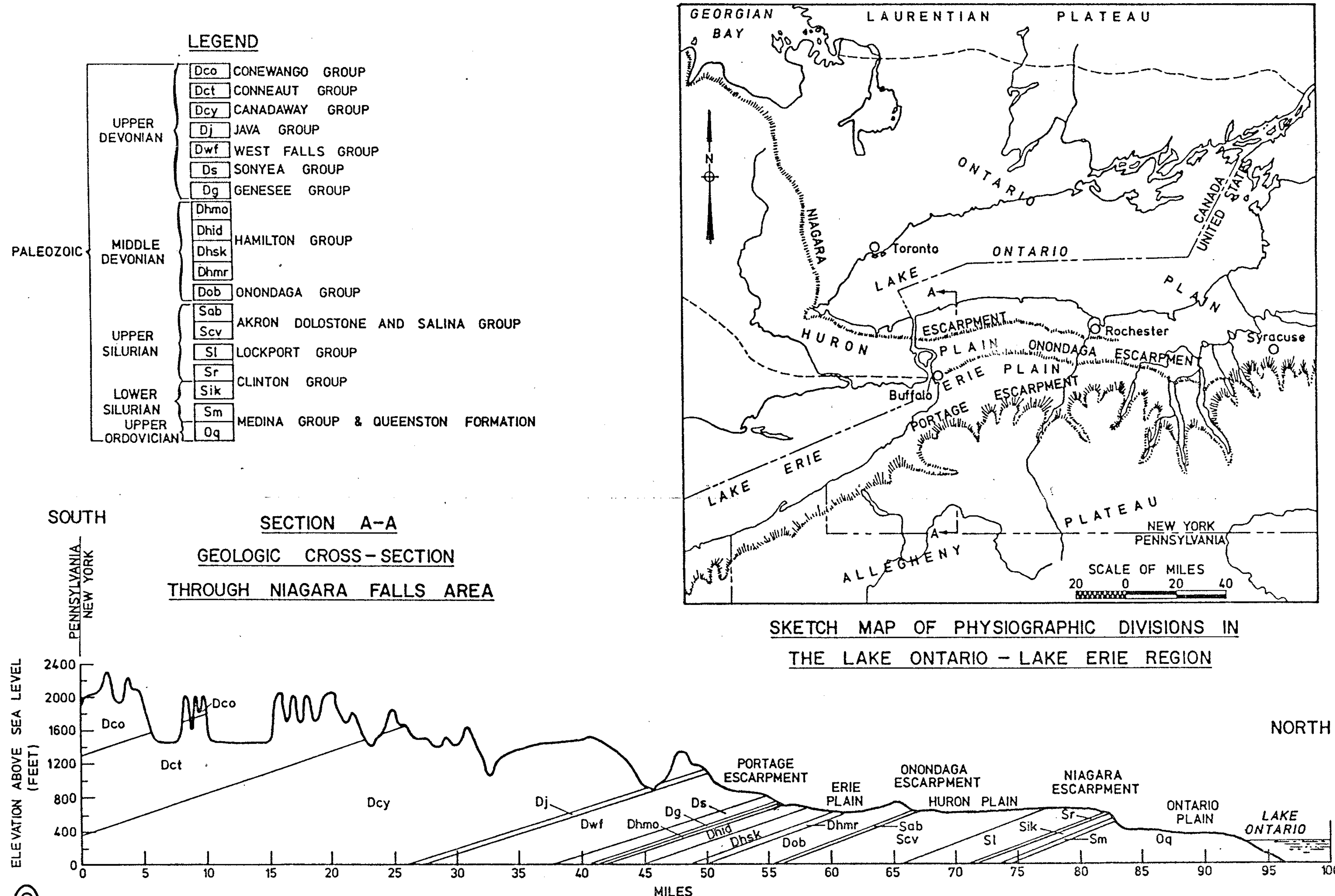

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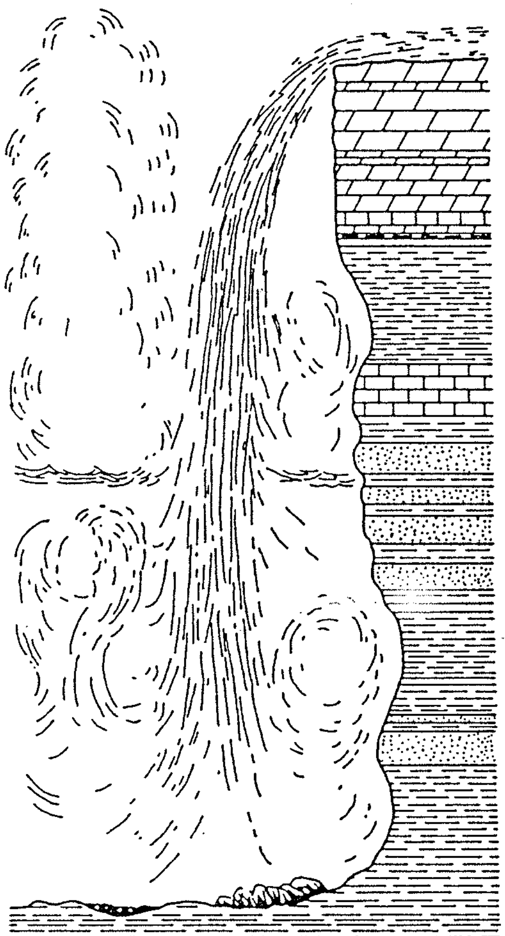
Figure II.1 Regional geology of the Niagara Falls area (after American Falls International Board, 1974)



System		Group	Formation	Thickness (feet) 1/	Description
Silurian	Middle		Lockport Dolomite	150	Dark-gray to brown, massive to thin-bedded dolomite, locally containing algal reefs and small, irregularly shaped masses of gypsum. At the base are light-gray, coarse-grained limestone (Gasport Limestone Member) and gray shaly dolomite (DeCew Limestone Member of Williams, 1919).
Silurian	Middle	Clinton	Rochester Shale	60	Dark-gray calcareous shale weathering light-gray to olive.
Silurian	Middle	Clinton	Irondequoit Limestone	12	Light-gray to pinkish-white coarse-grained limestone.
Silurian	Middle	Clinton	Reynales Limestone	10	White to yellowish-gray shaly limestone and dolomite.
Silurian	Middle	Clinton	Neahga Shale of Sanford (1933)	5	Greenish-gray soft fissile shale.
Silurian	Lower	Albion	Thorold Sandstone	8	Greenish-gray shaly sandstone.
Silurian	Lower	Albion	Grimsby Sandstone of Williams (1914)	45	Reddish-brown to greenish-gray cross-bedded sandstone interbedded with red to greenish-gray shale.
Silurian	Lower	Albion	Unnamed unit	40	Gray to greenish-gray shale interbedded with light-gray sandstone.
Silurian	Lower	Albion	Whirlpool Sandstone		White, quartzitic sandstone.
Ordovician	Upper		Queenston Shale	1,200	Brick-red sandy to argillaceous shale.

1/ Average figure for area. Thickness at falls is not necessarily the same.

Figure II.2 Bedrock formations in the Niagara Falls area as exposed at the Horseshoe Falls (from Johnston 1964)

APPENDIX III

<u>Full Size Isometric (30°) Projections</u>
<u>of the</u>
<u>Hooker Niagara Plant Stratigraphy</u>
<u>and Wastewater Sewer System</u>

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APPENDIX IV

Regional Hydrogeology

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Regional Hydrogeology

Glacial Deposits

In the Niagara Falls region, the water table is located in the glacially derived materials and tends to reflect the topography at a depth of several feet below the land surface. Because the topography is quite flat, horizontal gradients in the overburden are low. The relatively impermeable clays, silts and tills limit regional ground water movement in the overburden to relatively small amounts. The strongest gradients which exist are generally downwards. This downward flow path is the principal means of bedrock recharge on a regional scale.

Bedrock

Lockport Dolomite

The Lockport Dolomite is the only important aquifer within the Niagara Falls area. Within the Lockport, ground water is present in bedding joints, vertical joints and solution cavities. Of these, bedding joints are believed to be the dominant mechanism of ground water flow (Johnston, 1964). The nearly horizontal bedding joints, which follow the dip of the formation, are usually less than 1/8 inch in size although some have been enlarged by gypsum dissolution (Johnston, 1964). The bedding joints are of much higher permeability than the surrounding bedrock. The bedding joints are fairly continuous in areal extent (observed in PASNY conduit excavations over distances of up to 3 or 4 miles) so that groundwater may flow over long distances within a single bedding joint. Johnston (1964) identified seven distinct water bearing bedding joints within the Lockport formation. Piezometric levels within these joints were found to drop progressively with depth.

Ground water movement through vertically oriented joints is relatively significant in the top 10 to 15 feet of the formation (Johnston, 1964). In this zone, weathering and dissolution has widened the joints and created a relatively good aquifer at the top of the dolomite. This upper zone is generally considered much more permeable than the remainder of the sedimentary formations in the area.

Recharge to the Lockport over the entre region occurs by a number of mechanisms, of which infiltration from precipitation dominates. This infiltrating water enters the water bearing bedding joints in the bedrock via two means (Johnston, 1964): 1) downward movement of water through the vertical joints and 2) recharge directly to the water-bearing zones at the outcrop of the bedding planes. The latter is likely the most important since the major vertical jointing is confined to the top 10 to 15 feet of the bedrock (Johnston, 1964). Precipitation reaches the Lockport throughout the region by migrating through the glaciolacustrine sediments and glacial till. Somewhat higher recharge rates are believed to occur along the Niagara Escarpment where overburden is thin or absent.

In the immediate area surrounding Niaara Falls, N.Y., additional means of recharge exist. One of the important recharge sources is the 1900 acre storage reservoir (see Figure 1) operated by the Power Authority of the State of New York (PASNY). This reservoir averages 25 feet in depth with a 20 foot variation from low to high level (Johnston, 1964). The water in the reservoir is retained by clay-cored earth and rock-fill dykes. Approximately 10 feet of clay and silt overlie the Lockport beneath the reservoir, and the entire depth of the Lockport below the dykes was grouted to prevent seepage losses. However, monitoring wells indicate that substantial leakage occurs. Upon filling the reservoir in 1961, "significant increases in water levels were observed in the upper part of the bedrock, and locally artesian flow commenced" (Johnston, 1964). The reservoir represents a permanent and significant source of bedrock recharge in the Niagara Falls area.

The Niagara River is a source of bedrock recharge in locations such as between the City of Niagara Falls Water Treatment Plant (east of the Niagara Plant Site) and the Falls, where a positive head differential exists between the river and the Lockport. In many areas the river bottom remains covered by glacial sediments and these along with any accumulated bottom sediments impede direct recharge to the bedrock. However, areas of high bedrock recharge are known to exist in a 1/2 mile section of the river about 2 miles upstream of Niagara Falls (Johnston, 1964). In this section of river, fast moving water has apparently removed the bottom sediments, allowing a good hydraulic connection directly to bedrock.

Several high yield industrial wells located along the river take advantage of the good interconnection between the river and the upper Lockport. The Olin Corporation plant, located about 2 miles upstream of the Falls, operates 2 wells with an average total pumping rate of 5400 gallons per minute (G. Pietraszek, NYSDEC, personal communication, 1982). Both wells are located in the bedrock and are believed to create a marked influence on the ground water flow conditions in the immediate vicinity of the Olin Plant. However these wells are likely in good hydraulic connection with the Niagara River such that the zone of influence from pumping does not reach as far as the HNP site.

Clinton and Albion Groups

The uppermost formation of the Clinton Group is the Rochester Shale, which directly underlies the Lockport Dolomite. The hydrogeologic characteristics of the Rochester Shale have been the subject of concern between various parties in the recent Hyde Park Settlement Agreement proceedings. The opposing viewpoints on the shale can be stated as:

- The Rochester Shale is virtually impermeable and contaminant transport through the shale is negligible;

- The Rochester Shale contains a sufficiently interconnected fracture system to allow significant contaminant flux, principally in the vertical direction, to the underlying limestone/sandstone sequences which subsequently transport the contaminants to the Niagara River.

A recommended field investigation and hydraulic testing program has been recently submitted (GTC, 1982a) which included suggested minimum requirements for quantitative evaluation of the shale's hydraulic characteristics. The potential for contaminant transport across the shale can be inferred from the proposed hydraulic testing program. Actual tracer tests across the shale could be conducted with the proposed instrumentation if sufficient hydraulic connectivity is found.

The Rochester Shale is described as "massive" (American Falls International Board, 1974), with few joints, or fractures. The American Falls International Board report indicates the existence of apparent water bearing (stained) fractures is limited as one goes inland from the gorge face. Horizontal drillholes indicated fracture spacing varied from inches to tens of feet, with spacing increasing further away from the gorge. Their investigation was related to the rockfall areas around the Falls and, therefore, the data are concentrated in that area.

In the shale the vertical joints represent the most significant pathways for potential contaminant transport. It is virtually impossible to utilize a vertical borehole drilling and well/piezometer instrumentation program to evaluate widely spaced vertical joints. As a result, any existing boreholes, or new vertically oriented boreholes, are unlikely to provide the necessary information. The recommended borehole drilling, testing and instrumentation program (GTC, 1982a) utilizes inclined boreholes to evaluate the vertical hydraulic continuity across the shale.

At this point it can only be stated that the role of the Rochester Shale with respect to contaminant transport in the general Niagara Falls area is uncertain. However, it is clear that the overall permeability of the Rochester is quite low and that the volumetric flux of contaminants through the shale is unlikely to be as significant as the contaminant flux in the Lockport.

With regard to the role of the Rochester and other lower formations in a regional hydrogeologic context, the following discussion is excerpted from Johnston (1964).

"The Clinton and Albion Groups are little utilized as sources of ground water, mainly because they are overlain everywhere, except along the Niagara escarpment, by the more productive Lockport Dolomite. Accordingly, not much is known about their water- bearing properties. In general, the limestones and sandstones are the most permeable units in the Clinton and Albion Groups. The abundance of both vertical and bedding joints in outcrops and quarries in the limestones and sandstones suggests that they are as permeable as the Lockport. However, the position of the relatively impermeable Rochester Shale at the top of the Clinton Group drastically limits recharge to the more permeable sandstones and limestones below. As a result the uppermost part of the more permeable limestone units in the Clinton Group is dry in many places. Because of the lack of recharge, the average yield of wells in the Clinton and Albion Groups is only 2 to 3 gpm which is adequate only for small domestic and farm supplies".

Queenston Shale

The Queenston Shale is relatively insignificant to the overall hydrogeologic regime under discussion in this report, other than to represent a definitive lower boundary to the active hydrogeologic regime. The following discussion is also excerpted directly from Johnston (1964).

"Ground water occurs principally within a fractured and weathered zone at the top of the shale. This zone, according to drillers, is generally less than one foot thick. The unweathered Queenston Shale is less permeable than the overlying rocks in the Clinton and Albion Groups and much less permeable than the Lockport Dolomite. Considerable difficulty is experienced in developing adequate water supplies in areas where the fractured zone at the top of the Queenston is dry."

PASNY Conduits

A pair of subsurface conduits, each with a flow area of 2800 square feet and height of 70 feet, transport water beneath the city of Niagara Falls from the upper Niagara River to the PASNY power storage reservoir (see Figure 1). These conduits are located in the bedrock and slope to the north at about 3.2 feet/mile. The conduits are lined with concrete and constructed to prevent flow either in or out. There is, however, an external system of drains beneath and to the sides of the conduits. These drains are likely well connected to the Lockport Dolomite ground water system. The drain system is constructed such that when the ground water table rises above a certain elevation, inflow to the conduits will occur over a weir type structure. These weirs are located in 2 pump stations along the conduit length and are placed at an elevation which is believed to be slightly above the local water levels such that differential water pressures between the inside and outside of the conduits do not become excessive. The effect of the conduits on the regional ground water flow system is uncertain since a comprehensive water level measurement program has not been undertaken since completion of the Niagara River Power Project.

However, the drain system located along the entire length of the conduits likely provides excellent vertical hydraulic connection throughout the greater portion of the Lockport Dolomite. At the conduits' intake structures, located in the southwest portion of the HNP site, the conduits' excavations extended to within 75 feet of the bottom of the Lockport. The depth of the conduits increases to the north at the rate of 3.2 feet per mile, while the bottom of the Lockport rises at about 15 feet per mile. The Lockport Dolomite is fully penetrated by the northern portions of the conduit excavations as well as by the open canal leading from the reservoir to the gorge.

APPENDIX V

<u>Overlays of Isometric (30°) Projection</u>
<u>of the Wastewater Sewer System</u>

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APPENDIX VI

Summary of Datums in the Niagara Falls Area

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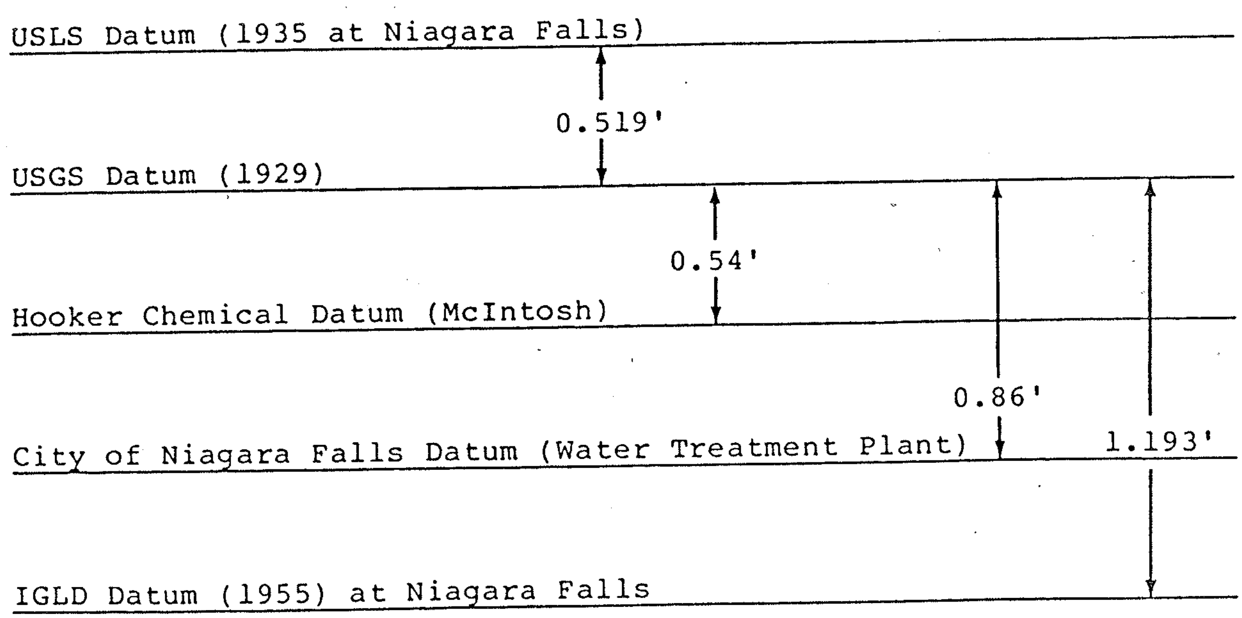
Summary of Datums in Existence in the Niagara Falls Area

(from Leggette, Brashears and Graham, 1980b)



APPENDIX VII

Overlays of Concentrations of Organics in Overburden Monitoring Wells

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