REPORT

HYDROGEOLOGIC ASSESSMENT OF THE ALLIED WASTE BEDS IN THE SYRACUSE AREA

VOLUME 1 OF 2

Allied-Signal, Inc.

Solvay, New York

April 1989

BLASLAND & BOUCK ENGINEERS, P.C.
BLASLAND, BOUCK & LEE
ENGINEERS & GEOSCIENTISTS

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SOLVAY, NEW YORK

APRIL 1989

BY

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April 10, 1989

Mr. Alfred J. Labuz
Superintendent of Env. Control
Allied-Signal Inc.
Environmental Control
& Product Safety
P.O. Box 6
Solvay, New York 13209

Re: Hydrogeologic Assessment of the Allied Waste Beds in the Syracuse Area

File: 131.02 #2

Dear Al:

Blasland & Bouck Engineers, P.C. is pleased to submit to Allied-Signal the "Hydrogeologic Assessment of the Allied Waste Beds in the Syracuse Area." This report has been prepared in accordance with a Consent Order Agreement, Case No. R7-0058-85-11 between Allied-Signal and the New York State Department of Environmental Conservation.

A detailed Feasibility Study is being prepared as a separate document and will analyze whether or not there is a need for remediation activities. The Feasibility Study will also evaluate appropriate remediation technologies that may be applicable, if any are found to be necessary.

We have appreciated this opportunity to provide professional services related to this project, and we will address any questions or comments you may have at your convenience.

Very truly yours,

BLASLAND & BOUCK ENGINEERS, P.C.

Tyler E. Gass

Tyler E. Gass, C.P.G.
Vice President

TEG/mey
Enclosures

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SECTION 1 - EXECUTIVE SUMMARY

In accordance with a Consent Order Agreement signed February 12, 1987 between Allied-Signal Inc. (Allied) and the New York State Department of Environmental Conservation (NYSDEC), a Hydrogeologic Assessment has been performed to determine the impact that the Allied Waste Beds and suspected former waste disposal areas have had on local ground-water and surface water resources.

The largest and "youngest" of the waste beds are located within the Nine Mile Creek Valley with progressively "older", and generally smaller, waste beds located along the shores of Onondaga Lake from the mouth of Nine Mile Creek, southeastward to the southeast end of the lake. Suspected "older" waste disposal areas were believed to be located along the southeastern end of the lake, the lower section of Ley Creek, and along other sections of the Onondaga Lake shore.

The assessment included an in-depth review of historic records, site reconnaissance, geophysical surveys, a drilling and well installation program, and ground-water and surface water quality sampling. Available historical information indicates that the region around the southern end of Onondaga Lake has historically been associated with natural salt brines and salt production. The salt springs that were located at the end of the lake prior to brine removal by pumping in the 1800's are thought to have derived their salt content from the same rock salt formations utilized by Allied for the production of brines used in the Solvay Process. This process utilizes salt brines along with limestone to produce sodium carbonate (soda ash). The wastes from the process are known as Solvay Wastes and consist primarily of calcium carbonate, calcium silicate, and magnesium hydroxide with small amounts of carbonates, sulfates, salts and metal oxides. These wastes were disposed in the waste beds as a slurry comprised approximately of 5 to 10 percent solids. The solids were allowed to settle out in the waste beds, and the slurry water was removed by evaporation or decanted by drainage systems.

Site reconnaissance and, to a limited extent, water quality sampling activities were performed for all waste bed and suspected disposal areas. However, the main focus of the field investigation program was by in large, the more recently active waste beds in the Nine Mile Creek Valley.

Based on a review of available historic information and site reconnaissance, it does not appear that significant volumes of Solvay Waste were placed in areas southeast of Hiawatha Boulevard. Area L, along Ley Creek, has reportedly received trash, and construction and demolition materials, but there is no verification that Solvay Waste was placed in this area.

No indication of Solvay Waste was observed or recorded for the Onondaga Lakefront (OLF) areas on the northeast and southwest sides of the lake. Natural salt springs have been reported along the northeast OLF, which fed "salty ponds" along Onondaga Lake Parkway.

During the last 19 years, Nine Mile Creek has been periodically monitored by other parties. This monitoring has indicated that Nine Mile Creek has been a significant contributor of chlorides to Onondaga Lake. Sampling performed as part of this investigation indicates that ground water is a significant source of chloride contribution to Nine Mile Creek.

The primary concern with the waste beds pertains to the potential impact that the leachate has on surface and ground-water resources in the area. The principle components of the leachate consist of calcium and sodium chlorides. Chlorides have been alleged by others as a potential cause of density stratification in Onondaga Lake which may delay the oxygenation of the deeper waters of the lake during spring and fall lake turnover.

Subsurface investigations reveal that the bedrock underlying the Nine Mile Creek Valley is a deep east-west trending erosional channel that was cut into the underlying Vernon Shale as a result of glacial melt-water runoff. This "cross-divide channel" then joins the deeper glacially scoured bedrock underlying Onondaga Valley. The Nine Mile Creek bedrock channel was subsequently filled with up to 130 feet of sands, gravels, silts and clays through a variety of natural depositional processes. These sediments were deposited such that the coarser and generally more permeable material is generally thicker and more extensive in the vicinity of Waste Bed 13, with finer, generally less permeable materials filling the remainder of the bedrock valley. In most areas a layer of silt and clay is present at the ground surface, which extends to varying depths within the valley.

Ground-water flow within the sediments is from the sides of the valley towards its center, as well as along the longitudinal axis of the valley towards the lake. In the areas west of Waste Bed 13, Nine Mile Creek is discharging to ground water and is, therefore, a "losing" stream. Near Waste Bed 13, ground water begins to discharge to the stream and the stream becomes a "gaining" stream. This is a result of ground water moving down the valley, within the more permeable deposits, and then being discharged to the surface as it encounters the less permeable sediments further down the valley.

Surface water samples indicate that concentrations of chloride, calcium and sodium increase in Nine Mile Creek as it flows towards Onondaga Lake. Chloride concentrations monitored in 1987 indicate an increase from 47 mg/l upstream of the waste beds, to 1,200 mg/l downstream of the beds at State Fair Boulevard.

Ground-water samples indicate increased concentrations of chlorides, calcium and sodium with depth within the Nine Mile Creek Valley. Samples obtained from some of the deeper wells within the valley indicate that ground-water quality may be impacted by natural brines within the Nine Mile Creek Valley. Chloride concentrations from 1987, which increase with depth to 61,000 mg/l in the deepest monitoring well installed during this investigation, indicate that density stratification of ground water is occurring in the valley.

Based on leachate samples from older waste beds, concentrations of chlorides, calcium and sodium decrease by up to two orders of magnitude with increasing age of the bed. This indicates that as the beds age, the impact of the bed on the surrounding surface water and ground-water bodies decrease. In addition, based on historic information, the total loading of chlorides to Nine Mile Creek has decreased from approximately 4,000 tons/day in the early 1980's, to approximately 400 tons/day in 1987.

Chloride loadings from the waste beds were estimated for the year 1987 based on the calculated amount of infiltration through the waste beds and the concentration of the typical waste bed leachate.

A flow and chloride loading balance was performed using 1987 data for Nine Mile Creek Valley which determined that a significant percentage of the chloride loading to Nine Mile Creek, and eventually Onondaga Lake, is a result of ground-water discharge from the sediments in the valley bottom. The primary contributors of chlorides to the lake via Nine Mile Creek are Waste Beds 9-15, two tributaries (Geddes Brook and Beaver Meadow Brook), and ground water that discharges to the creek. Ground-water sources include chlorides that have historically leached from the waste beds, as well as naturally-occurring brines.

Nine Mile Creek discharged approximately 62 percent of the total chloride loading to Onondaga Lake in 1987. Of this discharge, Beds 9-15 contributed approximately 5 percent, the two tributaries 6 percent, and calculated ground-water deficit discharges contributed approximately 51 percent of the total creek loading to the lake. Waste Beds 12-15 also contributed chlorides to the lake via the Metropolitan Sewage Treatment Plant (Metro). Leachate from these beds was pumped to Metro, and a portion of the chlorides from the leachate were discharged to the lake.

Conditions are anticipated to improve over those observed in 1987 as a result of the discontinuance of operations at Allied, the continued decline in leachate concentrations with time due to flushing of the waste beds, and the slow flushing of the sediments in Nine Mile Creek Valley. Also, LCP Chemicals-NY (A Division of the Hanlin Group, Inc.), which has historically discharged wastewater to Waste Bed 14, has temporarily discontinued operations as a production facility and no longer contributes to the chloride loading associated with Waste Beds 12-15.

This report also presents an overview of potential remedial technologies which could be performed at the waste beds to reduce the chloride loadings to the ground-water and surface water systems in the area. Potential technologies include those to address the waste beds themselves, and separately to address ground water with high chloride concentrations. The range of potential technologies reviewed that address the waste beds are:

- No Action;
- Grading, Cover & Vegetation;
- Grading, Low-Permeability Cap, and Vegetation;
- Grading, Low-Permeability Cap, Ground-Water Cutoff Wall, and Vegetation;
- Incorporate Sludge and Vegetation; and
- Excavation and Off-Site Disposal of Wastes.

The technologies reviewed that address ground water include:

- No Action;
- Leachate Discharge Control;
- Ground-Water Withdrawal and Discharge; and
- Ground-Water Withdrawal and Treatment.

It appears that a number of remedial technologies exist which could be applied to the waste bed area and provide a decrease in chloride loadings from the waste beds. The potential reduction in chloride loadings due to implementation of various remedial technologies will subsequently be addressed in a Feasibility Study (FS).

The FS will also identify appropriate objectives for potential remedial actions based on human health and environmental considerations. In addition, the FS will identify potential remedial technologies for different groups of waste beds or specific waste beds and study these technologies in detail. This analysis will include an assessment of technical and institutional feasibility, compliance with response objectives and criteria, implementability and cost-effectiveness. Finally, the FS will compare the various remedial alternatives on a waste bed group or waste bed-specific basis and provide recommendations as to the appropriate level of remediation for each of the waste beds or groups of waste beds.

The FS has been initiated based on a Work Plan for the report, which has been separately submitted to the NYSDEC. It is anticipated that the FS will be prepared over the course of the next nine months (completion date - 1/10/90), with on-going review by the NYSDEC of report sections as they become available.

It should be noted that remedial measures for the waste beds may have a limited effect on reducing the overall chloride concentrations to Onondaga Lake. Based on a chloride loading analysis for 1987, chloride loadings attributable to Waste Beds 1-15 accounted for approximately 12 percent of the total chloride loading to the lake. This percentage represents the chloride loadings due to infiltration through the waste beds, the contribution of LCP wastewater, erosion, and the leachate that is collected from Beds 12-15 and pumped to Metro for subsequent discharge to the lake.

Data analyses and calculations indicate that approximately 52 percent of the total chloride loading to Onondaga Lake in 1987 was attributable to ground-water discharges. In addition, it appears that more than half of the chloride loading to ground water discharging to the lake in 1987 is related to Allied's previous operations.

Recent observations and data recorded by several sources indicate that chloride loading to Onondaga Lake has decreased since 1987 and will continue to decrease with time. The decline in chloride loading is attributable to several factors. First, the natural flushing of chlorides from the waste beds; second, the gradual dewatering of the waste beds; and third, an increase in vegetation density occurring on the waste beds which results in a reduction of the amount of precipitation available for infiltration through the waste beds.

SECTION 2 - INTRODUCTION

2.1 General

The closure of Allied's Syracuse Works in Solvay, New York has resulted in the evaluation of the environmental impacts associated with Allied's past operations. As part of the plant closure program, attention has been directed at the large areas known as waste beds, or settling basins, that have accepted the by-products of the Solvay Process operation over the years.

The NYSDEC has expressed concern over the environmental impacts that the known waste beds and the areas suspected of having received Solvay Waste, which may have been in use as early as 1881, have on the ground-water and the surface water resources in the area. These waste beds and areas of suspected disposal are shown on Figure 1.

This report presents the results of the Hydrogeologic Investigation of the waste beds and their surroundings, including an analysis of their impact on ground water and surface water in the area. The report also presents an overview of appropriate remedial technologies which could be used to address environmental conditions associated with the waste beds.

This Hydrogeologic Investigation was implemented in accordance with an Order on Consent, Case No. R7-0058-85-11, signed February 12, 1987 between Allied and the NYSDEC. All investigative efforts were performed in accordance with the approved Work Plan, which outlined the procedures for the Hydrogeologic Field Investigation Program.

Section 3 of this report presents a history of the area and the individual waste beds. Section 4 presents a general characterization of the site, as well as the results of the field investigation program and the assessment of the impact on water quality. Section 5 presents a review of remedial technologies that may be applicable to the subject waste beds and/or ground water. Volume 2 of this report contains the field methods used during the investigation, as well as a summary of field data generated during the investigation.

2.2 Objectives

The objectives of this Hydrogeologic Assessment Program are as follows:

- Delineate the waste beds and areas where Solvay Waste may have been deposited, as well as identify the method and time period of deposition;
- Define the natural ground-water and surface water flow systems in the area;
- Define the degree of hydraulic connection between the waste beds and the surface water and ground water in the area;
- Characterize the chemical nature of Solvay Waste leachate and determine the concentration of the leachate originating from the waste beds and waste areas. Identify the leachate flow paths from the beds into the surface water and ground-water systems;
- Determine the effect waste bed age has on leachate quality;
- Evaluate the impacts that waste bed leachate has on ground-water and surface water quality; and
- Identify potential remedial technologies that may control, or reduce, the impact of Solvay Waste leachate on the quality of area water resources.

2.3 Background

The Solvay Process Company began operations in the Syracuse area in 1881. In 1920, several companies merged with Solvay Process and the name was changed to Allied Chemical & Dye Corporation. The name was changed in 1957 to the Allied Chemical Corporation and changed again in 1981 to Allied Corporation. In 1985, Allied Corporation merged with the Signal Companies, Inc. to form Allied-Signal Inc., a holding company.

The Solvay Process is a method of forming sodium carbonate (soda ash) from limestone and brine. The process is named for two Belgian brothers who devised the method. Syracuse, New York was selected as the location for the first plant in the United States because the necessary raw materials were readily available. Railroads delivered the coal which was used to produce steam and to burn the limestone. Limestone was available from local quarries and the salt was available from local springs and brine wells.

The location of the investigation has been divided into four areas for presentation and analysis purposes. The areas are Waste Beds 9-15, Waste Beds 1-8, Waste Beds A-E, and possible Waste Disposal Areas F-M including OLF (Onondaga Lakefront). These divisions are based not only on geographic location, but on history of use or suspected use, age, and the amount of data available. Figure 1 shows the locations of the waste beds and possible waste disposal areas.

Waste Beds 9-15 have been in operation from 1944 to 1985. These Beds were all engineered for the purpose of receiving Solvay Waste from Allied's operations. Data pertinent to this investigation were readily available for this group of Beds.

Waste Beds 1-8 were recipients of Solvay Wastes from approximately 1916 to possibly as late as 1950. This group of Beds has had other waste placed on it by another industry in the late 1970's and 1980's. A good deal of information exists on the other waste activities for these Beds, but little exists concerning the deposition of Solvay Waste.

Waste Beds A-E as a group were active in receiving Solvay Waste from approximately 1889 to 1926. In addition, Bed A was used from approximately 1920 to 1970 for the disposal of Semet Solvay tar wastes which were placed on top of Solvay Waste. Bed B was engineered for receiving Solvay Waste by constructing a bulkhead into Onondaga Lake. Sewer sludge was placed in trenches on Bed B by the City of Syracuse. Limited data are available on Waste Beds A-E.

Little data are available on Areas F-M and OLF in comparison to the amount of information available for the other waste beds. These areas (and suspected areas) were the first to receive Solvay Waste, with documentation existing back to 1892. In general, these areas became inactive between 1926 to 1930. These older beds have had the greatest change in land use of any of the other waste beds. The area designated as OLF is classified as a suspected fill area.

2.4 Solvay Process Waste Characteristics

The chemical and physical characteristics of the Solvay Waste material found in the beds are a function of: 1) the manufacturing process from which the waste was produced; 2) other wastes which may have been placed concurrently with the Solvay Wastes (e.g. fly and bottom ash); 3) the age, construction and size of the waste bed; and 4) cover material added to the top of the waste beds after the deposition of Solvay Wastes ceased.

Detailed information, however, is not available concerning all of the above variables and the information that is available has come from a variety of sources. The available chemical and physical characteristics are summarized in Tables 1 and 2 and is briefly reviewed below.

The chemical component of greatest quantity in Solvay Waste is calcium carbonate (20 percent), followed by lesser amounts of calcium silicate (17 percent), magnesium hydroxide (10 percent) and smaller amounts of other carbonates, sulfates, salts and metallic oxides (Table 1). Relative concentrations of ten metals and several other parameters were determined by Calocerinos & Spina (1980a) by analyzing a mixture of 10 grams of Solvay Waste and 90 grams of water. These results are included in Table 1 and show that Solvay Wastes have a high alkalinity (9,380 ppm) and relatively high concentrations of iron and aluminum. Also included in Table 1 are results from EP Toxicity testing performed on samples of Solvay Waste.

The Solvay Wastes were hydraulically placed as a slurry of about 90 to 95 percent water and 5 to 10 percent solids. When a bed filled up with slurry, another bed was used while the first bed dewatered by drainage and evaporation. This produced a layered "sediment" in which distinct bedding occurs because of cementation of the waste, or because of the fly ash and/or clinker included with original Solvay Waste.

Numerous physical tests have been conducted on Solvay Wastes, the results of which are included in Table 2. These test results indicate there is great variability in the grain size distribution of the waste material; however, it is comprised dominantly of silt and sand-sized particles. The strength of the waste material is reported to be a function of its water content and degree of post-depositional cementation as well as the proportion of ash or clinker included in the waste. Other physical parameters have been discussed by Kulhawy, et al. (1977) and include geotechnical engineering parameters which were found to be highly variable due to the variability of the components of the material and difficulties associated with obtaining the measurement in the material (Table 2).

In general, the soda ash operations at the plant have reportedly varied little with time and, therefore, the waste stream generated from this operation is also reported to have changed little. Other materials disposed of with the Solvay Wastes include fly ash and clinker from the coal burning power plant, and mercury, lead and asbestos from the sodium hydroxide and chlorine production facilities. The fly ash and clinker is probably present to some degree in all of the beds; however, the average grain size of the material is reportedly finer in the beds deposited after the mid 1950's due to an upgrading in the coal-fired power plant. Insoluble forms of mercury, lead and asbestos were deposited in the beds between 1970 and 1977 and are, therefore, only found in a few of the beds.

Because the Solvay Process has changed little with time and most other constituents added to the Solvay Waste have remained constant (with the exceptions noted above), the waste in the various beds, when evaluated in large volumes, is anticipated, in general, to have similar physical and chemical properties. Post-depositional changes as a function of time, leaching, cementation, vegetation cover, or other factors, have altered these parameters somewhat from the original conditions.

Based on the information reviewed above and EP Toxicity results shown in Table 1, Solvay Waste, including other concurrently deposited materials, would be classified as non-hazardous.

SECTION 3 - SITE HISTORY

3.1 General History

Historical information pertaining to the history of these various areas has been obtained from readily available sources including topographic maps, historical maps and atlases, historic aerial photographs, and interviews with people familiar with the history of the area. In general, more information is available concerning the waste beds most recently in use, and the quantity of available data decreases as the ages of the waste beds increase. The data for the older waste beds have been derived from maps, site plans, or photographic references.

The area covered by the waste beds and the volume of Solvay Waste within the beds is given in Table 3. These calculations are based on measurements from aerial photographs, topographic maps and boring log data. A chronologic presentation of filling activities in all the waste beds is shown in Figure 2.

Father Simeon LeMoyne reportedly was one of the first white visitors to the area in 1653. At that time, he described a spring on the Lake Shore as a "fountain of salt water." Prior to that, and up to the late 1700's, the area was occupied by the Onondaga Indians. Subsequently, Jesuit, followed by Moravian missionaries, started traveling through the area and settlement began in the Syracuse area. In 1788, Onondaga Indians showed Comfort Tyler the salt springs on the shores of Onondaga Lake. With this "discovery" more settlers came to the area, and in 1793, Moses DeWitt and William VanVleck built the first arch with four kettles to process the salt spring water into dry salt. Much of the area around the lake at that time was swamp;

in particular, the areas where tributaries such as Nine Mile Creek, Ley Creek, Harbor Brook and Onondaga Creek flowed into Onondaga Lake.

In 1794, James Geddes began the first large scale manufacturing of salt west of the lake. In the early stages of development of the salt industry, salt water from springs was available to anyone who wanted it. In 1798, when the free-flowing springs started to dry up at the surface, a 30-foot well was drilled by the Federal Company to provide salt water. The Federal Company also built eight arches with 32 kettles for processing the salt.

As the salt industry continued to prosper and demand for salt water increased, brine wells were drilled to deeper and deeper depths to obtain the salt water. The salt industry reached its peak in 1862 with over 100,000 "salt covers" (natural evaporation method for salt processing) in operation at that time. There was an approximate average of 65 salt covers to the acre. The locations of these salt covers, as shown on historic maps, were along the southeast and northeast shores of Onondaga Lake as well as back from the lake along Geddes Brook (USGS, 1923; Hopkins, 1914; Airmap 1926; USDA, 1938). At the peak of salt industry activity, ownership of nearly all the brine wells was transferred from the State to private ownership, although the State did retain a well at the southeast end of the lake.

The Syracuse area had been steadily growing over this time and many industries became established around the lake during this period. The proximity of the Erie Canal and the railroads permitted inexpensive transportation of products and raw materials. As a result, the area experienced rapid industrial growth in this era. It was in 1881 that the Solvay Process Company began at the present location of the Allied's

Syracuse Works. Because high salinity brine was needed as part of the Solvay Process, wells were drilled to over 1,000 feet deep in areas south of Syracuse to obtain brine from rock salt deposits. Numerous wells were drilled in the Syracuse area from 1881 until 1888, when rock salt was finally encountered at a depth of 1216 feet in the center of the Tully Valley. In the 1880's, the salt industry began to decline because of the expense of drilling to obtain rock salt and the discovery of more readily available and more abundant sources of salt in Michigan, Ohio and Virginia. During the period of 1797-1904, roughly 430,000,000 bushels (over 12,000,000 tons) of salt were produced around Onondaga Lake. In 1908, the State terminated its long-established interest in the well at the south end of the lake and the salt industry in the Onondaga Salt Reservation had virtually ended by this time. However, as the salt industry declined, other industries continued to grow.

As more and more industrial and residential areas were built around the lake, the swamps and wet lands were drained and filled, and land came under cultivation. These land-use changes which occurred at waste bed locations and suspected waste disposal areas will be discussed for each waste bed or waste disposal area. Table 4 presents a list of the present owners of Waste Beds 1-15 and A-E and possible Waste Disposal Areas F-M.

3.2 History of Areas F through M and OLF

Areas F through M and the OLF parcels are included as areas that may have received Solvay Waste, as indicated in the Consent Order. Due to the length of time since the possible deposition and the amount of development in the area it is not possible, based on the information available, to delineate the exact location and thickness of waste in these areas.

These areas, which are shown on Figure 1, are located at the southeast end of Onondaga Lake, except for Area L, which is located along both sides of Ley Creek near the point where the creek enters Onondaga Lake.

These eight areas comprise some 910 acres or roughly 1.4 square miles, much of which was originally swampy lowlands (Babcock, 1854). When the lake level was lowered in 1822, a zone along the lake's edge, in places as much as 800 feet wide, was reclaimed from the lake. Between 1854 and 1860, Geddes Road was constructed across the area in the approximate location of Hiawatha Boulevard. Between 1860 and 1874, railroad tracks of the Syracuse Junction Railroad were built along the southeast end of the lake in the approximate current location of the Conrail tracks. At the lake's southern extreme, the railroad embankment cut across a small area of the lake which was filled between 1892 and 1908. The Barge Canal at the southeast end of the lake was constructed prior to 1892, and this resulted in the rerouting of the northern portion of the inflowing Onondaga Creek which originally flowed into the lake further to the northeast. The portion of Onondaga Creek channel that was cut off apparently remained in existence as late as 1908 (Dawson, 1860; Walker, 1874; Vose, 1892; USGS, 1923; Hopkins, 1908).

Early industrial activity in this area was dominated by the production of salt. Numerous salt sheds were located to the southeast of Geddes Road (Hiawatha Boulevard), on both sides of Ley Creek, and along the lakeshore northwest of Ley Creek (USGS, 1923). However, by 1926, most of the salt sheds were apparently in disuse, or had been removed (Airmap, 1926) due to the decline of the industry in the Syracuse area. With the completion of the barge canal terminal in Area M, storage of petroleum products became important in the area, principally in the vicinity of Area K and to a lesser extent Areas H and J.

Other former industrial activity in the area included: the General Chemical Company's Syracuse Works (Area K), Syracuse Reduction and Manufacturing (a fertilizer producer) in Area G, both in existence by 1926; a water gas plant located in Area G, in existence from sometime before 1926 until before 1966; the Syracuse Garbage Reduction Plant (Area G) and the Syracuse Sewage disposal facility, in existence before 1938 to the present (now Metro). Industrial facilities currently located in the area, in addition to the oil storage facilities in "Oil City" and the Metro Plant include: the city regional markets (Area L); Will and Baumer, Candle Manufacturer (northwest portion of Area L); an auto recycling facility (Area H); and a cement plant (Area H).

Filling history in this area probably began sometime shortly after the Onondaga Lake level was lowered in the early 1800's. The first historical indication that Solvay Waste had been used as fill material is shown on a 1908 map which delineated an area east of Iron Pier Park, in Area H on the lakefront, as having been filled with "soda ash refuse." The Solvay Process Company also owned property at that time in Areas F and G, part of which is now occupied by the Metro Plant. Borings conducted for design of the Metro Plant indicate that there is discontinuous and variable thicknesses of Solvay Waste fill under the site ranging from 0 feet to more than 15 feet.

Review of historical air photos shows several areas where light-colored fill materials have been deposited. In 1926 photos, large portions of Areas

F and G are covered with what appears to be Solvay Waste, and this is substantiated by the borings for the Metro Plant. In addition, a relatively small area along the southeast side of Hiawatha Boulevard in Area J appears to be receiving Solvay Waste. At the same time, a large circular area in the center of Area H and a narrow zone along the northwest side of Hiawatha Boulevard, also in Area H, appears to be filled with a light-colored material.

The 1938 aerial photos do not show the same pattern of filling as the 1926 photos. In the 1938 photos, both Areas G and J appear to be receiving "hard" fill materials (fill which is not placed hydraulically as a slurry) of variable texture, and the light-colored fill in Area F is darker, possibly indicating inactivity. The large circular area in the center of Area H is lower than the surrounding area and may have contained standing water. Between 1951 and 1959, this depressed area was filled with hard fill materials. Hard fill was placed in the southeast portion of Area L sometime prior to 1959, possibly in association with the construction of Interstate 81. This area of hard fill was greatly expanded towards the northeast in Area L by 1966. A portion of this hard fill may possibly be refuse that had been landfilled by Onondaga County during this period (Allied communication). This area appears on aerial photographs to be mostly revegetated by 1978.

Based on the historical information and aerial photos reviewed, a number of the areas at the southwest end of Onondaga Lake do not appear to have been used for deposition of Solvay Wastes. These include Areas I, K, L, M, OLF and most of J except for a narrow zone along the southeast side of Hiawatha Boulevard as previously mentioned. Small amounts of "chemical waste" had been reported to be present in the borings conducted for I-81 in Area K; however, the material in these locations appears to be laterally discontinuous. Based on this information, it is thought that the "chemical waste" is there as a result of hard fill placement in association with road construction activities and not as a result of disposal by the Solvay Process Company, or Allied.

Historical information indicates that the Onondaga Lakefront (OLF) on the northeast side of the lake was the location of the Oswego Canal as early as 1854 (Babcock, 1854; Walker, 1874). The canal was present up through 1898 (USGS, 1923). The area occupied by the canal was, in part, replaced by roads and railroads by 1926 (Airmap, 1926) and the Onondaga Lake Park by 1939 (USGS, 1939). Further road development, particularly toward the southeast, with the construction of I-81 prior to 1958, occupied more of the lakefront area.

Activity on the southwestern OLF includes several beaches towards the northwest end (Maple, Rockaway, Manhattan and Pleasant Beaches) by 1898. Apparently, little activity occurred in this area during 1938 through 1958 (USDA, 1938; USGS, 1939; USGS, 1958). Dredging of the lake bottom off the point where Nine Mile Creek enters the lake reportedly occurred sometime during the late 1960's. The dredged materials were placed behind a bulkhead along the shoreline to create an Onondaga Lake Park along this portion of the shore by 1973 (USGS, 1978).

3.3 History of Waste Beds A-E

3.3.1 Waste Bed A

Bed A is located towards the northern side of the Allied Corporation building complex and several hundred feet southwest of the shoreline of Onondaga Lake (Figure 1).

This bed is roughly rectangular in shape, slightly elongate in a northwest-southeast direction and comprises about 1.67 million square feet or approximately 38.3 acres. The surface of this waste bed is at an approximate elevation of 390 to 400 feet [National Geodetic Vertical Datum (NGVD)] with a shallow depression of some four acres in area toward the southwest end of the bed (USGS, 1978).

Based on historical atlases and maps, this area was, at least in part, reclaimed from Onondaga Lake when the lake level was lowered approximately 2 feet in 1822 (French, 1858; Dawson, 1860; Walker, 1874; Calocerinos & Spina, 1982c). The area was reportedly used for the disposal of Solvay Waste prior to about 1920 (Ackenheil & Associates, 1980). Disposal occurred within constructed dikes which were raised further after 1920 to contain "tar residues" from the Semet Solvay works. As the level of the tar residue waste was increased, the dikes were raised to contain the material. Tar residue disposal ceased at Waste Bed A in 1970 (Ackenheil & Associates, 1980).

3.3.2 Waste Bed B

Waste Bed B was constructed into Onondaga Lake along the southwest shoreline. The bed is roughly trapezoidal-shaped with the base of the trapezoid along the former shoreline. The bed covers approximately 1.21 million square feet, or about 27.8, acres including the relatively flat area between the water's edge and the raised, bermed portion of the bed. Approximately between 1898 and 1908, filling of Bed B was initiated by construction of wooden bulkheads in the lake and placement of Solvay Waste out to the bulkhead line (USGS, 1923; Hopkins, 1908). By 1926, the bed may have been partially or wholly inactive, as some vegetation appears to be growing on the dike slopes (Airmap, 1926). By 1938, the surface of the basin appears to have been heavily vegetated (USDA, 1938). Not later than 1959, the surface vegetation had been stripped from the southeast end of the area and a regular back-and-forth pattern was evident on the surface (USDA, 1959). This pattern was the result of sewage sludge disposal from the City of Syracuse (Allied Telephone Comm., February, 1987). This activity appears to have ceased by 1966 (USDA, 1966).

Between 1938 and 1951, discharges from Allied's East Flume, which ran along the base of the dike, produced a large delta of calcium carbonate into the lake of approximately 2 million square feet (USDA, 1951). The delta surface decreased in size from 1951 to 1966, but the area adjacent to the southeast end of the bed along the shoreline was filled, apparently by shoreline erosion and deposition processes (USDA; 1951, 1959, 1966). Minor modification by erosional processes of the diked area has occurred with time (USDA, 1978, 1986).

3.3.3 Waste Bed C

Bed C is located adjacent to the southwest side of Interstate 690 and southwest of Bed B. Bed C is an elongate area which runs parallel to the Interstate and covers roughly one million square feet, or about 21.8 acres.

Historical information indicates that the bed was in use for disposal of Solvay Waste by 1908 (Hopkins, 1908) and it appeared to be inactive by 1926 (Airmap, 1926). By 1951, numerous storage tanks were located near the southwest end of the waste bed (USDA, 1951).

Between 1959 and 1986, additional large buildings and other storage tanks were constructed on Bed C (USDA, 1966; USGS, 1978; USDA, 1978; USDA, 1986).

3.3.4 Waste Beds D and E

Beds D and E are located south of the southern-most extent of Onondaga Lake. They lie on the southwest side of State Fair Boulevard and are bound by a spur railroad track on the northwest and southwest sides. Interstate 690 crosses the northeast side of Bed E. Combined surface area of the two beds is roughly 2 million square feet or about 44 acres.

Historical references reveal little information concerning the time during which Beds D and E were filled (Walker, 1874; Vose, 1892; Hopkins, 1908). The filling was apparently complete by 1926, but the area was not split into separate beds until sometime between 1926 and 1938 when a railroad bed transected the area from the northwest to the southeast. Little apparent change occurred until sometime between 1951 and 1958 when I-690 and an interchange for the Interstate was constructed on the northeast portion of Bed E. Between about 1959 and 1966, several buildings were constructed on the southeast end of Bed D with little noticeable change occurring after this time.

3.4 History of Waste Beds 1-8

Waste Beds 1-8 are located on the southwest side of Onondaga Lake and extend into the lake at Lakeview Point. These irregularly shaped beds extend roughly 1.5 miles along the shoreline and are a maximum of about 0.5 mile wide. The beds cover some 13.4 million square feet or roughly 315 acres with surface elevations varying from about 385 to 430 feet (NGVD).

The beds were constructed over an area known as the Geddes Marsh (Dawson, 1860; Walker, 1874) part of which was reclaimed from the lake when the lake level was lowered early in the 1800's.

Waste Beds 1-6 were in use by 1926 (Airmap, 1926) with the original dike along the lakeshore constructed of piles and sheeting, or earthen dikes, depending on location. Beds 1-4 were in use prior to Beds 5 and 6; however, exactly how much earlier is not known (Allied drawings). Construction of Beds 5 and 6 required the diversion of Nine Mile Creek which was rerouted to the north around the perimeter of Bed 6.

Beds 7 and 8 on the southwest side of Beds 1-6 were not in use until after 1939 (USDA, 1938; USGS, 1939). Beds 1-8 remained in use through 1944 when a dike failed flooding an area along State Fair Boulevard. At that time or shortly thereafter, deposition of Solvay Wastes in Beds 1-8 ceased.

Subsequent use of these beds has included the use of Bed 5 for landfilling of wastes by Crucible, Inc., parking lots for the State Fair and sewage sludge disposal by Onondaga County. Interstate 690 was constructed over Beds 7 and 8 prior to 1958 (USGS, 1958), and the interchange for 695 and I-690 was added between 1973 and 1978 (USGS, 1978). These beds are reportedly owned by the State of New York, Fairgrounds Parking.

The waterline along the north and northeastern sides of these beds have been modified slightly by shoreline processes. This is most noticeable along the northern extreme of Lakeview Point. Based on appropriately scaled and available aerial photographs for time periods after the beds were no longer receiving Solvay Waste, wave erosion over a 30-year period (USDA, 1951; Kucera, 1981) has caused a retreat in the waterline of approximately 40 feet. The 40 feet of erosion has occurred along an estimated 440 feet of waterline. The eroded material appears to have been transported by longshore currents to the southeast, where it was deposited, forming a spit that projects southeastward into Onondaga Lake.

3.5 History of Waste Beds 9-15

Waste Beds 9-15 as a group has received Solvay Waste from approximately 1944 through 1985. The sequence of activity progressed from Beds 9, 10 and 11 to 12, 14, 13 and finally Bed 15. Bed 15 has accepted demolition debris from the Allied facility beginning in the summer of 1987. Beds 9-15 cover approximately 662.6 acres. All these waste beds are presently owned by Allied Corporation.

3.5.1 Waste Beds 9, 10 and 11

Waste Beds 9 and 10 cover approximately 73.5 acres and Bed 11 covers approximately 52.8 acres. The volume of Waste Beds 9 and 10 is estimated as 224 x 10^6 ft^3, or 8.3 x 10^6 yd^3, and the volume of Bed 11 is estimated as 161 x 10^6 ft^3, or 5.96 x 10^6 yd^3. These beds were specifically engineered for the placement of Solvay Waste.

The area covered by Waste Beds 9, 10 and 11 was originally traversed by Nine Mile Creek (Army, 1946; Babcock, 1854; Dawson, 1860; French, 1858; Hopkins, 1938; Hopkins, 1914; USDA, 1938 (Soils Map and Photos); USGS, 1923; USGS, 1939). The Creek was rerouted in 1944 (Allied, 1944) and the old creek bed was filled with natural materials from within the bed areas prior to Solvay Waste filling. Nine Mile Creek is now located along the southern boundary of Waste Beds 9, 10 and 11. For the location of these beds, refer to Figure 1.

Dikes around the perimeter and between the waste beds were constructed with natural materials, some Solvay Waste and cinders prior to waste filling. In the area which separates Beds 9 and 10 from Bed 11, there are power transmission lines which were constructed at that location sometime before 1939. This "interbed" area also follows the town line between the Town of Geddes and the Town of Camillus.

Solvay Waste placement in Beds 9, 10 and 11 started in 1944 and continued until 1968. In addition to Solvay Waste, these beds received brine purification sediments, boiler water purification wastes, boiler bottom and fly ash. After these beds were no longer used for Solvay Waste disposal, they were vegetated as part of a formal reclamation program, which proved to be very successful.

3.5.2 Waste Bed 12

Waste Bed 12 covers approximately 128.6 acres at its base (USGS, 1978; USDA, 1966). Waste has been placed in this bed to an approximate height of 55 feet (Hough, 1950). An estimate of the volume of waste is 308×10^6 ft^3 or 11.4×10^6 yd^3.

The present Waste Bed 12, 13 and 14 Areas were originally undeveloped prior to operations associated with the Syracuse Municipal Airport. The airport, which was located in this area, began its operations between 1934 and 1938 (USDA, 1938 Soils Map and Air Photographs). Bed 12 is bounded by a railroad to the north (Figure 1). The railroad was located at the present location prior to 1854 (Babcock, 1854) and is now owned by Conrail. The southern boundary of Waste Bed 12 was originally the Old Erie Canal, but the Canal was filled sometime prior to 1974 (Dames & Moore, 1974) with trash placed by the Town of Camillus.

A stream, which flowed west to east, was located within the present boundaries of Bed 12 (USGS, 1938; USDA, 1938 Soils Map and Air Photos; Army, 1946). The stream extended into the present area of Waste Bed 14. Activity associated with Allied's operations began in 1950 with an investigation of the area to determine the feasibility of placing Solvay Waste at the locations of Waste Beds 12, 13, 14 and 15 (Hough, 1950).

Dikes for Bed 12 were constructed in 1951. One of the dikes was placed on a former portion of Airport Road. The old Syracuse Airport runways were removed prior to filling of this bed. The filling of Bed 12 began sometime between 1951 and 1959. This basin received Solvay Waste, brine purification sediments, treated mercury cell waste water, boiler water purification sediments, boiler bottom and fly ash, some Willis Avenue Plant waste water, and asbestos slurry. The asbestos slurry was placed from 1968 to 1972; the treated mercury cell waste water was placed from 1970 until 1972. It was in 1972 that this bed ceased to receive wastes associated with Allied's operations, and a formal reclamation process was begun. Onondaga County placed sanitary sludge in trenches on top of this bed from the summer of 1986 until January 1987.

3.5.3 Waste Bed 13

The base of Waste Bed 13 occupies approximately 163 acres (USGS, 1978; USDA, 1978), making this the largest of Allied's Waste Beds. The depth of the waste is approximately 55 feet. The volume of waste is roughly 391 x 10^6 ft^3 or 14.5 x 10^6 yd^3.

This bed is bounded on the north by Nine Mile Creek and Conrail Railroad tracks. On the west, it is bounded by the Onondaga County Garage, a gravel excavation owned by Allied, and a few residences located by Warners Road. To the south and east, Bed 13 is bounded by Waste Beds 14 and 12 (Figure 1).

The Bed 13 area is where the major portion of the old Syracuse Municipal Airport and its associated buildings were located. The runways and buildings were removed and a gravel operation existed within the bed boundaries after the airport was no longer in use (Army, 1946, 1955; NYSDOT, 1967; USDA, 1938, 1951, 1959, 1966). There were three areas within the bed boundaries from which gravel was extracted to approximate depths of 30 feet below original grade; these three pits encompassed nearly the entire bed area (Dames & Moore, 1975a; USDA, 1966).

Filling of Waste Bed 13 with Solvay Waste began in 1973 and continued until 1985. During the initial filling operations of this bed, large volumes of waste bed overflow were reported by Allied to not have been accounted for, and were presumed to have discharged to the underlying gravels. Other wastes placed in this basin were brine purification sediments, boiler bottom and fly ash, boiler water purification sediments, asbestos slurry and treated mercury cell waste water. The asbestos slurry was placed in Bed 13 from 1973 to 1985, and the treated mercury cell waste water was placed in this basin from 1973 until 1977.

3.5.4 Waste Bed 14

An estimate of the area covered by Waste Bed 14 is 133.4 acres (USDA, 1966; USGS, 1978). The height of the bed is approximately 55 feet (Dames & Moore, 1976). The volume of waste material is estimated as being 319 x 10^6 ft^3 or 11.8 x 10^6 yd^3. Refer to Figure 1 for the location of this waste bed.

Waste Bed 14 is bounded by Bed 13 to the north, Bed 12 to the east, and Bed 15 and the old Erie Canal location to the south. To the west, Bed 14 is bounded by a residential and a light industrial area along Warners Road, and what is left of one of the runways from the old Syracuse Municipal Airport.

The Waste Bed 14 area was undeveloped until the Syracuse Municipal Airport was built there between 1934 and 1938 (USDA, 1938 Soils Map and Air Photos). A small stream and pond was located in the bed area prior to Allied's activity at the bed (USDA, 1938; Army, 1946; USDA, 1951). A study of the area was performed in 1950 for the placement of dikes to enclose the bed (Hough, 1950).

The dikes around Bed 14 were constructed in 1951. At this time, one of the runways from the old Syracuse Airport was removed. One of the dikes on the eastern boundary was placed over the old Airport Road. The old Erie Canal was located to the south of the southern dike and apparently was filled with trash from the Town of Camillus prior to 1974 (Dames & Moore, 1974).

By 1959, active placement of waste into Bed 14 was well under way. Wastes placed in this bed include Solvay Waste, brine purification sediment, boiler water purification sediment, boiler bottom and fly ash, Willis Avenue Plant waste water, asbestos slurry and treated mercury cell waste water. The treated mercury cell waste water was placed in Waste Bed 14 from 1970 until 1977; the asbestos slurry was placed from 1968 to 1985.

3.5.5 Waste Bed 15

An estimate of land area occupied by Waste Bed 15 is 111.3 acres (USDA, 1978; USGS, 1978), with the height estimated at 25 feet. The volume of waste is approximately 121 x 10^6 ft^3 or 4.49 x 10^6 yd^3.

Waste Bed 15 is bounded on the north by Beds 12 and 14 and the former location of the old Erie Canal (Figure 1). The canal had been filled with rubbish by the Town of Camillus prior to 1974 (Dames & Moore, 1974) and most of this material was removed before Solvay Waste was deposited. The area south of the bed on the western portion has been excavated for dike material by Allied. At one time, this excavated area was proposed to be the site of the Onondaga County Landfill (W-M Engineers, 1985 and 1986). The Town of Camillus operates their landfill on the eastern portion of the southern boundary of Bed 15.

This bed overlies parts of the old Airport Road, Gere Lock Road and Bennett Road. Waste Bed 15 began receiving wastes in 1975; these wastes included Solvay Waste, brine purification sediment, treated mercury cell waste water, boiler purification water sediment, boiler bottom and fly ash, some Willis Avenue Plant waste water, and asbestos slurry. The treated mercury waste water was discharged to the bed from 1975 to 1977 and the asbestos slurry was placed from 1975 until 1985. The western half of this waste bed has received the demolition debris from the razing of buildings at Allied's main plant area. The eastern half of this waste bed received a layer of sewage treatment plant sludge in 1986.

SECTION 4 - SITE CHARACTERIZATION

4.1 General

During this investigation, numerous field activities were conducted to determine the nature and extent of the impact of the Allied Waste Beds on the surrounding area. These activities included a field reconnaissance of the Waste Bed Areas; an electrical resistivity survey; a seismic survey across the Nine Mile Creek Valley; compilation of historical, precipitation, stream flow, and subsurface information; the drilling of 19 borings and the installation of 16 wells; obtaining 27 surface water samples and 21 ground-water samples; stream flow measurements; and a detailed topographic survey of the area from recent aerial photos. The information obtained during the site reconnaissance is discussed in Section 4.2, supplemented by Figures 3 through 6. The electrical resistivity survey, comprised of nine lines with a total of 31 stations (Figure 7), is discussed in Appendix A. Location of the seismic survey is shown on Figure 7 and is discussed in Appendix E. Figure 8 is a summary of the compilation of available subsurface information, supplemented by the drilling program undertaken during this investigation. Based on this information, the subsurface conditions, are discussed in Section 4.3 and are presented in Figures 9 through 13. Potentiometric surface maps of ground water in shallow and deep surficial sediments are included as Figures 25 and 26. Surface and ground-water analytical results are summarized in Tables 19 and 20 and are discussed in Section 4.4.

4.2 Site Reconnaissance

A field reconnaissance of the site was conducted during the end of April and early May 1987. Observations pertaining to general vegetation cover, buildings, roads, surface conditions, seeps, springs and surface water bodies were made during the reconnaissance. All observations were noted in a bound field book and referenced to station numbers located on low level aerial photographs taken in 1981. A summary of the observations is given in Figures 3 through 6. A general review of the reconnaissance, on an area by area basis, follows:

4.2.1 Areas F-M and OLF

Areas F-K and M are located at the southeast end of Onondaga Lake. Areas F, G and H are along the lakeshore. Area L is the low area along either side of Ley Creek from the lakeshore to Seventh North Street. The OLF, or Onondaga Lakefront, extends along the northeast and southwest lakeshore. Observation stations are summarized in Figures 3 and 4.

The area encompassing Areas F-K and M is developed with industrial, commercial and a limited amount of residential properties. "Oil City" is located in the vicinity of Areas H, J and K, which also includes Marley's scrap yard. The proposed site of Pyramid's Carousel Project is situated in Area H, and numerous industrial facilities including a pavement materials plant, are situated in Area J. Most of the property in these areas is privately held and access for the purpose of this investigation was limited. Surface drainage is controlled by a storm water drain system along the roadways. Neither seeps or springs were observed in the area.

Shallow hand-dug excavations were made in Areas G, J and I, and Solvay Waste was observed only in Area G at a point along the canal. An exposure along the northeast side of the canal revealed an area of white material. This information, in conjunction with historical data, substantiates the presence of Solvay material in the areas fronting Onondaga Lake. No white material or Solvay Waste was observed along the banks of the canal southeast of Hiawatha Boulevard in areas where the protective rip-rap was missing. The absence of Solvay Waste in a particular area is harder to document than the presence of this material; however, it appears that no significant volume of Solvay Waste was placed in Areas I, J, K or M, based on the reconnaissance observations or historical data.

Observations made during a reconnaissance of the Ley Creek Area (L) indicated that extensive dumping of construction and demolition debris had recently occurred in this area. Numerous piles of siding, blacktop, and concrete rubble, shingles, etc., were observed. Vegetative growth was moderately well-developed in this area with cobbles and gravel exposed at the ground surface, along with concrete rubble and brick. A steep bank along the northwest side of Ley Creek, approximately 8 feet high, exposed concrete and brick rubble. Based on this information, it appears that Area L has been used as a construction and demolition disposal area for some time.

Low swales on the ground surface contained some standing and running water. One southwest-northeast trending swale, roughly paralleled a dirt "track" that crosses the area. A pH of 7.4 and a specific conductance of 390 micromhos per centimeter (umhos/cm) was observed at this location. Ley Creek, near the U.S. Geological Survey (USGS) Stream Gaging Station, had a pH of 6.7 with a specific conductance of 850 umhos/cm. These values are markedly lower than the pH and specific conductance values noted in areas where Solvay Waste have been deposited more recently. If Solvay Waste is present in this area, it is likely that it is an insignificant volume of material.

Observations of the OLF Areas indicate that the northeast OLF has been strongly impacted by cultural activities. Several small ponds are located near the southeast end of the area, apparently fed by runoff and seeps. One seep with an estimated flow of 5 gallons per minute (gpm) fed a pond northwest of Route 57. This seep had a pH of 7.1 and a specific conductance of 1,787 umhos/cm.

Shallow excavations along the beach of the southwest OLF revealed only marl, typically fossil-rich, with occasional concretions. One excavation did find peat underlying the marl. A culvert pipe, draining an area along the Interstate, had surface water with a pH of 7.9 and a specific conductance of 630 umhos/cm. No indication of Solvay Wastes was observed in either of the OLF Areas.

4.2.2 Waste Beds A-E

These beds are located southeast of Beds 1-8 along a relatively narrow strip on both sides of I-690 extending to Hiawatha Boulevard and totalling approximately 130 acres. The limits of Beds C-E have been obscured by cultural development in this area; however, the present-day extent of these beds is indicated in Figure 1 and the observation stations are shown on Figure 3.

Bed A, located on the southwest side of I-690 and just to the southeast of the Crucible Facility, covers approximately 38.3 acres. Most of the northwest portion of the bed is covered with a black to brown tar-like material with no vegetation. The balance of the area is partially to well vegetated with some small trees. Most of the surface of the bed is rimmed by berms, thereby minimizing horizontal drainage of the bed. The banks of the bed are sparsely vegetated and are locally covered with concrete rubble, cinders and other similar hard fill materials. Numerous wells, most of which appear to be in relatively poor condition, have been installed into and around this bed during previous investigations. No seeps were observed along the perimeter of the bed. A drainage ditch runs along the base of the northwest side of the bed, flowing toward Onondaga Lake. This drainage has been historically identified as Tributary 5A. Flow in this ditch was estimated at the time of the reconnaissance to be on the order of 2 to 4 cubic feet per second (cfs) with a specific conductance of 1,000 umhos/cm and a pH of 7.8. Stream bottom sediments in the ditch were very soft and the upper several inches were stained red-brown. The material overlies at least six inches of oil-stained silt. Flow in the drainage ditch originates from a culvert pipe approximately 900 feet west of I-690.

Bed B is located along the northeast side of I-690 and extends out into the Onondaga Lake. The upper surface is relatively flat with a steep slope along the eastern margin, dropping roughly 18 to 20 feet down to lake level. Surface drainage is possible along most of the bed perimeter and by a drainage ditch running along the southeast margin of the bed that discharges to Harbor Brook. A small area of seepage was observed along the northeast side of the bed near the edge of Onondaga Lake. The seepage discharged to the lake and had a specific conductance of 12,000 umhos/cm and a pH of 8.7. No other seeps were observed near this bed.

Vegetation cover on Bed B is generally quite heavy. The flat upper surface of the bed was covered by a thick growth of "weeds" and bushes, and some areas support tree growth. Shallow excavations in the top of the bed revealed five to eight inches of dark brown to black, apparently organic-rich soil. Thick growths of "reed grass" extend along the bed's outer perimeter along the water's edge.

A long, narrow retention basin and pump station (thermal diffuser) is located along the bed's northwest side, parallel to the water's edge. This basin and pump station and the building adjacent to it is a part of a cooling water discharge system for Allied.

Bed C is located adjacent to Bed B on the southwest side of I-690. The bed is nearly obscured by cultural features including several buildings and storage tanks. Areas not covered by buildings are either paved or well vegetated. Surface drainage on the bed is well developed. At the northwest end of the bed, shallow excavations roughly 1 foot deep revealed topsoil overlying red silty sand and gravel. This material was apparently placed on top of Solvay Waste, as exposures of the waste were observed along the southwest side of the bed.

No seeps were observed issuing from this bed; however, a ponded area located between the bed and the railroad tracks to the southwest had a pH of 9.3 and a specific conductance of 1,100 umhos/cm.

Beds D and E were located southeast of Bed C. Interstate 690 has cut through the northeast side of these beds and Harbor Brook, contained in an open concrete culvert, borders the beds along the southwest side. Most of the beds' surfaces are covered with buildings, pavement, or construction and demolition rubble. Surface drainage is away from the beds in all directions. The southwest slope of the beds is also covered with rubble. No seeps were observed near these beds; however, a white precipitate was locally present on the surface of the concrete culvert containing Harbor Brook.

4.2.3 Waste Beds 1-8

Waste Beds 1-8 are located along the southwest side of Onondaga Lake, northeast of the State Fairgrounds. The observation stations for these beds are shown in Figure 5. A large portion of the Bed surface is utilized by the State for automobile parking during the time when the annual State Fair is open. The total area of these beds is roughly 314.5 acres, of which more than half is used for parking. Of the remaining area, Crucible Specialty Metals utilizes an estimated 20 acres for the disposal of wastes generated by its facility adjacent to State Fair Boulevard. Interstate 690 and part of the I-690/Rt. 695 interchange is located along the southwest side of the beds. The balance of the bed area is undeveloped.

In general, the area used for parking is unvegetated to poorly vegetated, the Crucible disposal area is unvegetated, and the remaining area of the beds is partially to well vegetated, as described below. During the reconnaissance conducted in late April and early May 1987, the area northwest of the I-690/Rt. 695 interchange was vegetated with a cover of grasses. Areas at the extreme northwest end of the bed and the point which extends out into the lake (Lakeview Point), were covered by a sparse cover of volunteer growth and small trees and shrubs. A thin strip northeast of the upper parking areas was well vegetated with trees and undergrowth. In this area, there appeared to be a relatively well developed soil which supported the growth of vegetation. The waste bed slope along the edge of the lake is generally well vegetated toward the southeast end; however, toward the northwest the vegetation cover became less developed and was nearly absent from slopes along Lakeview Point and further northward.

Along much of the lake's edge there is a flat area, sloping gently down into the water. Along the southeast portion of the beds, these "flats" are generally well vegetated, with the vegetation density decreasing toward the northwest to a point approximately half-way up the length of the lake's edge, where the vegetation disappears altogether. In the area along the flats where vegetation vigor begins to decline, seeps were observed. These seeps increased in size and density toward the northwest. During the reconnaissance, a sample of a seep near the southwest end of Lakeview Point had a specific conductance of greater than 50,000 umhos/cm and a pH of 11.0. In this area, the seeps along the flats had become almost continuous, with flows combining into channels and issuing into the lake. The flow from these channels was estimated to be generally less than 2 to 5 gpm. The flats became narrower along the southern side of Lakeview Point, where hardened waste was exposed in the sloping side of the bed. From Lakeview Point to the northwest, the flats were not present and the lower portion of the waste bed is directly exposed in places to wave attack, so that it forms a near vertical cliff roughly 10 feet high. Further to the west-northwest, the flats are again present; however, very few seeps were noted in this area. Along the area northwest of Lakeview Point, a pipe issues from the side of the bed and discharges an estimated 0.5 gpm of water with a pH of 11.9 directly to the lake. Other pipes were observed in this area; however, they were not observed to be flowing.

4.2.4 Waste Beds 9-11

Waste Beds 9-11 are located northeast of Beds 12-15 along the northern side of Nine Mile Creek. The beds occupy an area of approximately 126.3 acres. The site observation stations are shown in Figure 6. Historical information indicates that Beds 9 and 10 had been separated by a dike during their filling, but this dike is no longer apparent. During the site reconnaissance, these beds were observed to be generally well vegetated, both on their slopes and on their flat upper surfaces. Vegetation cover on the slopes was comprised mostly of grasses and some trees. This cover was not complete and exposures of cinders and clinker were observed along the lower portion of the slope with Solvay Waste exposed along the upper reaches of the slopes.

Beds 9-10 and 11 are separated by a low "interbed" area that reflects the original ground surface elevation in the area. Remnants of the Nine Mile Creek channel are still present in this "interbed" area. Nine Mile Creek was relocated from its original channel during the construction of these beds in about 1944. This "interbed" area was not filled with Solvay Waste due to the presence of an easement for the power transmission lines. Drainage of an estimated one to two gallons per minute from the "interbed" area discharges to the south-southeast. The discharge has a specific conductance of 50,000 umhos/cm and a pH of 9.7. Unlike the drainage from seeps around Beds 12-15, the seeps and surface water runoff from Beds 9-11 are not collected. Drainage from the "interbed" area ultimately discharges to Nine Mile Creek, as do numerous small seeps observed along the southern and eastern sides of the beds. Surface drainage from the north side of Beds 9-11 collects in a drainage ditch. Several ponded areas with heavy accumulations of calcium carbonate precipitate were observed along this drainage ditch. At the time of the site reconnaissance there was no apparent surface water discharge point for the accumulated flow in this ditch, and it appears that the flow dissipates by evaporation and/or infiltration.

4.2.5 Waste Beds 12-15

The youngest group of Waste Beds, Beds 12-15, comprise a total of approximately 536.3 acres. The site observation stations are shown in Figure 6. Surface elevations of these beds range from about 436 (NGVD) feet on Bed 13 to 457 feet on Bed 14. The surface of Beds 13, 14 and 15 were generally poorly vegetated to barren. Bed 12 was mostly covered with demolition debris and was generally the best vegetated bed in the group, supporting some small trees. Allied reported that the western portion of Bed 14 received process wastewater from LCP in 1987. This area of the waste bed was observed to be unvegetated. Beds 13 and 15 were poorly vegetated to barren.

Vegetation along the outer surface of the dikes was best developed on Bed 12 with less vigorous growth on Beds 13 and 14. Some erosion gullies were noted on the north and northwest sides of Bed 13 exposing the sand and gravel used to construct the dike. An area of seepage was observed along the outer perimeter of Bed 14 near the point where it joins with Bed 13. The seep has produced a precipitate on the face of the dike extending an estimated 10 to 20 feet up the dike surface. Liquids issuing from the seep, which had a specific conductance greater than 50,000 umhos/cm and a pH of 8.4, emptied into a drainage ditch used for leachate collection which runs along the outer perimeter of the beds. The drainage ditch begins near the southwest end of Bed 13 where a drainage culvert pipe discharges an estimated 5 to 10 gpm into the ditch. The fluid in the ditch had a specific conductance in excess of 50,000 umhos/cm and a pH of 11.8. The flow within the ditch did not appear to increase appreciably downstream of the seep at the northwest corner of Bed 14. In addition, no other seeps were observed along the western or northern perimeter of the dikes. Flow from a series of small seeps on the eastern side of Bed 12 discharges into a drainage ditch at the base of the bed. From there it flows to the north along the base of the bed and joins the drainage ditch running along the western and northern perimeter of Beds 13 and 14. The combined flow from the bed perimeter is diverted into the retention basins located east of Bed 12 by a diversion structure at the northeast corner of Bed 12. The liquid collected in these retention basins is pumped to the Metro Plant.

No seeps were observed along the southern edge of Bed 15, as the ground surface in this area rises to the south. Vegetation and variable amounts of soil have been removed from the area, allowing the development of erosional gullies which drain north towards these waste beds. Bedrock was observed in one of the erosional gullies towards the northwest extent of this area.

4.3 Geology and Hydrogeology

4.3.1 Site Geology

The area of this investigation straddles the boundary between two physiographic provinces; the Ontario Lowlands to the north and the northern margin of the Appalachian Uplands to the south (Muller, 1964). The geology of this border zone can be broken down into four very broad categories: bedrock; unconsolidated glacial deposits; post glacial sediments; and man-placed fill materials including industrial wastes. Because of the large size of the area, approximately 15 square miles, the geologic conditions vary greatly from one portion of the site to another. Generally, bedrock thinly covered by till underlies the highlands and unconsolidated glacial sediments fill the lowlands of the Onondaga Lake Basin and its tributaries. Glacial action has altered the preglacial topography by scouring and glaciofluvial erosion. Deposition of till and glaciofluvial and glaciolacustrine sediments has further altered the preglacial landscape. Man has altered the natural land surface by rerouting drainage channels, construction of the Erie Canal, and various cut and fill operations including the disposal of industrial wastes. A more detailed discussion of the site geology follows.

4.3.1.1 Bedrock

Central New York is dominated by nearly flat-lying Silurian and Devonian sedimentary rocks which have a variable but gentle dip toward the south of roughly 100 feet to the mile. The Upper Silurian Vernon Formation underlies most of the site and is exposed for some eight miles to the north of the site (Rickard, 1970). The Vernon Formation in this area is approximately 700 to 1,000 feet thick and consists of relatively soft, erodible, gray, red and green mudstones. The contact between the Vernon Formation and the overlying Syracuse Formation lies just to the south of the site at an elevation of about 450 feet (NGVD). The relatively less erodible Syracuse Formation underlies the topographically higher areas to the southwest and southeast of Onondaga Lake and the hill located northwest of Nine Mile Creek and southeast of Warners Road (Figure 9). This Formation is approximately 600 feet thick and is comprised of shales, dolostones, gypsum, and salt (Hopkins, 1914; Rickard, 1970).

Rock salt has not been observed in outcrops of the Syracuse Formation due to salt's high solubility; however, salt beds have been found to be up to 318 feet thick in boreholes located south of the City in the Onondaga Valley. Ground-water flow up-dip toward the north in this Formation is the mechanism for the transport of brines to the area around the southern end of Onondaga Lake and Nine Mile Creek Valley. The Syracuse Formation is exposed at the surface for about 0.5 miles to the south of its contact with the Vernon Formation and is there overlain by limestones, dolostones and shales of the Camillus and Bertie Formations.

4.3.1.2 Glacial Geology

The preglacial bedrock surface in the site area was extensively modified by overriding Pleistocene glaciers. Deepening of the preglacial Onondaga Valley by glacial ice, in the same manner as the formation of the Finger Lake Valleys, has produced a bedrock basin extending below sea level (Stewart, 1935). Glacial sculpting of the area has produced a pronounced north-northwest, south-southeast orientation of hills and valleys. This orientation is, in part, a result of erosion of the underlying bedrock by the ice and deposition of till into streamlined elliptical hills. These hills are known as drumlins and are composed predominantly of till. Till is typically a compact, unsorted, poorly stratified mixture of sands, silt, clay, gravel and boulders deposited directly by glacial ice. Till generally overlies bedrock in this area as a thin veneer 10 to 15 feet thick. In some locations, commonly in drumlins, it is much thicker and in other areas within the valleys and on the uplands, the till is absent.

During glacial retreat in the Onondaga Valley, preglacial drainage to the north was blocked by the ice front, producing a proglacial lake in which large volumes of glaciolacustrine sediments were deposited. Drainage in adjacent north-south trending valleys, both east and west of the Onondaga Valley, were also blocked, producing a series of lakes standing against the ice. As the level of these lakes rose, they utilized the lowest available drainage pathway which at times was to the south, over relatively high spillways, or to the east or west over inter-valley divides. The large volumes of melt-water spilling from one basin to another cut numerous, deep east-west trending channels into the valley divides (Fairchild, 1909). With progressive decay of the ice sheet, lower spillways opened resulting in drainage of the proglacial lakes and the eventual establishment of the modern-day system of lakes and surface drainage.

During the time that the preglacial lakes existed, they accumulated large volumes of sediment washed out from the ice and from the channels crossing valley divides. These sediments consist primarily of fine sand and silt; however, gravel, coarse to medium sand, and clay are also present at some locations. More than 250 feet of glaciolacustrine silt, clay and fine sand were deposited in the southern end of Onondaga Lake beneath the current location of the Metro Plant (O'Brien & Gere, 1971b). The sediments in this area were deposited into the proglacial lake by waters flowing through the "cross-divide" channels into the Onondaga Valley and by later reworking of deltaic sediments from a higher elevation in the Onondaga Valley by fluvial and wave action (Fairchild, 1914). In other areas of the Onondaga Lake Basin, where the bedrock and till elevations are higher, the thickness of the sediments is consequently thinner. For example, the glaciolacustrine sediments beneath the Lakeshore Beds are roughly 50 feet thick and are less than 15 feet thick under areas of the State Fair Grounds.

4.3.1.3 Post Glacial Sediments

Overlying the till and glaciolacustrine sediments are more recent post-glacial sediments. These include lacustrine deposits in the Onondaga Lake Basin, alluvial sediments along Nine Mile Creek and other tributaries to Onondaga Lake, and organic sediments deposited in post-glacial marshes and swamps.

The lacustrine sediments consist primarily of marl, a calcium-carbonate sediment precipitated from lake water which is locally rich in fossil shells. The marl also contains variable amounts of silts and fine sand, and was found to range in thickness from about 24 feet at Metro to only a few feet under Waste Beds 1-8.

In some areas, the lacustrine material is overlain by an organic-rich sediment including peat and organic silts. These sediments are deposited in marshy areas at or near the surface elevation of the lake, and are locally found under Waste Beds 1-8, and along parts of the southeast end of the lake.

Minor deposits of alluvium, or modern-day stream sediments, are found along the margins of the Onondaga Lake tributaries.

Man has altered the geologic conditions in the site area by (1) lowering the Onondaga Lake level by approximately 2 feet (Calocerinos & Spina, 1982), (2) diverting stream channels, and (3) cut and fill operations, principally filling of areas with Solvay Process Wastes. Onondaga Creek had been channelized into the Barge Canal sometime prior to 1892; Nine Mile Creek was diverted in at least two locations to accommodate accumulations of Solvay Process Waste; and Harbor Brook was diverted into a culvert for the last mile and a half of its course. Large amounts of Solvay Process Wastes, ranging in thickness from a few feet to more than 50 feet, have been placed in numerous waste beds along the southwest side of Onondaga Lake in the Nine Mile Creek Valley and smaller basins toward the southeast end of the lake.

4.3.1.4 Geology of the Nine Mile Creek Valley

During the course of this investigation, a large number of existing well and boring log data have been compiled to ascertain the subsurface conditions in and around the Nine Mile Creek Valley. This pre-existing information was supplemented with borings at eight new locations in the Nine Mile Creek Valley and one boring along the southwest side of the lake. The locations of subsurface information compiled and utilized for this investigation are summarized in Figure 8.

Most of the pre-existing borings within the Nine Mile Creek Valley failed to reach bedrock. Because the depth to bedrock was an important factor in characterizing the hydrogeologic system, the drilling program conducted for this investigation was designed to determine the type and, if possible, the configuration of the bedrock within the valley. Boring locations are shown on Figure 8. Field methods utilized during the boring program are summarized in Appendix A of this report.

Bedrock was reached in seven of the eight locations where "deep" borings were conducted. At the eighth location, difficult drilling conditions prevented the boring advancement to bedrock. In six of the seven locations where bedrock was reached, an NX core was taken to obtain a sample of the rock and confirm that the auger or spoon refusal was, in fact, due to the presence of bedrock. The cores recovered indicate that the site is underlain by shale which is light to dark gray, but in some areas is red and green. The rock varies from slightly weathered to very weathered, and gypsum is commonly found within the joints in the rock. In boring WB-1La, located southwest of Warners Road, approximately three feet of a dark gray, unweathered limestone was found overlying a soft weathered shale. Joints in the limestone were filled with a calcium carbonate cemented silty sand and gravel, resembling till. It is hypothesized that the limestone is a large glacial erratic lying directly on the underlying shale bedrock.

Rock weathering and jointing, either open or filled with gypsum, was common in the recovered cores. These cores generally represent only the upper few feet of the bedrock. It is anticipated that the intensity of weathering and the frequency of jointing will decrease with depth into the bedrock. Based on the rock type recovered and the location of the borings, it is believed that all borings encountered the Vernon Formation.

The configuration of the bedrock surface in the Nine Mile Creek Valley has been largely shaped by its role as a cross-divide channel during deglaciation. West of the study area, from approximately Marcellus Falls to Camillus, the upper reaches of the creek run through a steep bedrock-walled valley approximately one-quarter mile wide. This valley was cut by inter-valley flow (Fairchild, 1914). Approximately 4,000 feet downstream of Camillus, along the north side, an unnamed tributary channel joins the Nine Mile Creek channel from the north. At this point, the valley bottom widens to nearly half a mile and the valley wall becomes less steep. As shown on Cross Section A-A' (Figures 8 and 10) depth to bedrock in this area is at least 50 feet below the top of the valley fill (New York State DOT borings).

About 2 miles further downstream in the vicinity of Waste Beds 12-15, the valley again widens to roughly 5,000 feet where the Beaver Meadow Brook Valley joins the Nine Mile Creek Valley. Cross sections constructed across and parallel to the Nine Mile

Creek Valley, as shown in Figures 10 and 11, illustrate that depth to bedrock in this area is over 100 feet from the top of the valley fill. From this point downstream, the southern valley wall becomes less distinct as the valley continues to widen. Depth to bedrock also increases toward the lake, as shown on the Bedrock Contour Map, Figure 12. The bedrock contours indicate that the buried valley walls trend east-northeast in agreement with the surface expression. The side slope of the bedrock valley rises rather quickly from below 300 feet (NGVD) along the southeast valley wall to over 450 feet, with an average slope of approximately 0.09 ft/ft. In the vicinity of the waste beds, the rock surface along the northwest wall rises less steeply than along the southwest side. In this area, the majority of the valley bottom appears to be between 325 and 300 feet (NGVD) with a closed bedrock depression down to 252 feet in the vicinity of borehole WB-5L. Approximately 1,000 feet downstream (to the northeast) of WB-5L, the bedrock surface rises to between 275 and 300 feet (NGVD). Evidence for this rise in the bedrock is based on data from the seismic line (Figure 7 and Appendix E) which was run from the southeast toward the northwest between Beds 9-10 and 11 parallel to Cross Section B-B' (Figure 10), and is supported by drilling data (WB-7L). The seismic line formed the basis for Cross Section B-B', which indicates there are several depressions along the line; however none of these are as low as the bedrock found at location WB-5L. Cross Section C-C', run roughly perpendicular to B-B', illustrates the rise in the bedrock surface from WB-5L to WB-7L.

Several thousand feet downstream of the seismic line, the bedrock surface of the Nine Mile Creek Valley merges with the much lower bedrock surface of the glacially scoured Onondaga Lake Basin. No boring information was available with respect to the depth of bedrock northeast of WB-6; however, it is known from other areas within the Onondaga Lake Basin that the bedrock drops to below sea level (Stewart, 1935). It is believed that the Onondaga Lake Basin is typical of a glacially scoured valley in which the valley walls drop very quickly in a direction perpendicular to the former ice flow direction. If this is the case, the bedrock surface is likely to drop quickly at some point northeast of I-690 (Cross Section C-C', Figure 11).

The thickness of the till overlying the bedrock in the Nine Mile Creek Basin is highly variable. In the borings for this investigation, the maximum thickness of till observed was 25 feet in WB-7L. Information obtained during the seismic investigation (Appendix E), however, indicates that the till thickens to approximately 50 feet northwest of WB-7L (Figure 13), and then becomes thinner again further to the north. The till was found to consist primarily of a dense red sandy silt with variable amounts of gravel and clay. Grain size analysis curves performed on several till samples are shown in Figure 14.

Along the valley margins, a thin veneer of till is exposed at the ground surface. Boring logs from an area along the south side of the Nine Mile Creek Valley indicate that the veneer of till varies in thickness from non-existent to more than 20 feet thick. Greater thicknesses of till are possible in this area within drumlins, such as those existing south of Bed 15 in the vicinity of the Camillus landfill.

In the lower areas of the Nine Mile Creek Valley, the till is covered by unconsolidated sediments of variable composition, distribution and thickness. Several features, however, were found to be relatively continuous across all, or a portion of the site. The most continuous unit was a relatively low permeable material present at the ground surface, and extending from several feet to about 50 feet below the surface. The material within the low permeable unit is quite variable in composition ranging from silty sand to varved silt and clay. These materials represent glaciolacustrine deposits, or material which was deposited in a lake that was present in the valley during deglaciation. In some areas this low permeable material is absent, most notably in the vicinity of Waste Bed 13. Boring logs indicate that sands and gravel were locally present at the original ground surface prior to gravel pit operations in the present day locations of Waste Bed 13 and the currently active pit west of Bed 13. However, the boring conducted in this area (WB-2L) for the current investigation encountered a ten-foot thick horizon of silty sand overlying 87 feet of sand and gravel. The sand and gravel found at WB-2 appear to be partially replaced by silty sand within several thousand feet to the northeast at HB-2 (Hough, 1950), and this material interfingers with interbedded gravelly clay, gravelly sand and sand within about another 1,500 feet at WB-4 (Figure 11).

The permeability of the unconsolidated deposits appears to further decrease downstream, as shown by the relatively thick accumulations of clay, silt and clayey sand and gravel in HB-4B (Hough, 1950) approximately 1,800 feet northeast of WB-4.

The variability in soil textures is best illustrated by the grain size analysis curves shown in Figures 14, 15 and 16. One sample was analyzed for grain size distribution from each screened horizon within each well cluster. These samples generally represent the more permeable zones within a cluster location, as these zones were preferentially selected for the installation of wells. At three clusters, a sample of the relatively impermeable upper unit was analyzed, and in each case was found to be comprised almost entirely of silt and clay (Figure 14).

The grain size curves from samples selected from within the screened intervals are much more variable than the overlying less permeable material. The grouping of the samples analyzed from the upper (U) and lower (L) screened intervals indicate that the zones where the upper screens are placed tend to be more consistent than the lower screened intervals. This is thought to reflect a more variable depositional environment in the lower portions of the valley.

Depositional Environment

In general, the unconsolidated subsurface materials in the Nine Mile Creek Valley are characterized best by their non-homogeneous nature. Rapid changes in sediment types, both vertically and horizontally, are typical of sediments deposited by variable stream flow. Such conditions are likely to have existed in this area during deglaciation when large volumes of melt-water were issuing off the ice into drainage channels that had been reconfigured by glacial scouring and deposition. Evidence that glacial ice was relatively nearby, while some of these sediments were deposited, arises from the sediments themselves. Till was found overlying stratified sands and gravel in Wells WB-1 and WB-7.

Till is typically deposited directly from the glacial ice or, in localized cases, a short distance out in front of the ice sheet. During ice retreat from the Nine Mile Creek Valley, stratified sediments were deposited on top of the till overlying the bedrock. Due to the low elevation of the bedrock, there was a lake standing in the valley. Large volumes of melt-water laden with sediments issued from the ice and melt-water streams into this lake, depositing the sediment on the lake bottom. However, on top of these stratified sediments, till was locally deposited either by a slight re-advance of the ice front or by a "till flow" out from under, or from the front of the ice. After deposition of the till occurred, deposition of stratified material continued above it.

As previously indicated in the Glacial Geology section, Central New York had a complex series of lakes which formed against the retreating ice front. The Nine Mile Creek Valley acted as one of the cross-divide channels during this time, which potentially contained very large volumes of water. The large volume of sand and gravel observed in the vicinity of WB-2 may have been deposited by the cross-divide flow as it emptied into a widening Nine Mile Creek Valley and into the lake within the valley. Sediment structures observed in the wall of the existing gravel pit west of Bed 13 support this type of deposition. The largest and heaviest sediments were deposited closest to where the flow enters the Nine Mile Creek Valley and the finer grained sand, silt and clay were deposited further from the point of inflow (Cross Section C-C', Figure 11) producing the sedimentary sequences observed in the boreholes within the valley. With time, the valley began to fill with sediment and the flow from the cross-divide channels subsided, producing a relatively calm water body in which silts and clays were deposited. As the ice front to the north continued to disintegrate, the ice dam finally gave way, releasing the proglacial lake waters. Minor reworking of the glacial sediments has occurred by the streams in the area and thick accumulations of marl have been deposited in Onondaga Lake. This produced the present day configuration of surface water bodies which have been partially altered by man.

4.3.1.5 Summary of Geologic Conditions

The site area is underlain by gently southward dipping Silurian and Devonian sedimentary rocks. The Onondaga Lake Valley and its tributaries are underlain by the relatively soft Vernon Formation, a gray, green, and red shale. The Syracuse Formation, comprised of shales, dolostones, gypsum, and rock salt, overlies the Vernon Formation and forms the highlands around the valley. Glaciation has altered the preglacial topography in the site area by glacial erosion and deposition. The bedrock surface below Onondaga Lake was scoured to a depth below sea level by the glacier moving from the north-northwest to the south-southeast.

In most areas, the ice also deposited a thin veneer of till over the bedrock surface. Within the valleys and overlying the till is a thick accumulation of stratified sediments. As melt-waters flowed off the ice, these sediments were deposited into a lake which existed in the Onondaga Valley and its during retreat of the glaciers. Additional sediments were deposited by large streams flowing into the Onondaga Valley tributaries from adjacent north-south trending valleys, which also contained lakes during deglaciation. These cross-divide streams locally cut deep channels into the bedrock due to the large volume of stream flow.

The upper reach of Nine Mile Creek, west of Camillus, is one of these erosional channels. Water flowing from the west cut down through this area providing a narrow, bedrock-walled channel. The bedrock valley widens and deepens to the east with a closed bedrock depression extending to more than 130 feet below the present-day land surface in the vicinity of Waste Bed 11. The bedrock surface rises up some 20 to 30 feet, approximately 1,000 feet downstream of this depression, and then drops again toward the much deeper Onondaga Valley trough further downstream.

As the stream flowed down into the wider and deeper sections of the glacial lake in the Nine Mile Creek Valley, it deposited the largest and heaviest portions of its sediment load. This occurred in the vicinity of Waste Bed 13 where there is an accumulation of sand and gravel extending to the bedrock surface more than 100 feet below the present-day land surface.

Downstream, finer sediments were deposited on the glacial lake bottom. As the ice continued to retreat from the area and melt-water volumes decreased, the flow from the west down the Nine Mile channel decreased. Therefore, the stream lost much of its carrying capacity and only finer sediments were transported into the valley, and subsequently deposited there. This then produced a sediment package which is locally very coarse (in the vicinity of Waste Bed 13), and is generally fine grained toward the surface.

Eventually the ice dam to the north gave way and the lake within the Onondaga Valley and its tributaries drained producing the present-day system of surface water bodies.

4.3.2 Site Hydrogeology

4.3.2.1 Surface Water

The area of investigation is situated within the Onondaga Lake Drainage Basin, which covers an area of approximately 233 square miles. The Onondaga Lake Basin is included within the larger (2,500 square miles) Eastern Oswego River Basin. Surface water drains from the Onondaga Lake Basin to the Seneca River, then to the Oswego River, and finally to Lake Ontario.

The surface water regime in the area of investigation is influenced by Onondaga Lake and by several of its tributaries. The tributaries of interest consist of Nine Mile Creek, flowing from southwest to northeast into the lake; Harbor Brook, flowing into the lake from the south; Onondaga Creek, flowing northward into the lake through the Onondaga Valley; Ley Creek, which enters the southeast corner of the lake; and a smaller tributary identified as Tributary 5A which flows into the lake between Harbor Brook and Nine Mile Creek. Two other tributaries to Onondaga Lake have been identified but are not included in the study area. These are Saw Mill Creek on the northeast side of the lake and Bloody Brook on the east side of the lake.

Numerous studies of the Onondaga Lake System have been conducted. These studies include Pitts (1948), NYSDOH (1951), and O'Brien & Gere (1971b), as well as ongoing annual monitoring reports from 1970 to the present, as issued by the Onondaga County Department of Drainage and Sanitation (OCDDS). In addition, various councils and subcommittees have been formed to evaluate the environmental conditions of the lake and to recommend management practices to improve the lake quality. These groups include the Onondaga Lake Scientific Council (1966), the Onondaga County Public Works Committee (1983), and the current State Onondaga Lake Advisory Committee.

Studies and committee reports, together with the Annual Lake Monitoring Reports prepared by OCDDS, have provided information for various periods on the flow rates of the tributaries and water quality parameters for various sampling locations on the tributaries and in the lake.

Onondaga Lake

Onondaga Lake covers an area of approximately 4.5 square miles and is approximately 4.5 miles long and averages about one mile wide. Average depth in the lake is reported to be 40 feet with a maximum depth of approximately 70 feet (Effler and Driscoll, 1986a). The volume of water in the lake is estimated to be 37 billion gallons, based on a water elevation of 360 feet (NGVD). The lake is reported to flush rapidly at a rate of 2.6 to 5.2 times per year (Effler, 1986b). Data from OCDDS monitoring for the period 1963 to 1985 indicate that the flushing rate of the lake varies from 1.5 to 9.9 times per year, with an average flushing rate of 3.2 times per year.

Onondaga Lake is one of the few lakes in New York State situated within the Ontario lowlands physiographic province. The quality of the lake, which is within the Syracuse Metropolitan area, has been degraded over the years due to a combination of discharges of untreated and treated sewage, surface runoff and industrial waste water.

Swimming and, until recently, fishing in the lake has been banned. There is a current advisory against eating any fish taken from the lake. The lake has been plagued by excessive algae growth due to an over supply of nutrients. This has contributed to a lack of water clarity and low levels of dissolved oxygen in the lake. It has been alleged that mixing of the upper and lower lake waters each spring and fall by lake turnover, which is necessary for oxygenating the lower level lake waters, has been partially delayed as a result of chemical or density stratification (Onondaga Lake Study, O'Brien & Gere, 1971). Chloride concentrations in the upper and lower waters of the lake can contribute to the establishment of this density gradient.

As discussed in the History and Geology Sections of this report, the Onondaga Lake Area has long been associated with salt. Salt springs with concentrated brines around the southern end of the lake led to the development of the salt industry and the settlement of Syracuse. Data from a map of the Village of Syracuse dated 1834 indicated that the brine solution associated with the salt industry at the southern end of Onondaga Lake contained approximately 67,000 ppm chloride, 57,000 ppm sodium, 3,200 ppm calcium and 2,400 ppm sulfate. At that time it was reported that 75 pounds of salt could be produced from 55 gallons of salt spring brine. There is, however, little other quantitative information available that describes the chemical components, or the variable concentrations of the brine from these springs, or the salt content of the lake itself.

A map developed by Guy Johnson, Indian Superintendent for the Province of New York in 1771, identifies the lake as "Salt Lake." Allied has identified the following references pertaining to the saltiness of the Onondaga Lake Waters:

- Thomas Ashe: Travels in America, performed in 1806, etc., London 1808 (rare documents vault #V917.3A82a2)

  "The Onondargo (sic), which (as I observed) has a portage-communication with this river, is a fine lake of brackish water, surrounded by springs, from two to five hundred gallons of the water of which make a bushel of salt."

  "The salt lakes and springs are also frequented by all the other kinds of beasts, and even birds; and from the most minute inquiries, I am justified in asserting that their visitations were periodical..."

- Gazetteer of the State of New York, Spafford ed., printed 1813 (917.47 S733)

  pg 90 "Lake Ontario forms a part of the boundary of the County of Onondaga, as does L. Oneida, Skaneateles L. (sic), and Cross Lake; while Onondaga or Salt L., Otisco, and Fish Lakes, are wholly within this county."

  pg 267 "Onondaga, or Salt Lake, is situated in the County of Onondaga, 7 miles N. of Onondaga, and near the Seneca River, into which it empties from the N. end. It is a small collection of dirty water, not exceeding 6 miles in length, and 1-2 in width; and on its borders are the justly celebrated Salines or Salt Springs, the largest and strongest in America."

- Gazetteer of the State of New York, Gordon ed., 1836 (917.47 G66)

  pg 50. "...white settlers. One of the latter, about 45 years since, with an Indian guide in a canoe, descended the Onondaga Creek, and by the lake approached the spring on Mud Creek. Salt water was obtained by lowering to the bottom, then four or five feet below the surface of the fresh

> water of the lake, an iron vessel, which filling instantly with the heavier fluid, was drawn up. In this way, by boiling the brine, a small quantity of brownish coloured (sic), and very impure salt, was obtained."

These references indicate the degree of salinity of the lake waters. However, as reported by Effler and Driscoll (1986a), early explorations by Clark (1849) indicated that a strong contrast existed between the salt concentration of the lake and the nearby salt springs, although this would be expected due to dilution from other fresh waters. Calculations presented in a report by USEPA (1974) state that 40 to 50 percent of the chlorides in Onondaga Lake come from natural sources within the drainage basin. It was also estimated that the probable average ambient level of chlorides in the lake is on the order of 630 mg/l. This conclusion is not supported by other references [i.e. Onondaga Lake Monitoring Program Reports and Effler and Driscoll (1986a)].

Periodic sampling of Onondaga Lake and several of its tributaries has been ongoing since 1968 by OCDDS. The Onondaga Lake Study of 1971 and the yearly monitoring reports have presented the results of those water quality studies. Up to 29 parameters have been sampled in the lake and its tributaries approximately every two weeks as part of this ongoing program. The primary ions of interest in assessing the potential impact of Solvay Waste are chloride, calcium and sodium because these ions represent the largest percentage of the total concentration of the Waste. The concentrations of these ions in Onondaga Lake for the period from 1981 to 1987 are presented in Figures 17, 18 and 19 for both the epilimnion (upper waters) and hypolimnion (lower waters). These figures show a sharp decrease in the concentrations in 1986.

Tributaries

The major tributaries to the lake that are of interest for purpose of this assessment of the Allied Waste Beds and suspected waste bed areas, Nine Mile Creek, Onondaga Creek, Harbor Brook, Ley Creek, and Tributary 5A. A summary of the characteristics of these drainages, as well as other tributaries to Onondaga Lake, is presented in Table 5. Historically, Nine Mile Creek has been the major source of salt loading to the lake.

Nine Mile Creek, which drains a watershed area of approximately 124.8 square miles, including the Otisco Lake drainage area, has an average annual flow of approximately 211 cfs prior to discharging to Onondaga Lake at Lakeview Point near the State Fair Grounds. Table 6 presents the yearly mean, maximum and minimum flows for Nine Mile Creek for the period 1971-1987 obtained from USGS Gaging Station data. The USGS stream gage on Nine Mile Creek at State Fair Boulevard has been reported to occasionally provide unreliable data due to sediment build-up in the stream bed and back-flushing effects of the lake. The original "provisional" data recorded at the gaging station is adjusted by USGS prior to finalization. The maximum flow recorded during this period was 2,460 cfs in 1982. The minimum flow, which may be indicative of ground-water base flow, was 13 cfs in 1985.

Downstream from Amboy, Nine Mile Creek passes between Waste Beds 9-11 and Waste Beds 12-15, and has been rerouted in this area. The stream has also been rerouted near its confluence with Onondaga Lake, and now flows on the northwestern edge of Waste Beds 1-8.

The New York State Water Quality Classification for the creek in this stretch is Class D. Average annual water quality values for concentration and loading rates of chlorides, calcium and sodium, as well as average flow for Nine Mile Creek are presented in Table 7. The annual values presented in this Table represent the average of the bi-weekly sampling events p[illegible]med by OCDDS. Figure 20 presents the average stream [illegible] and chloride, sodium and calcium concentrations in Nine Mil[illegible]eek. In general, trends indicate that as flow in the creek increases, chloride concentration decreases as a result of dilution. However, as stream flow increases, chloride loading also increases.

Geddes Brook joins Nine Mile Creek as a tributary just east of Waste Beds 12-15. Near its junction, it is also classified as Class D. Both Geddes Brook and Nine Mile Creek have received overflow from Allied Waste Beds during various periods of Allied operations. When waste was discharged to the newer waste beds, the liquid overflow was originally discharged to Geddes Brook. The overflow, which was high in calcium, mixed with the creek waters to form a calcium carbonate precipitate ($CaCO_3$), resulting in the lining of a portion of Geddes Brook and Nine Mile Creek with a white precipitate that is clearly visible on air photos.

After 1981, arrangements were made to utilize the waste bed overflow at the Metro Plant to precipitate phosphorous before Metro discharged its wastewater to Onondaga Lake. By 1983, all overflow from the active beds was conveyed to Metro. After Allied's closing, the large quantity of overflow was no longer available and Metro had acquired other sources of suitable precipitating reagents. Currently, the remaining seepage from the sides of Waste Beds 12-15 is collected by the same system and discharged to Metro. It is estimated that in 1987, an average of approximately 704,000 gallons per day were collected and conveyed to Metro from Waste Beds 12-15. It should be noted that during this time (1987), these waste beds were also receiving wastewater from the LCP Chemicals facility in the amount of 164,000 gallons per day.

Harbor Brook, which enters the southwest corner of Onondaga Lake, drains a watershed of 13.2 square miles and has an average annual flow rate that averages 14.3 cfs. This stream is restricted to an open culvert and then a buried culvert over its final stretch. As it approaches the lake, it flows past Waste Beds C, D and E and enters the lake at the southeast end of Waste Bed B. The New York State Water Quality Classification for Harbor Brook in this area is Class D. Stream flow data for Harbor Brook are presented in Table 8. Average water quality values for concentration and loading rates of chlorides, calcium and sodium are presented in Table 9. Average flow and concentrations of chloride, calcium and sodium are shown in Figure 21.

Onondaga Creek, which flows from south to north through the Onondaga Valley and the City of Syracuse, drains a watershed of approximately 102.5 square miles and has an average annual flow rate of 193.6 cfs before it discharges to the south end of Onondaga Lake at the Barge Canal terminal area. The creek has been relocated from its former discharge point which was located at the southeast corner of Onondaga Lake. At its current location, it flows past suspected Waste Bed Areas G, H, J, K and M. The New York State Water Quality Classification for this stretch of Onondaga Creek is Class D. Stream flow data for Onondaga Creek are presented in Table 10. Average water quality values for concentration and loading rates of chlorides, calcium and sodium are presented in Table 11. Average flow and concentrations for chlorides, calcium and sodium are shown in Figure 22.

Ley Creek drains an area of approximately 26.2 square miles east of Onondaga Lake before discharging to the southeast corner of the lake at an average annual flow rate of 45.3 cfs. This creek, below its junction with Beartrap Creek, is currently classified as Class D under the New York State Water Quality Classification system. In its lower reaches, southwest of Seventh North Street, it flows through suspected Waste Bed Area L. Stream flow data for Ley Creek are presented in Table 12. Average water quality values for concentration and loading rates of chlorides, calcium and sodium are presented in Table 13. Average stream flow and concentrations of chlorides, calcium and sodium are shown on Figure 23.

The Metro Plant is located at the south end of Onondaga Lake west of Onondaga Creek. The Metro Plant contributes a percentage of flow and ionic loading to Onondaga Lake. However, as previously discussed, a percentage of this flow and ionic loading discharged to the lake is attributable to Allied's Waste Beds 12-15 area. This will be further expanded in subsequent sections of the report. Average discharge rates, water quality values for concentration and loading rates for chloride, calcium and sodium are presented in Table 14. Average discharge rate and concentration of chlorides, calcium and sodium are shown on Figure 24.

4.3.2.2 Precipitation and Water Balance

Current hydraulic loading of the waste beds is significantly less than the loading during Allied's full-scale operations (until 1985). With the exception of past wastewater discharge from LCP (at an average 1987 daily rate of approximately 164,000 gallons per day to Waste Bed 14), loading to ground water beneath the beds results from infiltration of rainfall and dewatering of pore space in the newer beds. The volume of leachate generated from a given waste bed is therefore proportional to the amount of infiltration that enters the waste bed and function of the age of the bed. In general, however, a reduction in the amount of infiltration will result in reduced leachate generation.

Each waste bed has specific characteristics that influence the quantity of precipitation available for infiltration. Primarily, these characteristics include surface slope, vegetation cover, surface conditions, soil thickness, and waste bed thickness. Another bed-specific consideration may be the "age" of the bed or the time since the bed last received process waste. This is important in determining if the waste beds are still draining or if equilibrium conditions have been established between infiltration and leachate discharge. Given the conditions of each bed, it is possible to develop a water balance that will allow the determination of infiltration rates.

The current surface conditions of the waste beds have been discussed in Section 4.2, Site Reconnaissance, and are summarized below:

Waste Bed	Surface Conditions
A	Partial soil cover, partial tar bed, 60 percent closed surface drainage
B	Vegetated, soil cover, free surface drainage
C	Commercial development: tanks, buildings, free surface drainage
D/E	Buildings, soil cover, construction rubble, free surface drainage
F-M, OLF	Mixture of vegetation and commercial development, free surface drainage including storm sewers in some areas
1-8	Partial vegetation, combination parking lot, partial soil cover, partial closed drainage

9-11	Fair vegetation, little to no soil, closed drainage
12	Fair vegetation, construction rubble, soil cover, closed drainage
13-15	Little to no vegetation, no soil, closed drainage

Because of the difference in surface conditions between the beds, it was advantageous to combine and evaluate the waste beds in specific groups. This grouping was done to reflect differences between the various waste bed areas with respect to their age and surface characteristics.

The method for determining the infiltration values for the waste bed areas involved the extensive use of the EPA computer Model Hydrogeologic Evaluation of Landfill Performance (HELP) Version II, developed in August 1988. This model incorporates local climatological data coupled with input parameters related to surface and subsurface conditions for the calculation of infiltration rates.

Infiltration calculations, as performed by the model, rely heavily on the hydrology section of the National Engineering Handbook. Infiltration is calculated as the difference between daily precipitation and the sum of surface storage, evaporation, and runoff. The model also considers the hydraulic conductivity of the underlying soil layers to determine whether the underlying soils can accommodate the calculated infiltration value. Application of this model to the waste beds primarily involved the review of previous reports, evaluations and analyses (performed for this report and by others), supplemented with the review of aerial photography, site topography and the results of the site reconnaissance.

The climatological data used in this analysis was consistent for all of the waste beds. Daily precipitation data for 20 years of record (1968-1987) from the Syracuse Hancock International Airport weather station was utilized. The average annual precipitation for this 20-year period was 41.30 inches. Daily temperature and solar radiation values typical for Syracuse, New York were synthetically generated by the model using local rainfall data and various statistical coefficients describing the distribution of maximum and minimum temperatures and mean solar radiation. Additional input parameters necessary to perform the model were as follows:

- Leaf area index
- Evaporative zone depth
- Soil and waste bed design data:
  - number of layers
  - layer thickness
  - layer type
  - soil texture
  - initial water content
  - layer compacted (Y/N?)
  - vegetative cover type
  - closed drainage (Y/N?)
  - open drainage (Y/N?)
  - total surface area

Following input of the above parameters, the model simulates and applies the local climatological conditions to the surface and subsurface of the subject test case to calculate the infiltration rate.

As previously mentioned, the analysis of the waste beds involved several conditions subject to variation from waste bed to waste bed. The first input parameters subject to review were the leaf area index and the evaporative zone depth. The leaf area index is determined as the ratio of leaf surface area to ground surface area; the index is dependent on the vegetative cover type and vigor of growth. The evaporative zone depth is the maximum depth from which water may be removed from the soil. Its value is equal to the depth of root penetration plus the depth influences created by capillary suction. The evaporative zone depth is also dependent on the vegetative cover type and vigor of growth. The HELP Version II Model provides several "default" values typical for various growths of grass. The model uses the same cover descriptions as the Soil Conservation Service (SCS): "poor" condition (grass cover less than 50%), "fair" condition (grass cover between 50% and 75%), and "good" condition (grass cover greater than 75%). Based on the above descriptions and field observations concerning surface features, values for the leaf area index and evaporative zone depth were estimated for the waste beds. For the tar-like portion of Waste Bed A, it was reasoned that the black-colored surface of the bed should absorb more solar radiation, thus creating a higher potential for evaporation. Therefore, the evaporative zone depth for this portion of Bed A was adjusted from the "bare ground" value to the "fair" vegetation value to account for this potential.

Much of the soil and design data utilized in the HELP Version II Model was consistent throughout the waste beds. The SCS Runoff Curve Number was determined by the model based on the soil type and vegetative cover, and each soil layer was considered a vertical percolation layer. The selection of this layer restricts subsurface lateral flow, thus creating worst case conditions.

The primary material subject to analysis was the Solvay Waste. Based on review of available data and site descriptions, it was concluded that a low plasticity silt would best represent Solvay Waste material in the HELP Version II Model. This soil type was chosen for two reasons. First, Thomsen Associates (1982b) chose a low plasticity silt as the soil type representative of Solvay Waste. Utilizing a similar material type allows for a consistent approach between past and present evaluations. Secondly, the hydraulic conductivity used in the model for this soil type (3.7×10^{-4} cm/sec) is close to a reported hydraulic conductivity of Solvay Waste (4.9×10^{-4} cm/sec). Typical soil types were also chosen for other materials, such as a well compacted sandy silt for the parking lot surfaces of Beds 1-8, and a high plasticity clay for the tar portions of Waste Bed A. Due to the impermeable nature of the tar material, the permeability was also increased one order of magnitude above the value associated with the selection of high plasticity clay.

The total surface area of the waste beds and the thickness of Solvay Waste were taken from Table 3 when possible. In cases where information on thickness was not availabl€ (Waste Beds C, D and E), estimates were made based on comparisons between age and thickness, and historical use of similar beds. The thickness of waste in Beds 1-8 was estimated based on the range provided in Table 3.

The remaining information necessary to conduct the model (number of layers, compaction of layer, type of vegetative cover and type of drainage system) was determined from estimates made during site reconnaissance. Waste Beds A and 1-8 were divided into sub-areas since one vegetative cover type would not be representative of the entire cover area. Infiltration was then calculated on an area-weighted average using the infiltration for each sub-area. Surface area estimates for each different cover type within each waste bed were determined from the site reconnaissance. Waste bed groupings for analysis included A, B, C-E, 1-8, 9-11, 12 and 13-15, due to their respective similarities in age and past use.

The final input, subject to review, was the initial water content of each soil layer. As previously stated, the "age" of the waste bed determines whether equilibrium conditions have been established between infiltration and leachate discharge. To account for this, infiltration from the "newer" beds (Waste Beds 12-15) was modeled by starting with a high initial water content on the last full year of the use of the bed by Allied. The initial water content was assumed to be fully saturated as would be expected when the waste bed was in use. Under this scenario, the quantity of leachate generation is a function of both the discharge of infiltration and dewatering of pore waters.

Based on these variables, the HELP Model was utilized to calculate infiltration for each waste bed for 1987. A summary of the calculated infiltration rates for each waste bed area follows:

Waste Bed Area	Infiltration (inches)
A	10.96
B	10.43
C-E	11.60
1-8	12.97
9-11	12.09
12	14.73
13-15	15.44

The HELP Model inputs used to obtain the above infiltration rates are presented in Table 27. The application and impact of these infiltration rates on the water quality is discussed in Section 4.5 of this report.

4.3.2.3 Ground Water

The geology of the Onondaga Valley greatly impacts the movement of ground water in the valley and its tributaries. Man has altered the pre-development ground-water flow patterns and water quality by construction projects, disposal of wastes and ground-water pumping.

One of the earliest impacts man had on the area was the pumping of brines for the production of salt. Early white settlers in the Syracuse area came here, in part, for the brine springs observed around the southeast perimeter of Onondaga Lake.

Exploitation of the springs for salt production produced a rapid decline in the quality of brines at the ground surface, which led to the installation of brine wells of ever increasing depth as brine from the shallower wells lessened in salinity. Higgins (1955) attributed this decline in brine volume and concentration to depletion of a brine "reservoir" that consisted of brine saturated sediments underlying the southeast end of the Onondaga Valley Basin. Higgins (1955) hypothesized that the source of the brines was the rock salt deposits within the bedrock surrounding the valley.

As indicated in Section 4.3.1, rock salt is known to be present within the Syracuse Formation; however, it is not exposed at the ground surface due to its high solubility in water. The Syracuse Formation outcrops along a roughly east-west trending line north of the southern extent of Onondaga Lake (Figure 9) and has a gentle southward dip of roughly 100 feet per mile. Because of the dip of the beds, the Syracuse Formation is present in the subsurface south of the site area. Within several miles, the top of the Formation drops below the bottom of the glacially scoured Onondaga Valley. In the area where the Syracuse Formation is present above, or adjacent to the valley fill materials, salt is available for dissolution and transport by fresh water moving through the Formation and out into the valley fill materials.

Dissolution of rock salt leaves behind large void areas, producing high secondary porosity. This allows for preferential movement of ground water along the former salt horizon. A hydraulic gradient in the bedrock roughly following surface topography, will push ground water containing brines to the north into the sediments of the Onondaga Creek Valley. Once the brines are within the valley fill, they will move northward driven by ground-water flow in the unconsolidated sediments to the north.

Dissolution of rock salt from the buried valley walls and the bedrock underlying the valley has conceivably been occurring since the time that the ice sheet pulled out of the area during deglaciation and the first sediments were laid on top of the bedrock, more than 10,000 years ago. In comparison to this time frame, the removal of brines from the sediments at the southeast end of the lake occurred in just over 100 years. It is very likely that the removal of the brines by man occurred at a rate much faster than the replacement process, thereby depleting the reservoir.

Most of the brine production wells were located along the southeast and eastern portions of the lake, as were water supply wells with elevated chloride concentrations. This seems to indicate that brines were dominantly found within this portion of the valley. However, the Syracuse Formation underlies the northwest facing slopes south of Nine Mile Creek, and in the hill north of the creek and southwest of Warners Road, indicating that the proper conditions are available for the production of brines that could empty into the Nine Mile Creek Valley.

Ground water in this inter-valley area tends to move into adjacent valleys, or northward to lower discharge zones. This movement may be occurring at depth, directly from the bedrock into the valley fill materials. Kantrowitz's "Eastern Oswego Groundwater" report indicates that salty ground water may be found in the lower reaches of the Nine Mile Creek basin. Density stratification restricts the heavier brines situated in the deeper portions of the valley, as indicated by the chemical characterization of ground-water samples.

Ground-water flow in the tributary valleys to the Onondaga Valley are largely driven by topography. Water moves off the inter-valley divides and into the surface water and ground-water systems within each tributary valley. From here, it moves down-valley towards the lake. The type of flow patterns, flow velocities and the proportion of ground water versus surface water in each tributary valley are dependent on the local geologic conditions within that valley.

During the course of this investigation, the ground-water flow patterns within the Nine Mile Creek Valley were the main focus of attention as the predominance of waste beds are located in this area. It was found that the ground-water flow system within the valley is rather complex, with the sediments in the valley providing a portion of the complexity, compounded by the influence of the waste beds on the ground-water flow patterns.

As discussed in previous sections, the valley fill materials in the Nine Mile Creek Basin are generally heterogeneous. A relatively less permeable layer is at or near the ground surface in most areas. Underlying this horizon is a mixture of variable thicknesses of sand, gravel and silt which generally overlie till. These deposits tend to thicken downstream and drilling and seismic evidence indicate that there is a bedrock depression in the valley bottom near Waste Bed 11. From the bedrock low, the valley bottom rises roughly 20 feet before dropping again toward Onondaga Lake. Along the lake margin, it is expected that the bedrock surface drops quickly into a glacially-scoured lake basin.

The unconsolidated sediments are overlain by the waste beds. The beds within the Nine Mile Creek Valley can be broken into two groups: Beds 12-15 and Beds 9-11. The older beds, 9-11, are located along the north side of Nine Mile Creek, near the northern edge of the valley. The creek had been diverted south to its present day position during the construction of these beds. Beds 12-15 are located to the southwest of 9-11, south of Nine Mile Creek and abut the southern valley wall. Beds 9-11 cover roughly 126.3 acres and are approximately 70 feet thick. Beds 12-15 cover a larger area of approximately 436.2 acres and range in thickness from approximately 55 to 25 feet. Bed 13, at the northwest corner of this group, extends approximately 20 feet below the original land surface because this area was mined for sand and gravel prior to filling the bed with waste.

In addition to the beds within the Nine Mile Creek Valley are a group of beds near the confluence of Nine Mile Creek with Onondaga Lake. These beds (Waste Beds 1-8) cover approximately 314.5 acres and range in thickness from approximately 67 to 20 feet. Nine Mile Creek was diverted to the north, along the perimeter of these beds during their construction.

Ground-water flow in the Nine Mile Creek Valley is comprised of several components: flow in the bedrock, flow in the unconsolidated deposits, and flow between the bedrock and the unconsolidated deposits. Flow in the bedrock along the valley walls appears to be upward from the bedrock, into the overlying sediments and toward the center of the valley. Wells located on the higher areas to the south of Beds 12-15, which are in till and bedrock, indicate that ground-water elevations drop toward the Nine Mile Creek Valley. Closer to the beds and further down the side of the valley; however, ground-water elevations in wells along the valley wall appear to be lower than the anticipated elevations in Waste Bed 15, indicating that there may be flow from the waste bed to the south and toward the valley walls.

Ground-water and surface water flow within the Nine Mile Creek Valley is from the southwest. This portion of the valley is relatively narrow and has a relatively impermeable layer of varved silts and clays near the ground surface. Cross Section A-A' (Figure 10) has a saturated cross-sectional area of roughly 48,750 square feet. Ground-water elevations measured within this portion of the valley indicate Nine Mile Creek is a losing stream, that is, the stream elevation is higher than the surrounding ground water. This may, in part, be due to the relatively impermeable materials underlying the stream inhibiting equilibration between ground-water and surface water elevations.

Downstream of Section A-A' the valley begins to widen with a tributary valley entering from the north occupied by Beaver Meadow Brook. In about this same location along the northwest side of Bed 13, the hydrology of the system changes. Through this stream section, Nine Mile Creek becomes a gaining stream with shallow ground-water elevations adjacent to the stream higher than the elevation of the stream itself (Figure 25). This is thought to be a result of ground water moving down the valley within permeable sediments encountering lower permeability materials and being forced to flow upward into Nine Mile Creek.

Ground-water elevations within the waste beds, as indicated by piezometers and wells in the bed embankments and upper surfaces, are much higher (from 35 to 65 feet higher) than the ground-water elevations in wells adjacent to the bed perimeter (WB-2U). The ground-water levels beneath the beds are, in many cases, mounded with water levels in the waste material itself. The degree of mounding is dependent on many factors, including the bed's size, age, precipitation, surface drainage characteristics, and the amount of time since the bed last received process waste. At the time any one bed was in active use, the mound extended to the bed's upper surface. Once loading to a bed ceases, the height of the mound decreases until a quasi-equilibrium is reached between infiltration from precipitation on the bed's surface and outflow along the side and base of the bed.

Gradients along the edges of Beds 12-15 facing the stream are on the order of 0.1 to 0.3 ft/ft., while shallow ground-water gradients down the valley, along the stream, are approximately 0.0011 ft/ft. The rapid change in gradients is related to the difference in the permeability between Solvay Waste and the natural soils, combined with the high topographic relief along the edge of the waste beds.

From this point downstream, ground-water gradients within the valley remain relatively low. As with Beds 12-15, it is anticipated that mounding occurs within Beds 9-11 (Figure 25); however, no wells or piezometers are known to exist within the waste material of these beds to substantiate this. Wells do exist in the Lakeside Beds, which indicate that ground-water mounding does occur here, with gradients along the bed edges on the order of 0.06 to 0.01 ft/ft.

The ground-water flow system within the deeper sediments in the Nine Mile Creek Valley is markedly different than within the shallow system. Figure 26 depicts the potentiometric surface of the "deep" ground-water system as based on seven wells installed during this investigation, and five wells in the vicinity of the Crucible landfill. It is important to note that the wells are not necessarily all screened at the same depth or elevation interval, nor are they necessarily screened within the same horizontally continuous strata. Based on available data, lateral continuity of sediments does not exist within the Nine Mile Creek Valley. During installation, the deep wells were screened across intervals that were relatively more permeable than adjacent zones and as close above bedrock as possible. Because the bedrock surface elevation changed, it was not possible to set the well screens at identical elevations. Nonetheless, the ground-water elevation data appears to be generally consistent, allowing interpretation of a deep ground-water flow system.

Gradients of the deep ground-water system in the upper portion of the valley are generally steeper than the gradients in the lower valley reaches. Upstream of the waste beds, the potentiometric surface has a gradient of approximately 0.0016 ft/ft, while the gradients in the vicinity of Beds 9-11 and 12-15 are approximately 0.0003 ft/ft. These gradients range from about the same as the gradients in the shallow ground-water system to approximately one order of magnitude less.

The main difference between the shallow and deep ground-water flow systems is the apparent lack of mounding in the deep flow system below Beds 12-15 and 9-11 (Figure 26). It is possible that the configuration of the wells did not allow for the detection of a mound. It is more probable, however, that the sands and gravels underlying the beds, particularly Bed 13, may be acting as a permeable conduit through which the deeper ground water flows relatively freely, preventing ground-water mounding in the area. In contrast to Beds 9-11 and 12-15, there is mounding beneath Waste Beds 1-8 based on deep wells installed through these beds. Why mounding occurs here and not under the other newer beds is not known.

Gradients between the shallow and deeper ground-water systems vary between relatively strongly upward to relatively strongly downward. In general, the vertical gradient in the vicinity of Beds 9-11 and 12-15 along the stream tend to be downward, with the exception of upward flow at WB-5. North of Beds 9-10 the flow is also upward, as it is at WB-1, located upgradient of the Beds 12-15.

Vertical gradients through Beds 1-8 in the vicinity of the Crucible Landfill (Figure 26) were found to be downward based on ground-water elevations determined in December 1987 in wells installed for the Crucible Landfill studies (Thomsen, 1982b; Calocerinos & Spina, 1984). Downward gradients, combined with ground-water mounding, provide for radial flow away from the beds in all directions. Ground water discharging along the southwest side of these beds eventually becomes part of the regional flow down the Nine Mile Creek Valley and discharges toward the lake, either around the northwest end of Beds 1-8, or to the southeast between Beds 1-8 and Bed A.

An additional discharge related to these beds is the result of ground water discharging from the natural sediments underlying the Solvay Waste. Based on the averages of the hydrogeologic information in the Thomsen (1982b) report, a calculated 0.038 cfs of ground water discharges to the lake from the "lower lacustrine sand and ablation till" units underlying the Beds 1-8.

Shallow and deep ground-water elevations in Bed A also indicate that there is mounding beneath this bed, producing radial flow away from the bed. Due to the lower surface elevation and decreased thickness of wastes in Bed A, the ground-water mound is smaller in horizontal extent and in vertical magnitude, when compared with the younger beds.

Bed B, located along the southeast edge of Onondaga Lake, has a surface elevation roughly equal to or lower than that of the ground surface to the southwest of the bed. For this reason, it appears that mounding with radial flow does not occur here; rather, flow is toward the lake in both the deeper and shallower zones.

Detailed ground-water elevation data were not readily available for Beds C through E or Areas F through M. It is anticipated that the flow in these beds and areas will tend to follow the topography of the ground surface, discharging eventually towards Onondaga Lake.

In-situ hydraulic conductivity ("slug" tests) were conducted in seven of the sixteen monitoring wells installed during this investigation to determine the horizontal hydraulic conductivity of the material surrounding the screened interval. The results of the tests are included in Table 15, along with the depth and soil type adjacent to the screened interval. Three of the wells had hydraulic conductivities which exceeded the measuring capability of the method. Monitoring Wells WB-2U, WB-4L and WB-5M all recovered to the original static water level before the first reading could be determined after removing the slug. It is estimated, therefore, that the material in which the wells are screened has a hydraulic conductivity in excess of 6 x 10^{-3} cm/sec. One water level reading was obtained in WB-5L before stabilization occurred, indicating a horizontal hydraulic conductivity of approximately 4.2 x 10^{-3} cm/sec. The remaining three wells produced reliable recovery curves, and the horizontal hydraulic conductivity in these wells were determined to be 4.6 x 10^{-4} (WB-6), 2.6 x 10^{-4} (WB-BL), and 1.1 x 10^{-4} (WB-BU) cm/sec. WB-BU was screened in Solvay Waste in Waste Bed B. This horizontal hydraulic conductivity value is similar to the values determined for Solvay Waste in the Lakeside Beds performed by Calocerinos & Spina for the Crucible Landfill study (Thomsen, 1982b).

As previously discussed in Subsection 4.3.2.2, Precipitation and Water Balance, the different waste bed groups have different infiltration capacities based on the bed's surface drainage, cultural features, and vegetation.

Infiltration into the beds is eventually discharged to the underlying natural soils or out the side of the beds. Flow rates and the location of discharge from each bed varies based on the type of bed construction, the age of the bed, and the consistency of the waste placed in each bed. Flow out of each bed consists of flow out of the sides (seeps) and flow out the bottom. The flow out the sides has been observed to be highly variable in areas where it can be quantified and difficult to quantify in other areas due to the dispersed nature of the seepage. The amount of discharge from the newer beds (12-15) consists of infiltration plus water released from storage. The calculated rate of discharge from the waste beds is given in Table 17.

Most of the lateral discharge from Beds 12-15 is captured in trenches along the bed perimeter, which flow to the retention pond on the east side of the beds, and is then periodically pumped to Metro. In 1987, the transfer of water to Metro averaged 704,000 gallons/day (1.09 cfs). In addition to the infiltration due to precipitation and dewatering of the pore spaces, Allied reported that LCP discharged process wastewater at an average rate of 164,000 gpd (0.25 cfs) to Bed 14 in 1987. Subtracting the amount added by LCP from the amount discharged to the trenches (and subsequently transported to Metro) indicates that there is a net removal of 540,000 gpd (0.84 cfs) from the Waste Bed 12-15 hydrologic system. This net removal can be subtracted from the total input of water due to infiltration into Beds 12-15 (0.95 cfs), indicating that approximately 0.11 cfs discharges to the subsurface of Beds 12-15.

None of the other beds, however, have similar mechanisms by which water is collected and removed from the local hydrologic system. As such, water discharging from the other beds will either discharge directly to the ground water or discharge directly to surface water bodies. Based on the ground-water flow patterns, it can be assumed that water discharged to the subsurface will eventually be discharged to adjacent surface water bodies. Therefore, the total amount of water flowing from the

4.3.2.4 Summary of Hydrogeologic Conditions

The Onondaga Lake Valley, and its tributaries, are surrounded by highlands which are underlain by bedrock. Along the margins of the Nine Mile Creek Valley, ground water has been found to generally flow out of the bedrock into the unconsolidated deposits of the valley. Along the southeast margin of Onondaga Lake, where the rock salt containing the Syracuse Formation exists at or near the ground surface, the formation is the source of brines within the unconsolidated sediments in this area.

Within the tributary valleys, ground-water flow is down the valley walls toward the valley bottom. Depending on local hydrogeologic conditions, the ground-water may discharge to the valley's stream or remain within the ground-water system. In the upper reaches of Nine Mile Creek, upstream of Waste Bed 13, the creek appears to discharge to the ground water and is, therefore, a losing stream. However, in the vicinity of Bed 13, the stream becomes a gaining stream and ground water discharges to the stream. It is thought that Nine Mile becomes a gaining stream in this area for several reasons. A large accumulation of permeable materials exist in the area of Waste Bed 13. Downstream from this area, the sediments become less permeable. A large volume of ground water can pass through the permeable sediments; however, as the hydraulic conductivity decreases, the capacity of the sediments to transmit water decreases. The system responds by discharging ground water to the surface. The beds in any one year will, on average, equal the total amount of discharge to adjacent surface water bodies.

The volume of ground water within the Nine Mile Creek Valley sediments downstream of Warners Road and upstream of Cross Section B-B' was estimated to be approximately 8.5×10^8 ft^3, based on an average porosity of the valley fill materials of 30 percent.

The flow rate of this ground water down Nine Mile Creek Valley, within the underlying sediments, is estimated at the location of Cross Sections A-A' (upgradient) and B-B' (downgradient). The upgradient ground-water flow was calculated to be 0.043 cfs based on a down-valley ground-water gradient of 1.6×10^{-3} ft/ft, a hydraulic conductivity of 1.4×10^{-2} cm/sec., representative of sand and gravel from tests in WB-5M, and an estimated saturated cross-sectional area of 58,000 ft^2. The downgradient ground-water flow was calculated to be 0.026 cfs based on a down-valley ground-water gradient of 4×10^{-4} ft/ft, a hydraulic conductivity of 1.1×10^{-2} cm/sec., representative of the composite sand and gravel, and silt and sand from tests in UB-5L and WB-5M, and an estimated saturated cross-sectional area of 182,000 ft^2. The flow rate of 0.026 cfs discharging across the downgradient cross section is considered to be insignificant when compared to the average annual Nine Mile Creek flow rate of 137.4 cfs.

stream remains a gaining stream from this area to its confluence with Onondaga Lake.

Ground-water mounding occurs within beds. This produces ground-water flow which is normally radially away from the beds. In the area of Beds 9-11 and 12-15, the flow from the beds discharges to the subsurface and then eventually to the stream, as the stream is gaining in this area. Mounding of ground water in the Lakeside Beds produces radial flow, some of which discharges directly to the sediment below Onondaga Lake, and then into the lake itself.

Ground-water flow within the deeper portions of the valley is also towards the lake. In general, the deep system is less affected by surface topography and, as a result, has a lower overall gradient down valley than the shallow ground-water system.

The discharge of ground water to the lake from the Nine Mile Creek Valley at the downstream cross section has been calculated to be 0.026 cfs. This is considered an insignificant amount when compared to the average annual discharge of 137.4 cfs.

4.4 Water Quality Results

4.4.1 General

The list of chemical parameters for which surface water and ground water were sampled are listed in Table 18. The results of the analyses are presented in Table 19 for surface water and Table 20 for ground water. Ground-water and surface water sampling locations are shown in Figure 27. Several methods for evaluating the data were employed, including: Piper diagrams; linear regressions; comparisons of anion/cation ratios; plots of depth versus ion concentrations; and plots of time versus ion concentrations. Typical analyses for Tully brine, purified brine and waste bed overflow were also used for comparison purposes. These analyses are presented in Table 21.

Tully brine was the raw brine solution pumped from deep wells in the Syracuse Formation, and was then conveyed via pipeline from Tully, New York to Allied's Solvay facility. Before use in the Solvay Process, this brine underwent refining and resulted in a "purified" brine. Waste bed overflow was the supernate obtained from the beds when the Solvay Process waste water was placed in the beds.

The chemical characteristics of the Tully brine was used in this report to represent natural brines in the study area. The chemical characteristics of natural brines occurring in the Onondaga Lake Basin are not fully known. The brines which were pumped in the Onondaga Lake Basin are from the Syracuse Formation like the Tully brine. The assumption that these two brines have similar chemical characteristics is probably valid, however, the relative magnitude of the ionic concentrations may vary.

The major ions (based on percent concentration) of interest in Solvay Waste (and waste leachate) are chloride, calcium and sodium. Minor ions, such as magnesium and potassium, make up a small percentage of the total ionic balance. Other ions, such as iron and strontium, do not comprise significant percentages of the total ionic wells include WB-1U, WB-1L, Metro 1, WB-BU, WB-BL, DW-101 and MS-104.1.

There were several curves which had good closeness of fit, but statistically the population size was not large enough to have a high confidence level in the results. Another problem with the regressions was the high degree of variability in the data, which is also related to the small population size of the data.

Several combinations of anion/cation ratios were examined in an effort to characterize the water chemistry. These included: total alkalinity (hydroxide plus carbonate plus bicarbonate) versus calcium; chloride versus calcium; chloride versus sodium; calcium versus sodium; strontium versus sulfate; strontium versus calcium; sodium versus sulfate; chloride versus sulfate; chloride versus potassium; sodium versus carbonate; sodium versus bicarbonate; and calcium versus carbonate. In most cases, when these ratios were plotted against one another, the only conclusive results were that background water quality appeared different from the typical brine solutions and all the other water quality data values fell somewhere between these extremes. Some of these chemical ratios will be discussed later in this report.

Simple plots of depth versus different ionic concentrations were examined. The conclusion of this data manipulation was that, in general, chemical concentrations increased with depth.

A plot of age versus ion concentration of representative waste leachate was also examined. These graphs (Figures 31, 32 and 33) indicate that the chloride, sodium and calcium concentrations typically found in waste bed leachate, are decreasing over time. This is an important observation and will be discussed further in this report.

4.4.2 Surface Water

Surface water samples were obtained at 27 locations during December 1987 and the sampling locations are shown in Figure 27. The sampling locations were chosen during the site reconnaissance conducted in April-May 1987 and discussed in Section 4.2. Procedures used for surface water sampling are discussed in Appendix A.4.

In general, surface water sampling points were chosen to assess: 1) surface water quality entering the Waste Bed Area; 2) water, quality of tributaries to Nine Mile Creek and Onondaga Lake; 3) chemical quality of selected leachate seeps; and 4) water quality of surface water as it exits the study area.

The percent balance between anions and cations resulted in five samples (out of the 27 sampled) exceeding the generally accepted 7 percent. These samples were obtained at Stations SW-7, SW-14, SW-15, SW-16 and SW-17. Station SW-7 (located near the Conrail tracks east of the retention basins for the Metro Force Main) did have a high chloride concentration compared to other stream sampling locations nearby, but was close to balancing. The presence of other chemical constituents which were not analyzed for is the probable reason it did not balance to less than 7 percent. The other four surface water samples which did not balance were, in general, leachate samples rather than stream samples. SW-14 was leachate discharge originating between Waste Beds 9-10 and 11 and this sample also did not balance due to the presence of chemical constituents which were not analyzed. SW-17 was located in a drainage ditch northeast of State Fair Boulevard. This sample may be influenced by surface runoff, but in general, concentrations of chloride, sodium and calcium were not high (420 mg/l, 130 mg/l and 120 mg/l, respectively). Samples SW-15 and SW-16 were leachate seeps located along the lakeshore edge of Beds 1-6. The water quality at these locations may be indicating influence from landfilling occurring on top of the beds. The remaining 22 surface water samples all balanced within 7 percent.

The background surface water sample (SW-8) was located at the Warners Road bridge in Amboy on Nine Mile Creek. Other samples were collected along Nine Mile Creek and its tributaries. The results of these samples indicate that as Nine Mile Creek flows toward Onondaga Lake, concentrations of chloride, calcium and sodium are increasing. SW-8 (upstream) had concentrations of 47 mg/l chloride, 140 mg/l calcium, and 25 mg/l sodium, as compared to SW-12 (downstream) with concentrations of 1,200 mg/l chloride, 470 mg/l calcium, and 370 mg/l sodium. The concentrations at SW-13 (1,100 mg/l chloride, 460 mg/l calcium, and 330 mg/l sodium), located at the mouth of Nine Mile Creek, are slightly lower than observed upstream at sampling location SW-12, but this is thought to be due to the mixing of waters of Nine Mile Creek and Onondaga Lake.

A review of conductivity data collected by the NYSDEC along the length of Nine Mile Creek, downstream of Warners Road, substantiates a general increase in conductance with increased distance downstream. The data indicated that there may be several discrete zones of elevated conductivity inflow to the creek in the stretch between Beds 12-13 and 9-11. This stretch coincides with the area of Nine Mile Creek that has been identified as a gaining stream, as discussed in Subsection 4.3.2.3.

Beaver Meadow Brook, which enters Nine Mile Creek upstream of the bridge north of Waste Bed 13 was sampled at location SW-27. SW-27 had higher concentrations of chloride, calcium and sodium (120 mg/l, 180 mg/l, and 64 mg/l, respectively) than observed at SW-9 (63 mg/l chloride, 140 mg/l calcium, and 28 mg/l sodium), which was located in Nine Mile Creek upstream of the confluence with Beaver Meadow Brook. The sample collected at SW-27 is assumed to be representative of background surface water quality of the area which it drains.

Samples SW-6 and SW-7 were collected from unnamed tributaries which empty into Geddes Brook (and subsequently into Nine Mile Creek). SW-6 is a sample from a drainage ditch which originates near LCP Chemicals, and sample SW-7 is from a drainage ditch near the Conrail tracks east of the retention basins for the Metro Force Main. Sample SW-5 was collected from Geddes Brook upstream of the confluence of these two unnamed tributaries and had concentrations which were similar to the chemical concentrations of SW-27 (Beaver Meadow Brook). It is assumed that samples SW-5, SW-8 (upstream Nine Mile Creek location), and SW-27 are representative for surface water before it is impacted by the waste beds. At all three of these background sampling locations, calcium concentrations were higher than both sodium and chloride concentrations.

Two springs located upgradient (with respect to both surface and ground-water flow) of the study area were sampled. The water quality observed at these two locations (SW-20 and SW-26) was very different. The water quality at SW-26, located in the Nine Mile Creek Valley upstream from Waste Beds 12-15, had low concentrations of chloride (79 mg/l), calcium (89 mg/l), and sodium (45 mg/l). Sample SW-20, collected at the DPW Garage on Milton Avenue east of Horan Road, had higher concentrations for chloride, calcium and sodium (500 mg/l, 380 mg/l, and 240 mg/l, respectively). The water at SW-20 is originating from the Syracuse Formation, so it is believed that this sampling point may be representative of this bedrock formation, whereas the spring at SW-26 is originating from the sand and gravel overburden and is representative of the Nine Mile Creek Valley fill.

Harbor Brook was sampled at two locations. The upstream location, SW-18, was at the USGS Gaging Station and SW-1 was located downstream near Harbor Brook's confluence with Onondaga Lake, but upstream of a drainage ditch which feeds the brook (SW-2). The concentrations of chloride and sodium increased slightly at SW-1 (290 mg/l chloride and 180 mg/l sodium), as compared to SW-18 (210 mg/l chloride and 110 mg/l sodium). Calcium concentrations decreased from 230 mg/l at SW-18 to 220 mg/l at SW-1. Concentrations at SW-2 were high for chloride and sodium (630 mg/l and 430 mg/l, respectively), compared to those observed in Harbor Brook. The calcium concentration (48 mg/l) observed at SW-2 was much lower than observed at SW-1 and SW-18. The source of higher chloride and sodium concentrations and the lower calcium concentration at SW-2 are likely due to road de-icing activities along I-690. Road salts generally have less calcium in proportion to chloride and sodium. The waste bed overflow (as a representative sample of Solvay Waste leachate) has a higher proportion of calcium compared to sodium. Based on ratio of chloride to sodium concentration, compared to the ratio of chloride to calcium concentration, SW-2 appears to be influenced by road salting.

Two surface drainage points along the west shore of Onondaga Lake were sampled at SW-3 (on the lakeshore side of Waste Bed B) and SW-4 (on the lakeshore side of Waste Bed 1). The sample from SW-4 had concentrations of 2,200 mg/l, 810 mg/l, and 550 mg/l for chloride, sodium and calcium, respectively, and because it drains an area leading from I-690, it may be due to influence of road de-icing. SW-3 is at the outlet of a surface pond into the lake located northeast of I-690. The water in the pond is relatively rich in sodium and chloride relative to calcium; however, the ionic concentrations (710 mg/l chloride, 440 mg/l sodium, and 130 mg/l calcium) were less than those observed at SW-4.

SW-25, a spring, was sampled along the east shore of Onondaga Lake northwest of Ley Creek. Some ponding of water occurs in that area and these ponds were sampled and determined to be salty by the USEPA in 1974. Historical references indicate that this area was the location of past salt industry activities. The ponds, which have been historically salty, may also be influenced by road de-icing along Route 57. No Solvay Waste was apparent at this location.

Ley Creek was sampled at two points; one location upstream at the USGS Gaging Station (SW-23), and one downstream location at the creek's juncture with Onondaga Lake (SW-24). The water quality at these two locations was very similar, with only very slight increases (20 to 30 mg/l) in concentrations of chloride, calcium and sodium as the creek flows toward the lake. No Solvay Waste was apparent in this area.

Onondaga Creek was also sampled at two points; one upstream location at the USGS Gaging Station (SW-19), and one downstream location as the creek flows into Onondaga Lake (SW-22). Concentrations of chloride and sodium increase downstream along the creek. There is some chloride increases from 260 mg/l upstream to 660 mg/l downstream, and sodium increases from 150 mg/l to 400 mg/l downstream. Solvay Waste is apparent along the creek's banks, however, calcium concentrations at the upstream and downstream locations are the same (130 mg/l), indicating that there is little impact to Onondaga Creek from Solvay Waste.

The Metro effluent was sampled at location SW-21. A post-chlorination effluent sample was obtained at this location. The concentrations of the tested parameters were generally low (150 mg/l chloride, 96 mg/l calcium, and 120 mg/l sodium). This sample had the highest fluoride concentration of any of the samples due to fluoridation of the municipal water supply.

The trilinear diagram for the surface water samples indicates that in relation to the percent composition of the anions, the water ranges from sulfate type to no dominant type to chloride type water (Figures 28 and 29). The cations range from calcium type to no dominant type to sodium or potassium type. When the anion and cation trilinear diagrams are projected onto the Piper diagram, the intersection of most of the surface water sampling points fall into the upper region in which calcium plus magnesium, sodium plus potassium, and chloride plus sulfate and bicarbonate dominant water types overlap. There are several points which do not fall into that region and those samples represent the strongly dominant sodium chloride and calcium chloride type waters.

The Piper diagram also shows typical points for Tully brine, purified brine and waste bed overflow. The latter is a strongly dominant calcium chloride type water, whereas the brines are sodium chloride type waters.

Plots of different anion/cation ratios were constructed, but no conclusions could be drawn from them. The ratio of chloride to sodium was examined for the surface water, but no conclusions were drawn because the surface water can be affected by other environmental influences other than Solvay Waste.

From the concentrations of compounds that were analyzed and stream flow data, the loading rates to Onondaga Lake can be calculated. These loading rates to the lake will be discussed in Section 4.5

In general, the streams monitored for water quality all increased in concentration for the major ions (chloride, calcium and sodium) as they flowed toward Onondaga Lake. Solvay Waste leachate appears to directly impact Nine Mile Creek and also Onondaga Lake at some of the surface water seeps and springs along the shores of these surface water bodies. The other major tributaries which were sampled (Ley

Creek, Onondaga Creek, and Harbor Brook), do not appear to be as impacted as Nine Mile Creek, especially Ley Creek and Onondaga Creek, which have negligible impact from Solvay Waste.

4.4.3 Ground Water

Ground-water samples were obtained from 21 wells located as shown on Figure 27 during December 1987. The sixteen monitoring wells installed as a part of this investigation were sampled in addition to five pre-existing wells. Of the wells installed for this investigation, fifteen of the sixteen wells were installed as clusters; six two-well clusters and one three-well cluster. The remaining well was paired with a nearby pre-existing well to provide samples from different depths. One of the other four pre-existing wells was in a cluster, however, only one was sampled. The other pre-existing wells were not clustered.

Sampling procedures are presented in Appendix A.3. The details of the well installation and subsurface conditions are also given in Appendix A.3 and Table 25.

A chemical balance was performed on the ground-water quality results. Six samples out of the twenty-one ground-water samples did not fall within a 7 percent balance; these wells were WB-1U, WB-2U, WB-BU, WB-BL, MS-104.1 and WB-3L. When the percent balance of the anions and cations is not in close agreement, it is an indication that some ions have not been accounted for. The percent balance differed less than 8 percent in Wells WB-3L and MS-104.1. In Well WB-1U, the percent balance was differed by approximately 11.4 percent. Wells WB-2U, WB-BU and WB-BL, however, were in excess of 20 percent from balancing (WB-BL was approximately 52 percent). The imbalance of the cations and anions may be explained by the presence of other ions in the water samples which were not analyzed, and the difficulty in quantitatively analyzing chemical parameters such as carbonate and bicarbonate.

The anion trilinear diagram indicated that most of the ground-water samples were dominant chloride type waters (Figures 28 and 30). The three exceptions were: upgradient Well WB-1L has dominant sulfate type water; WB-1U (upgradient) has dominant bicarbonate type water; and the Metro 1 well has no dominant type water. The cation trilinear diagram indicated that most of the wells had dominant calcium type water.

There were two ground-water samples (WB-3U and WB-7L) which had no dominant type water, and Wells WB-5L, WB-2U, WB-BL, the Tully brine, and the purified brine were dominant in sodium plus potassium type waters.

The projection of the trilinear diagrams onto the Piper diagram indicated that most of the ground water in the wells and the waste bed overflow were in the region for dominant chloride plus sulfate type waters. The Tully brine and purified brine are within the region in which dominant chloride plus sulfate type water and dominant sodium plus potassium type water intersect. Upgradient Wells WB-1U and WB-1L have ground water which is classified as dominant calcium plus magnesium type water. Three wells (WB-BU, WB-3U and the Metro 1 well) have ground water which is within the region which includes dominant calcium plus magnesium, sodium plus potassium type water, and dominant chloride plus sulfate and bicarbonate type water.

In general, most of the wells sampled had ground water classified in the dominant chloride plus sulfate type water, and appear similar in chemistry to waste bed overflow in terms of the ion percentages. However, some of the deeper wells (such as WB-BL, WB-5L, and WB-7L, in particular) had chemical characteristics which start to approach the characteristics of the brine solutions. The piper diagram (Figure 30) indicates that the deeper brines in the Nine Mile Creek Valley, represented by samples from Well 5L, fall between the samples of waste bed overflow (representative of Allied discharge) and Tully Brine (representative of natural brine). This indicates that deeper ground water in the valley is a composite of both Allied's discharge and natural brine. Samples from well clusters 5 and 7 also indicate a trend towards the Tully Brine composition with increasing depth.

Linear regressions were performed on the ground-water quality data. As mentioned in Section 4.4.1, little confidence is placed on the linear regressions due to the small population size of the data.

By simply examining the data in units of mg/l and examining some of the ion ratios, based on their percent composition of the total anions or cations, several conclusions can be drawn. One of the two major observations made while examining the chemical data is that some of the major ions (chloride, sodium, and in most cases, calcium) increase in concentration with increasing depth. The second major observation is that the concentrations of some of the major ions (chloride, calcium and sodium) associated with a particular waste bed decrease with the age of the waste bed.

The anions and cations which have been a major interest in the Waste Bed Investigation are chloride, calcium and sodium. Chloride and sodium increase in concentration with increasing depth below the ground surface in all the wells monitored. Calcium increases with depth except near older Waste Bed B and Beds 1-8. At Waste Bed B, a higher calcium concentration is detected in Well WB-BU (shallow well screened in the waste) compared to WB-BL (deep well screened 56 feet below the bottom of Bed B). At Waste Bed B the decrease in calcium with depth could be an indication of natural brines existing in the Onondaga Lake Basin. The sample collected at WB-BL is very similar in chemical character to the Tully brine and purified brine solutions (as observed in the Piper Diagram, Figure 30). In the example of Wells MS-104.1 and DW-101, located at Waste Beds 5 and 3 respectively, the calcium concentrations are the same. Well MS-104.1 is constructed with a screen located approximately 10 feet below Bed 5 and DW-101 is constructed with a screen approximately 57 feet below Bed 3. The water quality at DW-101 resembles that of waste bed overflow, but because of the well's depth, the calcium concentrations may be partially attributed to naturally occurring marl deposits found around Onondaga Lake.

Magnesium chemically responds similar to calcium in some aspects of water chemistry, but their geochemical behaviors are substantially different. Magnesium ions tend to be mobile in the ground-water environment. The percentage of magnesium, with respect to the total cations, decreased with depth in all but four cases. At well cluster WB-5, there was an increase in percent magnesium between Wells

WB-5U and WB-5M. Only a slight increase was observed in Well WB-4L, compared to Well WB-4U. There were large increases of percent magnesium in Wells WB-BL and DW-101 (as compared to Wells WB-BU and MS-104.1, respectively). When the magnesium and calcium percentages are examined together, the trend is a decrease in percent for these two cations, as sodium increases with depth. This observation can be explained by considering the fact that these are among the deepest wells in the study area. Natural saline ground water with less percent calcium and magnesium than percent sodium could be present in the deeper portions of the Nine Mile Creek and Onondaga Lake Basins.

The higher the total dissolved solids (TDS), the greater the density of a solution. Therefore, fresh water floats on salt water, and brine with high TDS sinks beneath brine with lower TDS. Very little mixing of the solutions occurs, and chemical diffusion is limited to a thin zone of transition between different brines. Waste bed overflow has a TDS concentration which is approximately half that encountered in some of the deeper wells (i.e. WB-5L). Therefore, we can assume that the higher concentration brines may be partially attributed to a natural source.

The relative concentration of potassium in ground water decreased with depth in all the wells except one. In Well WB-BL, the percentage of potassium increases with depth. While potassium ions are larger than sodium ions, there is a greater tendency for potassium ions to be incorporated into some clay-mineral structures rather than sodium (Hem, 1985). Based on this fact, the decrease in the potassium percentage with depth may be a function of the clay minerals being present in the formation and, therefore, because the potassium is tied up in the clay structure, little potassium is available to be mobilized into ground water.

Iron is a minor ion which was evaluated with respect to concentration. The percentage of iron in terms of total anions was not calculated because chloride is such a high percentage that iron is essentially zero percent in comparison. Iron concentrations generally increased with depth. Two exceptions were noted from this general trend. The iron concentrations at WB-7U and WB-7L were the same; and at P-1, the concentration of iron (330 mg/l) was higher than at P-2 (6 mg/l) and WB-6 (39 mg/l). At Well P-1, the iron concentration was the highest of any of the wells sampled. It is suspected that the high concentration of iron is due to the deterioration of the steel well casing and is not representative of the ground water at this location.

The percent strontium, with respect to the total anions, was not calculated because of the dominance of the percentage of the chloride ions. Strontium, an ion that is present in the natural brines in the area, increased in concentration with depth as cited for some of the other minor ions. There were two exceptions to this observation, one occurring at Well WB-7L and the other at Well WB-3L. The difference in concentration was only 1 mg/l between WB-7U and WB-7L, and Wells WB-3U and WB-3L, so the concentrations were essentially the same at these two locations with increasing depth. In the other wells, the increase in strontium with depth was generally large (an average increase of 30 mg/l). Tully brine has a strontium concentration of 71 mg/l, whereas purified brine used in the Solvay Process has a concentration of 3.5 mg/l. No analyses for strontium were available for waste bed overflow, so the amount of strontium occurring in the overflow is uncertain. Well WB-BU is located within Solvay Waste and the sample collected there had a concentration of 6.2 mg/l. Well MS-104.1 had a ground-water concentration of 110 mg/l and this well is screened 10 feet below Solvay Waste. Because there are large differences in strontium concentrations in ground-water samples located very close to Solvay Waste, no conclusions based upon strontium concentrations can be drawn at this time.

Ratios of percent chloride to percent calcium, and percent chloride to percent sodium were evaluated. The Tully brine has a chloride to calcium ratio of 53:1 and a chloride to sodium ratio of 1:1. Waste bed overflow has a chloride to calcium ratio of 1.5:1 and a chloride to sodium ratio of 2.8:1.

With respect to ground water, the chloride to sodium ratio increased with depth at four well clusters (WB-1, WB-2, WB-4 and WB-6) and decreased with depth at the remaining well clusters. The decrease in the chloride to sodium ratio was observed at well clusters which included some of the deepest wells in this study, namely within clusters WB-3, WB-5, WB-7, and WB-B and in Well DW-101. At these well clusters, the ratio of chloride to sodium approached a 1:1 relationship similar to that observed for Tully brine.

The chloride to calcium ratios decreased with depth in well clusters WB-2, WB-3, WB-4 and WB-6 and increased with depth at the other well clusters sampled. Although the ratio of chloride to calcium did not reach the value of 53:1 (as observed for Tully brine), some of the deeper wells in the study such as WB-5L, WB-7L, WB-BL and DW-101 (which all indicated an increase of the chloride to calcium ratio with depth), had ratios of chloride to calcium that ranged from 1.5:1 at DW-101 to 4:1 at WB-BL. At well cluster WB-1, the ratio of chloride to calcium increased with depth from 0.04:1 in WB-1U to 0.11:1 in Well WB-1L. The magnitude of the change in the chloride to calcium ratio is much less than observed in the other wells; in addition, the concentrations of chloride (7 mg/l in WB-1U and 45 mg/l in WB-1L) are very low when compared to any of the other wells. Because the chloride concentrations are low in Wells WB-1U and WB-1L, the ground-water quality at these wells do not resemble a brine solution.

The concentrations of chloride, sodium and calcium from representative leachate samples (which include data from some of the shallow ground-water monitoring wells and leachate seeps which are surface expressions of the ground water) were plotted (Figures 31, 32 and 33). Waste bed overflow was considered "new" Solvay Waste. As the age of the Solvay Waste increases, the chloride, calcium and sodium concentrations of representative leachate samples decreases. This indicates that as the waste is continually flushed due to infiltration, the chloride, calcium and sodium leach out and the concentrations decrease over time.

4.4.4 Summary of Water Quality

The surface water quality results indicate that in Nine Mile Creek, concentrations of the major ions (chloride, calcium and sodium) increase as the creek flows toward Onondaga Lake. Surface water sampling of the other major tributaries to the lake in the study area (Ley Creek, Onondaga Creek, and Harbor Brook) indicate increasing concentrations of the major ions, but the impact of Solvay Waste on these tributaries appears to be negligible.

The background surface water quality at locations SW-5, SW-8, SW-27 and SW-20 (Figure 27) indicates that calcium concentrations, as compared to chloride and sodium concentrations, are greater than calcium concentrations in some of the other surface water samples in the study area. Several surface water samples (SW-2 and SW-4) indicate possible influence from road salting as evidenced by the ratio of chloride to sodium concentrations approaching a 1:1 relationship and a decrease in calcium concentration with respect to chloride and sodium.

The ground-water quality results generally indicated increasing concentrations of the tested parameters with depth; however, the relationships of some of the major and minor ions are different depending on location and depth. Some of the deeper wells sampled (WB-5L, WB-7L and WB-BL, in particular) may be influenced by natural brines occurring in the Nine Mile Creek Valley. This observation was based on the percent concentration of chloride to calcium and sodium to calcium. In general, at deep Wells WB-5L, WB-7L and WB-BL, both these ratios increase at depth indicating more chloride and sodium, as compared to calcium, as indicative of a natural brine solution. Based on this information, it is concluded that the brines currently at depth are a combination of Allied's past disposal practices and natural brines. This is a qualitative conclusion that cannot be quantified with available data, but it is estimated that Allied's portion is greater than 50 percent.

The concentrations of the major ions generated in the leachate from the waste beds, primarily chloride, sodium and calcium, decrease over time (Figures 31, 32 and 33).

4.5 Water Quality Impact Assessment

The following section presents the water quality impacts to Onondaga Lake of the waste beds, surface waters and the Metro Plant. All impacts discussed are representative of 1987 conditions.

4.5.1 Impact of Areas F-M and OLF

Areas F-M and OLF (SW and NE) were included in this investigation as specified in the Consent Order based on the potential that Solvay Waste may have be located in these areas. However, based on historical research and site reconnaissance, only Areas F, G and H are determined to have received significant amounts of Solvay Waste. These areas have undergone extensive cultural development since the time Solvay Waste was placed in these areas. The filling of waste in these areas was not uniform and the extent of the areas is estimated based upon historic information. Area OLF (NE) did not indicate the presence of Solvay Waste based on observations made during the site reconnaissance phase of this investigation. Areas OLF (SW), which reportedly received dredged material from the precipitate delta at the mouth of Nine Mile Creek, did not have an indication of typical Solvay Waste.

One ground-water sample was obtained in the F-M Waste Areas from a well located at Metro. There was no apparent impact on ground water at this location, based on the water quality of the Metro well sample. The concentrations of the parameters tested is similar to background concentrations in Nine Mile Creek Valley.

Onondaga Creek and Ley Creek were sampled at upstream and downstream locations. Little Solvay Waste was apparent along Onondaga Creek northwest of Hiawatha Boulevard; however, none was noted to the southeast and no waste was observed along Ley Creek. Increases in concentration of ions such as sodium and chloride can be attributed to activities occurring in the development areas. These activities include precipitation runoff from paved areas, de-icing of roads and surface water contamination from businesses located along the streams. The impact of Solvay Waste on surface water in this area is negligible.

4.5.2 Impact of Waste Beds A-E

The combined area of Waste Beds A-E is approximately 5.74 x 10^6 ft^2 (131.8 acres). Some development of these beds has occurred since the time Solvay Waste was deposited. The well-developed areas contain their own associated drainage systems, and therefore were not considered in determinations of water quality impact.

Two wells were constructed and sampled at Waste Bed B. One well was screened in Solvay Waste and the other was screened 56 feet below the waste. The ground water has been impacted in this area based upon the concentration of parameters tested in the wells at Bed B. Based on a comparison of ratios of chlorides to various cations, it appears there may be some potential contribution of natural brines at Bed B.

The impact that these beds have on surface water, ground water, and eventually Onondaga Lake, is estimated by calculating the loading rates of chlorides for representative waste bed leachate. The loading rates are calculated by multiplying the amount of leachate that is currently generated from each bed, based on infiltration estimates, times a representative leachate concentration. The amount of precipitation available to infiltrate Bed A is estimated as 10.96 inches/year, which, based on an area of 1.67×10^6 ft^2, results in an infiltration rate of 0.048 cfs. Bed A has a representative ground-water concentration for chloride of 18,500 mg/l, which is a value obtained from a ground-water monitoring well downgradient of Bed A (Geraghty & Miller, 1980). The resulting calculated loading rate of chloride to ground water from Bed A is 2.39 tons/day.

Bed B has an estimated infiltration rate of 0.03 cfs, based on 10.43 inches of available precipitation. A representative chloride concentration of 1,300 mg/l obtained from Well WB-BU which is screened at the bottom of Bed B was used to calculate the resulting loading. The calculated chloride loading to ground water from Bed B is 0.11 tons/day.

balance; however, the concentrations of these ions were of magnitudes that they are worthy of comment. The concentrations of the major ions are discussed in the surface water and ground-water quality subsections. The concentrations of minor ions are discussed for ground-water quality, but not for the surface water quality. The concentrations of the minor ions in the surface water varied from sample to sample and could not be used for any source quantitative identification.

The first step in evaluating the water quality data was to perform an ionic balance. This was done as a check to verify that the list of tested parameters constituted a relatively complete representation of the water quality. An ionic balance is performed by summing the cations and the anions independently and comparing the two sums. They should agree with only a small percent error. The USGS, Water Resource Division accepts data if the balance is within 7 percent.

The second method involved the use of Piper diagrams to evaluate the chemical data. A classification scheme for dominant water types, based on Piper diagrams, is shown in Figure 28. One diagram presents the surface water classification (Figure 29) and a second diagram presents the ground-water classification (Figure 30). A listing of the data points is presented in Table 22 for surface water, Table 23 for ground water, and Table 24 for Tully brine and waste bed overflow. The first step in creating the Piper diagrams was to convert the chemical data from milligrams per liter (mg/l) to milliequivalents per liter (meq/l). This conversion accounts for the ionic charge and formula weight of the anions and cations so that they will be equivalent.

Two trilinear diagrams are constructed based on the percent milliequivalents, one for the anions and one for the cations. The two trilinear diagrams are then projected upon one another to provide a more complete representation of the water quality characteristics. The anion trilinear diagram represents the percent of the total anions for chloride, sulfate, and carbonate plus bicarbonate. The cation trilinear diagram graphically represents magnesium, calcium and sodium, plus potassium as a percent of total cations. Typical analyses for Tully brine, purified brine and waste bed overflow were included on the diagrams to show the differences between these solutions and the surface and ground waters.

Linear regressions were applied to the ground-water chemical data in an attempt to find a relationship with natural brines or establish any other relationships of the data which was not readily apparent. The regression analyses were calculated and curves were generated for several combinations of the complete set of chemical data against the elevation at which the sample was obtained. The elevation of the midpoint of the screened interval was the assumed elevation of the ground-water sample. Regressions were also calculated for chloride as the dependent variable and all other chemical data as the independent variables. Ionic concentration in units of mg/l and meq/l were used in calculating the regression curves for the chemical parameters and for ratios of selected parameters. For each linear regression combination, the initial analysis included sample data from all wells followed by an analysis by linear regression for data from all the wells minus the background and older waste bed wells. Background and old waste bed

Waste Beds C-E have a total estimated infiltration rate of 0.04 cfs. Based on an estimated chloride concentration of 1,300 mg/l (WB-BU), the calculated loading rate of chloride to ground water is 0.14 tons/day.

The surface waters impacted by Waste Beds A-E are Onondaga Lake and Harbor Brook. The impact of Solvay Waste on Harbor Brook occurs close to the brook's convergence with Onondaga Lake, where the brook flows along the boundaries of Waste Beds D, E and B. The chloride concentrations observed in Harbor Brook are relatively low until the brook is joined by a surface water drainage ditch near Waste Bed B. The average loading rate for chloride in Harbor Brook was 3.81 tons/day in 1987. However, these values represent the sum of all local input including sources other than the waste beds.

The combined chloride loading from Waste Beds A-E is estimated at 2.64 tons/day. This is the estimated rate at which chlorides are leached from these beds and discharged to the environment.

4.5.3 Impact of Waste Beds 1-8

The total area covered by Waste Beds 1-8 is approximately 13.4 x 10^6 ft^2 (314.5 acres). Some of this area is paved and the Crucible landfill covers a portion of these beds.

Ground water was sampled at these waste beds and the results indicate that ground water is being impacted by Solvay Waste. The infiltration in the Beds 1-8 area is estimated as 12.97 inches/year, which results in an estimated infiltration rate of 0.46 cfs for the entire area. Based on an observed chloride concentration of 7,900 mg/l obtained from a leachate seep along the east side of the bed, the calculated chloride loading to the lake from infiltration is calculated to be 9.81 tons/day. In addition, deep ground water discharges to the lake at a flow rate of 0.038 cfs. Based on the measured chloride concentration of 59,000 mg/l in DW-101, deep ground water may potentially add chloride to the lake at a rate of 6.05 tons/day.

A second, less significant, source of chlorides to the lake from Beds 1-8 is from direct erosion of Solvay Waste from the beds along the lakefront. As discussed in Subsections 3.4 and 4.2.3, the northern side of Lakeview Point is exposed to direct wave attack. Over a 30-year period, from 1951 to 1981, an estimated 40 feet of erosion occurred along approximately 440 feet of lakefront. A 1981 topographic map indicates that the bed in this area extended approximately 16 feet above the waterline. Therefore, during that 30-year period, approximately 10,430 cubic yards of material had been eroded from this area of the bed. Based on the representative chemical analysis and unit weight of Solvay Waste, as given in Tables 1 and 2, Solvay Waste contains roughly 228 pounds of chloride per yard of waste. Over the 30-year period, this resulted in a total loading to the lake of approximately 1,190 tons of chlorides. This loading, averaged over 30 years, results in a daily chloride loading of 0.11 tons/day.

As discussed in earlier sections, ground-water mounding beneath these beds results in radial flow away from the beds. Flow from a portion of the beds is directly into Onondaga Lake, while the remainder of the flow is toward the south and west into Nine Mile Creek, or eventually around the beds and into the lake.

Nine Mile Creek Sampling Station SW-12 is upgradient of the area impacted by radial ground-water flow from Beds 1-8. The impact of Beds 1-8, therefore, is directly on the lake and has no impact on the water quality observed at Station SW-12.

The total chloride loading rate from Beds 1-8 is approximately 16.0 tons/day based on a contribution of 9.81 tons/day from infiltration and 6.05 tons/day from ground water, combined with 0.11 tons/day from direct wave erosion of Solvay Waste from the Lakeside Beds. This loading rate is significantly less than the individual loading rates of Onondaga Creek, Ley Creek and the Metro Plant, as shown on Tables 11, 13 and 14, respectively.

4.5.4 Impact of Waste Beds 9-15

The area covered by Waste Beds 9-11 is approximately 5.5×10^6 ft^2 (126.3 acres). Waste Bed 12 covers an approximate area of 5.6×10^6 ft^2 (128.6 acres). Waste Beds 13-15 cover an approximate area of 1.78×10^7 ft^2 (407.7 acres). Beds 9-12 are moderately vegetated, whereas Beds 13-15 have little to no vegetation.

Nine Mile Creek is a significant source of ionic loading to Onondaga Lake. The OCDDS estimated that in 1987, 360.5 tons/day were discharged to Onondaga Lake from Nine Mile Creek. Surface water sampling performed in 1987 indicates that the major increase in ion concentration is between the gravel pit on Airport Road near Waste Bed 13 and the Nine Mile Creek USGS Gaging Station at State Fair Boulevard. Sampling performed in December 1987 showed chlorides increased from 63 mg/l to 1,200 mg/l, calcium increased from 140 mg/l to 470 mg/l and sodium increased from 28 mg/l to 370 mg/l. In addition, samples from wells at WB-2, WB-3, WB-4, WB-5, WB-6, DW-101, MS-104.1, and to a lesser extent WB-7 and P-1 located in Nine Mile Creek Valley, indicate high concentrations of salt-related ions.

Based on the analysis of the water quality data, the salt ions that exist in Nine Mile Creek Valley and are discharging to Onondaga Lake in Nine Mile Creek are for the most part, attributed to the past disposal of Solvay Waste in the valley. However, a contribution from natural saline ground-water sources is indicated. Natural saline waters are indicted to be present at depths in the lower sediments of Nine Mile Creek Valley based on the relative increase (on a percent ionic basis) in sodium and decrease in calcium with depth as compared to shallow ground-water samples and leachate seep samples that are more indicative of Solvay waste bed overflow. Another indication of natural occurring brines is that the high chloride concentration, in excess of 60,000 mg/l at Well WB-5L, are higher than waste bed overflow chloride concentrations. These concentrations are in fact more comparable to the historic chloride concentrations found in the natural brines at the southern end of Onondaga Lake.

As discussed in the previous sections of this report, the mechanism exists for the deposition of natural brines in the Nine Mile Creek Valley. The increase in sodium relative to calcium with depth is an indication that natural brines may be underlying waste bed leachate at depth in the Nine Mile Creek Valley.

The mechanism for the mobilization, transport and discharge of salt ions to Nine Mile Creek and eventually Onondaga Lake consists of a combination of continued leaching of ions from Waste Beds 9-15 and upward discharge to the creek of saline ground water from the sediments in Nine Mile Creek Valley. A water balance approach was used to determine the current contributions from the waste beds and valley sediments.

Within the same relative time frame (1987), flow measurements and water quality sampling were performed on the creek both upstream and downstream of the waste beds. In addition, similar measurements were performed for two major tributaries, Geddes Brook and Beaver Meadow Brook. The approach involves calculating a loading rate of the system by multiplying a volumetric flow rate and a representative concentration. To balance the Nine Mile Creek System, known inputs were compared with observed outflows; the deficit in the balance is attributed to ground-water contributions to the creek.

Stream flow measurements during this sampling period indicate that there is a significant discharge of ground water to Nine Mile Creek between the area adjacent to Waste Bed 13 and State Fair Boulevard. Recall that, based on the shallow potentiometric surface map, the area near Bed 13 is where the creek becomes a "gaining" stream relative to ground water. It is also the area where the coarser soils are located in the valley. These soils are capable of receiving, storing and transmitting large quantities of ground water. Further down the valley, the soils become finer and, therefore, less capable of transmitting the same quantities of ground water as the coarse materials. The configuration results in ground water flowing into the permeable soils of the valley as a result of the higher hydraulic heads on the valley sides and in the waste beds. The ground-water hydraulic gradients tend to flatten along the valley axis due to the more permeable nature of the soils. However, the finer grained, lower permeability deposits located in the region beginning between Waste Beds 11 and 12 result in an upward flow gradient from ground water to the stream. This is evident by the marshy conditions along the creek bank in this area.

It should be noted that the values utilized to balance the Nine Mile Creek system represent specific conditions for a specific period of sampling. Since the various locations were sampled within the same relative time frame, they serve to accurately represent the overall dynamics of the system. Based on their 1987 data, OCDDS reports that 360.5 tons/day of chlorides are discharged from Nine Mile Creek to Onondaga Lake. The sampling event performed for the creek and associated tributaries identified 445 tons/day as the chloride loading to the lake. It may be concluded that the sampling event occurred during above average conditions. As such, conclusions regarding this system with respect to the chloride loading rate tend to represent a conservative analysis.

With this understanding of the flow system in the valley, the water balance was used to define the contributions from all sources. As discussed earlier in Section 4.3.2.2, Precipitation and Water Balance, the infiltration rate is estimated for Waste Beds 13-15 at 15.44 inches; for Waste Bed 12 at 14.73 inches, and for Waste Beds 9-11 at 12.09 inches/year. Based on the area of Beds 12-15, this infiltration rate results in an input of 614,000 gallons/day (0.95 cfs) to the beds. In 1987, LCP discharged 164,000 gallons/day (0.25 cfs) to Bed 14;

however, in 1987 Allied collected and pumped approximately 704,000 gallons/day (1.09 cfs) of waste bed overflow from Beds 12-15 to Metro. This results in a net loss of approximately 540,000 gallons/day (0.84 cfs) from the system resulting in a total net input to the Nine Mile Creek System of 74,000 gallons/day (0.11 cfs). For Waste Beds 9-11, the infiltration rate of 12.09 inches/year results in the total input of 0.18 cfs to the Nine Mile Creek system. No overflow or leachate drainage is collected or removed from Waste Beds 9-11. The total input from Waste Beds 9-15 is 0.29 cfs.

Flow balance components consisted of measured flows upstream of the location of the waste beds (97.9 cfs), tributary inputs from Beaver Meadow Brook (8.3 cfs) and Geddes Brook (14.5 cfs), and infiltration from Beds 9-11 (0.18 cfs) and Beds 12-15 (0.11 cfs). The total of these sources is 120.99 cfs; however, outflow from Nine Mile Creek at State Fair Boulevard was measured as 137.4 cfs, indicating a deficit of approximately 16.4 cfs. This gain in stream flow is attributed to ground-water discharge to the creek. Based on the minimum recorded stream flow for the periods from 1971-1987 for Nine Mile Creek of 13 cfs, which is an approximation of ground-water base flow, the flow attributed to ground water is reasonable.

Evaluations were made to determine if this system is capable of supplying a ground-water flow rate of 16.4 cfs to the creek and if the creek is capable of accepting this amount. Assuming the 16.4 cfs represents an average ground-water base flow, it would require a ground-water basin of approximately 22 square miles receiving approximately 10 inches of infiltration per year to supply this volume of ground water to the creek. A ground-water basin of this size, based on the configuration of the ground-water system, is reasonable. The second evaluation considered the amount of ground-water recharge per length of stream. Based on 14,000 feet of stream length, the average discharge of ground water per length of stream is approximately 0.00117 cfs per linear foot, or approximately 0.56 gpm per linear foot of stream length. Based on the high permeability of a portion of the sediments in the valley, this average discharge rate is reasonable.

Measured water quality concentrations for chloride, calcium and sodium were assigned to the flow rate to determine the loading rates of the three ions within the system. Typical representative leachate concentrations were assigned to the waste bed inputs. Table 26 presents a summary of the flow and ion loading balance for Nine Mile Creek.

Based on the balance presented on Table 26, approximately 370 tons/day of chloride, 85 tons/day of calcium, and 64 tons/day of sodium were discharged during 1987 to Nine Mile Creek from the ground water within the valley deposits. This ground-water contribution, of which it is estimated that greater than 50 percent is attributable to past Allied operations, represents 83 percent of the chloride, 49 percent of the calcium and 47 percent of the sodium load that Nine Mile Creek discharges to Onondaga Lake. The chlorides in this ground-water discharge represent approximately 51 percent of the total chloride loading to Onondaga Lake from all sources.

4.5.5 Impact of Surface Waters

Several other surface water flows impact Onondaga Lake directly. These include Ley Creek, Onondaga Creek, Harbor Brook, and Tributary 5A. The impact of these surface waters was determined from 1987 data obtained from OCDDS. As a 1987 daily average, OCDDS reports that Ley Creek contributes 17.9 tons/day, Onondaga Creek contributes 111.5 tons/day, Harbor Brook contributes 3.81 tons/day, and Tributary 5A contributes 0.98 tons/day of chlorides to Onondaga Lake.

4.5.6 Impact of Metro Plant

The chloride loading to Onondaga Lake from Metro in 1987 was reported as 124.0 tons/day (OCDDS), of which approximately 1.0 ton/day results from effluent chlorination operations. Review of Metro records indicate that for 1987, a daily average flow rate from Allied to Metro was 704,000 gpd (1.09 cfs); the average chloride concentration was 19,133 ppm, resulting in an input of 56.19 tons/day to the Metro Plant. Metro records also indicate that approximately 2.23 tons/day of chlorides are removed from the system in the form of sludge.

Using the above information, the influent chloride loading from Metro's other wastewater sources can then be calculated by performing a mass balance for the system. This value is approximately 69 tons/day (124 + 2.23 - 1.0 - 56.19 = 69.04). The relative proportion between influent loadings can be used to determine portions of effluent loading attributable to Metro (68.8 tons/day) and Allied (55.2 tons/day).

4.5.7 Summary of Impacts

The summary of 1987 chloride loadings to Onondaga Lake is presented in Table 28. The total loading was determined to be approximately 721 tons/day. The impact on the lake can be preliminarily estimated using the Lake Residence Equivalent (LRE) calculation for loading to the lake (Stearns & Wheler, 1978). Based on a loading rate of 721 tons/day, an average detention time of 114 days (assuming that the lake flushes 3.2 times per year) and a lake volume of 37 x 10^9 gallons, the concentration of chlorides in the lake would be 532 mg/l, excluding the contribution of any undefined sources. A review of OCDDS records indicates a yearly volume averaged chloride concentration of approximately 626 mg/l (629 mg/l hypolimnion and 623 mg/l epilimnion) in 1987. There are numerous outside sources of chloride loadings to the lake that would account for the difference between the calculated concentration from unknown sources and the measured lake concentration. Figure 34 represents the flow, chloride concentration and chloride loading for all waste beds. This figure also includes the quantities and concentration used in performing the flow and loading balance for Nine Mile Creek.

The portion of defined Onondaga Lake chloride loading which can be attributed to the Waste Bed 1-15 area in 1987 is approximately 86 tons/day (11.9 percent of defined source) which includes infiltration, LCP wastewater, erosion, and leachate collection and discharge by Metro. In addition, ground-water contributions from the Nine Mile Creek Valley (369.8 tons/day) and from the sediments below Waste Beds 1-8 (6.05 tons/day) represent approximately 52 percent of the total calculated loading to the lake. This source is a combination of chlorides historically leached from the waste beds and natural brines. Past Solvay Waste disposal operations account for more than half of the chloride loading to ground water.

Conditions are anticipated to improve with time as a result of slow flushing of the sediments in Nine Mile Creek Valley, the decrease in hydraulic loading from continued dewatering of Waste Beds 12-15, and the continued decline in leachate concentration from the waste beds themselves. In addition, the loadings attributed to the waste beds include a discharge from LCP which, at this time does not occur, and as previously stated, the estimates regarding Nine Mile Creek are considered conservative since the data utilized is greater than the annual average. The average chloride discharge from Nine Mile Creek to Onondaga Lake in 1987 was reported by OCDDS as 360.5 tons/day. However, data collected to perform the flow balance exercise indicated a chloride loading of 444.6 tons/day, which is approximately 20 percent above the average. This is significant when comparing the difference to the overall lake budget. The 444.6 tons/day loading accounts for 62 percent of the total lake loading. However, the 1987 OCDDS average value of 360.5 tons/day reduces the overall lake loading by 85 tons/day, so that the Nine Mile Creek contribution would then account for 57 percent of the total lake loading.

It is estimated that salt concentrations in the Nine Mile Creek Valley sediments will slowly be flushed by incoming fresh ground water and ultimately be released to Onondaga Lake in progressively lower concentrations. This trend is indicated by the decline in loading and concentration in Nine Mile Creek (Table 7) and in the decline in concentrations in the lake (Figures 17, 18 and 19).

As previously discussed, the modeling simulation for infiltration from the waste beds (HELP Version II) utilized saturated conditions for the "newer" beds (12-15). This means that equilibrium conditions have not been reached between infiltration and discharge, and the estimated 1987 infiltration values include a portion of flow that is actually continued dewatering of Solvay Waste. With time, equilibrium conditions will be reached and chloride loading will be reduced.

Finally, the continued decline in chloride loading is illustrated by the plot of waste bed age versus chloride concentrations (Figure 31). For the reasons discussed above, the chloride loadings from the waste beds can be expected to be significantly reduced over time.

SECTION 5 - OVERVIEW OF REMEDIAL TECHNOLOGIES

5.1 General

This section of the report serves to identify several potential remedial measures which could be implemented in an attempt to reduce chloride loadings associated with the waste beds. While this section of the report is useful in identifying the range of available technologies (and associated benefits and disadvantages), a detailed analysis of each has not been performed. To supplement the information presented herein, a detailed FS will be prepared that will provide a complete evaluation of remedial alternatives. The detailed study will define remedial objectives, evaluate and screen potential remedial measures, and recommend the remedial measure(s) considered appropriate for each waste bed or waste bed area.

5.2 Summary of Chloride Loadings to Onondaga Lake

As indicated in Section 4, each waste bed area contributes a chloride loading to the underlying ground-water system. In addition, it has been documented that the ground water beneath portions of the waste beds contains high chloride concentrations as a result of both naturally-occurring saline ground water in this area, and the previous leaching of chlorides from the waste beds or direct discharge of waste bed overflow to ground water. Chlorides currently discharge to Onondaga Lake via ground-water and surface water flow mechanisms. In addition, independent sources of chloride loading to Onondaga Lake have been identified, which contribute significant chloride quantities. The chloride concentrations within the lake have shown a decreasing trend over the past several years as a result of a number of activities, including the termination of discharges from Allied and LCP Chemicals to the waste beds, and the declining rate of chlorides leaching from the waste beds themselves.

As presented within previous sections of this report, the chloride loadings associated with each chloride contributor to Onondaga Lake have been calculated. Individually, the chloride loadings identify the mass loading from each contributing source. Collectively, the chloride loadings allow for the comparison of sources to identify the impact of each source on the water quality of Onondaga Lake. To provide an accurate basis for comparisons between chloride contributors, it is useful to develop a loading budget for a common time frame. This is particularly important with the waste beds, since the chloride loadings have been decreasing over the past several years. For this report, data for the year 1987 was used to generate the chloride budget. The budget is summarized in Table 28. Field data collected in 1987 was essential to the development of the chloride loadings, and the recent availability of 1987 discharge data from OCDDS reinforced the selection of 1987 as the "base" year.

For previous and subsequent years, the calculated chloride loading budget would be expected to vary based on a number of factors, including weather conditions, waste material age, and waste bed operation. In addition, LCP Chemical's temporary shutdown in June 1988 is expected to impact subsequent budgets prepared beyond 1987. In general, it can be concluded that the flow dynamics of the waste beds and adjacent surface waters are in a state of constant change, both on a daily basis and yearly basis. The availability of 1987 data represents, to the extent possible, the most comprehensive and current chloride loading conditions to Onondaga Lake.

Subsequently, the detailed FS will evaluate the impacts associated with various potential remedial measures based on a recalculated chloride loading budget. The FS will also evaluate and estimate the time associated with chloride loading decreases both with and without the application of remedial measures.

5.3 Development of Potential Remedial Technologies

The primary goal of any remedial activity for Allied's waste beds is the reduction of chloride loadings to Onondaga Lake. Potentially, this may be accomplished with activities directed towards the waste beds themselves and/or the ground water underlying the waste beds. Both of these areas have been identified within this report as contributors of chlorides to the lake. Secondary goals for remedial measures may also be developed during preparation of the detailed FS.

A review of the remedial measures potentially applicable to the waste beds has identified several technologies which are presented below. These include:

Potential Technologies to Address Waste Beds

- o No Action;
- o Grading, Cover and Vegetation;
- o Grading, Low-Permeability Cap, Vegetation;
- o Grading, Low-Permeability Cap, Ground-Water Cutoff Wall, Vegetation;
- o Sludge Incorporation and Vegetation; and
- o Off-Site Disposal.

Potential Technologies to Address Ground Water

- No Action;
- Leachate Discharge Control;
- Ground-Water Withdrawal and Discharge; and
- Ground-Water Withdrawal and Treatment.

While these technologies are broad and preliminary in nature, they represent the range of potential technologies that will be further evaluated within the detailed FS. It should also be noted that within the detailed evaluation, site remediation activities may involve a combination of the above technologies. This will allow some degree of flexibility with respect to individual waste bed areas and groups of waste beds, and their specific characteristics and remedial objectives.

5.4 Overview of Potential Remedial Technologies

The level of detail in this assessment is intended to provide basic information for each technology, including a general description as well as a preliminary analysis of potential environmental impacts (both positive and negative). The detailed FS will further evaluate each technology from which select remedial measures can be chosen.

5.4.1 Potential Technologies to Address Waste Deposits

5.4.1.1 "No Action"

Description - "No Action" would allow the waste beds to remain as they currently exist. This would result in the natural self-revegetation process (currently exhibited for Beds 1-8 and 12) to occur for Waste Beds 13-15. Self-revegetation would gradually create a vegetative cover over the waste beds, further reducing infiltration and chloride loadings. This technology does not restrict potential future uses of the land areas that may occur from implementation of some other remedial technologies.

Environmental Impacts - It is apparent by inspection of the older waste beds (1-8) that natural revegetation will occur with or without an active reseeding or nutrient-addition program. Although chloride loading to the underlying ground-water system would continue, the loading would be at a declining rate over time as a result of: (1) leaching of the available chlorides from the material in the waste beds; and (2) natural revegetation and the attendant decrease in rainfall infiltration. In addition, the chloride loading budget previously discussed would also be changed to reflect the temporary discontinuance of production operations at LCP Chemicals.

5.4.1.2. Grading, Cover and Vegetation

Description - This technology is intended to result in a reduction of infiltration into the waste beds by increasing evapotranspiration and surface water runoff, and therefore decreasing the chloride loading attributable to the waste bed areas. In general, this technology applies to those areas of the waste beds with exposed waste material since the other waste beds have either been naturally revegetated or have undergone a formal revegetation program in the past. It is expected that limited grading/material relocation would be necessary for the top of the affected waste bed areas. Grading or slope stabilization may also be appropriate for the side slopes of the waste beds. Once appropriate grading has been accomplished, a suitable layer of drainage material (demolition rubble or sand) would be placed. This layer would serve to provide a drainage layer to minimize the potential for saturation of vegetative roots. A cover soil suitable for plant growth will be placed on the drainage layer. The covered areas would then be vegetated. The detailed FS will further address this technology and the applicable considerations.

Grading, Cover and Vegetation would result in an established vegetative cover for the waste beds that would serve to increase evapotranspiration of water and decrease vertical infiltration of water through the waste beds and subsequent leachate generation.

Environmental Impacts - Potential benefits of Grading, Cover and Vegetation include the reduction of infiltration through the waste materials. An additional benefit may be the reduction of airborne dust that could periodically occur in some areas of the waste beds. Finally, a minor benefit would include the aesthetic improvement of applying vegetative cover to those beds with exposed waste materials. Conversely, several negative impacts may potentially result from implementation of this technology. Impacts may include increased levels of noise and dust during the initial regrading/relocation of waste material prior to covering and vegetation. Similar impacts would be expected during the construction of the cover layers. Also, there may be a period of time during the implementation of this technology that chloride loadings temporarily increase as a result of grading, relocating or general disturbance of the bed materials. The potential for temporarily releasing airborne dust from some areas of the waste beds would also be a possibility.

In the process of covering and vegetating the waste beds, it would be advantageous to create a grade such that ponding would be minimized. Side slope regrading would also be considered to allow for vegetation of these slopes.

The transport and placement of drainage and cover material will require a significant amount of time and expense. A complicating factor may be the availability of a sufficient source of cover materials. A source in close proximity to the waste beds would allow the Grading, Cover and Vegetation action to progress smoothly. However, if an adequate cover material source cannot be obtained at a nearby location, the consequences of utilizing a remote source would be two-fold: 1) an increase in transport costs and the time schedule would be impacted; and 2) the adverse environmental impacts created by the truck traffic would be extended over both a longer time frame and an increased area of travel.

5.4.1.3 Grading, Low-Permeability Cap, Vegetation

Description - This technology is similar to that previously presented since both technologies involve grading/relocation of waste bed materials, with a subsequent cover layer and vegetation. However, this technology includes a cover system utilizing a low permeability (i.e. impermeable) layer to further reduce infiltration while increasing runoff.

This technology consists of grading or reshaping the waste beds to achieve both a minimum and maximum slope. These slopes would allow for surface drainage during rainfall activity and allow for the establishment of consistent vegetation. The placement of a layer of low permeability clay (or an alternative system of bedding material with an impermeable synthetic liner), would be covered with a drainage layer (rubble or sand), soil, and then cover vegetation. A series of drainage areas would be constructed on the top of each bed to allow for the collection of rainfall from the surface, with subsequent channeling to a common collection area. This type of drainage would allow for runoff from the waste beds to occur, thus reducing the volume of water potentially infiltrating the waste bed surface. The vegetative cover would serve to also reduce the rate of infiltration through evapotranspiration.

Environmental Impacts - The potential benefits of this technology parallel those of Grading, Cover and Vegetation. A greater reduction of infiltration would be expected to occur due to the impermeable nature of the clay or membrane material. Similar changes to site aesthetics would result, however, the nature of the existing surface vegetation would change from varied grasses, shrubs and trees to consistent shallow-rooted vegetation. These shallow-rooted grasses would be necessary such that deep-rooted vegetation and trees do not breach the integrity of the impermeable layer.

As a result of the grading/relocation of large quantities of waste bed materials, adverse environmental impacts may occur, including increased dust, odors, noise and erosion/sedimentation. The duration of these impacts will be primarily affected by weather conditions and/or the availability of sufficient materials during the construction phase of the program.

If clay is the low permeability option selected, a source must be available near the site. Since the volume of clay is expected to be very large, the removal of the necessary amounts of clay from a borrow area (or areas) would impact the environment surrounding those sites. Also with the membrane cap option, a large quantity of bedding material (sand) would have to be brought on-site and placed. As with the Grading, Cover and Vegetation technology, this technology would also require the movement of large quantities of rubble (or sand) and soil to the waste bed area, causing potential increases in air and noise pollution, and temporarily disrupting local traffic patterns.

The placement of a low permeability cap over such a large area would also increase surface water flow into Nine Mile Creek and Onondaga Lake, especially during heavy rainstorms and periods of snow melt, resulting in subsequent increases in the flood stage within the immediate area. It should also be noted that placement of an impermeable cap over the waste beds could restrict the future use of this area due to potential concern regarding the disruption of the cap.

5.4.1.4 Grading, Low-Permeability Cap, Ground-Water Cutoff Wall, Vegetation

Description - This technology is essentially the same as the technology discussed previously, with the addition of ground-water cutoff walls. The cutoff walls would serve to impede ground-water flow from beneath the waste beds. Typically, a ground-water cutoff wall for this type of application would be constructed using a slurry trench method and low-permeability backfill. The cutoff wall would be "keyed" into an existing subsurface strata of low permeability (e.g. till or bedrock). Construction techniques for this technology are similar to those of the previous technology, with the additional slurry trench method for the cutoff wall construction. Due to the high chloride concentrations in the ground water, the long-term integrity of a cutoff wall may be jeopardized since the swelling characteristics, as well as the permeability of bentonite backfill, have been shown to be affected by high-ionic strength ground water. Other cutoff wall techniques and backfill materials may be more appropriate; however, disadvantages associated with other techniques could also jeopardize the cutoff wall installation. In addition, the coarseness of some of the valley deposits and the depth required in some locations (up to 150 feet) would significantly complicate, if not preclude, installation of the cutoff wall.

Environmental Impacts - The addition of a ground-water cutoff wall and low permeability cap would, in effect, provide an encapsulation of waste bed materials. This would serve to reduce the leaching of the waste beds into the surrounding environment from both the waste bed itself, and the high chloride ground water directly beneath the waste beds.

Significant quantities of chlorides would, however, still be present in the ground water within the valley deposits outside of the area beneath the waste beds. As such, the cutoff walls may not significantly decrease the overall ground-water impact in this area, as high chloride concentrations would continue to migrate from areas outside of the area directly beneath the waste beds. The placement of cutoff walls around a large area of the Nine Mile Creek Valley would also result in major rerouting of ground-water flow. This could alter ground-water recharge and discharge flows while creating drainage problems in new areas. The cutoff walls would create a hydraulic barrier that could nearly prohibit ground-water flow through the unconsolidated materials of the Nine Mile Creek Valley. Ground water could be forced to flow to the surface, dramatically impacting the flow and quality of the water in Nine Mile Creek, and also resulting in possible periodic flooding and erosional damage. Chloride concentrations in Nine Mile Creek could rise due to an increased contribution of deep ground water to Nine Mile Creek. This increase in chloride concentration may remain elevated for an extended period of time. Low lying areas, in addition to being subjected to periodic flooding, could become the inland equivalent of a salt marsh.

5.4.1.5 Sludge Incorporation and Vegetation

Description - In this alternative, a nutrient-bearing material (municipal sewage sludge) is mixed into the upper surface of the waste bed material, producing a soil-like material capable of supporting vegetative growth. Sludge mixing and vegetation would entail significant grading/relocation of waste materials involving the scraping of waste material from the surface, mixing the waste with sludge to form a soil-like material, replacement of the mixture, and subsequent vegetation.

Mixing of sludge with waste bed material can reportedly be maintained throughout the year, except in severe winter weather. Movement of the sludge, waste, and sludge-waste mixtures would utilize traditional hauling methods. Transport of the sludge to the site could involve the use of sludge trucks with water-proof seals.

This technology has been performed at similar sites with reports of acceptable results. In addition, this technology is currently being demonstrated on test plots within Waste Bed 13.

Environmental Impacts - The sludge-waste mixture that would be produced if this technology were implemented would be expected to provide the essential nutrients necessary to support vegetation. The mixing of waste with sludge is also expected to decrease the alkalinity of the waste, thereby providing a more suitable habitat for plants. It is anticipated that the decrease in chloride loadings would result due to enhanced evapotranspiration. This decrease would be expected to be more significant than the Grading, Cover and Vegetation technology, but not as significant as the Grading, Low Permeability Cap, Vegetation technology.

Activities would include removing waste, mixing with sludge and replacing the mixed materials. Due to the relatively large surface area of the waste beds and the anticipated supply rate of local sludge material, this technology would require an extended time period (20-25 years) to fully accommodate the waste beds. Since this time period would not be considered an appropriate remedial duration for the waste beds, this technology would normally be eliminated from further consideration. However, this technology could be combined with one or more of the other potential remedial technologies to result in a combined remedial alternative of greater applicability in a more reasonable time frame. Further, this technology potentially provides benefits beyond chloride loading reduction (i.e. beneficial re-use of sewage sludge), while also providing increased environmental benefits for the waste beds. As such, this technology will be considered within the FS.

Environmental impacts associated with dust, odors, noise, and erosion/sedimentation could potentially occur during implementation of this technology; however, engineering controls could be implemented to mitigate these impacts. As a final note, the transport of sludge to the waste bed area could also contribute to increased traffic, noise, dust and odors; however, again these impacts could be mitigated with appropriate engineering controls.

5.4.1.6 Off-Site Disposal

Description - Off-Site Disposal would involve the excavation and transport of waste materials from the waste beds to another site for disposal. A total of approximately 50 to 60 million cubic yards of material would have to be excavated, transported, and placed in an alternate site. Finding a location to accept the waste material is not believed to be either practical or probable. It would require the siting of a landfill several hundred acres in size in close proximity to the waste bed area.

Environmental Impacts - Removal of the waste materials and surrounding soil dikes would expose the natural surface topography, with the exception of the waste beds that extend below original surrounding grade. Under this option, the waste beds themselves would be removed, leaving only the underlying high chloride ground water to ultimately migrate to Onondaga Lake.

The disposal of the waste in off-site landfill facilities would result in the need to site and construct a facility large enough to accommodate the materials.

5.4.2 Potential Technologies to Address Ground Water

5.4.2.1 "No Action"

Description - "No Action" for remediation of area ground water would consist of continued monitoring of the existing ground-water conditions. As discussed in previous sections, the chloride loading into area ground water is expected to decrease with time as discharge from the waste beds continues to decrease in volume and chloride concentration.

Environmental Impacts - Concentrations of chloride in shallow ground-water regions would gradually continue to decrease with time, however, the natural saline contribution to the ground-water system in this area may be unchanged. Minimal increases of adverse impacts would be expected from this "No Action" alternative.

5.4.2.2 Leachate Discharge Control

Description - During the site investigations and ensuing report preparation, a number of discrete leachate discharges to surface waters were noted. These leachate sources included embankment seeps, discharge pipelines and runoff channels. The Leachate Discharge Control technology would be directed towards eliminating these direct discharges of high concentration chloride leachate. Depending on the specific source and volume of each leachate source, this technology may involve pipeline plugging or rerouting. For discrete seep areas, individual gravity collection systems may be utilized to eliminate the direct discharge of highly concentrated leachate to the surface waters. The leachate collected would be directly discharged or undergo treatment utilizing one of the remaining potential ground-water technologies.

Environmental Impacts - While this technology is not expected to provide significant impacts to the chloride loading to Onondaga Lake, the results of these measures would serve to improve site aesthetics and minimize concentrated "zones" of chloride discharge into the associated surface waters.

5.4.2.3 Ground Water Withdrawal and Discharge

Description - This technology involves the extraction of high concentration chloride ground water from the permeable soil deposits below the waste beds, with subsequent discharge to some other surface water without treatment. The NYSDEC has indicated that a waterbody, such as the Seneca River, would potentially be able to accept the flow without treatment. If this were to be the case, a ground-water recovery system and pipeline system would also be included as part of this technology.

The target of the ground-water recovery system would be the ground water existing in the high permeability gravel deposits, beneath portions of the waste beds. The size of the system is anticipated to be large due to the volume of ground water within the valley deposits.

Environmental Impacts - This technology would decrease the chloride loading rate to Onondaga Lake by removing this source of chlorides from the ground-water system. Removal of ground water would be required for an indeterminate time, as naturally-saline ground water might continue to flow into the deposits where ground-water removal is occurring. The receiving stream of this ground-water flow is subject to several potential negative impacts from the high chloride concentrations. In essence, this technology serves to reduce chloride loading to the lake, but does not remove, reduce or contain chlorides within the environment.

5.4.2.4 Ground Water Withdrawal and Treatment

Description - This technology would entail the extraction of high concentration chloride ground water from the permeable soil deposits in the Nine Mile Creek Valley, and the treatment of the ground water to remove the dissolved contaminants prior to discharge either to ground water or surface water.

Ground-water withdrawal could be accomplished using conventional pumping techniques from a number of wells. The target of well placement would be the ground water existing in the high permeability gravel deposits, beneath portions of the waste beds. As an alternative to treatment directed at the ground water in the valley deposits, it may be appropriate to consider ground water removal only to the extent necessary to reduce flow in Nine Mile Creek, thereby lessening its impact on the chloride loadings to Onondaga Lake. However, modifying the creek from a "gaining" stream to a "losing" stream would also involve large ground-water removal rates. The flow "increase" within the waste bed area of the creek has been calculated to be 16.2 cfs. Removal of this volume of flow would require a facility capable of handling a flow rate of approximately 7,400 gpm.

Treatment of water with such high concentrations of chlorides is limited to a small number of options; namely, reverse osmosis, and evaporation/distillation.

Reverse osmosis (RO) is typically used in desalinization plants which produce fresh water from ocean water. The RO process involves inducing a concentration gradient across a semi-permeable membrane, resulting in a large volume of highly concentrated brine and small volume (approximately 25 to 30 percent of total flow) of desalted water. Evaporation/distillation involves adding heat to the water to be treated, to boil off or distill water and leave behind residues consisting of soluble salts.

Environmental Impacts - This technology would decrease the chloride loading rate over time by removing this source of chlorides from the ground-water system. Treatment of this ground water would be required for an indeterminate time, as naturally saline ground water might continue to require treatment even after the waste bed leaching was reduced to insignificant levels. The operation of a ground-water withdrawal and treatment program would include the transportation and disposal of large quantities of treatment process residue, and the tremendous energy requirements in the case of the evaporation/distillation option. Further, withdrawal of ground water could result in an up-welling of naturally saline ground water negating the effect of the entire pump and treatment program.

5.5 Summary of Potential Remedial Technologies

The intent of this overview of remedial technologies is to demonstrate or identify the range of potential options available for the waste beds and associated ground water. This will be developed in greater detail in the subsequent FS. It should be noted that in addition to further evaluation of the identified technologies, additional technologies (if any) or a combination of technologies will be examined to optimize the reduction in chloride loading to Onondaga Lake. Each waste bed (1-15) or waste bed area (e.g., 1-8, 9-11, 12-15) will be subjected to a detailed review of each alternative to determine its applicability for the given waste bed(s).

5.6 Scope and Schedule of Future Activities

Based on the activities (and results) of efforts completed as part of this Hydrogeologic Assessment, a number of generalizations can be made regarding the scope and impact of potential future activities. As previously referenced, the information presented within the Overview of Remedial Technologies will be supplemented with a detailed FS.

The primary goal of any potential remedial actions will be to reduce the chloride loadings to Onondaga Lake that are attributable to Allied's Waste Beds. The chloride loading budget prepared as part of the Hydrogeologic

Assessment will be utilized to gauge the effectiveness of specific remedial alternatives presented within the FS.

Based on a chloride loading for 1987, chloride loadings attributable to Waste Beds 1-15 accounted for approximately 15 percent of the total chloride loading to the lake. This percentage represents the chloride loading due to infiltration through the waste beds, and leachate that is collected from Beds 12-15 and pumped to Metro for discharge to the lake. The other primary chloride contributor to the lake is the discharge of ground water from the Nine Mile Creek Valley deposits. This accounts for approximately one-half of the total chloride loading to the lake. At least 50 percent of the chlorides present in this ground water can be attributed to Allied's past operations, while the remaining chlorides are associated with naturally-saline ground water present in the area. Remedial actions (if any) developed for the waste beds and/or ground water would potentially decrease the loadings constituting the chloride load that is directly attributable to Allied. The extent of reductions (if any) will be evaluated in the FS.

The detailed FS will identify appropriate objectives for potential remedial actions based on human health and environmental considerations. In addition, the FS will group potential remedial technologies into waste bed-specific or waste bed group-specific remedial alternatives and study these alternatives in detail. This analysis will include an assessment of technical and institutional feasibility; compliance with response objectives and criteria; implementability; and cost-effectiveness. Finally, the FS will compare the various remedial alternatives on a waste bed-specific or waste bed group-specific basis and provide recommendations as to the appropriate level of remediation for each waste bed.

The FS has been initiated based on a Work Plan for the report which has been separately submitted to the NYSDEC. Figure 35 presents a schedule for preparation of the FS and subsequent project activities.

Respectfully Submitted:

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Tables

TABLE 1

CHEMICAL CHARACTERISTICS
OF SOLVAY PROCESS WASTE

Representative Chemical Analysis (from Kulhawy, et al., 1977)

$CaCO_3$	20%	NaCl	6%
2 $CaO \cdot SiO_2$	17%	$CaCl_2$	6%
H_2O of hydration	12%	R_2O_3	6%
$Mg(OH)_2$	10%	$Ca(OH)_2$	4%
$CaO \cdot CaCl_2$	8%	$CaSO_4$	4%
SiO_2	7%		

Where R = Aluminum, Iron

Minor Insoluble Chemical Constituents (from Calocerinos & Spina, 1980)
results reported in milligrams/kilogram (ppm)

Al	4800	Pb	30
As	16	Hg	0.04
Cd	2.0	Ni	13
Cr	9.0	Zn	30
Cu	10	CN^-	0.04
Fe	4520	Alkalinity	9380

Note: Analysis conducted on sample composed of 10 grams of Solvay Process Waste and 90 grams of H_2O.

EP TOXICITY TESTING ON SOLVAY PROCESS WASTE

Date (1980)	DO No.	As	Ag	Ba	Cd	Cr (mg/L)	Hg	Pb	Se
RCRA Limit		5.0	5.0	100.0	1.0	5.0	0.2	5.0	1.0
6/25	1	0.005	<0.004	0.52	<0.005	0.012	<0.00005	0.015	0.001
6/26	1	<0.003	<0.004	0.37	<0.005	0.010	0.00023	0.008	0.003
6/27	1	0.005	<0.004	0.49	<0.005	0.010	0.00069	0.006	<0.001
6/25	2	<0.003	<0.004	0.65	<0.005	0.029	<0.00005	0.024	<0.001
6/26	2	<0.003	<0.004	0.68	<0.005	0.025	<0.00005	0.022	<0.001
6/27	2	<0.003	<0.004	0.44	<0.005	0.029	0.00019	0.032	<0.001

TABLE 2

PHYSICAL CHARACTERISTICS
OF SOLVAY PROCESS WASTE

Property	Data Points	Mean	Standard Deviation	Extremes
Liquid limit (%)	28	134	40	72 - 235
Plastic limit (%)	28	89	35	29 - 192
Liquidity index	19	2.84	1.02	1.30 - 4.81
Specific gravity	22	2.71	0.09	2.51 - 2.83
Unit weight (kg/m^3)	28	1243.9	80.7	1079 - 1398
Compression index	8	2.87	0.44	2.15 - 3.36
Swelling index	6	0.08	0.02	0.06 - 0.11
Coef. of permeability (m/sec x 10^{-6})	10	4.87	2.24	2.71 - 10.30
Effective stress friction angle	(CIU triaxial compression, undisturbed)			$32^\circ \pm 6^\circ$
	(Drained direct shear, remolded)			$32^\circ \pm 2^\circ$

(From Kulhawy, 1977)

GRAIN SIZE DISTRIBUTION*

	Ackhenheil & Assoc. 1980	Kulhawy 1977
Gravel	11%	**
Sand	26%	46%-74%$\pm$
Silt and Clay	63%	54%-26%

* Values determined from grain size distribution curves
**Gravel sizes not included on curve

PERMEABILITY MEASUREMENTS (cm/sec)

6.2 x 10^{-5} to 2.0 x 10^{-6} (Average values) Thomsen Assoc. (1981)

"In the range of 10^{-6}" Ackhenheil & Assoc. (1980)

TABLE 3

WASTE BED AREA AND THICKNESS AND VOLUME OF SOLVAY PROCESS WASTE

	Area*	Thickness	Volume
A	1.67×10^6 ft^2 38.3 acres	30 ft(a)	50.1×10^6 ft^3 1.86×10^6 yd^3
B	1.21×10^6 ft^2(b) 27.8 acres	17 ft(c)	20.6×10^6 ft^3 0.76×10^6 yds^3
C	0.95×10^6 ft^2 21.8 acres	(d)	?
D	0.918×10^6 ft^2 21.1 acres	(d)	?
E	0.995×10^6 ft^2 22.8 acres	(d)	?
F	1.36×10^6 ft^2 31.2 acres	(d)	?
G	2.96×10^6 ft^2 68.0 acres	6 ft(e)	17.7×10^6 ft^3 0.66×10^6 yd^3
H	6.08×10^6 ft^2 139.6 acres	(d)	?
I	3.34×10^6 ft^2 76.7 acres	(f)	--
J	4.48×10^6 ft^2 102.9 acres	(g)	?
K	5.96×10^6 ft^2 136.8 acres	(f)	--
L	10.68×10^6 ft^2 245.2 acres	(f)	--
M	4.80×10^6 ft^2 110.2 acres	(f)	--
1-8	13.4×10^6 ft^2(h) 314.5 acres	67 to 20 ft	685.0×10^6 ft^3 25.4×10^6 yd^3
9-10	3.2×10^6 ft^2 73.5 acres	70 ft	224.0×10^6 ft^3 8.30×10^6 yd^3

TABLE 3

WASTE BED AREA AND THICKNESS AND
VOLUME OF SOLVAY PROCESS WASTE (Cont'd.)

	Area*	Thickness	Volume
11	2.3×10^6 ft^2 52.8 acres	70 ft	161.0×10^6 ft^3 5.96×10^6 yd^3
12	5.6×10^6 ft^2 128.6 acres	55 ft	308.0×10^6 ft^3 11.4×10^6 yd^3
13	7.1×10^6ft^2 163.0 acres	55 ft	391.0×10^6 ft^3 14.5×10^6 yd^3
14	5.81×10^6 ft^2 133.4 acres	55 ft	319.0×10^6 ft^3 11.8×10^6 yd^3
15	4.85×10^6 ft^2 111.3 acres	25 ft	121.0×10^6 ft^3 4.49×10^6 yd^3
1-15 Combined =	42.6×10^6 ft^2 977.1 acres		

* Estimated from USGS topographic maps, USDA and 1981 Kucera aerial photographs, and a 1"=200' topographic map made from the 1981 Kucera aerial photographs.

(a) Includes thickness of Semet and Solvay Waste.

(b) Area includes only the portion of this Bed behind approximate location of bulkhead.

(c) Thickness assumes bottom of Bed is at 363 feet NGVD and surface elevation of 380 feet NGVD.

(d) No information available on Bed thickness.

(e) Boring for Metro indicates great variability in Solvay thickness - 6 feet is an estimated average thickness extrapolated over the entire area.

(f) Historical information indicated no Solvay Waste disposal.

(g) Some portions of the site may have thin deposits of Solvay Waste, however, no subsurface information is available to determine thickness, if present.

(h) Area and volume calculations for these Beds were not divided by the assigned Bed 1-8 classification because the Beds are not in actuality divided up in this manner.

TABLE 4

PROPERTY OWNERSHIP OF
WASTE BEDS 1-15 AND A-E
AND AREAS F-M*

Waste Bed	Ownership
1-8	State of New York Fairgrounds Parking
9-11	Allied Corporation
12-15	Allied Corporation
A	Allied Corporation
B	Allied Corporation
C	Arcadian Corp. Chemical Properties Inc. Tonodo Asphalt Corp.
D/E	Dukes Realty Co. The NYC R.R. Co. The NYWS & B. Ry Co. Regal Buick Properties Route 690

Area	Ownership
F	Donald Elliott El. Roh Realty Corporation NYC and HRR Co. County of Onondaga Onondaga County Water Authority NYC and HRR Co.
G	Allied Corporation County Water Authority NYC and HRR Co. New York State Niagara Mohawk County of Onondaga Owsego-Syracuse Railroad Co. City of Syracuse
H	Abe Cooper Inc. Abe Cooper - Syracuse Inc. Amerada Hess Corporation Clark Concrete Co., Inc. The NYC Central and Hudson River R.R. Co. NYC R.R. State of New York

TABLE 4

PROPERTY OWNERSHIP OF
WASTE BEDS 1-15 AND A-E
AND AREAS F-M*
CONTINUED

Area	Ownership
H	Onondaga County Industrial Development Agency
	The County of Onondaga
	Rome, Watertown & Ogdensburg Railroad
	The Syracuse Northern Railroad Co.
I	Bieled Realty & Development Corp.
	Bieled Wrecking and Lumber Co.
	Dominick D. Carbone
	Don-Al Realty Co.
	Erie - Lackawanna R.R.
	I-690
	NY Central R.R.
	The NY West Shore Buffalo Ry Co.
	Residential
	Joseph T. Scuderi
J	Allied Realty Corp.
	Badger Northland Inc.
	Sam Celi
	Hiawatha Realty Corp.
	Hyperspace I Limited Partnership
	I-690
	Inland Chemical Corporation
	J.P.W. Erectors, Inc.
	J.P.W. Fabrications, Inc.
	Lawroy Land Co.
	Jack P. Lombardi
	Magnolia Pipeline Company
	Martins Realty Corp.
	Ronald and Patricia Mucci
	New York State
	Richfield Oil Corp.
	Anthony Santano
	Spencer Street Corp.
	Syracuse Plywood and Building Materials Inc.
	John P. Wozniczka
K	Atlantic Refining Co. Inc.
	Atlantic Refining and Marketing Corp.
	Beacon Oil Co. Inc.
	The Belcher Company of New York, Inc.
	Buckeye Pipeline Company
	Canada Oil Co.
	Citgo Petroleum Corporation

TABLE 4

PROPERTY OW''ERSHIP OF
WASTE BEDS 1-15 AND A-E
AND AREAS F-M*
CONTINUED

Area	Ownership
K	Cities Service Oil Co.
	Conn Realty Corp.
	Conrail
	Crew Levick Co.
	Henry M. and Joanne P. Drake
	Gulf Oil Corp.
	Interstate 81 (505)
	David Klibarow, Trustee
	Mobil Oil Corp.
	The Murry Corp. of America
	Onondaga County Industrial Development Agency
	NY R.R. Co.
	State of New York
	Socony Mobil Oil Company Inc.
	Standard Oil Co. of NY
	Sun Oil Co.
	Sun Refining and Marketing Company
	City of Syracuse
	City of Syracuse Industrial Development Agency
	The Texas Co. (of Deleware)
L	Central New York Market Authority
	Michael Creno
	Crouse Hinds Company
	Donald U. Murphy
	The New York Central and Hartford River Railroad Co.
	New York State
	County of Onondaga
	Schuster Realty Corp.
	City of Syracuse
	The Syracuse Junction Railroad Co.
M	Bradco Realty Corp.
	Vincent Dombroski
	Dwight Rigging and Crane Service, Inc.
	Falter Co.
	Hanover Partnership
	Imper Realty Corp.
	Brent W. Lambert and Eric Johnson
	McMillan Book Comp. Inc.
	State of New York
	County of Onondaga
	Residential
	Ryder Truck Rental, Inc.

TABLE 4

PROPERTY OWNERSHIP OF
WASTE BEDS 1-15 AND A-E
AND AREAS F-M*
CONTINUED

Area	Ownership
M	Irvine Schotz Irving S. Schotz South Penn Oil Company Spencer Street Association City of Syracuse Syracuse Dor Co. Inc. Richard J. Tindal West Genesee Corp. Edwin W. Zimmerman

* Property ownership was determined from records and plans on file at the Onondaga County Planning Agency and the Assessment Office, City of Syracuse in March 1987. This listing is intended to show the main property owners within each area, however, there is no guarantee that each and every owner is listed or that the records from which this information was obtained are valid, complete or up to date.

TABLE 5

TRIBUTARIES TO ONONDAGA LAKE

Tributary	Name	Watershed Area (mi^2)	Length of Major Channel (mi)
1	Sawmill Creek	2.78	3.6
2	Bloody Brook	4.52	2.2
3	Ley Creek	26.16	9.5
4	Onondaga Creek	102.46	27.5
5	Harbor Brook	13.22	7.5
5A	Unnamed	0.85	0.8
6	Nine Mile Creek	124.80	34.3

Source: Onondaga Lake Drainage Basin, New York State Department of Health, 1951.

TABLE 6

NINE MILE CREEK AT STATE FAIR BOULEVARD

FLOW (CFS)

Year	Mean	Max.	Min.
1971	(291[1])	(1,600)	(84)
1972	269	2,110	68
1973	310	1,500	76
1974	No Record		
1975	(211[1])	(1,610)	(109)
1976	282	1,850	88
1977	207	863	82
1978	307	1,730	100
1979	240	2,960	90
1980	170	1,640	45
1981	116	726	28
1982	203	2,460	73
1983	138	1,200	36
1984	No Record		
1985	148	1,220	13
1986	145	1,010	17
1987	(292[1])	(789)	(70)
Average	211[2]		

Source: USGS

Notes:

1 Partial Record

2 Based on Years 1972-1973, 1976-1983, 1985-1986

TABLE 7

NINE MILE CREEK

YEARLY FLOW AND QUALITY CHARACTERISTICS

Year	Average Flow (CFS)	Average Concentration Cl^- (mg/l)	Average Cl^- Loading Tons/Day	Average Concentration Ca^{+2} (mg/l)	Average Ca^{+2} Loading Tons/Day	Average Concentration Na^+ (mg/l)	Average Na^+ Loading Tons/Day
1970	344.98	2,721.0	2,530.3	1,986.1	1,846.9	1,694.2	1,575.5
1971	287.63	4,989.7	2,542.3	1,859.1	1,550.3	1,694.8	1,434.2
1972	346.91	3,073.1	2,480.2	1,278.6	963.0	1,061.7	781.7
1973	453.86	970.4	3,212.2	1,952.9	N/A	1,929.3	N/A
1974	192.02	2,862.2	1,090.3	690.7	283.7	1,385.5	449.7
1975	187.22	2,702.2	1,275.4	435.0	377.2	654.4	267.7
1976	289.44	2,485.0	1,938.5	745.0	581.3	695.0	542.5
1977	215.03	5,059.0	2,262.7	1,965.0	958.2	1,205.0	587.1
1978	230.81	7,566.0	2,258.8	2,065.0	641.0	1,576.0	505.3
1979	188.27	6,200.0	2,090.4	1,581.0	505.0	1,587.0	530.9
1980	364.78	7,267.0	4,278.2	3,407.0	2,632.0	2,176.0	1,727.8
1981	176.67	3,494.0	1,489.9	1,208.0	539.4	797.0	326.8
1982	137.22	3,272.0	1,157.7	1,236.0	472.9	855.0	321.0
1983	141.09	5,620.0	1,570.0	2,051.0	580.0	1,315.0	375.5
1984	198.02	2,440.0	1,005.0	606.0	266.5	376.0	164.5
1985	127.01	2,290.0	560.0	759.0	201.5	591.0	138.5
1986	153.77	1,280.0	484.0	471.0	176.5	317.0	115.0
1987	124.25	1,290.0	360.5	550.0	154.0	436.0	110.5

Source: Onondaga County Department of Drainage and Sanitation, Onondaga Lake Monitoring Program Reports 1970-1987.

TABLE 8

HARBOR BROOK AT HIAWATHA BOULEVARD

FLOW (CFS)

Year	Mean	Max.	Min.
1971	15.9	135	3.8
1972	19.3	230	4.0
1973	21.3	114	7.7
1974	25.8	350	7.9
1975	14.2	320	2.8
1976	18.8	408	4.3
1977	12.1	143	4.3
1978	21.3	433	3.5
1979	14.3	567	2.5
1980	11.0	130	3.2
1981	6.92	86	2.5
1982	10.1	282	2.3
1983	9.03	124	2.5
1984	11.3	96	2.3
1985	9.11	82	2.6
1986	9.62	95	2.5
1987	12.77	89	3.6
Average	14.29		

Source: USGS

TABLE 9

HARBOR BROOK

YEARLY FLOW AND QUALITY CHARACTERISTICS

Year	Average Flow (CFS)	Average Concentration Cl^- (mg/l)	Average Cl^- Loading Tons/Day	Average Concentration Ca^{+2} (mg/l)	Average Ca^{+2} Loading Tons/Day	Average Concentration Na^+ (mg/l)	Average Na^+ Loading Tons/Day
1970	29.82	240.9	17.7	365.7	29.6	85.5	6.8
1971	13.26	161.8	5.3	1,251.4	46.9	337.3	13.9
1972	37.66	110.4	9.7	173.9	16.6	124.9	11.4
1973	36.39	218.3	17.0	186.3	12.6	60.3	4.1
1974	29.52	204.0	10.5	156.0	10.9	46.0	3.3
1975	7.27	129.8	2.6	180.2	3.2	57.0	1.2
1976	21.50	179.0	7.8	200.0	10.1	60.0	2.2
1977	17.31	179.0	9.7	206.0	11.9	57.0	3.2
1978	17.17	279.0	14.7	194.0	5.4	162.0	4.1
1979	11.14	204.0	6.1	194.0	5.6	64.0	2.0
1980	10.52	461.0	15.3	193.0	4.8	504.0	16.8
1981	25.37	250.0	29.0	226.0	9.6	101.0	3.5
1982	7.27	170.0	3.5	277.0	5.3	76.0	1.5
1983	8.66	176.0	4.5	230.0	5.1	85.0	2.1
1984	11.14	215.0	5.9	245.0	6.2	87.5	2.4
1985	8.35	539.0	4.0	133.0	5.3	315.0	1.9
1986	9.28	194.0	4.6	250.0	6.0	93.5	2.3
1987	6.81	217.0	3.8	274.0	4.8	101.0	1.8

Source: Onondaga County Department of Drainage and Sanitation, Onondaga Lake Monitoring Program Reports 1970-1987.

TABLE 10

ONONDAGA CREEK AT SPENCER STREET

FLOW (CFS)

Year	Mean	Max.	Min.
1971	202	1,120	44
1972	231	1,800	38
1973	229	922	47
1974	207	1,900	47
1975	194	1,790	44
1976	273	1,500	62
1977	192	979	37
1978	268	1,590	37
1979	205	2,040	34
1980	132	1,190	28
1981	117	802	26
1982	190	1,790	34
1983	142	1,250	32
1984	178	1,140	33
1985	140	1,010	23
1986	171	1,050	39
1987	220.1	820	65
Average	193.6		

Source: USGS

TABLE 11

ONONDAGA CREEK

YEARLY FLOW AND QUALITY CHARACTERISTICS

Year	Average Flow (CFS)	Average Concentration Cl^- (mg/l)	Average Cl^- Loading Tons/Day	Average Concentration Ca^{+2} (mg/l)	Average Ca^{+2} Loading Tons/Day	Average Concentration Na^+ (mg/l)	Average Na^+ Loading Tons/Day
1970	381.32	452.6	260.5	443.8	78.5	231.6	69.0
1971	142.08	390.4	96.5	422.0	211.1	640.3	279.3
1972	212.65	213.9	95.6	117.5	61.3	184.4	85.1
1973	168.99	318.1	101.3	196.3	44.9	305.0	54.7
1974	206.04	193.8	75.7	90.4	55.6	108.1	47.6
1975	211.58	157.9	84.2	96.8	57.0	78.4	48.0
1976	390.62	291.0	187.1	102.0	101.0	111.0	94.6
1977	252.24	282.0	173.8	126.0	92.9	140.0	110.6
1978	221.38	381.0	159.5	122.0	57.2	217.0	188.3
1979	181.77	397.0	166.5	141.0	65.4	142.0	53.9
1980	153.31	414.0	96.3	140.0	46.5	277.0	53.3
1981	246.13	344.0	112.9	124.0	72.9	167.0	51.8
1982	134.28	405.0	121.9	137.0	45.0	196.0	55.3
1983	130.88	508.0	126.0	118.0	34.6	264.0	61.0
1984	183.16	313.0	131.0	116.0	49.9	179.0	63.0
1985	118.96	539.0	121.5	133.0	37.5	315.0	70.0
1986	185.95	408.0	178.0	115.0	52.5	216.0	83.5
1987	110.78	562.0	111.5	131.0	35.2	340.0	68.0

Source: Onondaga County Department of Drainage and Sanitation, Onondaga Lake Monitoring Program Reports 1970-1987.

TABLE 12

LEY CREEK AT PARK STREET

FLOW (CFS)

Year	Mean	Max.	Min.
1973	51.2	350	9.0
1974	50.8	514	10.0
1975	51.8	831	11.0
1976	59.7	602	5.6
1977	46.0	546	1.9
1978	69.8	631	8.5
1979	35.5	270	9.9
1980	29.2	660	5.2
1981	26.1	328	6.1
1982	44.0	748	5.9
1983	42.4	686	5.2
1984	46.8	580	7.1
1985	35.3	340	5.2
1986	45.0	423	6.5
1987			6.8
Average	45.26		

Source: USGS

TABLE 13

LEY CREEK

YEARLY FLOW AND QUALITY CHARACTERISTICS

Year	Average Flow (CFS)	Average Concentration Cl^- (mg/l)	Average Cl^- Loading Tons/Day	Average Concentration Ca^{+2} (mg/l)	Average Ca^{+2} Loading Tons/Day	Average Concentration Na^+ (mg/l)	Average Na^+ Loading Tons/Day
1970	105.70	1,039.6	260.5	253.9	78.5	216.5	69.0
1971	161.89	177.1	65.0	423.4	240.4	409.3	249.4
1972	213.38	153.0	62.5	114.0	56.6	142.5	65.8
1973	95.60	279.1	43.0	138.7	7.3	113.1	7.0
1974	113.39	217.6	44.0	86.7	23.2	90.8	20.5
1975	63.00	199.1	38.1	102.4	18.5	111.1	20.3
1976	64.21	279.0	38.0	130.0	19.0	95.0	10.8
1977	56.65	234.0	34.0	123.0	23.0	96.0	13.8
1978	58.94	334.0	32.6	110.0	13.2	108.0	12.2
1979	32.18	263.0	28.9	139.0	12.0	99.0	7.9
1980	59.71	182.0	26.0	142.0	17.9	131.0	13.7
1981	69.62	194.0	34.9	103.0	14.8	90.0	13.6
1982	30.32	271.0	20.0	125.0	9.8	127.0	10.9
1983	39.45	276.0	34.0	121.0	11.2	131.0	12.4
1984	117.57	304.0	79.0	122.0	37.7	137.0	34.8
1985	28.16	275.0	18.9	123.0	8.4	144.0	10.0
1986	49.19	249.0	28.1	120.0	14.0	139.0	15.6
1987	25.69	244.0	17.9	120.0	7.8	142.0	11.1

Source: Onondaga County Department of Drainage and Sanitation, Onondaga Lake Monitoring Program Reports 1970-1987.

TABLE 14

METRO PLANT

YEARLY FLOW AND QUALITY CHARACTERISTICS

Year	Average Flow (CFS)	Average Concentration Cl^- (mg/l)	Average Cl^- Loading Tons/Day	Average Concentration Ca^{+2} (mg/l)	Average Ca^{+2} Loading Tons/Day	Average Concentration Na^+ (mg/l)	Average Na^+ Loading Tons/Day
1970	92.47	660.9	169.9	588.6	148.7	646.4	165.5
1971	94.10	413.4	104.2	730.1	185.9	1,388.5	355.1
1972	103.97	530.7	138.5	136.7	40.0	345.5	93.5
1973	106.16	523.8	148.9	162.4	50.0	292.1	88.5
1974	119.38	538.6	172.8	111.4	35.8	249.6	80.1
1975	111.67	523.9	156.2	132.2	41.5	291.2	91.8
1976	118.96	543.0	174.2	138.0	57.1	298.0	95.6
1977	94.99	709.0	173.7	154.0	40.0	506.0	122.9
1978	80.91	588.0	135.1	193.0	41.4	306.0	68.0
1979	98.39	303.0	73.3	135.0	34.1	137.0	34.5
1980	99.94	344.0	91.7	131.0	33.5	280.0	70.5
1981	119.74	2,501.0	762.9	943.0	286.5	692.0	213.5
1982	94.68	2,988.1	699.1	886.0	213.7	797.0	194.2
1983	103.96	1,327.0	369.0	471.0	128.0	365.0	99.5
1984	129.17	3,330.0	1,150.0	1,170.0	404.5	893.0	308.5
1985	115.56	3,350.0	1,040.0	1,260.0	392.0	1,000.0	310.5
1986	129.02	1,020.0	363.5	309.0	106.5	371.0	132.0
1987	112.65	399.0	124.0	150.0	46.5	193.0	60.0

Source: Onondaga County Department of Drainage and Sanitation, Onondaga Lake Monitoring Program Reports 1970-1987.

TABLE 15

SLUG TEST HYDRAULIC CONDUCTIVITY

Well	K_h (cm/sec)	Screened Interval Depth	Screened Interval Material
WB-2U	* 6×10^{-3}	33.0 - 43.0	Sand & Gravel
WB-4L	* 6.6×10^{-3}	89.0 - 99.0	Gravelly Sand
WB-5M	* 1.4×10^{-2}	57.2 - 62.2	Gravelly Sand
WB-5L	** 4.2×10^{-3}	110.0 - 120.0	Sand
WB-6	4.6×10^{-4}	69.7 - 79.7	Silty Sand
WB-BU	1.1×10^{-4}	18.9 - 23.9	Solvay Waste
WB-BL	2.6×10^{-4}	80.4 - 85.4	Till

* Value represents a minimum hydraulic conductivity; these wells recovered completely before the first reading could be taken.

** Estimate value due to well recovery after only one reading.

TABLE 16

HYDRAULIC CONDUCTIVITIES AND VERTICAL GRADIENTS IN SOLVAY WASTE

Well	Depth (approx.)	Hydr. Cond. (cm/sec.)	Method	Ground-Water Elevation	Gradient ft/ft
WB-BU	24 - 29	1.1×10^{-4}	Slug Test		
MS-104.1*	74 - 79			381.1	
					0.90 down
MS-104.2	53 - 63	4×10^{-5}	Slug Test	398.4	
					0.16 down
MS-104.3	43 - 53	3×10^{-5}	Slug Test	400.05	
					0.12 down
MS-104.4	33 - 43	9×10^{-6}	Slug Test	401.25	
					0.35 down
MS-104.5	23-33	2×10^{-5}	Slug Test	404.8	
MS-105.1*	67-72			371.85	
					0.97 down
MS-105.2				382.1	
					0.39 down
MS-105.3	43-53	5×10^{-6} 5×10^{-5}	Lab Test Slug Test	394.1	
MS-105.4	33-43	7×10^{-6} 7×10^{-5}	Lab Test Slug Test		
MS-105.5	23-33	6×10^{-5}	Slug Test		
MS-106.3	45-55	6×10^{-5}	Slug Test		
MS-106.4	36-44	1×10^{-4}	Slug Test		
MS-106.5	23-33	3×10^{-6} 5×10^{-6}	Slug Test Lab Test		
MS-301.4*	66 - 71			379.0	
					0.52 down
MS-301.4	45-50			390.1	

Median of Slug Test Hydraulic Conductivities	4×10^{-5}	Average of Vertical Gradients in Solvay Waste	0.255 ft/ft. downward
		Average of Vertical Gradients between Waste & Natural Soils	.80 ft/ft. downward

* Well screened in material below Solvay Waste.

Source of Hydraulic Conductivity Data (Thomsen, 1982b; Calocerinos & Spina, 1984)

TABLE 17

INFILTRATION RATES
BEDS A-E AND 1-15

Bed	Area (ft^2)	Infiltration (inches/year)	Infiltration (cfs)
A	1.67×10^6	10.96	0.05
B	1.21×10^6	10.43	0.03
C-E	1.44×10^6	11.60	0.04
1-8	1.34×10^7	12.97	0.46
9-11	5.50×10^6	12.09	0.18
12	5.6×10^6	14.73	0.22
13-15	1.78×10^7	15.44	0.73

TABLE 18

WATER QUALITY SAMPLING PARAMETERS

Laboratory

- Hydroxide
- Carbonate
- Bicarbonate
- Calcium
- Chloride
- Conductance
- Fluoride
- Iron
- Magnesium
- Nitrate
- pH
- Potassium
- Sodium
- Strontium
- Sulfate
- Total Dissolved Solids

Field

- Conductance
- pH
- Temperature

TABLE 19

SURFACE WATER QUALITY RESULTS
ALLIED-SIGNAL INC.

Description	SW-1	SW-2	SW-3	SW-4	SW-5	SW-6	SW-7	SW-8	SW-9	SW-10	SW-11	SW-12	SW-13	SW-14
Sample #	G3272	G3273	G3274	G3275	G3276	G3277	G3278	G3334	G3335	G3336	G3337	G3338	G3339	G3340
HYDROXIDE	* 1.	22.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.
CARBONATE	* 1.	36.	* 1.	* 1.	* 1.	80.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	64.
BICARBONATE	270.	* 1.	200.	100.	240.	160.	200.	230.	230.	230.	230.	220.	230.	* 1.
CALCIUM	220.	48.	130.	550.	210.	270.	2300.	140.	140.	150.	180.	470.	460.	5300.
CHLORIDE	290.	630.	710.	2200.	110.	790.	10800.	47.	63.	140.	210.	1200.	1100.	19000.
FLUORIDE	0.21	0.32	0.39	0.31	0.24	0.22	0.1	0.17	0.18	0.17	0.17	0.17	0.19	* 0.1
IRON	0.13	* 0.05	0.09	0.60	0.10	0.40	6.0	0.14	0.12	0.14	0.15	0.36	0.37	0.35
MAGNESIUM	45.	3.9	20.	30.	37.	36.	1.2	29.	29.	29.	31.	52.	50.	26.
NITRITE, NITRATE NITROGEN	0.78	1.1	5.9	* 0.01	0.67	0.29	* 0.01	1.1	0.67	0.53	0.57	* 0.01	* 0.01	* 0.01
POTASSIUM	17.	27.	27.	39.	18.	20.	49.	12.	18.	4.5	5.2	7.7	7.8	98.
SODIUM	180.	430.	440.	810.	59.	400.	3300.	25.	28.	48.	71.	370.	330.	1200.
STRONTIUM	1.8	0.62	0.94	6.6	1.8	2.3	41.	1.4	1.3	1.3	1.3	2.1	2.1	21.
SULFATE	450.	89.	170.	88.	380.	250.	320.	230.	230.	210.	200.	250.	220.	100.
TOTAL DISSOLVED SOLIDS	1500.	1200.	960.	4700.	990.	1900.	19000.	400.	740.	780.	910.	3000.	3000.	33000.
SPECIFIC CONDUCTANCE	1900.	1800.	2200.	5500.	1100.	2400.	2200.	770.	780.	940.	1100.	3200.	3200.	41000.
pH (Laboratory)	8.1	9.0	8.3	8.0	8.1	8.4	7.0	8.0	8.0	8.0	8.0	7.9	7.9	8.8

* less than
All units mg/l (ppm) except specific conductance, pH.

TABLE 19 (Cont'd.)

SURFACE WATER QUALITY RESULTS
ALLIED-SIGNAL INC.

Description	SW-15	SW-16	SW-17	SW-18	SW-19	SW-20	SW-21	SW-22	SW-23	SW-24	SW-25	SW-26	SW-27
Sample #	G3445	G3446	G3447	G3448	G3475	G3476	G3477	G3478	G3479	G3480	G3481	G4058	G4059
HYDROXIDE	1900.	450.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.
CARBONATE	200.	100.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.
BICARBONATE	* 1.	* 1.	290.	260.	240.	290.	240.	240.	210.	230.	260.	180.	290.
CALCIUM	1250.	2700.	120.	230.	130.	380.	96.	130.	130.	140.	170.	89.	180.
CHLORIDE	1200.	7900.	420.	210.	260.	500.	150.	660.	210.	240.	270.	79.	120.
FLUORIDE	0.72	0.42	0.28	0.34	0.21	0.32	1.2	0.23	0.30	0.31	0.16	0.11	0.22
IRON	0.14	0.38	0.82	0.16	0.64	* 0.05	0.34	0.17	0.47	0.46	* 0.05	0.18	0.13
MAGNESIUM	0.05	0.27	17.	49.	29.	72.	20.	30.	29.	30.	58.	22.	39.
NITRITE, NITRATE NITROGEN	0.12	0.12	* 0.01	0.65	1.4	2.4	0.35	1.2	0.50	0.70	4.2	0.23	0.01
POTASSIUM	14.	29.	2.7	3.2	2.0	2.4	16.	2.8	3.3	3.7	3.7	3.2	3.0
SODIUM	130.	1200.	130.	110.	150.	240.	120.	400.	120.	140.	130.	45.	64.
STRONTIUM	6.3	14.	1.5	1.9	1.6	1.6	0.64	1.6	1.2	1.3	3.6	1.3	1.7
SULFATE	26.	43.	38.	540.	130.	610.	160.	150.	170.	170.	240.	95.	290.
TOTAL DISSOLVED SOLIDS	3900.	14000.	840.	1400.	970.	2000.	750.	1600.	820.	920.	1200.	510.	860.
SPECIFIC CONDUCTANCE	55000.	14000.	830.	1200.	1000.	1900.	800.	1700.	860.	1000.	1200.	490.	870.
pH (Laboratory)	9.3	11.6	7.7	7.0	8.1	7.5	7.6	8.1	7.6	7.6	7.5	7.9	7.9

* less than
All units mg/l (ppm) except specific conductance, pH.

TABLE 20

GROUND-WATER QUALITY RESULTS
ALLIED-SIGNAL INC.

Description	WB-1U	WB-1L	WB-2U	WB-2L	WB-3U	WB-3L	WB-4U	WB-4L	WB-5U	WB-5M	WB-5L	WB-6	P-1	P-2
Sample #	D3578	G3579	G3803	G3804	G3576	G3577	G3805	G3806	G3941	G3942	G3943	G3980	G4032	G4033
HYDROXIDE	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	160.	* 1.	* 1.	* 1.	* 1.	* 1.
CARBONATE	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	* 1.	40.	* 1.	* 1.	* 1.	* 1.	* 1.
BICARBONATE	370.	250.	60.	70.	210.	290.	60.	50.	* 1.	68.	60.	54.	32.	210.
CALCIUM	110.	270.	68.	19000.	150.	11000.	3300.	15000.	8200.	10000.	14000.	19000.	8400.	660.
CHLORIDE	7.	45.	350.	51000.	500.	39000.	11000.	43000.	24000.	32000.	61000.	56000.	22000.	900.
FLUORIDE	0.25	0.25	0.16	* 0.10	0.15	* 0.1	0.12	* 0.10	* 0.1	* 0.1	0.3	0.14	* 0.1	0.14
IRON	* 0.05	0.87	* 0.05	8.3	* 0.05	29.	0.18	22.	0.17	24.	28.	39.	330.	6.0
MAGNESIUM	53.	57.	11.	690.	76.	500.	220.	1000.	0.87	520.	240.	120.	91.	71.
NITRITE, NITRATE NITROGEN	* 0.01	* 0.01	1.7	* 0.01	* 0.01	* 0.01	* 0.01	* 0.01	0.47	* 0.01	* 0.01	* 0.01	* 0.01	* 0.01
POTASSIUM	5.4	2.9	12.	180.	2.0	48.	82.	250.	320.	130.	170.	280.	25.	11.
SODIUM	13.	24.	120.	8800.	110.	8300.	2300.	10000.	5800.	10000.	22000.	9500.	5000.	170.
STRONTIUM	0.49	2.9	1.5	35.	1.6	0.64	13.	41.	24.	38.	94.	42.	23.	12.
SULFATE	98.	560.	190.	130.	59.	590.	130.	150.	34.	350.	1100.	49.	64.	960.
TOTAL DISSOLVED SOLIDS	800.	1300.	890.	93000.	1500.	65000.	17000.	76000.	45000.	62000.	120000.	87000.	39000.	2900.
SPECIFIC CONDUCTANCE	530.	960.	1200.	79000.	1000.	58000.	19000.	68000.	45000.	56000.	96000.	80000.	41000.	2700.
pH (Laboratory)	7.4	7.2	8.3	6.4	7.4	6.5	8.0	6.6	11.	6.6	6.6	6.4	5.1	7.0

* less than
All units mg/l (ppm) except specific conductance, pH.

TABLE 20 (Cont'd.)

GROUND-WATER QUALITY RESULTS
ALLIED-SIGNAL INC.

Description	WB-7U	WB-7L	WB-8U	WB-8L	DW-101	MS-104.1	Metro 1
Sample #	G3944	G3945	G3978	G3979	G3807	G3808	G3999
HYDROXIDE	* 1.	* 1.	1200.	* 1.	* 1.	* 1.	* 1.
CARBONATE	* 1.	* 1.	400.	* 1.	* 1.	360.	* 1.
BICARBONATE	110.	96.	* 1.	280.	120.	20.	220.
CALCIUM	7500.	8400.	1200.	315.	23000.	23000.	140.
CHLORIDE	25000.	28000.	1300.	7200.	59000.	51000.	130.
FLUORIDE	* 0.1	* 0.1	0.69	0.57	* 0.10	0.25	1.1
IRON	32.	32.	0.06	0.62	130.	1.3	0.15
MAGNESIUM	390.	360.	* 0.05	56.	250.	2.0	28.
NITRITE, NITRATE NITROGEN	* 0.01	* 0.01	1.4	* 0.01	* 0.01	* 0.01	0.16
POTASSIUM	74.	39.	21.	36.	250.	150.	12.
SODIUM	7700.	9700.	200.	1100.	15000.	12000.	74.
STRONTIUM	59.	58.	6.2	32.	150.	110.	0.88
SULFATE	430.	440.	66.	630.	6.	39.	260.
TOTAL DISSOLVED SOLIDS	48000.	55000.	3500.	11000.	101000.	83000.	830.
SPECIFIC CONDUCTANCE	48000.	55000.	6600.	13000.	89000.	84000.	990.
pH (laboratory)	6.6	6.6	12.4	7.2	6.6	9.9	7.6

* less than
All units mg/l (ppm) except specific conductance, pH.

TABLE 21

WATER QUALITY DATA

TULLY BRINE AND WASTE BED OVERFLOW
ALLIED-SIGNAL INC.

Parameter	Tully Brine mg/l	Purified Brine mg/l	Waste Bed Overflow mg/l
Hydroxide (OH)		124	54
Carbonate (CO_3)		957	318
Bicarbonate (HCO_3)			0
Calcium (Ca)	2,014	31	20,761
Chloride (Cl)	188,510	186,885	55,388
Fluoride (F)			
Iron (Fe)			
Magnesium (Mg)	385	2.2	220
Nitrate (NO_3)			
Potassium (K)	204	204	
Sodium (Na)	121,030	120,734	12,720
Strontium (Sr)	71	3.5	
Sulfate (SO_4)	3,050	3,050	1,009
Total Dissolved Solidate			
Specific Conductance			
pH (Laboratory)			10.6

mg/l = milligrams per liter.

TABLE 22

PIPER DIAGRAM

SURFACE WATER DATA POINTS
ALLIED-SIGNAL INC.

Parameter	SW-1 meq/l	SW-1 %	SW-2 meq/l	SW-2 %	SW-3 meq/l	SW-3 %	SW-4 meq/l	SW-4 %	SW-5 meq/l	SW-5 %
Calcium (Ca)	10.98	47.84	2.40	10.83	6.49	23.20	27.45	41.49	10.48	63.32
Magnesium (Mg)	3.70	16.14	0.32	1.45	1.65	5.89	2.47	3.73	3.04	18.40
Potassium (K) +	0.43		0.69		0.69		1.00		0.46	
Sodium (Na)	7.83	36.02	18.71	87.72	19.14	70.92	35.24	54.78	2.57	18.29
Total	22.95	100	22.11	100	27.96	100	66.15	100	16.55	100
Chloride (Cl)	8.18	37.17	17.77	85.27	20.03	74.51	62.06	94.66	3.10	20.71
Sulfate (SO_4)	9.37	42.57	1.85	8.89	3.54	13.17	1.83	2.79	7.91	52.81
Carbonate (CO_3) +	0.03		1.20		0.03		0.03		0.03	
Bicarbonate (HCO_3)	4.43	20.26	0.02	5.84	3.28	12.32	1.64	2.55	3.93	26.48
Total	22.01	100	20.84	100	26.88	100	65.57	100	14.98	100

Parameter	SW-6 meq/l	SW-6 %	SW-7 meq/l	SW-7 %	SW-8 meq/l	SW-8 %	SW-9 meq/l	SW-9 %	SW-10 meq/l	SW-10 %
Calcium (Ca)	13.47	39.23	114.77	44.20	6.99	64.88	6.99	63.22	7.49	61.99
Magnesium (Mg)	2.96	8.63	0.10	0.04	2.39	22.16	2.39	21.60	2.39	19.76
Potassium (K) +	0.51		1.25		0.31		0.46		0.12	
Sodium (Na)	17.40	52.15	143.55	55.76	1.09	12.95	1.22	15.19	2.09	18.25
Total	34.35	100	259.67	100	10.77	100	11.05	100	12.07	100
Chloride (Cl)	22.29	67.99	304.67	96.83	1.33	13.37	1.78	17.14	3.95	32.57
Sulfate (SO_4)	5.21	15.88	6.66	2.12	4.79	48.28	4.79	46.18	4.37	36.06
Carbonate (CO_3) +	2.67		0.03		0.03		0.03		0.03	
Bicarbonate (HCO_3)	2.62	16.13	3.28	1.05	3.77	38.35	3.77	36.68	3.77	31.37
Total	32.78	100	314.64	100	9.92	100	10.37	100	12.12	100

meq/l = milliequivalents per liter.

TABLE 22 (Cont'd.)

SURFACE WATER DATA POINTS

Parameter	SW-11 meq/l	SW-11 %	SW-12 meq/l	SW-12 %	SW-13 meq/l	SW-13 %	SW-14 meq/l	SW-14 %	SW-15 meq/l	SW-15 %
Calcium (Ca)	8.98	60.88	23.45	53.27	22.95	55.15	264.47	82.31	67.38	91.20
Magnesium (Mg)	2.55	17.29	4.28	9.72	4.11	9.89	2.14	0.67	0.00	0.01
Potassium (K) +	0.13		0.20		0.20		2.51		0.36	
Sodium (Na)	3.09	21.83	16.10	37.01	14.35	34.97	52.50	17.03	5.65	8.79
Total	14.75	100	44.02	100	41.62	100	321.32	100	68.39	100
Chloride (Cl)	5.92	42.65	33.85	79.29	31.03	78.73	535.99	99.22	33.85	82.41
Sulfate (SO_4)	4.16	29.98	5.21	12.19	4.58	11.62	2.08	0.39	0.54	1.32
Carbonate (CO_3) +	0.03		0.03		0.03		2.13		6.67	
Bicarbonate (HCO_3)	3.77	27.38	3.61	8.52	3.77	9.65	0.02	0.40	0.02	16.27
Total	13.89	100	42.70	100	39.41	100	540.22	100	41.08	100

Parameter	SW-16 meq/l	SW-16 %	SW-17 meq/l	SW-17 %	SW-18 meq/l	SW-18 %	SW-19 meq/l	SW-19 %	SW-20 meq/l	SW-20 %
Calcium (Ca)	134.73	71.78	5.99	45.67	11.48	56.33	6.49	41.99	18.96	53.58
Magnesium (Mg)	0.02	0.01	1.40	10.67	4.03	19.79	2.39	15.45	5.92	16.74
Potassium (K) +	0.74		0.07		0.08		0.05		0.06	
Sodium (Na)	52.20	28.21	5.65	43.66	4.78	23.89	6.52	42.57	10.44	29.67
Total	187.69	100	13.11	100	20.38	100	15.45	100	35.39	100
Chloride (Cl)	222.86	98.13	11.85	67.99	5.92	27.60	7.33	52.36	14.10	44.65
Sulfate (SO_4)	0.90	0.39	0.79	4.54	11.24	52.39	2.71	19.32	12.70	40.20
Carbonate (CO_3) +	3.33		0.03		0.03		0.03		0.03	
Bicarbonate (HCO_3)	0.02	1.47	4.75	27.47	4.26	20.01	3.93	28.32	4.75	15.15
Total	227.10	100	17.43	100	21.46	100	14.01	100	31.59	100

meq/l = milliequivalents per liter.

TABLE 22 (Cont'd.)

SURFACE WATER DATA POINTS

Parameter	SW-21		SW-22		SW-23		SW-24		SW-25	
	meq/l	%	meq/l	%	meq/l	%	meq/l	%	meq/l	%
Calcium (Ca)	4.79	39.70	6.49	24.55	6.49	45.59	6.99	44.67	8.48	44.63
Magnesium (Mg)	1.65	13.64	2.47	9.34	2.39	16.77	2.47	15.79	4.77	25.11
Potassium (K) +	0.41		0.07		0.14		0.09		0.09	
Sodium (Na)	5.22	46.66	17.40	66.11	5.22	37.64	6.09	39.55	5.65	30.25
Total	12.07	100	26.43	100	14.23	100	15.64	100	19.01	100
Chloride (Cl)	4.23	36.70	18.62	72.42	5.92	45.79	6.77	47.97	7.62	45.05
Sulfate (SO_4)	3.33	28.89	3.12	12.15	3.54	27.36	3.54	25.08	5.00	29.55
Carbonate (CO_3) +	0.03		0.03		0.03		0.03		0.03	
Bicarbonate (HCO_3)	3.93	34.41	3.93	15.43	3.44	26.86	3.77	26.95	4.26	25.40
Total	11.53	100	25.71	100	12.94	100	14.11	100	16.91	100

Parameter	SW-26		SW-27	
	meq/l	%	meq/l	%
Calcium (Ca)	4.44	53.57	8.98	59.67
Magnesium (Mg)	1.81	21.84	3.21	21.32
Potassium (K) +	0.08		0.08	
Sodium (Na)	1.96	24.60	2.78	19.01
Total	8.29	100	15.05	100
Chloride (Cl)	2.23	31.00	3.39	23.82
Sulfate (SO_4)	1.98	27.51	6.04	42.49
Carbonate (CO_3) +	0.03		0.03	
Bicarbonate (HCO_3)	2.95	41.50	4.75	33.68
Total	7.19	100	14.21	100

meq/l = milliequivalents per liter.

TABLE 23

PIPER DIAGRAM

GROUND-WATER DATA POINTS
ALLIED-SIGNAL INC.

Parameter	WB-1U meq/l	WB-1U %	WB-1L meq/l	WB-1L %	WB-2U meq/l	WB-2U %	WB-2L meq/l	WB-2L %	WB-3U meq/l	WB-3U %
Calcium (Ca)	5.49	52.01	13.47	69.87	3.39	34.54	948.10	68.10	7.49	40.30
Magnesium (Mg)	4.36	41.32	4.69	24.33	0.91	9.21	56.78	4.08	6.25	33.67
Potassium (K) +	0.14		0.07		0.31		4.60		0.05	
Sodium (Na)	0.57	6.67	1.04	5.80	5.22	56.25	382.80	27.82	4.78	26.04
Total	10.55	100	19.28	100	9.83	100	1392.28	100	18.58	100
Chloride (Cl)	0.20	2.37	1.27	7.44	9.87	66.51	1438.71	99.29	14.10	74.99
Sulfate (SO_4)	2.04	24.48	11.66	68.34	3.96	26.65	9.16	0.63	1.23	6.53
Carbonate (CO_3) +	0.03		0.03		0.03		0.03		0.03	
Bicarbonate (HCO_3)	6.06	73.15	4.10	24.21	0.98	6.85	1.15	0.08	3.44	18.48
Total	8.34	100	17.06	100	14.85	100	1449.05	100	18.81	100

Parameter	WB-3L meq/l	WB-3L %	WB-4U meq/l	WB-4U %	WB-4L meq/l	WB-4L %	WB-5U meq/l	WB-5U %	WB-5M meq/l	WB-5M %
Calcium (Ca)	548.90	57.64	164.67	57.80	748.50	58.84	409.18	61.10	499.00	50.91
Magnesium (Mg)	41.15	4.32	18.10	6.35	82.29	6.47	0.07	0.01	42.79	4.37
Potassium (K) +	1.23		2.10		6.39		8.18		3.32	
Sodium (Na)	361.05	38.04	100.05	35.85	435.00	34.70	252.30	38.89	435.00	44.72
Total	952.32	100	284.92	100	1272.18	100	669.73	100	980.11	100
Chloride (Cl)	1100.19	98.47	310.31	98.81	1213.03	99.67	677.04	99.80	902.72	99.07
Sulfate (SO_4)	12.28	1.10	2.71	0.86	3.12	0.26	0.01	0.00	7.29	0.80
Carbonate (CO_3) +	0.03		0.03		0.03		1.33		0.03	
Bicarbonate (HCO_3)	4.75	0.43	0.98	0.32	0.82	0.07	0.02	0.20	1.11	0.13
Total	1117.26	100	314.03	100	1217.01	100	678.40	100	911.15	100

meq/l = milliequivalents per liter.

TABLE 23 (Cont'd.)

GROUND-WATER DATA POINTS

Parameter	WB-5L meq/l	WB-5L %	WB-6 meq/l	WB-6 %	P-1 meq/l	P-1 %	P-2 meq/l	P-2 %	WB-7U meq/l	WB-7U %
Calcium (Ca)	698.60	41.59	948.10	68.78	419.16	65.01	32.93	70.90	374.25	50.36
Magnesium (Mg)	19.75	1.18	9.87	0.72	7.49	1.16	5.84	12.58	32.09	4.32
Potassium (K) +	4.35		7.16		0.64		0.28		1.89	
Sodium (Na)	957.00	57.23	413.25	30.50	217.50	33.83	7.40	16.52	334.95	45.32
Total	1679.70	100	1378.38	100	644.79	100	46.45	100	743.19	100
Chloride (Cl)	1720.81	98.63	1579.76	99.88	620.62	99.70	25.39	51.97	705.25	98.49
Sulfate (SO_4)	22.90	1.31	1.02	0.06	1.33	0.21	19.99	40.91	8.95	1.25
Carbonate (CO_3) +	0.03		0.03		0.03		0.03		0.03	
Bicarbonate (HCO_3)	0.98	0.06	0.89	0.06	0.52	0.09	3.44	7.11	1.80	0.26
Total	1744.73	100	1581.70	100	622.51	100	48.85	100	716.04	100

Parameter	WB-7L meq/l	WB-7L %	WB-BU meq/l	WB-BU %	WB-BL meq/l	WB-BL %	DW-101 meq/l	DW-101 %	MS-104.1 meq/l	MS-104.1 %
Calcium (Ca)	419.16	48.08	59.88	86.63	15.72	22.75	1147.70	62.81	1147.70	68.57
Magnesium (Mg)	29.62	3.40	0.00	0.01	4.61	6.67	20.57	1.13	0.16	0.01
Potassium (K) +	1.00		0.54		0.92		6.39		3.84	
Sodium (Na)	421.95	48.52	8.70	13.36	47.85	70.58	652.50	36.06	522.00	31.42
Total	871.73	100	69.12	100	69.10	100	1827.17	100	1673.70	100
Chloride (Cl)	789.88	98.66	36.67	71.35	203.11	91.97	1664.39	99.87	1438.71	99.10
Sulfate (SO_4)	9.16	1.14	1.37	2.67	13.12	5.94	0.12	0.01	0.81	0.06
Carbonate (CO_3) +	0.03		13.33		0.03		0.03		12.00	
Bicarbonate (HCO_3)	1.57	0.20	0.02	25.97	4.59	2.09	1.97	0.12	0.33	0.85
Total	800.65	100	51.40	100	220.85	100	1666.52	100	1451.85	100

meq/l = milliequivalents per liter.

TABLE 23 (Cont'd.)

GROUND-WATER DATA POINTS

Parameter	METRO 1 meq/l	METRO 1 %
Calcium (Ca)	6.99	54.51
Magnesium (Mg)	2.30	17.98
Potassium (K) +	0.31	
Sodium (Na)	3.22	27.51
Total	12.82	100
Chloride (Cl)	3.67	28.83
Sulfate (SO_4)	5.41	42.56
Carbonate (CO_3) +	0.03	
Bicarbonate (HCO_3)	3.61	28.61
Total	12.72	100

meq/l = milliequivalents per liter.

TABLE 24

PIPER DIAGRAM

ADDITIONAL DATA POINTS
ALLIED-SIGNAL INC.

Parameter	Tully Brine meq/l	Tully Brine %	Purified Brine meq/l	Purified Brine %	Waste Bed Overflow meq/l	Waste Bed Overflow %
Calcium (Ca)	100.50	1.86	1.55	0.03	1035.97	64.45
Magnesium (Mg)	31.68	0.68	0.18	0.10	18.10	1.13
Potassium (K) +	5.22		5.22			
Sodium (Na)	5264.81	97.46	5251.93	99.87	553.32	34.42
Total	5402.21	100	5258.88	100		100
Chloride (Cl)	5317.87	98.82	5272.03	98.15	1562.50	98.02
Sulfate (SO_4)	63.50	1.18	63.50	1.78	21.01	1.98
Carbonate (CO_3) +			31.90		10.60	
Bicarbonate (HCO_3)		0.00	4.10	0.08		0.00
Total	5381.37	100	5371.53	100	1594.11	100

meq/l = milliequivalents per liter.

TABLE 25

WELL INSTALLATION DETAILS

	WELL/BORING #										
	WB-1U	WB-1L	WB-2U	WB-2L	WB-3U	WB-3L	WB-4U	WB-4L	WB-5U	WB-5M	WB-5L
Protective Casing Stickup	2.5	2.0	3.0	2.4	2.7	1.8	2.8	1.7	3.0	2.8	1.8
Riser Stickup	2.4	1.9	2.8	1.9	2.6	1.6	2.7	1.6	2.8	2.6	1.6
Top of Riser Elevation	406.45	405.80	403.20	402.64	404.25	403.10	398.86	397.98	388.86	388.73	387.59
Ground Surface Elevation	404.1	403.9	400.4	400.7	401.7	401.5	396.2	396.4	386.1	386.1	386.0
Grout	0-31.9	0-67.0	See Below*	0-90.1	0-30.0	0-62.9	0-25.1	0-85.7	0-4.6	0-55.3	0-107.0
Bentonite Seal	31.9-32.7	67.0-67.6	28.8-30.0	90.1-92.3	30.0-31.2	62.9-63.9	25.1-26.1	85.7-86.7	4.6-5.0	55.3-55.9	107.0-108.0
Screen											
Length	5'	5'	10'	10'	10'	10'	10'	10'	5'	5'	10'
Depth	34.0-39.0	69.9-74.9	33.0-43.0	94-104	33.3-43.3	66-76	28.8-38.8	89,0-99.0	6.9-11.9	57.2-62.2	110.0-120.0
Sump	---	---	---	104-108	---	---	---	---	---	---	---
Well Pack											
Sand	32.7-38	67.6-74.7	30.0-43.5	101.7-108.1	31.2-43.5	63.9-77.2	26.1-38.8	86.7-113.5	5.0-12.5	55.9-60.0	108.0-133.6
Formation Collapse	38-39	---	---	92.3-101.7	---	---	38.8-39.0	---	---	60.0-63.0	---
Depth of Boring	40.5	62.8	45.0'	111.6	45.0'	84.6	39.0	120.8	12.5	63.0	141.0
Borehole Backfill											
Material	Formation Collapse	Formation Collapse	Formation Collapse	Bentonite Pellets	Formation Collapse	Bentonite Pellets	---	Bentonite Pellets	---	---	Formation Collapse
Depth	39-40.5	74.7-82.8	43.5-45.0	108.1-111.6	43.5-45.0	77.2-80.8 Formation Collapse 80.8-84.6		113.5-119.8 Formation Collapse 119.8-120.8			133.6-134.3 Bentonite Pellets 134.3-139.2 Formation Collapse 139.2-141.0
			*0-6.1' Grout 6.1-7.0 Bentonite 7.0-10.0 Grade 0 Sand 10.0-25.8 Formation Collapse								

TABLE 25 (Continued)

WELL INSTALLATION DETAILS

	WELL/BORING #							
	WB-6	WB-7U	WB-7L	WB-8U	WB-8L	WB-11a	WB-21a	WB-7La
Protective Casing Stickup	2.1	3.0	2.4	3.0	2.0	N/A	N/A	N/A
Riser Stickup	2.0	2.8	2.2	2.9	1.8	N/A	N/A	N/A
Top of Riser Elevation	383.79	380.33	379.72	385.18	384.00	N/A	N/A	N/A
Ground Surface Elevation	381.8	377.5	377.5	382.3	382.2	404.3	400.5±	377.5±
Grout	0-67.0	0-45.7	0-69.3	0-16.6	0-76.7	N/A	N/A	N/A
Bentonite Seal	67.0-67.8	45.7-46.6	69.3-70.4	16.6-17.5	76.7-77.6	N/A	N/A	N/A
Screen								
Length	10'	5'	5'	5'	5'	N/A	N/A	N/A
Depth	69.7-79.7	48.0-53.0	72.2-77.2	18.9-23.9	80.4-85.4	N/A	N/A	N/A
Sump	---	---	---	---	---	N/A	N/A	N/A
Well Pack								
Sand	67.8-82.0	46.6-53.3	70.4-73.4	17.5-24.3	77.6-85.4	N/A	N/A	N/A
Formation Collapse	---	---	73.4-79	---	---	N/A	N/A	N/A
Depth of Boring	---	53.3	79'	24.3	85.4	N/A	N/A	N/A

TABLE 25 (Continued)

WELL INSTALLATION DETAILS

	WELL/BORING #							
	WB-6	WB-7U	WB-7L	WB-8U	WB-8L	WB-1La	WB-21a	WB-71a
Borehole Backfill Material Depth	Bentonite Pellets 82.0-83.8 Grade 0 Sand 83.8-86.0 Bentonite Pellets 86.0-86.5 Grade 0 Sand 86.5-91 Bentonite Pellets 91-96.7	---	Formation Collapse to 79'	---	---	Grout 0-50.4	Grout 0-5.0 Bentonite Pellets 5.0-5.5 Sand & Gravel Backfill 5.5-15.0 Formation Collapse 15.0-95.5	Grout 0-62.0 Grade 0 Sand & Formation Collapse 62.0-66.9 Bentonite Pellets 66.9-69.5 Formation Collapse 69.5-82.0 Grade 0 Sand 82.0-95.8 Formation Collapse 95.8-102.4 Bentonite Pellets 102.4-111.4 Formation Collapse 111.4-112.4

TABLE 26

NINE MILE CREEK FLOW AND ION LOADING BALANCE

	Flow (CFS)	Cl^- conc. mg/l	Cl^- loading tons/day	Ca^{+2} conc. mg/l	Ca^{+2} loading tons/day	Na^+ conc. mg/l	Na^+ loading tons/day
Upstream	97.9	47	12.4	140	37.0	28	7.4
Tributaries							
Beaver Meadow Brook	8.3	120	2.7	180	4.0	64	1.4
Geddes Brook	14.5	1,000	39.1	1,065	41.7	1,524	59.7
Ground Water Flux between upper and lower ends of valley	neglible		----		----		----
Beds 9-11	0.18	24,000(1)	11.7	8,200(1)	4.0	5,800(1)	2.8
Beds 12-15	0.11	30,000(2)	8.9	10,500(2)	3.1	6,300(2)	1.9
Total	120.99		74.8		89.8		73.2
Downstream	137.4	1,200	444.6	470	174.4	370	137.3
Deficit	16.4	8,350(3)	369.8	1,910(3)	84.6	1,450(3)	64.1

Notes:

(1) Typical leachate concentration for Waste Beds 9-11 from Well WB-5U.

(2) Typical leachate concentration for Waste Beds 12-15 from Leachate Seep Study (Blasland & Bouck Engineers, 1986).

(3) Calculated concentration.

TABLE 27

HELP MODEL PARAMETERS

Model Inputs	Waste Bed A					Waste Beds 1-8					
	Bare Ground Area	Poor Veg. Area	Fair Veg. Area	Waste Bed B	Waste Beds C-E	Bare Ground Area	Poor Veg. Area	Good Veg. Area	Waste Beds 9-11	Waste Bed 12	Waste Beds 13-15
Climatological Data											
Daily Precipitation Data	'68-'87	'68-'87	'68-'87	'68-'87	'68-'87	'68-'87	'68-'87	'68-'87	'68-'87	'72'-87	'84-'87
Daily Temp. & Solar Radiation	Syracuse	Syracuse	Syracuse	Syracuse	Syracuse	Syracuse	Syracuse	Syracuse	Syracuse	Syracuse	Syracuse
Leaf Area Index	0.0	1.0	2.0	3.3	2.0	0.0	1.0	3.3	2.0	2.0	0.5
Evaporative Zone Depth (in.)	20	14	20	28	20	8	14	28	20	20	11
Soil & Design Data											
Water Content Init. by Prog.?	Y	Y	Y	Y	Y	Y	Y	Y	Y	N(2)	N(2)
Number of Layers	2	1	1	2	3	2	1	2	1	3	1
Layer Thickness (in.)	144-216	360	360	6-204	6-12-204	6-480	480	6-480	840	6-48-660	660
Layer Type	VP-VP	VP	VP	VP-VP	VP-VP-VP	VP-VP	VP	VP	VP	VP-VP-VP	VP
Soil Texture	#15(1)-#8	#8	#8	#9-#8	#9-#4-#8	#4-#8	#8	#9-#8	#8	#4-#1-#8	#8
Layer Compacted?	N-N	N	N	N-N	N-N-N	Y-N	N	N	N	N-N-N	N
Vegetative Cover Type	Br.Ground	Poor	Fair	Good	Fair	Br.Ground	Poor	Good	Fair	Fair	Br.Ground
Closed Drainage?	Y	Y	Y	N	N	N	N	N	Y	Y	Y
Fraction of R.O. Avail. to Drain	0	0	0	N/A	N/A	N/A	N/A	N/A	0	0	0
Open Drainage?	N/A	N/A	N/A	Y	Y	Y	Y	Y	N/A	N/A	N/A
Total Surface Area (SF)	8.8×10^{5}	2.2×10^{5}	5.7×10^{5}	1.21×10^{6}	1.44×10^{6}	3.21×10^{6}	5.72×10^{6}	4.51×10^{6}	5.5×10^{6}	5.6×10^{6}	1.78×10^{7}

Notes:

(1) Permeability decreased one order of magnitude from default value
(2) Water content initialized for saturated conditions during year of shutdown

TABLE 28

ONONDAGA LAKE 1987 CHLORIDE LOADING SUMMARY

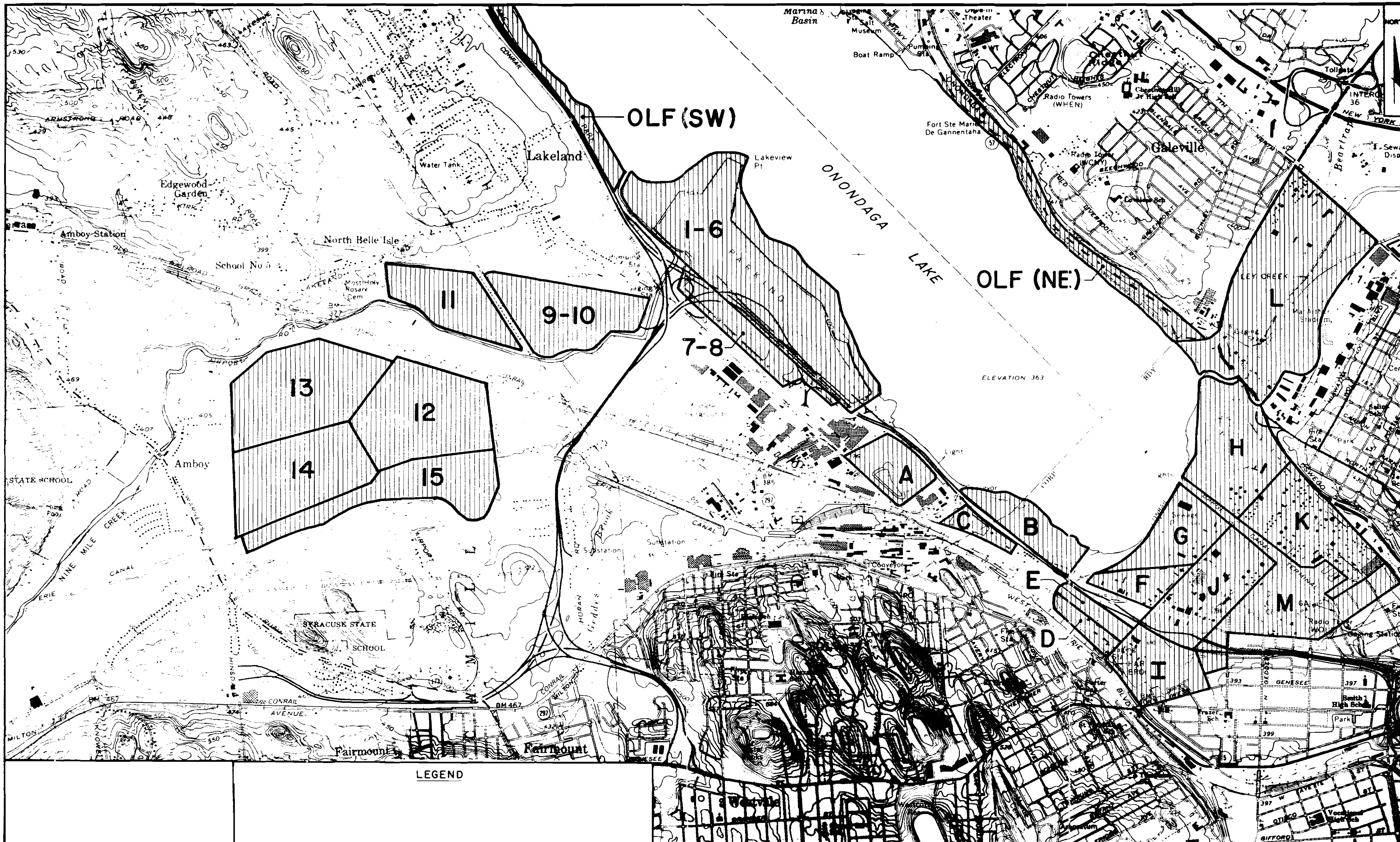
	Flow (cfs)	Concentration (ppm)		Loading (tons/day)	Percent of Total (%)
A. Contributions Directly to Lake					
1. Waste Bed A Infiltration	0.05	18,500		2.39	0.33
2. Waste Bed B Infiltration	0.03	1,300		0.11	0.02
3. Waste Beds C-E Infiltration	0.04	1,300		0.14	0.02
4. Waste Beds 1-8 Infiltration	.46	7,900		9.81	1.36
5. Waste Beds 1-8 Ground Water (see 4.5.3)	.04	59,000		6.05	0.84
6. Waste Beds 1-8 Erosion (see 4.5.3)	NA	NA		0.11	0.02
			Subtotal	18.61	2.59
B. Nine Mile Creek Contribution					
1. Nine Mile Creek Upstream	97.9	47		12.4	1.72
2. Waste Beds 9-11 Infiltration	0.18	24,000		11.7	1.62
3. Waste Beds 12-15 Infiltration	0.11 (1)	30,000		8.9	1.23
4. Beaver Meadow Brook	8.3	120		2.7	0.37
5. Geddes Brook	14.5	1,000		39.10	5.42
6. Ground Water (see Table 26)	16.4	8,350		369.8	51.26
			Subtotal	444.6	61.62
C. Other Surface Water Contribution					
1. Ley Creek	25.69	244		17.9	2.48
2. Onondaga Creek	110.79	526		111.5	15.45
3. Harbor Brook	6.81	217		3.81	0.53
4. Tributary 5A	1.27	287		0.98	0.14
			Subtotal	134.19	18.60
D. Metro Facility Contribution					
1. Leachate from Allied	1.09	19,133		55.2 (2)	7.65
2. Metro portion				68.8 (2)	9.54
			Subtotal	124.0	17.19
			TOTAL	721.40	100.00

Notes:

(1) Net infiltration calculated as rainfall infiltration (0.95 cfs) plus LCP wastewater (0.25 cfs) minus leachate to Metro (1.09 cfs).

(2) Adjusted chloride loading to reflect treatment processes (chloride addition at 1.0 tons/day from wastewater disinfection and 2.23 tons/day by sludge removal).

Figures



LEGEND

SCALE
1,000' 0 1,000'

DATE:

BLASLAND & BOUCK ENGINEERS, P.C.
Syracuse New York
White Plains New York

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

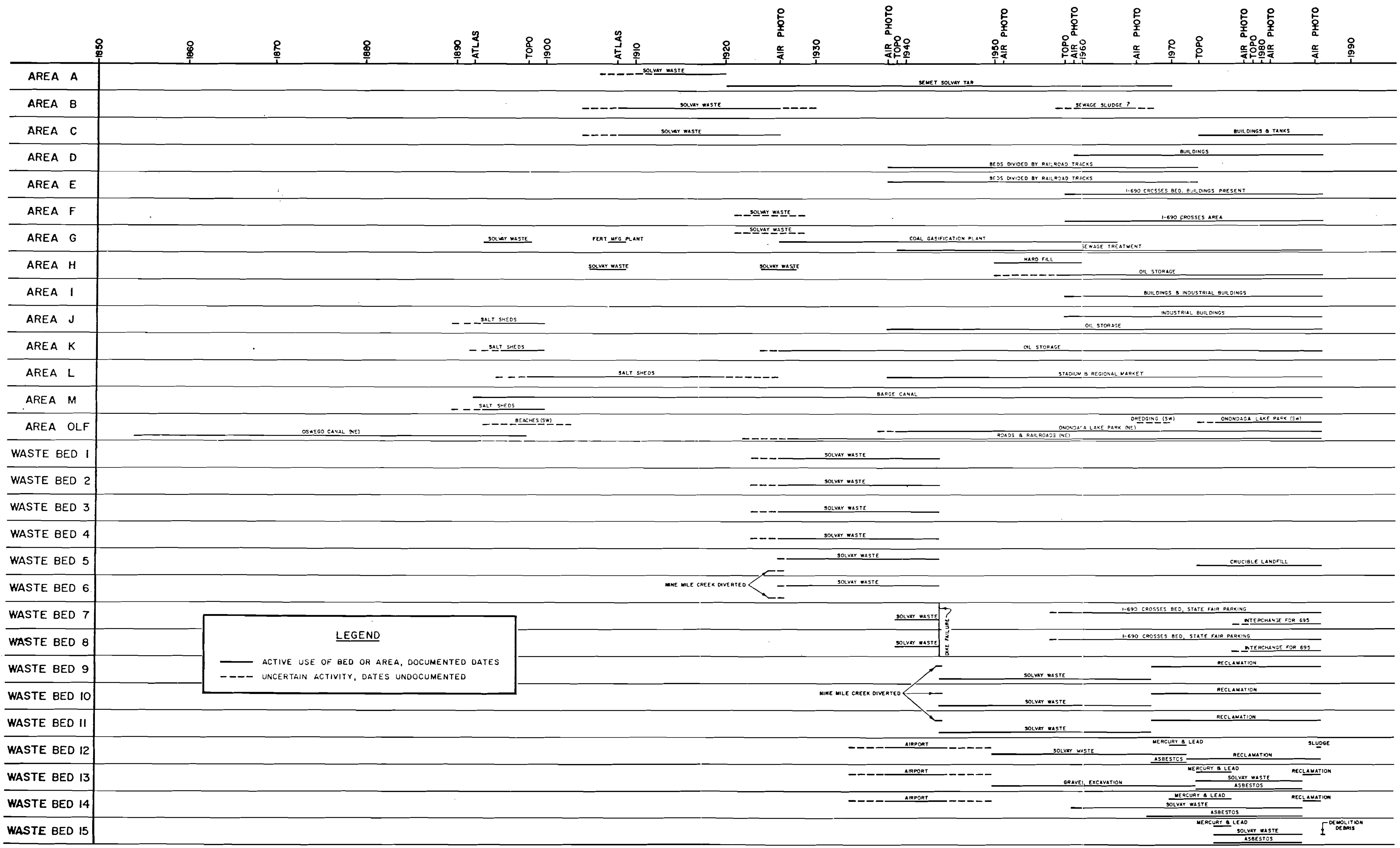
SITE LOCATION MAP

FIGURE
1

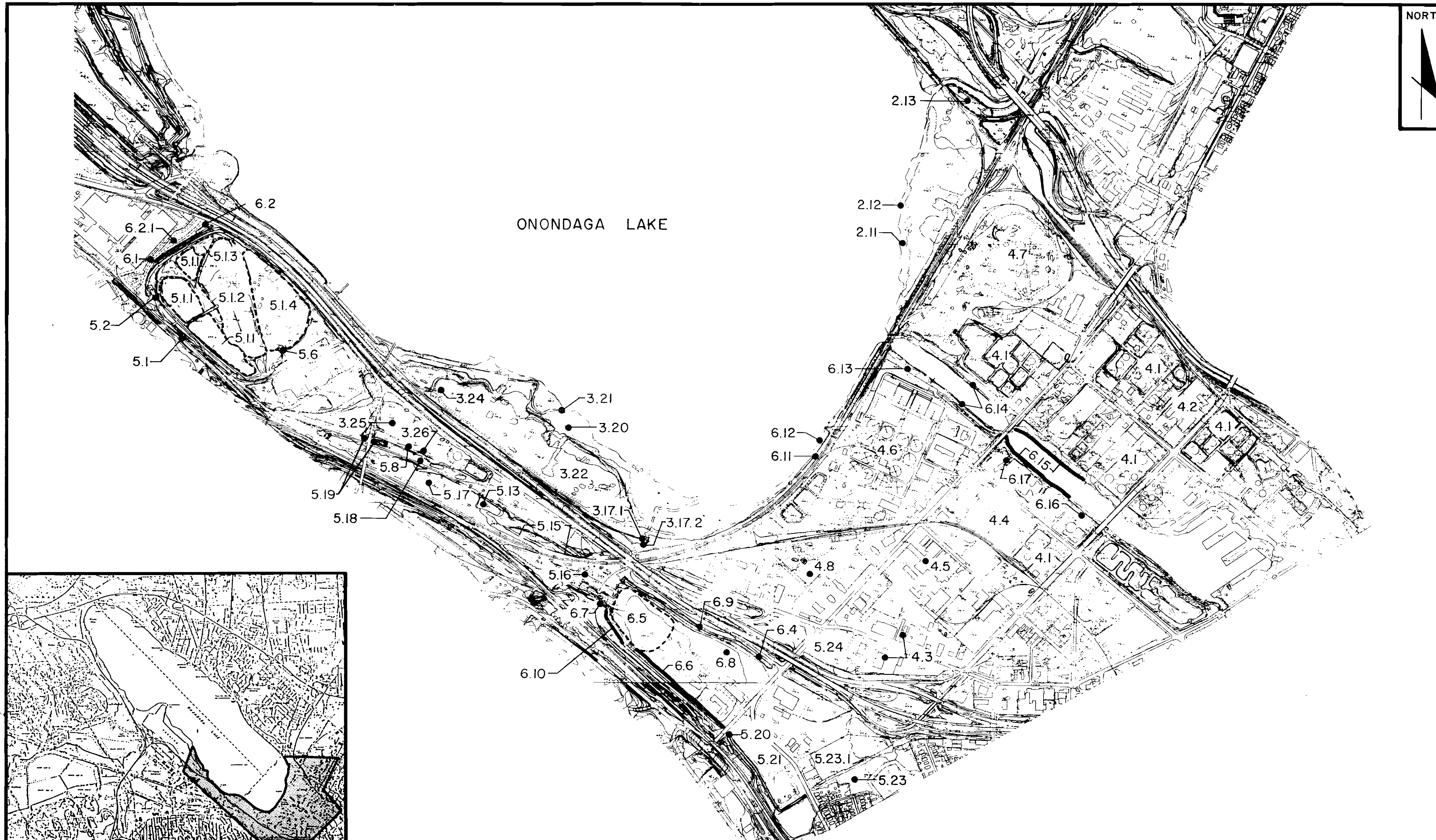
CHRONOLOGY OF WASTE DISPOSAL AREA UTILIZATION

FIGURE 2

ALLIED CORPORATION
SOLVAY, NEW YORK



BLASLAND & BOUCK ENGINEERS, P.C.



DATE:	5.23 Observation station and number, see attached sheets for explanation. Site observations made during walkovers of May 1-6, 1987.	BLASLAND & BOUCK ENGINEERS, P.C.	ALLIED-SIGNAL INCORPORATED HYDROGEOLOGIC ASSESSMENT OF THE ALLIED WASTE BEDS SYRACUSE, NEW YORK	WASTE BEDS A-E AND AREAS F-K & M SITE OBSERVATIONS	FIGURE 3
SCALE: 1,000' 0 1,000'					

SITE OBSERVATIONS MADE DURING SITE RECONNAISSANCE OF MAY 1-6, 1987

WASTE BEDS A-E AND AREAS F-K & M

3.17.1 Drainage off southwest side of Bed B, 1-2 gpm. pH - 10.7, specific conductance (SC) - 1,900.

3.17.2 Harbor Brook upstream of confluence with drainage swale where 3.17.1 was read. pH - 8.7, SC - 1,500.

3.20 Standing water fed from seeps off Bed. pH - 8.7, SC - 12,000.

3.21 Water in drainage swale. pH - 10.0, SC - 4,000.

3.22 Surface of bed is generally well vegetated with grasses, "reed grass", some small bushes and some areas of trees. The material in the upper 5-8 inches of "soil" is dark brown to black and appears to be organic-rich. This directly overlies white Solvay waste.

3.24 Sand and gravel fill at ground surface.

3.25 Open grass-covered area with 5-6 inches of black-brown topsoil overlying a hard coarse sand and final gravel in matrix of red silty clay.

3.26 Exposure in bank of bed exposing 4-5 feet of soil. No Solvay waste observed.

4.1 Oil terminals.

4.2 Print shop.

4.3 Small business.

4.4 Area filled to 3-4 feet above road grade. Concrete, blacktop, and sand and gravel exposed at ground surface, covered with weeds and small trees.

4.5 Syracuse Tank and Manufacturing Co. Outdoor storage of pipe, metal and tanks.

4.6 Onondaga County, Drainage and Sanitation Treatment Facility.

4.7 Marley's scrap yard (site of proposed "Carousel Center"). Numerous piles of metal scrap.

4.8 Roth Steel Corp., scrap metal.

5.1 Drain pipe at base of bed, no visible flow.

5.1.1 Surface of bed is is black tar-like material.

5.1.2 Surface of bed is brown with some vegetation growth.

5.1.3 Area covered by "reed grass".

5.1.4 Some trees with fair vegetation cover, numerous piles of rubble, brick and concrete block.

5.2 Exposure of Allied waste in side of bed with black material at surface.

5.6 Large manhole - for subsurface utilities?

5.8 Exposure of white gravelly material - Solvay waste?

5.10 No Solvay waste observed with 12" of ground surface. Thick growth of trees and grasses in this area.

5.11 Retention basin berm for oil tank located northwest of basin. Chips of Allied waste in soil excavated from base of berm by woodchucks.

5.13 Ponded area along railroad grade. pH - 9.3, SC - 1,100.

5.15 Drainage ditch with white precipitate along bottom and sides. Flow less than 1 gpm (estimated).

5.16 Some ponded water with no apparent outlet, some white precipitation on bottom.

5.17 Black material at ground surface, however, area is generally well vegetated.

5.18 Allied waste exposed in bank of bed along railroad siding.

5.19 Allied waste exposed at ground surface.

5.20 Harbor Brook at Hiawatha Boulevard. pH - 7.4, SC - 1,500.

5.21 Open field with gravel on ground surface and piles of rubble along bank of Harbor Brook.

5.23 0-6 inches organic-rich topsoil - mostly rotted wood.
6-18 inches black to light gray cinders and ash.

5.23.1 Syracuse Fire Training Facility.

5.24 2-3 feet construction excavation exposed only sand and gravel, no white material observed.

6.1 Culvert pipe outfall, flow is 6-8 inches deep and 4 feet wide, estimated 2 ft/sec.

6.2 Sample pH - 7.8, SC - 1,000.

6.2.1 Sediments along stream are reddish-brown for the top 1-2 inches underlain by more than 6 inches of black silt with an oily sheen.

6.4 Drainage swale along Hiawatha Boulevard - Exit off I-690. pH - 7.4, SC - 2,600.

6.5 Surface covered with construction rubble - concrete, wood, rock, railroad ties, metal, etc. Very little vegetation.

6.6 Slope along edge of Harbor Brook is approximately 20 feet high, largely covered with trash and rubble.

6.7 Drainage entering Harbor Brook from northwest. pH - 2.2, SC - 11,000.

6.8 Recently placed fill - possibly excavated from area towards Hiawatha Boulevard during construction of new building. Fill contained an estimated 5-10% Solvay waste.

6.9 Slump of surface soil exposed Solvay waste along exit ramp embankment.

6.10 White precipitate on concrete culvert for Harbor Brook, above the waterline and on the bottom of the brook.

6.11 Material at waterline is black and white - mixture of coal chips, cinders, shells and small pebbles.

6.12 Rock-like material at waterline, white to reddish-tan in color with numerous "inclusions" of material described under 6.11.

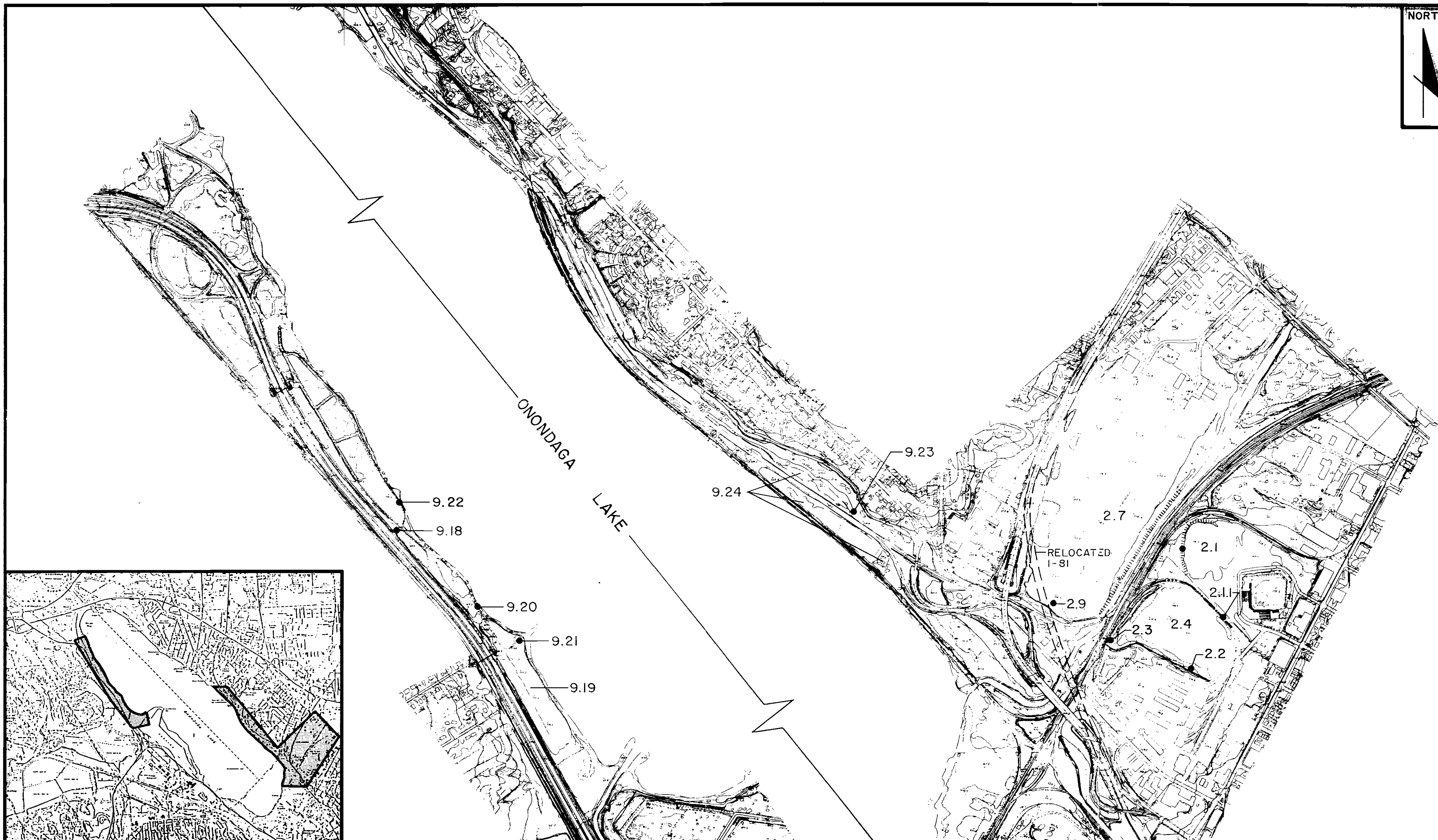
6.13 0-4 inches black to brown topsoil, 4-16 inches ± Solvay waste.

6.14 White material (probably Solvay waste) outcropping on both sides of barge canal, observed where riprap has slumped.

6.15 No riprap protecting sides of canal, however, no visible Solvay waste in this area.

6.16 0-2 feet brown topsoil grading to brown-gray silty fine sand.

6.17 Area surrounded with dike 6 to 7 feet high, center of area has strong growth of reed grass. Standing water in northern corner. pH - 6.5, SC - 1,100.



DATE:

SCALE: 1,000' 0 1,000'

2.12 Observation station and number, see attached sheets for explanation. Site observations made during walkovers of April 29, 1987.

BLASLAND & BOUCK ENGINEERS, P.C.

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

AREAS L AND OLF
SITE OBSERVATIONS

FIGURE 4

SITE OBSERVATIONS MADE DURING SITE RECONNAISSANCE OF APRIL 29, 1987

AREAS L AND OLF

2.1 Open, uneven lot with poor to fair grass cover. Fill slope 3+ feet high along west and north sides of lot. Fill composed of concrete rubble, gravel, wood and metal. Water sample from base of fill in swampy area that extends to railroad tracks to the west. pH - 7.0, SC - 800.

2.1.1 Sample from drainage swale. pH - 6.7, SC - 1,200.

2.2 Drainage swale in Regional Market area, observed hard fill in southwestern face of swale. pH - 6.7, SC - 700.

2.3 Drainage swale draining southwest. pH - 7.2, SC - 1,700.

2.4 Heavy cover of "reed grass" area appears to be fill with metal and concrete commonly observed at ground surface.

2.7 Large open area, coarse cobble gravel exposed at surface with concrete rubble and brick very commonly exposed. Fill slope along Ley Creek exposes brick and concrete. Localized standing water common, one small surface swale with minor southward flow. pH - 7.4, SC - 390. Area vegetated with grasses, golden rod, and "reed grass" in low areas.

2.9 Drainage swale draining along highway. pH - 6.9, SC - 5,200.

2.10 Ley Creek. pH - 6.7, SC - 850. Approximate location of of relocated I-81.

2.11 3 foot wave cut exposure with gray-brown marl overlying organic-rich sand.

2.12 2 foot wave cut exposure of gray-brown silty sand overlying fossil hash.

2.13 Area overgrown with "reed grass", very numerous piles of demolition debris.

9.18 Drainage culvert 1 gpm, pH - 7.9, SC - 630.

9.19 Area covered with thick growth of "reed grass".

9.20 Excavation in beach 0-4 in., peat 4-8 in. marl with shells and concretions.

9.21 Pleasant Beach.

9.22 Excavation in beach, 0-4 in. marl with shells.

9.23 Spring discharging to pond, flow estimated @ 5 gpm, pH - 7.1, SC - 1780 (values measured December 1987)

9.24 Ponds frozen over December 8, 1987, drainage to the northwest.

DATE:

SCALE:
1,000' 0 1,000'

1.26 Observation station and number, see attached sheets for explanation. Site observations made during walkovers of May 1, 1987.

BLASLAND & BOUCK ENGINEERS, P.C.

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

WASTE BEDS 1-8
SITE OBSERVATIONS

FIGURE
5

SITE OBSERVATIONS MADE DURING SITE RECONNAISSANCE OF MAY 1, 1987

WASTE BEDS 1-8

1.1 Area mostly flat to gently rolling, generally grass covered, some localized gravel covered areas with paved access roads.

1.5 Heavily vegetated slope, few small trees.

1.10 Blacktop-lined drainage swale. pH - 8.5, SC - 3,500.

1.11 Drainage swale at foot of Beds 7-8. Flow estimated to be less than 5 gpm. pH - 11.8, SC - 8,000.

1.14 Drainage swale at foot of Beds 7-8. pH - greater than 12, SC - 8,500. Drainage swale along southwest side of road at base of Beds 7-8. pH - 7.4, SC - 3,500.

1.15 Precipitate at seep location.

1.18 Poorly vegetated surface, some grass covered areas, and some gravel/dirt covered areas.

1.19 Thick grass cover, area sloping down to Nine Mile Creek. Waste exposed along bank of bed.

1.20 Piles of concrete rubble, soil, gravel, cinder and slag.

1.21 Wooded area.

1.22 Poor vegetation cover, few small scrubby bushes, lichen, golden rod.

1.24 Exposed, rock-like waste, white to gray, "bedding" is very contorted.

1.25 Heavy growth of "reed grass".

1.26 Generally flat, gravel covered surface, poor to fair vegetation cover, triple well cluster, under artesian conditions.

1.29 Diffuser retention pond. pH - NR, SC - 2,300.

3.1 Drainage ditch from outfall, flows to lake. pH - 10.9, SC - 11,000.

3.2 Vegetation cover is quite good on flat areas with fair to poor cover on waste bed slopes.

3.3 Rock-like Solvay waste along waterline. Reed grass in areas above waterline.

3.3.1 Vegetation cover good, with mixture of wooded areas containing trees up 12 inches in diameter and open areas with field-type vegetation. Excavation on slope indicates 2 to 3 inches of black organic-rich soil overlying white Solvay waste.

3.3.2 Steel drain pipe protruding from base of waste beds, flow less than 1 gpm. pH - 11.8, SC - 23,000.

3.4 Dried up seep location on flat area above waterline, ground surface covered by precipitate.

3.5 Seep with gray-brown precipitate around seep. pH - 10.0, SC - 15,000. Old wooden bulkhead protruding from waste southwest of seep.

3.6 Southeast of this point the flat area along lake edge and slopes above the flats are, in general, moderate to well vegetated. Northwest of this point the vegetation along the lake is either very poorly developed or absent. The slopes above the flats are poorly to moderately well vegetated.

3.7 Flow of seepage from this area of flats enters lake with flow of less than 2 gpm. pH - 11.6, SC - 14,000.

3.8 Between this point and point 3.7, there are two other drainage channels issuing from the combined seep to the lake.

3.9 Well 18.2, installed by C&S for Crucible Study. pH - 11.0, SC - greater than 50,000. Area around well is a large seep area devoid of vegetation.

3.10 Drain pipes issuing from edge of waste bed, currently no flow.

3.11 Vegetation in this area is very poorly developed, minor grass/weed cover, occasional stunted bush or tree.

3.11.1 Direct wave attach on 8-10 foot exposure of Solvay waste, very poor vegetation on flat above this area.

3.11.2 Two non-flowing drainage pipes issuing from waste slope.

3.12 Flowing seep from flats along lake. pH - 11.4, SC - greater than 50,000.

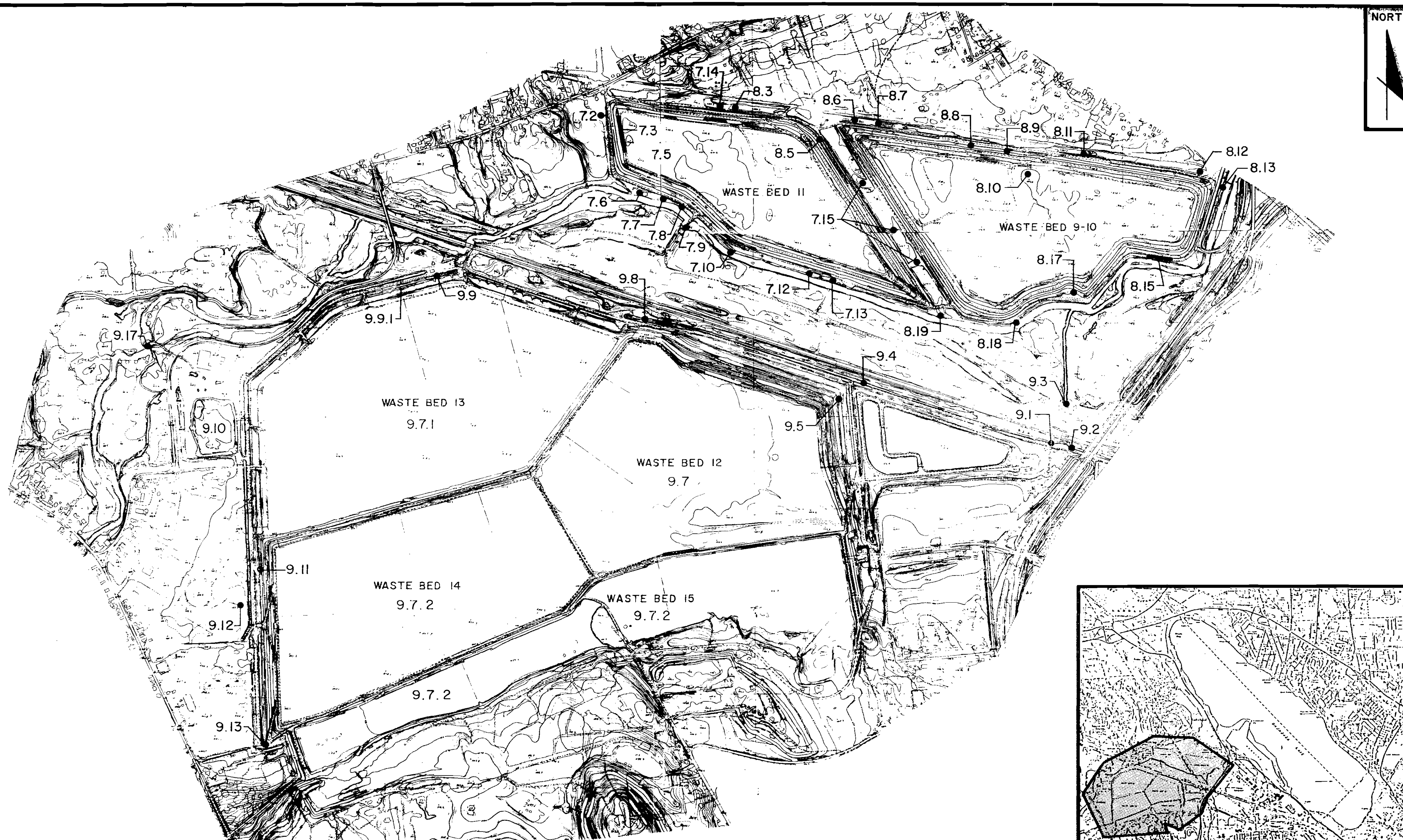
3.13 Two flowing pipes issuing from side of waste bed. pH - 11.9.

3.13.1 Very heavy "reed grass" growth along waters edge, 10± feet exposure of waste along water line and single non-flowing drain pipe protruding from slope.

3.14 Surface of bed has fair to poor vegetation cover, some small bushes, grass and weed growth, numerous dead trees.

3.15 Most of seeps along Nine Mile Creek are dry, ground surface crusty with precipitate.

3.16 Ponded seep water with precipitate all around perimeter.



DATE:

SCALE:
1,000' 0 1,000'

9.13 Observation station and number, see attached sheets for explanation. Site observations made during walkovers of May 8-12, 1987.

BLASLAND & BOUCK ENGINEERS, P.C.

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

WASTE BEDS 9-11 AND 12-15
SITE OBSERVATIONS

FIGURE
6

SITE OBSERVATIONS MADE DURING SITE RECONNAISSANCE OF MAY 8-12, 1987

WASTE BEDS 9-11 AND 12-15

7.2 Large metal cover for subsurface utility.

7.3 Side slope of bed is vegetated with grasses, some small trees on lower part of slope. Vegetation cover on side slop of bed is fair with exposures of cinder and clinker on lower portion and Solvay waste (hardened) exposed above. Drainage ditch borders road on west side of bed; no indication of precipitation in ditch.

7.5 Surface of bed is well vegetated with grass and small to moderate sized trees.

7.6 Area of surface seep along bank of Nine Mile Creek. Seep flows into the creek. pH - 11.4, SC - 42,000.

7.7 Seep area.

7.8 10 to 12 inch pipe; no indication of recent flow.

7.9 Nine Mile Creek at washed-out culvert pipe. pH - 8.2, SC - 1,400.

7.10 Iron precipitation on creek bed along north side of creek, fed by seepage out of stream bank.

7.12 Flow from pipe issuing into stream estimated less than 5 gpm. pH - 11.6, SC - 750,000.

7.13 Small seep runs across road into stream.

7.14 Ponded water, very prominent green color, approximately 1-2 feet deep. Apparently density stratified. Top 2 inches - pH - 16.5, SC - 40,000; bottom 6 inches - pH - 11.5, SC - greater than 50,000.

7.15 Former Nine Mile Creek channel, standing water with pale brown to greenish color to bottom. No vegetation in former stream bottom, vegetation in area between former channel is thick growth of "reed grass".

8.3 Drainage from ponded area is to the east, very heavy precipitate on stream bottom, in a step-like manner.

8.5 Seep out of bed, crossing road into "interbed" drainage area.

8.6 Drainage ditch, draining to the east.

8.7 Second ponded area. pH - 11.3, SC - 47,000.

8.8 Seep issues out from bed and runs to the west along the road. Drainage in ditch to north of road is to the west. The second ponded area appears to have no surface outlet.

8.9 The bank in this area is not as well vegetated as are the slopes further to the east.

8.10 Surface of bed well vegetated with grasses and small trees, some erosion gullies evident along banks.

8.11 Flow in drainage channel is to the east estimated to be less than 5 gpm.

8.12 Ponded water, green in color, no vegetation growth in water, no outlet observed. pH - 11.6, SC - 49,000.

8.13 Discharge to Nine Mile Creek via 30" culvert pipe. pH - 11.4, SC - 50,000.

8.15 Small seeps along stream bank.

8.17 Large seep with 2-5 gpm flow. Flow discharges to the creek. pH - 11.7, SC - 37,000. Heavy white precipitate noted along sides and bottom of drainage.

8.18 Flow out of 6 inch steel pipe 2-5 gpm, white precipitate on seepage channel bottom.

8.19 Flow out of interbed drainage area into Nine Mile Creek, estimated 5-10 gpm. pH - 9.7, SC - 50,000.

9.1 Flow to southeast along north side of dirt road. pH - 6.5, SC - 38,000.

9.2 Geddes Brook flowing from southeast. pH - 7.8, SC - 2,600.

9.3 Flow to the north in Geddes Brook, intermittent oil sheen noted. pH - 7.9, SC - 2,500.

9.4 Retention structure for waste bed overflow. pH - 10.9, SC - 48,000.

9.5 Slopes vegetated with grasses.

9.7 Surface partially vegetated with grasses and some small trees. Large areas covered with construction rubble.

9.7.1 Some small areas of grass cover.

9.7.2 Very little to no vegetation.

9.8 Heavy precipitate in drainage channel, resulting in "falls" over precipitate. pH - 11.0, SC - greater than 50,000.

9.9 Drainage ditch. pH - 11.0, SC - greater than 50,000.

9.9.1 Slopes unvegetated from here to the west and south.

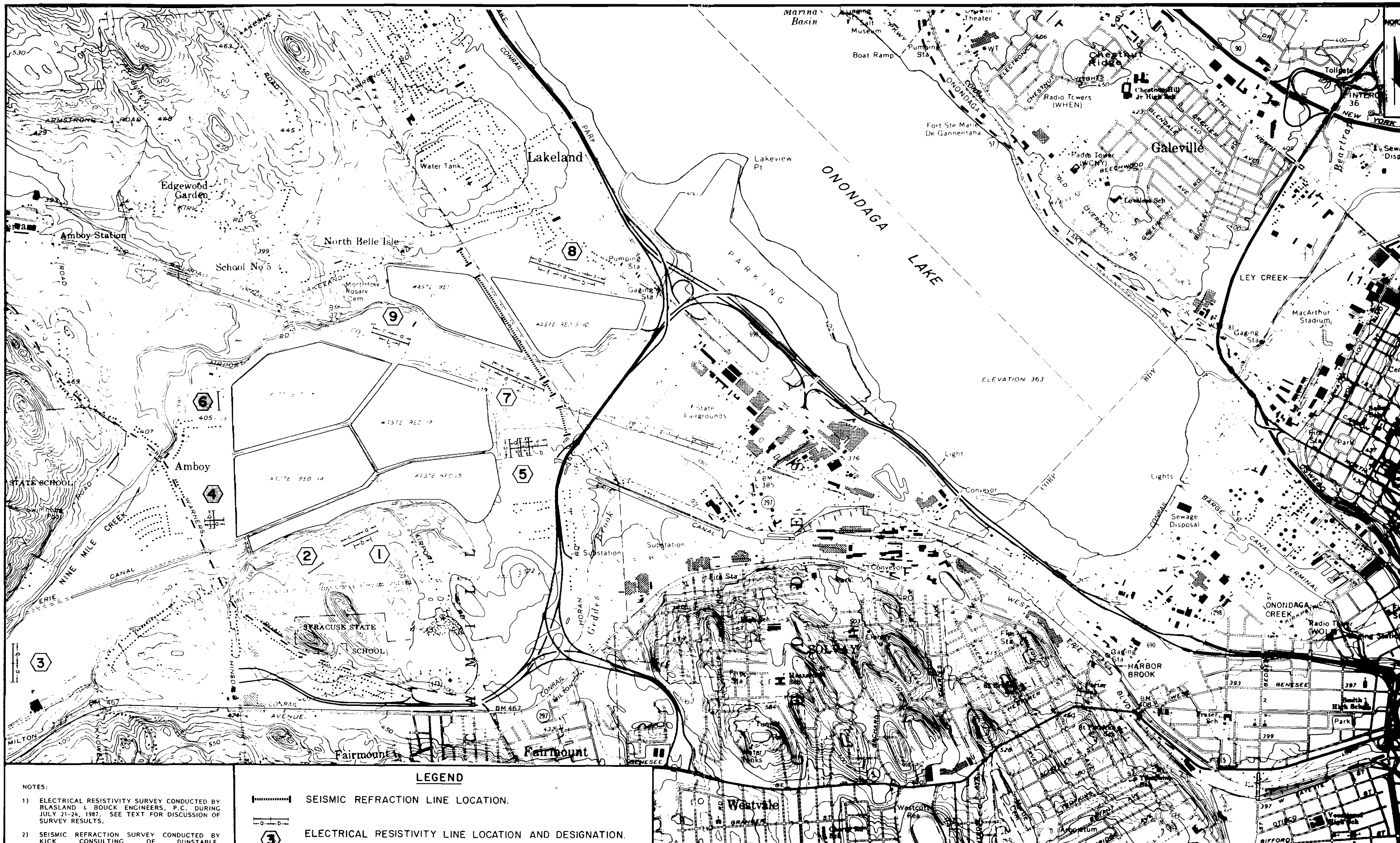
9.10 Standing water in base of gravel pit. pH - 8.1, SC - 800. Some algal growth on bottom with localized cattail growth.

9.11 Seeps with heavy precipitate. pH - 8.4, SC - greater than 50,000.

9.12 Standing water west of landscape berm around be perimeter. pH - 8.4, SC - 2,400.

9.13 Culvert pipe, flow is 5-10 gpm. pH - 11.6, SC - greater than 50,000.

9.17 Nine Mile Creek. pH - 7.9, SC - 630.



NOTES:

1) ELECTRICAL RESISTIVITY SURVEY CONDUCTED BY BLASLAND & BOUCK ENGINEERS, P.C. DURING JULY 21-24, 1987. SEE TEXT FOR DISCUSSION OF SURVEY RESULTS.

2) SEISMIC REFRACTION SURVEY CONDUCTED BY KICK CONSULTING OF DUNSTABLE, MASSACHUSETTS DURING OCTOBER 21-23, 1987. THE FINAL REPORT PREPARED BY KICK CONSULTING IS INCLUDED WITH THIS REPORT AS AN APPENDIX.

SCALE

1,000' 0' 1,000'

DATE:

LEGEND

SEISMIC REFRACTION LINE LOCATION.

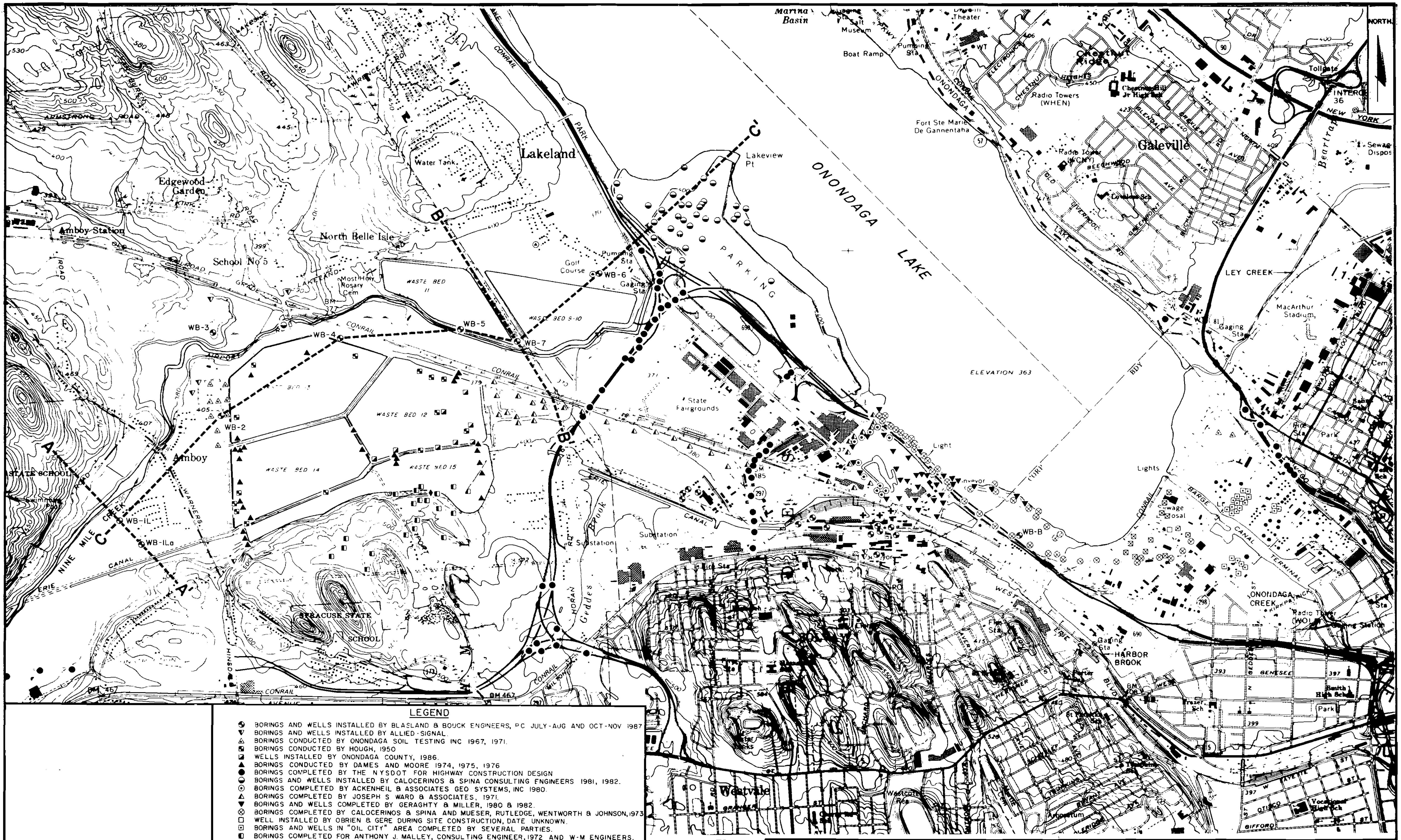
ELECTRICAL RESISTIVITY LINE LOCATION AND DESIGNATION.

BLASLAND & BOUCK ENGINEERS, P.C.
Syracuse New York
White Plains New York

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

GEOPHYSICAL EXPLORATION LOCATIONS

FIGURE 7



LEGEND

- BORINGS AND WELLS INSTALLED BY BLASLAND & BOUCK ENGINEERS, P.C. JULY-AUG AND OCT-NOV 1987
- BORINGS AND WELLS INSTALLED BY ALLIED-SIGNAL.
- BORINGS CONDUCTED BY ONONDAGA SOIL TESTING INC 1967, 1971.
- BORINGS CONDUCTED BY HOUGH, 1950
- WELLS INSTALLED BY ONONDAGA COUNTY, 1986.
- BORINGS CONDUCTED BY DAMES AND MOORE 1974, 1975, 1976
- BORINGS COMPLETED BY THE NYSDOT FOR HIGHWAY CONSTRUCTION DESIGN
- BORINGS AND WELLS INSTALLED BY CALOCERINOS & SPINA CONSULTING ENGINEERS 1981, 1982.
- BORINGS COMPLETED BY ACKENHEIL & ASSOCIATES GEO SYSTEMS, INC 1980.
- BORINGS COMPLETED BY JOSEPH S WARD & ASSOCIATES, 1971.
- BORINGS AND WELLS COMPLETED BY GERAGHTY & MILLER, 1980 & 1982.
- BORINGS COMPLETED BY CALOCERINOS & SPINA AND MUESER, RUTLEDGE, WENTWORTH & JOHNSON, 1973
- WELL INSTALLED BY OBRIEN & GERE DURING SITE CONSTRUCTION, DATE UNKNOWN.
- BORINGS AND WELLS IN "OIL CITY" AREA COMPLETED BY SEVERAL PARTIES.
- BORINGS COMPLETED FOR ANTHONY J. MALLEY, CONSULTING ENGINEER, 1972 AND W-M ENGINEERS, P.C 1985 & 1986
- CLUSTER WELLS INSTALLED ADJACENT TO CAMILLUS LANDFILL
- 6" DIAMETER WELLS INSTALLED BY POPE'S GROVE.
- BORINGS COMPLETED BY ONONDAGA SOIL TESTING, 1979
- WELLS INSTALLED BY GROUND-WATER TECHNOLOGY, 1985.
- BORINGS COMPLETED FOR O'BRIEN & GERE, 1971 FOR THE SYRACUSE METROPOLITAN SEWAGE TREATMENT PLANT.

GEOLOGIC CROSS SECTION LOCATION

SCALE 1,000' 0' 1,000'

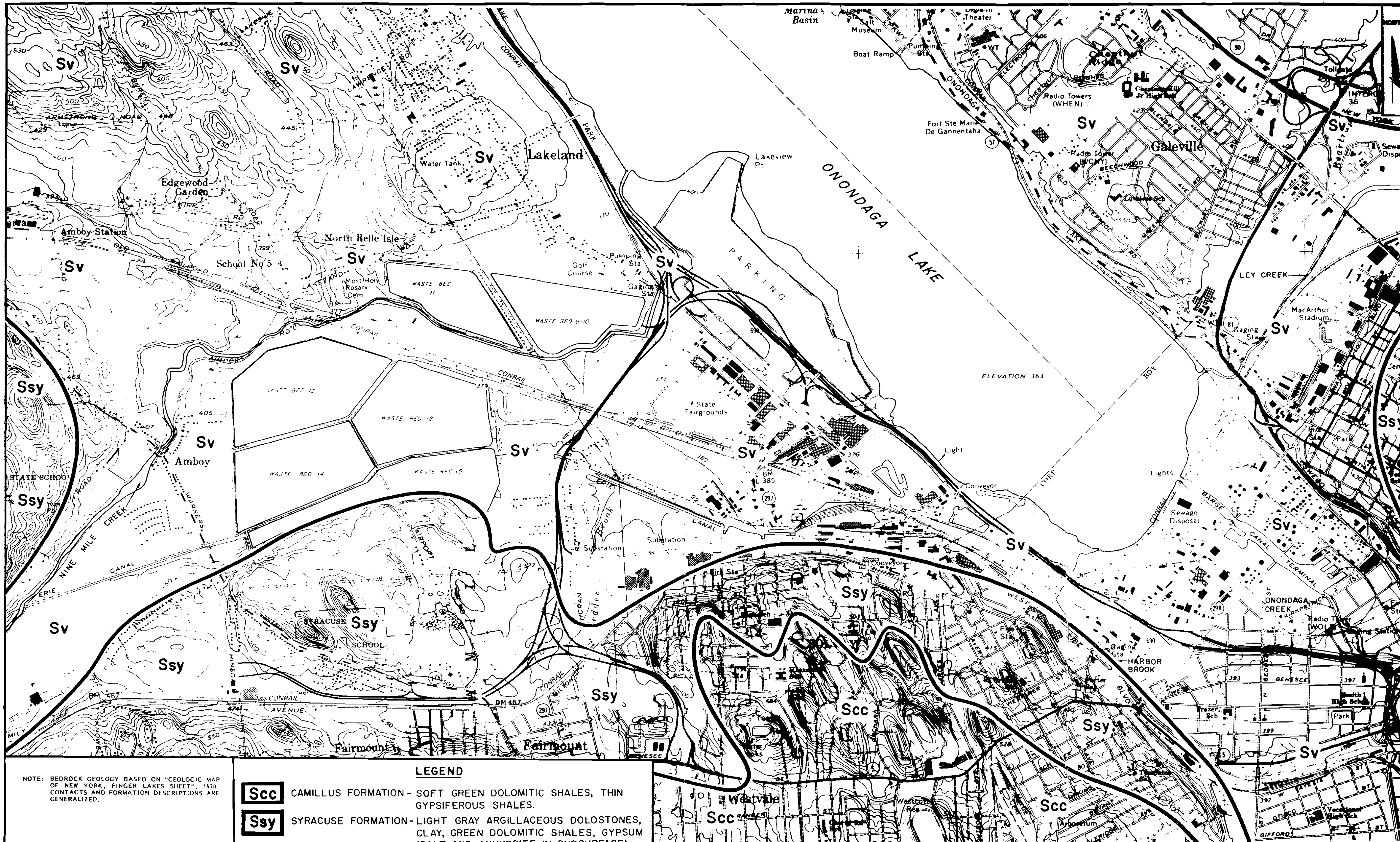
DATE:

BLASLAND & BOUCK ENGINEERS, P.C.
Syracuse, New York
White Plains, New York

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

SUMMARY OF SUBSURFACE INVESTIGATIONS

FIGURE 8



NOTE: BEDROCK GEOLOGY BASED ON "GEOLOGIC MAP OF NEW YORK, FINGER LAKES SHEET", 1970. CONTACTS AND FORMATION DESCRIPTIONS ARE GENERALIZED.

SCALE 1,000' 0' 1,000'

DATE:

LEGEND

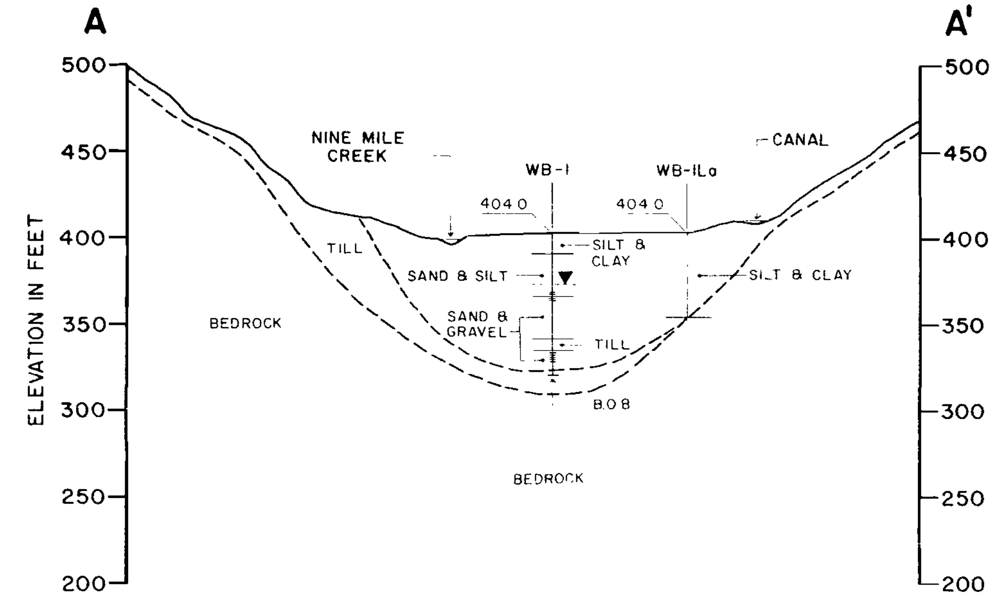
Scc	CAMILLUS FORMATION -	SOFT GREEN DOLOMITIC SHALES, THIN GYPSIFEROUS SHALES.
Ssy	SYRACUSE FORMATION -	LIGHT GRAY ARGILLACEOUS DOLOSTONES, CLAY, GREEN DOLOMITIC SHALES, GYPSUM (SALT AND ANHYDRITE IN SUBSURFACE).
Sv	VERNON FORMATION -	THICK BEDDED RED & GREEN MUDSTONES REPLACED WESTWARDLY BY GRAY ARGILLACEOUS DOLOSTONES AND GREEN DOLOMITIC SHALE, GYPSUM.

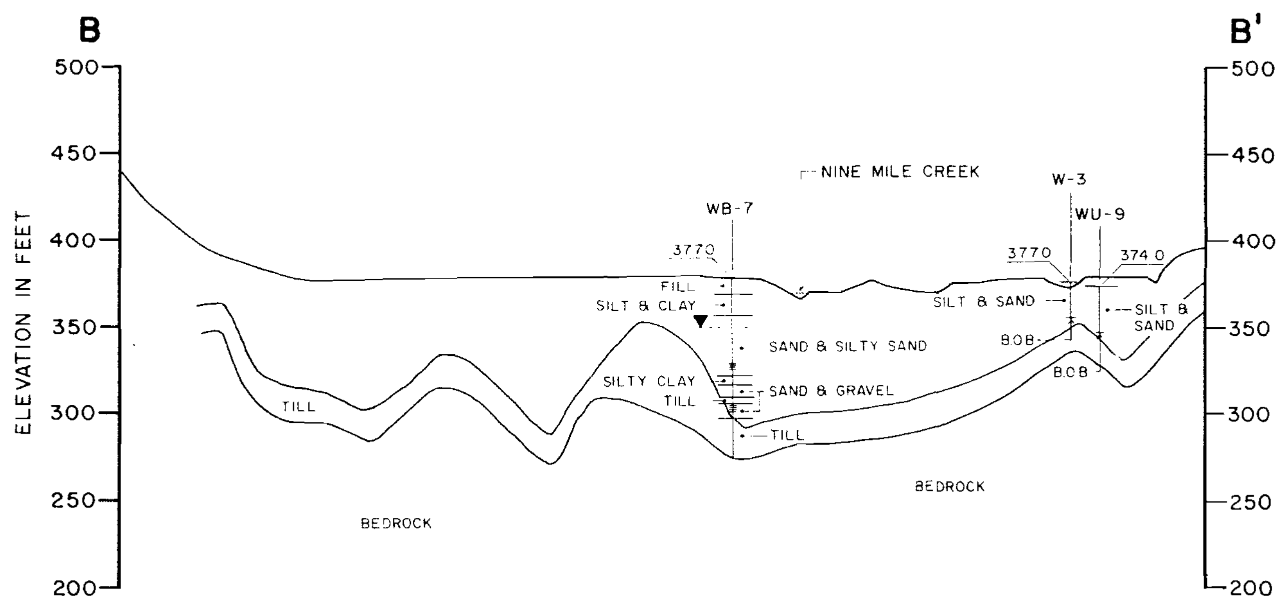
BLASLAND & BOUCK ENGINEERS, P.C.
Syracuse, New York
White Plains, New York

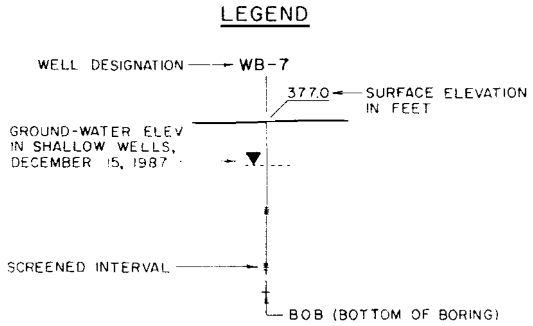
ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

BEDROCK GEOLOGY

FIGURE 9







HORIZONTAL SCALE

500' 0 500'

DATE

NOTES:

1) REFERENCES FOR BORINGS OTHER THAN WB BORINGS ARE AS FOLLOWS: W-3 AND WU-9 - JOSEPH S. WARD & ASSOCIATES, 1971.

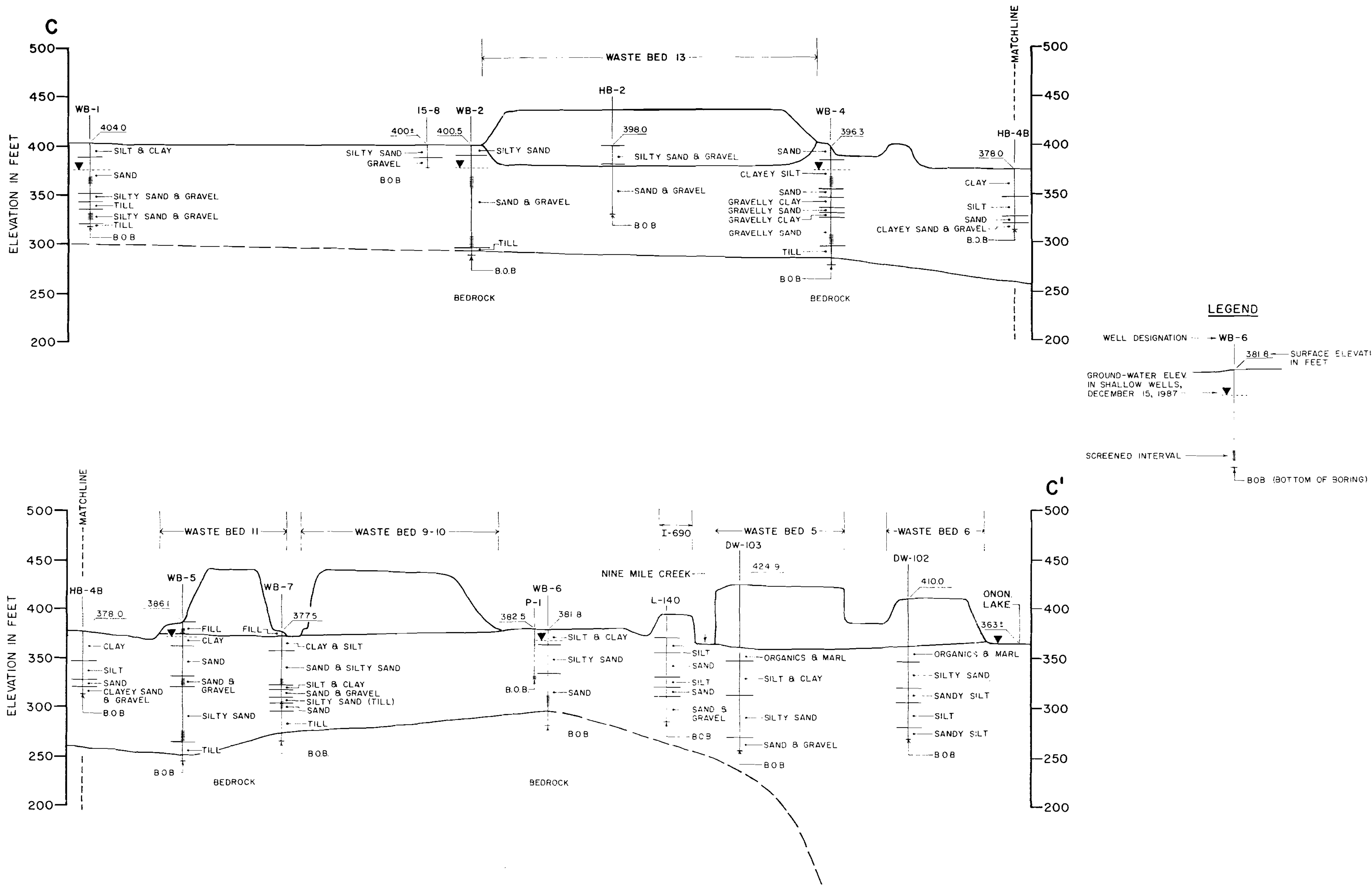
2) SECTION C-C' FOLLOWS SEISMIC LINE CONDUCTED BY KICK CONSULTING, 1987. UPPER CONTACT OF TILL AND BEDROCK SURFACE IN THIS SECTION IS BASED ON THE RESULTS OF THAT SURVEY.

BLASLAND & BOUCK ENGINEERS, P.C.
Syracuse, New York
White Plains, New York

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

GEOLOGIC CROSS SECTIONS A-A' AND B-B'

FIGURE 10



HORIZONTAL SCALE

500' 0 500'

DATE:

NOTE: REFERENCES FOR BORINGS OTHER THAN WB BORINGS ARE AS FOLLOWS: 15-8 - ONONDAGA SOIL TESTING, INC., 1958; HB-2 - HOUGH, 1950; P-1 - POPE'S GROVE GOLF COURSE; L-140 - NYSDOT HIGHWAY CONSTRUCTION DESIGN BORINGS; DW-103 & DW-104 - CALOCERINOS & SPINA CONSULTING ENGINEERS, 1981-1982.

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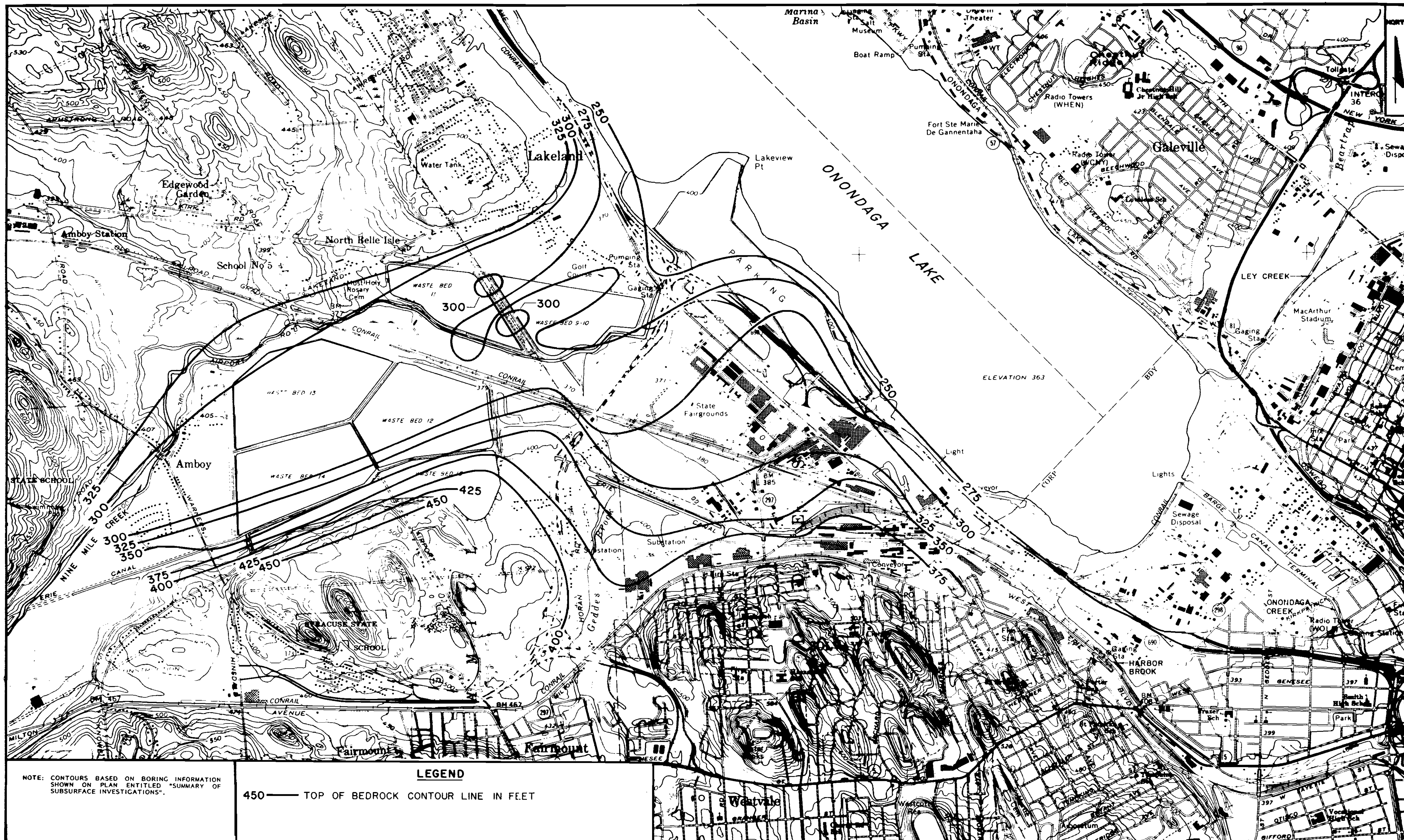
ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

GEOLOGIC CROSS SECTION C-C'

FIGURE 11



NOTE: CONTOURS BASED ON BORING INFORMATION SHOWN ON PLAN ENTITLED "SUMMARY OF SUBSURFACE INVESTIGATIONS".

SCALE
1,000' 0 1,000'

DATE:

LEGEND

450 —— TOP OF BEDROCK CONTOUR LINE IN FEET

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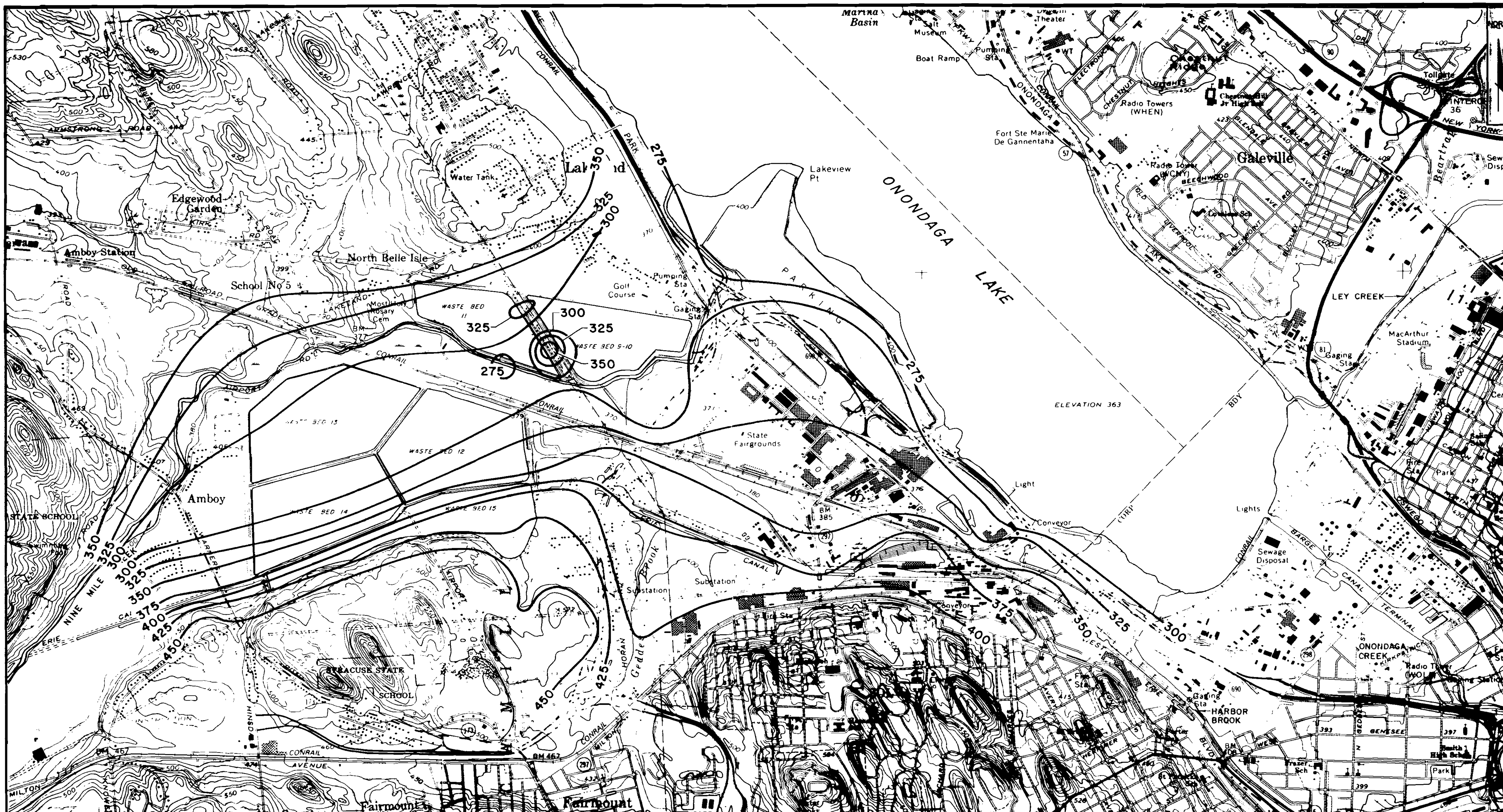
White Plains New York

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

TOP OF BEDROCK CONTOURS

FIGURE
12



NOTE: CONTOURS BASED ON BORING INFORMATION SHOWN ON PLAN ENTITLED "SUMMARY OF SUBSURFACE INVESTIGATIONS".

SCALE 1,000' 0 1,000'

DATE:

LEGEND

450——— TOP OF TILL CONTOUR LINE IN FEET

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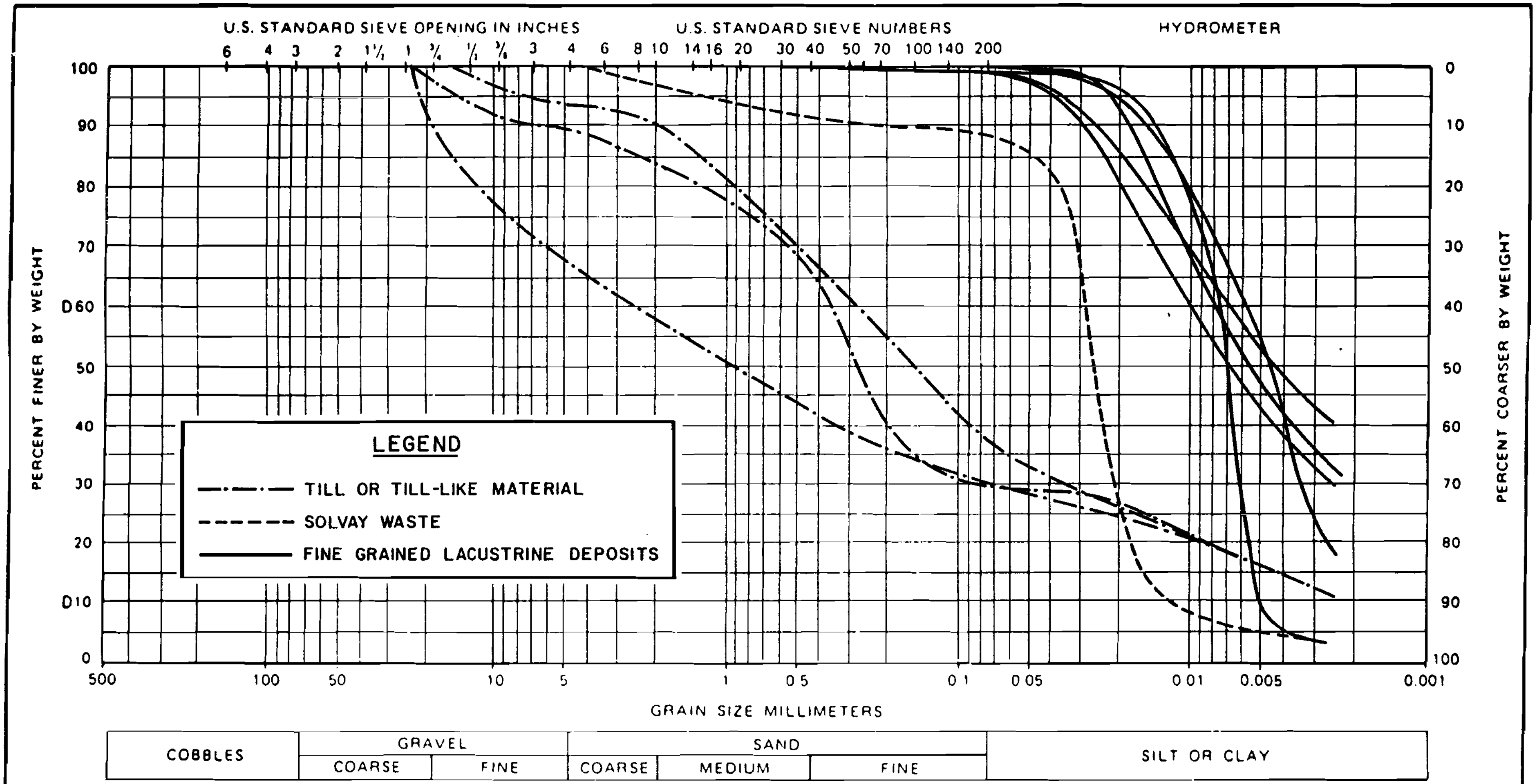
White Plains New York

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

TOP OF TILL CONTOURS

FIGURE 13

GRAIN SIZE DISTRIBUTION CURVES-TILL, SOLVAY WASTE & LACUSTRINE SEDIMENTS



SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	D10	D60	U.C.

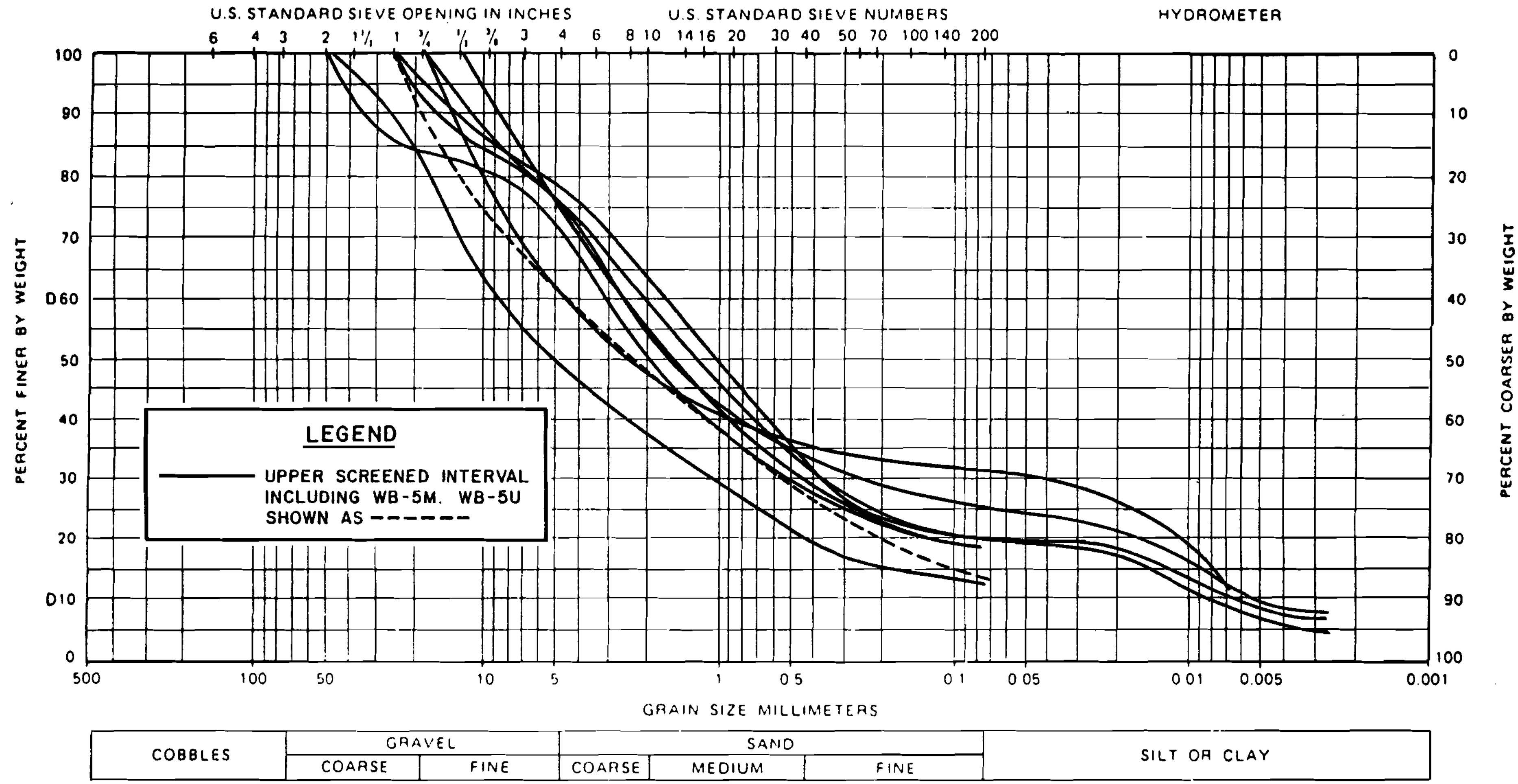
KEY: trace 0-10% some 20%-35% U.C. uniformity coefficient
little 10%-20% and 35%-50%

FIGURE 14

BLASLAND & BOUCK ENGINEERS, P.C.

Wiley-Fisk Form 16-7

GRAIN SIZE DISTRIBUTION CURVES-UPPER SCREENED UNIT



SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	D10	D60	U.C.

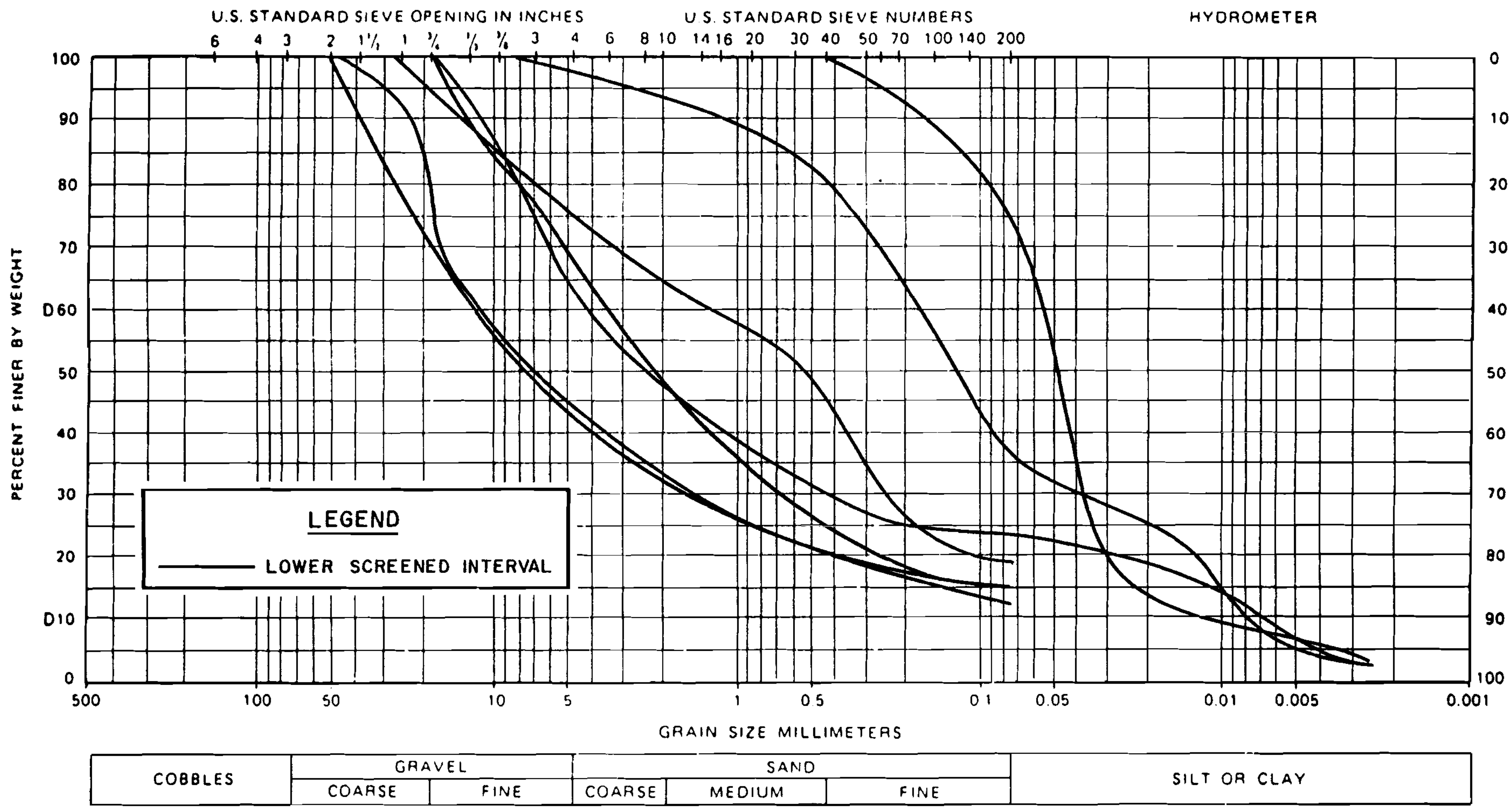
KEY: trace 0-10% some 20%-35% U.C. uniformity coefficient
little 10%-20% and 35%-50%

Wiley-Fisk Form 16-7

BLASLAND & BOUCK ENGINEERS, P.C.

FIGURE 15

GRAIN SIZE DISTRIBUTION CURVES-LOWER SCREENED UNIT



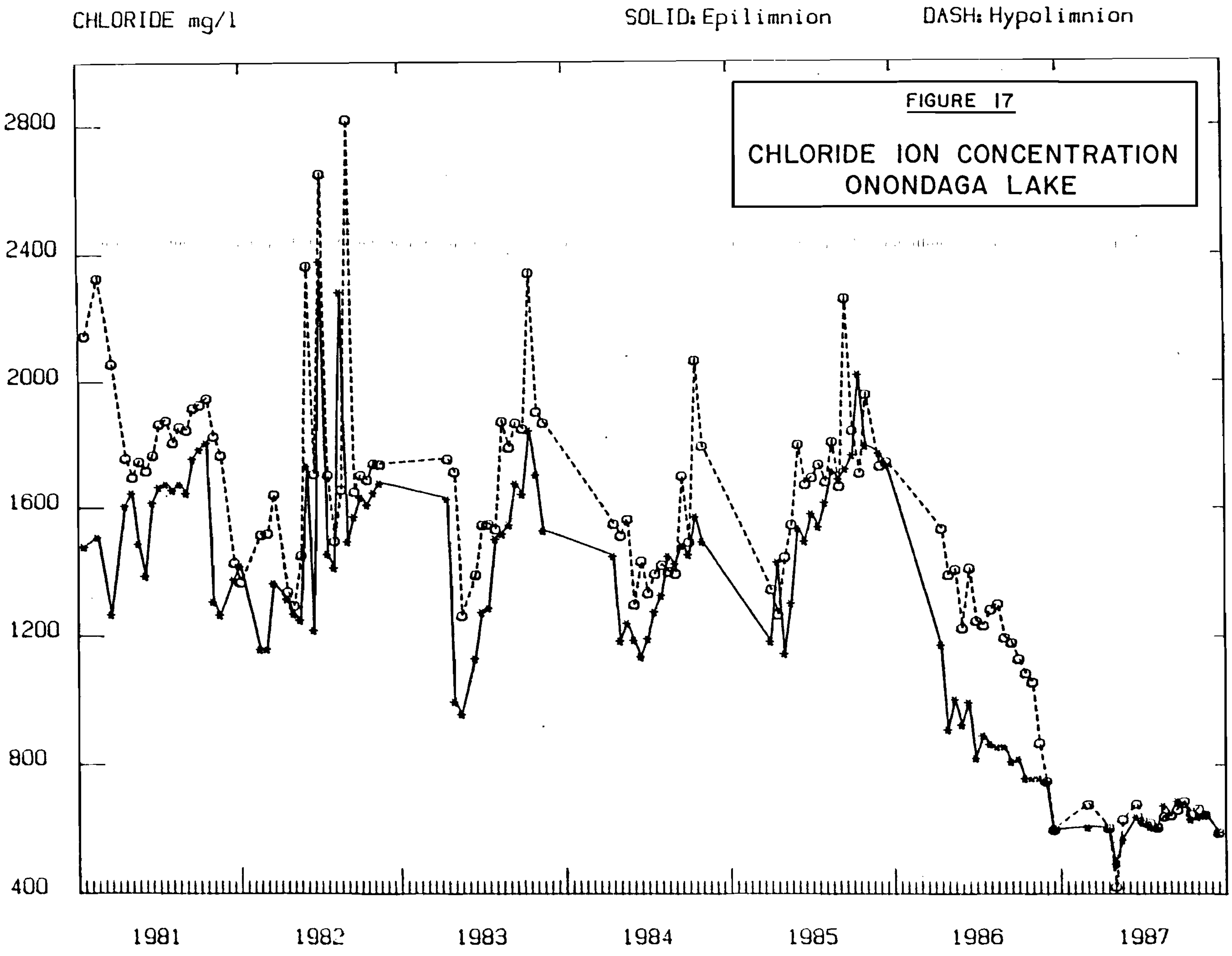
SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	D10	D60	U.C.

KEY: trace 0-10% some 20%-35% U.C. uniformity coefficient
little 10%-20% and 35%-50%

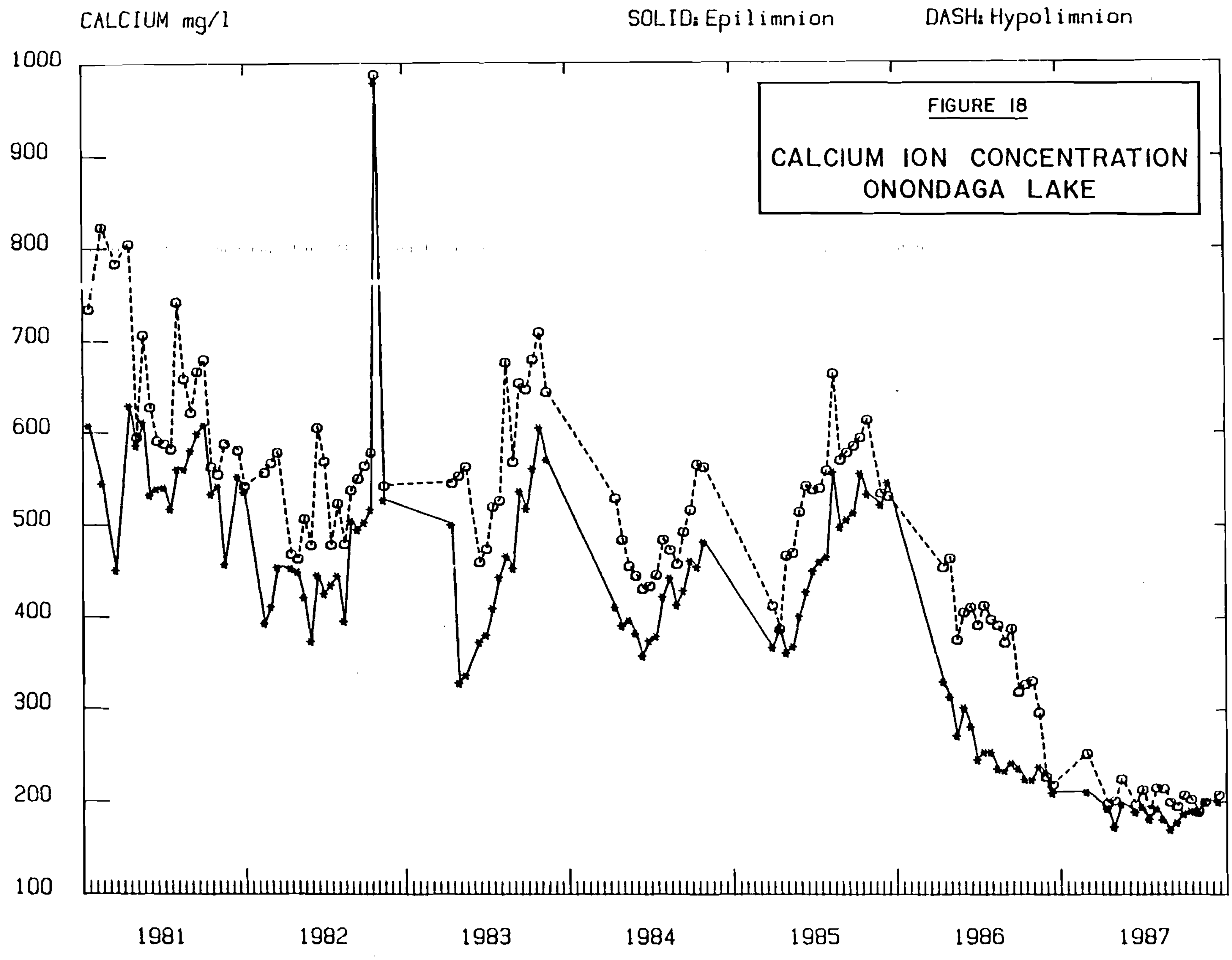
Wiley-Fisk Form 16-7

BLASLAND & BOUCK ENGINEERS, P.C.

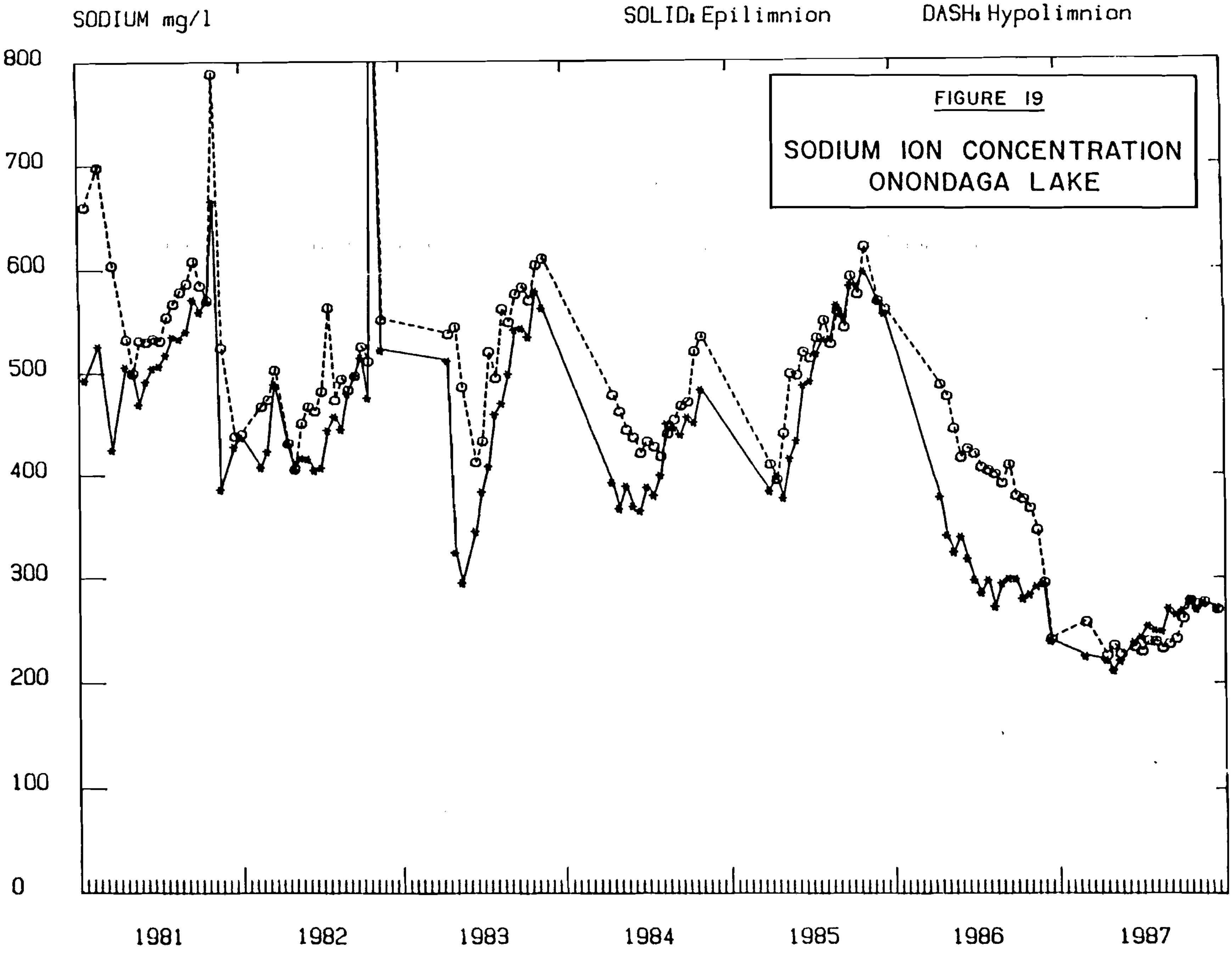
FIGURE 16



Source: 1987 Onondaga Lake Monitoring Program, Onondaga County Department of Drainage & Sanitation; Stearns & Wheler, February 1989



Source: 1987 Onondaga Lake Monitoring Program, Onondaga County Department of Drainage & Sanitation; Stearns & Wheler, February 1989



Source: 1987 Onondaga Lake Monitoring Program, Onondaga County Department of Drainage & Sanitation; Stearns & Wheler, February 1989

FIGURE 20

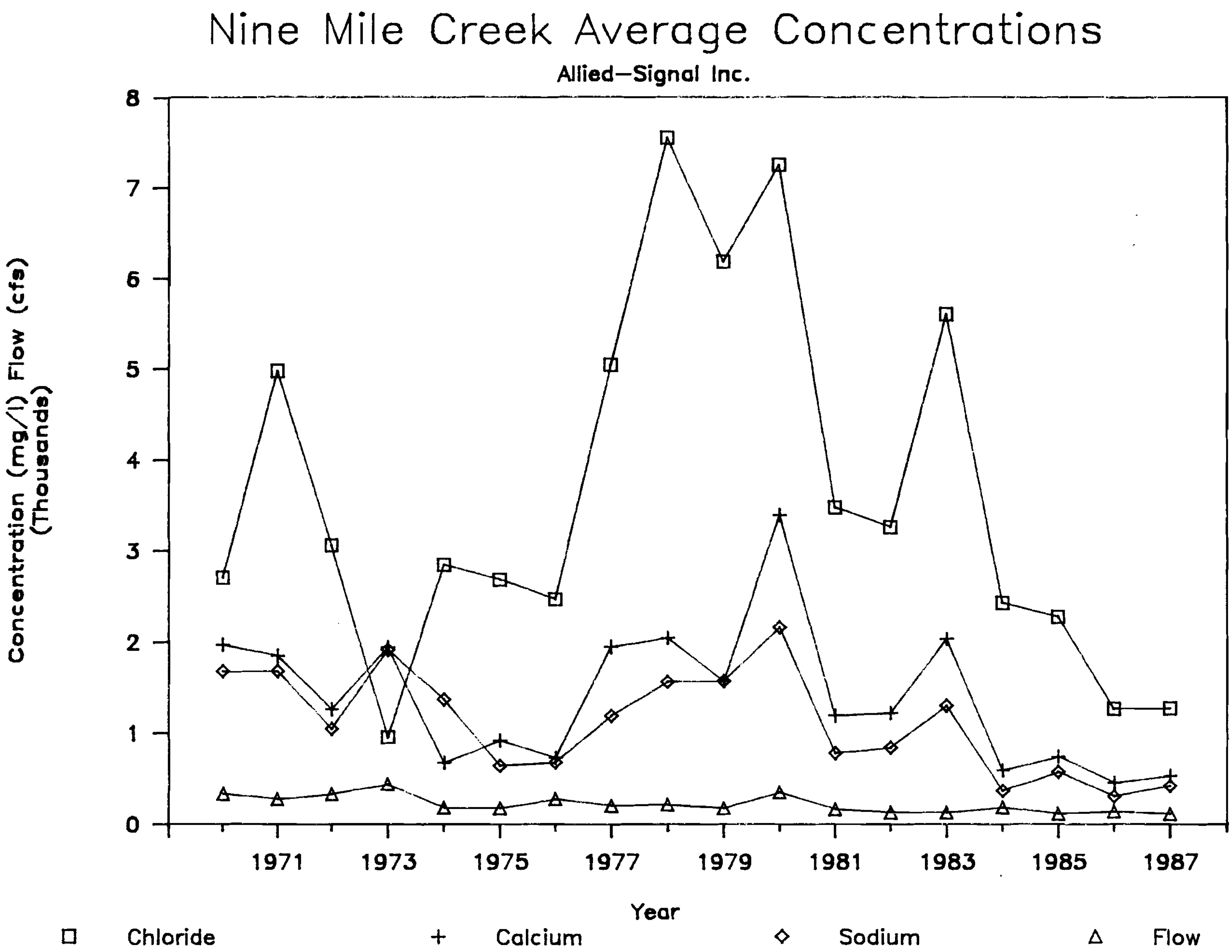
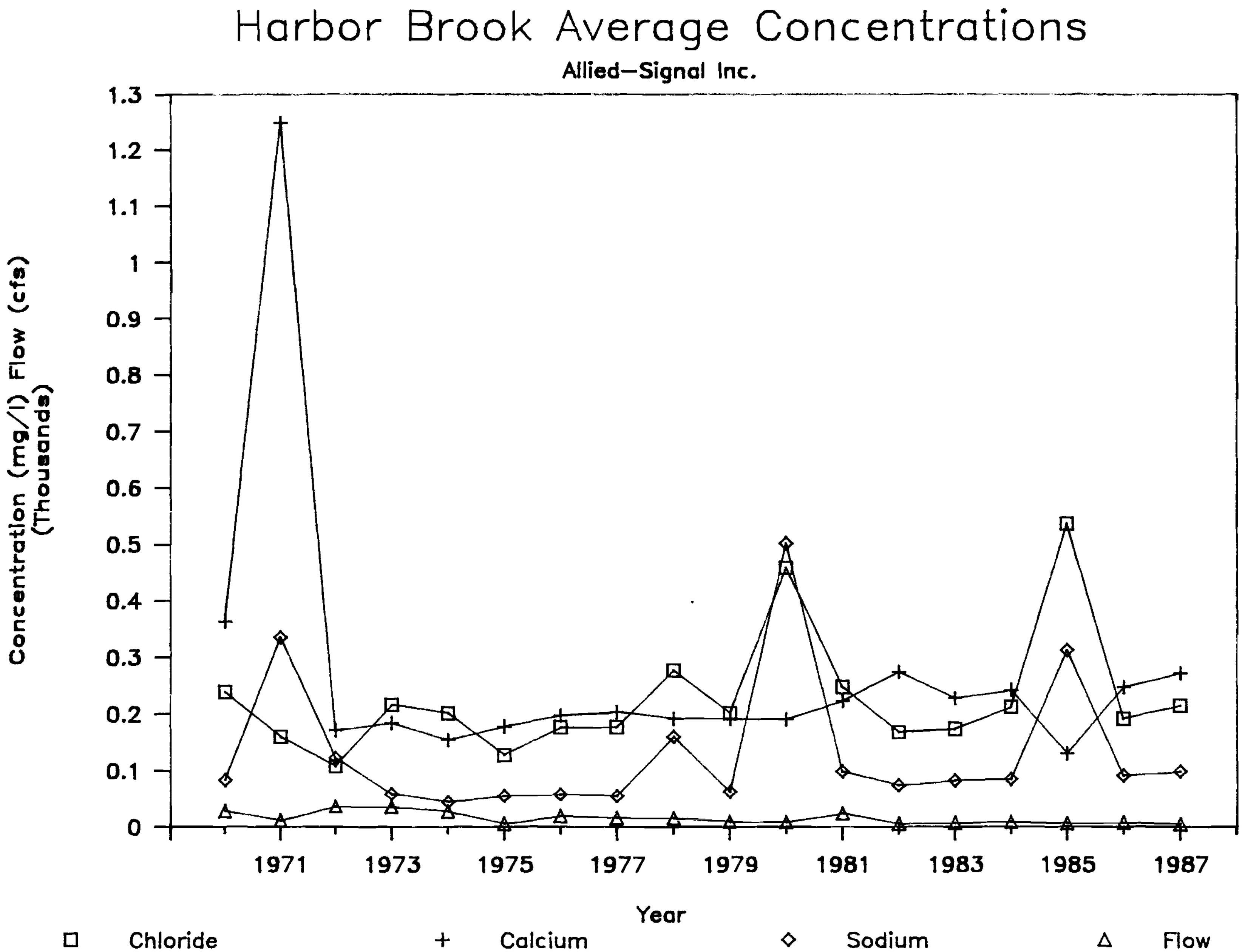
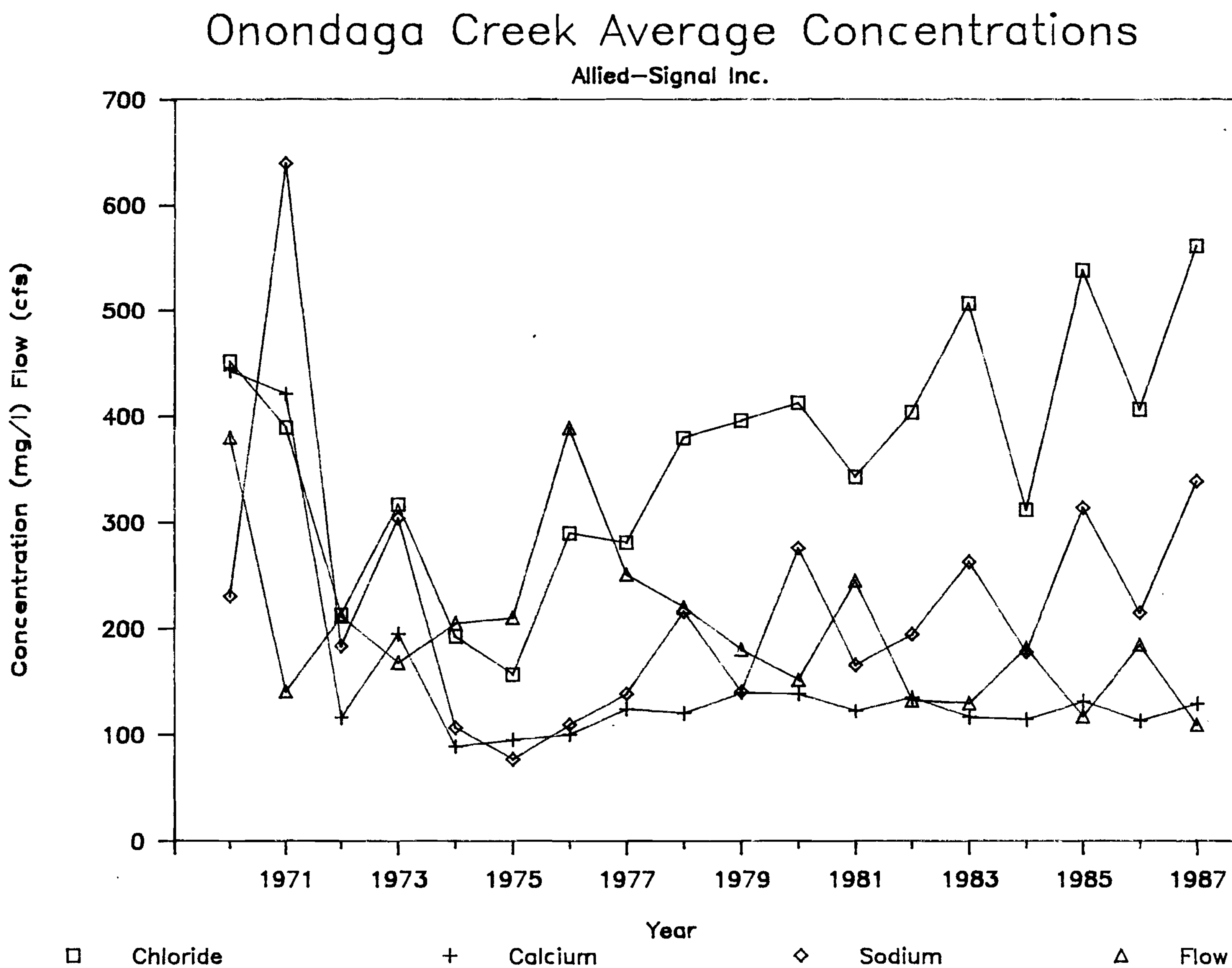

Nine Mile Creek Average Concentrations
Allied-Signal Inc.
Concentration (mg/l) Flow (cfs)
(Thousands)
0
1
2
3
4
5
6
7
8
1971
1973
1975
1977
1979
1981
1983
1985
1987
Year
Chloride
Calcium
Sodium
Flow

FIGURE 21



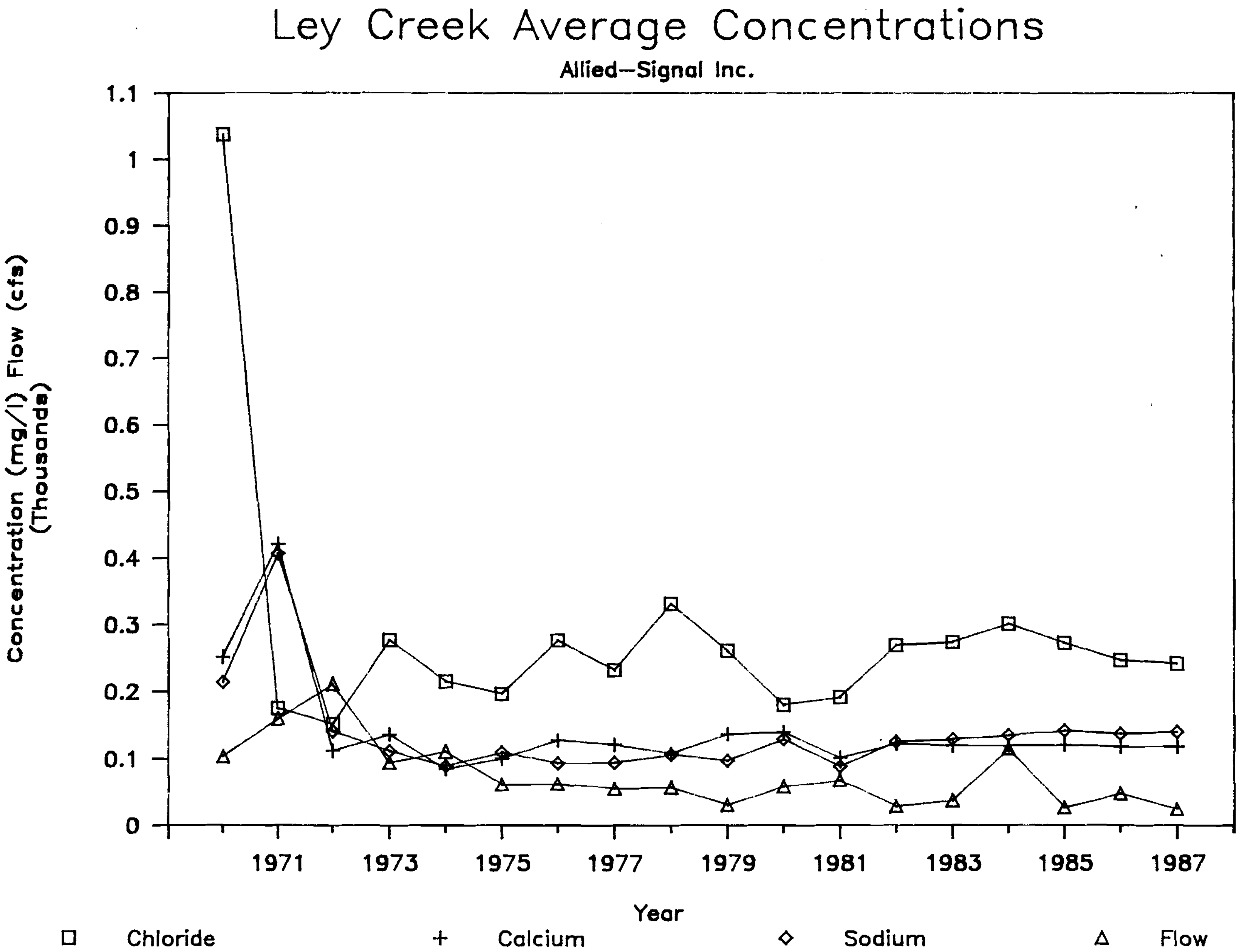
Harbor Brook Average Concentrations
Allied-Signal Inc.
Concentration (mg/l) Flow (cfs)
(Thousands)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1971
1973
1975
1977
1979
1981
1983
1985
1987
Year
Chloride
Calcium
Sodium
Flow

FIGURE 22



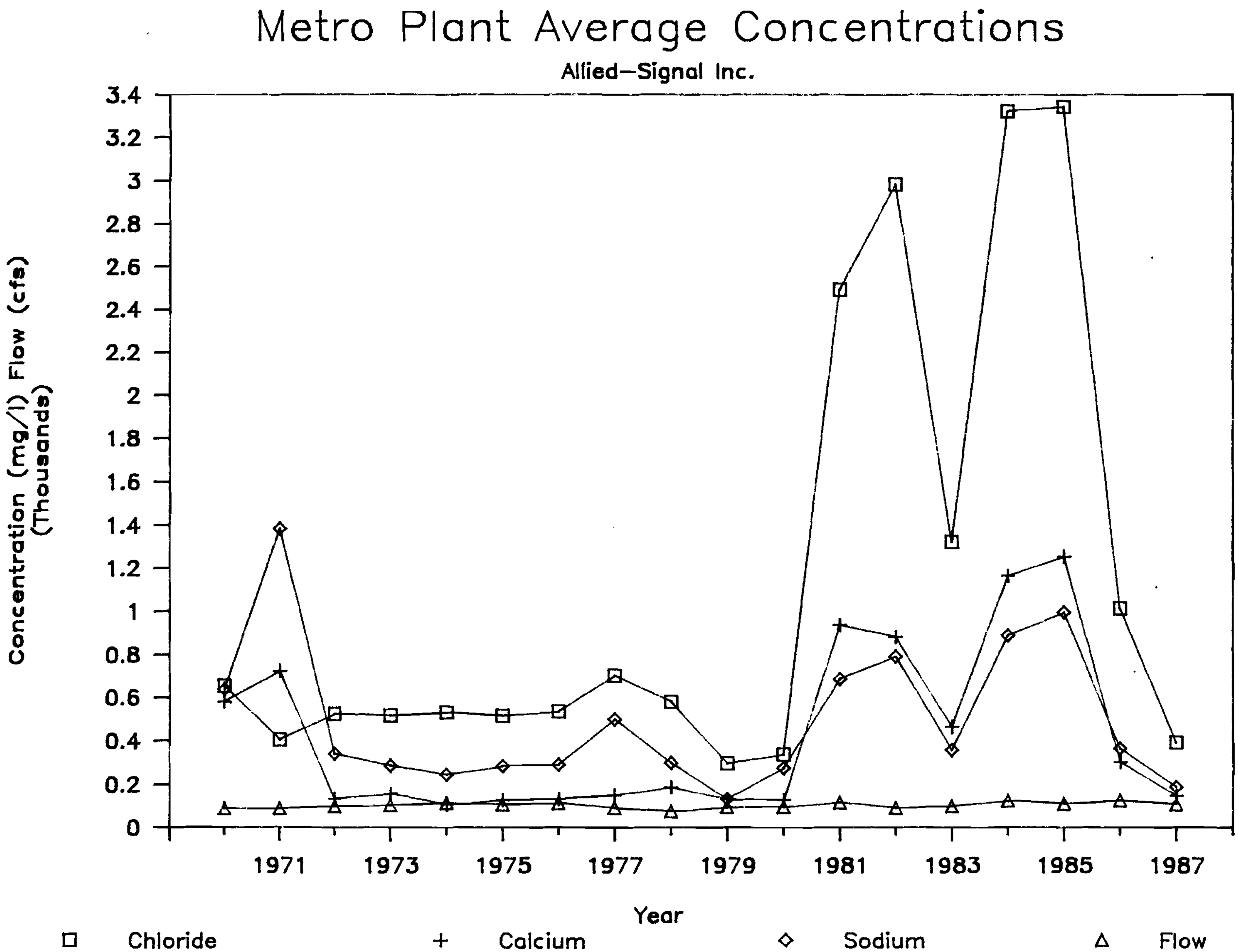
Onondaga Creek Average Concentrations
Allied-Signal Inc.
Concentration (mg/l) Flow (cfs)
700
600
500
400
300
200
100
0
1971
1973
1975
1977
1979
1981
1983
1985
1987
Year
Chloride
Calcium
Sodium
Flow

FIGURE 23

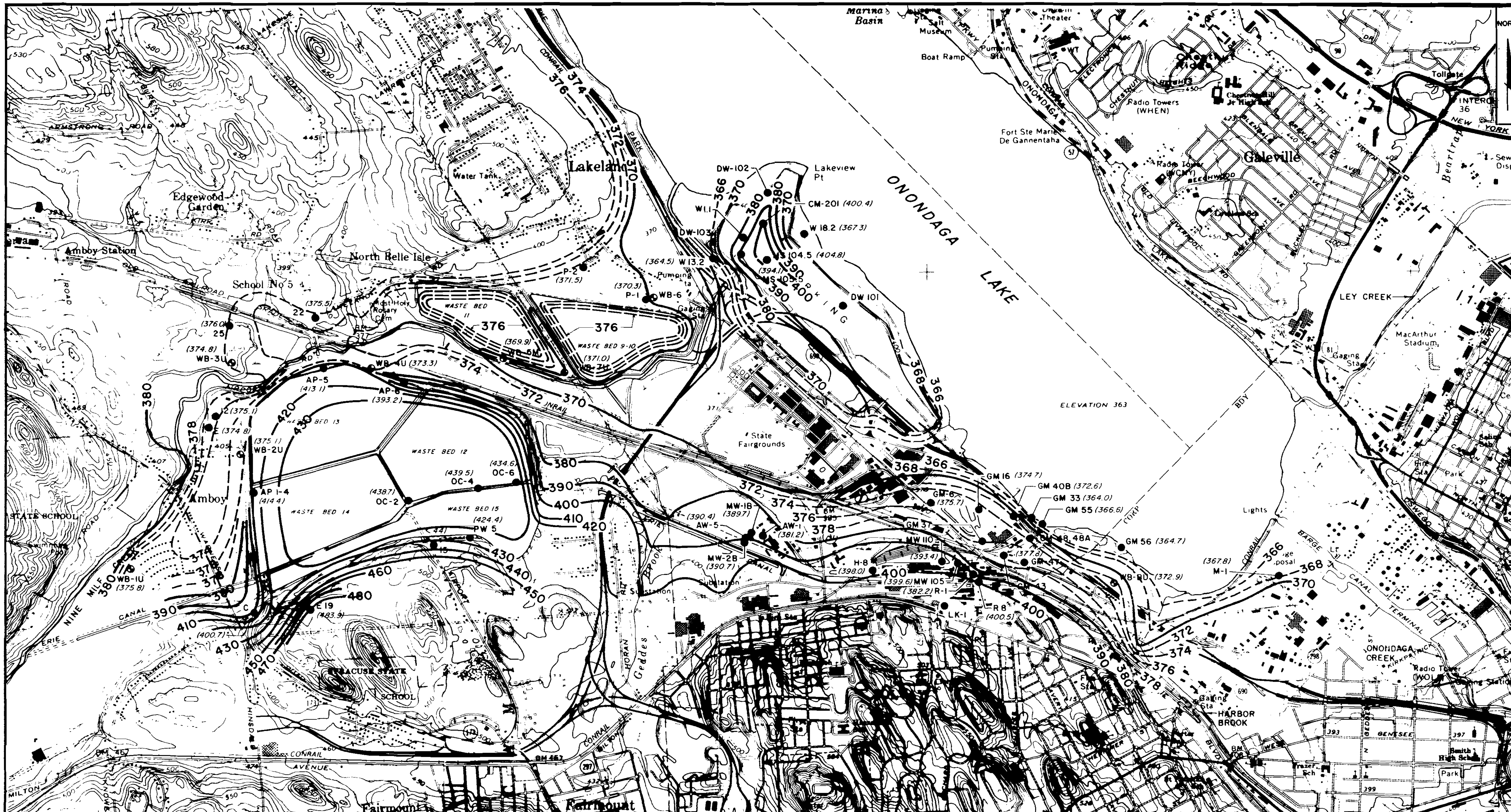


Ley Creek Average Concentrations
Allied-Signal Inc.
Concentration (mg/l) Flow (cfs)
(Thousands)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1971
1973
1975
1977
1979
1981
1983
1985
1987
Year
Chloride
Calcium
Sodium
Flow

FIGURE 24



Metro Plant Average Concentrations
Allied-Signal Inc.
Concentration (mg/l) Flow (cfs)
(Thousands)
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1971
1973
1975
1977
1979
1981
1983
1985
1987
Year
Chloride
Calcium
Sodium
Flow



LEGEND

- WELL INSTALLED BY BLASLAND & BOUCK ENGINEERS, P.C.
- WELL INSTALLED BY OTHERS.
- (485.8) GROUND-WATER ELEVATION IN FEET.
- 390 —— GROUND-WATER CONTOUR LINE, CONTOUR INTERVAL 10 FEET.
- 378 - - - GROUND-WATER CONTOUR LINE (BETWEEN ELEVATIONS 364 AND 378), CONTOUR INTERVAL 2 FEET.

SCALE 1,000' 0' 1,000'

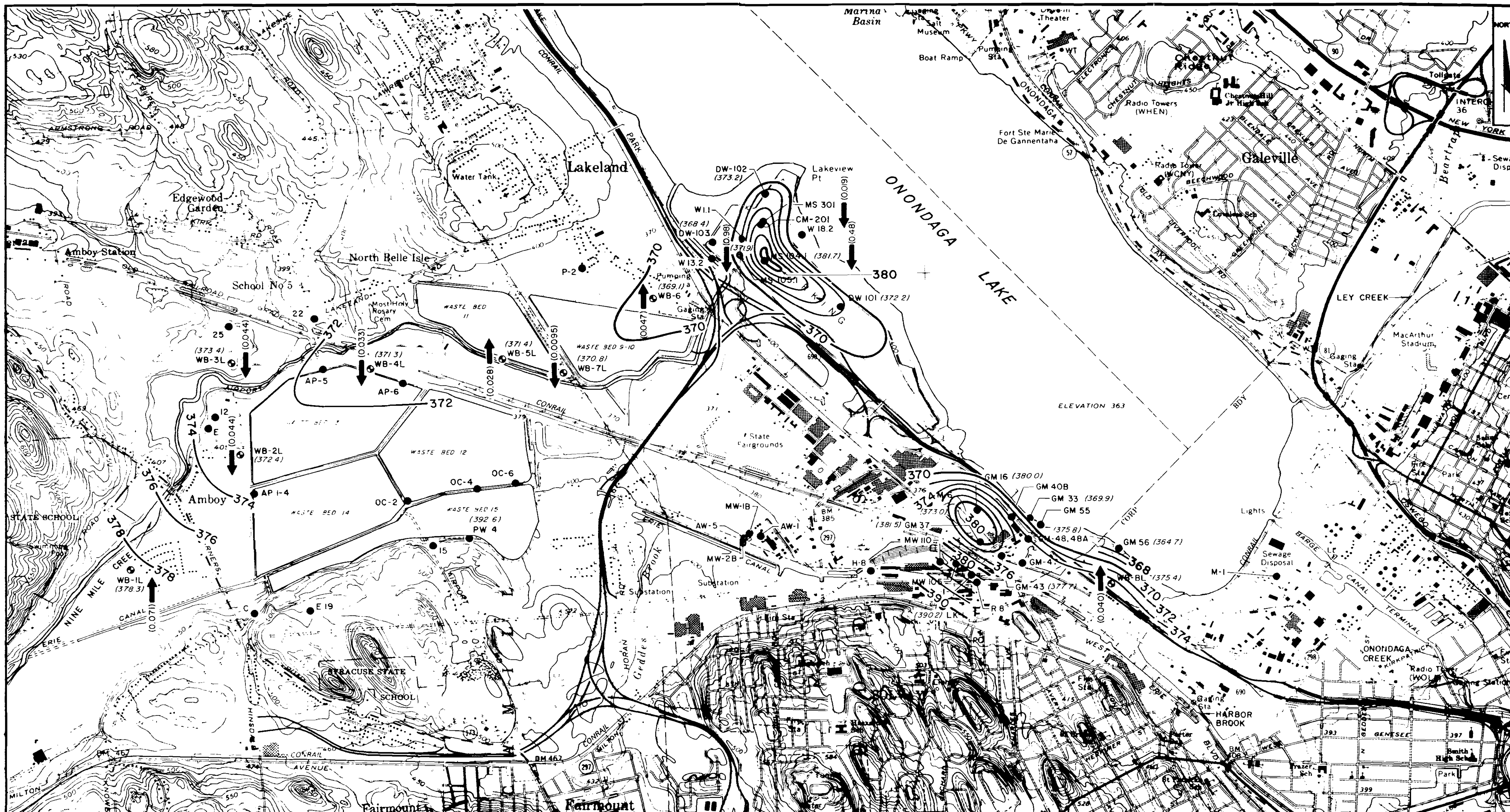
DATE:

BLASLAND & BOUCK ENGINEERS, P.C.
Syracuse, New York
White Plains, New York

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

SHALLOW GROUND-WATER CONTOURS
DECEMBER 15, 1987

FIGURE 25



LEGEND

- WELL INSTALLED BY BLASLAND & BOUCK ENGINEERS, P.C.
- WELL INSTALLED BY OTHERS
- (378.3) GROUND-WATER ELEVATION IN FEET
- 378 GROUND-WATER CONTOUR LINE, CONTOUR INTERVAL 2 FEET.
- (0.071) DIRECTION AND MAGNITUDE OF VERTICAL GRADIENT AT WELL CLUSTERS IN FEET/FEET

SCALE
1,000' 0' 1,000'

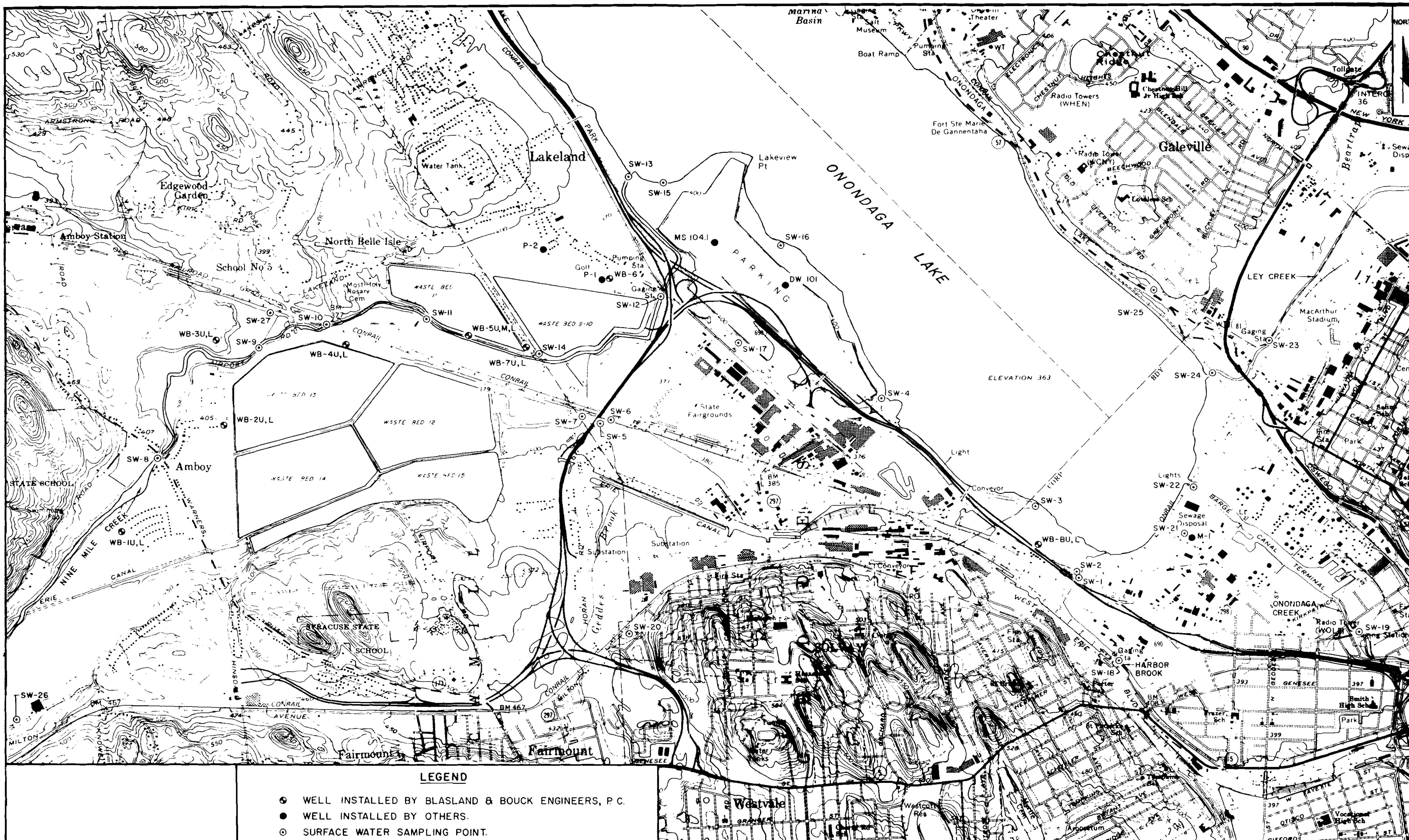
DATE:

BLASLAND & BOUCK ENGINEERS, P.C.
Syracuse New York
White Plains New York

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

POTENTIOMETRIC SURFACE
"DEEP" WELLS
DECEMBER 15, 1987

FIGURE
26



LEGEND

- WELL INSTALLED BY BLASLAND & BOUCK ENGINEERS, P.C.
- WELL INSTALLED BY OTHERS.
- SURFACE WATER SAMPLING POINT.

SCALE 1,000' 0' 1,000'

DATE:

BLASLAND & BOUCK ENGINEERS, P.C.
Syracuse, New York
White Plains, New York

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

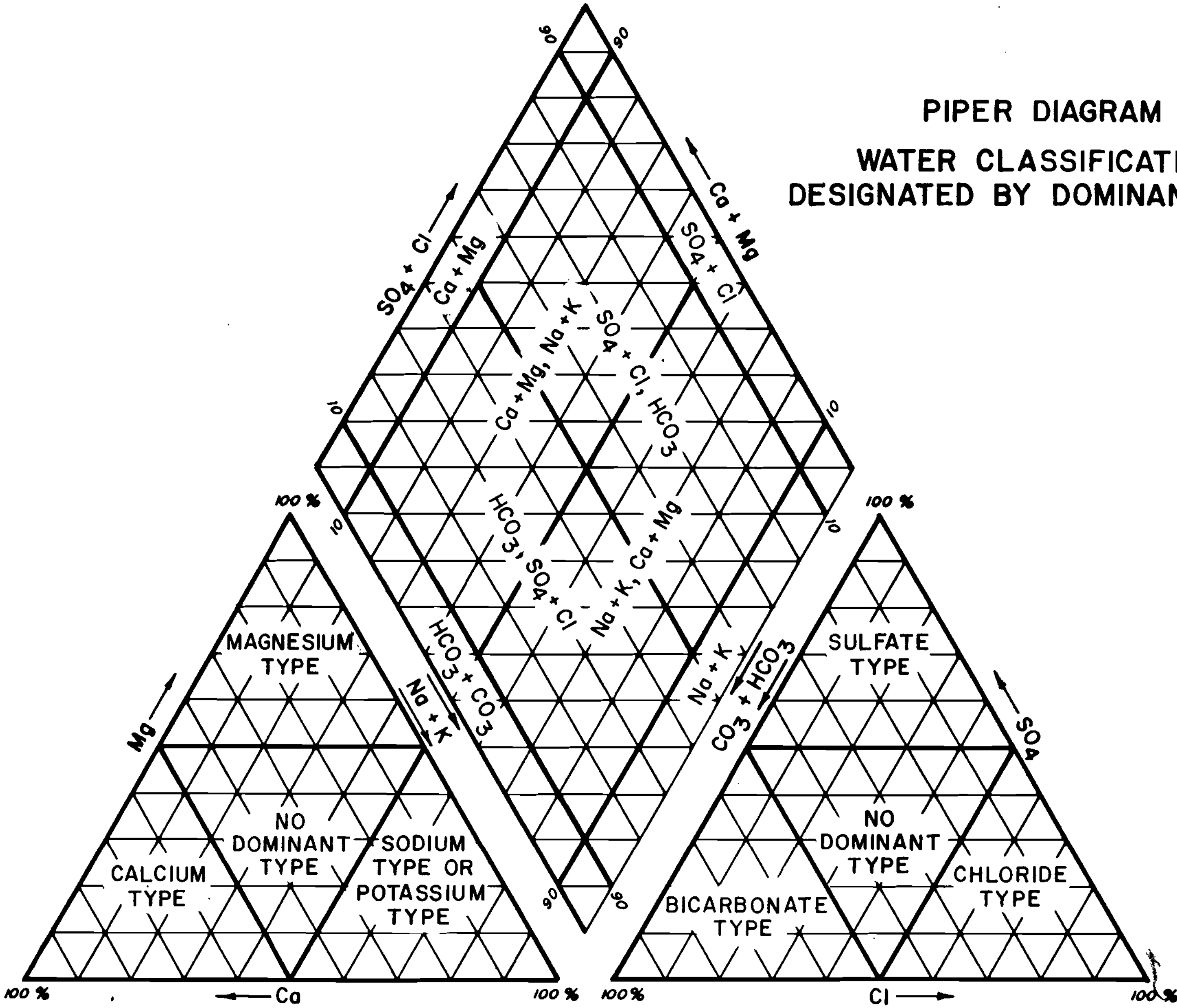
GROUND-WATER AND SURFACE WATER SAMPLING LOCATIONS

FIGURE 27

50663

PIPER DIAGRAM

WATER CLASSIFICATION DESIGNATED BY DOMINANT IONS

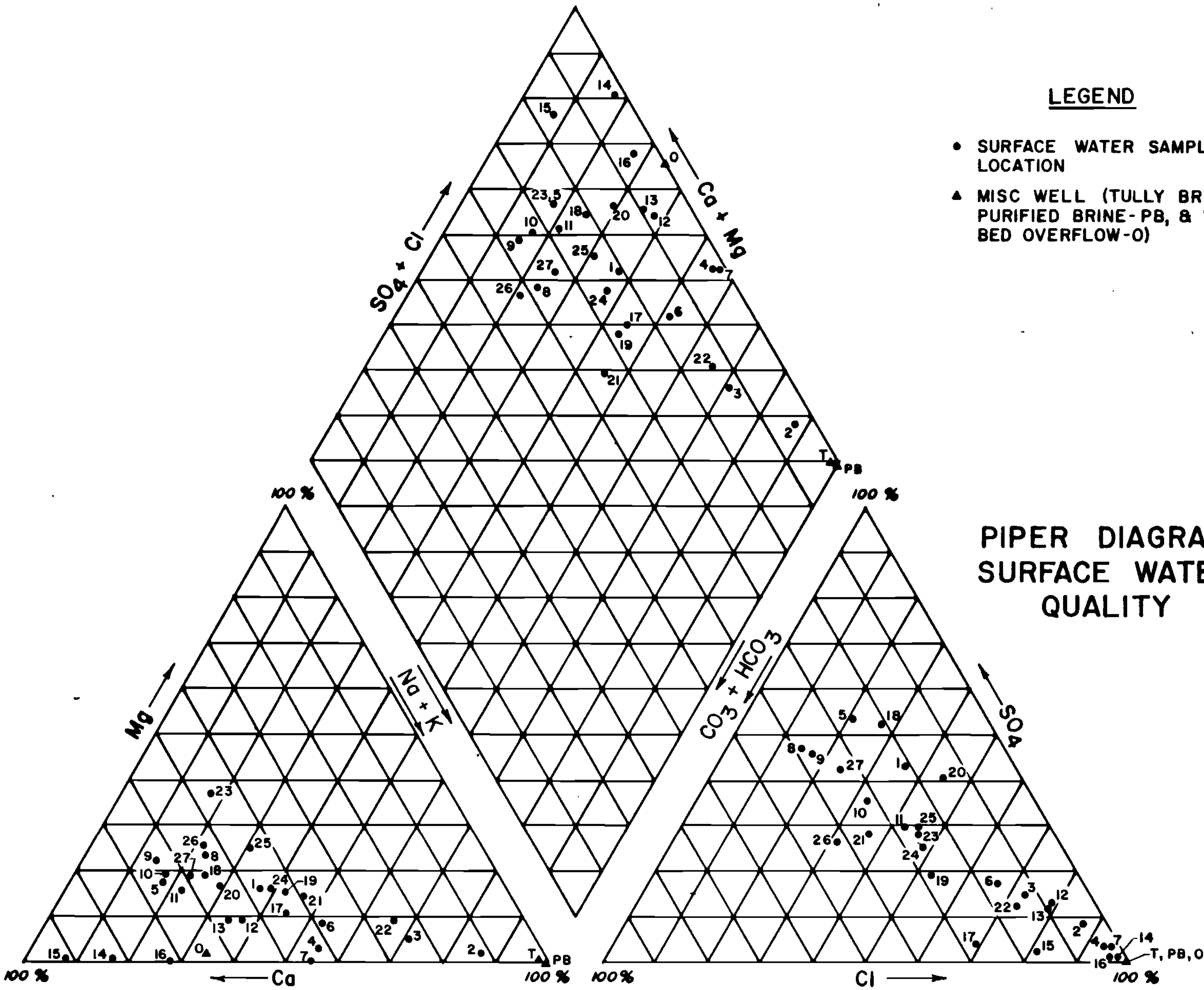


SOURCE: FREEZE & CHERRY, 1979

BLASLAND & BOUCK ENGINEERS, P.C.

FIGURE 28

50663



LEGEND

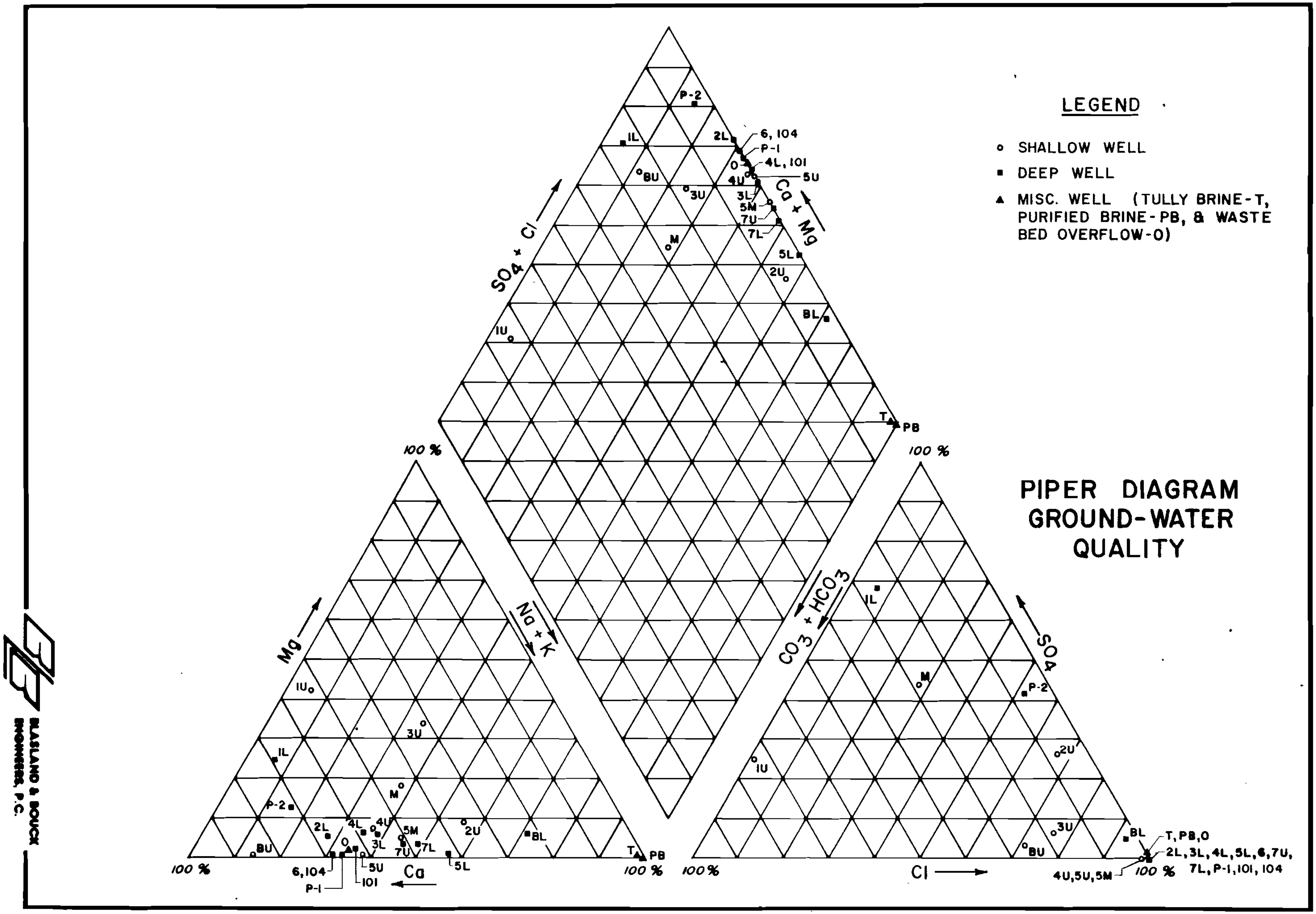
- ● SURFACE WATER SAMPLING LOCATION
- ▲ MISC WELL (TULLY BRINE - T, PURIFIED BRINE - PB, & WASTE BED OVERFLOW - O)

PIPER DIAGRAM SURFACE WATER QUALITY

BLASLAND & BOUCK ENGINEERS, P.C.

FIGURE 29

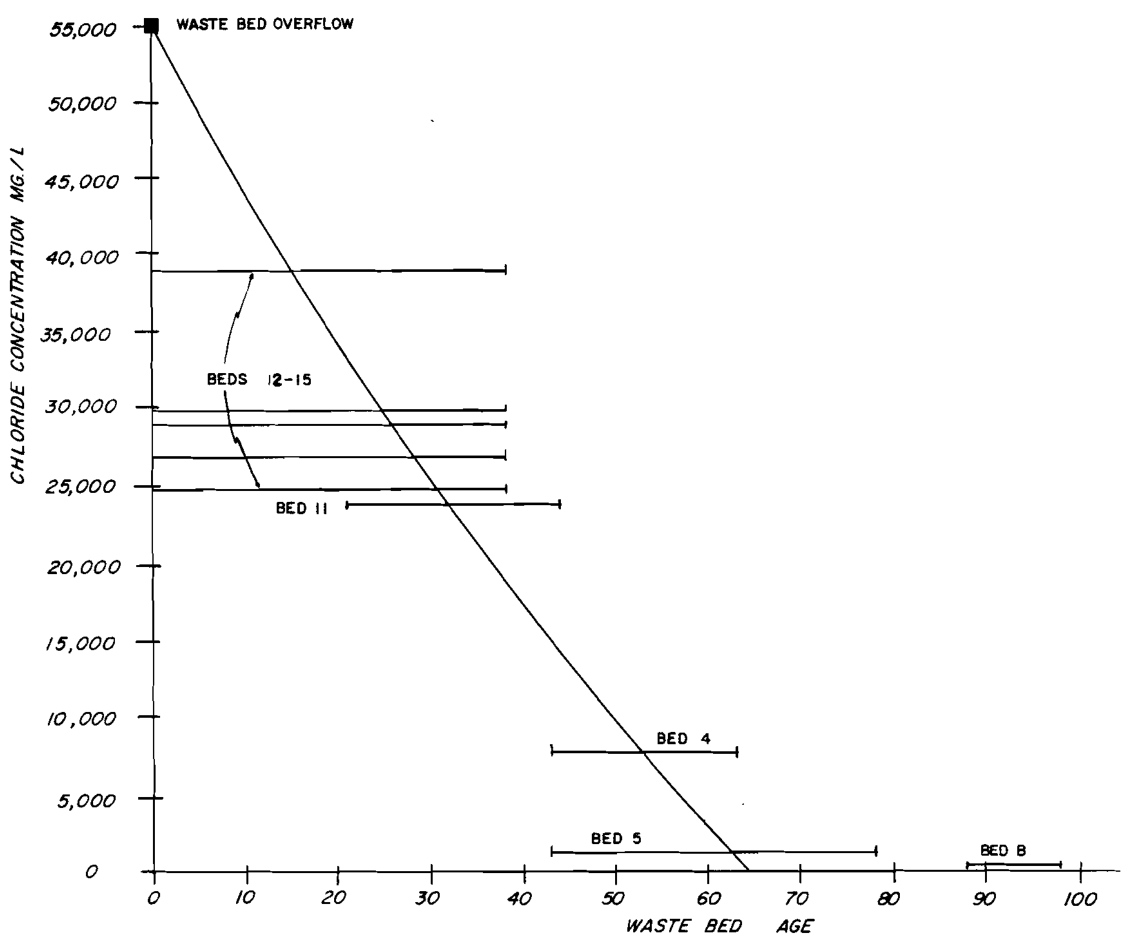
50663



PIPER DIAGRAM
GROUND-WATER QUALITY

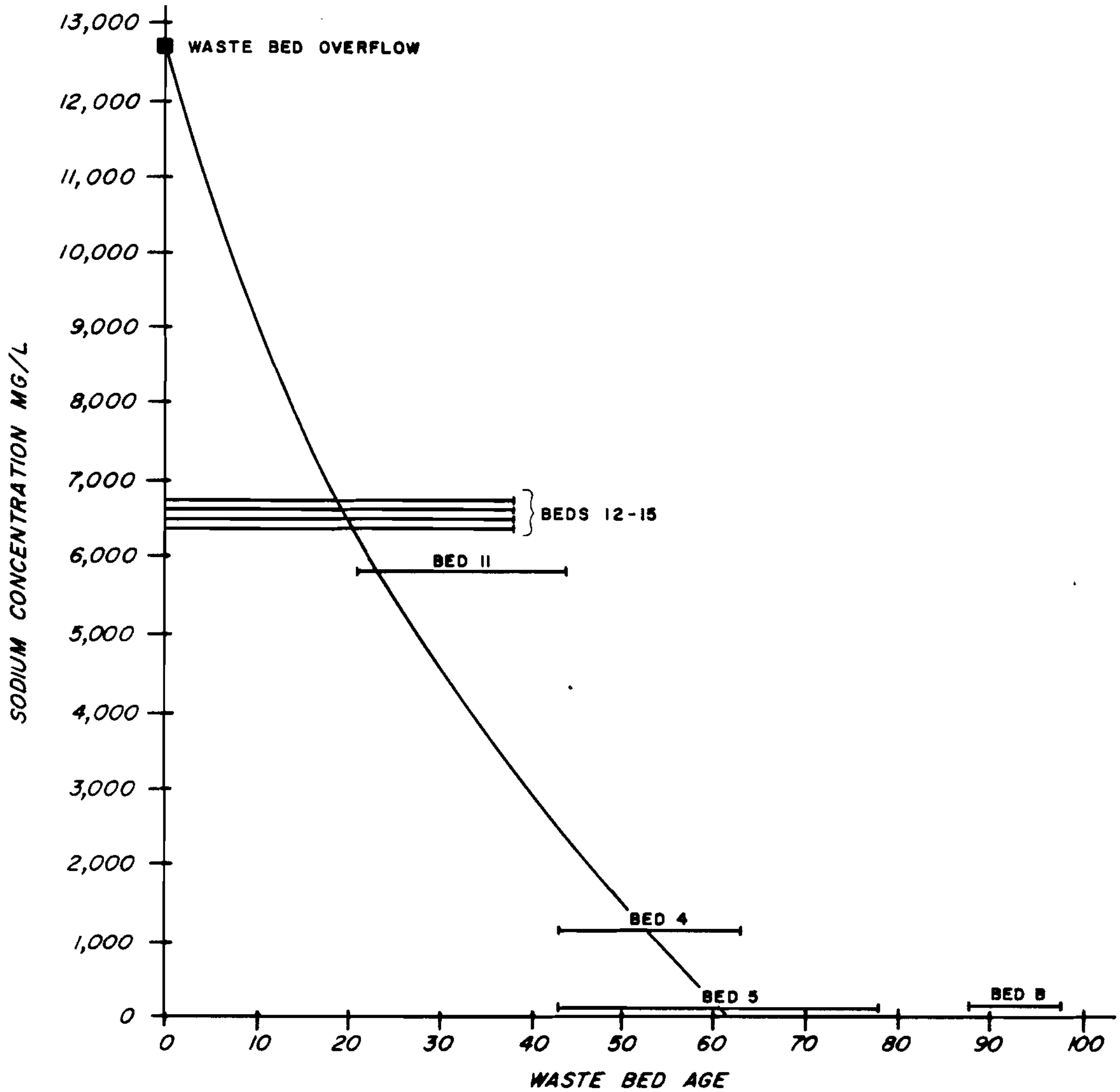
FIGURE 30

WASTE BED AGE VS. CHLORIDE CONCENTRATION

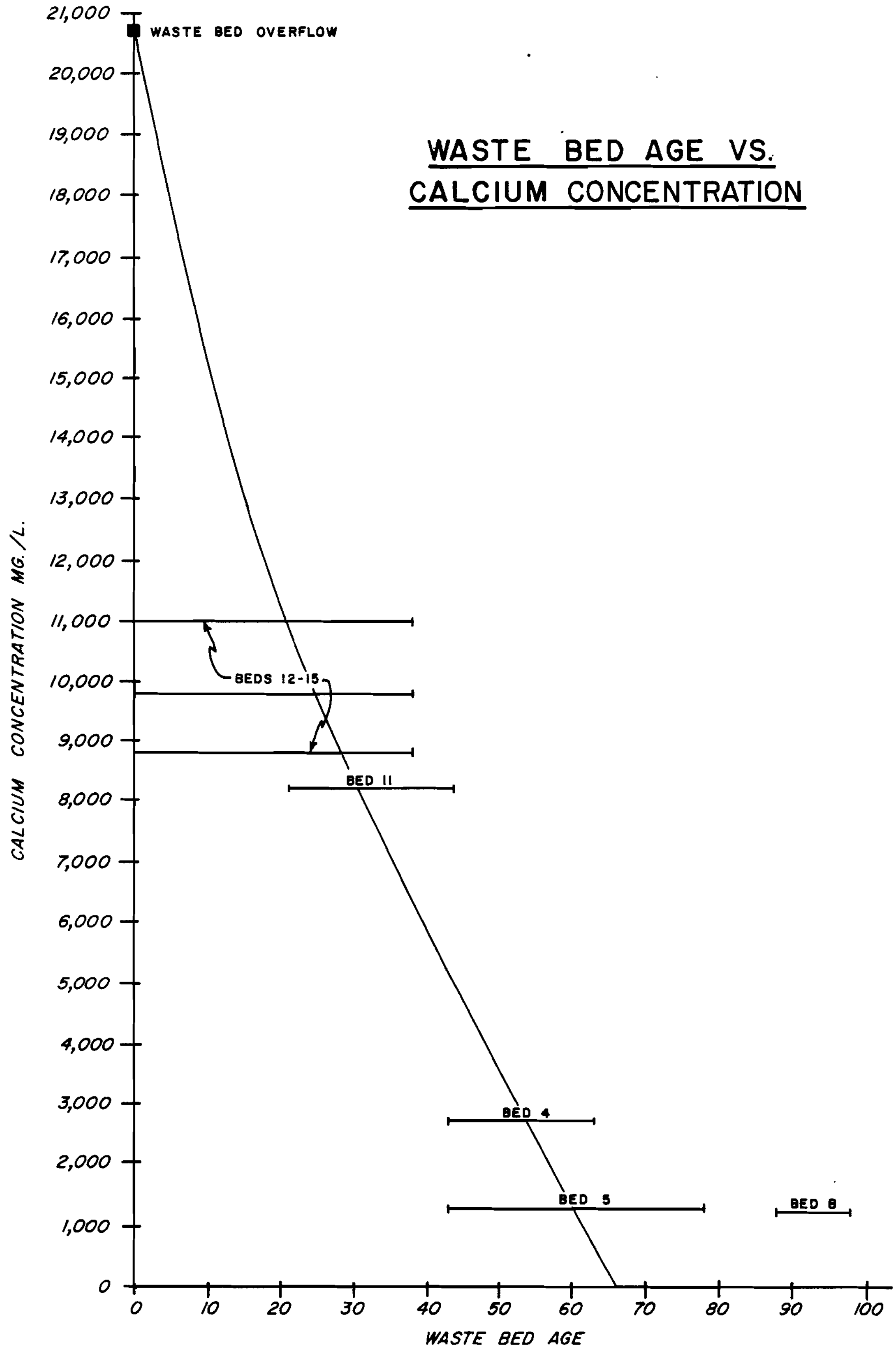


BLASLAND & BOUCK ENGINEERS, P.C.

WASTE BED AGE VS SODIUM CONCENTRATION

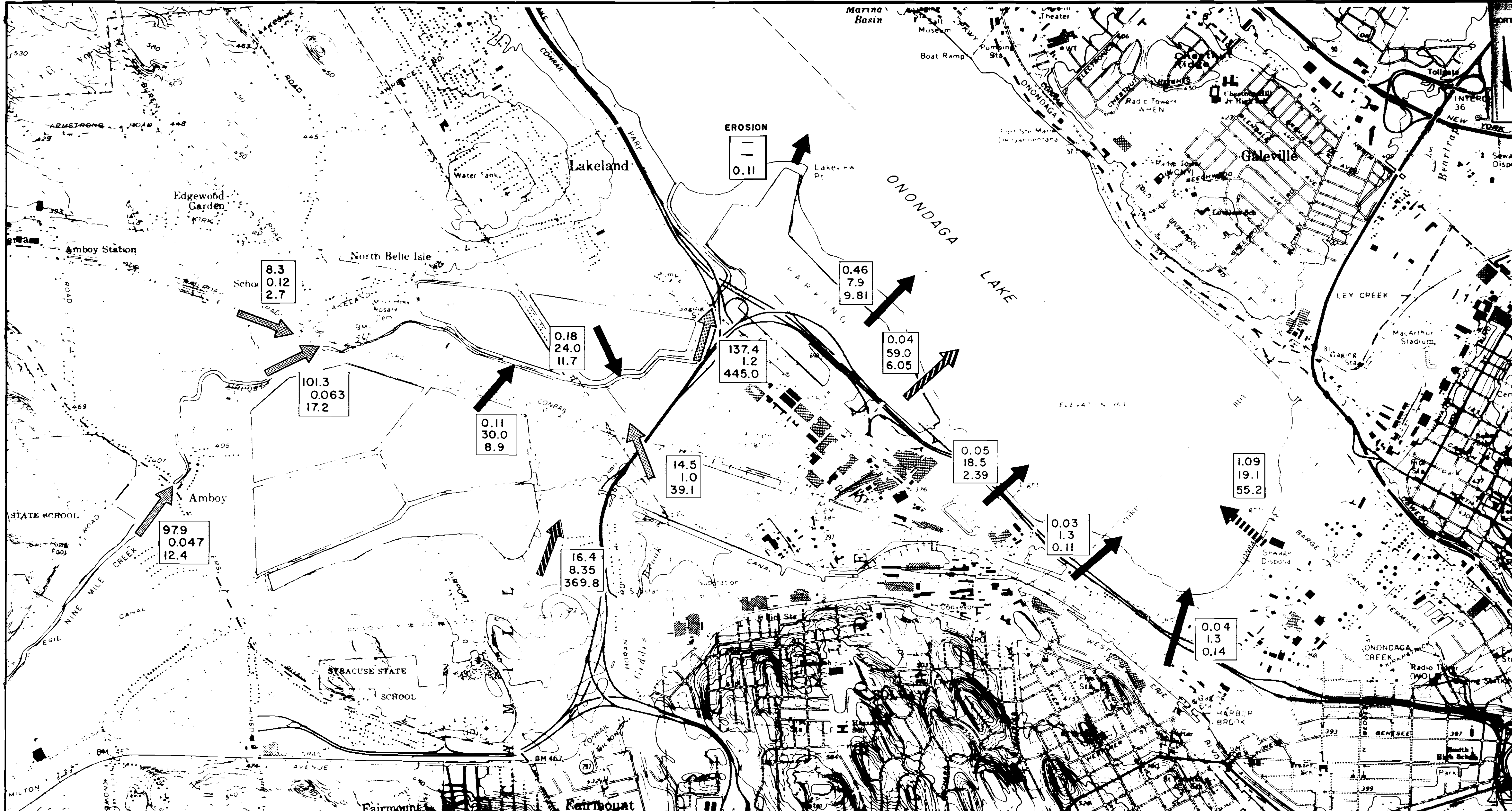


BLASLAND & BOUCK ENGINEERS, P.C.



BLASLAND & BOUCK ENGINEERS, P.C.

50663



LEGEND

8.3	FLOW IN c.f.s.
0.12	CONCENTRATION IN gm/l
2.7	TOTAL LOADING IN TONS/DAY
	SURFACE WATER FLOWS
	FLOW FROM BEDS
	CALCULATED GROUND-WATER FLOWS
	LEACHATE FROM BEDS DISCHARGED BY METRO

SCALE 1,000' 0 1,000'

DATE

BLASLAND & BOUCK ENGINEERS, P.C.

ALLIED-SIGNAL INCORPORATED
HYDROGEOLOGIC ASSESSMENT
OF THE ALLIED WASTE BEDS
SYRACUSE, NEW YORK

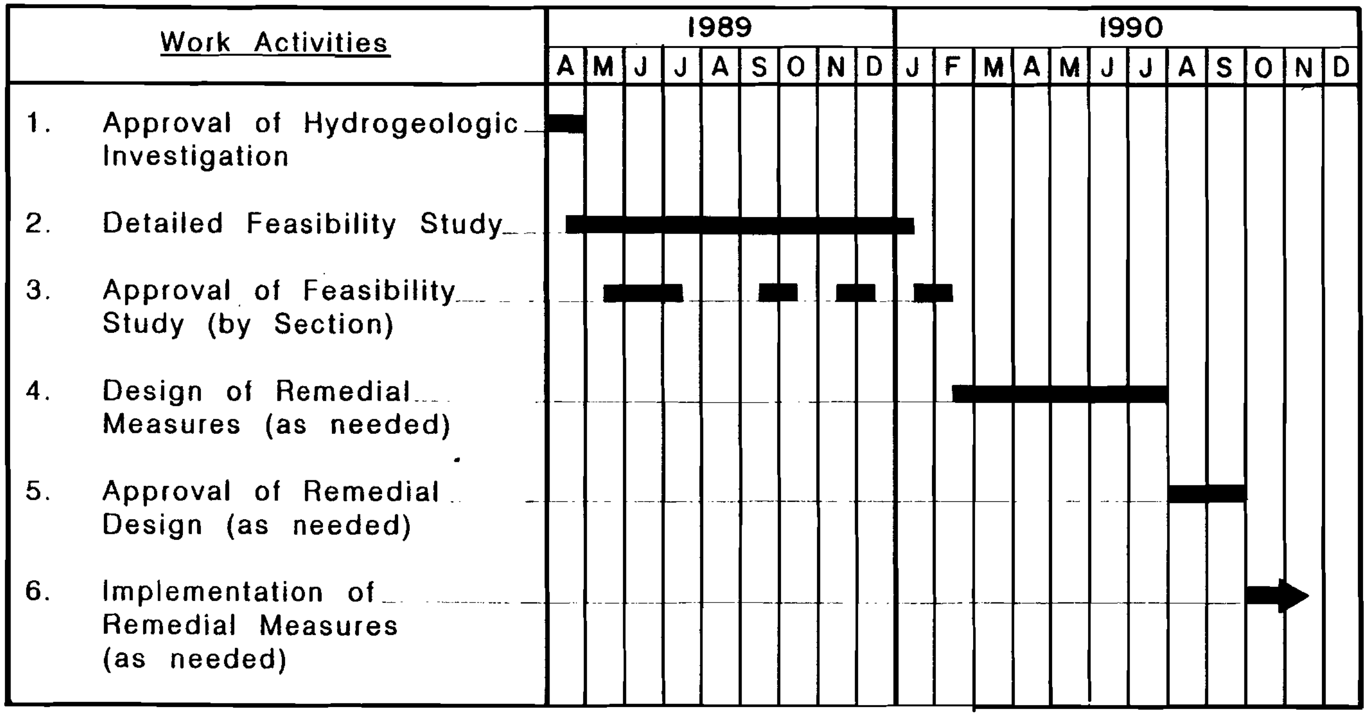
SUMMARY OF NINE MILE CREEK AND WASTE BED LOADINGS

FIGURE 34

50663

FIGURE 35

ALLIED-SIGNAL INC. - WASTE BED EVALUATION
PROGRAM SCHEDULE



BLASLAND & BOUCK
ENGINEERS, P.C.

Bibliography

BIBLIOGRAPHY

Ackenheil & Associates Geo Systems, Inc. Report on Stability and Seepage Study, Semet Solvay Waste Pond Dike - Syracuse Works, Syracuse, New York. Preliminary, January 1980.

Airmap Corporation of America. Airmap of City of Syracuse, New York, to a scale of 600 feet to the inch. 1926.

Allied Chemical Corporation. Miscellaneous drawings dated from 1924 to 1952.

Army Map Service, V821. Camillus, New York, to a scale of 1:25,000. 1943 with marginal revisions 1946.

Babcock, E.H., & Co., Syracuse, New York. Map of Onondaga County, New York, (to a scale of approximately 250 rods to the inch). 1854.

Baker, Anne Kathleen. A History of Old Syracuse, 1654-1899. Fayetteville, New York, Manlius Publishing Co., 1941.

Blasland & Bouck Engineers, P.C. Leachate Seep Assessment, Allied Corporation. Prepared for Bond, Schoeneck & King, February 1987.

Calocerinos & Spina Consulting Engineers. Foundation Investigation Reports, West Side Sanitary District, Contract No. 2, 36-Inch Force Main, Metropolitan Treatment Plant Modification, 12-Inch Sludge Disposal Force Main. 1973.

Calocerinos & Spina Consulting Engineers. Solid Waste Leachate Study Phase II. Crucible Incorporated, Geddes, New York. July 1980a.

Calocerinos & Spina Consulting Engineers. Preliminary Engineering Report and Plan of Operation to Accompany Application for Permit to Operate a Solid Waste Management Facility for Hazardous and Non-Hazardous Waste. Crucible Incorporated, Geddes, New York. December 1980b.

Calocerinos & Spina Consulting Engineers. Engineering Report and Plan of Operation to Accompany Application Application for Permit to Operate a Solid Waste Management Facility for Hazardous and Non-Hazardous Waste. Crucible Incorporated, Geddes, New York. July 1981.

Calocerinos & Spina Consulting Engineers. Engineering Report and Plan of Operation to Accompany Application for a Permit to Continue Operation of an Existing Solid Waste Management Facility for Industrial Non-Hazardous Solid Wastes, Volume 1a. Crucible Incorporated, Geddes, New York. June 1982a.

Calocerinos & Spina Consulting Engineers. Appendices to Engineering Report and Plan of Operation to Accompany Application for a Permit to Continue Operation of an Existing Solid Waste Management Facility for Industrial Non-Hazardous Solid Wastes, Volume 1b. Crucible Incorporated, Geddes, New York. June 1982b.

Calocerinos & Spina Consulting Engineers. Draft Environmental Impact Statement to Accompany Application for a Permit to Continue Operation of an Existing Solid Waste Management Facility for Industrial Non-Hazardous Solid Wastes, Volume 4. Crucible Incorporated, Geddes, New York. June 1982c.

Calocerinos & Spina Consulting Engineers. Final Report, Groundwater Quality Assessment Program, Crucible Specialty Metals Division Interim Status Landfill. Crucible Incorporated, Geddes, New York. January 1984.

Calocerinos & Spina Consulting Engineers. Draft Revised Landfill Closure Plan, Volume 1, Engineering Report. Crucible Specialty Metals, Geddes, New York. October 1985.

Calocerinos & Spina Consulting Engineers. Draft Revised Landfill Closure Plan, Volume 2, Appendices - Figures - Drawings. Crucible Specialty Metals, Geddes, New York. October 1985.

Calocerinos & Spina Consulting Engineers. Report 1984 Onondaga Lake Monitoring Program. Onondaga County Department of Drainage and Sanitation. November 1985.

Calocerinos & Spina Consulting Engineers. Revised Landfill Closure Plan, Volume 1, Engineering Report. Crucible Specialty Metals, Geddes, New York. January 1986.

Calocerinos & Spina Consulting Engineers. Revised Landfill Closure Plan, Volume 2, Appendices - Figures - Drawings. Crucible Specialty Metals, Geddes, New York. January 1986.

City of Syracuse, Department of Engineering. Pollution Survey of Onondaga Lake and Tributaries with the City of Syracuse, New York. 1948.

Dames & Moore. Report Embankment - Waste Disposal Pond No. 15 Subsurface Investigation. Allied Chemical Corporation, Syracuse, New York. July 1974.

Dames & Moore. Soil Engineering Studies Waste Embankment 13. Allied Chemical, Solvay, New York. January 1975a.

Dames & Moore. Soil Engineering Studies Embankment for Waste Pond 15 for Allied Chemical Corporation, Syracuse, New York. June 1975b.

Dames & Moore. Report Instrumentation and Subsurface Investigation Existing Waste Pond 14 for Allied Chemical Corporation, Solvay, New York. May 1976.

Dames & Moore. Report Increased Liquor Impoundment Investigation Solvay Waste Beds. Allied Chemical Corporation, Solvay, New York. September 1982.

Davis, John C. Statistics and Data Analysis in Geology. John Wiley & Sons, Inc. 1973.

Dawson, A.R.Z., Philadelphia, Pennsylvania. Map of Onondaga County, New York, to a scale of one-half inch to one mile. 1860.

Effler, Steven W.; Perkins, Mary Gail; Field, Stephen D. Onondaga Lake and the Dynamics of Chloride in the Oswego River. Water, Air and Soil Pollution, Volume 23, 1984. pp. 69-80.

Effler, Steven W.; Driscoll, Charles T. A Chloride Budget for Onondaga Lake, New York, U.S.A. Water, Air and Soil Pollution, Volume 27, 1986a. pp. 29-44.

Effler, Steven W.; Owens, Emmet M.; Schimel, Keith A. Density Stratification in Ionically Enriched Onondaga Lake, U.S.A. Water, Air and Soil Pollution, Volume 27, 1986b. pp. 247-258.

Effler, Steven W.; Owens, Emmet M. The Density of Inflows to Onondaga Lake, U.S.A., 1980 and 1981. 1986c.

Effler, Steven W.; Perkins, Mary Gail; Brooks, Carol. The Oxygen Resources of the Hypolimnion of Ionically Enriched Onondaga Lake, NY, U.S.A. Water, Air and Soil Pollution, Volume 29, 1986d. pp. 39-108.

Etter, Thomas R. A Report on Nine Mile Creek. Syracuse University, N.P., Syracuse, New York. 1966.

Fairchild, H.L. Glacial Waters in Central New York. New York State Museum, Museum Bulletin 127. 1909.

Freeze, Allan R. and Cherry, John A. Groundwater. Prentice-Hall, Inc. 1979.

French, J.H., Syracuse, New York. (Maps of the) Town and Village of Geddes, Onondaga County, New York. 1858.

Geraghty & Miller, Inc. Hydrogeologic Investigation at Allied Chemical Corporation, Syracuse Works, Solvay, New York. January 1980.

Geraghty & Miller, Inc. Ground-Water Quality Conditions at the Former Willis Avenue Plant, Allied Chemical Company, Solvay, New York. April 1982.

Higgins, Grove Lawrence, Jr., Saline Ground Water at Syracuse, New York. Unpublished Masters Thesis, Syracuse University, Syracuse, New York. 1955.

Hem, John D. Study and Interpretation of the Chemical Characteristics of Natural Water. United States Geological Survey Water-Supply Paper 2254, Third Edition. 1986.

Higgins, Grove Lawrence, Jr. Saline Ground Water at Syracuse, New York. Unpublished Masters thesis Syracuse University, Syracuse, New York. 1955.

Hopkins, G.M., Co., Philadelphia, Pennsylvania. Atlas of the City of Syracuse, New York, to a scale of 400 feet to an inch. 1908.

Hopkins, G.M., Co., Philadelphia, Pennsylvania. Map of City of Syracuse and Suburbs, Onondaga County, New York, plate 40, to a scale of 400 feet to an inch. 1938.

Hopkins, T.C. The Geology of the Syracuse Quadrangle. New York State Museum, Museum Bulletin 171. 1914.

Hough, B.K. Report on Subsurface Investigation and Stability Analysis for Proposed New Solvay Dyke and Waste Beds, Camillus, New York. August 1950.

Kantrowitz, I.H. Ground-Water Resources in the Eastern Oswego River Basin, New York. State of New York Conservation Department Water Resources Commission, Basin Planning Report ORB-2. 1970.

Keck, William G., Henry, George, Jr., Minning, Robert C. The Keck Method of Computing Apparent Resistivity. Keck Consulting Services, Inc.

Krall, Donald Bowman. Fluvioglacial Drainage Between Skaneateles and Syracuse, N.Y. Unpublished Masters thesis, Syracuse University, Syracuse, New York. 1966.

Kucera International, Inc. Aerial Photograph Coverage of Onondaga County, New York. March 28, 1981.

Kulhawy, F.H., et al. Geotechnical Behavior of Solvay Process Wastes. Proceedings of the Conference on Geotechnical Practice for Disposal of Solid Waste Materials, ASCE. 1977.

Linsley, Ray K., Jr.; Kohler, Max A.; Paulhus, Joseph L.H. Hydrology for Engineers. McGraw-Hill Book Company. Third Edition, 1982.

Malley, Anthony J. Report on Solid Waste Management for the Gere Lock Road Sanitary Landfill Site, Town of Camillus. November 1982.

McWhorter, D.B. and Sunada, D.K. Ground-Water Hydrology and Hydraulics. Water Resources Publications, Fort Collins, Colorado. 1981.

Moore, Richard Edward. Till Constitution in Western Oswego and Onondaga Counties, New York. Unpublished Masters thesis Syracuse University, Syracuse, New York. 1977.

Muller, E.H., Surficial Geology of the Syracuse Field Area. 36th Annual Meeting of the New York State Geological Association. 1964.

New York State Department of Environmental Conservation file labeled "Nine Mile Creek" reviewed by Blasland & Bouck personnel on February 9, 1987.

New York State Department of Environmental Conservation file labeled "Willis Avenue" reviewed by Blasland & Bouck personnel on February 9, 1987.

New York State Department of Health, Water Pollution Control Board, Onondaga Lake Drainage Basin, Oswego River Basin Survey Series Report No. 1. July 1951.

New York State Department of Transportation. Boring logs on file at the Nixon Drive Office, Onondaga, N.Y. Various dates.

New York State Department of Transportation. Camillus Quadrangle, New York, 7.5 Minute Series (planimetric), to a scale of 1:24,000. 1955 with partial revision 1967.

New York State Department of Transportation. Syracuse West Quadrangle, New York, 7.5 Minute Series (planimetric), to a scale of 1:24,000. 1958 with partial revision 1968.

O'Brien & Gere Engineers, Inc. Onondaga Lake Study. Prepared for Onondaga County and the Water Quality Office of Environmental Protection Agency. April 1971a.

O'Brien & Gere Engineers, Inc. Subsurface Investigation, Metropolitan Syracuse Sewage Treatment Plant. May 1971b.

Onondaga Lake Scientific Council. An Environmental Assessment of Onondaga Lake and its Major Contributory Streams. March 1966.

Onondaga Lake Subcommittee. Report of the Onondaga Lake Subcommittee to the Onondaga County Legislature Committee on Public Works. March 1983.

Onondaga Soil Testing, Inc. Subsurface Investigation Report on Proposed Gravel Exploration, Amboy, New York. April 1971.

Pitts, Nielson F., City Engineer, City of Syracuse Department of Engineering Pollution Survey, Onondaga Lake & Tributaries. 1948.

Proceedings of a Community Symposium on Onondaga Lake: The Inside Story. September 1984.

Rickard, L.V. and D.W. Fisher (compilers and editors). Geologic Map of New York, Finger Lakes Sheet. New York State Museum and Science Service Map and Chart Series No. 15. To a scale of 1:250,000. 1970.

Rufner, James A. and Blair, Frank E., editors. The Weather Almanac. Gale Research Company, Detroit, Michigan. Third Edition. 1981. p. 611.

Sanborn Map Company. Insurance Maps of Syracuse, New York, Volume One, plates 2-9, 72-74, to a scale of 50 feet to an inch. 1892 updated through 1906.

Sanborn Map Company. Insurance Maps of Syracuse, New York, Volume Three, plates 319, 320, 327, 339, 372, 386, 410, 411, 414, 415, 416, 417, to a scale of 50 feet to an inch. 1911 updated through 1952.

Stewart, Glenn William. Subsurface Conditions In and Around Syracuse, New York. Unpublished Masters thesis Syracuse University, Syracuse, New York. 1935.

Stearns & Wheler. Onondaga Lake Monitoring Program. Prepared for Onondaga County, New York, Department of Drainage and Sanitation. August 1978.

Syracuse University, Department of Civil Engineering. Proposed Studies for the Restoration of an Urban Natural Resource Onondaga Lake. March 1967.

Telford, W.M., et al. Allied Geophysics. Cambridge University Press. 1976, reprinted 1981.

Thomsen Associates. Hydrogeological Investigations, Crucible Incorporated, Solid Waste Management Facility. Prepared for Calocerinos & Spina. June 1981.

Thomsen Associates. Phase II Geotechnical Investigations Crucible Incorporated Solid Waste Management Facility, Report Volume 2 of 4 to Accompany Part 360 Application. Prepared for Calocerinos & Spina. May 1982a.

Thomsen Associates. Crucible Incorporated Solid Waste Management Facility Part 360 Application, Volume 3 of 4. Prepared for Calocerinos & Spina. May 1982b.

Thornthwaite, C.W. and Mather, J.R. Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance. Drexel Institute of Technology, Laboratory of Climatology, Publications in Climatology, Volume X, Number 3. 1957.

Thrivikramaji, K.P. Sedimentology and Paleohydrology of Pleistocene Syracuse Channels, Onondaga County, New York. Unpublished PhD Dissertation Syracuse University, Syracuse, New York. 1977.

U.S. Department of Agriculture, Agricultural Adjustment Administration, Project G21 - USDA 1758. Aerial photo coverage of Onondaga County, New York. 1938.

U.S. Department of Agriculture ASCS. Aerial photo coverage of Onondaga County, New York. 1951.

U.S. Department of Agriculture ASCS. Aerial photo coverage of Onondaga County, New York. 1959.

U.S. Department of Agriculture ASCS. Aerial photo coverage of Onondaga County, New York. 1966.

U.S. Department of Agriculture ASCS. Aerial photo coverage of Onondaga County, New York. 1978.

U.S. Department of Agriculture ASCS. Aerial photo Coverage of Onondaga County, New York. 1986.

U.S. Department of Agriculture, Bureau of Chemistry and Soils. Soil Survey of Onondaga County, New York. April 1938.

U.S. Department of Commerce. Climatological Data New York. Volumes 92-99, 1980 through 1987.

U.S. Environmental Protection Agency. Environmental Impact Statement on Wastewater Treatment Facilities Construction Grants for the Onondaga Lake Drainage Basin. May 1974.

U.S. Department of Agriculture, Soil Conservation Service. Soil Survey of Onondaga County, New York. 1973.

U.S. Geological Survey, Camillus Quadrangle, New York. 7.5 Minute Series (topographic), to a scale of 1:24,000. 1955.

U.S. Geological Survey, Camillus Quadrangle, New York. 7.5 Minute Series (topographic), toa scale of 1:24,000. 1955 photorevised 1978.

U.S. Geological Survey, Syracuse, New York Quadrangle. 15 Minute Series (topographic) to a scale of 1:62,500. Edition of 1898 reprinted 1923.

U.S. Geological Survey, Syracuse West Quadrangle, New York. 7.5 Minute Series (topographic), to a scale of 1:24,000. 1939.

U.S. Geological Survey, Syracuse West Quadrangle, New York. 7.5 Minute Series (topographic), to a scale of 1:24,000. 1958.

U.S. Geological Survey, Syracuse West Quadrangle, New York. 7.5 Minute Series (topographic) to a scale of 1:24,000. 1973 photorevised 1978.

Vose, J.W., & Co. Atlas of the City of Syracuse, Onondaga County, New York, Section 23, to a scale of 300 feet to one inch. 1892.

Walker Brothers & Co., New York. Sweet's New Atlas of Onondaga County, New York, to a scale of 150 rods to the inch. 1874.

Ward, Joseph S., & Associates. Report of Soils and Foundation Investigation Proposed Force Main and Holding Ponds, Allied Chemical Corporation, Syracuse, New York. February 1971.

W-M Engineers, P.C. Engineering Report Belle Isle Road Landfill - Cell No. 4. Town of Camillus, July 1985.

W-M Engineers, P.C. Belle Isle Road Landfill Closure Plan Cells No. 1-3. Town of Camillus, September 1986.