HYDROGEOLOGY, HYDROLOGY, AND WATER QUALITY AT THE CENTRAL AVENUE SITE, WYANDOTTE, MICHIGAN

For

BASF Wyandotte Corporation

20 March 1981

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FOR

BASF WYANDOTTE CORPORATION

INTRODUCTION

This report presents the results of an investigation conducted by Environmental Resources Management, Inc. (ERM) to determine the geologic and hydrologic conditions at the Central Avenue property, now owned by the city of Wyandotte. The property was sold to the city of Wyandotte by BASF Wyandotte Corporation. This report also includes the results of water quality sampling and a statement of site suitability for common construction materials.

Scope of Investigation

This investigation involved the following steps:

- Review of existing boring logs and past uses of the property
- Installation of 14 test borings which were constructed as small diameter wells
- Determination of depth to and directions of flow of ground water and its interrelationship with surface water on the site
- Determination of surface and ground water quality for select organic and inorganic constituents
- Determination of compatibility of typical construction materials with the soil/water quality conditions at the site

The field data were collected by ERM personnel during May, June, and September 1980. They were supplemented by data collected by BASF Wyandotte employees under direction from ERM. All field data, along with summaries of appropriate discussions, have been included in this report as described below or in the several attached Appendices.

Past Uses of Property

The data and results of previous BASF Wyandotte investigations of the fill and geologic deposits on the property have been incorporated into this report. In addition, discussions with BASF Wyandotte employees and others familiar with the geologic setting and past uses of the Central Avenue property provided useful information.

According to BASF Wyandotte employees, the Central Avenue property, purchased in 1905, was used for storage and marshalling of railroad cars, for the production of sodium chloride brine and as a storage area for a variety of materials and equipment. The major items stored were: lime waste, used chlorine cell parts, construction debris and rubble, used equipment, boiler house ashes, cement clinker and railroad track repair materials. The majority of the site was also used as a brine field during the period of the mid-1920's to the early 1960's. Periodic pipe leakage and casual spillage of brine during the period of use resulted in some crystallization and leaching of salts in and through the soil.

The majority of the site east of the railroad classification yard was used for the storage of large quantities of lime waste (mostly sand, silica, and unbaked limestone nodules) and minor amounts of lime and coke, for the period prior to the 1940's until most of this material was removed in 1974. Lime waste at least several feet high is still present in certain areas. Approximately 125,000 cubic yards of lime waste was removed during the fourth quarter of 1974 to level the hills of material to make the site potentially more useful and to improve site appearance. The review of older aerial photographs of the property and the on-site work conducted by ERM corroborates the descriptions of the types of materials previously stored on the site and the fact that very little debris or foreign material remains, as most of this material has been hauled away.

Mineralization of the ground water generally increases with depth in this area. Natural quality of the ground water can also be impaired by hydrocarbons, hydrogen sulfide, and methane gas. The fresh water from the surficial deposits generally serves to dilute and depress the more mineralized ground water entrapped in the bedrock. However, on the site, solution mining for the production of salt resulted in some casual spillage and pipe leaks which could have caused some localized salt crystallization and leaching in and through the surficial deposits. This may have locally altered the salt content of the fresh water zone near the surface.

HYDROGEOLOGY

Regional Setting

The Central Avenue property is located within Section 32, Township 3 S, Range 11 E, Section 32 (Michigan Meridian and Base line). It is bounded by Eighth Street and Central Avenue on the east and south, by the Wyandotte Terminal Railroad (WTRR) right of way on the west, and by Grove Street on the north (see Figure 1 in jacket). A railroad spur along Marshall Street divides the property into a north and south section. The total area of the property is about 21.8 acres.

The upper 10 feet of the subsurface material consists of mixed fill and soil which has largely been disturbed by man's activity on the site. The resultant mechanical mixing has made the original soils impossible to identify. Depressions and potholes, which were originally poorly drained and filled with natural organic matter, have been both leveled by removal of the higher ridges and filled in by borrow material from other sites. Subsequent cut and fill operations have created the present topography shown on Figure 1. A network of pipe trenches, storm sewers, and drainage ditches has also been superimposed on the reworked surface.

The texture of the materials present ranges from gravel to clay. In places, the deposits associated with former swamp bottom and original soil are encountered at a shallow depth. They are largely mixed, however, with recent fill and are not discernible as a continuous unit. Grass roots and recent decaying vegetation have produced a slight darkening in the upper several inches of the deposits and are the only signs of recent soil development on the site.

The reworked nature of the deposits is continuous over the site. West of the site, the soils are less disturbed and can be delineated as the Pewamo-Blount association. These soils are described by the Soil Conservation Service as nearly level and gently sloping, very poorly drained to somewhat poorly drained soils that have a moderately fine textured and fine textured subsoil.[1] They have slow permeability, slow to ponded runoff, and high available water. Wetness, frost action, and shrink-swell are major soil limitations in this association.

The geology and hydrology in the area of the site have been described in several published regional reports[2, 3, 4]. Beneath the upper 10 feet, the Central Avenue property is underlain by unconsolidated glacial drift to depths of 60-70 feet below land surface.[2] At greater depth, the site is underlain by northwest shallow dipping layers of sedimentary rock associated with the Michigan Basin. The glacial deposits are unconsolidated and variable in composition. The drift was deposited both as till and as glaciofluvial material in several major episodes of glaciation. Therefore, the composition of the drift is complex with many possible gradations between gravel and clay possible. The final retreat of the glaciers produced a lake on the site so that the upper portion of the glacial drift is largely lacustrine clay and deltaic sand. Some of the till and morainal deposits were likely reworked by the lake water.

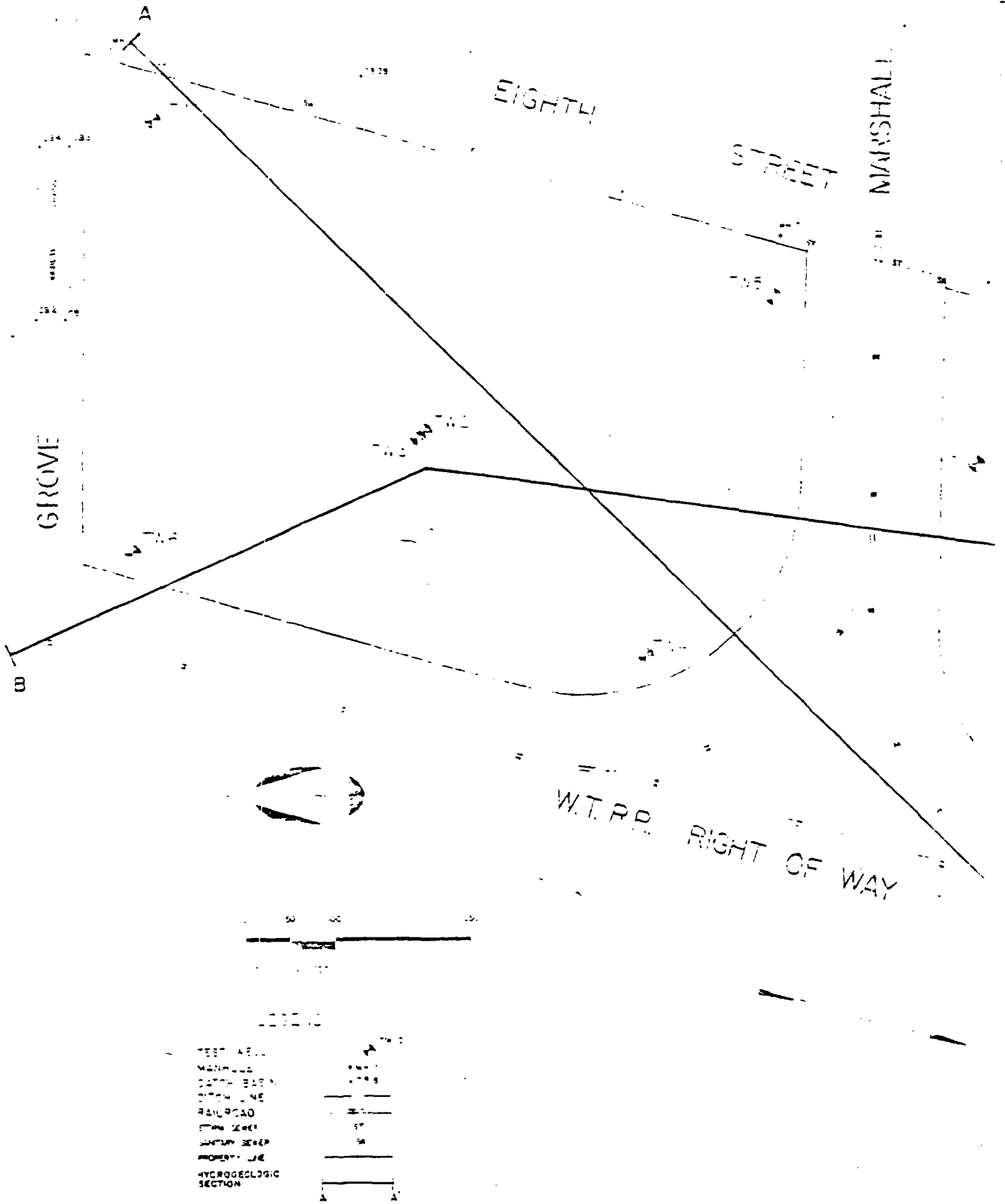
The bedrock unit directly beneath the site is the Dundee Limestone of middle Devonian age.[2] Beneath the Dundee Limestone is the Detroit River Group which is mostly dolomite. These units have an approximate maximum thickness of over 1000 feet[2] but are only about 200-300 feet thick in the area of the site. Erosion prior to and during glacial episodes produced many irregularities in the bedrock surface.

Water occurs under perched water table conditions in the surficial soils and fill and under confined (artesian) conditions within and beneath the glacial deposits. Several piezometric surfaces may be present within the glacial drift and bedrock. The majority of the glacial drift at this site functions as an aquiclude or aquitard, and there is no known hydrologic continuity with any regional aquifers in the area. Water level data in this report are largely from the perched water table in the fill. There is no known municipal or industrial use of the shallow water in the vicinity of this site. Due to the mineralization and hydrogen sulfide content, the bedrock aquifers near the site have not been developed. The waters of this region have been classified by the Michigan DNR as non-potable.

Soil Borings and Test Wells

Fourteen soil borings were drilled to shallow depths of less than 30 feet for this investigation (see Appendix A, Figures 1 and 2). A hollow stem auger was utilized to collect continuous split-spoon samples from all the borings.

FIGURE - 2 , LOCATION MAP



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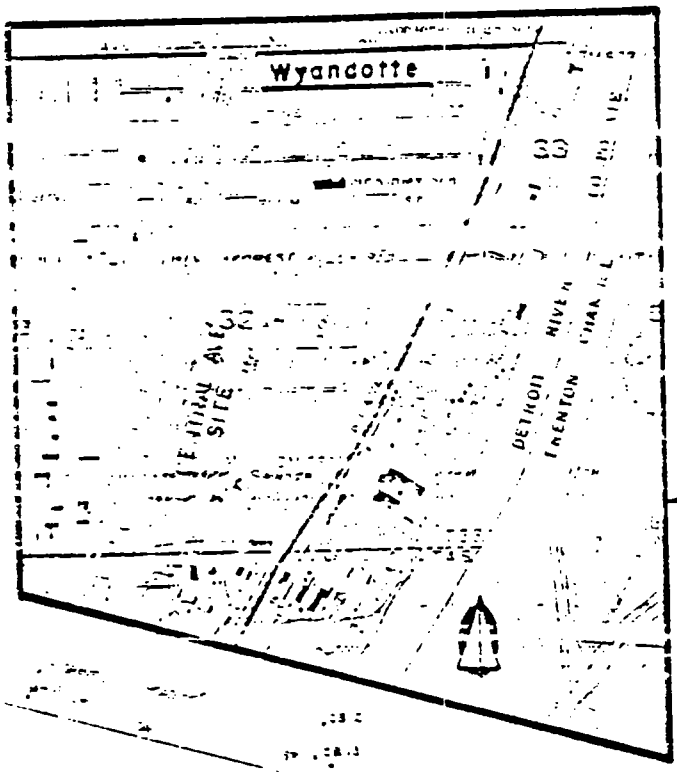

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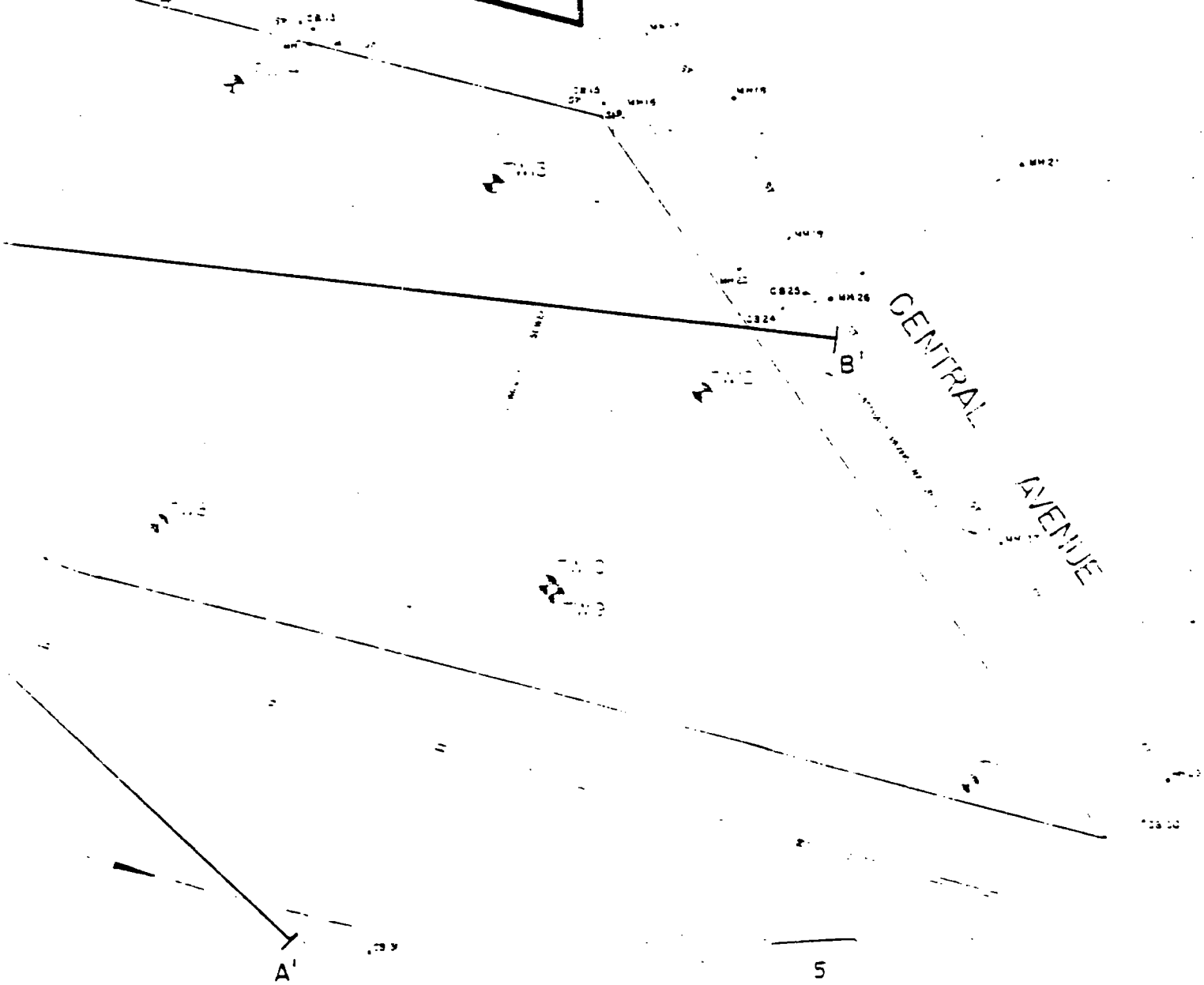
7.5 MINUTE SERIES



Each boring was completed as a monitoring well, with the insertion of a two-inch diameter PVC pipe, a five-foot length of .008 inch machine slotted PVC screen, and a sand pack. In order to restrict inflow of surface water, twelve of the wells were sealed near the surface with bentonite. The two deeper wells were sealed in the clay below the surficial materials to isolate and thus permit sampling of a deeper saturated zone. The auger stem, bit, rods, and spoon samplers were washed with soap and water and rinsed with acetone after completion of each boring to prevent cross contamination. No outside water was introduced in the drilling, installation, or development processes.

The materials encountered in the borings formed a consistent sequence of units, from land surface to depth, throughout the site as follows:

Unit 1 - dominantly recent fill (man-made),

Unit 2 - dominantly mixed former soil with natural organics (swamp bottom), and former fill (initial cut and fill operations),

Unit 3 - clay (borings were terminated in this clay).

The demarcation between Units 1 and 2 is indistinct and usually defined by the presence of more natural materials or by the absence of man-made materials. The clay contact is usually easily defineable. The depth below land surface to the clay unit ranges from 5.5 feet in TW-14 to 14 feet in TW-7 and averages 9 feet. However, the use of clay in the initial fill operations may cause misinterpretation. Ground water conditions within these units are described below.

The recent fill contains construction material such as brick, cement, block, wood, concrete, and stone in addition to glass, slag, lime waste, clinker, and ash. The texture is dominantly a sand which can be silty or gravelly. In places the sand is partially cemented or stained. The former fill contains mixed organic deposits, soil, and fill which ranges in composition from a clayey silt to a gravelly sand. Units 1 and 2 form a surficial zone capable of storing and/or transmitting water. Several zones of high permeability in the fill were encountered during drilling.

The clay was found to range in composition from clayey silt with low plasticity to a sticky clay of high plasticity. It generally contains small gravel from 1/4 to 1/2 inch in diameter that may be subrounded. Varying degrees of saturation cause apparent differences in the color and texture of the clay. Red, yellow, and brown are indicative of the oxidized forms of iron and manganese, while blue and gray are characteristic of reduced compounds. Where saturated, the clay is blue-gray to gray in color and is softer and more plastic. Where unsaturated, it is brown, firm to stiff, and less plastic. The clay contains vertical and diagonal fractures and root holes which are capable of transmitting insignificant amounts of water. The zone immediately adjacent to a structural parting or tube will frequently be gray and saturated, while most of the samples frequently will be brown and hard. Occasionally, water droplets were observed on joint surfaces. Also, horizontal partings, probably related to deposition, occur in some of the samples. Where the horizontal partings intersect vertical joints, a blocky structure results.

The saturated (gray) clay is dominant in a shallow zone immediately below the fill contact. This zone is generally less than two feet thick. It is underlain by a clay which is dominantly brown, unsaturated, and of variable thickness. At depths of approximately 15 feet, the gray clay again becomes dominant where saturated.

Previous Clay Investigation

In 1959, ten borings were made on the site and three were made immediately west of the site to determine the amount of fill overburden, thickness of brown clay, and depth to the blue clay contact.[5] These borings generally encountered the same sequence of deposits that were described above. However, recent fill thicknesses and composition have been substantially altered by cut and fill activities that have taken place since 1959. The absolute depths of the profile contacts cannot, therefore, be correlated with the recent borings.

The drilling logs showed "swamp bottom" and deposits of a transitional natural (fill, soil, etc.) to range in thickness from two to five feet. This thickness generally corresponds to the former soil, natural organic, and fill unit discussed above.

The brown clay was generally described in the logs as containing sand and pebbles, very stiff, moist, and having oxidized streaks and partings. It ranged in thickness from two to nine feet and was present in every hole.

The blue clay was encountered in each hole at depths below 10 feet. It was described as noticeably softer, with sand and pebbles. As discussed in the previous section, the apparent changes in texture and color of the clay are thought to be caused by the degree of saturation. Hence, the blue clay is indicative of a deeper saturated zone.

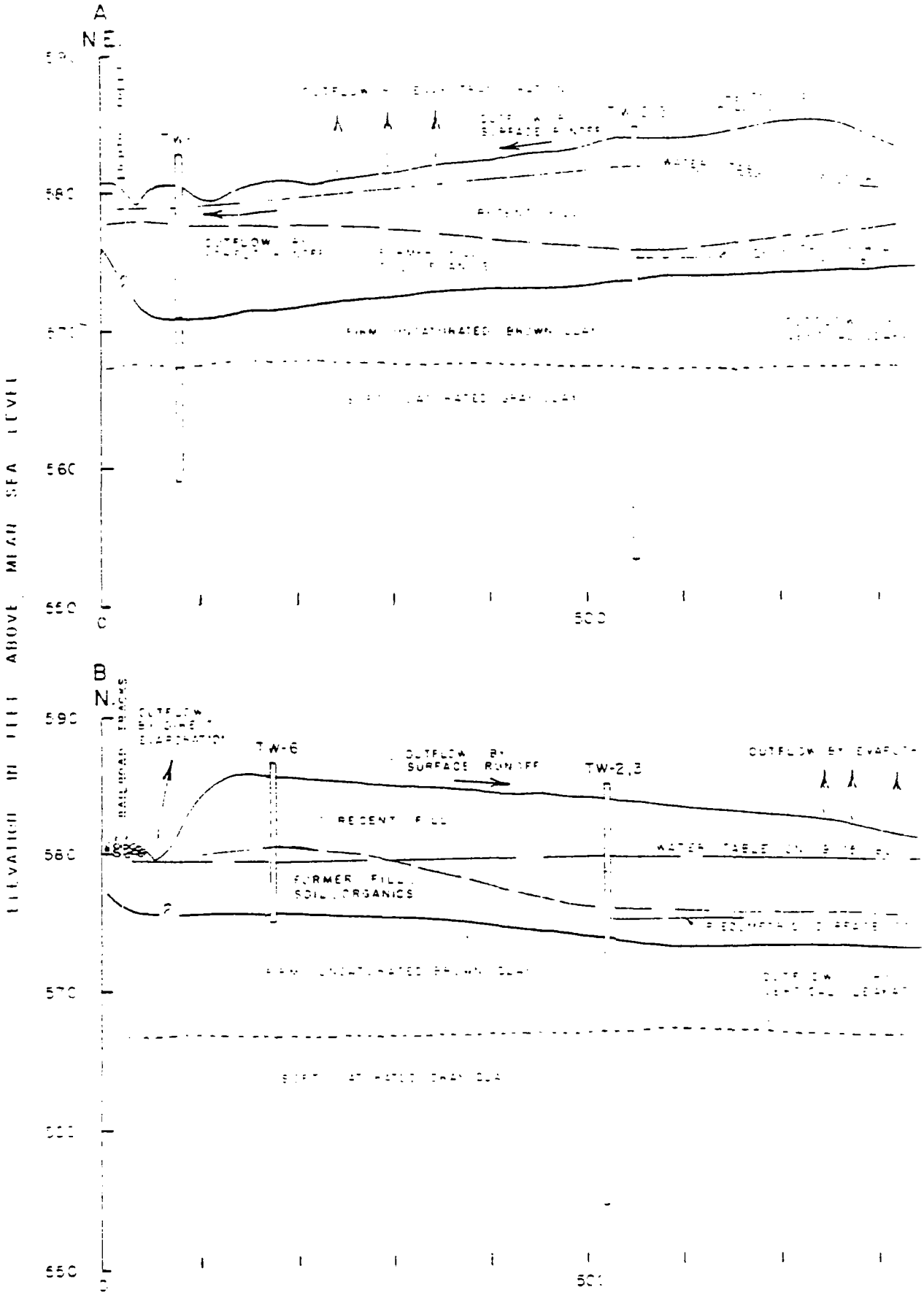
At the time these borings were made, the brown clay was at or near land surface in several of the borings. Under these conditions, no ground water was reported. However, where fill, swamp bottom, and transition deposits were present, ground water was reported to flow in heavy volumes from those units.

Shallow Ground Water

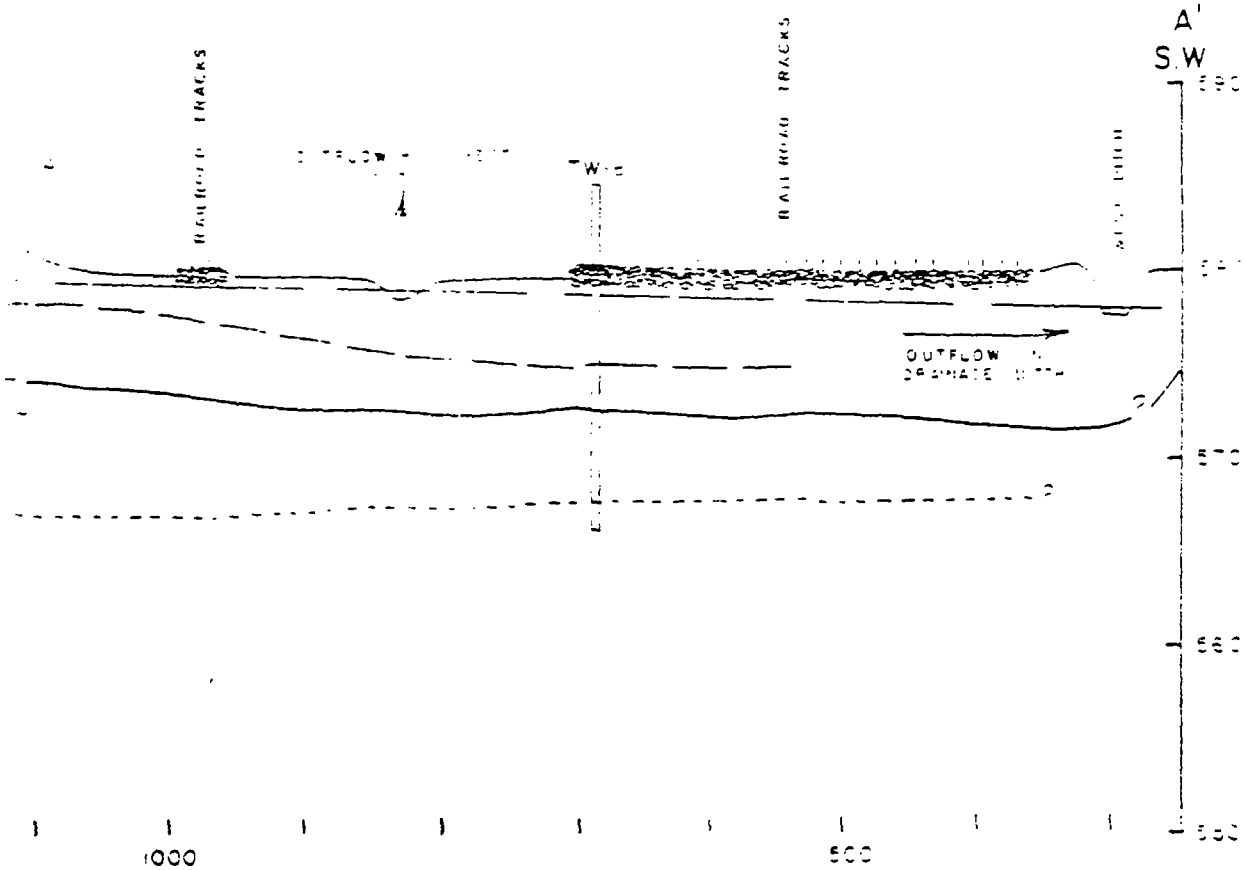
Water was found to occur in at least two distinct zones at shallow depths (Figure 3). The upper zone is a perched water table and is present in the deposits consisting of recent fill and former fill, soil and organic deposits. A zone of true ground water probably occurs under confined (artesian) conditions beneath the gray clay and thus contributes to the saturation of the deposits. The two saturated zones are separated by an unsaturated zone of dense brown silty clay which functions as a confining bed in this sequence. Very minor amounts of water are transmitted downward from the upper zone through small fractures and tubes in the unsaturated clay.

Water levels were measured throughout the summer in the fourteen test wells (Table 1). All of the wells except TW-2 and TW-9 are in the perched ground water system. These water levels responded rapidly to major rainfall events and declined slowly to relatively constant levels. This is thought to reflect rapid recharge by infiltration and relatively slower outflow to a constant level controlled by the major outflow areas.

FIGURE - 3 , HYDROGEOLOGIC



SECTIONS A-A AND B-B



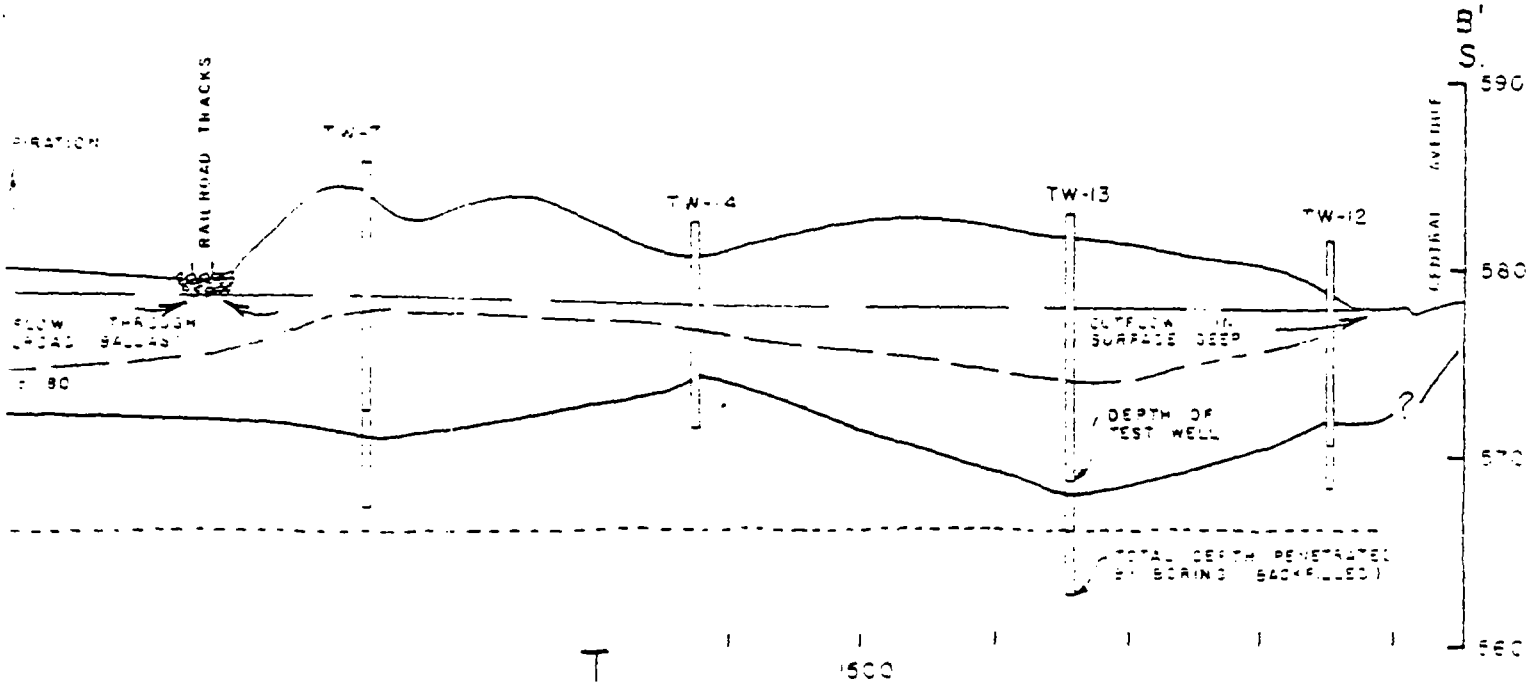


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TABLE 1

WATER LEVEL MEASUREMENTS (1)

Test (TW) Well Number	Depth Below Land Surface	Elevation (2) top of Casing	5/16/80		5/30/80		6/5/80		6/12/80		6/27/80		7/15/80		8/21/80		9/15/80	
			DTW*	Elev**	DTW	Elev.	DTW	Elev.	DTW	Elev.	DTW	Elev.	DTW	Elev.	DTW	Elev.	DTW	Elev.
1	10.1	583.24	4.25	578.99	4.53	578.71	3.50	579.74	5.83	577.41	4.45	578.79	5.60	577.64	5.20	578.04	4.36	578.88
2	29.9	584.64	6.00	578.64	6.31	578.33	6.53	578.11	13.67	570.97	13.30	567.34	13.40	571.24	12.80	571.84	10.04	574.60
3	9.8	586.51	5.75	580.76	5.76	580.75	5.63	581.88	4.82	581.69	5.65	580.86	6.60	579.91	6.80	579.71	6.71	579.80
4	8.9	584.44	6.63	577.81	5.21	579.23	4.67	579.77	5.99	578.45	4.90	579.54	5.40	579.04	5.65	578.79	5.07	579.37
5	8.0	584.95	5.90	579.05	6.07	578.88	4.99	579.96	5.40	579.55	6.00	578.95	6.70	578.25	6.65	578.30	5.71	579.24
6	9.9	587.68	6.63	581.05	7.43	580.25	6.71	580.97	6.76	580.92	7.35	580.33	8.50	579.18	8.50	579.18	8.01	579.67
7	13.0	588.65	9.32	579.33	8.83	579.82	8.70	579.95	8.36	580.29	8.50	580.15	9.40	579.25	9.65	579.00	9.72	578.93
8	9.3	585.09	7.19	577.90	6.29	578.80	5.64	580.05	5.42	579.67	6.10	578.99	6.80	578.29	6.70	578.39	6.05	579.04
9	30.0	584.45	2.78	581.67	6.91	577.54	7.46	576.99	12.06	572.39	9.50	574.95	7.70	576.75	7.30	577.15	7.13	577.32
10	8.3	585.32	8.23	577.09	6.48	578.84	5.59	579.73	5.81	579.51	6.45	578.87	7.10	578.22	6.60	578.72	6.39	578.93
11	10.2	584.40	12.09	572.31	10.74	573.66	10.09	574.31	11.98	572.42	11.65	572.75	10.70	573.70	10.40	574.00	8.90	575.50
12	9.1	582.13	5.40	576.73	4.15	577.98	3.74	578.39	5.34	576.79	4.20	577.93	4.70	577.43	4.50	577.63	4.01	578.12
13	11.3	582.67	6.15	576.52	4.10	578.57	3.66	579.01	5.66	577.01	4.15	578.52	5.40	577.27	5.50	577.17	4.66	578.01
14	8.5	583.59	7.40	576.19	4.44	579.15	4.00	579.59	4.71	578.88	4.50	579.09	5.50	578.09	5.50	578.09	5.23	578.36

Notes: 1) Wells were bailed or pumped as follows:

June 6-10, all wells - several times

July 18, TW-2, 9, 11

September 16, TW-2, 4, 5, 10, 13

2) TW-11 recovers at a 0.05 in/day rate and does not reflect accurate water levels. TW-2 and 4 recover at less than 1.0 in/hr and may not reflect accurate water levels until several days after pumping.

(1) All measurements in feet

(2) All elevations surveyed on May 7, 1980 (Wayne County Road Commission datum)

* Depth to water from top of casing

** Elevation of water level

It was noted in drilling that the color change in the clay was related to the degree of saturation in the soil (Appendix A). Wells TW-2 and TW-9 were both installed into the lower saturated zone identified by the gray clay. These wells were bailed dry several times to eliminate all perched water which may have entered the wells and the sand pack during their installation. The water levels in these wells have risen above the zone of saturation at a depth of approximately 15 feet to within several feet of the surface, but at a depth below the perched water table. Thus, the deeper saturated zone is considered to be confined beneath the site by the clay deposits. In addition, it responds much slower, or not at all, to precipitation events that were observed to affect the perched flow system.

Recharge to the perched water table is entirely by infiltration from rain and snowmelt on the site. Outflow from this water table, however, occurs by several mechanisms (Figure 3) including the following:

- Surface outflow where the water table intersects the land surface - expressed as seeps, depression springs, or ponds
- Direct evaporation from pond surfaces
- Evaporation of wetted shallow ground water from the soil surface by capillary forces in the soil
- Transpiration by vegetation having access to the capillary fringe
- Minor leakage through fractures and tubes in the brown unsaturated clayey silt
- Outflow into the railroad ballast which functions as a French drain to transmit the water to storm drains or ditches at the site periphery when water tables are high (i.e., immediately following a rainstorm)
- Lateral flow through permeable subsurface deposits to the open ditch immediately west of the property
- Potential flow into pipes, storm sewers, and sanitary sewers that traverse the property

Thus, numerous areas function to allow the infiltrated water to exit the site at varying rates throughout the year. The perched water table is continuously fluctuating and may change shape as water is recharged from precipitation events and is evacuated by these mechanisms. The major volume of outflow is via seeps along Central Avenue, the ditch along the west property boundary, and by evaporation from the ponds. Most of these points are at a higher elevation than the bottom of the saturated fill material (Figure 3).

These conditions together with the nature of the cut and fill operations that occurred on this site, create a "bathtub effect" with water seepage occurring at the discharge points when the more permeable fill deposits become saturated to very shallow depths or to land surface. An extended dry period could temporarily eliminate the ponds and the seeps, but a saturated zone would remain in the majority of the fill deposits. Following the next recharge event, the seeps and ponds would rapidly reappear as water outflows from this shallow "bathtub" system.

Summary

In summary, the water entrapped in the surficial deposits on the site functions as a perched water table above a confined flow system. The perched water occurs in the permeable fill deposits above the underlying clay of lower permeability. This system is recharged by precipitation events directly on the site and leaves the borders of the site at controlled elevations. A confined flow system is thought to occur beneath the gray clay with a piezometric (artesian) head present within the fill deposits.

HYDROLOGY

Surface water hydrology directly interacts with and affects ground water recharge and outflow at the site. This section estimates the normal annual and past year's recharge to the ground water from the overlying property, using a water balance methodology.[6] Observations during the five-month site study have been incorporated in this section under the heading, Stormwater.

The water balance methodology is based on the relationship among precipitation, evapotranspiration, surface runoff, and soil moisture storage. Precipitation is the driving factor, and the latter three factors subtract from this incident water to leave the remainder for ground water recharge or percolation to the permanent ground water below the site. Evapotranspiration, the combination of evaporation from the soil and plant surfaces and transpiration from plants, represents the transport of water from the earth back to the atmosphere, i.e., the reverse of precipitation. Surface runoff represents water which exits the site directly. Soil moisture storage capacity represents water which can be held in the soil and which does not reach the permanent ground water table.

The relative amounts of each of these factors depends, in a large measure, on the relationship between precipitation and evapotranspiration. Until the field capacity of the soil is reached, moisture in the soil is regarded as being a balance between what enters as a result of precipitation and what leaves through evapotranspiration.

Since precipitation and evapotranspiration are governed by different climatic factors, they are not often the same in amount or in distribution throughout the year. As will be discussed in the following sections, evapotranspiration normally exceeds precipitation during the warmer months of May through September, even though precipitation tends to be slightly higher during this part of the year as compared to the fall and winter.

Using monthly values for each of the four factors, the selected empirical prediction techniques provide a reasonable estimate of ground water recharge. The additional accuracy provided by daily field measurements, rather than monthly observations, was not warranted, considering the scope of the overall study.

Precipitation

Detailed rainfall records are kept by the United States Weather Bureau. The closest station to the Central Avenue site is the Detroit Metropolitan Airport, approximately 10 miles from Wyandotte. Their records, which date from 1941, should be representative of a long-term average.

The normal monthly precipitation and maximum monthly precipitation amounts for 1941 to 1970 are included in Table 2. This table also shows the precipitation for the past year (September 1979 to August 1980) and the departure from the 30-year normal values.

Precipitation is fairly evenly distributed through all months of the year. The spring and summer months, i.e., April through August, tend to have slightly higher rainfalls than the remainder of the year. This past year shows a 22 percent higher total annual precipitation than the normal annual. The data for 1980 show that the months of June, July, and August (when most of the field data were collected for this study) had much higher rainfalls than normal for those summer months.

Surface Runoff

Surface runoff is that portion of rainfall which runs off the site and is lost to overland flow before it infiltrates into the soil or becomes depression storage. Variables affecting runoff include intensity and duration of rainfall, existing soil moisture, soil permeability, ground slope, and the amount and type of vegetative cover.

Runoff has been estimated for the incident precipitation during each month of the normal year. As one method of determination for this study, empirical runoff coefficients have been applied to the normal monthly precipitation values.

The 21.8-acre site was divided into 13 drainage subareas. Based on mapping of the ground cover of the site and field observations, runoff coefficients[7] were assigned to each subarea (see Table 3) which reflect degree of imperviousness of the surface. A weighted average was then taken to give an estimated monthly surface runoff coefficient for the total site. Applying the resultant runoff coefficient of 0.3 for the site to the total normal annual precipitation of 31.7 inches, gives an estimated annual surface runoff of 9.5 inches.

TABLE 2

MONTHLY PRECIPITATION SUMMARY

Month	Precipitation (in.)[1] Normal Monthly	Sept. 1979 to Aug. 1980	Departure from Normal	Maximum Monthly
Jan	1.91	0.69	-1.22	3.63
Feb	1.73	1.00	-0.73	2.87
Mar	2.47	3.88	1.41	4.48
Apr	3.22	4.23	1.01	5.40
May	3.31	3.22	-0.09	5.88
Jun	3.42	6.42	3.00	6.60
Jul	3.10	4.33	1.23	6.02
Aug	3.28	6.09	2.81	7.83
Sep	2.16	0.94	-1.22	5.83
Oct	2.48	1.24	-1.24	4.87
Nov	2.32	4.19	1.87	3.31
Dec	2.27	2.36	0.09	6.00
Total Annual	31.7	38.6	6.9	-

[1]Precipitation values are those recorded at Detroit, Michigan Metropolitan Airport. Normal and maximum monthly values are based on the 1941-1970 period of record.

TABLE 3

DRAINAGE SUBAREAS AND
ESTIMATED RUNOFF COEFFICIENTS

Subarea No.	Area Sq. ft.	Area Acres		Estimated Runoff Coefficient
I	15,300	0.35		0.2
II	55,700	1.28		0.2
III	113,000	2.59		0.2
IV	90,700	2.08		0.4
V	81,000	1.86		0.2
VI	82,300	1.89		0.1
VII	29,900	0.69		0.6
VIII	19,300	0.44		0.3
IX	123,000	2.82		0.3
X	59,400	1.36		0.4
XI	103,000	2.36		0.1
XII	138,000	3.17		0.6
XIII	37,800	0.87		0.3
Total		21.76	Weighted Average	0.3

The Soil Conservation Service (SCS) technique of estimation of annual water yields from ungauged watersheds of 10 to 2,000 acres was also examined for comparison. Four specific factors were used to determine annual runoff from an SCS--developed nomograph[8]:

1) Drainage area of 21.8 acres

2) Ratio of precipitation to temperature of 0.54

3) A poor ground cover

4) Average annual precipitation of 31.7 inches

This SCS methodology produces an average annual runoff of 8.5 inches for the site. This compares favorably with the total derived above by applying the mean monthly surface runoff coefficients.

Soil Moisture Storage

The amount of precipitation retained as soil moisture storage depends on soil type, structure, and field capacity, as well as the depth of soil layer itself. The total amount of water stored in the soil at field capacity consists of two components: "hygroscopic" water, which is water bound to the soil particles and not available for transpiration, and secondly, available water, which ranges from the wilting point to the soil's field storage capacity. This latter type of water will undergo capillary movement and is subject to evapotranspiration losses.

For the water balance, the amount of available water must be estimated depending on assumed soil type, structure, and depth of root cells. The soil moisture storage capacity has been calculated according to Thornthwaite's technique of multiplying available water per unit depth of soil by estimated root zone depth. The Central Avenue site consists of a large amount of disturbed soil which does not have good ground cover. It has been assumed for the purposes of this water balance that the average type of soil for this site is a sandy loam which has 1.8 inches of available water per foot of soil.[6] Using an estimated root zone depth of 1 foot gives an average water holding capacity of approximately 2 inches. Infiltration greater than 2 inches will exceed the field capacity and result in ground water recharge. No adjustment has been made for the percentage of the site actually covered by vegetation.

Evapotranspiration

Evapotranspiration depends on climatic factors (i.e., precipitation, temperature, wind, and humidity), the type of soil, soil moisture, and vegetation. Evapotranspiration is estimated from an empirical methodology developed by C. W. Thornthwaite and J. R. Mather.[9] To account for the effect of soil moisture on calculated potential evapotranspiration (PET) rates, the soil moisture retention tables developed by Thornthwaite are also applied.

Table 4 summarizes the normal and past year's monthly temperatures and potential evapotranspiration (PET) rates for the site. The PET rates are based on the monthly temperatures and calculated indices using data from the Detroit Metropolitan Airport's weather station. An evapotranspiration correction factor is used to adjust potential evapotranspiration to the available sunlight at the latitude of the area. The details of these determinations appear in Tables 5 and 6.

The mean annual Class A Pan evaporation for the Detroit, Michigan area is approximately 41 inches per year. Applying an established empirical coefficient of 0.75 produces a potential annual evapotranspiration of 30.8 inches.[10] The mean annual lake evaporation has been determined to be 30.5 inches for the period of 1946 to 1955.[11] These values agree favorably with the normal annual value of 35.1 inches calculated by Thornthwaite's empirical methodology.

As would be expected, potential evapotranspiration rates are highest during the summer months and near zero during the winter. Table 4 indicates that 1980 has been significantly cooler than normal, and the PET values for the past year have averaged 29 percent below those calculated for the normal period of record.

When soil moisture is at or near field capacity, evapotranspiration occurs at its maximum potential rate. However, as soil moisture approaches the wilting point, i.e., moisture content below which moisture is unavailable for withdrawal by plants, the amount of water available begins to restrict the rate of evapotranspiration, resulting in reduced actual water losses. The water balance process takes this effect into account. Actual evapotranspiration rates are reduced during the period when soil moisture becomes depleted. The adjustment from potential to actual evapotranspiration is empirically calculated, based on soil moisture retention tables of Thornthwaite and Mather. This adjustment process will be discussed in the following section.

TABLE 4

BASF-WYANDOTTE
MONTHLY TEMPERATURE AND EVAPOTRANSPIRATION SUMMARY

	Temperature (°F)[1]		Potential Evapotranspiration (in.)[2]		
Month	Normal Monthly	Sept. 1979 to Aug. 1980	Normal Monthly	Sept. 1979 to Aug. 1980	Departure from Normal
Jan.	31.9	24.5	0.00	0.00	0.00
Feb.	34.3	22.2	0.03	0.00	-0.03
Mar.	43.8	31.3	0.50	0.00	-0.50
April	58.1	45.9	2.14	1.38	-0.76
May	69.1	59.8	4.20	3.43	-0.77
June	79.4	63.7	6.60	4.18	-2.42
July	83.4	72.7	7.42	5.49	-1.93
Aug.	82.0	72.7	6.52	5.09	-1.43
Sept.	74.8	62.6	4.54	3.29	-1.25
Oct.	64.1	50.5	2.47	1.56	-0.91
Nov.	47.8	39.9	0.67	0.52	-0.15
Dec.	35.4	31.9	0.05	0.00	-0.05
Average	58.7	48.1	-	-	
Total Annual	-	-	35.1	24.9	-10.2

[1]Temperature values are those recorded at Detroit, Michigan Metropolitan Airport. Normal values are based on the 1941-1970 period of record.

[2]Potential evapotranspiration values have been calculated according to the empirical methodology of Thornthwaite, C. W., and Mather, J. R., "Instructions and Tables for Computing Potential Evapotranspiration and Water Balance," Centerton, NJ, Drexel Institute of Technology Laboratory of Climatology Publication, Volume I, No. 3, 1957.

TABLE 5

NORMAL MONTHLY EVAPOTRANSPIRATION DATA

Month	Normal Monthly Temperature (T)[1] °F	°C	Heat Index[2]	Unadjusted Potential Evapo-transpiration[3] (in.)	ET Correction Factor[4]	Potential Evapo-transpiration
Jan.	31.9	-0.1	0.0	0.0	0.79	0.0
Feb.	34.3	1.3	0.13	0.03	0.88	0.03
Mar.	43.8	6.6	1.52	0.50	1.00	0.50
April	58.1	14.5	5.01	1.91	1.12	2.14
May	69.1	20.6	8.53	3.44	1.22	4.20
June	79.4	26.3	12.4	5.20	1.27	6.60
July	83.4	28.6	14.0	5.98	1.24	7.42
Aug.	82.0	27.8	13.4	5.67	1.15	6.52
Sept.	74.8	23.8	10.6	4.37	1.04	4.54
Oct.	64.1	17.8	6.84	2.69	0.92	2.47
Nov.	47.8	8.8	2.35	0.82	0.82	0.67
Dec.	35.4	1.9	0.23	0.06	0.76	0.05
Average	58.7	14.8	-	-	-	-
Total Annual	-	-	75.0	30.7	-	35.1

1) Normal temperature values are based on the record at Detroit, Michigan, Metropolitan Airport for the 1941-1970 period.

2) Heat index (i) $= \left[\frac{T(^{o}C)}{5}\right]^{1.514}$; Annual $I = \sum(i)$

3) Unadjusted Potential Evapotranspiration $= 0.63 \left[10 \frac{T(^{o}C)}{I}\right]^{a}$

where $a = (6.75 \times 10^{-7})I^3 - (7.71 \times 10^{-5})I^2 + (1.79 \times 10^{-2})I + 0.49$

4) ET Correction Factor, based on the mean possible monthly duration of sunlight at latitude of 42°, is used to multiply the unadjusted potential evapotranspiration to obtain the adjusted potential evapotranspiration.

TABLE 6

MONTHLY EVAPOTRANSPIRATION DATA
SEPT. 1979 TO AUG. 1980

Month	Year	Monthly Temperature (T)[1] °F	°C	Heat Index[2]	Unadjusted Potential Evapo-transpiration[3] (in.)	ET Correction Factor[4]	Potential Evapo-transpiratic
Jan.	80	24.5	-4.2	0.0	0.0	0.79	0.0
Feb.	80	22.2	-5.4	0.0	0.0	0.88	0.0
Mar.	80	31.3	-0.4	0.0	0.0	1.00	0.0
April	80	45.9	7.7	1.92	1.23	1.12	1.38
May	80	59.8	15.4	5.49	2.81	1.22	3.43
June	80	63.7	17.6	6.72	3.29	1.27	4.18
July	80	72.7	22.6	9.82	4.43	1.24	5.49
Aug.	80	72.7	22.6	9.82	4.43	1.15	5.09
Sept.	79	62.6	17.0	6.38	3.16	1.04	3.29
Oct.	79	50.1	10.1	2.9	1.70	0.92	1.56
Nov.	79	39.9	4.4	0.82	0.63	0.82	0.52
Dec.	79	31.9	-0.1	0.0	0.0	0.76	0.0
Average		48.1	8.94	-	-	-	-
Total Annual		-	-	43.9	21.7	-	24.9

1) Temperature and precipitation values are based on the record at Detroit, Michigan, Metropolitan Airport.

2) Heat index (i) $= \left[\frac{T(^{o}C)}{5}\right]^{1.514}$; Annual $I = \sum(i)$

3) Unadjusted Potential Evapotranspiration $= 0.63 \left[10 \frac{T(^{o}C)}{I}\right]^{a}$

where $a = (6.75 \times 10^{-7})I^3 - (7.71 \times 10^{-5})I^2 + (1.79 \times 10^{-2})I + 0.49$

4) ET Correction Factor, based on the mean possible monthly duration of sunlight at latitude of 42°, is used to multiply the unadjusted potential evapotranspiration to obtain the adjusted potential evapotranspiration.

Water Balance

The basic formula for the water balance accounting process is:

$$PERC = P - R/O - ST - AET$$

(Percolation) = (Precipitation) - (Surface Runoff)
- (Soil Moisture Storage)
- (Actual Evapotranspiration)

The four factors, discussed separately, have been determined and estimated on a mean monthly basis to create a water balance for the site. The normal monthly water balance is summarized in Table 7. The following paragraphs discuss the meaning and determination of each specified water balance factor on the table.

Precipitation (line 1), surface runoff (line 3), and potential evapotranspiration (line 5) have been discussed in the previous subsections. It was initially assumed that the surface runoff coefficient (line 3) remains a constant 0.3 for applying to each month's normal precipitation.

Infiltration (line 4) represents the amount of precipitation that enters the surface of the cover soil. It is simply the difference between the precipitation and the surface runoff (I = P - R/O).

Moisture excess and deficiency in the soil is necessary to obtain the difference between infiltration and potential evapotranspiration (I - PET in line 6). A negative value of I - PET indicates the amount by which infiltration fails to supply the potential water need of a vegetated area. A positive value of I - PET indicates the amount of excess water available during a month for elevating soil moisture and potentially recharging the ground water. The data on line 6 indicate that excess water is available from November through April, the so called "wet season".

The potential water losses to the atmosphere (i.e., negative values of I - PET from line 6) are accumulated or summed month by month in line 7. The negative total annual I - PET (-13.0 in line 6) indicates soil moisture is below field capacity at the end of the wet season. Therefore, Thornthwaite's method of successive approximations[9] is used to establish an initial value (-0.03 in line 7) with which to start accumulating the negative values of I - PET.

TABLE 7

WATER BALANCE

Water Balance Factor	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1) Precipitation (P)	1.91	1.73	2.47	3.22	3.31	3.42	3.10	3.28	2.16	2.48	2.32	2.27	31.7
2) Coefficient of Surface Runoff (C)	0.0	0.03	0.50	2.14	4.20	6.60	7.42	6.52	4.54	2.47	0.67	0.05	35.1
3) Surface Runoff R/O	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
4) Infiltration (I = P-R/O	0.57	0.52	0.74	0.97	0.99	1.03	0.93	0.98	0.65	0.74	0.70	0.68	9.5
5) Potention Evaportranspiration (PET)	1.34	1.21	1.73	2.25	2.32	2.39	2.17	2.30	1.51	1.74	1.62	1.59	22.2
6) I - PET	1.34	1.18	1.23	0.11	-1.88	-4.21	-5.25	-4.22	-3.03	-0.73	0.95	1.54	-13.0
7) $\sum$ Neg(I - PET)				(-0.03)	-1.91	-6.12	-11.4	-15.6	-18.6	-19.4			-
8) Soil Moisture Storage (ST)	2.00	2.00	2.00	1.97	0.72	0.08	0.03	0.03	0.03	0.03	0.98	2.00	-
9) ΔST	0.00	0.00	0.00	-0.03	-1.25	-0.64	-0.05	0.00	0.00	0.00	0.95	1.02	0.0
10) Actual Evapotranspiration (AET)	0.0	0.03	0.50	2.28	3.57	3.03	2.22	2.30	1.51	1.74	0.67	0.05	
11) Percolation (PERC)	1.34	1.18	1.23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.52	4.3

Notes

3) R/O = C(P)

4) I = P - R/O

11) PERC = P - R/O - ΔST - AET

All values, except the dimensionless surface runoff coefficient, are expressed in inches.

Soil moisture storage values (ST in line 8) are determined from Thornthwaite's soil moisture retention table (2 inch water holding capacity of soil root zone) using the summation values of negative I - PET (line 7) starting in April. After the soil moisture storage for each of the months with negative values of I - PET has been determined from the retention table, the positive values of I - PET (representing additions of moisture to the soil) are added to the previous month's ST values. No ST value can exceed soil moisture storage at field capacity, i.e., 2 inches. Any excess of I - PET above the maximum ST value becomes percolation or ground water recharge.

The Δ ST (line 9) represents the change in soil moisture from month to month.

Actual evapotranspiration (AET in line 10) represents the actual amount of water loss to the atmosphere during a given month. For those months where I - PET is positive (November through March), the rate of evapotranspiration is not limited by moisture availability, and actual is equal to potential evapotranspiration. For those months where I - PET is negative, soil moisture is below field capacity. The rate of actual evapotranspiration is limited by the soil moisture availability and is calculated from the formula : $AET = I - \Delta ST$.

Percolation values (line 11) are calculated monthly by solving the water balance equation: $PERC = P - R/O - \Delta ST - AET$. After the soil moisture storage reaches its maximum, any excess infiltration becomes percolation or ground water recharge. Therefore, significant ground water recharge will occur only during those months when I exceeds PET (i.e., I - PET is positive) and the soil moisture exceeds its maximum.

For the assumptions of the water balance at Wyandotte, Michigan, Table 7 shows a net ground water recharge during the months of December through March, which amounts to 4.3 inches of the total normal annual rainfall of 31.7 inches.

The ground water recharge calculated by the water balance methodology represents theoretical net ground water recharge to the ground water system in the area of the site during an average precipitation year. It does not fully represent local recharge from a wet year to the shallow perched flow system trapped in the fill and soil deposits, which is controlled by infiltration. The calculated ground water recharge

is, therefore, thought to be more representative of a properly graded site for a normal precipitation year. Actual recharge rates on this site for the current year could exceed the calculated value of 4.3 inches. However, large amounts of recharge would leave relatively quickly through the numerous outflow mechanisms described in the following subsection, Stormwater.

Precipitation and potential evapotranspiration are the two factors with the fewest sources of error in computing the monthly water balance for the site. Both are dependent on climatological data collected for a 30-year period of time at the Detroit Airport, 10 miles away.

The critical surface runoff and soil moisture factors are estimated from site observations and guidelines in Thornthwaite's water balance methodology. Table 8 presents a sensitivity analysis for these factors and their impact on percolation. There is a greater potential for ground water recharge or percolation with lower runoff and soil moisture storage capacity values.

Stormwater

Several sets of observations were made on the site immediately following rainstorms. During May, a 0.37 inch rainstorm over a two-hour period produced very little surface runoff. During June, a 1.02 inch rainstorm over a one-hour period produced large quantities of stormwater runoff. This storm was equal to the one year one hour rainfall storm.[12] During both storms, depression accumulation of water on the site was significant.

The majority of water from the May storm infiltrated into the soil on the site or formed shallow puddles. Very little water was observed to have immediately entered the drainage system of the area. However, the next day seeps along Central Avenue had noticeably increased in flow to the area's external drainage system. This suggests a delayed response from an interflow component of direct runoff and is consistent with the perched water table described previously. It is likely that the stormwater followed a relatively short path in the permeable material above the shallow ground water flow system and quickly appeared at the water outflow areas. Very little mixing occurred between this interflow water and the resident perched water within the fill materials.

TABLE 8

NORMAL WATER BALANCE

SENSITIVITY ANALYSIS

Trial	Surface Runoff Coefficient	Annual Surface Runoff (in.)	Soil Moisture Storage Capacity (ST) (in.)	Annual Percolation (in.)
Assumed Conditions	0.3	9.5	2	4.3
Low ST	0.3	9.5	1	5.2
High ST	0.3	9.5	6	0.7
Low R/O	0.15	4.8	2	8.4
Low R/O, High ST	0.15	4.8	6	11.1
High R/O	0.5	15.9	2	2.5

Runoff from the June storm was heavy enough to overtax the stormwater collection systems surrounding the site and resulted in temporary street flooding. Observations of flooded areas, directions of flow, and flow volumes immediately after the storm (Figure 4) indicate that major depressions on the site fill and act as temporary storage areas and infiltration-evaporation ponds. This serves to reduce the ultimate volume of surface runoff and increase interflow and shallow perched water recharge.

When the depression storage areas on the site become totally flooded, several drainage machanisms serve to reduce the load (Figure 4).

1) The ballast beneath the railroad tracks that divides the property acts as a French drain and transmits excess water toward several of the drainage systems of the area.

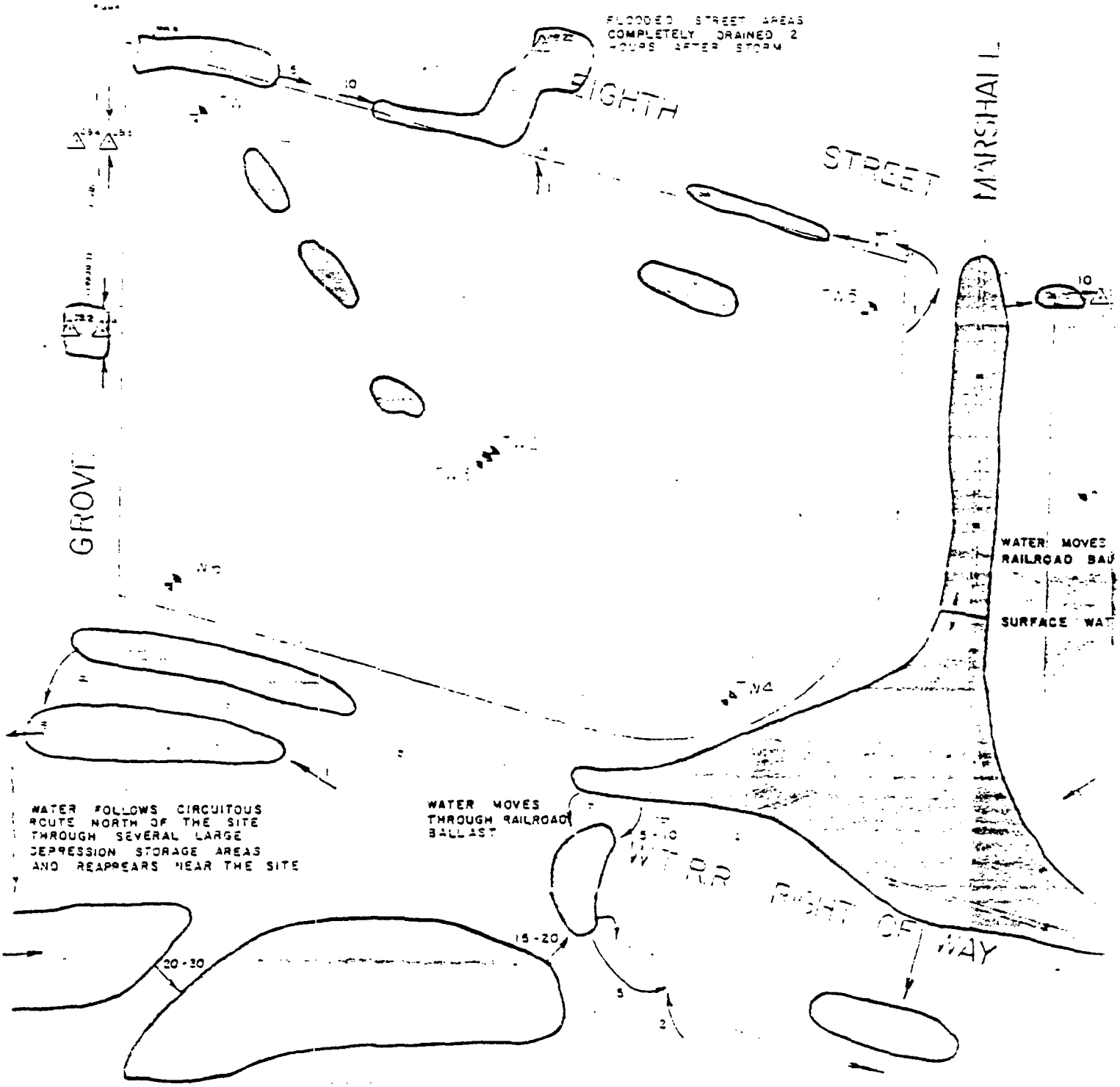
2) Seeps along Central Avenue allow for the outflow of large quantities of storm water along with their normal perched water. This starts immediately after a storm and may continue for several days. Visible separation of the gray-brown stormwater and the colored perched water, in addition to the variable flow of the stormwater and relatively constant flow of the perched water, indicate that mixing does not take place. This is further evidence of the "bathtub" effect on the property.

3) The west ditch collects both surface runoff and seepage from the site.

4) The swales and storm drains of Eighth Street, Grove Street, and Central Avenue receive "normal" runoff from over half the site.

5) The railroad ballast west of the site absorbs large quantities of stormwater from the site.

FIGURE - 4, STO



SURFACE WATER MOVEMENT AND ESTIMATED DISCHARGE IN GALLONS PER MINUTE

PONDED WATER ON 6/7/80 1-2 HOURS AFTER RAIN STOPPED.

STRUCTURE RECEIVING STORMWATER DISCHARGE

NOTE: 1.02 INCHES OF RAIN (MEASURED AT DETROIT METROPOLITAN AIRPORT) IN ONE HOUR.

WATER RUNOFF ON 6/7/80

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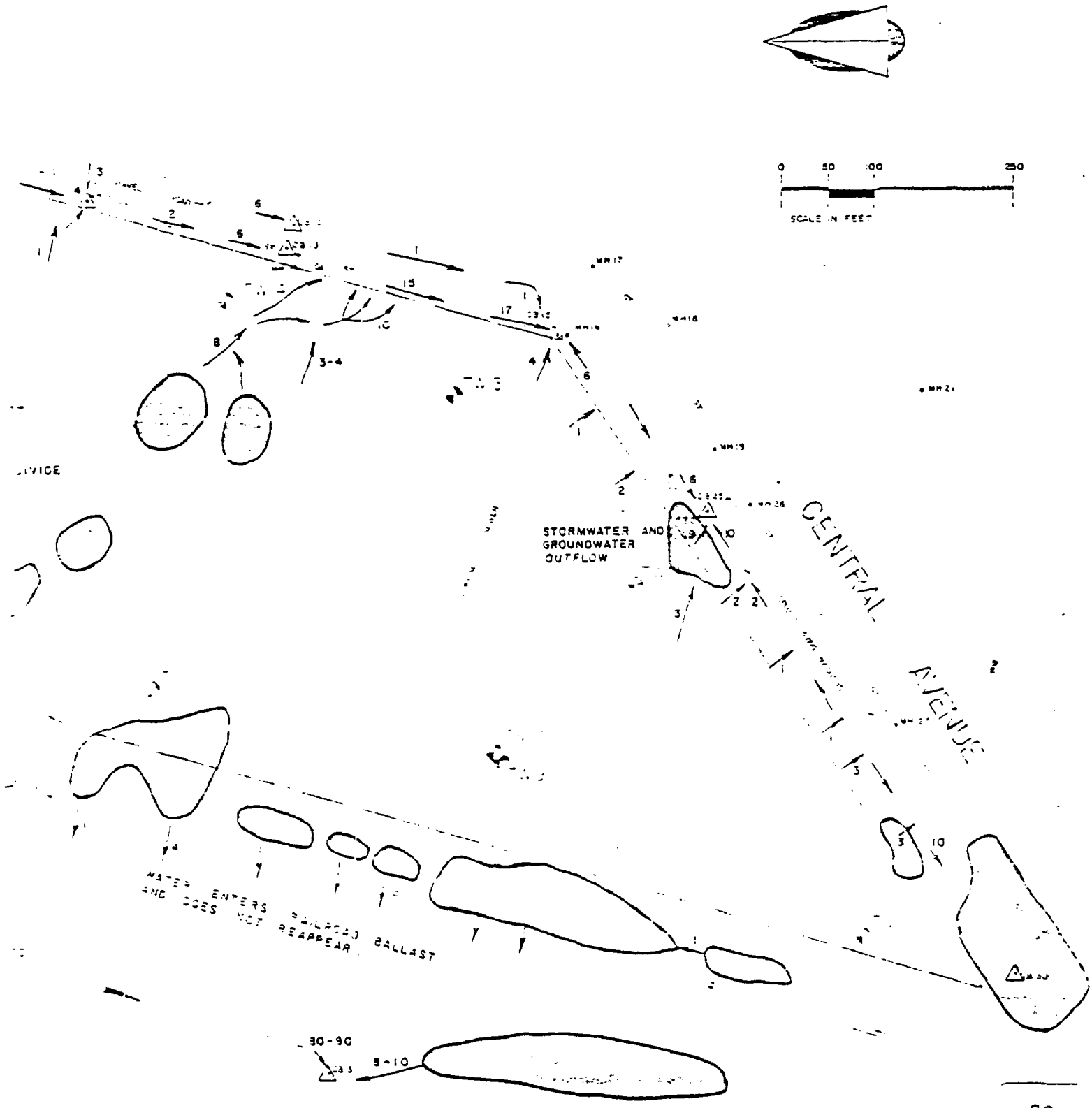


Summary

In summary, a small storm of low intensity will not produce surface runoff but will increase activity of the seeps by interflow. Significant quantities of water are held on the site in depression storage. This water will slowly infiltrate to the shallow perched flow system or will evaporate. After a major storm when the depression storage is full, water drains from the site through several drainage paths. Major water outflow areas are the west ditch, the drainage swales, and the storm drains.

WATER QUALITY

Introduction

More than 1390 analyses have been made to determine water quality at the Central Avenue site. This determination was based on the collection of 29 water samples on the dates of June 12, July 18, and September 16-18, 1980, from test wells, ponds, seeps, and drainage channels (Figure 5). Analyses were made for both inorganic and organic constituents. These analyses are given in Appendices B and C respectively. All samples were split with BASF Wyandotte at the time of sampling. Field measurements were made for temperature, pH, and specific conductance.

Water quality can be altered by chemical, biological, and physical impurities. The water quality data collected for this project deal mainly with: 1) the common dissociated ions which constitute nearly all dissolved inorganic material; and with 2) the organic compounds and metals specified by EPA as priority pollutants. Certain other properties of the water such as hardness, alkalinity, specific conductance, total dissolved solids, and chemical oxygen demand were included in the water analyses to better characterize the water. Minor dissolved constituents such as iron, manganese, forms of nitrogen (other than nitrate), and organic carbon were also included.

Thus, the water quality data collected for this project dealt mainly with constituents that would be indicative of the chemical character of the water. Some data were gathered on physical constituents such as color, temperature, and odor.

It should be emphasized that the four-month sampling period covered by this investigation was unusually wet and cool. This climatic condition, as explained earlier in the Hydrology section, precluded dry weather conditions that would normally be expected late in the summer and also precluded a determination of any changes in water quality that may be associated with dry weather conditions. Sampling coverage was also confined to the site and to a relatively shallow depth.

Sampling and Analytical Procedures

The sampling program was conducted in two phases. First, wells and surface water sources were sampled and analyzed for ground water quality characteristics, ions, and conventional pollutants. Second, certain locations were resampled and analyzed for priority pollutants.

General Ground Water Characterization

Water quality samples were collected on June 12, July 18, and September 16, 1980 from all or some of the 14 test wells and six surface water sources where ground water outflow was known to occur. All wells were developed one week prior to sampling by surging with a hand-operated device and by slow pumping with a diaphragm pump or slow bailing. The pump, bailer, surge apparatus, and all accessories were washed with laundry detergent, rinsed thoroughly with tap water, and air dried each time before use in every well. All wells were completely purged of water a few days prior to sampling. Wells that recovered sufficiently rapidly (see Appendix A) were evacuated to at least the volume of the casing immediately prior to sampling. NO!

Water was drawn from the twelve shallow wells (TW-1, 3-8, 10-14) with a hand-operated diaphragm pump and from the two deeper wells (TW-2, 9) with a bailer. The pump was a "Guzzler" brand, made from chemically resistant Delrin plastic with a reinforced Buna N rubber diaphragm and wire reinforced vinyl hose. Surface water was collected as grab samples. NO!

Field measurements of pH and specific conductance were made at the time of sampling with portable meters and were repeated in the laboratory. Temperature was measured immediately after a ground water sample was withdrawn or in-place for surface water samples.

Samples were collected and analyzed by personnel from Hydro Research Services in Pontiac, Michigan. Field collection of the samples was under the direction of ERM. The sampling schedule is summarized in Table 9.

Containers of samples for metals, hardness, COD, nitrogen compounds, and phenols were preserved according to sample volume and pH, with appropriate chemical additives. All samples were chilled with ice immediately following collection and were delivered to the laboratory within a few hours after collection. All laboratory procedures were conducted in accordance with "Standard Methods for the Examination of Water, Sewage, and Industrial Waste" (APHA/AWWA/WPCF).

TABLE 9

SUMMARY OF WATER QUALITY SAMPLING SCHEDULE

Date	Collection	Laboratory	Location (see Figure 5)	Parameters (Appendix B, C)
5/12/80	Hydro Research, ERM, BASF-W	Hydro Research	Six surface water points - TW-1, 3-8, 10-14	Major ions, minor constituents, water properties, phenols (except TW-11), physical, field tests
7/18/80	Hydro Research, BASF-W	Hydro Research	TW-2, 9	Major ions, minor constituents, water properties, phenols, physical
			TW-11	Phenols only
9/16/80	Hydro Research, ERM	Hydro Research	TW-5, 13, SW-2	Major ions, minor constituents, water properties, phenols, physical, field tests
			TW-2	Phenols, TOC, field tests
9/17/80	ERM, BASF-W	Compu/Chem	TW-1, 4, 5, SW-2	Priority pollutants (organic compounds and metals)
9/18/80	ERM, BASF-W	Compu/Chem	TW-10, 13	Priority pollutants, (organic compounds and metals)

Priority Pollutants

Samples for priority pollutants (organic compounds and metals) were collected by ERM on September 17 and 18, 1980 in a manner similar to the collection procedure for earlier samples. Wells TW-1, 5, 10, and 13 (all shallow wells) were purged at least once during the three days prior to sampling. Additionally, several gallons of water were pumped from TW-5 immediately prior to sampling. Due to the limited volume and extremely slow recovery rate (Appendix A), TW-4 was not purged during the week prior to sampling.

Water was drawn from wells TW-1, 4, 5, 10, and 13 with the hand-operated diaphragm pump, described earlier, and collected in glass beakers. The sample collected from the seep along Central Avenue was a grab sample. The beakers were used to fill "pre-preserved" sample containers in sampling kits provided by Compu/Chem of Research Triangle Park, North Carolina. Samples were split with BASF Wyandotte at the time of sampling.

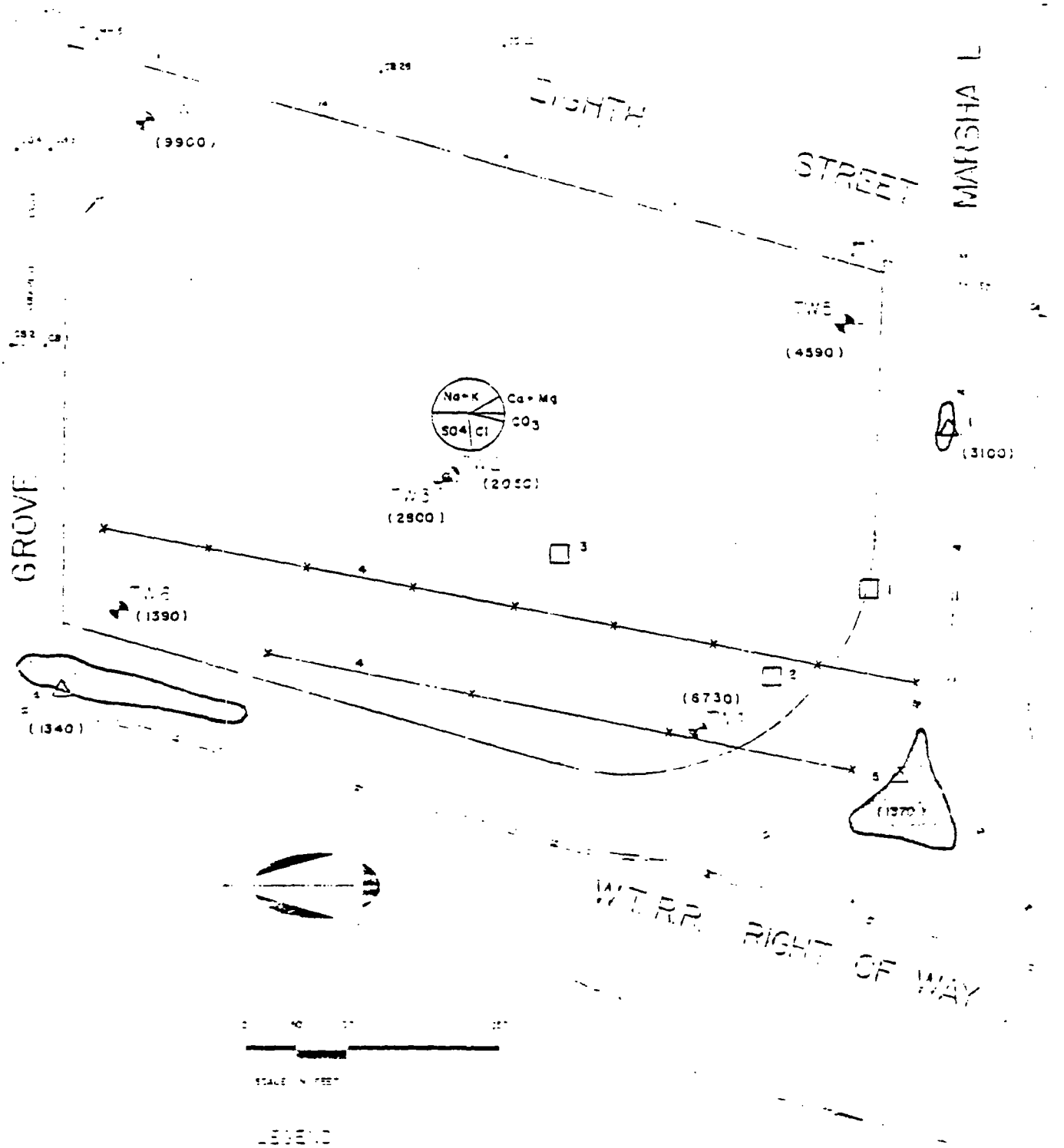
The samples were chilled with ice packs immediately following collection. The kits were shipped to the laboratory and received within 24 hours after collection. All EPA protocols for sample preparation, analysis, quality, assurance, sample custody, and document control were met or exceeded. Both the field and analytical methodology are detailed in Appendix C. Sampling schedules are summarized in Table 9 and detailed in Appendix C.

Ground Water Quality Analysis

Results of the numerous analyses for inorganic constituents, physical properties, and some organics are presented in Appendix B and are summarized in Table 10. Figures 5 and 6 show the chemical characteristics of both surface and ground water for select parameters by location on the property and location within the various water systems on the property, respectively.

Priority pollutant analyses are presented in Appendix C and summarized in Table 11.

FIGURE - 5, WATER QUALITY SAMPLES & CHE



NOTE: ANALYSES REPRESENTED BY CIRCULAR DIAGRAMS SUBDIVIDED ON THE BASIS OF PERCENTAGE OF TOTAL MILLIEQUIVALENTS PER LITER.

CHARACTER OF THE WATER

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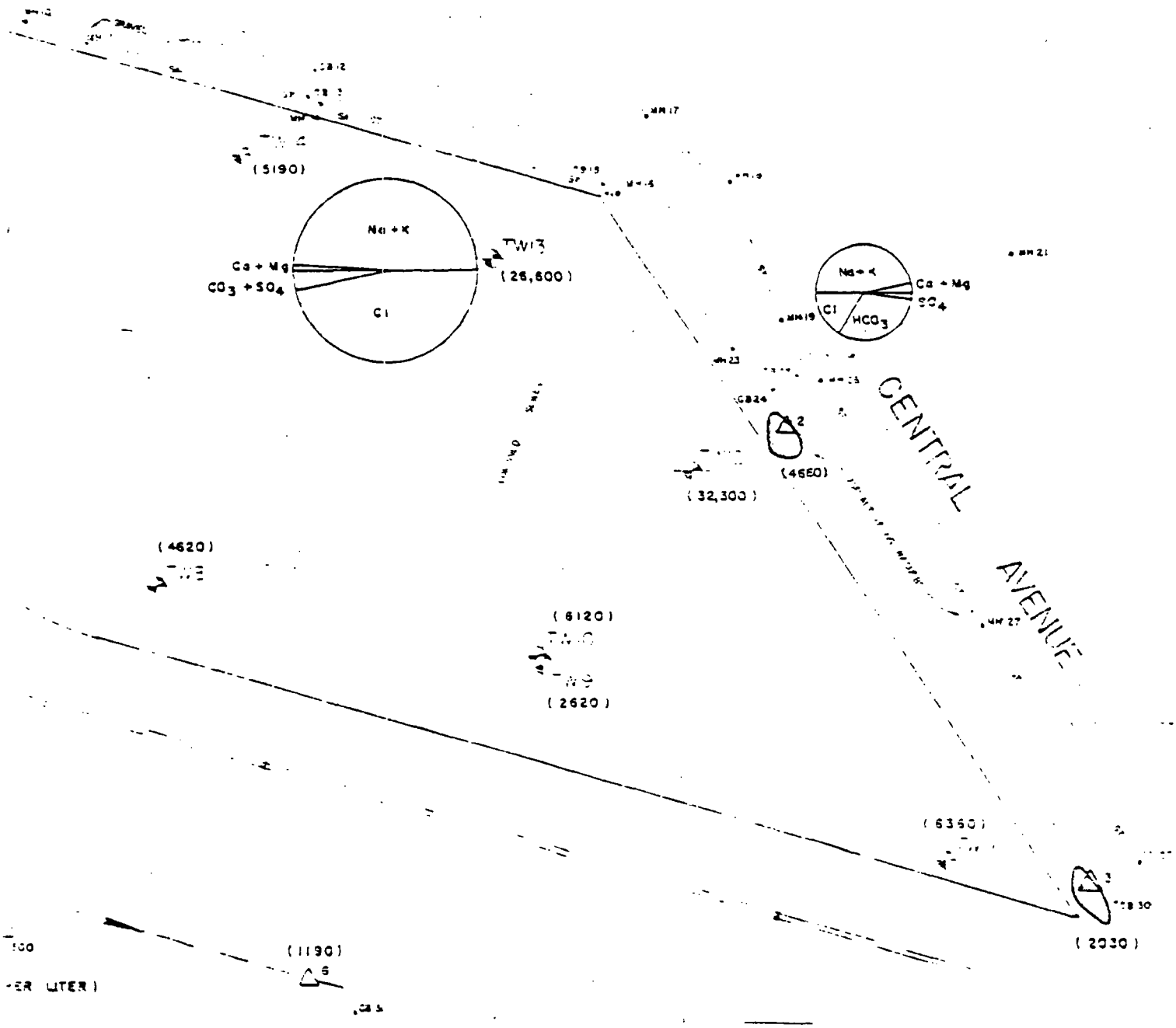

FIGURE - 6

ION CONCENTRATION DIAGRAMS FROM SELECTED SAMPLING POINTS

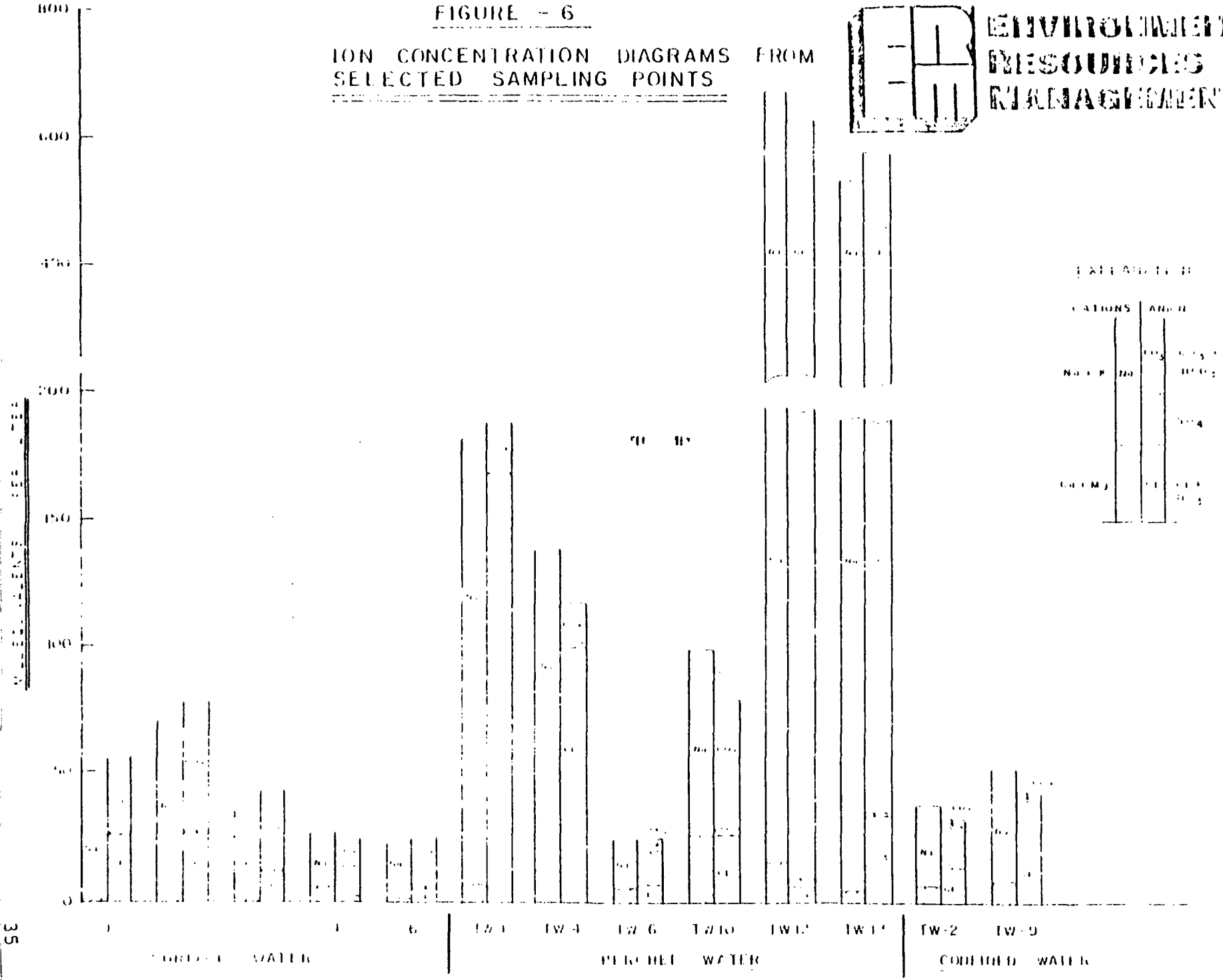

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TABLE 10

SUMMARY OF DETECTABLE ANALYTICAL DATA

Sampling Point	Color	pH (Units)	Specific Conductance µmhos/cm (Lab)	Temperature °C	pH (Lab)	Specific Conductance µmhos/cm (Lab)	Hardness, Total as CaCO3, mg/l	Alkalinity, Total as CaCO3, mg/l	Solids, Total Diss., mg/l	Carbonate, Alkalinity as CaCO3, mg/l	Bicarbonate, Alkalinity as CaCO3, mg/l	Chloride, Cl, mg/l	Sulfate, SO4, mg/l	Phenol, mg/l	Total Organic Carbon, mg/l	C.O.D., mg/l	Nitrogen Kjeldahl, N, mg/l	Nitrogen Nitrate, N, mg/l	Nitrogen Nitrite, N, mg/l	Nitrogen Ammonia N, mg/l	Manganese Mn, mg/l	Magnesium Mg, mg/l	Calcium Ca, mg/l	Potassium K, mg/l	Sodium Na, mg/l	Iron Fe, mg/l	Lead Pb, mg/l	Mercury Hg, mg/l
TW1 6/13/80	3200	10.5	>10000	14.5°C	11.16	>10000	34	560	9900	520	0	3460	4800	38	140	1000	10	<0.05	0.30	3.5	0.13	4.4	100	98	4000	3.1	0.31	20
TW2 7/16/80	30	10	2900	19°C	9.49	3300	240	46	2050	36	10	470	820	120	181	181	3.9	0.03	0.02	2.2	<0.002	1.4	130	9.0	700	0.06	<0.02	0.37
9/16/80	-	9.3	2300	16°C	-	-	-	-	-	-	-	-	-	16	203	-	-	-	-	-	-	-	-	-	-	-	-	-
TW3 6/13/80	35	11.6	5900	15°C	12.06	4700	270	1960	2800	280	0	400	170	15	41	150	6.1	<0.05	0.22	4.0	0.030	0.75	190	70	1100	0.50	<0.02	30
TW4 6/13/80	150	11.0	10000	15°C	11.16	8300	210	510	6710	400	110	3540	71	37	360	1240	12	<0.05	1.3	3.2	1.6	60	1100	48	1800	50	0.6	26
TW5 6/13/80	800	9.1	6600	14.5°C	9.26	6200	110	670	4200	400	410	1120	100	1640	53	160	11	0.07	1.4	3.5	0.070	26	20	280	1600	0.56	<0.02	1.1
9/16/80	1000	8.7	6100	19°C	8.16	4200	140	960	3030	80	880	390	1830	8	35	180	9.5	0.12	0.07	4.0	0.082	15	2.0	250	1000	2.5	0.32	1.5
TW6 6/13/80	50	7.5	1800	15.5°C	8.10	2000	290	240	1390	0	240	200	700	31	53	140	4.7	<0.05	<0.02	0.60	0.39	31	110	50	350	3.5	<0.02	0.3
TW7 6/13/80	1500	11.0	4000	14.5°C	11.15	4000	42	530	3530	340	0	54	38	650	26	93	33	0.05	1.2	5.0	0.32	6.0	50	50	600	3.5	0.10	0.3
TW8 6/13/80	600	11.7	>10000	15°C	12.15	>10000	26	1350	4620	500	70	280	450	380	48	350	9.6	<0.05	0.12	4.7	0.041	2.9	100	190	1400	3.5	<0.02	9.7
TW9 7/16/80	500	9.0	3600	19°C	7.34	4300	310	70	2620	0	70	810	790	6	24	207	3.9	<0.02	0.07	1.1	0.10	45	120	21	970	2.4	<0.02	0.55
TW10 6/13/80	300**	11.3	8100	19°C	11.06	7900	170	2260	6130	1420	0	980	110	740	180	630	13	<1*	<1*	0.80	3.3	36	510	85	1600	100	0.14	3.3
TW11 6/13/80	700**	10.5	5400	19°C	10.30	5000	100	2260	8360	620	1540	630	56	-	520	4700	26	<1*	<1*	6.6	2.0	25	270	85	2000	65	0.10	4.4
7/16/80														111														
TW12 6/13/80	300	9.4	>10000	16.5°C	9.69	>10000	340	240	32300	130	120	22000	65	140	280	660	2.4***	<0.05	0.05	12***	0.17	13	350	110	15000	4.5	0.36	2.0
TW13 6/13/80	2000	11.3	>10000	16°C	11.95	>10000	120	2930	26600	1030	0	19000	33	670	500	1370	14***	<0.05	0.14	45***	0.10	3.3	90	65	12000	3.5	0.20	33
7/16/80	3000	11.3	>10000	20°C	11.64	20750	380	3100	35300	1760	0	11900	205	955	940	5870	150	0.14	0.09	83	0.13	3.5	4.6	82	8000	4.6	0.35	91
TW14 6/13/80	50	3.5	8500	19.5°C	7.80	4900	220	930	5190	0	730	2800	490	330	140	570	8.95	<0.05	<0.02	0.40	4.8	130	1000	14	2500	31	0.20	0.3
SW 1 6/13/80	Dark	1800	10.3	4800	22.5°C	10.20	4100	46	1040	3100	860	0	860	41	3	27	89	5.3	<0.05	0.24	0.06	0.022	1.1	8.5	68	1100	0.42	<0.02	1.5
SW 2 6/13/80	Dark	2500	11.5	7600	23°C	11.55	3600	23	2160	4600	1500	0	950	50	14	51	160	10.0	<0.05	0.10	3.6	0.10	4.1	49	330	1500	3.1	<0.02	4.1
9/16/80	Dark	2500	10.4	5600	20°C	10.23	5500	340	1800	4460	1760	120	850	360	53	75	460	12	0.14	<0.02	2.6	0.15	6.0	2.5	90	1400	7.5	0.55	15
SW 3 6/13/80	Dark	1500	8.8	2700	18°C	9.84	2800	35	1130	2030	900	230	350	39	2	36	93	6.5	<0.05	0.15	0.25	0.086	4.5	20	35	800	0.70	<0.02	0.53
SW 4 6/13/80	Dark	70	8.6	1800	18.5°C	8.16	1900	280	730	1340	0	730	61	400	<2	15	85	1.3	<0.05	<0.02	0.10	0.055	40	50	50	440	1.0	<0.02	3.9
SW 5 6/13/80	Dark	150	8.4	2000	20.5°C	8.50	2200	110	450	1370	40	410	430	20	2	13	65	1.7	<0.05	0.02	0.17	0.063	22	40	50	600	1.4	<0.02	1.4
SW 6 6/13/80	Dark	610	9.5	1700	19.5°C	9.90	1400	42	630	1120	880	0	310	18	<2	<10	26	1.7	0.74	0.98	0.42	0.015	4.9	15	30	500	0.20	<0.02	0.5

TW = Test Well
SW = Surface Water Sampling Point

1/ Excluding priority pollutant analyses performed by CONMU/CHEM which are shown in Table 11.

* Interferences present preclude quantification below this concentration. The reported value is an upper limit of detectability established by the degree of interference. Intensive sample clean up techniques would be required to improve upon the detection limit.

** pH was adjusted to 7. Color on sample as received was approximately 11.000 - 12.500.

TABLE 11

SUMMARY OF DETECTABLE ORGANIC COMPOUNDS[1]

Organic Compound (µg/l)	TW-1	TW-4	TW-5	TW-10	TW-13	SW-2 (Seep)	Detection Limit[2]	Major Category of Compound
1-2 Dichloroethane	29	36	43	19000*	BDL	89	10	
1-2 Dichloropropane	BDL	BDL	BDL	17	BDL	BDL	10	
Methylene Chloride	BDL	BDL	BDL	BDL	11	BDL	10	Halomethanes
Toluene	BDL	130	BDL	BDL	190	BDL	10	
Vinyl Chloride	BDL	BDL	BDL	>10000*	BDL	19	10	
Phenol	50	BDL	BDL	BDL	29	BDL	25	
BIS(2-Ethylhexyl) Phthalate	88	BDL	140	250	340	32	10	Phthalate Ester
Di-N-Butyl Phthalate	BDL	BDL	BDL	BDL	24	BDL	10	Phthalate Ester

[1]All analyses performed by Compu/Chem (Appendix C).

[2]Promulgated by EPA, December 3, 1979 Federal Register

BDL - Below Detection Limit

*Saturated Ions

The data shown on Table 10 indicate a relatively wide variation in the concentration of certain parameters, particularly phenol and mercury. Comparison of concentrations for these same parameters for the analyses conducted by Hydro-Research Services and Compu/Chem also indicate a relatively wide variation. The reasons for these variations cannot be specifically explained, rather they would most probably relate to one or more of the following variables: different sampling dates; different laboratories sensitivity for analysis in low concentration; imprecision in laboratory technique; the "chemistry" of these elements, particularly phenol; and sample preservation. It is not uncommon to see wide ranges reported by several analytical laboratories on the same sample.

Asbestos Analyses

Three integrated soil samples from depths of 0-3 feet were collected by hand augering (Figure 5) for asbestos analysis. In addition, a composite sample was collected from a surface traverse (Figure 5). All of these samples were from an area on the site where asbestos was known to have been stored during the mid-1960's. Results of the asbestos analyses are given in Appendix D. They indicate that chrysotile type asbestos is present.

Compatability with Common Construction Materials

Water quality beneath the site can have a definite impact on common construction materials. Structures, a consulting engineering firm which ERM utilized as a materials specialist, described the effects of combinations of elevated constituents in the shallow ground water on common construction materials such as concrete, masonry, wood, steel, asphalt, and materials used for plumbing and electrical construction. Common procedures to treat construction materials so as to avoid disintegration from mineralized water and soil were also identified where appropriate. The complete letter report is included as Appendix E.

Structures concluded that major potential problems do exist for building on this site relative to the possibility of electro-chemical and electrolytic reactions affecting metallic building materials and the probable appearance of a florescence problem affecting all concrete and masonry. Protective measures for these conditions and the proper control of the shallow ground water table, however, would allow a suitable final design approach to be developed for building.