APPENDIX 2A

PROBABLE MAXIMUM FLOOD AND LOW WATER CONDITIONS

R. E. Ginna Plant

Reports by R.O. Eaton

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RICHARO 0. EATON. P. E.
CONSULTING ENGINEER

August 13, 1968

Subject: Robert Emmett Ginna
Nuclea Power Plant
Rochester, New York
Wave Runup Analysis

Mr. Wm. W, Lowe
Pickard, Lowe and Associates
Suite 1104, 1730 - M. St., N.W.
Washington, D.C. 20036

Dear Mr, Lowe:

Pursuant to your request I have conducted a study of wave runup under Probable Maximum Hurricane conditions (as established in my prior report, March 28, 1968).

The enclosed report by my Associate, Mr. T.E. Haeussner, presents this study in detail. I have carefully checked Mr. Haeussner's analysis and I concur in his conclusions, i.e., that there will be essentially no wave runup on the vertical plant wall. The rubble mound breakwall adequately intercepts nearly all of the wave energy and the small amount of overtopping will be almost entirely attenuated in the canal between the rubble structure and the plant wall. During winter months ice accumulation along the breakwall will probably entirely eliminate overtopping.

In summary, it is my considered opinion that there will be no hazard to plant operation due to wave runup.

Sincerely yours,

Richard O. Eaton

ROE:w
Encl. Haeussner Report

2A.1 ESTIMATE OF WAVE RUNUP ON VERTICAL PLANT WALL ROBERT EMMETT GINNA NUCLEAR POWER PLANT ROCHESTER, NEW YORK

2A.1.1 GENERAL

Accurate determination of the magnitude of wave runup to be expected on the vertical plant wall during an occurrence of the maximum probable Tropical Storm requires consideration of the following factors:

a. Maximum water level at the plant site.

b. Design wave conditions (height, period, etc.).

c. Near-shore topography.

d. Site conditions, i.e., ground elevations, structural measures and detail.

Waves approaching the plant site will be affected by water depths in the vicinity of the plant site, will break and runup on existing (or proposed) shoreline structures, and will overtop and move forward toward the plant wall. An evaluation was made, as described below, of each of the above factors, insofar as it will affect the mechanics of the height of wave runup on the vertical plant wall.

2A.1.2 DISCUSSION OF FACTORS

The Maximum Water Level to be expected in Lake Ontario at the plant site is 250.78 ft MSL, as indicated in *Reference 1*. That level would result from an occurrence of the probable maximum Tropical Storm over Lake Ontario. This factor together with near-shore topography, determine the breaking depth of water fronting the plant site. The various components comprising that elevation are outlined in that reference report.

Design Wave Conditions. The significant wave height and period resulting from an occurrence of the design storm as determined in *Reference 1*, would be 19 ft and 9.7 seconds, respectively. That wave, and its characteristics, would be affected by near-shore depth conditions as it approached the plant site.

Near-Shore Topography. An offshore bottom profile extending northward in Lake Ontario from the plant site is shown on Enclosure 1. Data were obtained from U. S. Lake Survey Map No. 23, dated 1962. The peak water level at shore is also shown on that sketch together with a pertinent portion of the setup water surface profile extending lakeward.

Site Conditions were obtained from Construction Print, Drawing No. 33013-171 c, printed June 12, 1968, R. G. & E. Eng. Dept. The plant is fronted by an armor stone breakwall with an approximate 1 on 1 slope from lake bottom to elevation 254 ft MSL. Concrete paving (@ elev. 253 ft MSL) will extend shoreward from the breakwall a variable distance (20-25 ft) to the discharge channel. That channel has a 1 on 1 sideslope with 30 ft bottom width at elevation 238 ft MSL. A concrete overhang deck (@ elev. 253.5 ft MSL) extends from the south channel wall 100 ft to the vertical plant wall. Waves overtopping the armor stone breakwall

will move across the paved area to the discharge channel and, conditions permitting, across the overhang deck to the plant wall.

2A.1.3 ANALYSIS

Standard procedures, described in *Reference 2*, were used to evaluate the effective water height, runup, and overtopping relationships involved in this problem. The breaking depth (d_b) affecting the design wave was taken from Enclosure 1 at a 100-ft distance lakeward of the armor stone breakwall, and is estimated to be 9.4 ft (250.8 ft-241.4 ft). The breaking wave height (H_b) is equal to 0.78 of that depth, or 7.3 ft. According to Equation 1-37 of *Reference 2* the equivalent deep water wave height

$H'_o = (1.837/T)\,(d_b)^{3/2} = (1.837/\,9.7)\times(9.4)^{3/2} = \underline{5.3\ \text{ft}}$

Parametric relationships relating to wave runup on rubble-mound slopes to the wave height period ratio are given on Figure 3-12 of *Reference 2*. The latter ratio

$$\frac{H_0'}{T^2} = \frac{5.3}{94} = \underline{0.563}$$

(Equation 1)

The slope of the armor stone breakwall is approximately 1 on 1, requiring interpolation of the runup curves on Figure 3-12. Entering that figure with the ratio 0.563, an R/H'_o value of 0.63 was obtained, giving a runup value of R = 3.34 ft. Adding that value to the peak wind tide elevation results in a wave runup elevation of 254.12 ft.

2A.1.4 DISCUSSION

The elevation of the armor stone breakwall fronting the plant site is 254.0 ft. Based on the computed wave runup the depth of overflow over the breakwall and onto the paved area fronting the discharge channel would be 0.12 ft per wave. That overflow would be blown into the discharge channel; as the water level in the channel exceeds the peak tide level outflow will occur to the lake. The water surface elevation in the discharge channel is therefore not expected to exceed the peak tide elevation by about 1 ft. Since the width of the discharge channel fronting the plant site is less than 30 ft width there will be no possibility of wave generation across that channel. Any wave action entering the channel from the lake will be dampened somewhat by friction and will run up the side slope of the channel and pond in the area east of the plant site.

2A.1.5 CONCLUSIONS

Based on the above analysis the following conclusions are drawn:

1. There will be no wave runup against the vertical plant wall during an occurrence of the design Tropical Storm.

2. Wave action entering the discharge channel will runup the channel side slope east of the plant and pond in the area indicated on Construction Print Drawing No. 33013-69 as the site for "Future Screen House", but will not affect the vertical plant wall.

Submitted by,
/s/ Theodore E. Haeussner
Hydraulic Engineer, Consultant
Jacksonville, Florida
August 3, 1968

Enclosures

1. Lake Ontario Bottom Profile
2. References.

REFERENCES

1. Haeussner, Theodore E., "Maximum Probable Water Levels for Robert Emmett Ginna Nuclear Power Plant, Lake Ontario". March 26, 1968.

2. U. S. Army Coastal Engineering Research Center, "Shore Protection, Planning and Design", Technical Report No. 4, Third Edition 1966. Department of the Army, Corps of Engineers.

2A.2 MAXIMUM PROBABLE WATER LEVELS IN LAKE ONTARIO AT THE ROBERT EMMETT GINNA NUCLEAR POWER PLANT SITE

Report dated
March 28, 1968

2A.2.1 INTRODUCTION

OBJECTIVE The basic objective of this report is to establish the "probable maximum" and "minimum" water levels to be expected in Lake Ontario at the Robert Emmett Ginna Nuclear Power Plant site near Rochester, New York; those levels to be based upon a set of conditions whose individual and collective occurrence frequency are sufficiently rare so as to provide a very high degree of plant safety.

PROBLEM The combination of conditions ultimately selected requires a detailed evaluation of the various hydrological and meteorological factors and events which can reasonably be expected to occur in the area. Hydrologically it involves the normal seasonal regulation criteria and levels prescribed for Lake Ontario, with due cognizance of unusual events or circumstances which could affect those levels and/or operating criteria. Meteorologically it involves consideration of both extratropical and tropical cyclonic storm occurrence, their paths, intensity, and frequency with respect to Lake Ontario, as well as their overall effect in terms of accompanying rainfall, winds, seiches or tides generated, pressure effect, and associated wave action. The element of time is also involved as it relates to lake stage, i.e., the most likely time of the year when deep intense extratropical cyclones occur as compared with the seasonal limitation on the occurrences of tropical storms, or hurricanes. Each of these meteorological factors and elements are examined below the evaluated in terms of their probable occurrence and effects in relation to the hydrologic conditions involved.

2A.3 ANALYSES OF ALTERNATIVE HYDROLOGIC AND METEOROLOGIC CRITERIA

A. LAKE ONTARIO REGULATION

GENERAL Water level records have been maintained for Lake Ontario since 1860 providing some 108 years of record. During that period the average lake stage has been about 246 feet above MSL (USC&GS 1935 Datum). Extreme ranges in monthly average stage have been from a low of about 242+ feet in 1934 to a high of about 249+ feet in 1952. The normal annual variation in lake levels is seasonal, ranging from low levels in November February (as a result of freezing temperature and more solid forms of precipitation), rising to maximums in May and June from Spring snowmelt and rainfall. Local short period extremes in stage have been observed around the lake perimeter and have resulted from wind action creating seiches at the extreme east and west ends of the lake, with minimal or negligible effect in the central north and south shore areas of the lake, including the plant site area.

REGULATION of Lake Ontario water levels is under the International St. Lawrence River Board of Control with supervision and direction from the International Joint Commission of the United States and Canada. Operation and regulation criteria have been developed by the Board and its staff and are contained in *References 1* and *2*. The initial regulation plan, 1958-A, was placed in effect April 20, 1960. Subsequent to that date several other modified plans have been initiated; the present plan 1958-D, was adopted July 1963. That plan has two sets of basic rule curves for discharge utilizing a basic "storage equation" and supply indicators for adjusting outflows from the lake. Seasonal adjustments to the outflow curves permit storage of water in winter, spring and early summer and the opposite in the late summer and fall, resulting in a high operating efficiency for maximum benefits to all water users. Approximately 85 percent of the annual inflow to Lake Ontario comes from the upper Great Lakes with the remaining 15 percent from local drainage. Thus the basic water supply to the lake changes very slowly permitting reasonably accurate forecasts and operating actions to maintain desired levels. Because of this only minor concern is given to "short term" supply changes, such as ice jams on the Niagara River or local winter floods.

During late winter and early spring these exceptions to the normal inflow and supply are not considered critical because of the large storage volume available in the lake. The storage increment per foot of stage is about 4.8 million acre feet. The discharge requirement to lower the lake one foot at relatively high stages is 348,000 c.f.s. for one week. The lake is to be regulated seasonally over a 5-ft range in elevation, between 243 ft and 248 ft. Lake regulation stages follow the "normal" high in summer low in winter levels. Period-of-record monthly routings (1860-1954) were made by the Board of Control to test the effectiveness of the present plan (1958-D) in maintaining desired levels and flows over a wide range of conditions to insure meeting all of the established criteria. Monthly mean adjusted stages and those resulting from application of Plan 1958-D are contained on Plates 6-1 through 6-10 of *Reference 1* for the period 1860-1954. Stage duration curves, based on those routing results can be found on Plates 12 through 23 for each month of the year. The 1 percent stage (percent of time monthly average stage is equalled or exceeded) taken from those curves is tabulated below for each month.

Month	1 Percent Stage (ft MSL)
January	246.45
February	246.75
March	246.90
April	247.60
May	248.00
June	248.00
July	248.05
August	247.70
September	247.10
October	246.55
November	246.25
December	246.05

Those stages are plotted graphically on Exhibit 3 of this report. Also plotted on that graph are the monthly mean stages for the period-of-record 1860-1966, and the monthly maximums and minimums of record with year of occurrence noted. Although the regulated 1 percent occurrence stage graph provides a limiting 2-ft range, as does the mean monthly record stage graph, there is an evident shift in peak month from June to July. This is believed due to the routing procedures and the rule curves employed in regulating periods of unusually heavy runoff.

REGULATION EXCEPTIONS As noted above, the week-to-week changes in inflow to Lake Ontario are highly predictable and can be compensated for by adjustments in outflow criteria. Because of the large storage volume per foot on the lake proper, day-to-day fluctuations in overall lake stage and storage (excluding wind effects along shore) must be related primarily to direct rainfall on the 7,500 square mile lake area and, to a lesser extent, from resultant local runoff. The occurrence of ice jams in the International Rapids Section is rather remote and limited to late winter or early spring months. Their effect in reducing outflow and overall resultant effect on lake stage would be small however. For example, if an ice jam occurred reducing normal winter outflow from the lake 50 percent, i.e., say from 300,000 c.f.s. to 150,000 c.f.s., the cumulative effect on lake stage per day would be 150,000 x 2 = 300,000 acre feet + inflow. If inflow = required outflow (i.e., 300,000 c.f.s.) the total effect would be 900,000 acre feet per day accumulated storage, or about 0.2 ft per day increase in overall lake stage. It is assumed some action would be taken by the Commission to eliminate such a condition before the cumulative effect became critical and endangered property around the lake. By far and large, the occurrence of unusually heavy and widespread rainfall on the lake proper is much more significant as to sudden short-period rises in both stage and storage. That parameter is evaluated in the following paragraph.

B. RAINFALL

GENERAL CLIMATOLOGY The occurrence of heavy widespread rainfall over much or all of the 7,500 square mile surface area of Lake Ontario is a significant factor in short-term rises in lake stage. Heavy concentrated rains, of the type which could raise lake levels half-a-foot or more within a matter of 24 to 48 hours, are associated with large-scale cyclonicity over central and northern latitudes and with hurricanes moving inland and overland from the Gulf of Mexico and the Atlantic Ocean. Various areas of the United States have experienced intense widespread rains from both sources; e.g., in the Hallett, Oklahoma storm of September 4, 1940 more than 6 inches of rain fell on 8,600 square miles in 11 hours (*Reference 3*); in hurricane Diane of August 17-20, 1955 nearly 11 inches of rain fell on 10,000 square miles in portions of New York, Vermont, Massachusetts and New Hampshire within 48 hours (*Reference 4*). Similarly, in the tropical storm of August 19, 1939 the city of Manahawkin, New Jersey recorded 17.8 inches of rainfall in 15 hours, with about 6 inches occurring over a 7,500 square mile area. In *Reference 5*, Figure 9, it was shown that the prime source of moisture for 140 winter-spring cases of heavy precipitation over central and northern U.S. was northward flow aloft from the Gulf of Mexico into a system of cold and warm fronts. Heavy rainfall of this type is usually associated with deep cyclonic lows having such attendant cold and warm fronts accompanied by overrunning and often occlusion. In *Reference 3* the total volume of precipitation in such type events was found to be a large fraction of the volume of atmospheric moisture flowing into the converging cyclonic area (from 50 up to 100 percent). In contrast to this type of storm-rainfall condition, hurricane rainfall such as that noted along the eastern seaboard in hurricane Diane, is primarily the result of orographic lifting of moist air, brought inland from the ocean by cyclonic circulation, over the coastal mountain ranges. As such, intense widespread rains of the type experienced in hurricane Diane are essentially limited to about a 100-150 mile distance inland from the Atlantic coast in the New York-New England area. The mechanism responsible for this limitation and a fairly reliable basis for predicting hurricane rainfall, intensity, and distribution, can be found in *Reference 3*.

LAKE ONTARIO RAINFALL The average monthly rainfall for the lake, based on an analysis of records contained in *Reference 7* for Rochester, New York and other stations on or near the lake does not vary widely - averages about 2 to 3 inches, with an average annual rainfall total of about 32 inches. Variations in annual totals are about ± 6 inches of that value. Extremes in monthly totals vary from 0.2 inch to around 6 inch. The extreme monthly rain-fall noted in *Reference 7* for Rochester, New York is 9.70 inches. No reference is given as to month or year of occurrence. In general the highest monthly amounts of rain occur in August; however, in terms of snowfall and equivalent water content, amounts of 3 to 4 inches can be found to occur in the months October to February. Analysis of maximum 24 hour rainfalls for Rochester, Buffalo, and Syracuse, from *Reference 7*, for the period 1921-1960 indicates values of 1.19 inches, 4.28 inches, and 4.79 inches, respectively, for those stations. In *Reference 6* the month of highest seasonal probability of occurrence of intense 24-hour rainfall with a return period in excess of 100 years is given as September for the Lake Ontario area.

WINDS The prevailing wind direction at Rochester, New York, from *Reference 7*, is west southwest. Analysis of wind directions associated with the "fastest mile" of wind at that station for the period 1956-1968 indicates that in only 20 months of the 144 months checked, or 14 percent, was the direction from a NE to NW quadrant. The remainder of the time the

fastest mile of wind during the month was predominantly from either the west or southwest. The fastest mile of wind recorded at Rochester, New York in the period 1931-1968 was 73 miles per hour. The months of highest winds from the west-southwest appear to be from January-June with values averaging from 55-60 mph.

C. EXTRATROPICAL CYCLONES

Numerous studies have been made relating to extratropical cyclones (termed Northeasters when over the ocean), their origin, paths, frequency, intensity, general monthly distribution, and effects as they relate to the Great Lakes (*References 8*, *9*, *10*, and *11*). Possibly the earliest study of this kind by Garriott, published in 1903, *Reference 12*, lists 238 cases covering a 25-year period. A more recent study by Irish and Platzman (*Reference 13*) investigated 76 such storms in the 20-year period 1940-1960 which caused setup in excess of 6 feet on Lake Erie. Those storms occurred from September through April; the maximum number - 26, occurred in November, 16 occurred in January, 13 in December, and 10 in March. The second highest observed set-up on Lake Erie was caused by a severe March storm, the highest by a January storm. The former storm, that of March 22, 1955 was an intense cyclone that began in east Texas and deepened rapidly as it moved up the Mississippi Valley. Near Lake Michigan it deepened to 975 mb. as it occluded. It then moved NE across northern Lake Ontario. Gusts up to 74 mph were reported. Perhaps the most all inclusive study of extratropical storms is contained in *Reference 14*. Nearly all of the destructive storms studied occurred in the months of November through April. Of 160 incidents of gale force winds recorded at Boston in the 75-year period 1870-1945, half were classified as northeast gales. Some 51 of these cyclonic storms studied in that report consisted of a single low pressure cell moving eastward from the central and upper United States across the New England area. The low pressure cell was usually associated with only one cold front and one warm front, although multiple lows and fronts were observed in many other storms. Exhibits 1 and 2 from *Reference 14* show such simple and complex pressure systems for April 2, 1958 and March 1, 1914, comprising of 972 mb. cell and two low centers of 960 mb. and 956 mb., respectively. The latter was the lowest pressure (28.25 inches) ever recorded at New Haven, Connecticut from such extratropical storms. Other notable cyclones listed in that report are those of December 2, 1942, 959 mb.; March 4, 1931, 961 mb.; and March 4, 1960, 961 mb. The average low pressure for the 51 storms was 983 mb. Observed wind speeds of 65-75 miles an hour are not unusual in these deep mature lows. In the March 1914 cyclone, wind speeds approached 80 m.p.h. Maximum winds in these storms are a function of pressure gradient; for the 51 storms the gradients ranged from 11 mb. per 150 naut. miles up to 25 mb. per 150 naut. miles (maximum). The origin of 73 percent of the 51 storms was found to be primarily the Texas-East Gulf and South Atlantic regions. Maximum cyclongenesis takes place in these source regions during the colder months because of the marked temperature contrast between maritime and continental air masses along the southern coasts. The forward speed of the 51 storms averaged 22 knots over the 12 hour period of their path prior to approaching the coast or passing into the Atlantic Ocean. Final deepening of those storms during that 12 hour period ranged from 6 mb. for storms moving in an eastward direction up to 11 mb. for storms moving more northward.

D. TROPICAL CYCLONES

The three principal areas of tropical cyclone, or hurricane, formation are the Gulf of Mexico, the Caribbean Sea and the north Atlantic Ocean. Literally hundreds of these storms have formed in these areas and, affected by largescale meteorological factors and sea surface temperatures, have moved on a wide variety of paths. Those paths have been chronicled by numerous authors, viz. *References 15* and *16*, as well as by the U.S. Weather Bureau in Monthly Weather Review and Climatological Data publications. Various authors have attempted to correlate the paths of tropical storms, areas of formation, and month of the year of occurrence. A study of the seasonal variation in the frequency of topical cyclones for various geographic areas along the eastern U.S. coast, in terms of the effect of general atmospheric circulation on storm path, was presented by Ballenzweig in *Reference 17*. Ballenzweig concluded that varying seasonal circulation patterns form the framework for steering tropical cyclones after their generation; and that recurrent positive and negative anamolies of the 700 mb. height in terms of departure from normal for the hurricane months could form the basis for predicting hurricane movement.

CYCLONES AFFECTING LAKE ONTARIO A study was made by the author of hurricane paths since 1888 using *References 15*, *16*, *18*, and U.S.W.B. Climatological Data publications to determine the relative occurrence of hurricanes and tropical disturbances moving inland, overland, and passing over or near Lake Ontario from their various areas of formation. Of especial interest were storms moving northward along the Atlantic seaboard whose movement was blocked and which ultimately recurved westward and/or northward toward or over Lake Ontario. In the 36 year period covered in *Reference 15*, 1888-1924, some 21 hurricanes and tropical depressions passed over or near Lake Ontario-17 from the Gulf of Mexico and 4 from the Atlantic Ocean. Of the latter, three passed directly over the lake in 1893, 1903, and 1923. Storm paths shown in *Reference 16* for the period 1924-1937 indicate 4 storms fell into that category. Since 1937, *Reference 18*, some 5 tropical storms have passed over or near the lake. All totalled, about 30 hurricanes and tropical disturbances in the last 80 years have affected Lake Ontario to some degree. Those storms occurred in the months of June through November, with a prevalence of occurrence in July, August and September. In the 31-year period, 1903-1933, four major Atlantic hurricanes recurved inland along the coasts of Maryland, Delaware, and New Jersey passing over Lake Ontario. Those storms had the shortest overland trajectory, some 200-300 miles, from the ocean to the lake. This fact is of prime importance in regard to the filling and deintensification process that occurs within the storm system in its overland trajectory.

2A.4 DESIGN STORM ANALYSIS FOR MAXIMUM PROBABLE WATER LEVEL

GENERAL As indicated earlier in this report the problem of evaluating the maximum probable water level to be expected at the plant site involves selection of a design storm, its time of occurrence in coincidence with lake level, and the cumulative effects of that storm in terms of wind setup at shore, pressure effect, antecedent or associated rainfall, and wave effect.

From the data presented and discussed above two types of cyclonic storms affect the area - extratropical cyclones and tropical cyclones. Each has its own set of characteristics, probable time of maximum occurrence and intensity, and its resulting effect on Lake Ontario in terms of maximum water elevation at the site area. Because of the basic differences associated with these two storm types, two separate analyses were made to determine the most critical combination of conditions for each and resultant maximum probable water levels. Those analyses are presented below.

2A.4.1 EXTRATOPICAL STORM ANALYSIS

CRITERIA The combination of conditions selected to represent an occurrence of this event is as follows:

a. Central Pressure. The minimum central pressure was based on the lowest storm pressure observed at New Haven, Conn. modified by the mean rate of deepening for storms moving eastward across the upper United States for the 12 hr period prior to reaching the coast. Po = 957 mb. + 9 mb. = 966 mb. (28.53 inches)

b. Path. The storm center would move eastward just south of Lake Ontario so that winds in the western part of the storm would be from the north, moving progressively from NNE-N-NNW over a period of about 6 hours.

c. Forward Speed. The storm would move at a rate of about 20 mph, an average speed for storms of this nature.

d. Wind Speeds. Average wind speeds over the lake for a North-South fetch to the plant site would be about 60 mph, based on a pressure gradient of 25 mb. per 150 naut. miles.

e. Lake Stage. The storm was assumed to occur in April; the 1 percent frequency stage from Exhibit 1 or 247.60 ft msl. was used as prestorm lake stage.

f. Antecedent rainfall of 4.2 inches (0.35 ft.), associated with frontal passage during the 24 hours preceding maximum wind setup was assumed to occur as an average value over the lake.

RETURN FREQUENCY The relative frequencies of the various criteria, in combination, represent a rate event, on the order of a once in 10,000 year occurrence. The return frequency of the selected storm is in excess of a 50-year event, the selected lake stage has a 1 percent return period; and the lakewide average rainfall of 4.2 inches is believed to be on the order of a 25-30 year event for the area.

PEAK WATER LEVEL Wind setup computations were made for a lake stage of 247.95 ft MSL (247.60 ft + 0.35 ft rainfall). Lake bottom elevations were averaged for 3 fetches, 22.5 degrees east and west of north, and a N-S fetch. An average wind speed of 60 mph was used

over the fetch and setup computations made beginning at a node line approximately 20 miles north of the plant site area. (The selection of that location was based on trail computations. Since the lake is extremely deep, over 500 ft for almost half the fetch, it was found that the difference in final wind setup would be on the order of .01 - .02 ft for a shift of a mile or more in either direction in node point location.) The peak computed wind setup was 0.45 ft at the plant site. Pressure effect on the lake was determined using a 4 mb. departure from storm center to the area of interest. The variation from normal pressure, converted to feet of additional rise in lake level at the site area, was determined as follows:

[977 mb. - (966 mb. + 4 mb.)/ 33.8 (conversion to inches)] x(1.14) = 0.91 ft

Wave effect was considered to add an additional foot of rise in water level at shore. Deepwater wave forecasting procedures, using V_{av} = 60 mph, Fetch = 45 miles, gave a significant wave height H_s = 16 ft, a wave period T_s = 9 seconds, for a required duration of 3+ hours.
The breaking depth for a 16 ft wave is about 20.5 ft. That wave would break about one-half mile from shore; successive wave trains would add to the depth of water near shore. The 1-ft value is believed to be reasonable.

SUMMARY The total maximum probable water level at the plant site from the design extratropical storm and associated phenomena would be:

Lake Stage	247.60 ft MSL
Rainfall	0.35 ft
Wind Setup	0.45 ft
Pressure effect	0.91 ft
Wave Effect	1.00 ft
Max. Water Level	**250.31 ft MSL**

2A.4.2 TROPICAL STORM ANALYSIS

CRITERIA The combination of conditions selected to represent an occurrence of this event is as follows:

a. Central Pressure. A maximum probable hurricane, derived by the author for the Barnegat Bay, New Jersey area, is considered applicable for transportation to the Lake Ontario area. The central pressure of that storm at the coast is 917.7 mb. (27.10 inches). Filling of that storm in its path from the coast to the lake would change its central pressure (+20 mb.) based on a study of filling in hurricanes, *Reference 19*. The central pressure at Oswego, New York would be 938 mb. (27.7 inches).

b. Path. The path of the storm was assumed to be similar to those of the major hurricanes of 1903, 1923, 1928, and 1933, all of which entered the east coast along the Maryland-New Jersey shoreline, curving northward and over or near Lake Ontario. The storm center was

assumed to pass close to Oswego, New York in order to obtain winds from the north over the lake.

c. Forward Speed. The forward speed of the hurricane would average about 25 mph in its overland trajectory to the lake.

d. Wind Speeds. Maximum wind speeds in the eastern semi-circle of the hurricane would be reduced from 120 mph at the open coast to about 105 mph at the lake. Winds in the western portion of the storm would be reduced from 90 mph to about 75 mph. An average wind speed of 70 mph was used on the lake over the fetch in computing setup at the plant site.

e. Lake Stage. The hurricane was assumed to occur in July; the 1 percent frequency stage from Exhibit 1 of 248.05 ft MSL was used as pre-storm lake stage.

f. Antecedent Rainfall. Analysis of past record hurricanes entering the east-coastal area (*Reference 3*) indicates that extreme convergence plus the orographic effect of coastal mountain ranges will precipitate a high percentage of moisture in the storm within the first hundred miles of its inland movement. Consequently, associated rainfall in the design hurricane over Lake Ontario was assumed to be nominal and estimated to average 2+ inches 0.17 ft) over the lake at the time of peak wind setup.

PEAK WATER LEVEL Wind setup computations were made for a lake stage of 248.22 ft MSL (248.05 ft + 0.17 ft rainfall). The same bottom elevations and fetch conditions noted above in the extratropical storm analysis were used. Using a wind speed of 70 mph over the average fetch a peak setup of 0.53 ft was computed at the plant site. Pressure effect was determined in the same manner as for the extratropical storm, using about a 30 mb. change in pressure in the 55 mile distance between Oswego and the fetch area. Pressure effect was computed to be 1.03 ft. Wave effect was considered to add an additional foot of rise in water level at shore. The significant wave height, H_S = 19 ft for a 70 mph average wind speed; T_S = 9.7 seconds, for a required duration of 3+ hours. The breaking depth for a 19 foot wave is about 24+ ft. That wave would break about 3,000 ft offshore; successive wave trains would add to the depth of water near shore.

SUMMARY The total maximum probable water level at the plant site from the design tropical storm and associated phenomena would be:

Lake Stage	243.05 ft MSL
Rainfall	0.17 ft
Wind Setup	0.53 ft
Pressure effect	1.03 ft
Wave effect	1.00 ft
Max. Water Level	250.78 ft MSL

2A.4.3 EXTREME LOW WATER LEVEL

GENERAL Several factors affect and, to a large extent, control the value of extreme low tide elevation to be expected at the Robert Emmett Ginna Plant site. They are essentially as follows:

1. Hurricane wind speed and direction in storms passing west of the plant, so as to have the zone of maximum winds directed offshore to the lake.
2. Offshore depths, both nearshore and with respect to the overall depth of the lake.
3. The general orientation of the bay axis with respect to hurricane wind direction.
4. Initial water level of the lake prior to storm occurrence.

For the project plant site area tide generating conditions on a north-south oriented fetch are maximum in comparison with the east-west tide generating potential. The site is located at or near the nodal point for the latter condition and would experience negligible setup or setdown for east-west oriented winds. As estimate of the maximum anticipated setdown to be expected at the plant site was based on an assumed occurrence of the Maximum Probable Hurricane transposed to the lake on a path from the south with the center passing some 40± miles west of the plant site. Peak hourly average winds from the south-southeast, blowing offshore, would be on the order of 90-95 mph during passage of the storm across the lake. The assumed lake level at the time of hurricane passage would be the lowest future lake level under the International Commission regulatory plan 1958D - 243.07 ft MSL. It is probable that this stage would occur as a result of a prolonged drought, extending over a period of a year or more, so that the low stage could occur during mid-summer and the hurricane season. Wind tide computations were made with that lake stage and the above wind and fetch criteria. The maximum setdown elevation at the plant site was determined to be 0.83 ft. This would result in an Extreme Low Water Elevation of 242.23 ft MSL (243.07 - 0.83 ft).

CONCLUSIONS

Based on the above analyses the undersigned has drawn the following conclusions:

1. That Lake Ontario is subject to the repeated occurrence of both extratropical and tropical cyclonic storms and their effects.
2. That hydrologic analyses of regulatory criteria established for the lake provide a sound and highly reliable basis for predicting the probable range in future stages.
3. That available meteorological analyses for both type storms are sufficiently detailed and accurate to permit derivation of events of rare frequency and their transportation to the lake area.
4. That the critical combination of assumed meteorological and hydrological conditions for a design tropical storm would result in a slightly higher maximum probable water level on the lake than would occur from a design extratropical storm.
5. That the Maximum Probable Water Level to be expected at the Robert Emmett Ginna Nuclear Plant Site is 250.78 ft MSL.
6. That the Extreme Low Water Level to be expected at the plant site is 242.23 ft MSL.

Submitted by,
/s/ Theodore E. Haeussner
Hydraulic Engineer, Consultant
Jacksonville, Florida
March 26, 1968

EXHIBITS

1. A typical single-cell single-front extratropical storm on April 2, 1958.
2. A complex double-cell double-front extratropical storm on March 1, 1914.
3. Mean monthly observed and regulated normal and extreme water levels for Lake Ontario.

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APPENDIX 2B

DRIFT AND DISPERSION CHARACTERISTICS OF LAKE ONTARIO NEARSHORE WATERS ROCHESTER, NEW YORK TO SODUS BAY, NEW YORK

A Specialized Limnological Study Sponsored by Rochester Gas and Electric Corporation Rochester, New York

Conducted by
Pritchard-Carpenter

208 MacAlpine Road
Ellicott City, Maryland

Including

2B Appendix A	OBSERVED TRACER DISTRIBUTIONS (PARTS PER BILLION)
2B Appendix B	WIND SPEED AND DIRECTION OBSERVATIONS METEOROLOGICAL TOWER ON BROOKWOOD SITE ANEMOMETER - ELEVATION 150 FEET
2B Attachment I	THE EFFECT ON LAKE DILUTION OF MOMENT MIXING

2B.1 DRIFT AND DISPERSION CHARACTERISTICS OF LAKE ONTARIO NEARSHORE WATERS ROCHESTER, NEW YORK TO SODUS BAY, NEW YORK

2B.1.1 SUMMARY

Drift and dispersion studies were conducted in Lake Ontario during April-May, July and October, 1965. The study area was along the south shore of the lake between Rochester and Sodus Point. The drift was found to be primarily wind induced, with speeds and directions correlated to wind speed and direction. A steady drift to the east of 0.05 knots was present during calm periods.

Tracer material was released continuously at the Brookwood site during the study periods. The observed distributions of released material were fitted to theoretical equations. The probable distribution of heat and materials released with the condenser cooling water flow under different discharge structure designs were computed from the observed diffusion data. These computations show that the use of a horizontal jet minimizes the thermal effect and produces the most rapid dilution of discharge constituents, so that a jet (approximately 2 ft/sec) discharge should be considered as optimum. With horizontal discharge, significant heating would not be present along the lake shore beyond the site boundary and the area with temperatures elevated by 5° would extend out into the lake approximately 3000 feet and have an average width of 200 feet.

The study showed that a twenty-fold or greater dilution would occur before the discharge reaches the area of the nearest public water intake (town of Ontario). This intake is located on the bottom at a depth of 11 feet. Thirty-fold dilution would be expected before the discharge could be drawn into the plant intake located on the bottom at a depth of 28 feet.

As a result of implementing the Extended Power Uprate (EPU) there will be an increase in the thermal discharge. In accordance with the Federal Clean Water Act (CWA) Section 316(a) and 6NYCRR Part 704 of the New York State Water Quality Standards Constellation Energy assessed the effect of the increased thermal discharge to assure the protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife in and on Lake Ontario. The analyses consisted of three separate studies designed to evaluate the size of the thermal plume under the planned EPU conditions and to assess thermal impacts to indigenous species of fish. The three reports, listed below, were submitted to the NYSDEC on March 8, 2005. Thermal Plume Study (Ocean Surveys, Inc. (OSI)), Near-Field and Far-Field Modeling Studies for the R.E. Ginna Power Plant (HyroQual Environmental Engineers & Scientists (Hydro Qual)), Biological Assessment: Near-Field and Far-Field Modeling (Northern Ecological) Associates, Inc. (NEA), along with a New York Form 2C (Attachments I-VII), Supplemental Form A to Form 2C, a SEQR LEAF, 401 Water Quality Application, and a State Coastal Zone management form.

OSI performed an insitu thermal plume study that was used as validation input for the near-field and far-field modeling studies. The extent of the thermal plume is a product of the velocity of the discharge water and wind influence, and is confined to a narrow stream in the lake. As expected, vertical profile data from the study showed a drop in temperatures as the

plume expands into the lake, limiting the thermal impact to the near-field. In the near-field study area (within 600-700 feet of the plant discharge), the thermal plume mapping survey showed complete vertical mixing from surface to bottom, while the plume was limited to the surface (upper 5 feet) in the far-field study area (10,000 feet north of the discharge and 6,000 feet both east and west of the centerline of the plume).

HydroQual modeled the thermal plume under existing operating conditions, SPDES permit conditions, and EPU conditions to determine the aerial extent of the 3°F isotherm. Modeling simulations were used to assess the plant's compliance against the SPDES permit Additional Requirement Number 5, which limits the allowable mixing zone, as defined above, to an area of no more than 320 acres. Under planned EPU conditions, the modeling results indicate that, during the summer and winter critical periods, the predicted plume sizes under all operating conditions occasionally will exceed the permit limit of 320 acres. More specifically, the modeled thermal plume is predicted to exceed 320 acres by approximately 12 percent approximately 2.5 days over a 30-day period. This results in a modeled plume size of 360 acres.

NEA assessed the thermal tolerance of ten selected Representative Important Species (RIS) under conditions expected in the Ginna Station thermal discharge under planned EPU conditions using actual discharge temperature data and literature values for species' thermal tolerance. Monitoring results from 2000 to 2004 indicate that during the summer months, the monthly average hourly discharge temperature in the discharge canal could potentially reach or exceed the upper thermal tolerance for most of the fish species evaluated. Fish are highly mobile species and would be able to seek ambient ideal waters to avoid impacts. During periods of adverse conditions, residency of any fish species in the discharge canal would be highly unlikely. During summer months, cold and coolwater species would avoid the near-shore waters of the lake area, thus avoiding impact. Warmwater species have a higher probability of being in the nearshore waters during summer months. Although the average temperature in the Ginna Station discharge canal would exceed the lower range of the upper thermal tolerance of warm water species, the majority of all fish species seek cooler waters for shelter, thus minimal impacts are expected.

In summary, the thermal plume currently affects only a small region of the southern shoreline of the Lake and the planned Extended Power Uprate (EPU) could only occasionally (i.e., during extreme summer conditions) result in a small increase in the area of Lake Ontario impacted by thermal discharges from Ginna Station.

2B.1.2 INTRODUCTION

The Rochester Gas and Electric Corporation is undertaking the installation and operation of a nuclear electric power station at the Brookwood site located about 18 miles east of Rochester. As a part of the preliminary environmental analysis, calculations of the distribution of materials released to Lake Ontario in the Brookwood region were undertaken. These calculations were based on experience in other bodies of water and the general characteristics of Lake Ontario.

During 1965, an observational program in Lake Ontario was undertaken. The purpose of the program was to obtain direct information on the drift and dispersion characteristics of the Lake waters, and to use these characteristics to predict the distribution of materials and heat

released at the site. The field study has provided a basis for estimates in which considerably greater confidence can be placed than was the case for the estimates made in the preliminary analysis. However, it is noted that the estimates are in general agreement with the preliminary analysis. In addition, the observational program was desirable to furnish evidence that no unusual (unexpected) features are present in the drift and dispersive characteristics of the area. This report summarizes the field observations made during the program and translates the data into forms useful in making predictions of the concentrations to be expected at various positions along the lake shore.

2B.1.3 GENERAL COMMENT ON EFFECT OF DISCHARGES ON LAKE ONTARIO

Lake Ontario is approximately 190 miles long and 60 miles wide and has a surface area of about 7,500 square miles.

Depths of 40 to 100 feet are found within one to two miles of shore and the maximum depth is 778 feet. The mean sectional depth is roughly 300 feet, so that the volume is approximately 6 x 10^{13} cubic feet.

The mean total flow through Lake Ontario corresponds to the discharge through the St. Lawrence River of 241,000 cfs, of which 85% is contributed by the Niagara River flowing from Lake Erie. The volume of Lake Ontario, therefore, represents discharge at the mean rate for

2.5 x 1.0^{8} seconds or 8.2 years. Changes in the bulk composition of Lake Ontario as a result of alteration in Lake Erie would be expected to take place with a time scale of ten to twenty years.

The ultimate concentration of materials discharged into Lake Ontario may be estimated from the volume of "new" water available. For a nuclear power plant discharging condenser water at 600-700 cfs, constituents of this effluent would be diluted 350 fold when mixed into the total "new" water. Even with partial mixing throughout only one-third of the Lake width, dilutions of 1:100 would be expected. In view of the flow-through time scale of eight years, it seems certain that mixing over much of the Lake volume will occur, since horizontal motions transport water from one end of the Lake to the other in a few months and complete vertical mixing takes place annually.

2B.1.4 CURRENTS IN LAKE ONTARIO

The predominant surface currents in Lake Ontario would be expected to move from west to east, since the predominant wind direction is from west to east and wind stress on the water surface appears to be the strongest current generating force. The currents associated with inflow from the Niagara and other rivers and outflow by the St. Lawrence are not strong. Even if it is assumed that this flow-through is intermittently confined to an upper 30 foot layer (the summer mixed layer), speeds of 0.04 feet per second would result.

Currents in the Brookwood region were measured in several ways during the course of the observational program. Continuous measurements at a position 800 feet offshore of the Brookwood site were obtained during May 1965. The current meter was suspended from a frame which rested on the Lake bottom, so that the meter was six feet below the water surface. The current meter was a direction resolving, time integrating device built by W. H.

Johnstone Laboratories of Baltimore, Maryland. Speed was sensed by the tilt of the suspended instrument case, which contained two compass cards with collimated beams of radioactivity. The radioactivity was detected with two ionization chambers that were shielded with absorbers that were machined to the function relating tilt angle to current speed (i.e., square foot of the tangent of the angle). The count rates were directly proportional to the North- South and East-West current vectors. The signals from the two ionization chambers were recorded on a two channel digital, integrating printer. The integrated currents were recorded each thirty minutes.

The results of these current measurements are shown in Figure 1. The East-West component of the wind is also shown in Figure 1. The wind speeds are taken from the hourly readings of the 50 foot anemometer at the Brookwood site, except for those days(2) when recording malfunction had occurred and on those days the wind speed that would have been recorded is inferred from the record for the 150 foot anemometer with a conversion factor of 0.7.

Covariance of lake currents with wind speed and direction are visually obvious in Figure 1. The relationship is particularly clear on the 27th and 30th of May, 1965. Lag in changes in speed in the same direction does not seem to be more than one hour; however, change in direction from east to west may take four or five hours for the moderate winds from the east observed during the recorded period.

The wind-driven currents are superimposed on an easterly drift of approximately 0.1 knots, as shown quite well on the 19th and 21st of May, 1965. This current was present throughout the period of the record, but is weaker (0.05 knots) during the later portion of the record (29-31, May 1965). The observed horizontal temperature distribution was in accord with a geostrophic current of the magnitude observed. Decreasing temperature with increasing distance offshore was found with a gradient of approximately 1° Celsius per 1500 feet. In considering a geostrophic current, cause and effect are not resolvable and it can only be stated that the observed density distribution would be in equilibrium with a current of the direction and magnitude observed. The observed density distribution could be produced by more rapid temperature increase in the shallow nearshore waters by solar heating and by the supply of warmer water from the Genesee River. Both of these processes were certainly occurring during the May period. These processes will not be as important during other seasons of the year and weaker geostrophic currents would be expected.

The relationship between wind speed and water current speed has been observed by several authors and values ranging from 1.6 to 2.3 percent reported for open water. Since observed wind speed is a function of elevation (anemometer height) and surface roughness, the observed relationship is dependent on the particulars of the wind observations. For our observations, the lake current (mph) was approximately 0.023 times the wind speed (mph) observed at the 50 foot anemometer on the Brookwood site. If the 150 foot anemometer record bad been used, the relationship would have been 0.016. The observed relationship may be used with the statistics of the wind speed observations to produce reliable statistics of Lake speed, with uncertainties of not more than 1.5 percent. Frequencies of particular directions and speeds may be derived after an adequate length of wind record at the site has been developed.

In addition to the observations with the fixed current meter, current measurements from the survey boat were made during all three study periods. On those days when wave height permitted anchoring without excessive swinging on the two anchor lines, currents were measured with a confined drag. When anchoring was impractical, a free drifting drogue was used and the time to travel known distances recorded. These observations were in general agreement with the results from the fixed meter. During October 1965, the persistent eastward current was 0.05 knots and the relationship between wind current and wind speed was 0.02.

Currents were measured during periods of increasing wind speed and time lags of less than one hour were observed.

Vertical current and temperature profiles were observed at three positions off the point on the site. These stations were located 1000, 3700 and 6000 feet north of the point. Essentially uniform speeds were found in the upper ten feet, except during periods (2-4 hours) of direction reversal to the west when the surface layer was found to move downwind, while the deeper (below 5 feet) water was still flowing to the east. Considerable horizontal shear was found, except during periods when the currents were 0.15 knots and less. Speeds offshore were frequently double those nearshore, when the nearshore speeds were in the range 0.2-0.4 knots.

The only observed currents that are not accounted for by wind stress and the density distribution are those on 25 July, 1965. Winds had been 7-11 mph from the northwest for the previous 18 hours. Currents at the nearshore station were 0.25 knots to the east. At the offshore stations, speeds of 0.63 knots in the upper 25 feet were found. This transitory current was perhaps the result of internal wave motion associated with the strong thermocline present during the July period. While no systematic series of observations were made for the purpose of detecting internal waves, the temperatures shown in Table 1 show large temperature changes at depths of 18 to 25 meters that can only be accounted for by internal wave motion with amplitudes of 8-10 meters.

Our interest was not in the details of the velocity field per se, but rather as confirmation of the tracer studies (below) which show strong dispersion of the released material. The time and space variations found in the current system would be expected to produce rapid dispersion.

2B.1.5 TRACER RELEASES

1. Technique.

   A tracer material, rhodamine B, was released continuously off the site at the rate of 8.3 pounds per day. Dye solution was discharged with a metering pump through a pipe line to an outfall 1000 feet north of the point on the site. A diffuser distributed the solution through the upper eight feet of the water at the discharge point. The periods of pumping were:

   1500, 29 April, 1965—2230, 16 May, 1965

   1730, 8 July, 1965—1000, 25 July, 1965

   1530, 6 Oct., 1965—1510, 16 October, 1965

Clogging of the discharge system with decaying, floating algae was a continuing problem during the study. Algae growth began in early May and extensive beds were present during July and October. Underwater observation showed the beds extended offshore to depths of 12-15 feet. Each period of strong winds broke the algae loose and produced dense mats along the shore line.

The concentration of the tracer material was measured with a fluorometer operated on the survey boat. An underway sampling system permitted continuous recording of tracer concentrations along horizontal transects. Vertical profiles were measured by lowering the intake of a hone through which the sample water flowed to the instrument. Temperatures were also monitored on the same sample stream and noted on the fluorometer record.

At distances greater than 3000 feet from the outfall, the vertical distribution of tracer was uniform during July and October, with the exception of the offshore edge of the dye plume. Higher concentration with depth was found on the outer edge, suggesting offshore movement in the deeper (10-20 feet) layers. During the first week of May, vertical mixing was incomplete due to the rapid heating of the upper ten feet and the dye was confined to this surface layer.

Horizontal transects were taken perpendicular to the shore at intervals of approximately 2500 feet from the discharge point to the area where the tracer was undetectable. These records have been used to construct charts of the horizontal distribution of the tracer, as shown in Appendix A. The wind speeds and directions during the observations are shown in Appendix B.

2. Results.

   a. April-May.

   The chart for 29 April shows the distribution four hours after the release was begun. The wind had been from WNW at approximately 13 mph (50 feet anemometer) during the four hours. The drift of the material over a distance of one mile during the four hours is an average rate of 0.25 knots. The ratio between tracer drift and wind speed was 0.02 in close agreement with the current measurements described above. The onshore set of the drift should be noted. Tracer material discharged 2000 feet off the proposed location of the cooling water outlet from the plant reached the shore area approximately 5000 feet down current. Discharge at greater distances offshore would not radically alter this pattern, and it would be expected that material released 4000 feet offshore would approach the shore at distances of 10,000 feet down current.

   The tracer release rate was not uniform on the 30 April due to interference by the algae noted above. The resulting distribution on 1 May with high concentrations in a patch off Bear Creek Harbor is a result of this artifact. The discharge was maintained constant throughout the remainder of the May test.

   The patterns observed during the two weeks of steady release show a slow drift to the west on 4 days and to the east on the other 13 days, which is a frequency that corresponds to average conditions as suggested by the wind record analyses described in the preliminary hazards evaluation. The distribution on 14 May is particularly significant. Drift to the east had begun on 9 May and had been persistent through the five days. During the afternoon of the 13th and again on the 14th, the winds were from the

NE and reversal of the drift to the west was being initiated. The reversal is associated with the development of a confused (turbulent) current pattern with large eddies (several thousand feet in diameter). This motion produces much more extensive dilution than that which occurs with persistent drift along the shore. It was striking that when drift direction reversed, return passage of the large quantity of water containing the previously released material could not be observed to any great extent. The observed rapid diluting process apparent in the 14 May chart is the probable reason for this effect. General accumulation of released material in the area was not observed and it is implied that the exchange rate of the nearshore waters with the bulk of the Lake proceeds so rapidly (weeks) that "new" (i.e., water whose tracer content corresponds to a dilution of 1:100 for the proposed rate of plant discharge) water is available for the development of the plumes that form with persistent winds from either the west or east.

b. July.

The July test period was dominated by drift to the east produced by west winds. The only drift to the west was found on 13 July. The effect of southwest winds are well represented in the July results. Both the 9th and 17th show the offshore drift resulting from southerly components in the wind.

c. October.

The October results are also dominated by drift to the east. However, the 7, 8, and 9 October distribution show the movement to the west developed by southeast winds. The 8 October distribution is the maximum excursion to the west observed during all three study periods. The return to east drift may be seen on 9 October and the rapid dilution due to large-scale turbulence is similar to that observed with reversal from east to west drift.

3. Interpretation.

The observed distribution of tracer material may be used to compute the comparable distribution of other materials discharged at the site on the basis that the ratios of concentration to the quantity discharged are identical. The tracer distributions are shown in units of parts per billion and, for the tracer discharge rate used, 1 ppb corresponds to 2.66 x 10^{-13} unit per cc per unit per day discharged. For example, for those areas where the dye concentration was 0.1 ppb, it would be predicted that, with a radioactive isotopes discharge rate of 1 millicurie per day, the concentration of radioactive isotopes would be 2.66 x 10^{-13} millicuries per cc in those areas. Similar scale factors may be derived from any other units chosen for expressing discharge rates.

If the tracer had been injected into a cooling water flow of 290,000 gpm (647 cfs), the concentration for our injection rate would have been 2.4 ppb. An alternate way of viewing the observed distributions would be on the basis of dilution from the base concentration of 2.4 ppb. In this case, 0.24 ppb would correspond to a dilution of 1 to 10, etc.

Inspection of the observed distributions show that concentrations greater than 2.4 ppb were observed several thousand feet down current from the tracer outfall. Natural turbulent dispersion does not furnish as rapid dilution as may be achieved in the cooling water discharge canal. Release of materials from the plant should be by way of the discharge

canal to eliminate these high concentrations present close to a single point discharge out in the lake. At distances greater than roughly four thousand feet, the manner of discharge will not modify the concentrations significantly, except for the effect of momentum mixing as discussed below.

In using the observed tracer distributions to anticipate the distribution of plant discharges, direct scaling can be used as outlined above. An alternate approach to developing predictions is the description of observations with theoretical equations, which may then be used to compute distributions for various assumed conditions. An example of this type is the simple peak concentration equation used in the preliminary environmental analysis to predict peak concentrations on the basis of an assumed diffusion velocity and a point source discharge.

It seems clear that release of materials from the site with condenser cooling water flow has distinct advantages and it is assumed that this will be the manner of release. This cooling water flow is not equivalent to a mathematical point (vertical line) source. The relationship proposed by Okubo and Pritchard (Okubo, Akira. 1962. A Review of Theoretical Models of Turbulent Diffusion in the Sea. Chesapeake Bay Institute, The Johns Hopkins University, Technical Report 30, Reference 62-20) for horizontal diffusion from a vertical line source at times so that steady state has been achieved is *equation (1)*.

$$S_c(x, y-y_0, t_s) = \frac{q}{2\sqrt{\pi}\cdot D\cdot w[x^2+(y-y_0)^2]^{1/2}} \exp\left[-\frac{U(y-y_0)^2}{x^2+(y-y_0)^2}\right]\left[1+erf\frac{(xU)}{w(x^2(y-y_0)^2)}\right] \quad \text{(Equation 1)}$$

where: $S_c(x, y-y_0, t_s)_l$ =concentration of material in mass per unit volume from a continuous vertical line source located at x = 0, y = y_0.

w = diffusion velocity.

U = velocity in x-direction (It is assumed to be constant in this model; in addition V = W = 0).

q = rate of discharge of material uniformly over a depth, D.

and the x axis points along the plume and the y axis across the plume.

Equation (1) may be applied to a vertical plane source of length b and depth D running from x = 0,y = 0 to x = 0, y = b by integrating as shown in *equation (2)*. The boundary effect is incorporated as a virtual source running from y = 0 to y = -b.

$$S_c(x, y, t_s)_p = \frac{1}{b}\int_{-b}^{+b} S_c(x, y-y_0, t_s)_l \, dy \quad \text{(Equation 2)}$$

where: $S_c(x, y, t_s)_p$ =concentration of material in mass per unit volume from a continuous plane source of length b and depth D.

Conditions described by *equation (2)* are shown schematically in Figure 1.

Equation (2) may be non-dimensionalized as follows:

Let:

$$x = bx' \qquad y = by' \qquad y_0 = by_0' \qquad \frac{U}{w} = U' \quad \text{(Equation 3)}$$

Equation (2) then becomes

$$\frac{S_c(x', y', t)_p \cdot 2\sqrt{\pi} \cdot D \cdot w \cdot b}{q} \equiv S_c' = \int_{-1}^{+1} \frac{1}{(x'^2 + (y' - y_0')^2)^{1/2}}$$

$$\exp\left[-\frac{U'^2(y' - y_0')^2}{(x'^2 + (y' - y_0')^2)}\right]\left[1 + erf\left(\frac{x'U'}{(x'^2 + (y' - y_0')^2)^{1/2}}\right)\right] \quad \text{(Equation 4)}$$

The right-hand side of *equation (4)* is not integrable except by machine methods. It has been evaluated for representative values of U ′ as a function of x ′ and y ′ and may be considered as known from this point on.

Using U ′ = U/w and *equation (4)* we obtain

$$S_c' = \frac{S_c\sqrt{\pi}\,DUb}{U'q} \quad \text{(Equation 5)}$$

Multiplying both aides of *equation (5)* by Q, the discharge rate of condensor-cooling water into the lake, we obtain

$$S_c'Q = \frac{S_c\sqrt{\pi}}{U'} \cdot \frac{DUb}{q/Q} \quad \text{(Equation 6)}$$

but q/Q is the initial concentration of material, so on making this substitution and rearranging *(6)* we obtain

$$Dilution \equiv \frac{S_0}{S_c} = \left[\frac{DUb}{Q}\right]_{1st\ stage\ dilution}\left[\frac{\sqrt{\pi}}{U'S_c'}\right]_{2nd\ stage\ dilution} \quad \text{(Equation 7)}$$

Equation (7) describes the dilution of introduced material as proceeding in two stages. The first stage is the dilution that occurs between injection and formation of the vertical plane source and the second stage is the dilution produced by natural dispersion as the material moves with the lake current.

The variation in dilution with distance down the plume for various values of U ′ is shown in Figure 2. These dilutions are the minimum to be expected at each distance, since they are for y - 0, i.e., the shore line of the lake.

The lateral distribution of material is shown in the form of second-stage dilution for a representative value of U ′ in Figure 3. The value of U ′ is derived from the observational data in the following way. The simplest characteristic of the observed plumes is the maximum concentration found along the plume. In considering *equation (1)*, if we define the x coordinate as running along the center of the plume and y = 0 along this line, the peak concentration, s_p, is given by the following relationship:

$$S_p = \frac{q}{2\sqrt{\pi}\, D \cdot w \cdot x}$$

The values of w are most readily found from a plot of peak concentration versus distance. In considering the observations, it must be remembered that the theoretical equations apply to steady-state conditions, which are only present in the lake after a persistent wind. Also, steady- state conditions do not exist along the entire length of the plume and the one-third of the plume farthest down current from the source is not at steady state. The equations apply to the mean concentration at each position and the observations are essentially instantaneous concentrations, so that considerable scatter about the theoretical functions must be expected.

Data under conditions approximating steady state have been selected from the complete set of observations for use in estimating the diffusion velocity, w. Plots of peak concentration versus distance are shown in Figures 4, 5, 6, 7 and 8. Figures 4, 5 and 6 are for drift to the east and Figures 7 and 8 are for data during drift to the west. During the July study period, significant drift to the west did not occur and no west plot is made for July.

For drift to the east, the data for May, July and October are in close correspondence, being described by a diffusion velocity of 0.33 cm/sec during all three periods. Mean drift speed during the intervals when near steady state was approached was approximately 0.2 knots (10 cm/sec). The corresponding value of U ′ is 30, which is the value used in constructing Figure 3.

Drift to the west did not occur for a sufficient length of time to produce steady state at distances of greater than 4000 meters. The May results in Figure 7 suggest that a diffusion velocity of 0.33 cm/sec is descriptive of dispersion during drift to the west. The October results appear to be better fitted by larger values of w, but steady state was not established and 0.33 cm/sec may be taken for prediction purposes with conservatism.

2B.1.6 DISCUSSION

Predictions of the distribution of released materials may be based on the above data and the characteristics of the discharge as it leaves the site. As noted above for *equation 7*, the dilution process may be viewed in two distinct steps for which the first stage is controlled by the geometry and momentum of the discharge and the second stage results from the natural turbulent dispersive motions in the lake.

2B.1.7 POINT SOURCE

If the condenser cooling water were released to the lake through a relatively wide and deep canal so that the discharge had velocities of a few tenths of feet per second (negligible momentum) or through a single outlet on the bottom a few thousand feet offshore, the point source equation would be applicable and the first stage dilution quite small. In this case decrease in concentration requires travel over relatively great distances and 6600 feet would be required for dilution of 1 to 2 and 13,000 feet required for a dilution of 1 to 4. These dilutions correspond to temperatures of 11 and 5.5°F in excess of natural temperatures, neglecting heat transfer to the atmosphere. Since further dilution would be beneficial, other modes of discharge were examined as indicated below.

2B.1.8 LINE SOURCE

The first stage dilution may be increased by distributing the discharge along a line running perpendicular to the shore. This distribution could be provided by a multiple outlet pipe (diffuser) or by moderate (0.5 ft/sec) velocity canal discharge to produce a plume which moves an equal distance offshore before losing its momentum.

2B.1.9 DIFFUSER SOURCE

Optimum diffuser design with a large (50-100) number of ports in a 1500 ′ length could provide first stage dilution with all the water flowing across the diffuser length. The second stage dilution would be as described by *equation 7* and Figure 2. Dilution under the various lake current speeds is estimated by considering three examples.

1. Average lake current speed. With a speed of 0.2 knots (10 mph wind), the first stage dilution would be 1 to 4.1 for 700 cfs and the surface excess temperature along the distributor would be 5.4°F for a condenser temperature rise of 22°. Having generated this line (vertical plane) source of excess heat or material, significant second stage dilution requires travel over great distances, as shown in Figure 3. The computed distance for a second stage dilution of 1 to 2 is 13.5 miles, with a travel time of 2.8 days. Heat loss to the atmosphere would be significant and this minimum dilution would not be observed at 13.5 miles unless the flow persisted for approximately five days. Excess temperatures of less than one degree may be anticipated at a distance of 13.5 miles, due to cooling but dilution of conservative (stable) materials would be 1 to 8.2.

   At a distance of six miles (for example, off Pultneyville to the east of the site), the second stage dilution would be 1 to 1.1 and the total dilution 1 to 4.5. Excess temperature would be 4.9° without considering heat loss to the atmosphere and using a heat loss coefficient of 0.1 ft/hr as typical of summer conditions, a temperature elevation of 2.9° would be expected. The travel time is 1.25 days so that steady state would be approached after approximately two days, which would frequently occur. These calculations are in agreement with the observed tracer distributions, as for example, on 13 October, 1965 with persistent east drift for the previous four days, tracer concentrations off Pultneyville were 0.5 ppb and the computed concentration with the dilution of 1 to 4.5 derived above is 0.53 ppb.

2. Minimum lake current speed. The minimum speed that persists for more than a few hours is 0.05 knots. The first stage dilution with 1500 feet of distributor length would be 1 to 2.3.

Further dilution (second stage) of 1 to 2 would be expected at a distance of 5 miles down current. The total dilution of 1 to 4.6 at five miles for these conditions is not greatly different from that computed above under average conditions, which was 1 to 4.5 at six miles. Temperature elevation at the surface over the distributor area would be 9.6°. For this minimum lake current speed case, atmospheric cooling would be more important than second stage dilution. Drift over the five mile distance would provide dilution of 1 to 4.6 or a temperature excess of 4.7°, but heat loss to the atmosphere would have reduced the temperature excess to 1.1° during the 4.2 days required to travel the five miles.

It should be noted that the distributor would produce an area approximately 1500 by 2000 feet with an excess temperature of greater than 9° during periods of minimum lake current speeds.

3. High lake current speeds. The maximum observed current speed was 0.5 knots under the influence of 20 mph winds. For this speed, the first stage dilution would be 1 to 10.5. Further dilution by natural turbulence (second stage), even if it is assumed that the diffusion velocity is 0.6 cm/sec (the maximum observed), would occur only after drift for large distances. Second stage dilution of 1 to 2 is computed to occur 25 miles down current. The distributor system would be quite effective near the site under conditions of high lake current speeds, which are not frequent, and would not greatly change the concentrations several miles from the site.

2B.1.10 JET SOURCE

Another manner of cooling water discharge is release of the flow through a restricted opening so that the discharge has velocities considerably greater than the lake velocity. Literature review and model studies of warm-water jet behavior are described by Yuan Jen, R. L. Wiegel and Ismail Mobarek (1966, Surface discharge of horizontal warm-water jet, Journal of the Power Division, ASCE, No. PO2, 4801). A more extensive literature is available for gases (smoke stacks, wind tunnels, etc.) released at right angles to moving air streams. The model studies of Jen, et al were run at very high densiometric Froude numbers, which will not be present in many jet discharge situations and the effects of heated discharge do not appear to be adequately scaled. Observations of discharges with the desirable velocity and volume are not available. Observations on gases and model studies are extrapolated to the conditions possible at the Brookwood site using conservative choices of assumptions to produce a conservative prediction.

Jet discharge into a stationary fluid produces a plume which consists of an initial mixing zone that has a length that is 3 to 5 times the original discharge width and beyond this region the velocity decreases as the volume flux increases due to entrainment of the receiving fluid. For an unbounded jet, the velocity decreases to 0.1 of the initial velocity at distances approximately 60 times the nozzle diameter and the velocity decreases in proportion to the reciprocal of the distance from the nozzle. For large volume flows like condenser cooling water discharged at the surface, the jet is bounded by the free water surface and, due to its buoyancy from heating, may be assumed not to mix vertically and, therefore, is bounded by a lower surface represented by the abrupt density change with depth. Some vertical mixing will occur, but it is neglected here since there are no reliable estimates of this mixing and this procedure

is conservative. For the bounded jet, the velocity decreases with the reciprocal of the square root of the distance from the nozzle.

Observations of jets have shown angles of spread ranging from 1 to 5 through 1 to 8. With wider angles of spread, the entrainment processes is proceeding rapidly with distance. We assume an angle of spread of 1 to 6 as being conservative. From this assumption and the distance dependence assumed above, the shape and concentrations in the jet may be calculated. The effect of the horizontal movement in the lake is taken into account as momentum contributed to the jet by entrainment to produce a deflection of the jet. This momentum mixing process is described in Attachment I to this Appendix.

Figure 9 shows the calculated jet pattern for a 50 by 6 feet nozzle (canal) discharging 700 cfs into water with 0.5 feet per second flow at right angles to the initial jet axis. This pattern is translated into a predicted temperature distribution as shown in Figure 10, where the effect of recirculation on the downstream (wake) side of the jet is taken into account to produce an accumulation of heat in this area. As may be seen by comparing Figures 9 and 10, recirculation along streamlines corresponding to rough semicircles with a radius of 1000 feet is assumed. The probable pattern along this downstream edge has not been described in the studies available in the literature on jets. However, if the recirculation is by way of streamline patterns of smaller or greater radius, lower temperatures will be present in this area and Figure 10 seems to be a conservative estimate. The most likely pattern is recirculation along streamlines with a radius of a few hundred feet, which will produce lower temperatures than shown in the wake region.

These predicted concentrations of heat and material have been made without considering processes other than dilution. Heat loss to the atmosphere and radioactive decay would be significant if such rapid dilution were not available.

The dilutions have been calculated assuming the discharge will not be mixed deeper than six feet; an assumption that produces higher concentrations than would be calculated if greater vertical mixing occurs. If the cooling water intake is located off shore on the bottom, possible recirculation could occur only with extensive vertical mixing (high speed winds). With an intake depth of 28 feet, complete mixing would produce a dilution of 1:4.7 in addition to that shown above and the water drawn into the intake would be a 30 fold dilution of discharged water.

The public water intake nearest to the Brookwood site is the town of Ontario pumping station, which draw water from an inlet about 1100 feet off shore at a depth of 11 feet. Momentum mixing would produce a dilution of 1:10 in the upper six feet, and complete vertical mixing would produce a total dilution of approximately 1:20 for water drawn into this intake.

The anticipated temperature distribution of the surface waters off the Brookwood site is not expected to produce significant effects. Fish may not prefer the limited area (1000 by 100 feet) immediately adjacent to the discharge canal. There is no evidence in the form of fishing activity in the area now that suggests significant fish populations. The larger area (6000 by 2000 feet) with temperatures a few degrees above ambient may attract fish, as has been observed in other localities where discharge of similar quantities and temperatures of heated water has been studied.

Table 1
Temperature (°C) at a station 6000 feet offshore of Brookwood

Depth (meters)	9 July	10 July	12 July	16 July	17 July	25 July
S	19.02	18.10	17.69	18.97	19.09	20.36
2	18.84	17.27	17.59	18.80	18.59	20.15
4	18.19	17.20	17.45	18.61	18.56	20.00
6	16.85	17.20	17.26	18.58	18.55	19.97
8	16.50	17.20	17.14	18.55	18.55	19.97
10	16.44	17.13	17.03	18.53	18.55	19.97
12	15.66	17.06	16.91	18.10	18.50	19.80
14	14.23	16.95	16.84	17.80	18.41	19.70
16	10.44	16.84	16.83	17.71	18.38	18.58
18	5.35	15.52	16.82	17.65	18.37	17.73
20	4.99	12.22	16.80	17.60	18.30	16.81
22	4.94	10.09	16.80	17.31	16.08	12.50
25	4.94	6.70	16.71	11.76	6.25	7.00

APPENDIX A TO APPENDIX 2B

OBSERVED TRACER DISTRIBUTIONS (PARTS PER BILLION)

APPENDIX B TO APPENDIX 2B

WIND SPEED AND DIRECTION OBSERVATIONS METEOROLOGICAL TOWER ON BROOKWOOD SITE ANEMOMETER - ELEVATION 150 FEET

Table 1

	29 April	30 April	1 May	2 May	3 May
0100	W/12	SW/17	NNW/4	SSW/13	SE/2
0200	WNW/12	SW/16	NNE/5	SSW/9	ESE/5
0300	WNW/11	SW/16	NE/3	S/7	SSE/5
0400	WNW/13	SW/17	SSW/2	S/2	S/5
0500	W/12	SW/16	S/5	ENE/5	SSE/3
0600	W/12	WSW/16	SW/8	ESE/8	SSW/3
0700	WSW/11	WSW/19	SW/12	E/7	SSW/1
0800	W/13	WSW/20	SW/6	ESE/4	SW/3
0900	W/13	WSW/17	SSW/6	ENE/5	WSW/6
1000	WNW/11	W/19	ENE/7	ENE/7	W/8
1100	WNW/14	W/20	ENE/5	ENE/7	W/3
1200	WNW/10	WNW/18	NE/7	ENE/7	WNW/6
1300	NW/11	WNW/21	ENE/6	ENE/6	W/13
1400	WNW/10	WNW/22	ENE/7	E/9	W/17
1500	NW/16	WNW/23	ENE/6	E/8	WSW/10
1600	WNW/18	WNW/25	E/6	ENE/9	W/25
1700	W/15	WNW/24	NE/4	ENE/8	WSW/23
1800	W/17	WNW/24	E/2	ENE/9	WSW/26
1900	W/19	WNW/22	E/3	E/16	WSW/17
2000	WSW/22	W/20	E/4	E/15	WSW/20
2100	WSW/20	WNW/17	SSE/4	E/12	WSW/20
2200	WSW/21	NW/13	S/3	E/12	WSW/21
2300	WSW/19	WNW/5	SSE/7	SE/8	WSW/21
2400	WSW/17	WNW/4	S/12	SSE/7	WSW/21

	4 May	5 May	6 May	7 May	8 May
0100	W/23	SW/3	S/12	ESE/9	SSE/14
0200	WSW/22	SW/0	SW/5	ESE/0	SSE/12
0300	WNW/18	NE/2	NNE/5	ENE/5	SSE/14
0400	W/14	ENE/3	SSE/0	SSE/6	SSE/13
0500	W/12	E/3	ENE/0	SE/12	SSE/15
0600	WNW/15	E/1	WNW/2	SE/16	SSE/11
0700	NW/17	ENE/3	NNW/0	SE/10	SSE/11
0800	W/9	E/5	SSE/3	SE/11	SSE/10
0900	WSW/5	E/5	ENE/0	ESE/8	SSE/15
1000	WNW/8	E/3	ENE/3	ESE/9	SSE/13
1100	WNW/10	ENE/6	ENE/5	SE/11	S/9
1200	NNW/3	ENE/7	ENE/10	SSE/18	SSE/8
1300	ESE/5	NE/9	ENE/5	SSE/21	SSE/10
1400	E/6	NE/11	ENE/11	SSE/21	SSE/11
1500	ESE/5	NE/7	ENE/9	SSE/21	SE/8
1600	E/4	ENE/8	ENE/5	SSE/23	SSE/7
1700	E/3	ENE/9	ENE/6	SSE/16	SE/9
1800	ESE/1	ENE/6	E/9	SSE/16	SE/9
1900	SSE/2	E/6	E/11	SSE/15	SSE/18
2000	SSE/5	E/8	E/12	SSE/16	SSE/16
2100	SW/5	ESE/6	E/12	SSE/17	S/16
2200	WSW/4	SE/7	E/12	SSE/17	SSE/18
2300	WSW/2	SSE/11	ESE/10	SSE/16	S/15
2400	SSW/2	S/12	ESE/5	SSE/14	S/15

	9 May	10 May	11 May	12 May	13 May
0100	SSW/14	WNW/11	SW/15	W/9	W/11
0200	SSW/16	SSW/6	WSW/17	W/10	WNW/11
0300	W/15	WSW/8	W/17	SW/5	WNW/14
0400	SSW/3	SW/11	W/16	WSW/9	NNW/14
0500	SSW/9	WSW/10	W/22	WSW/11	N/19
0600	SW/6	SW/8	W/15	SW/12	NNE/15
0700	WSW/7	SW/9	W/15	SW/11	N/18
0800	WSW/8	WSW/8	W/14	SW/9	N/15
0900	W/11	WSW/11	W/14	SW/9	N/14
1000	WNW/17	SW/10	WNW/11	WSW/8	N/19
1100	WSW/6	W/7	WNW/16	WNW/12	NNW/14
1200	SW/8	N/5	WNW/16	WNW/13	NNW/15
1300	SSW/17	NE/5	WNW/13	NW/15	NNW/12
1400	SW/15	NE/5	W/15	NW/15	NN@/11
1500	W/12	NNE/4	WNW/17	NW/9	NW/9
1600	WNW/17	ENE/2	WNW/17	WNW/5	WNW/11
1700	NW/5	E/5	W/17	NW/7	WNW/8
1800	WNW/1	ENE/0	WNW/21	W/17	WNW/6
1900	WSW/8	WNW/2	WNW/18	W/12	WNW/9
2000	WSW/7	SW/5	W/12	WSW/15	WNW/10
2100	WSW/9	SW/5	W/8	WSW/15	WNW/9
2200	WSW/9	SSW/8	SW/11	WSW/17	S/0
2300	SW/11	SSW/10	WSW/11	WSW/17	S/0
2400	SSW/13	WSW/14	WSW/11	W/14	SSW/3

	14 May	15 May	16 May
0100	S/5	S/12	S/13
0200	ESE/7	S/13	S/12
0300	SSE/8	SSW/13	S/14
0400	S/7	S/11	SSW/14
0500	SSW/4	S/5	SSW/13
0600	WSW/8	S/5	SSW/13
0700	W/4	SE/5	SSW/11
0800	WSW/0	SSW/2	SSW/10
0900	N/2	S/4	SSW/11
1000	N/3	SSE/5	SSW/12
1100	NNE/3	SE/2	SW/14
1200	NE/5	ENE/6	SW/13
1300	ENE/4	ENE/8	SW/12
1400	ENE/5	ENE/7	SSW/13
1500	ENE/5	ENE/8	SSW/16
1600	E/6	ENE/7	W/9
1700	ENE/6	E/13	NE/0
1800	E/6	E/11	SW/11
1900	E/10	E/8	SSW/14
2000	E/8	E/9	S/14
2100	ESE/6	ESE/10	SSW/16
2200	SE/7	SE/11	SSW/15
2300	SSE/9	SE/11	WNW/11
2400	SSE/10	SSE/13	W/8

	9 July	10 July	11 July	12 July	13 July
0100	S/12	WSW/12	WNW/13	WNW/8	N/7
0200	S/12	W/13	WNW/10	WNW/9	N/7
0300	S/12	W/15	WSW/9	WNW/8	N/5
0400	S/9	WNW/12	WSW/8	W/6	N/1
0500	S/11	WNW/16	W/10	SW/10	N/2
0600	S/11	W/12	W/10	WSW/11	N/5
0700	S/11	W/14	WSW/6	WSW/9	N/1
0800	SSW/9	WNW/16	WNW/12	W/7	N/4
0900	SSW/5	WNW/12	WNW/9	WNW/10	N/5
1000	SSW/6	WNW/14	WNW/8	WNW/11	N/8
1100	SSW/5	WNW/13	WNW/9	WNW/9	N/2
1200	SSW/9	NW/9	WNW/11	NW/7	N/2
1300	SSW/14	NW/7	WNW/9	NNW/4	N/3
1400	SSW/14	NNW/3	WNW/11	NNW/4	N/4
1500	SSW/13	NNW/1	WNW/9	NNE/8	N/4
1600	S/14	NNW/1	WNW/8	NNE/4	N/6
1700	S/14	NNW/3	WNW/9	NNE/2	N/5
1800	S/12	WNW/14	W/10	N/3	N/6
1900	S/11	WNW/6	WNW/10	ENE/0	N/2
2000	SW/23	WNW/5	W/7	SE/0	N/2
2100	WSW/18	W/9	W/10	SE/0	N/3
2200	WSW/13	WNW/15	W/10	N/2	N/7
2300	SW/17	WNW/15	W/10	N/3	N/12
2400	WSW/12	WNN/13	WNW/8	N/5	N/12

	14 July	15 July	16 July	17 July	18 July
0100	N/14	WNW/7	W/9	WSW/10	N/3
0200	N/13	WNW/10	W/9	SW/9	N/2
0300	N/13	NW/16	WSW/10	W/10	ENE/4
0400	N/12	W/12	SW/9	WSW/4	NE/6
0500	N/14	W/13	WSW/10	SW/7	NE/16
0600	N/16	W/11	SW/11	SW/2	ENE/10
0700	N/18	W/13	SW/9	S/3	NE/11
0800	N/15	WNW/13	SSW/7	E/0	ENE/7
0900	N/16	WNW/14	SSW/7	SE/3	ENE/6
1000	N/15	NNW/16	WSW/4	SE/1	NE/5
1100	N/11	NW/15	NW/2	E/0	NE/4
1200	N/13	WNW/12	NE/5	ENE/4	NNE/8
1300	W/14	NW/10	NE/7	ENE/4	NNE/18
1400	W/16	NW/7	ENE/7	ENE/5	NNE/11
1500	W/15	NW/5	ENE/7	NE/7	N/10
1600	W/20	NW/10	E/6	ENE/6	NNW/10
1700	W/8	NW/9	E/9	ENE/5	NNW/9
1800	W/5	NNW/7	ESE/5	E/5	NNW/11
1900	NW/5	NW/3	ESE/3	NE/4	NNW/7
2000	NW/8	WNW/5	SE/5	NE/4	NNW/6
2100	WSW/12	W/11	SE/5	ENE/1	NNE/4
2200	WSW/10	W/10	SSW/6	SE/3	NNW/7
2300	W/8	W/9	SW/8	NNE/1	NNE/9
2400	W/8	W/9	SW/9	NNW/1	NNE/15

	19 July	20 July	21 July	22 July
0100	NNE/13	NNE/14	WSW/10	S/10
0200	N/12	NNE/11	WSW/9	S/11
0300	N/12	NNE/8	WSW/10	S/10
0400	N/11	N/7	WSW/11	S/9
0500	NNW/9	NW/2	SW/11	S/8
0600	N/12	NW/3	WSW/11	S/8
0700	NNW/9	WNW/6	WSW/10	S/7
0800	NNW/9	W/5	WSW/6	WSW/3
0900	NW/11	NW/14	WNW/6	SW/4
1000	NW/16	NW/15	WNW/7	WNW/7
1100	NW/18	NW/14	WNW/7	WNW/5
1200	NW/17	NW/11	NW/4	WNW/5
1300	NW/20	WNW/11	NNW/4	NNW/3
1400	WNW/17	NW/10	NNW/6	N/0
1500	WNW/16	NW/11	NNW/5	NE/1
1600	WNW/17	WNW/10	NNW/4	ENE/0
1700	WNW/18	WNW/8	NNW/3	NE/1
1800	WNW/21	WNW/7	N/3	ESE/6
1900	N/5	WNW/5	N/2	S/1
2000	NW/6	W/3	E/0	SSE/3
2100	WNW/13	WNW/5	SSE/3	SE/6
2200	NNW/11	W/9	SSW/2	SSE/9
2300	N/11	W/11	SSW/5	SSE/10
2400	N/14	W/12	S/9	S/7

	23 July	24 July	25 July
0100	S/8	WNW/6	WNW/16
0200	SSW/8	WSW/7	WNW/13
0300	SSW/9	WSW/6	W/12
0400	SSW/6	SW/7	WNN/12
0500	SSW/7	SW/9	W/9
0600	S/5	SSW/9	WSW/7
0700	SSW/5	N/0	WSW/7
0800	SSW/4	SSW/6	W/9
0900	SW/1	SSW/8	WNW/10
1000	NNW/2	SW/6	WNW/8
1100	NNE/3	WNW/12	NW/9
1200	N/2	NW/5	NW/7
1300	NNE/2	NE/3	NNW/6
1400	NNE/5	ENE/3	N/4
1500	NE/4	E/2	NNW/3
1600	NE/5	WNW/10	NNW/9
1700	NE/4	W/17	NW/6
1800	NE/3	WNW/12	WNW/5
1900	N/0	W/15	WNW/8
2000	WNW/2	W/14	W/5
2100	WNW/3	NNW/11	W/8
2200	W/5	WNW/12	WSW/10
2300	W/6	WNW/10	SW/10
2400	WNW/5	WNW/11	SW/10

	7 Oct.	8 Oct.	9 Oct.	10 Oct.	11 Oct.
0100	S/17	ESE/8	SSW/8	SW/10	WSW/8
0200	SSE/17	SSE/4	SW/13	WNW/14	WSW/8
0300	S/15	SSW/1	SW/14	WNW/14	W/11
0400	S/15	S/4	SW/15	WNW/15	SW/6
0500	SSE/16	SSW/10	SW/16	NW/17	WSW/7
0600	SSE/15	SW/12	SW/15	W/11	SW/9
0700	S/15	SSW/14	SSW/16	WNW/14	SSW/7
0800	S/16	SSW/10	SW/15	WSW/10	SSW/7
0900	SSE/18	SSW/12	SW/18	W/9	SSW/7
1000	S/16	SW/12	SW/16	NW/15	SSW/8
1100	SSE/18	SW/19	SW/17	WNW/12	S/8
1200	S/19	SW/13	WSW/18	WNW/11	S/11
1300	SSE/18	SSW/15	WSW/22	WNW/14	S/6
1400	SSE/18	SSW/17	WSW/21	WNW/10	SSW/5
1500	SSE/16	SSW/18	WSW/13	NW/15	SW/9
1600	SE/17	WSW/15	SW/16	WNW/18	WSW/16
1700	SE/13	W/7	WSW/16	WNW/12	NW/15
1800	SE/11	SSW/7	SW/9	W/8	W/10
1900	SE/13	WSW/11	SW/9	W/9	WSW/9
2000	SE/12	W/11	SW/7	W/11	WSW/11
2100	SE/15	SW/15	SW/8	WSW/8	SW/9
2200	SE/17	SW/11	SSW/9	W/8	W/11
2300	SE/15	SSW/11	SSW/9	WSW/9	W/8
2400	ESE/15	SSW/11	SSW/8	WSW/10	W/7

	12 Oct.	13 Oct.	14 Oct.	15 Oct.	16 Oct.
0100	WSW/6	WSW/13	S/11	S/14	NW/14
0200	WSW/7	WSW/12	S/11	S/16	WNW/10
0300	WSW/9	WSW/11	SSE/11	S/16	W/10
0400	SW/9	WSW/11	S/9	S/15	W/12
0500	WSW/10	WSW/10	S/9	S/14	W/12
0600	SW/10	SW/10	SSE/7	S/15	WNW/11
0700	SSW/11	SW/10	W/1	S/15	W/9
0800	SSW/10	SW/9	SW/2	SSW/13	NNW/16
0900	SW/10	WSW/11	SSW/2	SSW/14	N/12
1000	SW/14	N/-0	SSE/1	SW/21	N/13
1100	SW/14	WNW/11	ENE/4	SW/24	N/13
1200	SSW/11	WNW/14	ENE/7	WSW/26	NNE/10
1300	WSW/25	WNW/18	ENE/7	WSW/23	NNE/8
1400	SW/26	NW/17	ENE/8	WSW/19	NNE/9
1500	W/14	NW/18	ENE/9	W/18	NNE/7
1600	W/21	NW/17	E/8	W/21	N/5
1700	W/23	W/10	E/6	W/14	N/7
1800	W. 20	W/4	E/8	WNW/15	NE/1
1900	WNW/14	S/5	E/10	WNW/21	ESE/0
2000	WSW/10	S/10	ESE/11	WNW/17	SW/0
2100	WSW/11	S/8	SE/11	NNW/18	SW/1
2200	SW/10	SSW/9	SSE/9	NW/15	WSW/2
2300	SW/12	S/9	S/13	WNW/15	NNW/0
2400	N/0	S/11	S/15	NW/17	WNW/1

APPENDIX 2B ATTACHMENT I

THE EFFECT ON LAKE DILUTION OF MOMENT MIXING

At distances greater than about 8 miles from the site, the equation used for the computation is given on page 2.4-10. The limnological data derived from the continuous tracer release tests are used in the form of the empirical diffusion velocity. The best fit to the observed data was given by a diffusion velocity of 3.3 x 10 m/sec and this value was used in the computations.

At distances less than about 8 miles from the site, the dilution is produced primarily by the momentum mixing resulting from the horizontal discharge of the circulating water system. This process may be evaluated from the following considerations.

Our coordinate system is as follows:

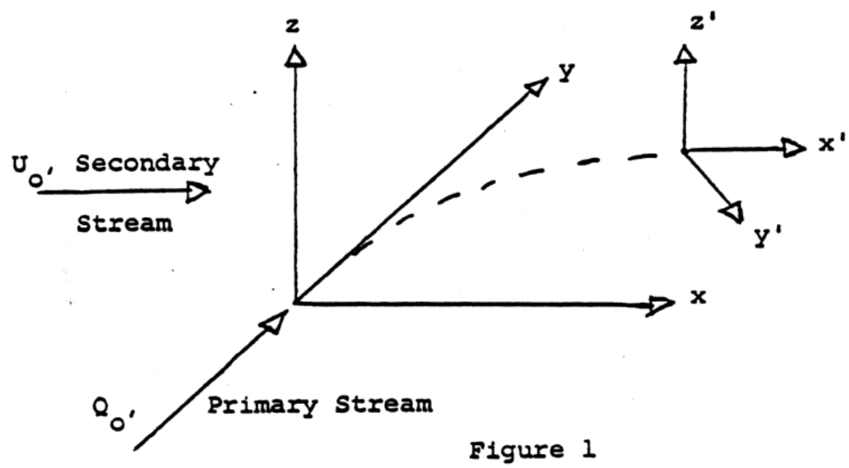

Figure 1

Subject to the following assumptions:

1. That longitudinal diffusion may be neglected,
2. That momentum and material spread at the same rate, and
3. That profiles of mean fluid attached properties such as concentration, velocity, etc. along an x ′ = constant plane, when scaled by their peak or centerline values, are expressable as a universal function of z ′/1_o and y ′/l_o where 1_o (x ′) is a length scale. In our case we have chosen a simple top-hatted distribution function, i.e., at a particular x, values along y ′ are constant throughout the plume and zero outside the plume.

$$\bar{\sigma}(x') = \bar{\sigma}_M(x')\, f(y'/b(x')) \text{ where } f = 1 \text{ for } |y'| \leq b(x') \text{ and } f = 0 \text{ for } |y'| > b(x')$$

and where $\bar{\sigma}_M$(x ′) is the fluid attached property and b(x ′) is the width of the top

hat. the conservation of material for 3 dimensions may be written as

$$\frac{d}{dx'}\{D(x')\, b(x')\, Q_M(x')\, \bar{\sigma}_M(x')\} = 0$$ (Equation 1)

or for a system bounded in the z ′ direction by the sea surface and by a level bottom we have

$$\frac{d}{d(x')}\{b(x')\,Q_M(x')\,\bar{\sigma}_M(x')\} = 0 \quad \text{(Equation 2)}$$

where $Q_M(x')$ is the centerline velocity and $\bar{\sigma}_M(x')$ is the centerline concentration of material.

Integrating (2) with respect to x' from $x' = 0$ to x' we obtain

$$\frac{\bar{\sigma}_M(x')}{\sigma_0}\cdot\frac{Q_M(x')}{Q_0}\cdot\frac{b(x')}{b_0} = 1 \quad \text{(Equation 3)}$$

In general it may be shown that assumption 3) requires that the lateral spread of the fluid attached properties be linear or that

$$\frac{db(x')}{dx'} = constant$$

Therefore, we write

$$\frac{b(x')}{b_0} = 1 + x'/x'_v,\ for\ x' \geq 0 \quad \text{(Equation 4)}$$

where x'_v is the distance from the orifice to the boundary between the zone of establishment and the zone of established flow. See Figure 2.

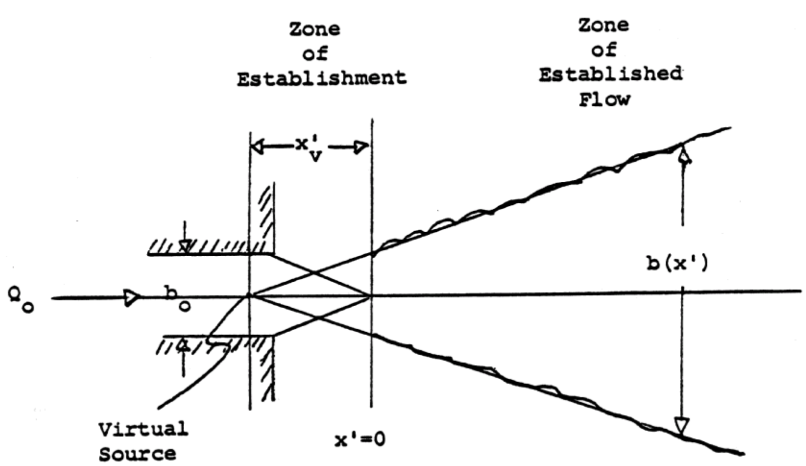

Figure 2

From (3) and (4) we obtain

$$\frac{\bar{\sigma}_M(x')}{\sigma_0}\cdot\frac{Q_M(x')}{Q_0} = \frac{1}{1 + x'/x'_v} \quad \text{(Equation 5)}$$

It now remains to relate $\frac{\bar{\sigma}_M(x')}{\sigma_0}$ and $\frac{Q_M(x')}{Q_0}$. To show this we proceed as follows.

It should be remembered that we are mixing two streams of water. The jet, or primary stream, initially possesses no x-momentum. By entrainment of the surrounding fluid, or secondary stream, it gains X-momentum and gives up Y-momentum and material. The jet continues to spread by entrainment into the secondary stream until such time as it has given up all of its material and Y-momentum. This occurs theoretically at infinity. We may express the foregoing concepts more formally as follows.

Consider a mixture of n parts of the secondary stream and m parts of the jet, or primary stream. We may write for concentration

$$\bar{\sigma}(x') = \frac{n \cdot 0 + m \cdot \sigma_0}{n + m} = \frac{m}{n + m} \cdot \sigma_0$$

or

$$\frac{\bar{\sigma}_M(x')}{\sigma_0} = \frac{m}{n + m} \equiv dilution \quad \text{(Equation 6)}$$

Similarly for X-momentum we have

$$U(x') = \frac{n \cdot U_0 + m \cdot 0}{n + m} = \frac{n}{n + m} \cdot U_0$$

or

$$\frac{U(x')}{Q_0} = \frac{n}{n + m} \cdot \frac{U_0}{Q_0} = \frac{n}{n + m} \cdot R \quad \text{(Equation 7)}$$

where $R \equiv U_0 / Q_0$ (Equation 8)

and for Y-momentum $\frac{V(x')}{Q_0} = \frac{m}{n + m} = \bar{\sigma}_M(x') / \sigma_0$ (Equation 9)

Combining equations (5), (6), (7), (8), (9) and remembering that

$$\frac{Q_M(x')}{Q_0} = \sqrt{\left(\frac{U(x')}{Q_0}\right)^2 + \left(\frac{V(x')}{Q_0}\right)^2} \quad \text{(Equation 10)}$$

on the centerline, we obtain

$$\frac{\bar{\sigma}_M(x')}{\sigma_0} = \left\{\frac{1}{1 + x'/x'_v}\right\}^{1/2} \qquad \left\{\frac{m^2}{n^2R^2 + m^2}\right\}^{1/4} \quad \text{(Equation 11)}$$

In order to compute $\bar{\sigma}_M(x')/\sigma_o'$, the dilution, as a function of x'/x'_v we rearrange (11) and obtain

$$x'/x'_v = \frac{1 - \left(\frac{\sigma_M(x')}{\sigma_0}\right)^2 \sqrt{\frac{n^2}{m^2} \cdot R^2 + 1}}{\left(\frac{\bar{\sigma}_M(x')}{\sigma_0}\right)^2 \sqrt{\frac{n^2}{m^2} \cdot R^2 + 1}} \quad \text{(Equation 12)}$$

and tabulate as follows for R = 1/5 remembering that

$$\frac{n}{n+m} + \frac{m}{n+m} = 1$$

Dilution or $\bar{\sigma}_M(x')/\sigma_o$ is plotted as a function of $1 + x'/x'_v$ in Figure 3 from Table 1. It shows a decrease to the -1/2 power at early time and a decrease to the -l power at late time.

The centerline trajectory may be defined by the following equation

$$\frac{d(x'/x'_v)}{Q_M(x')} = \frac{d(x/x'_v)}{U_M(x')} = \frac{d(y/x'_v)}{V_M(x')} \quad \text{(Equation 13)}$$

or

$$\Delta(x/x'_v) = \frac{U_M(x')}{Q_M(x')}\,\Delta(x'/x'_v) \quad \text{(Equation 14)}$$

and

$$\Delta(y/x'_v) = \frac{V_M(x')}{Q_M(x')}\,\Delta(x'/x'_v) \quad \text{(Equation 15)}$$

That is, the trajectory may be computed by computing $\sigma_M(x')$, $V_M(x')$, and $Q_M(x')$ from Figure 3 and *equations (7)*, *(9)*, and *(10)* and substituting the values thus obtained in *equations (14)* and *(15)* to obtain x/x'_v and y/x'_v. This computation has been made for $R = \frac{U_0}{Q_0} = 1/5$ and is shown in Table 2.

The results of this computation are shown as Figure 9 of Appendix 2B.

Table 1

$\frac{\bar{\sigma}_M(x')}{\sigma_0}$	$\frac{m}{n+m}$	$\frac{n}{n+m}$	$\left(\frac{n}{m}\right)^2$	R^2	$\sqrt{\frac{n^2}{m^2} - R^2 + 1}$	x'/x'_v
1	1	0	0	1/25 = 0.04	1	0
0.9	0.9	0.1	0.0124	"	1	0.235
0.8	0.8	0.2	0.0625	"	1	0.562
0.7	0.7	0.3	0.184	"	1.003	1.003
0.6	0.6	0.4	0.445	"	1.009	1.756
0.5	0.5	0.5	1	"	1.02	2.920
0.4	0.4	0.6	2.250	"	1.043	5.00
0.3	0.3	0.7	5.44	"	1.101	9.10
0.2	0.2	0.8	16	"	1.280	18.50
0.1	0.1	0.9	81	"	2.06	47.5
0.05	0.05	0.95	361	"	3.92	101.0
0.02	0.02	0.98	2401	"	9.88	252

Table 2

TABLE 2

$\frac{x'}{x'_v}$	$\Delta\frac{x'}{x'_v}$	$\frac{\bar{\sigma}_M(x')}{\sigma_o}$	$\frac{V_M(x')}{Q_o}$	$\frac{U_M(x')}{Q_o}$	$\frac{Q_M(x')}{Q_o}$	$\frac{U_M(x')}{Q_M(x')}$	$\overline{\frac{U_M(x')}{Q_M(x')}}$	$\Delta\frac{x}{x'_v}$	$\frac{x}{x'_v}$	$\frac{V_M(x')}{Q_M(x')}$	$\overline{\frac{V_M(x')}{Q_M(x')}}$	$\Delta\frac{y}{x'_v}$	$\frac{y}{x'_v}$
0		1	1	0	1	0			0	1			0
	1						0.043	0.043			1.000	1.000	
1		0.70	0.70	0.060	0.70	0.086			0.043	1			1.000
	1						0.116	0.116			0.992	0.992	
2		0.575	0.575	0.085	0.584	0.146			0.159	0.984			1.992
	1						0.171	0.171			0.982	0.982	
3		0.500	0.500	0.100	0.51	0.196			0.330	0.980			2.974
	1						0.222	0.222			0.975	0.975	
4		0.44	0.44	0.112	0.454	0.247			0.552	0.970			3.949
	1						0.268	0.268			0.964	0.964	
5		0.40	0.40	0.120	0.418	0.288			0.820	0.958			4.913
	1						0.308	0.308			0.952	0.952	
6		0.366	0.366	0.127	0.388	0.328			1.128	0.945			5.865
	1						0.344	0.344			0.938	0.938	
7		0.341	0.341	0.132	0.366	0.360			1.472	0.931			6.803
	1						0.376	0.376			0.926	0.926	
8		0.320	0.320	0.136	0.348	0.391			1.848	0.920			7.729
	1						0.405	0.405			0.915	0.915	
9		0.304	0.304	0.139	0.334	0.418			2.253	0.910			8.644
	1						0.434	0.434			0.901	0.901	

TABLE 2 (Cont 'd)

$\frac{x'}{x'_v}$	$\Delta\frac{x'}{x'_v}$	$\frac{\bar{\sigma}_M(x')}{\sigma_o}$	$\frac{V_M(x')}{Q_o}$	$\frac{U_M(x')}{Q_o}$	$\frac{Q_M(x')}{Q_o}$	$\frac{U_M(x')}{Q_M(x')}$	$\overline{\frac{U_M(x')}{Q_M(x')}}$	$\Delta\frac{x}{x'_v}$	$\frac{x}{x'_v}$	$\frac{V_M(x')}{Q_M(x')}$	$\overline{\frac{V_M(x')}{Q_M(x')}}$	$\Delta\frac{y}{x'_v}$	$\frac{y}{x'_v}$
10		0.285	0.285	0.143	0.319	0.450			2.687	0.893			9.545
	2						0.473	0.946			0.880	1.760	
12		0.258	0.258	0.148	0.298	0.496			3.633	0.866			11.305
	2						0.520	1.040			0.853	1.706	
14		0.236	0.236	0.153	0.281	0.543			4.673	0.840			13.011
	2						0.562	1.124			0.828	1.656	
16		0.219	0.219	0.156	0.269	0.580			5.797	0.815			14.667
	2						0.598	1.196			0.802	1.604	
18		0.203	0.203	0.159	0.258	0.616			6.993	0.788			16.271
	2						0.632	1.232			0.774	1.548	
20		0.190	0.190	0.162	0.250	0.648			8.225	0.760			17.819
	5						0.684	3.420			0.728	3.640	
25		0.162	0.162	0.168	0.233	0.720			11.645	0.696			21.459
	5						0.743	3.715			0.668	3.340	
30		0.143	0.143	0.171	0.223	0.766			15.360	0.640			24.799
	5						0.784	3.920			0.616	3.080	
35		0.129	0.129	0.174	0.217	0.801			19.280	0.593			27.879
	5						0.825	4.125			0.563	2.815	
40		0.112	0.112	0.178	0.210	0.848			23.405	0.532			30.694
	10						0.869	8.690			0.495	4.950	

TABLE 2 (Cont'd)

$\frac{x'}{x'_v}$	$\Delta\frac{x'}{x'_v}$	$\frac{\bar{\sigma}_M(x')}{\sigma_o}$	$\frac{V_M(x')}{Q_o}$	$\frac{U_M(x')}{Q_o}$	$\frac{Q_M(x')}{Q_o}$	$\frac{U_M(x')}{Q_M(x')}$	$\overline{\frac{U_M(x')}{Q_M(x')}}$	$\Delta\frac{x}{x'_v}$	$\frac{x}{x'_v}$	$\frac{V_M(x')}{Q_M(x')}$	$\frac{V_M(x')}{Q_M(x')}$	$\Delta\frac{y}{x'_v}$	$\frac{y}{x'_v}$
50		0.093	0.093	0.181	0.208	0.890			32.095	0.457			35.644
	10						0.903	9.030			0.424	4.240	
60		0.079	0.079	0.184	0.201	0.916			41.125	0.391			39.884
	20						0.933	18.660			0.347	6.980	
80		0.061	0.061	0.188	0.198	0.950			59.785	0.307			46.864
	20						0.960	19.200			0.281	5.620	
100		0.050	0.050	0.190	0.196	0.970			78.985	0.255			52.484
	50						0.977	48.850			0.238	11.900	
150		0.0335	0.0335	0.193	0.196	0.984			127.835	0.171			64.384
	50						0.987	49.350			0.150	7.500	71.884
200		0.0251	0.0251	0.195	0.197	0.990			177.185	0.128			
	50						0.993	49.650			0.115	5.750	77.634
250		0.0201	0.0201	0.196	0.197	0.995			226.835	0.102			
	50						0.995	49.750			0.094	4.700	82.334
300		0.0169	0.0169	0.197	0.198	0.995			276.585	0.085			

APPENDIX 2C

REPORT, SUPPLEMENTARY FOUNDATION STUDIES, PROPOSED BROOKWOOD NUCLEAR POWER PLANT (R. E. GINNA NUCLEAR POWER PLANT), ONTARIO, NEW YORK

EARTH SCIENCES

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CONSULTANTS IN APPLIED EARTH SCIENCES
SOIL MECHANICS · ENGINEERING GEOLOGY · GEOPHYSICS

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ASSOCIATE: FRANCIS E. RANFT

June 2, 1966

Gilbert Associates, Incorporated
Engineers and Consultants
525 Lancaster Avenue
Reading, Pennsylvania 19603

Attention: Mr. Hans Lorenz

Gentlemen:

We submit herewith ten copies of our "Report, Supplementary Foundation Studies, Proposed Brookwood Nuclear Power Plant, Ontario, New York, Rochester Gas and Electric Corporation."

The scope of our studies was planned in cooperation with Mr. D. K. Croneberger of Gilbert Associates, Incorporated. Our preliminary conclusions were transmitted verbally to Messrs. Croneberger and H. Lorenz during the course of our studies.

Yours very truly,

DAMES & MOORE

Robert M Perry

Robert M. Perry, P.E.

RMP:ts

2C.1 INTRODUCTION

2C.1.1 GENERAL

This report presents the results of our supplementary foundation studies for the proposed Brookwood Nuclear Power Plant presently under construction near Ontario, New York, for the Rochester Gas and Electric Corporation. Detailed information relative to environmental conditions, site and subsurface features, and general foundation recommendations are presented in our report[a] dated June 14, 1965.

2C.1.2 PURPOSE

The purpose of our supplementary studies was to:

1. recommend specific bearing pressures for use in the design of foundations supported by the natural compact granular soils, compacted granular fill and sound bedrock;
2. present more detailed information on the depths at which the compact natural granular soils and the bedrock are encountered;
3. further explore the condition of the bedrock in the reactor area; and
4. evaluate the effects of the dynamic load imposed by the turbine-generator on the soil-foundation system.

2C.1.3 SCOPE OF WORK

The field phase of our supplementary studies consisted of drilling seven test borings. Two of the borings were drilled in the reactor area and extended 50 feet into the bedrock. The remaining five borings were terminated when bedrock was encountered. Undisturbed soil samples, suitable for laboratory testing, were extracted from each test boring. Rock cores were recovered from the two borings in the reactor area.

The locations of the borings drilled for these studies are shown in relation to the proposed construction and previously drilled borings on the Plot Plan, Plate 1. The field explorations were performed under the technical direction of a Dames & Moore Engineering Geologist.

The results of the field explorations and laboratory tests, which provide the basis for our engineering analyses and recommendations, are presented in the Appendix to this report.

2C.1.4 SITE CONDITIONS

The plant will be located in a relatively level meadow area with surface elevations[b] on the order of +275 feet. Grading operations were underway during our field explorations.

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a. "Report, Site Evaluation Study, Proposed Nuclear Power Plant, Ontario, New York, Rochester Gas and Electric Corporation"

b. All elevations presented in this report refer to United States Coast and Geodetic Survey Datum.

The subsurface conditions encountered in the borings drilled during this investigation are similar to those previously encountered in the plant area. In general, the plant area is underlain by four basically different types of material. These are, in order of increasing depth:

1. firm brown surficial silty and clayey soils;
2. soft gray silty clay;
3. compact sandy and gravelly soils; and
4. bedrock.

Detailed descriptions of the materials encountered in the plant area are shown on the boring logs presented in the Appendix. In general, the compact granular soils were encountered at depths ranging from about five feet to 35 feet below the original ground surface. Bedrock generally was observed at depths ranging from about 34 feet to 40 feet below the surface. The southwest corner of the proposed plant revealed bedrock at somewhat shallower depths.

Contours of the surface of the compact granular soils and the underlying bedrock are presented on the Plot Plan. This contour map was prepared by interpolation between borings. Consequently, local variations may occur between the boring locations which are not indicated by the contours.

2C.2 DISCUSSION AND RECOMMENDATIONS

2C.2.1 GENERAL

It is understood that foundations for the major plant facilities will be installed at depths of 25 or more feet below the original ground surface. In our prior report, we recommended that spread or mat foundations be installed on the natural compact granular soil, compacted granular backfill or sound bedrock.

Spread and mat foundation installation and design criteria are presented in subsequent sections of this report. The results of our analyses evaluating the effects of the turbine generator on the soil foundation system are presented in the final section of this report.

2C.2.2 FOUNDATION INSTALLATION PROCEDURES

Natural Soils: Spread or mat foundations can be installed directly on the compact granular soils at elevations below those indicated by the contours on the Plot Plan. We recommend that the sand and gravel at foundation depth be proof rolled with heavy pneumatic-tired equipment. The proof rolling will recompact soils which are disturbed during excavation operations. Any local pockets of loose or soft material requiring additional excavation also will be revealed by the proof rolling operations. Soils removed below proposed foundation grade should be replaced with compacted structural fill or lean concrete.

Compacted Backfill: Foundations which are to be installed above the elevation of the surface of the natural granular soils should be supported by compacted granular backfill placed after the clayey soils are removed. Prior to placing the backfill, the exposed underlying natural granular soil should be proof rolled. The structural fill then should be placed in layers approximately eight inches in thickness. Each layer should be compacted to a density of at least 95 percent of the maximum density obtainable by the Modified AASHO[a] Method of Compaction, Test Designation T180-57. We suggest that large vibratory or heavy pneumatic tired equipment be used to compact the granular backfill soils.

We believe that most of the natural granular soils excavated in the plant area below the elevations indicated on Plate 1 can be reused as back fill. The upper silty and clayey soils should not be used as structural fill.

It will be necessary to dewater all deep excavations. Information regarding ground water levels and soil permeability was presented in our previous report. We recommend that adequate dewatering measures be taken prior to final excavation and that the dewatering be continuously maintained during:

1. final excavation;
2. proof rolling operations;
3. placement of structural backfill;
4. foundation installation; and

---

a. American Association of State Highway Officials

5. general backfilling operations.

We recommend that an experienced Soils Engineer be present during site preparation in order to inspect the excavation and proof rolling operations and to technically supervise the placement of structural backfill.

2C.2.3 FOUNDATION DESIGN CRITERIA

Soil: Based upon the results of our field explorations and laboratory tests, we recommend that spread and mat foundations be designed utilizing the net bearing pressures presented on Plate 2, Foundation Design Data. The bearing pressures presented on Plate 2 are applicable for the compact natural granular soil and structural granular fill compacted in accordance with our aforementioned recommendations. The recommended bearing pressures apply to the total of all design loads, dead and live. The term "net bearing pressures" refers to the foundation pressure that can be imposed in excess of the lowest adjacent overburden pressure. The recommended bearing pressures apply to foundations at least ten feet in width.

We recommend that the maximum net bearing pressures imposed on the natural compact soils and the compacted structural fill should be limited to 10,000 and 8,000 pounds per square foot, respectively. Although, from a stability standpoint, greater bearing pressures could be used in the design of large spread and mat foundations, we recommend that these limiting vales be maintained in order to restrict foundation movements to small elastic deformations.

Rock: We recommend that foundations installed on the underlying sound rock be designed utilizing a bearing pressure not in excess of 35 tons per square foot. This pressure applies to the total of all design loads, dead and live. It is possible that weathered rock may be encountered at the soil-rock interface. Our field explorations indicate that the weathered zone is relatively thin, generally less than one to two feet in thickness.

We understand that the bedrock in the reactor area will be required to provide resistance to lateral forces. We believe that a lateral resistance of 25,000 pounds per square foot of vertical contact area can be relied upon in the sound rock. This lateral resistance applies only to foundations poured in "neat" excavations directly against the exposed rock faces. The 25,000 pounds per square foot value does not take into account the additional resistance which would be provided by any adjacent overburden above the surface of the bedrock.

The exposed bedrock should be inspected by a qualified Engineering Geologist in order to examine the condition of the foundation material and to check for any unusual or unanticipated joint patterns.

2C.2.4 TURBINE-GENERATOR FOUNDATION

The turbine generator will be supported on a mat foundation approximately 40 feet by 150 feet in plan dimensions. The base of the mat will be installed at approximately Elevation +243 feet, some four to seven feet above the rock surface. The center-line of the turbine generator will be approximately 50 feet above the base of the mat foundation. The dead weight of the equipment and the foundation will impose a pressure of about 4,000 pounds per square foot on the foundation soils.

We understand that the turbine generator will operate at approximately 1,800 revolutions per minute. During start-up and operation, an unbalanced moment on the order of 2,000,000 foot-pounds will be transmitted to the soils at the base of the mat. This moment is a steady-state condition and does not vary with the operating speed. Unbalanced dynamic forces will be negligible. A torque approximately ten times the operating torque will result from a short-circuit load. This, short-circuit torque will be balanced within the equipment foundation and will not be transmitted to the foundation soil.

Our analyses indicate that the deflection resulting from the unbalanced moment will be on the order of 0.004 inches at the edge of the unit. We believe that there will be no influence from any small unbalance in the equipment since the operating frequency is well above the resonant frequency of the soil-foundation system.

The following Plates and Appendix are attached and complete this report:

Plate 1 - Plot Plan

Plate 2 - Foundation Design Data

Appendix - Field Explorations and Laboratory Tests

Respectfully submitted,

DAMES & MOORE

Robert M. Perry

State of New York

P.E. Registration No. 35284

Arthur Rothman

RMP-AR: ts

2C.3 REPORT APPENDIX - FIELD EXPLORATIONS AND LABORATORY TESTS

2C.3.1 FIELD EXPLORATIONS

The subsurface conditions in the plant area were explored during this investigation by drilling 7 supplementary test borings to depths ranging from 35 feet to 90 feet below the ground surface. The locations of the borings are shown on the Plot Plan. The field exploration program was conducted under the technical direction of a Dames & Moore Engineering Geologist.
The borings were drilled approximately four inches in diameter utilizing truck-mounted rotary drilling equipment. Driller's mud was used where necessary to prevent the walls of the borings from caving.

Continuous observations of the materials encountered in the borings were recorded in the field during drilling operations. Undisturbed soil samples, suitable for laboratory testing, were extracted from the borings utilizing the Dames & Moore sampler illustrated in Figure 3 of this Appendix. The sampler is three and one-quarter inches in outside diameter and approximately two and one-half inches in inside diameter. Rock cores were obtained from the two test borings in the reactor area to a depth of 50 feet below the rock surface utilizing a Series NX core barrel. The cores recovered are two and one-eight inches in diameter. The soil samples and rock cores were shipped to our New York office and laboratory where they were further examined and subjected to appropriate laboratory tests.

Detailed descriptions of the soils and rock encountered in the borings are presented on Plates A-1A and A-lB, Log of Borings. The soils were classified in accordance with the Unified Soil Classification System described on Plate A-2.

The number of blows required to drive the sampler a distance of one foot into the soil utilizing a 500-pound drive weight, falling a distance of 18 inches is presented in the column at the left of the log of each boring. The percent of core recovery obtained during coring operations is also presented in this column.

The elevations which appear at the top of each boring log refer to United States Coast and Geodetic Survey Datum and were determined by representatives of Rochester Gas and Electric Company.

2C.3.2 LABORATORY TESTS

Soil: A number of undisturbed samples of the natural compact granular soils were tested to evaluate their strength characteristics. Triaxial compression tests were performed on the soil samples in the manner described in Figure 4. In addition to the tests on samples of the natural undisturbed soils, triaxial compression tests were performed on samples of remolded and recompacted granular material. These tests were used in our compacted fill studies to evaluate the variation in strength characteristics with changes in density.

A load-deflection curve was plotted for each strength test and the shearing strength of the soil was determined from this curve. Determinations of the moisture content and dry density of the soils were made in conjunction with each strength test.

The results of the strength tests and the corresponding moisture and density determinations are tabulated in Table 1. Summary of Soil Strength Test Data.

Rock: Unconfined compression, triaxial compression and tension tests were performed on selected rock cores extracted from the borings. These tests were performed by subjecting rock cores approximately two and one-eight inches in diameter and four to six inches in height to an axial strain and recording the resisting stress developed by the rock. A stress-strain curve was plotted for each of the compression tests and the shearing strength of the rock was determined from this curve. The results of the strength tests on the rock cores are presented below:

BORING	DEPTH (feet)	CELL PRESSURE (psi)	ONE-HALF DEVIATOR STRESS (psi)	TYPE OF TEST
201	42	-	50[a]	Tension
201	45	-	50[a]	Tension
201	49	1,000	4,700	Triaxial Compression
202	47	-	3,900	Unconfined Compression
202	$50^{1/2}$	1,500	4,400	Triaxial Compression

a. Indicates peak tensile stress normal to bedding planes.

The following Plates are attached and complete this Appendix:

Plate A-lA - Log of Borings (Borings 201 and 202)

Plate A-1B - Log of Borings (Borings 203 through 207)

Plate A-2 - Unified Soil Classification System and Key to Test Data

Table 1
SUMMARY OF SOIL STRENGTH TEST DATA

BORING	DEPTH (feet)	DRY DENSITY (pcf)	MOISTURE CONTENT (percent)	CELL PRESSURE (psf)	ONE-HALF DEVIATOR STRESS (psf)	REMARKS
202	$30^{1/2}$	114	11.2	1,500	3,900	Natural
		110	11.0	1,500	2,100	Recompacted
				2,000	2,900	Recompacted
				3,000	4,400	Recompacted
		115	10.6	1,500	3,300	Recompacted
				2,000	3,750	Recompacted
		127	10.5	1,500	4,150	Recompacted
203	$10^{1/2}$	117	10.8	500	1,400	Natural
				1,500	2,700	Natural
		124	11.2	500	2,700	Recompacted
				1,500	4,300	Recompacted
203	$15^{1/2}$	120	12.1	1,500	1,600	Natural
				3,000	3,800	Natural
				6,000	8,300	Natural
		111	11.5	500	800	Recompacted
				1,000	1,800	Recompacted
				3,000	4,000	Recompacted
204	$20^{1/2}$	112	7.3	2,000	4,000	Natural
		111	7.6	2,000	3,500	Recompacted
205	$15^{1/2}$	125	11.6	1,000	3,000	Natural
		122	11.8	1,000	1,800	Recompacted

BORING	DEPTH (feet)	DRY DENSITY (pcf)	MOISTURE CONTENT (percent)	CELL PRESSURE (psf)	ONE-HALF DEVIATOR STRESS (psf)	REMARKS
207	16 1/2	144	6.5	2,000	5,200	Natural