CHAPTER 125

Jamaica Bay Hurricane Barrier

by
Frank L Panuzio 1/
Fellow American Society of Civil Engineers

ABSTRACT

A 12 4 mile beach erosion control and hurricane flood protection project includes Jamaica Bay and the Rockaway Inlet in the southwest corner of Long Island, New York. The project would provide 6 1 miles of beach fill and floodwalls along the Atlantic Ocean shore and 6 3 miles of inland structures to tie back to high ground, including a 0 9 mile barrier across the inlet The barrier, with a 300 foot gated opening and a 300 foot ungated opening, would permit suppression of the design hurricane surge so as to eliminate the need of flood protection works within the bay Linear mathematical models were used to determine these openings Because of the limitation of these models to produce adequate data in the bay pertinent to environmental and ecological considerations, three hydraulic models were utilized General conclusions drawn from the hydraulic model test data are that the results of the mathematical models were upheld, a design storm with high peak is critical for determining the height of protection, a design storm with high volume rather than high peak plus rainfall runoff is critical in determining ungated openings and suppression of bay levels, and there is a combination of gated and ungated openings that would meet the flood protection, navigation, environmental and ecological objectives

GENERAL

Project The Jamaica Bay hurricane barrier is a part of a 12 4 mile, Federal beach erosion control and hurricane flood protection project, authorized by the Congress of the United States in June 1965 at more than 50 million dollars [1,2]

Location The project extends along the Atlantic Ocean side of the Rockaway peninsula from high ground in the vicinity of East Rockaway Inlet to high ground in the vicinity of Rockaway Inlet and includes Jamaica Bay (Figure 1) Jamaica Bay is a coastal body of water in the southwest corner of Long Island and connects to the lower bay of New York Harbor and the Atlantic Ocean through the Rockaway Inlet The bay is bounded by the boroughs of Brooklyn and Queens and Rockaway peninsula in New York City and by Nassau County, all in the southeast corner of New York State Long Island is a long, narrow island in the north Atlantic Ocean at a significant indentation of the northeastern coast line of the United States The Rockaway peninsula is a barrier beach which extends westward from the mainland of Long Island and separates Jamaica Bay from the Atlantic Ocean

Objectives The project objective is to provide protection against storm water flooding due to hurricanes along the developed shore line of the Rockaway peninsula and of Jamaica Bay and to restore and to stabilize the beach along the ocean shore line of the Rockaway peninsula

The barrier objective is to provide a practicable solution of a tieback to high ground for the coastal works and to suppress the design hurricane surge to a non-damaging level in the bay so as to eliminate the need of protective works along the shores of the bay without any detrimental change in the existing bay environment and ecology during the no-storm period

Problem In the preauthorization studies, the size of the barrier openings during normal and storm periods was determined by the use of a simplified linear mathematical model While this model is adequate to predict water surface elevations and the discharges and average velocities in the openings, it did not produce adequate values of local hydraulic changes in the bay such as local

1/ Senior Engineer Consultant for Civil Works
U S Army, Corps of Engineers, New York District

OBLIQUE LOOKING GENERALLY EASTWARD

ROCKAWAY INLET TO EAST ROCKAWAY INLET

FIGURE 1 JAMAICA BAY, LONG ISLAND, NEW YORK, U.S.A.

velocities and currents, salinities, tidal levels and circulation which are essential to pollution, fish and wildlife, and other environmental and ecological considerations [1,5,6] Therefore, environmental and ecological interests, recognizing this deficiency, requested that additional field studies and hydraulic model investigations be conducted during the final design of the project to determine the specific effects of the hurricane barrier on water quality, fish and wildlife, and currents in Jamaica Bay The authorization by Congress was subject to this consideration

AUTHORIZED PROJECT

Description The authorized project from east to west, with all elevations referred to mean sea level, would consist of (Figure 1) a 0 3 mile concrete closure wall at East Rockaway Inlet with a top elevation from 18 to 15 feet at closure and with a 6 foot high and 40 foot wide stoplog structure, a beach fill of more than 4 million cubic yards with a 100 to 200 foot wide berm at an elevation of 10 feet and with a 1 on 20 oceanward slope, backed up by a concrete-clad, steel sheet pile floodwall with a top elevation of 18 feet along 6 1 miles of the ocean side of the Rockaway peninsula, a 0 9 mile flood dike with a top elevation of 18 to 15 feet across the Rockaway peninsula to Rockaway Inlet, a 0 6 mile concrete floodwall and levee along the inlet with a top elevation of 15 to 18 feet, a 0 9 mile gated barrier across the inlet with a top elevation of 18 feet, a 1 2 mile levee and dike, and a 2 4 mile natural ground closure with a top elevation of 18 feet at the barrier to 15 feet at the closure

The Barrier The solid portion of the barrier would consist of (Figure 2) two sections with lengths of 1,860 and 1,670 feet, with a top width of 12 feet at an elevation of 18 feet, with side slopes of 1 on 1 5 and with fishing platforms on both sides at an elevation of 8 0 feet The middle 1,000 feet of the barrier with a bottom elevation of minus 42 5 feet would consist of a 600 foot navigation opening and two side rolling gates, each 150 feet wide with gate recesses, to permit closure of this opening to 300 feet during the storm periods

Still Water Level The design still water level for the authorized project is the peak of the Standard Project Hurricane surge occurring at the mean astronomical tide (Figure 3) For the prediction of surges at the mouth of the New York Harbor for a design storm, a research investigation was conducted at The A and M College of Texas [4] From this research, a correlation-prediction formula was developed empirically, with some degree of theoretical guidance, from observed tides and corresponding meteorological parameters of storms inducing them On this basis, using the meteorological parameters of the September 1944 hurricane transposed to a path critical to the New York Harbor area, the Standard Project Hurricane surge was determined to be 12 3 feet [3,4] The meteorological parameters were a maximum wind of 116 miles per hour, a central pressure range of 27 55 to 27 95 inches of mercury with a normal pressure of 30 12 inches of mercury, a radius to maximum winds of 30 nautical miles and a foreward speed of 40 knots

Protection Height The design height of the protection works is the design still water level plus the wave runup Based on the solitary wave theory, the maximum breaking wave at the beach fill was found to be 20 5 feet with a 12 second period Using the composite slope method and experimental data, [7] the runup for this wave would be 5 7 feet Thus, the top of protection was placed at an elevation of 18 feet At the barrier, based on a generalized relationship between winds and wave observations, [8] an effective fetch of 3 9 miles, a wind speed of 80 miles per hour and an effective depth of 32 feet at the design still water level would result in a wave of 6 7 feet with a period of 5 seconds This wave, based on experimental data on riprap structures, [7,8] would produce a wind setup and runup of 5 7 feet Thus, the top of protection was also placed at elevation 18

Mathematical Model The propagation of tides inside a bay may be expressed by dynamic and continuity equations [1,5,6] These equations, due to boundary conditions

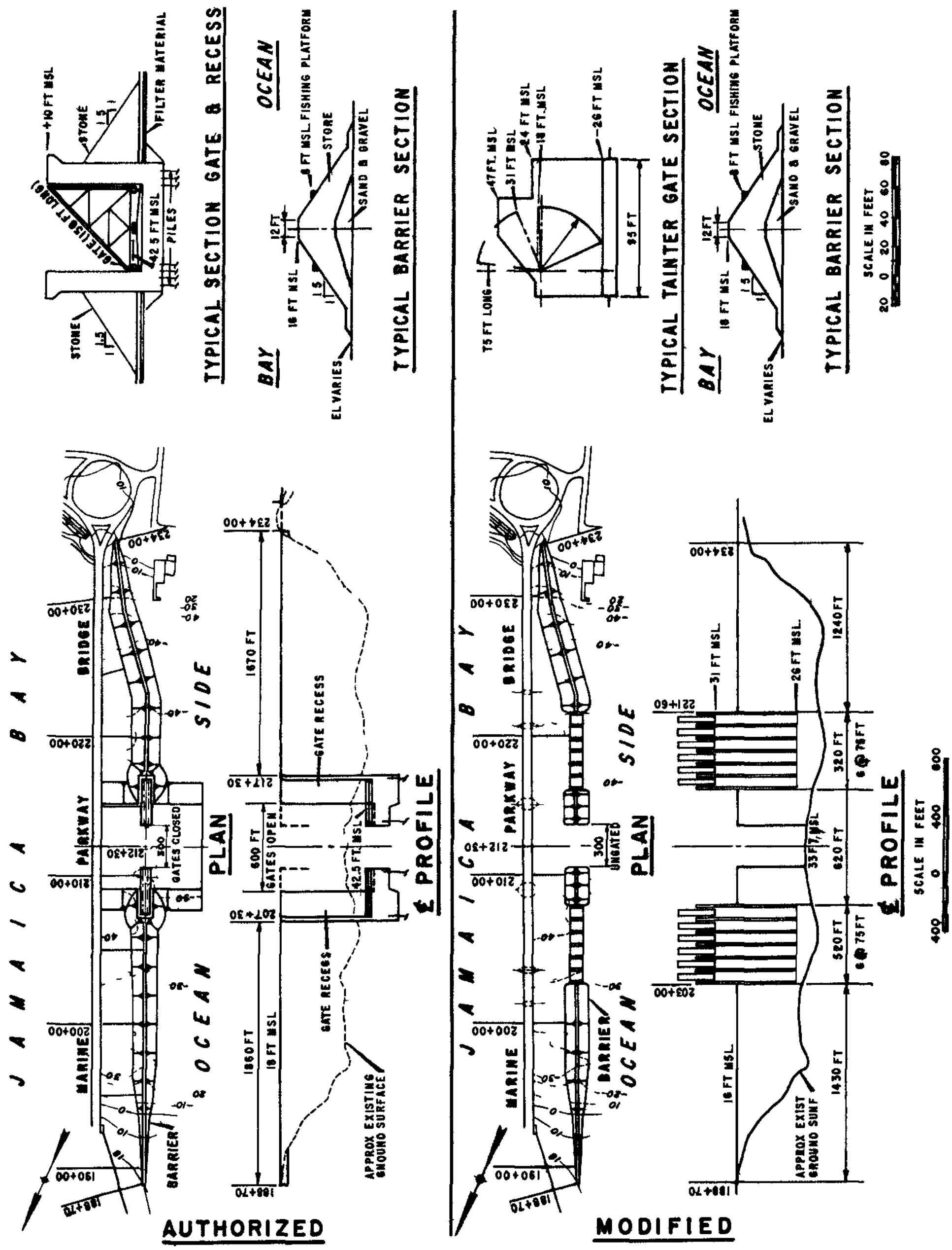


FIGURE 2 JAMAICA BAY BARRIER

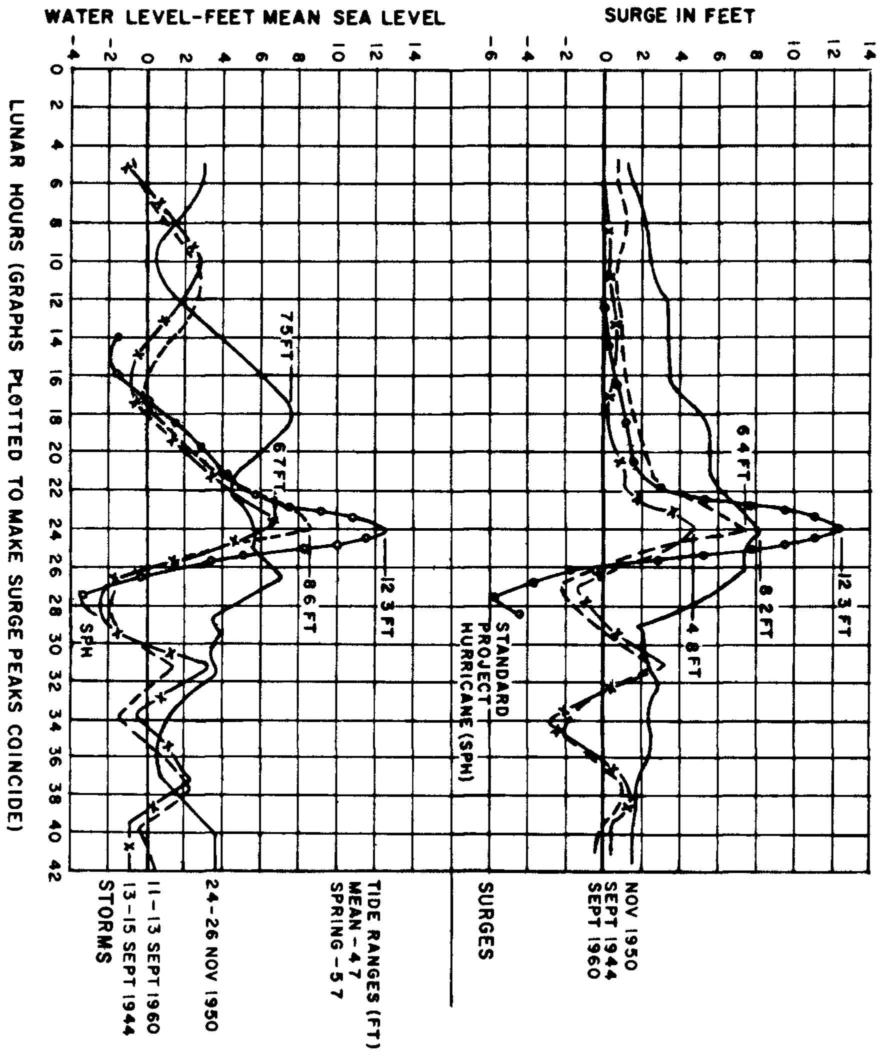


FIGURE 3 CRITICAL DESIGN HURRICANES-FORT HAMILTON, NY

and many complex terms involved, could not be solved analytically within the scope and time frame of the study In order to obtain a practical solution, assumptions were made to simplify the equations by neglecting and simplifying the terms of the equations without substantial loss in accuracy The bay is, basically, a basin connected to the ocean by a relatively long and narrow channel of the Rockaway Inlet So, a simple, one-dimensional model for current natural conditions of the bay was developed on the assumption that the flow through the channel is governed only by the functional resistance in the channel with negligible inertia forces and that the level inside of the bay is variable only with time with an adjustment for wind setup and rainfall The adequacy and adjustment of this model were developed by routing the hurricane of September 1960 to produce recorded bay levels When the barrier is placed across the natural Rockaway Inlet, the mathematical model must be adjusted for the increased resistance to flow at the barrier Thus, the one-dimensional model was based on two principal assumptions The resistance to flow through the barrier opening and the inlet channel is the only significant force acting on the dynamic system The water surface throughout the bay is assumed horizontal and related to the ocean surface elevation only by the law of continuity and the loss through the barrier and inlet channel With these basic assumptions, the dynamic relationships were expressed by the following equations

$$Q = \pm C A_b \sqrt{2g} \sqrt{Z_a - Z_J}$$

in which Q = discharge through barrier opening, C = discharge coefficient, A_b = area of opening, Z_a = water surface elevation on ocean side, and Z_J = water surface elevation on bay side

$$Q = \frac{S_J \; dZ_J}{dt} - I_r$$

in which S_J = surface area of bay, and dZ_J = change in bay water surface elevation for time interval of dt and I_r = rainfall-runoff inflow rate

Barrier Opening The initial barrier opening was sized to be large enough to minimize any change in the natural bay environment and ecology during no-storm periods, to satisfy the projected navigation vessel and traffic, and to suppress the design hurricane level to about zero damage stage in the bay To accomplish the first two objectives, 14 routings were made for the spring astronomical tidal range of 5 7 feet, utilizing the mathematical model, the area capacity curve, navigation depths of 15 to 42 6 feet mean sea level and openings from 100 to 1,000 feet with results as shown on Figure 4 On the basis of these results, the minimum opening that would have minimal effect on the astronomical spring tidal range and would satisfy the navigation depths and velocities was the 600 foot opening with a depth of 42 5 feet at mean sea level, a 4 5 knot maximum velocity in the opening, and a reduction in range of 0 10 feet The 1,000 foot opening showed no significant change in tidal range, and a 3 0 knot maximum velocity The average velocity in the Rockaway Inlet for tbe existing conditions is in the order of 2 7 knots However, average velocities up to 5 knots are considered tolerable for navigation

Based on a gross appreciation of the hydraulic system of Jamaica Bay and Rockaway Inlet, a quasi theoretical mathematical model of BOD vs Tidal Prism relationship for Jamaica Bay was developed [9] This relationship assumed that change in total waste load as measured by the BOD is directly related to the volume of the tidal prism This model was used with waste loads measured during the summer of 1959-1962 and anticipated future waste loads obtained from city sources to predict accumulation of waste in Jamaica Bay and Rockaway Inlet for the tidal prism change estimated from the effect of each barrier opening The results from the model for the 600 and 1,000 foot openings were that the change in waste load accumulation

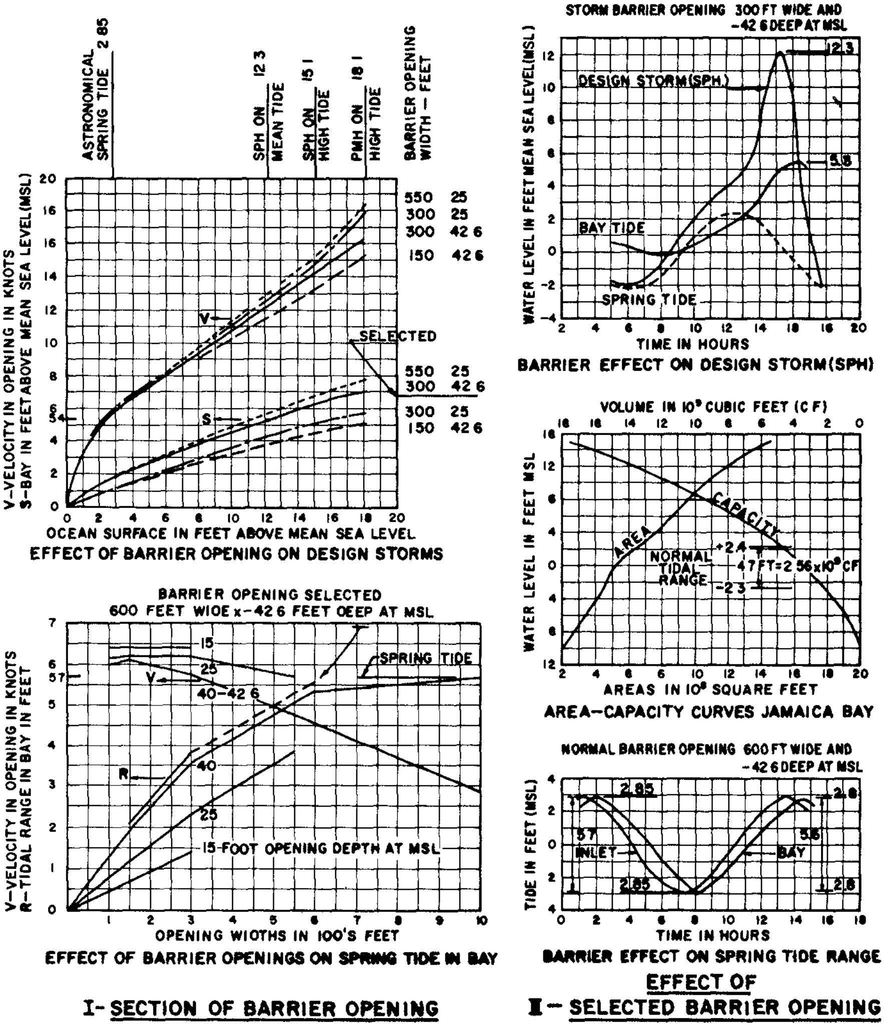


FIGURE 4 BASIS OF AUTHORIZED BARRIER OPENING DESIGN

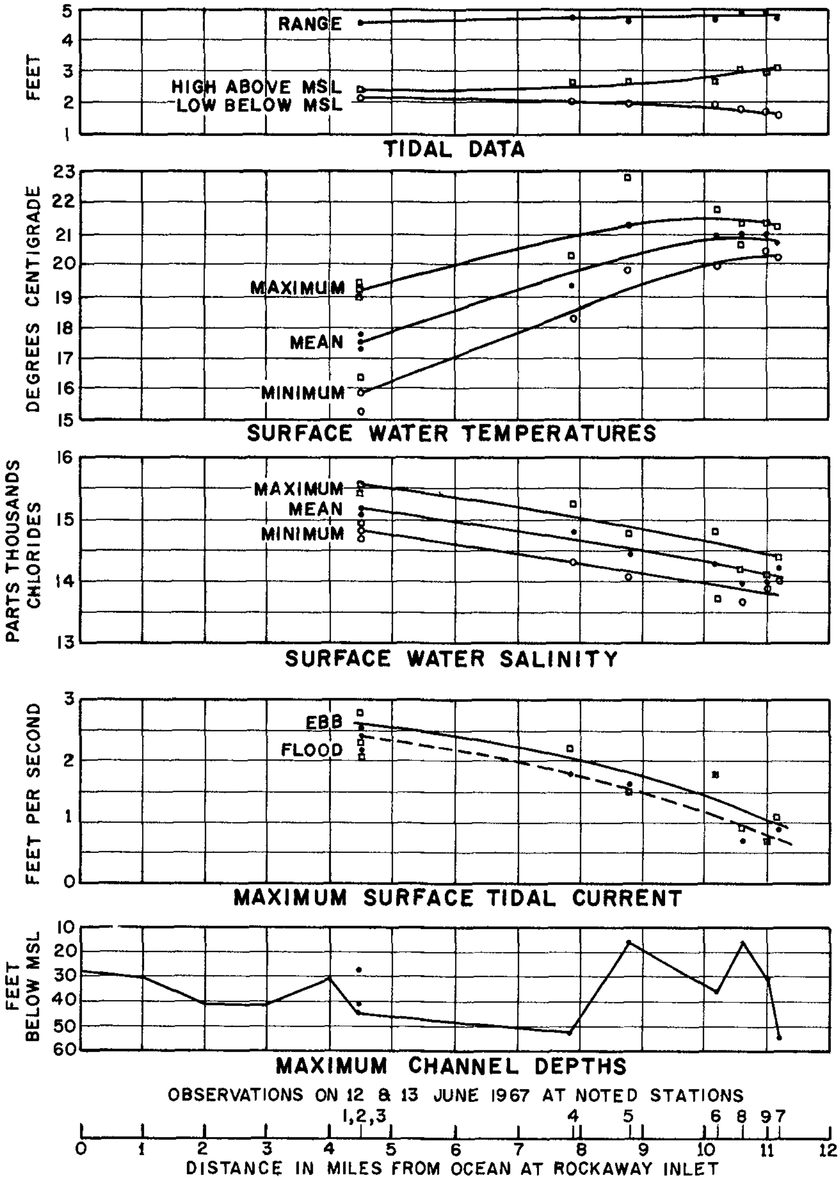
would be virtually zero and that there would be no significant damage to water quality In the interest of minimum first cost, since the selected opening would have to be gated to obtain suppression of the design hurricane, the 600 foot opening was selected for the normal operating conditions

To obtain the third objective, to suppress the design hurricane level to about zero damage stage in the bay, 13 routings were performed utilizing the mathematical model, the area capacity curve, navigation depths of 25 and 42 6 feet below mean sea level and openings of 150,300, and 550 feet with results as shown in Figure 4 On this basis, the storm opening of 300 feet with a depth of 42 6 feet at mean sea level was selected to produce a bay level for the Standard Project surge on mean tide of 5 3 feet at mean sea level, about zero damage stage

Limitations While these models are adequate to predict water surface elevations, discharges and average velocities in the opening, and gross evaluation of the water quality, they cannot produce adequate values of local hydraulic changes in various parts of the bay such as velocities and currents, salinities, tidal levels and circulation which are essential to pollution, fish and wildlife, and other environmental and ecological considerations Therefore, recognizing this deficiency, the Congressional authorization was subject to the condition that additional field studies and hydraulic model investigations would be conducted in the final stage of design to evaluate and to minimize the specific effects of the hurricane barrier on water quality, fish and wildlife, and currents in Jamaica Bay

FIELD INVESTIGATIONS

Measurements Field measurements were started in January 1967 with a view to developing data to construct and verify a hydraulic model of Jamaica Bay To develop the physical characteristics of the bay, a photographic and topographic survey of the area was made to a horizontal scale of 1 inch = 1,000 feet and to a vertical relief of two foot contours up to elevation 20 feet mean sea level The underwater contours were developed by a sounding survey at sufficient sections to delineate the underwater topography For hydraulic verification, measurements were made on 12 and 13 June 1967 Current velocities were recorded at nine stations in Jamaica Bay at locations shown on Figure 1 and identified by letter V Current velocities were taken every one half hour over a complete tidal cycle at surface, mid-depth, and bottom Tidal current observations were timed generally to cover a period between successive low tides, during daylight hours, for a period in excess of 13 hours when the diurnal inequality was a minimum Simultaneous measurements were taken at stations 1V, 2V, and 3V, at stations 2V, 4V, 5V, and 6V, and at stations 2V, 7V, 8V, and 9V in order to obtain the distribution of flow in the channel system of the bay Each group of stations was tied into the other two groups through continuous reading at station 2V Three Ott meters with F4 counter and two Gurley Price meters with 611 counter were used Each meter was connected to an electric revolution counter and watch Reduction of field data was by use of laboratory calibration curves for each meter At each station, current meter measurements were made for a total period of one minute at just below the surface, at 2 feet above the bottom and at mid-depth where depths exceed 6 feet at mean low water At each velocity station depth, water samples were taken with one or two liter Kemmerer samplers after water was permitted to flow freely out of the sampler The temperature of each sample was taken immediately with armored thermometers with a range of -1° to 50° Centigrade in 0 1° divisions The salinity of each sample was determined in the laboratory and recorded in parts per thousands of chlorides The hydrography at each of these stations was also obtained with depths referred to mean sea level Data were also developed as to sanitary and storm water inflow at four sewage treatment plant overflows and five storm water outfalls and on weather conditions as to rain, wind, and temperature



FIGURES 5 FIELD OBSERVATIONS—JAMAICA BAY CHARACTERISTICS

<u>Results</u> The Jamaica Bay characteristics measured as to tidal currents, tidal range, temperatures, salinities and hydrography are shown in Figure 5 [10] The water depth varies from 15 to 55 feet at mean sea level For the measured tidal cycle, the tidal range varies from 4 6 to 4 9 feet with the higher values in the interior of the bay and with time of high and low water almost identical at the five interior stations The surface tidal currents vary from 2 5 to 0 7 feet per second on flood and from 2 8 to 0 7 feet per second on ebb with the lower values at the interior The currents were found to be greatest at the surface and minimum at the bottom Slack water was found to be coincident with or within one half hour of the times of high and low tides The surface water salinity varied between 15 2 and 14 0 parts per thousand of chloride with the higher values at the entrance The salinities increased with depth and were maximum near the end of flood and minimum near end of ebb The surface water temperature varied from 17 3° to 21 0° Centigrade with the higher temperatures in the interior The temperature decreased with depth and was greatest near end of ebb and least near end of flood

HYDRAULIC MODEL INVESTIGATIONS

<u>Purpose</u> The model studies of Jamaica Bay were to determine the effects of the hurricane surge protection barrier in the Rockaway Inlet on (a) water quality in the bay as to public health, recreation, and fish and wildlife, (b) recreational and commercial navigation, and (c) suppression of the design storm surge to such a level as to provide protection to the area surrounding the bay from storm flooding

<u>Facilities</u> The hydraulic model studies were carried out in three research facilities at the U S Army, Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, Figure 6 Jamaica Bay is a small section of the basic comprehensive model of the New York Harbor complex This model, constructed to linear scale ratio (model to prototype) of 1 100 vertically and 1 1,000 horizontally, produces velocities at the ratio of 1 10, time at 1 100, discharge at 1 1,000,000 and salinity at 1 1 The Jamaica Bay area was reconstructed to reproduce prototype hydrographic and topographic conditions below +20 feet mean sea level as of June 1967 Tides and their associated flood and ebb tidal currents are controlled in the model by the interaction of a primary programmable tide generator located in the Atlantic Ocean at Sandy Hook and two secondary tide generators, one located in Long Island Sound and another located in the Hudson River at Hyde Park at the upstream limit of the model Weirs are used to control the upland freshwater inflow from tributaries A surge generator is used to produce the time-elevation history of the design storms This model is used to develop data on the tidal regime, currents, salinities, dispersion characteristics, surge suppression and the barrier composition

A second model reproduced a short reach of the Rockaway Inlet to an undistorted linear scale of 1 100 The velocity or time ratio is 1 10 and the discharge ratio is 1 100,000 Various designs of gated and ungated barrier openings were tested to determine their hydraulic efficiency under conditions of normal tides and storm surges and to determine in detail the flow patterns and velocities in and adjacent to the openings that might be significant to the design of the structure or to navigation through the structure

The third model, to the scale of the basic model, was used to develop the distorted scale structures that have the hydraulic efficiencies as developed in the undistorted model for use in the distorted comprehensive model This procedure ensured that when the distorted scale structures are placed in the comprehensive model they would pass the proper flows into and out of Jamaica Bay under any combination of head differentials imposed by the tides and storm surges

<u>Bay Model Verification</u> The Jamaica Bay portion of the comprehensive model was first corrected to reproduce the latest topographic and hydrographic conditions Then, the bay area was adjusted to reproduce prototype data for tides, tidal currents, and salinities, as observed on 12 and 13 June 1967 (Figure 5) [10] The high

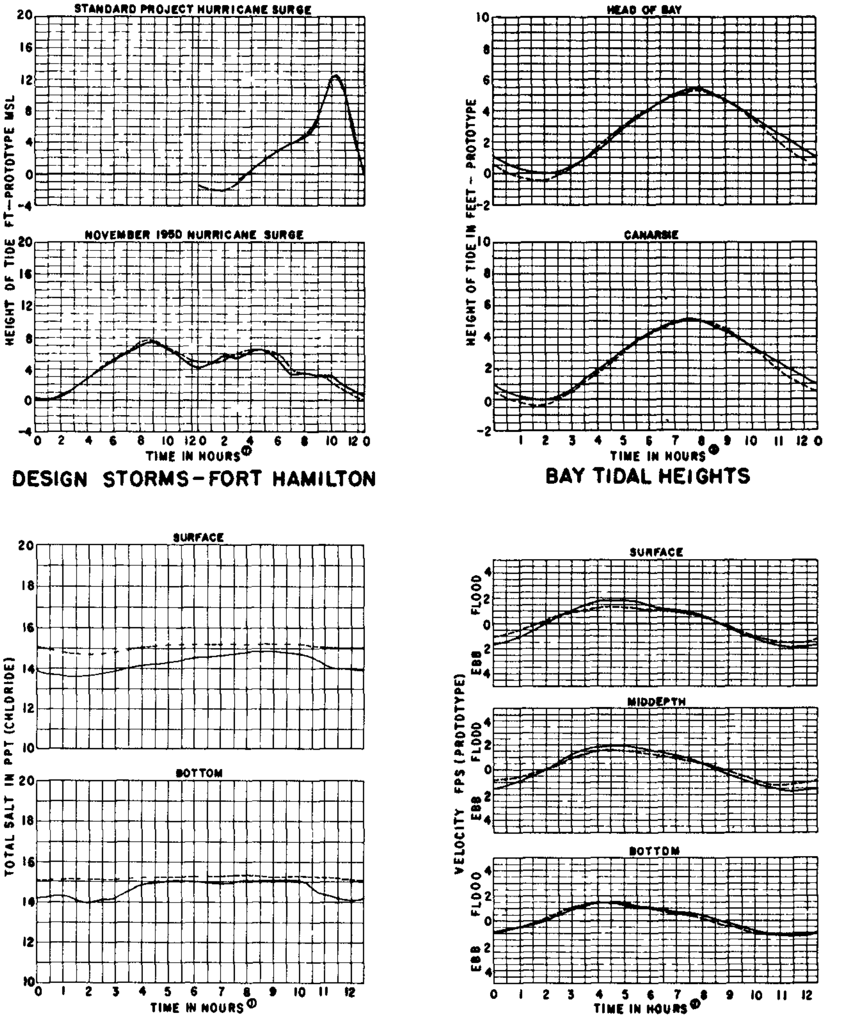
FIGURE 6 JAMAICA BAY MODELS

degree of accuracy attained in the model verification as to tides, current velocities, salinities, and design storms is illustrated by the comparative model and prototype curves shown on Figure 7 [11] While there are some differences between model and prototype data, these differences were probably attributable to local winds and other disturbances that occurred when the prototype measurements were taken and that could neither be identified nor simulated to scale in the model verification tests

Barrier Model Verification The barrier gated and ungated openings were constructed to the undistorted scale of the second model (Figure 6) For steady flood flow conditions, and various combinations of the ungated opening with open gates, the ocean level was varied and the bay levels were determined The procedure was reversed for the ebb conditions, the bay levels were varied and the ocean levels were determined The results of this procedure for a 150 foot opening are shown on Figure 8 A distorted model was designed and adjusted until its calibration by the same procedure would match the undistorted model calibration The results of this procedure for a 150 foot opening are shown on Figure 8 These tests were made to develop undistorted models for ungated openings of 300, 150, and 110 foot openings with combinations of 12 or 16 gate openings and sill levels in the ungated openings at natural ground, -23 feet and -26 feet at mean sea level The hydraulic efficiency of the openings expressed as a discharge coefficient for various degrees of submergence and differential head for various steady flow discharges were developed as shown for the 150 foot ungated opening on Figure 8 It is noticeable that with decrease of submergence and increase in differential head and discharge, the efficiency of the opening becomes constant as the discharge coefficient becomes constant, a value slightly greater than 0 90 The conditions of surface currents are developed by vertical photographs of three-second time lapse exposure of floating confetti in the undistorted model (Figure 8) The length of confetti streak is converted to surface velocity The barrier openings so developed in the distorted scales were inserted in the comprehensive model for water quality, navigation, and environmental tests

Base Tests Once the model verification was accepted as being sufficiently accurate, model base tests or tests of existing conditions under carefully controlled conditions of tides, freshwater inflow, pollution input and hurricane surges were conducted The results of these base tests (Figure 9), rather than the verification tests (Figure 7), were used to evaluate the effects of the barrier plans investigated in subsequent model tests Thus, the model tests with and without barriers were made under identical and carefully controlled conditions In this manner, any differences noted in tides, tidal currents, salinities, dispersion of pollutants or surge elevations with various barrier plans installed are attributable to the barrier plan under study and are not affected in any way by minor differences between model and prototype phenomena noted during verification

The base tests were conducted with a mean repetitive tide, a constant source of salinity, freshwater inflows and pollution sources and rates All necessary phenomena were measured at predetermined sampling stations that would reflect conditions throughout the bay area The repetitive mean tide had a duration of 12 45 hours and a range of 4 7 feet measured at Sandy Hook The sump salinity was maintained at 30 parts per thousand (ppt) The primary freshwater inflow was 12,000 c f s from the Hudson River at Hyde Park and 1,770 c f s from the Raritan River at head of tide Additional freshwater inflow sources were from treatment plant outfalls and storm water overflows in the amount of 130 69 c f s from two sources into the inlet downstream of any barrier and of 236 93 c f s from seven sources into the bay upstream of any barrier Under these conditions, the model was operated for 25 cycles, equivalent to 12 5 days in nature to assure that salinity stability had been obtained before data collection was begun Tides were measured with point gauges graduated to the nearest 001 foot (0 1 foot prototype)



DESIGN STORMS-FORT HAMILTON

BAY TIDAL HEIGHTS

BAY SALINITIES-STATION 6V

BAY CURRENT VELOCITIES-STATION 6V

①—AFTER MOON S TRANSIT OF 74TH MERIDIAN

LEGEND

——— PROTOTYPE
----- BASE TEST

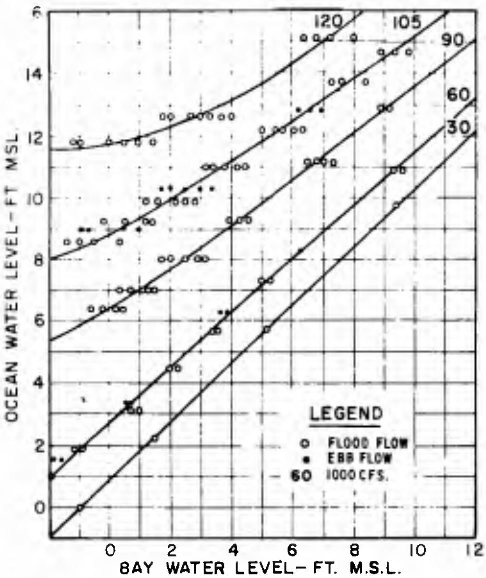
MODEL TEST DATA

TIDE	MEAN RANGE = 47 FEET
FRESH WATER DISCHARGES	
	HUDSON R —12 000 CFS
	RARITAN R— 1 770 CFS.
OCEAN SALINITY	30 PPT

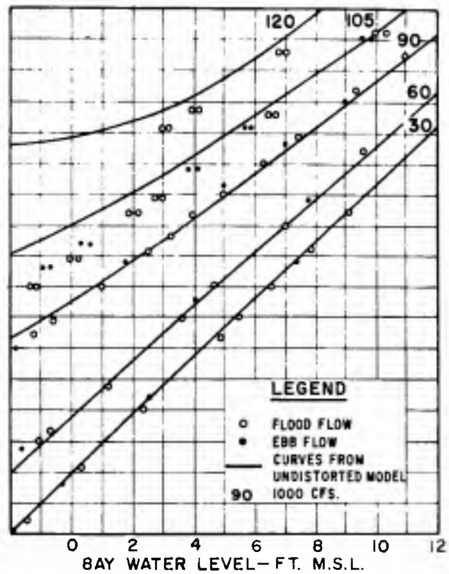
MODEL SCALE

HORIZONTAL - 1 1 000
VERTICAL - 1 100

FIGURE 7 BASIC MODEL VERIFICATION

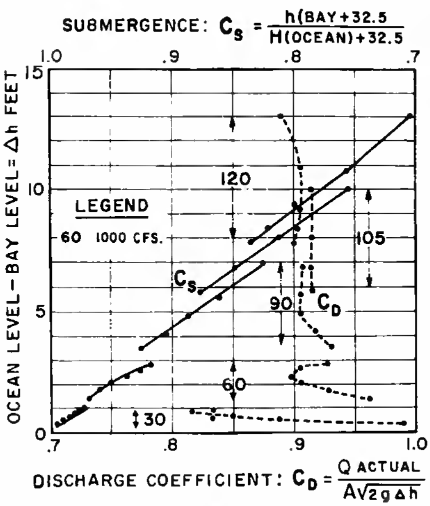


UNDISTORTED MODEL

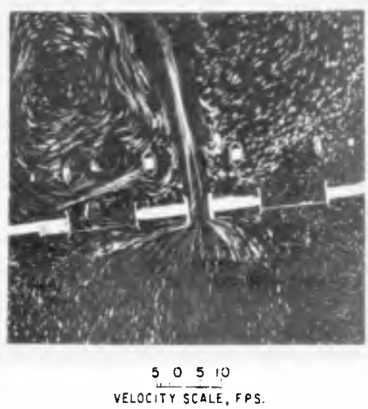


DISTORTED MODEL

DEVELOPMENT AND CALIBRATION OF DISTORTED MODEL OPENING



CALIBRATION COEFFICIENT



90,000 CFS. – FLOOD TIDE – Δh = 6.7 FEET

CURRENT STUDY – UNDISTORTED MODEL

FIGURE 8 CALIBRATION OF 150 FOOT UNGATED OPENING (ONLY) NO SILL

Current velocities were measured for each lunar half hour at 23 locations throughout Rockaway Inlet and Jamaica Bay (Figure 1) At each location where depths were 15 feet or more, velocities were measured at surface and bottom depths Where depths were less than 15 feet, only mid-depth measurements were made Current velocity measurements were made in the model by using miniature Price-type current meters The meter cups are 0.02 foot in diameter, and the diameter of the cup wheels is about 0 08 foot Wheel revolutions per 10 seconds were visually counted and subsequently converted to current velocities in feet per second prototype by referring to calibration curves which were checked frequently The meters are capable of measuring actual velocities of 0 05 foct per second (0 5 fps in prototype)

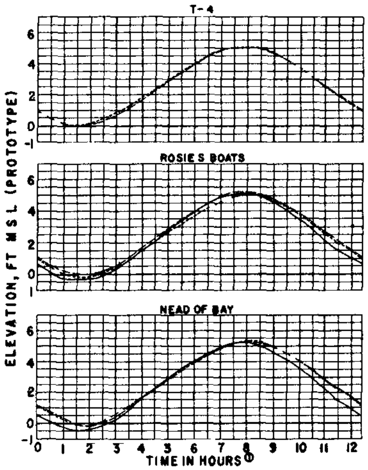
Salinities were measured for each lunar hour at surface and bottom depths at 18 stations located throughout Rockaway Inlet and Jamaica Bay At each station, 5 milliliter samples were taken, labeled as to depth and time, and stored under a constant temperature until salinities were determined Meters, operating on an electrical conductivity principle, were used to measure the sampled salinities The electrical output of the conductivity meter, attached to a dip cell, is calibrated in terms of total salts within the concentration range of 0 to 40 parts per thousand

Water samples for determination of dye concentration were taken at 34 stations at surface and bottom depths during high and low water slack periods The model was operated until salinity stability had been obtained Then, either uranine or pontacyl, brilliant pink dye, was injected at the nine pollution sources (Figure 9) Freshwater with pontacyl dye adjusted to an initial concentration of 10,000 ppb was released continuously at the two sources in the Rockaway Inlet, located oceanward of Jamaica Bay Freshwater with uranine dye adjusted to an initial concentration of 10,000 ppb was released continuously at the seven pollution sources inside Jamaica Bay. The introduction of the dyed inflows was continued for 100 tidal cycles, which is equivalent to about 50 lunar days During this time, water samples were taken and stored for later analysis Dye concentrations were measured by utilizing G K Turner Fluorometers capable of accurately measuring concentrations ranging from 0 to 10,000 ppb, (parts per billion)

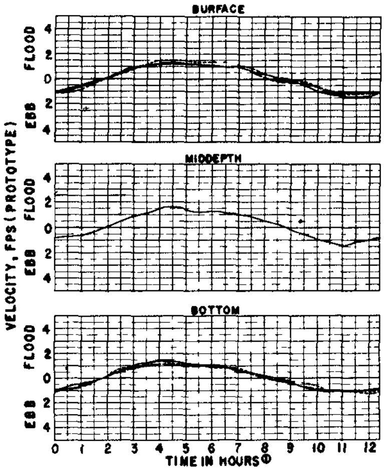
The hurricane surge generator used to simulate hurricane surges in the model was a vertically displacing steel constructed box with variable speed automatic drive mechanism which could be programmed to cause the water surface elevation to rise and fall as required with respect to time to reproduce the desired hurricane surges Elevations were recorded throughout the problem area by means of automatic float-type recording gauges and by utilizing manual observations with the permanent point gauges described previously

Barrier Plan 3 The first plan subjected to model testing, Barrier Plan 3, consisted of a 300 foot wide, ungated opening at natural bottom at about 32 5 feet below mean sea level, flanked by two gated sections (Figures 2 and 6) Each gate section consisted of six 75 foot wide tainter gates with sills at 26 feet below mean sea level (Figure 2) The tidal ranges with the gates fully open were not affected significantly (Figure 7) The time phasing of the tides in the interior of the bay was somewhat delayed, a matter of minutes The mean low water was raised slightly, a matter of tenths of a foot (Figure 7) The current velocities on the whole throughout the bay were not changed significantly (Figure 7)

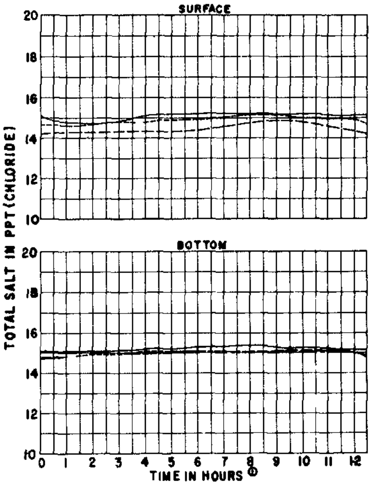
The results of the dye dispersion test of plan 3 are summarized in Figure 9 For the purpose of this summary, the region seaward from the barrier was divided into three areas (the approach channel, Coney Island Beach, and the basins), and Jamaica Bay was divided into four areas (Beach Channel, Island Channel, the tidal flats, and the basins) For the last 10 tidal cycles of the base and plan tests, the results of all sampling performed in the above seven areas were averaged, and the average concentrations are shown on Figure 9 for both dye sources seaward and



TIDAL HEIGHTS



VELOCITIES—STATION 6V



SALINITIES—STATION 6V

MODEL DATA

TIDE	MEAN
FRESH WATER	HUDSON R - 12 000 CFS
	RARITAN R - 1 770 CFS
OCEAN SALINITY	30 PPT

LEGEND

——— BASE TEST
- - - - PLAN 3 (300 FT UNGATED OPENING)
① AFTER MOON S TRANSIT OF 74 TH MERIDIAN

SIMULATED CONTINUOUS PROTOTYPE IN FLOWS

STATION	NAME OF PLANT	C F S
	INLET	
A	SHEEPSHEAD BAY OVERFLOW	1 86
B	CONEY ISLAND PLANT & OVERFLOW	128 83
	BAY	
C	PAERDEGAT BASIN OVERFLOW	21 97
D	FRESH CREEK OVERFLOW	10 68
E	26TH WARD PLANT & OVERFLOW	77 38
F	BERGEN BASIN OVERFLOW	7 74
G	JAMAICA PLANT OUTFALL	77 68
H	THURSTON BASIN OVERFLOW	14 24
I	ROCKAWAY PLANT & OVERFLOW	27 24
	TOTAL	367 62

FOR STATION LOCATION SEE FIGURE 1

MEASURED DYE CONCENTRATIONS*

LOCATION (SEE FIGURE 1)	DYE SOURCES OUTSIDE BARRIER		DYE SOURCES INSIDE BARRIER	
AREAS OUTSIDE BARRIER	BASE	PLAN	BASE	PLAN
APPROACH CHANNEL	35	32	196	136
CONEY ISLAND BEACH	24	11	39	26
BASIN	183	231	115	34
AREAS INSIDE BARRIER				
BEACH CHANNEL	70	47	708	327
ISLAND CHANNEL	89	53	867	579
TIDAL FLATS	76	33	813	696
BASINS	80	59	1949	1807

*PARTS PER BILLION (PPB)

INITIAL DYE CONCENTRATIONS AT RELEASE POINT 100 000 PPB

100 CYCLES 50 LUNAR DAYS

DYE DISPERSION TESTS

FIGURE 9 BASE TEST RESULTS

landward from the barrier For dye sources seaward from the barrier, average dye concentrations for the plan test were reduced slightly in six of the seven areas from those observed in the base test For dye sources inside Jamaica Bay, the plan test showed slightly reduced concentrations in all seven areas as compared to the base test The results of these tests do not prove conclusively that pollutants will be flushed from Jamaica Bay as rapidly or more rapidly under plan 3 conditions than under existing conditions, since the sampling performed was not sufficiently comprehensive to account for all dye released in the model for the tests However, the fact that the average plan dye concentrations for plan 3 were less than those of the base test in essentially all areas used for this evaluation suggests strongly that the flushing characteristics of the bay will be as good or better under plan 3 conditions than for existing conditions

The two storm surges were used for the hurricane surge tests in the model as shown on Figures 2 and 7 One is an actual hurricane surge that occurred in November 1950 and the other is the Standard Project Hurricane (SPH) surge that would be produced by a hurricane of maximum recorded intensity moving over the problem area on a critical path It is important to note that the November 1950 surge with a peak of 8 2 feet is considerably less in amplitude but is of much longer duration than the SPH surge with a peak of 12 3 feet The duration of rise of the surge or the volume of the surge is critical in considering total flow through an ungated opening, and the resulting bay level due to available bay storage

These surges were reproduced with the model water surface pooled at mean sea level For these tests, the gated openings were closed so that the passage of the surge into the bay was only through the ungated opening A comparison of levels with and without Barrier Plan 3 is shown on Table 1 The maximum elevation recorded in Jamaica Bay for the Standard Project Hurricane base test was 11 3 feet above mean sea level for a natural bay suppression of about 1 foot Under the Barrier Plan 3, the bay elevation was reduced to 4 8 feet above mean sea level for an additional bay suppression of 6 5 feet For the November 1950 hurricane surge, the maximum elevation recorded in the bay was 8 4 feet above mean sea level for no natural bay suppression Under Barrier Plan 3, the bay elevation was reduced to 6 6 feet above mean sea level for a bay suppression of 1 8 feet These suppressions would have to be reduced because of the increase in bay level that would occur due to runoff from a coincidental rainfall No correction was made for wind setup

Bay Rise Due to Rainfall The drainage area that reaches Jamaica Bay through drainage systems or overland was determined from U S G S quadrangles as being 102 square miles of which 18 square miles would represent bay water area at mean sea level A study of rainfall associated with hurricane storms and extra-tropical storms for the last 30 years showed that rainfall accompanying the hurricane of September 1944 would yield the greatest rainfall excess The study also revealed that the bulk of the rainfall would preceed the hurricane surge so as reasonably to assume that the rainfall excess would totally contribute to the bay rise The total rainfall for this storm would be 3 62 inches of which 1 15 inches would be rainfall excess On this basis, the runoff into the bay would result in a rise of 3 74 inches which, added to rainfall onto the bay of 3 62 inches, would equal 7 36 inches or about 0 6 foot rise in the bay surface

Discussion of Barrier Plan 3 The plan could meet the environment and navigation objectives Further, the plan could meet the flood damage level objective of 5 3 feet mean sea level if the Standard Project Hurricane were the critical storm However, it is apparent from the surge tests that although the Standard Project Hurricane Surge with the higher peak is the basis for establishment of the height of the protective works, the November 1950 surge with the greater volume is critical for determining the size of the ungated opening that will obtain the no-damage level for the bay Therefore, the Barrier Plan 3 opening does not meet the zero flood damage bay level objective

TABLE I - EFFECTS OF BARRIERS ON HURRICANE TIDES

A - DIMENSIONS OF BARRIER OPENINGS FOR SURGE TESTS

Plan No	Ungated Opening [a] Width (FT)	Ungated Opening [a] Depth at MSL (FT)	Ungated Opening [a] Area Below MSL (SQ FT)	Gated Openings [a,b] No of Gates	Gated Openings [a,b] Depth at MSL (FT)	Gated Openings [a,b] Area Below MSL (SQ FT)	Total Opening Area [a] of Openings Below MSL (SQ FT)
Base	3,700	--	117,750	--	--	--	117,750
6	110	33	3,630	16	26	31,200	34,830
8	150	23	3,450	16	26	31,200	34,650
7	150	26	3,900	16	26	31,200	35,100
9	200	23	4,600	16	26	31,200	35,800
3	300	33	9,900	12	26	23,400	33,300

a - MSL = mean sea level b - all gates 75 feet wide

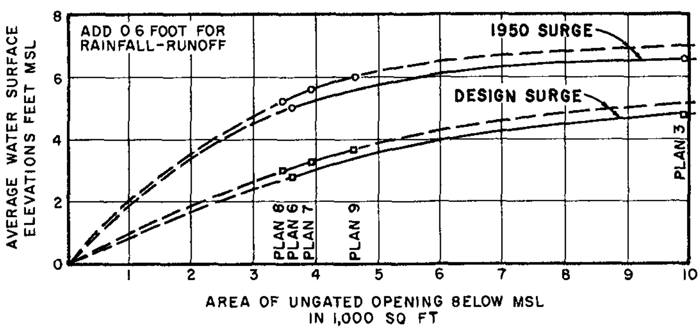
B - MAXIMUM BAY LEVELS FOR PLANS 3 AND 6 (FT MSL)

Location	1950 Surge Without Barrier	1950 Surge With Barrier Plan 3	1950 Surge With Barrier Plan 6	Standard Project Hurricane(SPH) Without Barrier	SPH With Barrier Plan 3	SPH With Barrier Plan 6
OUTSIDE BARRIER						
Fort Hamilton	8 2	8 1	8 2	12 3	12 3	12 3
Parkway West	8 2	8 0	8 3	11 7	11 6	11 6
INSIDE BARRIER						
Parkway East	8 3	6 6	4 8	11 0	4 6	2 6
Canarsie	8 3	6 7	5 0	11 3	4 8	2 9
Grassy Bay	8 4	6 7	5 0	11 3	4 8	2 8
Rosie's Boats	8 3	6 6	5 0	11 3	4 9	2 8

C - SUMMARY OF MAXIMUM BAY LEVELS FOR ALL PLANS (FT MSL)

Plan No	1950 Surge	Rain Runoff*	Total	Design Surge	Rain Runoff*	Total
Base	8 4	0 6	9 0	11 3	0 5	11 8
6	5 0	0 6	5 6	2 8	0 7	3 5
8	5 3	0 6	5 9	2 9	0 7	3 6
7	5 6	0 6	6 2	3 3	0 6	3 9
9	6 0	0 6	6 6	3 7	0 6	4 3
3	6 6	0 6	7 2	4 8	0 6	5 4

* - computed based on 3 65 inch rainfall and 1 15 inch rainfall excess



Other Barrier Plans Alternative plans were developed to meet the multiobjectives The overall open area through the barrier was generally maintained to meet the environmental objective as to tides, currents, velocities, salinities, and diffusion and flushing of pollutants by compensating any loss in ungated area by an increase in the gated area (Table 1) The reduction in ungated area to meet the zero damage flood level was effected by reduction in width and depth of the ungated opening The principal elements of four alternative plans are shown in Table 1 The Barrier Plan 6 with 110 foot ungated opening and with all gates open had only minor effects on tides, current velocities, salinities, and dye dispersion, generally less than measured for Barrier Plan 3 The results of the suppression tests for both the November 1950 and Standard Project Hurricane surges, as shown in Table 1, most closely meet the flood surge suppression objective However, the needs of commercial navigation require that the ungated opening be not less than 150 feet wide with a sill at a depth not less than 28 5 feet below mean sea level From the test results for the plans tested, it is noted that either a 110 foot wide opening at natural depth, or a 150 foot wide opening with a sill at 23 feet below mean sea level, would hold the maximum water surface elevation in Jamaica Bay essentially at or below the critical zero damage level Wider openings, or those with lower sill elevations, would have to be partially gated to insure necessary surge suppression during a recurrence of the November 1950 hurricane surge to about zero damage level in the bay

CONCLUSIONS

General Findings Hydraulic model techniques, utilizing distorted and undistorted scale models, can be used to resolve the multiobjectives with a moderate amount of field investigations to assure acceptable degrees of verification of the model required to obtain reliability and acceptability of results The results of the mathematical models were upheld The discharge coefficient of the ungated opening is fairly constant except for low discharges and submergence above 97 percent The suppression is more sensitive to width changes than depth changes The design storm for determination of height of protection must be based on a high-peak storm such as Standard Project Hurricane The design of ungated barrier openings to suppress bay levels must be based on the hurricane of critical volume, in this instance, the November 1950 hurricane Any future change in bay storage would effect the degree of suppression A bay barrier having the necessary combination of ungated and gated openings can be constructed that will simultaneously meet the requirements of hurricane surge suppression, recreational boating and commercial navigation, and environmental and ecological objectives as water quality, recreation, and fish and wildlife considerations

ACKNOWLEDGEMENTS

The material presented herein is the result of studies conducted by the U S Army, Corps of Engineers, New York District, and model studies conducted at the Corps of Engineers Waterways Experiment Station at Vicksburg, Mississippi The permission of the Chief of Engineers to use this information is appreciated Corps of Engineers personnel to whom acknowledgement is due for their assistance are Colonel James W Barnett, District Engineer, Messrs Jesse Rosen, Herman Simensky, Joseph Tennen, Joseph Palminteri, Laszlo Makai, and Mrs Arlene Posner of the New York District, Messrs Henry Simmons, William H Bobb, Thomas C Hill, and Richard A Sager of Waterways Experiment Station Any conclusions drawn are those of the author and do not necessarily reflect the policy or views of the Corps of Engineers or the Chief of Engineers

REFERENCES

1 New York District, Corps of Engineers - Cooperative Beach Erosion Control and Hurricane Study of the Atlantic Coast of New York City from East Rockaway Inlet to Rockaway Inlet and Jamaica Bay (Interim Survey Report, 1964), printed as House Document No 215, 89th Congress, 1st Session, 1965

2 Panuzio, Frank L - The Atlantic Coast of Long Island Proceedings of Eleventh Conference on Coastal Engineering, Volume II, 1968, published by American Society of Civil Engineers

3 Gofseyeff, Samuel and Panuzio, Frank L - Hurricane Studies of New York Harbor Journal of the Waterways and Harbors Division, Proceedings of American Society of Civil Engineers, February 1962

4 Wilson, Basil W - The Prediction of Hurricane Storm Tides in New York Bay Final Technical Report No 165-3, October 1959, Department of Oceanography and Meteorology, The A and M College of Texas

5 Tippetts-Abbett-McCarthy-Stratton, Engineers and Architects, New York - Study of Hurricane Barriers Across Jamaica Bay for Corps of Engineers, U S Army Engineer District, New York (unpublished), February 1963

6 Balloffet, Armando and Kupferman, Arnold - Hydraulic Studies of Jamaica Bay Journal of the Hydraulics Division, Proceedings of American Society of Civil Engineers, November 1964

7 Coastal Engineering Research Center, Corps of Engineers, U S Army, Technical Report No 4 Shore Protection Planning and Design, 1966

8 Saville, J T , McClendon, E W , and Cochran, A L - Freeboard Allowances for Waves in Inland Reservoirs Journal of the Waterways and Harbors Division, Proceedings of American Society of Civil Engineers, May 1962

9 Taft, Robert - Investigation of the Effects of Hurricane Surge Control Structures on the Water Quality of Jamaica Bay Division of Water Supply and Pollution Control, Public Health Service, U S Department of Health, Education, and Welfare, Appendix N of Reference No 1

10 Norman Porter Associates, Engineers - Current Velocity Measurements in Jamaica Bay on 12-13 June 1967, for U S Army, Corps of Engineers, New York District, (unpublished)

11 U S Army, Corps of Engineers, Waterways Experiment Station - Test Data, Model Studies of Jamaica Bay Hurricane Barrier, 1970, (unpublished)