g. Height Requirement for Risk and Uncertainty. See section on Tidal Hydraulics.

14. PROJECT OPERATION AND REGULATION

a. General. This paragraph serves as a guide for regulation procedures and duties of the Metropolitan District Commission (MDC) for operation of the Saugus River Floodgate structure during coastal storms and hurricanes.

The project, designed by the New England Division, Corps of Engineers (NED), will be maintained and operated by the MDC. Appurtenant features are the navigation and floodgate structures, consisting of a pair of miter gates for boat passage, and eight bays with tainter gates for normal flushing of tides. The floodgate is located approximately 600 feet to the east of the General Edwards Bridge between Lynn, and Revere, Massachusetts. Detailed plans of the structure are shown in the GDR, and a location map is shown on figure 12.

Responsibilities of the MDC, Corps of Engineers, and other appropriate parties follow:

(1) Metropolitan District Commission

(a) Complete operation of the project during coastal storms and hurricanes.

(b) Establish and maintain an adequate communication system with the National Weather Service to obtain forecasts and timely advisories on storm movements.

(c) Establish and maintain an adequate communication system with the U.S. Coast Guard for issuance of timely and pertinent information bulletins to mariners.

(d) Determine phases of the operations as related to forecasts and positions of the storms

(e) Train personnel in specific duties and perform periodic practice operations.

(2) Corps of Engineers. New England Division will be responsible for developing regulation procedures for operation of the floodgate structure. These procedures will be fully coordinated with MDC personnel, U.S. Coast Guard, local officials, and navigation interests. In addition, necessary training of MDC personnel will be provided by NED, during and after construction of the project. Although the MDC will be responsible for operation of the project, it is

expected that observers from NED will monitor the first few storm operations to determine if revisions, to adopted regulation procedures, are necessary. In an effort to aid this monitoring, a voice radio and telephone communication link between the MDC office in Boston and NED will be implemented. In addition, a GOES Data Collection Platform will be installed at the floodgate structure to transmit hydrologic data to NED as well as to MDC.

(3) National Weather Service. The responsibility of the National Weather Service (NWS) is to forecast and keep the public informed on the progress and movement of hurricanes and coastal storms. The NWS has no direct role in operation of the floodgate structure and, cannot designate various operational phases. However, we anticipate that their forecasters, in close liaison with Corps and MDC personnel, will indicate storm and tidal conditions that could develop, even though the probability of such development is uncertain such that warning to the public is unwarranted.

(4) U.S. Coast Guard. If closure of the navigation gate is or may be necessary, the MDC will issue special bulletins to the U.S. Coast Guard in Boston, Massachusetts, for broadcasts to mariners. Following receipt of bulletins, concerning possible floodgate operations, the Coast Guard will broadcast them via the marine radio network. Bulletins for hurricanes will probably be issued at least 6 hours in advance of closing the navigation gates; however, less than 1 or 2 hours advance notice will be given during most coastal storms.

b. Regulation and Operational Considerations

(1) General. Various elements that must be considered and evaluated in prescribing and directing operational procedures for coastal storms, hurricanes, and unusual conditions at the project are: (a) forecasting the storm, (b) time needed by MDC personnel to mobilize, (c) interior runoff coincident with storm tides, and (d) gate operating procedures.

(2) Forecasting

(a) Coastal Storms. A coastal storm, of an extra-tropical nature, will probably be the most prevalent event for operation of the floodgate structure. This type of storm, occurring predominantly during the fall, winter, and spring, can produce a long period of sustained east to northeast gales, along the easterly facing coast of New England. This type of storm has the potential to produce higher tide surges, coincident with time of peak tides, than a hurricane. The project will become operational for coastal storms whenever normal astronomical tides plus surges predicted by the National Weather Service result in a tide elevation of over 7.5 feet NGVD. Generally, time of the highest abnormal tides, during a coastal storm coincides with time of predicted high tides, and, therefore, operational time requirements can be more readily determined than for hurricane surges. However, prolonged coastal storms can often produce abnormal high ocean levels for consecutive tide cycles. As forecasting tide surges, associated with coastal storms, is sometimes difficult and uncertain, it is anticipated that mobilization and preparation will be completed for some expected high tides that do not materialize.

(b) Hurricanes. The two most important factors affecting operations for hurricanes are speed of the storm moving northerly towards New England, and track of the storm center crossing land or veering eastward off Cape Cod. The speed of the storm, which often accelerates as it moves into the northern latitudes, affects awaited time for mobilization, closure of gates, and preparation for the tidal surge. Location of the storm track, relative to the coastal community (Saugus), influences the magnitude of the surge. As all hurricanes, as well as other low pressure systems in the northern hemisphere, rotate in a counter clockwise direction, the winds will be southerly and highest if the storm center is west of the project. However, if the storm center is east of the project, the counter clockwise rotation of the storm produces northerly winds, which are generally offshore and in the opposite direction of the storm movement.

Although hurricanes can and have produced devastating high tide surges along the southern New England coast from Long Island Sound to Cape Cod, the easterly facing coastline of New England has not experienced the extremely high surge conditions. The reason for this is due to the high forward speed of a hurricane, combined with its counter clockwise wind direction. It generally only takes a few hours for a hurricane to pass through and beyond New England. If the storm were to take longer than this to approach the area, it would most likely weaken, due to colder ocean waters surrounding New England. In addition, winds would be the strongest from the south (including forward speed of the storm) if the center passed to the west of the Saugus floodgate structure, and from the north at a lesser velocity if it passed offshore to the east.

The National Weather Service is responsible for forecasting all storms that may affect New England; however, the reliability of forecasting a hurricane track, while several hundred miles to the south of New England, is not high. Therefore, it is necessary, in operating the project, to assume that every hurricane, or tropical storm that may develop into a hurricane, located within the alert area (see paragraph c(3) will affect the North Atlantic coast, and pass close enough to require mobilization of personnel and closure of the floodgates.

(3) Mobilization. The actual time required to mobilize personnel and prepare for a tidal surge is dependent on many items, which at present can only be estimated. To provide sufficient time to overcome unforeseeable mechanical difficulties or personnel problems, allowing for possible acceleration of the storm, the National Weather Service should be contacted for tide surge forecasts for Boston Harbor. Usually 3 to 4 hours, in advance of the predicted peak tide, are necessary to mobilize at the floodgate for approaching coastal storms. For hurricanes, mobilization should be initiated when the NWS Service declares a "hurricane watch" for New England. With more operating experience and meteorological forecasting improvements, mobilization times can be adjusted and improved.

(4) Interior Runoff Characteristics. The total water surface area in the estuary varies from about 260 acres at normal low tide to about 700 acres at normal high tide (elevation +5.0 feet NGVD). Under a storm tide condition, with a level of +8.0 feet NGVD, the water surface area is about 1,800 acres. Presently, sufficient estuary area exists, for safe storage of interior runoff during periods of floodgate closure, eliminating the need for a costly pumping station. Gate closing elevations and subsequent duration of gate closure are directly proportional to height of the expected storm tide, volume of interior runoff, and availability of estuary storage. A streamflow gaging station is located upstream of the project on the Saugus River. Concurrent runoff from the Saugus River, at the time of tidal surge, is a necessary parameter for determining the appropriate elevation to initiate gate closing. A discharge rating table for the Saugus gage is shown on plate 14.

Results from interior runoff simulation studies, utilizing the HEC-1 Saugus River watershed model (discussed in paragraph 13(b), were used to develop a gate operation guide curve, applicable for tides expected to exceed +7.5 feet NGVD. The guide curve was based on volumes of interior runoff expected for various storm simulations, using anticipated floodgate closure durations of 4.5 hours, 5.5 hours, and about 7 hours for 100-year, 500-year, and SPN designs, respectively. Peak runoff from the upper Saugus watershed, as measured at the gage, was determined, and estuary rise was computed from area capacity curves to determine the tide elevation required for complete gate closure at the project. The guide curve, shown on figure 26, presents discharge at the Saugus gage versus estuary elevation at time of complete closure of floodgates. The curve assumes that for most storms, the estuary will be maintained between +7.0 to +7.5 feet NGVD. For comparison purposes, and to judge the accuracy of the adopted guide curve, a 10-year rainfall was simulated over the entire Saugus watershed. The developed HEC-1 model that was utilized, simulates runoff from both the upper and lower combined Saugus River. In this example, the 10-year rainfall produced an estimated peak discharge of 980 cfs at the gage (runoff from the upper Saugus River). Applying this interior runoff with a coincident tide of +9.0 feet NGVD, use of the curve indicates that the floodgates be closed completely at a tide elevation about +6.0 feet NGVD. Further results from the simulation model indicated the floodgates would remain closed for approximately 4 hours, producing an interior runoff volume of about 1,400 acre-feet, with the estuary rising to about +7.0 feet NGVD. It is also known that actual closures are dependent on the rate of rise of ocean level, surge forecasts from NWS, knowledge gained from operating experiences, etc., and will most likely tend to deviate, at times, from this guide curve.

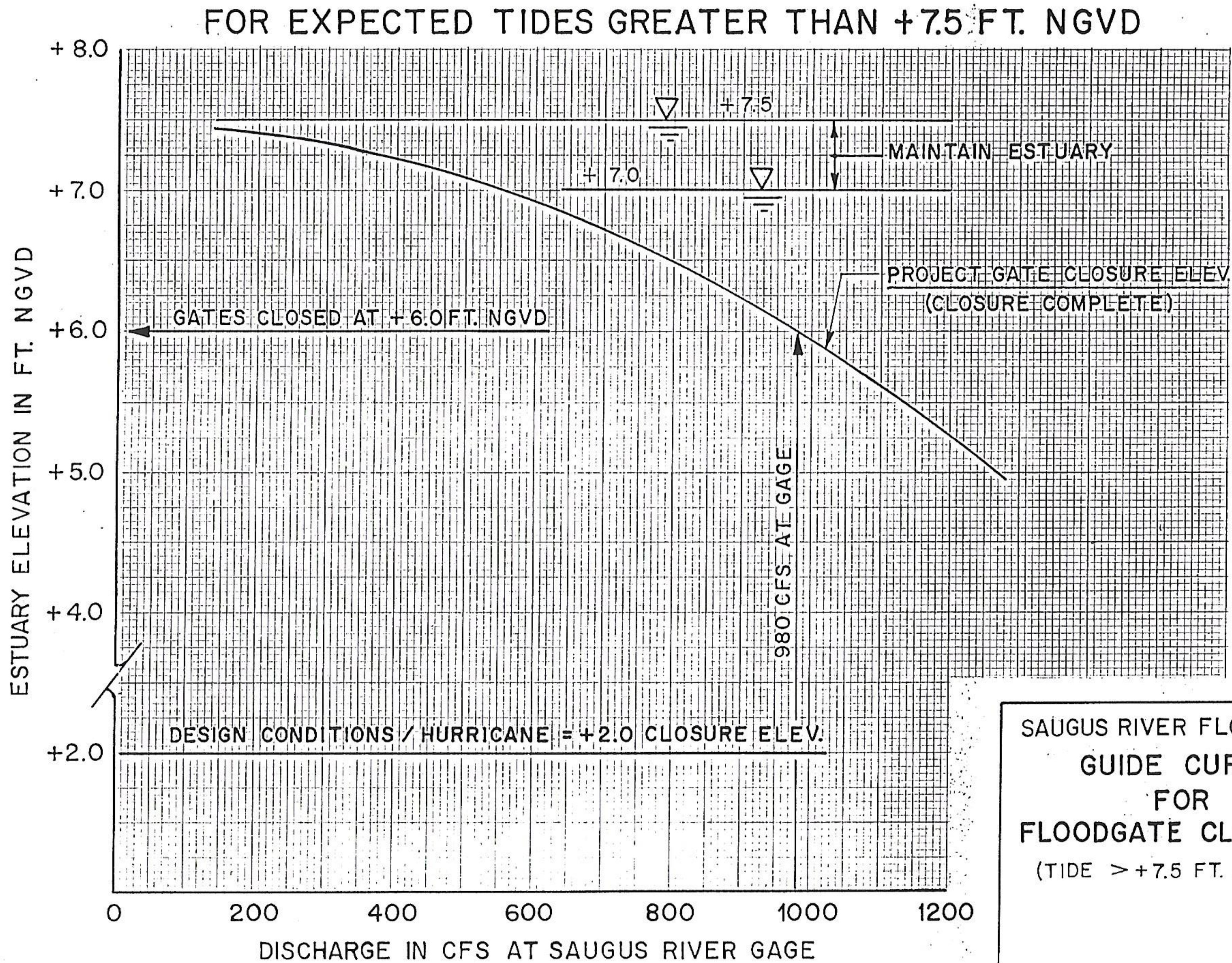
(5) Navigation Gate Procedure

(a) The time of gate opening or closing sequences is approximately 20 minutes.

(b) To prevent extreme velocities through the navigation opening, the navigation gates should be closed before the tainter flushing gates, opened only after the tainter gates are opened, in accordance with basic criteria outlined in Appendix C of the General Design Report and the Physical Model Study; (Appendix IV).

(c) Discretion should be used in initiating closure if approaching vessels are a short distance from the navigation gates and will be passing through within a few minutes. The size of the ship in the narrow entrance channel, ocean level, and rate of rise must also be considered in delaying closure for marine traffic.

(6) Estuary "Flushing" Tainter Gates. Eight openings in the project allow the Saugus River to discharge through the floodgate structure, as well as maintain the natural flushing action interchange that currently exists within the estuary. As mentioned above, during all floodgate operations, in order to prevent extreme velocities through



SAUGUS RIVER FLOODGATE
GUIDE CURVE
FOR
FLOODGATE CLOSURE
(TIDE > +7.5 FT. NGVD)

FIGURE 26

the navigation gate opening, the tainter gates should be closed after the navigation gates, and opened prior to the navigation gates being opened, in accordance with criteria outlined in Appendix C of the GDR.

c. Standard Operating Procedures (SOP) for Coastal Storms and Hurricanes

(1) General. Operational procedures during regulation periods are divided into phases to assure delineation of responsibilities and actions by MDC personnel as a coastal storm or hurricane approaches New England. These phases, illustrated on plates 15 and 16, are described below.

(2) Regulation Procedures for Coastal Storms

(a) Phase I - Alert. The National Weather Service forecasts that a storm system is likely to develop along the Atlantic coast and poses a high tide threat to easterly facing coastlines of New England.

1. MDC will alert all personnel connected with operation of the project, and will closely follow National Weather Service reports on the movement and possible intensification of the storm.

2. MDC will check monitoring gages and indicators for accuracy and reliability.

3. MDC will arrange to receive further advisories from the NWS.

(b) Phase II - Watch. NWS announces that a coastal storm off the Atlantic coast poses a possible threat to the east facing coastline of New England within the next two high tide cycles (approximately 12 to 18 hours).

1. MDC will alert floodgate personnel for possible staffing times, and arrange to receive further advisories from the NWS.

2. MDC will issue appropriate bulletin to the U.S. Coast Guard at Boston for radio transmission (see plate 17). The bulletin will also be furnished to the floodgate operator in order to prepare appropriate recorded telephone messages for public information.

3. MDC will plot predicted tides at Boston for the expected duration of the storm, as well as observed tides at the floodgate.

(c) Phase III - Warning. NWS announces that damaging high tides will occur within the next high tide cycle (6 hours).

1. MDC will activate required personnel and have project staffed with at least two qualified operators.

2. Floodgate operators will make observations of tide and weather conditions, and transmit data to MDC on a scheduled basis.

3. MDC will analyze tide, weather, and wind conditions at the project, and determine tide level and time for gate closure.

4. MDC will issue bulletin to the U.S. Coast Guard announcing gate closure time, and furnish copy to the floodgate operator in order to prepare appropriate recorded telephone messages for public information.

NOTE: Should the storm slow down, stagnate offshore, or pass without producing tides high enough to initiate the "Operation" phase, the MDC will remain in the "Warning" phase and be prepared to resume operations within the next high tide cycle if necessary. When the NWS notes the storm poses no threat to estuary tidal flooding, the "Cessation" phase can be initiated.

(d) Phase IV - Operation. Tide approaches established level for start of gate closure. Actual time of gate closure must take into account a 20-minute duration for closure. Therefore, it is necessary to estimate when the tide level will equal the prescribed stage level so closure procedures can be initiated 20 minutes in advance of predicted time. Table 23 presents guidelines for closing floodgate gates for coastal storms.

1. MDC will instruct the floodgate operator to initiate boat traffic warning system, and check for boats entering the channel. Time permitting, early notification of closure should be made to permit operator sufficient time to initiate traffic control procedures.

2. MDC will instruct the floodgate operator to initiate gate closing sequence (navigation followed by tainter gates). Considerable discretion must be used when initiating closure if approaching vessels are only a short distance from the floodgate and will be passing

through within a few minutes. The ocean elevation and rate of rise must be considered in delaying closure for marine traffic. The floodgate operator must be in communication with the MDC during this sensitive phase of operation if vessels are approaching.

3. MDC will issue appropriate advisories to the Coast Guard concerning gate closure, and prepare appropriate recorded telephone bulletins.

4. MDC will plot actual ocean and estuary tide levels reported by the floodgate operator at one-half hour intervals, and keep a complete log of all operations and data.

(e) Phase V - Cessation. Ocean tide level has receded to estuary level and falling.

1. MDC will instruct floodgate operator to initiate gate opening sequence (tainter gates followed by navigation).

NOTE: Opening of gates should be initiated early enough so the estuary level does not exceed the falling ocean level by more than one-half foot during the navigation gate opening period.

2. All boat traffic warning signals should be returned to normal and operations ceased.

3. MDC will issue appropriate bulletin concerning floodgate gate opening to Coast Guard and floodgate operator.

4. MDC may direct personnel to demobilize when threat of high tides has receded.

5. MDC will complete the operation log, and prepare a report for the Reservoir Control Center, New England Division, Corps of Engineers in Waltham, MA (see plate 18).

TABLE 23

CRITERIA FOR FLOODGATE OPERATION
DURING COASTAL STORMS

1. Coastal Storm Conditions

   a. None or Light Rain:

      (1) Expected tide 7.5 or less - No Operation

      (2) Expected tide greater than 7.5 - Maintain estuary between 7.0 and 7.5 feet NGVD.

   b. Moderate Rain (300 to 500 cfs from Saugus river gage):

      Operate to keep estuary between 7.0 and 7.5 feet NGVD, in accordance with guide curve on figure 26.

   c. Heavy Rain (greater than 500 cfs from Saugus gage):

      Operate to keep estuary between 7.0 and 7.5 feet NGVD, in accordance with guide curve on figure 26.

      Example: Expected tide = 8.5 feet NGVD

      Saugus river gage flow is, or expected = 700 cfs

      Operate floodgate so estuary is 6.7 feet NGVD upon completion of total gate closures (i.e., closure operations will be initiated at an ocean elevation lower than 6.7 feet, taking into consideration rate of rise of the tide, the 20-minute gate closure time, etc, so upon completion of gate closure, the estuary is not greater than 6.7 feet NGVD).

2. Notes:

   a. All tide elevations are given in feet NGVD and referenced to the Boston Harbor Tide gage.

   b. Expected tide = predicted astronomical plus surge forecasted by NWS.

   c. Start of tangible damages is 8.0 feet NGVD.

(3) Regulation Procedures for Hurricanes. Regulation procedures, prior to and during hurricanes, are divided into phases to delineate responsibilities and actions to be taken by MDC personnel. Refer to plate 19 for "Alert", "Watch", and "Warning" phases.

(a) Phase I - Alert. National Weather Service announces that a hurricane poses a possible threat to New England, or its center is located north of 27 degrees latitude and west of 67 degrees longitude.

1. MDC will alert all personnel connected with operation of the project, and arrange to receive continuous NWS advisories.

2. MDC will plot the position and movement of hurricane on a hurricane plotting chart.

3. MDC will check monitoring gages and indicators for accuracy and reliability, and adjust or make corrections, if necessary.

(b) Phase II - Watch. Hurricane "Watch" announced by NWS for New England, or hurricane center crosses 35 degrees latitude and possibly headed for New England.

1. MDC will activate regulation personnel associated with operation of the project.

2. MDC will advise city officials of Saugus and Lynn that the project is staffed.

3. MDC will issue advisory to the Coast Guard and transmit appropriate telephone bulletins for public information.

4. MDC will discuss proposed regulation procedures with the floodgate operator in case of communication problems during the hurricane.

(c) Phase III - Warning. Hurricane "Warning" announced by NWS, or hurricane center crosses 38 degrees latitude and still moving towards New England.

1. MDC will issue appropriate bulletin to Coast Guard concerning time of probable gate operation, and provide appropriate telephone recorded bulletin.

2. The floodgate operator will continue to report project conditions to MDC, as requested.

(d) Phase IV - Tidal Surge. Rising hurricane tide is commencing and approaching +2.0 feet NGVD or starting to rise before the ocean level recedes to +2.0 feet NGVD from the previous tide cycle.

1. The MDC will instruct floodgate operator to initiate marine traffic control signal system.

2. MDC will instruct floodgate operator to initiate gate closure sequence (navigation followed by tainter gates), and report to MDC when closure complete.

NOTE: Considerable discretion is necessary in initiating closure if approaching vessels are only a short distance from the navigation gate and will be passing through within 2 or 3 minutes. The ocean elevation and rate of rise must be considered in delaying closure for marine traffic. The floodgate operator should be in communication with MDC during this sensitive phase of the operation if vessels are approaching.

3. MDC will issue appropriate bulletins to Coast Guard and prepare telephone recorded messages concerning gate closure.

(e) Phase V - Cessation. Ocean tide level has receded to estuary level and falling.

1. MDC will initiate gate opening sequence.

2. All traffic control signal systems will be shut off and returned to normal.

3. MDC will issue appropriate bulletin to Coast Guard and prepare a recorded telephone message for public information concerning gate openings.

4. If the hurricane moves away and no longer a threat to the Saugus area, MDC will direct personnel to demobilize. However, if it appears that tides again may be above normal, MDC may need to continue staffing the project.

5. MDC will complete the operation log and prepare a report for the Reservoir Control Center, New England Division, Corps of Engineers in Waltham, MA (see plate 18).

(4) Emergency Operating Procedures

(a) Failure of Communications. In the event the floodgate operator is unable to communicate with MDC by normal or emergency methods, during phase III or IV procedures for a hurricane or coastal storm, has full authority and responsibility to operate the project according to instructions and procedures in table 23 and plates 15 and 16.

(b) Gate Inoperable. If at any time the navigation or tainter gates become inoperable, MDC will notify the cities of Lynn, Saugus, and Revere. If the gates become inoperable during an approaching storm tide, the MDC will immediately notify these cities of the situation and possible consequences. If the navigation gate becomes inoperable in the closed position, the floodgate operator will maintain the tainter gates as directed by MDC.

(c) Extraordinary Tide Condition. It is conceivable that an extraordinary or unpredictable tidal condition may arise, such as a tidal wave resulting from an earthquake. Since the primary purpose of the floodgate structure is to prevent tidal flooding in the estuary, closure of the gates, if time allows, during such unusual conditions, may not follow previously described rules, but will be governed by urgency of the circumstances. MDC has the authority and responsibility to act in order to prevent tidal flooding from endangering people and property.

(d) Hydrologic Equipment. All recording and nonrecording gages should be checked monthly and kept in operation at all times with charts changed at appropriate times. Gaging equipment will be installed so it can be continually monitored at the floodgate operating room for the following hydrologic parameters:

- Precipitation
- Wind speed and direction
- Barometric Pressure
- Temperature
- Ocean and Harbor levels
- Saugus River streamflow

GOES data collection platforms will be installed to relay hydrologic data to the MDC office in Boston. In addition, a weather wire, or similar means providing weather forecasts, storm warnings, and tidal forecasts from the Boston office of the National Weather service, will be provided at the floodgate operating room, as well as at the MDC office in Boston.

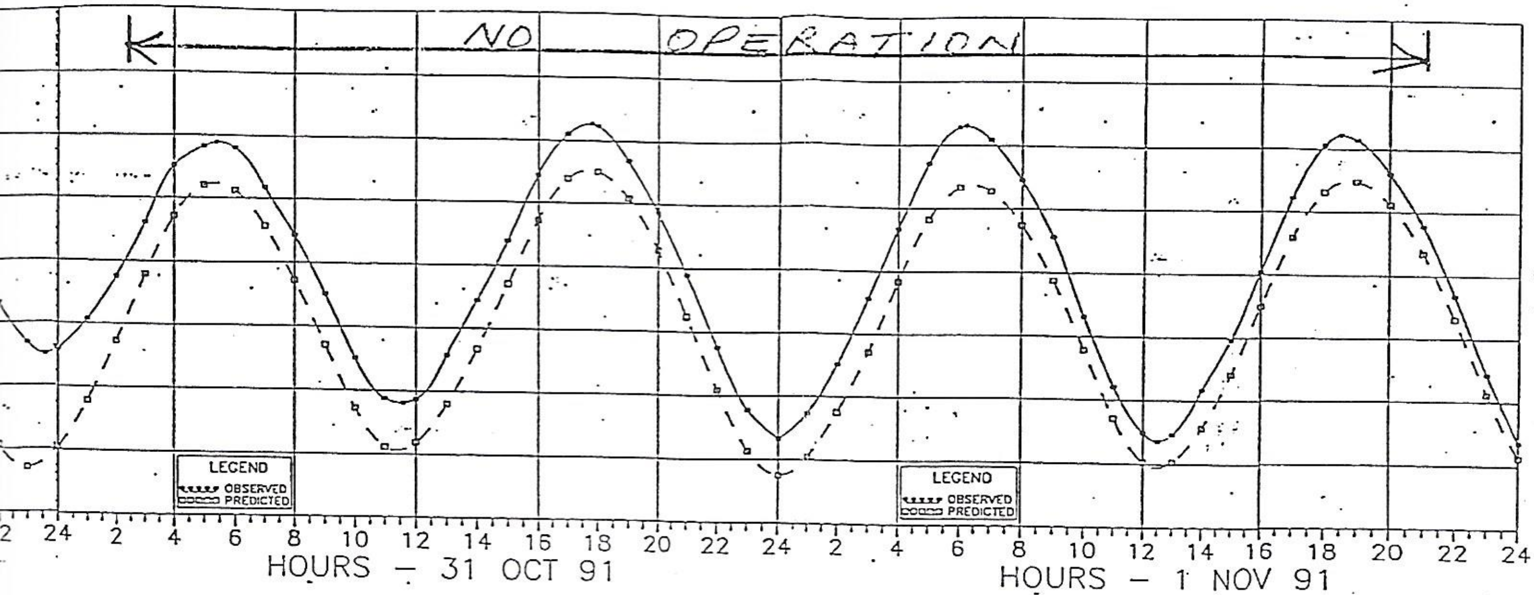
(5) Example Operation--October 1991 Storm. In order to aid MDC personnel in operating the floodgate during coastal storm events, the October 1991 historic flood event has been analyzed under the previously described regulation criteria. Figure 27 graphically describes how the project most likely would have been operated during this event.

(a) General. A major storm battered the New England coastal areas from 29 October to 1 November 1991. Originating as an extratropical storm, an unusual aspect was that it moved westward directly toward New England, incorporating energy from hurricane "Grace," which had been travelling up the eastern seaboard, and was absorbed into the extratropical storm. On 30 October, during peak intensity, minimum central pressure was about 972 mb or 28.30 inches of mercury, and estimated sustained winds at sea were nearly 60 knots (69 mph). The storm caused phenomenal seas, with reported wave heights over the open Atlantic, reaching 80 to 100 feet. The storm made landfall near Halifax, Nova Scotia, on 2 November. This "Halloween Nor'easter" was one of the great storms affecting the New England coast in recorded history. Its extreme storm surge and exceptional waves caused coastal damage not experienced in this area since the great "Blizzard" of February 1978. The storm's occurrence, simultaneously with a period of normal astronomic tides, was the event that spared many coastal areas even greater disaster. Had the storm hit during a period of high spring astronomic tides, observed stillwater levels could have been up to 2.5 feet higher.

(b) Tide Surge. The increase in tide level, due to meteorological effects, is called the storm surge. This storm produced a tide surge at Boston of 5.1 feet on 30 October and is the greatest of modern record, surpassing the previous one that occurred during the November 1945 "northeaster." Peak tide level of +9.4 feet NGVD occurred at 1650 hours on 30 October. *

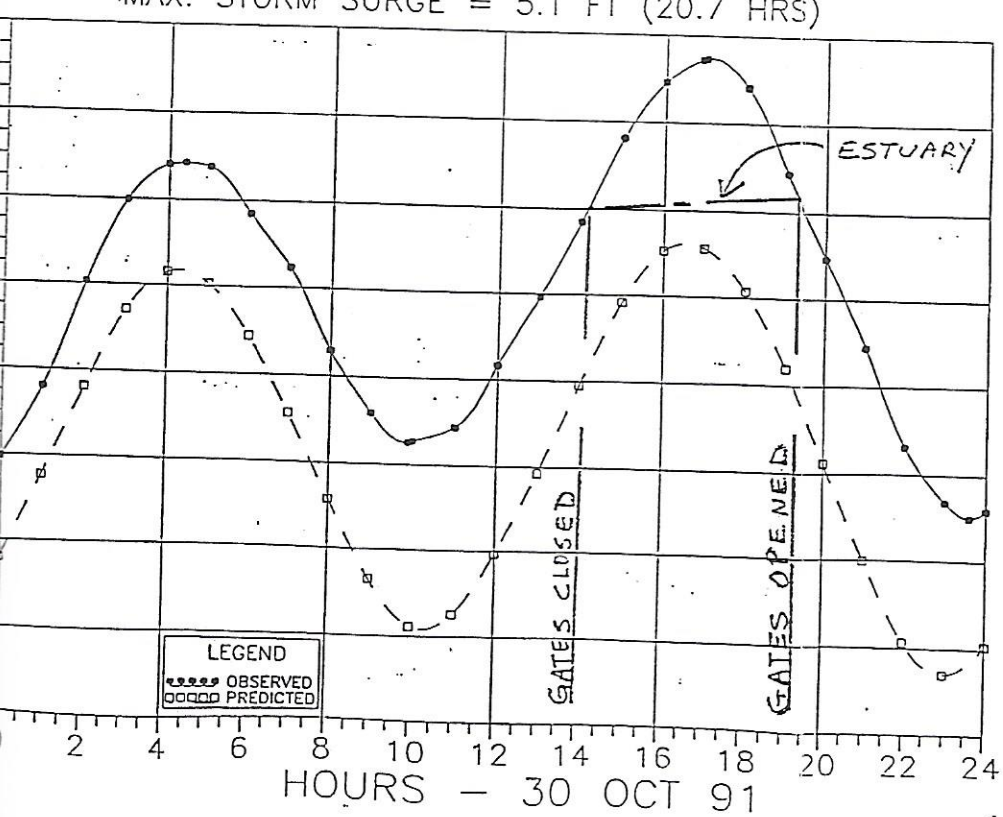
(c) Operation. Had the floodgate been in place during this storm, an example of how it could have been operated, is indicated on figure 27. Hours prior to peak tide, northeast winds were sustained between 30-38 mph, and with the barometric pressure dropping, tide surges increased. The example shows gate closure at a tide level of +6.0 feet NGVD. We believe that, owing to the magnitude of this storm system, the floodgate would have been operated conservatively due to extreme conditions during the afternoon tide cycle. In addition, data are not available to determine the effects wave overtopping, along existing shorefront structures, might have had on estuary levels. As there was no rainfall occurring during the peak tide of 30 October, runoff was not an immediate factor; however, due to the severity of this

7.5 Astro Tide
+ 5.1 Surge
+ 1.0 Sea level rise
13.6 ft. NGVD



BOSTON, MASS. TIDES

MAX. OBSERVED = 9.4 FT NGVD (16.9 HRS)
MAX. STORM SURGE = 5.1 FT (20.7 HRS)



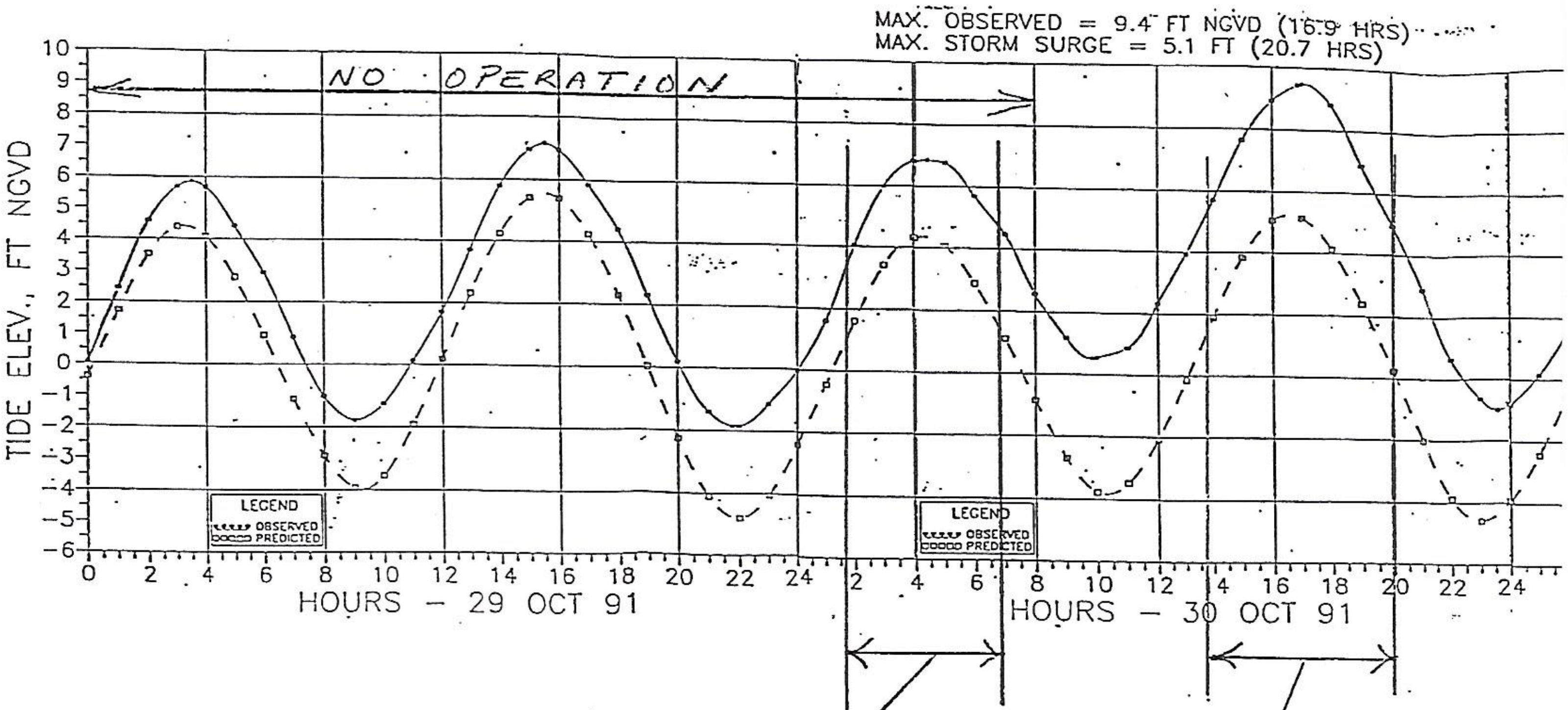
SAUGUS RIVER FLOODGATE

COASTAL STORM
OCT. 1991

EXAMPLE FLOODGATE OPERATION

FIGURE 27

BOSTON T



30 October 1991 - 0400 HRS High Tide

WIND - midnight to 0400 hrs: North at 18-20 MPH (Gusts to 25 MPH)
RAINFALL: Minor
PREDICTED PEAK TIDE: +4.2 FT. NGVD @ 0400 hrs
SURGE AT ZERO TIDE (0130 hrs): +2.0 feet
SURGE AT 0200 hrs: +2.2 feet
SURGE AT 0300 hrs: +2.5 feet

PROJECTED PEAK TIDE WITH SURGE 2.0 to 2.5 ft: +6.7 FT NGVD

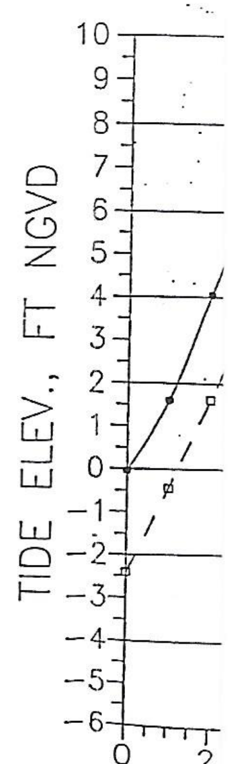
NOTE: With rainfall being minor and observed surge projecting a peak tide of only +6.7 ft NGVD, which is below +7.5 ft NGVD, the floodgate probably would not have been operated.

30 October 1991 - 1630 HRS High Tide

WIND - Noon to 1600 hrs: Northeast at 32-38 MPH (Gusts to 55 MPH)
RAINFALL: Minor
PREDICTED PEAK TIDE: +5.4 FT. NGVD @ 1630 hrs
SURGE AT ZERO TIDE (1300 hrs): +4.0 feet
SURGE AT 1400 hrs: +4.0 feet
SURGE AT 1500 hrs: +4.0 feet
SURGE AT 1600 hrs: +4.0 feet

PROJECTED PEAK TIDE WITH SURGE 4.0 ft: +9.4 FT NGVD

NOTE: With rainfall/runoff being minor, the governing factors requiring floodgate closure would be (a) the observed tide surge of 4.0 feet, which projected a peak tide of over 9.0 ft NGVD, and (b) sustained winds over 35 MPH from Northeast.

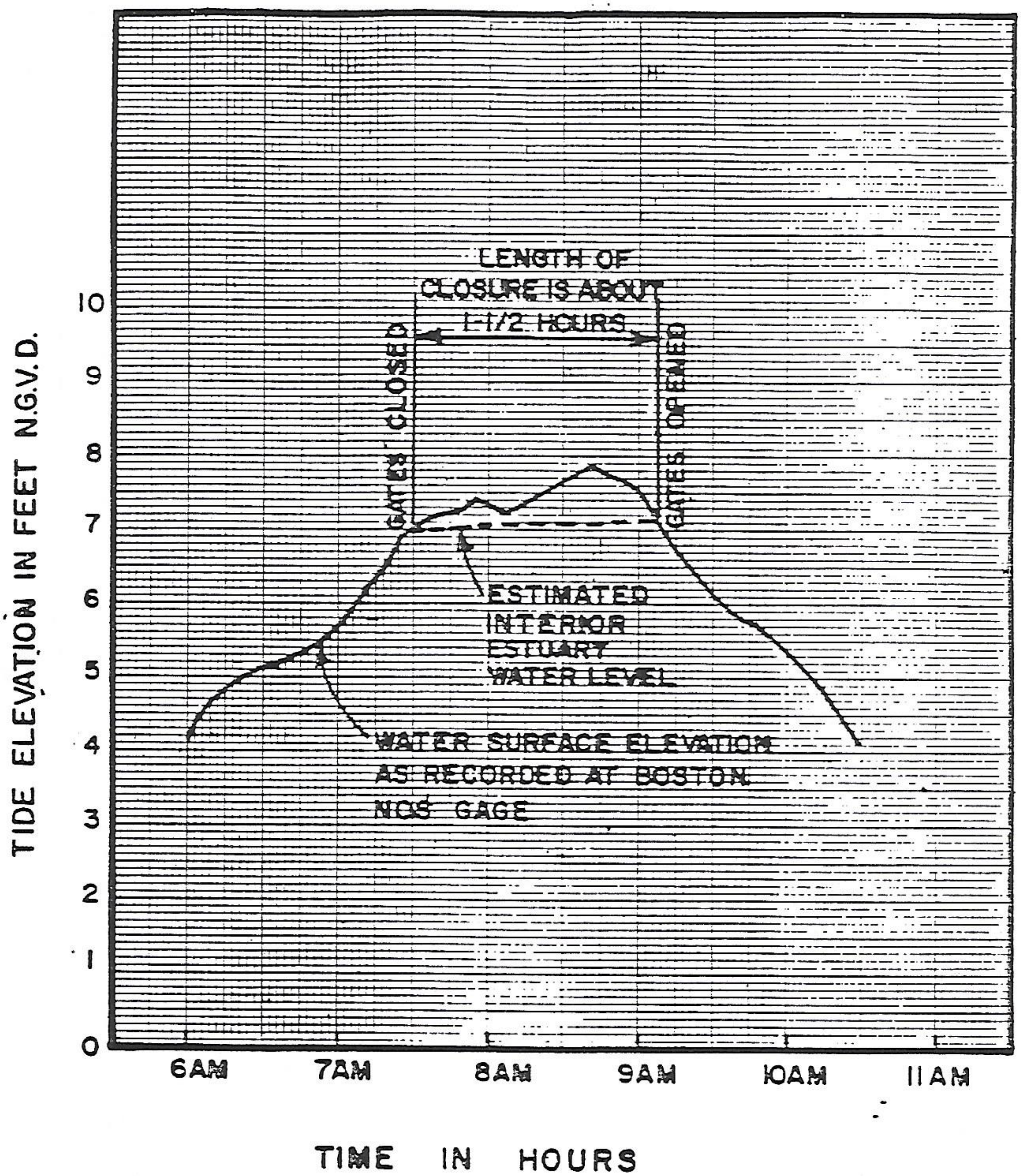


storm and its unpredictable nature, the potential for heavy rainfall, as well as sustained wave overtopping, could not have been ruled out in determining start of gate closure. For the 5 to 6-hour duration floodgates would have been closed, we believe the estuary would have risen no more than 0.2 foot.

(6) Typical Annual Event Operation. As stated throughout this report, the Saugus River Floodgate project would, under normal conditions, have gates in an open position with resulting minimal effect on the present tidal regime of the estuary. Under storm tide conditions, the gates would be closed in an effort to prevent tide levels in the estuary from exceeding about +8.0 feet NGVD. In so doing, with allowance for interior runoff and wind generated interior wave action, it is expected that the regulated level, on average, would be more nearly +7.0 feet NGVD with infrequent rises to nearly +8.0 feet NGVD. This is not to infer that the gates be closed every forecasted tide of +7.0 feet. Since the duration of gate closure and potential for interior runoff storage is proportional to the height of storm tide, the tide level for closure would be dependent on the forecasted tide level and weather conditions. Figure 28 shows the estimated operation for the tide of October 22, 1988, considered to be representative of a typical annual event. Although start of tangible damage is about +8.0 feet NGVD, decisions to close the floodgate would most likely be made in anticipation of potential significant flooding. Some of the closures each year will most likely be false alarms, such as this, as peak tide levels were below +8.0 feet.

15. RISING SEA LEVEL

a. Historic Rise. Sea level has been rising worldwide at varying rates for thousands of years. The overall long term historic rate of rise on the east coast has generally been 1 to 1-1/2 feet per century. Figure 29 depicts the historic relative sea level from records at the Boston Navy Yard and Boston National Ocean Service (NOS) tide gages. At the Boston Harbor NOS tide gage, the rise relative to the land has been estimated by the NOS to be about 0.010 ft/yr from 1921 through 1986. Sea level determination has generally been revised at intervals of about 25 years to account for the changing sea level phenomenon. The NOS recently reduced tide data from the 1960 to 1978 tidal datum epoch to make such a revision. Thus, the present local mean level of the sea, at a given location along the coast, can be expected to be several tenths of a foot higher than the National Geodetic Vertical Datum that was established as the mean sea level in 1929, and which remains basically fixed in time and space.



PREDICTED HIGH TIDE = +5.5 FT, NGVD AT 8:09 AM

ESTIMATED FLOOD GATE OPERATION FOR TIDAL SURGE OF OCTOBER 22, 1988

HYD. & W.Q. SECT. NOV. 1988

FIGURE 28

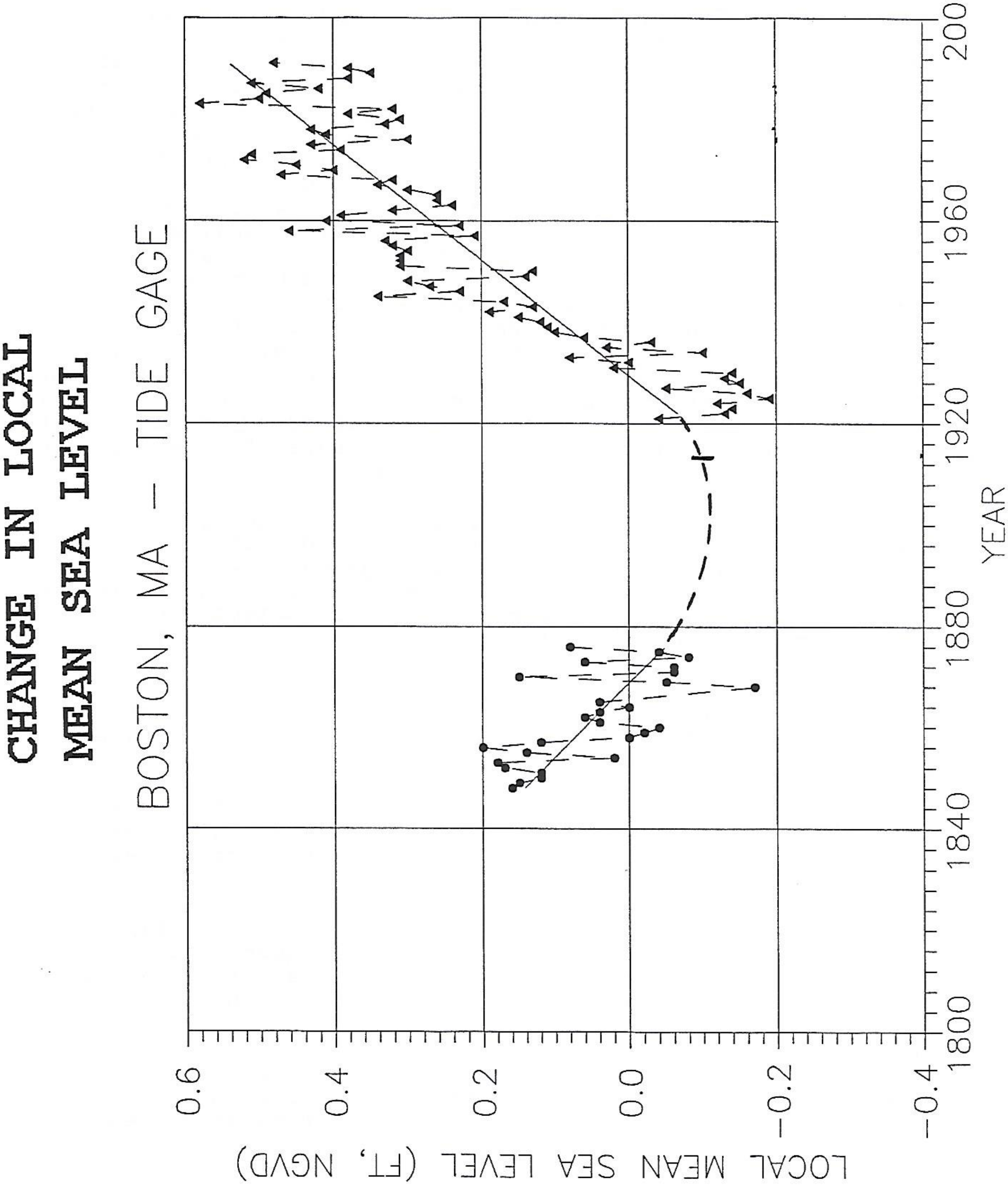

CHANGE IN LOCAL
MEAN SEA LEVEL
BOSTON, MA - TIDE GAGE
LOCAL MEAN SEA LEVEL (FT, NGVD)
YEAR
0.6
0.4
0.2
0.0
-0.2
-0.4
1800
1840
1880
1920
1960
2000

FIGURE 29

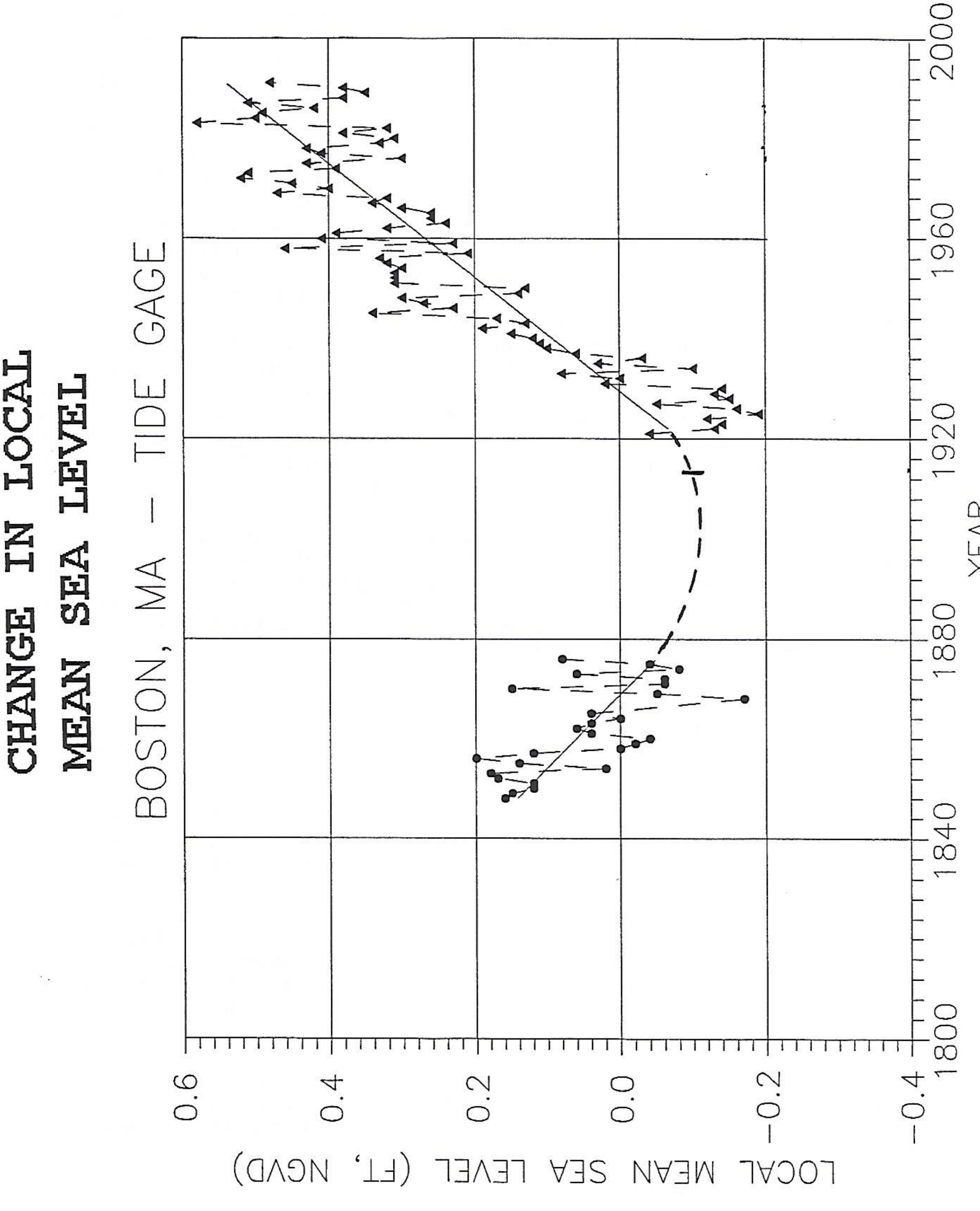

CHANGE IN LOCAL
MEAN SEA LEVEL
BOSTON, MA — TIDE GAGE
LOCAL MEAN SEA LEVEL (FT, NGVD)
YEAR
0.6
0.4
0.2
0.0
-0.2
-0.4
1800
1840
1880
1920
1960
2000

FIGURE 29

b. Future Sea Level Rise. In recent years there has been much discussion regarding a potential increased rate of future sea level rise. This phenomenon is related to a gradual warming of the earth's atmosphere associated with increased emissions of carbon dioxide and other gases on earth. The warmed atmosphere may promote expansion of near surface ocean water and increase the rate of glacier melting, thereby, hastening the rate at which ocean levels appear to be rising. The scientific community is generally in agreement that the rate of global sea level rise will increase; however, there is lack of precision and agreement as to how much the increase will be. Several scientists have made projections, employing mathematical models which simulate the processes involved. Predicted increase in global sea level by 2,075 range from as little as 1 foot to as much as 7 feet. A middle estimate of 3 to 4 feet is accepted by many experts. This middle ground would yield an increase of nearly fourfold over historic rates in New England. In 1987, the National Research Council suggested that the sensitivity of design calculations and policy decisions be evaluated, based on three plausible variations in sea level rise to the year 2100; all showing greater rate of rise in the distant future than in the next decade, and all with an increased rate of rise relative to the presents 1.6, 3.3, and 4.9 feet.

c. General Corps Policy Regarding Sea Level Rise. The Corps policy regarding sea level rise is one of concern rather than alarm. The Corps is aware of ongoing developments to further define the complex issue, keeping in mind the inherent uncertainty in any projections. A 21 March 1986 letter, from the Office of the Chief of Engineers, stated our policy as follows:

(1) Predicting future sea level rise is risky because there are so many variables and, as yet undefined interrelationships.

(2) Until substantial evidence indicates otherwise, we will maintain the procedure of considering only local regional history of sea level changes to project a rise or fall for a specific project.

(3) Where long periods of tidal records exist and are used in determining the exceedance frequency relationship for coastal flood levels, it may be necessary to adjust water level records for relative sea level changes when such changes are significant.

(4) Prudence may require an allowance in a project design, for continuation over the project design life, of an established significant long-term trend in relative sea level rise.

(5) Consideration must be given to the relative magnitude of the suggested allowance and confidence band of the data the designer is using, and the tolerance allowed in constructing the project.

(6) Consider whether it is more cost effective to include the allowance for significant sea level rise in the initial construction, or to plan for modification later after the need for such is demonstrated.

As events continue to unfold and more precision is gained in estimating future sea level rise, additional Corps policy guidance is sure to follow. EC 1105-2-186, dated 21 April 1989, provides guidance relating to incorporation of sea level rise in feasibility studies. This guidance recommended a sensitivity analysis using historic and NRC case III projections.

d. Incorporation of Sea Level Rise in Project Design. In accordance with previously referenced Corps policy, the present day stage-frequency curves have been developed considering historic sea level rise. In addition, stage-frequency relationships have been developed, accounting for projection of the long term uniform historic rate of sea level rise (0.010 ft/yr) over the project life, approaching an increase in stage of 1.0 foot over a 100-year period. The feasibility study determined that an increase in height of protection was not presently justified, based on future sea level rise. However, detailed design of project features must consider a likely continuation of at least historic rates of sea level rise, or the possibility of accelerated rise due to global warming. Consideration should be given to a possible increase in project height in the future, should it become justified by future sea level rise. Alternatives ill-suited for retrofitting should be avoided. The effectiveness of any flood protection scheme built today, and subjected to significant sea level rise in the future, would be a function of the project's durability and height. Obviously, significant sea level rise could cause greater wave or sea level overtopping, as well as undermining the structural integrity of any flood protection device. It is, therefore, important to consider these factors in the detailed design of project features.

e. Effects of Future Sea Level Rise on Tidal Flood Plain Zones

(1) General. The effects of future sea level rise on existing natural and modified stage frequencies for the various flood plain zones have been examined. This information is to be used by others to determine approximate economic

benefits, attributable to the project, due to future rising sea level. As previously discussed, estimates of future rates of rise vary considerably. However, Corps of Engineers policy considers only local regional history of sea level changes in determining economic benefits. Therefore, the historic rate of rise of about 0.1 foot per decade was used for this cursory economic assessment.

(2) Effects on Existing Boston Stillwater Curve. Recognizing the difficulties in trying to precisely determine impacts of a future gradual rise in sea level on existing stage-frequency relationships, it was decided, for simplicity sake, to estimate stage-frequency relationships at a distant future time (say 100 years hence). Since the historic rate of rise is about 0.1 foot per decade, the future sea level condition elevation frequencies would be the existing condition elevations plus approximately 1 foot. It is noted that this assumption is not precisely correct; however, it is felt that it is adequate for the current investigation. Thus, based on the above assumptions, the adopted future sea level condition Boston stillwater elevation frequencies would be as follows in 100 years.

Percent Chance Occurrence	Existing Condition Elevation (ft, NGVD)	Future Condition 100-Year Elevation (ft, NGVD)
SPN	12.0	13.0
0.2 (500-yr)	11.2	12.2
1.0 (100-yr)	10.3	11.3
10 (10-yr)	9.1	10.1
50 (2-yr)	8.3	9.3

(3) Effects on Natural Stage Frequencies for Interior Zones. For interior zones (i.e., those not directly bordering the estuary) where the Boston stillwater curve is not directly applicable, several techniques were explored in attempting to determine future sea level condition natural curves. First, as with the Boston stillwater curve, it was assumed to simply add 1 foot to all previously developed natural stage-frequency elevations. Second, noting that most zones have experienced 1978 flood elevations available, it was decided to assign respective experienced 1978 interior flood elevations the frequency of occurrence that the 1978 flood ocean stillwater level would have on the future sea level condition Boston stillwater curve (about a 7 percent chance). This single point in general was slightly higher than the curve from the first method; however, overall

comparison was fairly good. Also, we believe that for the extremely rare frequencies, interior flood levels (related to wave overtopping and local drainage) would tend to reach a maximum elevation, most likely not exceeding elevation 14 to 15 feet NGVD for a 1 foot rise in sea level over the next 100 years. For simplicity sake and due to numerous uncertainties (i.e., the magnitude of sea level rise) it was decided to use existing interior curves plus 1 foot. This approach will allow reasonable estimates of sensitivity of the area to continue historic sea level rise. The effects of the recent Revere Beach sandfill was also considered in developing the interior curves.

(4) <u>Effects on Project Modified Stage-Frequencies</u>. Trying to quantify the effects of future sea level rise with a tidal floodgate project is more difficult. A 1-foot rise in sea level would have effects on resulting waves and wave overtopping. Attempting to quantify such effects, is considered beyond the scope of current studies. A simplified mean of determining future sea level condition, project modified curves was developed as follows:

(a) The existing and future sea level conditions (existing plus 1 foot) natural relationships were analyzed.

(b) For a given frequency of occurrence, the existing sea level condition, project modified elevation was determined (i.e., 1 percent chance, project modified elevation of 7.4 feet NGVD), reference table 17.

(c) This project modified elevation was then assigned a future sea level condition frequency, based on the natural curve frequency shift from existing to future sea level conditions. In the case of the existing natural 1 percent chance flood, its future frequency of occurrence would be about 7 percent. This was repeated for a range of frequencies to produce the future sea level condition, project modified curves. Typical estimated future sea level condition natural and project modified curves are shown on plate 20. Estimated future condition elevation frequencies, with and without project (SPN design level) with the 1991 beach profile, are shown in table 24. Only flood zones 1, 2A, 2B, 3A, 4A, 4B, 4C, and 5B are affected by the new Revere Beach, therefore, table 24A presents the resulting elevation frequencies for these zones for the estimated future sea level rise condition with the 1978 beach profile (no beach).

f. <u>Effect of Rising Sea Level on Project Hydraulics</u>. Future sea level rise will allow larger waves to reach project shorefront features. In the Park Dike area, the physical model was used to specifically evaluate the effect of sea

TABLE 24

REVERE, MASSACHUSETTS
ESTIMATED FUTURE FLOOD STAGE FREQUENCIES
(feet NGVD)

Location - Condition	Annual Frequencies (%) 0.2	1.0	10	50	90
Future Sea Level Condition, Boston Stillwater (Existing + 1 Foot)	12.2	11.3	10.2	9.4	9.0
Zone 1 - Estimated Future Sea Level Natural	9.6	8.0	6.0	4.8	4.5
Modified By Tidal Protection	9.6	8.0	4.9	4.1	4.0
Zone 2A - Estimated Future Sea Level Natural	9.5	8.8	7.6	7.5	7.4
Modified By Tidal Protection	6.8	6.8	6.6	6.5	6.4
Zone 2B - Estimated Future Sea Level Natural	7.6	6.9	5.6	4.8	4.4
Modified By Tidal Protection	5.0	4.8	4.6	4.4	4.2
Zone 4A - Estimated Future Sea Level Natural	9.3	7.5	6.2	5.0	4.4
Modified By Tidal Protection	6.1	5.6	5.2	4.6	3.4
Zone 4B - Estimated Future Sea Level Natural	9.3	7.5	4.8	4.2	4.0
Modified By Tidal Protection	5.3	4.7	4.1	4.0	4.0
Zone 4C - Estimated Future Sea Level Natural	10.5	8.7	6.8	6.2	6.0
Modified By Tidal Protection	5.8	5.6	5.4	5.2	5.0
Zone 5A - Estimated Future Sea Level Natural	12.2	11.3	10.2	9.4	9.0
Modified By Tidal Protection	8.2	7.7	7.3	7.2	7.1
Zone 5B - Estimated Future Sea Level Natural	12.2	11.3	9.2	8.1	8.0
Modified By Tidal Protection	10.4	9.8	8.6	7.1	7.0
Zone 5C and 5D - Estimated Future Sea Level Natural	12.2	11.3	10.2	9.4	9.0
Modified By Tidal Protection	8.2	7.7	7.3	7.2	7.1
Zone 6 - Estimated Future Sea Level Natural	12.8	11.7	10.0	8.9.	8.4
Modified By Tidal Protection	8.1	7.5	7.2	7.1	7.0

TABLE 24

REVERE, MASSACHUSETTS
ESTIMATED FUTURE FLOOD STAGE FREQUENCIES
(feet NGVD)

Location - Condition	Annual Frequencies (%)				
	0.2	1.0	10	50	90
Future Sea Level Condition, Boston Stillwater (Existing + 1 Foot)	12.2	11.3	10.2	9.4	9.0
Zone 1 - Estimated Future Sea Level Natural	9.6	8.0	6.0	4.8	4.5
Modified By Tidal Protection	9.6	8.0	4.9	4.1	4.0
Zone 2A - Estimated Future Sea Level Natural	9.5	8.8	7.6	7.5	7.4
Modified By Tidal Protection	6.8	6.8	6.6	6.5	6.4
Zone 2B - Estimated Future Sea Level Natural	7.6	6.9	5.6	4.8	4.4
Modified By Tidal Protection	5.0	4.8	4.6	4.4	4.2
Zone 4A - Estimated Future Sea Level Natural	9.3	7.5	6.2	5.0	4.4
Modified By Tidal Protection	6.1	5.6	5.2	4.6	3.4
Zone 4B - Estimated Future Sea Level Natural	9.3	7.5	4.8	4.2	4.0
Modified By Tidal Protection	5.3	4.7	4.1	4.0	4.0
Zone 4C - Estimated Future Sea Level Natural	10.5	8.7	6.8	6.2	6.0
Modified By Tidal Protection	5.8	5.6	5.4	5.2	5.0
Zone 5A - Estimated Future Sea Level Natural	12.2	11.3	10.2	9.4	9.0
Modified By Tidal Protection	8.2	7.7	7.3	7.2	7.1
Zone 5B - Estimated Future Sea Level Natural	12.2	11.3	9.2	8.1	8.0
Modified By Tidal Protection	10.4	9.8	8.6	7.1	7.0
Zone 5C and 5D - Estimated Future Sea Level Natural	12.2	11.3	10.2	9.4	9.0
Modified By Tidal Protection	8.2	7.7	7.3	7.2	7.1
Zone 6 - Estimated Future Sea Level Natural	12.8	11.7	10.0	8.9.	8.4
Modified By Tidal Protection	8.1	7.5	7.2	7.1	7.0

TABLE 24 (cont'd)

REVERE, MASSACHUSETTS
ESTIMATED FUTURE FLOOD STAGE FREQUENCIES
POINT OF PINES
(feet NGVD)

Location - Condition	Annual Frequencies (%)				
	0.2	1.0	10	50	90
Future Sea Level Condition, Boston Stillwater (Existing + 1 Foot)	12.2	11.3	10.2	9.4	9.0
Zone 1 - Estimated Future Sea Level Natural	14.8	14.0	12.0	11.0	10.8
(7A) Modified by Tidal Protection	14.8	13.0	9.8	9.7	9.6
Zone 2 - Estimated Future Sea Level Natural	13.6	13.0	11.2	9.6	9.2
(7B) Modified by Tidal Protection	13.6	12.0	7.8	7.8	7.7
Zone 3 - Estimated Future Sea Level Natural	12.0	11.0	9.6	8.8	8.5
(7C) Modified by Tidal Protection	12.0	10.5	7.2	7.2	7.2
Zone 4 - Estimated Future Sea Level Natural	12.0	10.8	9.0	8.0	7.9
(7D) Modified by Tidal Protection	12.0	10.0	6.3	6.2	6.2

TABLE 24A

PRE-REVERE BEACH FILL, REVERE, MASSACHUSETTS
ESTIMATED FUTURE FLOOD STAGE FREQUENCIES
(feet NGVD)

Location - Condition	Annual Frequencies (%)				
	0.2	1.0	10	50	90
Future Sea Level Condition, Boston Stillwater (Existing + 1 Foot)	12.2	11.3	10.1	9.2	8.9
Zone 1 - Estimated Future Sea Level Natural	9.6	8.1	6.0	4.8	4.5
Modified By Tidal Protection	9.6	8.7	4.4	3.8	3.5
Zone 2A - Estimated Future Sea Level Natural	14.0	12.3	8.6	7.5	7.4
Modified By Tidal Protection	6.8	6.7	6.6	6.5	6.4
Zone 2B - Estimated Future Sea Level Natural	11.9	10.3	6.8	4.8	4.4
Modified By Tidal Protection	4.8	4.6	4.4	3.8	3.4
Zone 3A - Estimated Future Sea Level Natural	10.0	7.1	5.0	4.4	4.1
Modified By Tidal Protection	9.4	6.5	5.0	4.4	4.1
Zone 4A - Estimated Future Sea Level Natural	10.8	9.3	6.5	4.8	4.4
Modified By Tidal Protection	4.8	4.6	4.2	3.8	3.4
Zone 4B - Estimated Future Sea Level Natural	9.4	7.5	4.8	4.2	4.0
Modified By Tidal Protection	3.7	3.5	3.3	3.2	3.0
Zone 4C - Estimated Future Sea Level Natural	10.5	8.7	6.8	6.2	6.0
Modified By Tidal Protection	9.6	5.4	5.3	5.2	5.0
Zone 5B - Estimated Future Sea Level Natural	12.2	11.3	10.1	9.2	8.9
Modified By Tidal Protection	12.0	10.0	9.2	7.3	7.0

level rise on wave overtopping (see Appendix IV). In other areas, best estimates of increased overtopping, due to sea level rise, were made for use in estimating results and interior flooding. The following table presents results, based on the Park Dike and Rubble-Mound physical model evaluation for the SPN, with and without one foot of sea level rise. A 5-foot depth of erosion of the 1991 beach is assumed for the first four test results shown on the table.

Year of Survey	Dike	Stillwater Levels (ft, NGVD)	Wave Height (ft)	Wave Period (sec)	Overtopping Rate (cfs/linear ft)
1991	Park	12.0	12.7	15.9	0.0003
1991	Park	13.0	12.7	15.9	0.0068
1991	Rubble-Mound	12.0	12.7	15.9	*
1991	Rubble-Mound	13.0	12.7	15.9	0.0005
1978	Park	13.0	8.9	15.9	0.2574

* Overtopping rate too small to be measured.

Some increased overtopping would be expected with 5 feet of beach erosion and one foot of sea level rise. The Park Dike would need to be raised approximately 4 feet to return to 1991 expected overtopping. Erosion to the 1978 beach, with a 1-foot rise, would cause a major increase in overtopping as shown by the fifth test result shown on the table. These evaluated scenarios point out the need to maintain the 1991 beach.

The numerical model evaluated effects of the proposed floodgate structure on basin tide levels with sea level rise of one foot. It concluded that water levels at the peak flood and peak ebb tides will increase 1.0 foot (see Appendix V) in the study area. Also, the floodgate will not significantly affect water levels in the estuary for the 1-foot rise in sea level, assuming no change in gate closure operation.

The physical model evaluated near field currents at the floodgate structure, with sea level rise of one foot (Appendix VI), found little change.

The test was conducted with Plan 2C+7 installed in the model. No base test with conditions of a 1.0 foot sea level rise was conducted. Therefore, comparisons of water surface elevations and current velocities was made against Plan 2C+7 spring tide conditions (base test for this situation). Plan 2C+7, water surface elevation boundary conditions were, as expected, about 1.0 foot higher than Base Plan 2C+7.

Differences between Plan 2C+7 and Base Plan 2C+7 water surface elevations for floodflow conditions were slightly greater than 1.0 foot, while elevations occurring during ebb flow conditions were slightly less than 1.0 foot.

Current velocity observations on ranges 2.43 and 2.44 made during Plan 2C+7's increase of 1.0 foot in sea level testing were not significantly changed from those observed during the base tests. Current velocities on ranges 2.43 and 2.44 during floodflow conditions were approximately 0.2 to 0.4 fps lower than observed for the base test. However, current velocity observations made during the ebb flow condition on these two ranges were generally 0.2 to 0.6 fps higher than observed for base conditions. This general trend was observed at other stations monitored during the testing.

No specific navigation modelling was performed for the one foot sea level rise case. However, it can be concluded, from the small change in currents in the physical model, that navigation would not be significantly affected.

The ice evaluation considered sea level rise of one foot over the project life, as well as the factor in recommending a top of flushing gate opening at elevation 7 feet NGVD in the floodgate structure (see Appendix VIII).

16. MAINTENANCE OF EXISTING FEDERAL AND NON-FEDERAL PROTECTIVE WORKS

Existing shorefront features are an integral part of the regional flood reduction plan previously described in this report. The seawalls along Revere Beach and some walls/ revetments along Point of Pines were considered to remain in place and function in reducing overtopping and erosion with the Federal project. Local assurances should require continued maintenance of these features. As a minimum, they should remain at the present dimensions and elevation.

The Revere Beach Nourishment project, that was completed separately from the present project, provides significant reduction in flooding caused by wave overtopping in low lying neighborhoods along Revere Beach. Its continued maintenance throughout and beyond its economic life would be prudent. However, the regional floodgate plan, including the Park Dike, would still function well in providing flood protection, if the beach were allowed to erode. Loss of the present beach and resulting flood protection would be an unfortunate occurrence. Wave heights used for design of the present project were based on sheltering provided by Nahant Island and causeway. Although the causeway does not appear to be significantly threatened now, or with continued increase in sea level at the historic rate of one foot per 100 years, its condition and maintenance should be closely monitored. Accelerated sea level rise up to 9 feet will stress the causeway, as well as other coastal locations. The present Corps project is designed, assuming wave protection provided by the causeway will continue over the project life. For flood reduction to be realized as indicated in this report, particularly from Point of Pines to Lynn Harbor, the sheltering effect of the causeway must continue. Therefore, continued maintenance of this feature is recommended.

17. DEPARTURES FROM APPROVED PLAN

The minimum estuary quide taking elevation has been reduced from 7 to 6 feet NGVD. The number of flushing gates in the floodgate structure has been reduced from 10 to 8 and the top of the gated opening raised from elevation 0 to elevation 7 feet NGVD. At Point of Pines, the revetment under the existing sand dunes was deleted. It appears as though the top elevation of Park Dike can be lowered from 23 to 19.5 feet NGVD. This will be evaluated through further design studies.

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* Includes references not specifically spelled out in report

RATING

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION
EXPANDED RATING TABLE
DATE PROCESSED: 10-01-1992 @ 14:36 BY RGADOURY

TYPE: L_G

01102345
SAUGUS R AT SAUGUS IRON WORKS AT SAUGUS, MA
OFFSET: .50

DD: 1 TYPE: 001 RATING NO: 1
START DATE/TIME: 10-01-91 (0001)

BASED ON MEASUREMENTS 1-7 AND IS WELL DEFINED BETWEEN 10 AND 100 CFS, AND FAIRLY WELL DEFINED BELOW 10 CFS.
RATING USED OCT. 1, 1991, TO
COMP BY DM CKD BY RAG

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (STANDARD PRECISION) .00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
1.50	2.30*	2.38	2.46	2.54	2.63	2.71	2.80	2.89	2.99	3.08	.880
1.60	3.18	3.28	3.38	3.48	3.59	3.70	3.81	3.92	4.03	4.15	1.09
1.70	4.27	4.39	4.52	4.64	4.77	4.91	5.04	5.18	5.32	5.46	1.34
1.80	5.61	5.75	5.90	6.06	6.21	6.37	6.53	6.70	6.87	7.04	1.60
1.90	7.21	7.39	7.56	7.75	7.93	8.12	8.31	8.51	8.71	8.91	1.90
2.00	9.11	9.32	9.53	9.75	9.96	10.18	10.41	10.64	10.87	11.11	2.23
1.50	2.3*	2.4	2.5	2.5	2.6	2.7	2.8	2.9	3.0	3.1	.90
1.60	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.2	1.1
1.70	4.3	4.4	4.5	4.6	4.8	4.9	5.0	5.2	5.3	5.5	1.3
1.80	5.6	5.8	5.9	6.1	6.2	6.4	6.5	6.7	6.9	7.0	1.6
1.90	7.2	7.4	7.6	7.7	7.9	8.1	8.3	8.5	8.7	8.9	1.9
2.00	9.1	9.3	9.5	9.7	10.0	10.2	10.4	10.6	10.9	11.1	2.2
2.10	11.3	11.6	11.8	12.1	12.3	12.6	12.9	13.1	13.4	13.7	2.6
2.20	13.9	14.2	14.5	14.8	15.1	15.4	15.7	16.0	16.3	16.6	3.0
2.30	16.9	17.2	17.6	17.9	18.2	18.6	18.9	19.3	19.6	20.0	3.4
2.40	20.3	20.7	21.1	21.4	21.8	22.2	22.6	23.0	23.4	23.8	3.9
2.50	24.2*	24.6	25.0	25.5	25.9	26.3	26.8	27.2	27.6	28.1	4.4
2.60	28.6	29.0	29.5	30.0	30.5	30.9	31.4	31.9	32.4	32.9	4.9
2.70	33.5	34.0	34.5	35.0	35.6	36.1	36.7	37.2	37.8	38.3	5.4
2.80	38.9	39.5	40.1	40.7	41.3	41.9	42.5	43.1	43.7	44.3	6.1
2.90	45.0	45.6	46.2	46.9	47.6	48.2	48.9	49.6	50.3	51.0	6.6
3.00	51.6	52.4	53.1	53.8	54.5	55.2	56.0	56.7	57.5	58.2	7.4
3.10	59.0	59.8	60.6	61.4	62.2	63.0	63.8	64.6	65.4	66.2	8.1
3.20	67.1	67.9	68.8	69.6	70.5	71.4	72.3	73.2	74.1	75.0	8.8
3.30	75.9	76.8	77.8	78.7	79.7	80.6	81.6	82.5	83.5	84.5	9.6
3.40	85.5	86.5	87.5	88.6	89.6	90.6	91.7	92.7	93.8	94.9	10.5
3.50	96.0	97.0	98.1	99.3	100	101	103	104	105	106	11.0
3.60	107	108	110	111	112	113	114	116	117	118	12.0
3.70	119	121	122	123	125	126	127	129	130	131	14.0
3.80	133	134	135	137	138	140	141	142	144	145	14.0
3.90	147	148	150	151	153	154	156	157	159	160	15.0
4.00	162	164	165	167	168	170	172	173	175	177	16.0
4.10	178	180	182	183	185	187	189	190	192	194	18.0
4.20	196	197	199	201	203	205	207	209	210	212	18.0
4.30	214	216	218	220	222	224	226	228	230	232	20.0
4.40	234	236	238	240	242	244	246	249	251	253	21.0*
4.50	255*										

PLATE 14

ING PROCEDURES
M SURGE BARRIER

STORMS)

PHASE IV OPERATION	
CONDITIONS	PROCEDURAL DUTIES
Tide approaches level at which gates should be closed in order to maintain estuary at or below prescribed level as shown in Table 23.	1.MDC will instruct the barrier operator to initiate boat traffic warning system and check for boats entering the channel. 2. MDC will instruct the barrier operator to initiate gate closing sequence when the channel is clear of boats. 3. MDC will issue bulletin to the U.S. Coast Guard at Boston for radio transmittal, and to the barrier for telephone recording. 4. MDC will keep a log of all operations at one-half hour time intervals.

PHASE V CESSATION	
CONDITIONS	PROCEDURAL DUTIES
Tide level in Lynn Harbor or ocean has receded to elevation of estuary.	1. MDC will instruct barrier operator to initiate gate opening sequence, then return boat traffic signals to normal and cease operations. 2. MDC will issue bulletin concerning opening for transmittal by the U.S. Coast Guard and barrier operator. 3 If the coastal storm moves away and is no longer a threat to the area, MDC may direct personnel to demobilize. However, if it appears that the storm may linger off the coast and tides continue to be high again on the next high tide cycle, personnel will have to remain close to the barrier. 4. MDC will complete the operations log, prepare report and send to NED.

SAUGUS RIVER FLOODGATE

STANDARD OPERATING PROCEDURES

COASTAL STORMS

SAUGUS MASSACHUSETTS

STANDARD OPERA
SAUGUS RIVER STC

(COASTAI

PHASE I ALERT	
CONDITIONS	PROCEDURAL DUTIES
National Weather Service (NWS) announces that a severe coastal storm is likely to develop along the Atlantic coast and pose a possible high tide threat to eastern New England.	1. MDC will alert all personnel for possible duty. 2. MDC will check monitoring gages and indicators for accuracy and reliability and adjust or note corrections, if necessary. 3. MDC will arrange to receive further advisories from the NWS.

PHASE II WATCH	
CONDITIONS	PROCEDURALS DUTIES
NWS announces that a coastal storm poses a possible threat to the east facing coast of New England within the next two tide cycles.	1. MDC will alert barrier personnel for possible staffing times, and will arrange to receive further advisories from NWS. 2. MDC will issue bulletins to the U.S. Coast Guard at Boston for radio transmittal (See plate 17). The bulletin will also be furnished to the barrier operator for a telephone recording. 3. MDC will plot predicted tides at Boston and observed tide at the floodgate for the duration of the storm.

PHASE III WARNING	
CONDITIONS	PROCEDURAL DUTIES
NWS forecasts that damaging high tides are posible within the next high tide cycle.	1. MDC will activate their personnel and have the barrier staffed with at least two qualified operators. 2. Barriers operators will make observations of tide and weather conditions and transmit data to MDC on a scheduled basis. 3. MDC will analyze tide, weather and wind conditions at the barrier and determine tide level and time for gate closures. 4. MDC will issue bulletin to the U.S. Coast Guard and also furnish to the barrier foi telephone recording.

Plate 15(2)

TING PROCEDURES
M SURGE BARRIER

ANES)

PHASE IV SURGE	
CONDITIONS	OPERATIONS
Tide level approaches +2.0 feet NGVD at which gates should be closed in order to maintain estuary at or below prescribed level.	1. MDC will instruct the barrier operator to initiate boat traffic warning system and check for boats entering the channel. 2. MDC will instruct the barrier operator to initiate gate closure sequence when the channel is clear of boats. 3. MDC will issue bulletin to the U.S. Coast Guard at Boston for radio transmittal, and also to the barrier for telephone recording 4. MDC will keep a log of all operations at one-half hour time intervals.

PHASE V CESSATION	
CONDITIONS	OPERATIONS
Tide level in Lynn Harbor or ocean has receded to elevation of estuary.	1. MDC will instruct barrier operator to initiate gate opening sequence. Then return boat traffic signals to normal and cease operations. 2. MDC will issue bulletin concerning opening for transmittal by the U.S. Coast Guard and barrier operator. 3 If the coastal storm moves away and is no longer a threat to the area, MDC may direct personnel to demobilize. However, if it appears that the storm may linger off the coast and tides continue to be high again on the next high tide cycle, personnel will have to remain close to the barrier. 4. MDC will complete the operation log, prepare a report and send to NED.

SAUGUS RIVER FLOODGATE

STANDARD OPERATING PROCEDURES

HURRICANES

SAUGUS MASSACHUSETTS

STANDARD OPERATING
SAUGUS RIVER STORM SU

(HURRICANE

<table>
<tr><td colspan="2">PHASE I ALERT</td><td></td></tr>
<tr><td>CONDITIONS
National Weather Service (NWS) announces that a hurricane off the Atlantic Coast poses a possible threat to New England and/or its center is located north of 27 degrees latitude and west of 67 degrees longitude. .</td><td>PROCEDURAL DUTIES
1. MDC will alert personnel for possible staffing.
2. MDC will check monitoring gages and indicators for accuracy and reliability and adjust or note corrections, if necessary.
3. MDC will arrange to receive further advisories from the NWS
4. MDC will plot the position and movement of the hurricane (See plate 19).</td><td>Tide
NG
clos
at or</td></tr>
<tr><td colspan="2">PHASE II WATCH</td><td></td></tr>
<tr><td>CONDITIONS
Hurricane "Watch" announced by NWS for New England and/or hurricane crosses 35 degrees latitude and is possibly headed for New England.</td><td>PROCEDURAL DUTIES
1. MDC will have barrier staffed with at least two qualified operators and will arrange to receive further advisories from NWS.
2. MDC will issue bulletins to the U.S. Coast Guard at Boston for radio transmittal (See plate 17). The bulletin will also be furnished to the barrier operator for a telephone recording.
3. MDC will plot predicted tides at Boston and observed tides at the floodgate for the duration of the hurricane.</td><td>Tide
has</td></tr>
<tr><td colspan="2">PHASE III WARNING</td><td></td></tr>
<tr><td>CONDITIONS
Hurricane "Warning" announced by NWS for New England and/or hurricane crosses 38 degrees latitude and is still heading for New England.</td><td>OPERATIONS
1. Barriers operators will make observations of tide and weather conditions and transmit data to MDC on a scheduled basis.
2. MDC will analyze tide, weather and wind conditions at the barrier and determine tide level and time for gate closures.
3. MDC will issue bulletin to the U.S. Coast Guard and also furnish to the barrier for telephone recording.</td><td></td></tr>
</table>

Plate 16 (2)

BULLETINS CONCERNING OPERATION OF
SAUGUS FLOODGATE NAVIGATION CLOSURE

(To be issued to U.S. Coast Guard and entered on telephone tape recorder.)

BULLETIN 1 - THE MDC ADVISES THAT THE NAVIGATION GATES AT THE SAUGUS BARRIER ARE OPEN TO TRAFFIC. PLEASE USE CAUTION WHILE PASSING THROUGH THE BARRIER.

BULLETIN 2 - THE MDC ADVISES THAT DUE TO THREATENING HIGH TIDES THE NAVIGATION GATES AT THE SAUGUS BARRIER WILL (MAY) BE CLOSED ABOUT ____(Hour)____ HOURS (EST OR EDST) ON ____(Day)____, ____(Date)____.

BULLETIN 3 - THE MDC ADVISES THAT, IF THE STORM _____(Name?)______ CONTINUES ON ITS PRESENT COURSE, IT WILL (MAY) BE NECESSARY TO CLOSE THE NAVIGATION GATES AT THE SAUGUS BARRIER ABOUT ____(Hour)____ HOURS (EST OR EDST) ON ____(Day)____, ____(Date)____. MARINERS SHOULD BE ALERT FOR FURTHER ADVISORIES.

BULLETIN 4 - THE MDC ADVISES THAT THE NAVIGATION GATES AT THE SAUGUS BARRIER ARE CLOSED AND WILL REMAIN CLOSED UNTIL THE STORM HAS PASSED. MARINERS SHOULD BE ALERT FOR FURTHER ADVISORIES.

BULLETIN 5 - THE MDC ADVISES THAT THE NAVIGATIONS GATES AT THE SAUGUS BARRIER ARE CLOSED. THE ESTIMATED TIME OF OPENING WILL BE AT ____(Hour)____ HOURS (EST OR EST) ON ____(Day)____, ____(Date)____. MARINERS SHOULD BE ALERT FOR FURTHER ADVISORIES.

BULLETIN 6 - (Put on telephone tape recorder at barrier 24 hours before scheduled time of closure. Notify US Coast Guard in writing 3 weeks before date of closure).

THE MDC ADVISES THAT THE NAVIGATION GATES AT SAUGUS BARRIER WILL BE CLOSED FOR MAINTENANCE BETWEEN ____(Hour)____ AND ____(Hour)____ HOURS (EST OR EDST) ____(Day)____, ____(Date)____.

BULLETIN 7 - (Any telephone recorded warning pertaining to special conditions while passing through the barrier, such as obstructions, fog, ice, wind, etc.)

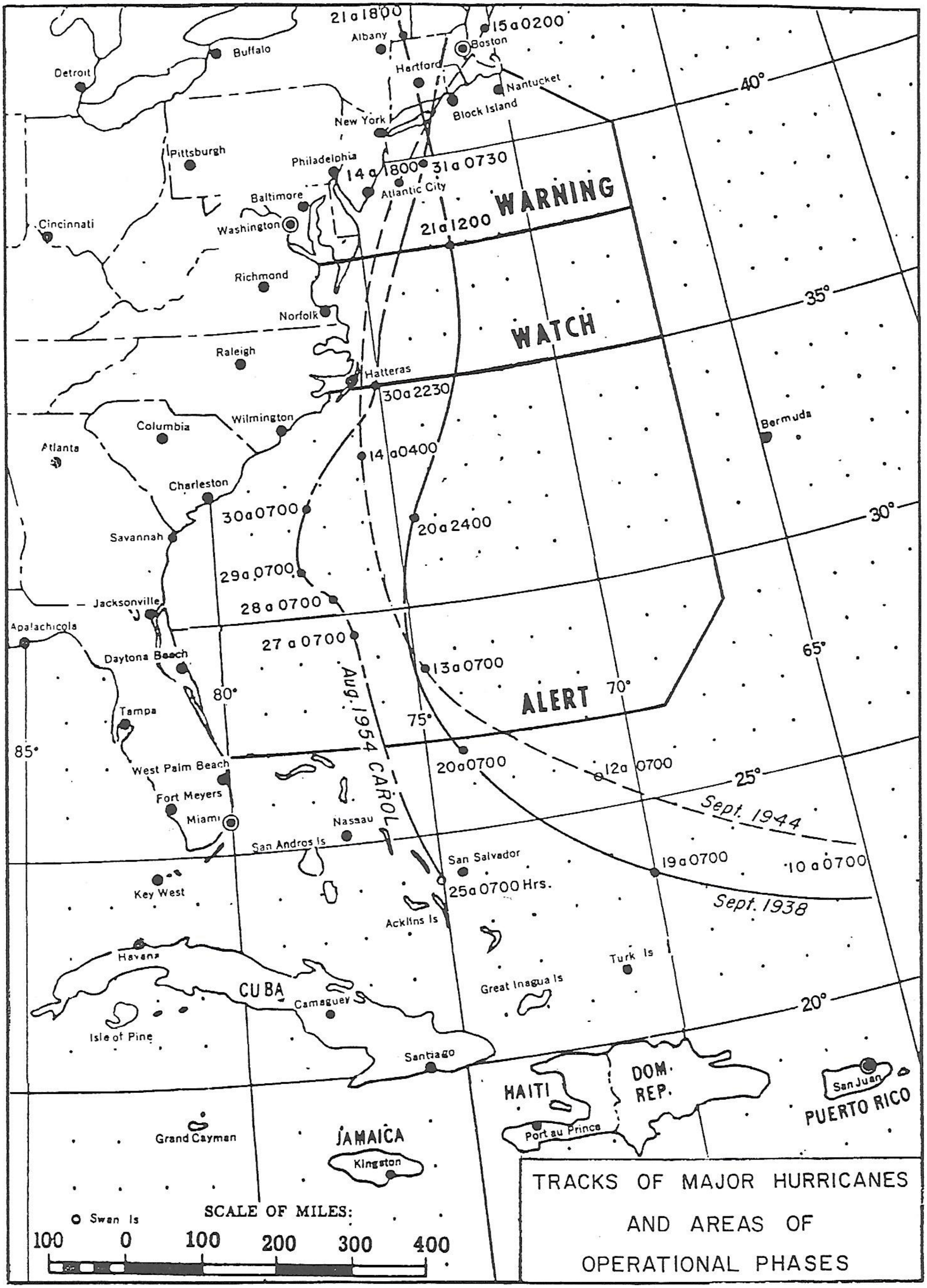
U.S. COAST GUARD TELEPHONE NUMBER - 617-223-8337

LOG OF REPORTS

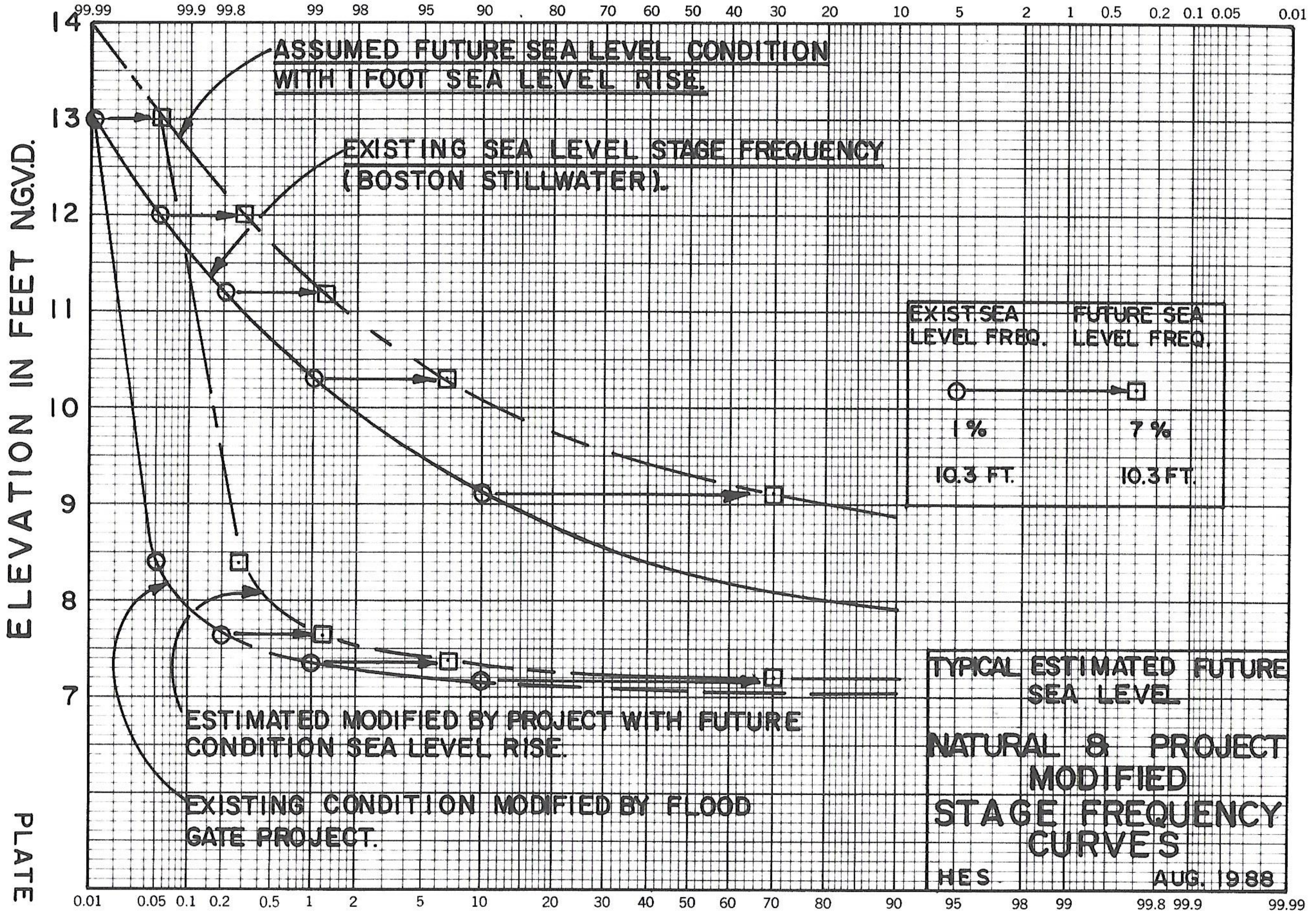
	METEOROLOGY					
1 DATE-TIME	2 PRECIP.-IN. (LAST 24-HRS.)	3 FORM OF PRECIPITATION	4 PRESENT WEATHER	5. WIND DIRECTION	6 * WIND VELOCITY (K)	7 BAROMETRIC PRESSURE (IN.

SAUGUS FLOODGATE PROJECT

TIDE DATA				
8 OCEAN EL. (FT. N.G.V.D.)	9 HARBOR EL. (F.T. N.G.V.D.)	10 PRED. TIDE (FT. N.G.V.D.)	11 SURGE (FEET)	REMARKS AND/OR INSTRUCTIONS



TRACKS OF MAJOR HURRICANES AND AREAS OF OPERATIONAL PHASES


ASSUMED FUTURE SEA LEVEL CONDITION
WITH 1 FOOT SEA LEVEL RISE.
EXISTING SEA LEVEL STAGE FREQUENCY
(BOSTON STILLWATER).
EXIST SEA LEVEL FREQ.
FUTURE SEA LEVEL FREQ.
1 %
7 %
10.3 FT.
10.3 FT.
ESTIMATED MODIFIED BY PROJECT WITH FUTURE
CONDITION SEA LEVEL RISE.
EXISTING CONDITION MODIFIED BY FLOOD
GATE PROJECT.
TYPICAL ESTIMATED FUTURE
SEA LEVEL
NATURAL & PROJECT
MODIFIED
STAGE FREQUENCY
CURVES
HES
AUG. 1988
ELEVATION IN FEET N.G.V.D.
14
13
12
11
10
9
8
7
99.99
99.9
99.8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01