HYDROLOGIC AND HYDRAULIC ANALYSIS
WETLANDS RESTORATION INVESTIGATION
BALLARD STREET SALT MARSH
SAUGUS, MASSACHUSETTS

Prepared for
Town of Saugus

In Cooperation with
Essex Conservation District

Prepared by

United States Department of Agriculture
Natural Resources Conservation Service
Amherst, Massachusetts

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Cover Photo- Tidal channel looking west toward Eastern Stamping and Tool Company. This is the site of the proposed tide gate location.

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INTRODUCTION

Background

The Massachusetts Executive Office of Environmental Affairs, Wetlands Restoration and Banking Program (WRBP), on behalf of the Town of Saugus, requested that the Natural Resources Conservation Service (NRCS) evaluate the hydrologic and hydraulic effects of salt marsh restoration at Ballard Street, in East Saugus. This area is within the Rumney Marsh Area of Critical Environmental Concern as designated by the State of Massachusetts. It has been identified as a location to restore about 12 acres of salt marsh. Restoration can, in part, be accomplished by relocating the existing Ballard Street tide gate. Restoration of this area has also been considered in the Coastal America initiative.

A previous tide gate at Ballard Street broke in 1990. The Town temporarily repaired it with a steel plate suspended on chains. The existing tide gate location and condition restricts salt water flow and the interior salt marsh is degrading. The existing tide gate does provide some flood protection and its failure during a storm could cause flooding of numerous buildings.

Relocating the Ballard Street tide gate will improve tidal flow to the interior marsh. The proposal to restore this salt marsh by relocating the tide gate was originally made by the U.S. Environmental Protection Agency. Initial reviews of the proposal raised concern as to how the proposed changes would affect the potential for flooding to nearby homes and businesses. This study was undertaken to address that concern.

Authority

This study was prepared under the authority of the Watershed Protection and Flood Prevention Act, Public Law 83-566, as amended (16 U.S.C 1001-1008). The NRCS provides assistance to communities in cooperation with the Essex Conservation District.

Purpose and Scope

The purpose of this study is to evaluate the hydrologic and hydraulic effects of alternatives for replacing the temporary tide gate at Ballard Street, which, in turn, will provide for salt marsh restoration that is consistent with flood protection needs for the town. Meetings were held with a variety of town, state, regional, and federal agencies, and the Saugus River Watershed Council at which it was agreed that the following alternative conditions would be evaluated:

- Existing Conditions (Do nothing)
- Replace the existing Ballard Street culvert tide gate
- Relocate the tide gate to a location at the end of the Interstate 95 embankment

This report documents the methodology and results of the hydrologic and hydraulic analyses. Economic investigations (Appendix A) were also done to assist in evaluating the hydrologic and hydraulic study results.

SETTING AND PROBLEM

Watershed and Salt Marsh Description

Figure 1 is a general location map for the study area. Figure 2 is a simple detail of the study area. The Ballard Street salt marsh watershed has a drainage area of approximately 0.34 square miles or 217 acres. Of this area, approximately 157 acres is predominantly urban upland. The remaining 60 acres is, or was, salt marsh lying between Eastern Avenue and Route 107 and bounded by Bristow and Ballard Streets. The marsh area is roughly bisected by fill placed in the 1960's for a now abandoned section of Interstate 95. Surface runoff is collected in large drainage ditches west of Eastern Avenue. It flows to the Saugus River at Ballard Street where it discharges through a culvert 4 feet in diameter. The Eastern Avenue ditches have bottom elevations in the range of 0.0 to 2.0 feet NGVD, and were historically flooded by daily tidal fluctuations in the Saugus River.

Description of Problem

The natural daily tidal flooding and channel flushing was altered many decades ago by, among other actions, the building of the first roads. Tidal barriers or gates were often placed on road culverts to control flooding or for other reasons, keep tidal waters out of the marsh. The tide gate at Ballard Street deteriorated and required repair or replacement. It was repaired by the town with a loose fitting steel plate that allowed about one-third the normal culvert flow into the marsh. Throughout this time the marsh, increasingly taken over by "undesirable plants" such as the common reed (phragmites australis), continued to degrade. Meanwhile, residential development continued to expand west of Eastern Avenue.

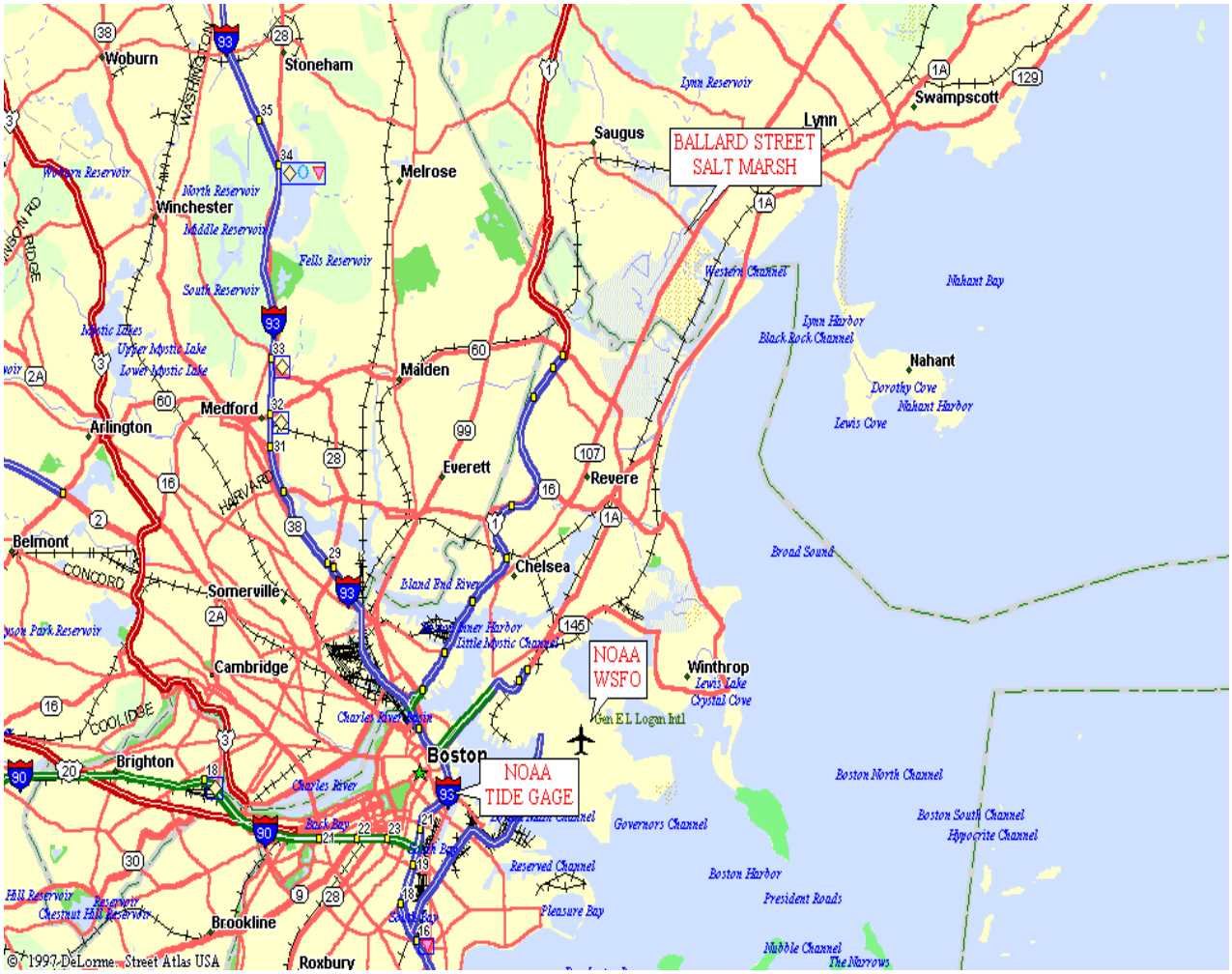


Figure 1 - Location Map

No Scale

Figure 2 – Study Area Map

Map of Bristow-Ballard-Eastern-Route 107 Area

This entire situation constitutes the "existing condition". The problem then is this: is it possible to restore some of the degraded salt marsh without causing or adversely affecting anything else? -The proposal is to relocate the Ballard Street tide gate to allow restoration of the interior salt marsh adjacent to Route 107, without aggravating any existing flooding, disease vector, or other social problems.

Reference Elevations

Flooding within the study area can occur as a result of fresh water runoff from upland runoff and from salt water from the Saugus River to the north or the Pines River to the south. The tide gate at Ballard Street partially regulates the flow of salt water into the study area from the Saugus River. There is also a large culvert under the abandoned Bristow Street, between Route 107 and the I-95 fill. This culvert is presently blocked with plywood and little water flows through it.

Table 1 lists reference elevations at key locations in the study area.

Table 1 - Reference Elevations

Location	**Elevation** (Feet NGVD)
Ballard Street, between the culvert and Rte 107	8.0 *
Low ground between Ballard Street and Saugus River	8.5
Bristow Street (abandoned) between Rte 107 and I-95 fill	8.1
Bristow Street between I-95 fill and Eastern Avenue	8.4
Buildings (floor) south side of Ballard Street, between Eastern Avenue and Rte 107	9.5 – 9.7
Buildings (lowest start of damage for overland flow) west of Eastern Avenue	6.7
Flood Insurance Study 10-percent chance (10-year) flood in the study area	8.8

* Water must flow over the low ground between the street and the river first, therefore elevation 8.5 controls.

Water from the Saugus River overtops Ballard Street and water from the Pines River overtops Bristow Street (two locations) between elevations 8.1 to 8.5. Once these roads are overtopped, salt water flows uncontrolled into the study area. At these elevations the existing tide gate as well as any future relocated tide gates have *little or no effect* on controlling water levels in the study area because the area available for flow is far greater than the area of the existing culvert at Ballard Street.

Building Flooding

There are commercial/industrial buildings located on Ballard Street between Eastern Avenue and Route 107. Buildings in the Eastern Avenue/Bristow Street area are primarily residential.

Buildings on the north side of the Ballard Street are affected only by floodwater from the Saugus River. The presence or absence of a tide gate at Ballard Street has no impact on these structures.

The remaining buildings in the study area could potentially be flooded by either water in the study area or by seawater overflowing Ballard and Bristow Streets. The floor elevations of the two buildings on the south Side of Ballard Street (Table 1) are at least 1.0 feet above the low point on Ballard Street. It is unlikely that these buildings are affected by the present or future tide gate locations because water from within the study area will overflow Ballard and Bristow Streets before if reaches the first floor elevations. The remaining buildings in the study area are lower in elevation. In any event, *once seawater elevations exceed the road elevations, tide gate location will have no significant effect on the water level or flooding in the study area*.

SITE HYDROLOGY

Tidal Regime

In the study area tides are semi-diurnal with two high and two low water occurrences during each lunar day (approximately 24 hours and 50 minutes). The resulting tide range is constantly varying in response to relative positions of the earth, moon, and sun, with the moon having the primary influence. A complete sequence of tide ranges is repeated over an interval of approximately 19 years, a period known as a tidal epoch. Long term tidal measurements at the site are not available, but adequate approximation can be made from historic and current tide data collected at the Boston Harbor tidal gage. This gaging station, about 10 miles from the marsh, is operated by the National Ocean Service (NOS). The tidal datums (Table 2) are based on a tidal epoch from 1960-1978.

The 100-year flood elevation along the Saugus River adjacent to the salt marsh is 10.0 NGVD from the latest Flood Insurance Study (FIS) completed for the Town of Saugus, MA dated July 19,1982. Based on examination of existing mapping (1 foot contour interval) and a surveyed profile of Ballard Street, Saugus River tidal still water elevations greater than 8.5 feet NGVD will overtop Ballard Street and enter the marsh. This would be less than a 10-year tidal flood of 8.8 feet NGVD. The southeast end of the site at Bristow Street is subject to tidal flooding from the Pines River at about the same frequency or Elevation 8.1 NGVD (Figure 2).

Table 2 – Estimated Tidal Datum Planes

Estimated Tidal Datum Plane	Referenced to:	
	NGVD	**MLLW**
Highest Observed Water Level (02/07/1978)	10.40	15.25
100-year Flood Event	10.0	14.85
50-year Flood Event	9.6	14.45
10-year Flood Event	8.8	13.65
Mean Higher High Water	5.48	10.33
Mean High Water	5.04	9.89
Mean Tide Level	0.27	5.12
National Geodetic Vertical Datum **(NGVD)**	0.00	4.85
Mean Low Water	-4.51	0.34
Mean Lower Low Water **(MLLW)**	-4.85	0.00
Lowest Observed Water Level (03/24/1940)	-8.45	-3.60

Upland Drainage

As the first restriction above free-flowing tides, the Ballard Street culvert is the outlet for this study area. Using the 1:24000 scale USGS map (Lynn quadrangle) and 1:960 scale 2-foot contour topographic maps, by Avis Airmap Inc., the watershed area above the Ballard Street culvert was determined to be 217 acres. Of this total area, about 157 upland, mostly urban, acres contribute runoff to the marsh, of which 144 acres is west of Eastern Avenue. In addition, precipitation falls directly on about 60 acres of current or former salt marsh.

Hydrologic Analysis

In light of the local flooding concerns, the hydrologic and hydraulic analysis of the Ballard Street salt marsh and its upland tributaries requires consideration of a significant rainfall – runoff event with a coincident high tide.

The NRCS computer model TR20 generated the necessary runoff data. TR20 is the designation for a watershed computer model entitled Computer Program for Project Formulation-Hydrology. The program is a physically based event model, which computes direct runoff resulting from any synthetic or natural rainstorm. There is no provision for recovery of initial abstraction or infiltration during periods of no rainfall during an event. It takes into account conditions having a bearing on runoff, develops a surface runoff hydrograph, and can route the flow through stream channels, reservoirs, and natural storage areas. Routed hydrographs can be combined with those from other streams. Provisions for diversion of flow and the addition of base flow are included, but TR20 does not have a groundwater component. Peak discharges, the times of

occurrence, volumes of runoff and duration of flows can be computed at any desired design point.

The 217-acre watershed was divided into four subwatersheds, with areas of 36-, 37-, 56-, and 88-acres. Figure 3 shows the watershed boundary and the 4 subwatersheds. TR20 utilizes the Runoff Curve Number procedure to determine runoff volumes from rainfall as described in the NRCS National Engineering Handbook Section 4, Hydrology. Detailed soils information for the watershed was available from the Essex County Soils Report (NRCS). Land use data was determined from available mapping, aerial photographs (soils) and field observations. Composite runoff curve numbers were determined using the soils and land use data for each of the subwatersheds. Routine manual/computer aided computations were made for subwatershed times of concentration with the aid of large-scale topographic maps.

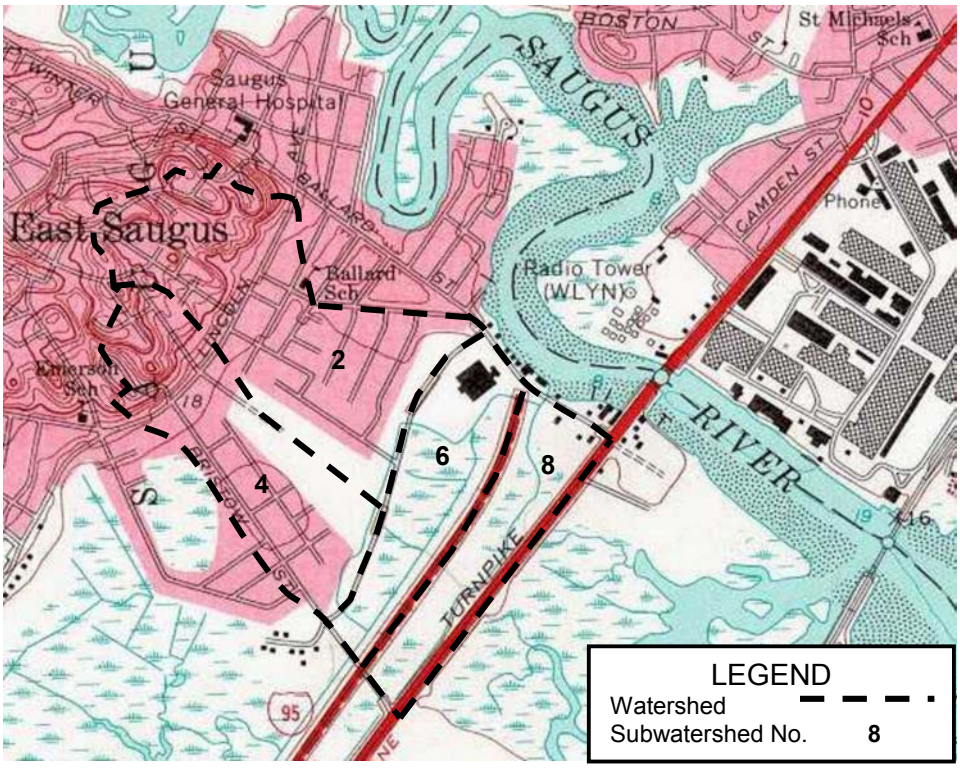
The TR20 model was used to generate hydrographs and frequency – runoff relationships for several synthetic rainfall events. Historical rainfall data (October 20-21, 1996 storm) was obtained from the Boston, MA Weather Service Forecast Office (WSFO) for possible use in the TR20 model. However, flood damage surveys within the watershed later determined that little or no flood data from the October 1996 storm existed. Since no other historical hydrographs or hydrologic data for the watershed were available, calibration or verification of the hydrology model was not attempted. The rainfall depths for each synthetic storm were taken from Weather Bureau Technical Paper 40. The duration of each synthetic event was 24 hours. Refer to Table 3 below for the precipitation values used (Annual Map).

Table 3 - 24-hour Precipitation-Frequency

Return Period (years)	Partial Duration (inches)	Conversion to Annual Series	Annual Map (inches)
2	3.10	0.88	2.73
5	4.00	0.96	3.84
10	4.60	0.99	4.55
25	5.40	1.00	5.40
50	6.05	1.00	6.05
100	6.65	1.00	6.65

Figure 3

Watershed and Subwatershed Map



The TR20 model was processed for the synthetic evaluation storms with return periods (recurrence interval) of 2-, 5-, 10-, 25-, 50-, and 100-years. Because of the urban nature of the upland watershed and the absence of a well-defined stream system, the peak discharge of the generated hydrographs was not considered as relevant as the volume of runoff. The "design point" of the hydrographs was actually the low-lying area west of Eastern Avenue. Therefore the analysis focused on the runoff volume rather than a single "peak discharge" (see Table 4).

Table 4 – Runoff Volume in Acre-Feet

Return Period (Years)	Subwatershed			
	2	4	6	8
2	10.5	7.8	2.9	2.7
5	17.5	12.5	5.4	5.0
10	22.3	15.7	7.2	6.7
25	28.0	19.5	9.4	8.8
50	32.5	22.4	11.2	10.5
100	36.7	25.2	12.9	12.1

Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood which equals or exceeds the 100-year flood (1-percent chance of annual exceedance) in any 50-year period is approximately 40 percent (4 in 10), and for any 90-year period, the risk increases to approximately 60 percent.

ANALYSES

Data Collection

Field surveys of the salt marsh area to be restored were conducted during the summer of 1997. Surveys were referenced to NGVD. Channel and high marsh cross sections were obtained from Ballard Street to Bristow Street and to Eastern Avenue. In addition, culvert geometry and elevation data were obtained at five locations including Ballard and Bristow Streets and Eastern Avenue. Channel cross sections of the ditches along Eastern Avenue were also surveyed.

These surveys are in support of topographic mapping prepared for the New England District, Corps of Engineers by James W. Sewall Company. The maps, prepared in 1991, are preliminary copies prepared at a scale of 1:480 and a one-foot contour interval. Spot elevations obtained from the field surveys verified the datum and relative accuracy of the maps.

These surveys were obtained with a total station, and each occupied station was referenced as part of an open traverse. Digital cross section data were converted to Corps of Engineers HEC-2 data format for use in the analysis computer model, UNET.

Topographic and tidal monitoring data were collected to describe the existing salt marsh tidal regime, and to obtain information to calibrate the analysis model. In addition to the marsh area, the adjacent residential area and other development required field information, survey and interview data.

Five staff gages were erected, four within the marsh and one in the Saugus River to monitor a flood tide. All five gages were surveyed to NGVD control. One gage was located at the outlet of the Ballard Street culvert in the Saugus River and a second at the culvert inlet in the marsh. A third gage was located at the outlet of the Eastern Avenue culvert near Gates Road. The other two gages were located in the marsh channel along Route 107, one at the end of the marsh at the abandoned Bristow Street and one between Ballard and Bristow Streets at a side channel (see Figure 4).

The tidal monitoring was conducted on December 2, 1997, between the hours of 8:00AM and 3:00PM (see Appendix B). The existing steel plate gate on the outlet of Ballard Street culvert was removed for the duration of the incoming flood tide. The culvert was free flowing in both directions for the duration of monitoring. A high tide occurred at 12:15PM on the Saugus River at the outlet of the salt marsh.

Figure 4 – Tide Monitoring Locations

Hydraulic Model

The UNET model was selected as the primary analysis tool due to its many capabilities described below and because it accepted both time-based flow and stage hydrographs in an easy to input format.

UNET is a numerical model that simulates one-dimensional unsteady flow through a full network of open channels. Because of its capability to include off-channel storage and overbank storage areas, UNET may be thought of as quasi-two-dimensional. In addition to solving the network system, UNET provides the user with the ability to apply many external and internal boundary conditions including flow and stage hydrographs, rating curves, spillways, bridges, culverts and levee systems.

UNET, using the properties of continuity and momentum, applies a linearized, implicit finite difference scheme to solve a set of linear equations. The equations are linearized using the first order Taylor approximation. For subcritical flow, stages are a function of channel geometry and downstream backwater effects. UNET has the capability to accurately model culverts since it is able to use the Federal Highway Administration procedures for determining hydraulic capacities (rating curves) for culverts using inherent nomographs. Cross sections are input in a modified HEC-2 format.

A preliminary UNET model dataset was developed utilizing the field surveyed cross sections, culvert data, and other data obtained from the topographic maps. Manning's frictional "n" values were assigned to cross section segments based on field observations and handbook guidance. Initially, the dataset consisted of four reaches containing two culverts, and two storage areas, both in line with the channel gradient. This initial model ran successfully, but was only a skeleton of the full dataset needed to represent all hydraulic features of the alternatives evaluated.

Model Calibration

The water surface elevations recorded at the five gage locations on December 2, 1997 were used to calibrate the model. Following the monitoring of the gages, it was necessary to re-survey approximately one-half mile of channel and overbank areas within the marsh. During the late fall, the "channel" had been excavated by the Northeast Massachusetts Mosquito Control and Wetland Management District (NEMMC&WMD). While this greatly increased the storage volume within the marsh area, it was the existing condition when the water level (monitoring) measurements were obtained. Therefore it was necessary to survey the changes.

Measured tidal levels from the Boston Harbor gage (Location Map, Figure 1) were used to simulate the flood and ebb tides in the Saugus River. They were used to run the UNET model dataset for three days (see Figure 5) prior to the monitored period of December 2. This was recommended so the model is not reacting to startup conditions during the important simulation period.

The initial runs showed that one storage area was not going to fill properly within the range of allowable discharge coefficients. This storage area was converted to channel Reach 2, and the resulting calculated stages closely reflected the observed staff gage measurements.

Results of the final calibration run for December 2 are shown on Figure 6 for the four monitored locations within the marsh. Graphs of the individual gage locations are included in Appendix C. Tide elevations measured in the Saugus River along with the Boston Harbor tide record are shown in Figure 7. The Boston Harbor recorded tide levels (electronic file) were edited to match the recorded Saugus River levels for the monitored period for input to the UNET model. The final computed results compare very closely to the observed water levels, indicating proper calibration.

Figure 5

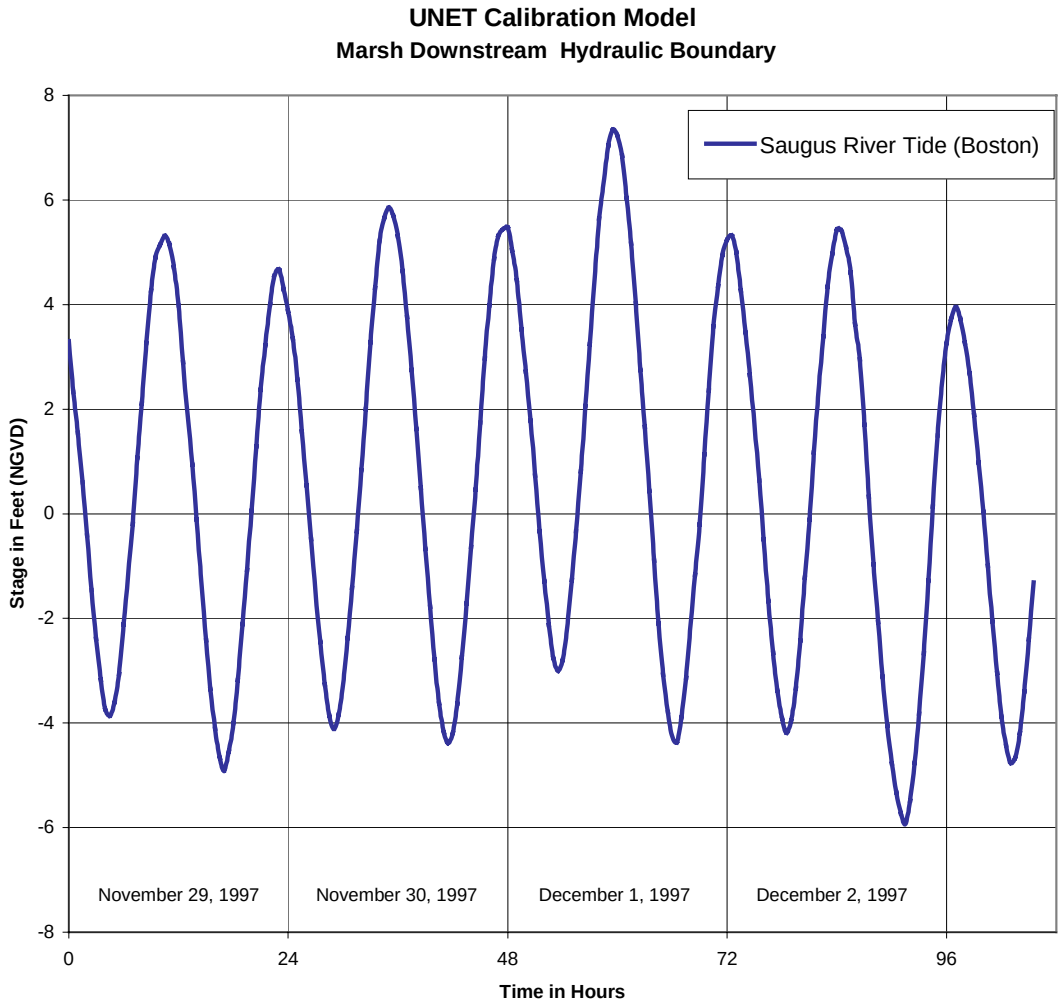
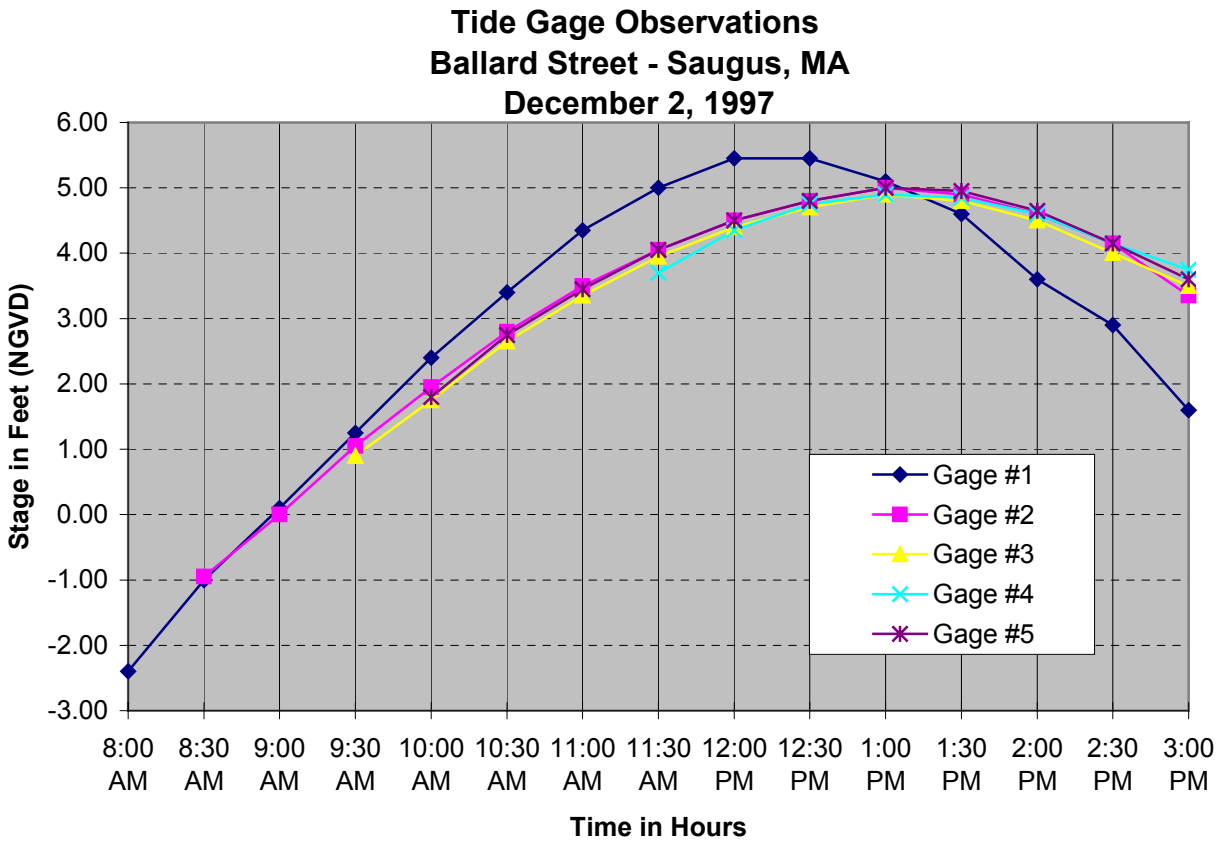


Figure 6


Tide Gage Observations
Ballard Street - Saugus, MA
December 2, 1997
Stage in Feet (NGVD)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
8:00 AM
8:30 AM
9:00 AM
9:30 AM
10:00 AM
10:30 AM
11:00 AM
11:30 AM
12:00 PM
12:30 PM
1:00 PM
1:30 PM
2:00 PM
2:30 PM
3:00 PM
Time in Hours
Gage #1
Gage #2
Gage #3
Gage #4
Gage #5

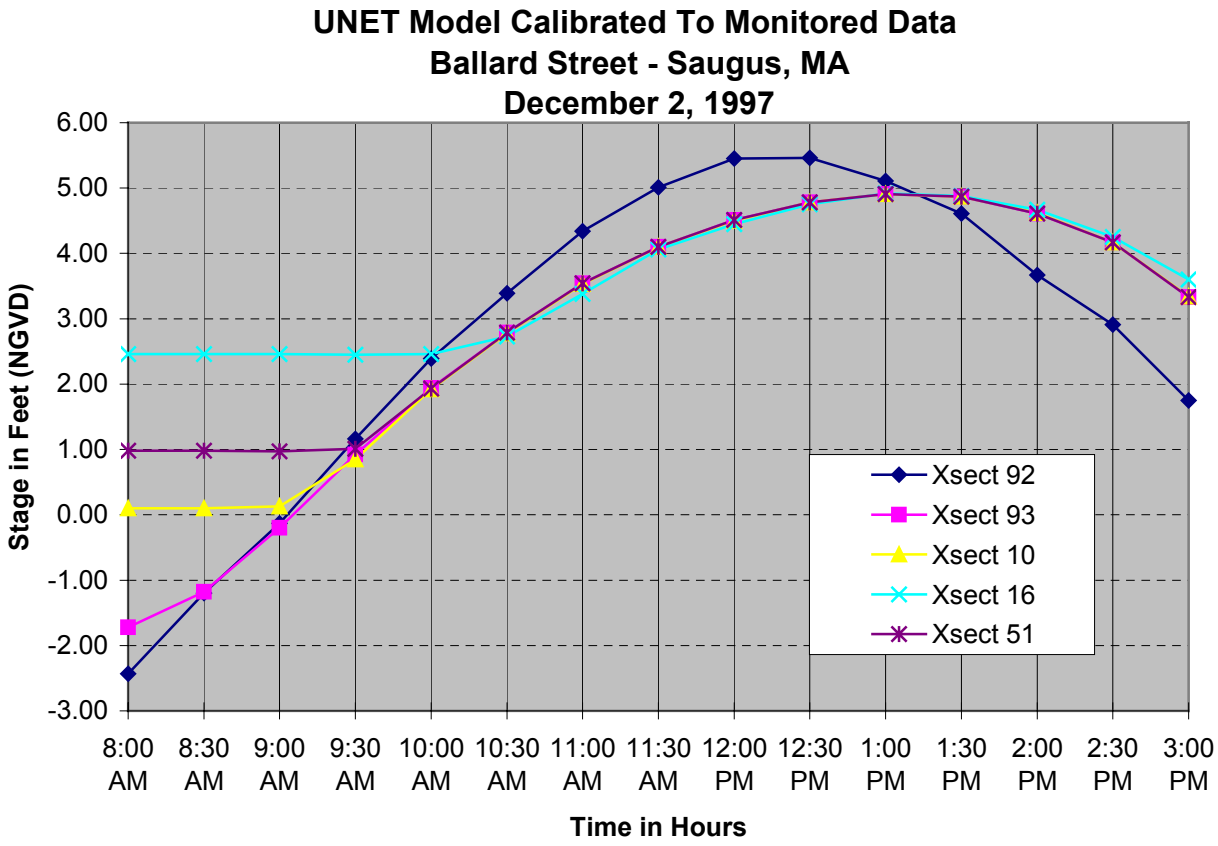
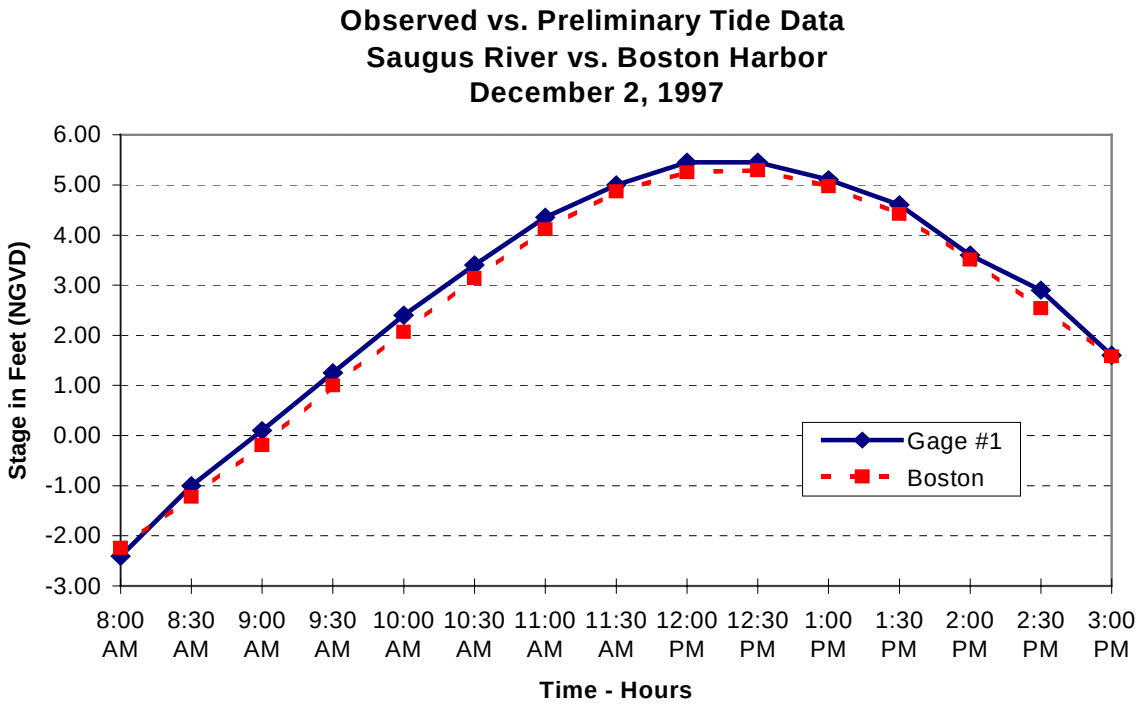
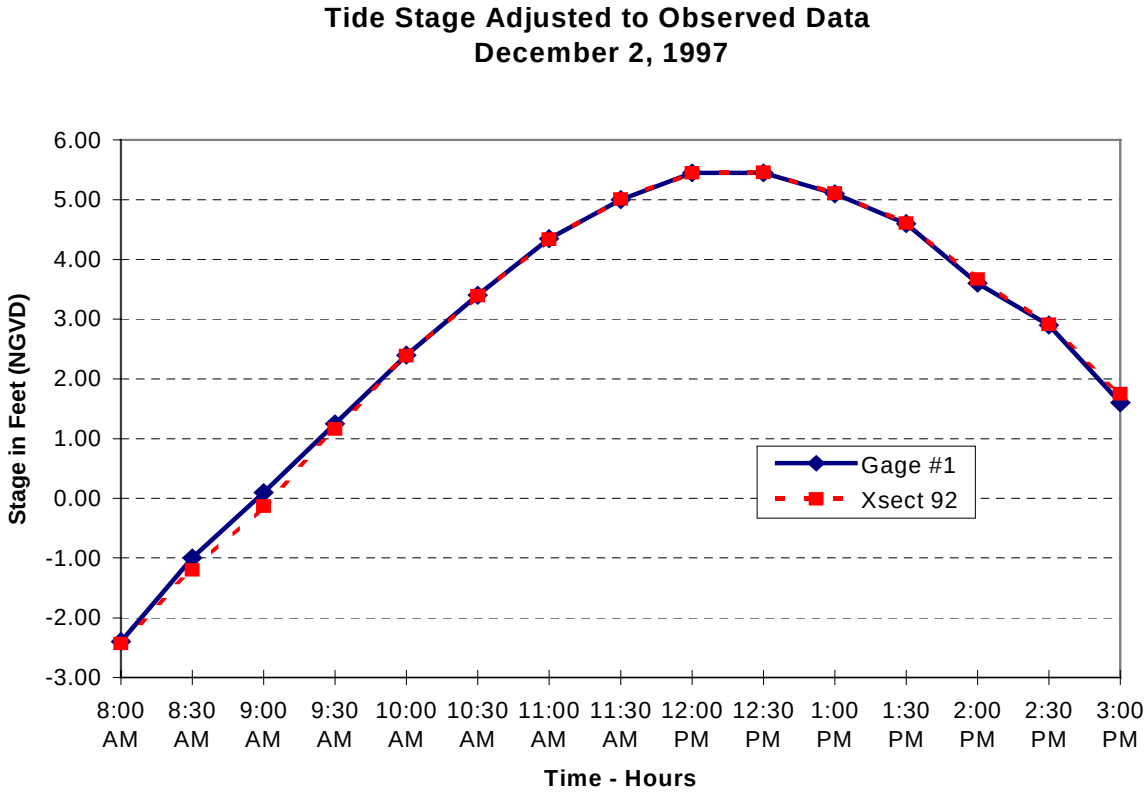

UNET Model Calibrated To Monitored Data
Ballard Street - Saugus, MA
December 2, 1997
Stage in Feet (NGVD)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
8:00 AM
8:30 AM
9:00 AM
9:30 AM
10:00 AM
10:30 AM
11:00 AM
11:30 AM
12:00 PM
12:30 PM
1:00 PM
1:30 PM
2:00 PM
2:30 PM
3:00 PM
Time in Hours
Xsect 92
Xsect 93
Xsect 10
Xsect 16
Xsect 51

Figure 7


Observed vs. Preliminary Tide Data
Saugus River vs. Boston Harbor
December 2, 1997
Stage in Feet (NGVD)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
8:00 AM
8:30 AM
9:00 AM
9:30 AM
10:00 AM
10:30 AM
11:00 AM
11:30 AM
12:00 PM
12:30 PM
1:00 PM
1:30 PM
2:00 PM
2:30 PM
3:00 PM
Time - Hours
Gage #1
Boston


Tide Stage Adjusted to Observed Data
December 2, 1997
Stage in Feet (NGVD)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
8:00 AM
8:30 AM
9:00 AM
9:30 AM
10:00 AM
10:30 AM
11:00 AM
11:30 AM
12:00 PM
12:30 PM
1:00 PM
1:30 PM
2:00 PM
2:30 PM
3:00 PM
Time - Hours
Gage #1
Xsect 92

It is important to note that the present temporary tide gate at Ballard Street cannot be predictably modeled. During the incoming tide, the gate does not seal completely. The amount of water that leaks through varies depending on elevation, wind, waves, and other factors. In order to compare the effects of relocating the tide gate on flood levels, datasets that bracket existing conditions were used.

Building on the calibrated model, three alternatives were developed and analyzed for comparison. For each alternative, a normal daily flow scenario was analyzed along with a significant rainfall-runoff event. The one-percent chance (or 100-year) flood was selected and used because it is the standard on which flood plain management decisions are based. The three alternatives are:

- No Tide Gate (Remove the existing steel sheet hanging on the Ballard Street culvert. (Model Schematic Drawing #1, Figure 8)
- Install New Tide Gate on Ballard Street culvert. (Model Schematic Drawing #2, Figure 9)
- Relocate New Tide Gate at End of I-95 embankment. (Model Schematic Drawing #3, Figure 10)

The first two alternatives involve only alterations to the Ballard Street conduit. In the first case removing the temporary tide gate altogether; and in the second replacing the temporary tide gate with a non-leaking tide gate.

Complete removal of the tide gate represents conditions that would occur if the existing temporary gate failed, allowing full tidal access to the study area. This alternative was evaluated as a reference to what could occur. With this alternative some of the existing storage in the study area is periodically occupied by saltwater and is not available for freshwater runoff. Complete failure or removal of the Ballard Street tide gate would increase the risk of flooding in the residential neighborhood (See Figure 8).

Installation of a new tide gate at Ballard Street would prevent tidal access to the study area until tide elevations were high enough to flow over Ballard or Bristow Streets. From a flood control perspective only, this represents the best and simplest alternative. With this alternative, all of the existing storage in the study area is available for freshwater runoff. However, this alternative would result in continuing degradation and eventual loss of the salt marsh.

The third scenario involves removal of the existing steel sheet at Ballard Street and installing a tide gate structure at the end of the I-95 embankment adjacent to Ballard Street. Relocation of the tide gate would reduce the amount of storage available for freshwater runoff during storms. In order to offset this loss, compensatory storage must be excavated in the area bounded by Eastern Avenue, Ballard Street, Bristow Street,

Figure 8

Figure 9

Figure 10

and the I-95 fill. An auxiliary culvert (4-foot diameter) under Eastern Avenue and maintenance of the Eastern Avenue culvert near Bristow Street are also necessary to improve drainage from the residential area. This alternative would improve tidal interchange in the salt marsh area between Route 107 and the I-95 fill.

Comparison of Alternatives

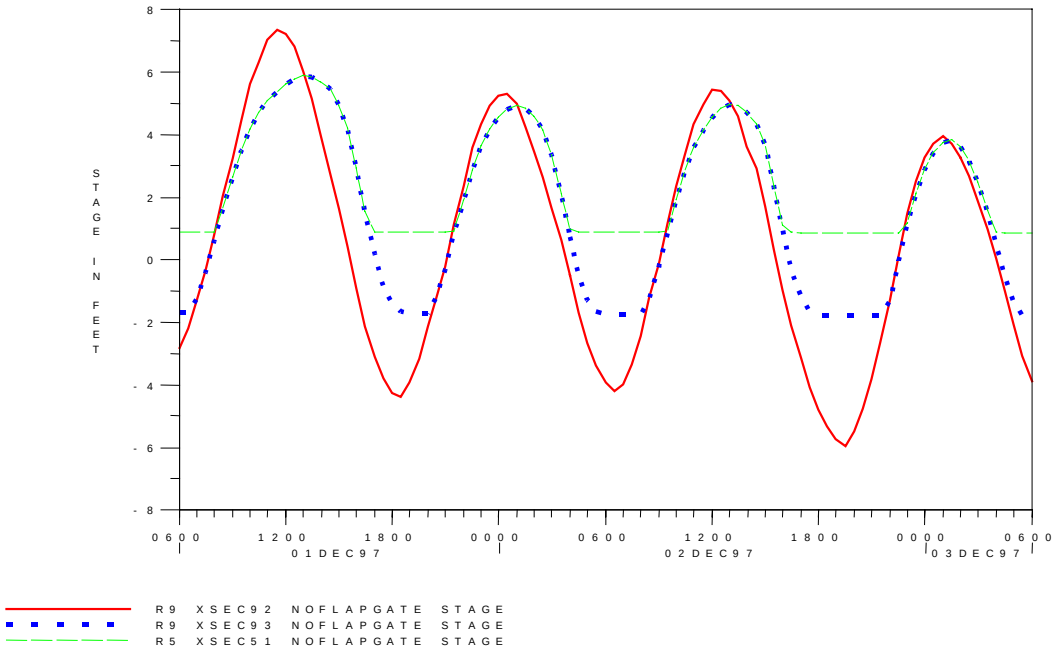
Comparisons between or among alternatives have been prepared for two distinct scenarios: 1) Normal Inflow and 2) One-Percent Chance Flood. In the Normal Inflow scenario the water movement in the model is driven by a relatively small fresh water base flow entering the salt marsh from the upland drainage area and the flood and ebb tidal flow entering and leaving the salt marsh through the Ballard Street culvert (as alternatives allow). The One-Percent Chance Flood scenario has the same tidal flows, however the fresh water inflow includes not only the small base flow but also superimposes a large storm with the resulting interior runoff reaching the salt marsh just as high tide occurs.

In both scenarios the comparisons are made, first graphically, followed by a brief narrative pointing out various important factors displayed in the graph. In the Normal Inflow scenario, Figures 11, 12, and 13 have three lines comparing the water surface fluctuations at the Saugus River and two points in the salt marsh for one of the three alternatives. The One-Percent Chance Flood scenario comparisons are made on five graphs (Figures 15-19). Each graph depicts water surface fluctuations at a particular salt marsh location for the pertinent alternatives. *These five graphs are preceded by a single graph (Figure 14) that provides a time reference for when the flood runoff reaches the salt marsh.* This time reference is useful in understanding and interpreting the graphs that follow.

The legend accompanying each graph (Figures 11-19) refers to a location shown on the Schematic Drawings (Figures 8-10). For example, R9 xsec 92 is Reach 9, cross section 92, the Saugus River side of Ballard Street. With respect to numbering of reaches and locations of cross sections, the three schematic drawings are identical.

Figure 11

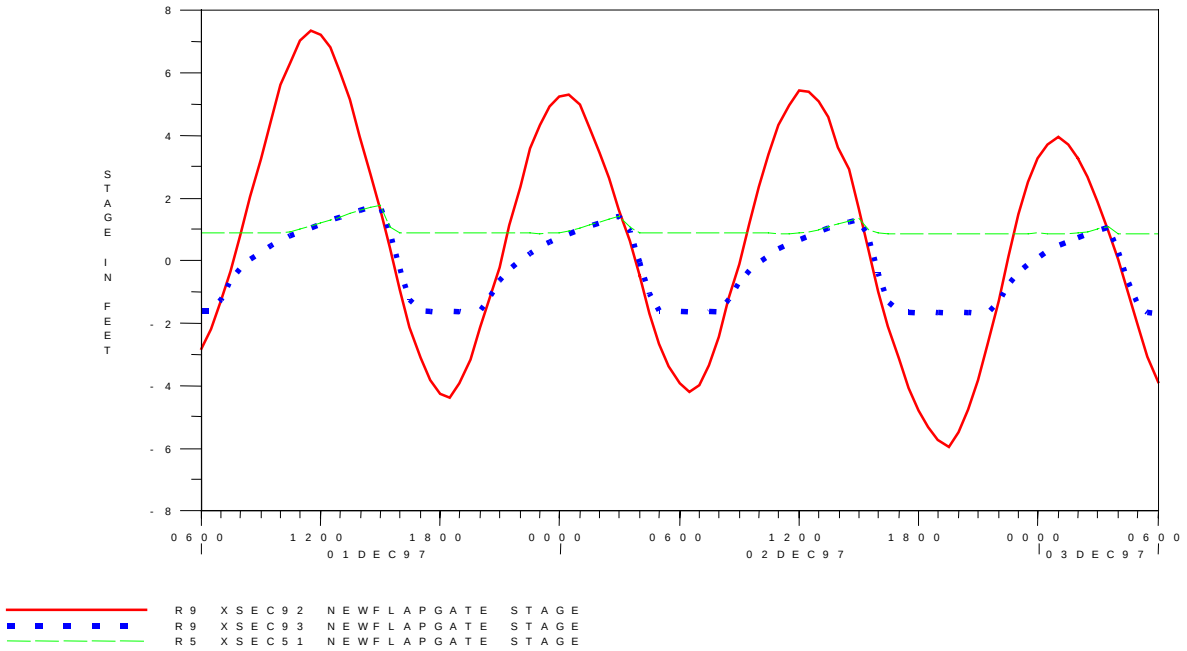
Alternative Elevation Comparison (No Tide Gate) – Normal Inflow Saugus River (xsec92) vs. Salt Marsh at Ballard Street (xsec93) and Eastern Avenue (xsec51)



This graph shows the water surface elevations inside the Ballard Street salt marsh at two locations in comparison with the water surface on the Saugus River (solid line). Notice that the salt marsh near Ballard Street (dotted line) and at the Eastern Avenue culvert (dashed line) are essentially coincident except when the tide is low and each location dries out at the channel bottom elevation for that location. Notice also that the peak water elevations in the salt marsh locations lag about one hour behind the Saugus River and never quite reach the height attained in the river. This graph also shows another feature that can be observed in the field, that is, just after the tide starts to fall on the Saugus River the salt marsh water level continues to rise until they are at the same elevation after which the salt marsh elevations start to fall, again lagging behind the river on the outgoing (ebb) tide. The cause of this time lag and reduced elevation is the restriction imposed by the Ballard Street culvert for water moving into and out of the marsh.

Figure 12

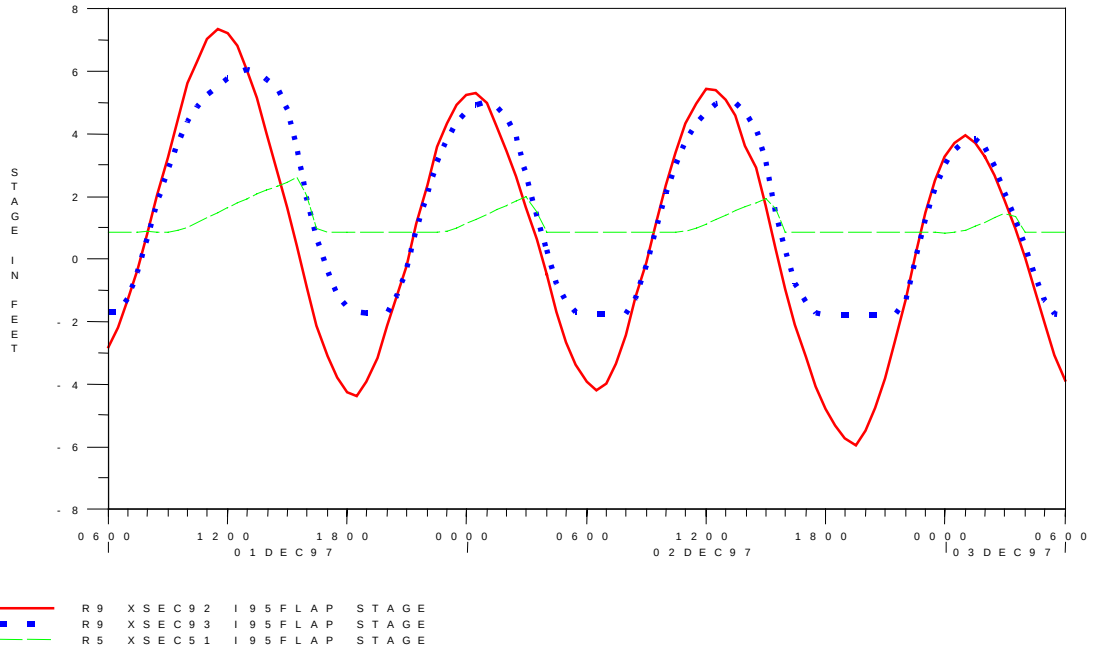
Alternative Elevation Comparison (New Ballard Tide Gate) – Normal Inflow Saugus River (xsec92) vs. Salt Marsh at Ballard Street (xsec93) and Eastern Avenue (sec51)



This graph shows the water surface elevations inside the Ballard Street salt marsh at two locations in comparison with the water surface on the Saugus River (solid line). Notice that the elevations in the interior salt marsh do not rise nearly as high as the Saugus River. In fact they would not rise at all from tidal influence because of the new, 100 percent effective Ballard Street tide gate included in this alternative. The reason for the small rises that do occur is the fresh water inflow from the watershed that accumulates behind the Ballard Street tide gate when the Saugus River is high enough to close the flap gate. The same is true for the location in the marsh at the Eastern Avenue culvert except that the accumulating freshwater barely makes it a little above the channel bottom elevation at that point. When the tide ebbs so that the Saugus River is again below the elevation of the freshwater in the marsh, the tide gate opens and the fresh water is released into the river. The elevations attained by freshwater in the marsh are not a prediction, only a reflection of the arbitrary base flow supplied to the model to account for normal runoff and for operational stability.

Figure 13

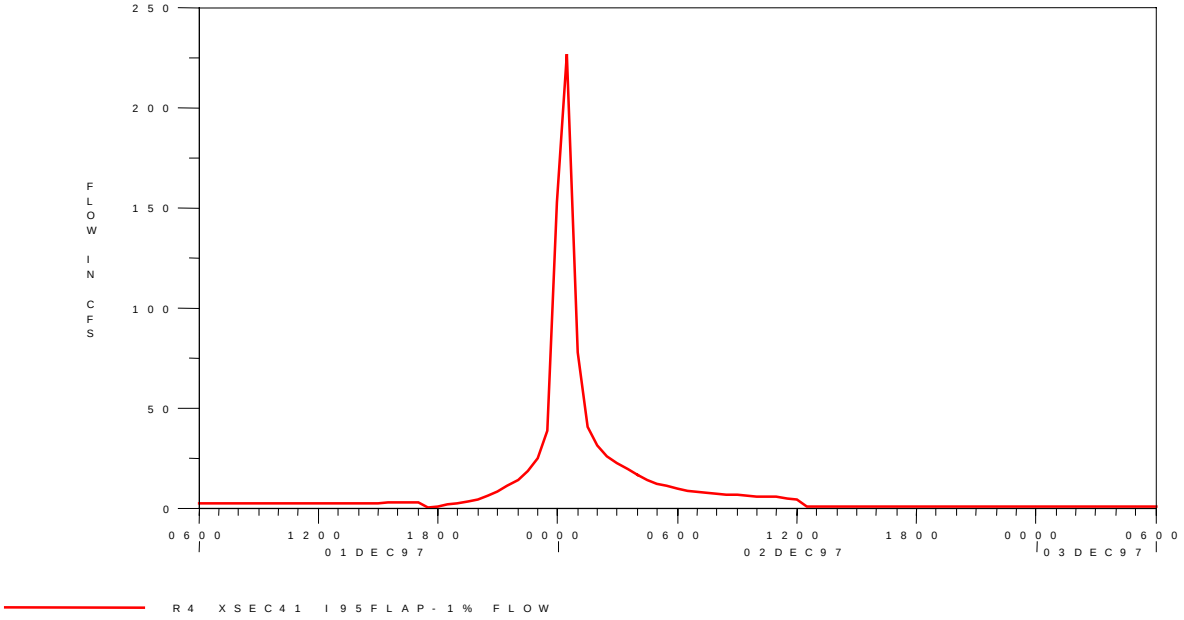
Alternative Elevation Comparison (Relocated I-95 Tide Gate) – Normal Inflow Saugus River (xsec92) vs. Salt Marsh at Ballard Street (xsec93) and Eastern Avenue (sec51)



This graph shows the water surface elevations inside the Ballard Street salt marsh at two locations in comparison with the water surface on the Saugus River (solid line). Notice that the elevations in the salt marsh near the Ballard Street culvert (dotted line) rise and fall in response to the tides in the Saugus River. However, the water surface elevations at the Eastern Avenue culvert (dashed line) are effected by the relocated I-95 tide gate included in this alternative. The water surface only rises at this location as a result of freshwater base flow being accumulated behind the I-95 tide gate when the tide rises in the restored portion of the salt marsh below the relocated tide gate. When the tide ebbs in the restored salt marsh and its water surface falls below the elevation of the freshwater above the relocated tide gate, the tide gate opens and the fresh water is released into the restored salt marsh. It then flows through the now ungated Ballard Street culvert into the Saugus River. The elevations attained by freshwater in the marsh are not a prediction, only a reflection of the arbitrary base flow supplied to the model to account for normal runoff and for operational stability.

Figure 14

One-Percent Chance Flood Inflow
At Eastern Avenue Culvert (Cross Section 41)

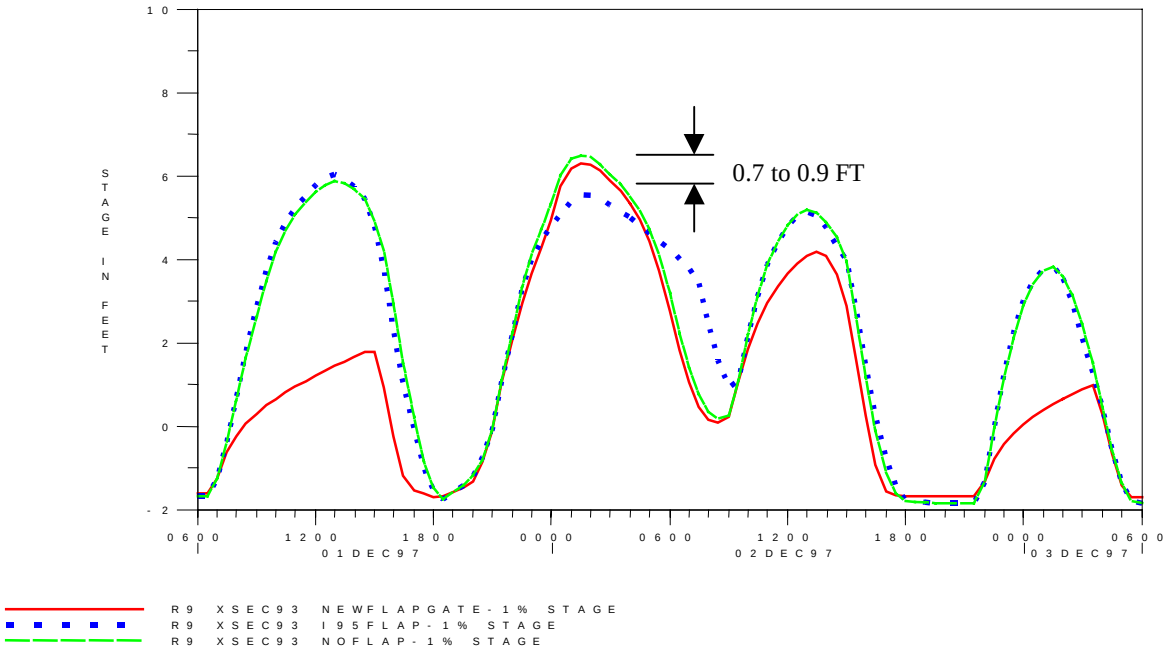


This graph provides a time reference for when the flood runoff reaches the salt marsh. This time reference is useful in understanding and interpreting the graphs that follow. It shows the peak inflow and timing of the One-Percent Chance Flood from subwatershed 2 where the freshwater storm inflow enters the Ballard Street Marsh complex. Note that the peak is artificially positioned to occur at 0000 hours on the morning of December 2, 1997. All of the storm related elevation comparisons shown on graphs for various locations in the salt marsh are at or immediately following this critical time period.

Elevation fluctuations prior to runoff effects of the one-percent chance flood are related to the interaction of normal tidal flow and an assumed freshwater base flow into the marsh.

Figure 15

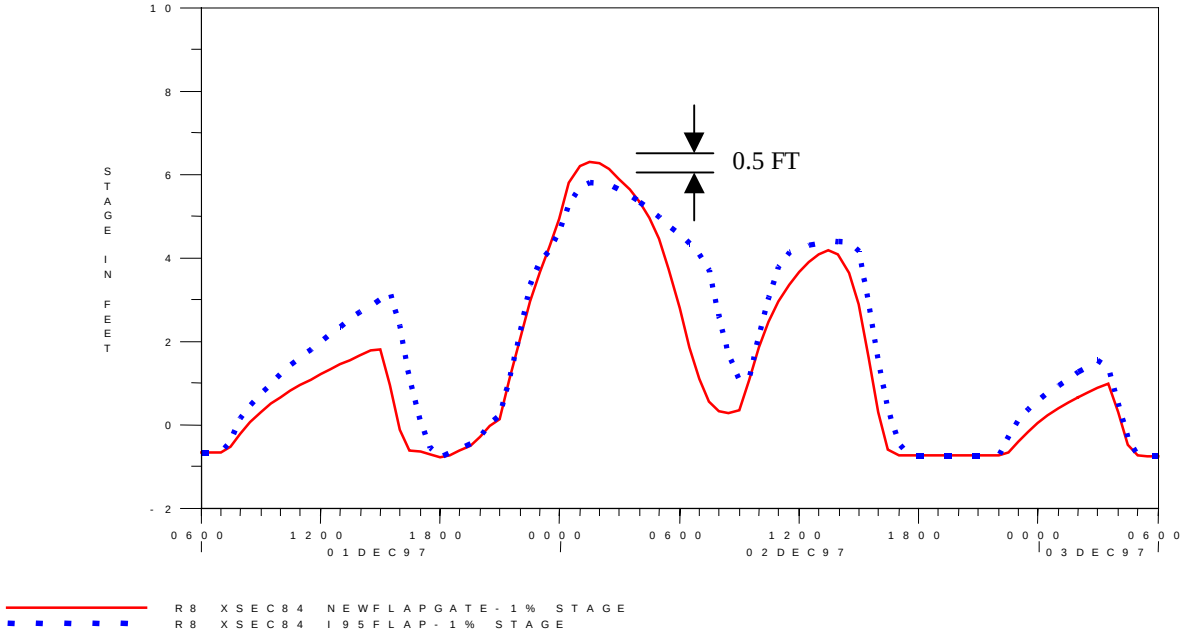
Ballard Street (xsec93) Elevation Comparison –
One-Percent Chance Flood Scenario
Relocated I-95 Tide Gate vs.
New Ballard Street Tide Gate and No Tide Gate



This graph shows that immediately following the peak inflow to the marsh, during a one-percent chance flood, Alternative 3 (the relocated I-95 tide gate alternative-dotted line) results in a lower peak flood level in the marsh area at Ballard Street. The primary reason for this is the associated excavated storage capacity between the I-95 fill and Eastern Avenue that is an integral part of this alternative. Alternative 2 (new Ballard Street tide gate alternative-solid line) and Alternative 1 (no tide gate alternative-dashed line) must store storm water runoff in the salt marsh at higher elevations for two different reasons. In the case of the no tide gate alternative, the storm water arrives at the marsh when it is already partially full of sea water at high tide. For the new Ballard Street tide gate alternative, the existing storage of the empty salt marsh is simply not adequate to lower the final flood elevation significantly.

Figure 16

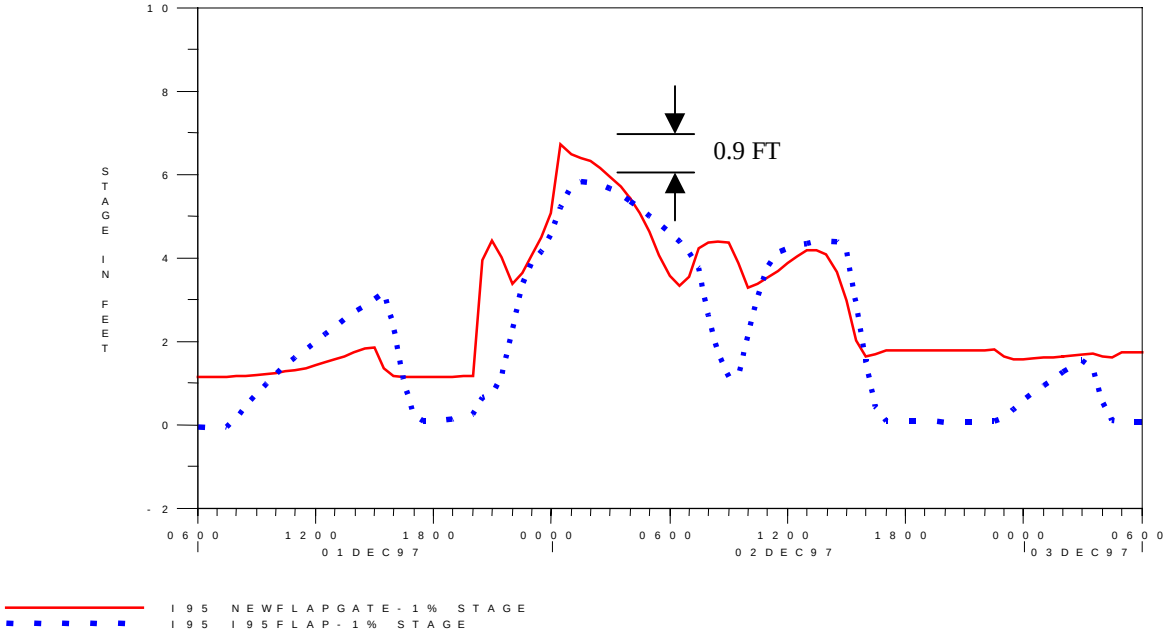
Reach 8 (xsec84) Elevation Comparison – One Percent Chance Flood Scenario Relocated I-95 Tide Gate vs. New Ballard Street Tide Gate



This graph shows that the relocated I-95 tide gate alternative (dotted line) with its associated excavated storage between the I-95 fill and Eastern Avenue provides for a lower peak flood elevation in the area of Eastern Tool and Stamping than does a 100% effective new tide gate at Ballard Street (solid line).

Figure 17

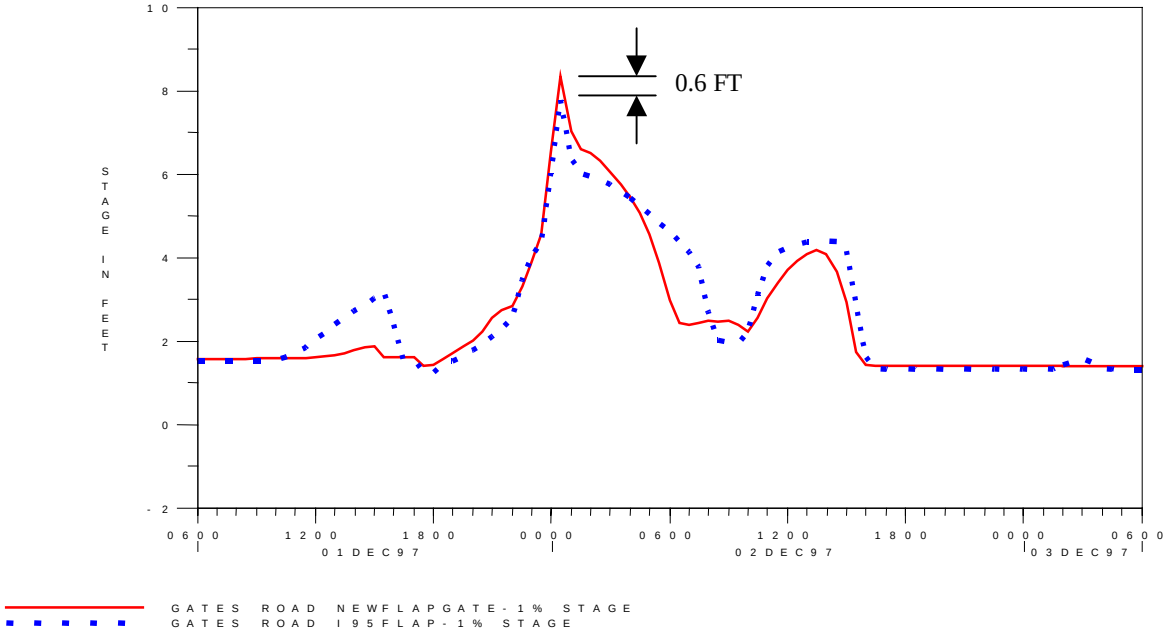
Storage Area 3 Elevation Comparison – One Percent Chance Flood Scenario
Relocated I-95 Tide Gate vs. New Ballard Street Tide Gate



This graph shows that the relocated I-95 tide gate alternative (dotted line), with its associated excavated storage between the I-95 fill and Eastern Avenue, provides for a lower peak flood elevation in the area of the I-95 storage area than does a 100% effective new tide gate at Ballard Street (solid line).

Figure 18

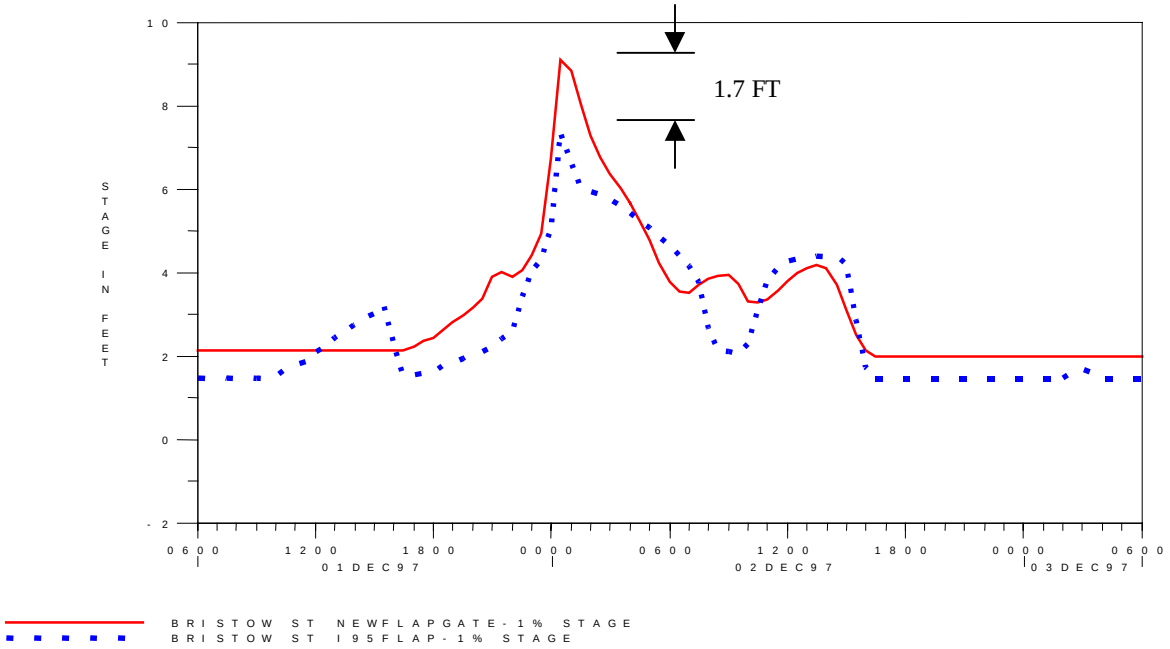
Storage Area 1 (Gates Road) Elevation Comparison – One Percent Chance Flood Scenario Relocated I-95 Tide Gate vs. New Ballard Street Tide Gate



This graph shows that the relocated I-95 tide gate alternative (dotted line) with its associated excavated storage between the I-95 fill and Eastern Avenue provides for a lower peak flood elevation in the area of Gates Road than does a 100% effective new tide gate at Ballard Street (solid line).

Figure 19

Storage Area 2 (Bristow Street) Elevation Comparison – One Percent Chance Flood Scenario Relocated I-95 Tide Gate vs. New Ballard Street Tide Gate



This graph shows that the relocated I-95 tide gate alternative (dotted line) with its associated excavated storage between the I-95 fill and Eastern Avenue provides for a lower peak flood elevation in the area of Bristow Street than does a 100% effective new tide gate at Ballard Street (solid line).

SUMMARY AND RECOMMENDATIONS

The results of this study document that it is practical to relocate the existing Ballard Street tide gate without increasing existing flood conditions at developed properties along Ballard Street and Eastern Avenue and above. The alternative of simply removing the Ballard Street tide gate would enhance salt marsh restoration, but is not practical because it would increase flood levels and associated damages in developed areas. The alternative of replacing the existing Ballard Street tide gate with a properly sealing one may be desirable from a local flood control standpoint, but has continuing and increased detrimental effects on the existing salt marsh.

Based on this study, the following measures are recommended. All of the measures are necessary to achieve the goals of salt marsh restoration and flood control benefits.

Recommended Components (see Figure 20)

I-95 Culvert and Tide Gate – In order to provide adequate capacity for interior runoff, the analysis used a 4 foot high by 8 foot wide concrete box culvert located in the existing drainage channel. Figure 21 is a sketch of the location and other culvert parameters including required invert elevations. The culvert requires a tide gate in order to provide flood control benefits.

There are numerous options for materials and culvert configuration that should be considered in design. The main consideration is that the capacity approximates a 4-foot x 8-foot opening. For example, if costs or other factors dictate, two 4 foot x 4 foot openings could be used. Options include concrete box culverts and headwalls, with an earth dike to block the existing channel area. These materials would allow the construction of vehicle access over the channel if desired. If access is not desired, steel sheet pile could be driven and the portion above the channel encased in concrete. The required opening could be cut and formed in the wall. Either option provides a mounting surface for a tide gate.

Excavated Storage Area – Under the recommended alternative, a portion of the existing marsh (east of the abandoned I-95 fill) is expected to be open to normal tidal flow for restoration purposes. The area west of the I-95 fill must provide sufficient storage to insure that interior flooding is not made worse. The following conservative assumptions were made in determining the proper amount of flood storage needed:

- The 1-percent chance storm peak runoff coincides with the time of high tide.

Figure 20 – Recommended Measures

Figure 21 – New Culvert at Ballard Street

- All storm runoff west of the I-95 fill ends up in the new excavated storage area. That is, there is no overland flow to the Pines River and no storage other than the existing ditches and the excavated storage area is available.

The runoff volume required to contain the 1-percent chance flood is 60 acre-feet. The excavated storage area should be designed to contain that volume with a maximum water surface elevation of 6.4 feet NGVD. This is just below the elevation where surface flooding of residential properties begins (see Table 1). *This storage area provides more volume for storage of interior runoff and reduces interior flood levels below what they are now.*

The excavated storage area used in the analyses is a long, narrow wedge shape. The southern end is 200 feet wide at the parking area near the Bristow Street-Eastern Avenue intersection. At the northern end, 1700 feet away, the width is 600 feet. The entire excavated area is flanked and crisscrossed with channels to fill and drain the area efficiently. Where appropriate, these channels should be laid out in curves for a more natural appearance and where necessary for mosquito control. The floor of excavated storage area is sloped from an elevation of 3.0 NGVD at the narrow southern end down to elevation 2.0 at the northern end to approximate the slope of the channel along the I95 fill. This will provide for relatively shallow and uniform channel bank depths throughout the storage area. The required excavation volume to construct the storage area as described is estimated to be 51-acre feet (82,800 cubic yards). This volume of excavation is the amount required to provide the necessary 60-acre feet of runoff storage indicated above. Existing land in the northwestern corner should be sloped to encourage drainage from the excavated area to enter the main channel at a point well downstream from the existing Eastern Avenue culvert.

The layout of this storage area was for evaluation purposes. During final design numerous options are possible depending on the desired final use of the area. The only requirement is that the required storage volume be provided at an elevation less than 6.4 feet NGVD to realize flood reduction benefits.

Auxiliary Eastern Avenue Culvert – Under existing conditions, runoff is unable to efficiently pass under Eastern Avenue. In conjunction with the excavated storage area, an additional culvert is needed to convey water from drainage ditches on the west (upstream) side of Eastern Avenue, to the storage area. A four-foot diameter pipe is needed. This culvert will help insure that runoff can exit the residential area and be efficiently conveyed to the excavated storage area. The culvert should be located at the lowest point in the residential area, which is about 1400 feet south of Gates Road.

Drainage Channel Maintenance – The existing channel network in the study area is in very poor condition. Ditches are clogged with sediment, vegetation, and dumped trash. In some areas, off road vehicle trails have blocked the channels. These obstructions impede surface drainage and cause water to pond

and stagnate in ditches. This in turn creates mosquito habitat, odors, and likely contributes to drainage problems and flooding in the residential area.

The excavated storage area measure will provide adequate storage on the east side of Eastern Avenue. Ditches and associated culverts on the west side of Eastern Avenue need to be cleaned and perhaps graded to assure proper drainage of runoff to the new storage area.

Conclusions

Implementation of the recommended measures will provide many benefits for the study area. The measures will:

- Allow the restoration of tidal flow to an estimated 12 acres of salt marsh in the area bounded by Ballard Street, State Route 107, Bristow Street (abandoned portion) and the I-95 fill.

- Provide an excavated storage area of about 15 acres between the I-95 fill and Eastern Avenue for compatible future use to be determined by the sponsors. This area can be managed for any use consistent with periodic flooding including wetland, salt marsh, recreation, open space, etc. If the sponsors want to manage this area for salt marsh, a self regulating tide gate can be used on the new I-95 culvert as long as the required storage described under Recommended Components is provided.

- Improve flood protection benefits to residential buildings by improving interior drainage, providing storage for storm runoff, and providing an outlet for future drainage improvements that the town may undertake.

- Reduce mosquito and odor problems associated with stagnant water in obstructed drainage ditches.

Of the three alternatives selected for study, only the alternative of relocating the tide gate and associated measures allows for the restoration of significant salt marsh acreage while maintaining or improving local flood protection.

REFERENCES

U. S. Geological Survey Quadrangle Map of Lynn, Massachusetts, 1:24000 scale, 1970.

National Engineering Handbook Section 4, Hydrology. Revised 1969. USDA Natural Resources Conservation Service.

UNET One-Dimensional Unsteady Flow Through a Full Network of Open channels, Users Manual, 1995. U. S. Army Corps of Engineers Hydrologic Engineering Center (HEC).

Soil Survey of Essex County, Massachusetts, Southern Part, May 1984. USDA Natural Resources Conservation Service.

Flood Insurance Study, Town of Saugus, Massachusetts Essex County (FIS), July 19,1982. Federal Emergency Management Agency.

HEC-2 Water Surface Profiles User's Manual. September 1990. Revised September 1991. U. S. Army Corps of Engineers Hydrologic Engineering Center (HEC).

APPENDIX A – ECONOMIC INVESTIGATIONS

BACKGROUND

During the spring and summer of 1997 economic field investigations were conducted within the area generally bounded by Bristow Street, Lincoln Street, Ballard Street, and State Route 107. The purpose of these investigations was to gather information on the flood history of local residents and businesses. This information was to be used to assist in evaluating the results of the ongoing hydrologic and hydraulic evaluation of relocating the Ballard Street tide gate.

DESCRIPTION

Approximately 80 property owners were contacted and, with the assistance of town officials, requested to complete a flood damage survey (see cover letter and a copy of the survey at the rear of this Appendix). A total of 31 of the surveys were completed and returned directly to the NRCS. Seventeen respondents indicated that they had some type of water problems in the past. Ten of those indicated that they experienced periodic ponding of water in their yards, street drainage problems, and sewer backups. Seven respondents indicated that they had experienced flooding by salt water. Of these, three reported that water entered their building.

Follow-up contact was made with people reporting flooding of buildings, particularly those in the area of Eastern Avenue. Building elevations were surveyed on about 40 buildings to establish low elevations. One historical high water mark, related to the storm of record in 1978, was found and surveyed.

The area experienced a significant rainfall October 23 and 24, 1996. An estimated 7 inches of rain fell over a 30-hour period. Although this was a major event, the town reports of flooding were minimal in this area. All were related to drainage and sewer backup.

SUMMARY

Information gathered indicates that there are not widespread problems associated with upland runoff causing overland flooding. The Saugus Flood Insurance Study information shows that coastal storms greater than a 10-percent chance event overtop Ballard and Bristow Streets and can cause significant flooding. There are, however, problems with poor drainage, including cellar drain and sewer backups, and surface ponding in streets and in yards, which damages some buildings. Residents have expressed significant concern about these localized problems.

Homes in the area are of two distinct age groups. The older homes are notable for the fact that their first floors are elevated three to five feet above the ground, while the newer ones are not. Nearly all of the building damage occurs to newer homes.

Economics Survey Letter

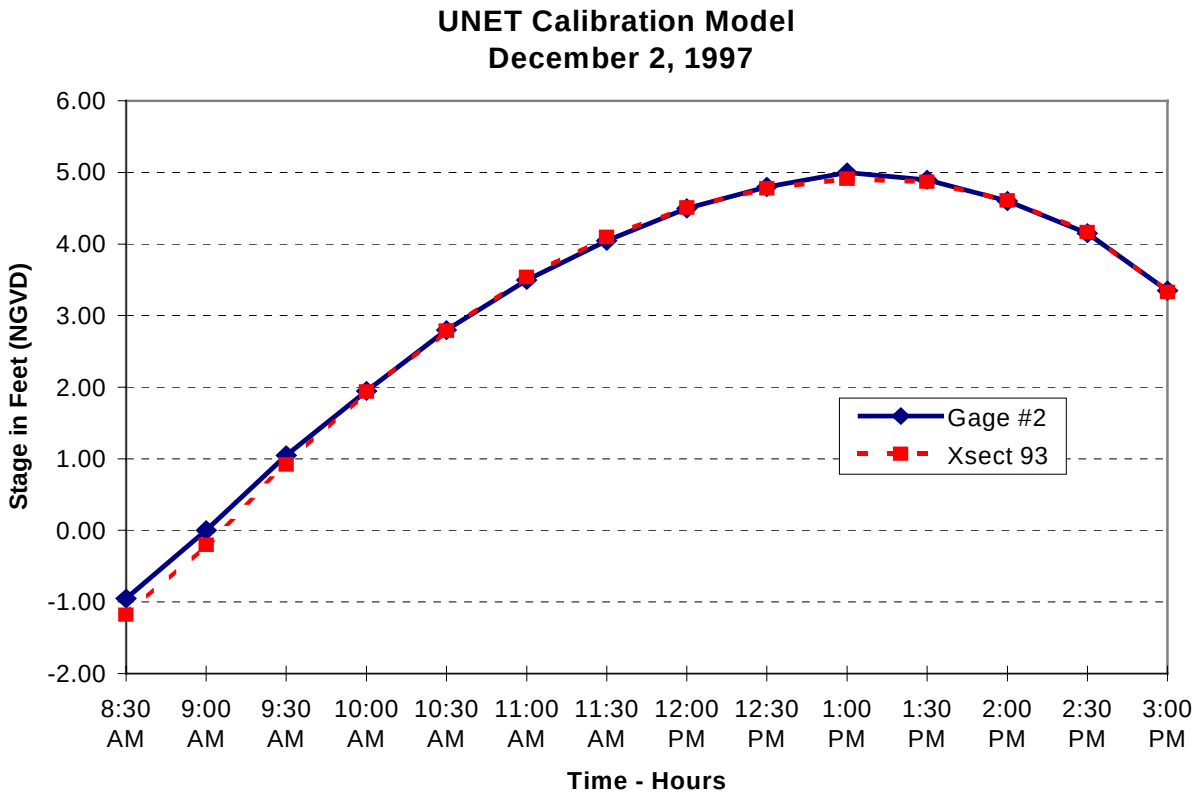
Economics Survey

APPENDIX B – MEASURED TIDAL DATA

Insert Appendix B table with staff gage readings

APPENDIX C – ADDITIONAL CALIBRATION CURVES

Figure C-1


UNET Calibration Model
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Stage in Feet (NGVD)
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5.00
4.00
3.00
2.00
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0.00
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-2.00
8:30 AM
9:00 AM
9:30 AM
10:00 AM
10:30 AM
11:00 AM
11:30 AM
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1:00 PM
1:30 PM
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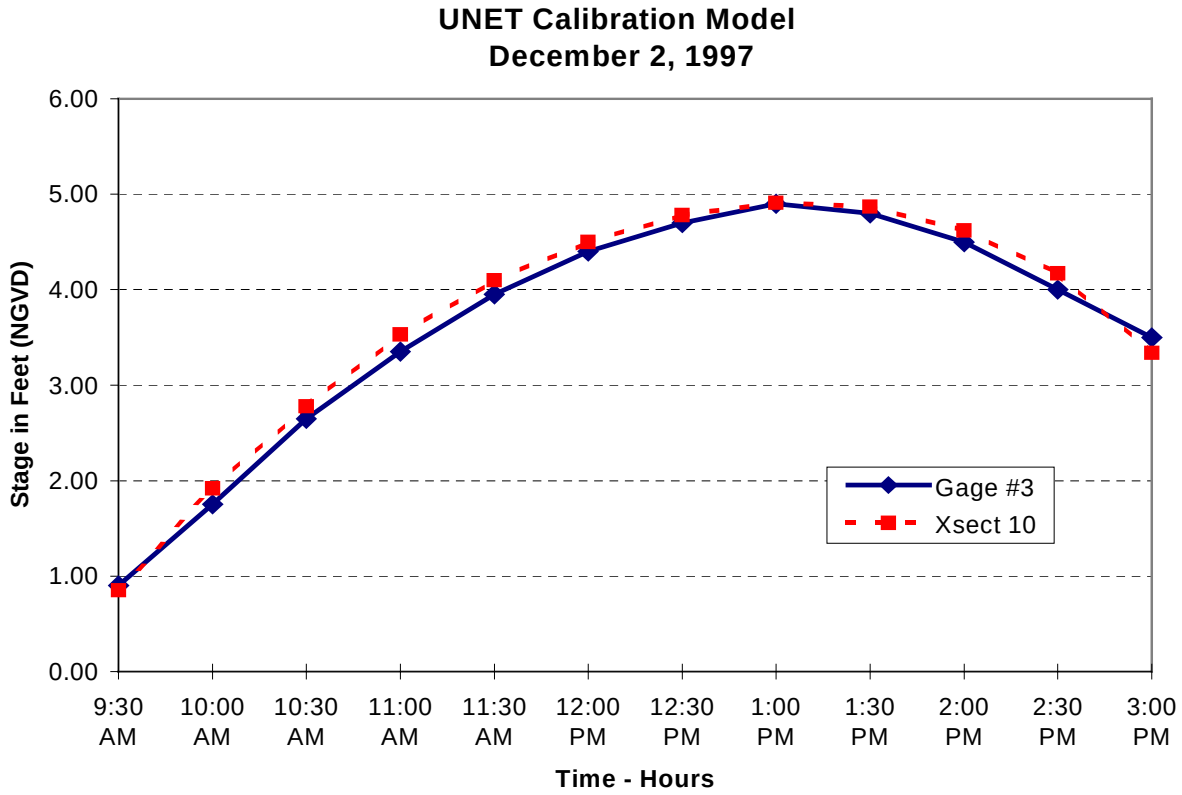
3:00 PM
Time - Hours
Gage #2
Xsect 93


UNET Calibration Model
December 2, 1997
Stage in Feet (NGVD)
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3.00
2.00
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10:00 AM
10:30 AM
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12:00 PM
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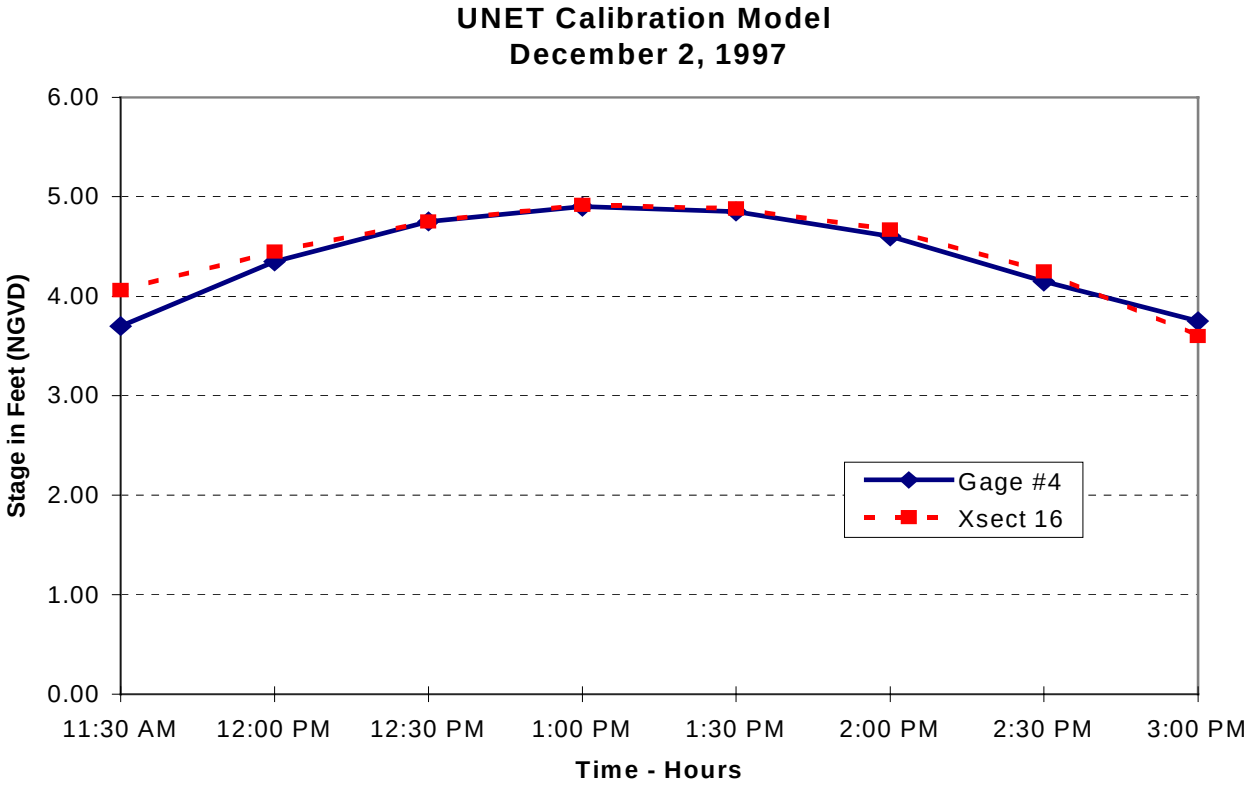
3:00 PM
Time - Hours
Gage #3
Xsect 10

Figure C-2


UNET Calibration Model
December 2, 1997
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5.00
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3.00
2.00
1.00
0.00
Stage in Feet (NGVD)
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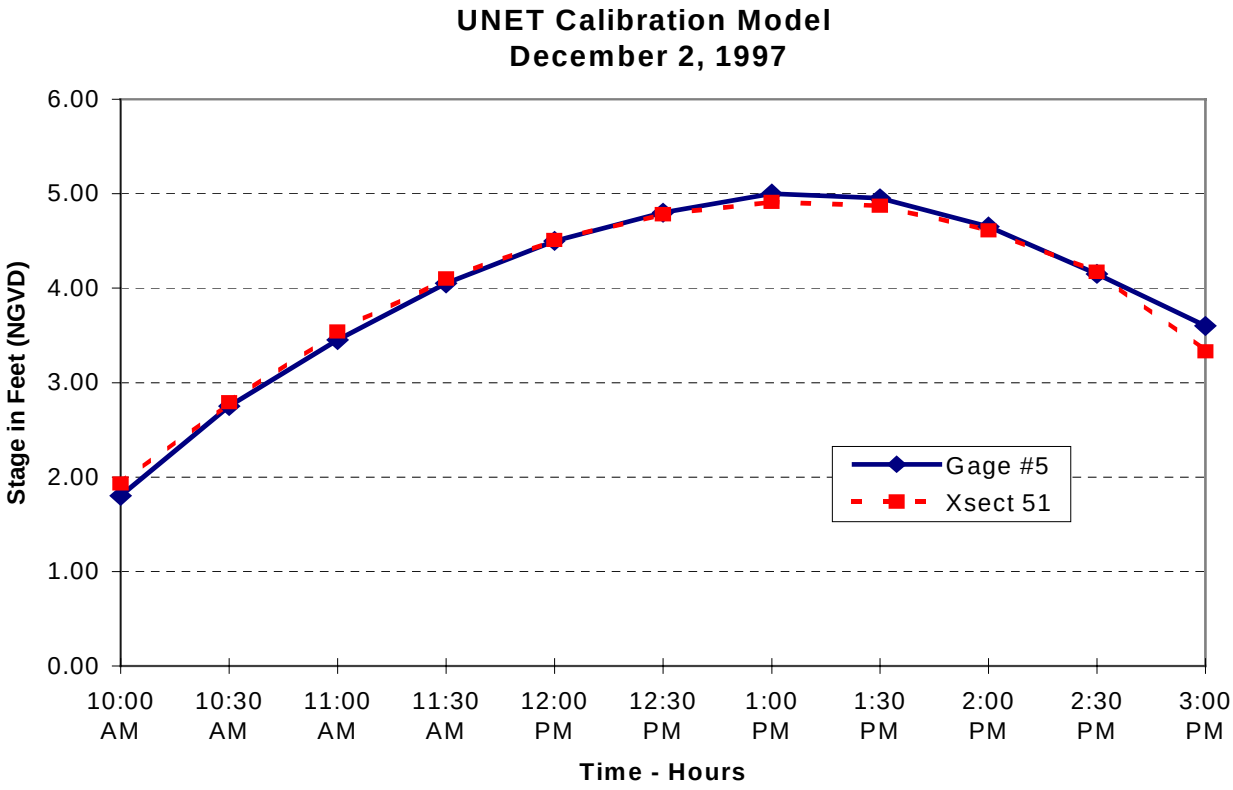
Time - Hours
Gage #4
Xsect 16


UNET Calibration Model
December 2, 1997
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Stage in Feet (NGVD)
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2:30 PM
3:00 PM
Time - Hours
Gage #5
Xsect 51

APPENDIX D – COMMENTS AND RESPONSES FROM THE PRELIMINARY DRAFT

HYDROLOGIC AND HYDRAULIC ANALYSIS, WETLAND RESTORATION INVESTIGATION, BALLARD STREET SALT MARSH, SAUGUS, MA

Response to Corps of Engineers Comments - November 16, 1998

1. The proposal is to move the tide gate from the existing location at Ballard Street (Ballard St. low point is 8.5 feet) to a location on the tidal creek near the abandoned I-95 embankment. This would require construction of some sort of new outlet structure to include a tide gate and culvert.

Response – None required

2. In order to provide the same amount of stormwater storage with the new tide gate as with the old, the report proposes excavating a compensatory area upstream of the new tide gate of 51-acre feet (82,800 cubic yards). This is a significant amount of excavation in the existing (albeit deteriorated) wetlands.

Response – The purpose of this study was to evaluate the effects of moving the tide gate on flood levels, and to determine the volume of compensatory storage. No other potential effects were studied.

3. This new structure would likely need to be designed provide the same protection from tidal flooding for the areas behind it as the existing tide gate (e.g. 8.5 feet). On the south side the structure would tie into the I-95 embankment, however on the north side a dike may be required. The dike may only need to be about 8 feet high as the existing culvert at Ballard St. restricts flow about 0.5 feet.

Response – We agree that the new structure must provide at least the same level of protection. Based on NRCS surveys of Ballard Street, the low point is about elevation 8.0. However, the controlling low elevation on ground between Ballard Street and the Saugus River is 8.5 in the Fox Hill Yacht Club parking lot. This compares favorably with the Corps of Engineers 1991 topographic maps. Elevations on the north side of the new culvert location are about elevation 8. The elevation of the abandoned portion of Bristow Street at the south of the study area is 8.1. This is a source of floodwater into the study area from the Pines River under existing conditions. Since Bristow Street will continue to overtop at elevation 8.1as in the past, we do not believe that a dike is needed at the proposed structure location. If desired, the parking lot at the north side of the new culvert location can be raised a few tenths of a foot. No buildings or roads are affected.

5. It is not clear from the report that "the no tide gate" at Ballard Street" and new tide gate at I-95 will not result in flooding of Route 107 and a fish market on the south side of the site. Elevation information should be added to report to clarify.

Response – We agree. Elevation information and a discussion will be added to the report. Buildings on the north side of Ballard Street are first flooded by water from the Saugus River. Neither the existing or new tide gates should have any effect on flooding of these buildings. Buildings on the south side of Ballard Street have floor elevations at 9.5 to 9.7. The Route 107 intersection is at elevation 10.2. The low elevation of Ballard Street is about 8.0; however, the controlling low elevation of the land between Ballard Street and the Saugus River is 8.5. The elevation of the abandoned Bristow Street (south end of the study area) is 8.1. Regardless of the origin of floodwater (fresh or salt), it will over top Ballard Street and Bristow Street before flooding buildings or Rte 107. The tide gate location should not change the frequency of flooding at these locations.

5. Also information is not included on the elevations of houses in the Eastern Ave. residential area. The model predicts a 100-year runoff event will peak at about 5.5 feet NGVD with the new I-95 tide gate and excavated storage. Need to compare this to road and house elevations.

Response – We agree. The report will be clarified to show that the start of damage elevation (lowest building) in the study area is 6.7. This house is located west of Eastern Avenue.

6. Also there was no calibration of the run-off model developed for the site, so it is not clear how accurately this predicts actual conditions.

Response - The report indicates that data was not available (damage surveys) to assist in calibration of the hydrology model (TR20). The runoff from the hillside reaches the ditch at Eastern Avenue via streets, and fills the ditch and adjacent areas, eventually rising high enough to cause damage. The analysis focused on runoff volume (ponded) and not peak discharge. Standard NRCS procedures were used in this evaluation. The hydraulic model UNET was calibrated to observed conditions.

7. The amount of marsh area to be restored is noted in the introduction as about 12 acres. Although no costs are provided the project is likely to be expensive. The proposal includes a new tide gate culvert structure, significant excavation (51-acre feet), a new culvert under Eastern Avenue to improve drainage in this area.

Response – This study was limited to evaluating the hydrologic and hydraulic effects of moving the tide gate and recommending measures to insure that that salt marsh could be restored without increasing flood damages.

8. The existing four-foot culvert at Ballard Street (no gate condition) restricts tidal flow to the marsh, about 0.5 foot. No discussion is provided as to whether or not replacement of the culvert at Ballard St. with something larger would be beneficial to the marsh area to be restored.

Response – This was not an objective of the study, but intuitively it would help. However, at some later date, it may be possible to remove the flow obstruction at Bristow Street (between Route 107 and the I-95 fill) to augment tidal flow.

Response to Corps of Engineers Comments - December 30, 1998.

1. Page 5, Table 1, lists the following elevation frequency data:

	Elev.
100 year	10.0
50 year	9.6
10 year	8.8

Corps of Engineers studies have determined the following flood elevations:

	Elev.
100 year	10.4
50 year	10.0
10 year	9.2

Response – This study used the current Federal Emergency Management Agency Flood Insurance elevations. The additional 0.4 feet will not alter the study conclusions.

2. Page 5, last paragraph, states that the low spot of Ballard Street is elevation 8.5 feet NGVD. Past Corps studies used 7-8 – minor point but has something changed?

Response – The low point on Ballard Street was surveyed by NRCS to be 8.0, however, the low ground elevation between the street and the Saugus River is 8.5 in the Fox Point Yacht Club parking lot. This agrees with the Corps of Engineers 1991 topographic maps. The report will be revised accordingly.

3. General Comment: All of the flood analyses conducted assume normal tide and an extreme (100-year) interior rainfall runoff. This is definitely a possibility. However, it is also highly probable that significant interior runoff can occur coincident with a storm tide. Were any analyses done to address this issue?

Response – No. The analyses actually used a coincident tide approximating mean higher high water of 5.5 feet (NGVD), preceded by a high tide of 7.0 feet. A storm tide would cause flooding without interior runoff according to elevation data and topography at Ballard and Bristow Streets. The February 1978 storm caused a stage of 7.6 feet in the residential area west of Eastern Avenue. The overflow elevations of both streets are lower than the 10-Year tidal flood. Considering the existing situation, we do not believe that analyzing an extreme tide would produce significantly different results. The

assumed conditions of the study were agreed to at a meeting on March 5, 1998, which included representatives of partnering agencies and organizations.

4. Flood History of the Saugus – The Revere area shows that northeaster type storms cause severe tidal flooding. These storms tend to be of long duration lasting over numerous tidal cycles. Past Corps studies indicate that many interior areas do not totally drain during low tides during some of these storms. If this is the case, would additional interior storage be utilized by freshwater runoff because draining might be limited?

Response – The purpose of this study was to determine if the tide gate could be moved to allow salt marsh restoration, without increasing flood damages to property in the study area. Flood damage reduction was not a purpose of the study or project. The results show that the tide gate can be moved if compensatory storage is provided to offset the storage that is lost. The recommended measures actually provide a measure of flood protection that is better than under existing conditions and also provides a better outlet for drainage. Figures 15 through 19 show that the recommended measures will result in peak flood elevations that are 0.5 to 1.7 feet lower during the 1-percent chance flood.

5. During the January 1987 coastal storm, our data shows that the Boston Stillwater elevation (also Saugus River) was 9.4 feet NGVD and that the area behind the Ballard Street tide gate reached an elevation of 7.2 feet NGVD. With the new tide gate location, it would appear that the marsh area east and south of the new tide gate would approach the Saugus River elevation of 9.4 feet NGVD or over 2 feet higher than experienced in 1987. Has it been determined that this would not be a problem in terms of increased flood damages?

Response – Please see the response to November 16, 1998 comment number 4.

HYDROLOGIC AND HYDRAULIC ANALYSIS, WETLAND RESTORATION INVESTIGATION, BALLARD STREET SALT MARSH, SAUGUS, MA

Response to Environmental Protection Agency Comments - July 10, 1998

1. The report did not discuss the existing additional large box culvert at Bristow Street which currently has no tidegate but was blocked off for temporary flood protection purposes. FYI, Walter Montgomery of NEMMCWMD and I measured the culvert as 7'3 foot wide by 5'4" in height. The Pines River side of the culvert has a steel plate on it with two rusted openings of approximately two square feet each, and a central 42- inch round opening which appears to have held a flapper gate in the past. No flapper was present, and the opening was temporarily fitted with a wooden barrier for flood protection purposes. During modeling efforts, the barrier was in place and allowed only minimal tidal leakage.

Do you think that it may be useful to mention this, i.e. as to how the opening of the temporary barrier and potential removal of the steel plate will (1) help to restore the marsh tidal flow on the Rt. 107 side if restoration is pursued and perhaps (2) as to how it was not important in your modeling efforts at least for the western side (Eastern Avenue side). I don't really know the answers about this, but believe if we don't acknowledge it's presence and condition, some people would question it.

Response - The study objective was to compare existing flood conditions with those that would occur if the tide gate were relocated. The analyses used the current condition of the culvert blocked. The study evaluated the loss of existing flood storage in the marsh east of the I-95 fill and the mitigation (compensatory storage) necessary to compensate for it. If the tide gate is relocated, opening the Bristow Street culvert may enhance the restoration and will not change the results of the study. If the Bristow Street culvert is opened before relocating the tide gate, it could contribute to increased flooding and damage in the study area.

2. Was the Auxiliary Eastern Avenue Culvert required due to high inverts at the culverted section of the channel on the west side of Eastern Avenue? Would this culvert still be needed if all the ditches were cleaned out on the west side of Eastern Avenue? Could this additional expense be avoided by enlarging the existing culvert nearer Bristow Street instead? Should we consider restoring the open channel by daylighting the culverted portion? Did you have an estimate of the inverts needed for the four foot auxiliary culvert if it is required?

Response - Referring to the recommended Auxiliary Eastern Avenue culvert –

a. *The auxiliary Eastern Avenue Culvert is proposed to provide efficient access for freshwater runoff to the excavated storage area. The existing culvert parallel to Eastern Avenue is small and does not convey flow directly to the storage area.*

b. *Ditch cleanout is a required measure in conjunction with the new culvert.*

c. *Enlarging the existing culvert under Eastern Avenue near Bristow Street would be a less effective alternative. The cost would be similar, but its location at the far end of the storage area makes it less desirable for conveying runoff across Eastern Avenue. The proposed alternative is closer to the lowest part of the damage area. It also includes cleaning out the existing culvert near Bristow Street.*

d. *The existing culvert parallel to Eastern Avenue cannot be removed or "daylighted" because it is near houses and in their yards.*

e. *NRCS has the invert recommendations for the new culvert. This and other information will be available to the design team.*

3. Do we have to discuss anything about why the existing four commercial buildings on the east side of Route 95 embankment won't be harmed by increased flooding with the relocated tidegate option (including opening of the Bristow Street box culvert on the Route 107 side? I believe the Corps would likely question this. I believe the elevation info on the buildings would help to demonstrate no adverse impact. DEP., Corps, and the affected property owners would likely want this to be discussed.

Response - As mention in 1 above, opening the Bristow Street culvert was not part of the evaluation. Buildings on the north side of Ballard Street adjacent to the Saugus River are flooded by the river. The lowest building on the south side of Ballard Street, adjacent to the marsh is the fish market. A review of survey and map elevations shows the following:

Location	*Elevation Feet NGVD*
Building Floor	*9.5*
Parking Lot	*8.7*
Low point on Ballard Street	*8.0*
Low Ground between Ballard Street and Saugus River	*8.5*

Based on these elevations, water will flow over Ballard Street in both directions, before it floods the fish market. When the Saugus River stage exceeds the elevation of Ballard Street, water elevations in the marsh will be the same whether or not Bristow Street is opened. It should also be noted that the low point on the abandoned Bristow Street is elevation 8.1. When the Pines River exceeds that elevation, it can flow into the marsh.

The report will be revised to include a discussion of the road and building elevations and the effects of moving the tide gate on them.

4. Assuming a new relocated tidegate at an opening of two four by four box culverts, would it be sufficient to have one opening fitted with a Self-Regulating Tidegate and the other fitted with a standard tidegate to achieve salt marsh restoration flows at least up to elevation 3.0 NGVD for the western side?

If you want, I can inquire of the Waterman Industries sales Representative, what the estimated cost of such SRT's or Standard tidegates would be in a four by four dimension. I believe if one SRT is sufficient and is used in combination with a standard flapper, this may be a good means of saving costs and assuring good drainage even when the SRT locks closed. If the locking closed condition is a problem and additional drainage flow is needed prior to SRT lock release, the standard side discharges may still be required on the SRT design.

Should we discuss more about how this muted tidal flow on the western side would still provide the flood storage required. Would the flood storage be required above elevation 2.0 always free of tides, or to what level may we be able to keep tidal flow (2.0, 3.0, 3.1 etc.)

Response - The study did not evaluate the alternative of restoring tidal flow to the area west of the I-95 fill, which is the area proposed for excavating compensatory storage. If the sponsors want to restore salt marsh in that area, a self-regulating tide gate could be used as long as the required flood storage is provided as described in the report. The allowable elevation of the tidal flow will have to be determined when the storage area is developed in final design. If a self regulating tide gate is used, you could have two four by four foot box culverts fitted with one self-regulating gate and one standard gate.

5. While I understand that this report was not intended to address all ecological questions, and that additional assessment will be required, I believe it would be beneficial to state explicitly in the report, that the area of the proposed Excavated Storage Area was historically a salt marsh according to old aerial photos and USGS Maps. (You can possibly add the date of the USGS map on Figure 3 to depict this, and add a figure of one older and one newer USGS map if this is useful. I also suggest adding the north arrow and a scale to all figures that do not have it already).

Response - Page two states that the area between Eastern Avenue and Route 107 was historically salt marsh and subject to daily tidal flushing. The north arrows and scales will be added where needed.

6. Furthermore, and more importantly, I believe we should state that due to the tidegate and road constructions, this former marsh lost the majority of it's hydrology which was historically tidally driven. In fact, in large part with some exceptions in the ditches and lowest areas, the majority of the excavated storage area would not qualify as a federal or state wetland. By mentioning this, It would help alleviate fears by some

regulators that a large-scale wetland alteration would be needed to create the excavated storage area.

Response - This is beyond the scope of this study. The environmental impacts of the recommended measures will have to be evaluated and documented.

7. We should put our best foot forward and stress the multifaceted wetland restoration – flood storage - water quality renovation - and wildlife habitat benefits of this excavated storage area.

Response - We very much agree, but that is beyond the scope of this study.

8. Lastly, by mentioning the possibility of maintaining muted tidal flow in it by use of a Self-Regulating Tidegate similar to as used at the Martin Street Tidegate in Revere, we can provide for salt marsh restoration and open-marsh water management benefits which would be beneficial from the perspective of mosquito populations and Phragmites Control objectives. The maintenance of either a new standard type tidegate at a relocated tidegate location would not lend itself to effective mosquito or Phragmites control management objectives.

Response - See number 4 above.

9. I understand that some of my comments may be more appropriately dealt with or included in other environmental permitting documentation, however, to the extent that the H&H report can assist, I believe it would be beneficial to do so.

Response – We agree.