Green Harbor River
Tidal Hydraulics Study
Marshfield, Massachusetts

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March 2007

SECTION 1 - INTRODUCTION

This study considers the impact of altering the flow through the tide gates located on Dike Road (Route 139) at the mouth of the Green Harbor River marsh system in Marshfield, Massachusetts (Figure 1). The present configuration has four hinged doors which all allow water to exit the marsh system when water levels outside the marsh fall below the level inside the marsh. On a rising tide, a single gate is propped open so that limited flow is allowed back into the marsh.

This study considers the impact of propping open the remaining 3 gates in the same manner in which the single gate is currently held open. The evaluation of structural modifications to the existing gate/culvert system or the evaluation of any new or modified gates was not included in the scope of this study.

The study aims to identify if the opening of additional tide gates would improve tidal excursion and water quality. The impact that raised water levels might have on neighboring developments is also of major importance. Of particular concern is the Marshfield Municipal Airport along the northwest edge of the system and the residential neighborhoods adjacent to Bass Creek along the northeast edge of the system.

Figure 1. Topographic map detail of the Green Harbor study area.

SECTION 2 - HYDRODYNAMIC FIELD DATA COLLECTION AND ANALYSIS

In order to better understand the changing water levels in the system, a series of instruments were deployed throughout the interior of Green Harbor marsh as well as one instrument placed outside of the tide gates.

In addition to the hydrodynamic data, the pond geometry is an important variable. System geometry is defined by the edges of the marsh as well as the water depths throughout. The three-dimensional surface of the marsh must be accurately mapped, since the resulting hydrodynamic behavior is strongly dependent upon features such as channel widths and depths, sills, and holes. Hence, this study included an effort to collect bathymetric information in the field. While the geometry of Green Harbor is straight forward based on aerial photos, the varying water depths are an integral part to the hydrodynamic modeling.

Section 2.1 Bathymetry

Bathymetry data (i.e., depth measurements) for the hydrodynamic model of the Green Harbor system was assembled from a recent boat based hydrographic survey.

The hydrographic survey of September 13, 2006 was designed to cover the entire main basin of Green Harbor marsh as well as the tributaries of Wharf and Bass Creeks. The survey was conducted from a 10' skiff with an installed precision fathometer (with a depth resolution of approximately 0.1 foot), coupled together with a differential GPS to provide horizontal position measurements accurate to approximately 1-3 feet. As the boat was maneuvered around the system, digital data output from both the echo sounder fathometer and GPS were logged to a laptop computer, which integrated the data to produce a single data set consisting of water depth as a function of geographic position. In very shallow areas in the upper reaches of the marsh, sounding with a rod were taken and recorded with GPS locations.

The raw measured water depths were merged with water surface elevation measurements to determine bathymetric elevations relative to the NAVD88 vertical datum. Once rectified, the finished processed data were archived as 'xyz' files containing x-y horizontal position (in Massachusetts State Plan 1983 coordinates) and vertical elevation of the bottom (z). These xyz files were then interpolated into the finite element mesh used for the hydrodynamic simulations.

Section 2.2 Tide Data

Changes in water surface elevation were measured using internal recording tide gauges. The tide gauges were installed in five locations throughout the study area (see Figure 2) from August 25, 2006 to October 10, 2005.

The tide gauges used for the study consisted of Brancker XR-420 instruments. Data sampling was set for 10-minute intervals, with each 10-minute observation resulting from an average of 16 1-second pressure measurements. Each of these instruments use strain gauge transducers to sense variations in pressure, with resolutions on the order of 1 cm head of water. Each gauge was calibrated prior to installation to assure accuracy. Each gauge returned 100% of the desired data.

Figure 2. Map of the study region identifying locations of the tide gauges used to measure water level variations throughout the system. Gauges were deployed from late August to early October, 2006. Each yellow circle represents the approximate locations of the tide gauges.

Once the data were downloaded from each instrument, the water pressure readings were corrected for variations in atmospheric pressure. Hourly atmospheric pressure readings were obtained from the NDBC station 44013 in Massachusetts Bay, interpolated to 10-minute intervals, and subtracted from the pressure readings, resulting in variations in water pressure above the instrument. Further, a (constant) water density value of 1025 kg/m^3 was applied to the readings to convert from pressure units (psi) to head units (for example, feet of water above the tide gauge). Each instrument elevation was surveyed relative to a vertical datum using RTK GPS. The result from each gauge is a time series record representing the variations in water surface elevation relative to the NAVD 1988 vertical datum. Plots of all tide gauges are presented in Figure 3 while Figure 4 shows the data from inside the marsh only.

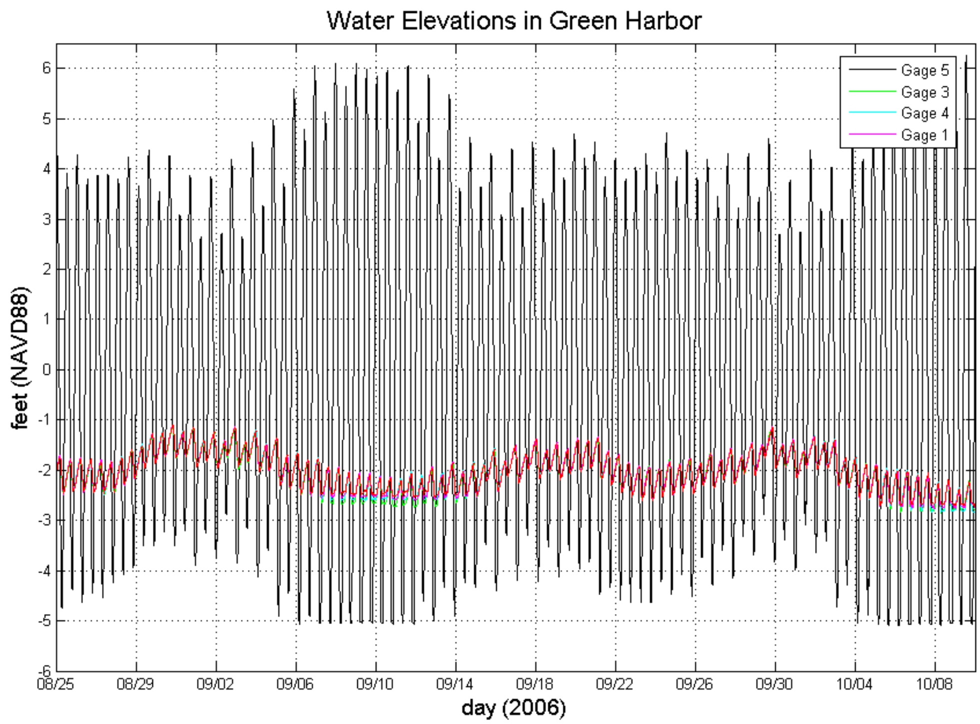

Figure 3. Water elevation variations as measured at the 5 locations within the Green Harbor System.

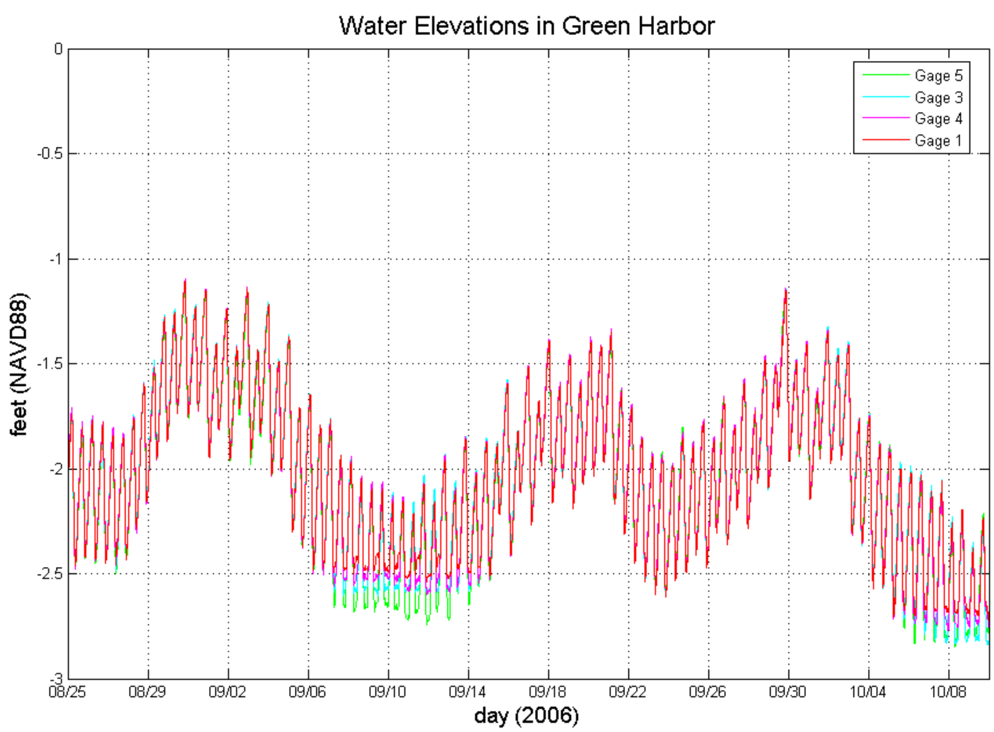

Figure 4. Water elevation variations as measured at the 4 locations Green Harbor locations inside the tide gates.

The data show that there is no appreciable delay in the tide propagating across the system once the water passes through the tide gates. There is also no noticeable attenuation of the tide as it travels to the upper reaches of the marsh. The only separation between the data within the system is seen around September 10 and October 6. This is a result of the instruments going dry during the spring low tides. After noticing this occurring in September, the field team attempted to relocate the instruments out further in the marsh channels and hopefully to deeper water. Due to the softness of the channel bottoms it was not possible to safely move the instruments fully into the center of the channels, but a best effort was made. This effort was partially successful as evidenced by the recorded lows in October being below those in September. However, the water levels still fell below the instruments and so the bottom of the spring low tides was excluded from the data set.

To better quantify the changes to the tide outside the system, the standard tidal statistics were computed from the 30-day records. These statistics are presented in the first column of Table 1. The tides in Massachusetts Bay are semi-diurnal, meaning that there are typically two tide cycles (two highs and two lows) each day and there is usually a difference in elevation between the two high tides and between the two low tides. The Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW) levels represent the average of the single highest or lowest water level recorded each day. The Mean High Water (MHW) and Mean Low Water (MLW) statistics represent the average of the two highest or two lowest elevations recorded each day. The Mean Tide Level (MTL) is simply the average of MHW and MLW.

Because the water levels inside the marsh system are controlled by the tide gates, the standard tidal statistics are listed only for the station outside the tide gates in Green Harbor. For each of the interior locations, only extreme water levels and the mean water level are shown. The matching mean water levels and standard tide plots shown above reveal that there is little variation in water level inside the marsh. There are no constrictions or other impediments to flow which would cause a delay in tidal propagation across the system. These data also reveal that the average water elevation inside the marsh is two feet below the mean tide level outside. It can also be seen that a typical spring tide raises the water level inside the marsh to an elevation of -1.1 feet NAVD88.

Table 1. Tidal statistics computed from records collected in the Green Harbor system August 25 - October 10, 2004. Elevations are given in feet relative to NAVD 88.

	Green Harbor Outside (Gage 2)	Green Harbor River Downstream (Gage 5)	Wharf Creek (Gage 3)	Bass Creek (Gage 4)	Green Harbor River Upstream (Gage 1)
Highest Water Level	6.3	-1.1	-1.1	-1.1	-1.1
MHHW	4.9	--	--	--	--
MHW	4.4	--	--	--	--
MTL	0.1	-2.0	-2.0	-2.0	-2.0
MLW	-4.3	--	--	--	--
MLLW	-4.4	--	--	--	--
Lowest Water Level	-5.1	-2.8	-2.8	-2.8	-2.8

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SECTION 3 - HYDRODYNAMIC MODELING

This study of the Green Harbor marsh system utilized a state-of-the-art computer model to evaluate tidal circulation and flushing. The particular model employed was the RMA-2 model developed by Resource Management Associates (King, 1990a). It is a two-dimensional, depth-averaged finite element model, capable of simulating transient hydrodynamics. The model is widely accepted and tested for analyses of estuaries or rivers.

Section 3.1 Model Theory

In its original form, RMA-2 was developed by William Norton and Ian King under contract with the U.S. Army Corps of Engineers (Norton et al., 1973). Further development included the introduction of one-dimensional elements, state-of-the-art pre- and post-processing data programs, and the use of elements with curved borders. Recently, the graphic pre- and post-processing routines were updated by Brigham Young University through a package called the Surfacewater Modeling System or SMS (BYU, 1998). Graphics generated in support of this report primarily were generated within the SMS modeling package.

RMA-2 is a finite element model designed for simulating one- and two-dimensional depth-averaged hydrodynamic systems. The dependent variables are velocity and water depth, and the equations solved are the depth-averaged Navier Stokes equations. Reynolds assumptions are incorporated as an eddy viscosity effect to represent turbulent energy losses. Other terms in the governing equations permit friction losses (approximated either by a Chezy or Manning formulation), Coriolis effects, and surface wind stresses. All the coefficients associated with these terms may vary from element to element. The model utilizes quadrilaterals and triangles to represent the system. Element boundaries may either be curved or straight.

The time dependence of the governing equations is incorporated within the solution technique needed to solve the set of simultaneous equations. This technique is implicit; therefore it is unconditionally stable. Once the equations are solved, corrections to the initial estimate of velocity and water elevation are employed, and the equations are re-solved until the convergence criteria is met.

Section 3.2 Model Setup

There are three main steps required to implement RMA-2:

- Grid generation
- Boundary condition specification
- Calibration

The finite element grid was generated within the shoreline as determined by aerial photos. A time-varying water surface elevation boundary condition (measured tide) was specified at the tide gate based on the analysis discussed below. The upper reach of Green Harbor River was provided a freshwater recharge of 6.7 cfs as based on field measurements. Once the grid and boundary condition were set, the model was calibrated to ensure accurate predictions of tidal flushing. Various friction and eddy viscosity coefficients were adjusted, through numerous model calibration simulations for the system, to obtain agreement between measured and modeled tides. The calibrated model provides the requisite information for future detailed water quality modeling.

Section 3.2.1 Grid Generation

The grid generation process was simplified by the use of the SMS package. The aerial photos and bathymetry data were imported to SMS, and a finite element grid was generated to represent the estuary. Figure 5 illustrates the finite element grid covering the entire Green Harbor system.

The edges of the open water portions of the marsh are clearly visible in the aerial photo and serve as the boundaries of the numerical mesh. Those portions of the marsh plain which flood periodically are more difficult to discern and additional topographic data was needed. It was decided that only the lowest portions of the marsh, up to elevation 0 feet NAVD would be included at this stage of the modeling effort. Water levels reaching much above an elevation of 0 could result in the flooding of areas which are presently populated by dense grass, shrub and tree growth, and the residential areas abutting Bass Creek. Accurately including overland flow for these areas which are not currently subject to flooding would add a great deal more complexity to the modeling effort and is beyond the scope of the work presented here.

The finite element grid provided the detail necessary to evaluate accurately the variation in hydrodynamic properties of the estuary. Fine resolution was required to simulate the channel constrictions in the upper reaches of the marsh as well as the transition from marsh channel to the grassy overbank areas. The SMS grid generation program was used to develop quadrilateral and triangular two-dimensional elements throughout the estuary. Reference water depths at each node of the model were interpreted from bathymetry data obtained in the field survey.

Grid resolution was governed by two factors: 1) expected flow patterns, and 2) the bathymetric variability present. Relatively fine grid resolution was employed where complex flow patterns were expected or where the channel geometry was very narrow. For example, smaller node spacing in the vicinity of the tide gate was chosen to provide a more detailed analysis in these regions of rapidly varying flow. Similarly, small spacing was needed to accurately reproduce flow through the channels in Wharf and Bass Creeks. More widely spaced nodes were defined for the central regions of Green Harbor River where flow patterns do not change dramatically.

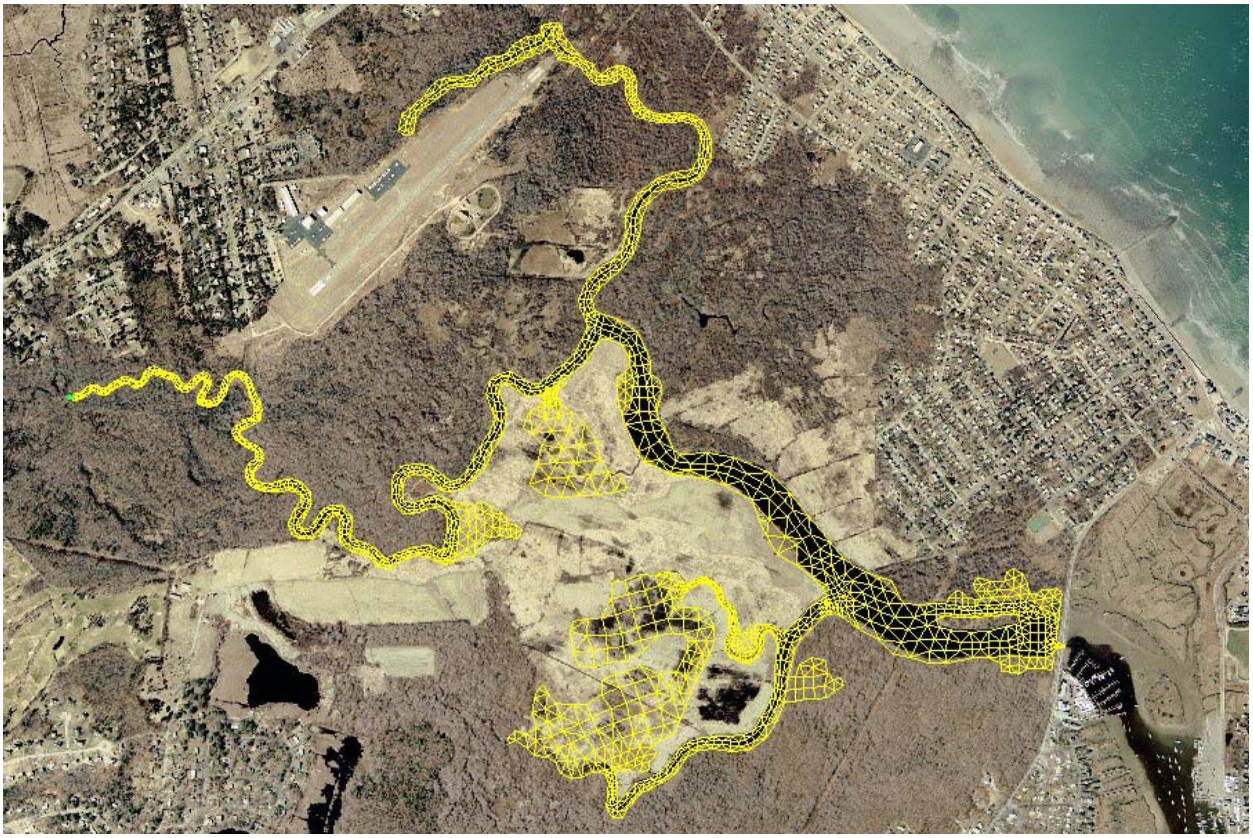


Figure 5. The yellow lines show the element boundaries of the numerical grid used for hydrodynamic modeling of Green Harbor.

Once the grid is constructed, the system is broken down into regions with each region given its own material type. The material types contain information primarily about element roughness and eddy viscosity which are used to calibrate the model. By dividing the system into regions and assigning each its own material type, the model can be more easily calibrated, with unique attributes assigned for each creek or marsh area. In total there were 6 material types used.

Section 3.2.2 Boundary Condition Specification

Two types of boundary conditions were employed for the RMA-2 model: 1) "slip" boundaries and 2) tidal elevation boundaries. All of the elements with land borders have "slip" boundary conditions, where the direction of flow is constrained to be shore-parallel. The model generated all internal boundary conditions from the governing conservation equations. A water elevation boundary condition was specified at the tide gate.

The complex geometry of the culverts inside the tide gate in addition to the fact that the single gate that allows flow to enter the marsh is propped open makes the direct modeling of flow through the tide gates very complex. In place of modeling the hydraulics directly, the water levels immediately on either side of the gate were recorded and rating curves were developed for the structure based on the measured data. A single gate is propped open so that limited flow is allowed into the system on a rising tide while all four gates are free to swing open on a falling tide.

Using the measured tide data on either side of the tide gate, the change in elevation over time is used to calculate the volume of water which has moved through the gates. The entire tide record was used to compute these raw data which show actual measured values of head difference and flow rate. A curve is fit through the raw data, any point that lies outside of 1.5 standard deviations from the curve fit is removed and then a new curve is drawn through this refined data. The refined data and final rating curves are presented in Figures 6 and 7 below.

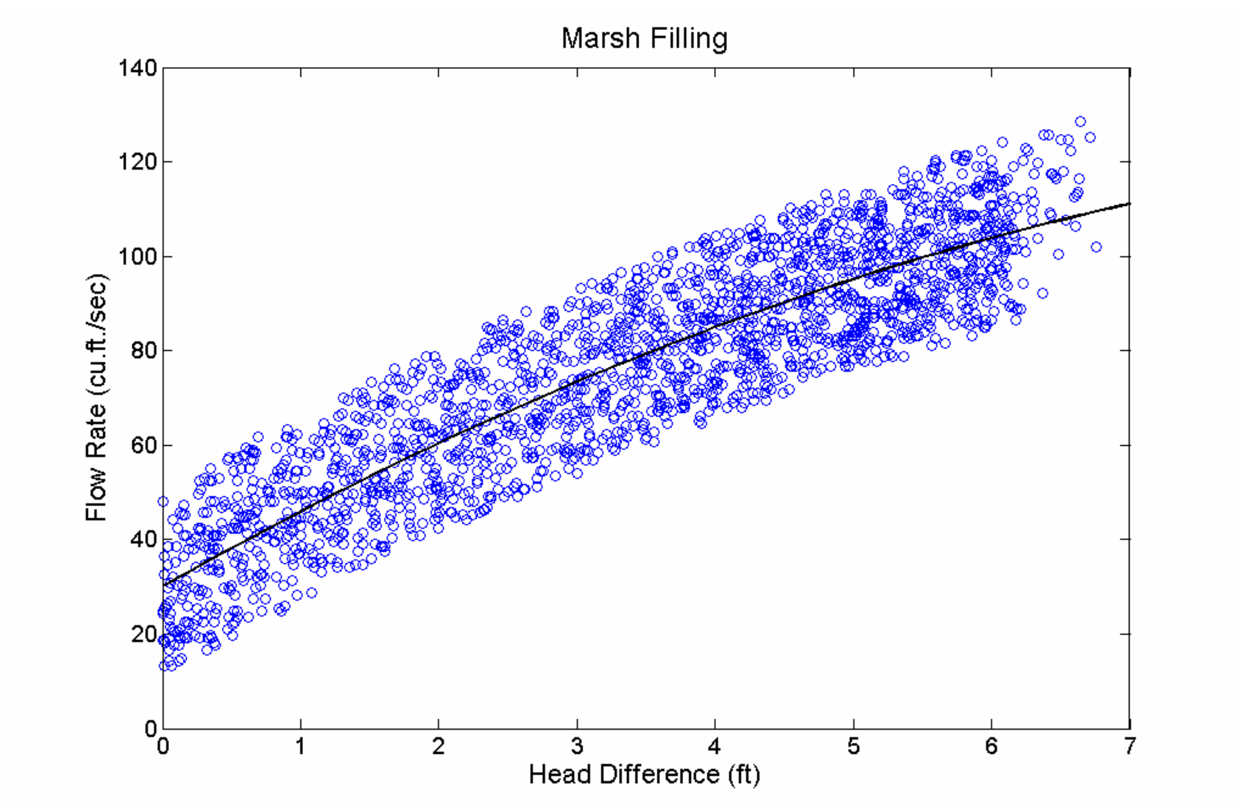


Figure 6. Rating curve for the tide gate under flooding conditions. The blue circles represent measured data points of flow rate through and head difference across, the tide gate. The solid black line through the data is the best fit curve.

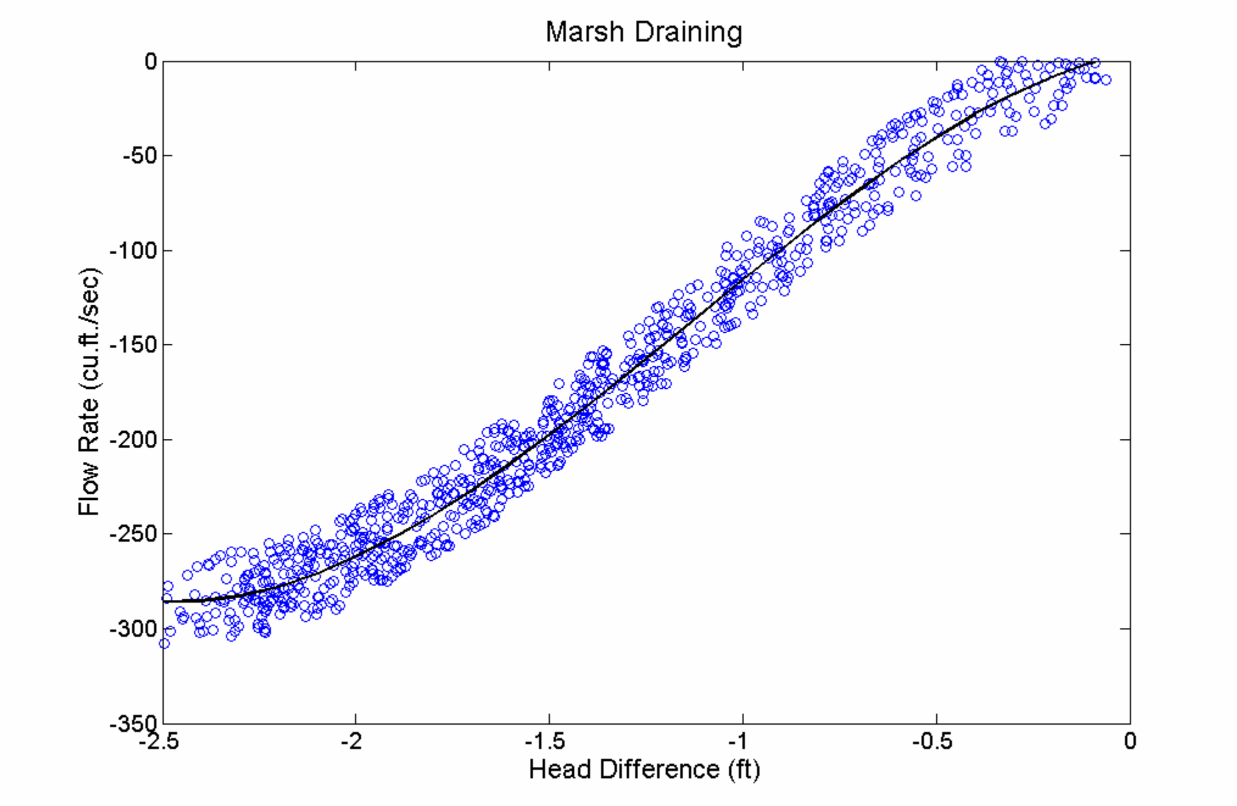


Figure 7. Rating curve for the tide gates under ebbing conditions. The blue circles represent measured data points of flow rate through and head difference across, the tide gate. The solid black line through the data is the best fit curve.

The plots clearly show that the single gate propped open is inefficient at conveying water into the marsh, while the draining with all four gates active allows water to leave the system more readily. This discrepancy explains why the mean water level inside the marsh is lower than the mean water level outside, as the system is much more efficient at draining than filling.

Strictly speaking, one expects the curves to predict zero flow at zero head difference. However, in the case of the filling curve we see a small amount of flow predicted for zero head while on the draining curve we see that a small amount of head is required to allow any flow at all. The issue here is that very few (if any) of the data points reflect an exactly zero head condition. Without measured data with zero head, the curves are slightly biased. The filling curve predicts small amounts of flow under low head conditions as a result of the tide gate being propped open and always ready to convey water. The draining curve is slightly biased to show that a small amount of head is required to allow any flow to pass, which is to be expected as some head is required to push the other 3 gates open.

These rating curves were used to predict flow through the culvert for the existing conditions (1 tide gate propped open) as well as the scenarios of having 2, 3 or 4 of the gates propped open. It was assumed that a second gate propped open would allow twice as much water into the system for a given head difference, 3 gates open would convey three times the amount of water and so on. It was also assumed that the draining of the marsh would remain unchanged, seeing as all four gates are currently functional when the marsh is draining.

SECTION 4 - MODEL CALIBRATION

The first step in the modeling effort was to match the model results for the existing conditions to the water levels which were measured during the field deployment. These calibration runs simulated the period from September 19 to September 26, 2006. Plots comparing the modeled versus measured water levels throughout the system are shown below in Figures 8-11.

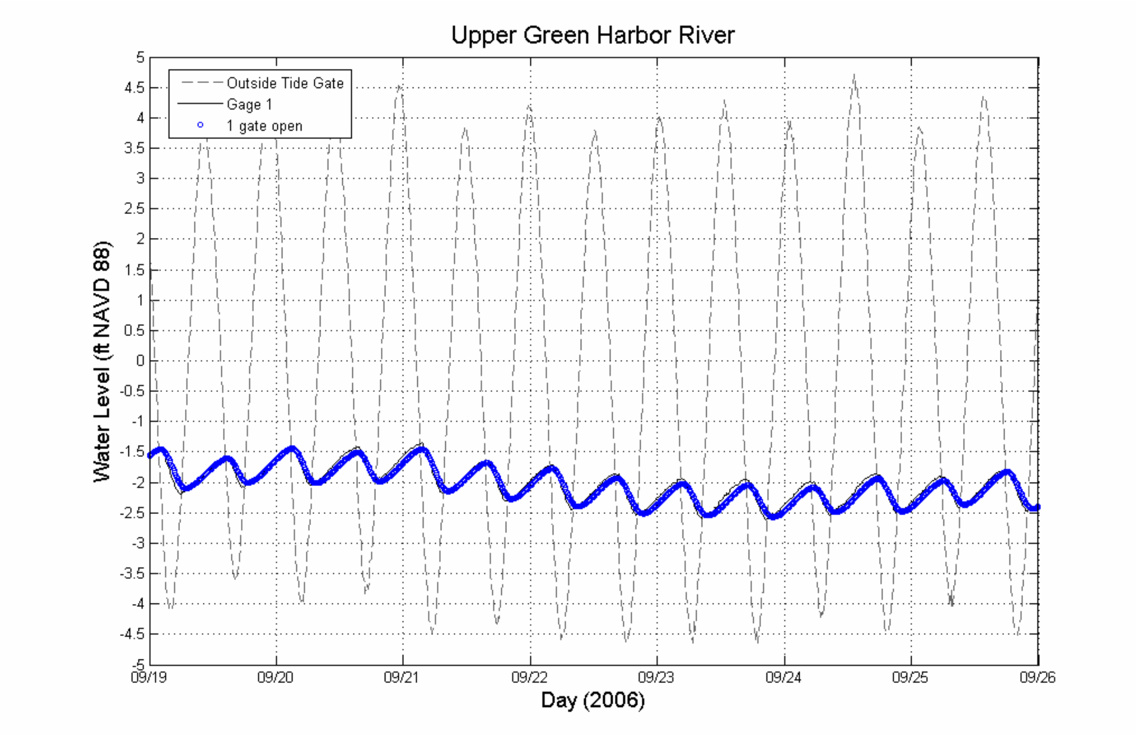


Figure 8. Modeled and measured water levels under current conditions. The blue circles represent modeled water surface elevation in Lower Green Harbor River. The solid black line is the measured water levels and the dashed gray line shows the tide levels outside the tide gates.

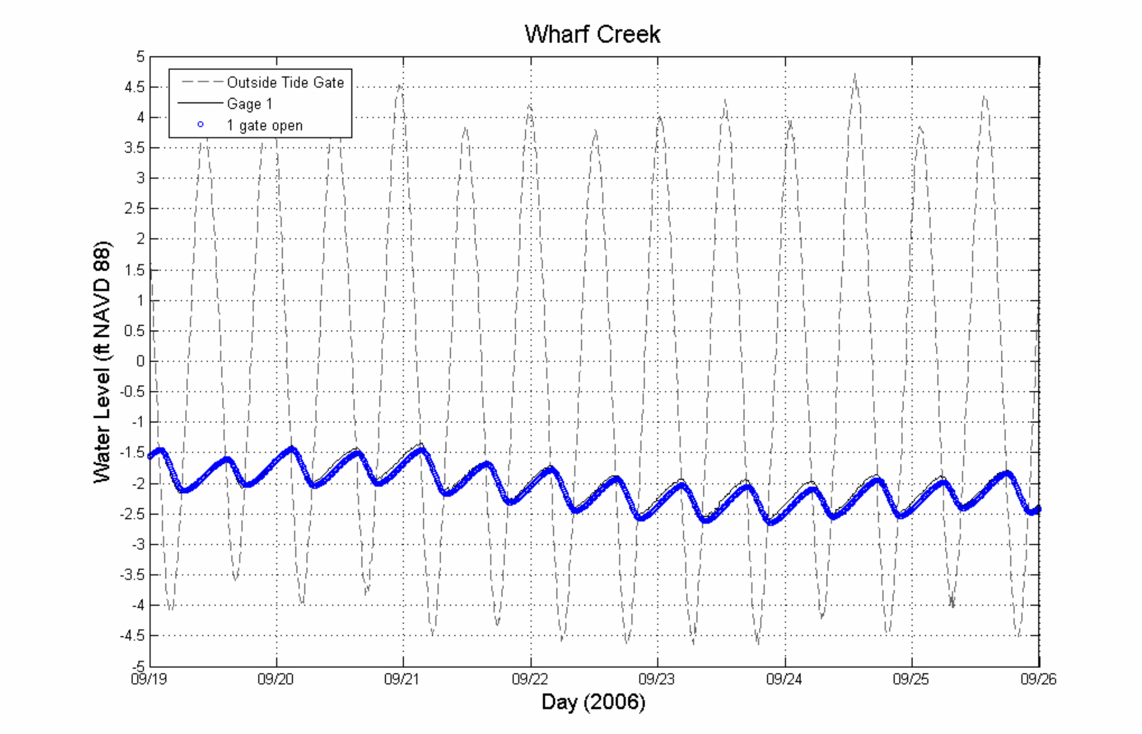


Figure 9. Modeled and measured water levels under current conditions. The blue circles represent modeled water surface elevation in Wharf Creek. The solid black line is the measured water levels and the dashed gray line shows the tide levels outside the tide gates.

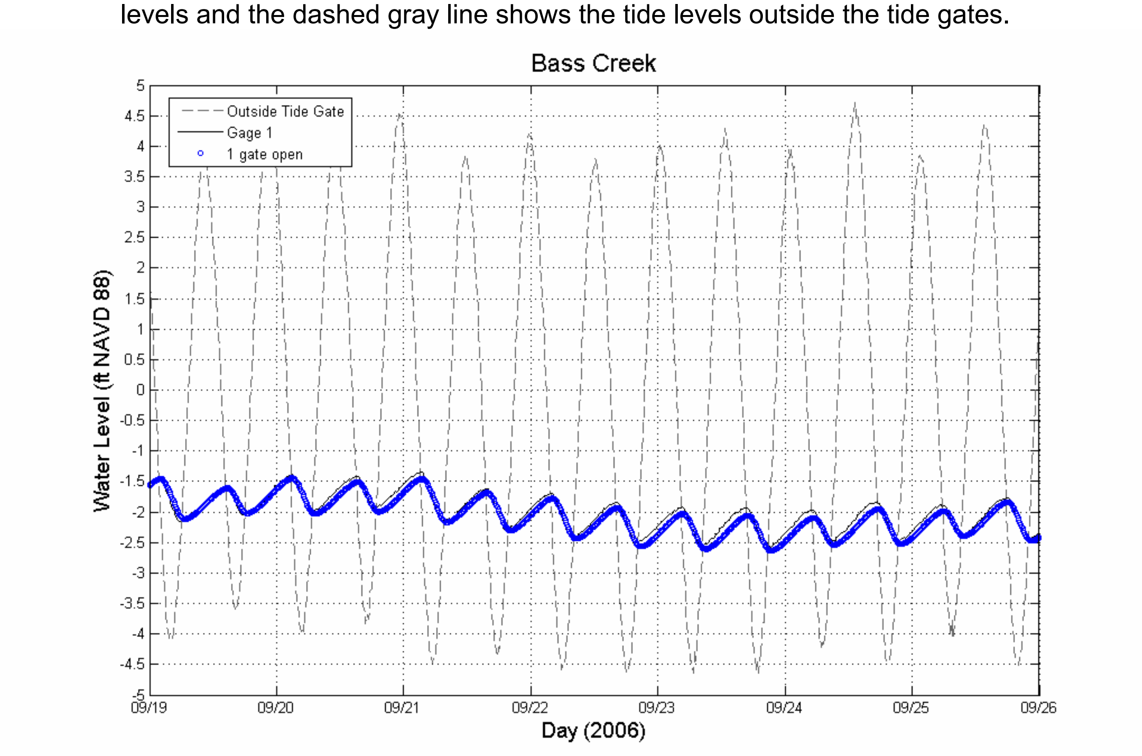


Figure 10. Modeled and measured water levels under current conditions. The blue circles represent modeled water surface elevation in Bass Creek. The solid black line is the measured water levels and the dashed gray line shows the tide levels outside the tide gates.

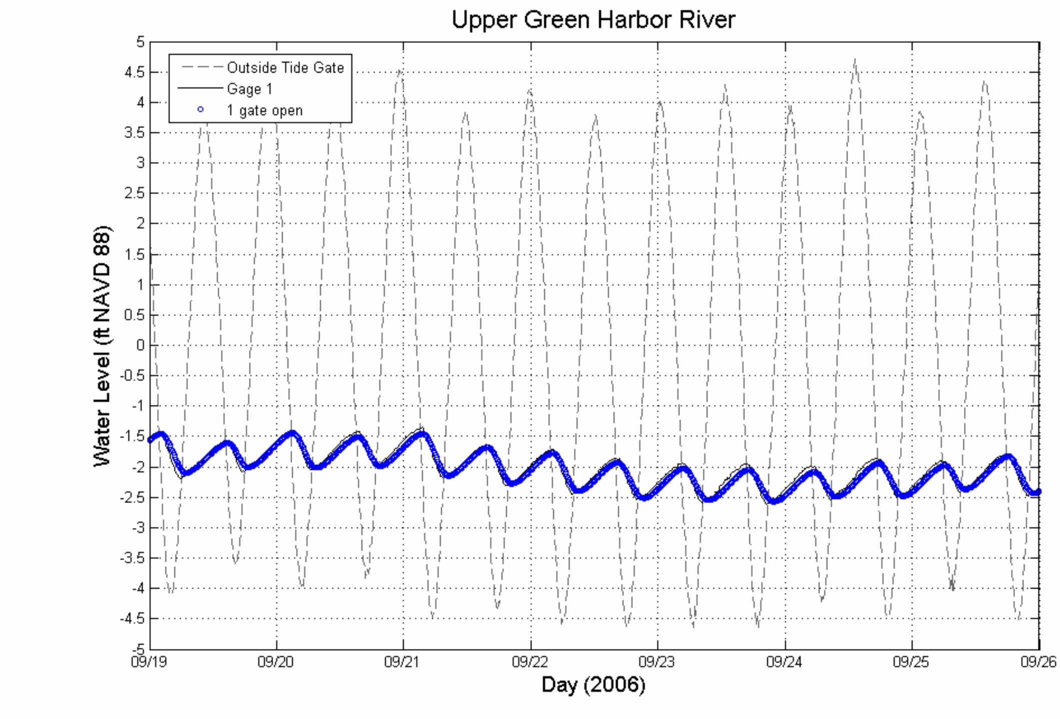


Figure 11. Modeled and measured water levels under current conditions. The blue circles represent modeled water surface elevation in Upper Green Harbor River. The solid black line is the measured water levels and the dashed gray line shows the tide levels outside the tide gates.

The modeled data match the recorded water levels quite closely. The single issue is a slight under-prediction of the high water level between 9/23 and 9/25. The most relevant values of the average range of tide within the system together with the mean water level in the marsh are seen to match very well.

SECTION 5 - ALTERNATIVE SCENARIOS

With the model matching the measured data for the existing conditions, the model boundary condition at the tide gate was changed to simulate the opening of multiple gates. The assumption was made that each additional gate would be propped open in the same way that the current gate is secured and that the flow into any additional gates would be equal to the flow already observed to pass through the single gate. The draining of the marsh is assumed to remain unchanged as all four gates are currently available to open to let water exit the system.

Figures 12-14 show the model results at Lower Green Harbor River for 2-4 gates opened respectively. The results for the other locations within the system are similar. A complete set of plots for all conditions are shown in Appendix A.

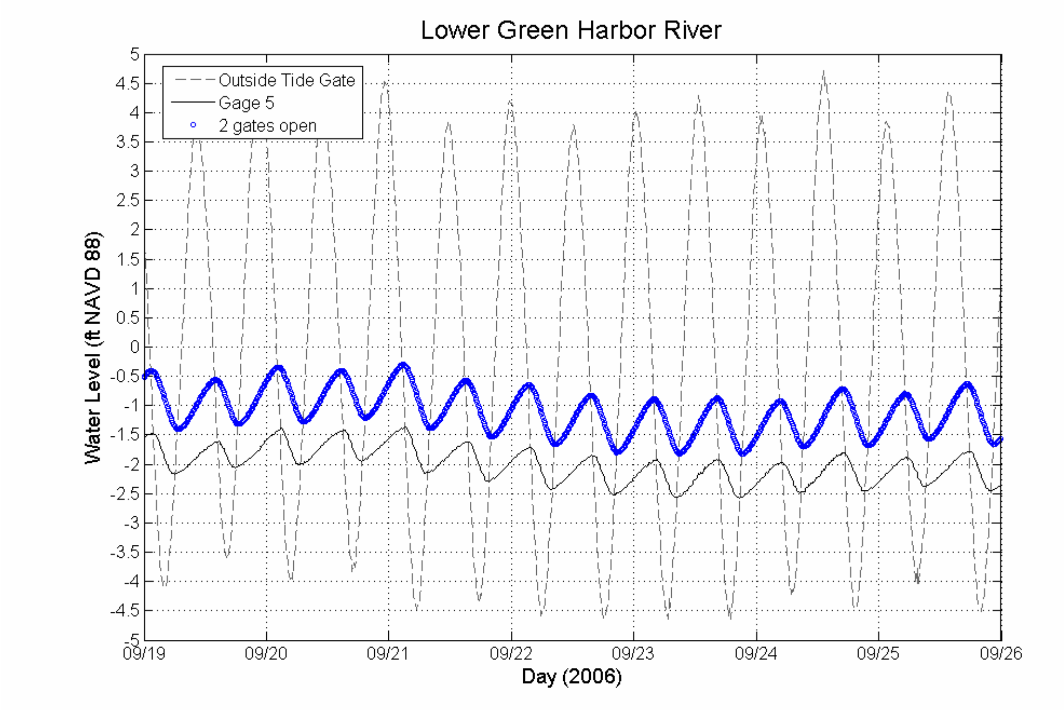


Figure 12. Modeled water levels with 2 gates opened. The blue circles represent modeled water surface elevation in Lower Green Harbor River. The solid black line show the water levels under current conditions and the dashed gray line shows the tide levels outside the tide gates.

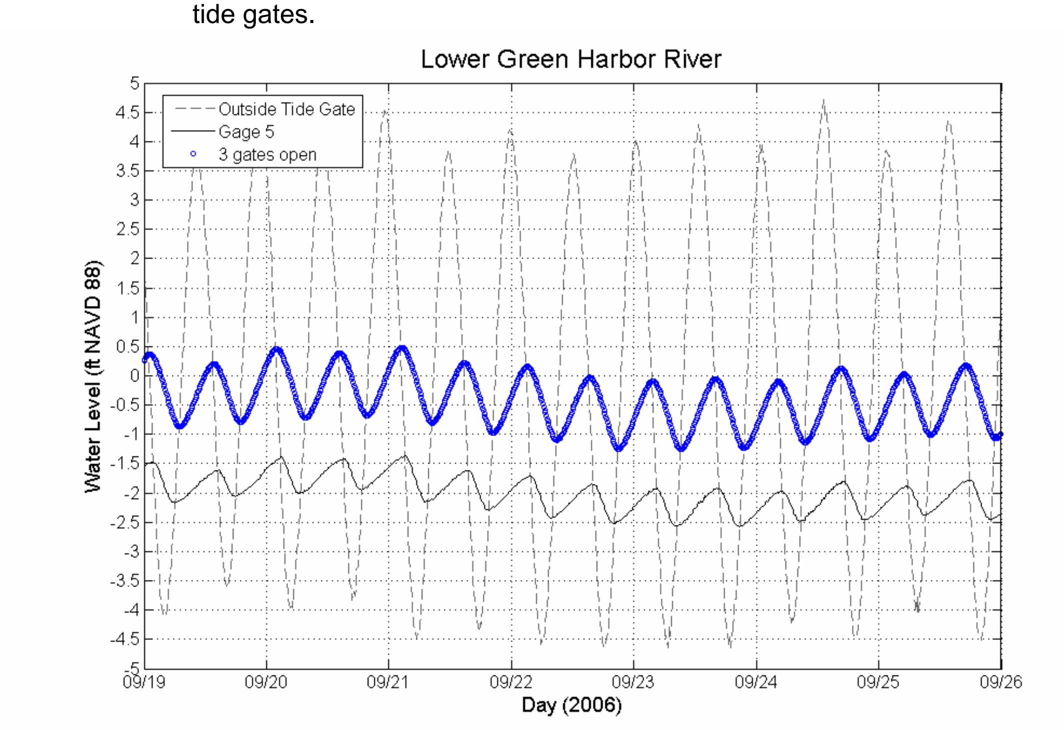


Figure 13. Modeled water levels with 3 gates opened. The blue circles represent modeled water surface elevation in Lower Green Harbor River. The solid black line show the water levels under current conditions and the dashed gray line shows the tide levels outside the tide gates.

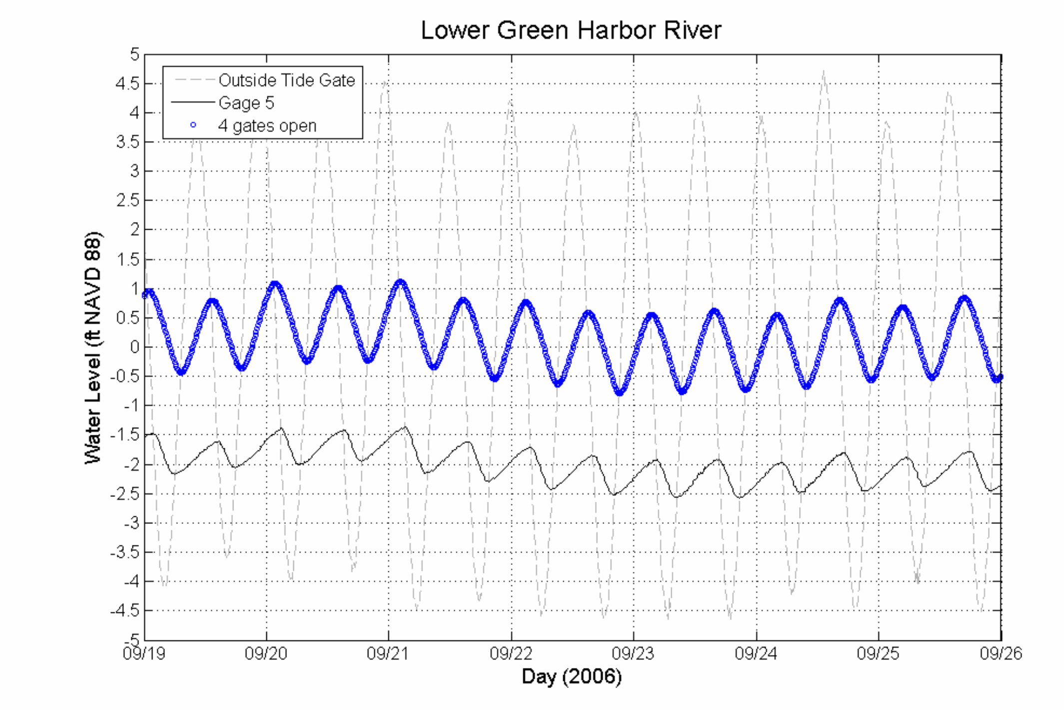


Figure 14. Modeled water levels with 2 gates opened. The blue circles represent modeled water surface elevation in Lower Green Harbor River. The solid black line show the water levels under current conditions and the dashed gray line shows the tide levels outside the tide gates.

With the opening of successive gates, the marsh is subject to an increasing tide range and also a rising mean water level. The mean water level for each case is listed below in Table 2. It should be noted that the modeled time period is during which the tides outside the marsh are of average range. The mean water levels and highest water level reached daily would be higher during the spring tide each month.

Table 2. Mean Water Levels in Green Harbor Marsh System

	Mean Water Level (feet, NAVD88)	Maximum Water Level (feet, NAVD88)
1 Gate	-1.9	-1.4
2 Gates	-1.1	-0.3
3 Gates	-0.5	0.5
4 Gates	0	1.1

SECTION 6 - FLUSHING CHARACTERISTICS

The exchange of water between the marsh system and Massachusetts Bay is defined as tidal flushing. The calibrated hydrodynamic model is a tool to evaluate quantitatively tidal flushing of the system, and was used to compute flushing rates (residence times) and tidal circulation patterns.

Flushing rate, or residence time, is defined as the average time required for a parcel of water to migrate out of a system from points within the system. For this study, a **system residence time** was computed as the average time required for a water parcel to migrate from a point within the marsh to the entrance of the channel. System residence times are computed as follows:

$$T_{system} = \frac{V_{system}}{P} t_{cycle}$$

where T_{system} denotes the residence time for the system, V_{system} represents volume of the pond at mean tide level, P equals the tidal prism (or volume entering the pond through a single tidal cycle), and t_{cycle} the period of the tidal cycle, typically 12.42 hours (or 0.52 days).

Residence times are provided as a first order evaluation of water quality within the system. Lower residence times generally correspond to higher water quality; however, residence times may be misleading depending upon pollutant/nutrient loading rates and the overall quality of the receiving waters.

It should be noted that the rate of pollutant/nutrient loading and the quality of water outside the marsh would need to be evaluated in conjunction with residence times to obtain a clear picture of water quality. Efficient tidal flushing (low residence time) is not an indication of high water quality if pollutants and nutrients are loaded into the system faster than the tidal circulation can flush the system. Neither are low residence times an indicator of high water quality if the water flushed into the pond is of poor quality. As such, the flushing times are a simple first order estimate of potential water quality.

Under existing conditions, the average volume calculated for Green Harbor was 5,559,000 ft^3 with a tidal prism of 1,284,000 ft^3. This results in a residence time of approximately 2.2 days. The details of volumes and flushing rates for the other scenarios are presented below in Table 3.

Table 3. Marsh Volumes and Flushing Times

	Mean Volume (ft^3)	Mean Prism (f^3)	Flushing Time (days)
1 Gate	5,559,000	1,284,000	2.2
2 Gates	9,098,000	2,903,000	1.6
3 Gates	12,082,000	4,754,000	1.3
4 Gates	14,872,000	6,499,000	1.2

SECTION 7 - CONCLUSIONS

The modeling results indicate that opening additional gates on the current structure will result in a larger tidal range within the Green Harbor Marsh system and an increase in the mean water level also. An increased tidal prism would also serve to reduce the flushing time of the system which could serve to improve water quality. It appears that opening a second gate in the same manner that the existing gate is opened would provide these benefits without having water levels routinely rise above the 0 foot NAVD88 elevation.

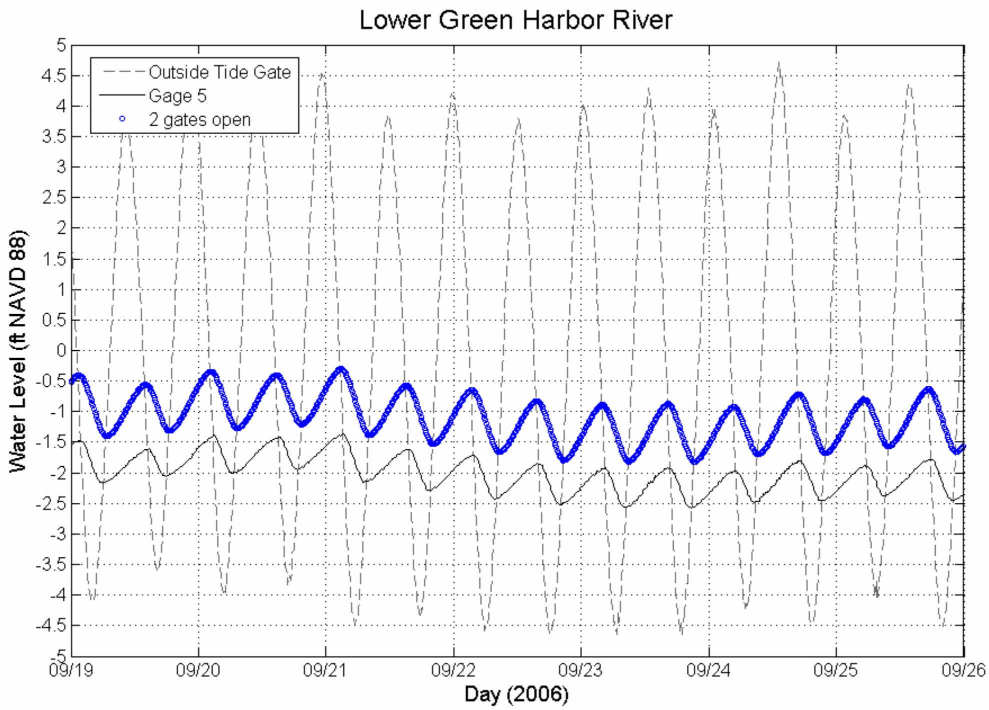
It is important to note that the current work focuses solely on the tidal hydrodynamics of the system. Many important questions are not addressed by this work. An increase in mean water level within the system means that less storage volume is available to accept runoff during a heavy rain event or from coastal flooding along the northeast portion of the marsh. And while an increased water level may remain below levels that would cause above ground flooding to neighboring development, the raised water levels may be enough to impact basements or septic systems. In addition to these flooding concerns, elevated water levels in the marsh system will undoubtedly impact the surrounding plant ecosystem. A full understanding of the potential flooding and biological impacts should be included in any assessment of the benefit of changing the tidal hydraulics in the Green Harbor River marsh system.

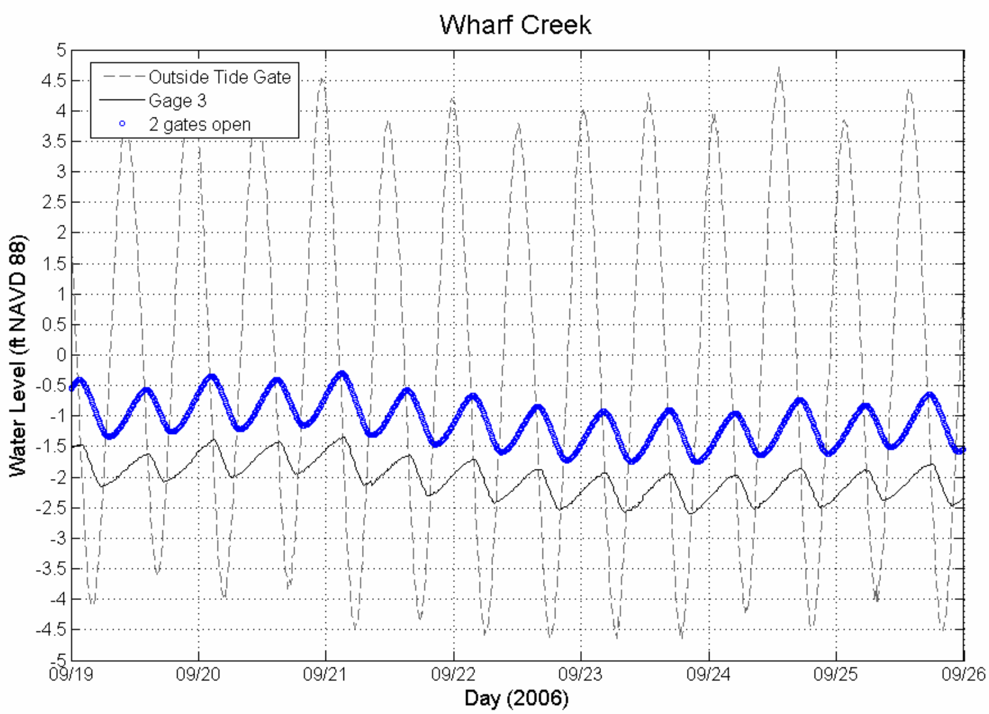
Appendix A

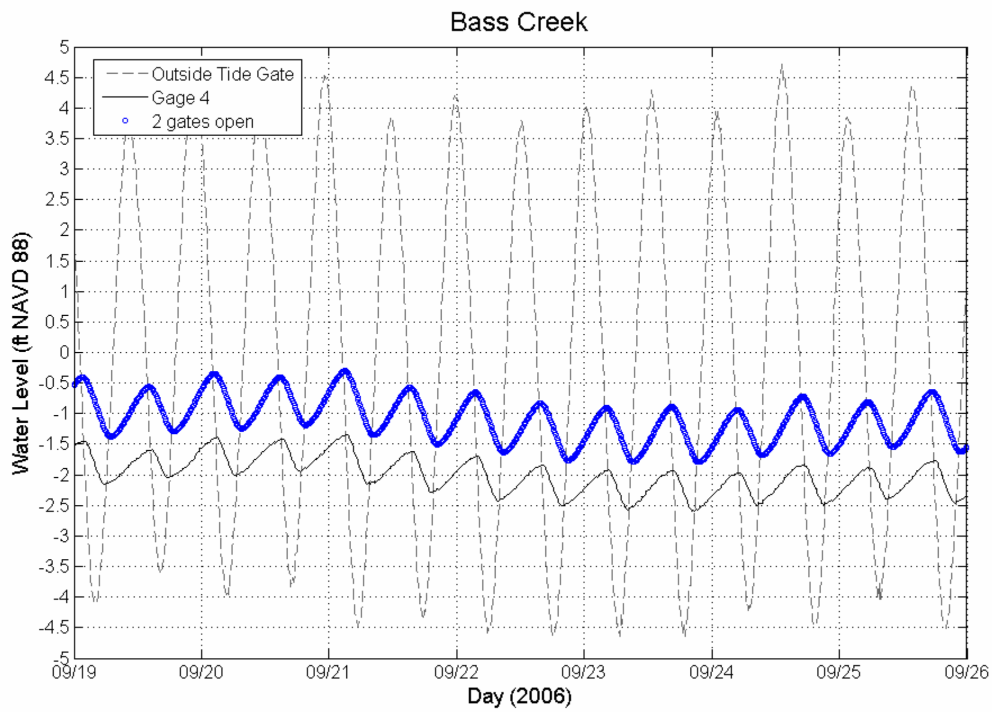
Complete Model Results for the 2, 3 and 4 Gate Scenarios

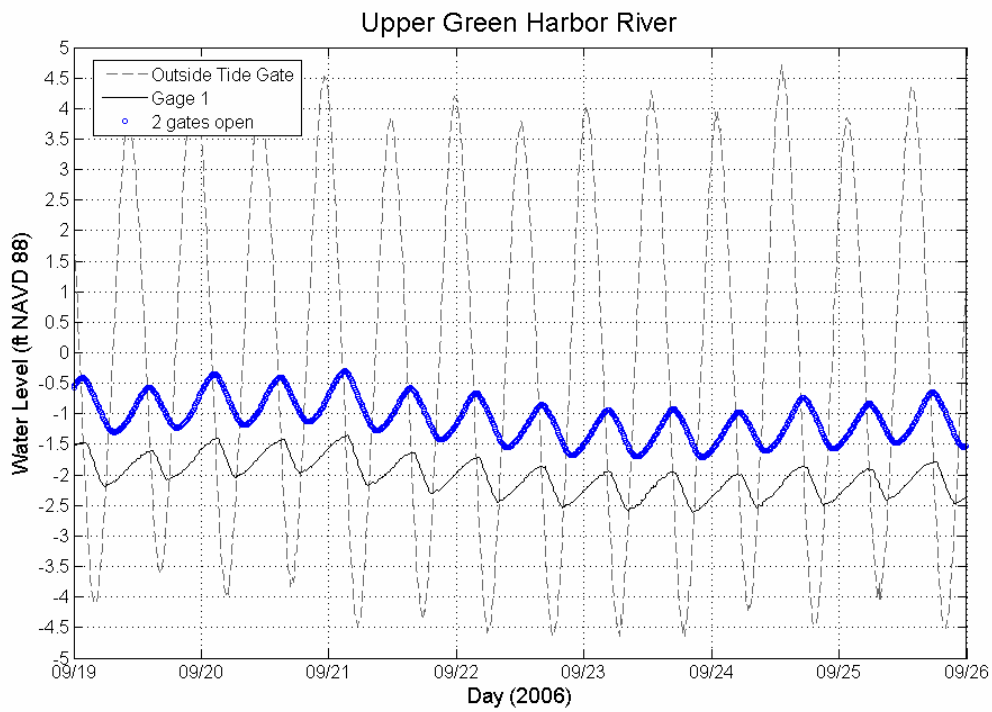
2 Gates Open

MWL = -1.1 feet


Lower Green Harbor River
Outside Tide Gate
Gage 5
2 gates open
Water Level (ft NAVD 88)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
09/19
09/20
09/21
09/22
09/23
09/24
09/25
09/26
Day (2006)

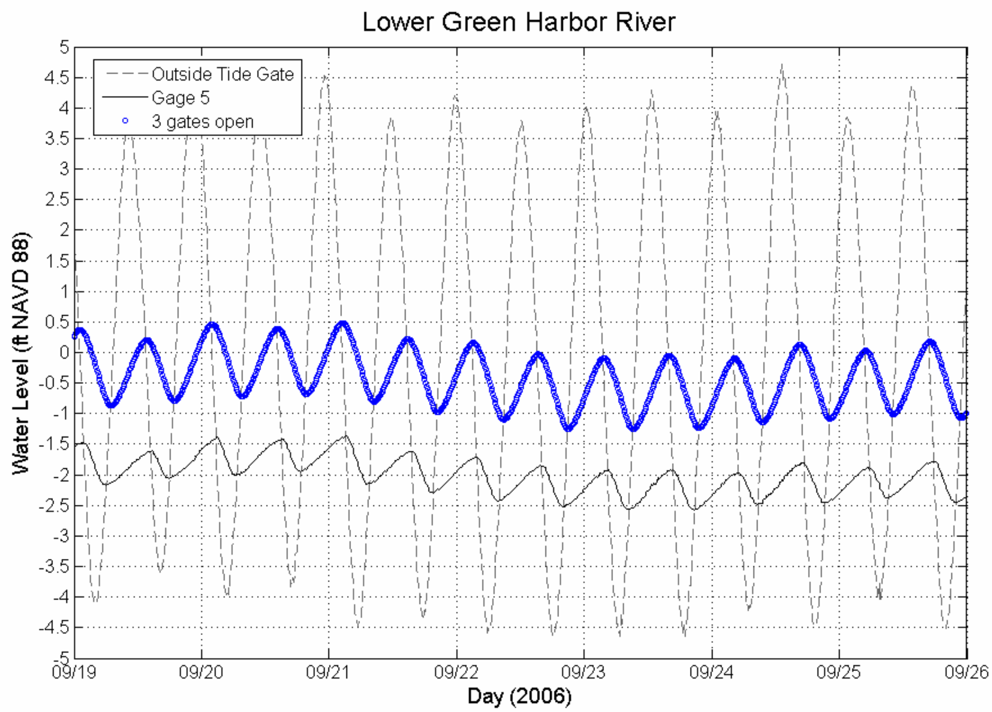

Wharf Creek
Outside Tide Gate
Gage 3
2 gates open
Water Level (ft NAVD 88)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
09/19
09/20
09/21
09/22
09/23
09/24
09/25
09/26
Day (2006)

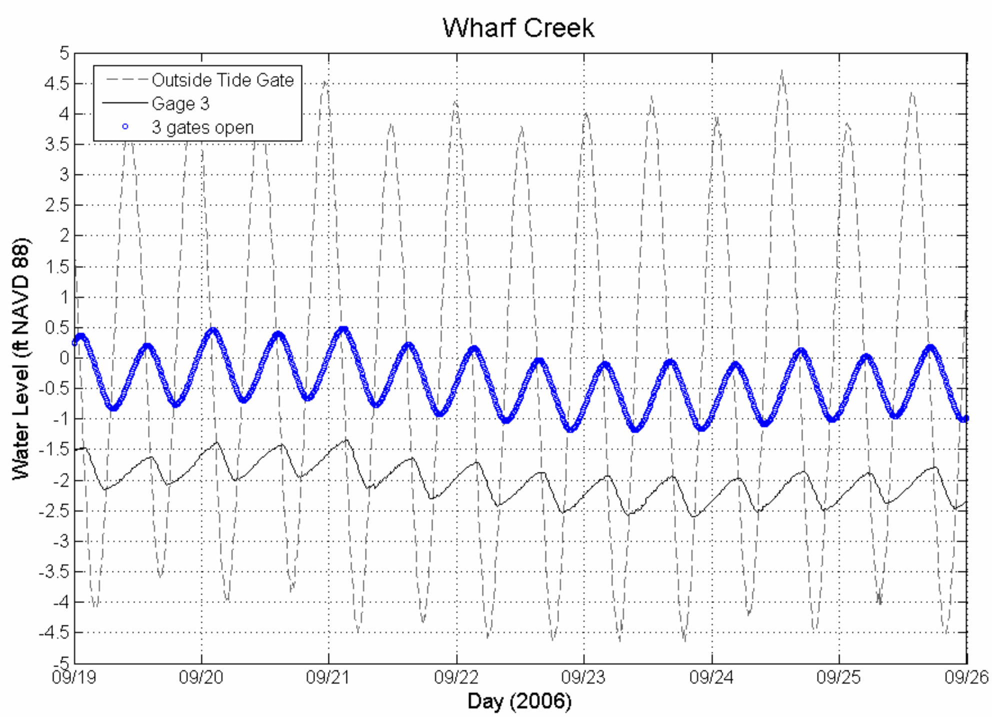

Bass Creek
Outside Tide Gate
Gage 4
2 gates open
Water Level (ft NAVD 88)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
09/19
09/20
09/21
09/22
09/23
09/24
09/25
09/26
Day (2006)

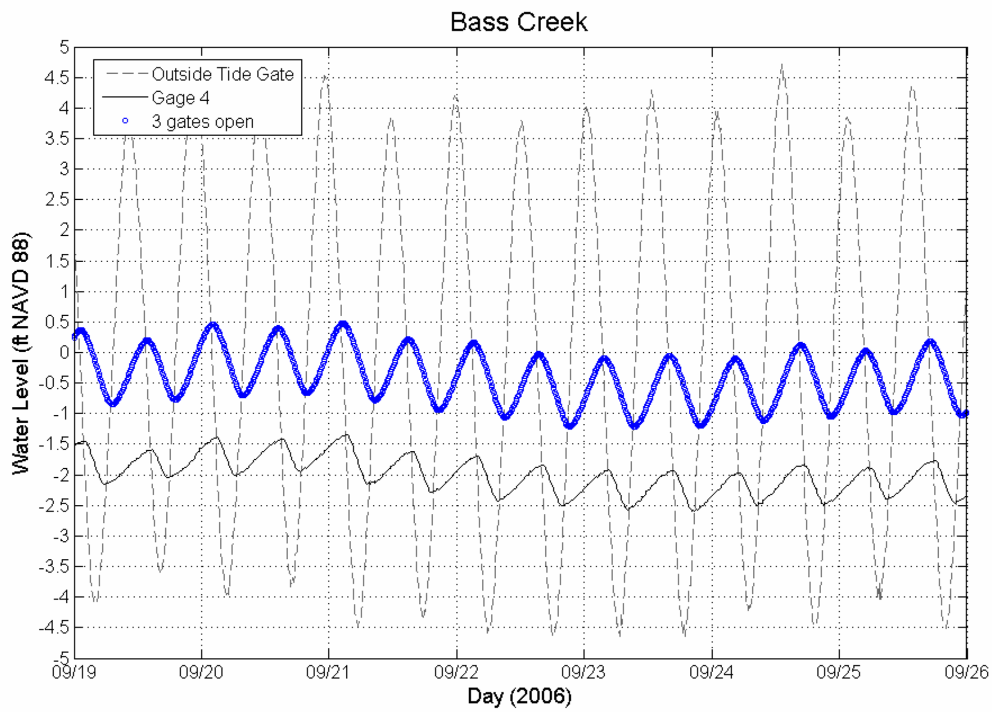

Upper Green Harbor River
Outside Tide Gate
Gage 1
2 gates open
Water Level (ft NAVD 88)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
09/19
09/20
09/21
09/22
09/23
09/24
09/25
09/26
Day (2006)

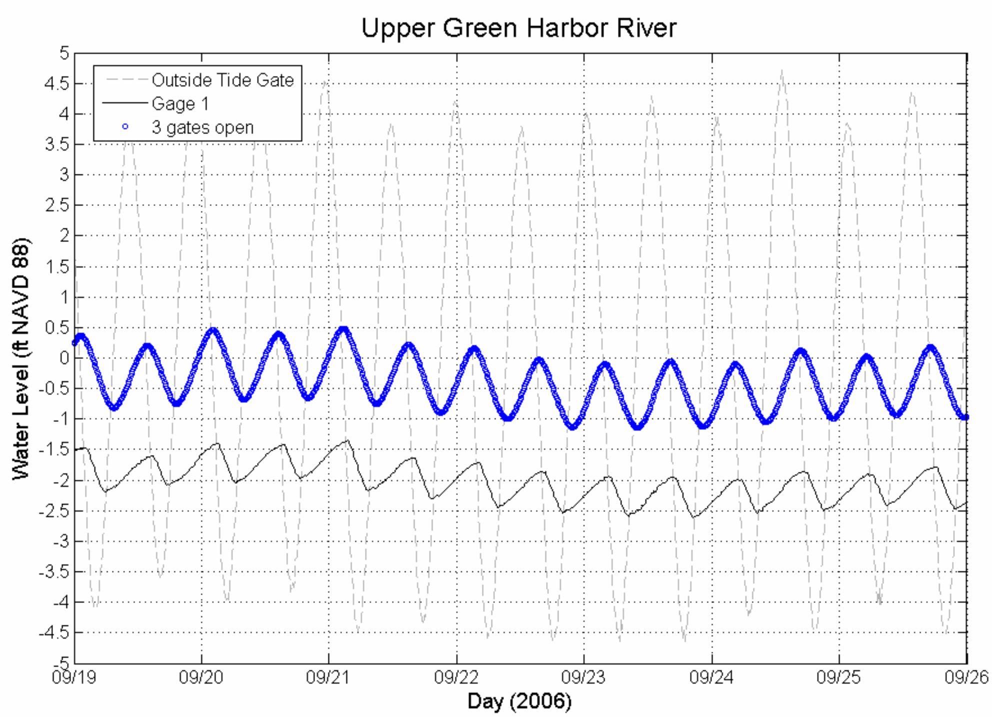
3 Gates Open

MWL = -0.5 feet


Lower Green Harbor River
Outside Tide Gate
Gage 5
3 gates open
Water Level (ft NAVD 88)
Day (2006)
09/19
09/20
09/21
09/22
09/23
09/24
09/25
09/26

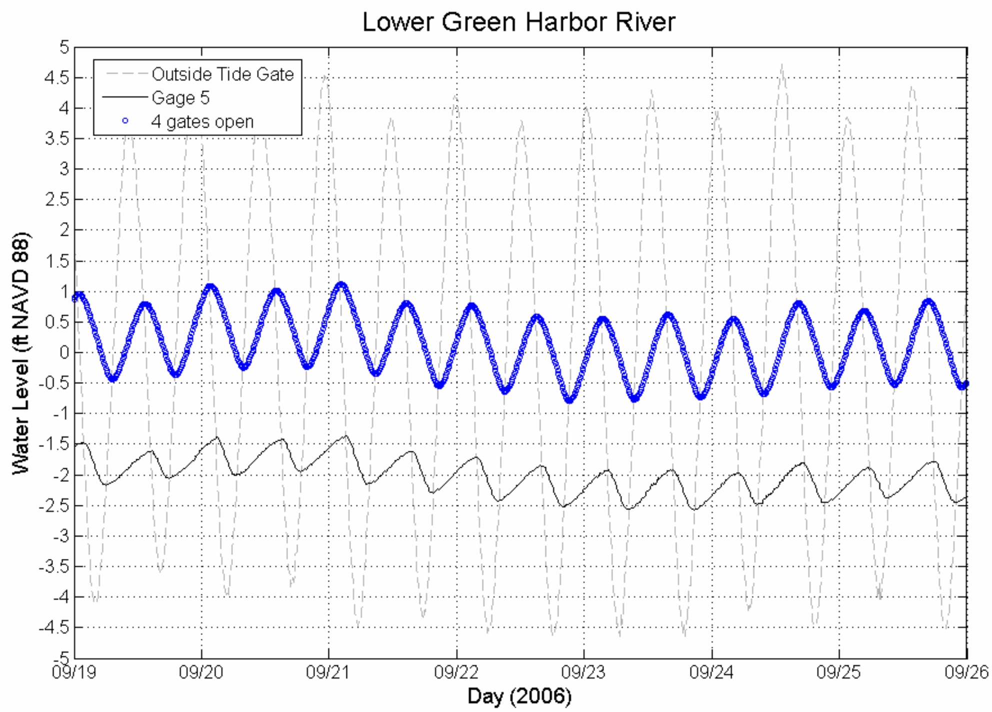

Wharf Creek
Outside Tide Gate
Gage 3
3 gates open
Water Level (ft NAVD 88)
Day (2006)
09/19
09/20
09/21
09/22
09/23
09/24
09/25
09/26

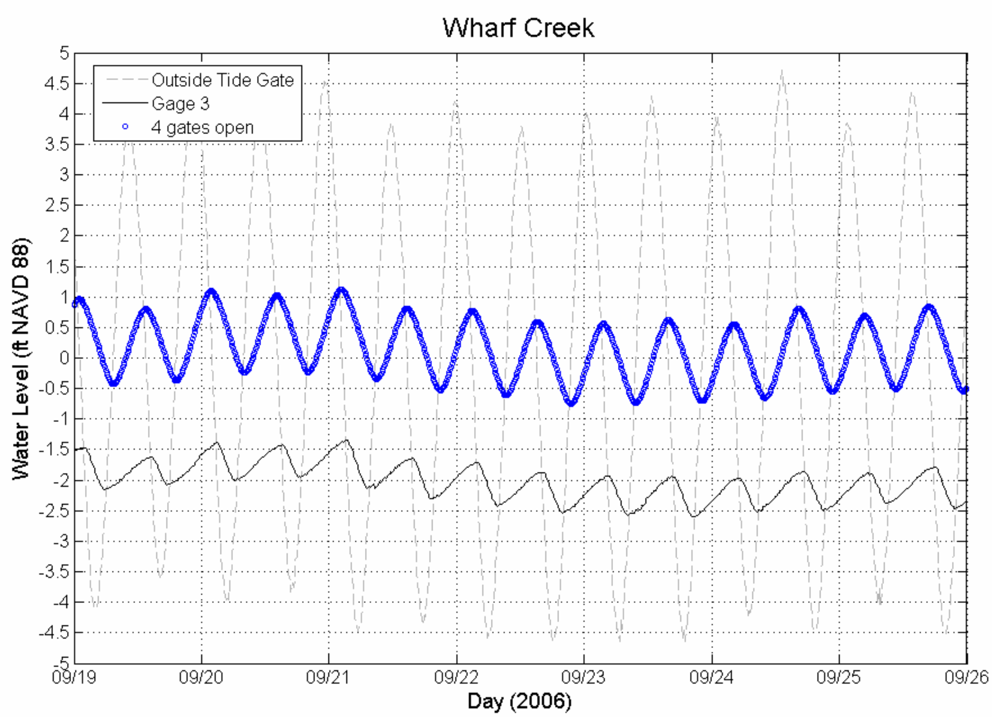

Bass Creek
Outside Tide Gate
Gage 4
3 gates open
Water Level (ft NAVD 88)
Day (2006)
09/19
09/20
09/21
09/22
09/23
09/24
09/25
09/26

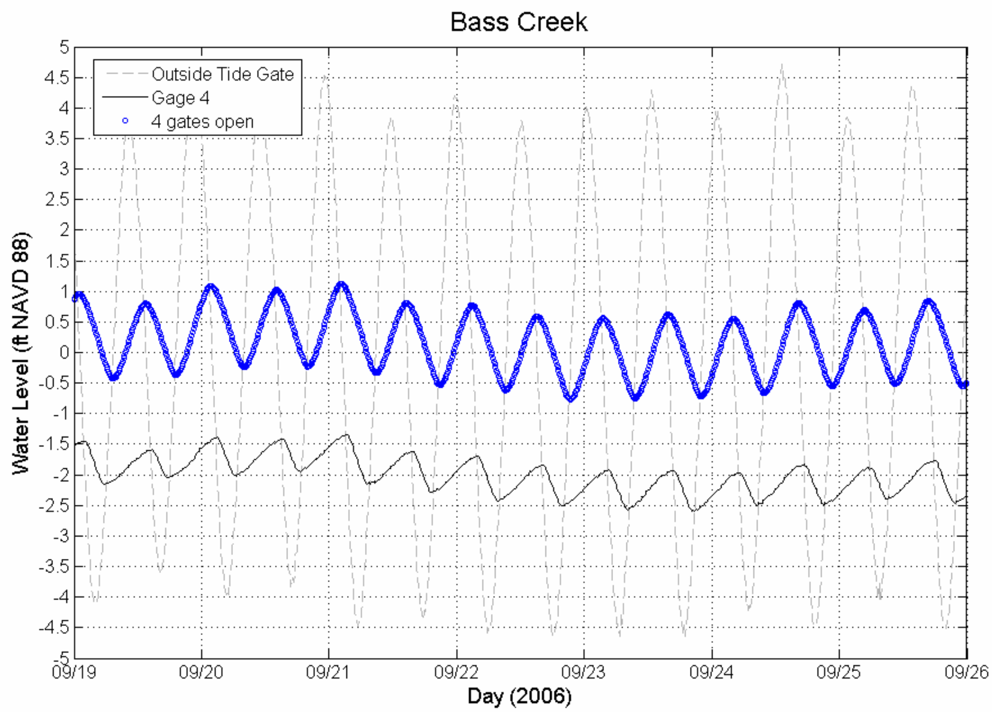

Upper Green Harbor River
Outside Tide Gate
Gage 1
3 gates open
Water Level (ft NAVD 88)
Day (2006)
09/19
09/20
09/21
09/22
09/23
09/24
09/25
09/26

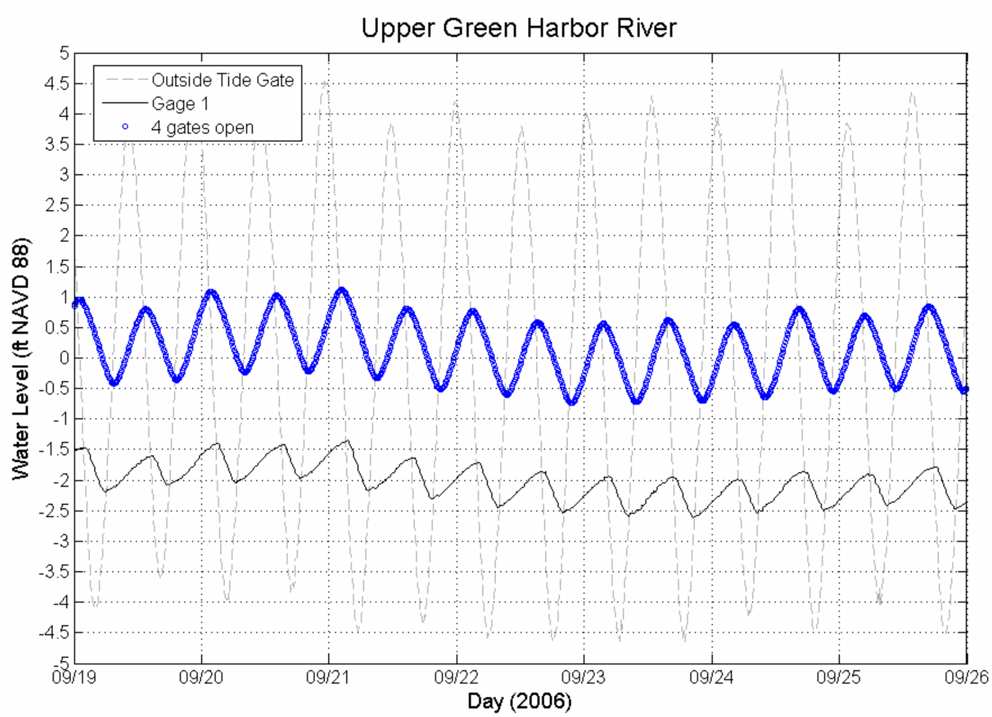
4 Gates Open

MWL = -0.0 feet


Lower Green Harbor River
Outside Tide Gate
Gage 5
4 gates open
Water Level (ft NAVD 88)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
09/19
09/20
09/21
09/22
09/23
09/24
09/25
09/26
Day (2006)


Wharf Creek
Outside Tide Gate
Gage 3
4 gates open
Water Level (ft NAVD 88)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
09/19
09/20
09/21
09/22
09/23
09/24
09/25
09/26
Day (2006)


Bass Creek
Outside Tide Gate
Gage 4
4 gates open
Water Level (ft NAVD 88)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
09/19
09/20
09/21
09/22
09/23
09/24
09/25
09/26
Day (2006)


Upper Green Harbor River
Outside Tide Gate
Gage 1
4 gates open
Water Level (ft NAVD 88)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
09/19
09/20
09/21
09/22
09/23
09/24
09/25
09/26
Day (2006)