NOAA Technical Report NOS CS 7

SKILL ASSESSMENT OF THE CHESAPEAKE AREA FORECAST EXPERIMENT (CAFE) SYSTEM

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noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Coast Survey Development Laboratory
Marine Modeling & Analysis Programs

Office of Coast Survey
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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EXECUTIVE SUMMARY

This skill assessment of the Chesapeake Area Forecast Experiment (CAFE) shows that the model's water level nowcasts and forecasts are of sufficient accuracy to recommend that the system be made operational. The system produces nowcasts and forecasts of water level at eleven monitored locations throughout the bay. The skill assessment of CAFE is a comparison of nowcast and forecast water level values with observations and simple now/forecasts based on astronomical values obtained from tidal tables. The skill assessment parameters for these comparisons are defined in "NOS Procedures for Developing and Implementing Operational Nowcast and Forecast Systems for PORTS" (NOS, 1999).

The skill assessment statistics are presented for five "scenarios" (Table B.1 of NOS (1999)) 1) Model reproduction of Astronomical Tide, 2) Test Nowcast model run with best data, 3) Semi-Operational Nowcast, 4) Test Forecast with best data, and 5) Semi-Operational Forecast. Finally a comparison of forecast skill relative to a reference forecast based upon persisted water level and astronomical predicted tide is presented. For each scenario time series of modeled water levels and reference water levels are compared at each of the eleven stations within the bay: Chesapeake Bay Bridge Tunnel, Sewell's Point, Kiptopeke, Gloucester Point, Lewisetta, Colonial Beach, Solomons Island, Cambridge, Annapolis, Baltimore and Tolchester Beach. The test nowcast and forecast runs with best data span the year 1997. The semi-operational nowcast was created during the year of 1997 by running the model twice a day using data as it was acquired in real time. The semi-operational forecast for the 1997 year was tainted by an error in the application of forecast water levels. This problem was corrected and a slightly different version of the model was run with the corrected forecast method to obtain the semi-operational forecast run for the time period of August-December 1998. In all cases the geometry and physical parameters of the numerical model are held identical to the version which will be ported to operational status with CO-OPS in 1999.

The skill assessment statistics specified in Table B.2 of NOS (1999) are used to demonstrate the ability of the model to consistently reproduce observed water levels. The Central Frequency, CF, describes how often the predictions are within a narrow range of the observed values. Positive Outlier Frequency and Negative Outlier Frequency (POF and NOF) describe how often the values are either over or under predicted. The chance that a mistake will continue for a long duration is measured with the Duration Of Positive (or Negative) Outliers. The Worst Outlier Frequency describes the occurrence of an unacceptable error while the astronomical prediction is closer to the observed value, i.e. when the tide tables are working much better than the model.

Results for water levels in each scenario are as follows:

<u>Astronomical Tide Only:</u>
The model was forced with astronomical predictions at the mouth of the Bay to produce water levels at the eleven stations for comparison to astronomical predictions. All lower-bay stations are in very close agreement with tidal constituents. The mid-bay and upper-bay stations have

larger semi-diurnal phase errors. The phase of the semi-diurnal tide has a largest error at the mid-bay stations of Cambridge and Solomons. However, these phase errors are small enough that modeled tides at all stations pass the assessment criteria.

Test Nowcast:
The Test Nowcast water levels pass all assessment criteria with the exception of mid and upper bay stations, Colonial Beach, Cambridge, Annapolis, Baltimore and Tolchester which exceed the Central Frequency criteria by 2-3 percent.

Semi-Operational Nowcast:
The Semi-Operational Nowcast behaved very similarly to the Test Nowcast and passed all criteria with the exception of a few percentage points in the Central Frequency criteria at the upper bay locations.

Test Forecast:
The Test Forecast errors drift out of the Central Frequency band after +6 hour. The Positive and Negative Outlier Frequencies are satisfied up to the +18 hour of the forecast. Several long duration events caused the Maximum Duration of Outliers to be in excess of 36 hours several times during the test period. The Worst Outlier Frequency was only exceeded at the Tolchester station during the test period.

Semi-Operational Forecast (Aug-Dec. 1998):
For the Semi-Operational Forecast the Central Frequency drops below 90% at all stations by +6 hour and is about 80% at most stations by +12 hour. Most stations exceed the Negative Outlier Frequency criteria by hour +12 hour. Only upper bay stations exceed Positive Outlier Frequency criteria in the forecast hours. A single event which occurred during the test period was just sufficient to cause the Maximum Duration of Outliers to exceed the 30 hour criteria at CBBT, Gloucester and Lewisetta. The same event was of the Worst Outlier Frequency type, causing most stations to fail that criteria.

Two alternative forecast methods are compared to model forecast, 1) Predicted tides based only on astronomical tidal constituents, and 2) Persisted observation added to the astronomical forecast. The tidal constituent alone forecast method contains no wind driven non-tidal water level information and was shown to be incapable of meeting the skill assessment criteria. The reference forecast of a persisted observation added to the astronomical forecast has an error which is defined to be zero at hour = +0 and thus surpasses the model forecast skills for the first 6 hours of forecast. However, it is inferior to the forecast model by the +12 hour in all skill assessment criteria.

The skill assessment statistics were applied to the scenarios for high and low water amplitude and times. The criteria for obtaining water level heights of high and low tides (within 15 cm) is easily met by all scenarios. However, the criteria of obtaining the time of high and low water within a bound of 30 minutes is not met due to a persistent error in the ability of the model to reproduce the phase of the major tidal constituent, M2. The average offset of 10-20 minutes in this constituent allows random perturbations to exceed the 30 minute criteria too often.

In summary, the model is able to pass water level nowcast/forecast tests for the test period with the exception of a small number of storm events. The forecast model is an improvement upon the persisted water level plus astronomical prediction reference case and can thus be a useful improvement upon printed tidal tables for mariners.

1. INTRODUCTION

The Chesapeake Area Forecast Experiment (CAFE) seeks to improve water level predictions delivered to the marine community who now rely upon predictions of the astronomical tides and a few real time data observations. A bay-wide model can provide improved coverage of nowcast fields and may incorporate non-tidal effects such as wind and coastal ocean water level set-up or set-down, to improve forecasts up to 24 hours in advance. CAFE uses observations of wind and water level to force a numerical model of water level height throughout Chesapeake Bay (Bosley, 1996; Bosley and Hess, 1997). Forecasts of water level were also produced with the same model by using atmospheric model predictions of winds and forecast models of sea level height. The system is designed to produce a 12 hour nowcast and 24 hour forecast twice daily. During pseudo-operational test periods of all of 1997 and August-December 1998 the model was run continuously and observations and model results were recorded. After the test year was completed, quality controlled, checked and appropriately filled data were available from NOS's Center for Operational Oceanographic Products and Services (CO-OPS) and National Data Buoy Center (NDBC) archives. Using this clean data the model was rerun for the test period to demonstrate the best results available. This report describes these data sets and reports the skill assessment parameters.

The CAFE system consists of a numerical hydrodynamic model of the water levels throughout Chesapeake Bay and several sources of data which are used to force the model. The model is forced by a water level specification at the mouth of the bay and the wind field over the whole bay. In nowcast mode the forcing water levels are supplied from a gauge located on the Chesapeake Bay Bridge Tunnel. The nowcast wind field is derived from observations made at Thomas Point Lighthouse and the Chesapeake Bay Bridge Tunnel (CBBT). In forecast mode the forcing water levels are provided by a summation of the tidal constituent based prediction of water level for the CBBT location and the non-tidal sea level extratropical storm surge model provided by NWS Techniques Development Laboratory (TDL) (Chen et al., 1993; Kim et al., 1996). The forecast wind field is provided by the NWS Eta29 model which supplies forecast surface winds on a 29km spaced grid over most of North America (Black 1994).

The hydrodynamic model is the Model for Estuarine and Coastal Circulation Assessment (MECCA) (Hess, 1989; Hess, 2000). The MECCA code is capable of solving the hydrodynamic equations of motion for momentum, mass, salt and heat conservation. It is three-dimensional in space, uses a vertical sigma coordinate, has a time-varying free surface, and incorporates non-linear horizontal momentum advection. For the CAFE application the MECCA is run in two dimensional mode with barotropic pressure gradients, solving for momentum and mass, but not salt and heat. Variables are placed on an Arakawa C-grid of square cells in the horizontal, with nominal 5.6 km extent. In all scenarios of this skill assessment study the geometry and physical parameters of the MECCA model are held identical to the version which will be ported to operational status with CO-OPS in 1999.

The operational system consists of twice daily nowcasts and forecasts of water level. Initial conditions for the forecasts come from the previous nowcast run. Initial conditions for nowcasts can come from previous nowcast runs or from previous spinup runs from rest. The previous nowcast initial condition method was used for the 1997 run. This method is easily interrupted by data drop outs and requires more operator intervention to maintain, so the alternative spinup method was evaluated in the August-December 1998 time period. The eight day spinup method consists of an independent run of the MECCA model using quality controlled data, that has been correctly filled for any gaps. Because the Chesapeake Bay tides are so strongly dissipative, and the bay seiche time scale is only about 1.6 days, the spinup to tidal equilibrium is fully completed within eight days.

The Semi-Operational Nowcast runs of CAFE require data for water level at CBBT and winds at CBBT and Thomas Point provided as close to real time as possible. A direct feed of the National Water Level Observation Network, (NWLON), water level gauge and wind sensor at CBBT was provided for the 1997 period of testing (Scherer, 1986; Mero and Stoney, 1988; Burton, 2000). The Thomas Point Lighthouse is a Coastal Marine Automated Network, (CMAN), station which requires a separate cooperative agreement to obtain the meteorological data in real time using the NOAA's Air Resources Laboratory data feed from the NDBC. A Physical Oceanographic Real Time System (PORTS) is now installed in Chesapeake Bay, providing water level and meteorological data at the CBBT site which can be accessed in real time every six minutes (Burton, 2000). The PORTS system was used to access the CBBT water level and wind data for the August-December 1998 time period and will be used for the operational model when ported to CO-OPS.

The Semi-Operational Forecast runs of MECCA require forecast water levels and winds for the 24 hour forecast period. The results of the NWS Eta-29 and later Eta-32 North American atmospheric model were downloaded from the National Center Environmental Prediction model as soon as they were available, twice a day, approximately 4 hours after their first valid time (i.e. the 1200 UTC cycle is available at 1600 UTC). Similarly the NWS Techniques Development Laboratory model results for extra tropical storm surge were downloaded twice a day, with a 5 hour delay after first valid time.

The results of the CAFE nowcast/forecast runs can be disseminated in several forms to the public. The most common is the time series of water level height at a station, with available observation data, Fig. 1. The astronomical tidal prediction and observations are provided to compare the quality of the model and the deviation from standard tidal predictions which were previously all that was available. This image can be made available on the World Wide Web or provided by a fax-on-demand system. The images are updated twice daily after the model runs.

This report provides an assessment of the quality of the nowcast/forecast water levels by comparing the model results with observations. The skill assessment tests and techniques are mandated by the "NOS Procedures for developing and implementing operational nowcast and forecast systems for PORTS", (NOS, 1999). This report will present a summary of the scenarios and data to be tested, the statistics and methods of calculations. The skill assessment test results are presented in Appendix A. The results of a tidal constituent analysis of the model is presented in Appendix B. The results of the assessments applied to the different scenarios and the tidal constituent analysis will be presented. A final summary of the water level skill assessment will conclude that sufficient evidence has been presented to recommend implementation of the operational system for the Chesapeake Bay water level nowcast and forecast system.

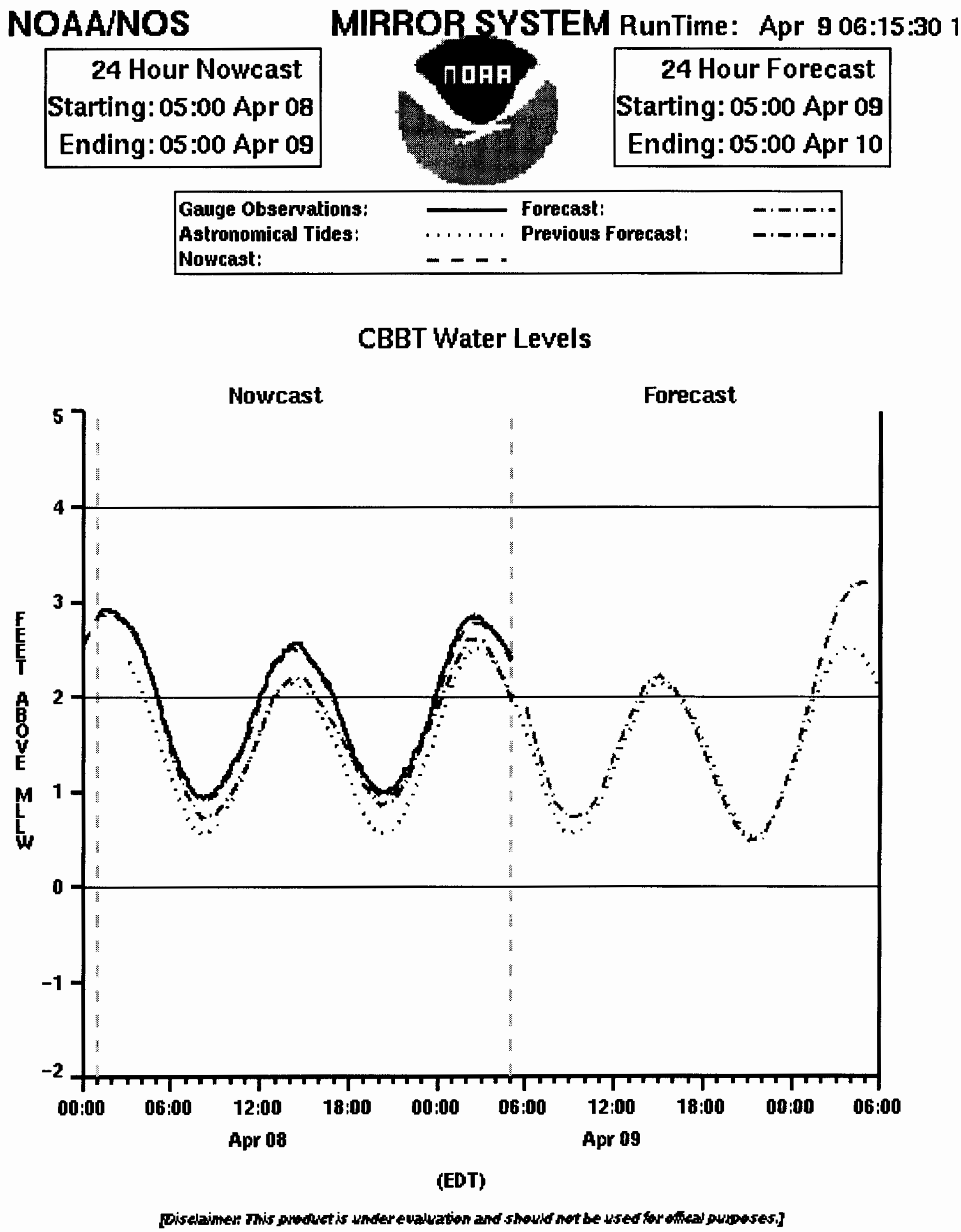

Figure 1. Sample output of Nowcast/Forecast of CAFE model.

2. SCENARIO AND DATA DEFINITIONS

The assessment of the CAFE system is performed by comparing the results of model runs and data for a suite of scenarios and methods specifed by NOS (1999). The scenarios are one year runs of the system using different forcing data. They are: Astronomical Tide Only which uses only astronomical tidal constituent forcing, Test Nowcast which uses the best, backfilled and quality controlled observation data, Semi-Operational Nowcast which uses the data as available at the time of a semi-operational test, Test Forecast which uses the Eta and TDL forecast model results for forcing (run after the fact when all Eta and TDL model runs are available), Semi-Operational Forecast which uses the Eta and TDL forecasts available at the time of a semi-operational test (late Eta and TDL forecasts create data gaps in the forcing). In addition to these scenarios several simple forecast methods are compared against the model results. The methods are: Astronomical Tidal Predictions, i.e. the tide tables presently available, Persisted Observation plus Astronomical Forecast, where the tide tables are combined with an observation of the present non-tidal water level to project a forecast based on persistence of the non-tidal component.

The assessment of the model requires a suite of time series of model output and observations which can be inter-compared. The skill assessment parameters will be computed at a series of stations where all of these time series will be specified. These locations were chosen where observations and tidal height constituents are available (Table 1). The water height time series represent either observations, tidal constituent reconstructions or model runs with different forcing combinations. The time series are about one year long. For comparison the time series will be interpolated to a common time sampling (hourly on the hour).

Table 1. Stations where model and observation water levels are compared.

Station Name	Station #	Latitude	Longitude
Chesapeake Bay Bridge Tunnel,	8638863	36°58.0'N	76°6.8'W
Sewells Point, Hampton Roads	8638610	36°56.8'N	76°19.8'W
Kiptopeke, Chesapeake Bay	8632200	37°10.0'N	75° 59.3'W
Gloucester Point, York River	8637624	37°14.8'N	76°30.0'W
lLewisetta, Potomac River	8635750	37°59.8'N	76° 27.8'W
Colonial Beach, Potomac River	8635150	38° 15.1'N	76° 57.6'W
Solomons Island, Patuxent River	8577330	38°19.0'N	76° 27.2'W
Cambridge, Choptank River	8571892	38°34.5'N	76° 4.3'W
Annapolis, Severn River,	8575512	38°59.0'N	76° 28.8'W
Baltimore (Fort McHenry)	8574680	39°16.0'N	76° 34.7'W
Tolchester Beach, Chesapeake Bay	8573364	39°12.8'N	76° 14.7'W

2.1. Nowcasts

The nowcast data arrays are specified as two-dimensional arrays H(time, station number). A 2-D data array was prepared for each of the follow data types:

- Astronomical Tides Time series of heights reconstructed from the tidal constituents for the tide gauge locations.
- Tide Only Heights simulated by the model forced only by tidal constituent at the open boundary (CBBT constituents transferred to the offshore boundary with tuned amplitude and time shift.)
- Observations Observations of sea level from the tidal gauge stations. The NOAA DPAS archives of sea level are quality controlled and most of the gaps are appropriately filled.
- Test Nowcast Model nowcast forced by best observations. The MECCA model forced with observed water level at CBBT and winds from CBBT and Thomas Point. The model is run in 12 hour steps to spawn an initial condition file for the forecast runs. Because the model is run with fully corrected and gap filled data the difference between the sequential nowcast initial condition files and the 8 day spinup initial condition files is negligible (less than 1 part in 1000 of water level variability).
- Semi-Operational Nowcast Model semi-operational nowcast forced by observations available at the time of the model run. The observation data base will be incomplete and gappy, so this run tests the ability of the model under working conditions.

2.2. Forecasts

The forecast model runs twice a day for the year, creating a time series of 24 hour forecasts. The Forecast data can be treated as 25 time series each corresponding to the forecast hour and having two data points per day corresponding to the two daily runs. The Forecast data is structured into 3-D arrays: H3d(t_o,25,11) Height at 0-24 hours after time t_o, at 11 stations. t_o, time of start of a forecast, increments by 12 hours for the twice daily forecasting model. The following data types were prepared to 3D data arrays.

- Observations NOAA DPAS observations put into 3-D array for comparisons.
- Test Forecast Model forecast forced by best forecast wind (Eta) and water levels at CBBT (TDL surge model forecasts plus tides reconstructed from tidal constituents).
- Semi-Operational Forecast Model forecast forced by observations and forecast data available at the time of the model run. The observation data base will be incomplete, affecting the initial condition of the forecast. The forecast fields from TDL and Eta are at times delayed by computer problems. This run tests the ability of the model under working conditions. The 1997 year long data set included an error later discovered in the application of the TDL-OBS water level heights. The error caused a bias of the forecast forcing of 23 cm. The 1997 semi-operational forecasts trend to a 23 cm offset near the mouth of the bay, an error felt to lesser degree by the up-Bay sites. This problem was corrected in early 1998, allowing another semi-operational test for six months of 1998. The semi-operational

forecast tests are therefore performed on this six month time series of 1998.

- Persisted Astronomical Tides The subtraction of astronomical predictions from observational water level produces the non-tidal component of water level. This non-tidal water level from time t_0 is added to astronomical tidal predictions for the duration of the 24 hour forecast. This synthesizes the information available to a mariner under normal conditions, a now observation and tide tables.

3. ANALYSIS METHODS

3.1. Skill Assessment Statistics

As per NOS (1999), a standard suite of assessment statistics is defined which will be applied to the time series of water level error (E = P - R, Error = Predicted minus Reference) at every station. These will be calculated for pairs of times series data:

- SD: Standard deviation of the difference between two time series.
- RMSE: Root mean squared value of the difference between two time series. Unlike SD, RMSE retains the mean differences. $RMSE^2 = SD^2 + (mean(E))^2$
- F(X), Probability Frequency: Given a criteria X for the difference of the time series the Frequency is the fraction of the data which are surpassed by the criteria (also known as cumulative probability density, F(-inf) = 0, F(+inf)=1.0).
- CF(X) Central Frequency: F(+X) - F(-X). The fraction of data which lie in the range between $-X < E < +X$.
- POF(X) Positive Outlier Frequency: 1.0 - F(+X). The fraction of data which exceed the value X.
- NOF(X) Negative Outlier Frequency: F(-X). The fraction of data which are less than minus X.
- WOF(X) Worst Case Outlier Frequency: Same as Positive Outlier Frequency, but restricted to worst cases where the simulated value is greater than astronomical and the observations are below astronomical. If a mariner were to use such a forecast rather than tide tables the chances of running aground would be worse.
- DPO(X,h) Duration of Positive Outliers: Probability histogram of error runs. An error run is the number of consecutive hours, h, an error exceeds a value, X.
- MDPO(X): Maximum Duration of Positive Outliers. The length of the longest error run during which the error exceeds the criteria, $+X<E$.
- MDNO(X): Maximum Duration of Negative Outliers. The length of the longest error run during which the error is less than the negative criteria, $E<-X$.

3.2. High and Low Water Calculations

NOS (1999) also requires time series of time and amplitude of high and low water. Since model results are reported hourly, a method of interpolation is required to derive these parameters from time series of model, data or reconstructed tidal constituents. Since the data are dominated by an M2 tide the approximate time of the high and low water is known. A number of height estimates surrounding this point (spanning 4 hours) are used in a least squares method to fit a fifth degree polynomial. The minimum or maximum (low or high water) of the fit polynomial is located, giving the time and amplitude of low or high water. The standard suite statistics of SD, RMSE, POF, CF, NOF may be applied to these values. Worst Case Outlier Frequency is not applicable for the high/low water statistics and is excluded from the test suite. The high and low waters occur during different times in the forecast cycles, but all 24 hours are grouped as forecast statistics. (The technique for finding high and low water excludes high or low water occurring within 2 hours of the beginning or end of a 24-hour forecast.)

3.3. Tidal Constituent Calculations

The tidal response of the MECCA Model was investigated by forcing the oceanic outside boundary with the astronomical tidal constituents published for the CBBT station, modified by a simple phase and amplitude correction to account for the propagation time from the outer boundary to the water level station at CBBT. No wind forcing and no subtidal water level height variation is added, i.e. no TDL ocean setup is included. The response of the model at the location of the eleven stations throughout the bay is compared with the published tidal constituents at those locations. A derivation of the tidal constituents from the model run time series will return values comparable to the published statistics only if the analysis is done over the same time period used by the original tidal analysis. Therefore, the tidal constituent analysis is applied to both the model time series and a time series of the tidal height created directly from the published astronomical tidal constituents. The tidal constituent decomposition and spectra of model and astronomical tidal time series are compared. In this manner the comparison can be made between two time series which have passed through identical processing steps.

Several methods of tidal constituent decomposition are available, each with strengths and weaknesses. First is the broad stroke Fourier transform analysis resulting in a continuous spectrum of sines and cosines. This does not separate and identify many tidal constituents, but it does account for 100% of the variance of a signal which may contain non-tidal signals. Another is the full least squares fit to all tidal constituent frequencies as a single system. Because the constituents are not "orthogonal" the solution using this method is not unique and will depend on starting time and duration of record. Differences become obvious when the length of the time series is short (2-8 weeks) and the starting and ending times are varied by just a day or two.

The technique used for the present assessment study is described by Schureman (1971) and used by the NOS tidal analysis programs (Zervas, 1999). This tidal decomposition technique solves the full least squares system and orders the constituent frequencies by amplitude. The largest individual component is subtracted from the time series. The process is re-applied to the resultant time series until all constituents have been removed (or a minimal residual variance is approached). This sequential removal avoids the problem of the non-orthogonal least squares where two adjacent frequencies might obtain large amplitudes but compensate by being close to 180 degrees out of phase. The sequential removal least squares recovers the tidal constituents used to generated the time series to within 0.01%. Unlike published harmonic tidal constituent tables, the model (and observation) time series have many more over-tides and tend toward continuous spectra at higher frequencies.

4. DISCUSSION OF RESULTS AND SCENARIOS

The skill assessment statistics were calculated for the scenarios and the alternate forecast methods described in NOS (1999). The application and results from the scenarios and methods are discussed in general terms in this section. The following section provides a summary of the scenario and method statistics which are used to assess the quality of the model and how it satisfies the requirements of NOS (1999).

4.1. Tide Constituent Results

Analysis of the model's ability to reproduce tidal constituents reveals a source of variance which will be present in all the other comparisons. Tidal constituent analysis (Appendix B) shows errors of around 6-10% in M2 amplitude with up to 30 minute phase errors. The phase errors are smallest at the mouth of the bay and increase to maximum errors in mid bay (Solomons, Cambridge) and become slightly lower near Baltimore. The phase and amplitude errors combine to create 15-30% total errors in M2 and other individual component reproduction. However the water level comparisons show that the model reproduces the total signal better than the individual constituents. The model produces water level time series which contain spectral energy which is not represented by an astronomical harmonic constituent. This non-tidal constituent energy corrects for the inaccuracies at the harmonics producing a smaller percentage error for the total water level than the percentage errors found for individual tidal constituents.

There is a large error from the total astronomical tides at Baltimore. Baltimore's tidal constituents include sizable sa annual frequency component (12 cm) but the modeled amplitude of sa is only 5 cm. The forcing at CBBT contains about 5 cm at sa and ssa, which is the only contribution to annual and semi-annual forcing. The large discrepancy of 7 cm (12cm - 5cm) is probably accounted for by seasonal meteorological forcing which is not included in this comparison. At Baltimore, within the M2 band there is a 0.38 hour advance of the model high water before the astronomical high water.

The standard suite of statistics are reported in Appendix A for the model forced by only tide constituents and compared to tidal constituent reconstructed data, (Scenario: Astronomical Tide Only), and the predicted astronomical tide compared to observations (Method: Astronomical Tidal Predictions). The modeled tide error variance is smallest at CBBT, 1cm, where there is only a slightly imperfect reproduction of CBBT due to the remote forcing by its tidal constituents. At upper and mid bay stations the errors are larger. The differences will add directly to errors incurred in comparisons with real data forcing. The tidal imperfections contribute only 3-7 cm to the variance calculated for model-observation comparisons (next section). The comparison of Astronomical Tidal Predictions to observations reveals the magnitude of non-tidal water level variation in the observed data. The non-tidal variance is 15-20 centimeters at all stations.

4.2. Water Level Comparisons

A first order result of the model should be the mean sea levels. However, the tidal mllw to sea level datum published for the stations cannot be simply used to compare to the model. Essentially the model has a single well defined sea level datum, z=0, the sea surface with no slope. However the sea level reported in observations is a local value calculated from data. The zero level implied by sea level at all stations may not be the same as the unforced zero level of the model. The persistent forcing of the real world includes a yearly average wind stress and the baroclinic effect that persists within the bay, where the freshwater to salt water gradient is compensated by a sea level difference which makes upper bay stations almost 10 cm higher than a geopotential might imply. These are subtle problems which produce barely noticeable 3-9 cm differences in the barotropic model datum. Since these are constant offset corrections the factor can be applied once to each station model results. For the data comparisons there are two datum factors to choose between to convert the observation mllw values to mean sea level. The first h_o values are as published with the tidal data. The h_{omodel} values used are average offsets for the station across the year and include the difference of mllw from mean tide level plus the constant sea level set up. The h_{omodel} values were developed using the 1997 data set and are presented in Table 2. The h_{omodel} values are applied to the data for all scenarios and method comparisons. The same values were applied to the 1998 skill assessment. The residual errors for the 1998 test are at most 1 cm, indicating that this term is a constant of the model, and not variable between years.

4.3. Test Nowcast and Test Forecast Scenarios

The Test Nowcast and Test Forecast Scenarios are the model run using quality controlled data for the water levels and winds of the nowcast, and the Eta-29 wind forecasts and TDL extra-tropical storm surge model's water levels for the forecasts. The nowcast-observation comparison tests the ability of the model to successfully reproduce low frequency changes in the water level forced by outside variations of the coastal water height (represented by the CBBT observations) and atmospheric forcing (winds at Thomas Point and CBBT). The forecast-observation comparisons test the ability of the model to use the Eta-29 and TDL forecasts to predict water levels throughout the bay. The drop in skill with forecast hours is a reflection of persistence of water level height and of the skill of the Eta-29 and TDL forecasts. The sensitivity of the model to the wind and water level forecasts is not greater than the model's tendency to maintain persistence of non-tidal water levels and thus poor Eta-29 and TDL forecasts degrade the model only after 6-12 hours.

Table 2. MLLW tidal datum, h_o and barotropic model's derived datum, h_{omodel} (meters).

Station Name	h_o	h_{omodel}	difference
Chesapeake Bay Bridge Tunnel,	0.442	0.410	-0.032
Sewells Point, Hampton Roads	0.4206	0.3886	-0.032
Kiptopeke, Chesapeake Bay	0.4450	0.3970	-0.048
Gloucester Point, York River	0.4176	0.3616	-0.056
Lewisetta, Potomac River	0.2377	0.1717	-0.066
Colonial Beach, Potomac River	0.2774	0.2314	-0.046
Solomons Island, Patuxent River	0.2347	0.1477	-0.081
Cambridge, Choptank River	0.3170	0.2300	-0.087
Annapolis, Severn River,	0.2195	0.1385	-0.081
Baltimore (Fort McHenry)	0.2499	0.1729	-0.077
Tolchester Beach, Chesapeake Bay	0.2591	0.1731	-0.086

4.4. Semi-Operational Scenarios

The Semi-Operational Forecast scenario of the model for the year of 1997 was contaminated by an error in the TDL forecast water level forcing of CAFE which was found and corrected in February 1998. The 1997 semi-operational forecasts have a trend of some 10-20 cm toward negative errors which greatly affects all of the statistics. The model, therefore, fails the NOF test at all locations for the forecasts of the 1997 semi-operational test. Failure of this test of the semi-operational capabilities of the model does not represent the current ability of the model. Therefore another semi-operational data set was analyzed from part of 1998, as explained below.

From August 1998 through December 1998 an experimental version of CAFE was run continuously in a version referred to as "Mirror1". Mirror1 was intended as a test-bed for several enhancements and simplifications of the CAFE system. The most significant change to the system was the routine use of the PUFFFs data sources for water level and wind forcing at the CBBT station. In early 1998 the NWS replaced the Eta-29 model with Eta-32. Another major change was the use of recomputed hot-start files everyday. Because the nowcasts are based on 6 minute old data, the results of the runs can be suspect as the quality control has not been applied to these data. More extensively quality controlled and back filled data are downloaded from the archive at NOAA/NOS/CO-OPS Water Level Computer (Burton, 2000). This data source can be many hours old and thus does not serve as real-time forcing. However by using only this data a quality controlled hot-start file can be created for 12-24 hours in the past. The hot-start file is created each day at 1230 UTC by spinning up the model from a state of rest eight days in the past to the 0000 hour twelve and half hours previous to the time of the run. The nowcasts are then run from the midnight point up to the present and then only the last twelve hours are output for the 12 hour nowcast. This technique also allows greater hands-off operation of the system. A bad real-time data point or gap or a computer hardware problem, which can crash the model, will only interrupt operations for one day. After a new hot-start file is created with a data set which does not contain the invalid data, the model continues to run with no operator intervention. As Mirror1 was not maintained, or even looked at, on a daily basis, this ability was necessary to remain semi-operational.

Mirror1 has corrected the forecast mode water level forcing problem of the 1997 semi-operational model, and thus is a better demonstration of the ability of the model to run in an operational environment than the 1997 CAFE model. However, several data links did fail through the test periods which must be mentioned when interpreting the statistics. Several data sources and scripts failed on January 1, 1999 and were not fully repaired till early February (Lessons were learned which prepared CAFE for Y2K compliance). Therefore the skill assessment will only be over the period August 11, 1998 - December 31, 1998. For the period August 28 - October 22 the winds at CBBT were still being accessed from the pre-PUFFFs source, which was actually shut down on August 28. The model continues to run with just the Thomas Point winds. Perhaps not too surprisingly the model performance is not strongly degraded during this period. The wind forcing near the mouth of the bay is not as important as it is to the upper bay, and fortuitously there were no wind events during this period exceeding 10 m/s for more than a few hours. In fact the skill assessment statistics are surprisingly good, and agree with the Test Nowcast results within 1cm in the standard deviation statistic.

Appendix A presents the skill assessment results of the Semi-Operational Forecast for the August-December 1998 period, but both the nowcast and the forecast were fully analyzed for this period. Over this 4.5 month period only one dramatic weather event occurred. The Semi-Operational model handled the event fairly well, under predicting the event at 12-24 hour forecast time, but did a good job on the nowcast. The Semi-Operational nowcasts and forecasts are only slightly degraded (~1cm in RMSE) verses the Test case. The Semi-Operational Nowcast and Forecast statistics are very similar to the Test Nowcast and Forecast case and meet the same skill assessment criteria. This 1998 Semi-Operational test is a much better representation of operational performance than the 1997 Semi-Operational Forecast case which contained the unfortunate error.

4.5. Astronomical Tidal Prediction Compared with Persisted Observations plus Astronomical Forecast Method

The full model is to be compared to a forecast method consisting only of an astronomical tide prediction with a persisted non-tidal component, to determine if the full model is worthwhile improvement upon the method which is already available to anyone with access to tidal tables and an observation of current water level. The full model has some error based on the errors from the tidal constituent analysis for the upper bay sites, and is thus initially inferior to the tide tables plus an observation. But these errors are swamped by uncertainty of mean water level setup or down on the time scale of 12-24 hours. It is this change on the order of 6-24 hours which we hope the model will be able to predict. The persistence method uses a perfect nowcast and astronomical tides to forecast 24 hours of water level. This is the information available today to anyone, a single observation of setup or setdown and the tide tables. The persistence model is perfect at +0 hours and very good for up to +6 hours because there is little error in local tidal constituents and low frequency wind driven sea level seldom changes much over a few hours. But without the low frequency drift of water level on time scales of 12-24 hours it does worse than the model. The results of Appendix A shows the persistence model to be better or comparable than the numerical test forecast scenario for 0-6 hours into a forecast. The test forecast scenario is better in the range 6-24 hours when wind effects have accumulated to invalidate the simple persistence model. Both methods become comparable again at 24 hours, the apparent limit of the Eta wind and TDL coastal sea level forecast skill.

5. WATER LEVEL SKILL ASSESSMENT SUMMARY

In accordance with the "NOS Procedures for Developing and Implementing Operational Nowcast and Forecast Systems for PORTS" (NOS, 1999), skill assessment parameters were calculated for each scenario and forecast method. NOS (1999) specifies acceptable ranges for the skill assessment parameters. The scenarios are model runs and data comparisons, while the methods are two plausible techniques for producing water level forecasts using tide tables rather than the model. The assessment tables in Appendix A contain all of the results. A summary of the skill assessment parameters and how they compared to the NOS (1999) acceptance criteria are given for each comparison.

5.1. Scenarios

Astronomical Tide Only

The comparison of model derived and actual tidal constituents is presented in Appendix B. As the model is forced with CBBT data, lower Bay stations are all in close agreement with tidal constituents. Of the lower bay stations of CBBT, Hampton Roads, Kiptopeke Beach and Gloucester Point, the maximum M2 error of 14% occurs at Gloucester Point, the station which is farthest up a river of these four. The midbay and upper bay stations have larger M2 phase errors. The M2 phase has a largest error of -0.8 hr at Cambridge, -0.49 hr at Solomons, -0.47 hours at Baltimore,-0.35 hr at Annapolis, , +0.31 hr at Colonial Beach. These phase errors with the constituent amplitude errors produces M2 errors of 15-42%. However the year average statistics, SM, RMSE, NOF, CF, POF, MDPO, MDNO and WOF (Appendix A) all pass the criteria and with better scores than the test nowcast. This indicates that somehow the 19% error of M2 at Baltimore, for example, is compensated by errors in other constituents when the full time series is reconstructed.

Test Nowcast (1997)

- RMSE<15cm at all stations. The highest value was Cambridge (=11.2cm) Note that RMSE is greater than 8cm at all stations north of Colonial Beach.
- CF(15cm) >90% failed at Colonial Beach (88.7%), Cambridge (82.4%), Annapolis(89.5%), Baltimore (87.9%), Tolchester (87.8%).
- NOF(30cm)<1% and POF(30cm)<1% passed at all locations.
- MDPO(30cm) and MDNO(30cm)< 24 hours passed at all locations.
- WOF(30cm)<0.5% passed at all locations.

Semi-Operational Nowcast (1997)

- RMSE<15cm at all stations, with the maximum at Cambridge (=11.1cm)
- CF(15cm)>90% failed at Colonial Beach (88.5%), Cambridge (82.5%), Annapolis(89.3%), Baltimore (88.2%), Tolchester (87.6%).
- NOF(30cm)<1% and POF(30cm)<1% passed at all locations.
- MDPO(30cm) and MDNO(30cm) < 24 hours passed at all locations.
- WOF(30cm)<0.5% passed at all locations.

Test Forecast (1997)

- RMSE<15cm at all stations out to 24 hour forecasts.
- CF(15cm)>90% CF drops below 90% at almost all stations by +6 hour.
- NOF(30cm)<1% and POF(30cm)<1% Up to +18 hour all Upper bay locations passed these tests. In the lower bay NOF values of 1-6% occur after +6 hours.
- MDPO(30cm) or MDNO(30cm) < 36 hours Fails for most stations at forecast hours of 18-24 hours.
- WOF(30cm)<0.5% Passes at all locations except Baltimore and Tolchester where the +24 hour forecast fails this test.

Semi-Operational Forecast (Aug-Dec. 1998)

- RMSE<15cm at all stations out to 24 hour forecasts.
- CF(15cm)>90% CF drops below 90% at all stations by +6 hour and is about 80% at most stations by +12 hours.
- NOF(30cm)<1% and POF(30cm)<1% Most stations have exceeded a 2% NOF by hour +12. Only upper bay stations exceed 1% POF in the forecast hours
- MDPO (30cm) or MDNO(30cm) <36 hours. CBBT has an event which exceeds the prescribed error bounds for more than 30 hours of +6, +12, +18 and +24hr forecasts. Glouster and Lewisetta also have an event which exceeds the criteria for 30 hours of the +24 forecast.
- WOF(30cm)<0.5% A large event occurred during the test period driving WOF past 0.5% at most of the upper bay locations.

High and Low Water Assessment

Skill assessment comparisons of the modeled high and low water levels and times against either the astronomical tidal predictions or the observation high and low waters required a 15 cm interval for the amplitude of the high and low water levels and a 30 minute interval for the time of the high and low water. The high and low water amplitude statistics are extremely similar to the water level statistics and pass the required assessment tests. The average time lags at the middle bay stations, Solomons and Cambridge, approach the 30 minute error limits. The persistent offset of -20 to -30 minutes caused the CF and NOF errors to be large and they often exceed the required limits in nowcast and forecast modes. With few exceptions the error of the time of high or low water is due to the phase mismatch evidenced by the comparison of the pure tidal constituent model and data. This can be seen by comparison of the mean high or low times to the phase error of the main tidal constituent, M2. An additional small increase in the error of the amplitude is evidenced in the nowcast/observation comparison. The time lag errors are not appreciably different between nowcast and forecast results, suggesting that they are the result of errors in reproducing tidal constituents and not errors due to non-tidal forcing and response. The high/low water phase shift along the bay reaches a maximal error of -33 minutes at Solomons Island (and on the East Shore at Cambridge of -50 minutes) and decreases to -15 minutes at Baltimore. While most stations successfully pass the 30 minute time error criteria, the persistent mean offsets of -10 to -30 minutes causes the CF(30 min) error band to contain less than 90% of errors and the NOF(-30 cm) band to often exceed 1%.

5.2. Forecast Methods

Astronomical Tidal Predictions

The inability of the astronomical tidal prediction to reproduce the non-tidal water level variations causes this method to fail all the skill assessment tests. This method just demonstrates that a model is necessary to provide adequate water level nowcasts and forecasts.

Persisted Observation plus Astronomical Forecast

- RMSE<15cm Passes at all lower bay stations. In the upper bay, although it is defined to be zero at hour=0 it surpasses 15cm by the 12 hour forecast.
- CF(15cm)>90% By definition CF(0hr)=100% but drops below 90% at all stations by +12 hour. Upper Bay stations drop below 90% by +6 hour. In most cases CF drops below Test Forecast by +12 hour.
- NOF(30cm)<1% and POF(30cm)<1% By definition NOF=COF=0 at 0 hour. Almost all stations exceed 1% by +12 hour, and are several percent by +18, greatly exceeding the Test Forecast case.
- MDPO(30cm) and MDNO(30cm) is not a well defined quantity for forecast time series which are only 24 hours long.
- WOF(30cm)<0.5% The upper bay locations exceed 1% after +12 hour.

The comparison of forecast methods indicates that tide-only predictions are less skillful than tides plus persistence. The model forecast scenarios out perform both forecast methods at times greater than 12 hours. Because the nowcasts have some error the model forecast cannot outperform the tide plus persistence method at zero forecast hour, but it will provide better forecasts after 12 hours.

6. CONCLUSIONS

The ability of CAFE on the average, is well within the skill assessment bounds. The only trouble exists with some of the outlier statistics which are not passed by all stations. Several large weather events occur which alter the water levels by as much as 1 meter beyond predicted tides for time periods of up to 36 hours. Under these conditions the 15 cm skill assessment interval becomes as small as 15% of the total change which must be modeled. The statistics which measure outliers are directly affected by this and the one or two events per year of several day duration are capable of creating the 1% outliers. Nevertheless these errors were only approached in forecasts at greater than 6 hours for some mid and upper bay stations.

The ability of the model to meet criteria is a strong function of the location of the test station within the Bay. Because the lower bay is closer to the open ocean boundary condition the phase errors and most amplitude errors are smaller than for those stations remote from the forcing conditions, the upper bay. However, as the lower bay tides are larger amplitude those stations are more likely to exceed the 30 cm error criteria and thus some of their outlier statistics may be worse than the upper bay. Cambridge is a difficult location because it is up a channel in a shallow area of the Eastern Shore. The important commercial stations of Hampton Roads and Baltimore are predicted adequately. Wind effects at Baltimore are a necessary component of the model and must be included for successful water level predictions.

The model is able to pass water level nowcast/forecast tests for the test period with the exception of a small number of storm events. The forecast model is an improvement upon the persisted water level plus astronomical prediction reference case and can thus be a useful improvement upon printed tidal tables for mariners.

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APPENDIX A. SKILL ASSESSMENT STATISTICS FOR WATER LEVELS AND HIGH AND LOW WATER AT EACH STATION

The standard suite of water level skill statistics are evaluated for a value of X = 0.15 m
The units of Series Mean (SM), Root Mean Square Error (RMSE), Standard Deviation (SD) are meters. Negative Outlier Frequency, NOF(2X), Central Frequency , CF(±X), Positive Outlier Frequency, POF(2X) and Worst case Outlier Frequency, WOF(2X), are presented as percentages. The duration of error variables, Maximum Duration of Positive Outliers, MDPO(2X), and Maximum Duration of Negative Outliers, MDNO(2X) are in units of hours.
The error bars are in meters. 90% of the errors fall between the 5% and 95% limits. 50% of errors fall above and below the median value.

The time and amplitude of high and low water were calculated and compared to observations and predicted tides by applying the standard suite of assessment comparisons. Series Mean (SM), Root Mean Square Error (RMSE), Standard Deviation (SD) and 5%, median, 95% error ranges are presented in meters for amplitude of high or low water (Amp) or in minutes for time of high or low water (Time). Negative Outlier Frequency, Central Frequency and Positive Outlier Frequency are presented in percentage. Maximum Duration of Positive Outliers and Maximum Duration of Negative Outliers are presented in number of sequential high or low tides. A High Amplitude MDPO of 3 corresponds to three consecutive high tides which differ from the reference by more than 30 cm. The high and low water skill assessment statistics are evaluated for a value of X=0.15m for the amplitude, and X=30min for the time.

Table A.1. Chesapeake Bay Bridge Tunnel

	SM	RMSE	SD	NOF	CF	POF	MDPO	MDNO	WOF	5%	median	95%
First Group: Scenarios												
Scenario: Astronomical Tide Only												
Water Level	0.011	0.014	0.009	0.0	100.0	0.0	0	0	0.000	-0.004	0.009	0.026
High Amp	0.014	0.016	0.008	0.0	100.0	0.0	0	0	n.a.	-0.001	0.013	0.027
Low Amp	0.014	0.016	0.009	0.0	100.0	0.0	0	0	n.a.	0.000	0.013	0.029
High Time	2.890	3.185	1.339	0.0	100.0	0.0	0	0	n.a.	1.122	2.661	4.630
Low Time	-2.341	2.675	1.294	0.0	100.0	0.0	0	0	n.a.	-4.859	-2.154	-0.741
Scenario: Test Nowcast												
Water Level	0.000	0.027	0.027	0.0	100.0	0.0	0	0	0.000	-0.043	-0.003	0.047
High Amp	0.005	0.027	0.026	0.0	100.0	0.0	0	0	n.a.	-0.035	0.002	0.050
Low Amp	0.000	0.027	0.027	0.0	100.0	0.0	0	0	n.a.	-0.043	-0.001	0.047
High Time	4.282	5.268	3.070	0.0	100.0	0.0	0	0	n.a.	-0.309	3.932	8.941
Low Time	-0.939	3.689	3.567	0.0	100.0	0.0	0	0	n.a.	-6.519	-0.748	3.209
Scenario: Semi-Operational Nowcast												
Water Level	0.001	0.025	0.025	0.0	99.8	0.0	0	0	0.000	-0.036	-0.003	0.036
High Amp	0.006	0.024	0.024	0.0	99.6	0.0	0	0	n.a.	-0.027	0.002	0.039
Low Amp	0.002	0.024	0.024	0.0	100.0	0.0	0	0	n.a.	-0.034	0.001	0.037
High Time	4.929	7.177	5.216	0.0	99.6	0.0	0	0	n.a.	-1.736	4.276	12.057
Low Time	-1.730	5.670	5.400	0.0	99.2	0.0	0	0	n.a.	-9.013	-1.524	4.130
Scenario: Test Forecast												
WL @ 0hr	-0.001	0.027	0.027	0.0	100.0	0.0	0	0	0.000	-0.045	-0.003	0.043
WL @ 6hr	0.007	0.108	0.108	1.4	86.2	0.6	2	2	0.282	-0.204	0.012	0.153
WL @ 12hr	-0.020	0.121	0.119	2.8	83.5	0.4	2	3	0.141	-0.237	-0.014	0.136
WL @ 18hr	-0.011	0.130	0.130	3.7	80.9	0.6	1	3	0.141	-0.271	-0.001	0.156
WL @ 24hr	-0.036	0.142	0.137	4.4	78.3	0.4	2	3	0.000	-0.294	-0.022	0.137
High Amp	0.012	0.121	0.121	2.2	82.3	0.7	2	2	n.a.	-0.217	0.023	0.165
Low Amp	-0.023	0.120	0.118	3.2	84.8	0.1	1	3	n.a.	-0.247	-0.014	0.122
High Time	3.542	12.518	12.006	0.3	96.6	0.1	1	1	n.a.	-14.401	2.484	21.992
Low Time	0.172	12.120	12.119	0.1	97.2	0.1	1	1	n.a.	-18.300	-0.787	17.819
Scenario: Semi-Operational Forecast												
WL @ 0hr	0.000	0.021	0.021	0.0	100.0	0.0	0	0	0.000	-0.033	-0.003	0.034
WL @ 6hr	0.007	0.119	0.119	1.4	88.1	0.6	2	4	0.196	-0.188	0.010	0.148
WL @ 12hr	0.003	0.124	0.124	2.2	86.6	0.4	1	5	0.000	-0.190	0.008	0.157
WL @ 18hr	-0.004	0.134	0.134	2.8	82.8	0.6	1	6	0.000	-0.218	0.002	0.169
WL @ 24hr	-0.008	0.140	0.140	4.0	81.4	0.6	1	7	0.198	-0.270	-0.001	0.162
High Amp	0.038	0.114	0.108	0.4	85.8	0.4	1	1	n.a.	-0.110	0.032	0.215
Low Amp	-0.013	0.106	0.105	2.4	92.5	0.0	0	2	n.a.	-0.164	-0.005	0.116
High Time	3.213	11.965	11.526	0.4	98.4	0.0	0	1	n.a.	-13.255	1.976	21.436
Low Time	-1.872	11.513	11.359	0.0	97.3	0.4	1	0	n.a.	-18.742	-1.587	13.833
Second Group: Comparison of Forecast Methods												
Method: Astronomical Tidal Predication												
Water Level	-0.003	0.157	0.157	2.2	70.3	4.0	58	46	0.000	-0.237	-0.025	0.261
High Amp	-0.176	0.233	0.152	19.0	45.5	0.0	0	13	n.a.	-0.436	-0.168	0.045
Low Amp	-0.209	0.263	0.159	24.3	36.8	0.0	0	14	n.a.	-0.492	-0.195	0.009
High Time	0.751	12.570	12.547	0.4	96.9	0.1	1	1	n.a.	-18.907	0.580	17.593
Low Time	0.041	12.263	12.263	0.1	96.8	0.1	1	1	n.a.	-19.348	-0.728	18.284
Method: Persisted Observation Plus Astronomical Prediction												
WL @ 0hr	0.000	0.001	0.001	0.0	100.0	0.0	0	0	0.000	0.000	0.000	0.000
WL @ 6hr	0.010	0.071	0.071	0.0	95.1	0.1	1	0	0.000	-0.111	0.009	0.114
WL @ 12hr	0.000	0.091	0.091	0.7	90.1	0.1	1	1	0.000	-0.156	-0.001	0.142
WL @ 18hr	0.010	0.122	0.122	1.3	80.6	1.4	1	1	0.424	-0.189	0.009	0.196
WL @ 24hr	0.000	0.136	0.136	2.1	75.5	2.1	2	2	0.850	-0.237	0.003	0.223
High Amp	0.023	0.094	0.091	0.3	89.9	0.6	1	1	n.a.	-0.132	0.021	0.159
Low Amp	-0.011	0.091	0.090	0.7	90.8	0.3	1	1	n.a.	-0.158	-0.010	0.123
High Time	0.775	12.572	12.548	0.4	96.9	0.1	1	1	n.a.	-18.907	0.580	17.593
Low Time	0.042	12.268	12.268	0.1	96.8	0.1	1	1	n.a.	-19.348	-0.728	18.284

Table A.2. Hampton Roads

	SM	RMSE	SD	NOF	CF	POF	MDPO	MDNO	WOF	5%	median	95%
First Group: Scenarios												
Scenario: Astronomical Tide Only												
Water Level	0.027	0.049	0.041	0.0	99.2	0.0	0	0	0.000	-0.027	0.017	0.103
High Amp	0.011	0.029	0.027	0.0	100.0	0.0	0	0	n.a.	-0.030	0.008	0.060
Low Amp	0.060	0.065	0.026	0.0	100.0	0.0	0	0	n.a.	0.021	0.056	0.104
High Time	-5.744	7.521	4.855	0.0	99.9	0.0	0	0	n.a.	-12.965	-6.483	1.684
Low Time	-20.595	21.710	6.869	0.0	90.8	0.0	0	0	n.a.	-33.576	-20.107	10.230
Scenario: Test Nowcast												
Water Level	0.000	0.056	0.056	0.0	98.1	0.0	0	2	0.000	-0.083	-0.010	0.093
High Amp	-0.008	0.052	0.051	0.0	98.4	0.0	0	0	n.a.	-0.080	-0.015	0.079
Low Amp	0.027	0.059	0.052	0.0	97.8	0.0	0	0	n.a.	-0.065	0.028	0.103
High Time	-3.541	11.557	11.002	0.3	97.8	0.1	1	1	n.a.	-17.985	-4.055	10.111
Low Time	-16.969	21.863	13.785	1.6	88.2	0.0	0	2	n.a.	-39.353	-16.072	-1.018
Scenario: Semi-Operational Nowcast												
Water Level	0.006	0.057	0.057	0.1	98.2	0.3	6	1	0.093	-0.069	-0.006	0.089
High Amp	-0.007	0.052	0.052	0.0	99.2	0.4	1	0	n.a.	-0.066	-0.015	0.059
Low Amp	0.040	0.068	0.055	0.0	97.7	0.4	1	0	n.a.	-0.022	0.034	0.105
High Time	-4.746	16.211	15.500	0.8	96.1	0.4	1	2	n.a.	-21.790	-5.264	12.470
Low Time	-18.112	23.006	14.186	0.8	86.4	0.0	0	1	n.a.	-38.838	-18.320	1.899
Scenario: Test Forecast												
WL @ 0hr	-0.009	0.053	0.052	0.0	98.9	0.0	0	0	0.000	-0.087	-0.015	0.075
WL @ 6hr	0.015	0.108	0.107	1.1	86.7	0.6	2	1	0.282	-0.179	0.021	0.168
WL @ 12hr	-0.020	0.124	0.122	3.4	84.7	0.4	2	3	0.000	-0.254	-0.010	0.137
WL @ 18hr	-0.005	0.135	0.135	3.7	78.2	0.8	2	3	0.141	-0.264	0.009	0.171
WL @ 24hr	-0.038	0.147	0.142	5.4	78.3	0.4	1	4	0.000	-0.321	-0.030	0.137
High Amp	-0.003	0.130	0.130	3.4	82.2	0.9	2	2	n.a.	-0.258	0.008	0.179
Low Amp	0.015	0.115	0.114	1.8	85.1	0.6	2	2	n.a.	-0.198	0.025	0.160
High Time	-2.906	13.027	12.699	0.6	96.9	0.0	0	1	n.a.	-23.543	-2.850	14.991
Low Time	-13.506	19.289	13.772	0.6	90.8	0.0	0	2	n.a.	-37.735	-13.504	6.649
Scenario: Semi-Operational Forecast												
WL @ 0hr	0.006	0.049	0.048	0.0	98.8	0.0	0	0	0.000	-0.066	0.000	0.085
WL @ 6hr	0.012	0.114	0.114	1.0	89.9	0.4	2	3	0.195	-0.170	0.015	0.139
WL @ 12hr	0.012	0.122	0.121	1.8	86.9	0.4	1	5	0.196	-0.175	0.015	0.158
WL @ 18hr	0.006	0.135	0.134	2.1	83.8	0.6	1	6	0.195	-0.203	0.014	0.175
WL @ 24hr	0.001	0.139	0.139	2.7	82.2	0.4	1	7	0.196	-0.243	0.010	0.172
High Amp	0.018	0.122	0.121	1.2	86.6	0.8	1	3	n.a.	-0.136	0.009	0.183
Low Amp	0.030	0.098	0.094	0.4	91.1	0.0	0	1	n.a.	-0.139	0.035	0.143
High Time	-2.251	14.641	14.466	0.8	98.4	0.0	0	1	n.a.	-15.710	-1.659	10.867
Low Time	-14.597	19.460	12.869	0.4	90.0	0.0	0	1	n.a.	-34.423	-15.261	4.289
Second Group: Comparison of Forecast Methods												
Method: Astronomical Tidal Predication												
Water Level	0.010	0.163	0.162	2.1	69.0	4.4	70	57	0.000	-0.237	-0.010	0.279
High Amp	-0.187	0.242	0.154	19.9	41.4	0.0	0	14	n.a.	-0.441	-0.183	0.041
Low Amp	-0.217	0.274	0.167	27.3	34.4	0.0	0	16	n.a.	-0.505	-0.204	0.011
High Time	3.148	13.999	13.640	0.0	97.2	0.3	1	0	n.a.	-18.306	3.194	20.138
Low Time	4.121	12.897	12.221	0.1	97.1	0.0	0	1	n.a.	-16.532	3.927	22.517
Method: Persisted Observation Plus Astronomical Prediction												
WL @ 0hr	0.000	0.001	0.001	0.0	100.0	0.0	0	0	0.000	0.000	0.000	0.000
WL @ 6hr	-0.002	0.074	0.074	0.1	95.5	0.1	1	1	0.141	-0.122	-0.003	0.107
WL @ 12hr	0.000	0.096	0.096	1.0	88.3	0.3	1	1	0.141	-0.174	0.000	0.147
WL @ 18hr	-0.002	0.124	0.124	1.3	79.2	1.1	2	1	0.282	-0.211	0.001	0.193
WL @ 24hr	0.000	0.138	0.138	2.3	75.2	1.7	1	2	0.567	-0.242	-0.003	0.218
High Amp	0.015	0.091	0.089	0.4	90.9	0.4	1	1	n.a.	-0.128	0.015	0.152
Low Amp	-0.012	0.094	0.094	0.6	88.9	0.3	1	1	n.a.	-0.177	-0.010	0.130
High Time	3.151	13.997	13.638	0.0	97.2	0.3	1	0	n.a.	-18.306	3.186	20.138
Low Time	4.116	12.926	12.253	0.1	97.1	0.0	0	1	n.a.	-16.677	3.946	22.530

Table A.3. Kiptopeake Beach

	SM	RMSE	SD	NOF	CF	POF	MDPO	MDNO	WOF	5%	median	95%
First Group: Scenarios												
Scenario: Astronomical Tide Only												
Water Level	0.006	0.026	0.025	0.0	100.0	0.0	0	0	0.000	-0.036	0.005	0.047
High Amp	-0.022	0.026	0.014	0.0	100.0	0.0	0	0	n.a.	-0.044	-0.022	0.001
Low Amp	0.030	0.033	0.013	0.0	100.0	0.0	0	0	n.a.	0.008	0.030	0.051
High Time	2.984	5.088	4.122	0.0	100.0	0.0	0	0	n.a.	-4.570	3.199	9.049
Low Time	-6.129	6.810	2.970	0.0	100.0	0.0	0	0	n.a.	-11.277	-5.893	-2.107
Scenario: Test Nowcast												
Water Level	0.000	0.047	0.047	0.0	99.3	0.0	0	0	0.000	-0.073	-0.005	0.080
High Amp	-0.017	0.046	0.042	0.0	99.6	0.0	0	0	n.a.	-0.080	-0.022	0.057
Low Amp	0.016	0.048	0.046	0.0	99.1	0.0	0	0	n.a.	-0.053	0.011	0.092
High Time	3.288	8.368	7.695	0.0	99.0	0.0	0	0	n.a.	-7.736	1.948	15.810
Low Time	-5.026	10.202	8.878	0.0	98.7	0.0	0	0	n.a.	-19.153	-5.398	9.591
Scenario: Semi-Operational Nowcast												
Water Level	-0.009	0.040	0.039	0.0	100.0	0.0	0	1	0.000	-0.072	-0.013	0.050
High Amp	-0.019	0.039	0.035	0.0	100.0	0.0	0	0	n.a.	-0.074	-0.021	0.039
Low Amp	0.001	0.036	0.036	0.0	100.0	0.0	0	0	n.a.	-0.053	0.000	0.070
High Time	5.516	8.273	6.165	0.0	100.0	0.0	0	0	n.a.	-4.309	5.293	17.660
Low Time	-3.924	8.266	7.276	0.0	99.5	0.0	0	0	n.a.	-14.886	-4.312	6.225
Scenario: Test Forecast												
WL @ 0hr	0.000	0.045	0.045	0.0	99.4	0.0	0	0	0.000	-0.069	-0.006	0.075
WL @ 6hr	0.005	0.100	0.099	0.8	88.3	0.4	1	1	0.141	-0.184	0.011	0.138
WL @ 12hr	-0.020	0.117	0.115	2.8	84.7	0.3	1	3	0.142	-0.225	-0.014	0.125
WL @ 18hr	-0.013	0.125	0.125	3.0	81.9	0.4	2	3	0.142	-0.253	0.000	0.152
WL @ 24hr	-0.034	0.135	0.131	4.1	79.9	0.6	2	3	0.000	-0.288	-0.022	0.130
High Amp	-0.011	0.123	0.122	2.6	83.1	1.0	2	3	n.a.	-0.250	-0.002	0.146
Low Amp	-0.011	0.117	0.116	2.7	85.9	0.1	1	3	n.a.	-0.235	0.000	0.137
High Time	2.110	11.219	11.019	0.0	97.9	0.0	0	0	n.a.	-15.565	1.267	20.911
Low Time	-3.860	10.953	10.250	0.0	98.5	0.0	0	0	n.a.	-20.883	-4.319	11.840
Scenario: Semi-Operational Forecast												
WL @ 0hr	-0.008	0.037	0.036	0.0	100.0	0.0	0	0	0.000	-0.065	-0.011	0.056
WL @ 6hr	0.013	0.109	0.109	1.3	88.7	0.5	2	4	0.000	-0.183	0.016	0.145
WL @ 12hr	0.014	0.108	0.107	0.5	85.3	0.5	1	1	0.258	-0.186	0.015	0.169
WL @ 18hr	0.009	0.115	0.115	1.3	82.9	0.5	1	1	0.259	-0.200	0.011	0.180
WL @ 24hr	0.005	0.122	0.122	2.1	83.1	0.5	1	3	0.260	-0.235	0.007	0.183
High Amp	0.030	0.112	0.108	0.5	83.0	0.0	0	1	n.a.	-0.166	0.023	0.205
Low Amp	-0.001	0.102	0.102	2.0	89.3	0.0	0	2	n.a.	-0.195	0.006	0.142
High Time	4.220	9.714	8.750	0.0	99.0	0.0	0	0	n.a.	-7.626	3.509	17.967
Low Time	-4.987	10.106	8.789	0.0	99.5	0.0	0	0	n.a.	-21.348	-3.518	6.745
Second Group: Comparison of Forecast Methods												
Method: Astronomical Tidal Predication												
Water Level	-0.010	0.140	0.139	1.3	75.1	2.4	46	22	0.000	-0.217	-0.031	0.230
High Amp	-0.161	0.210	0.135	15.6	49.0	0.0	0	13	n.a.	-0.400	-0.154	0.037
Low Amp	-0.205	0.247	0.137	22.1	36.2	0.0	0	14	n.a.	-0.455	-0.192	-0.012
High Time	-0.584	11.567	11.552	0.0	98.5	0.1	1	0	n.a.	-19.100	-1.517	17.164
Low Time	-0.428	10.543	10.534	0.0	98.8	0.0	0	0	n.a.	-17.889	-1.090	16.664
Method: Persisted Observation Plus Astronomical Prediction												
WL @ 0hr	0.000	0.000	0.000	0.0	100.0	0.0	0	0	0.000	0.000	0.000	0.000
WL @ 6hr	0.011	0.067	0.066	0.0	97.3	0.3	1	0	0.142	-0.096	0.010	0.106
WL @ 12hr	0.000	0.079	0.079	0.4	94.0	0.0	0	1	0.000	-0.134	0.001	0.114
WL @ 18hr	0.011	0.108	0.108	1.0	85.5	0.7	1	3	0.284	-0.174	0.013	0.176
WL @ 24hr	0.001	0.117	0.117	1.4	82.0	0.6	1	2	0.000	-0.209	0.000	0.189
High Amp	0.030	0.085	0.079	0.1	91.8	0.4	1	1	n.a.	-0.103	0.030	0.153
Low Amp	-0.013	0.077	0.076	0.3	94.4	0.0	0	1	n.a.	-0.147	-0.011	0.106
High Time	-0.574	11.577	11.563	0.0	98.5	0.1	1	0	n.a.	-19.100	-1.509	17.164
Low Time	-0.428	40.358	40.355	0.1	98.5	0.1	1	1	n.a.	-28.296	-8.665	12.720

Table A.4. Gloucester Point

	SM	RMSE	SD	NOF	CF	POF	MDPO	MDNO	WOF	5%	median	95%
First Group: Scenarios												
Scenario: Astronomical Tide Only												
Water Level	0.020	0.052	0.048	0.0	99.9	0.0	0	0	0.000	-0.061	0.018	0.095
High Amp	-0.019	0.033	0.027	0.0	100.0	0.0	0	0	n.a.	-0.067	-0.016	0.021
Low Amp	0.075	0.081	0.030	0.0	99.7	0.0	0	0	n.a.	0.016	0.076	0.122
High Time	9.992	10.757	3.983	0.0	100.0	0.0	0	0	n.a.	4.275	9.913	14.897
Low Time	4.983	8.271	6.602	0.0	100.0	0.0	0	0	n.a.	-5.516	4.571	16.507
Scenario: Test Nowcast												
Water Level	0.000	0.063	0.063	0.0	98.4	0.0	0	0	0.000	-0.101	-0.003	0.098
High Amp	-0.047	0.069	0.050	0.0	98.4	0.0	0	0	n.a.	-0.124	-0.054	0.037
Low Amp	0.059	0.074	0.045	0.0	96.9	0.0	0	0	n.a.	-0.015	0.056	0.136
High Time	9.871	14.575	10.723	0.1	96.3	0.3	1	1	n.a.	-5.683	9.033	25.654
Low Time	4.227	14.727	14.107	0.1	94.7	0.3	1	1	n.a.	-19.857	4.281	23.481
Scenario: Semi-Operational Nowcast												
Water Level	0.000	0.065	0.065	0.1	98.2	0.2	5	2	0.031	-0.101	-0.004	0.087
High Amp	-0.038	0.066	0.054	0.0	98.1	0.4	1	0	n.a.	-0.108	-0.044	0.040
Low Amp	0.053	0.076	0.054	0.0	97.7	0.4	1	0	n.a.	-0.015	0.047	0.115
High Time	9.954	15.227	11.523	0.0	95.4	0.4	1	0	n.a.	-8.191	9.157	26.852
Low Time	2.075	19.947	19.838	1.9	92.2	0.4	1	1	n.a.	-29.542	3.519	18.758
Scenario: Test Forecast												
WL @ 0hr	0.001	0.062	0.062	0.0	98.9	0.0	0	0	0.000	-0.096	0.000	0.096
WL @ 6hr	-0.003	0.096	0.096	0.7	88.0	0.0	0	1	0.000	-0.185	0.003	0.134
WL @ 12hr	-0.015	0.117	0.116	2.7	83.6	0.3	1	2	0.141	-0.235	-0.002	0.144
WL @ 18hr	-0.022	0.131	0.130	3.8	80.6	0.3	1	3	0.000	-0.269	-0.009	0.146
WL @ 24hr	-0.029	0.139	0.136	5.0	78.8	0.3	1	3	0.142	-0.305	-0.015	0.148
High Amp	-0.043	0.127	0.120	3.5	81.6	0.3	1	3	n.a.	-0.264	-0.037	0.118
Low Amp	0.036	0.113	0.107	1.5	83.9	0.3	1	3	n.a.	-0.172	0.047	0.171
High Time	8.455	15.209	12.642	0.1	95.5	0.1	1	1	n.a.	-11.820	8.197	26.985
Low Time	6.225	17.239	16.076	0.0	93.1	0.6	1	0	n.a.	-18.225	3.766	29.670
Scenario: Semi-Operational Forecast												
WL @ 0hr	0.001	0.058	0.058	0.0	99.4	0.0	0	0	0.000	-0.097	0.000	0.087
WL @ 6hr	0.008	0.095	0.095	1.0	93.0	0.4	2	3	0.000	-0.142	0.010	0.123
WL @ 12hr	0.007	0.112	0.112	1.2	87.0	0.2	1	3	0.000	-0.177	0.010	0.152
WL @ 18hr	0.002	0.123	0.123	1.8	84.8	0.4	1	4	0.000	-0.204	0.008	0.169
WL @ 24hr	0.001	0.130	0.130	2.5	82.5	0.2	1	5	0.000	-0.249	0.009	0.184
High Amp	-0.017	0.109	0.108	1.2	88.7	0.0	0	2	n.a.	-0.167	-0.019	0.145
Low Amp	0.046	0.108	0.098	1.2	89.5	0.0	0	3	n.a.	-0.086	0.047	0.177
High Time	5.920	10.931	9.189	0.0	98.8	0.0	0	0	n.a.	-8.245	4.985	19.087
Low Time	0.847	12.856	12.828	0.4	95.0	0.0	0	1	n.a.	-17.425	0.380	16.928
Second Group: Comparison of Forecast Methods												
Method: Astronomical Tidal Predication												
Water Level	-0.003	0.150	0.150	1.8	71.4	3.2	56	42	0.000	-0.224	-0.027	0.251
High Amp	-0.193	0.242	0.145	21.9	41.1	0.0	0	13	n.a.	-0.457	-0.187	0.022
Low Amp	-0.190	0.245	0.154	22.7	43.6	0.0	0	15	n.a.	-0.457	-0.173	0.021
High Time	0.434	12.462	12.454	0.1	97.4	0.0	0	1	n.a.	-20.486	1.102	16.679
Low Time	0.356	15.119	15.114	0.3	95.5	0.3	1	1	n.a.	-21.962	-0.648	20.671
Method: Persisted Observation Plus Astronomical Prediction												
WL @ 0hr	0.000	0.000	0.000	0.0	100.0	0.0	0	0	0.000	0.000	0.000	0.000
WL @ 6hr	0.000	0.072	0.072	0.3	95.6	0.1	1	1	0.141	-0.114	-0.003	0.101
WL @ 12hr	-0.001	0.090	0.090	0.4	90.3	0.3	1	1	0.141	-0.162	-0.003	0.135
WL @ 18hr	0.000	0.115	0.115	1.0	83.3	1.0	1	1	0.282	-0.189	-0.006	0.179
WL @ 24hr	0.000	0.127	0.127	1.4	78.2	1.1	1	2	0.708	-0.219	-0.007	0.198
High Amp	-0.001	0.085	0.085	0.1	92.7	0.3	1	1	n.a.	-0.133	-0.007	0.133
Low Amp	0.005	0.088	0.087	0.3	90.3	0.3	1	2	n.a.	-0.146	0.003	0.152
High Time	0.473	12.499	12.490	0.1	97.2	0.0	0	1	n.a.	-20.486	1.102	16.704
Low Time	0.367	15.137	15.133	0.1	95.5	0.3	1	1	n.a.	-21.973	-0.640	20.797

Table A.5. Lewisetta

	SM	RMSE	SD	NOF	CF	POF	MDPO	MDNO	WOF	5%	median	95%
First Group: Scenarios												
Scenario: Astronomical Tide Only												
Water Level	0.026	0.049	0.042	0.0	100.0	0.0	0	0	0.000	-0.048	0.027	0.089
High Amp	0.003	0.036	0.036	0.0	100.0	0.0	0	0	n.a.	-0.064	0.008	0.056
Low Amp	0.059	0.069	0.035	0.0	100.0	0.0	0	0	n.a.	0.000	0.067	0.109
High Time	-10.356	11.408	4.783	0.0	100.0	0.0	0	0	n.a.	-18.865	-10.231	-2.954
Low Time	-6.731	10.003	7.400	0.0	99.4	0.0	0	0	n.a.	-19.276	-6.803	4.761
Scenario: Test Nowcast												
Water Level	0.000	0.069	0.069	0.0	96.5	0.0	0	0	0.000	-0.109	-0.006	0.122
High Amp	-0.016	0.076	0.074	0.0	94.8	0.0	0	0	n.a.	-0.123	-0.029	0.130
Low Amp	0.025	0.064	0.059	0.0	97.3	0.0	0	0	n.a.	-0.075	0.021	0.128
High Time	-11.112	20.799	17.582	1.3	88.4	0.4	1	1	n.a.	-37.486	-11.557	14.528
Low Time	-8.493	21.151	19.371	1.3	88.5	0.1	1	2	n.a.	-41.529	-8.860	18.533
Scenario: Semi-Operational Nowcast												
Water Level	0.007	0.069	0.069	0.2	96.9	0.0	0	6	0.000	-0.093	-0.001	0.117
High Amp	-0.010	0.070	0.070	0.0	97.8	0.0	0	0	n.a.	-0.108	-0.019	0.117
Low Amp	0.034	0.069	0.060	0.0	95.6	0.0	0	0	n.a.	-0.058	0.026	0.139
High Time	-9.760	22.532	20.309	0.9	90.6	1.3	1	1	n.a.	-32.644	-12.083	15.606
Low Time	-8.191	23.310	21.824	1.3	83.6	1.3	2	1	n.a.	-45.083	-8.251	25.699
Scenario: Test Forecast												
WL @ 0hr	0.003	0.067	0.067	0.0	96.0	0.0	0	0	0.000	-0.099	-0.006	0.130
WL @ 6hr	-0.007	0.063	0.062	0.0	98.1	0.0	0	0	0.000	-0.112	-0.006	0.095
WL @ 12hr	-0.008	0.080	0.080	0.1	93.5	0.0	0	1	0.000	-0.147	-0.007	0.111
WL @ 18hr	-0.026	0.100	0.096	1.3	88.2	0.0	0	2	0.000	-0.191	-0.021	0.114
WL @ 24hr	-0.020	0.112	0.111	1.7	83.9	0.1	1	3	0.000	-0.224	-0.015	0.126
High Amp	-0.027	0.091	0.087	0.4	91.2	0.0	0	1	n.a.	-0.169	-0.030	0.109
Low Amp	0.006	0.080	0.080	0.9	94.2	0.0	0	2	n.a.	-0.131	0.010	0.112
High Time	-12.143	21.614	17.881	1.6	87.6	0.0	0	2	n.a.	-45.408	-11.021	9.143
Low Time	-6.899	20.244	19.032	1.2	89.1	0.1	1	1	n.a.	-40.403	-6.490	18.131
Scenario: Semi-Operational Forecast												
WL @ 0hr	0.008	0.066	0.065	0.0	97.9	0.0	0	0	0.000	-0.094	-0.001	0.118
WL @ 6hr	0.008	0.076	0.075	0.0	94.2	0.0	0	0	0.000	-0.112	-0.002	0.143
WL @ 12hr	0.011	0.096	0.095	0.9	89.9	0.4	1	2	0.000	-0.141	0.009	0.161
WL @ 18hr	0.013	0.108	0.107	1.1	85.8	0.4	1	3	0.000	-0.167	0.016	0.173
WL @ 24hr	0.011	0.121	0.121	1.7	81.9	0.9	1	4	0.215	-0.200	0.013	0.211
High Amp	-0.003	0.090	0.090	0.4	92.5	0.4	1	1	n.a.	-0.122	-0.013	0.151
Low Amp	0.029	0.087	0.082	0.4	90.4	0.0	0	1	n.a.	-0.089	0.023	0.158
High Time	-8.860	16.414	13.818	0.0	95.6	0.4	1	0	n.a.	-28.535	-9.884	12.340
Low Time	-9.062	17.766	15.281	0.9	92.1	0.4	1	1	n.a.	-35.570	-7.217	5.345
Second Group: Comparison of Forecast Methods												
Method: Astronomical Tidal Predication												
Water Level	-0.003	0.151	0.151	2.2	68.8	2.7	43	30	0.000	-0.246	-0.023	0.246
High Amp	-0.185	0.240	0.153	21.4	40.6	0.1	1	13	n.a.	-0.454	-0.181	0.066
Low Amp	-0.198	0.247	0.148	23.1	39.7	0.1	1	14	n.a.	-0.459	-0.185	0.022
High Time	-1.412	20.117	20.067	0.7	87.9	1.0	1	1	n.a.	-35.603	-2.207	28.270
Low Time	-2.379	23.084	22.961	1.9	85.7	0.7	1	2	n.a.	-42.653	-2.457	26.673
Method: Persisted Observation Plus Astronomical Prediction												
WL @ 0hr	0.000	0.001	0.001	0.0	100.0	0.0	0	0	0.000	0.000	0.000	0.000
WL @ 6hr	-0.009	0.063	0.063	0.0	95.8	0.3	1	0	0.288	-0.107	-0.014	0.095
WL @ 12hr	-0.001	0.098	0.098	0.4	88.2	0.6	1	2	0.144	-0.155	-0.010	0.174
WL @ 18hr	-0.010	0.134	0.134	1.6	77.4	2.6	2	2	1.297	-0.218	-0.019	0.202
WL @ 24hr	-0.001	0.151	0.151	1.9	73.0	3.3	3	3	2.023	-0.254	-0.006	0.251
High Amp	-0.001	0.106	0.106	0.3	86.1	1.5	1	1	n.a.	-0.169	-0.015	0.194
Low Amp	-0.012	0.103	0.102	1.2	87.6	0.7	1	2	n.a.	-0.168	-0.017	0.154
High Time	-1.434	20.059	20.008	0.7	87.9	1.0	1	1	n.a.	-36.248	-2.200	28.310
Low Time	-1.319	36.606	36.582	1.9	85.6	0.9	1	2	n.a.	-46.570	-5.216	24.873

Table A.6. Colonial Beach

	SM	RMSE	SD	NOF	CF	POF	MDPO	MDNO	WOF	5%	median	95%
First Group: Scenarios												
Scenario: Astronomical Tide Only												
Water Level	0.029	0.077	0.071	0.0	96.6	0.0	0	0	0.000	-0.097	0.026	0.141
High Amp	-0.037	0.058	0.045	0.0	100.0	0.0	0	0	n.a.	-0.117	-0.031	0.027
Low Amp	0.099	0.109	0.046	0.0	88.5	0.0	0	0	n.a.	0.015	0.106	0.161
High Time	22.319	22.870	4.987	0.0	94.2	0.0	0	0	n.a.	14.400	21.954	30.140
Low Time	15.592	16.492	5.374	0.0	99.9	0.0	0	0	n.a.	7.214	15.427	23.705
Scenario: Test Nowcast												
Water Level	0.000	0.097	0.097	0.0	88.7	0.4	13	1	0.175	-0.150	-0.008	0.166
High Amp	-0.057	0.106	0.089	0.0	88.0	0.4	1	0	n.a.	-0.171	-0.077	0.118
Low Amp	0.063	0.097	0.074	0.0	88.2	0.4	1	0	n.a.	-0.049	0.053	0.194
High Time	20.550	25.239	14.652	0.2	80.2	0.9	1	1	n.a.	-0.325	19.582	42.426
Low Time	11.838	20.276	16.461	0.2	88.5	0.7	1	1	n.a.	-16.938	11.664	34.986
Scenario: Semi-Operational Nowcast												
Water Level	0.003	0.097	0.097	0.3	88.7	0.1	3	7	0.000	-0.148	-0.005	0.166
High Amp	-0.054	0.107	0.092	0.4	89.3	0.4	0	1	n.a.	-0.168	-0.075	0.123
Low Amp	0.067	0.098	0.072	0.0	86.7	0.4	1	0	n.a.	-0.052	0.056	0.199
High Time	21.966	29.101	19.089	0.8	75.1	3.1	1	1	n.a.	-0.515	20.435	45.197
Low Time	10.999	20.901	17.773	0.4	88.2	0.8	1	1	n.a.	-19.723	10.525	40.896
Scenario: Test Forecast												
WL @ 0hr	-0.007	0.094	0.093	0.0	88.4	0.4	2	0	0.211	-0.153	-0.014	0.165
WL @ 6hr	0.000	0.089	0.089	0.0	92.8	0.2	1	0	0.211	-0.144	-0.002	0.143
WL @ 12hr	-0.004	0.082	0.082	0.0	93.9	0.0	0	0	0.000	-0.138	0.000	0.120
WL @ 18hr	0.001	0.096	0.096	0.0	88.2	0.2	1	0	0.000	-0.164	0.004	0.150
WL @ 24hr	-0.007	0.101	0.101	0.6	85.7	0.0	0	2	0.000	-0.182	-0.002	0.147
High Amp	-0.047	0.095	0.082	0.2	89.5	0.2	1	1	n.a.	-0.168	-0.057	0.094
Low Amp	0.059	0.091	0.070	0.0	91.3	0.0	0	0	n.a.	-0.057	0.051	0.172
High Time	17.040	23.282	15.865	0.0	83.4	0.9	1	0	n.a.	-5.842	16.353	42.888
Low Time	9.258	17.986	15.421	0.2	91.3	0.4	1	1	n.a.	-12.508	7.205	37.198
Scenario: Semi-Operational Forecast												
WL @ 0hr	0.003	0.092	0.092	0.0	89.2	0.0	0	0	0.000	-0.149	-0.005	0.166
WL @ 6hr	0.005	0.103	0.102	0.4	86.3	0.4	1	2	0.193	-0.154	-0.005	0.182
WL @ 12hr	0.008	0.112	0.112	0.8	82.4	0.2	1	2	0.000	-0.170	0.004	0.196
WL @ 18hr	0.012	0.125	0.125	0.8	78.1	1.2	3	1	0.971	-0.207	0.009	0.217
WL @ 24hr	0.010	0.138	0.138	2.5	75.9	2.3	4	3	1.751	-0.239	0.006	0.238
High Amp	-0.037	0.123	0.118	1.1	81.1	1.5	3	2	n.a.	-0.195	-0.057	0.169
Low Amp	0.068	0.112	0.089	0.4	81.7	1.2	2	1	n.a.	-0.066	0.057	0.225
High Time	14.854	18.879	11.652	0.0	90.9	0.0	0	0	n.a.	-4.657	14.705	33.123
Low Time	4.597	11.284	10.306	0.0	97.7	0.0	0	0	n.a.	-10.264	2.541	23.053
Second Group: Comparison of Forecast Methods												
Method: Astronomical Tidal Predication												
Water Level	-0.004	0.148	0.148	2.5	73.0	2.6	33	23	0.000	-0.242	-0.021	0.257
High Amp	-0.186	0.237	0.147	20.0	39.9	0.2	1	14	n.a.	-0.450	-0.184	0.063
Low Amp	-0.196	0.246	0.149	20.5	39.7	0.0	0	14	n.a.	-0.475	-0.185	0.019
High Time	0.098	15.320	15.320	0.2	95.2	0.2	1	1	n.a.	-23.228	-0.715	22.279
Low Time	-1.969	18.347	18.241	0.9	91.7	0.4	1	2	n.a.	-34.009	-1.787	22.241
Method: Persisted Observation Plus Astronomical Prediction												
WL @ 0hr	0.000	0.000	0.000	0.0	100.0	0.0	0	0	0.000	0.000	0.000	0.000
WL @ 6hr	-0.005	0.068	0.068	0.4	96.0	0.0	0	1	0.000	-0.109	-0.007	0.095
WL @ 12hr	0.000	0.100	0.100	0.4	87.9	1.3	1	1	0.423	-0.157	-0.007	0.165
WL @ 18hr	-0.005	0.128	0.128	0.8	79.1	2.3	2	1	1.268	-0.216	-0.011	0.207
WL @ 24hr	0.000	0.150	0.150	1.5	71.8	3.4	2	1	2.123	-0.249	-0.009	0.222
High Amp	0.001	0.097	0.097	0.2	88.6	1.1	1	1	n.a.	-0.149	-0.011	0.179
Low Amp	-0.010	0.097	0.097	0.4	88.2	1.1	1	1	n.a.	-0.193	-0.008	0.130
High Time	0.021	15.319	15.319	0.2	95.2	0.2	1	1	n.a.	-23.668	-0.764	21.803
Low Time	-2.122	18.192	18.067	0.9	91.7	0.4	1	2	n.a.	-33.634	-2.054	21.589

Table A.7. Solomons Island

	SM	RMSE	SD	NOF	CF	POF	MDPO	MDNO	WOF	5%	median	95%
First Group: Scenarios												
Scenario: Astronomical Tide Only												
Water Level	0.028	0.058	0.051	0.0	99.8	0.0	0	0	0.000	-0.064	0.027	0.106
High Amp	0.018	0.046	0.043	0.0	100.0	0.0	0	0	n.a.	-0.056	0.019	0.086
Low Amp	0.052	0.064	0.037	0.0	100.0	0.0	0	0	n.a.	-0.016	0.059	0.100
High Time	-33.866	35.069	9.108	1.2	39.0	0.0	0	1	n.a.	-51.577	-32.526	-21.805
Low Time	-25.947	27.793	9.960	0.0	68.6	0.0	0	0	n.a.	-43.010	-26.171	-10.719
Scenario: Test Nowcast												
Water Level	0.000	0.085	0.085	0.0	92.3	0.1	4	0	0.047	-0.132	-0.008	0.149
High Amp	-0.004	0.087	0.087	0.0	92.0	0.1	1	0	n.a.	-0.133	-0.019	0.161
Low Amp	0.020	0.073	0.071	0.0	95.0	0.0	0	0	n.a.	-0.093	0.013	0.140
High Time	-34.283	40.503	21.568	7.2	34.6	0.7	1	2	n.a.	-65.380	-35.861	-4.260
Low Time	-30.340	37.653	22.299	7.7	46.9	0.1	1	3	n.a.	-66.591	-31.635	2.862
Scenario: Semi-Operational Nowcast												
Water Level	0.005	0.083	0.082	0.2	93.6	0.2	4	7	0.000	-0.120	-0.006	0.144
High Amp	0.002	0.083	0.083	0.0	92.6	0.0	0	0	n.a.	-0.121	-0.011	0.157
Low Amp	0.024	0.072	0.068	0.0	94.9	0.0	0	0	n.a.	-0.076	0.016	0.138
High Time	-34.804	41.642	22.863	7.4	36.6	0.8	1	3	n.a.	-68.116	-35.629	-3.684
Low Time	-29.143	38.140	24.604	8.2	53.9	0.4	1	2	n.a.	-65.915	-29.142	4.305
Scenario: Test Forecast												
WL @ 0hr	0.008	0.089	0.089	0.0	90.8	0.0	0	0	0.000	-0.131	-0.004	0.165
WL @ 6hr	-0.012	0.074	0.073	0.0	95.8	0.0	0	0	0.000	-0.128	-0.015	0.104
WL @ 12hr	-0.003	0.087	0.087	0.0	91.7	0.1	1	0	0.000	-0.147	-0.004	0.140
WL @ 18hr	-0.031	0.101	0.096	1.1	88.4	0.0	0	2	0.000	-0.199	-0.028	0.112
WL @ 24hr	-0.016	0.118	0.117	1.6	81.6	0.3	1	3	0.000	-0.215	-0.015	0.153
High Amp	-0.013	0.090	0.089	0.1	91.1	0.1	1	1	n.a.	-0.154	-0.017	0.135
Low Amp	-0.001	0.076	0.076	0.6	95.5	0.0	0	1	n.a.	-0.127	0.001	0.106
High Time	-34.159	39.028	18.877	6.4	38.5	0.1	1	2	n.a.	-63.791	-35.191	-3.675
Low Time	-26.722	34.191	21.330	6.4	57.2	0.1	1	3	n.a.	-64.706	-27.375	5.853
Scenario: Semi-Operational Forecast												
WL @ 0hr	0.008	0.081	0.081	0.0	93.2	0.2	1	0	0.000	-0.111	-0.004	0.150
WL @ 6hr	0.004	0.092	0.092	0.0	90.1	0.4	1	0	0.000	-0.126	-0.008	0.166
WL @ 12hr	0.010	0.108	0.108	0.6	84.0	0.6	1	2	0.195	-0.172	0.000	0.200
WL @ 18hr	0.012	0.120	0.120	0.8	80.2	0.6	1	2	0.196	-0.188	0.006	0.220
WL @ 24hr	0.012	0.135	0.134	1.8	75.1	1.8	3	2	0.588	-0.214	0.003	0.240
High Amp	0.008	0.106	0.106	0.4	87.5	0.4	1	1	n.a.	-0.118	-0.013	0.185
Low Amp	0.019	0.086	0.084	0.0	90.7	0.0	0	0	n.a.	-0.129	0.017	0.154
High Time	-28.306	34.494	19.713	4.7	56.0	0.0	0	2	n.a.	-59.138	-28.968	1.163
Low Time	-23.483	31.006	20.247	2.7	64.9	0.8	2	1	n.a.	-56.922	-24.441	2.624
Second Group: Comparison of Forecast Methods												
Method: Astronomical Tidal Predication												
Water Level	-0.003	0.157	0.157	3.4	68.5	2.4	35	32	0.000	-0.267	-0.018	0.250
High Amp	-0.188	0.247	0.160	23.4	37.4	0.4	3	13	n.a.	-0.454	-0.190	0.079
Low Amp	-0.194	0.246	0.151	23.4	40.6	0.3	2	13	n.a.	-0.458	-0.185	0.032
High Time	-0.060	22.142	22.142	0.6	87.3	1.5	2	1	n.a.	-33.286	-1.641	33.928
Low Time	-3.163	26.418	26.228	2.8	81.9	1.3	1	2	n.a.	-48.013	-3.847	38.295
Method: Persisted Observation Plus Astronomical Prediction												
WL @ 0hr	0.000	0.000	0.000	0.0	100.0	0.0	0	0	0.000	0.000	0.000	0.000
WL @ 6hr	-0.007	0.071	0.071	0.1	95.5	0.3	2	1	0.141	-0.116	-0.012	0.100
WL @ 12hr	-0.001	0.117	0.117	0.8	83.1	1.7	1	2	0.847	-0.186	-0.008	0.200
WL @ 18hr	-0.008	0.155	0.155	2.8	72.0	3.4	2	2	1.836	-0.250	-0.013	0.229
WL @ 24hr	0.000	0.176	0.176	4.1	68.1	4.8	3	3	2.975	-0.290	-0.014	0.290
High Amp	-0.003	0.122	0.122	0.7	83.3	2.5	2	1	n.a.	-0.192	-0.019	0.204
Low Amp	-0.006	0.119	0.119	1.5	83.2	1.2	1	1	n.a.	-0.204	-0.009	0.189
High Time	0.002	22.103	22.103	0.6	87.3	1.5	2	1	n.a.	-33.300	-1.608	33.943
Low Time	-3.171	26.426	26.235	2.8	81.9	1.3	1	2	n.a.	-48.013	-3.851	38.295

Table A.8. Cambridge

	SM	RMSE	SD	NOF	CF	POF	MDPO	MDNO	WOF	5%	median	95%
First Group: Scenarios												
Scenario: Astronomical Tide Only												
Water Level	0.029	0.090	0.086	0.0	91.4	0.0	0	0	0.000	-0.110	0.023	0.161
High Amp	-0.026	0.047	0.039	0.0	100.0	0.0	0	0	n.a.	-0.095	-0.020	0.033
Low Amp	0.096	0.104	0.040	0.0	95.3	0.0	0	0	n.a.	0.020	0.104	0.149
High Time	-45.406	45.963	7.130	3.1	0.3	0.0	0	3	n.a.	-57.807	-45.307	-34.835
Low Time	-49.914	50.279	6.045	5.8	0.0	0.0	0	5	n.a.	-60.965	-49.169	-41.580
Scenario: Test Nowcast												
Water Level	0.000	0.112	0.112	0.1	82.4	0.5	5	4	0.091	-0.175	-0.008	0.180
High Amp	-0.056	0.104	0.088	0.0	87.8	0.0	0	0	n.a.	-0.182	-0.074	0.110
Low Amp	0.070	0.099	0.070	0.0	88.0	0.0	0	0	n.a.	-0.038	0.068	0.185
High Time	-47.391	50.083	16.198	14.9	8.6	0.0	0	3	n.a.	-72.028	-48.007	-23.359
Low Time	-54.387	57.850	19.716	34.3	8.1	0.0	0	6	n.a.	-90.823	-54.635	-21.038
Scenario: Semi-Operational Nowcast												
Water Level	-0.001	0.113	0.113	0.3	83.4	0.7	5	8	0.525	-0.174	-0.009	0.181
High Amp	-0.052	0.106	0.093	0.4	84.6	0.0	0	1	n.a.	-0.180	-0.070	0.102
Low Amp	0.066	0.102	0.078	0.0	88.4	0.8	1	0	n.a.	-0.058	0.063	0.194
High Time	-45.210	51.309	24.263	18.8	14.6	0.4	1	3	n.a.	-83.319	-46.020	-10.155
Low Time	-53.534	59.762	26.562	34.0	14.7	0.0	0	4	n.a.	-94.270	-52.214	-19.859
Scenario: Test Forecast												
WL @ 0hr	0.011	0.118	0.118	0.0	79.0	0.4	0	0	0.219	-0.182	0.006	0.203
WL @ 6hr	-0.017	0.102	0.101	0.2	86.7	0.0	0	1	0.000	-0.168	-0.029	0.153
WL @ 12hr	0.016	0.119	0.117	0.0	79.7	0.7	1	0	0.437	-0.180	0.012	0.213
WL @ 18hr	-0.013	0.113	0.113	0.4	81.5	0.2	1	2	0.000	-0.198	-0.017	0.167
WL @ 24hr	0.015	0.136	0.136	1.1	71.6	1.3	2	2	0.437	-0.211	0.009	0.241
High Amp	-0.056	0.107	0.090	0.7	86.0	0.2	1	2	n.a.	-0.188	-0.068	0.098
Low Amp	0.060	0.095	0.073	0.0	88.3	0.2	1	0	n.a.	-0.064	0.056	0.186
High Time	-46.795	50.434	18.809	17.4	13.5	0.0	0	5	n.a.	-76.578	-46.881	-20.694
Low Time	-53.157	58.038	23.298	35.7	12.0	0.2	1	9	n.a.	-90.095	-55.047	-17.280
Scenario: Semi-Operational Forecast												
WL @ 0hr	0.003	0.110	0.109	0.0	84.9	0.8	1	0	0.386	-0.158	-0.009	0.181
WL @ 6hr	0.001	0.122	0.122	0.2	79.5	1.5	2	1	0.965	-0.176	-0.016	0.200
WL @ 12hr	0.007	0.139	0.139	1.4	71.6	1.7	1	2	0.967	-0.207	-0.013	0.248
WL @ 18hr	0.009	0.147	0.147	1.6	70.0	2.5	3	2	2.132	-0.225	-0.004	0.256
WL @ 24hr	0.010	0.160	0.159	2.5	67.8	4.1	3	1	3.495	-0.242	0.001	0.282
High Amp	-0.050	0.124	0.113	1.5	79.5	0.4	1	1	n.a.	-0.212	-0.065	0.150
Low Amp	0.057	0.116	0.101	0.0	82.7	1.5	2	0	n.a.	-0.118	0.055	0.223
High Time	-36.483	41.811	20.424	9.5	34.5	0.0	0	3	n.a.	-69.608	-37.885	-2.691
Low Time	-42.663	48.210	22.451	20.8	26.5	0.0	0	4	n.a.	-80.792	-44.594	-2.669
Second Group: Comparison of Forecast Methods												
Method: Astronomical Tidal Predication												
Water Level	-0.002	0.138	0.138	1.6	75.5	2.3	31	19	0.000	-0.216	-0.019	0.236
High Amp	-0.197	0.240	0.136	19.4	34.5	0.2	1	12	n.a.	-0.440	-0.196	0.016
Low Amp	-0.187	0.233	0.138	19.0	40.9	0.0	0	11	n.a.	-0.446	-0.176	0.013
High Time	1.206	18.438	18.399	0.5	90.1	0.7	1	1	n.a.	-28.501	0.654	30.103
Low Time	-2.214	24.651	24.552	2.9	85.6	0.7	1	2	n.a.	-45.495	-1.947	29.112
Method: Persisted Observation Plus Astronomical Prediction												
WL @ 0hr	0.000	0.000	0.000	0.0	100.0	0.0	0	0	0.000	0.000	0.000	0.000
WL @ 6hr	0.004	0.076	0.076	0.0	95.0	0.2	1	0	0.219	-0.120	0.001	0.115
WL @ 12hr	-0.001	0.114	0.114	0.7	84.5	1.5	1	1	1.313	-0.191	-0.009	0.181
WL @ 18hr	0.004	0.141	0.141	2.0	76.8	2.6	2	2	1.751	-0.233	0.000	0.235
WL @ 24hr	0.000	0.155	0.155	2.2	72.6	3.3	2	2	2.632	-0.259	-0.010	0.259
High Amp	0.000	0.110	0.110	0.0	86.6	2.0	1	0	n.a.	-0.166	-0.012	0.163
Low Amp	0.009	0.106	0.106	0.9	86.6	1.4	1	1	n.a.	-0.189	0.010	0.182
High Time	1.218	18.549	18.509	0.5	89.8	0.7	1	1	n.a.	-29.214	0.581	31.515
Low Time	-2.368	24.675	24.561	2.9	85.7	0.7	1	2	n.a.	-45.617	-2.019	28.746

Table A.9. Annapolis

	SM	RMSE	SD	NOF	CF	POF	MDPO	MDNO	WOF	5%	median	95%
First Group: Scenarios												
Scenario: Astronomical Tide Only												
Water Level	0.029	0.061	0.053	0.0	99.9	0.0	0	0	0.000	-0.068	0.036	0.107
High Amp	0.021	0.054	0.049	0.0	100.0	0.0	0	0	n.a.	-0.076	0.031	0.088
Low Amp	0.041	0.063	0.048	0.0	100.0	0.0	0	0	n.a.	-0.044	0.046	0.108
High Time	-20.570	24.073	12.507	0.0	77.0	0.0	0	0	n.a.	-39.961	-21.848	0.171
Low Time	-19.636	21.160	7.886	0.0	89.5	0.0	0	0	n.a.	-33.655	-19.309	-8.647
Scenario: Test Nowcast												
Water Level	0.000	0.093	0.093	0.0	89.5	0.5	16	3	0.294	-0.147	-0.010	0.160
High Amp	-0.010	0.097	0.096	0.0	88.3	0.9	2	0	n.a.	-0.157	-0.025	0.160
Low Amp	0.016	0.088	0.086	0.0	91.5	0.4	1	0	n.a.	-0.126	0.012	0.153
High Time	-22.828	33.802	24.929	4.4	60.4	0.6	2	2	n.a.	-60.522	-25.436	15.855
Low Time	-22.886	34.707	26.092	6.7	63.6	0.6	1	2	n.a.	-68.709	-23.302	14.503
Scenario: Semi-Operational Nowcast												
Water Level	0.016	0.095	0.094	0.2	88.5	0.5	8	8	0.278	-0.117	-0.001	0.182
High Amp	0.002	0.096	0.096	0.4	87.3	0.4	1	1	n.a.	-0.129	-0.018	0.180
Low Amp	0.034	0.094	0.088	0.4	89.6	0.4	1	1	n.a.	-0.095	0.023	0.187
High Time	-22.255	34.755	26.695	4.2	61.0	1.2	1	2	n.a.	-60.441	-23.481	14.198
Low Time	-23.613	37.620	29.287	9.3	63.3	1.2	1	2	n.a.	-73.189	-23.134	20.446
Scenario: Test Forecast												
WL @ 0hr	0.000	0.094	0.094	0.0	89.1	0.3	1	0	0.141	-0.150	-0.012	0.157
WL @ 6hr	-0.005	0.088	0.087	0.0	90.4	0.0	0	0	0.000	-0.144	-0.013	0.151
WL @ 12hr	-0.010	0.086	0.086	0.1	92.9	0.4	1	1	0.282	-0.146	-0.017	0.120
WL @ 18hr	-0.020	0.102	0.100	0.7	87.0	0.4	1	1	0.141	-0.192	-0.018	0.123
WL @ 24hr	-0.026	0.120	0.117	1.6	82.0	1.0	2	2	0.283	-0.223	-0.031	0.148
High Amp	-0.013	0.091	0.090	0.0	91.8	0.3	1	0	n.a.	-0.149	-0.026	0.131
Low Amp	-0.008	0.083	0.083	0.1	92.1	0.0	0	1	n.a.	-0.154	-0.009	0.124
High Time	-23.198	34.746	25.867	6.6	62.7	0.1	1	3	n.a.	-65.005	-23.832	13.189
Low Time	-17.605	31.732	26.401	4.8	69.3	0.9	1	2	n.a.	-61.073	-18.659	22.830
Scenario: Semi-Operational Forecast												
WL @ 0hr	0.020	0.095	0.093	0.0	87.6	0.2	1	0	0.193	-0.112	0.003	0.194
WL @ 6hr	0.015	0.113	0.112	0.2	83.4	1.7	2	1	0.772	-0.143	-0.002	0.228
WL @ 12hr	0.017	0.124	0.123	0.6	79.3	2.5	3	2	1.934	-0.170	0.005	0.222
WL @ 18hr	0.024	0.138	0.136	1.4	77.1	3.9	7	2	2.907	-0.188	0.016	0.256
WL @ 24hr	0.025	0.150	0.148	1.9	74.8	4.3	5	3	3.301	-0.197	0.017	0.273
High Amp	0.012	0.117	0.117	0.8	81.7	1.9	2	1	n.a.	-0.154	-0.006	0.225
Low Amp	0.030	0.115	0.111	1.2	84.9	2.3	1	1	n.a.	-0.119	0.020	0.199
High Time	-15.871	26.828	21.630	1.9	74.1	1.1	1	1	n.a.	-51.648	-15.126	11.438
Low Time	-16.891	27.099	21.191	3.9	80.6	0.0	0	1	n.a.	-57.945	-15.708	7.369
Second Group: Comparison of Forecast Methods												
Method: Astronomical Tidal Predication												
Water Level	-0.005	0.179	0.179	4.7	64.3	4.0	41	36	0.000	-0.303	-0.012	0.274
High Amp	-0.191	0.263	0.180	25.1	34.5	0.9	2	12	n.a.	-0.487	-0.203	0.106
Low Amp	-0.186	0.257	0.177	26.2	38.7	0.7	3	11	n.a.	-0.485	-0.193	0.087
High Time	-0.414	32.527	32.524	3.5	75.4	3.4	2	2	n.a.	-55.830	-2.337	47.445
Low Time	-1.407	34.180	34.151	5.1	72.7	2.9	2	2	n.a.	-62.921	-0.542	47.353
Method: Persisted Observation Plus Astronomical Prediction												
WL @ 0hr	0.000	0.000	0.000	0.0	100.0	0.0	0	0	0.000	0.000	0.000	0.000
WL @ 6hr	0.007	0.090	0.089	0.7	90.3	0.6	1	2	0.141	-0.130	0.004	0.156
WL @ 12hr	-0.001	0.153	0.153	3.1	73.9	4.0	3	2	2.119	-0.261	-0.008	0.265
WL @ 18hr	0.006	0.198	0.198	5.2	62.9	6.5	2	2	3.955	-0.318	-0.002	0.337
WL @ 24hr	0.000	0.225	0.225	7.5	60.8	8.9	3	3	5.807	-0.373	-0.017	0.375
High Amp	0.001	0.158	0.158	3.2	74.1	3.4	2	2	n.a.	-0.264	-0.011	0.244
Low Amp	0.006	0.157	0.156	2.6	77.2	3.7	2	2	n.a.	-0.233	0.002	0.255
High Time	-0.365	32.521	32.519	3.5	75.5	3.4	2	2	n.a.	-55.844	-2.320	47.475
Low Time	-1.339	34.179	34.152	5.1	72.8	2.9	2	2	n.a.	-63.002	-0.420	47.386

Table A.10. Baltimore Harbor

	SM	RMSE	SD	NOF	CF	POF	MDPO	MDNO	WOF	5%	median	95%
First Group: Scenarios												
Scenario: Astronomical Tide Only												
Water Level	0.035	0.077	0.068	0.0	98.8	0.0	0	0	0.000	-0.091	0.049	0.123
High Amp	0.034	0.074	0.066	0.0	100.0	0.0	0	0	n.a.	-0.094	0.055	0.114
Low Amp	0.042	0.075	0.062	0.0	100.0	0.0	0	0	n.a.	-0.074	0.063	0.117
High Time	-27.299	29.410	10.943	0.3	58.6	0.0	0	1	n.a.	-44.048	-27.536	-9.355
Low Time	-14.827	18.598	11.227	0.0	91.4	0.0	0	0	n.a.	-36.717	-15.265	1.922
Scenario: Test Nowcast												
Water Level	0.000	0.097	0.097	0.1	87.9	0.4	7	4	0.216	-0.155	-0.009	0.170
High Amp	-0.007	0.101	0.101	0.0	86.2	0.6	1	0	n.a.	-0.157	-0.025	0.186
Low Amp	0.015	0.091	0.090	0.2	89.1	0.2	1	1	n.a.	-0.149	0.013	0.159
High Time	-14.079	33.351	30.234	5.2	71.8	1.7	2	2	n.a.	-63.171	-15.315	29.689
Low Time	-16.336	45.077	42.013	11.2	49.4	3.5	2	2	n.a.	-81.701	-19.713	52.281
Scenario: Semi-Operational Nowcast												
Water Level	0.013	0.098	0.097	0.2	88.2	0.7	8	7	0.309	-0.125	-0.004	0.190
High Amp	0.002	0.106	0.106	0.4	85.7	1.2	1	1	n.a.	-0.139	-0.017	0.198
Low Amp	0.029	0.090	0.085	0.0	91.6	0.8	1	0	n.a.	-0.110	0.018	0.173
High Time	-13.790	34.330	31.438	5.0	67.6	2.7	1	1	n.a.	-62.486	-16.474	33.438
Low Time	-11.805	42.134	40.447	8.4	60.5	4.6	2	2	n.a.	-79.487	-15.399	56.885
Scenario: Test Forecast												
WL @ 0hr	-0.005	0.099	0.099	0.5	88.3	0.3	1	1	0.000	-0.157	-0.016	0.169
WL @ 6hr	0.004	0.105	0.105	0.0	83.1	0.6	2	0	0.610	-0.168	-0.005	0.190
WL @ 12hr	-0.014	0.100	0.099	0.5	87.2	0.3	1	1	0.305	-0.172	-0.020	0.145
WL @ 18hr	-0.010	0.108	0.107	0.6	85.9	1.1	1	1	0.459	-0.199	-0.016	0.154
WL @ 24hr	-0.032	0.126	0.121	1.7	80.1	1.4	2	2	0.613	-0.237	-0.037	0.148
High Amp	-0.013	0.105	0.104	0.5	86.2	0.5	1	1	n.a.	-0.172	-0.029	0.169
Low Amp	0.001	0.095	0.095	0.5	88.8	0.2	1	1	n.a.	-0.164	0.003	0.144
High Time	-13.639	28.332	24.833	3.0	78.0	1.1	1	2	n.a.	-55.147	-14.025	20.887
Low Time	-11.314	35.589	33.743	7.3	64.2	2.5	2	2	n.a.	-69.938	-10.827	44.008
Scenario: Semi-Operational Forecast												
WL @ 0hr	0.019	0.105	0.103	0.2	85.5	0.8	1	1	0.386	-0.133	0.000	0.203
WL @ 6hr	0.012	0.123	0.122	0.6	80.7	1.9	2	2	1.351	-0.160	-0.009	0.245
WL @ 12hr	0.009	0.133	0.133	0.6	77.0	2.7	3	2	1.741	-0.189	-0.006	0.237
WL @ 18hr	0.018	0.147	0.146	1.4	73.6	3.9	9	2	2.713	-0.203	0.006	0.272
WL @ 24hr	0.023	0.157	0.155	2.5	73.4	4.9	5	4	3.689	-0.212	0.012	0.295
High Amp	0.009	0.130	0.129	0.4	79.5	3.0	3	1	n.a.	-0.160	-0.018	0.248
Low Amp	0.026	0.130	0.127	1.5	78.7	3.0	3	1	n.a.	-0.159	0.010	0.240
High Time	-10.318	25.248	23.043	2.7	83.3	0.8	1	2	n.a.	-53.205	-8.478	20.661
Low Time	-11.484	30.195	27.926	4.6	73.0	1.5	1	1	n.a.	-59.989	-10.226	34.686
Second Group: Comparison of Forecast Methods												
Method: Astronomical Tidal Predication												
Water Level	-0.013	0.200	0.200	6.7	60.9	5.0	43	46	0.000	-0.346	-0.018	0.292
High Amp	-0.193	0.280	0.203	28.7	32.8	2.2	3	11	n.a.	-0.505	-0.215	0.137
Low Amp	-0.168	0.259	0.197	23.3	41.5	1.4	3	10	n.a.	-0.490	-0.177	0.130
High Time	16.852	35.118	30.810	1.3	66.1	6.2	2	2	n.a.	-35.402	15.584	66.002
Low Time	1.043	43.871	43.859	6.5	59.7	9.5	3	3	n.a.	-68.344	-2.450	77.760
Method: Persisted Observation Plus Astronomical Prediction												
WL @ 0hr	0.000	0.000	0.000	0.0	100.0	0.0	0	0	0.000	0.000	0.000	0.000
WL @ 6hr	0.008	0.105	0.105	0.9	85.8	0.6	1	2	0.459	-0.169	0.006	0.179
WL @ 12hr	-0.001	0.179	0.179	5.2	70.5	5.5	3	2	2.905	-0.313	-0.013	0.306
WL @ 18hr	0.008	0.227	0.227	7.8	60.4	8.6	2	2	5.215	-0.366	-0.006	0.404
WL @ 24hr	0.000	0.262	0.262	10.3	55.1	10.8	3	4	6.759	-0.442	-0.018	0.448
High Amp	-0.009	0.184	0.184	5.2	70.8	4.9	3	2	n.a.	-0.310	-0.024	0.285
Low Amp	0.013	0.186	0.185	4.1	71.2	6.2	2	2	n.a.	-0.265	0.000	0.333
High Time	16.841	35.125	30.824	1.3	66.1	6.2	2	2	n.a.	-35.995	15.584	66.002
Low Time	2.092	51.421	51.379	6.5	59.5	9.7	3	3	n.a.	-71.450	-5.124	77.815

Table A.11. Tolchester

	SM	RMSE	SD	NOF	CF	POF	MDPO	MDNO	WOF	5%	median	95%
First Group: Scenarios												
Scenario: Astronomical Tide Only												
Water Level	0.037	0.087	0.078	0.0	89.6	0.0	0	0	0.000	-0.076	0.018	0.171
High Amp	0.024	0.080	0.077	0.0	93.6	0.0	0	0	n.a.	-0.088	0.001	0.152
Low Amp	0.058	0.095	0.076	0.0	84.0	0.0	0	0	n.a.	-0.047	0.037	0.188
High Time	-17.239	19.193	8.437	0.0	94.4	0.0	0	0	n.a.	-30.944	-17.763	-2.284
Low Time	-8.131	14.008	11.406	0.0	95.9	0.0	0	0	n.a.	-27.885	-7.964	9.042
Scenario: Test Nowcast												
Water Level	0.000	0.099	0.099	0.1	87.8	0.6	16	5	0.165	-0.159	-0.009	0.169
High Amp	-0.017	0.107	0.105	0.1	85.4	1.2	1	1	n.a.	-0.178	-0.037	0.186
Low Amp	0.028	0.094	0.090	0.0	89.5	0.3	1	0	n.a.	-0.125	0.028	0.175
High Time	-18.956	29.754	22.934	2.2	69.6	0.3	1	2	n.a.	-53.347	-21.035	15.421
Low Time	-11.115	30.794	28.718	4.0	72.5	1.6	2	1	n.a.	-57.589	-12.996	34.914
Scenario: Semi-Operational Nowcast												
Water Level	0.009	0.094	0.093	0.2	89.4	0.4	7	5	0.124	-0.132	-0.004	0.172
High Amp	-0.007	0.097	0.097	0.0	86.8	0.4	1	0	n.a.	-0.146	-0.024	0.181
Low Amp	0.036	0.089	0.081	0.0	91.1	0.8	1	0	n.a.	-0.090	0.028	0.172
High Time	-19.027	30.209	23.463	3.1	70.8	1.2	1	2	n.a.	-49.880	-20.899	15.849
Low Time	-9.004	30.753	29.405	3.5	74.0	1.6	1	2	n.a.	-53.238	-8.705	34.762
Scenario: Test Forecast												
WL @ 0hr	-0.002	0.100	0.100	0.3	87.7	0.3	2	1	0.000	-0.168	-0.008	0.160
WL @ 6hr	-0.001	0.100	0.100	0.0	85.3	0.4	1	0	0.141	-0.163	-0.008	0.173
WL @ 12hr	-0.012	0.098	0.098	0.3	88.4	0.3	1	1	0.282	-0.179	-0.016	0.140
WL @ 18hr	-0.014	0.107	0.107	0.7	86.2	1.0	1	1	0.565	-0.199	-0.018	0.145
WL @ 24hr	-0.029	0.124	0.120	2.1	81.2	1.3	2	2	0.850	-0.243	-0.030	0.145
High Amp	-0.020	0.107	0.105	0.3	85.7	0.9	1	1	n.a.	-0.184	-0.033	0.156
Low Amp	0.010	0.091	0.090	0.4	90.5	0.0	0	1	n.a.	-0.153	0.014	0.139
High Time	-18.781	30.221	23.677	4.5	72.5	0.1	1	2	n.a.	-59.275	-18.969	14.533
Low Time	-6.870	27.674	26.808	3.1	77.5	2.0	1	2	n.a.	-52.581	-8.648	41.092
Scenario: Semi-Operational Forecast												
WL @ 0hr	0.011	0.096	0.095	0.2	88.6	0.4	1	1	0.000	-0.133	-0.003	0.183
WL @ 6hr	0.008	0.118	0.118	0.2	81.0	2.1	2	1	1.163	-0.160	-0.008	0.222
WL @ 12hr	0.007	0.129	0.128	0.6	78.3	2.5	3	1	1.550	-0.186	-0.006	0.226
WL @ 18hr	0.017	0.143	0.142	1.4	75.3	3.7	7	2	1.748	-0.212	0.006	0.266
WL @ 24hr	0.018	0.153	0.152	2.5	72.8	4.5	5	3	2.529	-0.216	0.010	0.284
High Amp	0.002	0.128	0.128	0.4	79.0	1.9	1	1	n.a.	-0.168	-0.018	0.234
Low Amp	0.036	0.114	0.109	0.4	83.5	2.0	1	1	n.a.	-0.135	0.024	0.222
High Time	-15.220	26.369	21.533	3.1	77.8	0.4	1	2	n.a.	-46.399	-14.752	12.572
Low Time	-7.096	21.239	20.018	1.6	89.4	0.4	1	1	n.a.	-46.013	-4.621	17.170
Second Group: Comparison of Forecast Methods												
Method: Astronomical Tidal Predication												
Water Level	0.005	0.194	0.194	4.9	61.1	6.0	47	46	0.000	-0.308	-0.008	0.308
High Amp	-0.208	0.289	0.200	29.4	31.9	0.9	2	11	n.a.	-0.532	-0.221	0.117
Low Amp	-0.189	0.267	0.188	25.3	40.7	0.9	3	9	n.a.	-0.500	-0.192	0.079
High Time	0.611	29.513	29.507	2.3	77.8	3.9	1	2	n.a.	-45.996	-2.040	53.295
Low Time	-1.144	36.230	36.212	5.4	71.6	4.8	2	2	n.a.	-62.659	-4.167	57.139
Method: Persisted Observation Plus Astronomical Prediction												
WL @ 0hr	0.000	0.000	0.000	0.0	100.0	0.0	0	0	0.000	0.000	0.000	0.000
WL @ 6hr	0.001	0.101	0.101	0.8	88.8	1.1	1	2	0.424	-0.153	-0.002	0.165
WL @ 12hr	-0.001	0.174	0.174	4.5	69.2	4.8	2	2	2.825	-0.291	-0.011	0.283
WL @ 18hr	0.000	0.218	0.218	8.1	61.2	8.5	2	2	4.944	-0.356	-0.017	0.400
WL @ 24hr	0.000	0.248	0.248	8.6	55.0	9.8	3	3	5.382	-0.418	-0.014	0.415
High Amp	-0.009	0.186	0.186	5.1	69.1	5.1	2	2	n.a.	-0.310	-0.024	0.297
Low Amp	0.007	0.182	0.181	4.0	71.3	5.1	2	2	n.a.	-0.276	-0.007	0.295
High Time	0.624	29.538	29.531	2.3	77.7	4.0	1	2	n.a.	-46.010	-1.948	53.326
Low Time	-1.128	36.208	36.190	5.4	71.6	4.8	2	2	n.a.	-62.659	-4.239	57.139

APPENDIX B. TIDAL ANALYSIS RESULTS

The following tables list the tidal constituents, the period of the constituent in hours and the amplitude and phase of the harmonic analysis for the model run and the original NOS tidal constituents. The model based time series is a result of forcing at the ocean boundary by a harmonic predicted tide using the constituents for the Chesapeake Bay Bridge Tunnel, but with an amplitude and phase shift to account for the distance between the CBBT station and the outer boundary location. An initial model run with the tidal constituents of CBBT applied directly to the oceanic boundary provided the amplitude and phase shift at CBBT relative to the ocean boundary for the M2 tide of 1.13 amplitude and 0.31 hours. Other amplitude and phase differences occur at other frequencies, but as the final model can not apply a cross spectral correction, these two values were used on the time series of water height at CBBT to derive the forcing height at the Ocean. Using these amplitude and phase shifts the comparison at CBBT is fit quite well, which, therefore, should not be considered a comparison station.

The harmonic analysis was performed for the single year, 1997. The adjustments to a standard year for the 19 year epoch were not applied. The phase shifts are therefore relative to a epoch origin of Jan. 1, 00:00.

The last column, "Error %Amplitude", is the amplitude of the sinusoid produced by differencing the Model-based and the Harmonic Predicted sinusoids, divided by the amplitude of the larger of the two sinusoids. This takes into account both the amplitude difference and the phase difference when presenting a single number for the error. If the model and predicted sinusoids should be a full 180 degrees out of phase the amplitude of the error will be the sum of the two amplitudes and the percent error can therefore be as large as 200%. The Harmonic Predicted time series were often created with fewer than 37 harmonics. In these cases the error is presented as -0.00%, rather than 100%, to indicate the special case.

Table B.1. CBBT

	Period	MODEL-based		:	Harmonic-Predicted		:	Error
	hour	meter	hour		meter	hour	:	%Amplitude
M2	12.421	0.40883	6.45	:	0.40876	6.44	:	0.45
S2	12.000	0.07416	1.58	:	0.07407	1.57	:	0.23
N2	12.658	0.09159	1.08	:	0.09207	1.07	:	0.58
K1	23.934	0.05290	11.89	:	0.05221	11.75	:	3.87
M4	6.210	0.00906	2.06	:	0.00657	2.82	:	69.59
O1	25.819	0.03927	1.70	:	0.03813	1.53	:	4.97
M6	4.140	0.00835	0.86	:	0.00749	0.85	:	10.53
MK3	8.177	0.00190	0.65	:	0.00000	0.00	:	-0.00
S4	6.000	0.00308	4.67	:	0.00335	4.64	:	8.83
MN4	6.269	0.00340	5.92	:	0.00361	0.51	:	81.09
NU2	12.626	0.01768	3.88	:	0.01772	3.87	:	0.41
S6	4.000	0.00003	3.71	:	0.00000	0.00	:	-0.00
MU2	12.872	0.01292	12.23	:	0.01329	12.24	:	2.81
2N2	12.905	0.01183	8.54	:	0.01202	8.54	:	1.63
OO1	22.306	0.00090	9.67	:	0.00089	9.52	:	4.47
LAM2	12.222	0.00300	2.65	:	0.00285	2.56	:	6.78
S1	24.000	0.00843	17.19	:	0.00853	17.09	:	2.94
M1	24.833	0.00505	1.52	:	0.00500	1.34	:	4.43
J1	23.098	0.00316	19.81	:	0.00303	19.58	:	7.52
MM	661.309	0.00371	296.32	:	0.00000	0.00	:	-0.00
SSA	4382.905	0.05070	2352.53	:	0.04481	2352.28	:	11.63
SA	8765.821	0.06035	5765.31	:	0.05395	5766.10	:	10.61
MSF	354.367	0.00349	216.65	:	0.00000	0.00	:	-0.00
MF	327.859	0.00073	20.60	:	0.00000	0.00	:	-0.00
RHO	26.723	0.00143	24.62	:	0.00148	24.77	:	4.70
Q1	26.868	0.00963	17.35	:	0.00935	17.17	:	5.14
T2	12.016	0.00458	1.52	:	0.00457	1.50	:	0.95
R2	11.984	0.00062	7.55	:	0.00061	7.64	:	4.30
2Q1	28.006	0.00104	9.73	:	0.00098	9.81	:	5.91
P1	24.066	0.01756	13.32	:	0.01768	13.16	:	4.28
2SM2	11.607	0.00023	4.35	:	0.00000	0.00	:	-0.00
M3	8.280	0.00346	7.37	:	0.00354	7.50	:	10.21
L2	12.192	0.00915	4.91	:	0.00897	4.82	:	4.93
2MK3	8.386	0.00137	5.44	:	0.00000	0.00	:	-0.00
K2	11.967	0.01456	6.84	:	0.01459	6.83	:	0.27
M8	3.105	0.00011	2.70	:	0.00000	0.00	:	-0.00
MS4	6.103	0.00662	5.40	:	0.00475	5.51	:	29.66

Table B.2. Hampton Roads

	Period	MODEL-based		:	Harmonic-Predicted		:	Error
	hour	meter	hour		meter	hour	:	%Amplitude
M2	12.421	0.36068	7.20	:	0.38314	7.37	:	10.22
S2	12.000	0.06617	2.31	:	0.06675	2.56	:	13.02
N2	12.658	0.08044	1.82	:	0.08669	2.04	:	12.78
K1	23.934	0.04745	12.81	:	0.04629	12.75	:	2.93
M4	6.210	0.01302	2.00	:	0.00361	5.20	:	127.63
O1	25.819	0.03641	2.63	:	0.03370	2.63	:	7.44
M6	4.140	0.00850	1.79	:	0.00000	0.00	:	-0.00
MK3	8.177	0.00541	0.96	:	0.00307	5.34	:	155.85
S4	6.000	0.00252	5.63	:	0.00000	0.00	:	-0.00
MN4	6.269	0.00471	5.50	:	0.00000	0.00	:	-0.00
NU2	12.626	0.01565	4.62	:	0.01709	4.60	:	8.44
S6	4.000	0.00002	3.00	:	0.00000	0.00	:	-0.00
MU2	12.872	0.01125	0.05	:	0.01076	0.81	:	36.12
2N2	12.905	0.01014	9.26	:	0.01076	9.55	:	14.75
OO1	22.306	0.00086	10.67	:	0.00089	10.42	:	8.25
LAM2	12.222	0.00271	3.58	:	0.00253	3.52	:	7.29
S1	24.000	0.00725	18.07	:	0.01067	18.69	:	34.68
M1	24.833	0.00451	2.48	:	0.00409	2.39	:	9.68
J1	23.098	0.00315	20.86	:	0.00278	20.52	:	14.67
MM	661.309	0.00970	296.41	:	0.01998	54.23	:	137.23
SSA	4382.905	0.05088	2352.86	:	0.04298	2414.37	:	17.52
SA	8765.821	0.05945	5764.34	:	0.05822	5758.79	:	2.12
MSF	354.367	0.00916	217.11	:	0.00000	0.00	:	-0.00
MF	327.859	0.00186	21.45	:	0.00000	0.00	:	-0.00
RHO	26.723	0.00117	24.93	:	0.00123	25.92	:	23.23
Q1	26.868	0.00902	18.28	:	0.00787	18.10	:	13.32
T2	12.016	0.00417	2.31	:	0.00396	2.49	:	10.28
R2	11.984	0.00064	8.15	:	0.00061	8.62	:	24.92
2Q1	28.006	0.00100	10.10	:	0.00074	11.04	:	32.01
P1	24.066	0.01534	14.32	:	0.01524	14.00	:	8.44
2SM2	11.607	0.00062	4.60	:	0.00000	0.00	:	-0.00
M3	8.280	0.00255	7.84	:	0.00000	0.00	:	-0.00
L2	12.192	0.00790	5.80	:	0.01374	5.55	:	43.59
2MK3	8.386	0.00404	5.71	:	0.00347	1.62	:	185.80
K2	11.967	0.01284	7.58	:	0.01322	7.74	:	8.77
M8	3.105	0.00074	2.44	:	0.00000	0.00	:	-0.00
MS4	6.103	0.00817	5.88	:	0.00000	0.00	:	-0.00

Table B.3. Kiptopeake Beach

	Period	MODEL-based		:	Harmonic-Predicted		:	Error
	hour	meter	hour		meter	hour	:	%Amplitude
M2	12.421	0.39374	6.83	:	0.42047	6.84	:	6.40
S2	12.000	0.07150	1.95	:	0.07285	1.91	:	2.61
N2	12.658	0.08874	1.46	:	0.09080	1.48	:	2.39
K1	23.934	0.05244	12.29	:	0.05437	12.23	:	3.84
M4	6.210	0.00577	2.94	:	0.00558	4.91	:	165.25
O1	25.819	0.03841	2.10	:	0.03886	1.95	:	3.71
M6	4.140	0.00477	1.14	:	0.00579	0.83	:	46.61
MK3	8.177	0.00054	0.02	:	0.00391	5.35	:	108.57
S4	6.000	0.00300	5.13	:	0.00366	5.14	:	18.02
MN4	6.269	0.00272	0.72	:	0.00361	1.96	:	104.20
NU2	12.626	0.01709	4.26	:	0.01835	4.22	:	7.22
S6	4.000	0.00002	2.25	:	0.00000	0.00	:	-0.00
MU2	12.872	0.01290	12.63	:	0.01012	12.72	:	21.83
2N2	12.905	0.01160	8.94	:	0.01171	9.05	:	5.77
OO1	22.306	0.00091	10.13	:	0.00104	10.04	:	13.00
LAM2	12.222	0.00270	2.93	:	0.00285	2.93	:	5.13
S1	24.000	0.00856	17.62	:	0.00000	0.00	:	-0.00
M1	24.833	0.00499	1.89	:	0.00500	1.80	:	2.24
J1	23.098	0.00308	20.18	:	0.00303	20.08	:	3.08
MM	661.309	0.00196	300.23	:	0.00000	0.00	:	-0.00
SSA	4382.905	0.05071	2353.35	:	0.03779	2472.82	:	29.44
SA	8765.821	0.06033	5763.59	:	0.06218	5719.82	:	4.28
MSF	354.367	0.00181	218.81	:	0.00000	0.00	:	-0.00
MF	327.859	0.00043	18.98	:	0.00000	0.00	:	-0.00
RHO	26.723	0.00147	25.27	:	0.00148	25.15	:	2.86
Q1	26.868	0.00945	17.75	:	0.00935	17.20	:	12.77
T2	12.016	0.00441	1.90	:	0.00457	1.84	:	4.48
R2	11.984	0.00062	8.06	:	0.00061	7.98	:	4.32
2Q1	28.006	0.00100	10.28	:	0.00098	10.17	:	3.17
P1	24.066	0.01768	13.71	:	0.01890	13.73	:	6.45
2SM2	11.607	0.00020	4.19	:	0.00000	0.00	:	-0.00
M3	8.280	0.00348	7.86	:	0.00000	0.00	:	-0.00
L2	12.192	0.00852	5.19	:	0.01122	5.54	:	28.82
2MK3	8.386	0.00041	4.86	:	0.00434	1.81	:	106.51
K2	11.967	0.01413	7.21	:	0.01505	7.20	:	6.12
M8	3.105	0.00027	1.69	:	0.00000	0.00	:	-0.00
MS4	6.103	0.00493	5.92	:	0.00000	0.00	:	-0.00

Table B.4. Gloucester Pt.

	Period	MODEL-based		:	Harmonic-Predicted		:	Error
	hour	meter	hour		meter	hour	:	%Amplitude
M2	12.421	0.31410	7.70	:	0.36004	7.56	:	14.38
S2	12.000	0.05763	2.80	:	0.06340	2.66	:	11.54
N2	12.658	0.06970	2.33	:	0.07973	2.14	:	15.24
K1	23.934	0.03875	13.42	:	0.04333	12.51	:	25.05
M4	6.210	0.01145	1.70	:	0.00460	0.76	:	83.34
O1	25.819	0.02879	3.27	:	0.03001	2.49	:	19.03
M6	4.140	0.00645	2.72	:	0.00477	2.40	:	48.39
MK3	8.177	0.00460	0.62	:	0.00307	6.10	:	144.52
S4	6.000	0.00343	0.46	:	0.00396	0.45	:	13.45
MN4	6.269	0.00497	4.90	:	0.00000	0.00	:	-0.00
NU2	12.626	0.01363	5.14	:	0.01519	4.91	:	14.78
S6	4.000	0.00013	2.57	:	0.00000	0.00	:	-0.00
MU2	12.872	0.00951	0.58	:	0.00981	0.90	:	15.49
2N2	12.905	0.00884	9.81	:	0.01076	9.64	:	19.25
OO1	22.306	0.00069	11.23	:	0.00074	10.09	:	31.81
LAM2	12.222	0.00241	4.04	:	0.00664	4.03	:	63.75
S1	24.000	0.00612	18.76	:	0.00914	19.13	:	34.00
M1	24.833	0.00364	3.10	:	0.00409	2.19	:	24.20
J1	23.098	0.00245	21.31	:	0.00252	20.24	:	28.89
MM	661.309	0.00711	300.01	:	0.00000	0.00	:	-0.00
SSA	4382.905	0.05108	2356.53	:	0.02713	2405.86	:	47.17
SA	8765.821	0.05910	5758.99	:	0.07010	5330.22	:	32.19
MSF	354.367	0.00686	217.28	:	0.00000	0.00	:	-0.00
MF	327.859	0.00147	21.48	:	0.00000	0.00	:	-0.00
RHO	26.723	0.00098	26.24	:	0.00123	25.82	:	22.15
Q1	26.868	0.00707	18.97	:	0.00640	18.18	:	19.94
T2	12.016	0.00362	2.84	:	0.00549	2.23	:	42.77
R2	11.984	0.00065	9.11	:	0.00061	8.75	:	19.35
2Q1	28.006	0.00075	11.05	:	0.00074	11.00	:	1.77
P1	24.066	0.01283	14.95	:	0.01433	13.69	:	32.60
2SM2	11.607	0.00123	3.62	:	0.00000	0.00	:	-0.00
M3	8.280	0.00241	0.55	:	0.00387	0.39	:	39.05
L2	12.192	0.00711	6.27	:	0.01514	6.24	:	53.08
2MK3	8.386	0.00335	5.35	:	0.00347	2.67	:	165.70
K2	11.967	0.01155	8.08	:	0.01277	7.93	:	12.31
M8	3.105	0.00089	0.27	:	0.00000	0.00	:	-0.00
MS4	6.103	0.00814	0.28	:	0.00316	0.21	:	61.36

Table B.5. Lewisetta

	Period	MODEL-based		:	Harmonic-Predicted		:	Error
	hour	meter	hour		meter	hour	:	%Amplitude
M2	12.421	0.16664	11.71	:	0.19647	11.82	:	16.03
S2	12.000	0.02922	6.78	:	0.03017	6.76	:	3.31
N2	12.658	0.03819	6.33	:	0.04208	6.40	:	9.80
K1	23.934	0.02793	17.80	:	0.01992	17.82	:	28.70
M4	6.210	0.00317	4.19	:	0.00492	2.98	:	98.83
O1	25.819	0.02191	7.87	:	0.01550	8.34	:	30.79
M6	4.140	0.00182	3.76	:	0.00409	0.55	:	102.96
MK3	8.177	0.00150	4.12	:	0.00000	0.00	:	-0.00
S4	6.000	0.00057	3.30	:	0.00000	0.00	:	-0.00
MN4	6.269	0.00140	1.29	:	0.00000	0.00	:	-0.00
NU2	12.626	0.00743	9.17	:	0.00823	9.35	:	13.05
S6	4.000	0.00010	3.22	:	0.00000	0.00	:	-0.00
MU2	12.872	0.00546	4.50	:	0.00000	0.00	:	-0.00
2N2	12.905	0.00500	0.87	:	0.00569	0.77	:	13.00
OO1	22.306	0.00055	15.18	:	0.00045	14.94	:	19.90
LAM2	12.222	0.00122	8.28	:	0.00127	7.85	:	22.03
S1	24.000	0.00444	23.15	:	0.00640	8.91	:	162.34
M1	24.833	0.00266	7.61	:	0.00182	7.77	:	31.77
J1	23.098	0.00193	2.51	:	0.00126	2.22	:	35.30
MM	661.309	0.00895	304.57	:	0.00000	0.00	:	-0.00
SSA	4382.905	0.05173	2363.09	:	0.03231	2402.21	:	37.81
SA	8765.821	0.05747	5742.89	:	0.09266	5393.55	:	42.77
MSF	354.367	0.00809	222.82	:	0.00000	0.00	:	-0.00
MF	327.859	0.00187	25.83	:	0.00000	0.00	:	-0.00
RHO	26.723	0.00076	3.91	:	0.00049	5.21	:	42.84
Q1	26.868	0.00561	23.66	:	0.00320	26.17	:	61.28
T2	12.016	0.00175	6.89	:	0.00183	6.69	:	10.91
R2	11.984	0.00043	1.56	:	0.00031	0.83	:	43.19
2Q1	28.006	0.00060	15.74	:	0.00049	17.49	:	39.47
P1	24.066	0.00935	19.39	:	0.01006	19.53	:	7.94
2SM2	11.607	0.00024	8.30	:	0.00000	0.00	:	-0.00
M3	8.280	0.00051	3.62	:	0.00000	0.00	:	-0.00
L2	12.192	0.00347	10.38	:	0.00505	10.72	:	34.46
2MK3	8.386	0.00120	0.59	:	0.00000	0.00	:	-0.00
K2	11.967	0.00583	0.12	:	0.00616	0.12	:	5.28
M8	3.105	0.00053	2.45	:	0.00000	0.00	:	-0.00
MS4	6.103	0.00138	2.36	:	0.00000	0.00	:	-0.00

Table B.6. Colonial Beach

	Period	MODEL-based		:	Harmonic-Predicted		:	Error
	hour	meter	hour		meter	hour	:	%Amplitude
M2	12.421	0.18760	1.00	:	0.25532	0.69	:	29.83
S2	12.000	0.03082	8.56	:	0.03932	8.26	:	25.65
N2	12.658	0.04120	8.06	:	0.05189	7.81	:	23.34
K1	23.934	0.02778	19.24	:	0.02691	18.94	:	8.56
M4	6.210	0.00196	0.82	:	0.00624	5.27	:	110.93
O1	25.819	0.02161	9.31	:	0.02115	9.06	:	6.42
M6	4.140	0.00129	1.07	:	0.00000	0.00	:	-0.00
MK3	8.177	0.00102	6.11	:	0.00000	0.00	:	-0.00
S4	6.000	0.00036	3.85	:	0.00000	0.00	:	-0.00
MN4	6.269	0.00078	4.19	:	0.00000	0.00	:	-0.00
NU2	12.626	0.00831	10.87	:	0.01012	9.84	:	49.16
S6	4.000	0.00015	2.18	:	0.00000	0.00	:	-0.00
MU2	12.872	0.00453	6.72	:	0.00000	0.00	:	-0.00
2N2	12.905	0.00503	2.73	:	0.00664	2.31	:	30.11
OO1	22.306	0.00046	16.52	:	0.00060	16.39	:	22.46
LAM2	12.222	0.00223	9.51	:	0.00190	9.24	:	19.73
S1	24.000	0.00441	0.56	:	0.00884	7.11	:	117.93
M1	24.833	0.00260	9.26	:	0.00272	8.70	:	14.69
J1	23.098	0.00167	4.04	:	0.00177	3.49	:	15.52
MM	661.309	0.00930	307.39	:	0.00000	0.00	:	-0.00
SSA	4382.905	0.05213	2365.38	:	0.01798	2155.07	:	67.84
SA	8765.821	0.05604	5728.27	:	0.08595	4957.71	:	56.13
MSF	354.367	0.00821	224.78	:	0.00000	0.00	:	-0.00
MF	327.859	0.00196	26.75	:	0.00000	0.00	:	-0.00
RHO	26.723	0.00076	5.14	:	0.00074	5.74	:	14.36
Q1	26.868	0.00544	25.22	:	0.00394	26.67	:	39.77
T2	12.016	0.00184	8.79	:	0.00213	8.20	:	31.64
R2	11.984	0.00050	3.22	:	0.00030	2.33	:	53.41
2Q1	28.006	0.00065	17.93	:	0.00049	17.76	:	24.40
P1	24.066	0.00915	20.80	:	0.01128	21.85	:	31.02
2SM2	11.607	0.00062	10.01	:	0.00000	0.00	:	-0.00
M3	8.280	0.00042	5.83	:	0.00000	0.00	:	-0.00
L2	12.192	0.00626	12.02	:	0.01206	11.83	:	48.56
2MK3	8.386	0.00062	2.23	:	0.00000	0.00	:	-0.00
K2	11.967	0.00629	1.87	:	0.01003	1.84	:	37.32
M8	3.105	0.00024	0.47	:	0.00000	0.00	:	-0.00
MS4	6.103	0.00096	4.88	:	0.00000	0.00	:	-0.00

Table B.7. Solomons Island

	Period	MODEL-based		:	Harmonic-Predicted		:	Error
	hour	meter	hour		meter	hour	:	%Amplitude
M2	12.421	0.16379	12.11	:	0.17907	0.18	:	24.91
S2	12.000	0.02943	7.19	:	0.02469	7.35	:	17.81
N2	12.658	0.03716	6.75	:	0.03543	7.13	:	18.96
K1	23.934	0.02759	18.91	:	0.02557	20.56	:	42.02
M4	6.210	0.00792	4.93	:	0.00591	4.25	:	63.57
O1	25.819	0.02241	8.98	:	0.02435	9.82	:	21.21
M6	4.140	0.00145	1.17	:	0.00375	0.86	:	67.84
MK3	8.177	0.00243	4.71	:	0.00335	3.08	:	103.65
S4	6.000	0.00080	4.27	:	0.00000	0.00	:	-0.00
MN4	6.269	0.00346	2.07	:	0.00000	0.00	:	-0.00
NU2	12.626	0.00728	9.58	:	0.00696	10.08	:	24.88
S6	4.000	0.00004	2.54	:	0.00000	0.00	:	-0.00
MU2	12.872	0.00533	5.00	:	0.00000	0.00	:	-0.00
2N2	12.905	0.00481	1.33	:	0.00475	1.46	:	6.24
OO1	22.306	0.00054	16.07	:	0.00060	18.78	:	71.30
LAM2	12.222	0.00117	8.47	:	0.00127	8.54	:	8.54
S1	24.000	0.00436	0.24	:	0.01128	7.38	:	117.30
M1	24.833	0.00266	8.73	:	0.00318	9.90	:	31.57
J1	23.098	0.00192	3.51	:	0.00177	5.53	:	52.46
MM	661.309	0.00958	304.77	:	0.00000	0.00	:	-0.00
SSA	4382.905	0.05188	2364.69	:	0.04023	2383.93	:	22.59
SA	8765.821	0.05724	5740.12	:	0.09418	5164.66	:	50.57
MSF	354.367	0.00841	221.95	:	0.00000	0.00	:	-0.00
MF	327.859	0.00201	25.92	:	0.00000	0.00	:	-0.00
RHO	26.723	0.00078	4.96	:	0.00098	6.08	:	31.57
Q1	26.868	0.00580	24.72	:	0.00467	0.07	:	49.97
T2	12.016	0.00180	7.36	:	0.00152	7.29	:	15.76
R2	11.984	0.00048	1.95	:	0.00030	1.42	:	42.55
2Q1	28.006	0.00061	16.86	:	0.00049	17.49	:	22.77
P1	24.066	0.00923	20.48	:	0.01250	22.59	:	53.63
2SM2	11.607	0.00026	10.91	:	0.00000	0.00	:	-0.00
M3	8.280	0.00051	4.28	:	0.00000	0.00	:	-0.00
L2	12.192	0.00352	10.59	:	0.01150	0.29	:	86.66
2MK3	8.386	0.00179	1.14	:	0.00000	0.00	:	-0.00
K2	11.967	0.00588	0.55	:	0.00502	0.71	:	16.50
M8	3.105	0.00016	1.01	:	0.00000	0.00	:	-0.00
MS4	6.103	0.00298	2.83	:	0.00000	0.00	:	-0.00

Table B.8. Cambridge

	Period	MODEL-based		:	Harmonic-Predicted		:	Error
	hour	meter	hour		meter	hour	:	%Amplitude
M2	12.421	0.18768	1.46	:	0.24551	2.25	:	42.22
S2	12.000	0.03322	8.94	:	0.03688	9.70	:	38.73
N2	12.658	0.04192	8.52	:	0.04651	9.20	:	33.58
K1	23.934	0.03521	20.56	:	0.04199	22.03	:	38.69
M4	6.210	0.01070	0.94	:	0.01116	0.95	:	4.25
O1	25.819	0.02836	10.48	:	0.03271	12.12	:	39.21
M6	4.140	0.00246	3.54	:	0.00000	0.00	:	-0.00
MK3	8.177	0.00367	6.21	:	0.00419	5.39	:	59.48
S4	6.000	0.00080	0.37	:	0.00000	0.00	:	-0.00
MN4	6.269	0.00478	4.29	:	0.00460	4.27	:	4.50
NU2	12.626	0.00833	11.33	:	0.00981	11.94	:	31.69
S6	4.000	0.00007	1.16	:	0.00000	0.00	:	-0.00
MU2	12.872	0.00556	6.76	:	0.00000	0.00	:	-0.00
2N2	12.905	0.00536	3.13	:	0.00633	3.52	:	23.28
OO1	22.306	0.00061	17.63	:	0.00089	19.53	:	54.04
LAM2	12.222	0.00166	10.28	:	0.00158	10.75	:	23.93
S1	24.000	0.00556	1.88	:	0.01524	7.98	:	107.34
M1	24.833	0.00336	10.38	:	0.00409	11.77	:	36.33
J1	23.098	0.00225	5.15	:	0.00278	6.62	:	40.43
MM	661.309	0.00965	305.63	:	0.00000	0.00	:	-0.00
SSA	4382.905	0.05206	2365.85	:	0.03566	2489.86	:	34.76
SA	8765.821	0.05688	5735.65	:	0.08992	5152.48	:	49.39
MSF	354.367	0.00840	223.78	:	0.00000	0.00	:	-0.00
MF	327.859	0.00212	24.66	:	0.00000	0.00	:	-0.00
RHO	26.723	0.00099	6.26	:	0.00123	8.78	:	55.91
Q1	26.868	0.00718	26.21	:	0.00640	2.84	:	75.75
T2	12.016	0.00214	9.14	:	0.00213	9.64	:	26.01
R2	11.984	0.00066	3.35	:	0.00031	3.76	:	55.53
2Q1	28.006	0.00079	18.71	:	0.00074	20.76	:	44.55
P1	24.066	0.01157	22.12	:	0.01646	23.33	:	39.77
2SM2	11.607	0.00070	9.56	:	0.00000	0.00	:	-0.00
M3	8.280	0.00056	6.56	:	0.00000	0.00	:	-0.00
L2	12.192	0.00457	0.33	:	0.01346	1.83	:	79.24
2MK3	8.386	0.00252	2.53	:	0.00405	1.47	:	71.85
K2	11.967	0.00692	2.26	:	0.00798	2.88	:	32.78
M8	3.105	0.00022	2.52	:	0.00000	0.00	:	-0.00
MS4	6.103	0.00366	5.08	:	0.00316	5.03	:	14.17

Table B.9. Annapolis

	Period	MODEL-based		:	Harmonic-Predicted		:	Error
	hour	meter	hour		meter	hour	:	%Amplitude
M2	12.421	0.13085	3.04	:	0.13952	3.39	:	17.98
S2	12.000	0.02256	10.50	:	0.02255	10.83	:	17.52
N2	12.658	0.02955	10.12	:	0.02721	10.43	:	16.72
K1	23.934	0.03539	22.20	:	0.05114	23.20	:	37.73
M4	6.210	0.00238	0.75	:	0.00394	0.56	:	42.32
O1	25.819	0.02860	12.08	:	0.04034	12.81	:	32.73
M6	4.140	0.00025	3.01	:	0.00000	0.00	:	-0.00
MK3	8.177	0.00114	7.31	:	0.00000	0.00	:	-0.00
S4	6.000	0.00036	0.87	:	0.00000	0.00	:	-0.00
MN4	6.269	0.00114	4.14	:	0.00000	0.00	:	-0.00
NU2	12.626	0.00583	0.30	:	0.00538	0.74	:	22.33
S6	4.000	0.00007	3.79	:	0.00000	0.00	:	-0.00
MU2	12.872	0.00391	8.34	:	0.00000	0.00	:	-0.00
2N2	12.905	0.00384	4.72	:	0.00380	4.83	:	5.32
OO1	22.306	0.00056	19.23	:	0.00104	21.11	:	60.21
LAM2	12.222	0.00119	11.81	:	0.00095	11.88	:	20.34
S1	24.000	0.00562	3.53	:	0.01646	7.06	:	83.94
M1	24.833	0.00338	12.00	:	0.00545	12.71	:	40.39
J1	23.098	0.00216	6.75	:	0.00328	8.01	:	44.00
MM	661.309	0.00917	308.22	:	0.00000	0.00	:	-0.00
SSA	4382.905	0.05259	2371.39	:	0.03200	2682.22	:	52.16
SA	8765.821	0.05533	5716.87	:	0.10363	5213.36	:	53.48
MSF	354.367	0.00790	225.36	:	0.00000	0.00	:	-0.00
MF	327.859	0.00199	26.28	:	0.00000	0.00	:	-0.00
RHO	26.723	0.00103	7.87	:	0.00148	9.24	:	40.49
Q1	26.868	0.00722	0.92	:	0.00787	3.25	:	52.20
T2	12.016	0.00146	10.67	:	0.00122	10.77	:	17.24
R2	11.984	0.00045	4.66	:	0.00031	4.90	:	34.04
2Q1	28.006	0.00082	20.53	:	0.00098	20.88	:	18.42
P1	24.066	0.01162	23.74	:	0.01463	0.30	:	25.18
2SM2	11.607	0.00024	11.02	:	0.00000	0.00	:	-0.00
M3	8.280	0.00038	7.85	:	0.00000	0.00	:	-0.00
L2	12.192	0.00325	1.94	:	0.00982	2.31	:	67.83
2MK3	8.386	0.00088	3.60	:	0.00000	0.00	:	-0.00
K2	11.967	0.00468	3.77	:	0.00456	4.18	:	21.55
M8	3.105	0.00013	2.60	:	0.00000	0.00	:	-0.00
MS4	6.103	0.00059	4.94	:	0.00000	0.00	:	-0.00

Table B.10. Baltimore Harbor

	Period	MODEL-based		:	Harmonic-Predicted		:	Error
	hour	meter	hour		meter	hour	:	%Amplitude
M2	12.421	0.15348	4.78	:	0.15566	5.15	:	18.93
S2	12.000	0.02647	0.23	:	0.02652	0.34	:	5.61
N2	12.658	0.03455	11.86	:	0.03322	12.22	:	18.21
K1	23.934	0.03974	23.63	:	0.05867	0.20	:	34.08
M4	6.210	0.00570	3.70	:	0.00000	0.00	:	-0.00
O1	25.819	0.03204	13.44	:	0.04255	13.97	:	27.11
M6	4.140	0.00090	2.34	:	0.00000	0.00	:	-0.00
MK3	8.177	0.00311	0.88	:	0.00000	0.00	:	-0.00
S4	6.000	0.00026	3.95	:	0.00000	0.00	:	-0.00
MN4	6.269	0.00264	0.82	:	0.00000	0.00	:	-0.00
NU2	12.626	0.00687	2.03	:	0.00664	2.53	:	24.49
S6	4.000	0.00015	3.11	:	0.00000	0.00	:	-0.00
MU2	12.872	0.00451	10.13	:	0.00000	0.00	:	-0.00
2N2	12.905	0.00445	6.49	:	0.00443	6.66	:	8.40
OO1	22.306	0.00063	20.74	:	0.00000	0.00	:	-0.00
LAM2	12.222	0.00144	1.27	:	0.00000	0.00	:	-0.00
S1	24.000	0.00630	4.96	:	0.01951	8.42	:	83.99
M1	24.833	0.00379	13.42	:	0.00545	13.75	:	31.25
J1	23.098	0.00251	8.18	:	0.00328	8.82	:	28.02
MM	661.309	0.01061	309.37	:	0.00000	0.00	:	-0.00
SSA	4382.905	0.05328	2376.47	:	0.02256	2463.08	:	58.23
SA	8765.821	0.05368	5695.84	:	0.12314	5077.01	:	63.45
MSF	354.367	0.00897	226.35	:	0.00000	0.00	:	-0.00
MF	327.859	0.00220	28.67	:	0.00000	0.00	:	-0.00
RHO	26.723	0.00110	9.11	:	0.00000	0.00	:	-0.00
Q1	26.868	0.00805	2.27	:	0.00812	1.31	:	22.18
T2	12.016	0.00180	0.43	:	0.00000	0.00	:	-0.00
R2	11.984	0.00058	6.21	:	0.00000	0.00	:	-0.00
2Q1	28.006	0.00092	21.73	:	0.00000	0.00	:	-0.00
P1	24.066	0.01300	1.17	:	0.02256	1.06	:	42.41
2SM2	11.607	0.00036	1.34	:	0.00000	0.00	:	-0.00
M3	8.280	0.00033	2.85	:	0.00000	0.00	:	-0.00
L2	12.192	0.00396	3.63	:	0.00365	4.22	:	30.07
2MK3	8.386	0.00219	5.30	:	0.00000	0.00	:	-0.00
K2	11.967	0.00550	5.50	:	0.00547	5.68	:	9.54
M8	3.105	0.00008	1.61	:	0.00000	0.00	:	-0.00
MS4	6.103	0.00170	1.55	:	0.00000	0.00	:	-0.00

Table B.11. Tolchester

	Period	MODEL-based		:	Harmonic-Predicted		:	Error
	hour	meter	hour		meter	hour	:	%Amplitude
M2	12.421	0.15165	5.04	:	0.16768	5.26	:	14.27
S2	12.000	0.02576	0.50	:	0.02256	0.32	:	15.20
N2	12.658	0.03425	12.12	:	0.03544	12.48	:	17.86
K1	23.934	0.04142	23.67	:	0.05921	23.67	:	30.04
M4	6.210	0.00627	3.82	:	0.00361	3.24	:	61.03
O1	25.819	0.03352	13.46	:	0.04329	13.64	:	22.89
M6	4.140	0.00061	1.58	:	0.00000	0.00	:	-0.00
MK3	8.177	0.00262	0.98	:	0.00335	7.49	:	107.88
S4	6.000	0.00013	3.99	:	0.00000	0.00	:	-0.00
MN4	6.269	0.00285	0.95	:	0.00000	0.00	:	-0.00
NU2	12.626	0.00678	2.31	:	0.00601	2.05	:	16.68
S6	4.000	0.00013	0.06	:	0.00000	0.00	:	-0.00
MU2	12.872	0.00440	10.39	:	0.00000	0.00	:	-0.00
2N2	12.905	0.00440	6.75	:	0.00475	6.26	:	23.96
OO1	22.306	0.00066	20.79	:	0.00149	0.22	:	64.13
LAM2	12.222	0.00146	1.58	:	0.00696	1.74	:	79.18
S1	24.000	0.00649	5.01	:	0.01951	7.14	:	73.86
M1	24.833	0.00393	13.47	:	0.00772	4.77	:	136.31
J1	23.098	0.00270	8.26	:	0.00404	5.02	:	77.25
MM	661.309	0.01169	309.21	:	0.00000	0.00	:	-0.00
SSA	4382.905	0.05370	2378.90	:	0.07498	2286.54	:	30.51
SA	8765.821	0.05242	5679.47	:	0.14387	4926.04	:	71.25
MSF	354.367	0.00980	226.05	:	0.00000	0.00	:	-0.00
MF	327.859	0.00235	29.65	:	0.00000	0.00	:	-0.00
RHO	26.723	0.00112	9.01	:	0.00246	8.98	:	54.66
Q1	26.868	0.00842	2.27	:	0.00959	1.26	:	25.27
T2	12.016	0.00170	0.75	:	0.00122	0.22	:	36.79
R2	11.984	0.00059	7.00	:	0.00030	6.42	:	53.17
2Q1	28.006	0.00096	21.63	:	0.00123	22.13	:	24.35
P1	24.066	0.01347	1.25	:	0.01890	0.33	:	35.07
2SM2	11.607	0.00033	1.94	:	0.00000	0.00	:	-0.00
M3	8.280	0.00032	3.03	:	0.00000	0.00	:	-0.00
L2	12.192	0.00399	3.92	:	0.00645	5.16	:	62.19
2MK3	8.386	0.00183	5.39	:	0.00290	3.59	:	105.82
K2	11.967	0.00533	5.81	:	0.00730	5.67	:	27.59
M8	3.105	0.00008	2.02	:	0.00000	0.00	:	-0.00
MS4	6.103	0.00201	1.69	:	0.00000	0.00	:	-0.00