Validation, Calibration, and Evaluation of a Severn River Delft3D-FLOW Model

MIDN 1/C Terry A. Renfro-Pihut and CDR William A. Swick

Introduction:

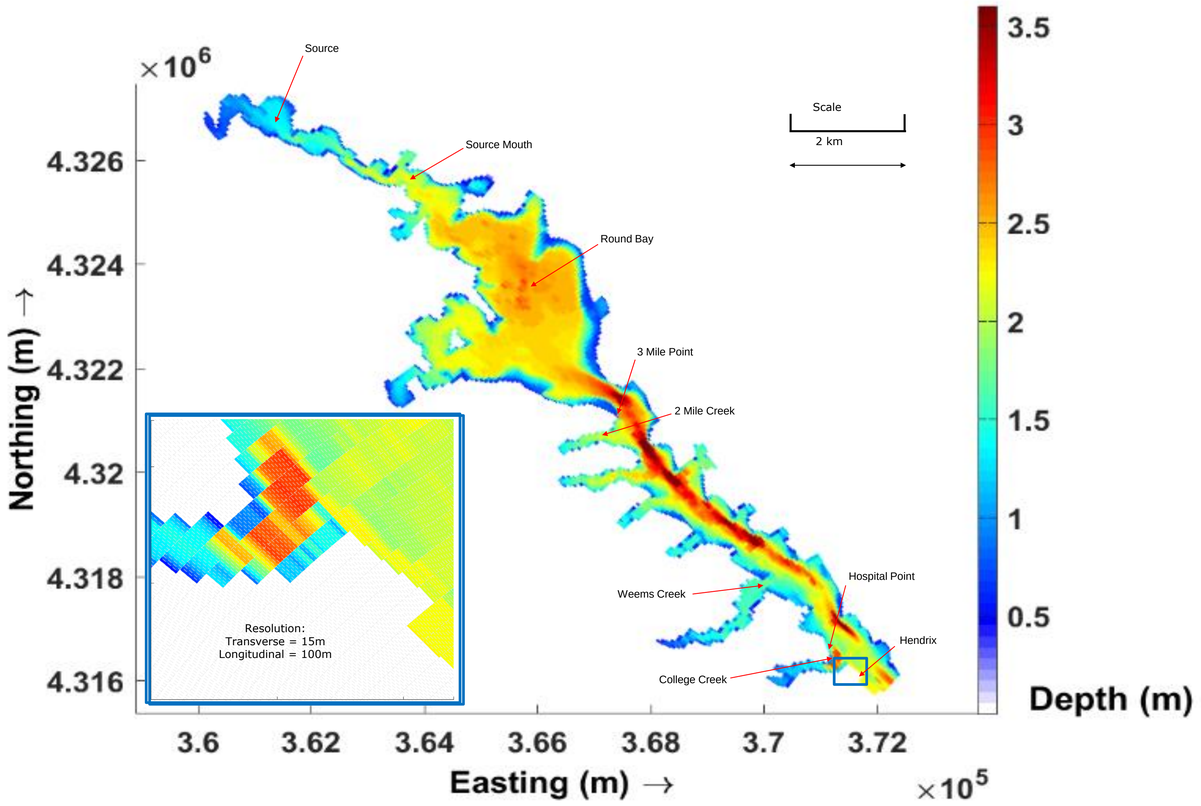
- Fluid flow in the Severn River has been historically characterized in models by harmonic tidal forcing. There are, however, many other drivers in the complex system that is the Chesapeake Bay, which often influences how observations compare to simulations.
- The Severn River generally does not conform to the tidal predictions set for it. There is typically a very large residual tidal signal between observations and model data.
- The model developed to simulate fluid flow in the Severn River was validated by tidal data taken from NOAA 8575512 Tidal at Hendrix Oceanography Laboratory.
- The goal of this study was to initialize and validate a 3D Hydrodynamic Model using the Delft3D software suite in the Severn River, MD, USA to study non-linear effects due to bathymetry and river geometry.

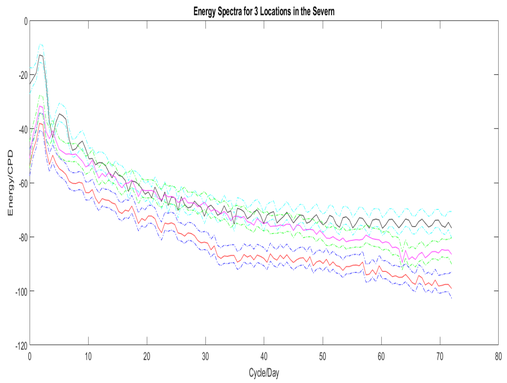
Numerical Model (Delft3D):

- The software used in this analysis was the FLOW module as part of the Delft-3D modeling suite from Deltares. The module itself is a multi-dimensional hydrodynamic simulation that calculates transport phenomena from tidal or meteorological forcing fitted to a curvilinear grid.
- The Delft-3D software uses Reynolds Averaged Navier Stokes (or RANS) equations of motion to describe non-linear fluid flow.
- Model boundary conditions, parallel to Triton Light Seawall at the Naval Academy, utilized 37 tidal harmonic constituents from the NOAA 8575512 Tidal Station at Hendrix Oceanography Laboratory.

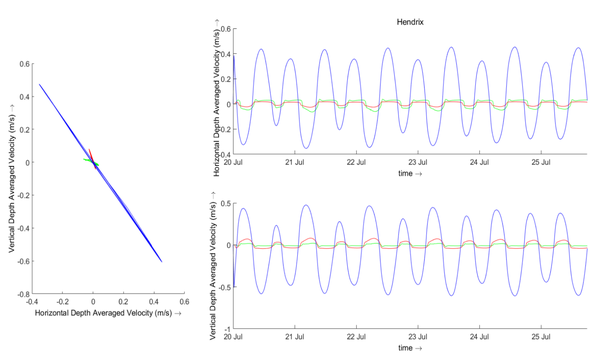
TABLE 1. List of Dominant Harmonic Tidal Constituents on the Severn River

Name	*Amplitude(feet)*	*Phase(degrees)*	*Speed*	*Description*
M2	0.46	146.6	28.984104	Principal lunar semi-diurnal constituent
S2	0.07	169.5	30.0	Principal solar semi-diurnal constituent
N2	0.1	128.3	28.43973	Larger lunar elliptic semi-diurnal constituent
K1	0.19	281.4	15.041069	Lunar diurnal constituent
O1	0.16	296.2	13.943035	Lunar diurnal constituent
SSA	0.12	44.0	0.0821373	Solar semiannual constituent
SA	0.34	128.1	0.0410686	Solar annual constituent

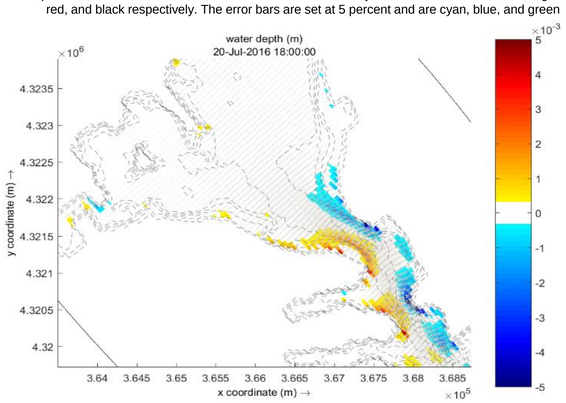




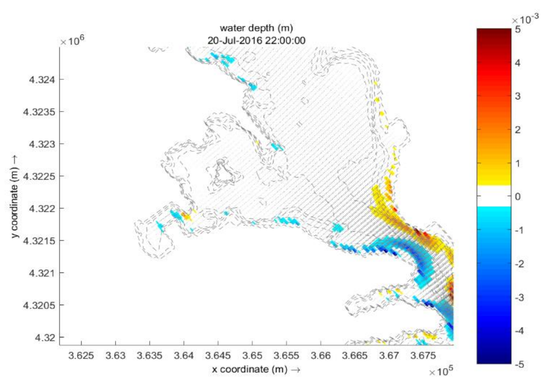
Energy Spectra in the Severn showing the dominant harmonic frequencies. The green lines represent data from the Source, the red lines from Round Bay, and the blue at Hendrix in magenta, red, and black respectively. The error bars are set at 5 percent and are cyan, blue, and green



Depth Averaged Velocity in the Model measured at three different locations: Hendrix (blue), Round Bay (red), and the Source (green).



Vorticity and Depth Averaged Velocity in the area extending from 3 Mile Point into Round Bay at Flood Tide on 20 July 2016.



Vorticity and Depth Averaged Velocity in the area extending from 3 Mile Point into Round Bay at Ebb Tide on 20 July 2016.

Conclusions:

- The model generated in the Delft3D software suite matched closely with the observations taken from NOAA.
- When fitted with a linear regression the model data compared to observational data returned an R^2 value of 0.82.
- Additionally, the slope of the equation indicated an almost 1 to 1 relationship existed, with a value of 1.004. The root mean squared error was also only 18.3 centimeters, indicating good results.
- The Severn River has complex bathymetry and geometry that can affect tidal signals, and as such is a good area for study.

Literature Cited:

Anne Arundel County, cited 2017: Severn River Watershed. [Available online at http://www.aacounty.org/departments/public-works/wprp/watersheds/severn%20river/].

Deltares Systems, 2014: Delft3D-FLOW, User Manual. [Available online at http://oss.deltares.nl/documents/183920/185723/Delft3D-FLOW User Manual.pdf].

National Oceanic and Atmospheric Administration, cited 2017: Harmonic Constituents for 8575512, Annapolis MD. [Available online at https://tidesandcurrents.noaa.gov/harcon.html?id=8575512].

Severn Riverkeeper, 2016: Preserving and Restoring the Severn River. [Available online at http://severnriverkeeper.org/about-the-severn-river/].

Future Work:

- Additional sensitivity analyses of how differing model parameters affect output would help to better understand the river to include: stratification in the water column, the addition of salinity and temperature transport, and external forcing such as wind and Susquehanna River influences.
- Data collection in the river itself could be improved by adding pressure sensors, UUV transects, and ADCP data to gain more data about the fluid flow upriver of the tidal station.
- The model can provide high resolution spatial and temporal data which can be used to identify fundamental spatial modes of the Severn River.