DYNHYD5 HYDRODYNAMIC MODEL (VERSION 2.0) AND CHLORIDE WATER QUALITY MODEL FOR THE DELAWARE ESTUARY

Delaware River Basin Commission

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This report was prepared by the Delaware River Basin Commission staff: Carol R. Collier, Executive Director. Dr. Namsoo S. Suk was the principal author of the report. Dr. Suk is a Water Resources Engineer/Modeler in the Modeling and Monitoring Branch of the Commission. Significant technical recommendations and support were provided by Scott C. Hinz and Dr. Victor J. Bierman, Jr. of LimnoTech, Inc., and Dr. Thomas J. Fikslin, head of the Modeling and Monitoring Branch of the Commission.

Overall technical guidance and comments were provided by the PCB Model Expert Panel established by the Commission. The current and former members of the PCB Model Expert Panel during the model development process are (in alphabetical order):
Robert B. Ambrose, USEPA; Dr. Joel Baker, University of Maryland; Dr. Steven C. Chapra, Tufts University; Dr. Steven Eisenreich, Rutgers University; Dr. Kevin Farley, Manhattan College; Dr. Rolland Hemmett, USEPA Region II; Dr. James L. Martin, Mississippi State University; Dale Rushneck, Interface Inc.; and Dr. Lisa Totten, Rutgers University.

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EXECUTIVE SUMMARY

A new hydrodynamic model was needed as a part of the development of Stage 1 TMDLs for polychlorinated biphenyls (PCBs) for the Delaware River Estuary. The downstream boundary of the existing DYNHYD5 hydrodynamic model (Version 1.0) was updated to establish a hydrodynamic and mass transport link to the ocean boundary. High resolution of Zone 6 would require a more comprehensive data collection effort and result in unacceptable increases in simulation time. Alternatively, introducing nine junctions to represent Zone 6 allowed for improved simulations, resulting from this linkage to the ocean boundary, while minimizing impacts to simulation time and model stability. Furthermore, since PCBs TMDLs to be derived using this hydrodynamic model applies only to Zones 2 through 5, a more coarse representation in Zone 6 was acceptable. The newer version of the hydrodynamic model (Version 2.0) extends the downstream boundary to the mouth of the Delaware Bay (Zone 6), and consists of 105 junctions and 111 channels.

The concept of a rolling calibration was used. In rolling calibration, as more data becomes available, the simulation period of the model is sequentially extended, and the model is re-calibrated to the expanded data set for each extension. The final calibration covers the period from September 1, 2001 to March 31, 2003, which is19 months or 577 days.

The tidal datum for the C&D Canal, Chesapeake City, MD, was modified to correctly simulate the magnitude and the amount of net flow through the C&D Canal. Version 2.0 DYNHYD5 hydrodynamic model was calibrated against tidal heights to ensure that the model correctly simulated the advective water mass movements within the Estuary. The simulated tidal heights were compared with the hourly observed tidal heights at six locations along the Estuary. Linear regression yielded slopes ranging from 0.945 to 1.027, and intercepts ranging from -0.087 to 0.035 with R-squared values of 0.930 to 0.994, respectively. The cumulative frequency distribution comparisons showed good agreement between the simulated and the observed tidal heights throughout the ranges of the tidal heights. Lastly, temporal comparisons confirmed that the model reasonably simulated both the amplitudes and the phases of the tidal heights throughout the calibration period. The predicted current velocities were also compared with the limited observed data to further confirm the Model. Based upon these results, the DYNHYD5 hydrodynamic model for the Delaware River Estuary (Version 2.0) correctly generates the advective movement of the water mass throughout the Delaware Estuary for the entire calibration period.

A TOXI5 (water quality) model consisting of 87 water column segments was then linked with the outputs from the calibrated DYNHYD5 hydrodynamic model and calibrated against the chloride concentrations. The main objective in this calibration process was the determination of an advection factor and a set of dispersion coefficients for the water quality model to correctly simulate the dispersive mixing within the Estuary. Review of comparison plots and the results of regression analyses indicated that the model was able to reproduce the temporal and spatial trends, and the magnitude of the chloride concentrations, within a reasonable range throughout the tidal portion of the Delaware River. It was therefore concluded that the calibrated model properly simulates the advective and dispersive movement of the chloride for the entire Estuary.

Even though Version 2.0 of the DYNHYD5 hydrodynamic model for the Delaware River Estuary could be further enhanced with additional data collection and refinements, the calibrated model demonstrates the capability to accurately simulate the advective and dispersive movement of a conservative substance in the Delaware River Estuary over a wide range of hydrologic conditions.

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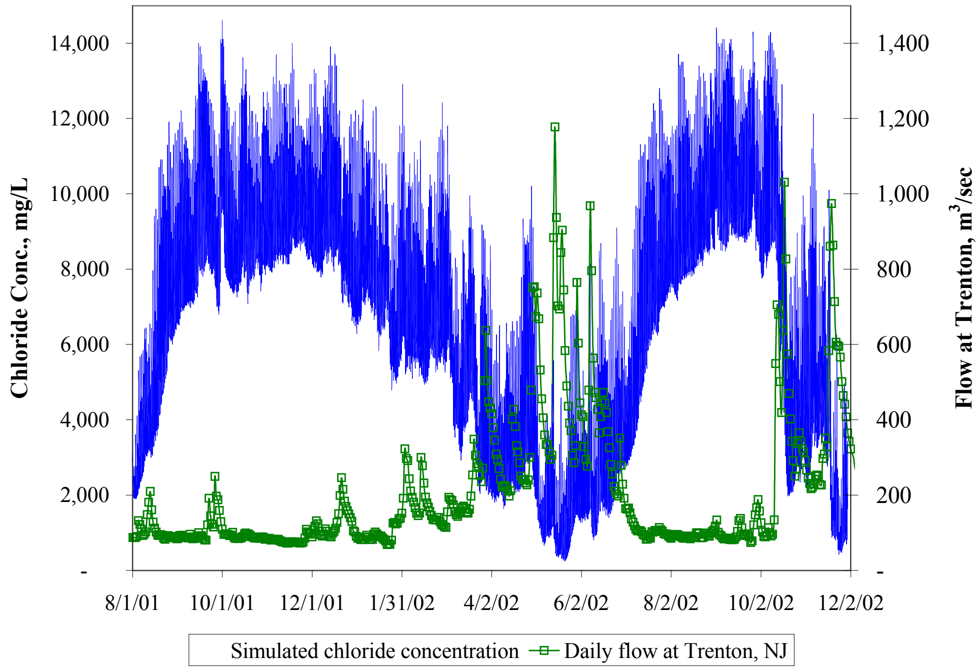


Figure 4-5: Temporal variations of the simulated chloride at RM 54 related to the inflows at Trenton.

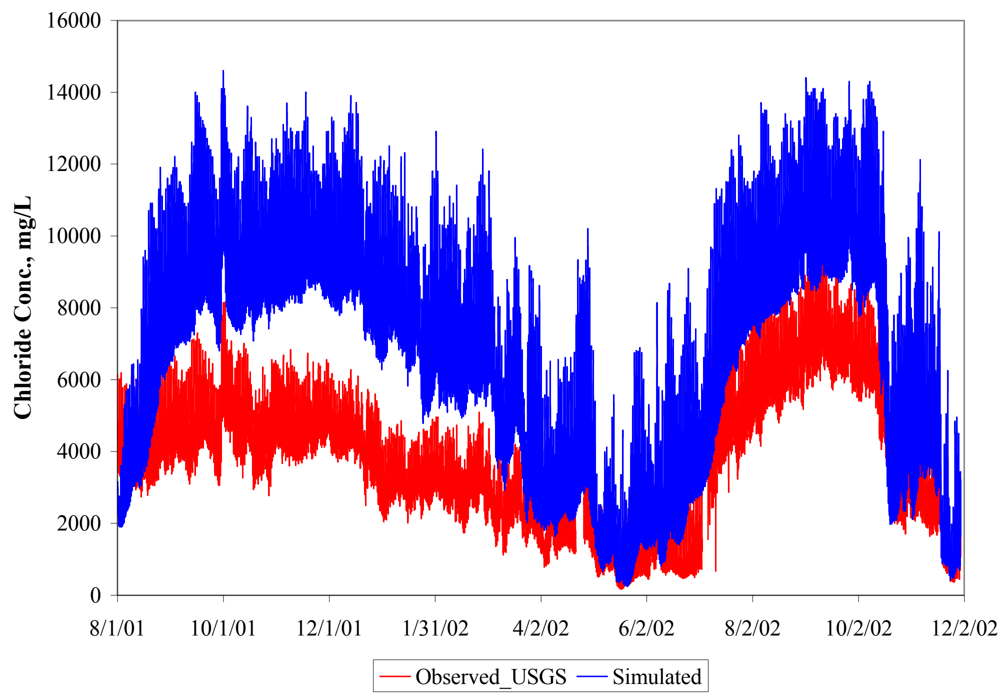


Figure 4-6: Temporal variations of the simulated and the observed chloride concentration at RM 54.

4.3.4.2 Approach and Modification to the Tidal Datum at Chesapeake City, MD

Because the manipulation of dispersion coefficients could not resolve the intrusion of chloride, an advective movement correction was performed within the C&D Canal. A certain level of adjustment was required to correctly simulate the direction and magnitude of the net flow through the C&D Canal. The major components that determined the direction and the magnitude of the flows within the C&D Canal were the tidal heights at both ends of the Canal, Chesapeake City and Reedy Point, in this model. It was decided that adjustments on the tidal heights at the Chesapeake City would be made and not to make any adjustment on tidal heights at Reedy Point Station, because the tidal heights at Reedy Point were actually observed. On the other hand, the tidal heights at the Chesapeake City were derived from the Reedy Point station's observed data. To force the net flow direction eastward (from Chesapeake to Delaware Estuary), the tidal heights at the west end (Chesapeake City) were raised. The tidal datum at Chesapeake City was shifted up at different levels and compared to the results of the sensitivity simulations on chloride concentrations (Figure 4-7). Ten (10) centimeters up-shift of the tidal datum at the Chesapeake City was chosen based upon the simulated chloride concentration profiles.

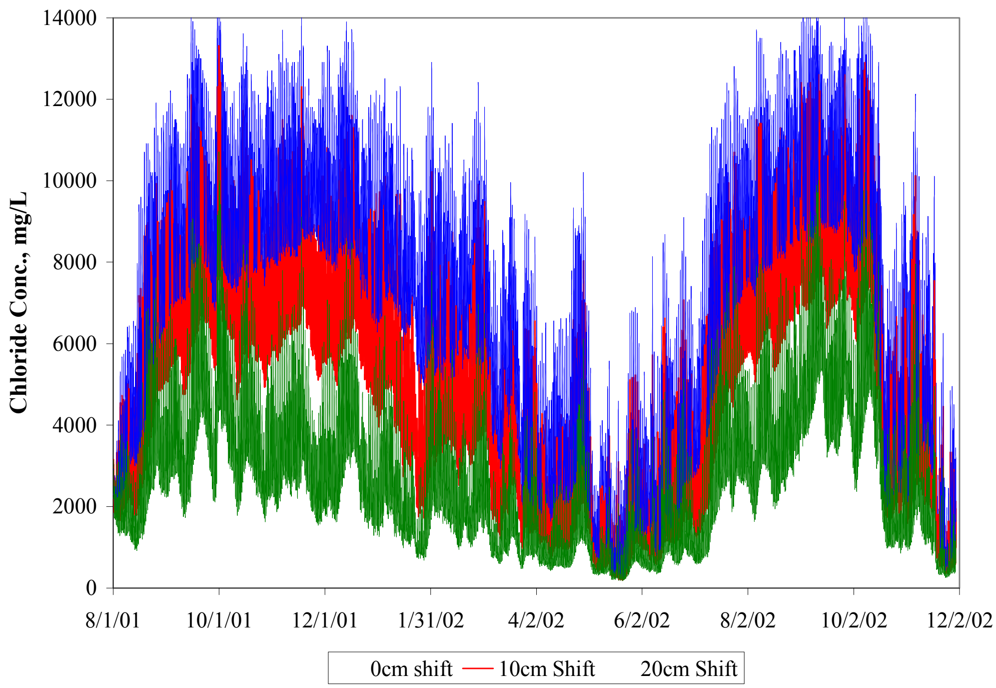
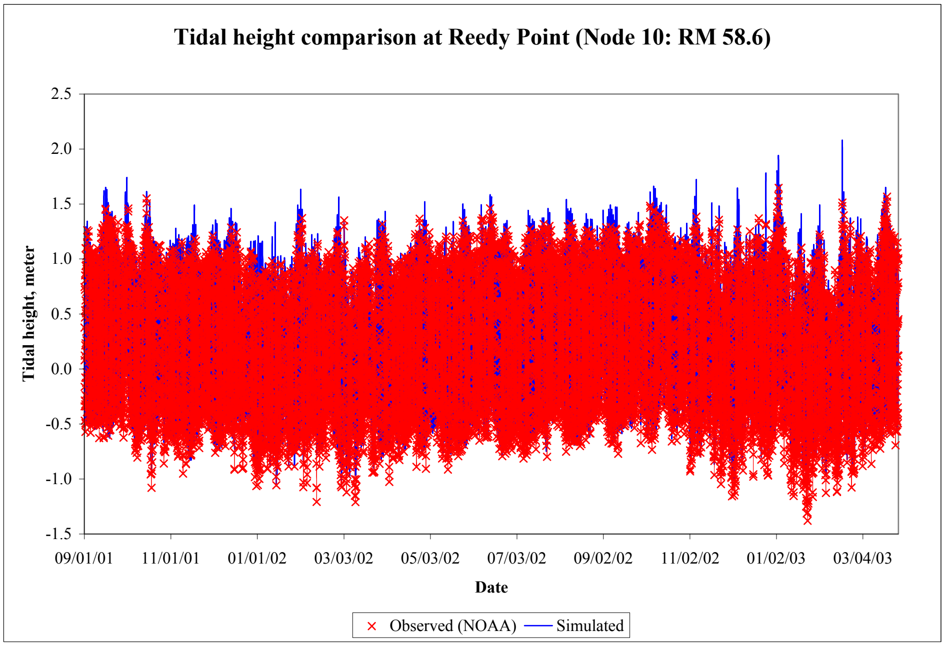


Figure 4-7: Sensitivity simulation results: Impact on chloride concentrations by the datum shift at the Chesapeake City.

(a)



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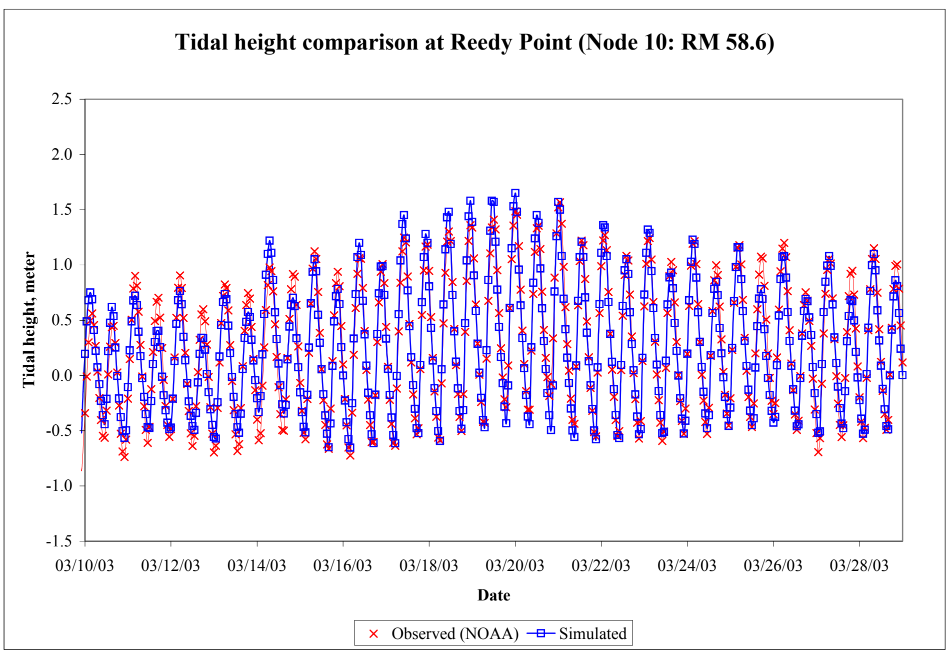
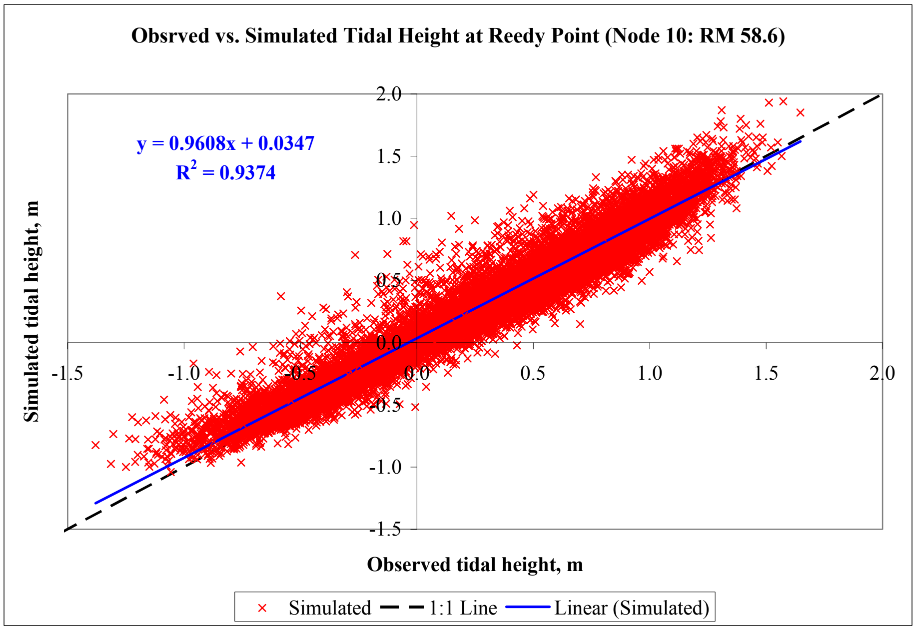


Figure 4-9: The observed and the simulated tidal heights at Reedy Point (River Mile 58.6): (a) for the entire calibration period; (b) from the period March 10, 2003 to March 31, 2003.

(c)



(d)

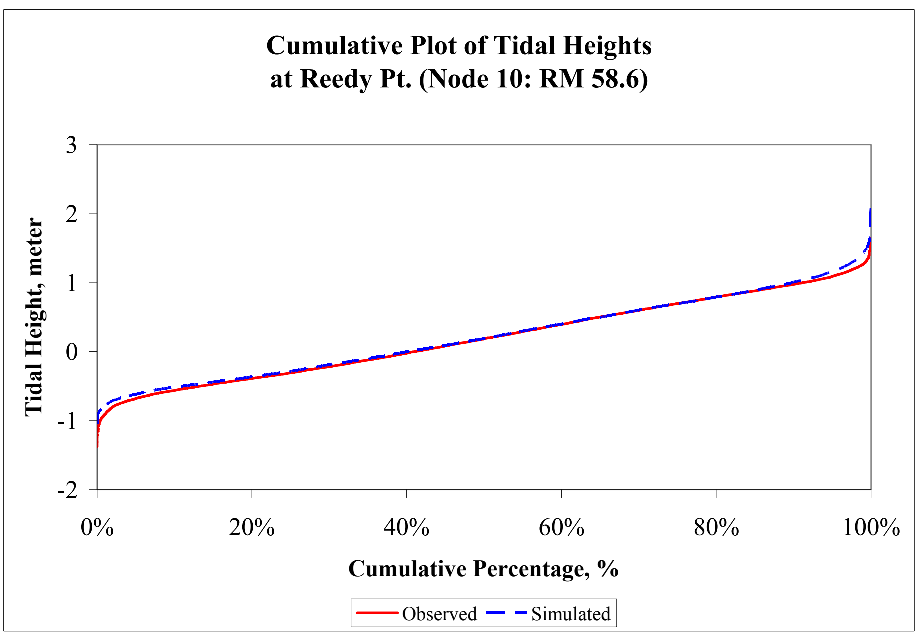
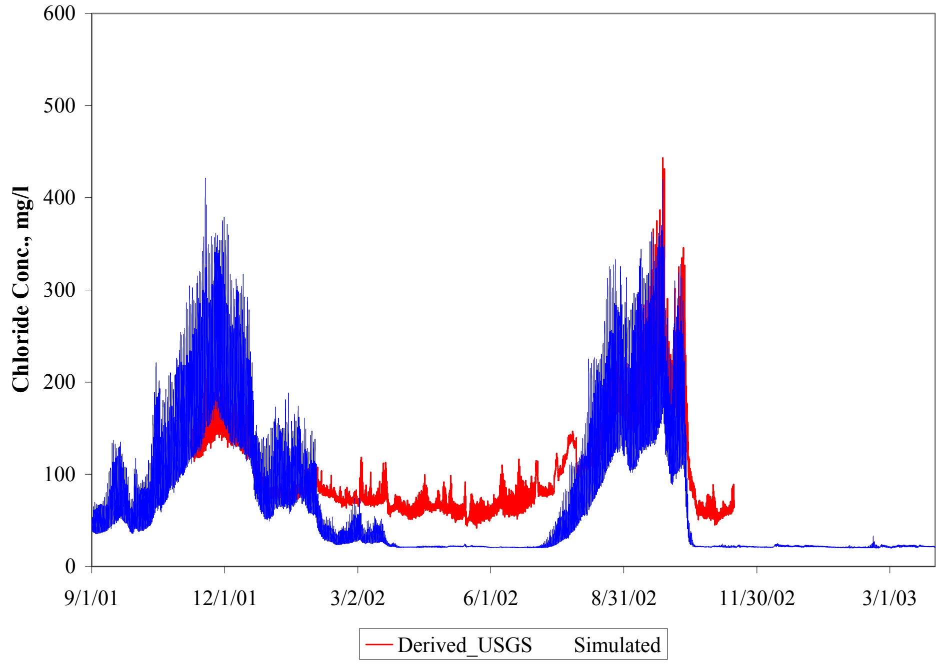


Figure 4-9: The observed and the simulated tidal heights at Reedy Point (River Mile 58.6): (c) Linear regression results (n=13,777); (d) cumulative frequency distribution curve.

(a)



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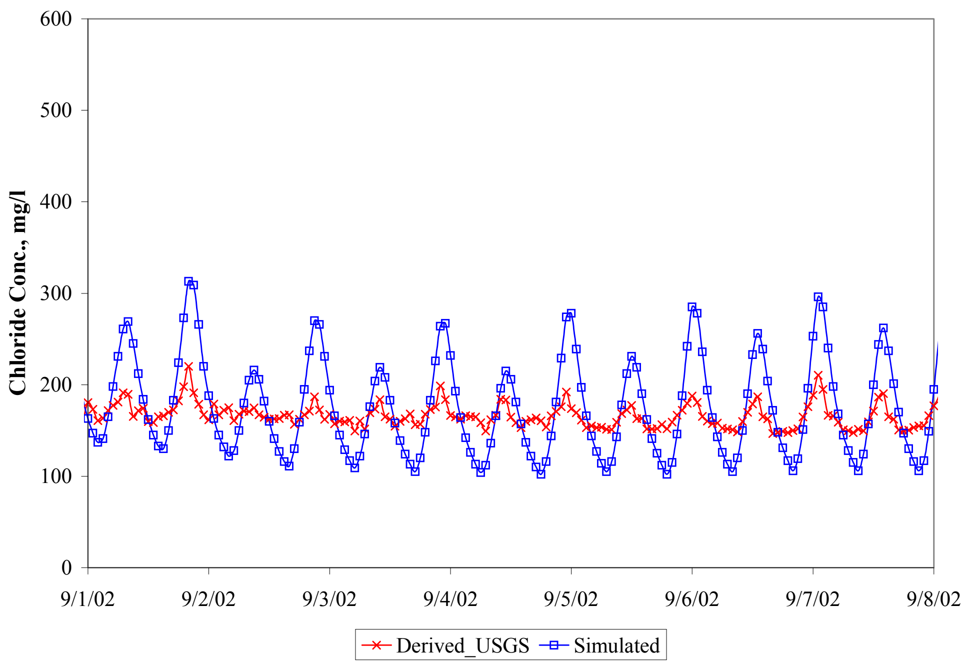


Figure 5-9: Temporal comparison between the observed data (derived from specific conductance from USGS Fort Mifflin Station) and the simulated chloride concentrations for (a) entire simulation period; (b) first week of September 2002.

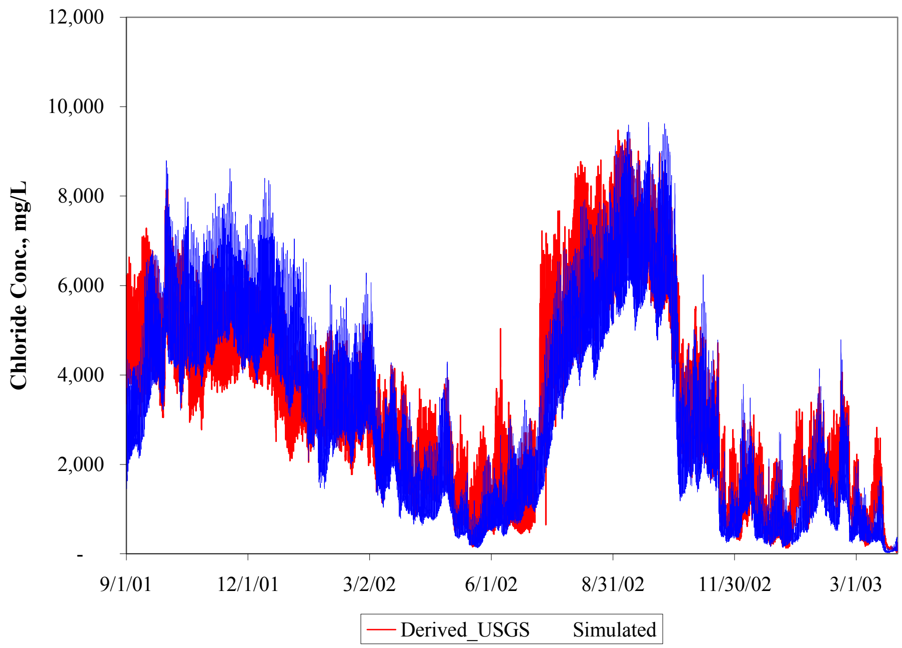
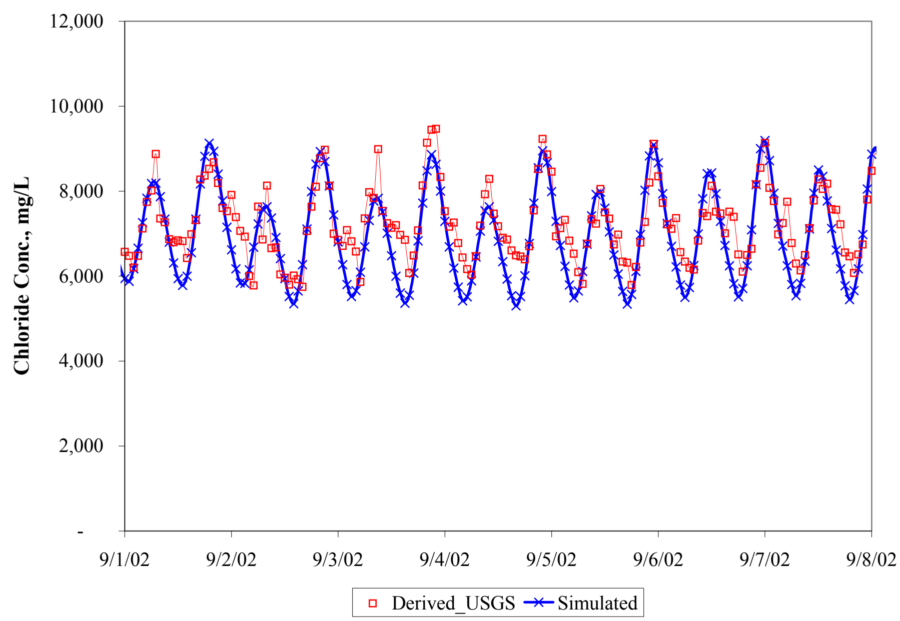


Figure 5-11: Temporal comparison between the observed data (derived from specific conductance from USGS Reedy Is. Station) and the simulated chloride concentrations for the calibration period.



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