

**FINAL STUDY REPORT
SALINITY AND SALT WEDGE ENCROACHMENT STUDY
RSP 3.20**

CONOWINGO HYDROELECTRIC PROJECT

FERC PROJECT NUMBER 405



Prepared for:



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EXECUTIVE SUMMARY

Exelon Generation Company, LLC has initiated with the Federal Energy Regulatory Commission (FERC) the process of relicensing the 573-megawatt Conowingo Hydroelectric Project (Conowingo Project). The current license for the Conowingo Project was issued on August 14, 1980 and expires on September 1, 2014. FERC issued the final study plan determination for the Project on February 4, 2010, approving the revised study plan with certain modifications. The final study plan determination required Exelon to conduct a Salinity and Salt Wedge Encroachment Study, which is the subject of this report. The objectives of this study are to: 1) determine if Project operations adversely impact downstream salinity levels; 2) determine if Project operations have the ability to change the frequency and duration of exceedences of salinity levels above drinking water standards; and 3) identify and evaluate the potential for impacts to biota from salinity changes in the lower Susquehanna River due to Project operations.

An initial study report (ISR) was filed on February 22, 2011, containing Exelon's 2010 study findings. An ISR meeting was held on March 9, 10 and 11, 2011 with resource agencies and interested members of the public. Formal comments on the ISR including requested study plan modifications were filed with FERC on April 27, 2011 by Commission Staff, several resource agencies and interested members of the public. Exelon filed responses to the ISR comments with FERC on May 27, 2011. On June 24, 2011, FERC issued a study plan modification determination order. The order specified what, if any, modifications to the ISRs should be made. For this study, FERC's June 24, 2011 order required no modifications to the original study plan. An updated study report (USR) was filed on January 23, 2012 addressing comments from stakeholders received at the March ISR meeting, those comments addressed by Exelon in the May 27, 2011 responses to ISR comments, as well as editorial and minor text changes. This final study report is being filed with the Final License Application for the Project.

Salinity levels in the lower Susquehanna rise during periods of low flow and high tidal elevations. These salinity changes impact water treatment intakes and, potentially, salinity-sensitive biota. Salinity levels at the City of Havre de Grace water treatment plant located near the mouth of the Susquehanna River have exceeded the EPA taste and odor guideline of 0.25 ppt once in the past 13 years.

The City of Havre de Grace has been collecting instantaneous daily salinity levels at their water treatment plant since 1997, while the Maryland Department of Natural Resources has been collecting 15-min salinity observations during the spring, summer and fall since 2007. Observed salinity values were compared to streamflow, tidal elevation, and wind speed and direction data to determine what most influenced salinity levels and whether Conowingo Dam operations impact downstream salinity levels.

It was found that observed salinity levels were correlated best with 30 to 60-day average flows. In addition, tidal influences were evident during higher salinity periods. Wind speed and direction did not appear to impact salinity levels. A least-squares regression found that 30-day average flows best predicted 15-min salinity levels ($R^2 = 0.758$). Streamflow comparisons showed that Conowingo Dam operations only slightly impacted flows on a daily time step, and minimally influenced weekly and longer flows up to 30 days. Therefore, it was concluded that Project operations do not substantially influence salinity levels in the Lower Susquehanna River, and therefore also do not impact the frequency or duration of salinity level exceedances.

The river's observed salinity levels were compared with target species' salinity tolerances. Observed salinity levels are an order of magnitude lower than target species' salinity tolerances, and are within target species' suitable ranges. While salinity observations suggest the Project does not influence Susquehanna River salinity levels, the observed fluctuations are well below target species' salinity tolerance thresholds anyway.

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LIST OF ACRONYMS

cfs	Cubic Feet per Second
EPA	Environmental Protection Agency
Exelon	Exelon Generation Company, LLC
FERC	Federal Energy Regulatory Commission
HDG	Havre de Grace
ILP	Integrated Licensing Process
ISR	Initial Study Report
MDNR	Maryland Department of Natural Resources
mgd	Million Gallons a Day
NOI	Notice of Intent
PAD	Pre-Application Document
ppt	Parts Per Thousand
Project	Conowingo Hydroelectric Project
PSP	Proposed Study Plan
RMSE	Root Mean Square Error
RSP	Revised Study Plan
SRBC	Susquehanna River Basin Commission
USGS	United States Geological Survey
USR	Updated Study Report

1. INTRODUCTION

Exelon Generation Company, LLC (Exelon) has initiated, with the Federal Energy Regulatory Commission (FERC), the process of relicensing the 573-megawatt Conowingo Hydroelectric Project (Project). Exelon is applying for license renewal using the FERC's Integrated Licensing Process (ILP). The current license for the Conowingo Project was issued on August 14, 1980 and expires on September 1, 2014.

Exelon filed its Pre-Application Document (PAD) and Notice of Intent (NOI) with FERC on March 12, 2009. On June 11 and 12, 2009, a site visit and two scoping meetings were held at the Project for resource agencies and interested members of the public. Following these meetings, formal study requests were filed with FERC by several resource agencies. These study requests were in Exelon's Proposed Study Plan (PSP), which was filed on August 24, 2009. On September 22 and 23, 2009, Exelon held a meeting with resource agencies and interested members of the public to discuss the PSP.

Formal comments on the PSP were filed with FERC on November 22, 2009 by Commission staff and several resource agencies, local communities and nongovernment organizations. Exelon filed a Revised Study Plan (RSP) for the Project on December 22, 2009. FERC issued the final study plan determination for the Project on February 4, 2010, approving the RSP with certain modifications.

The Susquehanna River Basin Commission (SRBC) filed comments describing how the City of Havre de Grace has experienced intermittent salinity issues at its drinking water treatment plant intake. SRBC expressed concern that Project operations may influence salinity levels in the tidally influenced portions of the river. The final study plan determination required Exelon to conduct a Salinity and Salt Wedge Encroachment Study, which is the subject of this report.

The objectives of this study are to: 1) determine if Project operations adversely impact downstream salinity levels; 2) determine if Project operations have the ability to change the frequency and duration of exceedences of salinity levels above drinking water standards; and 3) identify and evaluate the potential for salinity-related biota impacts in the lower Susquehanna River due to Project operations.

An initial study report (ISR) was filed on February 22, 2011, containing Exelon's 2010 study findings. An ISR meeting was held on March 9, 10 and 11, 2011 with resource agencies and interested members of the public. Formal comments on the ISR including requested study plan modifications were filed with FERC on April 27, 2011 by Commission Staff, several resource agencies and interested members of the public. Exelon filed responses to the ISR comments with FERC on May 27, 2011. On June 24, 2011, FERC issued a study plan modification determination order. The order specified what, if any,

modifications to the ISRs should be made. For this study, FERC's June 24, 2011 order required no modifications to the original study plan. An updated study report (USR) was filed on January 23, 2012 addressing comments from stakeholders received at the March ISR meeting, those comments addressed by Exelon in the May 27, 2011 responses to ISR comments, as well as editorial and minor text changes. This final study report is being filed with the Final License Application for the Project.

2. BACKGROUND

2.1 Project Description and Hydrology

The Susquehanna River below Conowingo Dam flows approximately ten miles before entering Chesapeake Bay. The non-tidal portion of the Susquehanna River encompasses approximately four miles of river length, from Conowingo Dam downstream to the mouth of Deer Creek (a tributary), which is the approximate natural tidal influence boundary. The Chesapeake Bay stretches about 200 miles from the Susquehanna River in the north to the Atlantic Ocean in the south. Much of the bay is quite shallow. At the point where the Susquehanna River flows into the bay, the average depth is approximately 30 ft.

The City of Havre de Grace, located at the mouth of the Susquehanna River, uses the river for its public drinking water supply. Current drinking water production averages approximately 1.7 million gallons a day (mgd) (City of Havre De Grace, 2009). This is equivalent to approximately 2.6 cubic feet per second (cfs), on average. As SRBC stated, periodic increases in salinity have been an issue at the water supply intake for the City of Havre de Grace. A salinity level above 0.25 parts per thousand (ppt) violates the Environmental Protection Agency (EPA) taste and appearance standard

The Conowingo Project is a 573 MW hydroelectric facility that uses limited active storage within the 8,500 acre Conowingo Pond for generation purposes. The maximum hydraulic capacity of the Conowingo powerhouse is approximately 86,000 cfs. The current license permits water levels from elevations 101.2 to 110.2 ft¹, but the pond normally fluctuates between elevations 105.2 ft and 109.2 ft. The effective storage between elevations 105.2 ft and 109.2 ft is approximately 34,164 acre-ft, which amounts to about 5 hours of generation at full capacity (86,000 cfs), assuming no inflow.

The current minimum flow regime below Conowingo Dam was formally established with the signing of a settlement agreement in 1989 between the Project owners and several federal and state resource agencies (FERC 1989). The established minimum flow regime below Conowingo Dam is the following:

March 1 – March 31	3,500 cfs or natural river flow, whichever is less
April 1 – April 30	10,000 cfs or natural river flow, whichever is less
May 1 – May 31	7,500 cfs or natural river flow, whichever is less
June 1 – September 14	5,000 cfs or natural river flow, whichever is less

¹ Refers to the National Geodetic Vertical Datum of 1929 (NGVD29), in contrast to Conowingo Datum. Conowingo Datum elevations are 0.7 ft lower than NGVD29 elevations. For example, elevation 109.2 ft in NGVD29 is equal to elevation 108.5 ft in Conowingo Datum.

September 15 – November 30	3,500 cfs or natural river flow, whichever is less
December 1 – February 28	3,500 cfs intermittent (maximum 6 hours off followed by equal amount on) or natural river flow, whichever is less

The downstream discharge must equal these values or the discharge measured at the Susquehanna River at the Marietta United States Geological Survey (USGS) gage (No. 01576000), whichever is less. The Marietta USGS gage is located approximately 35 miles upstream of Conowingo Dam above the Safe Harbor Hydroelectric Project.

2.2 Salt Wedge Formation

While the hydrodynamics of a freshwater/saltwater interface are complex, they can generally be divided into three main categories: salt-wedge, slightly stratified, or well-mixed (NOAA, 2011). Interfaces with a relatively high amount of freshwater input and weaker tides tend to result in salt wedge estuaries, while strong tides and less freshwater input result in well-mixed estuaries. Slightly stratified estuaries result from relatively equal freshwater and tidal influences. The mouth of the Susquehanna typically has a relatively large amount of freshwater input relative to Chesapeake Bay, which results in a salt-wedge type estuary.

Salt-wedge estuaries have a fairly discrete transition from saltwater to freshwater, where the layer of relatively rapid transition is referred to as the “salt wedge”. The large amount of freshwater inflow is less dense than saltwater, and tends to ride above the saltwater. At the river mouth, the freshwater layer is thick, while the saltwater layer is relatively thin, and sits on the bottom of the estuary. As you travel farther from the river mouth, the layer of freshwater on top becomes thinner, and the layer of saltwater on the bottom becomes thicker, thus forming the salt wedge. Mixing occurs rapidly at the interface of the saltwater and freshwater. This results in a relatively high salinity gradient within the salt wedge, with relatively low salinity gradients found upstream and downstream of the salt wedge. Typically, higher flows push the salt wedge further from the river mouth, while lower flows result in the wedge pushing farther inland.

3. METHODS

The following methods were used to meet the study objectives:

- Salinity duration analyses were conducted over the data collection period.
- 15-min and daily salinity readings were correlated to streamflow, tidal elevations, and wind speeds.
- Time series plots were used to compare salinity levels to streamflow, tidal elevations, and wind speeds.
- Habitat suitability criteria were used to evaluate salinity variations' potential impact on target species.

Data used for this study included salinity, streamflow, tidal elevations and wind speed values.

Salinity data were available from two sources. The two salinity recording stations' locations are shown in [Figure 3-1](#). Beginning in 1997, the City of Havre de Grace started collecting instantaneous salinity values at the Havre de Grace water supply intake when the river was at approximately high tide each day (D. Geiger, Personal Communication, 2010). Since a tidal cycle is approximately 12.5 hours, readings occurred at slightly different times in consecutive days. Specific data collection times were not recorded. In 2007, the MDNR began operation of a continuous water quality monitoring station in the Susquehanna River near Havre de Grace. The station measures several water quality parameters, including salinity levels, at 15 min intervals from late March through late October. The daily instantaneous readings do not present as detailed of a picture as the 15-min MDNR salinity observations. However, since instantaneous readings were taken at high tide, they should represent the most saline conditions expected in the river throughout the day².

15-min and daily average streamflow data were available for two gaging locations on the Susquehanna at Marietta (USGS Gage No. 01576000), and below Conowingo Dam (USGS Gage No. 01578310).

15-min wind speed and direction data were available from the City of Havre de Grace water treatment plant weather station beginning in 2007. Hourly tidal data were available from gages located near

² The relationship between salinity and tidal levels is assessed in Section 4.3 and Section 4.4.

Chesapeake City, MD (Station ID: 8573927) for the period of record 1979-2009, and the City of Havre De Grace, MD (Station ID: 8574070) for the period of record 1979-2005.

Habitat suitability criteria for several parameters, including salinity for target species (e.g., American Shad, Hickory Shad, Blueback Herring, Alewife Herring, White Perch, Striped Bass, Yellow Perch, Submerged Aquatic Vegetation, Walleye, Largemouth Bass, Smallmouth Bass, Atlantic Sturgeon, Shortnose Sturgeon, and American Eel) in the Susquehanna River below Conowingo Dam, was available from various literature sources (MDNR, Personal Communication, 2009).

4. RESULTS AND DISCUSSION

4.1 Time Series Analysis

Time series plots revealed MDNR (15-min) and City of Havre De Grace (HDG) (instantaneous daily) salinity values did not match well in magnitude, but generally follow similar temporal trends during the overlap period between 2007 and 2010 ([Figure 4.1-1](#)). HDG salinity readings were consistently ten times lower than the MDNR salinity readings (e.g. 0.01 vs 0.1 ppt). This is likely because the MDNR station was approximately 0.5 miles downstream of the HDG WTP, and closer to the saline Chesapeake Bay waters. Though the magnitudes are different, the 15-min MDNR salinity readings typically did not change faster than daily when salinity values were below 0.20 ppt. Therefore, longer term HDG daily salinity readings were used to complement the MDNR 15-min salinity data prior to 2007 and during wintertime data gaps.

Though SRBC comments stated that Havre de Grace experienced several salinity events over the past 30 years, instantaneous daily salinity records were not collected until 1997. Over the 13 year data collection period at the HDG water intake, there was one period when salinity exceeded the EPA taste and appearance threshold of 0.25 ppt ([Figure 4.1-2](#)). At the MDNR station, there were three events in which the salinity exceeded 0.25 ppt in four years ([Figure 4.1-1](#)).

Salinity values appeared to vary by season. For each day of the year, the median daily instantaneous salinity value was calculated using all 13 years of data. The annual median time series showed that salinity levels were generally greatest in the fall and late winter, and were lowest during spring and summer ([Figure 4.1-3](#)). Median daily salinity levels were between 0.005 and 0.02 ppt.

4.2 Duration Analysis

Duration analyses showed that salinity values rarely exceeded 0.25 ppt at the HDG station, but exceedances were more frequent at the MDNR station ([Figure 4.2-1](#)). Annual analyses showed that only 0.1% of the 13 years of daily instantaneous readings at the HDG station met or exceeded this threshold, which was equivalent to three days. Though salinity levels exceed 0.25 ppt in three of the four monitored years at the MDNR station, only 0.05% of the 15 min readings met or exceeded this threshold.

The 15-min MDNR monthly duration analysis showed that August, September and October had the highest salinity levels while April, May and June had the lowest salinity levels ([Figure 4.2-2](#)). Instantaneous daily salinity duration analyses at the HDG Station also showed that August, September and October had the highest salinity levels, and April, May and June had the lowest salinity levels ([Figure 4.2-3](#)).

4.3 Streamflow, Tide Levels, and Wind Correlations

Correlations were performed comparing 15-min (2007-2010) and daily instantaneous salinity (1997-2010) observations to 15-min and daily flow, wind and tidal data for common periods.

Daily instantaneous salinity readings were correlated against average daily flow reciprocals (1/Average Daily Flow) for the Susquehanna River at Marietta and Conowingo USGS gages ([Figure 4.3-1](#)). Though neither location correlated very well, the Marietta gage flows ($R^2 = 0.177$) were correlated slightly better than Conowingo flows ($R^2 = 0.158$).

15-min and daily salinity observations were also correlated against the reciprocals of Conowingo USGS gage 1, 3, 5, 7, 14, 21, 28, 45 and 60-day moving average flows (daily and 15-min data), shown in [Table 4.3-1](#). Salinity readings correlated better with longer moving average periods, while shorter moving average periods had increasingly worse correlations. The 30-day moving average flow reciprocal correlated best to 15-min salinity observations ($R^2 = 0.758$) and daily instantaneous salinity observations ($R^2 = 0.234$).

15-min salinity data were plotted versus tidal elevations and wind speed between 2007 and 2009 ([Figure 4.3-2](#)), but both were poorly correlated. However, unique salinity and tidal level relationships during high-salinity events are discussed in Section 4.4. No wind data were available for 2010. Wind direction was plotted against salinity values, but no trend was found.

Correlations showed that flow was the best salinity predictor, particularly over longer time periods. The flow correlations showed that day-to-day and shorter term flows have a relatively small impact on salinity levels near the mouth of the Susquehanna. Longer term flows were a much better predictor for 15-min and daily instantaneous salinity observations. Tidal elevations and wind speeds did not correlate well with salinity levels overall.

4.4 High Salinity Periods

There were three high salinity periods (salinity ≥ 0.25 ppt) at the MDNR station between 2007 and 2010. Salinity did not exceed 0.25 ppt at the HDG plant during any of these events. All three events followed extended periods with daily average flows at or below 10,000 cfs ([Figure 4.4-1](#) and [Figure 4.4-2](#)). 2009 had relatively greater flows, and as a result did not experience a high salinity period. Longer term daily instantaneous salinity readings agreed with 15-min data in showing that high salinity periods were associated with extended low flow periods ([Figure 4.4-3](#) and [Figure 4.4-4](#)).

There appeared to be unique phenomena influencing salinity levels during the high salinity periods. While overall dataset comparisons showed that long-term river flows generally correlated well with salinity observations, a comparison of 2007 and 2008 salinity observations versus river flow during high salinity periods shows that salinity levels varied somewhat independently of long-term and instantaneous flows measured at the Marietta and Conowingo USGS gages ([Figure 4.4-5](#) and [Figure 4.4-6](#)). During high salinity events, tidal influences clearly influenced salinity levels, which contradict what the composite data analysis showed ([Figure 4.4-7](#) and [Figure 4.4-8](#)).

The apparent change in controlling phenomena during high salinity events is likely due to the Chesapeake Bay salt wedge encroaching on the monitoring station. During extended low flow periods, the salt wedge travels progressively farther upstream over time. Conversely, the salt wedge is pushed downstream during higher flow periods. Additionally, the salt wedge is pushed upstream and downstream in the river as the tide rises and falls. Once the salt wedge reaches the monitoring station, salinity levels vary rapidly, explaining why tidal influences only appear to be important during high salinity periods.

4.5 Project Flow Influences

The Project's maximum theoretical influence on Susquehanna River flows over different time periods was quantified in [Table 4.5-1](#) by assuming the pond utilized all of its normal storage (between 105.2 ft and 109.2 ft) to reduce the river flow. It showed that while flow can be substantially reduced in the short term (21,300 cfs in one day), over 30 days the flow can be reduced by a maximum of 711 cfs. While this is very small compared to the Susquehanna's average daily flow (37,000 cfs), during low flow periods 711 cfs is a proportionally larger amount of the river flow. The Project must pass net inflow when natural river flow is below 3,500 cfs (the lowest allowable minimum flow), and would, therefore, not store any water. Thus, the lowest inflow that would allow the reservoir to fill over 30 days would be 4,211 cfs, with a constant outflow of 3,500 cfs. This is equivalent to a 17% flow reduction.

Comparisons between Project flows and upstream Marietta daily average flows show that, on a daily timestep, the plant normally passes as much water as it receives ([Figure 4.5-1](#)), with a high agreement between the flow of both locations ($R^2 = 0.983$). This agreement is greater for thirty day flows, with an $R^2 = 0.989$. Though Project operations impact the river's flow regime on a sub-daily timestep, they do not significantly change the flow of the river over daily or longer timesteps. Therefore, while the Project could theoretically influence flows over a fairly long time period during low-flow periods, in practice, this does not normally occur.

4.6 Comparison to Biotic Tolerances

Observed salinity levels at the HDG station ranged from 0 to 0.26 ppt, and salinity levels at the MDNR station ranged from 0.07 to 0.46 ppt. These ranges were compared with target species' salinity tolerances provided to Exelon by MDNR (MDNR, Personal Communication, 2009), which are summarized in [Table 4.6-1](#). The listed salinity tolerances are one to two orders of magnitude greater than the highest observed salinity levels for all target species.

5. CONCLUSIONS

Salinity levels rarely exceed 0.25 ppt at the HDG or MDNR monitoring stations, with high salinity events occurring less than once per year. Salinity variations ranged from 0.01 ppt to 0.26 ppt at the HDG monitoring station, and from 0.08 ppt to 0.46 ppt at the MDNR monitoring station.

Salinity levels appear to be primarily driven by longer term flows (30, 45, and 60-day moving average), with short-term flow variations having little impact. During high-salinity periods, tidal influences also influence salinity levels. Analyses show that Conowingo Dam operations primarily alter short-term flows, and minimally impact weekly or longer term average flows, including the 30-day average flow. Therefore, it appears that Project operations do not substantially impact salinity levels during either high or low salinity periods.

Other salinity influences were also investigated, but correlations to composite salinity observations were poor. 15-min time series plots showed that during higher salinity periods salinity levels did not noticeably respond to Project operations, and varied closely with tidal elevations. Tidal influences appeared to be nonexistent when salinity levels were below 0.20 ppt. The influence of wind on salinity levels is unclear. Though a plot of salinity versus wind speed showed higher wind speeds were generally associated with lower salinity levels, it is not clear why. Wind direction appeared to have no correlation to salinity levels. In addition, there may be other factors controlling salinity levels not studied in this analysis, such as seasonally varying salinity levels in Chesapeake Bay, or mixing of Chesapeake Bay and Susquehanna River water due to ship traffic or extreme storms.

Salinity exceedances were very rare and only occurred once in the 13 years of monitored data at HDG. While the MDNR station showed salinity levels exceeded 0.25 ppt three out of four years, the station was located farther downstream where higher salinity levels were expected.

Project operations do not appear to impact target species in the context of salinity concerns for two reasons. First, analyses suggest that Project operations have had no impact on salinity levels at the HDG or MDNR monitoring stations. Long term average flows appear to drive salinity levels, and the Project does not appear to impact flows on such a long time step. Secondly, published target species' salinity tolerances were found to be orders of magnitude higher than observed salinity levels. Therefore, though Project operations do not appear to impact Lower Susquehanna River salinity levels, the salinity variations observed are within the suitable range for all of the target species.

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TABLE 4.3-1: SALINITY CORRELATIONS TO MOVING AVERAGE FLOW RECIPROCAL (1/MOVING AVERAGE FLOW). CORRELATIONS WERE CALCULATED USING 15-MIN FLOW DATA³.

Moving Average Window	MDNR salinity observations		HDG salinity observations	
	R ²	RMSE (ppt)	R ²	RMSE (ppt)
Instantaneous	0.394	0.0245	N/A	N/A
1-hour	0.394	0.0245	N/A	N/A
3-hours	0.397	0.0244	N/A	N/A
6-hours	0.406	0.0242	N/A	N/A
12-hours	0.439	0.0235	N/A	N/A
18-hours	0.477	0.0227	N/A	N/A
1-day	0.493	0.0224	0.158	0.0125
3-days	0.556	0.0210	0.200	0.0122
5-days	0.601	0.0199	0.213	0.0121
7-days	0.627	0.0192	0.220	0.0121
14-days	0.698	0.0173	0.224	0.0120
21-days	0.746	0.0159	0.225	0.0120
30-days	0.758	0.0155	0.234	0.0120
45-days	0.756	0.0156	0.227	0.0120
60-days	0.734	0.0162	0.215	0.0121

TABLE 4.5-1: TIME OF STATION INFLUENCE VERSUS MAXIMUM FLOW REDUCTION. CALCULATIONS ASSUME THE PROJECT UTILIZES ALL STORAGE (42,300 ACRE-FT) OVER THE TIME OF INFLUENCE

Time of Influence (days)	Maximum Flow Reduction (cfs)
1	21,326
3	7,109
5	4,265
7	3,047
14	1,523
30	711
45	474
60	355

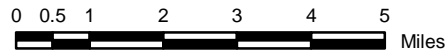
³ For example, the 1-day moving average flow for a salinity reading on 7/29/2007 7:30 was calculated as the average flow observed between 7/28/2007 7:45 and 7/29/2007 7:30, while the 1-day moving average flow for a salinity reading on 7/29/2007 7:45 was calculated as the average flow between 7/28/2007 8:00 and 7/29/2007 7:45.

TABLE 4.6-1: PUBLISHED TARGET SPECIES' SALINITY TOLERANCES

Species	Juvenile Salinity Tolerance (ppt)	Adult Salinity Tolerance (ppt)	Source
Striped Bass	0-16	0-33.7	MDNR 2009
Yellow Perch	0-5	0-13	MDNR 2009
White Perch	0-3	5-18	MDNR 2009
Alewife	0-5	0-30	MDNR 2009
Blueback Herring	0-2	0-35	MDNR 2009
American Shad	0-30	0-30	MDNR 2009
Hickory Shad	0-30	0-30	MDNR 2009
Walleye	--	4-8	MDNR 2009
Largemouth Bass	<4	<4	MDNR 2009
Smallmouth Bass	<4	<4	MDNR 2009
American Eel	--	0.0-30.0	MDNR 2009
Atlantic Sturgeon	0-12	0-35	Shirey et al. 2009
Shortnose Sturgeon	0-16	0-30	Ziegweid et al. 2008



- Legend**
- NOAA Tidal Gages
 - USGS Streamflow Gages
 - Salinity Monitoring Stations



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1 inch equals 2.6 miles

Figure 3-1
Monitoring station locations relative to Conowingo Dam

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FIGURE 4.1-1: TIME SERIES COMPARING HDG AND MDNR SALINITY OBSERVATIONS

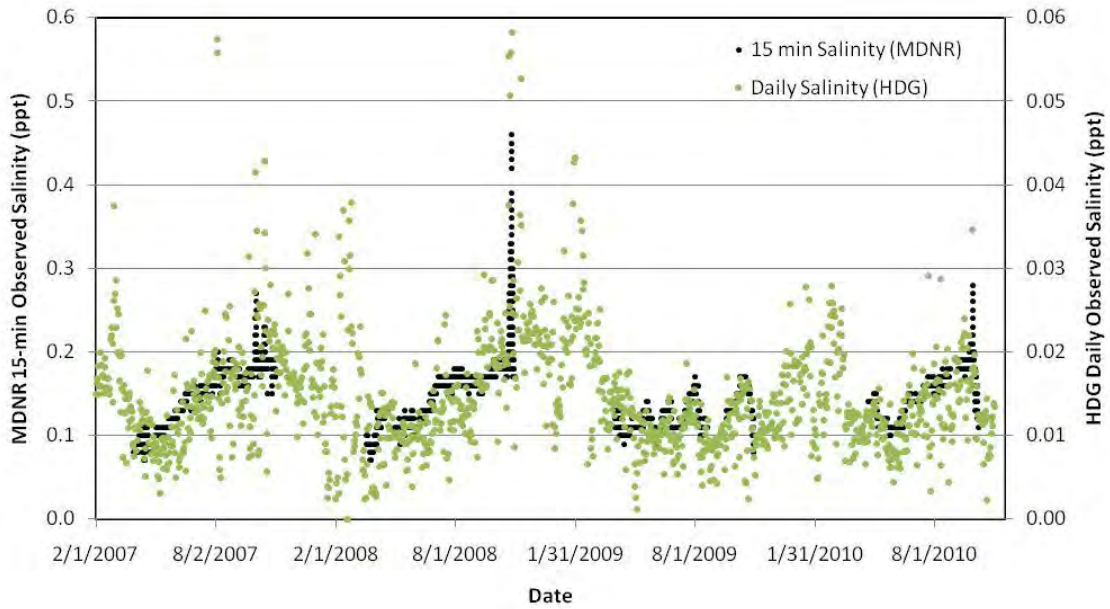


FIGURE 4.1-2: HDG DAILY SALINITY TIME SERIES

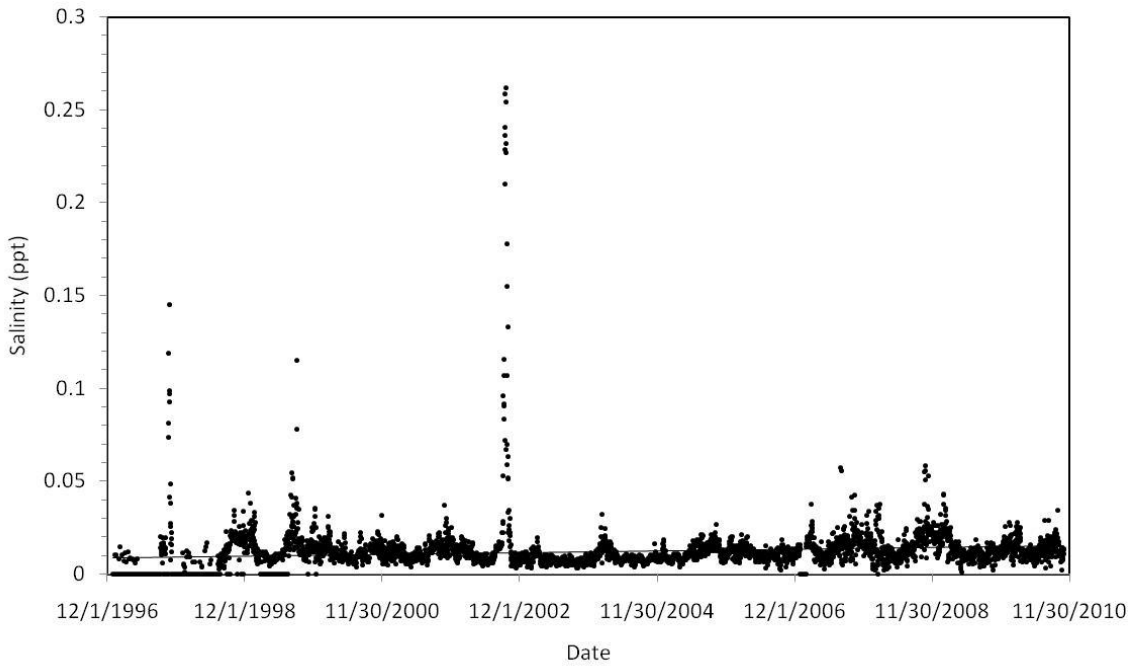


FIGURE 4.1-3: DAILY MEDIAN HDG SALINITY OBSERVATIONS, INCLUDING DATA BETWEEN 1997 AND 2010

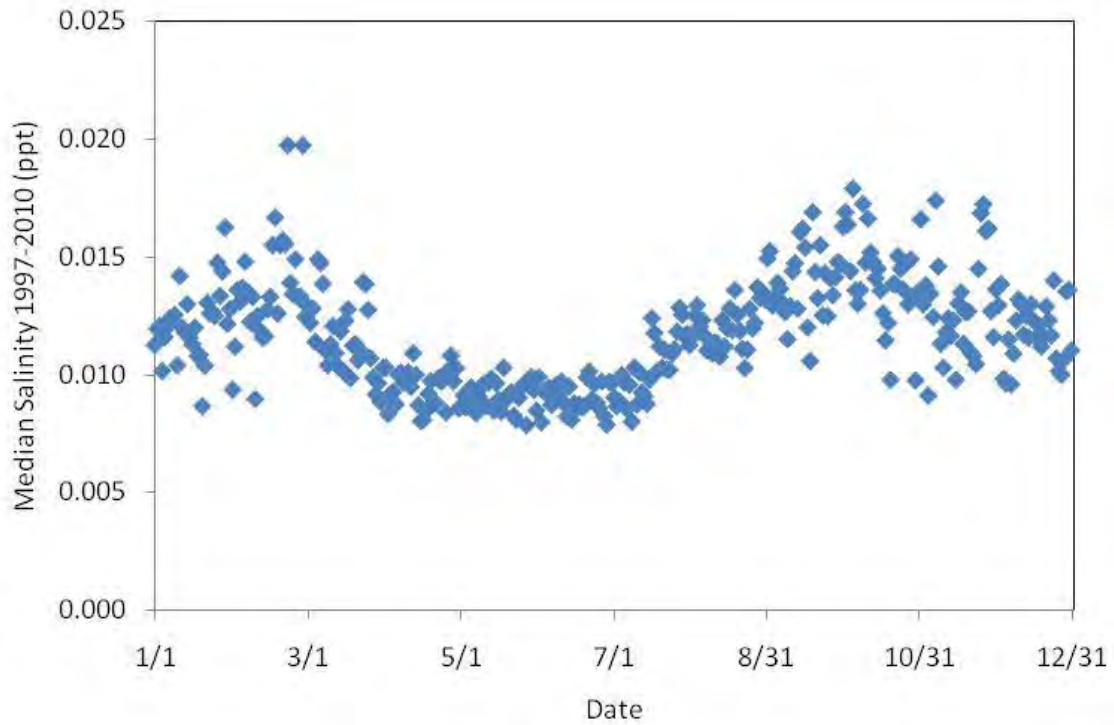


FIGURE 4.2-1: HDG AND MDNR SALINITY DURATION CURVES

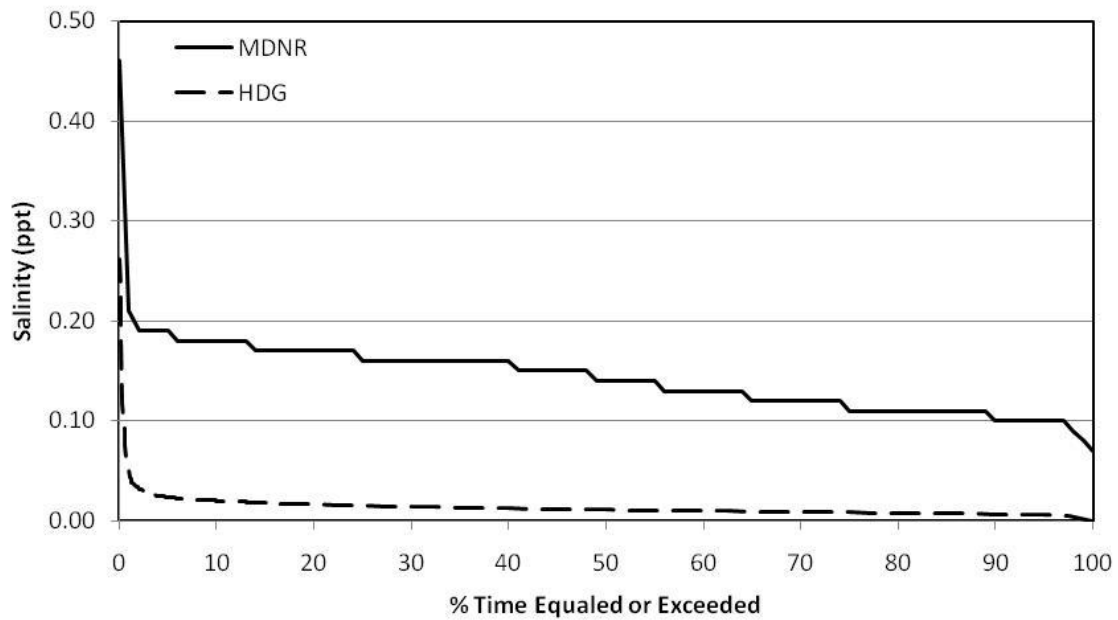


FIGURE 4.2-2: MDNR (15-MIN) DURATION CURVES BY MONTH

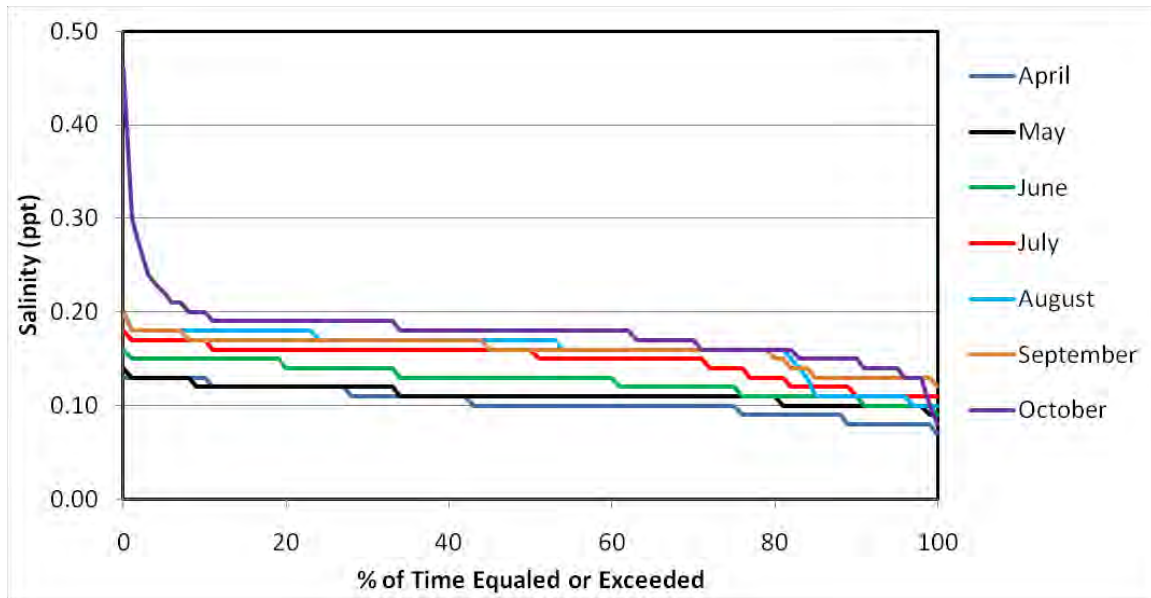


FIGURE 4.2-3: MONTHLY HDG INSTANTANEOUS DAILY DURATION CURVES

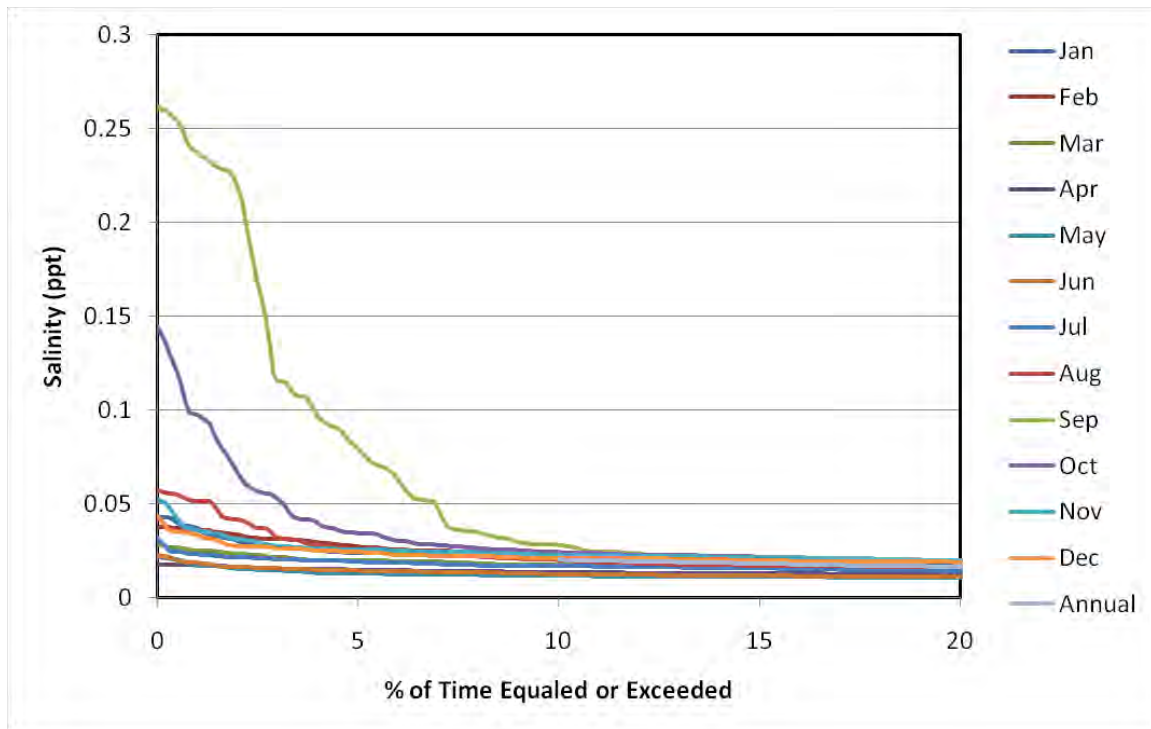


FIGURE 4.3-1: HDG SALINITY OBSERVATIONS VERSUS DAILY AVERAGE FLOW

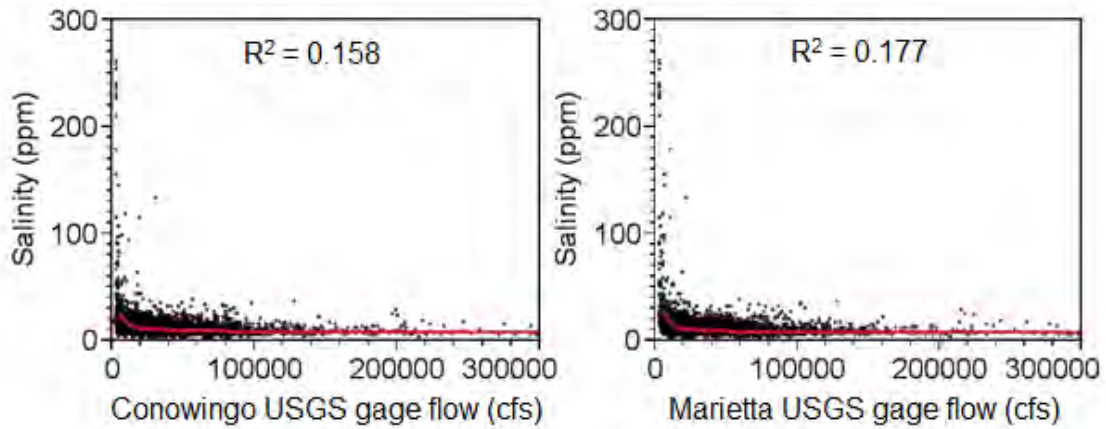


FIGURE 4.3-2: 15-MIN SALINITY OBSERVATIONS VERSUS TIDAL ELEVATION AND WIND SPEED

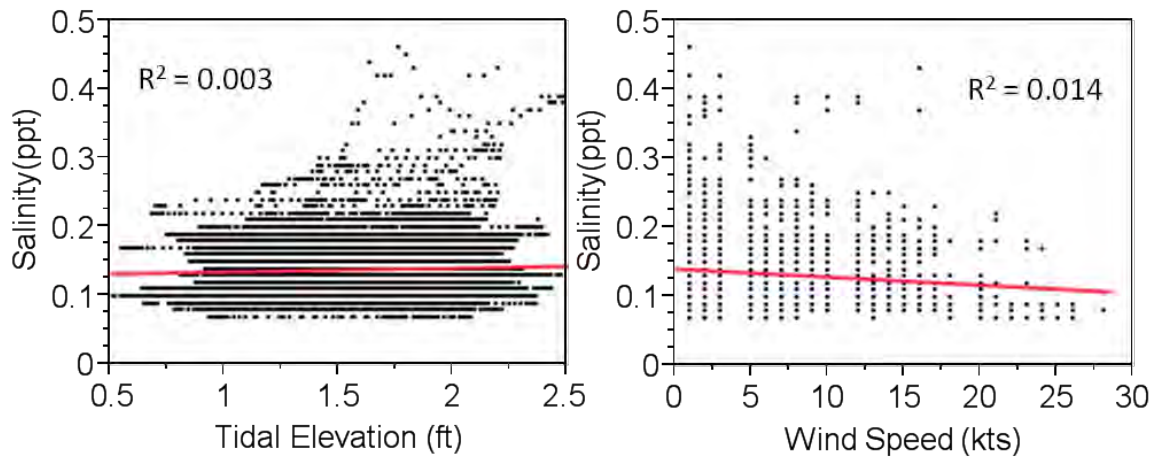


FIGURE 4.4-1: MDNR SALINITY OBSERVATIONS AND CONOWINGO USGS GAGE AVERAGE DAILY FLOW, 2007-2008

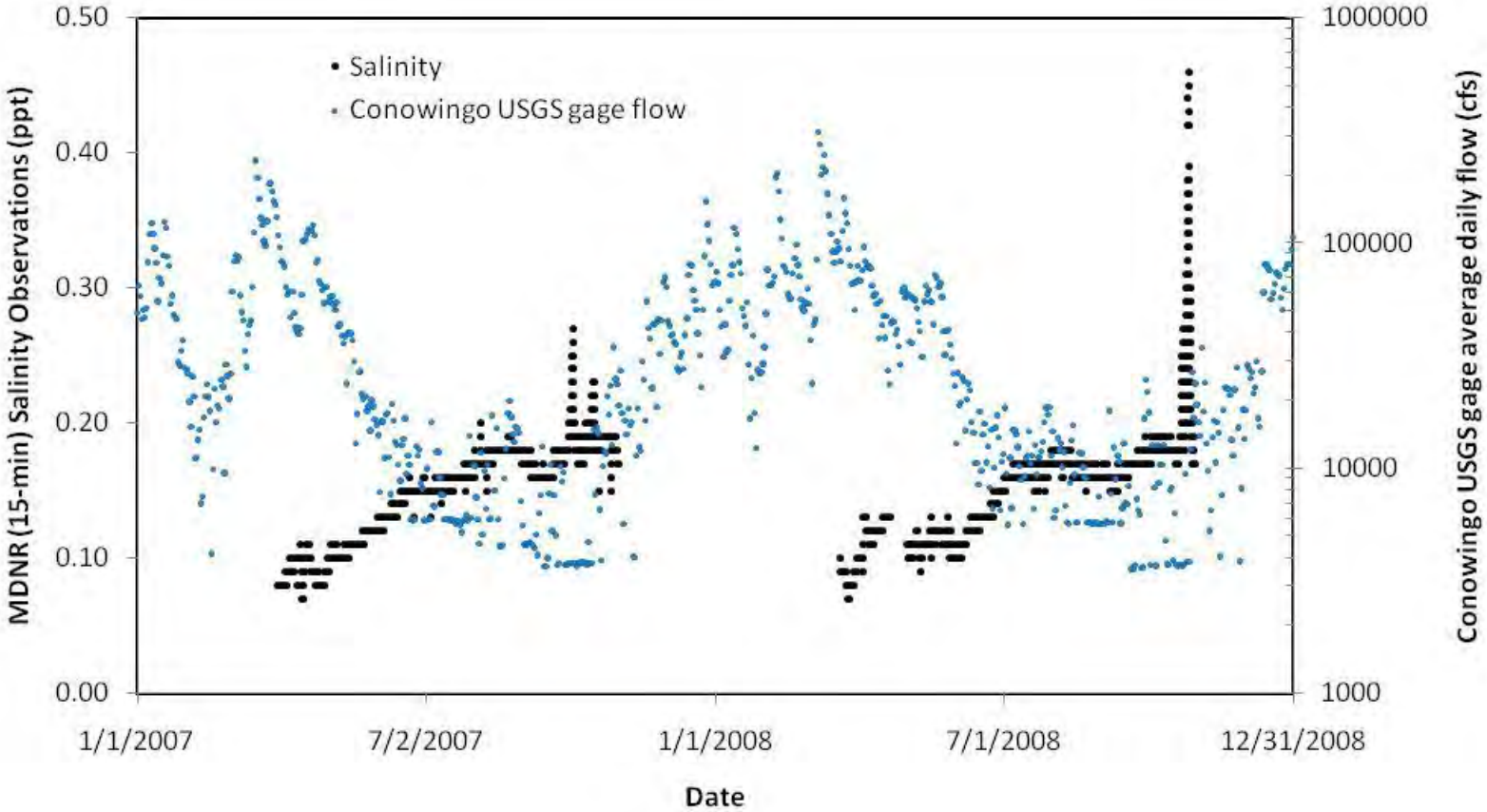


FIGURE 4.4-2: MDNR SALINITY OBSERVATIONS AND CONOWINGO USGS GAGE AVERAGE DAILY FLOW, 2009-2010

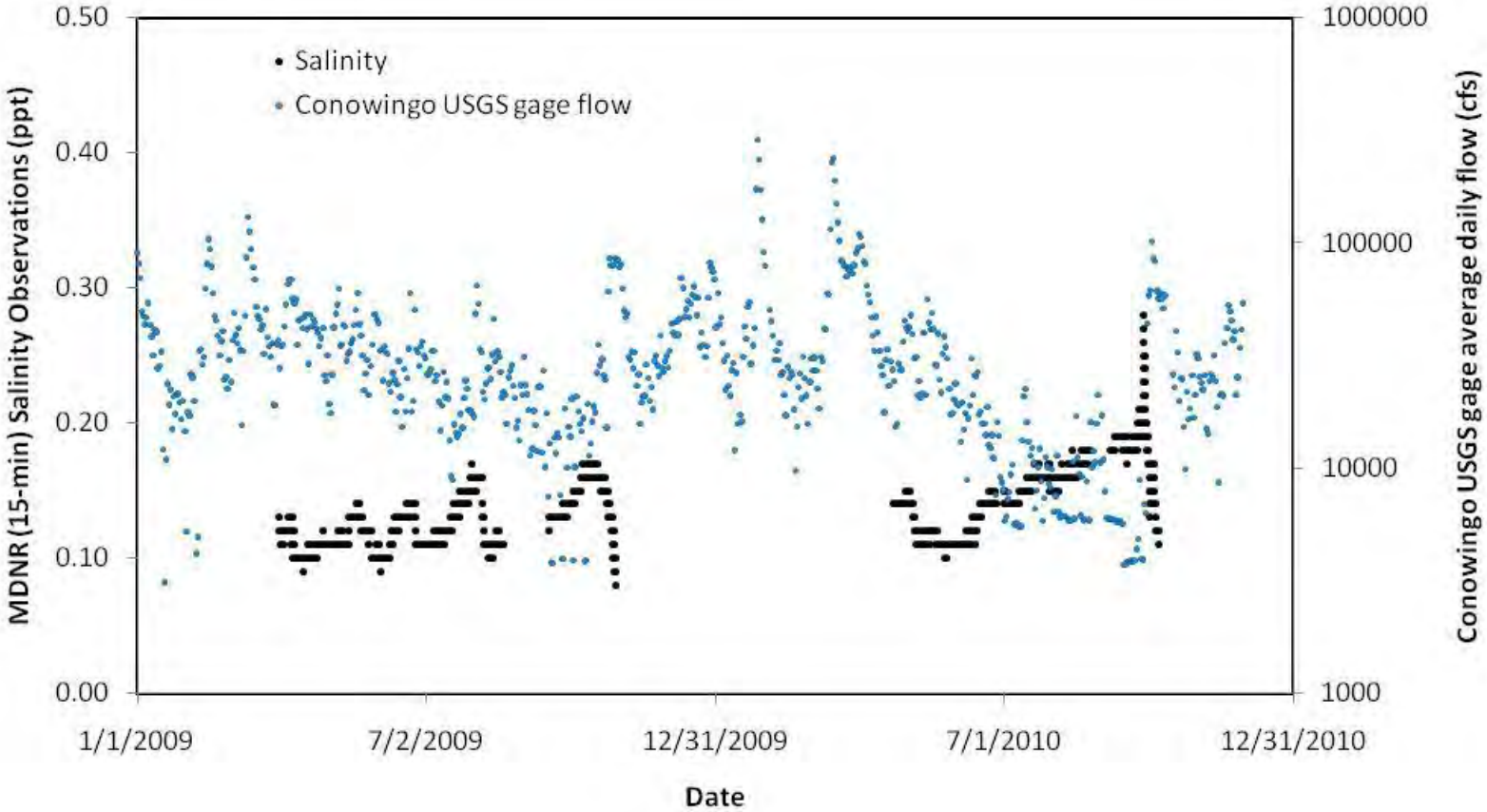


FIGURE 4.4-3: TIME SERIES OF HDG SALINITY OBSERVATIONS AND CONOWINGO USGS GAGE DAILY AVERAGE FLOW (1997-2003)

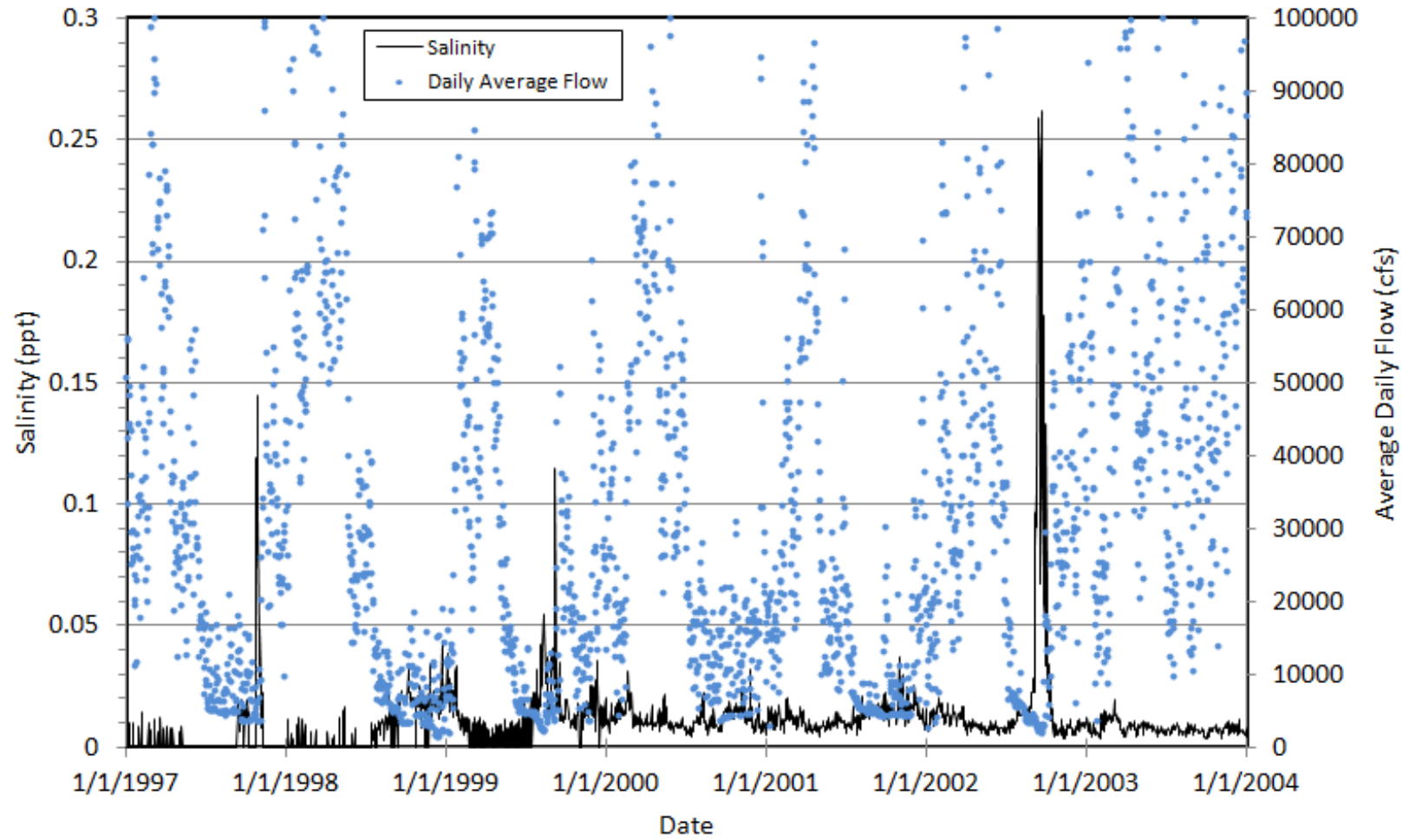


FIGURE 4.4-4: TIME SERIES OF HDG SALINITY OBSERVATIONS AND CONOWINGO USGS GAGE DAILY AVERAGE FLOW (2004-2010)

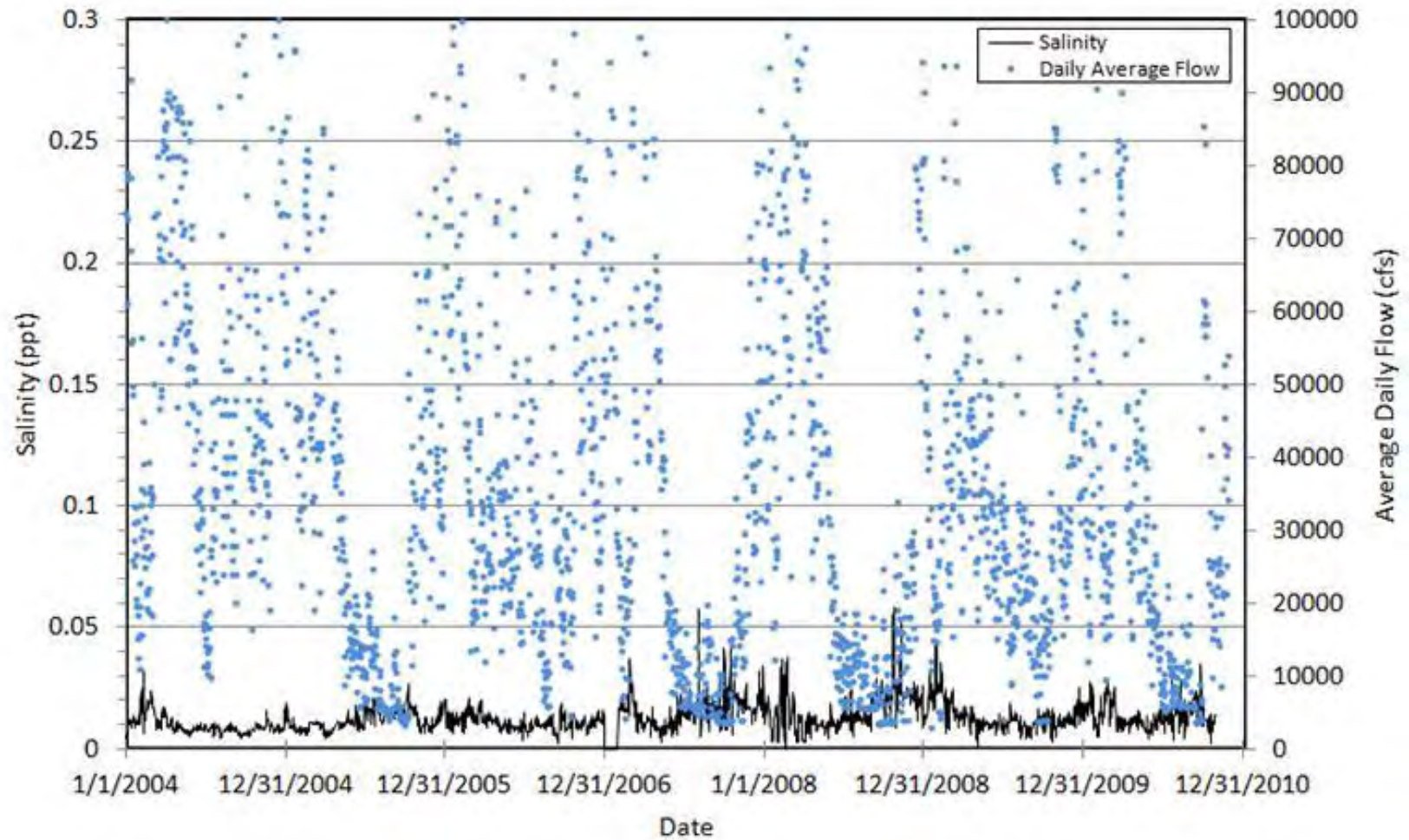


FIGURE 4.4-5: 15-MIN MDNR SALINITY OBSERVATIONS AND 15-MIN CONOWINGO AND MARIETTA USGS GAGE FLOWS, 2007 AND 2008

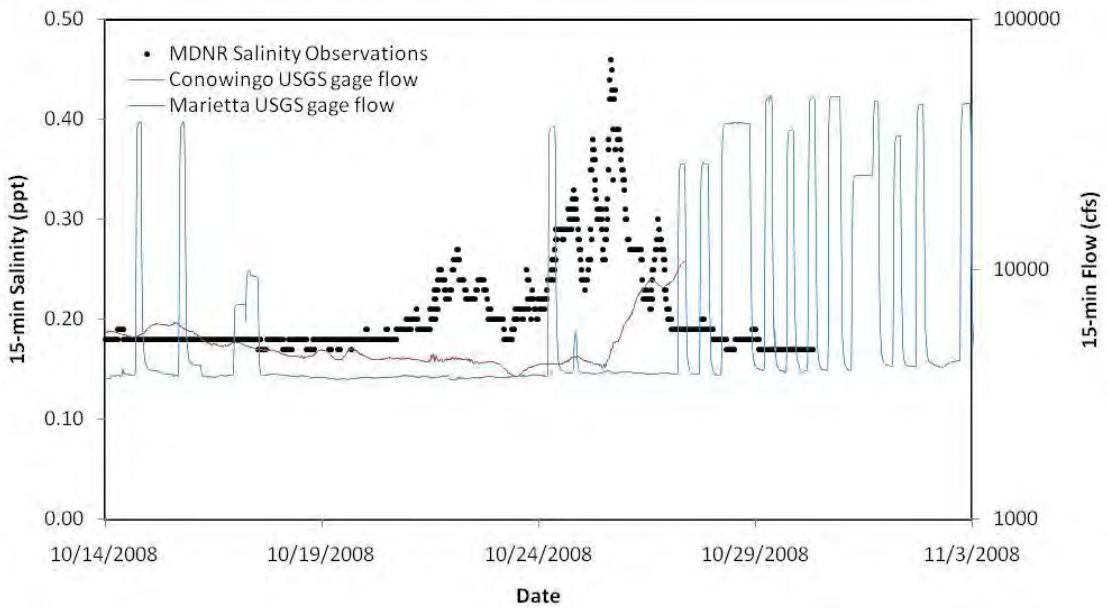
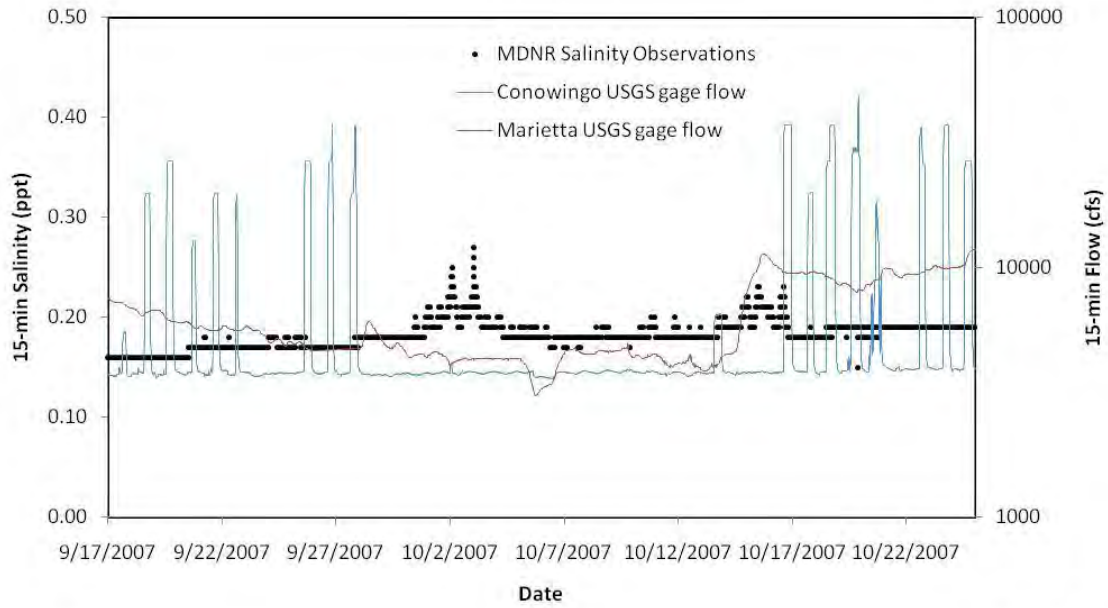


FIGURE 4.4-6: 15-MIN MDNR SALINITY OBSERVATIONS AND 15-MIN CONOWINGO AND MARIETTA USGS GAGE FLOWS, 2009 AND 2010

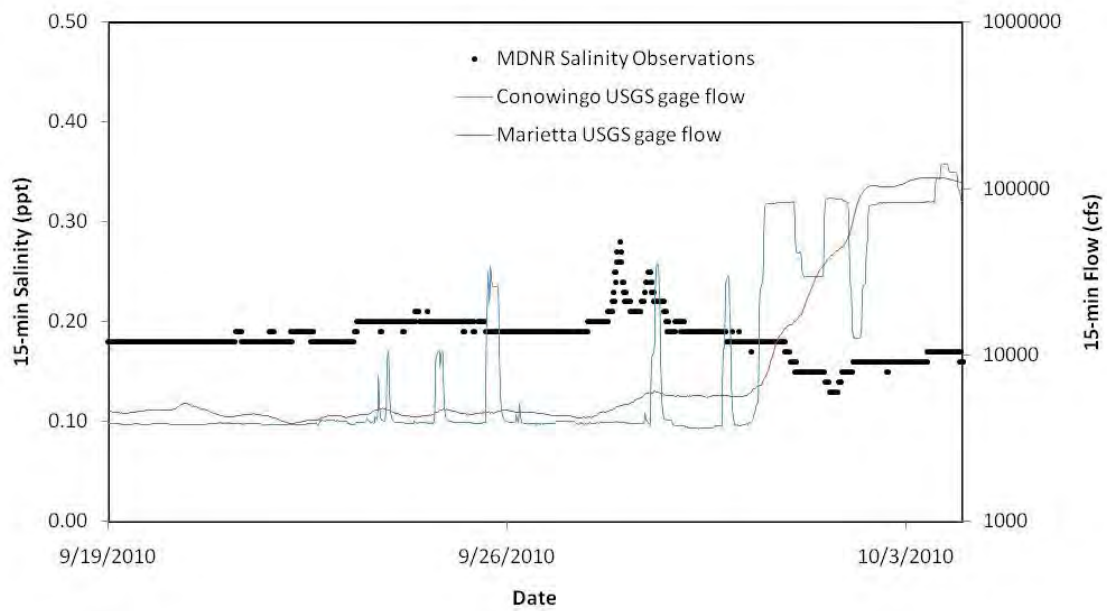
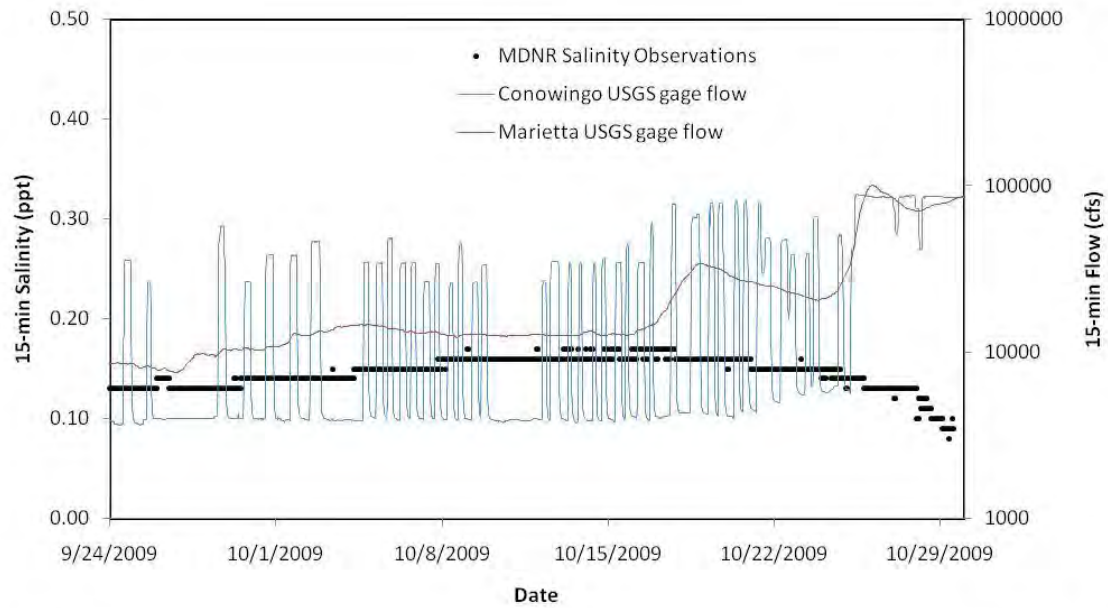


FIGURE 4.4-7: MDNR SALINITY OBSERVATIONS AND TIDAL ELEVATIONS DURING A HIGH SALINITY EVENT (2007)

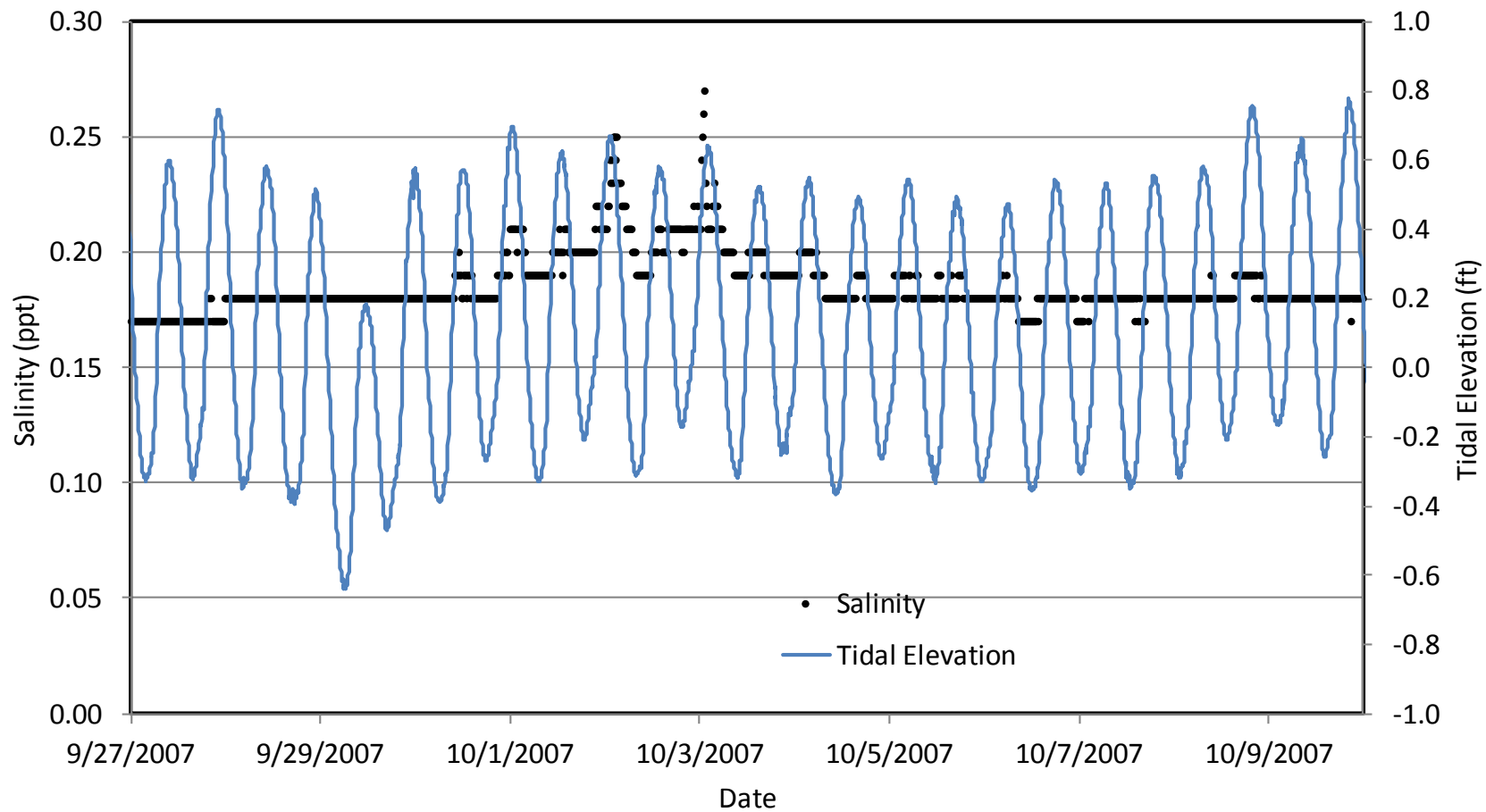


FIGURE 4.4-8: MDNR SALINITY OBSERVATIONS AND TIDAL ELEVATIONS DURING A HIGH SALINITY EVENT (2008)

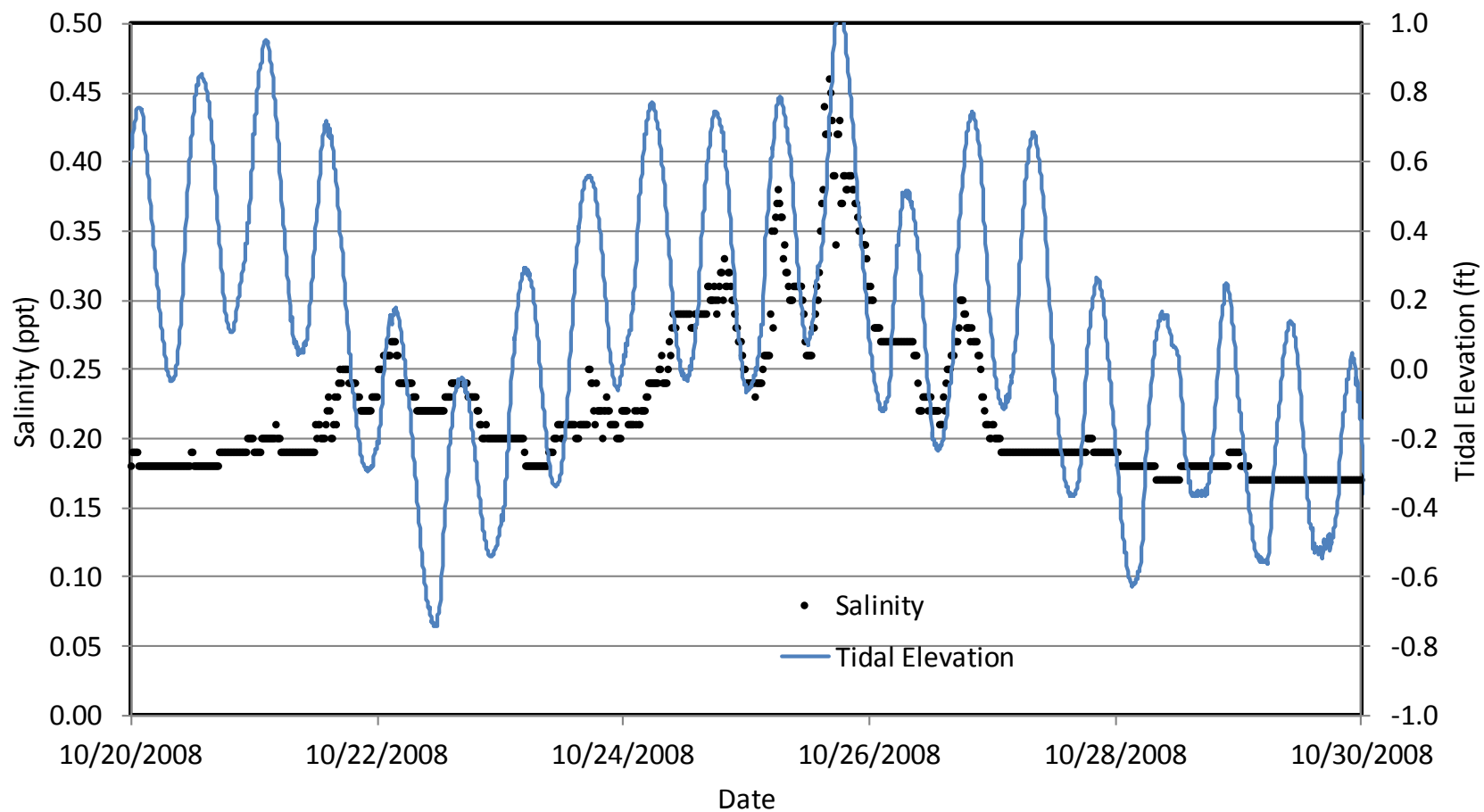


FIGURE 4.5-1: CONOWINGO DAM DAILY AVERAGE FLOW VERSUS MARIETTA GAGE DAILY AVERAGE FLOW, 1997-2009. EACH POINT REPRESENTS A PAIR OF MARIETTA AND CONOWINGO FLOWS FROM THE SAME DAY.

