FINAL STUDY REPORT
FISH PASSAGE IMPEDIMENTS STUDY
Analysis of 2010 RadioTelemetry Data

RSP 3.7

CONOWINGO HYDROELECTRIC PROJECT

FERC PROJECT NUMBER 405

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EXECUTIVE SUMMARY

Exelon Generation Company, LLC (Exelon) 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 Fish Passage Impediments Study below Conowingo Dam, which is the subject of this report. The objectives of this study were to: 1) determine if project operations adversely impact upstream migrations of American shad, river herrings (blueback herring and alewife), and Hickory shad; and 2) utilize the River2D model (see Conowingo Study 3.16-Instream Flow Habitat Assessment below Conowingo Dam) to ascertain if areas in the tailrace and other portions of the river below Conowingo Dam could present adverse velocity barriers under typical dam operating regimes.

An initial study report (ISR) was filed on February 22, 2011, containing Exelon's 2010 study findings. An initial study report 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) analyzing the 2010 study data was filed on January 23, 2012. The USR addressed comments from stakeholders received at the March initial study report meeting, as well as those comments addressed by Exelon in the May 27, 2011 responses to ISR comments. This final study report detailing the analysis of 2010 data is being filed with the Final License Application for the Project. A separate report will be developed to analyze additional American shad radiotelemetry data collected in 2012.

Overall, 130 separate upstream migrations (of less than 72 hr elapsed time) were completed by 68 individual radio tagged American shad in the Susquehanna River during the spring 2010 study (Conowingo Study 3.5-Upstream Fish Passage Effectiveness Study). These migrations were accomplished during Conowingo Dam discharges ranging between 8,618 and 82,085 cfs. There was no clear indication that migratory behavior or movement was adversely influenced by operations of Conowingo Dam in the 5-mile river reach between the dam tailrace and the Lapidum boat launch area.

Variations in migration times did occur among upstream forays but these could not be positively correlated to Conowingo Dam discharge. Based on the data of radio-tagged American shad gathered during the spring of 2010, no velocity barriers existed in the stretch of river between the tidal reach at Port Deposit and Conowingo Dam.

The Acoustic Doppler Current Profiler (ADCP) survey of the Susquehanna River downstream of Conowingo Dam provided empirical data to use in the River 2D model to predict velocities under three Project discharge rates. Based on model outputs for discharges of 10,000 and 40,000 cfs, there were relatively few areas within the river where velocities were greater than the burst speeds of American shad and River herring were evident; there were some isolated areas of velocities approaching, but not exceeding, six fps. American shad and river herrings exhibit burst swim speeds of at least, if not greater than, six fps. Predicted velocities for a discharge of 86,000 cfs did show more areas of higher velocities approaching as high as seven to nine fps. These highest velocities were concentrated primarily in the tailrace and both sides of Rowland Island. It is expected that if migrating fish enter these higher velocity areas, they will likely avoid overpowering velocity fields and swim around the areas.

There is no evidence to suggest that extreme water velocities present a barrier to upstream migration of American shad or River herrings. The modeled velocities at the highest discharge rate show many high velocity areas in the river which could impede upstream migration, but the results of the telemetry study reveal that regardless of Project discharge, tagged shad migrated upstream with little observable difficulty. In many cases, multiple trips upstream by the same fish occurred.

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ADCP	Acoustic Doppler Current Profiler
cfs	cubic feet per second
Exelon	Exelon Generation Company, LLC
FERC	Federal Energy Regulatory Commission
fps	feet per second
hr	hour
ISR	Initial Study Report
ILP	Integrated Licensing Process
m	meter
m/hr	meters per hour
min	minute
mm	millimeter
MW	megawatt
NOI	Notice of Intent
PAD	Pre-Application Document
PSP	Proposed Study Plan
RSP	Revised Study Plan
U	critical swim speed
USGS	United States Geological Survey
USR	Updated Study Report

1.0 INTRODUCTION

Exelon Generation Company, LLC (Exelon) has initiated with the Federal Energy Regulatory Commission (FERC) the process of relicensing the 573-megawatt (MW) 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. Many of these study requests were included 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. 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 final study plan determination required Exelon to conduct a Fish Passage Impediments Study below Conowingo Dam, which is the subject of this report. Concern was expressed about potential velocity barriers in the tailwater of the dam as well as in any zone of passage well downstream of the dam during both peaking and minimum flow regimes. The objectives of this study were to: 1) determine if project operations adversely impact upstream migrations of American shad, river herrings (blueback herring and alewife), and Hickory shad; and 2) utilize the River2D model (see Conowingo Study 3.16-Instream Flow Habitat Assessment below Conowingo Dam) to ascertain if areas in the tailrace and other portions of the river below Conowingo Dam could present adverse velocity barriers under typical dam operating regimes.

An initial study report (ISR) was filed on February 22, 2011, containing Exelon's 2010 study findings. An initial study report 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) analyzing the 2010 study data was filed on January 23, 2012. The USR addressed comments from stakeholders received at the March initial study report meeting, as well as those comments addressed by Exelon in the May 27, 2011 responses to ISR comments. This final study report detailing the analysis of 2010 data is being filed with the Final License Application for the Project. A separate report will be developed to analyze additional American shad radiotelemetry data collected in 2012.

2.0 BACKGROUND

The Susquehanna River below Conowingo Dam flows approximately 10 miles before entering the 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 upstream limit of tidal influence. 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 30 feet.

The Conowingo Project uses limited active storage within Conowingo Pond for generation purposes. Maximum hydraulic capacity of the Conowingo powerhouse is 86,000 cubic feet per second (cfs). The current minimum flow requirements below Conowingo Dam were formally established with the signing of a settlement agreement in 1989 between the Project owners and several federal and state resource agencies (46 FERC ¶61,063) (FERC 1989). The established minimum flow regime below Conowingo Dam is the following:

March 1 – March 31	3,500 cfs or natural river flow
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
September 15 – November 30	3,500 cfs or natural river flow, whichever is less
December 1 – February 28	3,500 cfs intermittent (maximum six hours off followed by equal amount on)

The downstream discharge must equal these values or the discharge (natural river flow) 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 Dam.

3.0 METHODS

3.1 Telemetered Shad Performance Evaluation

Historical data gathered on radio telemetered American shad migration during studies conducted from 1984 through 1986 and new data collected in 2010 were reviewed to ascertain relevancy of data collected to assess possible delays in migration due to high water velocities and/or barriers due to high or low flow velocities. The historical studies from 1984 through 1986 did not adequately quantify radio tagged shad migration patterns as well as the most recent 2010 study did. Downstream remote continuous monitoring was not conducted in the earlier studies so accurate migration rates were not discerned. Data collected during the 2010 shad radio telemetry study (see Conowingo Study 3.5-Upstream Fish Passage Effectiveness Study) were much more comprehensive than data obtained from earlier studies, both in terms of river locations monitored and numbers of fish radio tagged and available to be monitored in the river below Conowingo Dam. Consequently, analysis of the 2010 telemetry study data was conducted exclusively.

American shad were captured for tagging from Conowingo Dam tailrace by angling and from the West Fish Lift. Radio transmitters were inserted through the esophagus and implanted in the stomach of each fish (termed gastric tagging). After tagging, shad were either released directly into the tailrace or transported approximately five miles downstream and released at the Lapidum boat launch area. Monitoring stations were deployed along the base of the dam, at the lower tip of Rowland Island, at the lower tip of Spencer Island, at Lapidum, and at the Tomes Landing boat launch in Port Deposit (Figure 3.1-1). Monitoring stations were downloaded frequently and data were reduced and sorted by individual fish. Each data set was analyzed to identify tagged shad that exhibited substantial upstream migrations from lower river areas; these fish either moved downstream from the tailrace after tagging and then migrated back up to the dam, or released downstream at Lapidum before migration up to the dam.

Spatial and temporal data for these fish were correlated with Conowingo Station discharge in an attempt to characterize shad upstream movements over the spring migration period and to identify whether any delays could be due to velocity impediments or barriers. Conowingo Dam discharge data were derived from USGS gage 01578310 which is located on the downstream face of Conowingo Dam. While analysis and correlations are addressed in Section 4, preliminary results showed that Conowingo operated under typical peaking operations throughout the study period (Figure 3.1-2 and Figure 3.1-3). Differences in flow exceedence percentiles (the percent of time the river flows are equal to or greater than a given flow) for select flows during the study period (April 15 – June 15) are shown in Table 3.1-1 as well.

3.2 Flow Velocity Modeling Evaluation

A literature review of relevant swim speed studies was conducted to identify swimming characteristics of American shad and other river herrings. These data were used to define the velocity thresholds for these species and were correlated with velocity data from a 2-dimensional hydraulic model (River2D) of the study reach (See Conowingo Study 3.16-Instream Habitat Assessment below Conowingo Dam for a description of model calibration procedures and methods). Velocity profiles along multiple transects were surveyed with an ADCP between June 14 and June 17, 2010 (Figure 3.2-1) when Conowingo Station generation flow was approximately 40,000 cfs. These data were compiled and used to calibrate the River2D model, which was used to predict velocity profiles for areas of the river between Rowland Island and Spencer Island to identify high velocity areas and possible impediments or barriers to migration.

4.0 RESULTS AND DISCUSSION

4.1 Shad Migration Evaluation

Overall, 151 American shad were radio tagged and released during the spring 2010 study. A total of 100 were angled in Conowingo Dam tailrace, tagged and released immediately back to the tailrace. Forty-nine shad collected in the West Fish Lift were radio tagged and transported to Lapidum boat launch and released just off shore. Two additional shad were taken from the West Fish Lift, radio tagged, and released directly to the dam tailrace.

Of the 151 American shad radio tagged and released, 89 (59%) provided data to evaluate upstream movement into the tailrace of Conowingo Dam. Of these 89, 70 had been angled from, tagged and released back into the tailrace and 19 were taken from the west lift, tagged, and released at Lapidum (Table 4.1-1). The other 62 shad that had been radio tagged and released never migrated up into the tailrace of the Project. Eight of those were never detected again after release and were presumed to have left the river. The remaining 54 shad generally remained in the tidal reaches of the river near Spencer Island, Lapidum and Tomes Landing for a period of time ranging from two hours to more than 32 days.

Fifty-one of the 100 (50%) fish captured in the tailrace, tagged, and immediately released back to the tailrace moved downstream to the tidal portion of the river shortly after release and eventually migrated back to the tailrace. Only 19 of the 49 (39%) shad transported to and released at Lapidum migrated upstream to the tailrace. Overall, 70 (46% of all radio tagged shad) individuals were monitored undertaking substantial upstream migrations from the lower tidal reaches (Lapidum, Tomes Landing, and Spencer Island) of the Susquehanna River to the Conowingo tailwaters (Rowland Island and tailrace monitor stations). However, two fish migrated from the tidal area to the tailwaters in 99 and 153 hr; these fish were not included in further analyses because elapsed times for their forays were considered excessive and not reflective of directed migrations. Five trips monitored by multi-migration shad were also excessive in elapsed times and those trips were also excluded from further analyses. Although these five trips upstream took relatively long time periods to complete (five to 29 days), they were considered individual behavioral characteristics as opposed to flow impediments since many other shad migrated upstream unimpeded during the same time periods. The excluded trips were considered an inaccurate accounting of upstream migration.

Many of the 68 radio tagged shad (70 shad excluding the two fish with excessive travel times) making upstream migrations from the tidal reaches of the river made more than one migration (Table 4.1-2). Most fish made two or three separate forays and at least two made seven or more separate trips; fish 54-176 made eight separate upstream migrations and fish 21-111 made seven (Table 4.1-2). Overall, there were 130 separate upstream trips completed by these 68 shad between April 22, 2010 and May 29, 2010. Mean and median distance traveled per trip was 4.3 miles. The median time to travel from the tidal portion of the river to the tailwaters was 6.7 hr; the shortest time was just 1.2 hr and the longest time was just less than 72 hr (Table 4.1-2). Mean elapsed time for trips was 11.6 hr. Average speed during the trips for individuals was 1.0 feet/ second (fps). Speed per trip varied from 0.1 fps to just less than 6 fps. Overall, station discharge ranged from 8,618 cfs to 82,085 cfs during the time upstream forays were occurring; average flow during the period was 41,120 cfs.

Each upstream migration event is listed by ascending trip duration in Table 4.1-3. For each trip, Conowingo Station discharge and average speed of each shad is presented. Shad 21-132 was monitored traveling from Lapidum to the Conowingo tailrace, a distance of approximately 4.9 miles, in an elapsed time of 1.2 hr. This translates to an average speed of 5.9 fps. Station discharge remained steady at 20,960 cfs throughout the migration. An additional 18 upstream forays were completed in less than 4 hr elapsed time by 14 other radio tagged shad. Generation during these trips varied between 9,060 and 80,733 cfs (Table 4.1-3); station generation generally remained steady during most of the trips. Overall, 74 (57%) of the 130 forays took less than eight hr (Figure 4.1-1). The majority (90%) of the upstream migrations were completed in less than 24 hr elapsed time.

Upstream forays by radio tagged American shad were completed during an array of Conowingo Dam discharges. Shad migrated up to the dam during flows as low as 8,618 cfs and as high as 82,085 cfs. Overall, 11 trips upstream were completed by 11 individual shad during generation flows of 70,000 to 85,000 cfs (Table 4.1-4). Between 60,000 and 70,000 cfs, 15 individuals completed 15 upstream migrations. As flow ranges decreased, upstream forays generally increased in numbers as well as numbers of individual shad making the trips (Table 4.1-4). However, at the lower flow ranges, 5,000 to 20,000 cfs, the number of forays was lower and numbers of individuals were fewer. Most upstream movement events (53%) occurred during average discharge flows of between 20,000 and 50,000 cfs.

The initial upstream migration events by radio tagged shad occurred during the final week of April. Figure 4.1-2 is a chart illustrating the individual shad upstream movement events (solid lines) superimposed over hourly river flow readings during this peak movement period. Although river flows were highly variable over the time period April 22 to May 1, 2010, radio-tagged shad completed upstream migrations in relatively short elapsed times (range from 2.0 to 10.74 hr). There was no clear relationship between flow and onset or completion of the migrations. This same general trend is evident throughout the migratory period (Figures 4.1-3 through 4.1-8). During the period between May 1 and May 6, 2010, station generation appeared to be full to near full generation during the day with minimum flow during the overnight hours (Figure 4.1-3). Some shad initiated upstream movement during high flows, while others began movement upstream during low flows. Again, there was no clear relationship between flow levels and migration events. Station generation generally declined between May 7 and May 12, 2010 with daytime flows of 35,000 to 60,000 cfs (Figures 4.1-4 and 4.1-5). During this period, upstream forays were primarily initiated during times of higher than minimum flows; only a few trips were begun at minimum flow generation (approximately 10,000 cfs). However, most of the trips initiated at minimum flow were completed during the lower flow regimes, as were some of the forays initiated at the higher flow levels. The trend of high to near full generation during daytime and reduced generation overnight continued throughout the remainder of the migration period (through May 30, 2010). Upstream migration events occurred throughout this time frame, regardless of flow patterns or time of day. In addition, frequency of upstream migration events could not be correlated to either time of week, (i.e., weekday versus weekend) or changes in Conowingo discharges (Figure 4.1-2 thru 4.1-8).

There is no clear indication that low flow (minimum flow – 10,000 cfs) or higher flows (up to 82,085 cfs) impeded the timely upstream migration of radio tagged American shad. The slopes of the solid lines in Figures 4.1-2 through 4.1-8 provide a general indication of elapsed time for each upstream migratory event. Some trips are clearly longer than others, but frequently the onset of these longer trips is within the same time frame and flow regime as much shorter trips.

Overall, 130 separate upstream migrations (of less than 72 hr elapsed time) were completed by 68 individual radio tagged American shad in the Susquehanna River during the spring 2010 study. These migrations were accomplished during Conowingo Dam discharges ranging between 8,618 and 82,085 cfs. There was no clear indication that migratory behavior or movement was adversely influenced by operations of Conowingo Dam in the river between Lapidum and the dam tailrace. Variations in migration times could not be positively correlated to river flow. Based on the data of radio-tagged American shad gathered during the spring of 2010, no velocity barriers existed in the stretch of river between the tidal reach at Port Deposit and Conowingo Dam.

4.2 Flow Velocity Modeling Evaluation

Three swim speed modes are generally recognized for fishes though terminology differs slightly among authors. Following the nomenclature of Beamish (1978) sustained swim speed is that which can be maintained for an indefinite period (longer than 200 minutes) and does not involve fatigue; prolonged swim speed can last between 15 seconds and 200 minutes and if maintained will end in fatigue; and burst swim speed is characterized by rapid movements of short duration and high speed, maintained for less than 15 seconds. Laboratory testing of prolonged swim speeds for specific time intervals, frequently related to an expected or required time to pass through fishways or culverts, results in estimates of critical swim speed (U), accompanied by a time stamp (*e.g.*, $Ucrit_2$ = maximum prolonged speed for 2 minutes). Burst or sprint swim speeds (also startle, fast-start, or dart) are the fastest attainable and are also those generally associated with fish well-being or survival (Beamish 1978; Wardle 1980), as they are also related to a fish's ability to capture prey, avoid predators, or in the present case, avoid water intake velocities or structural elements. Among the three swim speed modes, burst swim speed is harder to quantify in a laboratory and, thus, fewer burst swim speed studies with adequate sample sizes are available (Castro-Santos and Haro 2005).

Turbulence and eddies as well as flow velocity may be integral in impeding upstream migration of fish by disorienting them. Environmental stimuli in a water body for migrating fish to cue on, in addition to physical structures, include turbulence, flow acceleration, pressure changes, sound, etc. (Castro-Santos and Haro 2005). Other conditions which may exacerbate the ability for fish to overcome velocity barriers or flow fields may include darkness or turbidity, or reduced swimming ability as water temperatures approach or exceed cold water tolerances.

Table 4.2-1 presents swim speeds for the species of interest in the Susquehanna River. Burst speeds range from 6.7 (Herring spp.) to 16.4 fps (alewife). American shad can swim seven fps at a prolonged rate and as a species has a maximum burst speed of 13.0 fps. No burst speed for any species is less than 6.7 fps.

At a Conowingo Dam discharge of 10,000 cfs, predicted water velocities for the study reach from Rowland Island to Spencer Island are depicted graphically in Figure 4.2-1. Velocities were modeled with River2D, which was calibrated with data collected by the ADCP survey at Project discharges near 40,000 cfs. The map indicates very low velocities from zero to two fps with a few isolated areas of up to four fps near Rowland Island. A closer view of that area shows a narrow reach near the west shoreline to the west of Rowland Island at a velocity of near 4.5 fps (Figure 4.2-2). Continuing downstream (Figure 4.2-3 and Figure 4.2-4) velocities are all predominantly low, in the one to three fps range. Velocities in the areas around Robert, Wood and Spencer Islands are all relatively low with a few isolated areas reaching 3.5 fps (Figure 4.2-5). With a discharge of 10,000 cfs from Conowingo Dam, there are no high velocity areas posing a challenge to upstream migration of fish.

A discharge of 40,000 cfs was also modeled to predict river water velocities in the study reach. Water velocities increased virtually throughout the river (Figure 4.2-6). Velocities from five to six fps appear to occur in the mid-channel areas on the west and east sides of Rowland Island and upstream of the Island in select areas of the tailrace (Figure 4.2-7). The narrow area of higher velocity to the west of Rowland Island extends along the near west shoreline to a distance downstream of Bird Island (Figure 4.2-8). Further downstream in the reach between Bird and Reuben Islands, velocities were primarily between 1 one and 4 four fps. Water velocity approached 5 five fps in a several isolated locations. A relatively small pocket of higher velocity (5.5 fps) located on the eastern shoreline may be associated with an outcropping from the shore. The stretch of river between Reuben and Robert Islands encompasses a wide variety of differing flow velocities. This reach also has several isolated areas with velocity nearing six fps (Figure 4.2-9). These areas of higher flow velocities generally stretched from the east shoreline across the river from Reuben Island to downstream towards the west shoreline. Another line of isolated higher velocity pockets stretched across the river from the west shoreline to the upper tip of Robert Island (Figure 4.2-9). The lowermost area of non-tidal river reach exhibits a few areas of higher velocities. The area around Robert and Spencer Islands has at least six to ten isolated areas of velocities approaching and in some cases exceeding six fps (Figure 4.2-10). Overall, for the stretch of the Susquehanna River from the lower tip of Rowland Island to the upper tidal area, higher velocity areas are isolated and velocities on the order of one to three fps are most prevalent. In and around Rowland Island, higher flow velocities are most prevalent and pronounced, but even at the highest velocity (six fps) all species of concern are capable of avoidance and/or overcoming that flow (Figures 4.1-2 thru 4.1-8).

The River2D model was used to predict flow velocities in the study reach at maximum generation (discharge of 86,000 cfs). Water velocities increased markedly over the 40,000 cfs discharge throughout the river (Figure 4.2-11). High velocity areas were prevalent in the channel between the west shoreline and Rowland Island, as well as in the tailrace proper and just to the east of the Island (Figure 4.2-12). Velocities are approaching eight fps in select areas and the mid-channel portion of these areas from the tailrace downstream to both sides of the island show velocities between six and seven fps. Narrow areas along the stream margin exhibit velocities in the one to four fps range. Velocities in the river between Bird Island and the east shoreline show large areas of at least four fps currents. Extending downriver (Figure 4.2-13), large areas of the river near the east shoreline between Bird and Reuben Islands indicate water velocities in the four to five fps range with a few isolated areas as high as six fps. In this stretch, however, velocities appear to moderate for the most part; two to three fps velocities seem to be most prevalent, especially areas toward the west shoreline. The areas of relatively high velocities between Reuben and Robert Islands tend to stretch from the east shoreline above Reuben almost across the entire river to the east shoreline (Figure 4.2-14). Velocities ranging from four to six fps appear most prevalent in this area. Another section of higher velocities is shown stretching from the east shore line to the upper tip of Robert Island; velocities are typically between four and six fps. The area of upper tidal reach, near and around Robert, Wood, and Spencer Islands show some higher velocity areas in the river. A relatively large area of water velocities up to and greater than six fps stretches almost entirely across the river from the east shoreline to lower Robert Island (Figure 4.2-15). The model indicates another relatively large region of higher velocities from the west shoreline, just above Deer Creek confluence, to upper Robert Island. Two areas of velocities approaching six fps are located just to the west of Spencer Island. However, results of the radio tagging evaluation indicate that shad had very little trouble traversing this river reach (Figures 4.1-2 thru 4.1-8).

The modeling results for discharges of 10,000 and 40,000 cfs yielded select areas of velocities nearing a maximum of six to seven fps. All species of interest exhibit burst swim speeds of at least, if not greater than, six fps. It is expected that if migrating fish enter these higher velocity areas, they will likely have the ability to swim through the areas or avoid the areas and seek slower currents. The River2D model results for a 86,000 cfs discharge from the Project indicates that there may be more of a challenge for some species to migrate upstream, particularly near the Rowland Island and tailrace areas. There is, however, no clear blockage to upstream migration due to high velocities. There are many areas with high velocity but if a migrating fish encounters an overpowering velocity field, it can likely avoid and divert around the area to slower moving waters, and reach its intended destination.

5.0 CONCLUSIONS

There is no evidence available to suggest that extreme water velocities present a barrier to upstream migration of American shad or River herrings. Only at the highest Project discharge rate modeled, do velocities in some areas of the river appear to be in excess of the fishes' swimming abilities. This does not preclude migrating alosines from reaching the dam, however. No matter what the strategy, seeking slower currents, avoiding excessive velocity, swimming and resting, etc, American shad and River herring reach the dam as evidenced by numbers in the fishlift. In addition, the radio telemetry study conducted in 2010 clearly illustrated the American shad's ability to traverse the length of the riverine portion of the Susquehanna River below Conowingo Dam with relative ease. Many radio tagged fish migrated upstream from lower portions of the river multiple times. In addition, the rates of migration did not appear to be related to Conowingo Dam discharge (Figures 4.1-2 thru 4.1-8).

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TABLE 3-1-1: FLOW EXCEEDENCE PERCENTILE COMPARISON BETWEEN MARIETTA AND CONOWINGO USGS GAGES, APRIL 15, 2010 TO JUNE 15, 2010.

	% of Time Equaled or Exceeded	
Flow (cfs)	Marietta	Conowingo
5,000	100	100
7,500	100	85.9
10,000	100	65.5
15,000	99.3	49.9
20,000	84.1	48.3
30,000	36.5	40.2
40,000	13.4	26.8
50,000	1.4	17.9
60,000	0	14.4
70,000	0	7.9
80,000	0	1.7
86,000	0	0

TABLE 4.1-1: SUMMARY OF AMERICAN SHAD CAPTURE, RADIO TAGGING, AND RELEASE NEAR CONOWINGO DAM, SPRING 2010.

Date	Capture Location	Release Location	No. Released	Monitored in Tailrace		Upstream Migrants
				No.	%	
4/20/2010	Tailrace	Tailrace	18	14	78	13
4/22/2010	Tailrace	Tailrace	32	25	78	21
4/28/2010	West Fishlift	Lapidum	25	12	48	12
5/7/2010	Tailrace	Tailrace	27	16	59	9
5/10/2010	Tailrace	Tailrace	23	14	61	7
5/12/2010	West Fishlift	Tailrace	2	1	50	1
5/12/2010	West Fishlift	Lapidum	24	7	29	7
Sub-Totals		Tailrace	102	70	69	51
		Lapidum	49	19	39	19
Total			151	89	59	70

TABLE 4.1-2: SUMMARY OF THE 68 RADIO TAGGED AMERICAN SHAD WHICH MADE SUBSTANTIAL UPSTREAM MIGRATIONS DURING 2010.

Fish	Trips	Between Date	Date	Average[1] Trip Distance (mi)	Time (hr)	Average[1] Speed mph	fps
21-100	2	4/27	5/2	4.2	10.99	0.38	0.56
21-101	1	5/6		3.9	10.17	0.38	0.56
21-102	1	5/5		4.9	12.92	0.38	0.55
21-105	4	4/27	5/5	4.1	9.06	0.46	0.67
21-109	2	4/22	4/30	4.3	9.83	0.44	0.65
21-110	2	4/22	4/26	3.9	31.17	0.13	0.18
21-111	7	5/5	5/19	4.3	6.36	0.67	0.99
21-112	3	4/26	5/4	4.4	9.76	0.45	0.67
21-113	3	4/27	5/11	4.1	7.06	0.58	0.85
21-114	1	5/7		3.9	9.41	0.42	0.61
21-115	1	5/12		4.4	11.99	0.37	0.54
21-116	1	5/5		4.9	5.41	0.90	1.32
21-117	1	4/28		4.7	54.60	0.09	0.13
21-118	2	5/5	5/7	4.6	39.72	0.12	0.17
21-120	1	5/1		4.4	4.33	1.02	1.50
21-121	1	5/2		4.4	19.21	0.23	0.34
21-122	1	5/4		4.4	10.32	0.43	0.63
21-123	5	5/7	5/22	4.3	6.25	0.68	1.00
21-124	2	4/30	5/5	4.3	36.75	0.12	0.17
21-127	3	4/26	5/3	4.1	23.41	0.17	0.26
21-130	2	5/4	5/9	4.2	4.33	0.96	1.41
21-132	3	4/26	5/12	4.2	17.26	0.24	0.36
21-133	1	4/26		4.3	51.82	0.08	0.12
21-135	2	5/1	5/3	4.4	26.11	0.17	0.25
21-141	1	5/14		4.1	8.18	0.50	0.73
21-143	2	5/18	5/22	4.5	24.60	0.18	0.27
21-147	3	5/14	5/21	4.2	5.99	0.70	1.03
21-149	2	5/14	5/16	4.1	3.76	1.09	1.61
21-158	1	5/19		4.3	16.60	0.26	0.38
21-159	3	5/20	5/27	4.4	16.21	0.27	0.39
21-160	1	5/23		4.9	7.43	0.65	0.96
21-169	2	5/19	5/21	4.3	8.31	0.52	0.76
21-170	1	5/12		4.4	10.06	0.44	0.64
21-171	1	5/23		4.9	4.92	0.99	1.45
54-137	4	5/15	5/20	4.7	4.86	0.96	1.41
54-140	1	5/18		5.2	16.84	0.31	0.45

Fish	Trips	Between Date	Date	Average[1] Trip Distance (mi)	Time (hr)	Average[1] Speed mph	fps
54-141	2	5/11	5/15	4.1	4.35	0.95	1.39
54-142	4	5/9	5/18	4.2	5.38	0.78	1.15
54-144	1	5/13		2.9	4.91	0.59	0.87
54-149	1	5/22		4.9	71.24	0.07	0.10
54-151	1	5/12		4.4	9.81	0.45	0.66
54-156	2	5/26	5/29	4.9	11.02	0.44	0.65
54-159	1	5/18		4.3	6.74	0.64	0.94
54-160	1	5/14		4.3	6.24	0.69	1.02
54-173	1	5/14		4.3	4.36	0.99	1.45
54-176	8	5/3	5/19	4.3	5.43	0.80	1.17
54-178	2	5/5	5/7	4.2	12.58	0.33	0.49
54-179	1	5/14		4.4	4.49	0.98	1.44
54-183	1	5/19		4.4	3.59	1.23	1.81
54-186	4	5/13	5/24	4.3	4.72	0.92	1.35
54-191	1	5/8		3.9	2.31	1.69	2.48
54-192	1	5/2		4.7	23.36	0.20	0.30
54-193	1	4/27		4.9	28.99	0.17	0.25
54-194	2	4/23	4/30	4.3	5.43	0.78	1.15
54-196	2	4/25	5/4	4.2	3.91	1.06	1.56
54-197	1	4/29		4.0	24.47	0.16	0.24
54-198	2	5/3	5/6	4.3	5.56	0.78	1.14
54-199	1	5/5		4.9	8.61	0.56	0.83
54-200	2	5/17	5/26	4.6	9.88	0.46	0.68
54-200a	2	4/26	5/1	4.3	5.91	0.73	1.07
54-202	1	5/1		4.7	7.51	0.63	0.93
54-203	1	4/26		3.9	6.11	0.64	0.94
54-204	1	5/2		4.4	12.30	0.36	0.53
54-207	1	5/3		3.6	20.49	0.18	0.26
54-208	3	5/3	5/11	4.6	15.32	0.30	0.44
54-209	2	5/12	5/15	4.1	4.27	0.96	1.41
54-210	1	5/12		4.3	3.89	1.11	1.63
54-211	1	5/19		3.8	15.95	0.24	0.35

Totals		Between		Average[1] Trip		Average[1] Speed	
Fish	Trips	Date	Date	Distance (mi)	Time (hr)	mph	fps
68	130	4/22	5/29				
			Min	2.9	2.3	0.1	0.1
			Mean	4.3	13.5	0.6	0.8
			Median	4.3	9.2	0.5	0.7
			Max	5.2	71.2	1.7	2.5

1 - Average for fish with two or more trips.

TABLE 4.1-3: LISTING OF ALL UPSTREAM FORAYS BY RADIO TAGGED AMERICAN SHAD WHICH MADE SUBSTANTIAL UPSTREAM MIGRATIONS DURING 2010.

	Upstream Movement				Speed		Conowingo Discharge		
Fish	Date	Time	Distance (mi)	Time (hr)	mph	fps	Start	Average	End
21-132	5/12	13:17	4.86	1.20	4.04	5.94	20960	20960	20960
54-191	5/8	13:45	3.91	2.31	1.69	2.48	36345	36075	35744
21-109	4/22	18:57	4.73	2.83	1.67	2.45	58748	58748	58748
21-123	5/15	1:04	3.91	2.84	1.37	2.02	9325	9325	9325
54-186	5/13	1:05	3.91	2.91	1.34	1.98	43479	18248	9378
54-176	5/12	19:19	3.91	2.93	1.33	1.96	80733	80733	80541
21-123	5/20	9:22	4.31	2.95	1.46	2.15	34795	34677	34795
21-123	5/7	13:13	4.31	3.27	1.32	1.94	35149	54914	61829
21-149	5/16	17:09	3.91	3.32	1.18	1.73	78256	78824	79013
21-111	5/7	14:32	3.91	3.42	1.14	1.68	60846	61135	60034
54-141	5/11	9:43	3.91	3.48	1.12	1.65	35149	18009	13387
54-183	5/19	22:45	4.42	3.59	1.23	1.81	9325	9124	9060
54-137	5/15	14:42	4.31	3.63	1.19	1.75	76195	76796	79013
54-196	4/25	17:43	3.91	3.66	1.07	1.57	26206	25463	22389
54-176	5/9	13:22	3.91	3.68	1.06	1.56	45793	45600	45243
54-142	5/9	14:51	3.91	3.69	1.06	1.56	45655	45490	45243
21-111	5/10	8:34	3.91	3.85	1.01	1.49	33629	29503	26911
54-210	5/12	6:29	4.31	3.89	1.11	1.63	46627	41785	21578
21-169	5/21	13:51	4.73	3.93	1.20	1.77	35744	72431	81311
54-200a	5/1	12:38	4.73	4.14	1.14	1.68	35387	66374	73983
54-176	5/8	5:18	3.91	4.16	0.94	1.38	8618	9120	9378
54-196	5/4	9:47	4.42	4.16	1.06	1.56	26809	46698	74716
21-147	5/15	11:26	3.91	4.16	0.94	1.38	45655	58393	76567
54-209	5/12	13:20	3.91	4.17	0.94	1.38	20960	21083	21400
21-149	5/14	8:35	4.31	4.19	1.03	1.51	79013	61175	34795
54-137	5/20	10:27	4.86	4.21	1.15	1.70	34560	46920	65853
21-132	5/7	8:52	3.91	4.22	0.93	1.36	33169	34603	35149
21-130	5/9	12:51	3.91	4.25	0.92	1.35	45655	45610	45243
21-143	5/18	16:36	4.31	4.31	1.00	1.47	77879	77841	77879
21-120	5/1	13:12	4.42	4.33	1.02	1.50	73618	74166	74349
54-209	5/15	11:07	4.31	4.36	0.99	1.45	45655	58393	76567
54-173	5/14	10:24	4.31	4.36	0.99	1.45	78067	61175	79394
54-186	5/18	3:11	4.31	4.36	0.99	1.45	10829	9594	9271
21-130	5/4	14:08	4.42	4.41	1.00	1.47	74532	74239	74166
54-198	5/3	12:45	4.73	4.41	1.07	1.57	62822	65092	65512
54-194	4/23	20:05	4.31	4.42	0.98	1.43	35984	23029	13735

Fish	Upstream Movement				Speed		Conowingo Discharge		
	Date	Time	Distance (mi)	Time (hr)	mph	fps	Start	Average	End
54-179	5/14	5:40	4.42	4.49	0.98	1.44	73618	77830	78067
54-176	5/15	6:27	4.31	4.56	0.95	1.39	43345	45247	45655
21-105	5/5	6:21	4.42	4.63	0.95	1.40	9165	9433	9702
54-176	5/6	1:26	4.86	4.77	1.02	1.50	9218	8982	8904
21-105	4/27	11:35	3.91	4.78	0.82	1.20	27216	23637	55140
21-112	5/4	13:57	4.42	4.88	0.91	1.33	74716	74319	74166
54-144	5/13	19:47	2.90	4.91	0.59	0.87	63488	29025	9325
21-171	5/23	12:11	4.86	4.92	0.99	1.45	34677	34659	34093
21-111	5/9	11:28	3.91	4.92	0.79	1.17	44560	45496	45655
54-142	5/18	14:03	4.31	5.16	0.84	1.23	78067	77942	78067
21-111	5/14	9:05	4.58	5.20	0.88	1.29	79203	59715	79394
54-141	5/15	0:29	4.31	5.22	0.83	1.21	9486	9343	9271
54-137	5/17	6:41	4.31	5.25	0.82	1.21	45380	51845	72169
21-111	5/19	12:49	4.31	5.36	0.80	1.18	26306	52733	57163
54-156	5/29	7:27	4.86	5.39	0.90	1.32	9008	9228	9325
21-116	5/5	5:28	4.86	5.41	0.90	1.32	9165	9388	9702
54-194	4/30	11:12	4.22	5.45	0.77	1.14	48463	63399	66539
54-186	5/16	7:22	4.31	5.51	0.78	1.15	46487	46580	46627
21-113	5/11	21:46	3.91	5.69	0.69	1.01	45518	16643	9060
54-142	5/15	16:06	4.31	5.70	0.76	1.11	76195	67341	46348
21-113	4/27	11:31	3.95	6.01	0.66	0.97	27216	27027	60521
54-186	5/24	0:07	4.86	6.10	0.80	1.17	9113	9113	9113
54-203	4/26	21:27	3.91	6.11	0.64	0.94	35268	16656	13249
54-160	5/14	2:47	4.31	6.24	0.69	1.02	9271	52098	79203
21-147	5/21	10:05	4.31	6.29	0.69	1.01	34913	55066	82085
54-137	5/16	8:33	5.16	6.35	0.81	1.19	46767	46607	46627
54-200	5/26	11:17	4.86	6.37	0.76	1.12	34209	60308	78256
21-111	5/17	6:00	4.86	6.70	0.73	1.07	45380	54800	72530
54-198	5/6	16:33	3.91	6.71	0.58	0.86	81504	58072	9113
54-159	5/18	12:38	4.31	6.74	0.64	0.94	10370	69000	78067
54-142	5/13	9:26	4.31	6.98	0.62	0.91	9486	9594	9702
54-176	5/3	22:14	4.42	7.08	0.62	0.92	82085	49532	9271
21-160	5/23	3:29	4.86	7.43	0.65	0.96	9113	12399	33514
54-176	5/5	8:40	4.42	7.44	0.59	0.87	9486	46471	65853
54-202	5/1	12:40	4.73	7.51	0.63	0.93	35387	69756	73800
21-147	5/14	7:15	4.37	7.51	0.58	0.86	78634	63447	79394
21-105	5/4	10:24	4.42	7.67	0.58	0.85	26911	64209	74166
54-200a	4/26	9:02	3.91	7.69	0.51	0.75	35864	35700	35268

Fish	Upstream Movement				Speed		Conowingo Discharge		
	Date	Time	Distance (mi)	Time (hr)	mph	fps	Start	Average	End
21-141	5/14	5:16	4.01	8.18	0.49	0.72	73618	67071	78823
21-127	5/3	9:05	4.42	8.30	0.53	0.78	9271	46626	65512
54-199	5/5	16:16	4.86	8.61	0.56	0.83	65853	59636	11600
54-176	5/19	21:37	4.86	8.84	0.55	0.81	10946	9280	9060
21-114	5/7	18:13	3.91	9.41	0.42	0.61	59872	25100	8678
21-113	5/4	2:20	4.42	9.49	0.47	0.68	39692	19806	31256
21-110	4/22	21:16	3.91	9.65	0.40	0.59	58748	18270	13456
21-100	4/27	18:18	3.91	9.78	0.40	0.59	60034	30521	12977
54-151	5/12	4:27	4.42	9.81	0.45	0.66	9008	31522	20960
21-170	5/12	3:37	4.42	10.06	0.44	0.64	9060	30440	20960
21-101	5/6	19:24	3.91	10.17	0.38	0.56	82085	24824	8904
54-178	5/5	6:06	4.42	10.25	0.43	0.63	9165	39693	65853
21-122	5/4	17:47	4.42	10.32	0.43	0.63	73983	41833	9165
21-124	4/30	11:59	3.91	10.72	0.36	0.54	48463	60848	19416
21-123	5/14	5:47	4.42	10.84	0.41	0.60	73618	71068	78823
21-112	5/1	18:32	4.42	10.93	0.40	0.59	73983	34891	9008
21-118	5/5	6:21	4.42	11.06	0.40	0.59	9165	41844	65512
21-123	5/22	2:58	4.42	11.36	0.39	0.57	8852	18689	45793
21-159	5/20	12:31	3.91	11.92	0.33	0.48	34795	38506	9378
21-115	5/12	5:39	4.42	11.99	0.37	0.54	44969	30864	21400
21-100	5/2	12:31	4.42	12.20	0.36	0.53	35387	63913	13113
54-204	5/2	8:32	4.42	12.30	0.36	0.53	9325	52457	74532
21-159	5/27	17:21	4.73	12.39	0.38	0.56	79013	32742	8904
21-169	5/19	11:20	3.91	12.68	0.31	0.45	26206	38674	9060
21-102	5/5	13:18	4.86	12.92	0.38	0.55	66539	53861	9008
54-200	5/17	16:50	4.31	13.38	0.32	0.47	71809	44854	9218
21-112	4/26	9:38	4.42	13.46	0.33	0.48	35864	32660	13456
54-208	5/5	6:00	4.86	13.82	0.35	0.52	9165	45226	65683
54-178	5/7	14:55	3.91	14.92	0.26	0.38	60846	32048	8618
21-111	5/5	4:30	4.42	15.07	0.29	0.43	9165	40718	65683
21-135	5/1	14:34	4.42	15.60	0.28	0.42	74716	42642	9008
54-208	5/11	22:51	4.42	15.69	0.28	0.41	16010	24572	20960
54-211	5/19	22:43	3.78	15.95	0.24	0.35	9325	23149	65853
54-208	5/3	20:54	4.42	16.45	0.27	0.39	81891	46562	74716
21-158	5/19	13:40	4.31	16.60	0.26	0.38	56536	33089	23780
54-156	5/26	1:37	4.86	16.66	0.29	0.43	9486	35845	78256
21-127	4/26	15:08	3.91	16.67	0.23	0.34	35864	22449	13456
21-109	4/30	17:37	3.91	16.83	0.23	0.34	66367	31364	35149

Fish	Upstream Movement				Speed		Conowingo Discharge		
	Date	Time	Distance (mi)	Time (hr)	mph	fps	Start	Average	End
54-140	5/18	11:21	5.16	16.84	0.31	0.45	9702	47848	9113
21-105	4/29	18:20	3.80	19.17	0.20	0.29	65512	42961	66539
21-121	5/2	10:45	4.42	19.21	0.23	0.34	33399	47219	8852
54-207	5/3	10:35	3.59	20.49	0.18	0.26	9271	51595	9378
54-192	5/2	12:21	4.73	23.36	0.20	0.30	35387	38810	10541
21-159	5/23	12:45	4.42	24.31	0.18	0.27	34677	22955	59872
54-197	4/29	16:43	3.95	24.47	0.16	0.24	65342	48996	66367
54-193	4/27	8:57	4.86	28.99	0.17	0.25	13735	27917	36466
21-135	5/3	4:26	4.42	36.62	0.12	0.18	8852	45920	73983
21-143	5/22	1:30	4.73	44.89	0.11	0.15	8904	23557	9812
21-127	4/30	9:09	3.91	45.26	0.09	0.13	48320	41533	9008
21-132	4/26	11:25	3.91	46.34	0.08	0.12	35744	25891	26107
21-133	4/26	5:48	4.31	51.82	0.08	0.12	34209	26964	26107
21-110	4/26	2:11	3.91	52.70	0.07	0.11	13045	26710	12977
21-117	4/28	20:39	4.73	54.60	0.09	0.13	35864	38339	9008
21-124	5/5	8:19	4.73	62.77	0.08	0.11	9486	36641	8852
21-118	5/7	20:33	4.86	68.38	0.07	0.10	59389	21875	13249
54-149	5/22	16:33	4.86	71.24	0.07	0.10	45380	27696	60521

Data include only those trips which took less than 72 hr and are sorted by trip elapsed time.

TABLE 4.1-4: SUMMARY BY AVERAGE DISCHARGE FROM CONOWINGO DAM OF ALL RADIO TAGGED AMERICAN SHAD WHICH MADE A SUBSTANTIAL UPSTREAM MIGRATION DURING SPRING 2010

Average Conowingo Discharge (cfs)	No. Trips	No. Fish	Average Distance (mi)	Average Time (hr)	Average Speed mph	Average Speed fps
70,001 - 85,000	11	11	4.32	4.75	1.00	1.48
60,001 - 70,000	15	15	4.37	6.57	0.75	1.11
50,001 - 60,000	15	12	4.37	7.38	0.77	1.13
40,001 - 50,000	26	18	4.35	12.51	0.57	0.84
30,001 - 40,000	22	19	4.32	15.51	0.49	0.72
20,001 - 30,000	21	20	4.16	23.31	0.59	0.87
10,001 - 20,000	8	7	4.15	7.01	0.71	1.05
5,000 - 10,000	12	9	4.49	5.19	0.92	1.36
Total Trips	130	**Min.**	2.90	1.20	0.07	0.10
		Mean	4.32	11.81	0.68	1.01
		S.D.	0.37	13.47	0.48	0.71
		Median	4.31	6.73	0.63	0.93
		Max.	5.16	71.24	4.04	5.94

Only trips which took less than 72 hr are included.

Data are derived by calculations of individual trips. Average distance, time and speed are determined from trips per average discharge thus for example at discharge 5,000 to 10,000 cfs, average distance of 12 trips was 4.49 miles. Average time to complete a trip within those 12 trips was 5.19 hr.

TABLE 4.2-1: REPORTED SWIMMING SPEEDS FOR TARGET SPECIES IN THE SUSQUEHANNA BELOW CONOWINGO DAM.

Species	Life Stage	Fish Size	Swim Speed fps			Literature Source - Comments
			Max. Sustained	Prolonged or Critical	Burst or Startle	
Alewife	adult	250 mm TL			11.5-16.4	Range of burst swim speed in fishway; Dow 1962 cited in Beamish 1978.
	adult	235 mm FL			11.2	Haro et al, 2004.
Herring spp.	adult	152 - 280 mm FL	~ 5.0		~ 6.7	Est. from Bell, 1991. dart speed maintained for 7.5 sec.
American shad	Adult	unknown	2.36 - 2.47	-	-	Dodson and Leggett 1973; boat speed while following sonic tagged fish, not from laboratory test
	Adult	unknown	-	7	-	Bell 1991
	Adult	unknown	-	-	11.5 – 13.0	Weaver 1965, in Beamish 1978.

EXELON GENERATION COMPANY, LLC

CONOWINGO HYDROELECTRIC PROJECT
PROJECT NO. 405

N

1 inch = 3,000 feet

0 1,500 3,000 6,000 Feet

Figure 3.1-1:
Referenced Landmarks in the Susquehanna River Below the Conowingo Dam

Path: X:\GISMaps\project_maps\study_plan\conowingo\Study_3.07\landmarks_in_susquehanna.mxd

FIGURE 3.1-2: TIME SERIES PLOT COMPARING MARIETTA AND CONOWINGO USGS GAGE FLOWS, APRIL 15, 2010 TO MAY 1, 2010.

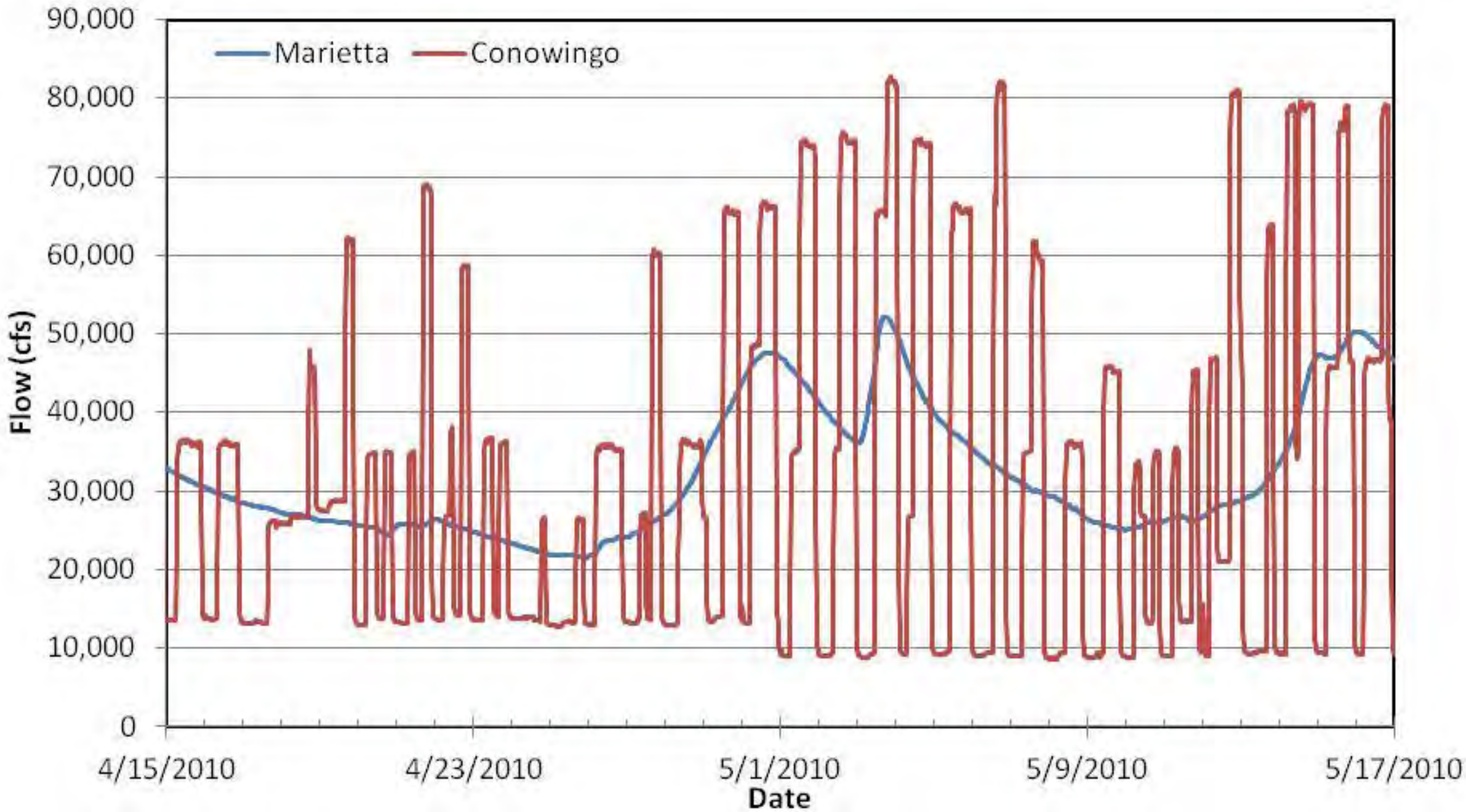


FIGURE 3.1-3: TIME SERIES PLOT COMPARING MARIETT AND CONOWINGO USGS GAGE FLOWS, MAY 15 TO JUNE 16, 2010.

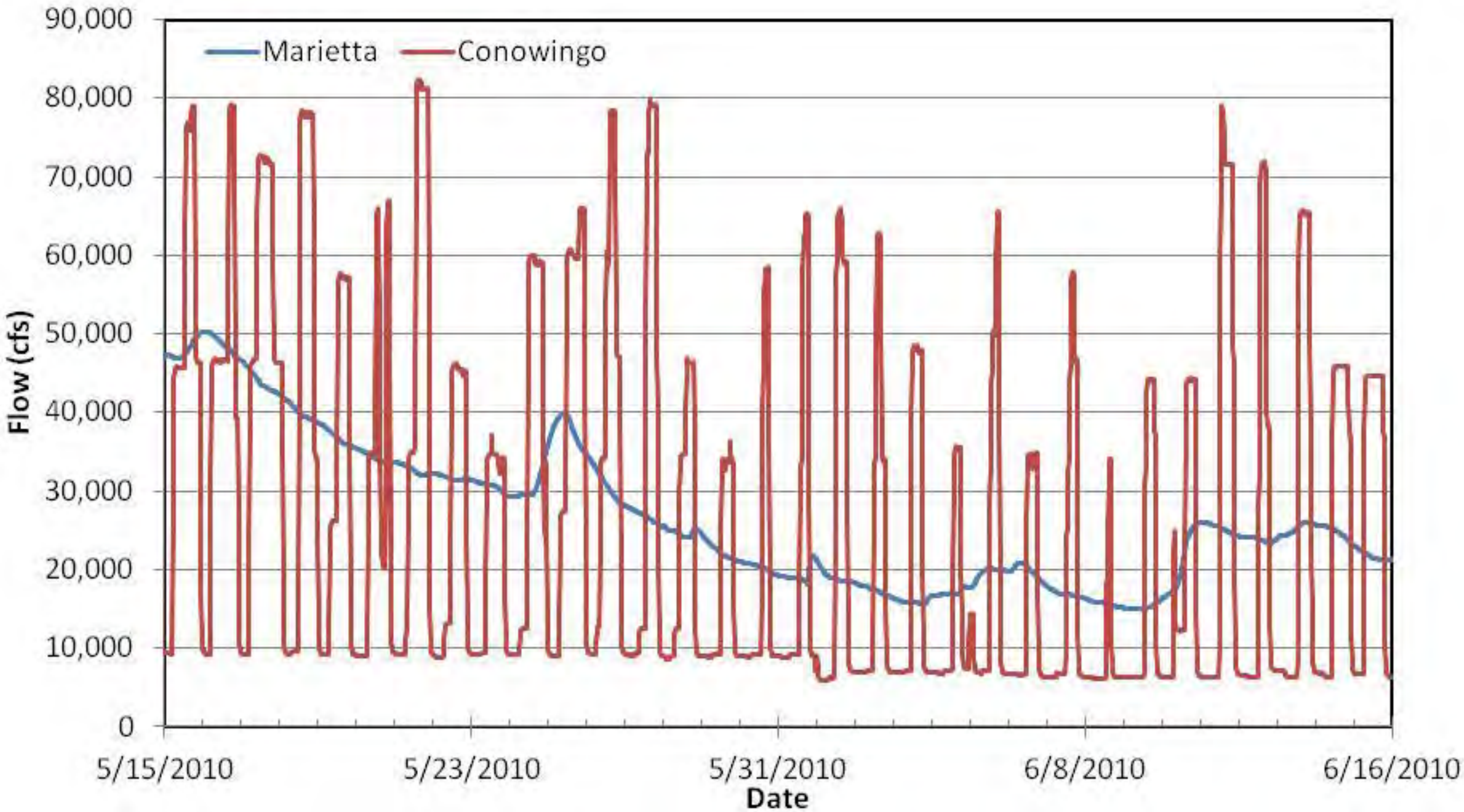
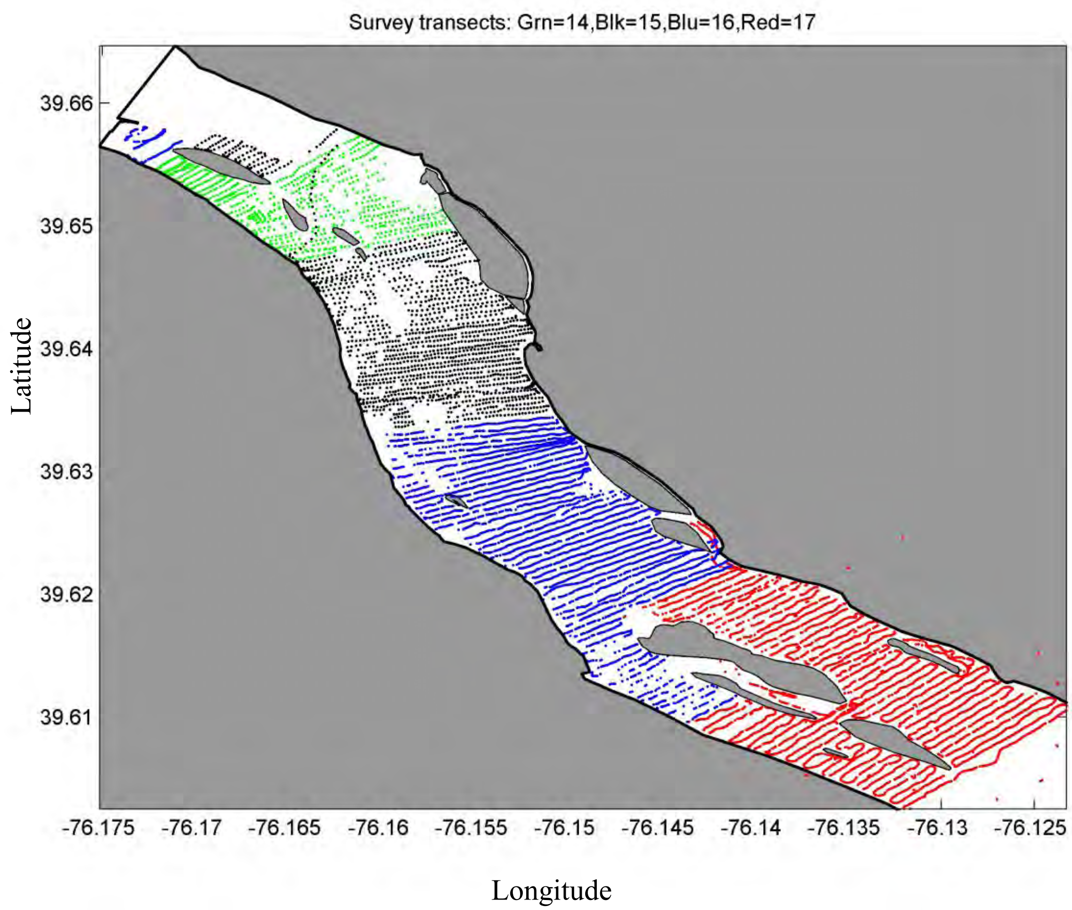


FIGURE 3.2-1: A.D.C.P. TRANSECT LOCATIONS IN THE SUSQUEHANNA RIVER DURING JUNE 14, 2010 TO JUNE 17, 2010 SURVEY



Green coloring indicates transects surveyed on June 14, black coloring indicates transects surveyed on June 15, blue coloring indicates transects surveyed on June 16, and red coloring indicates transects surveyed on June 17.

FIGURE 4.1-1: FREQUENCY DISTRIBUTION OF AMERICAN SHAD UPSTREAM MIGRATIONS BY TIME INTERVAL.

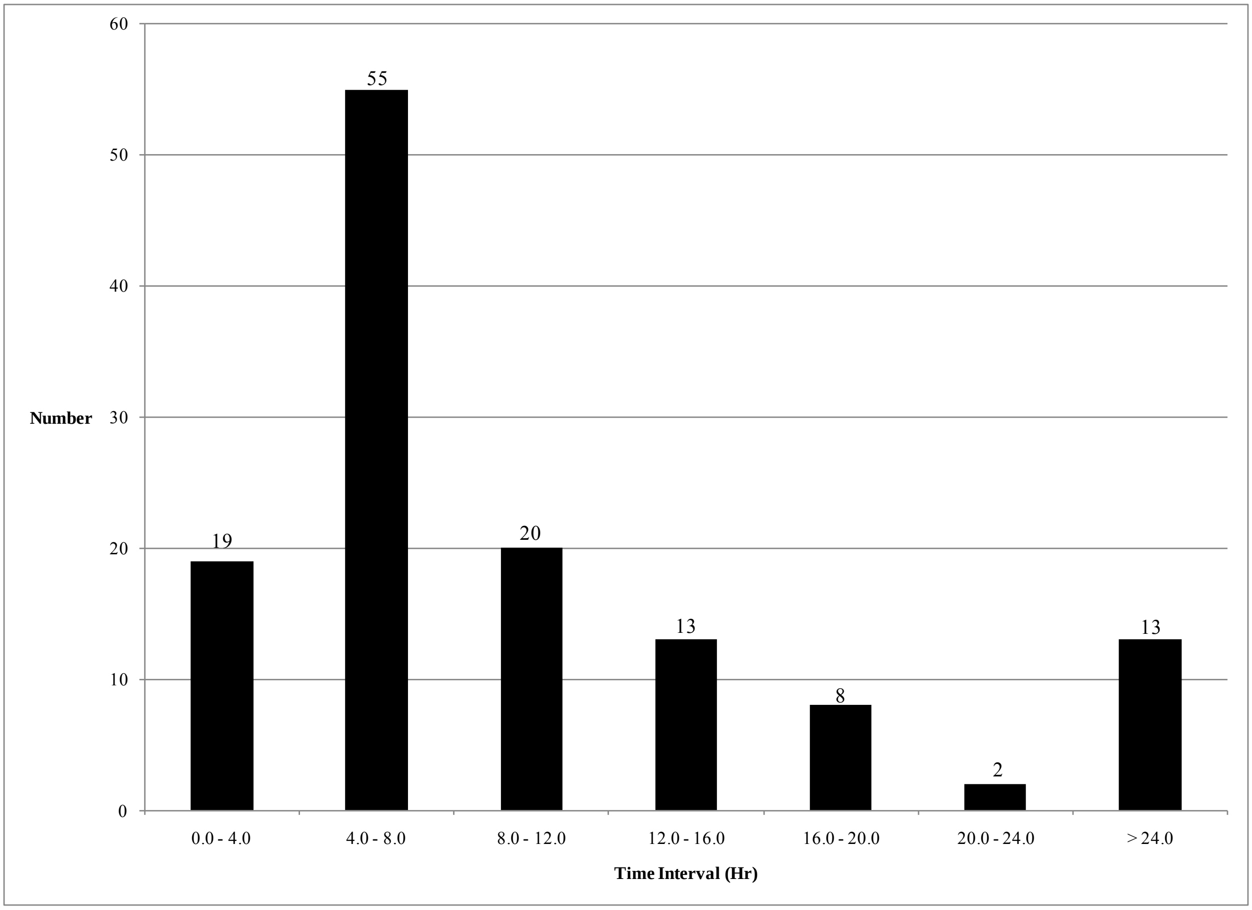
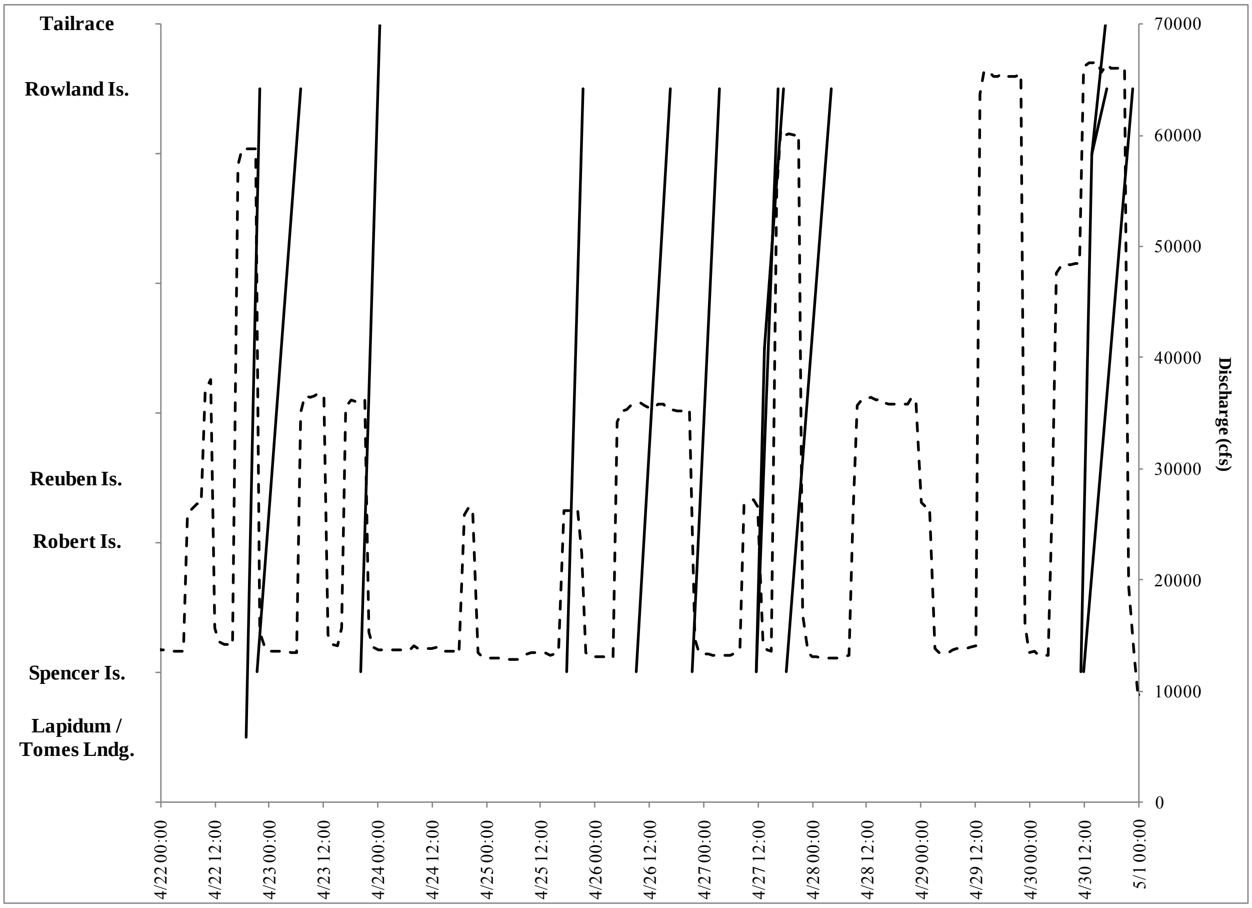
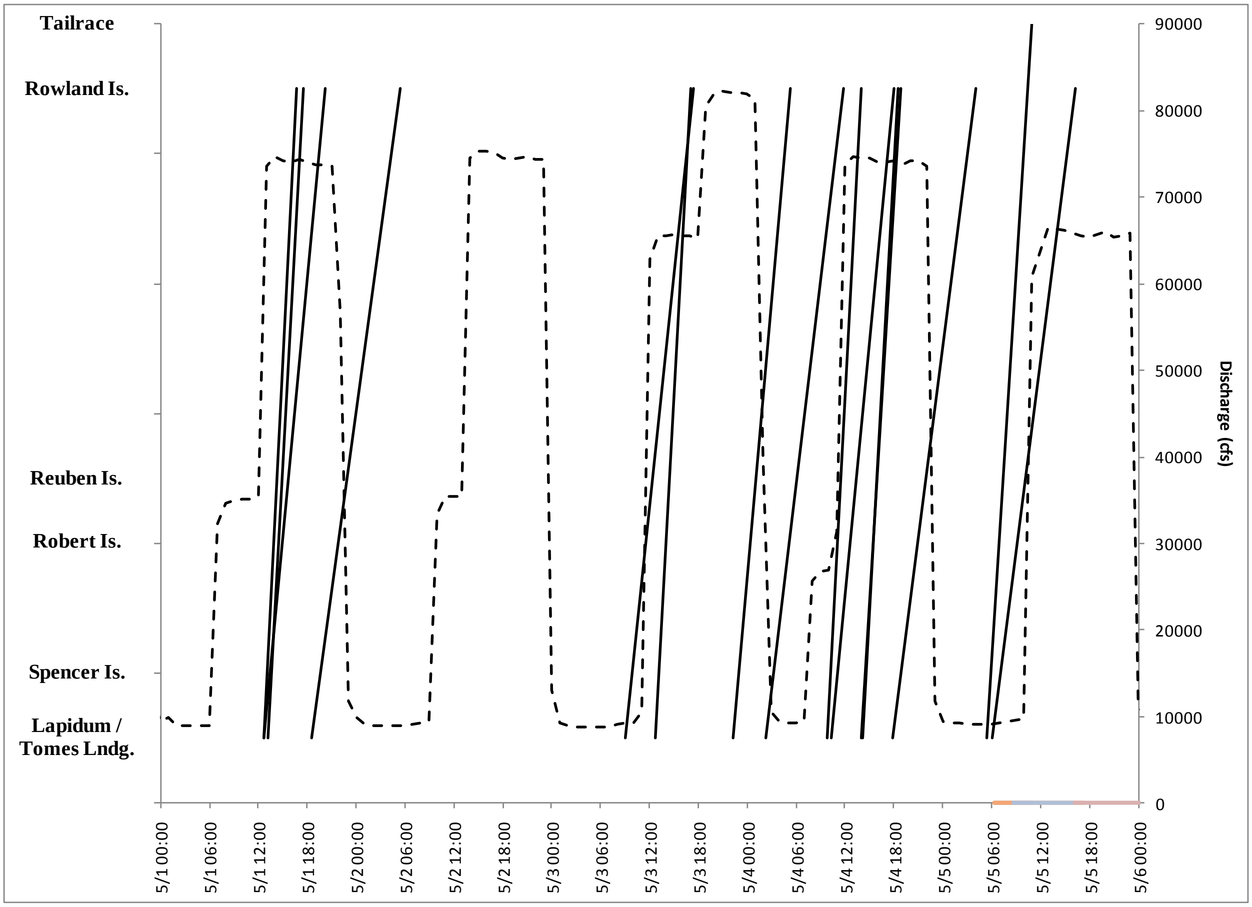


FIGURE 4.1-2: DEPICTION OF RADIO TAGGED AMERICAN SHAD INDIVIDUAL UPSTREAM MOVEMENT EVENTS IN THE SUSQUEHANNA RIVER BETWEEN APRIL 22, 2010 AND MAY 1, 2010.



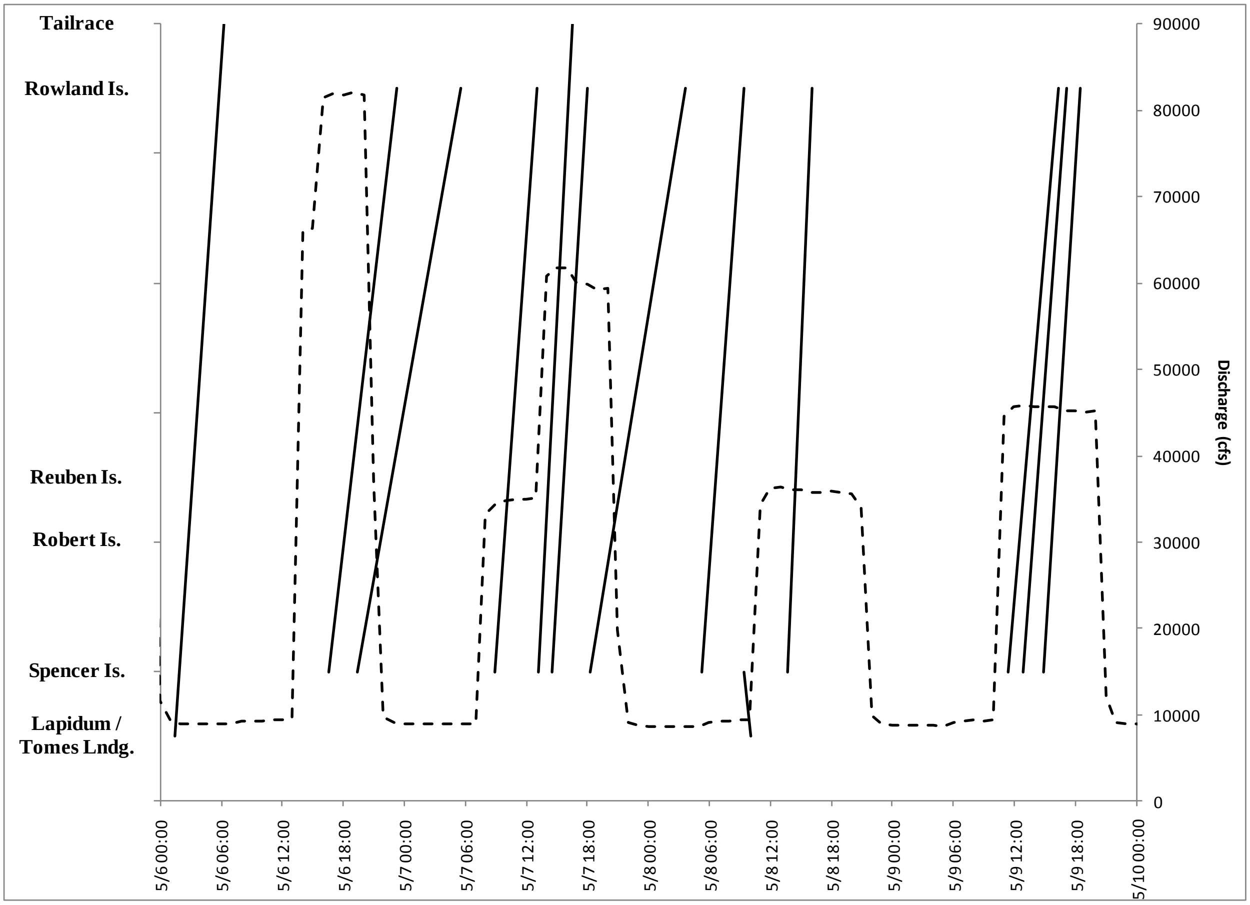
Discharge is represented by the dashed line and is USGS data from gage #01578310. Fifteen separate forays are illustrated.

FIGURE 4.1-3: DEPICTION OF RADIO TAGGED AMERICAN SHAD INDIVIDUAL UPSTREAM MOVEMENT EVENTS IN THE SUSQUEHANNA RIVER BETWEEN MAY 1, 2010 AND MAY 6, 2010.



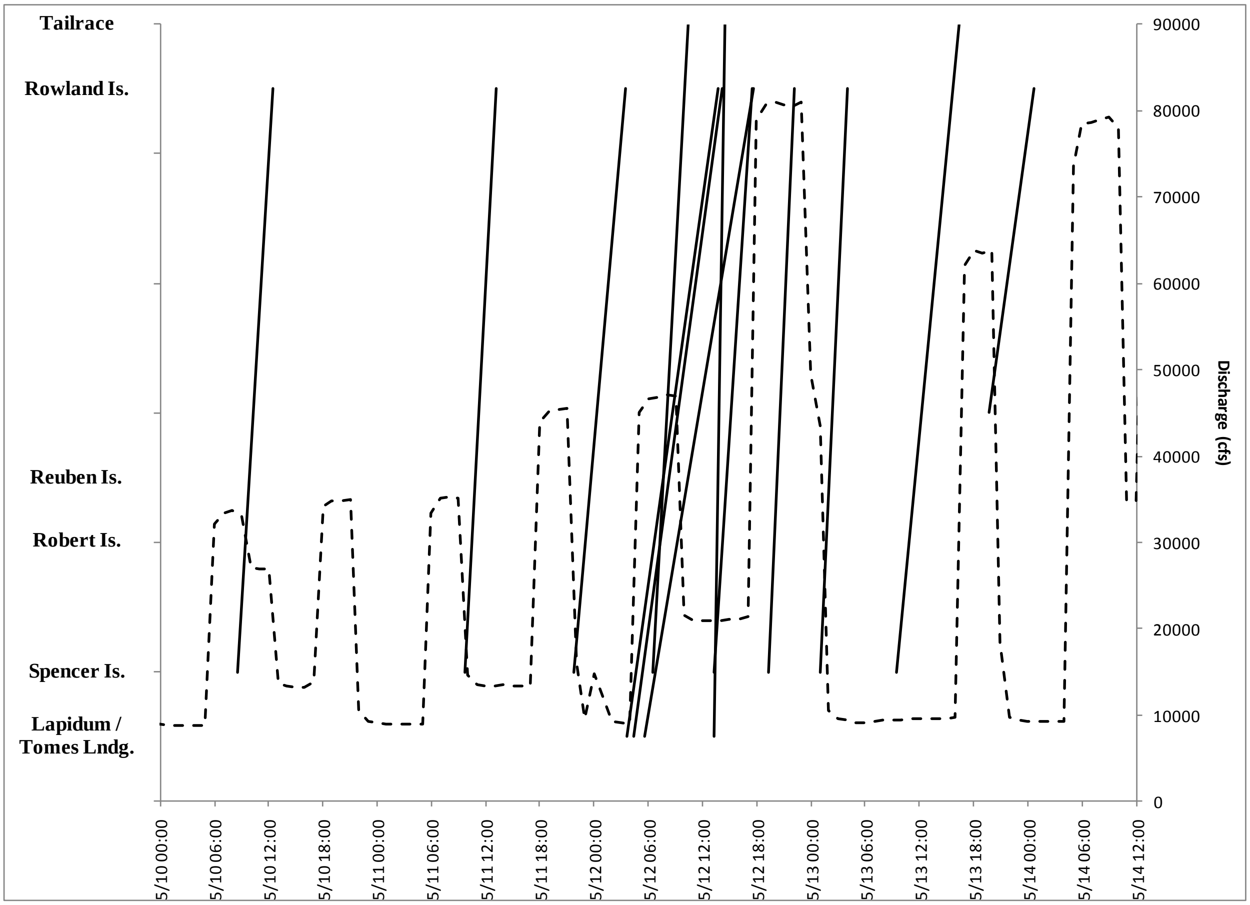
Discharge is represented by the dashed line and is USGS data from gage #01578310. Nineteen separate forays are illustrated.

FIGURE 4.1-4: DEPICTION OF RADIO TAGGED AMERICAN SHAD INDIVIDUAL UPSTREAM MOVEMENT EVENTS IN THE SUSQUEHANNA RIVER BETWEEN MAY 6, 2010 AND MAY 10, 2010.



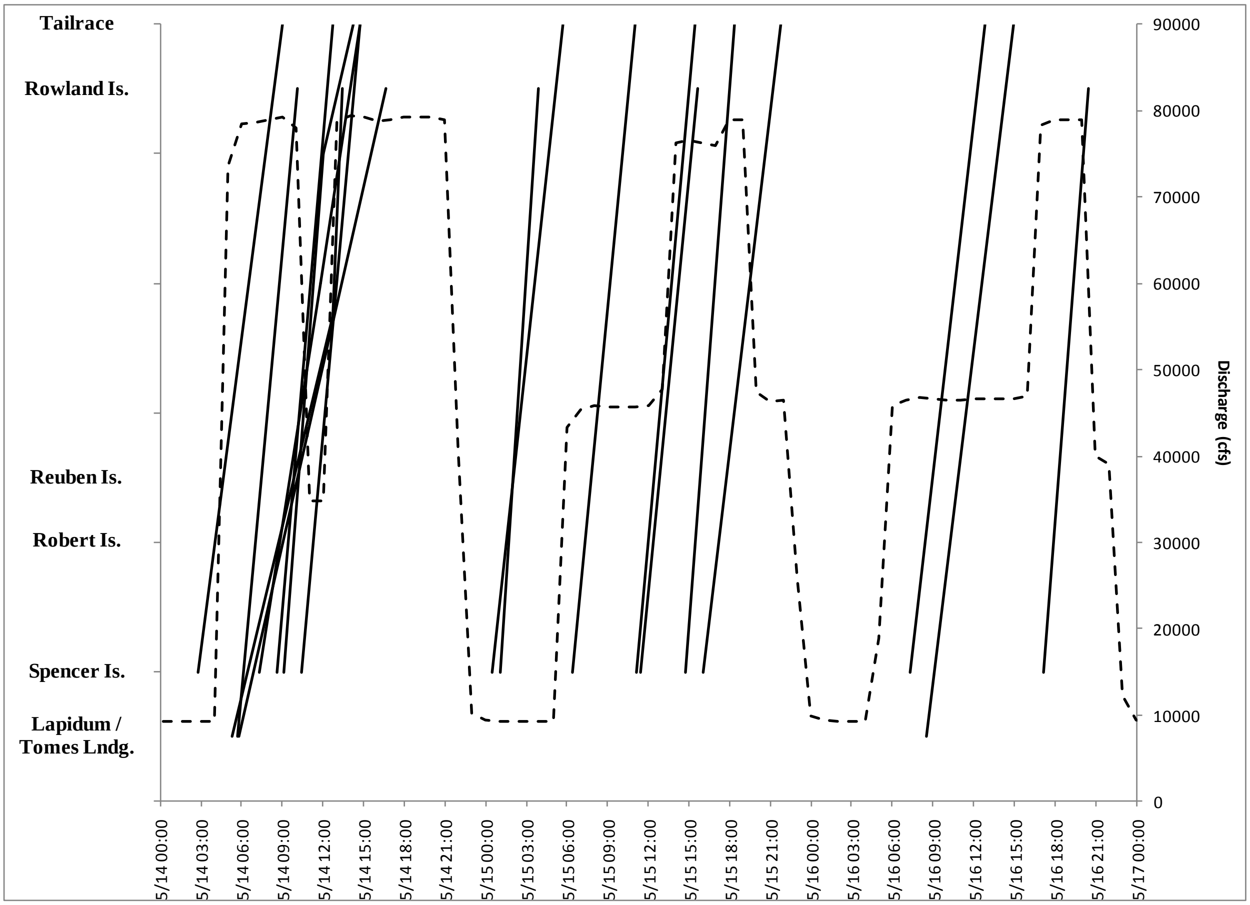
Discharge is represented by the dashed line and is USGS data from gage #01578310. Fourteen separate forays are illustrated.

FIGURE 4.1-5: DEPICTION OF RADIO TAGGED AMERICAN SHAD INDIVIDUAL UPSTREAM MOVEMENT EVENTS IN THE SUSQUEHANNA RIVER BETWEEN MAY 10, 2010 AND MAY 14, 2010.



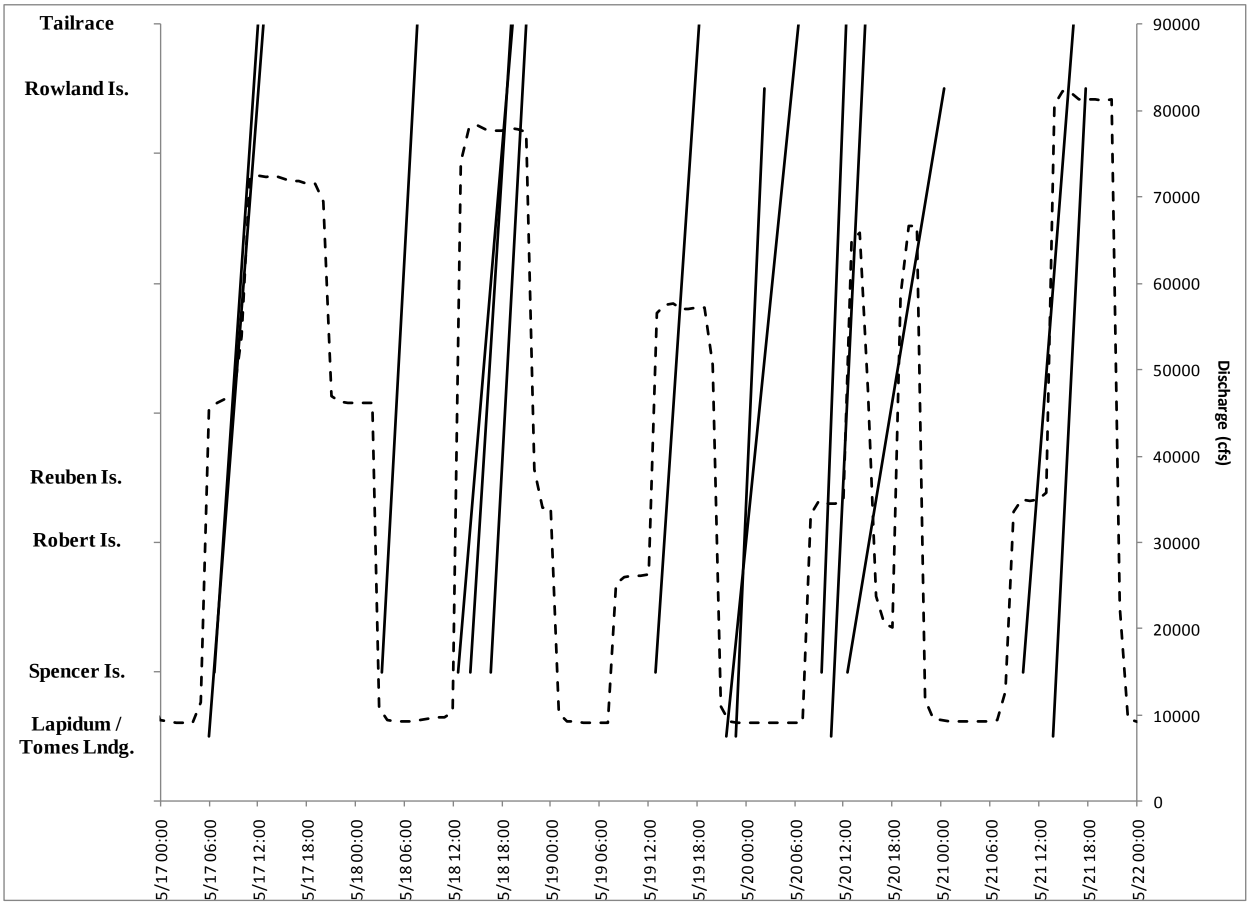
Discharge is represented by the dashed line and is USGS data from gage #01578310. Thirteen separate forays are illustrated.

FIGURE 4.1-6: DEPICTION OF RADIO TAGGED AMERICAN SHAD INDIVIDUAL UPSTREAM MOVEMENT EVENTS IN THE SUSQUEHANNA RIVER BETWEEN MAY 14, 2010 AND MAY 17, 2010.



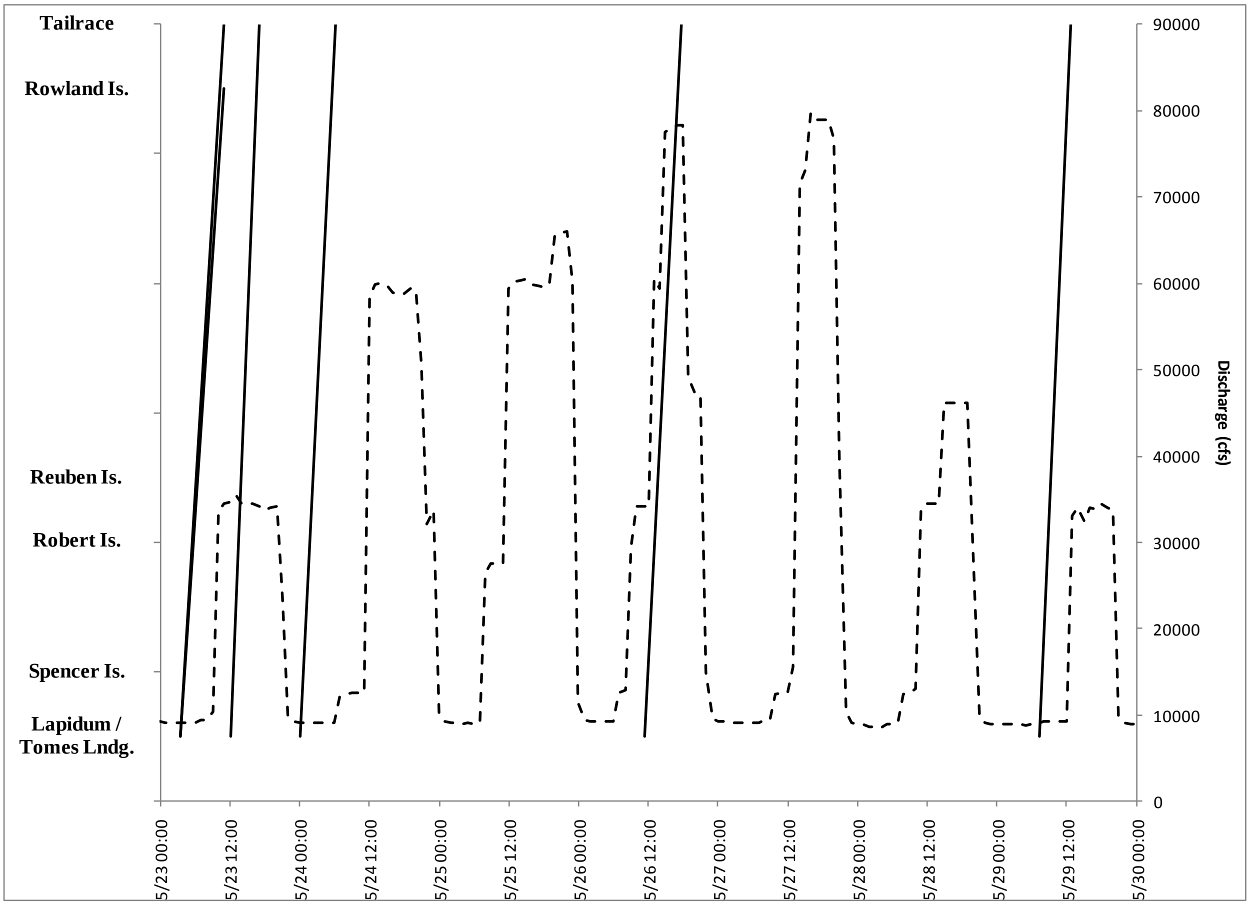
Discharge is represented by the dashed line and is USGS data from gage #01578310. Twenty one separate forays are illustrated.

FIGURE 4.1-7: DEPICTION OF RADIO TAGGED AMERICAN SHAD INDIVIDUAL UPSTREAM MOVEMENT EVENTS IN THE SUSQUEHANNA RIVER BETWEEN MAY 17, 2010 AND MAY 22, 2010.



Discharge is represented by the dashed line and is USGS data from gage #01578310. Fourteen separate forays are illustrated.

FIGURE 4.1-8: DEPICTION OF RADIO TAGGED AMERICAN SHAD INDIVIDUAL UPSTREAM MOVEMENT EVENTS IN THE SUSQUEHANNA RIVER BETWEEN MAY 23, 2010 AND MAY 30, 2010.



Discharge is represented by the dashed line and is USGS data from gage #01578310. Six separate forays are illustrated.

FIGURE 4.2-1: WATER VELOCITY IN THE SUSQUEHANNA RIVER BETWEEN CONOWINGO DAM AND SPENCER ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 10,000 CFS DISCHARGE FROM CONOWINGO DAM.

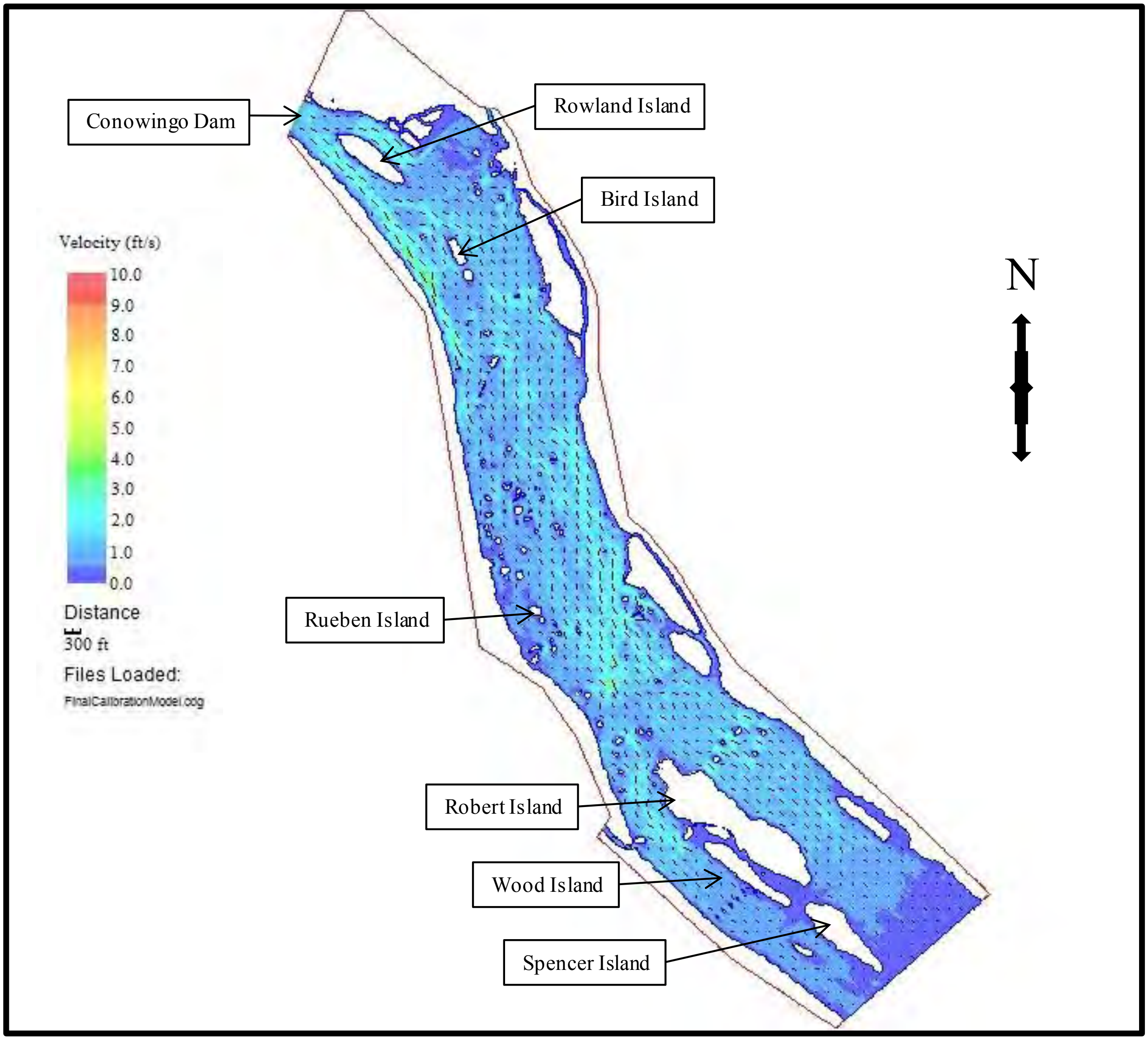


FIGURE 4.2-2: WATER VELOCITY IN THE SUSQUEHANNA RIVER IN THE VICINITY OF ROWLAND ISLAND AND BIRD ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 10,000 CFS DISCHARGE FROM CONOWINGO DAM.

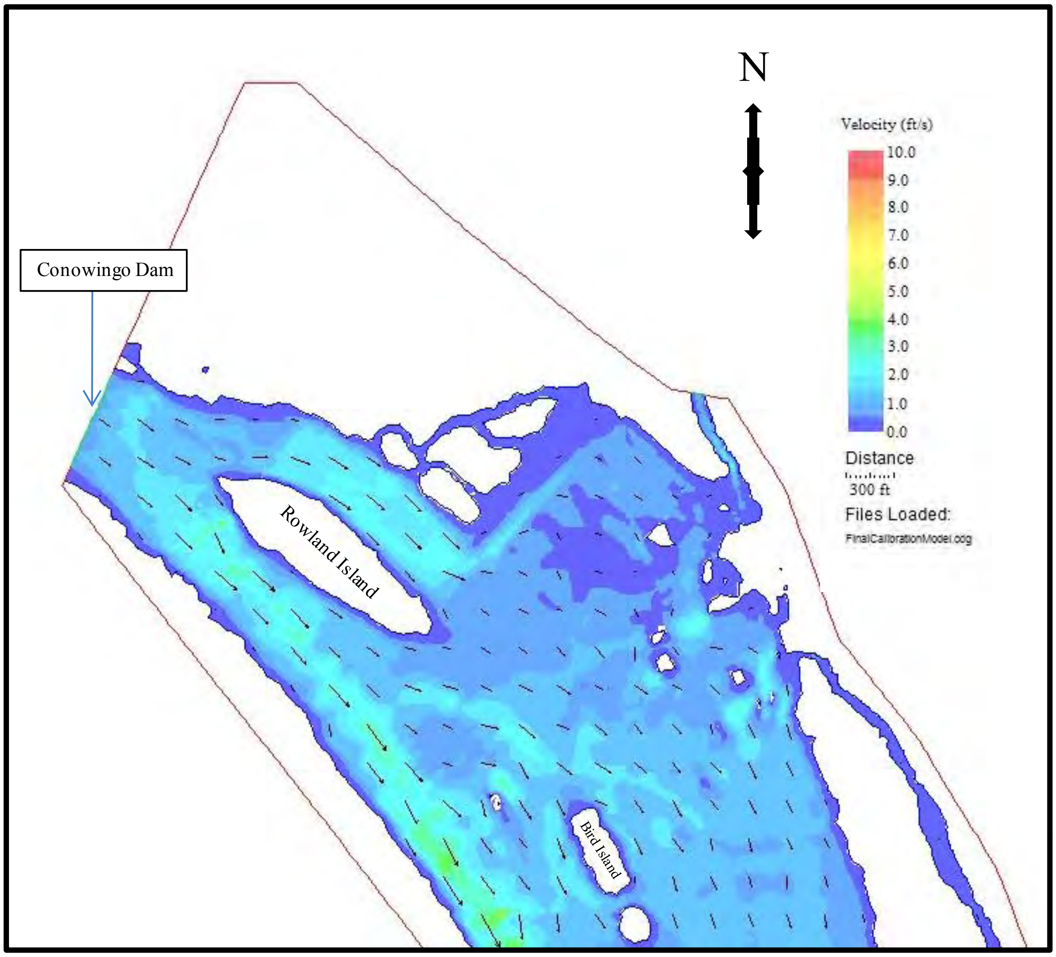


FIGURE 4.2-3: WATER VELOCITY IN THE SUSQUEHANNA RIVER IN THE VICINITY OF BIRD ISLAND AND REUBEN ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 10,000 CFS DISCHARGE FROM CONOWINGO DAM.

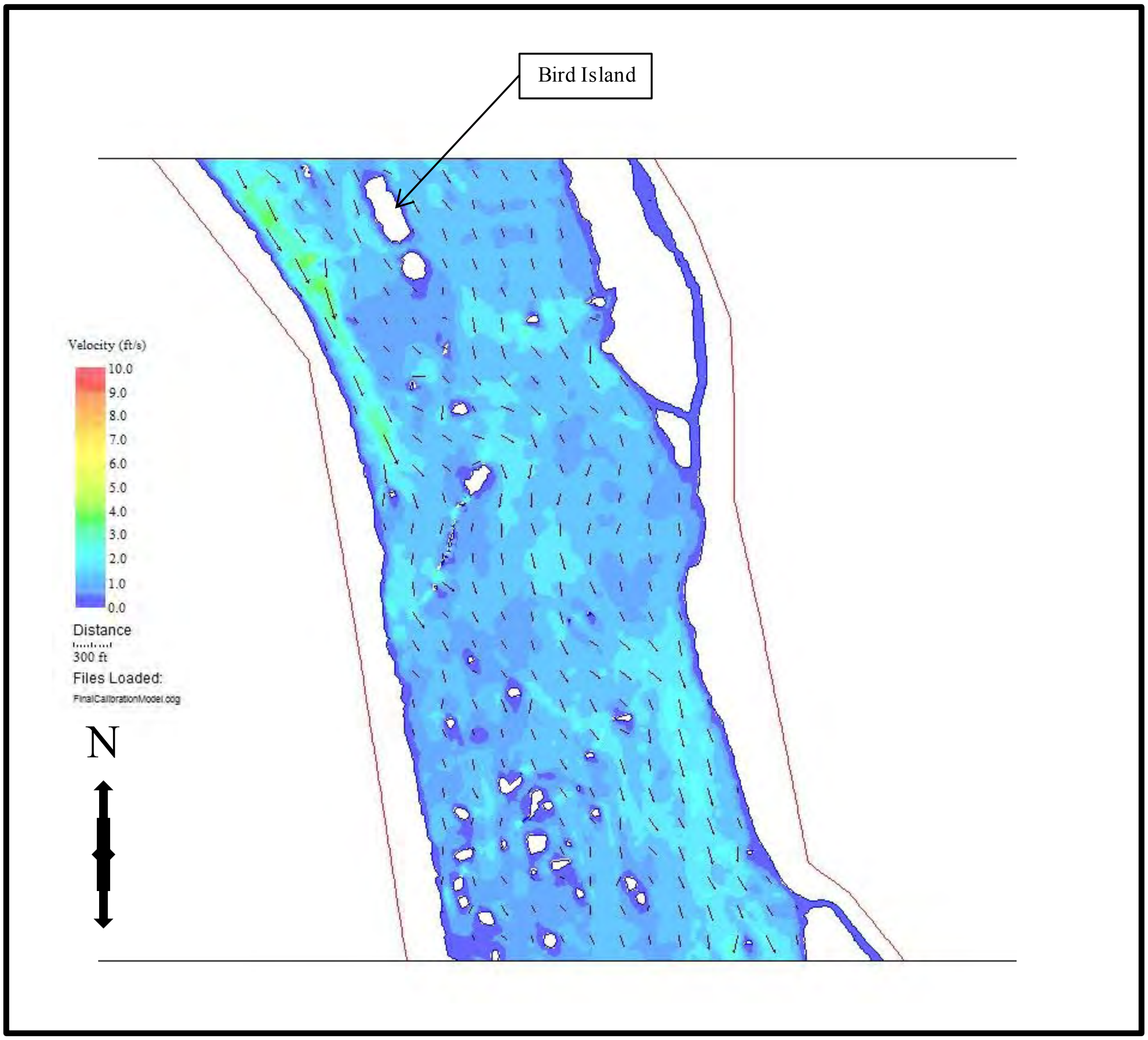


FIGURE 4.2-4: WATER VELOCITY IN THE SUSQUEHANNA RIVER IN THE VICINITY OF REUBEN ISLAND AND ROBERT ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 10,000 CFS DISCHARGE FROM CONOWINGO DAM.

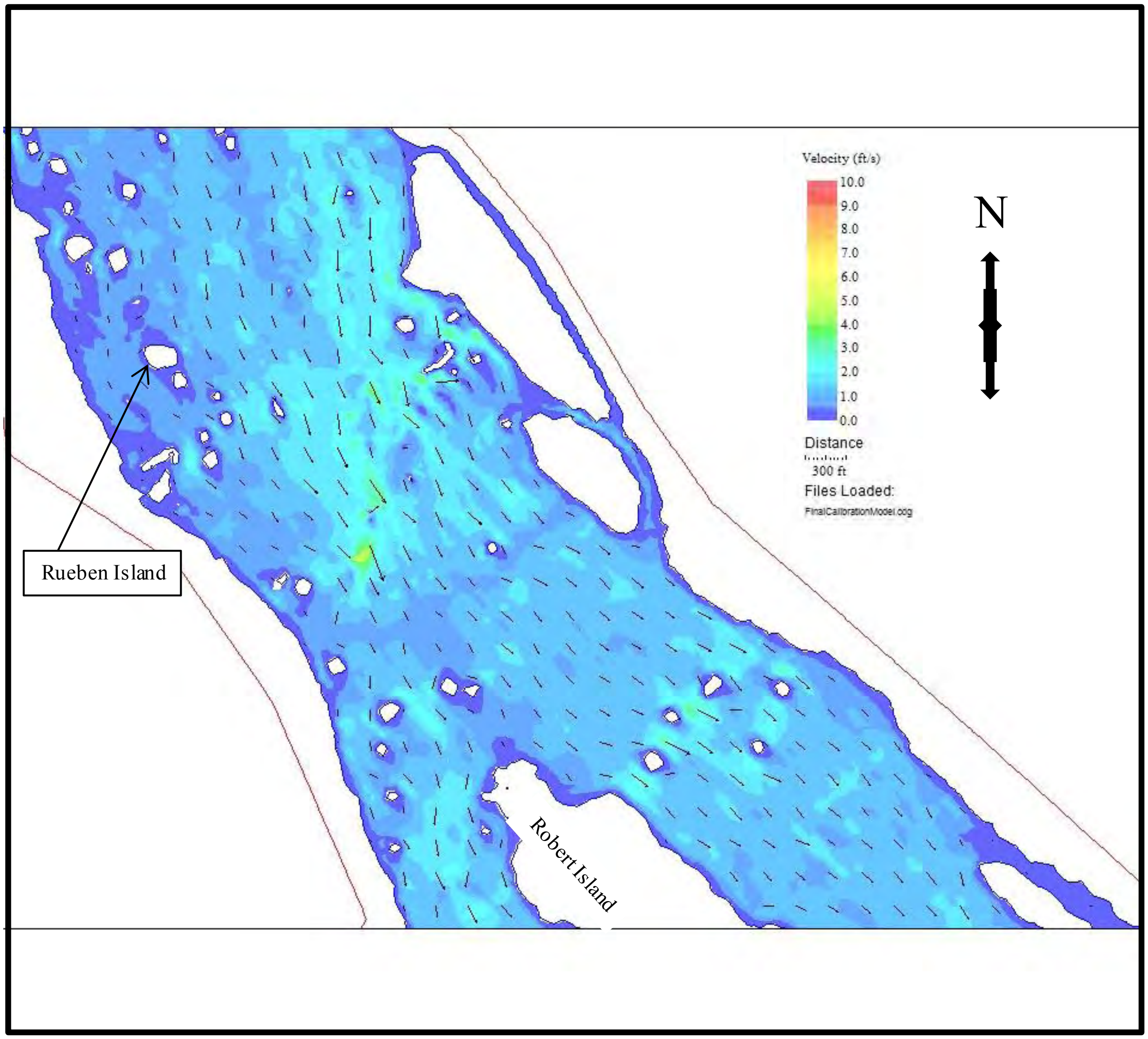


FIGURE 4.2-5 WATER VELOCITY IN THE SUSQUEHANNA RIVER IN THE VICINITY OF SPENCER ISLAND AND ROBERT ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 10,000 CFS DISCHARGE FROM CONOWINGO DAM.

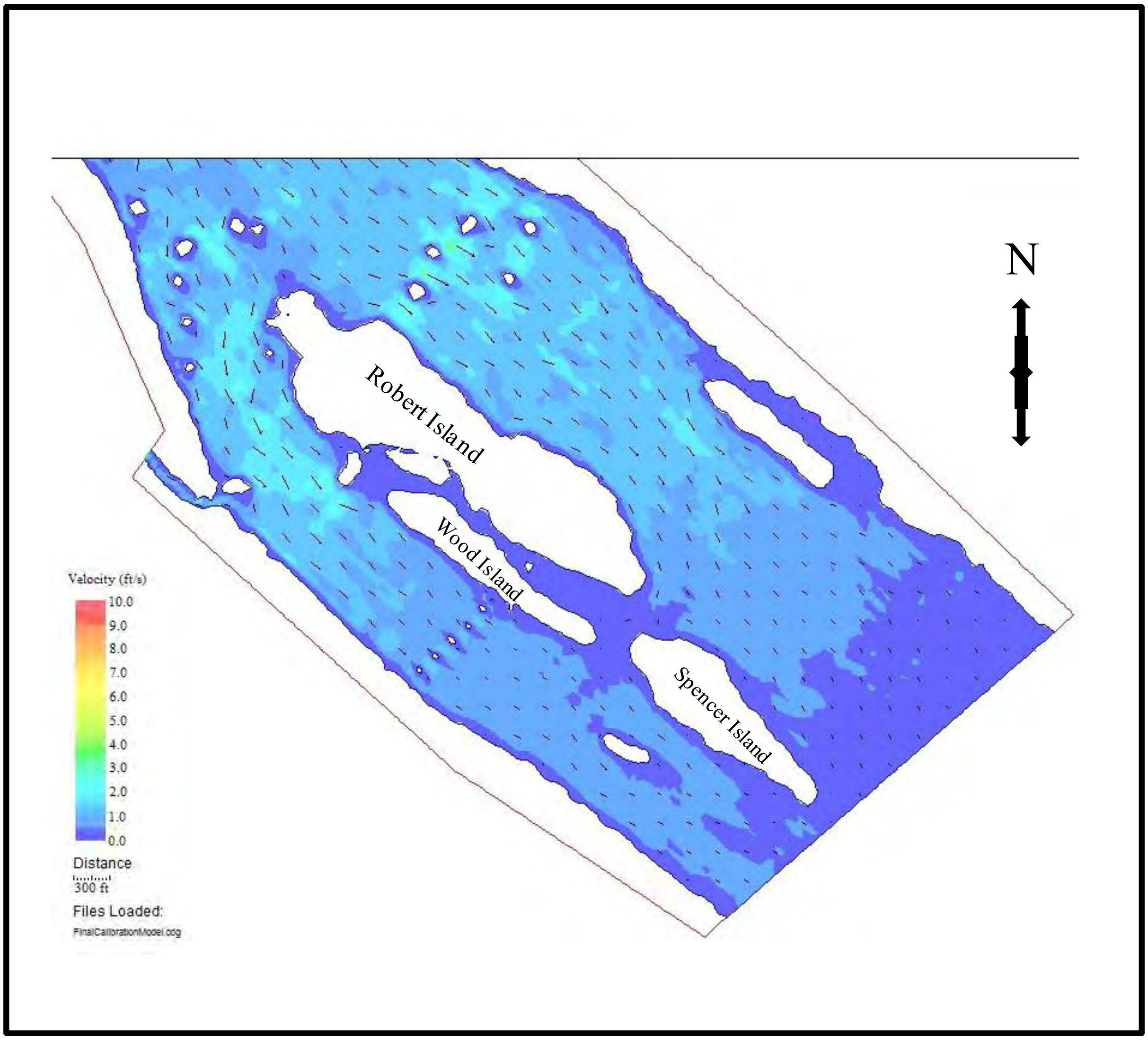


FIGURE 4.2-6: WATER VELOCITY IN THE SUSQUEHANNA RIVER BETWEEN CONOWINGO DAM AND SPENCER ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 40,000 CFS DISCHARGE FROM CONOWINGO DAM.

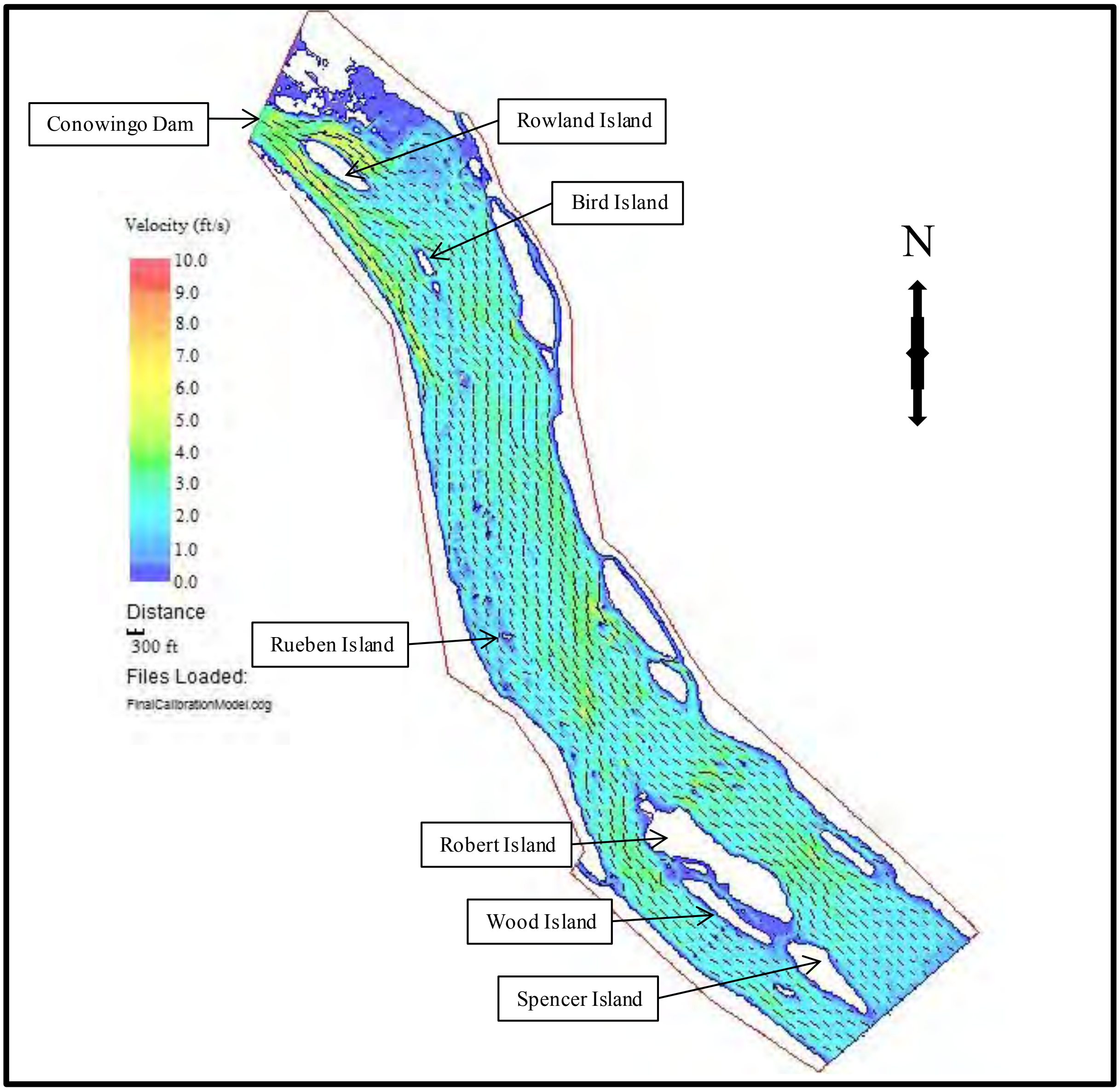


FIGURE 4.2-7: WATER VELOCITY IN THE SUSQUEHANNA RIVER IN THE VICINITY OF ROWLAND ISLAND AND BIRD ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 40,000 CFS DISCHARGE FROM CONOWINGO DAM.

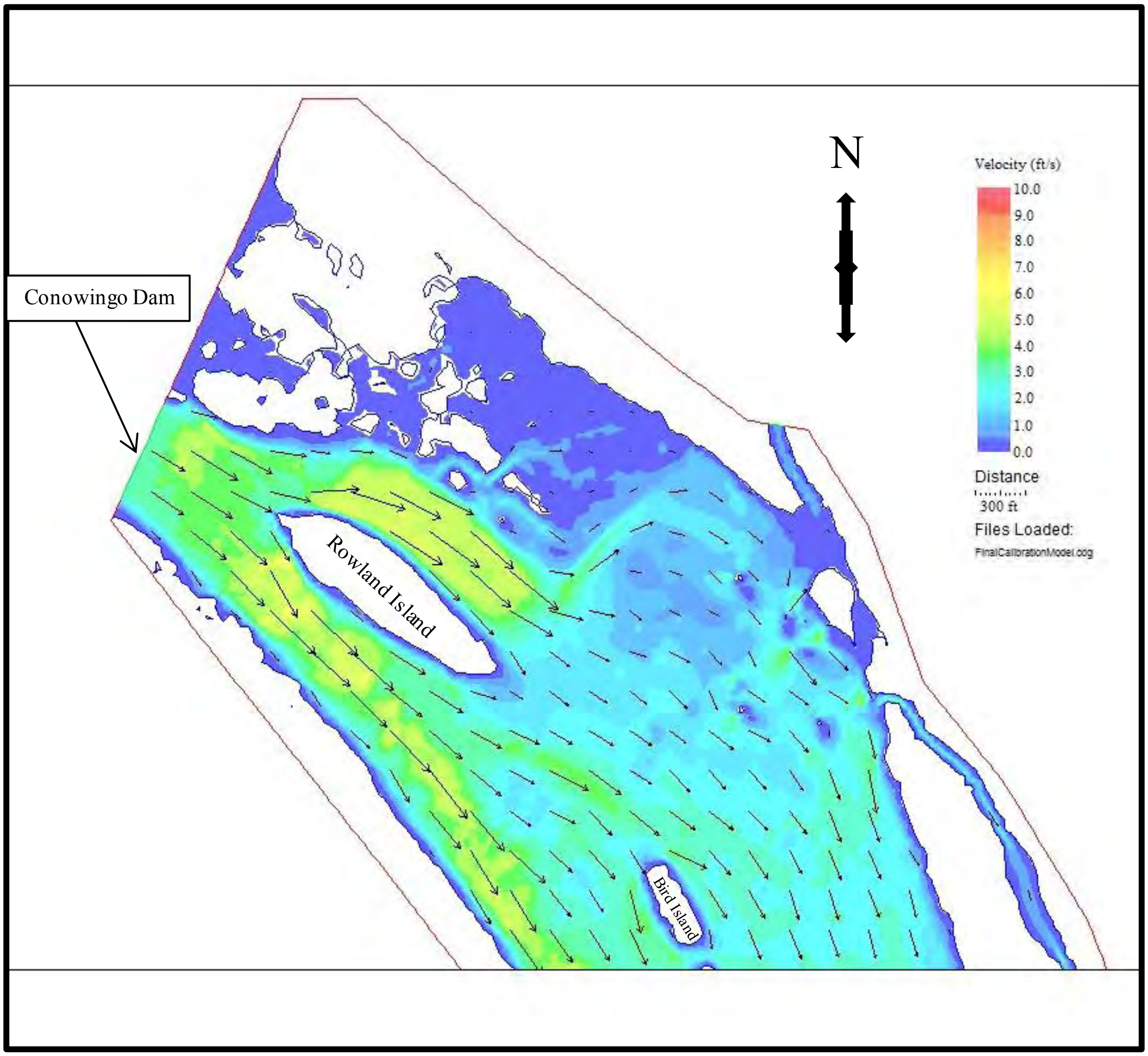


FIGURE 4.2-8: WATER VELOCITY IN THE SUSQUEHANNA RIVER IN THE VICINITY OF BIRD ISLAND AND REUBEN ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 40,000 CFS DISCHARGE FROM CONOWINGO DAM.

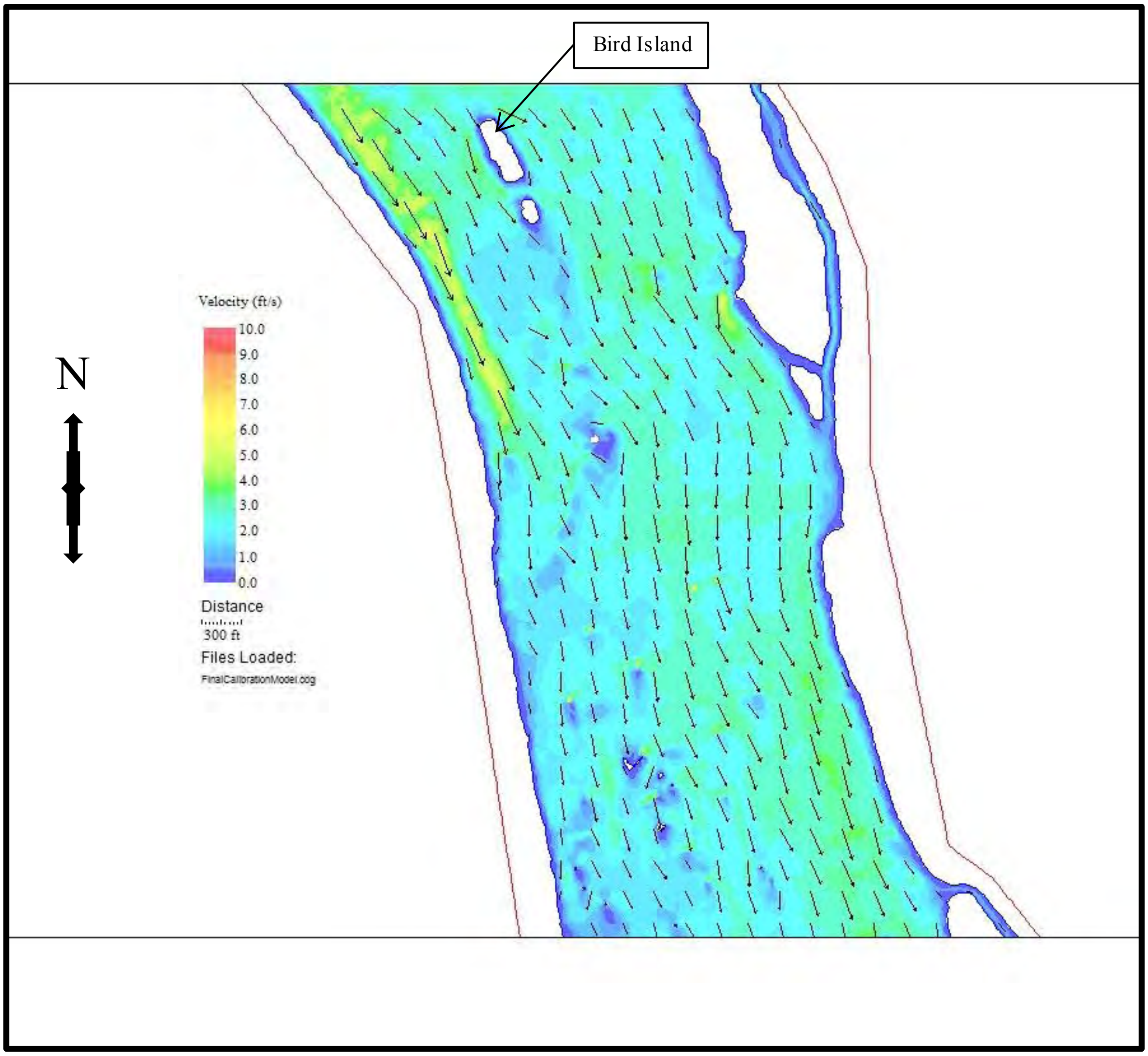


FIGURE 4.2-9: WATER VELOCITY IN THE SUSQUEHANNA RIVER IN THE VICINITY OF REUBEN ISLAND AND ROBERT ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 40,000 CFS DISCHARGE FROM CONOWINGO DAM.

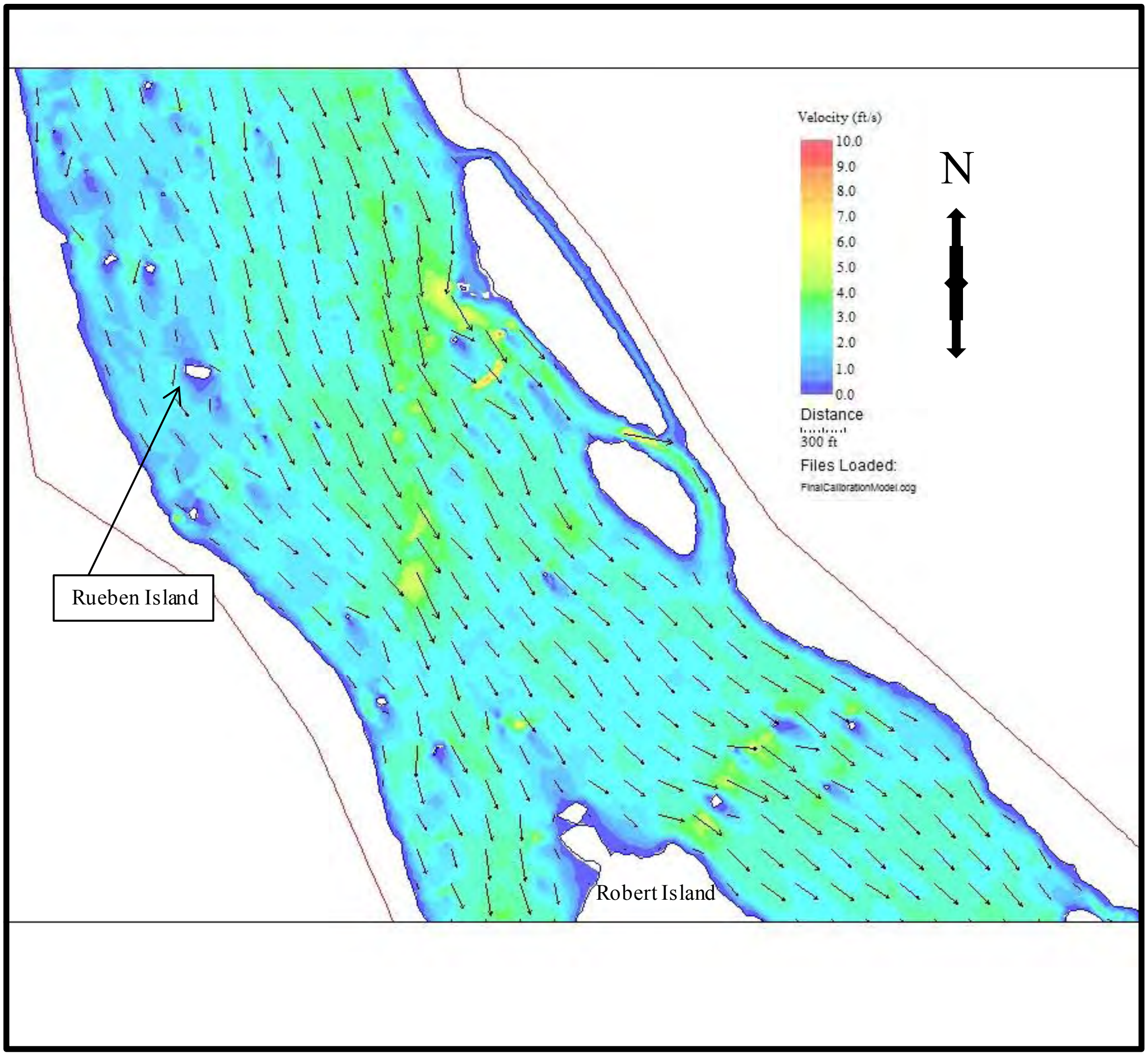


FIGURE 4.2-10 WATER VELOCITY IN THE SUSQUEHANNA RIVER IN THE VICINITY OF SPENCER ISLAND AND ROBERT ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 40,000 CFS DISCHARGE FROM CONOWINGO DAM.

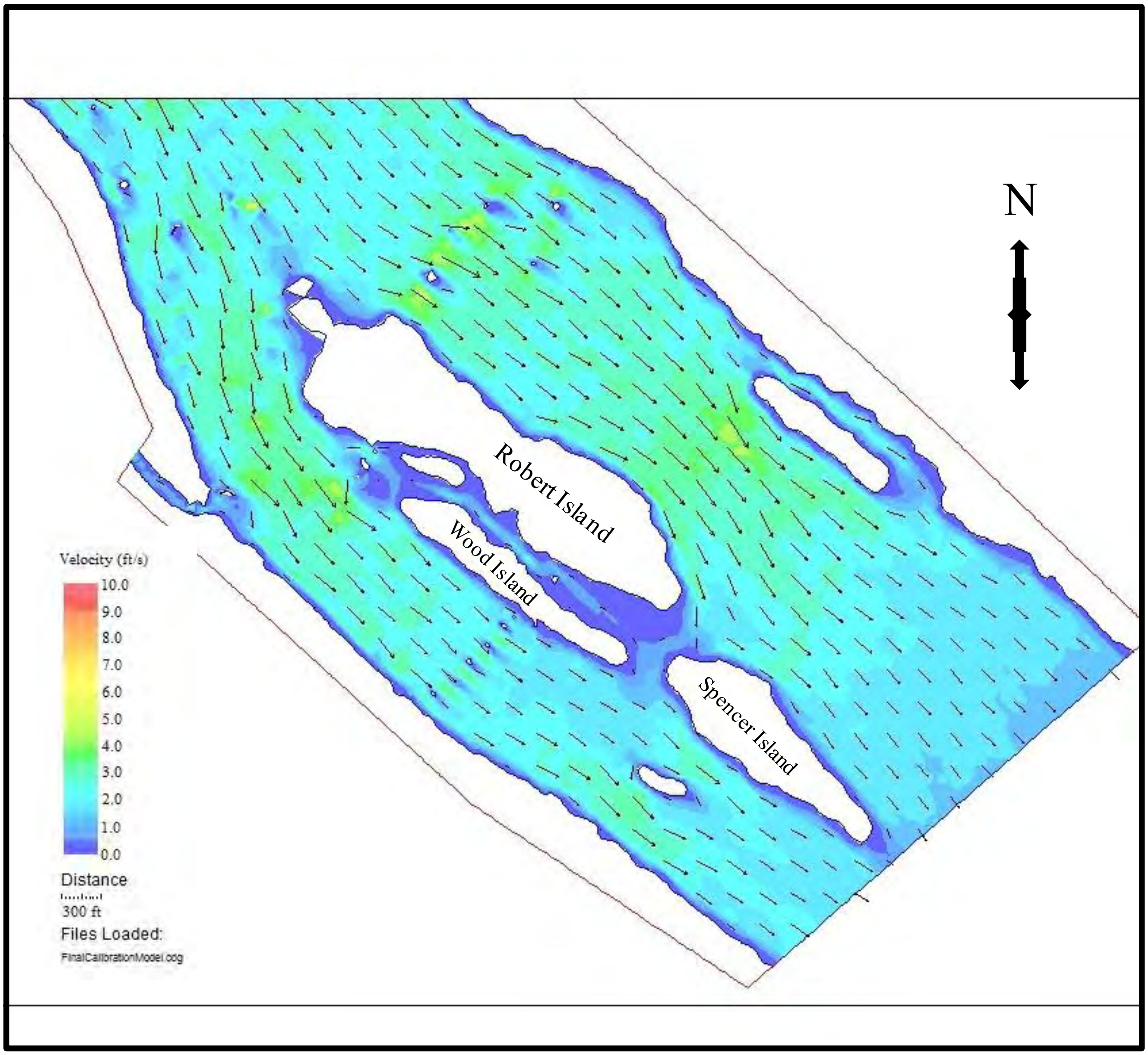


FIGURE 4.2-11: WATER VELOCITY IN THE SUSQUEHANNA RIVER BETWEEN CONOWINGO DAM AND SPENCER ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 86,000 CFS DISCHARGE FROM CONOWINGO DAM.

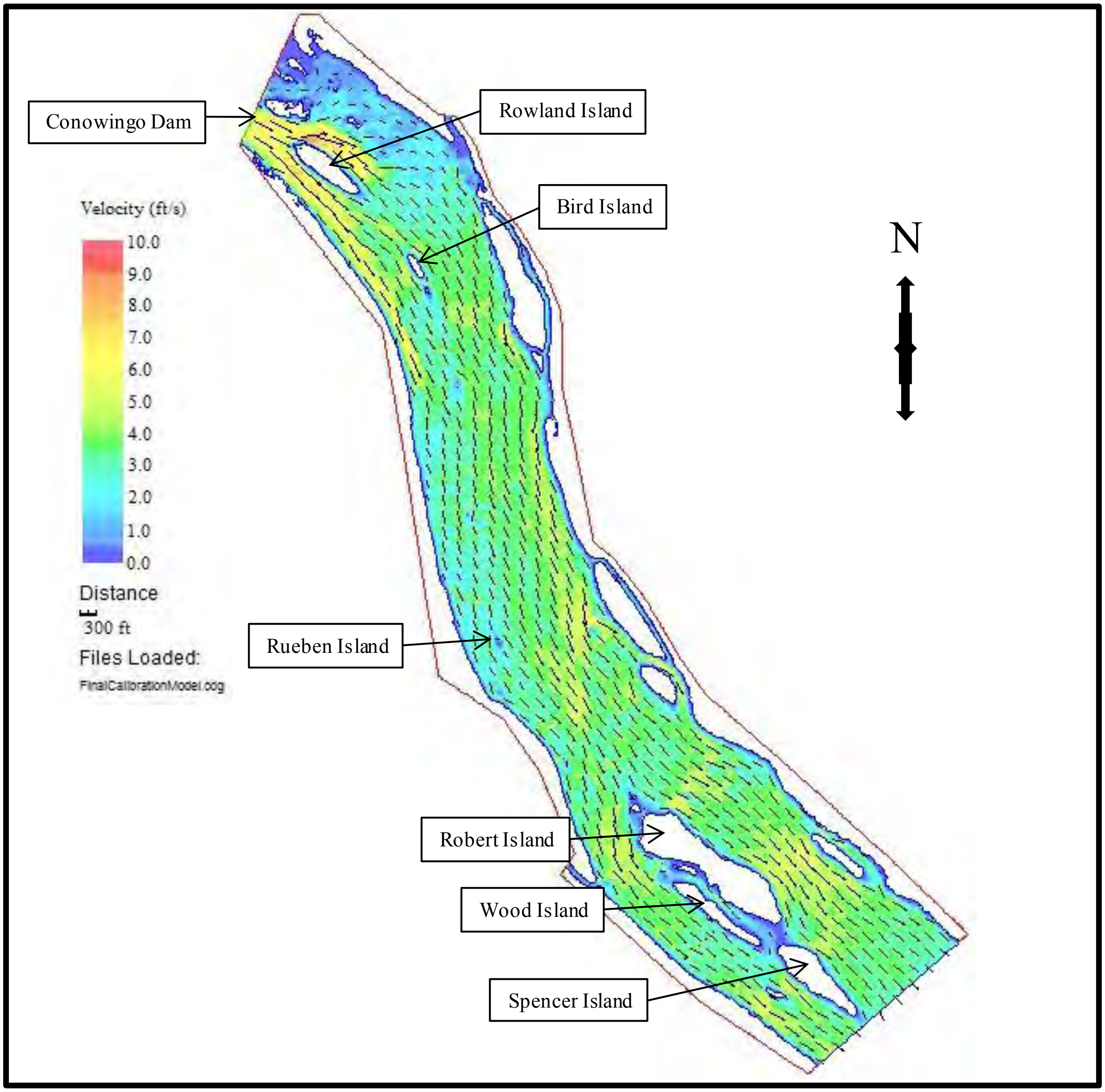


FIGURE 4.2-12: WATER VELOCITY IN THE SUSQUEHANNA RIVER IN THE VICINITY OF ROWLAND ISLAND AND BIRD ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 86,000 CFS DISCHARGE FROM CONOWINGO DAM.

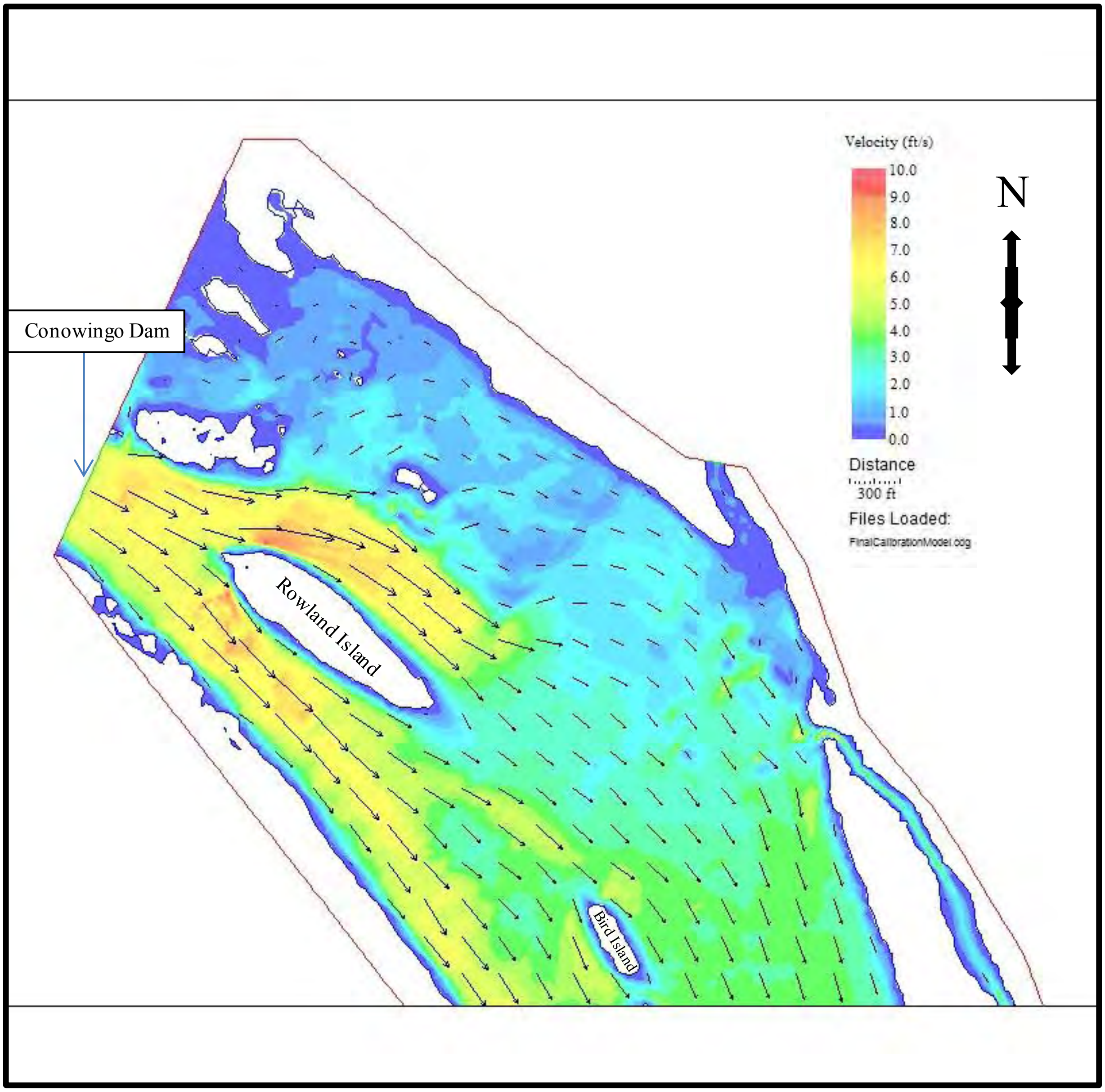


FIGURE 4.2-13: WATER VELOCITY IN THE SUSQUEHANNA RIVER IN THE VICINITY OF BIRD ISLAND AND REUBEN ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 86,000 CFS DISCHARGE FROM CONOWINGO DAM.

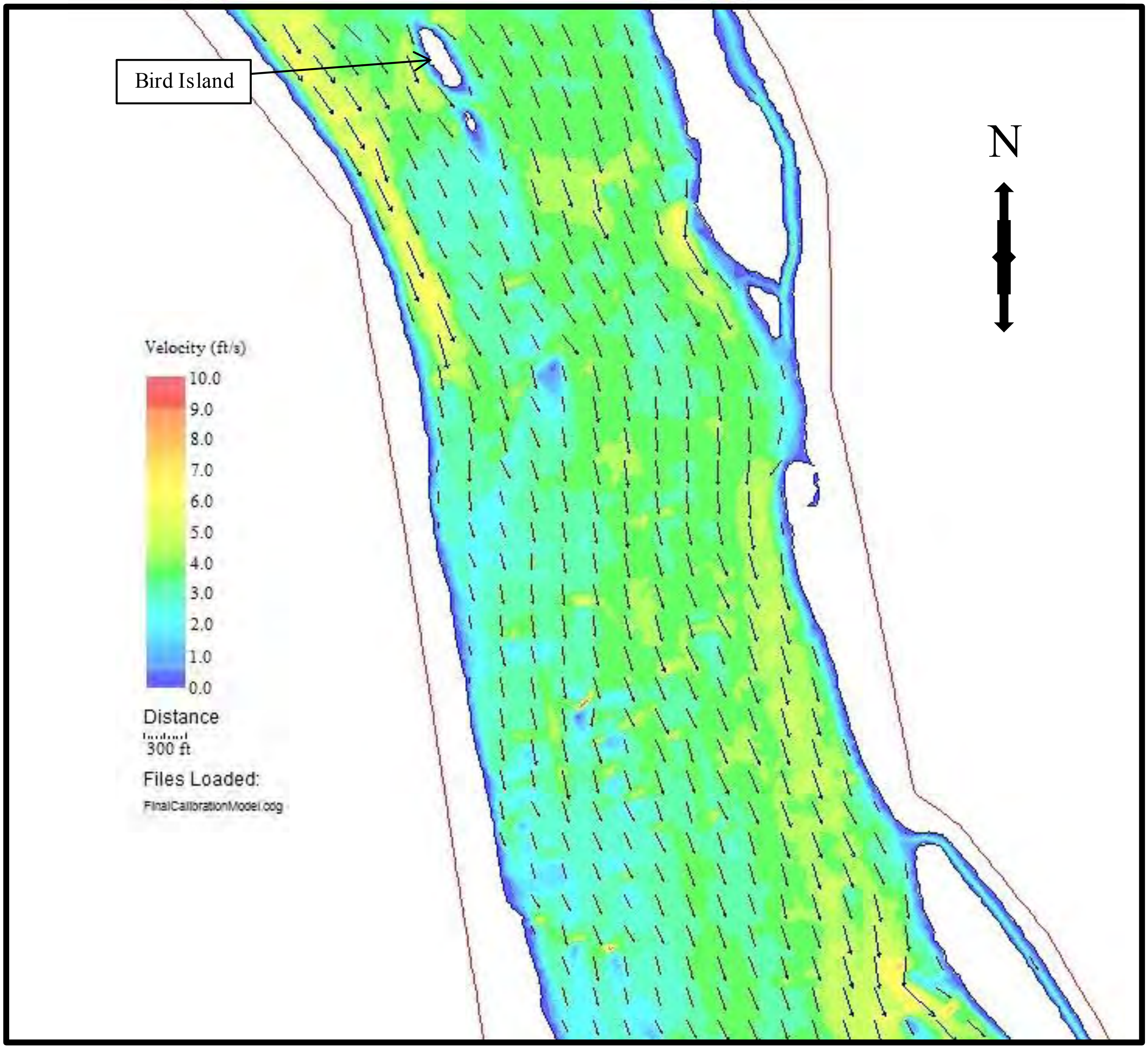


FIGURE 4.2-14: WATER VELOCITY IN THE SUSQUEHANNA RIVER IN THE VICINITY OF REUBEN ISLAND AND ROBERT ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 86,000 CFS DISCHARGE FROM CONOWINGO DAM.

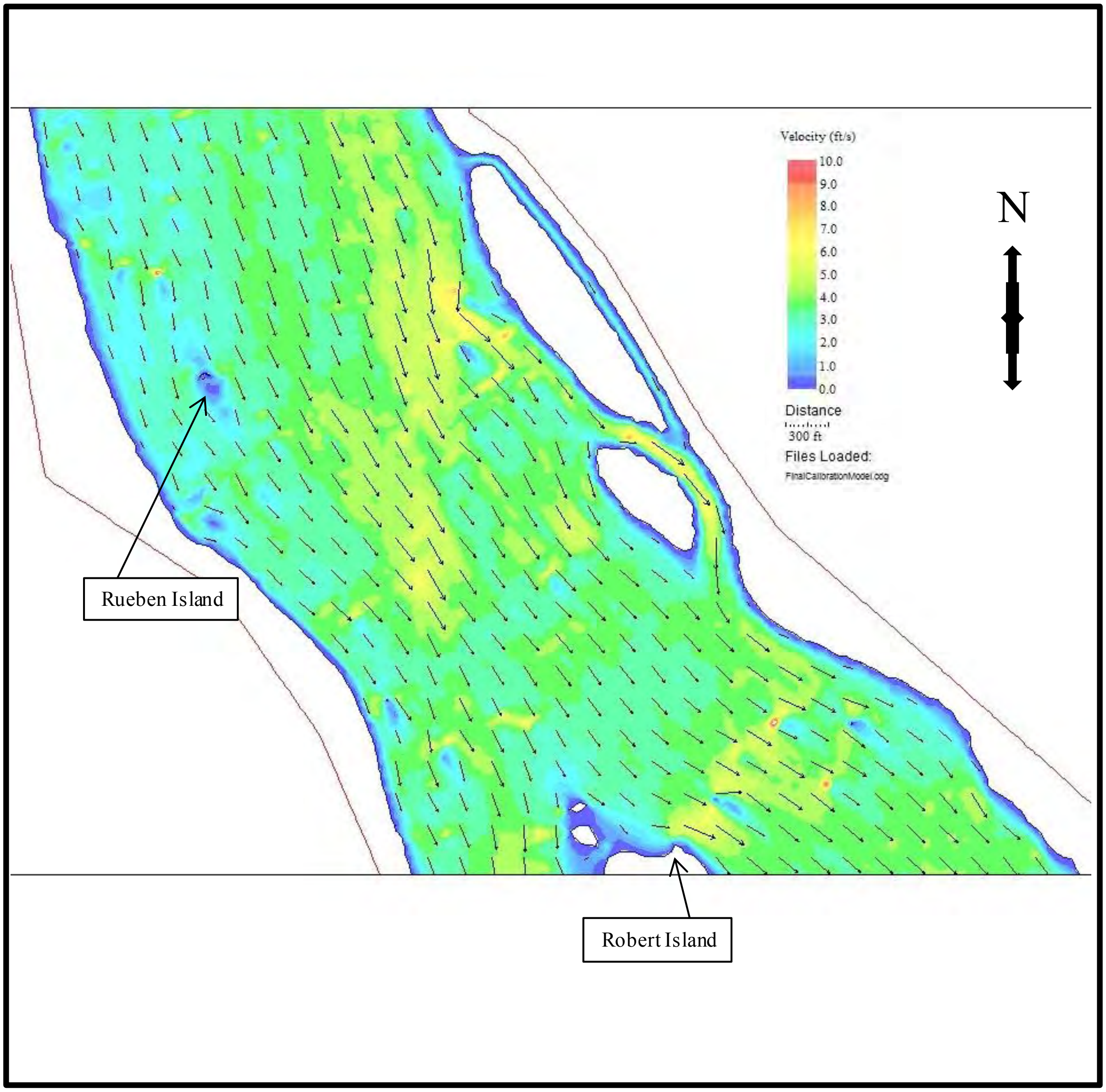
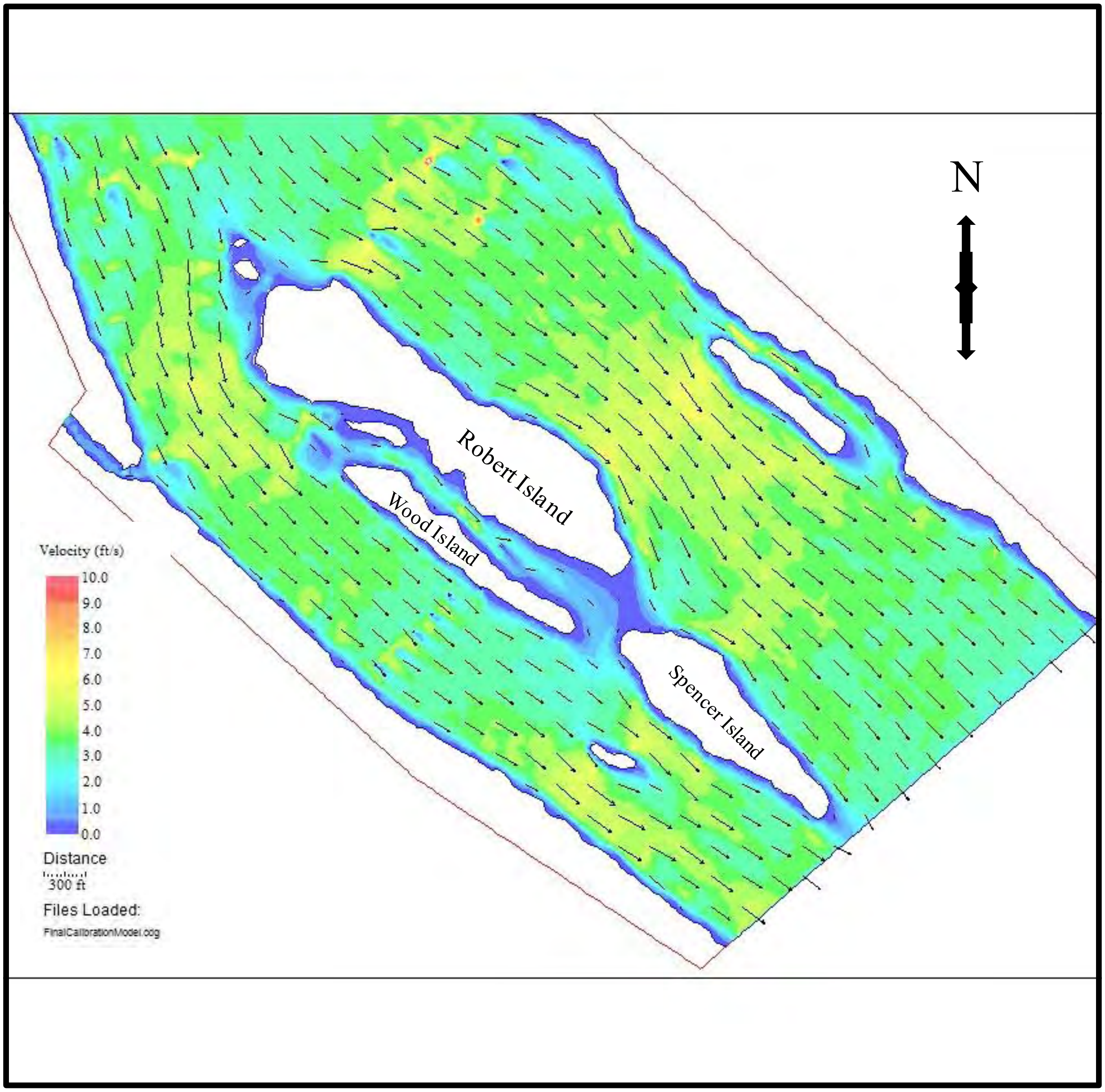


FIGURE 4.2-15 WATER VELOCITY IN THE SUSQUEHANNA RIVER IN THE VICINITY OF SPENCER ISLAND AND ROBERT ISLAND AS DETERMINED BY RIVER 2D MODEL FOR 86,000 CFS DISCHARGE FROM CONOWINGO DAM.



APPENDIX A-ADDITIONAL RADIO TAGGING DATA

APPENDIX A: LISTING BY INDIVIDUAL RADIO TAGGED AMERICAN SHAD WHICH MADE A SUBSTANTIAL UPSTREAM MIGRATION DURING SPRING 2010. DATA INCLUDE ONLY THOSE TRIPS WHICH TOOK LESS THAN 72 HR. TWO ADDITIONAL FISH AND FIVE ADDITIONAL TRIPS WERE MORE THAN 72 HR THUS NOT INCLUDED.

			General	General			Travel		Average[1] Speed		Conowingo Discharge		
Fish	**Date**	**Time**	**Downstream Location**	**Upstream Location**	**Date**	**Time**	**Distance (mi)**	**Time (hr)**	**mi/hr**	**ft/sec**	**Start**	**Average**	**End**
21-100	4/27	18:18	Spencer Island	Rowland Island	4/28	4:05	3.9	9.78	0.40	0.59	60034	30521	12977
21-100	5/2	12:31	Lapidum	Rowland Island	5/3	0:43	4.4	12.20	0.36	0.53	35387	63913	13113
21-101	5/6	19:24	Spencer Island	Rowland Island	5/7	5:35	3.9	10.17	0.38	0.56	82085	24824	8904
21-102	5/5	13:18	Lapidum	Tailrace	5/6	2:13	4.9	12.92	0.38	0.55	66539	53861	9008
21-105	4/27	11:35	Spencer Island	Rowland Island	4/27	16:22	3.9	4.78	0.82	1.20	27216	23637	55140
21-105	4/29	18:20	Spencer Island	Off Shures Landing	4/30	13:30	3.8	19.17	0.20	0.29	65512	42961	66539
21-105	5/4	10:24	Lapidum	Rowland Island	5/4	18:04	4.4	7.67	0.58	0.85	26911	64209	74166
21-105	5/5	6:21	Lapidum	Rowland Island	5/5	10:59	4.4	4.63	0.95	1.40	9165	9433	9702
21-109	4/22	18:57	Tomes Landing	Rowland Island	4/22	21:47	4.7	2.83	1.67	2.45	58748	58748	58748
21-109	4/30	17:37	Spencer Island	Rowland Island	5/1	10:27	3.9	16.83	0.23	0.34	66367	31364	35149
21-110	4/22	21:16	Spencer Island	Rowland Island	4/23	6:55	3.9	9.65	0.40	0.59	58748	18270	13456
21-110	4/26	2:11	Spencer Island	Rowland Island	4/28	6:53	3.9	52.70	0.07	0.11	13045	26710	12977
21-111	5/5	4:30	Lapidum	Rowland Island	5/5	19:34	4.4	15.07	0.29	0.43	9165	40718	65683
21-111	5/7	14:32	Spencer Island	Rowland Island	5/7	17:58	3.9	3.42	1.14	1.68	60846	61135	60034
21-111	5/9	11:28	Spencer Island	Rowland Island	5/9	16:23	3.9	4.92	0.79	1.17	44560	45496	45655
21-111	5/10	8:34	Spencer Island	Rowland Island	5/10	12:25	3.9	3.85	1.01	1.49	33629	29503	26911
21-111	5/14	9:05	Spencer Island	Tailrace	5/14	14:17	4.6	5.20	0.88	1.29	79203	59715	79394
21-111	5/17	6:00	Lapidum	Tailrace	5/17	12:42	4.9	6.70	0.73	1.07	45380	54800	72530
21-111	5/19	12:49	Spencer Island	Tailrace	5/19	18:11	4.3	5.36	0.80	1.18	26306	52733	57163
21-112	4/26	9:38	Lapidum	Rowland Island	4/26	23:06	4.4	13.46	0.33	0.48	35864	32660	13456
21-112	5/1	18:32	Lapidum	Rowland Island	5/2	5:28	4.4	10.93	0.40	0.59	73983	34891	9008
21-112	5/4	13:57	Lapidum	Rowland Island	5/4	18:50	4.4	4.88	0.91	1.33	74716	74319	74166
21-113	4/27	11:31	Spencer Island	Rowland Island	4/27	17:32	4.0	6.01	0.66	0.97	27216	27027	60521

			General	General			Travel		Average[1] Speed		Conowingo Discharge		
Fish	Date	Time	Downstream Location	Upstream Location	Date	Time	Distance (mi)	Time (hr)	mi/hr	ft/sec	Start	Average	End
21-113	5/4	2:20	Lapidum	Rowland Island	5/4	11:50	4.4	9.49	0.47	0.68	39692	19806	31256
21-113	5/11	21:46	Spencer Island	Rowland Island	5/12	3:28	3.9	5.69	0.69	1.01	45518	16643	9060
21-114	5/7	18:13	Spencer Island	Rowland Island	5/8	3:38	3.9	9.41	0.42	0.61	59872	25100	8678
21-115	5/12	5:39	Lapidum	Rowland Island	5/12	17:38	4.4	11.99	0.37	0.54	44969	30864	21400
21-116	5/5	5:28	Lapidum	Tailrace	5/5	10:52	4.9	5.41	0.90	1.32	9165	9388	9702
21-117	4/28	20:39	Tomes Landing	Rowland Island	5/1	3:15	4.7	54.60	0.09	0.13	35864	38339	9008
21-118	5/5	6:21	Lapidum	Rowland Island	5/5	17:25	4.4	11.06	0.40	0.59	9165	41844	65512
21-118	5/7	20:33	Lapidum	Tailrace	5/10	16:56	4.9	68.38	0.07	0.10	59389	21875	13249
21-120	5/1	13:12	Lapidum	Rowland Island	5/1	17:32	4.4	4.33	1.02	1.50	73618	74166	74349
21-121	5/2	10:45	Lapidum	Rowland Island	5/3	5:58	4.4	19.21	0.23	0.34	33399	47219	8852
21-122	5/4	17:47	Lapidum	Rowland Island	5/5	4:06	4.4	10.32	0.43	0.63	73983	41833	9165
21-123	5/7	13:13	Spencer Island	Tailrace	5/7	16:30	4.3	3.27	1.32	1.94	35149	54914	61829
21-123	5/14	5:47	Lapidum	Rowland Island	5/14	16:38	4.4	10.84	0.41	0.60	73618	71068	78823
21-123	5/15	1:04	Spencer Island	Rowland Island	5/15	3:55	3.9	2.84	1.37	2.02	9325	9325	9325
21-123	5/20	9:22	Spencer Island	Tailrace	5/20	12:19	4.3	2.95	1.46	2.15	34795	34677	34795
21-123	5/22	2:58	Lapidum	Rowland Island	5/22	14:20	4.4	11.36	0.39	0.57	8852	18689	45793
21-124	4/30	11:59	Spencer Island	Rowland Island	4/30	22:42	3.9	10.72	0.36	0.54	48463	60848	19416
21-124	5/5	8:19	Tomes Landing	Rowland Island	5/7	23:06	4.7	62.77	0.08	0.11	9486	36641	8852
21-127	4/26	15:08	Spencer Island	Rowland Island	4/27	7:49	3.9	16.67	0.23	0.34	35864	22449	13456
21-127	4/30	9:09	Spencer Island	Rowland Island	5/2	6:24	3.9	45.26	0.09	0.13	48320	41533	9008
21-127	5/3	9:05	Lapidum	Rowland Island	5/3	17:22	4.4	8.30	0.53	0.78	9271	46626	65512
21-130	5/4	14:08	Lapidum	Rowland Island	5/4	18:33	4.4	4.41	1.00	1.47	74532	74239	74166
21-130	5/9	12:51	Spencer Island	Rowland Island	5/9	17:06	3.9	4.25	0.92	1.35	45655	45610	45243
21-132	4/26	11:25	Spencer Island	Rowland Island	4/28	9:46	3.9	46.34	0.08	0.12	35744	25891	26107
21-132	5/7	8:52	Spencer Island	Rowland Island	5/7	13:06	3.9	4.22	0.93	1.36	33169	34603	35149
21-132	5/12	13:17	Lapidum	Tailrace	5/12	14:29	4.9	1.20	4.04	5.94	20960	20960	20960
21-133	4/26	5:48	Spencer Island	Tailrace	4/28	9:38	4.3	51.82	0.08	0.12	34209	26964	26107

			General	General			Travel		Average[1] Speed		Conowingo Discharge		
Fish	Date	Time	Downstream Location	Upstream Location	Date	Time	Distance (mi)	Time (hr)	mi/hr	ft/sec	Start	Average	End
21-135	5/1	14:34	Lapidum	Rowland Island	5/2	6:10	4.4	15.60	0.28	0.42	74716	42642	9008
21-135	5/3	4:26	Lapidum	Rowland Island	5/4	17:03	4.4	36.62	0.12	0.18	8852	45920	73983
21-141	5/14	5:16	Lapidum	Rowland Island	5/14	13:27	4.0	8.18	0.49	0.72	73618	67071	78823
21-143	5/18	16:36	Spencer Island	Tailrace	5/18	20:55	4.3	4.31	1.00	1.47	77879	77841	77879
21-143	5/22	1:30	Tomes Landing	Rowland Island	5/23	22:24	4.7	44.89	0.11	0.15	8904	23557	9812
21-147	5/14	7:15	Spencer Island	Tailrace	5/14	14:46	4.4	7.51	0.58	0.86	78634	63447	79394
21-147	5/15	11:26	Spencer Island	Rowland Island	5/15	15:36	3.9	4.16	0.94	1.38	45655	58393	76567
21-147	5/21	10:05	Spencer Island	Tailrace	5/21	16:22	4.3	6.29	0.69	1.01	34913	55066	82085
21-149	5/14	8:35	Spencer Island	Tailrace	5/14	12:46	4.3	4.19	1.03	1.51	79013	61175	34795
21-149	5/16	17:09	Spencer Island	Rowland Island	5/16	20:28	3.9	3.32	1.18	1.73	78256	78824	79013
21-158	5/19	13:40	Spencer Island	Tailrace	5/20	6:16	4.3	16.60	0.26	0.38	56536	33089	23780
21-159	5/20	12:31	Spencer Island	Rowland Island	5/21	0:26	3.9	11.92	0.33	0.48	34795	38506	9378
21-159	5/23	12:45	Lapidum	Rowland Island	5/24	13:04	4.4	24.31	0.18	0.27	34677	22955	59872
21-159	5/27	17:21	Tomes Landing	Rowland Island	5/28	5:44	4.7	12.39	0.38	0.56	79013	32742	8904
21-160	5/23	3:29	Lapidum	Tailrace	5/23	10:55	4.9	7.43	0.65	0.96	9113	12399	33514
21-169	5/19	11:20	Spencer Island	Rowland Island	5/20	0:01	3.9	12.68	0.31	0.45	26206	38674	9060
21-169	5/21	13:51	Tomes Landing	Rowland Island	5/21	17:47	4.7	3.93	1.20	1.77	35744	72431	81311
21-170	5/12	3:37	Lapidum	Rowland Island	5/12	13:40	4.4	10.06	0.44	0.64	9060	30440	20960
21-171	5/23	12:11	Lapidum	Tailrace	5/23	17:06	4.9	4.92	0.99	1.45	34677	34659	34093
54-137	5/15	14:42	Spencer Island	Tailrace	5/15	18:20	4.3	3.63	1.19	1.75	76195	76796	79013
54-137	5/16	8:33	Tomes Landing	Tailrace	5/16	14:54	5.2	6.35	0.81	1.19	46767	46607	46627
54-137	5/17	6:41	Spencer Island	Tailrace	5/17	11:56	4.3	5.25	0.82	1.21	45380	51845	72169
54-137	5/20	10:27	Lapidum	Tailrace	5/20	14:39	4.9	4.21	1.15	1.70	34560	46920	65853
54-140	5/18	11:21	Tomes Landing	Tailrace	5/19	4:12	5.2	16.84	0.31	0.45	9702	47848	9113
54-141	5/11	9:43	Spencer Island	Rowland Island	5/11	13:12	3.9	3.48	1.12	1.65	35149	18009	13387
54-141	5/15	0:29	Spencer Island	Tailrace	5/15	5:42	4.3	5.22	0.83	1.21	9486	9343	9271
54-142	5/9	14:51	Spencer Island	Rowland Island	5/9	18:32	3.9	3.69	1.06	1.56	45655	45490	45243

Fish	Date	Time	General Downstream Location	General Upstream Location	Date	Time	Travel Distance (mi)	Travel Time (hr)	Average[1] Speed mi/hr	Average[1] Speed ft/sec	Conowingo Discharge Start	Conowingo Discharge Average	Conowingo Discharge End
54-142	5/13	9:26	Spencer Island	Tailrace	5/13	16:24	4.3	6.98	0.62	0.91	9486	9594	9702
54-142	5/15	16:06	Spencer Island	Tailrace	5/15	21:47	4.3	5.70	0.76	1.11	76195	67341	46348
54-142	5/18	14:03	Spencer Island	Tailrace	5/18	19:12	4.3	5.16	0.84	1.23	78067	77942	78067
54-144	5/13	19:47	Near Robert Island	Rowland Island	5/14	0:41	2.9	4.91	0.59	0.87	63488	29025	9325
54-149	5/22	16:33	Lapidum	Tailrace	5/25	15:48	4.9	71.24	0.07	0.10	45380	27696	60521
54-151	5/12	4:27	Lapidum	Rowland Island	5/12	14:16	4.4	9.81	0.45	0.66	9008	31522	20960
54-156	5/26	1:37	Lapidum	Tailrace	5/26	18:17	4.9	16.66	0.29	0.43	9486	35845	78256
54-156	5/29	7:27	Lapidum	Tailrace	5/29	12:51	4.9	5.39	0.90	1.32	9008	9228	9325
54-159	5/18	12:38	Spencer Island	Tailrace	5/18	19:23	4.3	6.74	0.64	0.94	10370	69000	78067
54-160	5/14	2:47	Spencer Island	Tailrace	5/14	9:02	4.3	6.24	0.69	1.02	9271	52098	79203
54-173	5/14	10:24	Spencer Island	Tailrace	5/14	14:46	4.3	4.36	0.99	1.45	78067	61175	79394
54-176	5/3	22:14	Lapidum	Rowland Island	5/4	5:19	4.4	7.08	0.62	0.92	82085	49532	9271
54-176	5/5	8:40	Lapidum	Rowland Island	5/5	16:07	4.4	7.44	0.59	0.87	9486	46471	65853
54-176	5/6	1:26	Lapidum	Tailrace	5/6	6:12	4.9	4.77	1.02	1.50	9218	8982	8904
54-176	5/8	5:18	Spencer Island	Rowland Island	5/8	9:28	3.9	4.16	0.94	1.38	8618	9120	9378
54-176	5/9	13:22	Spencer Island	Rowland Island	5/9	17:03	3.9	3.68	1.06	1.56	45793	45600	45243
54-176	5/12	19:19	Spencer Island	Rowland Island	5/12	22:14	3.9	2.93	1.33	1.96	80733	80733	80541
54-176	5/15	6:27	Spencer Island	Tailrace	5/15	11:01	4.3	4.56	0.95	1.39	43345	45247	45655
54-176	5/19	21:37	Lapidum	Tailrace	5/20	6:27	4.9	8.84	0.55	0.81	10946	9280	9060
54-178	5/5	6:06	Lapidum	Rowland Island	5/5	16:20	4.4	10.25	0.43	0.63	9165	39693	65853
54-178	5/7	14:55	Spencer Island	Rowland Island	5/8	5:50	3.9	14.92	0.26	0.38	60846	32048	8618
54-179	5/14	5:40	Lapidum	Rowland Island	5/14	10:09	4.4	4.49	0.98	1.44	73618	77830	78067
54-183	5/19	22:45	Lapidum	Rowland Island	5/20	2:21	4.4	3.59	1.23	1.81	9325	9124	9060
54-186	5/13	1:05	Spencer Island	Rowland Island	5/13	4:00	3.9	2.91	1.34	1.98	43479	18248	9378
54-186	5/16	7:22	Spencer Island	Tailrace	5/16	12:52	4.3	5.51	0.78	1.15	46487	46580	46627
54-186	5/18	3:11	Spencer Island	Tailrace	5/18	7:33	4.3	4.36	0.99	1.45	10829	9594	9271
54-186	5/24	0:07	Lapidum	Tailrace	5/24	6:13	4.9	6.10	0.80	1.17	9113	9113	9113

			General	General			Travel		Average[1] Speed		Conowingo Discharge		
Fish	**Date**	**Time**	**Downstream Location**	**Upstream Location**	**Date**	**Time**	**Distance (mi)**	**Time (hr)**	**mi/hr**	**ft/sec**	**Start**	**Average**	**End**
54-191	5/8	13:45	Spencer Island	Rowland Island	5/8	16:04	3.9	2.31	1.69	2.48	36345	36075	35744
54-192	5/2	12:21	Tomes Landing	Rowland Island	5/3	11:43	4.7	23.36	0.20	0.30	35387	38810	10541
54-193	4/27	8:57	Lapidum	Tailrace	4/28	13:56	4.9	28.99	0.17	0.25	13735	27917	36466
54-194	4/23	20:05	Spencer Island	Tailrace	4/24	0:30	4.3	4.42	0.98	1.43	35984	23029	13735
54-194	4/30	11:12	Spencer Island	Tailrace	4/30	16:39	4.2	5.45	0.77	1.14	48463	63399	66539
54-196	4/25	17:43	Spencer Island	Rowland Island	4/25	21:23	3.9	3.66	1.07	1.57	26206	25463	22389
54-196	5/4	9:47	Lapidum	Rowland Island	5/4	13:56	4.4	4.16	1.06	1.56	26809	46698	74716
54-197	4/29	16:43	Spencer Island	Rowland Island	4/30	17:12	4.0	24.47	0.16	0.24	65342	48996	66367
54-198	5/3	12:45	Tomes Landing	Rowland Island	5/3	17:10	4.7	4.41	1.07	1.57	62822	65092	65512
54-198	5/6	16:33	Spencer Island	Rowland Island	5/6	23:15	3.9	6.71	0.58	0.86	81504	58072	9113
54-199	5/5	16:16	Lapidum	Tailrace	5/6	0:53	4.9	8.61	0.56	0.83	65853	59636	11600
54-200	5/17	16:50	Spencer Island	Tailrace	5/18	6:12	4.3	13.38	0.32	0.47	71809	44854	9218
54-200	5/26	11:17	Lapidum	Tailrace	5/26	17:39	4.9	6.37	0.76	1.12	34209	60308	78256
54-200a	4/26	9:02	Spencer Island	Rowland Island	4/26	16:43	3.9	7.69	0.51	0.75	35864	35700	35268
54-200a	5/1	12:38	Tomes Landing	Rowland Island	5/1	16:46	4.7	4.14	1.14	1.68	35387	66374	73983
54-202	5/1	12:40	Tomes Landing	Rowland Island	5/1	20:10	4.7	7.51	0.63	0.93	35387	69756	73800
54-203	4/26	21:27	Spencer Island	Rowland Island	4/27	3:34	3.9	6.11	0.64	0.94	35268	16656	13249
54-204	5/2	8:32	Lapidum	Rowland Island	5/2	20:50	4.4	12.30	0.36	0.53	9325	52457	74532
54-207	5/3	10:35	Spencer Island	Rowland Island	5/4	7:04	3.6	20.49	0.18	0.26	9271	51595	9378
54-208	5/3	20:54	Lapidum	Rowland Island	5/4	13:21	4.4	16.45	0.27	0.39	81891	46562	74716
54-208	5/5	6:00	Lapidum	Tailrace	5/5	19:49	4.9	13.82	0.35	0.52	9165	45226	65683
54-208	5/11	22:51	Lapidum	Rowland Island	5/12	14:33	4.4	15.69	0.28	0.41	16010	24572	20960
54-209	5/12	13:20	Spencer Island	Rowland Island	5/12	17:31	3.9	4.17	0.94	1.38	20960	21083	21400
54-209	5/15	11:07	Spencer Island	Tailrace	5/15	15:29	4.3	4.36	0.99	1.45	45655	58393	76567
54-210	5/12	6:29	Spencer Island	Tailrace	5/12	10:22	4.3	3.89	1.11	1.63	46627	41785	21578
54-211	5/19	22:43	Lapidum	Near Bird Island	5/20	14:40	3.8	15.95	0.24	0.35	9325	23149	65853