# SUMMARY OF OPERATIONS AT THE HOLTWOOD DAM FISH PASSAGE FACILITY SPRING 2011

January 2012

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## EXECUTIVE SUMMARY

High river flow events in March and April, 2011 delayed the start of fish lift operations at the Conowingo East fish lift (EFL) until 25 April, 2011. The passage of over one-thousand American shad at the Conowingo EFL on 11 May would have normally triggered the start of fish lift operations at Holtwood. However, the high river flows deposited large amounts of rock debris in the tailrace hopper pit and crowder channel that had to be removed prior to the commencement of Holtwood lift operations. Fishway operations at Holtwood Dam began on 20 May, 2011. The tailrace lift was operated on 9 days while the spillway lift operated on 3 days. Lift operations were terminated for the season, with agency concurrence, on 5 June. During late May, fish lift operations were suspended for six days due to high river flows and a tailrace hopper mechanical problem. The 2011 fish passage season marks the fifteenth year of operation at Holtwood.

The lifts passed 5,052 fish of 15 taxa. Gizzard shad (4,535), channel catfish (229), and walleye (122), dominated the catch, and comprised nearly 97% of the total fish collected and passed. American shad represented the sole *Alosa* species collected and passed at Holtwood in 2011.

A total of 18 American shad (nearly 86% of total shad catch) was passed in the tailrace lift while the spillway lift accounted for 3 American shad (14% of total shad catch). The highest daily shad catch occurred on 25 May when 5 shad moved upstream during 9.4 hours of operation. On a daily basis, American shad passed through the fishway between 0900 hrs and 1659 hrs with 71% (15 of 21 shad) passed between 1100 and 1659 hrs.

Fishway operations were conducted at water temperatures ranging from 62.7°F to 74.6°F and river flows between 139,700 and 41,800 cfs. Spillage occurred on all 10 days of operation. River water temperatures were within the observed historic range, but river flows were uncommonly high throughout the passage season, (Figure 1).

For most of the season, water clarity was poor, making it difficult to identify American shad with attached Maryland DNR floy tags if they passed by the viewing window. The number of floy tags observed at Holtwood in 2011 was 0.

The 2011 American shad passage rate at Holtwood versus Conowingo (0.10% of fish passing Conowingo passed Holtwood) was below the historical average of 33.2% (1997-2010).

A low, stable, river flow appears to be critical for enhancing American shad passage rates. In 2010, we documented 95% of American shad passed at river flows less than 40,000 cfs, with 5% passing at river flows greater than 40,000 cfs but less than 60,000 cfs. In 2011, only the last two days of the season (4 and 5 June) occurred at river flows less than 60,000 cfs but above 40,000 cfs with no shad passage. The fifteen day period from 20 May through 3 June occurred at river flows greater than 60,000 cfs and all 21 American shad were passed during this time. It should be noted that in 2011, unfavorably high river flows did not allow flashboard repairs to be completed prior to or during the fish passage season. Future operations of the fishway will build on the past fifteen years of operation experience.

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# 1.0 INTRODUCTION

On 1 June 1993 representatives of PPL, two other upstream utilities, various state and federal resource agencies, and two sportsmen clubs signed the 1993 Susquehanna River Fish Passage Settlement Agreement. This agreement committed the Holtwood Hydroelectric Project (Holtwood) and the two other upstream hydroelectric projects to provide migratory fish passage at their facilities by the spring of 2000. A major element of this agreement was for PPL, the owner/operator of Holtwood, to construct and place a fishway into operation by 1 April 1997. PPL started construction on the fishway in April 1995, and met the spring 1997 operational target. The upstream passage facility consisting of a tailrace and spillway lift successfully operated during spring 1997 through spring 2011. This year marked the fifteenth operational season.

Objectives of 2011 upstream fishway operation were (1) monitor and maximize passage of migratory and resident fishes through the fishway; and (2) minimize interruptions to fish passage operations due to equipment breakdowns or malfunctions.

# 2.0 HOLTWOOD OPERATION

## 2.1 Project Operation

Holtwood, built in 1910, is situated on the Susquehanna River (river mile 24) in Lancaster and York counties, Pennsylvania (see figure in Normandeau Associates, Inc. 1998). It is the second upstream hydroelectric facility on the river. The project consists of a concrete gravity overflow dam 2,392 ft long by 55 ft high, a powerhouse with ten turbine units having a combined generating capacity of 107 MW, and a reservoir (Lake Aldred) of 2,400 acres surface area. Each unit is capable of passing approximately 3,000 cfs. Spills occur at the project when river flow or project inflow exceeds the station hydraulic capacity of approximately 31,500 cfs.

Hydraulic conditions in the spillway at the project are controlled by numerous factors that change hourly, daily and throughout the fishway operating season. The primary factors are river flows, operation of the power station, installation and integrity of the flash boards, and operation of the Safe Harbor Hydroelectric Station.

In spring 2011, all rubber dams were inoperable (not inflated) due to irreparable damage that occurred in previous years and current redevelopment activities. Wooden flashboards have been installed in place of these rubber dam sections. However, in March and April 2011, the flashboards were severely damaged due to several high flow events and repairs could not be conducted until after cessation of fish lift operations because of consistent high river flows. Due to heavy accumulations of sediment and rock debris in the tailrace hopper pit and crowder channel deposited by the high river flows, fish lift operations at Holtwood did not begin immediately after the passage of one-thousand shad at Conowingo Dam on 11 May. Since river flows were greater than station capacity, spill occurred on all days of fish lift operation, (Table 2). In 2011, station capacity was limited to eight units (approximately 26,000 cfs) due to redevelopment activities. Passage operations ended on 5 June, with agency concurrence, due to high river flows, and extremely poor American shad passage.

## 2.2 Fishway Design and Operation

### 2.2.1 Fishway Design

The Holtwood fishway is sized to pass a design population of 2.7 million American shad and 10 million river herring. The design incorporates numerous criteria established by the USFWS and state resource agencies. Physical design parameters for the fishway are given in Normandeau Associates, Inc. (1998).

The fish passage facility at Holtwood is comprised of a tailrace and spillway lift (see figure in Normandeau Associates, Inc. 1998). The tailrace lift has two entrances (gates A and B) and the spillway lift has one entrance (gate C). Each lift has its own fish handling system that includes a mechanically operated crowder, picket screen(s), hopper, and hopper trough gate. Fishes captured in the lifts are sluiced into the trough through which the fish swim into Lake Aldred. Attraction flows, in, through, and from the lifts, are supplied via a piping system and five diffusers that are gravity fed from two trough intakes. Generally, water conveyance and attraction flow is controlled by regulating the three entrance gates and seven motor-operated valves. Fish that enter the tailrace and/or spillway entrances are attracted by water flow into the mechanically operated crowder chambers. Once inside, fish are crowded into the hoppers (6,700 gal capacity). Fish are then lifted in the hoppers and sluiced into the trough. Fish swim upstream through the trough past a counting facility and into the forebay through a 14 ft wide fish lift exit gate.

During fish lift operations in 2011flashboards were unable to be installed due to persistent, high river flows.

Design guidelines for fishway operation include four entrance combinations. These are: (1) entrance A, B, and C; (2) entrance A and B; (3) entrance A and C; and (4) Entrance C. Completion of the attraction water system after the 1997 season resulted in the drafting of operating protocols and guidelines that are flexible and utilize experience gained during previous years of fish lift operation. In 2011, the following gate combinations were utilized: Entrances B and C (2 days); Entrance C (1day); Entrance B (7 days). Entrance A was found to be inoperable during pre-season inspections and attempts to repair it could not be completed prior to the termination of lift operations in 2011. The spillway lift, (Entrance gate C), is used less frequently when river flows are greater than 40,000 cfs or flashboard sections are damaged/missing as spillage may mask or interfere with the attraction flow from the spillway entrance gate.

### 2.2.2 Fishway Operation

Daily operation of the Holtwood fishway was based on the American shad catch, and managed to maximize that catch. Constant oversight by PPL and Normandeau staff ensured that maintenance activities and mechanical or electrical problems were dealt with immediately to minimize fish lift operational interruptions. Pre-season equipment preparations began in March 2011, after a high river flow event that peaked at 423,000 cfs, and all equipment functioned properly. In April 2011, a 363,000 cfs river flow event occurred and additional equipment checks were performed. During these checks, it was discovered that large amounts of rock debris and sediment had been deposited in the tailrace hopper pit and crowder channel, which prohibited the startup of operations until it could be cleared out by a construction crew and dive team. The rock debris originated from the temporary access pads and roads placed as part of expansion project activities and the material was dislodged during the high river flow events.

This year, Holtwood operations did not start two days after the passage of one-thousand American shad at Conowingo Dam due to an extensive clean-up operation required to remove large amounts of sediment and rock debris in the tailrace hopper pit and crowder channel deposited by high river flow events. Fish lift operations began on 20 May. This year we recorded 10 days of operation. The tailrace lift was operated 9 days during this year's fish passage operation and encountered one major mechanical problem. On 20 May, as the tailrace hopper was being lowered after completing the fifth lift, the hopper jumped out of the guide channels and cocked. Maintenance personnel were dispatched to investigate the cause of the failure and make repairs. During further inspections, it became clear that a main hoist cable was damaged during this incident and had to be replaced. Tailrace fish lift operations resumed on 25 May and continued with one other notable mechanical problem. The festoon power cable which travels with the tailrace crowder had to be replaced after it jammed and

tore apart. The spillway lift was operated on 3 days this season and encountered no mechanical problems.

The 2011 American shad passage rate at Holtwood versus Conowingo (0.10% of fish passing Conowingo passed Holtwood) was below the historical average of 33.2% (1997-2010). Several high river flow events this spring significantly hampered American shad passage at Holtwood and other fish passage facilities located on the Susquehanna River, (Table 6 and Figure 1). Operational hours varied throughout the season in an attempt to maximize the catch of American shad.

Operation of the Holtwood fishway followed methods established during the 1997 and 1998 spring fish migration seasons. A three person staff consisting of a lift operator, a supervising biologist, and biological technician manned the facility daily. A detailed description of the fishway's major components and their operation are found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998 and 1999).

### 2.3 Fish Counts

Fish passing the counting window are identified to species and counted by a biologist or biological technician. The counting area is located immediately downstream of the main attraction water supply area in the trough. As fish swim upstream and approach the counting area, they are directed by a series of fixed screens to swim up and through a 3 ft wide, 12 ft long channel on the west side of the trough. The channel is adjacent to a 4 ft by 10 ft window located in the counting room where fish are identified and counted. Passage from the fishway is controlled by two different gates. During the day, fish passage rates are controlled by the technician who opens/closes a set of gates downstream of the viewing window. At night fish are denied passage from the fishway by closing this gate. When necessary, flow is maintained through the exit channel to insure that adequate water quality exists for fish held overnight.

Fish passage data is handled by a single system that records and processes the data. The data (species and numbers passed) is recorded on a worksheet by the biologist or biological technician as fish pass the viewing window. At the end of each hour, fish passage data is entered into a Microsoft Excel spreadsheet and saved. Data processing and reporting is PC-based and accomplished by program scripts, or macros, created within Microsoft Excel spreadsheet software.

At day's end, the data is checked and verified by the biologist or biological technician. After data verification is completed, a daily summary of fish passage is produced and distributed to plant personnel. Each day's data is backed up to a diskette and stored off-site. Daily reports and weekly summaries of fish passage numbers are electronically distributed to members of the Holtwood FPTAC and other co-operators.

## 3.0 RESULTS

### 3.1 Relative Abundance

The diversity and abundance of fishes collected and passed in the Holtwood fishway during the spring 2011 operational period is presented in Table 1. A total of 5,052 fish of 15 taxa passed upstream into Lake Aldred. Gizzard shad (4,535), channel catfish (229), and walleye (122) comprised nearly 97% of the fishes passed. The 2011 American shad passage total was the lowest observed based on actual numbers of fish, and based on Conowingo results, this was the lowest passage percentage rate recorded in the fifteen years of fish lift operations at Holtwood, (Tables 1, 5, and 6). Other abundant fishes passed included carp (82), quillback (30) and American shad (21). The high passage day for all species combined occurred on 27 May, when 1,018 fish were passed, comprised mostly of gizzard shad (947), and channel catfish (21).

For most of the season, water clarity ranged from 5 to 15 inches of visibility, which made it difficult for viewing technicians to identify American shad with attached Maryland DNR floy tags. The number of floy tags observed at Holtwood in 2011 was 0.

### 3.2 American Shad Passage

A total of 21 American shad were passed at Holtwood during 2011; 18 American shad passed in the tailrace lift while the spillway lift accounted for 3 American shad (Table 4). The highest daily shad catch occurred on 25 May when 5 shad moved upstream during 9.4 hours of operation. On a daily basis, overall shad passage occurred through the fishway between 0900 hrs and 1659 hrs (Table 3). Fishway operations were conducted at water temperatures ranging from 62.7°F to 74.6°F and river flows between 41,800 cfs and 139,700 cfs, (as measured at Holtwood Dam), (Table 2). Spillage occurred on all ten days of operation. River water temperatures were within the observed historic range, but river flows were uncommonly high throughout the passage season.

The capture of shad at the fishway occurred over a relatively wide range of station operation and discharge conditions (Table 2). Shad were attracted to the tailrace lift at water elevations ranging from 115 ft. to 119 ft., (a tailrace elevation of 119 ft. occurred on 5 of the10 days of operation). Tailrace elevations correspond to unit operation, which varies from 0 to 10 units. In 2011, Units 1 and 2 remained offline due to redevelopment activities. During spring 2011, tailrace fishway operation generally coincided with an eight turbine operation/generation scenario. Spillway lift operation usually occurs during periods of no or minimal spillage, but high river flow events and mechanical difficulties led to limited use of the spillway lift during spill events. Simultaneous operation of both the spillway and tailrace fish lifts did not occur this year because the flashboards were not in place during the entire fish passage season.

Passage of shad into Lake Aldred occurred at Holtwood forebay elevations ranging from 167 ft to 170 ft (Table 2). Forebay elevations during passage operations ranged from 168 ft to 169.9 ft for approximately 40% of the 2011 season.

The hourly passage numbers of American shad at Holtwood are provided in Table 3. Nearly 71% (15 of 21 American shad) passed through the fishway between 1100hr and 1659hrs. American shad passage was low each day of operation, and no strong patterns relating to passage time were determined.

Each year, we attempt to qualitatively assess the relative number of shad using the tailrace and spillway lifts by viewing each hopper of fish and estimating the number of shad in each lift as they are sluiced into the trough. The spillway lift was operated on three days in an effort to pass any shad attracted into the spillway area adjacent to the fishlift. We summarized this information by lift, and applied results to the daily shad passage count. We determined the number of shad captured by each lift and/or the percentage of daily passage that was attributable to each lift. Based on this assessment, 18 and 3 shad were captured in the tailrace and spillway lifts over the total operating period in 2011, respectively (Table 4).

### 3.3 Passage Evaluation

In spring 2011, our fishway evaluation efforts focused on maximizing the passage of American shad at both the tailrace and spillway lifts with minimal interruptions to passage operations due to equipment breakdowns or malfunctions.

We present a summary of American shad passage at three river flow ranges in Table 5. As stated in previous reports, low, stable river flows are more conducive to fish passage at Holtwood. In 2011, spill events occurred during all 10 days of fishway operation. In 2010, we documented 95% of American shad passed at river flows less than 40,000 cfs, with 5% passing at river flows greater than

40,000 cfs but less than 60,000 cfs. In 2011, only the last two days of the season, (June 4 and 5), occurred at river flows less than 60,000 cfs but above 40,000 cfs with no shad passage. Fifteen days during the season (May 20-June 3) occurred at river flows greater than 60,000 cfs and passage of all 21 shad occurred during this time (Table 5 and Figure 2). During fish lift operations in 2011, river flows ranged from 41,800 cfs to139,700 cfs. The 2011 American shad passage rate at Holtwood versus Conowingo (0.10% of American shad passed at Conowingo were passed by Holtwood), was below the historical average of 33.2% observed at Holtwood from 1997 to 2010. In 2011, unfavorably high river flows did not allow flashboard repairs to be conducted prior to or during the fish passage season, which inhibited efforts to maintain forebay water levels that provide an ample volume of water to feed the entire fish lift water supply system and allow for the simultaneous operation of the tailrace and spillway fish lifts.

We hope to optimize future fishway operations by utilizing knowledge gained through these fifteen years of operation. Debugging of the fishway occurred as needed throughout the season, and operation was modified based on conditions encountered on a daily basis. Fish survival in the fishways was excellent; we observed 0 shad mortalities during the 2011 American shad passage season.

## 4.0 RECOMMENDATIONS

1) Review the current maintenance program to identify additional equipment maintenance inspection and testing activities to reduce in-season disruptions to operation. Unusual conditions, (e.g. severe flood events) require a more thorough review of the impacts to the equipment.
2) Operate the fishway at Holtwood Dam under annual operational guidelines developed and approved by the HFPTAC. Fishway operation should adhere to these guidelines; however, personnel must retain the ability to make “on-the-spot” modifications to maximize fishway performance.
3) Continue, as a routine part of fishway operation, a maintenance program that includes periodic scheduled drawdowns and cleaning of the exit channel as necessary, nightly inspections of picket screens, and daily checks of hopper doors. Routine maintenance activities minimize disruption of fishway operation.
4) Implement protocols/guidelines to spill trash through gates 7 and 9. This should be done on an as needed basis prior to or after daily scheduled fishway operations.

## 5.0 LITERATURE CITED

Normandeau Associates, Inc. 1998. Summary of operation at the Holtwood Fish Passage Facility in 1997. Report prepared for PPL, Inc., Allentown, PA.

Normandeau Associates, Inc. 1999. Summary of the operation at the Holtwood Fish Passage Facility in 1998. Report prepared for PPL, Inc., Allentown, PA.

# TABLES AND FIGURES

**Table 1**

**Summary of the daily number of fish passed by the Holtwood fish passage facility in 2011.**

| ***Date:*** | *20 May* | *25 May* | *26 May* | *27 May* | *28 May* | *1 Jun* | *2 Jun* | *3 Jun* | *4 Jun* | *5 Jun* | *Total* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Hours of Operation - Tailrace:*** | *3.0* | *9.4* | *9.4* | *10.3* | *10.0* | *8.2* | *1.0* | *0.0* | *5.2* | *7.7* | *64.2* |
| ***Number of Lifts - Tailrace:*** | *5* | *14* | *16* | *17* | *16* | *13* | *1* | *0* | *8* | *11* | *101.0* |
| ***Hours of Operation - Spillway:*** | *0.0* | *0.0* | *0.0* | *0.0* | *0.0* | *0.0* | *7.1* | *8.8* | *3.2* | *0.0* | *19.1* |
| ***Number of Lifts - Spillway:*** | *0* | *0* | *0* | *0* | *0* | *0* | *10* | *10* | *5* | *0* | *25.0* |
| ***Water Temperature (°F):*** | *62.7* | *64.2* | *66.3* | *68.0* | *69.8* | *73.5* | *74.6* | *73.3* | *71.9* | *72.0* | |
| American shad | 0 | 5 | 3 | 4 | 4 | 1 | 1 | 3 | 0 | 0 | 21 |
| Gizzard shad | 30 | 402 | 760 | 947 | 398 | 184 | 312 | 790 | 576 | 136 | 4,535 |
| Brown trout | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Muskellunge | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Carp | 0 | 6 | 11 | 14 | 8 | 1 | 1 | 22 | 17 | 2 | 82 |
| Quillback | 0 | 0 | 8 | 13 | 5 | 0 | 2 | 0 | 2 | 0 | 30 |
| Shorthead redhorse | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Channel catfish | 4 | 5 | 5 | 21 | 36 | 13 | 43 | 63 | 27 | 12 | 229 |
| Flathead catfish | 0 | 0 | 0 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 5 |
| Rock bass | 0 | 1 | 1 | 1 | 3 | 0 | 0 | 1 | 1 | 0 | 8 |
| Green sunfish | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Bluegill | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 5 |
| Smallmouth bass | 0 | 0 | 1 | 4 | 0 | 0 | 1 | 2 | 0 | 0 | 8 |
| Largemouth bass | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Walleye | 0 | 3 | 16 | 10 | 10 | 0 | 3 | 38 | 40 | 2 | 122 |
| ***Total*** | ***36*** | ***423*** | ***805*** | ***1,018*** | ***465*** | ***203*** | ***363*** | ***921*** | ***666*** | ***152*** | **5,052** |

**Table 2**

**Summary of daily average river flow, water temperature, unit operation, fishway weir gate operation, and project water elevations during operation of the Holtwood fish passage facility in 2011.**

| | River Flow | Ave.Water | Secchi | Number | Weir Gate Operation | | | Elevation (ft) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | (cfs) | Temp. (°F) | (in) | of Units | A | B | C* | Tailrace | Spillway | Forebay |
| 20 May | 139,700 | 62.70 | 3 | 8* | | X | | 119.6 | Spill | 170.7 |
| 25 May | 95,700 | 64.20 | 5 | 8* | | X | | 119.7 | Spill | 171 |
| 26 May | 81,200 | 66.30 | 15 | 8* | | X | | 119.3 | Spill | 170.1 |
| 27 May | 79,500 | 68.00 | 22 | 8* | | X | | 118.7 | Spill | 169 |
| 28 May | 88,200 | 69.80 | 22 | 8* | | X | | 119.1 | Spill | 169.9 |
| 1 Jun | 85,500 | 73.50 | 5 | 8* | | X | | 119.3 | Spill | 170 |
| 2 Jun | 76,900 | 74.60 | 8 | 8* | | X | X | 115 | Spill | 169.3 |
| 3 Jun | 59,900 | 73.30 | 10 | 8* | | | X | 118.1 | Spill | 168.7 |
| 4 Jun | 49,900 | 71.90 | 15 | 8* | | X | X | 118 | Spill | 167 |
| 5 Jun | 41,800 | 72.00 | 15 | 8* | | X | | 118 | Spill | 167 |

*For 2011, Units 1 and 2 not operating due to redevelopment activities; Spillway entrance gate C damaged by flooding prior to 2005 season.

**Table 3**

**Hourly summary of American shad passage at the Holtwood fish passage facility in 2011.**

| ***Date:*** | *20 May* | *25 May* | *26 May* | *27 May* | *28 May* | *1 Jun* | *2 Jun* | *3 Jun* | *4 Jun* | *5 Jun* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Observation Time (Start):*** | *9:10* | *8:50* | *8:10* | *8:00* | *8:10* | *9:00* | *8:50* | *8:08* | *8:40* | *8:40* | |
| ***Observation Time (End):*** | *11:30* | *17:45* | *17:50* | *18:00* | *17:45* | *17:06* | *16:50* | *16:50* | *16:50* | *15:50* | ***Total*** |
| **Military Time (hrs)** | | | | | | | | | | | |
| 0700 to 0759 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0 |
| 0800 to 0859 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0 |
| 0900 to 0959 | -- | 2 | -- | -- | 1 | -- | -- | -- | -- | -- | 3 |
| 1000 to 1059 | -- | -- | -- | -- | 1 | 1 | 1 | -- | -- | -- | 3 |
| 1100 to 1159 | -- | -- | -- | 1 | -- | -- | -- | -- | -- | -- | 1 |
| 1200 to 1259 | -- | -- | -- | -- | 1 | -- | -- | -- | -- | -- | 1 |
| 1300 to 1359 | -- | -- | 1 | -- | -- | -- | -- | 1 | -- | -- | 2 |
| 1400 to 1459 | -- | -- | 1 | 1 | -- | -- | -- | -- | -- | -- | 2 |
| 1500 to 1559 | -- | 1 | 1 | 2 | -- | -- | -- | 1 | -- | -- | 5 |
| 1600 to 1659 | -- | 2 | -- | -- | 1 | -- | -- | 1 | -- | -- | 4 |
| 1700 to 1759 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0 |
| 1800 to 1859 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0 |
| 1900 to 1959 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0 |
| 2000 to 2059 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0 |
| **Total** | **0** | **5** | **3** | **4** | **4** | **1** | **1** | **3** | **0** | **0** | **21** |

**Table 4**

**Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood Power Station in 2011.**

| | Shad | Number Collected | | Percent Collected | |
|---|---|---|---|---|---|
| Date | Catch | Tailrace | Spillway | Tailrace | Spillway |
| 20-May | 0 | -- | -- | 0% | -- |
| 25-May | 5 | 5 | -- | 100% | -- |
| 26-May | 3 | 3 | -- | 100% | -- |
| 27-May | 4 | 4 | -- | 100% | -- |
| 28-May | 4 | 4 | -- | 100% | -- |
| 1-Jun | 1 | 1 | -- | 100% | -- |
| 2-Jun | 1 | 1 | -- | 100% | -- |
| 3-Jun | 3 | -- | 3 | -- | 100% |
| 4-Jun | 0 | -- | -- | 100% | -- |
| 5-Jun | 0 | -- | -- | 100% | -- |
| Total | 21 | 18 | 3 | 86% | 14% |

**Table 5**

**Holtwood fishway summary table evaluating American shad passage at three river flow ranges.**

| | 1997 | 1998* | 1999 | 2000* | 2001 | 2002* | 2003* | 2004* |
|---|---|---|---|---|---|---|---|---|
| Migration season start date | 18 Apr | 27 Apr | 25 Apr | 06 May | 27 Apr | 15 Apr | 28 Apr | 26 Apr |
| Migration season end date | 14 Jun | 12 Jun | 03 Jun | 14 Jun | 08 Jun | 07 Jun | 02 Jun | 03 Jun |
| Season duration (days) | 58 | 47 | 40 | 40 | 43 | 55 | 36 | 39 |
| Number of days of operation | 55 | 41 | 40 | 36 | 42 | 35 | 34 | 39 |
| Am. shad season total (Conowingo) | 90,971 | 39,904 | 69,712 | 153,546 | 193,574 | 108,001 | 125,135 | 109,360 |
| Am. shad season total (Holtwood) | 28,063 | 8,235 | 34,702 | 29,421 | 109,976 | 17,522 | 25,254 | 3,428 |
| **River flow ≤40,000 cfs** | | | | | | | | |
| Number of days | 48 | 22 | 34 | 19 | 40 | 19 | 15 | 2 |
| Percent of season | 87% | 54% | 85% | 53% | 95% | 54% | 44% | 5% |
| No. of Am. shad passed | 26,201 | 7,512 | 34,069 | 19,712 | 109,342 | 10,322 | 20,229 | 2 |
| Daily ave. of Am. shad passed | 546 | 341 | 1,002 | 1,037 | 2,733 | 543 | 1,348 | 1 |
| Percent of total passage | 93% | 91% | 98% | 67% | 99% | 59% | 80% | 0% |
| **River flow 40,001 to 60,000 cfs** | | | | | | | | |
| Number of days | 7 | 2 | 6 | 12 | 2 | 14 | 18 | 20 |
| Percent of season | 13% | 5% | 15% | 33% | 5% | 40% | 53% | 51.3% |
| No. of Am. shad passed | 1,862 | 230 | 633 | 9,536 | 634 | 7,029 | 5,019 | 1,943 |
| Daily ave. of Am. shad passed | 266 | 115 | 106 | 795 | 317 | 502 | 279 | 97 |
| Percent of Total Passage | 7% | 3% | 2% | 32% | 1% | 40% | 19.8% | 56.7% |
| **River flow >60,000 cfs** | | | | | | | | |
| Number of days | 0 | 17 | 0 | 5 | 0 | 2 | 1 | 17 |
| Percent of season | 0% | 41% | 0% | 14% | 0% | 6% | 3% | 43.6% |
| No. of Am. shad passed | 0 | 493 | 0 | 173 | 0 | 171 | 6 | 1,483 |
| Daily ave. of Am. shad passed | 0 | 29 | 0 | 35 | 0 | 86 | 6 | 87 |
| Percent of total passage | 0% | 6% | 0% | 1% | 0% | 1% | 0.02% | 43.3% |

* Denotes seasons of high river flow or frequent spillage.

**Table 5 (continued)**

**Holtwood fishway summary table evaluating American shad passage at three river flow ranges.**

| | 2005 | 2006 | 2007 | 2008* | 2009* | 2010 | 2011* |
|---|---|---|---|---|---|---|---|
| Migration season start date | 27 Apr | 11 Apr | 01 May | 21 Apr | 03 May | 21 Apr | 20 May |
| Migration season end date | 10 Jun | 06 Jun | 04 Jun | 09 Jun | 07 Jun | 09 Jun | 05 Jun |
| Season duration (days) | 45 | 57 | 35 | 50 | 36 | 50 | 17 |
| Number of days of operation | 36 | 57 | 35 | 49 | 36 | 48 | 10 |
| Am. shad season total (Conowingo) | 68,926 | 56,899 | 25,464 | 19,914 | 29,272 | 37,757 | 20,571 |
| Am. shad season total (Holtwood) | 34,189 | 35,968 | 10,338 | 2,795 | 10,896 | 16,472 | 21 |
| **River flow ≤40,000 cfs** | | | | | | | |
| Number of days | 33 | 48 | 27 | 20 | 20 | 40 | 0 |
| Percent of season | 92% | 84% | 77% | 40% | 56% | 83% | 0% |
| No. of Am. shad passed | 34,060 | 35,302 | 9,549 | 2,242 | 8,939 | 15,606 | 0 |
| Daily ave. of Am. shad passed | 1,032 | 735 | 354 | 112 | 447 | 372 | 0 |
| Percent of total passage | 99.6% | 98.1% | 92.3% | 80.2% | 82% | 95% | 0% |
| **River flow 40,001 to 60,000 cfs** | | | | | | | |
| Number of days | 3 | 5 | 8 | 22 | 14 | 8 | 2 |
| Percent of season | 8% | 9% | 23% | 44% | 39% | 17% | 12% |
| No. of Am. shad passed | 129 | 566 | 789 | 533 | 1,846 | 866 | 0 |
| Daily ave. of Am. shad passed | 43 | 113 | 99 | 24 | 132 | 108 | 0 |
| Percent of Total Passage | 0.4% | 1.6% | 7.6% | 19.0% | 17.0% | 5% | 0.0% |
| **River flow >60,000 cfs** | | | | | | | |
| Number of days | 0 | 4 | 0 | 8 | 2 | 0 | 15 |
| Percent of season | 0% | 7% | 0% | 16% | 5% | 0% | 88% |
| No. of Am. shad passed | 0 | 100 | 0 | 20 | 111 | 0 | 21 |
| Daily ave. of Am. shad passed | 0 | 25 | 0 | 2 | 55 | 0 | 2 |
| Percent of total passage | 0.0% | 0.3% | 0.0% | 0.7% | 1.0% | 0% | 100% |

* Denotes seasons of high river flow or frequent spillage.

**Table 6**

**Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2011.**

| | Conowingo | Holtwood | | Safe Harbor | | York Haven | |
|---|---|---|---|---|---|---|---|
| | East | Number | % of C.E.L. | Number | % of Holt. | Number | % of S.H. |
| 1997 | 90,971 | 28,063 | 30.8% | 20,828 | 74.2% | - | - |
| 1998 | 39,904 | 8,235 | 20.6% | 6,054 | 73.5% | - | - |
| 1999 | 69,712 | 34,702 | 49.8% | 34,150 | 98.4% | - | - |
| 2000 | 153,546 | 29,421 | 19.2% | 21,079 | 71.6% | 4,687 | 22.2% |
| 2001 | 193,574 | 109,976 | 56.8% | 89,816 | 81.7% | 16,200 | 18.0% |
| 2002 | 108,001 | 17,522 | 16.2% | 11,705 | 66.8% | 1,555 | 13.3% |
| 2003 | 125,135 | 25,254 | 20.2% | 16,646 | 65.9% | 2,536 | 15.2% |
| 2004 | 109,360 | 3,428 | 3.1% | 2,109 | 61.5% | 219 | 10.4% |
| 2005 | 68,926 | 34,189 | 49.6% | 25,425 | 74.4% | 1,772 | 7.0% |
| 2006 | 56,899 | 35,968 | 63.2% | 24,929 | 69.3% | 1,913 | 7.7% |
| 2007 | 25,464 | 10,338 | 40.6% | 7,215 | 69.8% | 192 | 2.7% |
| 2008 | 19,914 | 2,795 | 14.0% | 1,252 | 44.8% | 21 | 1.7% |
| 2009 | 29,272 | 10,896 | 37.2% | 7,994 | 73.4% | 402 | 5.0% |
| 2010 | 37,757 | 16,472 | 43.6% | 12,706 | 77.1% | 907 | 7.1% |
| **2011** | **20,571** | **21** | **0.10%** | **8** | **38.10%** | **0** | **0.00%** |

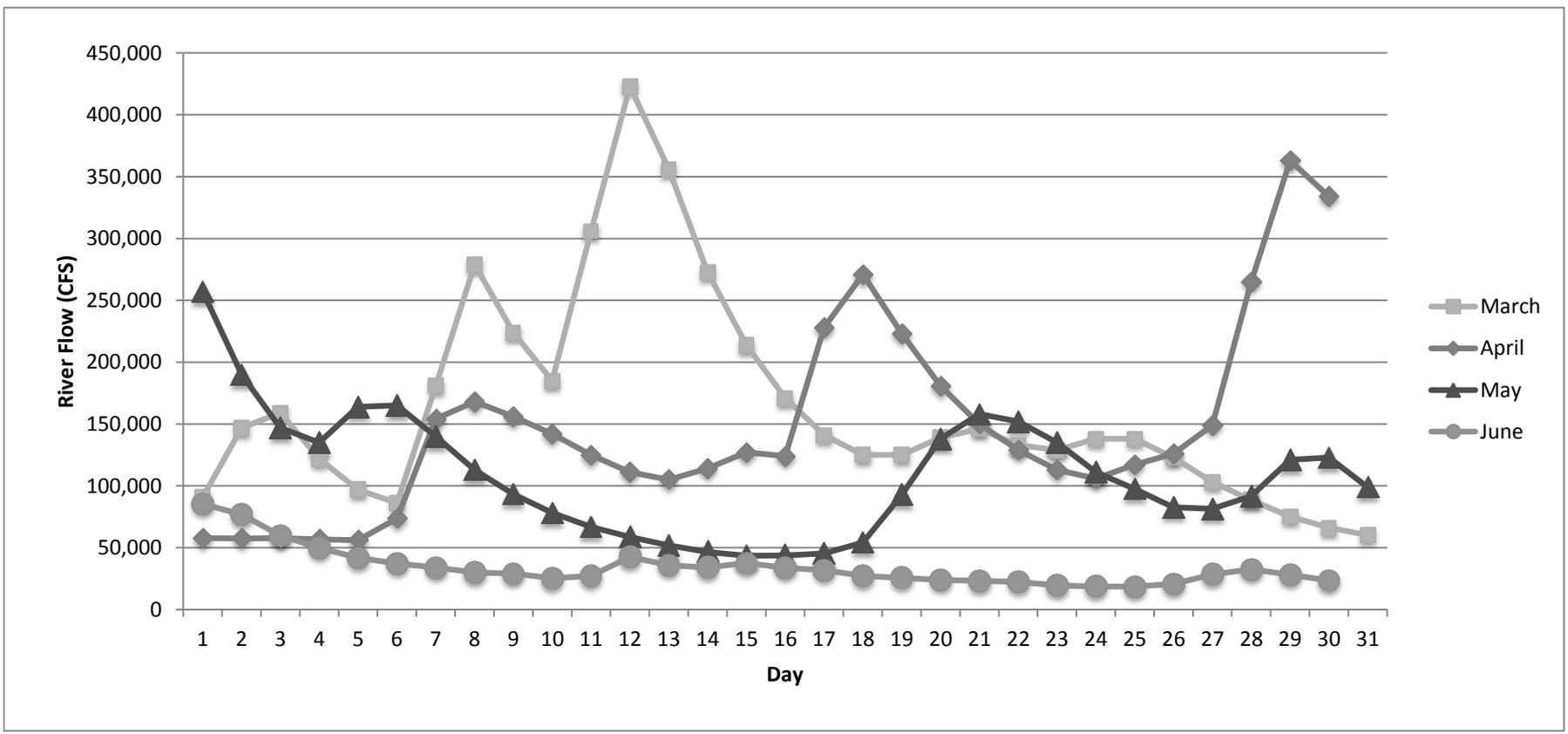


**Figure 1**

**Plot of River Flow as measured at Holtwood Dam for the period March through June, 2011**

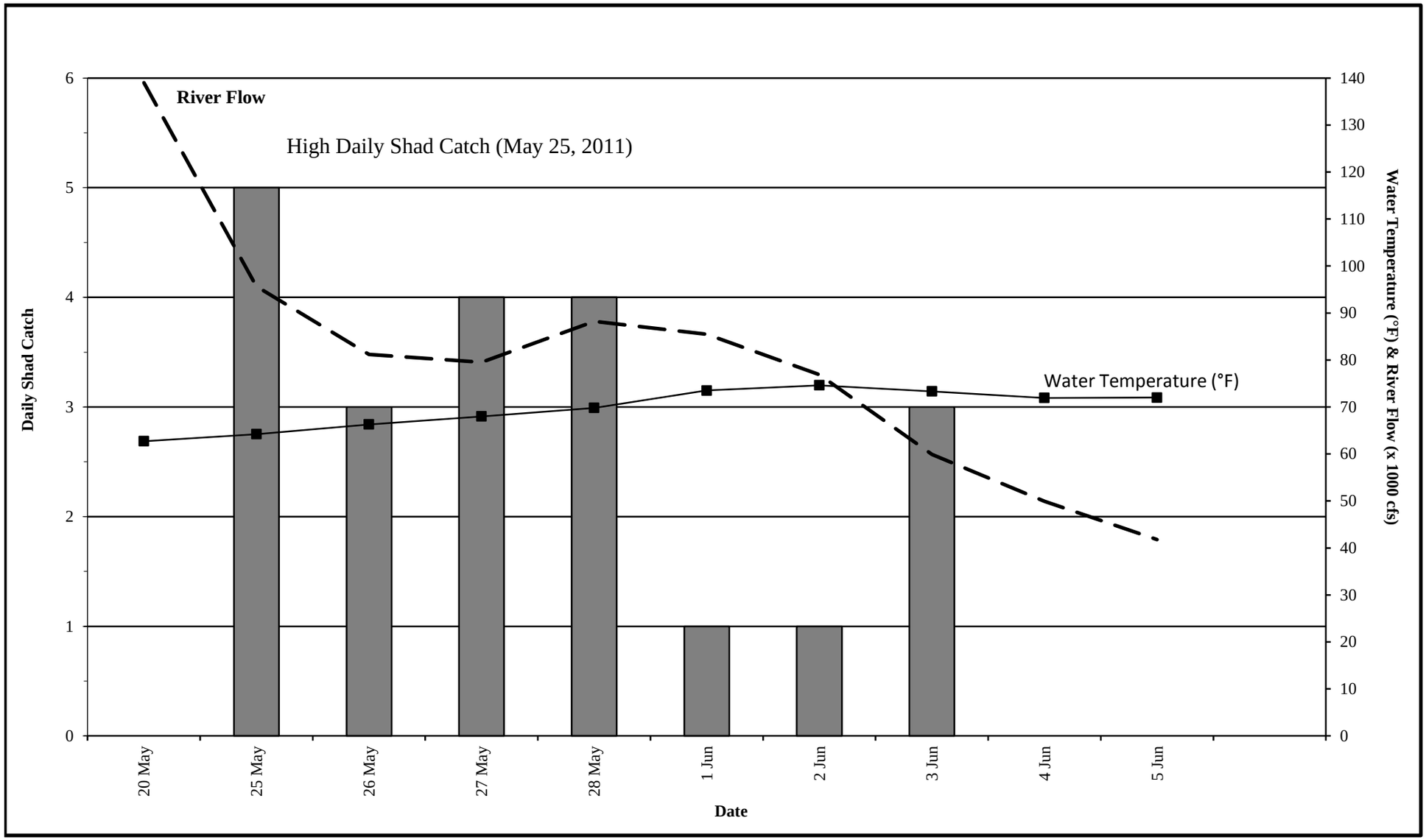


**Figure 2**

**A plot of river flow (x 1000) and water temperature (°F) in relation to the daily American shad catch at the Holtwood Fish Passage Facility, spring 2011.**