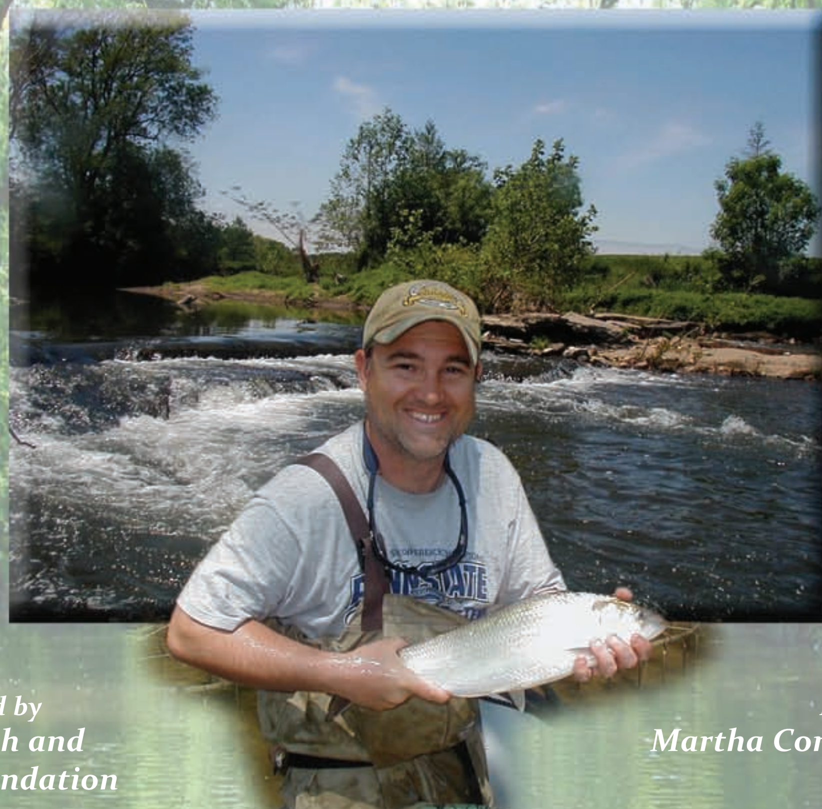
Restoration of Shad and Anadromous Fish to the White Clay Creek National Wild and Scenic River:

A Feasibility Report

June 2010



Project Funded by
National Fish and Wildlife Foundation

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Robert Lonsdorf
Maureen H.S. Nelson

A Report of the
Water Resources Agency

Institute for Public Administration
College of Education & Public Policy
University of Delaware

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PREFACE

I am pleased to present this Institute for Public Administration (IPA) project report, titled *Restoration of Shad and Anadromous Fish to the White Clay Creek National Wild and Scenic River: A Feasibility Report*.

This report was developed by IPA's Water Resources Agency (WRA). WRA provides water-resources planning and policy assistance to governments in Delaware, the Delaware Valley, and along the Eastern Seaboard through the University's land-grant public service, education, and research roles.

The aim of the project is to assess the feasibility of restoring fish passage and habitat to the White Clay Creek National Wild and Scenic River watershed. The long-term goal of the project is to restore shad and migratory-fish passage and habitat, increase spawning areas, and benefit the resident fish in the 107-sq.-mi. watershed. This report will serve the project collaborators and interested stakeholders in achieving the long-term goal of this project.

This project is funded by the National Fish and Wildlife Foundation.

Jerome R. Lewis, Ph.D.
Director
Institute for Public Administration

ACKNOWLEDGEMENTS

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- DNREC Division of Fish and Wildlife staff, specifically Matt Fisher and Mike Stangl, for the sampling efforts on the White Clay Creek, devising and helping to implement the angler log and creel survey, and providing a tour of the Nanticoke shad hatchery and input on shad stocking.
- IPA Water Resources Agency staff members Gerald Kauffman and Andrew Homsey and graduate research assistants Erika Farris, Maureen H.S. Nelson, and Kelly Wolfe, for conducting the angler log and creel survey.
- IPA Water Resources Agency staff member Andrew Homsey and graduate research assistants Erin McVey, Sarah Chatterson, and Stacey Mack, for their assistance in building and maintaining the Shad in Schools' shad hatchery and the final release of the shad fry.
- IPA Water Resources Agency staff member Nicole Minni, for designing the shad poster.
- Robert Lonsdorf, for providing invaluable information, feedback, and collaboration on this project.
- White Clay Creek Shad Restoration committee members who provided a plethora of input and data that helped IPA's Water Resources Agency create this feasibility report.

This report was edited and formatted and the cover designed by IPA staff member Mark Deshon.

Cover image of fisheries biologist Matt Fisher holding an American shad is courtesy of the DNREC Division of Fish and Wildlife.

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EXECUTIVE SUMMARY

The Water Resources Agency (WRA), a unit of the University of Delaware's Institute for Public Administration (IPA) assessed the feasibility of restoring fish passage and habitat to the White Clay Creek National Wild and Scenic River watershed. This project is funded by the National Fish and Wildlife Foundation (NFWF) and is one of 17 projects being undertaken by a number of regional organizations that are striving to improve the environment of the Delaware Estuary—the tidal portion of the Delaware River.

The long-term goal of the White Clay Creek watershed project is to restore shad and migratory-fish passage and habitat, increase spawning areas, and benefit the resident fish in the 107-sq.-mi. watershed. To achieve this, WRA conducted a feasibility study for restoring fish passage to the federally designated National Wild and Scenic White Clay Creek.

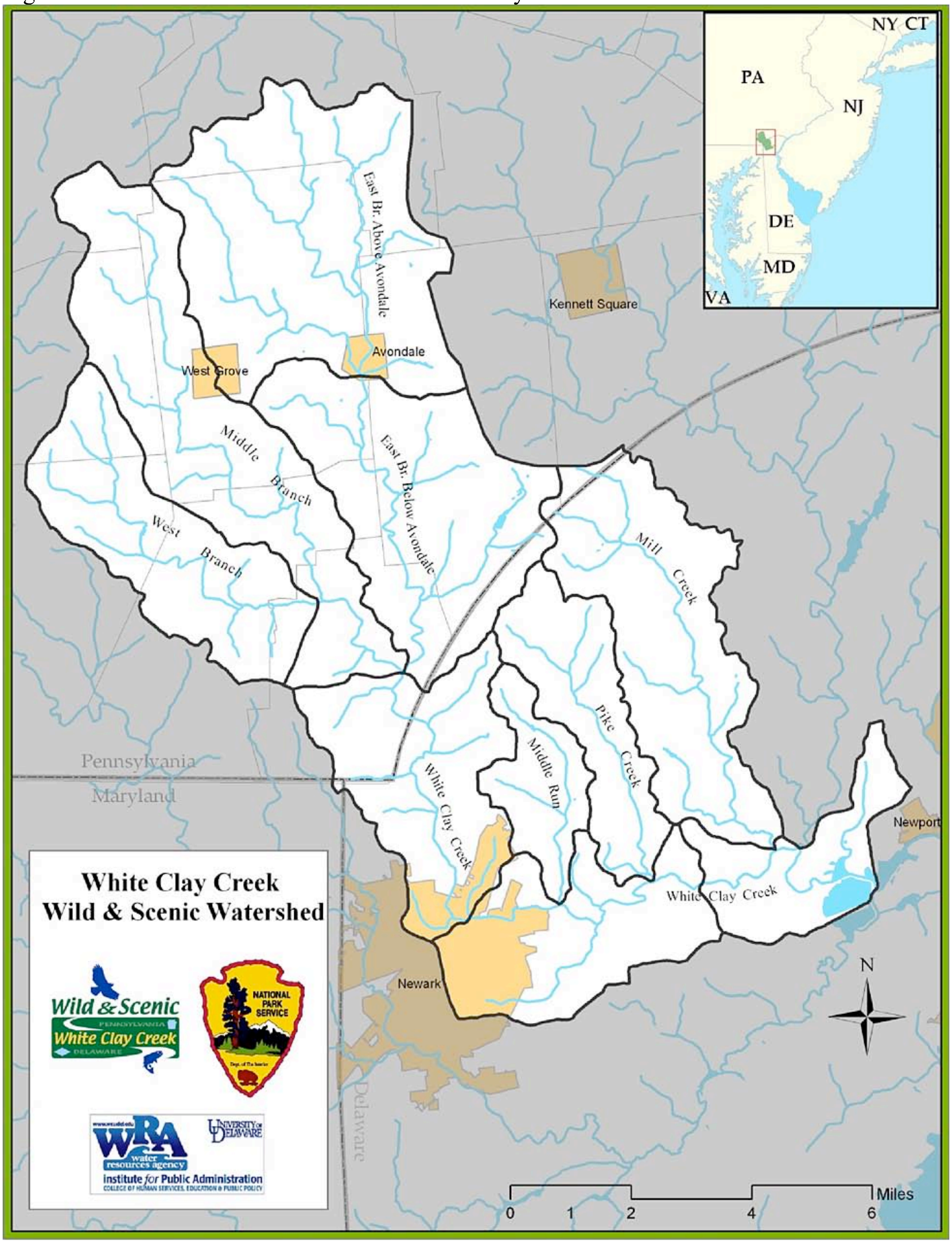
In order to identify and achieve the most effective options for restoring fish passage and habitat, WRA collaborated with the Brandywine Conservancy, the City of Newark, DNREC, Delaware Park, Duffield Associates, United Water Delaware, White Clay Outfitters, Trout Unlimited, the White Clay Wild and Scenic Watershed Management Committee, citizens, and interested stakeholders.

Project tasks included the following:

- Conduct a literature review of successful fish-restoration projects on the East Coast.
- Research to determine abundance and extent of the historic and current fish population.
- With DNREC, conduct fish-abundance surveys along the tidal and freshwater White Clay Creek.
- Research and develop a fish-stocking plan.
- Carry out a field survey and inventory of existing dams along the White Clay Creek in Delaware and Pennsylvania.
- Explore the feasibility of restoring fish passage utilizing a variety of techniques.
- Recommend the most feasible fish-passage alternative for each dam based on environmental, ownership, historic-value, and cost criteria.
- Create a shad-restoration committee and implement public education and outreach programs.

This project serves as an expansion of the Brandywine Creek Shad Restoration effort, and research was done in partnership with Christina Basin Clean Water Partnership restoration efforts. WRA has a long-term commitment to implementing the recommendations set forth in this study.

Figure 1.1. The National Wild and Scenic White Clay Creek watershed



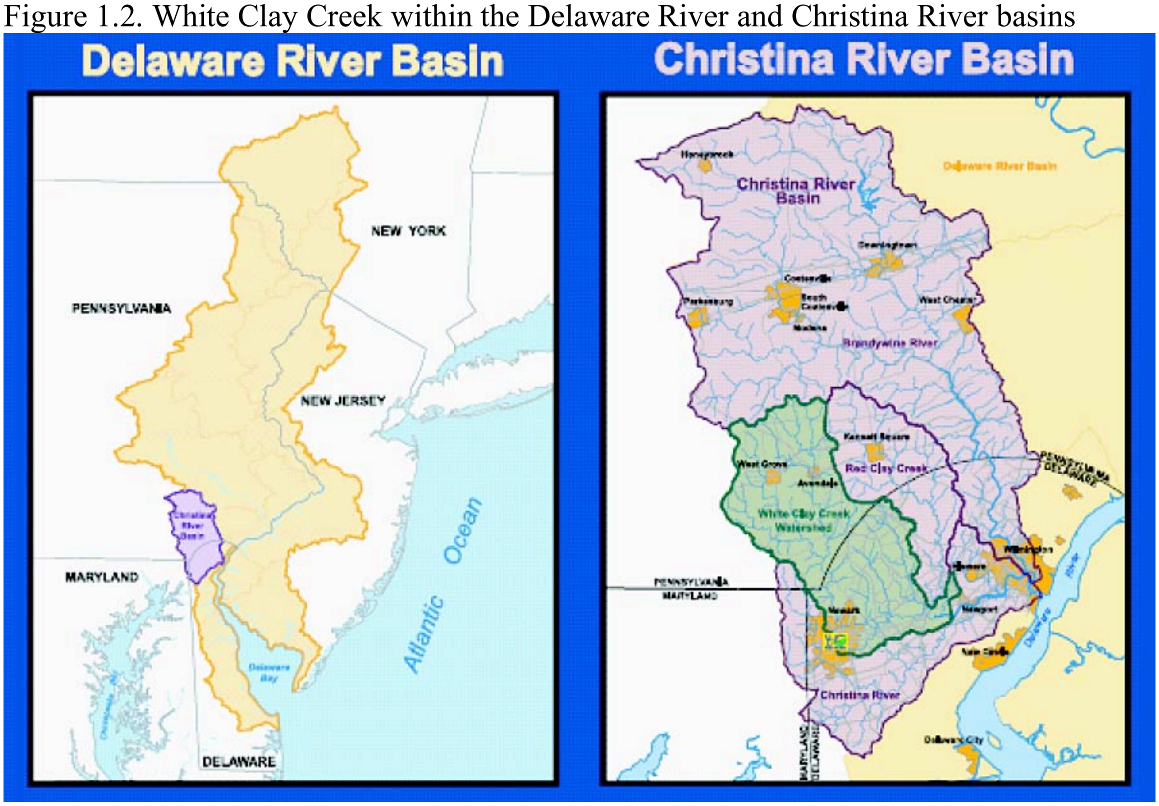
CHAPTER 1: THE WHITE CLAY CREEK WATERSHED

The White Clay Creek (Figure 1.1) drains 107 square miles and is one of the four major watersheds in the 565-sq.-mi. Christina River Basin. The Christina River Basin is part of the larger 13,000-sq.-mi. Delaware River Basin (Figure 1.2). In 2000 the President signed a law adding 190 miles of the White Clay Creek and its tributaries to the National Wild and Scenic Rivers System. The White Clay Creek is the first National Wild and Scenic River in the United States designated as such on a watershed basis rather than as a single river corridor.

Approximately 55 percent of the White Clay Creek watershed is located in Pennsylvania, 45 percent in Delaware, and a negligible portion in Maryland. The northern portion of the watershed in Chester County, Pa., includes the East, Middle, and West Branches of the White Clay Creek. The White Clay Creek flows southeast into New Castle County, Del., and is joined by Middle Run and Pike and Mill Creeks before emptying into the Christina River. Towns within the White Clay Creek watershed include Newark, Del., and Avondale and West Grove, Pa.

The White Clay Creek watershed includes many unique and outstanding resources. The unique qualities and assets of this watershed are described in more detail below.

Figure 1.2. White Clay Creek within the Delaware River and Christina River basins



Botanical Resources

The White Clay Creek watershed contains a rich assortment of flora. Botanical surveys have found that there are over 500 plant species native to the watershed and more than 500 wild flowers, including nine native orchids. Trees also contribute significantly to the area's character, as tall tulip trees, stark sycamores, massive beeches, and oaks define the landscape. A survey of the White Clay Creek State Park and Preserve found 24 Delaware "species of special concern" and numerous plant species from Pennsylvania's endangered-plants list.

Designated Uses

The tributaries of the White Clay Creek have several state designations that garner protection and regional significance. The Pennsylvania Department of Environmental Protection (DEP) has identified the East Fork of the White Clay Creek's East Branch, from the northern boundary of the Avondale Borough to the headwaters, as Exceptional Value Waters, while the remainder of the East Branch is designated as Cold Water Fisheries for the propagation of trout. DEP has provided additional protection to the Middle and West Branches through its trout-stocking designations. The Delaware Department of Natural Resources and Environmental Control (DNREC) classifies the White Clay Creek from the Delaware state line to the dam at the former Curtis Paper Mill in Newark as Exceptional Recreational or Ecological Significance Waters.

Educational and Research Opportunities

The White Clay Creek watershed and the resources contained within it play an important role in research and education. The Stroud Water Research Center (SWRC)—an internationally acclaimed nonprofit organization for its pioneering work on streams and rivers—hosts a 1,800-acre experimental watershed located on the East Fork of the White Clay Creek. The SWRC uses this experimental watershed for educational outreach and research and applies many of the principles learned in the White Clay Creek watershed to ecosystems throughout the world. The University of Delaware is partially located in the White Clay Creek watershed. Various University units, such as the Water Resources Agency and the Department of Entomology and Wildlife Ecology, conduct research in and incorporate the White Clay Creek, the watershed, and its natural resources into course curricula.

Fish and Wildlife Resources

The watershed is home to a wide variety of fish and wildlife. The waters of the White Clay Creek support over 24 species of fish. The creek is stocked annually by both Delaware and Pennsylvania and is considered Delaware's premier trout-fishing stream. Fish abundance surveys in the tidal creek have detected andromous fish such as the American and hickory shad, striped bass, and white perch. Surveys estimate that 93 species of birds nest in the White Clay Creek watershed. Migrants include the hooded and cerulean warblers, the latter a rare northern species that breeds in Delaware only in the Piedmont province of the watershed. Thirty-three species of small mammals have been documented in the watershed. Beavers and an occasional river otter are seen swimming in the creek. On summer evenings, bats—red, big brown, little brown, hoary, and eastern pipistrel—flutter skyward from daytime perches. Twenty-seven species of amphibians and reptiles live in the watershed, among them the rare bog (Muhlenberg's) turtle, which is on the U.S. Fish and Wildlife Service's list of threatened species. The rare long-tailed salamander and the four-toed salamander have also been found breeding in the springs, streams, and marshes of the White Clay Creek watershed.

Geology

The White Clay Creek watershed is perched along the geologically significant fall line that runs along the East Coast between Alabama and New England. The fall line runs between Newark and Wilmington in Delaware and separates the hilly, rocky Piedmont from the flat, sandy Coastal Plain. This transition zone results in a wider array of flora and fauna and enhances the opportunities for nearby researchers.

Historical Significance

The White Clay Creek watershed is historically significant. The region was originally settled by native Americans, followed by the Dutch and Swedes in the early- to mid-1600s. Many noteworthy historical events followed, including: William Penn's acquisition of the land (including White Clay Creek) in the 18th century; the flourish of farms and small mills; the march of American and British armies through the watershed on their way to battle for Philadelphia in 1777; the advent of railroad tracks throughout the region; and the opposition of a proposed dam on the White Clay Creek, which resulted in the creation of the White Clay Creek Watershed Association in 1965. Today, after the hard work of many citizens, the states' acquisition of land, and the donation of thousands of acres of land, the total area of Pennsylvania's White Clay Creek Preserve and Delaware's White Clay Creek State Park exceeds 5,000 acres. In 2000 the National Park Service designated the White Clay Creek watershed as a National Wild and Scenic River.

Land Use

The Pennsylvania portion of the watershed is largely rural with a few small towns and villages, such as West Grove and Avondale, and some suburban clusters. The Delaware portion of the watershed includes the City of Newark and is highly suburbanized, although several very large tracts of public open space remain intact and flank the river. Normal rainfall for this region supplies enough water to support a mature deciduous forest and an extensive freshwater tidal wetlands system downstream.

Open Space and Recreation

About 17 percent of the watershed is protected open space, two-thirds of which is in Delaware. Open space is a major platform for recreation in the White Clay Creek watershed. The White Clay Creek State Park, managed by Delaware, and the White Clay Creek Preserve, managed by Pennsylvania, are maintained as natural areas accommodating passive recreation. Other parks in the watershed are designed for heavier uses, including sport fields, basketball courts, and picnic facilities. Additionally, the streams of the White Clay Creek are an extremely popular fishing destination in the tri-state region. More than 20,000 brown and rainbow trout are stocked in the

Pennsylvania portion of the White Clay Creek, while over 18,000 trout are stocked in the Delaware portion.

Water Supply

The surface water of the White Clay Creek and the aquifers in the watershed provide more than 120,000 residents with drinking water. The creek serves as a major drinking water source for much of northern Delaware, accounting for 33 million gallons per day (mgd) of the overall production of water supply from the watershed. Delaware and Pennsylvania residents in the White Clay Creek watershed also receive a significant amount of their water supply from groundwater resources in the watershed. The City of Newark's groundwater supplies provide up to 1.8 mgd from five wells in the watershed. The Artesian Water Company operates six wells that provide up to 1.9 mgd in the Cockeysville Marble Formation near Hockessin, Del. The Cockeysville Marble Formation is an exceptional aquifer and serves as an important source of drinking water. It also supplies continuous and relatively high base flows to the stream.

CHAPTER 2:
SHAD AND THE MID-ATLANTIC REGION

2.1 American and Hickory Shad

American shad (*Alosa sapidissima)*, the largest of the herrings, were once an abundant migratory fish and were an important part of American history and the early settler's way of life. American shad reach a maximum size of 12-14 pounds and 30 inches in length (Raasch and Altemus, Sr., 1991). American shad are distinguished by their large size and do not have the protruding lower jaw of the hickory shad. American shad are also distinguished by the silver on their abdomen and a greenish- or bluish-metallic sheen on their back (Brandywine Conservancy, date unknown).

Hickory shad (*Alosa mediocres)*, also part of the herring family, are an abundant migratory fish in the White Clay Creek. Hickory shad can grow up to 24 inches. The hickory shad are faintly marked with lengthwise stripes and the tip of the snout is dusky-colored. The hickory shad has a thin, grayish-green body and an iridescent-silver belly and sides. Adults have a dark shoulder spot followed by several obscure spots (http://www.chesapeakebay.net/bfg_hickory_shad.aspx?menuitem=14398). Hickory shad can be distinguished by their lower jaw, which projects beyond the upper when the mouth is closed (Raasch and Altemus, Sr., 1991).

Shad are anadromous fish that spend their life at sea except for a spawning run into fresh water at 3-5 years of age. Larval development cannot occur in salt water and this journey provides a safe environment for the juveniles to grow. Shad can travel hundreds of miles to get to their spawning destination. The female releases her eggs into the water column, which are then fertilized by the males. A single female may spawn several times and may produce from 200-250,000 eggs during a single year. Shad are open-water batch spawners, meaning they do not spawn in one spot or all at the same time. Shad going up the Delaware River may make three successive spawning runs, but most do not repeat.

The eggs hatch after 4-9 days in early summer and metamorphose into juveniles approximately a month later (http://www.bio.umass.edu/biology/conn.river/shad.html). During the fall following the spawning, the juveniles (2-3 inches in length) return to the ocean and continue to grow. Shad migrate south during the winter to areas off the coast of North Carolina and north during the spring to summer feeding grounds in the Bay of Fundy.

2.2 Migratory Fish–Restoration and Dam-Removal Projects in the Mid-Atlantic Region

There are numerous shad restoration and fish-passage projects in the Mid-Atlantic region. The majority of the programs were created in an effort to restore American and hickory shad to their historically native habitat. Primarily, the decline in shad populations has been the result of human activities, such as commercial fishing. In addition, the construction of human-made dams and barriers prevent shad and other migratory fish from returning to their spawning grounds, thus impeding the natural reproductive cycle of migratory fish species. The actions taken to return migratory fish populations to native stream habitats include fish population studies, removal of barriers or construction of fish passages, fish stocking, and the monitoring of fish populations to track the success of the particular program.

A summary of seven Mid-Atlantic region shad restoration and fish-passage projects is presented below. In each case, when possible, the key partners, the cost and funding of the project, the location of the project, the success of the project and how the success was measured are identified, as well as any common themes found throughout the projects.

Chesapeake Bay Program Shad Restoration

The initial goal of the Chesapeake Bay Programs' fish-passage efforts was to restore 1,357 stream miles to allow for the passage of migratory fish. Between 1988 and 2005, the program exceeded the goal by almost 500 miles, totaling 1,838 miles of fish passage restoration. In 2005 a new goal for 2014 was set to complete 100 projects to open up 2,807 river miles to migratory and resident fish species in sections of Maryland, Pennsylvania, Virginia, and Washington, D.C. During the first three years of this project phase, a total of 460 miles were restored through the completion of 40 fish-passage projects, reaching 81 percent of the goal (Chesapeake Bay Program, 2008).

Virginia Department of Game and Inland Fisheries: American Shad Restoration

In 1992 the Department of Game and Inland Fisheries initiated the American Shad Restoration program in Virginia. The primary goal of the program is to reintroduce and enhance American shad populations in the James, Pamunkey, Potomac, and Rappanhannock River systems. In 2008, more than 6,900,000 fry were stocked in the James River system, nearly 900,000 in the Potomac River System, and over 4,800,000 in the Rappahannock River system. This resulted in a total of 160,606,549 fry since restoration efforts began in 1992.

The Virginia program uses hatchery shad fry to stock the river system and reintroduce the migratory fish. The method of gathering fish eggs makes this program stand out from the others. In the Virginia program electroshock is not used, rather, a net is used to collect brood-stock shad for eggs. These fish are brought to shore where the egg-taking process occurs. Free-flowing females (those that are of mature brood) are manually spawned into bowls by massaging the fish belly. Once these eggs hatch and the fry are large enough, they are tagged to distinguish them from the wild fish.

Monitoring on the James River for the return of spawning American shad indicates remarkable success in the stocking program. Considerable increases in American Shad populations returning to the James River have been observed, with a large portion of the returning adults from fry stockings. In addition, the offspring of hatchery fish are returning to the James River as adult shad and are spawning successfully. In addition to restocking efforts, in 1994 a moratorium on the inland harvest of shad was implemented, ending the commercial and recreational fishing of American shad (Virginia Department of Game and Inland Fisheries, 2009).

Partners:
- Virginia Department of Game and Inland Fisheries
- U.S. Fish and Wildlife Service

Potomac River American Shad Restoration Project

The Potomac River project began in 1995 by the Interstate Commission on the Potomac River Basin. The main goal of the project is to restore shad populations to the Potomac River by imprinting shad to spawning and nursery waters. Since the beginning of the program over 19 million American shad fry have been stocked in the Potomac. An additional 211,000 fry have been released in the Potomac River system through a "shad in schools" program. In addition, the removal of Little Falls dam in January 2000 added to the effort to restore American shad populations to the area. At this site, electrofish and dip net monitoring shows that the number of adult American shad collected at Great Falls has steadily increased from 0 in the four years prior to the passage, to 2 in 2000, 15 in 2001, and 44 in 2002. Since the program began, Year-of-the-Young shad have set records in both Maryland and the United States Fish and Wildlife Service/Interstate Commission on the Potomac River Basin monitoring surveys. A continued increase in American shad populations is expected in the coming years. Future success of the project depends upon monitoring restoration progress. Restoration is important to reopen commercial and recreational American shad fisheries and valuable to the economy. Another continuing program need is funding. While funding has been available in the past, the program directors recognize that it is becoming increasingly difficult to obtain (Administrator, 2009).

Susquehanna River American Shad

On the lower Susquehanna River fish-passage facilities (fish-lifts) are located at the Conowingo, Holtwood, and Safe Harbor hydroelectric dams, and a vertical-slot fish ladder is present at the York Haven Dam. Monitoring of each of these facilities, from 1997-2004, indicates an increasing trend of shad populations returning to the Susquehanna River. However, since 2004, records signify a decline in the shad-passage final count. Future plans include the construction of a fish ladder at the Fabri-Dam at Sunbury and an upgrade of the fish ladder at the Hepburn Street dam in Williamsport on the West Branch of the Susquehanna River.

Typically, fish-passage operations begin at the Conowingo dam on April 1st, or when the water temperature reaches 50˚F, and continue through mid-June. As of April 4, 2009, American shad had not been observed passing through the Conowingo Hydro Facility. By April 24, 2009, 517 American shad had been observed passing through the fish lift, and by the end of the migration season (June 6th), a total of 29,272 American shad had passed through the lift. To date, shad have been observed at the other three hydroelectric dams, Holtwood, Safe Harbor, and York Haven, on the lower Susquehanna River (Pennsylvania Fish and Boat Commission, 2009).

Partners:
- Dam operators
- U.S. Fish and Wildlife Service
- Pennsylvania Fish and Boat Commission

Maryland Shad Restoration Project

The Maryland Department of Natural Resources Shad Restoration Project began in 1993 with an American shad pilot program. The following year experimental spawning commenced. In 1995 a non-funded, full-scale hatchery production was undertaken. Hickory shad were introduced to the program in 1996. By 1998 the program obtained long-term funding to continue operations.

The Maryland Shad Restoration Project included the stocking of 25.9 million hatchery-produced American shad between 1994 and 2008 and 95.1 million hickory shad in the Choptank River, Patuxent River, Patapsco River, and the Nanticoke River. The first appearance of adult American shad from the hatchery in the Patuxent River occurred in 1999. The return of hatchery-produced American shad to spawning grounds increased from 2000 to 2001. In 1998 the first wild juveniles were caught and increased to 11 percent of the juvenile population in 2001 (Maryland Department of Natural Resources, 2008; Richardson, Stence, Baldwin & Mason, 2007).

Partners:

- Maryland Department of Natural Resources Fisheries Service
- Mirant (power company)
- Exelon
- U.S. Fish and Wildlife Service
- Mettiki Corporation (coal company)
- State of Delaware, DNREC, Division of Fish and Wildlife
- University of Maryland Center for Environmental Science: Chesapeake Biological Laboratory (shad); Horn Point Laboratory (yellow perch); Center of Marine Biotechnology (shad)

American and Hickory Shad Restoration on Delaware's Nanticoke River

The primary goal of the Nanticoke program is to continue restocking efforts into the Upper Nanticoke until natural reproduction is deemed adequate to sustain shad populations or no improvements in the number of returning juveniles and adults are observed in three tributaries of the Nanticoke.

Similar to the previous programs, the process of collecting American shad for the hatchery effort is accomplished through electrofishing. Each fish is marked with a fin clip. A major difference between this program and the Maryland program is that no hormones are used to induce spawning. Monitoring is used to estimate the percentage of hatchery-produced juveniles that returned as adults to the Nanticoke.

Between 2000 and 2005, 1,492,165 American shad were stocked in the Nanticoke River. Between May 3, 2007, and May 17, 2007, approximately 231,000 American shad larvae from the Nanticoke Hatchery were stocked in the tributaries of the Nanticoke at four sites. The 2007 spawning differed from years prior in that it produced many small batches of eggs compared to fewer batches with a larger volume of eggs.

The bi-weekly sampling of fishery-independent adult and juveniles results found that, in the first five years of the study (1999-2003), the greatest number of American shad was caught at the sampling site farthest upriver near Seaford, Del. From 2004 to 2007, the greatest percentage of fishery-independent juveniles was sampled from a site on lower Broad Creek, which was only 11 percent of the total number of American shad initially stocked. This indicates a relatively high rate of natural reproduction (or lower predation) in Broad Creek over the past four years, assuming they were initially spawned in Broad Creek. No monitoring of fishery dependent adult shad occurred in 2007 due to Delaware's moratorium on the commercial and recreational harvest of American shad and hickory shad, which went into effect in February 2000 (Delaware Department of Natural Resources and Environmental Control (DNREC), 2006; DNREC, 2008).

Maryland Department of Natural Resources Fish-Passage Program

Within the Chesapeake Bay watershed there are over 2,500 human-made barriers that prevent anadromous fish from reaching spawning grounds. Approximately 1,300 stream miles were opened up with the 2003 Fish Passage Goal. The goal was adopted by the Chesapeake Bay Program signatory partners. Some of the priority areas were those that exhibited the highest quality habitats; preference is given to dam removal over fish passageways; when fish passage is necessary, natural fish passage (i.e., rock ramps) are preferred; and projects that increase passage of migratory fish or shad passage are given priority over resident fish.

Projects:

- The Octoraro Creek Dam was removed in October 2005, which opened up 19 stream miles. For this particular project it was determined that the sediment built up since the construction of the dam 100 years earlier was not enough to impair water quality during dam removal. Therefore, a cofferdam was not required, significantly decreasing the cost of and expediting the project. It was completed within a week. The majority of the time was allowing for the pond behind the dam to drain after a small section was removed from the center of the dam. The rocks from the dam were used to stabilize the banks that had eroded. Additional stream restoration was completed by planting trees and shrubs along the banks, which will stabilize and enhance the quality of the banks.
- Ravenrock Dam removal was completed in October 2007. It reopened two stream miles to brook trout and resident species along Raven Rock Creek in the Potomac River watershed in Washington County, Md. The removal is expected to reduce thermal pollution and decrease algal blooms. The removal of the cement and mortar dam cost $35,900 for design and $91,462 for construction.
- Puckum Branch Dam was removed in January 2007. The dam/culvert was located in the Nanticoke watershed on the Pucknam Branch in Caroline County. It reopened 4.5 miles to alewife herring, blueback herring, and perch.
- The removal of White Hall Dam is slated for the fall of 2009. The structure is a concrete dam 10 feet tall, 125 feet wide, and 4 feet thick, located in the Gunpowder Watershed on the fourth-order Little Falls stream, which is a tributary to Big Falls. The removal of the White Hall Dam will open up 46 square miles upstream of the dam. The target species are brown and rainbow trout. The total cost of the project design is $87,396 and the total cost of construction is $177,827.
- The Green Branch Culvert is located on the second-order Green Branch in the Patuxent Watershed in Prince George’s County, Maryland. The details for this project are scant, but it includes removal or pool and weir passage for herring and resident fish to open up two stream miles on the Green Branch.
- Simkins Dam will be removed between 2009 and 2010. It is on the fourth-order Patapsco Stream in the Patapsco watershed, southeast of Ellicott City. The removal of this concrete dam will open up over eight stream miles to American eel, shad, and herring. The project design costs a total $50,000, and the construction costs total $247,827.
- Scotchman’s Creek in the Bohemia watershed in Cecil County is slated to have a dam removed by 2010. The removal of the rubble dam will open up five miles, the target species are herring, perch, and resident fish. The estimated costs for design are $110,000 and $296,000 for construction (MDNR, 2009; Richardson et al., 2007).

Partners:
- MDE
- Ducks Unlimited

Common Themes

There are several common themes that were found in researching the migratory fish–restoration and dam-removal projects in the Mid-Atlantic region:

- There are numerous successful dam-removal projects occurring through the Mid-Atlantic region.
- The preferred method to restore migratory-fish passage is dam removal.
- All projects include public-private partnerships.
- A variety of funding sources have been utilized to implement these projects.
- Shad are density-dependent spawners. In an attempt to increase the likelihood of shad returning to tributaries to spawn, shad captured or marked are kept in large groups to represent the higher spawning density preferred by shad (Richardson et al., 2007; Stangl, 2008).
- Techniques to induce spawning vary from chemical inducement to natural, manual excretion of eggs.
- Stocking is a critical component of a migratory fish–restoration project.
- All programs collect eggs from brooding females and grow the fish in hatcheries. The fish released in the tributaries typically return as juveniles. With each year, progress has been observed with rising wild fish populations and overtaking the hatchery-produced fish.

CHAPTER 3:
DISTRIBUTION OF ANADROMOUS AND DIADROMOUS FISH

3.1 Historic Distribution

There are multiple sources that document the presence of American shad in the Delaware River Basin since the arrival of European settlers to the Delaware River Basin Region. Some sources discuss the presence of American shad in the Delaware River Basin as a whole, while other sources specifically address the Delaware River, the Brandywine River, and the White Clay Creek. Historical documentation of American shad, whether by basin, state, or local river, provides substantiation for the restoration of American shad in the White Clay Creek watershed.

The article, *Fish or Foul: A History of the Delaware River Basin Through the Perspective of the American Shad, 1682 to the Present,* divides the history of the American shad into five distinct periods of increasing and decreasing population trends due to detrimental and positive human influences on this migratory species. The five distinct phases can be summarized as follows:

- Phase 1 (Colonial Open River Fishery): Shad provide early settlers a plentiful food source.
- Phase 2 (1820s): Economic development and the construction of dams blocked access to spawning grounds. In addition, the growth of a thriving commercial shad fishery leads to overfishing and the destruction of the shad fishery, which ended this phase in the 1840s.
- Phase 3 (1870s): Resource exploitation and development in the 1880s and 1890s of the Delaware River as the nation's most productive commercial shad fishery led to further decline in the shad fishery. Shad also became a cultural artifact during this time.
- Phase 4 (early 1900s): Overfishing and water pollution mark this phase while the Delaware becomes one of the nation's most polluted rivers. Shad are nearly eliminated from the river.
- Phase 5 (1940s): Improvements in water quality due to new regional and federal laws help to bring the shad back to the river. Presently, groups are working to restore shad to the rivers and reverse the negative trends of river blockages and improving water quality throughout the Delaware River Basin in order to return to the open river fishery (Hardy, 1999).

According to the *Delaware's Freshwater and Brackish Water Fishes: A Popular Account* (1991), the peak of the shad fishery in the state of Delaware was 1895-1901, annual landings were reported to be 1,500,000 pounds. After 1901 a decline occurred. In 1990 the catch was 494,000 pounds valued at $148,225. American shad spawning takes place in the Delaware River above the Delaware Water Gap in Pennsylvania. An estimated 831,600 adult shad ascended the Delaware River in 1989. Aside from the Delaware River, American shad are caught in its Broadkill River tributary and the Nanticoke River system. Shad swimming up the Delaware River may make three successive spawning runs, but most do not repeat.

An American shad run occurred in the Brandywine Creek in 1960, the first time in many decades. The following year the run did not occur, yet in 1962 another run occurred. There was a heavy run in 1966. In 1967 and 1968 over 150 quarts of eggs were dispersed in the Brandywine Creek to encourage the development of the American shad population (Raasch and Altemus, Sr.). Unfortunately, several dams blocked the passage of these fish. Fish transport and fishways were used to assist the shad's efforts to return to their spawning grounds. On May 2, 1972, a record American shad entered in the state fishing contest (6 lbs., 12 oz.) was caught in the Brandwine Creek. In 1975 American shad were netted in the Brandywine Creek by workers from the Delaware River Anadromous Fishery Project. In a netting survey in 1976, five American shad were caught in the Christina River but none in the Brandywine Creek.

According to historic reports, there have been numerous diadromous fish species sighted (detected) in the White Clay Creek. According to the *Water Supply Plan for New Castle County Delaware, Supplemental Environmental Studies, Sampling Conducted Spring 1996* the following fish were cited at the lower White Clay Creek at Churchman's Marsh: striped bass, white perch, American eel, and gizzard shad. This same study analyzed the species identity of the ichthyoplankton at the lower White Clay Creek at Churchman's Marsh and found the following species: alewife, gizzard shad, striped bass, and white perch. According to the *Report on the Joint Task Force for Northern New Castle County, Phase 2, 7Q10 Assessment Sampling* conducted in the fall of 1995, the following fish species were identified as present in the White Clay Creek near Stanton (at United Water's surface-water withdrawal):

- Alewife
- American eel
- Blueback herring
- Sea lamprey
- Largemouth bass
- Smallmouth bass
- Yellow perch

This same study sampled the White Clay Creek near Newark (at the City of Newark's water-treatment plant at Paper Mill Rd.) and found the following fish species:

- American eel
- Sea lamprey
- Largemouth bass
- Smallmouth bass

Additional fishery survey results collected by Metcalf and Eddy in 1996 are included in Table 3.1.

According to eyewitness accounts on the Web, shad are present in the lower White Clay Creek. A local discussion forum on the Web has reports on April 28, 2003, that shad were working their way up the Christina River into the White Clay Creek. The fisherman describes the shad as "all over the place" and "flashing, moving, and breaking the surface." Another participant in the forum states these are American shad. In May 2003, a local fisherman's account reads, "Did some shaddin' this mornin' on the lower part of White Clay, picked up a few shad" (May 2003).

A YouTube video (www.youtube.com/watch?v=TjDwqyl1WAY&feature=related) documents a shad catching frenzy with 14 hickory shad caught in about 20 minutes.

Although historic reports of American shad in the White Clay Creek are sparse, the record of American shad in nearby river systems in the Christina Basin (e.g., Brandywine Creek) and Delaware River Basin indicate there is a high likelihood that there was an American shad run in the White Clay Creek. In addition, WRA is continuing to conduct research on historic records that may contain additional record of American shad in the White Clay Creek but were not available at the time of this report. Additional sources may include the Curtis Paper Mill and Green Bank Mill keeper logs along the White Clay and Red Clay Creeks, which may record shad runs from a century ago.

Table 3.1. White Clay Creek fishery survey results

Date of Sampling	**June 6**	**June 6**	**June 7**	**June 28**
Location	**WCA**	**WCB**	**TT**	**CK**
Seconds Shocked	**2,319**	**3,232**	**1585**	**815**
Common Name	**Number of Fish**			
American Eel	4	8	3	4
Am. Brook Lamprey	7	1	2	
Margined Madtom		2		
White Sucker	69	54	40	4
Rosyside Dace		65	88	59
Satinfin Shiner	24	23	1	1
Cutlips Minnow	6	11		
Common Shiner	15	35	23	
Spottail Shiner	3	14		
Swallowtail Shiner	38	15		
Bluntnose Minnow	2	1	1	
Blacknose Dace	23	23	42	48
Longnose Dace	1	52		
Creek Chub	21	14	28	21
Tesselated Darter	44	31		1
Rainbow Trout		1		
Rock Bass		4		
Redbreast Sunfish	1			
Pumpkinseed	1			
Bluegill	1		2	
Total Fish	**260**	**354**	**230**	**138**
Number of Species	**16**	**17**	**10**	**7**
TT - Thompson Station Tributary CK - Corner Ketch Tributary WCA - White Clay Creek at Hopkins Bridge WCB - White Clay Creek below confluence of Thompson Station Tributary				

Source: Metcalf and Eddy, 1996

3.2 Current Distribution: DNREC Sampling Events

In order to obtain accurate data on the current distribution of American shad in the White Clay Creek, WRA, with the assistance of DNREC's Division of Fish and Wildlife, conducted two sampling events (April and May 2010) and an angler log and creel survey (April–May 2009) along the White Clay Creek.

DNREC Division of Fish and Wildlife conducted two anadromous fish–sampling events on the lower White Clay Creek watershed. These sampling events were conducted on April 22, 2010, and May 13, 2010. Detailed information about each sampling event is provided below. The sampling locations are shown in Figure 3.7.

Sampling: April 22, 2010:
The starting point for the sampling on April 22, 2010 was about a quarter-mile downstream from Dam No. 1 (Delaware Park Dam). The water clarity was exceptional (approximately 4 ft.) combined with above-average flows and a warm, sunny day, making it a good day to sample anadromous fish. Sampling was conducted at three sites:

- Site 1, below Dam No. 1, River Mile (RM) 4.6, to the Mill Creek confluence, water temp. 14.2°C.
- Site 2, Mill creek confluence to Hale-Byrnes House, tidal capture structure (TCS) was lowered.
- Site 3, Hale-Byrnes to RM 0, water temp. 16.7°C.

The data collected during this sampling event are summarized in Table 3.2.

Observations

American shad
- One large female (unripe) was observed and netted at site 1 (Figure 3.1).
- No other American shad were observed; however, a small American shad could have easily blended in with the numerous Hickory shad.

Hickory shad
- Hickory shad were very thick, catch per unit effort (CPUE) of almost 500 at site 1 with densities tapering off traveling downstream to a CPUE of 70 at site 3.
- The hickory shad were too numerous to net and hold in the live well; therefore, once the CPUE was recorded, a visual count was estimated at 1000, 450, and 70 at sites 1, 2, and 3, respectively.
- The females ranged from unripe, to running, to spent, which indicates their spawning was probably peaking at the time of sampling.
- For a creek that averages 150 cubic feet per second (cfs) this time of year, DNREC fisheries biologists were very impressed with the hickory shad run.

Alewives
- Alewives were also abundant, CPUE of 71 at site 2 (Figure 3.2).
- Visual counts estimated at 0, 350, and 130 at sites 1, 2, and 3, respectively.

Blueback herring

- No blueback herring were observed.
- It could be possible that the blueback herring could be migrating later because they typically follow alewives and Hickory shad runs.

Sea Lamprey

- One adult sea lamprey was observed at site 2 (Figure 3.3).

Eels

- Eels were observed at all sites.

Other species

- Other observed species that make a local migration upriver to spawn include the occasional white perch and a lot of white suckers.
- Other species noted—smallmouth bass, quillback, yellow perch, largemouth bass, redbreast sunfish, pumpkinseed sunfish, rainbow trout (Site 2), fallfish, carp, chubs and a tiger trout (Site 3).

Table 3.2. Summary of sampling data, April 22, 2010

Fish Species	**CPU**			**Visual Count**			**Description**
	Site 1	**Site 2**	**Site 3**	**Site 1**	**Site 2**	**Site 3**	
Hickory Shad	Approx. 500		70	1000	450	70	Very thick at Site 1
Alewives		71		0	350	130	Abundant
American Shad				1	0	0	One large female (unripe)
Blueback Herring				0	0	0	None observed, could be coming later, typically follow alewives and hickory shad runs
Sea Lamprey				0	1	0	
Eels				Present	Present	Present	Observed at all sites

Figure 3.1. DNREC Fisheries biologist Matt Fisher shows the American shad found in the White Clay Creek at Site 1 on April 22, 2010.

Figure 3.2. Alewives and a hickory shad at Site 1 in the White Clay Creek on April 22, 2010

Figure 3.3. Sea lamprey found in the White Clay Creek at Site 2 on April 22, 2010

Sampling: May 13, 2010

The launch site for the sampling on May 13, 2010, was at Dam No. 2 (Red Mill Dam). Flows were 50 percent above normal. From Dam No. 2 to Dam No. 1, there were no anadromous fish present with 3,390 seconds of effort. The water temperature was 12.2°C. The data collected at the sampling event on May 13, 2010, are summarized in Table 3.3. The team of biologists and the sampling equipment is shown in Figure 3.5.

American shad

- No American shad were seen.

Hickory Shad

- Below Dam No. 1 (water temp 14.4°C), there was a school of hickory shad bunched up by the dam, not able to pass, CPUE of 350.
- Hickory shad were still present in good numbers from Dam No. 1 to Hale-Byrnes, CPUE of 340. This count is down from previous sampling efforts on April 22, 2010, which is expected later in the year.

Alewives

- No alewives

Sea Lamprey

- Eight adult sea lamprey were seen.

Other species

- Twenty striped bass, most in the deep water around the TCS, all males. Figure 3.6 shows the largest striped bass that was found during the sampling.
- One white perch.
- No flathead catfish were seen.

Table 3.3. Summary of sampling data, May 13, 2010

Fish Species	Number of Fish Present
Hickory Shad	340
White Perch	1
Striped Bass	20
White Perch	1
Sea Lamprey (adult)	8
Alewives	0
American Shad	0

Figure 3.5. Fisheries biologists electro-survey the White Clay Creek on May 13, 2010.

Figure 3.6. DNREC Fisheries biologist holds the largest striped bass found in the White Clay Creek on May 13, 2010.

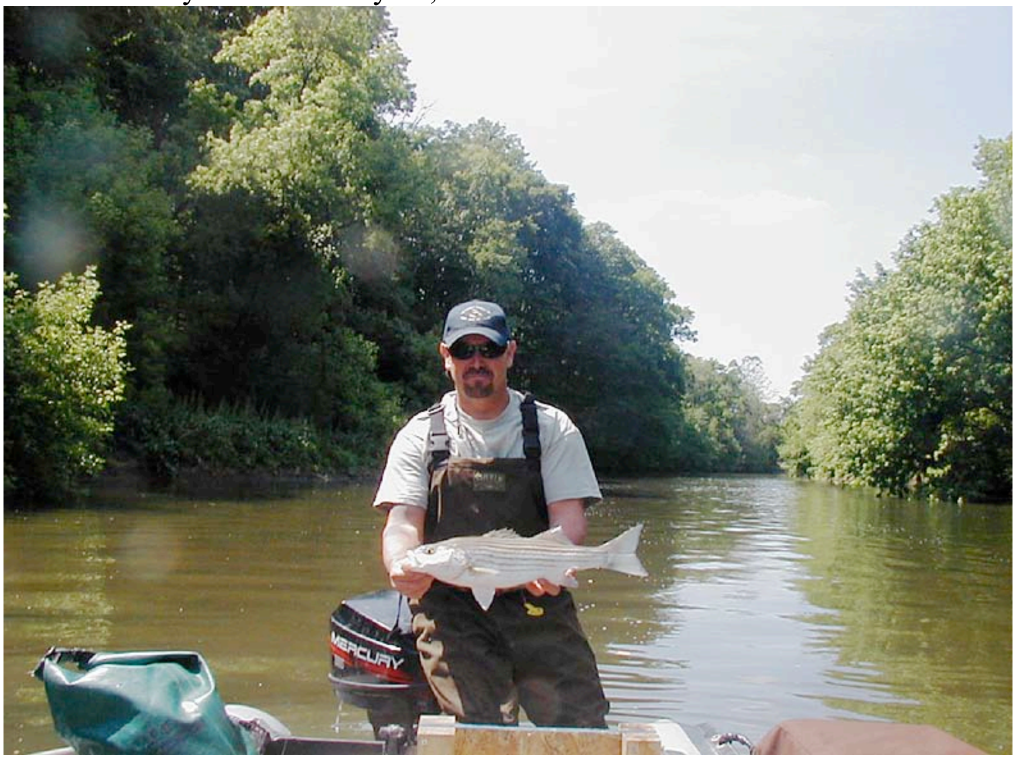
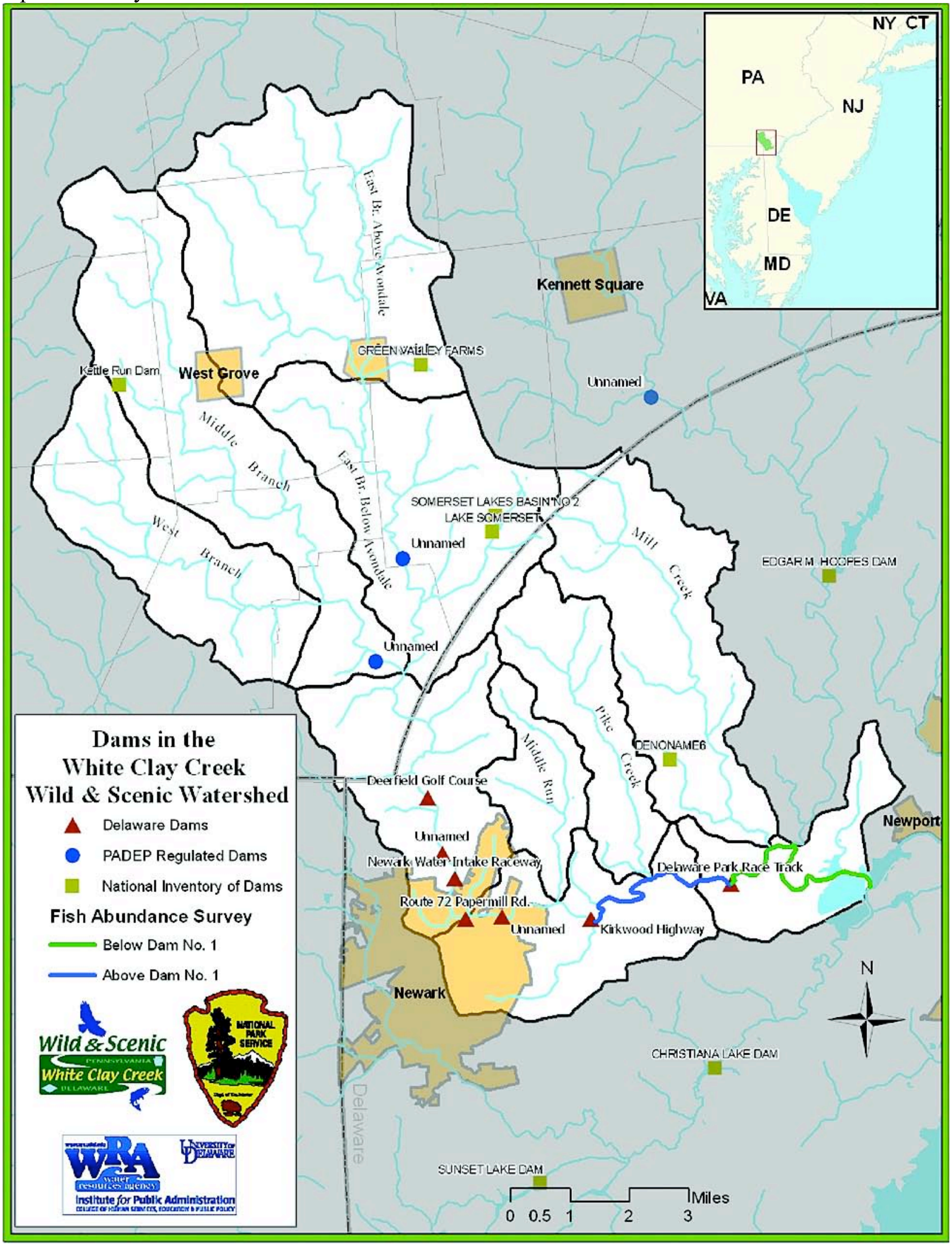


Figure 3.7. Location of Delaware DNREC fish abundance surveys along the White Clay Creek, April and May 2010



3.3 Current Distribution: Angler Log and Creel Survey

In order to obtain accurate data on the current distribution of American shad in the White Clay Creek, WRA, with the assistance of DNREC's Division of Fish and Wildlife, conducted an angler log and creel survey (April–May 2009) along the White Clay Creek. Graduate research assistants Erika Farris, Maureen Nelson, and Kelly Wolfe and staff members Martha Corrozi Narvaez, Gerald Kauffman, and Andrew Homsey collected data from April 19, 2009–May 29, 2009. Matt Fisher, fisheries biologist with DNREC's Division of Fish and Wildlife, provided the survey schedule, angler logs used for the interviews, and advisement. These data and analysis will be used to assist WRA's efforts to restore shad migration to the National Wild and Scenic White Clay Creek. WRA has also provided the final data and the analysis to DNREC.

Background Information
DNREC fisheries biologists determined the data-collection times for the six-week survey period (April 19, 2009–May 29, 2009). Over the period, the volunteer angler log and creel survey was conducted weekly on two randomly selected weekdays (Monday-Thursday), each Friday, and twice on one of the two weekend days. Over the six-week survey period, of the 25 scheduled days (or 32 scheduled times), only one day (2 scheduled times) was missed. These survey times were missed because they coincided with the University of Delaware's Commencement. A site visit occurred on the remaining 24 days at the specified times. This resulted in data collection on 12 weekdays, 6 Fridays, 3 Saturdays, and 3 Sundays. However, despite the surveyors' efforts, no data were collected on 11 of these days (or 12 scheduled times) because no anglers were present on the White Clay Creek at the designated survey time.

The survey instrument, created by DNREC, consisted of seven questions:
1. What county and state did you travel from to fish in the White Clay?
2. What species do you fish for most in the White Clay?
3. How many years have you fished the White Clay?
4. What was your fishing location?
5. How long did you spend fishing on this fishing trip?
6. What type of fishing equipment do you typically use?
7. How many and what species of fish did you catch (and did you release or keep them)?

The survey was conducted on the White Clay Creek at the Hale-Byrnes House on old Route 7, south of Stanton, Del., near the intersection of Route 4 and Route 7, upstream of the confluence of the Christina River and the White Clay Creek. The site is located on state property and open to the public with a parking lot that overlooks the Creek. Anglers park in the lot and fish upstream and downstream of the house. The shoreline upstream and downstream of the house has relatively little vegetation, making the creek highly accessible for fishing. United Water Delaware owns and operates a tidal capture structure (TCS), or inflatable dam, at this site and it is located just upstream of the house. Downstream of the house is a site where kayakers can put in, at which point the shoreline is vegetated and not easily accessible to anglers. Figure 3.8 shows the survey site.

Figure 3.8. Survey Site located at the historic Hale-Byrnes House on the White Clay Creek.

The data collected over the 24 days show a total of 63 anglers fishing on the White Clay Creek either below the TCS or between the Route 4 dam and the TCS. One-on-one interviews were conducted with 50 of the 63 anglers, a 79 percent response rate. The reasons interviews were not conducted include:

- The location of the angler made it difficult or impossible to approach.
- The angler was not interested in being interviewed.
- The angler had already been interviewed and was not interested in being interviewed but preferred to fill out the form that was given to them in a previous interview.
- Rain caused the angler to leave the site quickly.

Upon arrival the surveyor recorded an instantaneous count of anglers present at the site at the beginning of the survey period, totaling 22 anglers. Overall, the anglers were supportive of the project and willing to provide information about their fishing experiences on the White Clay Creek.

In addition to the surveys conducted at the Hale-Byrnes House, the surveyors distributed a copy of the survey to anglers (after they were interviewed) and to local fishing groups. The anglers were asked to fill out the survey each time he or she fished at or near the Hale-Byrnes House on the White Clay Creek. The anglers were asked to mail the completed surveys to DNREC after the six-week period ended. Forms were handed out to most anglers, but only one angler returned a completed form to DNREC, while five anglers refused interviews because they preferred completing the form over being interviewed. Since only one of these forms was returned, WRA does not recommend handing out the forms to the anglers in the future, with the assumption that the response rate will improve.

Data Analysis

It is important to note that the results from the one returned survey are only included in one part of the data analysis. The mail-in survey results are not included in the overall data analysis because the times the angler fished vary from the scheduled survey times. The catch per unit effort (CPUE) calculated includes a CPUE for both with and without the mail-in survey data due to the significant number of fish that are recorded on the mail-in survey. These values are provided in more detail below.

At the beginning of the survey period, United Water Delaware's TCS was inflated. An email was sent to United Water Delaware on April 20th stating that the TCS was impeding fish passage upstream. Sometime between April 21st and April 24th the TCS was deflated. The data collection results indicate that the total weekly hours anglers reported fishing decreased significantly from 24.41 hours in the first week when the dam was inflated, to 8.52, 4.33, 0.59, 11.5, and 1.25 hours respectively in the remaining weeks of the survey when the dam was deflated.

The majority of the anglers interviewed were from New Castle County, Del. (98%), while one angler was from Chester County, Pa. (Figure 3.9). Of the 50 interviews conducted, 45 anglers provided information on how many years he or she has been fishing on the White Clay Creek. The average number of years fished on the White Clay Creek was 12.4 years. Responses ranged from zero, or just starting to fish, to 55 years. Anglers reported that they fish for the following species (Table 3.4):

- Shad
- Bass (Smallmouth and Largemouth)
- Trout
- Catfish
- Anything

Shad are the most targeted fish species with 56 percent of the anglers responding that they fish for shad.

A total of 29 fish were reported caught, and 25 of the 29 fish that were reported caught were released, resulting in an average of 0.58 fish caught per angler and a mortality rate of 0.14 (Table 3.5). The interview results indicate that the hickory shad was the most commonly caught fish, totaling 12 of the 29 (41%) of the total fish. The second most commonly caught fish was the smallmouth bass. According to the anglers' reports, 6 of the 29 (21%) total fish caught were smallmouth bass (Figure 3.10). It is important to note that one angler reported catching one American shad; however, two anglers commented that they have never found American Shad in the White Clay Creek and that they have only observed American shad in the Brandywine River. Overall, the anglers reported catching the following fish species:

- American Shad
- Hickory Shad
- Channel Catfish
- Smallmouth Bass
- Largemouth Bass
- Sunny/Blue Gill

- Striped Bass
- Brown Trout
- Carp

The largest portion of fish, 14 of a total of 29 (48%), was caught in the first week of the survey period. It is important to note this was also the week with the largest number of hours fished, 24.41 hours. The total number of fish caught per week and total hours fished per week decreased over the survey period (Table 3.6).

The survey results of the on-site interviews indicate that the catch per unit effort (CPUE) for the six-week period was 0.57 fish per hour (Table 3.7). However, one mail-in survey received at the end of the study period added the following fish to the total fish count: 136 hickory shad, 1 smallmouth bass, and 2 redbreast sunfish. Using these additional data, the CPUE for the six-week period increased from 0.57 fish per hour to 3.32 fish per hour. If looking at only those anglers targeting shad (American or hickory), the CPUE for shad for the six-week period is 0.369 fish per hour. The CPUE for shad for the six-week period increases from 0.369 to 2.63 fish per hour when the data from the mail-in survey are included in the calculation.

The total estimated hours of angler effort from April 19–May 29 is 100.92 hours (Table 3.8). The total estimated angler effort from April 19–May 29 in terms of total number of angler trips is 210 (Table 3.9).

Of the 50 anglers interviewed, 49 responded to the question asking the amount of money spent (whole dollars) on his or her fishing trip. The average amount spent was $3.74 (Table 3.10). The total amount spent by all 49 respondents for the six-week survey period was $785.40.

Of the 50 anglers interviewed, 49 responded to the question asking how much time was spent on the river on this specific fishing trip. Based on the recorded data during the six-week survey period, the average amount of time spent per trip was 1.03 hours. This estimate may be slightly lower than the true average time, because some of the anglers who were interviewed were not finished fishing when the scheduled survey time ended and the angler may have continued to fish after the data collection time ended.

Forty-six of the anglers interviewed (92%) used spinning rods. All but one of the anglers interviewed were fishing from the shoreline or in the creek. One angler was observed launching a kayak equipped with a fishing pole. This angler was not interviewed because he did not return within the interview time period.

Figure 3.9. White Clay Creek Angler Origin 4/19/2009–5/29/2009

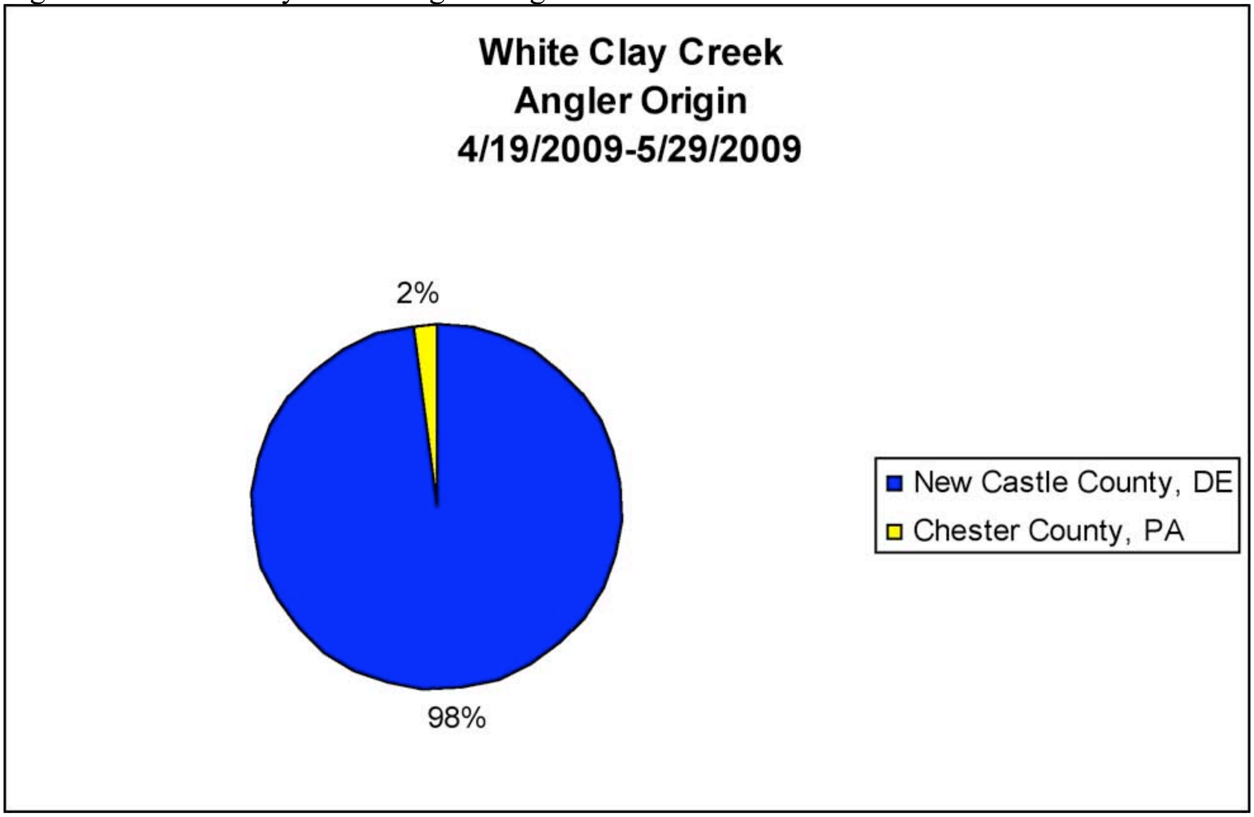


Figure 3.10. Fish Species Caught in White Clay Creek, 4/19/2009–5/29/2009

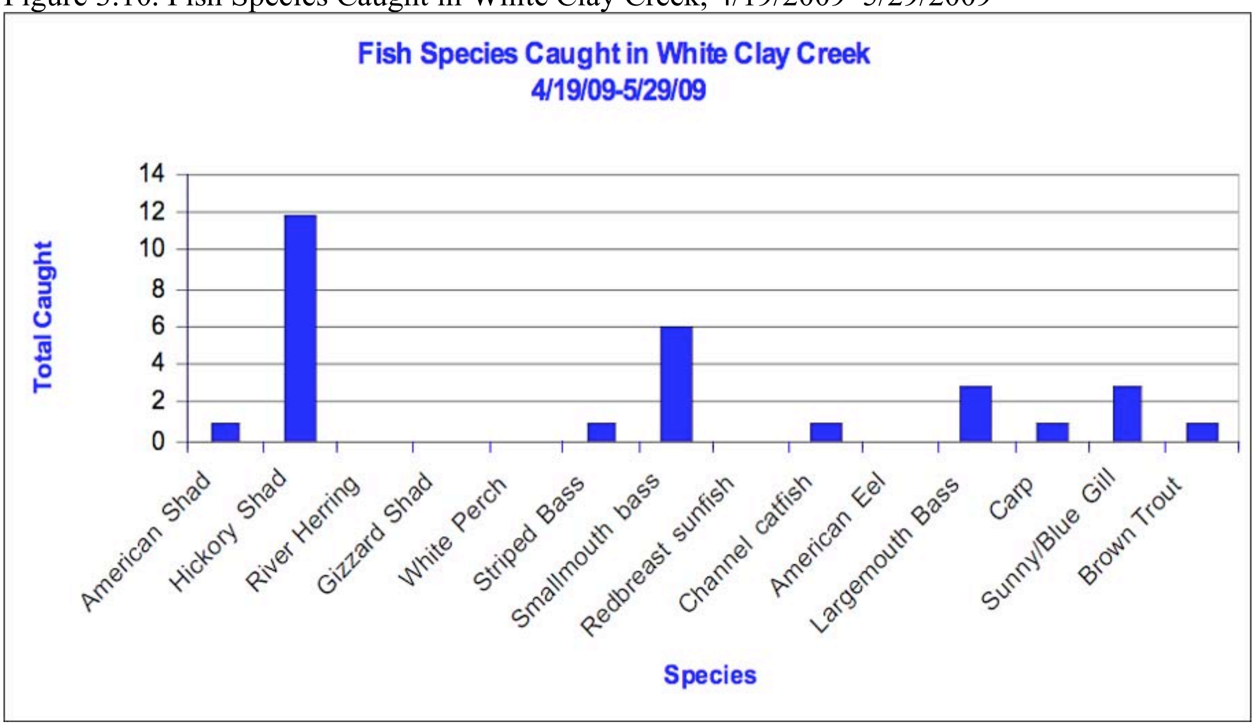


Table 3.4. Targeted Fish Species

Targeted Fish Species	Number of Anglers	Percent
Shad	28	56
Bass	8	16
Trout	5	10
Catfish	2	4
Anything/All	7	14
Total	**50**	**100**

Table 3.5. Fishing Mortality Rate

Species	Caught	Released	F
American Shad	1	1	0.00
Hickory Shad	12	8	0.33
River Herring	0	0	--
Gizzard Shad	0	0	--
White Perch	0	0	--
Striped Bass	1	1	0.00
Smallmouth Bass	6	6	0.00
Redbreast Sunfish	0	0	--
Channel Catfish	1	1	0.00
American Eel	0	0	--
Largemouth Bass	3	3	0.00
Carp	1	1	0.00
Sunny	3	3	0.00
Brown Trout	1	1	0.00
Total	**29**	**25**	**0.14**

Table 3.6. Weekly Hours Fished and Fish Caught

Week	Hours fished	Fish Caught	Percent of Total Fish Caught
Week 1	24.41	14	48
Week 2	8.52	8	28
Week 3	4.33	4	14
Week 4	0.59	0	0
Week 5	11.50	3	10
Week 6	1.25	0	0
Total	**50.60**	**29**	**100**

Table 3.7. Catch per Unit Effort (CPUE) Sunday-Saturday*

Week	Number Caught	Hours Fished	CPUE
April 19–25	14	24.41	0.573535
April 26–May 2	8	8.52	0.938967
May 3–9	4	4.33	0.923788
May 10–16	0	0.59	0
May 17–23	3	11.50	0.26087
May 24–30	0	1.25	0
CPUE for Six-Week Period	**29**	**50.60**	**0.573123**

* Species-specific CPUE is also available upon request.

Table 3.8. Total Angler Effort per Hour

Time	Hours	Anglers Interviewed	Hours/Anglers Interviewed	Instantaneous Count	Value for Equation	Total Angler Effort/Hr
Weekdays	21.19	20	1.06	11	A= 11.65	69.927
Friday	3.17	6	0.53	3	B= 1.59	4.755
Weekends	26.24	24	1.09	8	C= 8.75	26.240
Total	**50.60**	**50**	**2.68**	**22**		**100.920**

*Use the following formula (A*6)+(B*3)+(C*3)=total estimated angler effort from April 19-May 29 in terms of total angler hours.

Table 3.9. Total Angler Effort per Trip

Day	Value	Total Number of Anglers	Total Angler Effort/Trips
Weekdays	A	20	120
Fridays	B	6	18
Weekends	C	24	72
Total		**50**	**210**

*Use the following formula (A*6)+(B*3)+(C*3)=total estimated angler effort from April 19-May 29 in terms of total angler trips.

Table 3.10. Total Spent by Anglers

$3.74	Average dollars spent by anglers interviewed
210	Estimated angler trips
$785.40	Estimated fishing dollars spent on trip day from April 19–May 29

3.4 Current Distribution: Summary

The data collected in the two sampling events and the angler log and creel survey provide a valuable snapshot of the current distribution of anadromous fish in the White Clay Creek. These data also provide an excellent source of baseline pre-dam-removal information. These data show that anadromous species are present and spawning in the White Clay Creek and that they will benefit from dam removal and more upstream habitat after the dam removal. In addition to the benefits the dam removal will provide to anadromous fish, the local species that are present will gain from a restoration of habitat connectivity. Non-native and invasive species, such as flathead catfish that would also benefit from dam removal and cause damage to native populations, were not found to be present, which bears optimism for any future dam removal and habitat restoration projects. Subsequently, the data collected on the current distribution of anadromous fish on the White Clay Creek demonstrate that the fish ecology on a whole will benefit from dam removal, and ecologically there are no real drawbacks or downsides to consider for dam removal projects on the White Clay Creek.

3.5 Fish-Stocking Plan

WRA and the Brandywine Conservancy are committed to working with DNREC, the Pennsylvania Fish and Boat Commission (PFBC), and others to develop a fish stocking plan for the bi-state Christina River Basin shad-restoration efforts, focusing on the White Clay Creek and the Brandywine River, which together make up approximately three-fourths of the Christina River Basin.

Currently American shad are the focus of a long-term restoration program under the DNREC Division of Fish and Wildlife. DNREC has been working on shad restoration projects since 2000, when it closed sport and commercial harvests of American and hickory shad in order to promote restoration of the species in the Nanticoke system, part of the Chesapeake Bay watershed. The Division released its first batch of 91,000 fry as part of a joint effort involving the Maryland Department of Natural Resources and the Pennsylvania Fish and Boat Commission. The Division’s Nanticoke Shad Hatchery near Bethel, Del., was constructed in 2005. Last spring (June 2009) the hatchery released approximately 713,000 shad fry into the upper Nanticoke River and its tributaries, the largest number of fry produced since operations began in 2005, up from the 2008 record of 574,000. The White Clay Creek Shad Restoration Committee attended a tour of the hatchery in April 2010. Appendix B provides a detailed write-up of the Division’s hatchery.

Each year in mid-April, the Division collects adult American shad from their spawning grounds in the Nanticoke River and Deep Creek and transports them to the hatchery. The shad are placed in a 4,000-gallon circular tank for live spawning. After the shad have spawned, they are released, and after the eggs have hatched, the fry are released; both are released into the Nanticoke. This controlled environment is predicted to decrease the natural predation on the eggs and fry and increase their rate of survival. The shad fry will remain in the river and bay for their first year of life and then will migrate to the ocean where they will mature and grow for four to six years.

The Division has been an active participant in both the Brandywine River and the White Clay Creek Shad Restoration projects and is committed to the restoration of American shad in both systems. The Division has determined that the Nanticoke River stock is a unique genetic sub-population that is not appropriate for release in the Brandywine River or the White Clay Creek. The Division is committed to implementing a stocking plan once access to spawning habitat is restored, again in cooperation with the PFBC and others.

The Division has not yet developed a stocking plan, but there are several options that could be incorporated into a stocking plan for the bi-state Brandywine and White Clay Creek shad-restoration efforts. PFBC currently collects shad eggs and milt on the Delaware River at Smithfield Beach for use in a Pennsylvania State hatchery located in central Pennsylvania. The Delaware Shad Fisherman’s Association, a shad-restoration advocacy organization located in Easton, Pa., is discussing a possible new shad hatchery to be constructed in Easton, primarily for Lehigh River stocking purposes. It is possible that fry from this hatchery could be used to stock the Brandywine and White Clay. It is not known what the status of this new hatchery idea is, but it is probably at least several years off. Another preliminary idea is that the Stroud Water Research Center, located in the White Clay Creek watershed near Avondale, Pa., could construct and operate a shad hatchery specifically for Brandywine–White Clay stocking efforts. There appears to be some preliminary level of interest at Stroud in this concept. Another possible option is to construct and operate a shad hatchery at the University of Delaware, utilizing on-campus expertise. Further discussion with DNREC, PFBC, and others to develop a definitive shad-stocking plan is a necessary next step for the success of these restoration efforts.

CHAPTER 4: DAM SURVEY AND ANALYSIS

4.1 Dam Survey of the White Clay Creek in Delaware

The National Park Service's National Wild and Scenic Rivers program states that the designated rivers, "shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of future generations." Through its Resolution on the Importance of Habitat Connectivity to Commission-Managed Species (November 2009), the Atlantic States Marine Fisheries Commission has committed to work toward restoring diadromous fish with effective fish passage and suitable historic spawning and nursery habitat and that dam removal should be utilized whenever feasible. Currently, the White Clay Creek watershed, a designated National Wild and Scenic River, has seven known dams in the watershed that have the potential to block fish passage and prevent fish migration throughout the entire 107-sq.-mi. watershed (Figures 4.1 and 4.2). This chapter describes the research conducted to define the characteristics of each of the seven known dams, the extent to which each dam blocks fish passage, and the feasible options to remove or retrofit each barrier identified. Figure 4.3 is a detailed matrix of the data discussed in this section.

Figure 4.1. Dams in Delaware by elevation and distance from the mouth of the White Clay Creek.

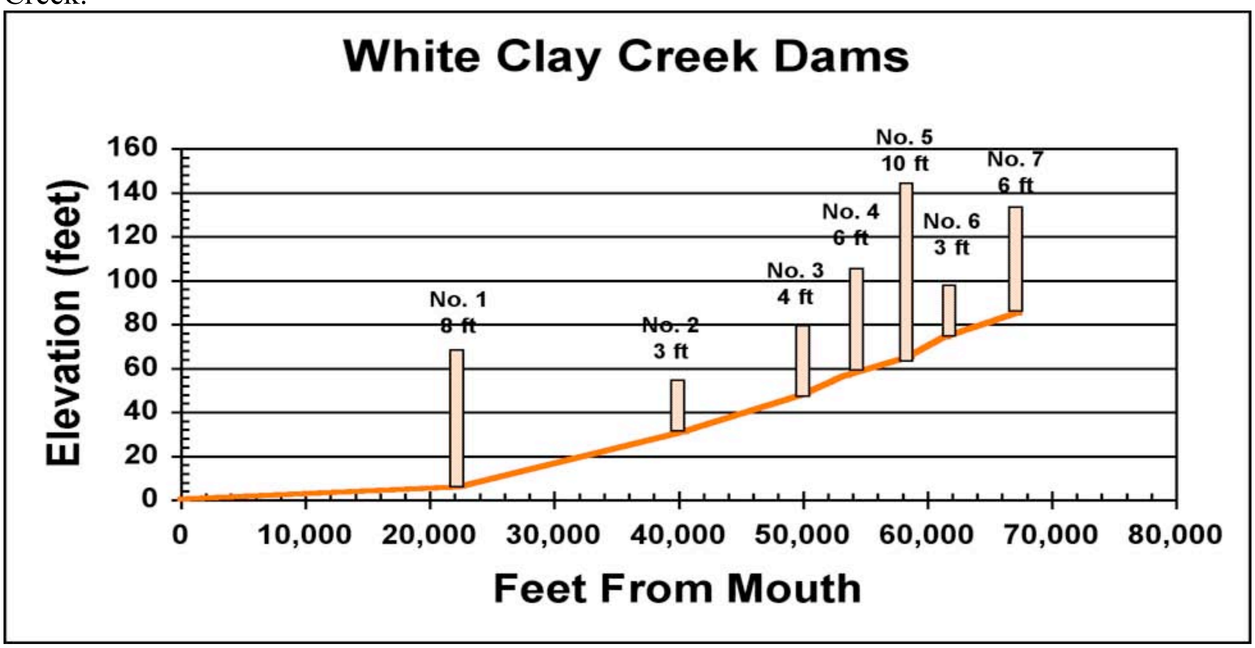


Figure 4.2. Aerial view showing the location of dams on the Delaware portion of the White Clay Creek

Figure 4.3. Analysis of the dams on the Delaware portion of the White Clay Creek

Dam	River Mile	Function	Owner	Condition	Limitations	Recommendation	Comments	Complexity for Removal
TCS (United Water Dam)	0.6	United water supply.	United Water Delaware	Inflatable dam. Inflated and deflated based on flows and spring migration. DRBC docket governs conditions of operation.	It is important to ensure that it is not inflated during the spring migration season.	None necessary, passable if operated in accordance with the DRBC docket.	This is not an obstacle to fish passage unless it is inflated.	None
Dam #1 (Delaware Park Dam)	4.1	None.	Delaware Racing Association	Rock-fill, approx. 3-8 ft. The dam is breached in several areas.	All construction must be done through the golf course, will need to get permission or access.	Dam removal.	Duffield has been working with Delaware Park on other site BMPs, Delaware Park is open to discussions related to the dam.	Low
Dam #2 (Red Mill Dam)	7.6	Pools water for historic mill race then flows to the Red Mill downstream of Red Mill Road.	Mac Shar Enterprises and New Castle County (own adjacent parcels).	Rock-fill, approx. 3 ft.	Access is limited by the CSX railroad. There may be access to the site from Red Mill Road through the paint ball course.	Dam removal, rock ramp with existing rocks.	Get contact information for the owner of the paint ball course and determine if it's feasible to use this area for access to the dam. Full dam removal may impact mill race, need further research.	Medium
Dam #3 (Karpinski Park Dam)	9.5	Sewer line crossing.	City of Newark	Concrete dam, approx. 2-3 ft., good condition.	Sewer line runs through the center of the dam.	Dam removal, rock ramp.	The sewer line is about 18-20 inch pipe, cannot be moved. Recommend rock ramp.	High
Dam#4 (Paper Mill Dam)	10.1	Hydraulic control for USGS White Clay Creek at Newark streamgage station, originally the NVF mill dam. Currently not a stable gaging station.	City of Newark	Concrete dam, approx. 6 ft. This dam is not in good condition, the south side is breeching and not stable.	USGS streamgage and possible historic site.	Dam removal, fishway.	If dam is notched this provides the option to use it periodically and close it when necessary but this would require maintenance and a high engineering cost. Dam may also be too high for notching to effectively allow shad to pass. The dam is too high for a rock ramp and the road bridge may be too close.	High
Dam #5 (Newark Intake Dam)	11.1	Newark Water Supply, intake dam for raceway that flows ¾ mile to White Clay Creek water treatment plant. Originally constructed for Curtis Paper Mill dam.	City of Newark	Concrete dam, approx. 10 ft. Patch work on dam, undercut and in need of a retrofit.	Serves as intake dam.	Dam removal, bypass channel.	Critical to Newark's water supply operation. Too high for notching or a rock ramp. Repairing this dam is in the works for the City of Newark. Integrity of dam must be considered. Rather than intake, install wellfield yet this option requires pumps and structure that will pool water that is not a dam.	High
Dam #6 (Creek Road Dam)	11.6	Pools water for fishing. Could be historic Indian fish weir.	N/A	Rock-fill, approx. 3 ft.	None	None necessary, passable.	Does not appear to be an obstacle to fish passage in current state.	None
Dam #7 (Deerfield Dam)	12.7	Pools water for intake to pump water to the Deerfield Country Club. Withdraw governed by DRBC docket.	State of Delaware	Rock-fill, approx. 6 ft., breeched (may be passable).	Unknown	Dam removal, rock ramp.	Rocks could be repositioned to create a rock ramp. May need to do work downstream to maintain stream integrity. Intake is used at this site. Determine whether dam is passable due to the significant breech.	Medium

Dam ID	TCS
Dam Name	United Water Delaware (UWD) Tidal Capture Structure (TCS)
River Mile	0.6
Latitude/Longitude	39.701799°/-75.649879°
Type/Height	Inflatable Structure/0–5 ft.
Owner	United Water Delaware
Impediment to Fish Passage	No
Complexity for Removal	None
Historic Status	None
Recommendation	The TCS shall be operated according to DRBC operating plan.

Dam Characteristics and Function

The White Clay Creek surface water intakes provide raw water to the adjacent Stanton Water Treatment Plant. United Water Delaware (UWD) maintains a tidal capture structure (TCS) located on the White Clay Creek, a tributary of the Christina River, at River Mile 70.73 (Delaware River), 10.3 (Christina River), and 1.8 (White Clay Creek), approximately 4,500 feet downstream from the Stanton intakes (Figures 4.4-4.6).

Figure 4.4. United Water Delaware's TCS (deflated), looking downstream

The TCS was constructed in 1997 for the primary purpose of improving UWD's ability to withdraw water from the White Clay Creek during low stream flows. The TCS facility is an inflatable structure approximately 125 feet long installed across the White Clay Creek. The structure inflates to approximately five feet above the stream bed. Bypass sluice gates are used for the purpose of controlling pass-by flows as required. The facility is controlled remotely from UWD's Stanton Water Treatment Plant to provide for immediate operational adjustments as needed. Operations include inflation to improve intake conditions or to provide protection from downstream contamination, which may be incoming with the tide. Deflation, to ensure upstream flooding is not exacerbated, is also part of the remotely controlled operation system. An adjustable sluice gate at the south side of the TCS controls passing flow. When deflated, the TCS is not an impediment to fish passage.

Figure 4.5. United Water Delaware's TCS (deflated) at right bank (looking downstream)

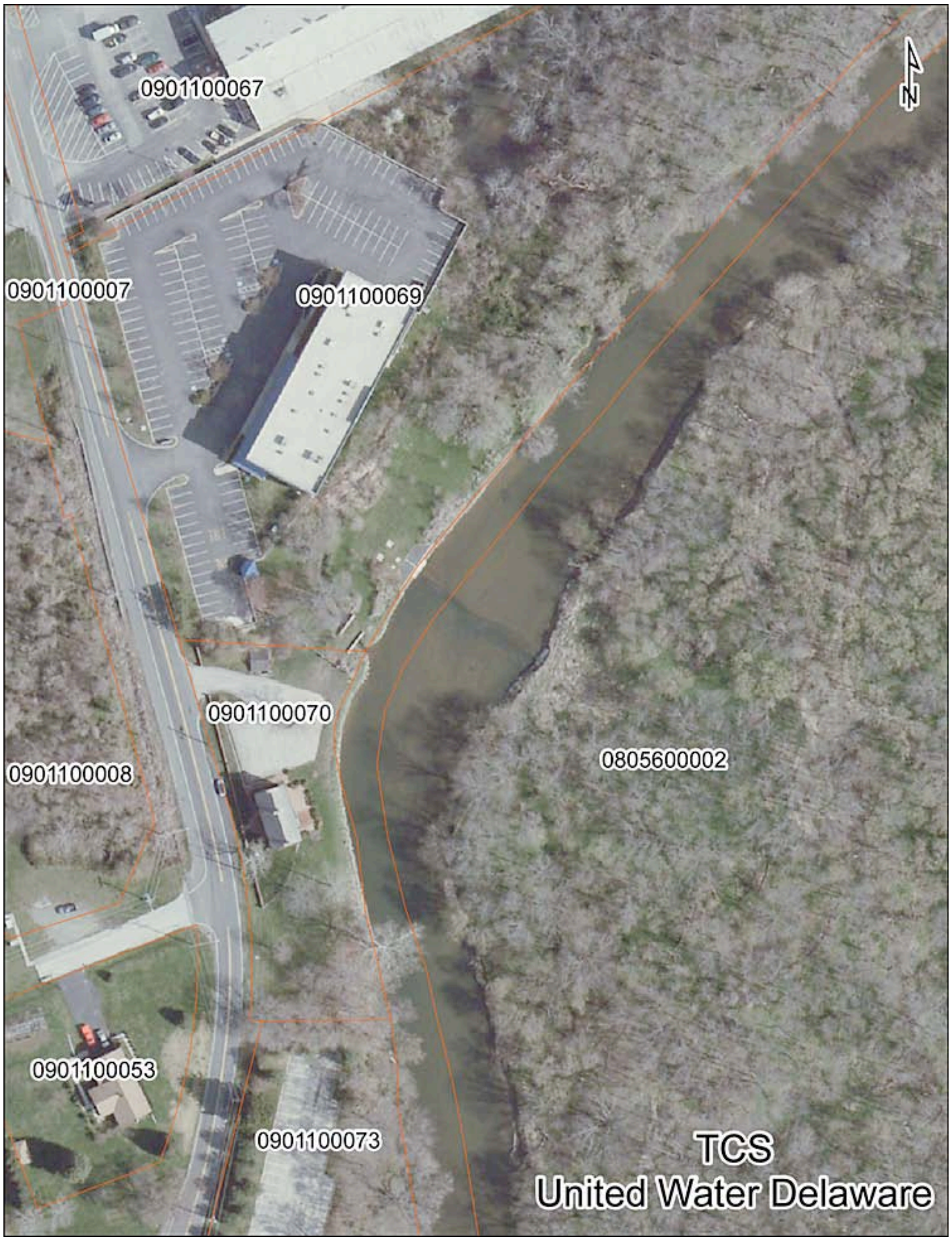
The Delaware River Basin Commission (DRBC) Docket No. D-96-50 CP-2 governs the operation of the TCS (Appendix B). This docket requires that the inflation and deflation of the TCS is based on regular monitoring of stream flows as published continuously by the Delaware Geologic Survey's calibrated stream gages and chloride levels. According to the DRBC Docket, the TCS can be inflated when the natural stream flow is less than 47.2 million gallons per day (mgd) but greater than or equal to 17.2 mgd and chlorides immediately at the outlet of the TCS bypass structure downstream of TCS are less than 250 ppm. The TCS may be operated twice daily (full inflation/deflation at tidal cycles). The minimum flow-by rate of 17.2 mgd must be maintained for the two, half-hour periods daily when there is an absence of tide immediately downstream of the TCS (DRBC Docket No. D-96-50 CP-2). Since 1997, the stream flows and chloride levels that trigger the inflation of the TCS typically occur in late summer/early fall.

In addition to abiding by the DRBC operating plan, DNREC's Division of Fish and Wildlife has advised UWD to consider the upstream and downstream fish migration in the TCS's operating procedure. UWD, with direction from the Division, has committed to consider the upstream (March 15–June 15) and downstream (September 15–October 15) migrations in the operation of the TCS. This addition to the current operating plan provides additional protection to the biology of the stream and further recognizes the need for the TCS to remain deflated during these ecologically significant time periods.

Figure 4.6. United Water Delaware's TCS, looking upstream (inflated).

Photo courtesy of United Water Delaware

Figure 4.7. Aerial Photograph of United Water Delaware's Tidal Capture Structure

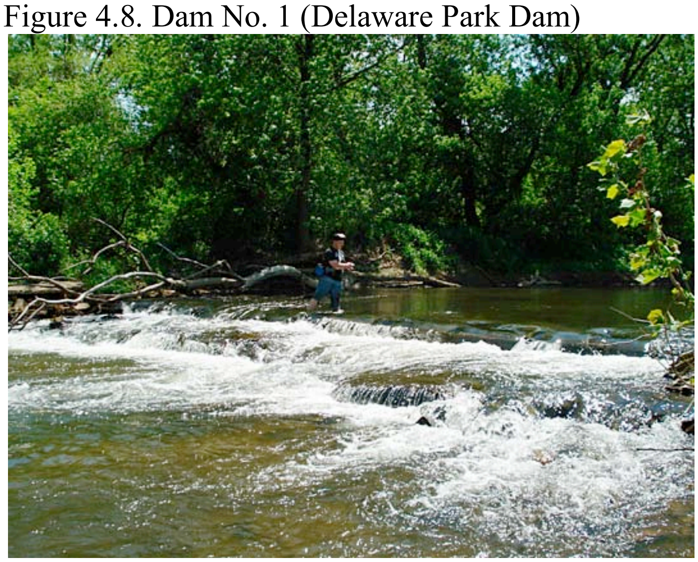


Dam ID	Dam No. 1
Dam Name	Delaware Park Dam
River Mile	4.1
Latitude/Longitude	39.698134°/-75.665308°
Type/Height	Stone and timber/3–8 ft.
Owner	Delaware Racing Association
Impediment to Fish Passage	Yes
Complexity for Removal	Low
Historic Status	None
Recommendation	Dam removal

Dam Characteristics and Function

Dam No. 1 (Delaware Park Dam) is a relatively low dam, approximately 3–8 feet high, made of stone-and-timber-crib construction and partially breached along the right bank (looking upstream) (Figures 4.8–4.10). Little is known about the original purpose of the dam, but it does appear on 1936 aerial photos and most likely pooled water for a long-defunct water diversion or mill. The dam is crumbling, and much of the deposited sediment has scoured over the dam during floods. The dam does not serve any purpose and has breached during floods at points with adjacent streambank erosion in need of reforestation. There is no known historical value to this dam.

Figure 4.8. Dam No. 1 (Delaware Park Dam)



Dam No. 1 is privately owned and is located at the White Clay Creek Country Club and Delaware Park horseracing track. According to the deed research conducted at the New Castle County Recorder of Deeds, the Delaware Racing Association (owner of the White Clay Creek

Country Club) owns the low dam. In 2009 the White Clay Creek Shad Restoration Committee met with the White Clay Creek Country Club's Director of Grounds, John Mizikar, and discussed removing this dam to restore shad migration and improve the habitat. Since this dam does not serve a function, Mr. Mizikar and the White Clay Creek Country Club expressed interest as willing partners in removing this dam and restoring fish habitat to this stretch of the White Clay Creek. If funding can be provided, the Director of Grounds is willing to work with the entity removing the dam to provide access points for the removal. According to the Delaware State Code and Constitution, the area of the creek flowing between the stream banks is in the public trust.

Figure 4.9. Channel resulting from the partial breech along the right bank of Dam No. 1

Fish abundance surveys through electrofishing conducted in April and May 2010 by Delaware DNREC Division of Fish and Wildlife biologists indicate Dam No. 1 is indeed the upstream barrier to anadromous fish migration, as up to 500 hickory shad were detected downstream from the dam and no anadromous fish were detected upstream from the barrier. The old rockfill and timber dam is breached along the right stream bank (looking upstream) and was heavily damaged by floods from Hurricane Floyd in September 1999 and Tropical Storm Henri in September 2003. The low dam is now surrounded by a golf course owned by the Delaware Racing Association (a willing project proponent) along the right bank of the creek. A forest lines the left bank.

Research has been conducted by accessing the National Historic Register and State Historic Preservation Office (SHPO) database of Delaware historic sites. There are no historic structures or archeological sites at or near the project site, and no historic records have been found for this dam. There are no known environmental concerns that exist at this site, as the project is in a National Wild and Scenic River, where water quality had improved substantially between 1995 and 2009.

Due to the nature of this site, the function and condition of the dam, the relative low cost of removing this dam, and the willing landowner, it is recommended to remove Dam No. 1 to restore fish passage at this site. Removing Dam No. 1 will cost approximately $74,980 (Table 4.1). In order to remove the dam WRA proposes the use of low-impact hydraulic construction equipment and working from the streambank to remove the stone and boulder-sized rocks and timber from the crumbling dam. The rocks can be repositioned along both streambanks at the site of the dam as part of a stream restoration. Timber and concrete debris will be removed from the site. The dam will be removed from right to left (looking upstream) starting at an existing breach in the dam to allow for a gentle flushing of accumulated sediment. Tree plantings, to reforest the streambanks and increase effective shading area to reduce stream water temperatures and improve spawning habitat, will be the final stage of the dam-removal project. Removing Dam No. 1 will reopen 3.5 miles of the White Clay Creek for anadromous-fish passage and restore 42 acres of the White Clay Creek substrate for anadromous-fish spawning.

Table 4.1. Dam No. 1 – Delaware Park (dam removal, rockfill)

Task	Effort	Budget
1. Public education/outreach	40 hrs @ $50/hr	$2,000
2. Field survey	40 hrs @ $50/hr	$2,000
3. Pre-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
4. Design drawings/specifications	40 hrs @ $80/hr	$3,200
5. Obtain permits	40 hrs @ $50/hr	$2,000
6. Remove Dam No. 1	Construction mobilization Rock/timber excavation Site cleanup	$ 5,000 200 CY @ $200/CY $40,000 $ 5,000
7. Stream habitat restoration	Reforest/purchase trees Volunteer labor	$2,000 $0
8. Post-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
9. Contingency costs	@15%	$9,780
Total		**$74,980**

Figure 4.10. Aerial photograph of Dam No. 1 (Delaware Park Dam) and adjacent tax parcels

Dam ID	Dam No. 2
Dam Name	Red Mill Dam
River Mile	7.6
Latitude/Longitude	39.689478°/-75.709395°
Type/Height	Rock-fill/3 ft.
Owner	Mac Shar Enterprises of New Castle County
Impediment to Fish Passage	Yes
Complexity for Removal	Medium
Historic Status	None
Recommendation	Dam removal

Dam Characteristics and Function

Dam No. 2 (Red Mill Dam) (Figure 4.8 and 4.9) is a rockfill dam that is approximately 3 feet high and 140 feet long. The dam pools water for a raceway for the Red Mill situated 60 feet upstream from the low dam along the left bank looking upstream. The dam is located immediately adjacent to an open natural area used for commercial recreation (paintball course, MacShar Enterprises) and an area of New Castle County open-space parkland on the opposite bank.

Figure 4.11. Dam No. 2 (Red Mill Dam)

Dam No. 2 constitutes more than a century of habitat impairment. The dam is an impediment to fish passage and has created a more lentic habitat upstream within its backwater influence. This dam is beginning to fail at points, creating severe downstream bank erosion and areas of heavy upstream sediment deposition. The failing banks are an increasing hazard to individuals utilizing the adjacent areas.

There are no known environmental concerns that exist at this site, as the project is in a National Wild and Scenic River, where water quality had improved substantially between 1995 and 2009. Research has been conducted by accessing the National Historic Register and SHPO database of Delaware historic sites. No historic records have been found for this dam, yet there is a historic mill structure (Red Mill) and race situated 60 feet upstream along the left bank (looking upstream). The historic mill dam and race is mentioned in the deed to the property adjacent to Dam No. 2. A hydraulic study was conducted to determine the impact of removing Dam No. 2 on the historic Red Mill Race. The methodology and results of the hydraulic study are included in Appendix C. Both depths of flow and flow velocity will be impacted, though slightly, by removing the dam.

Removing Dam No. 2 is recommended. Removal of the dam will restore the natural characteristics of this portion of the creek and improve habitat and fish passage. Dam removal and stream restoration will alleviate the failing banks while adding to the aesthetics of the area. The removal of the dam will likely offer flood relief for smaller- to moderate-storm events. Due to the volume of sediment that is currently released during moderate storm events and the height of the dam, dam removal should not release a significant volume of sediment trapped behind the dam. Removing Dam No. 2 will cost approximately $63,480 (Table 4.2).

Table 4.2. Dam No. 2 – Red Mill (dam removal, rockfill)

Task	Effort	Budget
1. Public education/outreach	40 hrs @ $50/hr	$2,000
2. Field survey	40 hrs @ $50/hr	$2,000
3. Pre-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
4. Design drawings/specifications	40 hrs @ $80/hr	$3,200
5. Obtain permits	40 hrs @ $50/hr	$2,000
6. Remove Dam No. 2	Construction mobilization Rock excavation Site cleanup	$ 5,000 150 CY @ $200/CY $30,000 $ 5,000
7. Stream habitat restoration	Reforest/purchase trees Volunteer labor	$2,000 $0
8. Post-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
9. Contingency costs	@15%	$8,280
Total		**$63,480**

Figure 4.12. Aerial photograph of Dam No. 2 (Red Mill Dam) and adjacent tax parcels

Dam ID	Dam No. 3
Dam Name	Karpinski Park Dam
River Mile	9.5
Latitude/Longitude	39.689857°/-75.737641°
Type/Height	Concrete/4 ft.
Owner	City of Newark
Impediment to Fish Passage	Yes
Complexity for Removal	High
Historic Status	None
Recommendation	Dam removal, rock ramp

Dam Characteristics and Function

Dam No. 3 (Karpinski Park Dam) is approximately 4 feet high, 10 feet wide, and 75 feet long (Figures 4.13–4.15). Dam No. 3, the highest of the first three dams, is of concrete construction and encases an 18–20-inch sanitary sewer line. The dam is located immediately adjacent to City of Newark parkland on both banks.

Figure 4.13. Dam No. 3 (Karpinski Park Dam)

It is believed that the original utility crossing was constructed at or below streambed grade, and, due to erosion and streambed incising, the utility crossing is currently functioning as a dam. The sewer line, encased in the concrete that creates the dam, runs along the north side of White Clay

Creek and serves downtown Newark, Delaware (population approximately 28,000). The sewer line is a necessity for the City's wastewater-transmission system, yet it prevents fish passage.

There are no known environmental concerns that exist at this site, as the project is in a National Wild and Scenic River, where water quality had improved substantially between 1995 and 2009. Research has been conducted by accessing the National Historic Register and SHPO database of Delaware historic sites. No historic records have been found for this dam.

Figure 4.14. Dam No. 3 (Karpinski Park Dam)

Several options to remove the barrier have been discussed. These include notching the dam, installing a sewer line siphon, placing a pump near the crossing and lowering the sewer line below the streambed, and reburying the sewer line below the streambed. Due to the location of the sewer line, the size of the service area, and the cost of relocating the sewer line, a rock ramp appears to be the most feasible option to restore fish passage at this site. Installing a rock ramp will cost approximately $97,980. As in all fish-passage projects, dam removal is the preferred option but would cost significantly more, $287,960. Tables 4.3 and 4.4 provide cost estimates for the two fish passage options.

The dam owner, the City of Newark, has demonstrated strong support for the project and is willing to work toward a solution that works for both fish habitat and migration and their utility. Discussions with the City have led to the recommendation that a rock ramp would be the best option to restore fish passage. A rock ramp is significantly cheaper than relocating the sewer line, and the height of the dam makes this a feasible solution.

Table 4.3. Dam No. 3 – Karpinski Park (dam removal, concrete)

Task	Effort	Budget
1. Public education/outreach	40 hrs @ $50/hr	$2,000
2. Field survey	40 hrs @ $50/hr	$2,000
3. Pre-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
4. Design drawings/specifications	80 hrs @ $80/hr	$6,400
5. Obtain permits	40 hrs @ $50/hr	$2,000
6. Remove Dam No. 3	Construction mobilization Concrete excavation/hauling Sanitary sewer relocation Site cleanup	$10,000 140 CY @ $800/CY $112,000 1000 LF @ $100/LF $100,000 $10,000
7. Stream habitat restoration	Reforest/purchase trees Volunteer labor	$2,000 $0
8. Post-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
9. Contingency costs	@15%	$37,560
Total		**$287,960**

Table 4.4. Dam No. 3 – Karpinski Park (rock ramp)

Task	Effort	Budget
1. Public education/outreach	40 hrs @ $50/hr	$2,000
2. Field survey	40 hrs @ $50/hr	$2,000
3. Pre-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
4. Design drawings/specifications	40 hrs @ $80/hr	$3,200
5. Obtain permits	40 hrs @ $50/hr	$2,000
6. Install rock ramp, Dam No. 3	Construction mobilization Rock ramp Site cleanup	$ 5,000 3 vert. ft @ $20,000/vert. ft $60,000 $ 5,000
7. Stream habitat restoration	Reforest/purchase trees Volunteer labor	$2,000 $0
8. Post-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
9. Contingency costs	@15%	$12,780
Total		**$97,980**

Figure 4.15. Aerial photograph of Dam No. 3 (Karpinski Park Dam) and adjacent tax parcels

Dam ID	Dam No. 4
Dam Name	Paper Mill Dam
River Mile	10.1
Latitude/Longitude	39.689285°/-75.749001°
Type/Height	Concrete/6 ft.
Owner	City of Newark
Impediment to Fish Passage	Yes
Complexity for Removal	High
Historic Status	None
Recommendation	Dam removal, fishway

Dam Characteristics and Function
Dam No. 4 (Paper Mill Dam) is a concrete dam approximately 6 feet high (Figure 4.16–4.18). This dam is in poor condition; the south side is breeching and not stable. Dam No. 4 is located adjacent to City of Newark property.

Figure 4.16. Dam No. 4 (Paper Mill Dam)

Prior to its use by the Curtis Paper Mill, this dam was associated with National Vulcanized Fibre (NVF). The dam currently functions as a hydraulic control for the USGS White Clay Creek at Newark streamgage station. This is not a stable gaging station. The USGS must consistently readjust the rating curve of the gaging station because the dam is constantly capturing rocks, tree limbs, and debris, which changes the stream's cross-section.

The dam owner, the City of Newark, has provided strong support for this project and is willing to work with the committee to find a solution that works for the City and improves habitat and fish passage. The City's main interest in this dam is its role as a gaging station. The Delaware Geological Survey (DGS) and USGS were consulted on removing the dam and its impact on the gaging station. The USGS representative noted that removing the dam would not eliminate the possibility of the gaging station remaining at this site and it would not have a negative impact on future data collected at this site. Minor adjustments would need to be made at the gaging station to adjust for any changes at the site.

There are no known environmental concerns that exist at this site, as the project is in a National Wild and Scenic River, where water quality had improved substantially between 1995 and 2009. Research has been conducted by accessing the National Historic Register and SHPO database of Delaware historic sites. No historic records have been found for this dam.

The height of Dam No. 4 limits several fish-passage options, including notching, because shad will not be able to effectively pass over the dam. A rock ramp is not feasible at this site because the dam is in close proximity to Paper Mill Road. Due to the current condition of the dam and site characteristics, the preferred option to restore fish passage is to remove Dam No. 4. It will cost approximately $320,160 to remove Dam No. 4. A secondary, less preferred, relatively cheaper option, is to install a fishway, an approximate cost of $168,830. Table 4.5 and 4.6 provide cost estimates for the two fish-passage options.

Figure 4.17. Dam No. 4 (Paper Mill Dam)

Table 4.5 Dam No. 4 – Paper Mill Road (dam removal, concrete)

Task	Effort	Budget
1. Public education/outreach	40 hrs @ $50/hr	$2,000
2. Field survey	40 hrs @ $50/hr	$2,000
3. Pre-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
4. Design drawings/specifications	80 hrs @ $80/hr	$6,400
5. Obtain permits	40 hrs @ $50/hr	$2,000
6. Remove Dam No. 4	Construction mobilization Concrete excavation/hauling Site cleanup	$20,000 300 CY @ $800/CY $240,000 $20,000
7. Stream habitat restoration	Reforest/purchase trees Volunteer labor	$2,000 $0
8. Post-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
9. Contingency costs	@15%	$41,760
Total		**$320,160**

Table 4.6 Dam No. 4 – Paper Mill Road (fishway)

Task	Effort	Budget
1. Public education/outreach	40 hrs @ $50/hr	$2,000
2. Field survey	40 hrs @ $50/hr	$2,000
3. Pre-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
4. Design drawings/specifications	60 hrs @ $80/hr	$4,800
5. Obtain permits	40 hrs @ $50/hr	$2,000
6. Install fishway, Dam No. 4	Construction mobilization Fishway Site cleanup	$5,000 6 vert. ft @ $20,000/vert. ft $120,000 $5,000
7. Stream habitat restoration	Reforest/purchase trees Volunteer labor	$2,000 $0
8. Post-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
9. Contingency costs	@15%	$22,030
Total		**$168,830**

Figure 4.18. Aerial photograph of Dam No. 4 (Paper Mill Road Dam) and adjacent tax parcels

Dam ID	Dam No. 5
Dam Name	Newark Intake Dam
River Mile	11.1
Latitude/Longitude	39.698930°/-75.752620°
Type/Height	Concrete/10 ft.
Owner	City of Newark
Impediment to Fish Passage	Yes
Complexity for Removal	High
Historic Status	None
Recommendation	Dam removal, bypass channel

Dam Characteristics and Function
Dam No. 5 (Newark Intake Dam) is a concrete dam approximately 10 feet high. The dam is in need of repair; there are patchwork repairs on the dam, and it is undercut. Dam No. 5 is adjacent to City of Newark property.

Figure 4.19. Dam No. 5 (Newark Water Supply)

The dam was originally constructed for the Curtis Paper Mill. The dam now serves as the City of Newark's intake dam for the raceway that flows three-quarters of a mile to the White Clay Creek water-treatment plant. The dam is critical to Newark's water supply operation. Repairing this dam will be necessary in the next 5–10 years. The integrity of the dam must be considered when analyzing fish-passage options.

Research has been conducted by accessing the National Historic Register and SHPO database of Delaware historic sites. No historic records have been found for this dam. There are no known environmental concerns that exist at this site, as the project is in a National Wild and Scenic River, where water quality had improved substantially between 1995 and 2009.

Figure 4.20. Dam No. 5 (Newark Water Supply)

Dam No. 5 is too high for notching or a rock ramp. The White Clay Creek Shad Restoration Committee met with the City of Newark (dam owner) to discuss alternative options to restore fish passage at this dam. City officials are in full support of this project and restoring fish passage but the City emphasized its need to supply residents with drinking water from the White Clay Creek. The following options to achieve these goals were discussed.

- Remove the dam and install a wellfield. There is a concern about the geology of the site and whether there is enough porosity in the rock for a wellfield to work. Installing a wellfield will ensue a significant cost due to the cost to pump the water and the maintenance required. These costs may be offset by the costs involved in repairing the dam. Newark can treat 5 mgd (3,500 gallons/minute) with 12-13 required pass by in the stream; other wells in Newark can pump up to 400 gallons/minute. This would require about 15 wells (10 wells plus 5 for back up) to sustain the existing pumping capacity. The "Rainey well" (one column with several feeder arms and 1-2 pumps) may be the most suitable well option to consider. A potential site for the wellfield may be the state park area or the Paper Mill Road park. The City of Newark recommends a study to further investigate this option. The estimated cost to remove the dam and install a wellfield is approximately $1,861,160.

- Repair the dam and use the existing mill race as a bypass channel. The mill race is located in the state park and could serve as a bypass channel for the fish to use to migrate upstream around the dam. Bypass channels have proven to be less effective than dam removal. The cost for this option is significantly cheaper, approximately $159,160.

Table 4.7 and 4.8 provide cost estimates for the two fish-passage options.

Table 4.7. Dam No. 5 – Newark Intake Dam (dam removal, concrete)

Task	Effort	Budget
1. Public education/outreach	40 hrs @ $50/hr	$2,000
2. Field survey	40 hrs @ $50/hr	$2,000
3. Pre-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
4. Design drawings/specifications	80 hrs @ $80/hr	$6,400
5. Obtain permits	40 hrs @ $50/hr	$2,000
6. Remove Dam No. 5	Construction mobilization Concrete excavation/hauling Install wellfield Site cleanup	$20,000 700 CY @ $800/CY $560,000 5 mgd @ $200,000/mgd $1,000,000 $20,000
7. Stream habitat restoration	Reforest/purchase trees Volunteer labor	$2,000 $0
8. Post-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
9. Contingency costs	@15%	$242,760
Total		**$1,861,160**

Table 4.8. Dam No. 5 – Newark Intake Dam (bypass channel)

Task	Effort	Budget
1. Public education/outreach	40 hrs @ $50/hr	$2,000
2. Field survey	40 hrs @ $50/hr	$2,000
3. Pre-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
4. Design drawings/specifications	80 hrs @ $80/hr	$6,400
5. Obtain permits	40 hrs @ $50/hr	$2,000
6. Install bypass channel, Dam No. 5	Construction mobilization Fishway Site cleanup	$10,000 10 vert. ft @ $10,000/vert. ft $100,000 $10,000
7. Stream habitat restoration	Reforest/purchase trees Volunteer labor	$2,000 $0
8. Post-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
9. Contingency costs	@15%	$20,760
Total		**$159,160**

Figure 4.21. Aerial photograph of Dam No. 5 (Newark Intake Dam) and adjacent tax parcels

Dam ID	Dam No. 6
Dam Name	Creek Road Dam
River Mile	11.6
Latitude/Longitude	39.705389°/-75.756974°
Type/Height	Rockfill/3 ft.
Owner	N/A
Impediment to Fish Passage	No
Complexity for Removal	None
Historic Status	None
Recommendation	None necessary, not an impediment to fish passage.

Dam Characteristics and Function

Dam No. 6 is no longer functioning as a dam and is not an obstacle to fish passage (Figure 4.22). It is likely that the rockfill dam was breached during heavy flood events including tropical storms Henri and Jeanne in September 2003 and 2004.

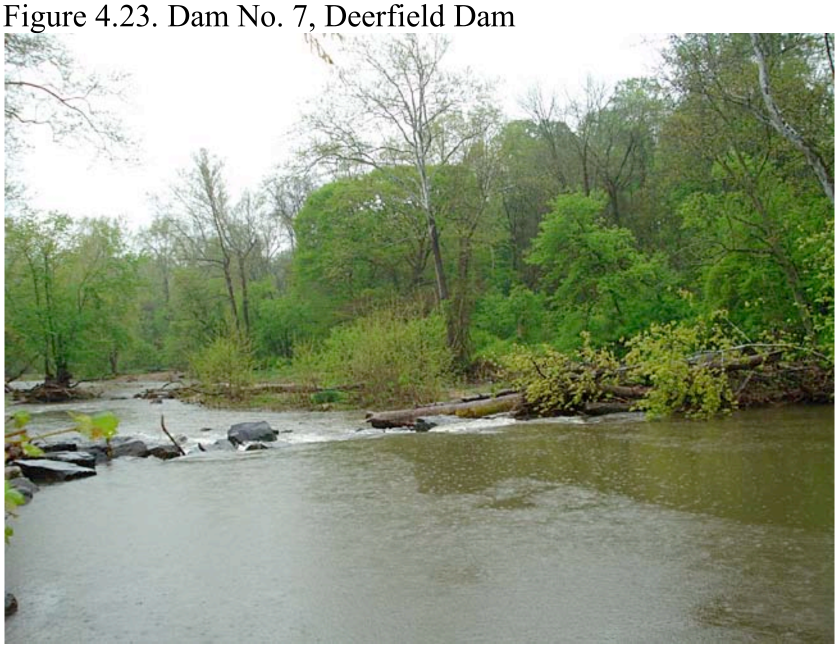
Figure 4.22. Aerial photograph of Dam No. 6 (Creek Road Dam) and adjacent tax parcels

Dam ID	Dam No. 7
Dam Name	Deerfield Dam
River Mile	12.7
Latitude/Longitude	39.718669°/-75.761227°
Type/Height	Rockfill/6 ft.
Owner	State of Delaware
Impediment to Fish Passage	Yes
Complexity for Removal	Medium
Historic Status	None
Recommendation	Dam removal, rock ramp

Dam Characteristics and Function

Dam No. 7 (Deerfield Dam) is a rockfill dam, approximately 6 feet high (Figure 4.23–4.25). The dam on the Deerfield Country Club property, owned by the state of Delaware, pools water for the surface water intake to pump water to the Deerfield Country Club's golf course. The intake is currently being used to irrigate the golf course in times of drought. Approximately 600 gallons per minute are pumped from the creek. The country club has three additional groundwater wells used for irrigation that pump a total of approximately 150 gallons per minute.

Figure 4.23. Dam No. 7, Deerfield Dam



Deerfield was originally built by the DuPont Company for its employees in 1955; the club was called Louviers Country Club. In 1994 MBNA purchased the club from DuPont and built the new clubhouse ballroom and recreational building, renaming it Deerfield Golf & Tennis Club. In 2005 the state of Delaware acquired the 145-acre property to protect the land from development.

In 1977 DRBC granted Louviers Country Club permission to withdrawal surface water, for the sole use of irrigating fairways, tees, and greens. According to the DRBC Docket No. D-77-25, which governs the withdraw, whenever flows at the USGS gage no. 01478500 near the project site fall below the seven-day once-in-ten-year low flow of the White Clay Creek, 7.3 cfs (4.7 mgd); water shall not be withdrawn for irrigation.

There are no historic structures or archeological sites at or near the project site. Research has been conducted by accessing the National Historic Register and SHPO database of Delaware historic sites. There are no known environmental concerns that exist at this site, as the project is in a National Wild and Scenic River, where water quality has improved substantially between 1995 and 2009.

Based on cost estimates, dam removal is recommended for Dam No. 7. The cost difference between installing a rock ramp and dam removal is minimal, $113,160 and $159,160, respectively (Table 4.9 and 4.10). Although dam removal is recommended, it is important to consider that this dam pools the water that is pumped to irrigate the golf course. This surface-water source has a significantly higher pumping capacity than the groundwater sources on the property. Due to this, a rock ramp may be a more feasible alternative. Table 4.9 and 4.10 provide cost estimates for the two fish-passage options.

Figure 4.24. Dam No. 7, Deerfield Dam

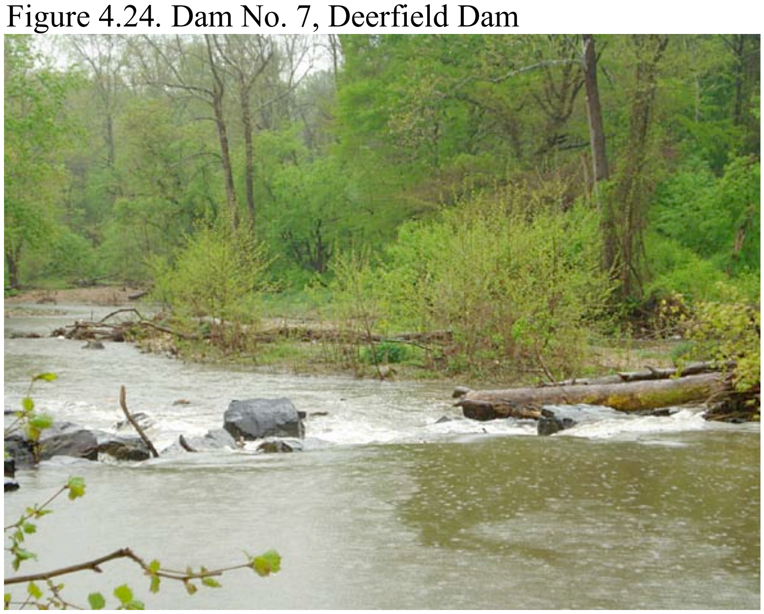


Table 4.9. Dam No. 7 – Deerfield Dam (dam removal, rockfill)

Task	Effort	Budget
1. Public education/outreach	40 hrs @ $50/hr	$2,000
2. Field survey	40 hrs @ $50/hr	$2,000
3. Pre-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
4. Design drawings/specifications	60 hrs @ $80/hr	$6,400
5. Obtain permits	40 hrs @ $50/hr	$2,000
6. Remove Dam No. 5	Construction mobilization Rock excavation Site cleanup	$10,000 500 CY @ $200/CY $100,000 $10,000
7. Stream habitat restoration	Reforest/purchase trees Volunteer labor	$2,000 $0
8. Post-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
9. Contingency costs	@15%	$20,760
Total		**$159,160**

Table 4.10. Dam No. 7 – Deerfield Dam (rock ramp)

Task	Effort	Budget
1. Public education/outreach	40 hrs @ $50/hr	$2,000
2. Field survey	40 hrs @ $50/hr	$2,000
3. Pre-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
4. Design drawings/specifications	40 hrs @ $80/hr	$6,400
5. Obtain permits	40 hrs @ $50/hr	$2,000
6. Install rock ramp, Dam No. 7	Construction mobilization Install rock ramp Site cleanup	$10,000 6 vert. ft @ $10,000/vert. ft $60,000 $10,000
7. Stream habitat restoration	Reforest/purchase trees Volunteer labor	$2,000 $0
8. Post-project monitoring/fish abundance survey	40 hrs @ $50/hr	$2,000
9. Contingency costs	@15%	$14,760
Total		**$113,160**

Figure 4.25 Aerial photograph of Dam No. 7 (Deerfield Dam) and adjacent tax parcels

4.2 Dams in the Pennsylvania Portion of the White Clay Creek Watershed

Native American Uses of the Creek

Native Americans inhabited the White Clay Creek watershed starting some 10,000 years ago, in the early Archaic Period, according to the archeological record (*http://www.dcnr.state.pa.us/stateparks/parks/whiteclaycreek.aspx#history*). Small bands lived a "hunter and gatherer" lifestyle and formed only temporary camps. Gradually, as climate warmed and technologies increased food-gathering capabilities, populations grew, and the seasonal camps grew into more permanent villages. By the time the lower White Clay Creek and the land now comprising the White Clay Creek State Preserve was "sold" to William Penn in 1683 by Lenni Lenape Chief Kekelappen, there was an "Indian Town" named Opasiskunk, located at the confluence of the Middle and East branches of White Clay Creek, according to a survey map of 1699. This area is now part of the Preserve.

Opasiskunk was a large settlement, covering several acres. Frequent flooding over the past two centuries obliterated all surface evidence of this once-important settlement (*http://www.dcnr.state.pa.us/stateparks/parks/whiteclaycreek.aspx*). The village was almost certainly located at the confluence of the two creeks due in large part to the presence there of migratory fish, and particularly shad.

According to local historian Marshall Joseph Becker, "In the case of the Lenape, it is clear that anadromous fish collecting was central to their way of life" (Becker, 2006). Although they have been absent from the area since about 1730, the Lenni Lenape tribal website still recalls the importance of shad and shad fishing (*http://www.delawaretribeofindians.nsn.us/fishing.html*). An illustration of the tribe engaged in fishing is described - “A fish weir consisting of wooden stakes arranged in a fence-like manner, and weighted fish net, are being used to gather the shad so that they may be easily speared, or caught with bare hands. A previous catch of fish has already been gutted, split and placed near a fire-hearth and over racks to dry for storage. Anadromous shad swim up the major rivers by the millions in March and April to spawn in freshwater streams. Abundant fish enabled the Lenape to congregate in larger numbers than usual, and to remain at one site for longer times.” Their numbers in the White Clay were likely at least in the thousands, and the fish provided an early and readily available source of fresh protein in the spring.

These Native American rock and brush weirs could be considered the first dam-like structures in the White Clay Creek, though none of them were permanent and none are known to survive.

The Colonial and Early American Periods

Things quickly changed in the colonial and early American period. As a steep river located near to eastern markets and ports, the White Clay Creek, like the Brandywine and others in the region, was heavily utilized as a source of water power for a variety of types of mills. Research suggests there were approximately 41 dams in the Pennsylvania portion alone, including approximately 22 on the East Branch (Table 4.11 and Figure 4.30).

Including additional dams known and unknown in Delaware, there were at its height probably at least 50 dams in the watershed. All were what we would consider ‘small’ dams (‘run-of-the-river’ dams, less than 15 feet high). For nearly 300 years, these dams have blocked migratory fish runs, to the point where today many people have never heard of shad.

Table 4.11. Historic dams on the Pennsylvania portion of the White Clay Creek watershed.

Tributary	Dams
East Branch	22
Middle Branch	14
West Branch	5
Mainstem	0
Total	**41**

The White Clay Creek watershed as a whole was undergoing rapid changes on several fronts during the 18th and early 19th centuries, as were many others in the region. The watershed was once almost completely forested. The dams were built over the same time period as most of those watershed forests were cleared. This clearing, combined with the plowing of the soils, led to large-scale, massive surface erosion across much of the watershed. The results were still measureable when the USDA, Soil Conservation Service (now Natural Resource Conservation Service, or NRCS) conducted soil surveys throughout Chester County in the mid-1900s (USDA, Soil Conservation Service, et al., Soil Survey Chester and Delaware Counties, Pennsylvania, May 1963). Over 60 percent of the White Clay watershed was identified as moderately or severely eroded. That is, 25–75 percent, or greater than 75 percent, respectively, of the top soil horizons were transported off the land and into and along the streams (see Map 2, *Historic Soil Erosion, White Clay Watershed* of USDA, Soil Conservation Service, et al., Soil Survey Chester

Erosion, White Clay Watershed of USDA, Soil Conservation Service, et al., Soil Survey Chester and Delaware Counties, Pennsylvania, May 1963). Some was washed down towards the Christina and, ultimately, Delaware Bay, while much of it was deposited in layers from 2–10 feet thick on the floodplains of the creeks.

These soils, sometimes called “legacy” sediments, can still be seen as the steeply incised banks and the filled and smothered floodplains of the creeks. Much of this soil is subject to re-erosion and is thought to contribute significantly to much of the watershed’s impaired status today. The White Clay today is part of a Clean Water Act–based clean-up effort, along with the rest of the Christina Basin.

Today’s Dams

Of the 41 known dams that have been built in Pennsylvania on the White Clay Creek, three are known to still remain, one of which is failing, while another appears to be abandoned. It is possible there are additional existing dams today that could be discovered with further research and explorations. Most of the rest fell into neglect long ago and without regular costly maintenance have been breached over the course of time by large storms and relentless floodwaters.

Middle Branch Dams

There is one remaining dam on the Middle Branch of the White Clay Creek, and that is located in London Britain Township near London Tract Road, close to where the Middle Branch meets the East Branch to become the mainstem (Figures 4.26 and 4.27). This approximately four-foot-high dam does not appear to have been maintained recently and woody debris is strewn across the top and collected in wads on it, and pieces of concrete are slumping off the top. This dam, or an earlier version of it, may have been built sometime soon after 1714 by John Evans, a Welsh Baptist emigrant who purchased the land from commissioners of William Penn. The race is over one-quarter-mile long and parallels Sharpless Road, passing near the remaining manor house. In approximately 1829, the property was purchased by John Yeatman, in whose family it remained throughout most of the 19th century. Now this is part of the White Clay Creek Preserve. The mill race still exists and is still partially fed by the dam and river overflows, though the entrance is clogged with debris.

Figure 4.26. White Clay Creek Preserve Dam – Yeatman's (or "Yetman's") Mill Dam

Figure 4.27. Slumping concrete at the race entrance of the former Yeatman's Mill Dam

East Branch Dams

There is one remaining dam on the East Branch of White Clay Creek, which is located immediately south of the Village of Landenberg in New Garden Township along Penn Green Road (Figure 4.28). The dam, about five feet high, appears to be in good repair and abuts a short mill race that presumably once fed into an adjacent factory building (it was identified in the 1847 Painter and Bowen *Map of Chester County, PA*, as the Thorne's Factory Dam) but no longer does. The property here is listed as owned by Cornelia D. Crawford at 135 Penn Green Road.

Figure 4.28. Landenberg Dam – called Thornes Factory Dam in 1847

West Branch Dams

There is one remaining dam on the West Branch, which is located in Franklin Township in a wooded valley off Hillcrest Drive (Figure 4.29). It was identified in the 1847 Painter and Bowen *Map of Chester County, PA*, as the Fuey's Paper Mill Dam. Other than a short mill race, there do not appear to be any other buildings or structures located nearby. Today the dam sits alone at the bottom of sloped hillsides with residential houses on both hilltops. In fact, the land occupied by the dam is listed as having two owners – Thomas A. and Faye G. Sullivan of 224 Guernsey Road and James and Helene M. Dowd of 52 Beechwood Drive.

Figure 4.29. West Branch Dam – called Fuey's Paper Mill in 1847.

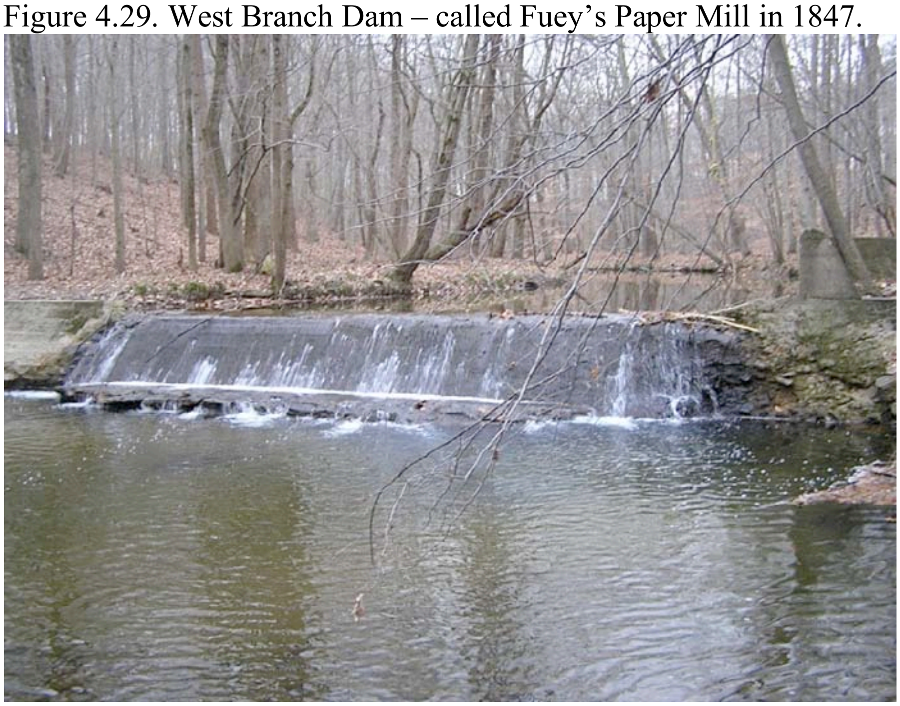
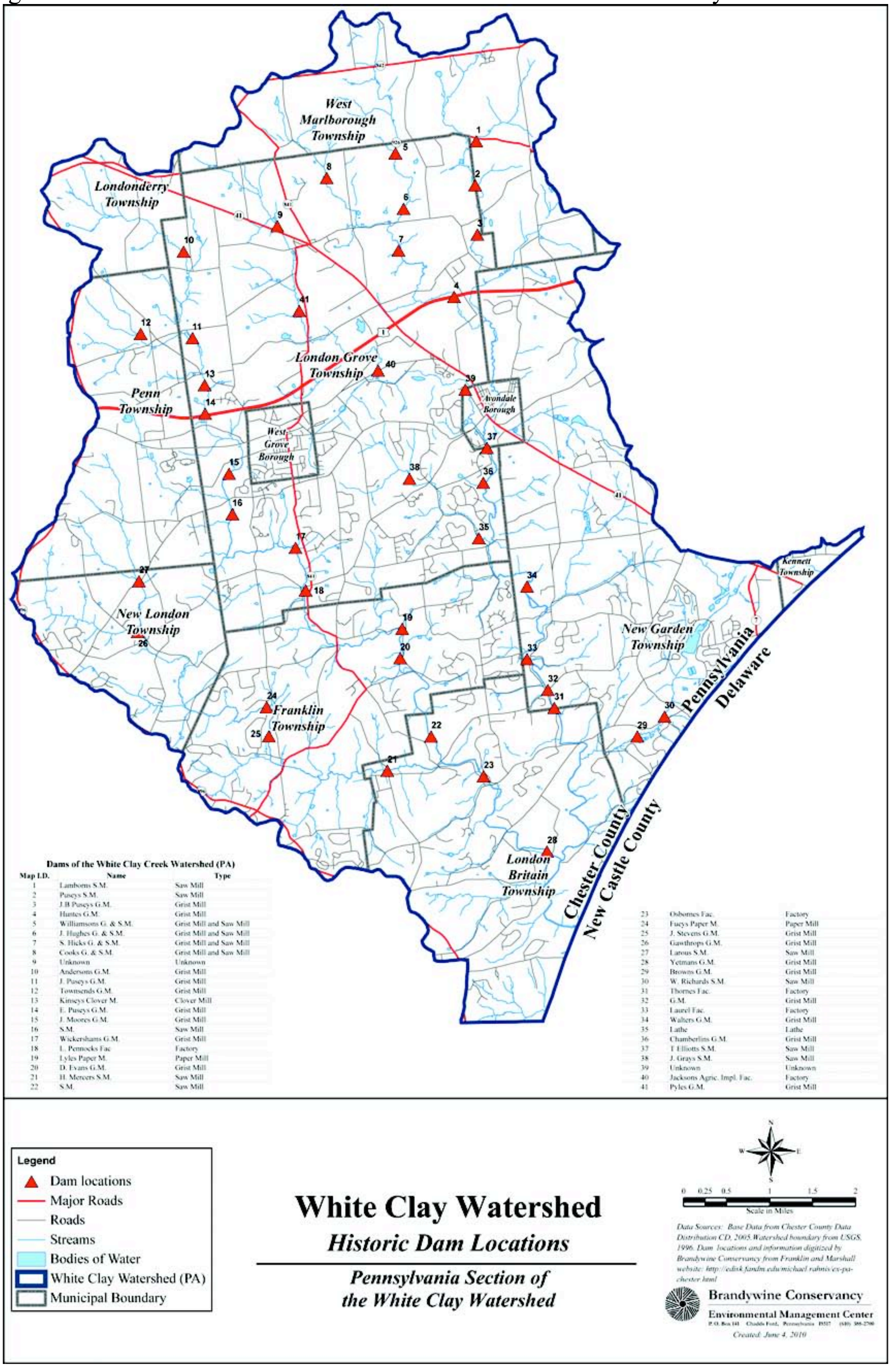


Figure 5.30. Historic dam locations in the Pa. section of the White Clay Creek watershed



Dams of the White Clay Creek Watershed (PA)

Map I.D.	Name	Type
1	Lamborns S.M.	Saw Mill
2	Puseys S.M.	Saw Mill
3	J.B Puseys G.M.	Grist Mill
4	Huntes G.M.	Grist Mill
5	Williamsons G. & S.M.	Grist Mill and Saw Mill
6	J. Hughes G. & S.M.	Grist Mill and Saw Mill
7	S. Hicks G. & S.M.	Grist Mill and Saw Mill
8	Cooks G. & S.M.	Grist Mill and Saw Mill
9	Unknown	Unknown
10	Andersons G.M.	Grist Mill
11	J. Puseys G.M.	Grist Mill
12	Townsends G.M.	Grist Mill
13	Kinseys Clover M.	Clover Mill
14	E. Puseys G.M.	Grist Mill
15	J. Moores G.M.	Grist Mill
16	S.M.	Saw Mill
17	Wickershams G.M.	Grist Mill
18	L. Pennocks Fac	Factory
19	Lyles Paper M.	Paper Mill
20	D. Evans G.M.	Grist Mill
21	H. Mercers S.M.	Saw Mill
22	S.M.	Saw Mill
23	Osbornes Fac.	Factory
24	Fuceys Paper M.	Paper Mill
25	J. Stevens G.M.	Grist Mill
26	Gawthrops G.M.	Grist Mill
27	Larous S.M.	Saw Mill
28	Yetmans G.M.	Grist Mill
29	Browns G.M.	Grist Mill
30	W. Richards S.M.	Saw Mill
31	Thornes Fac.	Factory
32	G.M.	Grist Mill
33	Laurel Fac.	Factory
34	Walters G.M.	Grist Mill
35	Lathe	Lathe
36	Chamberlins G.M.	Grist Mill
37	T Elliotts S.M.	Saw Mill
38	J. Grays S.M.	Saw Mill
39	Unknown	Unknown
40	Jacksons Agric. Impl. Fac.	Factory
41	Pyles G.M.	Grist Mill

4.3 Permitting for Dam Construction Activities in Delaware

Federal, state, and local permits must be acquired prior to implementing fish-passage projects on the White Clay Creek. The two primary permits required for dam removal are issued by the DNREC Division of Water Resources' Subaqueous Lands section and the U.S. Army Corps of Engineers. Examples of permits that may be required:

- Section 404 of the Clean Water Act authorization through the U.S. Army Corps of Engineers, Philadelphia, Pa.
- Section 401 of the Clean Water Act, Water Quality Certification (as delegated) through DNREC's Wetlands and Subaqueous Land Section.
- State of Delaware Coastal Zone Management Consistency Certification through DNREC's Division of Soil and Water.
- State of Delaware Subaqueous Lands Permit through DNREC's Wetlands and Subaqueous Land Section.
- Threatened and endangered species, State Historic Preservation Office (SHPO), NOAA-National Marine Fisheries Service (NMFS), and EPA coordination.

WRA has consulted with the Delaware SHPO as part of this project, and none of the dams in this study are known to have national or state historic significance. Prior to dam construction activities on any of these dams, WRA will work with SHPO to conduct a Phase I Cultural Survey. Local stormwater, floodplain, and soil erosion/sedimentation control permits will also be necessary for dam construction activities from the New Castle Conservation District and New Castle County Land Use Department.

Federal and state permit applications are reviewed monthly by a Joint Permit Review Committee in Dover, Del. The committee coordinates permit applications and policies and includes representatives from all relevant state and federal regulatory and advisory agencies.

CHAPTER 5: PUBLIC EDUCATION AND OUTREACH

5.1 White Clay Creek Shad Restoration Committee

WRA has utilized the National Park Service's Wild and Scenic White Clay Creek Watershed Management Committee and the committee's Fish and Wildlife subcommittee to serve as an umbrella group for this project. Through this group and agencies with which WRA has worked, WRA assembled and facilitated the White Clay Creek Shad Restoration Committee. This committee is a great example of a public-private partnership.

The White Clay Creek Shad Restoration committee, facilitated by UD WRA with assistance from the Brandywine Conservancy, is made up of approximately 20 members and consists of a diverse group of stakeholders. Committee members are from government, nonprofit, academic, and private entities, including:

- Federal, state, and local government representatives (NOAA, DNREC, City of Newark)
- Technical experts (Duffield Associates, DNREC)
- Anglers (Trout Unlimited)
- Wild and Scenic White Clay Creek River Administrator

Table 5.1 lists the names and organizations of the White Clay Creek Shad Restoration Committee members.

Since its inception, this group has met three times (May 28, 2009, September 8, 2009, and February 18, 2010) and has served multiple beneficial purposes. In forming the group, WRA gathered key stakeholders for the initial meeting (May 28, 2009). Requests were sent to technical experts, government representatives, dam owners, anglers, White Clay Creek watershed nonprofit groups, and interested stakeholders. WRA also requested that the initial group of participants reach out to key representatives that were not part of the initial committee meeting. Suggestions and contacts for additional committee members were made, and the committee was formed.

Committee meetings and email communication have proven to be beneficial for the exchange of information among committee members and stakeholders. Dam function, ownership, dam conditions, fish ecology and abundance, public outreach activities, and funding opportunities have been key issues discussed by the committee. One example of a benefit of this committee and the beneficial communication among members was discussions between United Water Delaware (UWD) and DNREC's Division of Fish and Wildlife. These two groups had not formerly had the opportunity to work together until they were invited to participate on the White Clay Creek Shad Restoration Committee. Due to their involvement with the committee, staff from the Division of Fish and Wildlife and UWD (operators of the TCS) have met to discuss revising the operating plan for the TCS. Previously UWD considered only the flows and salinity levels when operating the TCS. Since the Division of Fish and Wildlife has met with them, UWD is now aware of the impact of the TCS on fish migration, and UWD has committed to consider the spring and fall migrations in the operating plan for the TCS. In addition, through the communication among this group, research activities related to this project such as dam tours, electrosurveys, hydraulic studies, and funding opportunities have been achieved. The committee is also committed to the long-term success of this process and the implementation of the recommendations developed through this project.

Table 5.1 White Clay Creek Shad Restoration Committee Members

Name	Organization
Bethany Bearmore	NOAA Restoration Center
Sarah Chatterson	Water Resources Agency, IPA, University of Delaware
Erika Farris*	Water Resources Agency, IPA, University of Delaware
Matt Fisher	DNREC
George Haggerty	New Castle County
David Hawk	White Clay Watershed Association
Andrew Homsey	Water Resources Agency, IPA, University of Delaware
Doug Janiec	Duffield Associates
Gerald Kauffman	Water Resources Agency, IPA, University of Delaware
Robert Lonsdorf	Brandywine Conservancy
Erin McVey	Water Resources Agency, IPA, University of Delaware
Bill Mentzer	Trout Unlimited
Roy Miller	DNREC
Martha Corrozi Narvaez	Water Resources Agency, IPA, University of Delaware
Ed O'Donnell	White Clay Creek Wild and Scenic Management Committee
Susan Skomorucha	United Water Delaware
Maureen H.S. Nelson*	Water Resources Agency, IPA, University of Delaware
Craig Shirey	DNREC
Roy Simonson	City of Newark
Linda Stapleford	WCC Wild and Scenic Management Committee
Jim Takarski	Angler

*former member

5.2 Public Education and Outreach Materials

WRA, with assistance from the Brandywine Conservancy, created a poster to illustrate the White Clay Creek Shad Restoration project. This poster (Figure 5.1) has been used at public events to teach the general public about shad, their life cycle and habitat, and the project to restore American shad to the White Clay Creek watershed. This public education tool was used at two public outreach events and will be used for future public outreach events.

The first event during which the poster was used, held October 2009, was the University of Delaware's annual Coast Day. This event is held each fall in Lewes, Del., and introduces thousands of people to research and topics in marine, coastal, and water resources each year. Thousands of visitors learned about American shad's historic and cultural significance, biology, and life cycle, and the overall goals of the project to restore American shad to the White Clay Creek watershed. The second event, Creek Fest, is an annual event held in the White Clay Creek

State Park. This event includes nature talks and activities, displays, fly-fishing demonstrations, opportunities to learn about native gardening, historical information about the White Clay, and other education opportunities. WRA displayed this poster and discussed the shad restoration project at each of these events. The poster will be used at additional public outreach events in the future.

WRA has submitted articles to several University publications about the Wild and Scenic White Clay Creek Shad Restoration project. These articles (Figure 5.2 and 5.3) have publicized the project to University faculty, staff, and students.

Figure 5.1. Restoring American Shad on the White Clay Creek Wild and Scenic River: a public outreach poster

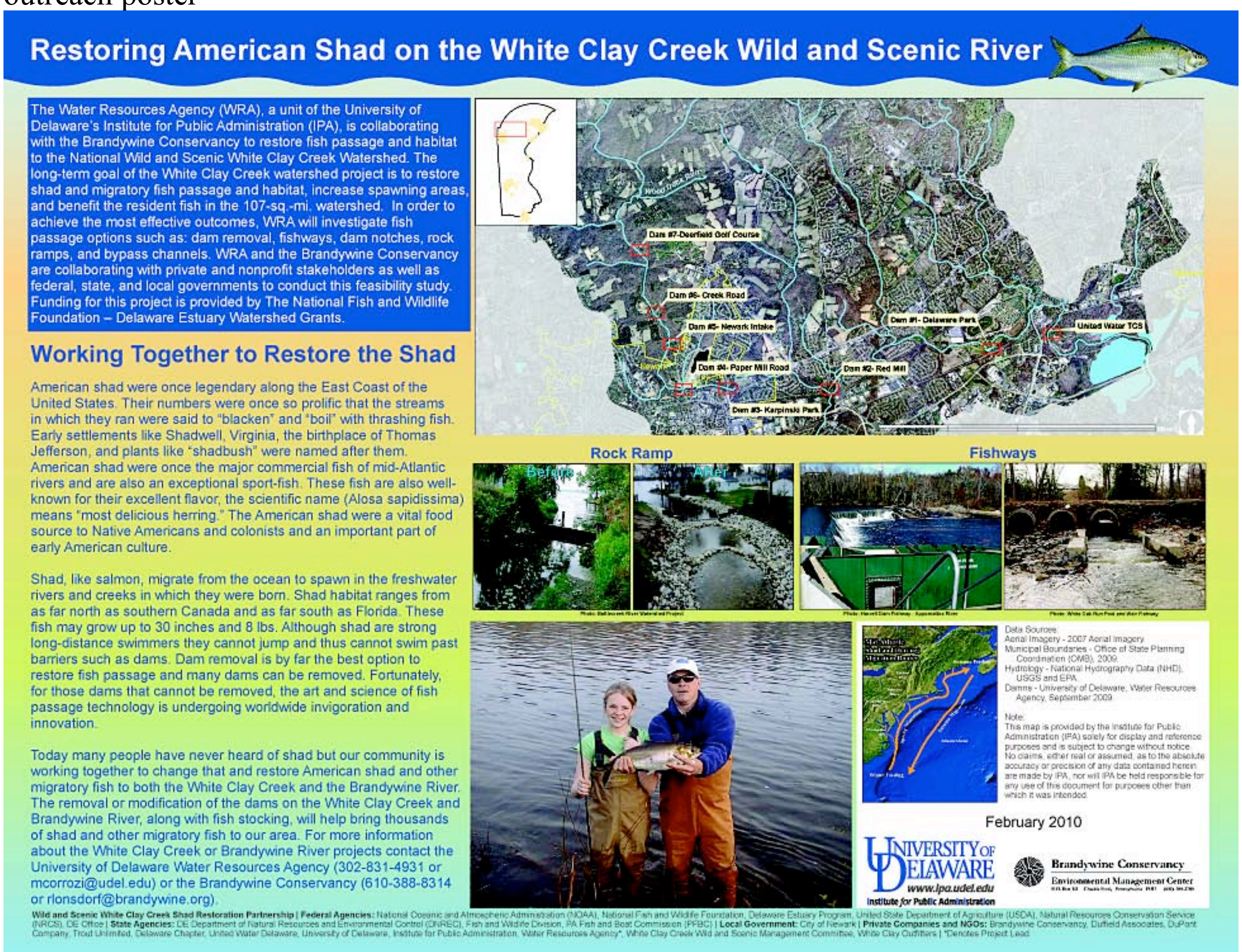


Figure 5.2. IPA web article describing the White Clay Creek shad restoration project grant

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SHARE

IPA Receives $40K Grant

Foundation grant funds research to help restore shad in White Clay Creek watershed

Fishermen like IPA's **Ed O'Donnell** may look forward to angling for shad in White Clay Creek as the result of this funded research.

IPA's **Water Resources Agency (WRA)** will receive $39,978 to assess the feasibility of restoring fish passage and habitat to the National Wild and Scenic White Clay Creek Watershed. The project began in March and will run through June 2010. IPA assistant policy scientist **Martha Corrozi Narvaez** is the principal investigator.

The grant, administered by the National Fish and Wildlife Foundation (NFWF), is one of 17 projects being undertaken by a number of regional organizations that are striving to improve the environment of the Delaware Estuary—the tidal portion of the Delaware River. NFWF funds total $650,503, and considering matching funds raised by the recipients, the total amount being funneled toward estuary projects is $1.44 million.

"I'm excited and honored that we've received funding to conduct a multidisciplinary study on this popular regional fishing area in collaboration with stakeholders throughout the White Clay Creek watershed," **Narvaez** says.

The long-term goal of the White Clay Creek watershed project is to restore shad and migratory fish passage and habitat, increase spawning areas, and benefit the resident fish in the 107-sq.-mi. watershed. To achieve this, WRA will conduct a feasibility study for restoring fish passage to the federally designated Wild and Scenic White Clay Creek.

Longtime area fisherman and IPA policy scientist **Ed O'Donnell** commented, "Research projects such as this are critical to the continued health and vitality of White Clay Creek. Without such research, the enjoyment that people like me—and future generations—get from fishing is in jeopardy."

In order to identify and achieve the most effective options for restoring fish passage and habitat, WRA will collaborate with the Brandywine Conservancy, the City of Newark, DNREC, Delaware Park, Duffield Associates, United Water Delaware, White Clay Outfitters, Trout Unlimited, the White Clay Wild and Scenic Watershed Management Committee, citizens, and interested stakeholders.
Project tasks include the following:

- **Research to determine abundance and extent of the fish population.**
- **Create a shad-restoration committee.**
- **Conduct a literature review of successful fish-restoration projects on the East Coast.**
- **Carry out a field survey and inventory of existing dams along the White Clay Creek in Delaware and Pennsylvania.**
- **With DNREC, conduct fish-abundance surveys along the tidal and freshwater White Clay Creek.**
- **Explore the feasibility of restoring fish passage utilizing a variety of techniques.**
- **Develop an alternatives analysis, based on environmental, ownership, historic-value, and cost criteria.**
- **Create and implement public education and outreach programs.**
- **Develop a fish-stocking plan.**
- **Recommend the most feasible fish-passage alternative with cost estimates for each dam.**

This project will serve as an expansion of the Brandywine Shad Restoration effort, and research will be done in partnership with Christina Basin watershed-restoration efforts. WRA has a long-term commitment to implementing the recommendations that will be set forth in this study.

A final report will be developed summarizing this information and recommending the most feasible fish-passage alternatives for each dam. The final recommendations will be provided to the White Clay Creek Watershed Management Committee, the National Park Service Wild and Scenic Program, and DNREC in order to begin implementation based on the recommendations provided in the report.

photo courtesy of Sean O'Donnell

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Figure 5.3. IPA web article describing the White Clay Creek shad restoration project

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SHARE

White Clay Creek Shad-Restoration Project

IPA partners to restore American shad to National Wild and Scenic River

A team of scientists and students from the IPA's **Water Resources Agency (WRA)** have partnered with biologists from the Delaware Division of Fish and Wildlife and the Brandywine Conservancy to restore American shad and hickory shad to the White Clay Creek, a National Wild and Scenic River near Newark, Del.

Funded by **National Fish and Wildlife Foundation** and the **U.S. National Park Service** through the White Clay Creek Watershed Management Committee, the UD team—IPA assistant policy scientist and principal investigator **Martha Corrozi Narvaez** and Urban and Regional Planning masters students **Sarah Chatterson**, **Erin McVey**, and Stacey Mack—is surveying the creek to determine the hydraulic, environmental, historic, and economic feasibility of removing seven dams along the White Clay Creek between I-95 and the UD campus above Newark into Pennsylvania.

IPA associate policy scientist **Andrew Homsey** and assistant policy scientist **Martha Corrozi Narvaez** and graduate students Sarah Chatterson, Stacey Mack, and Erin McVey have surveyed the White Clay Creek for the feasibility of removing seven dams.

This spring, schools of American shad are swimming upstream once again in their perennial odyssey to reach ancestral spawning grounds in the freshwater creeks of the Delaware Basin. However, after spending five years growing to adulthood in the Atlantic Ocean, shad return to the tidal creeks of their birth only to be obstructed from their spawning habitat by hundreds of low dams built centuries ago for primitive hydropower for mills. Removal of these obsolete dams is designed to reopen 13 miles of White Clay Creek habitat to spawning of American shad for the first time in a century.

Urban and Regional Planning graduate students **Erin McVey**, Stacey Mack, and **Sarah Chatterson** help principal investigator **Martha Corrozi Narvaez** (holding measuring tape) record hydraulic measurements at Red Mill Dam No. 2 for the White Clay Creek Wild and Scenic River Shad Restoration Project.

The WRA team recently navigated the lower White Clay Creek by kayak between Newark and tidewater, recording observations of historic dams and assessing the hydraulic feasibility of dam removal. WRA plans to file grant applications with American Rivers, U.S. Fish and Wildlife Service, and NOAA to carry out the implementation phase of this shad-restoration project.

Part of the project is to promote **Shad in Schools**, a program that serves as an education tool for primary and secondary school students about American shad and the importance of water quality and fish habitat. Next year WRA and the Brandywine Conservancy will begin working with the Delaware River Shad Fishermen's Association to obtain a source of American shad eggs for future Shad in Schools efforts in the Delaware Basin.

The future of the White Clay Creek as a shad fishery is promising. Through a sampling in late April 2010, biologists from state of Delaware fisheries discovered that hickory shad were more abundant than expected; they were able to net around 1,000 fish per hour.

Known as America's "founding fish" for their part in nourishing George Washington's troops after the freezing winter at Valley Forge, shad—anadromous fish in the herring family—are returning to the basin in numbers not recorded in a century, mainly due to remarkable water-quality improvements since the Clean Water Act was passed decades ago during the Nixon administration.

Since the White Clay Creek Wild and Scenic River legislation was introduced to Congress by then-Senator Joe Biden and signed by President Clinton in 2000, WRA policy scientists have partnered with the National Park Service and served as Delaware co-coordinators of the bi-state watershed management plan.

The White Clay Creek in Delaware and Pennsylvania was the first national Wild and Scenic River in the USA designated on a watershed basis rather than as a traditional river corridor. The **University of Delaware** in Newark along the White Clay Creek is one of only two land-grant universities in the United States that has a designated National Wild and Scenic River flowing through campus, the other being Colorado State University.

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UNIVERSITY OF DELAWARE

5.3 A Program to Involve Classrooms in Raising and Releasing Shad

As a part of the Brandywine Shad Restoration outreach and education efforts, the Brandywine Conservancy coordinated four schools and WRA in the spring of 2010 in raising shad and releasing the young "fry" into the Brandywine and White Clay creeks.

Four grade levels and both public and private schools in Pennsylvania and Delaware participated in this program this year, including Chadds Ford and Pocopson Elementary schools (3rd and 4th grades, respectively), Tower Hill School (5th grade), and Wilmington Friends School (7th grade). Each school funded the costs of their equipment (approximately $500) and attended a training workshop held in March in Washington, D.C. With funding support from NFWF and technical assistance from the Delaware Shad Fishermen's Association, WRA purchased hatchery equipment and set up a demonstration tank to publicize the White Clay shad restoration project and assess the program for expansion into schools in the White Clay Creek watershed.

The program has a distinct timeline that must be followed each year in order to mimic the natural conditions in the stream and prepare for the arrival of the American shad eggs. The schools and WRA followed protocols used for over 10 years by schools along the Potomac River.

The Shad in Schools program is an applied experience that educates students, teachers, and the public about the history, problems/decline, and life cycle of American shad while teaching math and science concepts through the balance of water conditions and temperature. The objectives of this program are as follows:

- Educate and inform students, teachers, and the public about American shad and their significance.
- Assist in improving American shad populations in the Delaware River Basin.
- Teach students about the importance of good water quality and habitat through hands-on testing and observations that utilize and teach science and math skills.

On Sunday evening, May 1, 2010, Brandywine Conservancy staff traveled with two teachers and one volunteer to the Potomac River to work with a fisheries biologist from the Interstate Commission on the Potomac River Basin (ICPRB) to secure about two cups of freshly harvested, fertilized shad eggs (several thousand eggs) per school. These eggs were delivered to the four schools and WRA on the following Monday morning, and the eggs were placed into the hatching chambers in pre-established classroom mini-hatchery tank set-ups (Figure 5.4).

The students were exposed to a shad-based curriculum for several weeks prior to receiving the eggs. They learned about shad biology and life cycles, their historical and ecological importance, problems concerning and the decline of shad populations, and water quality and aquatic habitat issues. The students were taught that the surviving fry will grow several inches before swimming downstream this fall (including over dams) and out to the Atlantic Ocean, where they will mature over the next 4-6 years. Then, if they continue to survive, they will return to spawn in the Brandywine or White Clay, the streams on which they were "imprinted" when young. The students were also taught about water pollution, over-fishing, loss of habitat, and how dams block the fish from their freshwater spawning habitat.

The students were actively involved with the eggs once they were received. They tested the hatchery water for a spectrum of water-quality parameters, including pH, ammonia levels, nitrates, temperature, and chlorine. They also separated out the non-viable eggs from the live, growing eggs. When the eggs hatched, in 3–4 days, the students examined and counted them under microscopes.

Figure 5.4. Shad-rearing tank located at WRA

Finally, the young fry (still transparent and barely more than "two eyes and a wiggle") were released into the Brandywine or White Clay on Friday, May 7, 2010. The schools and the Brandywine Conservancy staged "release events" for this activity, which involved many students gently pouring the fry into the creek (Figures 5.5 and 5.6). The Brandywine Conservancy coordinated press coverage of the releases, and there turned out to be significant interest from local press from both Delaware and Pennsylvania in this program and the release events.

In addition to the tremendous educational experience this program gives the students, it has numerous benefits as an outreach and education tool for the public. Through the press coverage of the releases, the Shad in Schools program serves to educate the public about shad and their historic significance and biology, the importance of good water quality, and restoring an important habitat to local rivers. Through the students' interactions with parents and the public, there is also an exchange of information about the program and shad that extends the benefits of the program beyond the classroom.

WRA, pending securing a source of fertilized eggs and interested schools, plans to implement this program in schools through the White Clay Creek watershed. At the same time, the Brandywine Conservancy hopes to expand the program to more schools in the Brandywine watershed.

Figure 5.5. A student from Pocopson Elementary School releases the shad fry into the Brandywine Creek.

Figure 5.6. University of Delaware master's student Erin McVey and IPA assistant policy scientist Martha Corrozi Narvaez pause a few minutes to allow American shad fry to acclimate to the water temperature before releasing them into the tidal portion of White Clay Creek.

5.4 Future Public Outreach Initiatives

In addition to the public outreach and education activities discussed above, WRA has several outreach activities planned for the near future.

- In July 2010 WRA and the Brandywine Conservancy will organize a tour of the dams in the Delaware portion of the watershed. This effort will coordinate a visit to each dam with select individuals visiting each dam. The most appropriate participants will be asked to visit each dam, and the select group will discuss the possible implementation of the recommendations developed for that specific dam. The group will include technical experts, dam owners, and state, regional, and local government representatives. WRA and the Brandywine Conservancy will lead the tour. A clear plan of action and next steps for dam removal will be developed for each plan.

- It is important for the long-term success of this project to continue publicizing the efforts to restore American shad to the White Clay Creek watershed. WRA will continue to publicize this project and any future implementation efforts at public events.

- WRA and the Brandywine Conservancy will continue to work together on this project and will continue to expand the public outreach materials. Public outreach materials from the Brandywine shad restoration project may be adapted to the White Clay Creek shad restoration project. In addition, the two groups will work together to emphasize these two projects as a coordinated Delaware River Basin shad-restoration effort.

- WRA will present the information gathered in this project and discuss the future implementation phase of this project at professional conferences and in publications in scientific journals.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The Water Resources Agency has drawn the following conclusions regarding the feasibility of restoring shad and other anadromous fish to the White Clay Creek Wild and Scenic River watershed.

1. **Wild and Scenic Watershed** - The White Clay Creek National Wild and Scenic River watershed in Delaware and Pennsylvania was designated by Congress in 2000, and the headwaters are one of the remaining unspoiled watersheds along the heavily populated I-95 corridor between Philadelphia and Baltimore. The shad and anadromous fish–restoration efforts are in line with the goal of the National Wild and Scenic River program to preserve the rivers in free-flowing condition.

2. **Fish Habitat Restoration** – Migratory-fish habitat-restoration projects in the adjacent Chesapeake Basin and Potomac and Nanticoke watersheds have been successful in restoring American shad, hickory shad, and other anadromous-fish populations. The preferred methods for habitat restoration and fish passage are dam removal accompanied by anadromous-fish stocking.

3. **Anadromous Fish** - American shad have historically been detected and caught in the White Clay Creek although not in large numbers lately. Fish abundance and angler log/creel surveys conducted during the spring spawning season (2009/2010) indicate that large schools of hickory shad (over 500 catch per unit effort) and reasonably abundant numbers of anadromous fish such as striped bass (20) and alewives (over 350) have been detected in the tidal White Clay Creek downstream from Dam No. 1 at Delaware Park (RM 4.2). No anadromous fish have been detected above Dam No. 1, indicating that this dam is indeed the upstream limit of fish migration and spawning.

4. **Fish Barriers** - In Delaware, six low mill dams present a barrier to fish migration and spawning along 12.7 miles of the White Clay Creek National Wild and Scenic River between tidewater and inland through the Piedmont and the City of Newark up to the Delaware/Pennsylvania state line.

5. **Dam No. 1 (RM 4.1)** - A crumbling and partially breached 3–8-foot-high rockfill-and timber-crib dam is presently the upstream barrier to fish migration and spawning along the White Clay Creek. As the downstream-most dam in the system, removal of Dam No. 1 is critical for anadromous fish restoration in this National Wild and Scenic River. As the dam is badly deteriorated, has a willing land owner, and has no function or historic value as a mill or diversion, removal of Dam No. 1 is feasible, provided reforestation and restoration of the stream banks is included. Removal of Dam No. 1 would be the first dam removal project for anadromous-fish restoration in the state of Delaware and would reopen 3.4 miles of the river for spawning and passage.

6. **Dam No. 2 (RM 7.6)** – A partially breached and deteriorating 3-foot-high rockfill dam that is capable of being removed at low cost. The rockfill dam pools water into a raceway for the historic Red Mill. The Red Mill and the raceway are listed on the National Historic Register. The low dam is not listed on the National Historic Register, and it is unlikely that the present dam had historic value as the original structure. Removal of Dam No. 2 would open up an additional 2.0 miles (5.4 miles total) to anadromous-fish spawning and migration along the White Clay Creek to as far inland as the City of Newark for the first time in over a century.

7. **Dam No. 3 (RM 9.5), Dam No. 4 (RM 10.1), and Dam 5 (RM 11.1)** – These concrete dams are owned by the City of Newark and have less feasibility for removal due to the high costs of concrete dam removal and present functions that serve the City water and wastewater systems. Dam No. 3 is a concrete dam that encases a sanitary sewer crossing of the creek. The sewer line can be relocated but at high cost. Dam No. 4 serves as the hydraulic-control structure for USGS stream gage No. 01478650 White Clay Creek at Newark, and the USGS has indicated that the stream gage could be relocated if need be. Dam No. 5 serves as the intake dam for the City of Newark water-treatment plant. The City Engineer indicates the dam could be removed and replaced with a wet well-capture system yet at a high cost. Since all three City-owned concrete dams have high concrete dam–removal costs with accompanying water/wastewater constraints, a lower-cost rock ramp at Dam No. 3, fishway at Dam No. 4, and bypass channel at Dam No. 5 may be more feasible alternatives. Removal of fish barriers at Dam No. 3, No. 4, and No. 5 would open a additional 4.0 miles (9.4 miles total) for anadromous-fish spawning and migration all the way inland to the White Clay Creek State Park, where fishermen would have ideal public access.

8. **Dam No. 6 (RM 11.6)** – This weir has been breached and effectively removed as a fish barrier likely due to powerful effects of floods from Hurricane Floyd in September 1999, Tropical Storm Henri in September 2003, Tropical Storm Jeanne in September 2004, and the cumulative effects of smaller floods since. Nature's powerful forces have removed Dam No. 6 as a fish barrier, opening an additional 1.6 miles (12.0 miles total) to fish passage almost as far inland as the Delaware/Pennsylvania state line.

9. **Dam No. 7 (RM 12.7)** – A six-foot-high partially breached rockfill dam was originally constructed and used as a diversion for a water supply to the Deerfield Golf Course (formerly DuPont Louviers Country Club). Deterioration by flood waters has reshaped the dam where it actually serves as a rough, undesigned rock ramp. The dam is also breached with a bypass channel on the right stream bank looking upstream. Dam removal, although more expensive, is an option. A rock ramp is offered as an alternative where the rocks in the presently configured dam would be reshaped into an engineered rock ramp using materials from onsite. Removal of Dam No. 7 would reopen fish passage all the way into Pennsylvania.

10. **Public Education/Outreach** - The White Clay Creek Shad Restoration Committee effectively serves as a coordinating group. This group provides a forum for discussion and sharing information among key stakeholders to restore fish passage to the river. This

group also serves to conduct shad restoration public education and outreach, including an annual stream cleanup in April.

11. **Shad Stocking** - Stocking of American shad and hickory shad to the White Clay Creek to imprint a spawning signature for native waters is an important step in the shad restoration project. Coordinating the Pennsylvania Fish and Boat Commission (PFBC) and Delaware's DNREC, among others, to develop a fish-stocking plan is critical to the success of the restoration project.

12. **Shad in Schools** - During Spring 2010, the Water Resources Agency effectively hatched American shad larvae and released the fry into the tidal White Clay Creek as a successful demonstration of the Shad in Schools techniques for future implementation in classrooms in the watershed beginning in 2011.

6.2 Recommendations

The Water Resources Agency recommends the following action steps to reopen more than 12 stream miles to anadromous-fish passage and spawning in the White Clay Creek National Wild and Scenic River watershed in Delaware.

1. **Implementation Plan -** Embark on a five-year project to remove dams and/or incorporate fish-passage techniques at the following seven dams.

Table 6.1. Five-year project time-line and recommendations for the seven dams in the Delaware portion of the White Clay Creek watershed

Dam No.	Name	RM	Ht. (ft.)	Type	Recommendation (Time Period)	Cost ($)	Considerations
TCS	UWD TCS	0.6	4	Rubber	Operate by DRBC docket	0	TCS usually inflated in late summer and fall. Operation should ensure it is not inflated during spring and fall migrations.
1	Delaware Park	4.1	3-8	Rock	Dam removal (2011)	$74,980	Downstream-most dam. Limit of fish spawning. Willing property owner. Deteriorating and breached.
2	Red Mill	7.6	3	Rock	Dam removal (2011)	$63,480	Deteriorating and breached. Dam not on National Historic Register but Red Mill and raceway are on National Historic Register.
3	Karpinski Park	9.5	3	Conc.	Dam removal (2012)	$287,960	Concrete dam encases sanitary sewer line requiring relocation.
					Rock ramp (2012)	$97,980	Rock ramp for 3 vertical feet is 3 times lower cost than dam removal. Less effective for fish passage than dam removal.

Dam No.	Name	RM	Ht. (ft.)	Type	Recommendation (Time Period)	Cost ($)	Considerations
4	Paper Mill Rd.	10.1	6	Conc.	Dam removal (2013)	$320,160	Concrete dam removal is expensive. Dam is hydraulic control for USGS stream gage.
					Fishway (2013)	$168,830	Fishway half the cost of dam removal. Less effective for fish passage than dam removal.
5	Newark Intake	11.1	10	Conc.	Dam removal (2014)	$1,861,160	Concrete dam removal and well installation to divert water to City treatment plant is expensive.
					Bypass channel (2014)	$159,160	Ten times less expensive than dam removal. Less effective for fish passage than dam removal.
6	Creek Rd.	11.6	3	Rock	Floods removed (Complete)	0	Nature's forces from floods of Hurricane Floyd (Sept. 1999) and Tropical Storm Henri (Sept. 2003) has removed fish barrier.
7	Deerfield GC	12.7	6	Rock	Dam removal (2015)	$159,160	Dam removal feasible provided golf course no longer diverts water for irrigation from White Clay Creek.
					Rock ramp (2015)	$159,160	Rock ramp would reposition existing rocks in dam to create more efficient fish passage.

2. **Stream Clean-Up** - Conduct an annual clean-up to remove tires, debris, cans, and bottles from the White Clay Creek between tidewater and the City of Newark, in conjunction with the annual Christina River Cleanup in April.

3. **Stream Reforestation/Restoration** - Conduct a stream reforestation and restoration project to increase shaded habitat and reduce water temperatures in the White Clay Creek downstream and upstream from Dam No. 1 (RM 4.1) within the White Clay Golf Course at Delaware Park. There is some severe habitat degradation occurring along the Delaware Park Golf Course, the bank is eroding and causing siltation, which degrades the deeper water that shad need to spawn. This erosion is due to tree- and vegetation-clearing on the bank. Stream reforestation and restoration accompanied with education about the benefits of these actions will help to restore the streambanks and canopy cover that will increase spawning habitat and improve the overall stream health.

4. **Fish Abundance Surveys** - The DNREC Division of Fish and Wildlife fisheries biologists should conduct an annual fish abundance survey during the spring spawning period.

5. **Shad Stocking/Hatchery** - Establish an American shad–stocking program in the White Clay Creek. Build a shad hatchery at the University of Delaware, Stroud Water Research Center, or other location in the Piedmont watersheds of northern Delaware.

6. **Shad in Schools** - In 2011 begin the Shad in Schools program at primary and secondary schools in the White Clay Creek watershed. School children will raise American shad larvae in specially made tanks in the classroom for release as fry into the creek.

7. **Funding** - The Water Resources Agency will apply for grant funding to finance dam removal and/or fish-passage facilities from grants-makers such as:
    - American Rivers
    - Fish America Foundation
    - US Fish and Wildlife Service
    - National Fish and Wildlife Foundation
    - National Oceanic and Atmospheric Administration (NOAA)

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APPENDIX A:
NANTICOKE RIVER SHAD HATCHERY

Source: Brian William Gish, Chief Planner, City of Easton

Nanticoke River Shad Hatchery
City of Easton, Delaware River Shad Fisherman's Association
Seaford, Delaware
April 30th, 2010

Hatchery Visit

Attendees:

Nanticoke River Hatchery:
- Mike Stangl
- Eric Cottman
- Jack Knowles

DRSFA:
- Ron Marks
- Roger Ratushny
- John Berry

City of Easton:
- Brian William Gish
- R. Michael Topping

Members of the Delaware River Shad Fisherman's Association with Mike Stangl

Facility Overview

- Site chosen from several possible locations
- Close run to Nanticoke River
- Site with nearby surveillance to prevent theft/vandalism
- 8 – 12 months to acquire necessary permits
- State, Army Corps of Engineers approval was required
- Likely DEP, PF&BC, NCCD approvals necessary in Easton
- Building roughly 24'x32'
- Clear ceiling panels to allow natural sunlight
- Roughly $260,000 (in 2005) when constructed

Shad hatchery building

Catching the Shad

- Nervous, skittish fish
- Circular, 6' diameter, ~400 gallon, irrigated tank, with air stone in center
- 1" Honda circulating pump
- Will kill themselves in corners without round tanks
- Fish given MS222, a mild anesthetic to reduce stress
- Insulated with reflective, bubble-wrap type wrapper
- Up to 50 shad able to be held in tank with sedation
- Heavy-duty, 5 ton trailer
- Tank weighs approximately 3,800 lbs loaded
- Tank colored black on inside to reduce stress
- Fish stunned electrically from boat, then removed by net
- Held temporarily by tub in boat
- Care taken to keep fish from being sucked into water circulator's intake
- Fish sexed at capture, females marked with hole punch
- Ideal ratio of 3 males to 2 females
- Females rarer, so all are kept

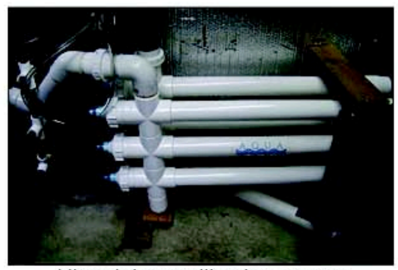
Shad transportation tank and trailer

Water Exchange System

- Direct exchange with river
- Aluminum cage with round pipe for water exchange in middle of Nanticoke River
- Line enters pump house via 3" diameter line
- Pump house roughly 3'x6'x3', about 100' from river
- 2HP pump
- Sanitized with ultraviolet filter, removing most bacteria, fungi, and parasites from inflow
- Water pumped to 1,200 gallon elevated water tank
- Tank allows several hours of gravity feed in the event of power failure
- Back-up generator in the event of long-term loss of power
- Blower adds ambient air to water to provide oxygen
- Line equipped with water chiller for use in hot weather; heater may be needed for ideal spawning temperatures in colder years
- Water filtered for coarse particulates
- River water use ideal for shad (shad aren't trout/salmon)
- Filter issues from silt
- Fish better able to imprint with river water, rather than spring/well water
- Problems with imprinting with fish raised in spring/well water
- Water measured for pH, dissolved solids, dissolved oxygen
- Water exchange limits build-up of nitrate, nitrite and ammonia

Nanticoke River

Pump house



Ultraviolet sterilization system

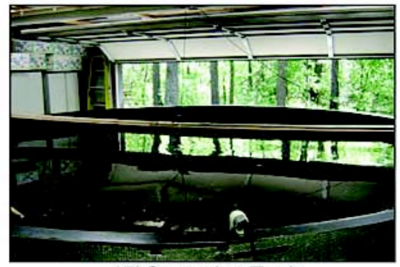
Water monitoring system and oxygenation tanks

1,200 gallon elevated water tank

Water outflow collected and returned to the Nanticoke River

Spawning Tank & Egg Collection

- Only shad 5 mortalities to date with 126 shad
- 80% to 90% live release rate
- Pure oxygen added via compressed tank to increase survival rate in spawning tank
- All spawning takes place at night
- Best spawns take place at 67ºF - 68ºF
- 126 fish in 15' diameter tank
- Tank colored black to reduce stress
- Turbidity actually helps to calm fish vs. clear water
- Eggs collected through drain
- Drain water passes through mesh sock
- Sock checked every morning for eggs
- Eggs sieved and rinsed with colander several times to remove debris
- Remote operated camera lowered in center of tank



15' Spawning Tank

Boom over tank, from which remote camera is suspended

"McDonald Jars" (Egg Incubators)

- Egg jars (incubators) are filled halfway with water and then eggs added
- Measurement taken to check volume of eggs, in increments of 1/16" fluid level
- Eggs treated with parasiticide/fungicide
- Typically incubate for 3 days
- Incubators made of roughly 8" diameter, 2' long clear pipe
- Aerated water circulated via 1" diameter center pipe
- Fertilization rate checked via sample under stereoscope

"McDonald Jar" incubation stand

Incubation jar with fertilized eggs

Culture (Fry Maturation) Tanks

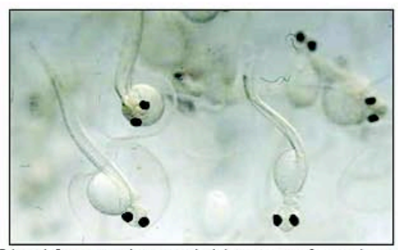
- Fry given 3 days to mature
- Tanks roughly 4' diameter
- Fry swim into outflow of incubator, with unfertilized eggs remaining in jar
- Fry not fed
- Released after yolk sac absorbed
- Otoliths (fish ear bones) marked chemically for identification on day 3 with Oxytetracycline (OTC), a swine antibiotic
- OTC creates distinct line on otolith
- OTC added with defoaming agent and sodium bicarbonate (to neutralize water acidity) with water circulation stopped
- Allowed to soak in OTC mixture for 4 to 6 hours
- Cooperative agreement with State of Maryland to check otoliths of subset of spawning shad
- Roughly 1 in 4 of otoliths in Nanticoke River come back with marks identifying hatchery birth
- Fry viewed under stereoscope to check level of maturity before release

Fry released from incubator into culture tank by swimming into water flow; unfertilized eggs remain at the bottom

Maturation tank with incubator removed

Fry and Adult Release

- Fry released after roughly 3 days in maturation tanks
- Fry collected from tanks, and placed in clear plastic bags
- Air injected into bags, followed by bags being tied off
- Bags placed in styrofoam coolers
- Coolers taken to river, where fry are released



Shad fry nearing a viable stage for release

APPENDIX B:
UNITED WATER DELAWARE OPERATING PLAN

Docket No. D-96-50 CP-2
Delaware River Basin Commission
United Water Delaware
Stream Encroachment Tidal Capture Structure and
Surface Water Withdrawal Project
White Clay Creek, Stanton, New Castle County, Delaware

Stage 1: Natural stream flow equal to, or greater than, 47.2 mgd and chlorides immediately at the outlet of the TCS bypass structure downstream of TCS less than 250 ppm.
TCS may be operated (partial inflation and gates open) in such a fashion that natural stream flows (less 30 mgd net withdrawal) will be released to the downstream side of TCS.

Stage 2: Natural stream flow less than 47.2 mgd but greater than or equal to 17.2 mgd and chlorides immediately at the outlet of the TCS bypass structure downstream of TCS less than 250 ppm.
TCS may be operated twice daily (full inflation/deflation at tidal cycles). Minimum flow-by rate of 17.2 mgd to be maintained for the two (2), ½-hour periods daily when there is an absence of tide immediately downstream of the TCS.

Stage 3: Natural stream flow less than 17.2 mgd and chlorides immediately at the outlet of the TCS bypass structure downstream of TCS less than 250 ppm.
The TCS may be operated twice daily (full inflation/deflation at tidal cycles). Minimum flow-by rate equal to the natural stream flow will be maintained for the two (2), ½-hour periods when there is an absence of tide downstream of the TCS.

Stage 4: Natural stream flow less than 17.2 mgd or chlorides immediately at the outlet of the TCS bypass structure downstream of the TCS greater than 250 ppm.
The TCS may be fully inflated and remain inflated throughout multiple tidal cycles. By-pass gates at the TCS to be used, as necessary, to blend, supplement and maintain the pool upstream of the TCS at chloride levels less than 250 ppm (average pool concentration). No minimum flow-by is required. 2

Salinity Monitoring

- When the natural stream flow at the Stanton WTP is equal to or less than 37 mgd for five (5) consecutive days, United Water will commence twice-weekly conductivity measurements at the bridge over the Christina River near Ciba Specialty Chemicals. Stream Flow at Stanton WTP = (White Clay Creek Stream Flow Near Newark USGS Gage #01479000 x 1.11) + (Red Clay Creek Stream Flow at Stanton USGS Gage #01480015)

- When specific conductance at the bridge over the Christina River near Ciba Specialty Chemicals correlates to 250 ppm chloride concentration, United Water will notify the Temporary Water Coordinator for New Castle County and will begin daily measurements at the DNREC Churchman's Road Boat Ramp, the downstream side of the Tidal Capture Structure (TCS) and the Stanton WTP Low Service #1 Pump house intake.

- When specific conductance begins to show an upward trend at the Churchman's Road Boat Ramp, United Water will notify the City of Wilmington of an impending request for water releases from Hoopes Reservoir.

- The monitoring frequency may revert back to the twice-weekly schedule at Ciba Specialty Chemicals after stream flows at the Stanton WTP exceed 37 mgd for five days.

- The monitoring may cease after significant rainfall events indicated chlorides are at normal background levels of around 50 ppm at the Churchman's Road Boat Ramp.

APPENDIX C: HYDRAULIC ANALYSIS OF DAM NO. 2 (RED MILL DAM) ALONG THE WHITE CLAY CREEK

Introduction

We conducted a hydraulic analysis using the U.S. Army Corps of Engineers HECRAS hydraulic model to determine potential water surface elevation, flow depth and velocity impacts of removing the Red Mill Dam No. 2 along the White Clay Creek (Figure 1). The rockfill dam is approximately 3 feet high and 140 feet long. The dam pools water for a raceway for the Red Mill situated 60 feet upstream from the low dam along the left bank looking upstream.

Methods

Water Resources Agency crews collected stream cross-section data using tape and level rod techniques on May 6, 2010 (Figure 2). The recorded streamflow on May 6 was 130 cfs along the White Clay Creek near Newark USGS gage (Table 1). Stream cross-section geometric data (Figure 3) were input to the HECRAS model for stations 0+00 (35 feet downstream from the dam), 0+25, 0+35 (at the dam), 0+40. 0+75, and 1+00 (65 ft upstream from the dam and adjacent to the raceway). A steady flow analysis was run for discharges ranging from 20 to 200 cfs for conditions with the dam and without the dam in place.

Results

Table 2 summarizes the results of the hydraulic analysis for with dam and without dam conditions at station 100, which is 65 feet upstream from the dam.

If the dam were removed, depths of flow upstream from the dam at station 1+00 would be reduced by 3 to 6 inches, from 1.24 feet to 0.71 feet for Q = 20 cfs and 1.78 feet to 1.49 feet for Q = 200 cfs. At the May median flow of 115 cfs, removal of the dam would reduce the flow depth by 5 inches with a flow depth of 1.3 feet.

Flow velocities upstream from the dam at station 1+00 would increase from 0.3 with the dam to 0.9 fps without the dam for Q = 20 cfs to 1.73 to 2.25 fps for Q = 200 cfs. At the May median flow of 115 cfs, removal of the dam would increase the velocity to 1.5 fps from 1.0 fps.

Table 1. Streamflow statistics at White Clay Creek near Newark (USGS Gage 01479000)

Statistic (May 1931-2009)	**Discharge (cfs)**
Recorded 5/6/10	130
Minimum	36
20th Percentile	75
Median	115
Mean	126
80th Percentile	148

Table 2. Summary of flow hydraulics at station 100 along White Clay Creek at Dam No. 2.

Discharge (cfs)	**w/dam WSEL (ft.)**	**wo/dam WSEL (ft.)**	**w/dam Depth (ft.)**	**wo/dam Depth (ft.)**	**w/dam Velocity (fps)**	**wo/dam Velocity (fps)**
20	99.64	99.11	1.24	0.71	0.30	0.90
50	99.77	99.36	1.37	0.96	0.64	1.18
100	99.93	99.58	1.53	1.18	1.08	1.62
150	100.06	99.75	1.66	1.35	1.43	1.97
200	100.18	99.89	1.78	1.49	1.73	2.25

Figure 1. Field survey of Dam No. 2 (Red Mill Dam) along the White Clay Creek on May 6, 2010

Figure 2. Plan view of Red Mill Dam No. 2 along the White Clay Creek

Figure 3. Stream cross-section geometric data along the White Clay Creek

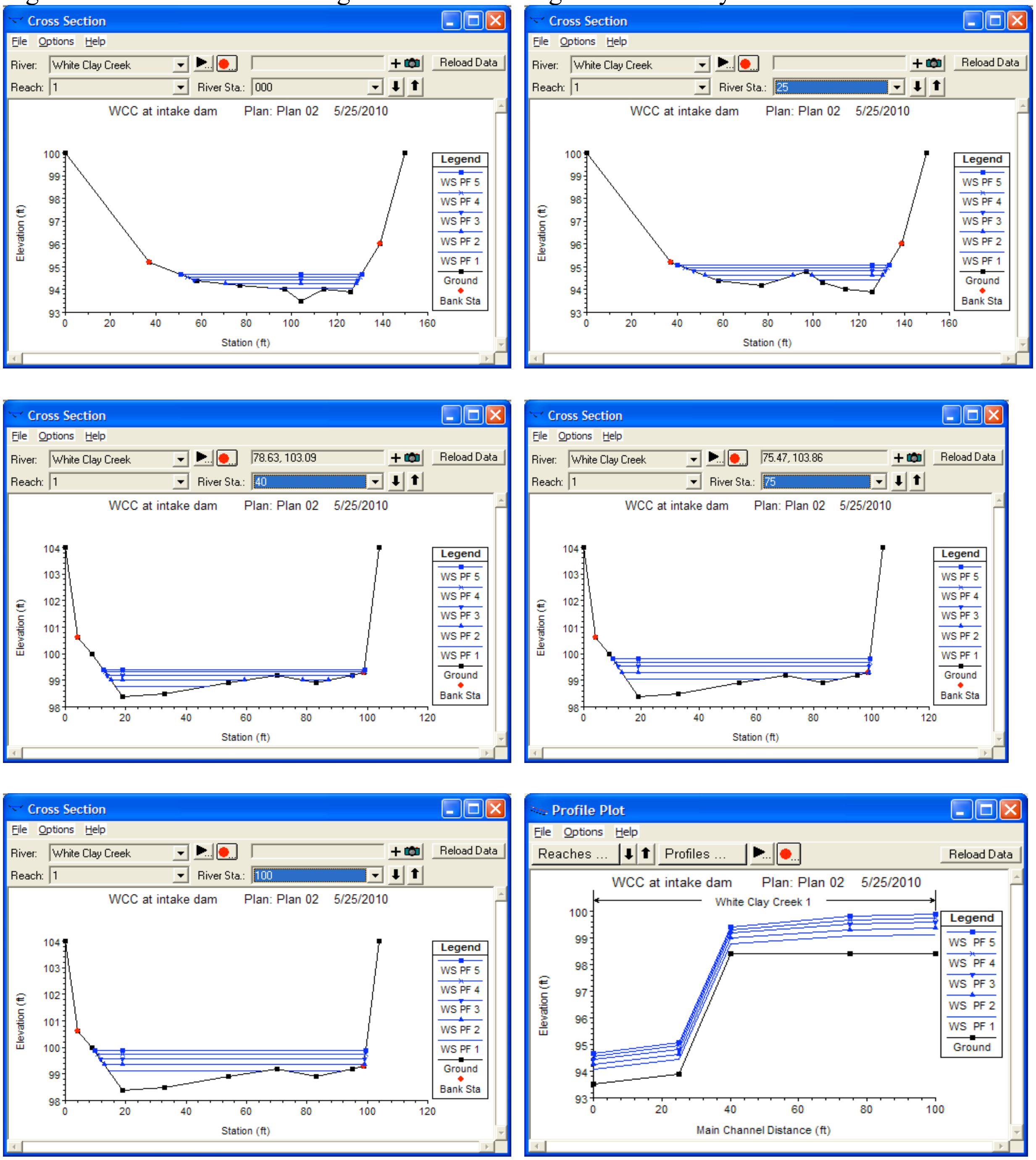


Table 3. Summary of HECRAS results with and without Red Mill Dam

HEC-RAS Plan: Plan 02 River: White Clay Creek Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	100	PF 1	20.00	98.40	99.64		99.65	0.000051	0.30	67.42	88.15	0.06
1	100	PF 2	50.00	98.40	99.77		99.78	0.000195	0.64	78.57	89.07	0.12
1	100	PF 3	100.00	98.40	99.93		99.95	0.000453	1.08	92.90	90.23	0.19
1	100	PF 4	150.00	98.40	100.06		100.09	0.000691	1.43	104.90	91.33	0.23
1	100	PF 5	200.00	98.40	100.18		100.22	0.000905	1.73	115.52	92.42	0.27
1	75	PF 1	20.00	98.40	99.64		99.64	0.000051	0.30	67.31	88.14	0.06
1	75	PF 2	50.00	98.40	99.77		99.77	0.000198	0.64	78.12	89.03	0.12
1	75	PF 3	100.00	98.40	99.92		99.94	0.000471	1.09	91.82	90.15	0.19
1	75	PF 4	150.00	98.40	100.04		100.08	0.000729	1.46	103.18	91.15	0.24
1	75	PF 5	200.00	98.40	100.15		100.20	0.000966	1.77	113.16	92.18	0.28
1	40	PF 1	20.00	98.40	99.64		99.64	0.000052	0.30	67.15	88.12	0.06
1	40	PF 2	50.00	98.40	99.76		99.76	0.000204	0.65	77.48	88.98	0.12
1	40	PF 3	100.00	98.40	99.90		99.92	0.000498	1.11	90.23	90.02	0.19
1	40	PF 4	150.00	98.40	100.02		100.05	0.000790	1.49	100.59	90.89	0.25
1	40	PF 5	200.00	98.40	100.11		100.17	0.001071	1.83	109.56	91.81	0.29
1	35	PF 1	20.00	99.50	99.59	99.59	99.64	0.123069	1.74	11.48	127.72	1.02
1	35	PF 2	50.00	99.50	99.66	99.66	99.75	0.106514	2.40	20.81	128.30	1.05
1	35	PF 3	100.00	99.50	99.77	99.77	99.90	0.081920	2.92	34.21	129.14	1.00
1	35	PF 4	150.00	99.50	99.85	99.85	100.02	0.074548	3.33	44.99	129.80	1.00
1	35	PF 5	200.00	99.50	99.92	99.92	100.13	0.070284	3.67	54.52	130.39	1.00
1	25	PF 1	20.00	93.90	94.44		94.47	0.006198	1.51	13.26	55.06	0.54
1	25	PF 2	50.00	93.90	94.62		94.68	0.006704	2.03	24.66	69.64	0.60
1	25	PF 3	100.00	93.90	94.82		94.91	0.006913	2.50	40.03	84.64	0.64
1	25	PF 4	150.00	93.90	94.96		95.09	0.006828	2.87	52.35	89.23	0.66
1	25	PF 5	200.00	93.90	95.08		95.24	0.006750	3.15	63.52	93.21	0.67
1	000	PF 1	20.00	93.50	94.08	94.08	94.19	0.025408	2.68	7.47	37.78	1.06
1	000	PF 2	50.00	93.50	94.27	94.27	94.41	0.019790	3.03	16.51	57.54	1.00
1	000	PF 3	100.00	93.50	94.44	94.44	94.64	0.017989	3.54	28.24	72.50	1.00
1	000	PF 4	150.00	93.50	94.56	94.56	94.82	0.017508	4.05	37.08	76.35	1.02
1	000	PF 5	200.00	93.50	94.67	94.67	94.97	0.016488	4.38	45.69	79.93	1.02

Table 4. Summary of HECRAS results with and without Red Mill Dam

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HEC-RAS Plan: Plan 02 River: White Clay Creek Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	100	PF 1	20.00	98.40	99.11		99.12	0.001443	0.90	22.33	67.91	0.28
1	100	PF 2	50.00	98.40	99.36		99.38	0.001475	1.18	42.25	86.03	0.30
1	100	PF 3	100.00	98.40	99.58		99.62	0.001712	1.62	61.67	87.67	0.34
1	100	PF 4	150.00	98.40	99.75		99.81	0.001925	1.97	76.33	88.88	0.37
1	100	PF 5	200.00	98.40	99.89		99.96	0.002092	2.25	88.88	89.91	0.40
1	75	PF 1	20.00	98.40	99.06		99.08	0.002048	1.04	19.28	61.15	0.33
1	75	PF 2	50.00	98.40	99.31		99.33	0.002083	1.31	38.03	85.67	0.35
1	75	PF 3	100.00	98.40	99.52		99.57	0.002255	1.77	56.67	87.25	0.39
1	75	PF 4	150.00	98.40	99.68		99.75	0.002493	2.13	70.49	88.40	0.42
1	75	PF 5	200.00	98.40	99.81		99.90	0.002682	2.43	82.30	89.37	0.45
1	40	PF 1	20.00	98.40	98.78	98.78	98.90	0.021807	2.76	7.25	31.31	1.01
1	40	PF 2	50.00	98.40	99.00	99.00	99.16	0.019940	3.15	15.90	52.66	1.01
1	40	PF 3	100.00	98.40	99.20	99.20	99.38	0.018760	3.43	29.15	81.00	1.01
1	40	PF 4	150.00	98.40	99.31	99.31	99.55	0.017949	3.89	38.54	85.72	1.02
1	40	PF 5	200.00	98.40	99.41	99.41	99.69	0.016730	4.26	46.92	86.43	1.02
1	25	PF 1	20.00	93.90	94.44		94.47	0.006198	1.51	13.26	55.06	0.54
1	25	PF 2	50.00	93.90	94.62		94.68	0.006704	2.03	24.66	69.64	0.60
1	25	PF 3	100.00	93.90	94.82		94.91	0.006913	2.50	40.03	84.64	0.64
1	25	PF 4	150.00	93.90	94.96		95.09	0.006828	2.87	52.35	89.23	0.66
1	25	PF 5	200.00	93.90	95.08		95.24	0.006750	3.15	63.52	93.21	0.67
1	000	PF 1	20.00	93.50	94.08	94.08	94.19	0.025408	2.68	7.47	37.78	1.06
1	000	PF 2	50.00	93.50	94.27	94.27	94.41	0.019790	3.03	16.51	57.54	1.00
1	000	PF 3	100.00	93.50	94.44	94.44	94.64	0.017989	3.54	28.24	72.50	1.00
1	000	PF 4	150.00	93.50	94.56	94.56	94.82	0.017508	4.05	37.08	76.35	1.02
1	000	PF 5	200.00	93.50	94.67	94.67	94.97	0.016488	4.38	45.69	79.93	1.02

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