Brandywine Environmental Action Network

(BEAN)

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Mission Statement:

BEAN's mission is to increase the safety of recreational activities in the Brandywine Creek by improving in-stream habitat quality by 2035.

Historical Background:

Before European colonization, the Brandywine watershed was inhabited by the Unami group of the Lenape Native Americans (Penn Treaty Museum). The Lenape fished for shad, hunted game, and harvested beans, squash, corn, sweet potatoes, and tobacco. Lenape farms could reach sizes of 200 acres so agricultural land use in the 17th century was quite extensive. The Algonquin-speaking Lenape had often been at war with Iroquois-speaking tribes which was only exacerbated by the arrival of the Europeans. One such tribe, the Susquehannock, attacked the Unami in the Brandywine around 1626 to obtain a trade monopoly with the Dutch. This war and smallpox devastated the Unami and they became a subject of the Susquehannock. They were so thoroughly conquered that the Unami had to ask permission from the Susquehannock in order to sell their lands to the new Swedish colonists. This loss of Lenape population opened the way for easier European settlement of the Brandywine.

Sweden established Fort Christina, the first European settlement in the Delaware Valley, at the confluence of the Brandywine and Christina rivers in 1636 (Swedish Colonial Society). At the time, the Brandywine was called the Fish Kill by the colonists due to the huge abundance of shad and alewives (The Brandywine). New Sweden would eventually number around 600 Swedes and Finns living in the fort plus various small settlements and farms. Sweden's colonies were short-lived as in 1654 the colonists took over a Dutch settlement and were promptly defeated, losing all their settlements. The English soon came to take over the Brandywine and granted the area in a charter to William Penn in 1681. Penn's religious tolerance attracted so many settlers from many different countries that the population would soon take a toll on the Brandywine's natural resources(History of Delaware County). In 1724, the Lenape lodged a formal complaint with the settlers that dams in the creek had impeded their ability to fish.

The Brandywine Valley would grow to become a major industrial center of early America. The Brandywine's strong waters gave it the "greatest concentration of mill industries in the Colonies"(Delaware, a Guide to the First State). The Brandywine's mills made the paper that the Declaration of Independence was written on and constructed

the Conestoga wagons that would settle the American West (The Brandywine). The invention of the automatic flour mill made Wilmington the flour center of the newly independent America and allowed the city to set the price of wheat (Gies) . Eleuthere Irenee DuPont set up a gunpowder mill on the Brandywine in 1802, starting the first steps towards the Dupont company's wealth and major presence in the watershed (Greenwood). Paper mills at the time used chlorine to bleach wood pulp and thus all these mills contributed pollution to the Brandywine Creek (Mixer Direct). The sediment from these mills old mills is contributing to sediment pollution in the watershed even today.

The environmental stressors of the Brandywine would only continue to grow in the 19th and 20th centuries. Wilmington gained enough people to be granted a city charter in 1832 and the Philadelphia, Wilmington & Baltimore Railroad's completion in 1837 brought more people to the region (History of Wilmington). Wilmington's industrial output grew during the Civil War, contributing ships, railcars and Dupont's gunpowder to the Union war effort (City History, Wilmington). Both World Wars had the same effect on Wilmington, boosting production and drawing more inhabitants to the city for work. Suburbanization began in 1864 with the first horsecar line in the city and really took off in the 1950s with the advent of highways and automobiles. Corporate-friendly tax policies drew companies into Wilmington with many workers choosing to live in the northern suburbs which include the Brandywine watershed. This huge increase in the suburban population from the late 19th century to the 20th century increased the amount of nonpoint source pollution entering the Brandywine.

Policies and Mandates in Place:

The Brandywine Conservancy (Conservancy) is a land trust located in Chadds Ford, PA. Their mission is to "conserve the land, water, natural and cultural resources of the Brandywine-Christina watershed" ("Our Mission & Approach"). Through grants, donations, and volunteer work, the Conservancy works to preserve land, conduct conservation planning, and complete projects to enhance water quality. By working with private landowners and individuals, local government, and other agencies, the Conservancy has planted riparian buffers along streams, created the Brandywine Creek Greenway for recreation, preserved multiple natural and historical sites, initiated conservation easements with landowners, designed stormwater management systems and much more. They employ a holistic approach to conservancy to build strong relationships with the community and produce sustainable results ("Our Mission &

Approach”). We would like to partner with the Brandywine Conservancy to meet the goals expanded upon in this plan.

As far as creating goals for the Brandywine Creek watershed, a Watershed Action Plan was completed in 2002 by the Chester County Water Resources Authority, Chester County Planning Commission, Camp Dresser and McKee, and Gaadt perspectives LLC. The plan lays out a number of goals and objectives for the watershed, including reducing stormwater runoff, utilizing Integrated Water Resources Planning, and safeguarding the recreational resources of the watershed. BEAN’s plan dovetails nicely with this Watershed Action Plan by seeking to increase the safety of recreational activities in the Brandywine Creek (Brandywine Creek Watershed Action Plan, 2002).

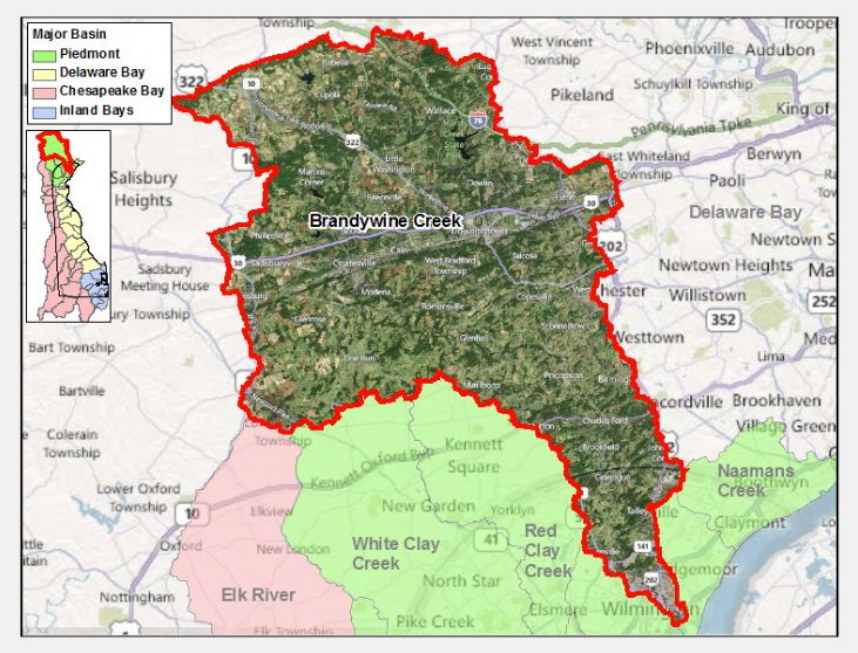

Figure 1. Watershed delineation for the Brandywine Creek in Pennsylvania and Delaware.

Brandywine Creek TMDL:

The Clean Water Act (1972) requires states to monitor and assess their waters every 2 years. State water bodies that don’t meet specific water quality criteria are placed on the 303(d) list, which is a record of impaired water bodies. Once water bodies are identified as impaired, the Clean Water Act requires total maximum daily loads (TMDLs) to be established for the pollutants of concern. The goal of a TMDL is to reduce point source and nonpoint source pollutants by creating a limit on the amount of pollution that

can be discharged into a water body. Limiting pollution discharge is an effective way to ensure good or improved water quality. The most common pollutants in the state of Delaware include sediments, nitrogen, phosphorus, and bacteria ("Watershed Assessment TMDLs", DNREC).

In 2006, the EPA created multiple TMDLs that target nutrients, sediment, and bacteria in the Christina River Basin, which holds the Brandywine Creek (Figure 2). The TMDL specifically targets high flow bacteria and low and high flow nutrients, and has specific reductions for each watershed within the basin. For example, the high-flow nutrients TMDL outlined reductions for nitrogen and phosphorus from combined sewer overflows in Wilmington, Delaware, that totaled 64.1% and 62.9%, respectively. Additionally, it called for a reduction in nitrogen and phosphorus at the PA-DE state line of 46.5% and 40.8% ("Revisions to Total Maximum Daily Loads for Nutrient and Low Dissolved Oxygen Under High-Flow Conditions Christina River Basin, Pennsylvania, Delaware, and Maryland", 2006).

Total nitrogen and total phosphorus allocations at PA-DE state line

Location	Baseline Load (kg/day)	Pennsylvania Allocation (kg/day)	Reduction
Total Nitrogen			
Brandywine Creek (at PA-DE Line)	6849.8	3663.8	46.5%
White Clay Creek (at PA-DE Line)	956.2	685.0	28.4%
Red Clay Creek (at PA-DE Line)	466.7	320.4	31.3%
Burroughs Run (at PA-DE Line)	43.4	43.4	0.0%
Total Phosphorus			
Brandywine Creek (at PA-DE Line)	423.8	250.8	40.8%
White Clay Creek (at PA-DE Line)	110.6	65.9	40.4%
Red Clay Creek (at PA-DE Line)	62.8	17.2	72.6%
Burroughs Run (at PA-DE Line)	0.8	0.8	0.0%

Figure 3. TMDL high flow nitrogen and phosphorus reduction targets at the PA-DE state line. ("Revisions to Total Maximum Daily Loads for Nutrient and Low Dissolved Oxygen Under High-Flow Conditions Christina River Basin, Pennsylvania, Delaware, and Maryland", 2006).

Although the reductions may seem high for nitrogen and phosphorus (Figure 3), the EPA requires that there be a "high degree of confidence" that the TMDL reductions can be met. In order to meet the listed reductions, and others that have been specified within the TMDL documents, a combination of NPDES permits, grant funding, and best management practices (BMPs) enforced at the state and local level will be implemented ("Revisions to Total Maximum Daily Loads for Nutrient and Low Dissolved Oxygen

Under High-Flow Conditions Christina River Basin, Pennsylvania, Delaware, and Maryland", 2006). Some potential solutions to nutrient, bacteria, and sediment reductions are listed below as part of BEAN's watershed management plan.

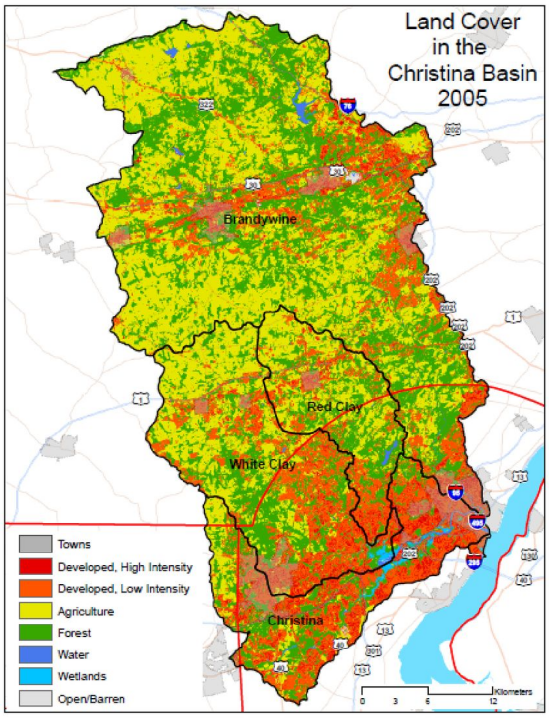

Figure 2. Land use map of the Christina River Basin, where the Brandywine Creek is the northernmost watershed that extends into Pennsylvania (Kauffman et al., 2010).

Problem 1: Nutrients

The EPA first listed the Lower Brandywine Creek (Brandywine) mainstem as impaired in 1996 due to nutrients and Polychlorinated Biphenyls (PCBs). Since that time, the Brandywine has also become impaired due to aquatic habitat alterations and bacteria. Although habitat alterations and PCBs in the Brandywine have not yet been addressed by a Total Maximum Daily Load (TMDL), the EPA has developed TMDLs for bacteria and nutrients, i.e. nitrogen and phosphorus ("2004 Waterbody Report for Lower Brandywine – Mainstem", 2018).

Excess nitrogen and phosphorus in the Brandywine Creek watershed result from both point and nonpoint sources. National Pollutant Discharge Elimination System (NPDES) permits set levels at which wastewater treatment plants—one of the major contributors of phosphorus—can discharge, according to the phosphorus allocations of the TMDL. However, NPDES permits do not regulate nonpoint sources of phosphorus and nitrogen because they are not discharged into the waterbody via a point source.

Therefore, the other major contributors of nutrients are stormwater runoff and agricultural runoff ("Revisions to Total Maximum Daily Loads for Nutrient and Low Dissolved Oxygen Under High-Flow Conditions Christina River Basin, Pennsylvania, Delaware, and Maryland", 2006). In Chester County, Pennsylvania, agricultural runoff is a problem because of the predominance of farming- 45% agricultural land use in the Brandywine Creek watershed (Figure 2). Fertilizer and manure contain high nitrate and phosphate concentrations. These nutrients enter water bodies such as the Brandywine via surface runoff (in solution and sediments), particularly when they are over-applied. Sediments and erosion will be discussed in the third section of this document. Livestock that have unlimited access to the creek deposit manure and urine directly into the water without filtration ("Revisions to Total Maximum Daily Loads for Nutrient and Low Dissolved Oxygen Under High-Flow Conditions Christina River Basin, Pennsylvania, Delaware, and Maryland", 2006).

Goals:

BEAN proposes to address these problems by establishing best management practices (BMPs) on farms, e.g. installing livestock exclusion fencing to prevent cattle from entering the stream or creating a stream crossing to limit access (Figure 4). Other BMPs include riparian buffers (discussed in Section 3) and roofed manure stacking structures to prevent runoff of these nutrients.

Figure 4. Stream crossing with livestock exclusion fencing to limit stream access (NRCS Alabama).

We will also encourage farmers who apply manure to obtain and implement a nutrient management plan. According to Pennsylvania Law, any farm that is a concentrated animal operation (CAO) is required to obtain and implement a nutrient management plan (NMP). A CAO is any operation with greater than 2 animal equivalent units (1 animal equivalent unit= 1,000 lbs.) per acre (Beegle and Martin, 2017). Similarly, Delaware Code (3 Del. C. §2247), requires a NMP for any individual who uses nutrients on more than 10 acres, whether they own, operate, or rent the land. A NMP is also required for animal feeding operations in excess of eight animal units, where one animal unit equals 1,000 lbs. (Delaware Code Online). To help fund these plans, both PA and DE offer financial assistance, and there are a number of state and federal programs such as the NRCS EQIP program to cover or supplement the costs of implementing BMPs ("Environmental Quality Incentives Program"). BEAN hopes to connect farmers in need with the appropriate resources and agencies to ensure that they develop and administer a NMP. We believe achievement of these goals will reduce nutrient concentrations in the Brandywine Creek watershed and ultimately enhance in-stream habitat quality.

Problem 2: Bacteria

Enterococcus is a genus of bacteria found in the intestines of warm-blooded animals including mammals and birds (EPA Enterococci). *Enterococcus* can cause urinary tract infections, endocarditis, bacteremia, wound infections, and intra-abdominal and pelvic infections in humans (emedicine). Though it is not particularly virulent or deadly, knowing the concentration of *Enterococcus* in waters is a useful public health tool. *Enterococcus* is used as a proxy for general fecal contamination and could indicate the presence of other more virulent bacteria in waters. The first federal fecal bacteria standard was the concentration of total coliforms, which was found to be inaccurate as the concentration included many similar non-virulent bacteria (Boehm & Sassoubre 2014). This was revised to a fecal coliform standard which was again inaccurate is it simply assumed a certain percentage of total coliforms were fecal. *Enterococcus* concentrations were recommended as the new standard by the World Health Organization after a suite of studies found that the concentration of these bacteria correlated with the number of swimmers with gastrointestinal illness in both marine and fresh waters. The fact that *Enterococcus* is becoming resistant to antibiotics stresses the need for an environmental approach that treats the problem at the source (Hyuck et al. 1998).

Goals:

Enterococcus levels will be kept below the EPA's Recommended 2012 Recreational Water Quality Criteria indicators by 2035. In more detail, this means that the Brandywine's mean concentration over any 30 day interval will not exceed 35 cfu(colony-forming units)/100 ml and that less than 10% of samples will exceed 130 cfu/100 ml (EPA 2015). To monitor this, weekly baseflow samples will be taken at the 3 existing Delaware monitoring stations and the 1 existing Pennsylvania station (DNREC Water Quality Portal, PA GIS). Two additional sampling sites will be established in Pennsylvania, a West Branch site near Coatesville and an East Branch site near Downingtown. Opportunistic samples will also be taken during storm events as storm runoff is likely the largest carrier of fecal bacteria to the Brandywine.

BEAN will adopt an adaptive approach to reducing *Enterococcus* levels, using different strategies depending on what source testing will reveal (Byappanahali). Samples taken from the first year of monitoring will undergo Polymerase Chain Reaction Tests to isolate gene fragments that can illuminate what species the bacteria came from. If the source is found to be human, the strategy will focus on sewage management. In rural reaches, nearby areas will be inspected for leaking septic systems and if found the owner will legally be held responsible for fixing or replacing it. In urban/suburban reaches, if the high concentrations were during baseflow, nearby sewers will be inspected for leakage and replaced by the municipality. If the high concentrations in urban/suburban reaches were found during storm events, then local combined sewer overflows will be replaced with a separate storm and sewer system. If the source is found to be livestock, then the strategy will focus on agricultural management. Livestock fencing will be constructed on the Brandywine and manure shares will be established to move manure from farmers who have too much to farmers who need it to make management easier (Modern Farmer). If the source is found to be dogs, education programs on cleaning up after your pet will be established in nearby areas. If the source is found to be wildlife and the responsible species is determined to be invasive or overpopulated, then culling/hunting programs will be instated. It is likely that sources will differ by reach and by season so BEAN's approach will also be adjusted by area and time of year. Stormwater runoff reduction will not depend on the source of *Enterococcus* and will start during the first year of sampling. Runoff reduction will focus on wetland and forest restoration, establishment of riparian buffers, and green infrastructure like green roofs and rain gardens.

Problem 3: Sediment

Upland and stream bank erosion are both sources of suspended sediments in stream systems. Sediment and siltation are the leading causes for stream impairment in Chester County, Pennsylvania (Pennsylvania Department of Environmental Protection, 2010, p.40). Upstream of the East Branch and West Branch of the Brandywine Creek impaired stream miles make up 13.9 percent and 8.4 percent of total stream miles, respectively, as a result of sedimentation.

The Brandywine Creek watershed is composed of 45 percent agriculture, 19 percent urban, and 35 percent forested land. While erosion is not absent in forested ecosystems, we know that urban and suburban areas have increased erosion due to impervious surfaces, which increase runoff by preventing water infiltration. Instead, water quickly runs over impervious surfaces and is emptied into streams, which raises stream flow and results in increased stream bank erosion . This results in a higher concentration of suspended sediments in streams during storm flow, which can have implications for in-stream habitat quality. Additionally, agriculture is also known for contributing high amounts of sediment to streams. When land is converted to agriculture, the topsoil is left exposed. This results in high amounts of runoff and sediment erosion, which contributes sediments and associated nutrients to streams. As a result, both agriculture and urbanization increase sediment loading in streams, and are both sources of sediment to the Brandywine Creek.

Goals:

In order to reduce sediment in the Brandywine Creek, both urban and agricultural sediment sources need to be addressed. In order to decrease urban and suburban erosion and runoff, permeable pavement will be installed in the Brandywine Creek state park as an alternative to concrete or asphalt sidewalks. Permeable pavement will allow water to infiltrate into the soil, which will reduce erosion and runoff. This not only reduces sediment input from upland sources, but will also reduce stream bank erosion associated with high flows from excess runoff. Rain gardens are another solution to reducing sediment. Installing rain gardens in Wilmington, Delaware, near places with increased runoff, such as parking lots, will funnel runoff into gardens that promote infiltration, sediment reduction, and the uptake of nutrients. Rain gardens are easily installed, aesthetically pleasing, and will reduce sediment inputs to the Brandywine Creek.

As previously mentioned, agricultural sediment sources also need to be addressed. Installing riparian buffer zones along the Brandywine Creek in Pennsylvania will reduce the amount of sediment entering streams for agricultural runoff. Riparian buffers consist of three zones: grass, growing forest, and mature forest (Figure 5). A grassy area will slow down the agricultural runoff and allow sediments to drop out of suspension before entering the stream. The growing forest will uptake nutrients, and the mature forest will provide stream bank stabilization and shading. As a result, the runoff coming from agriculture will have less sediment, and the mature forests along the stream banks will reduce stream bank erosion.

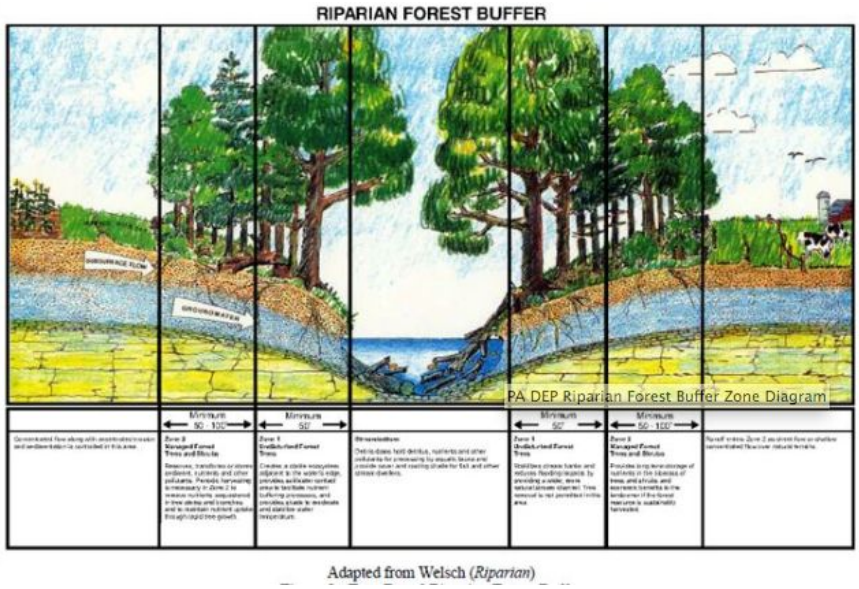

Figure 5. Conceptual drawing of a riparian buffer zone.

BEAN Summary of Goals:

A summary of the goals outlined in this plan include:

- Installing permeable pavement in Brandywine Creek State Park
- Creating rain gardens next to parking lots in Wilmington, Delaware.
- Planting riparian buffer zones along the Brandywine Creek where it abuts agriculture in Chester County, Pennsylvania.
- Installing agricultural BMPs, including livestock exclusion fencing.
- Ensuring that farmers obtain and implement a nutrient management plan.
- Reduce stormflow and use adaptive source-based strategies to decrease bacteria

References:

"2004 Waterbody Report for Lower Brandywine - Mainstem." EPA, 2018. https://ofmpub.epa.gov/waters10/attains_waterbody.control?p_list_id=DE040-001_(A)&p_report_type=T&p_cycle=2004

Beegle, Douglas & Jerry Martin (2017). "Pennsylvania's Nutrient Management Act (Act 38): Who Is Affected?" *Penn State University*, https://extension.psu.edu/programs/nutrient-management/act-38-law-and-regulations/copy_of_pa-planning-summary.

"Brandywine Creek." *Delaware Watersheds*, Delaware Department of Natural Resources and Environmental Control , delawarewatersheds.org/piedmont/brandywine-creek/.

Brandywine Creek Watershed Action Plan. Chester County, PA, 2002, www.chesco.org/DocumentCenter/View/7962.

"Brief History of New Sweden in America." *Swedish Colonial Society*, Swedish Colonial Society,web.archive.org/web/20051211144259/http:/www.colonialswedes.org/History/History.html.

"Delaware, a Guide to the First State." *Delaware, a Guide to the First State*, Hastings House, 1955, p. 92.

"Delaware Code Online." TITLE 3. http://delcode.delaware.gov/title3/c022/sc03/index.shtml

"Division of Soil and Water Conservation." *Watershed Assessment TMDLs*, DNREC, www.dnrec.delaware.gov/swc/wa/pages/watershedassessmenttmdls.aspx.

DNREC Water Quality Portal, demac.udel.edu/waterquality/.

"Environmental Quality Incentives Program."Natural Resources Conservation Service, https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/ .

Gies, Joseph. “THE GENIUS OF OLIVER EVANS.” *AmericanHeritage.com /*, web.archive.org/web/20090213172006/http:/americanheritage.com/articles/magazine/it/1990/2/1990_2_50.shtml.

Greenwood, Richard. *NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM ELUTHERIAN MILLS*. *NATIONAL REGISTER OF HISTORIC PLACES INVENTORY -- NOMINATION FORM ELUTHERIAN MILLS*.

“History of Delaware County, Pennsylvania: from the Discovery of the Territory Included within Its Limit to the Present Time, with a Notice of the Geology of the County, and Catalogues of Its Minerals, Plants, Quadrupeds, and Birds, Written under the Direction and Appointment of the Delaware County Institute of Science.” *History of Delaware County, Pennsylvania: from the Discovery of the Territory Included within Its Limit to the Present Time, with a Notice of the Geology of the County, and Catalogues of Its Minerals, Plants, Quadrupeds, and Birds, Written under the Direction and Appointment of the Delaware County Institute of Science*, by George Smith, Family Line Publications, 1998, pp. 233–235.

“History of the Brandywine Valley.” *The Brandywine*, www.thebrandywine.com/about/index.html.

“How Pulp Bleaching Works.” *Mixer Direct*, blog.mixerdirect.com/how-pulp-bleaching-works.

“Indicators: Enterococci.” *EPA*, Environmental Protection Agency, 16 Aug. 2016, www.epa.gov/national-aquatic-resource-surveys/indicators-enterococci.

Kauffman, Gerald & Homsey, Andrew & Corrozi Narvaez, Martha & Chatterson, Sarah &
McVey, Erin & Mack, Stacey. (2010). Christina Basin Trends, 1995-2010.

"Native Americans." *Penn Treaty Museum*, www.penntreatymuseum.org/americans.php.

NRCS, Alabama. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/al/home/?cid=nrcs141p2_023017.

"Our Mission & Approach." *Brandywine Conservancy and Museum of Art*. www.brandywine.org/conservancy/about/our-mission-approach.

Pennsylvania Department of Environmental Protection, 2010, Pennsylvania integrated water quality monitoring and assessment report clean water act section 305(b) report and 303(d) list: 67 p.

"Revisions to Total Maximum Daily Loads for Nutrient and Low Dissolved Oxygen Under High-Flow Conditions Christina River Basin, Pennsylvania, Delaware, and Maryland." *Division of Watershed Stewardship*, Sept. 2006, www.dnrec.delaware.gov/swc/wa/Documents/Xia/Christina_High-Flow_NutrientsTMDL_TechReport_2006.pdf

Sloto, Ronald A., and Leif E. Olson. "Estimated Suspended-Sediment Loads and Yields in the French and Brandywine Creek Basins, Chester County, Pennsylvania, Water Years 2008–09." *USGS*.

"United States History." *History of Wilmington, Delaware*, www.u-s-history.com/pages/h2279.html.

Water Quality Network, www.depgis.state.pa.us/WQN/.

"What To Do With All of the Poo?" *Modern Farmer*, 10 May 2016, modernfarmer.com/2014/08/manure-usa/.

"Wilmington, DE." *City History | Wilmington, DE*, www.wilmingtonde.gov/about-us/about-the-city-of-wilmington/city-history.