

Economic Value of the Brandywine Creek Watershed

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The Christina Basin Clean Water Partnership

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Executive Summary

The water, natural resources, and ecosystems in the Brandywine Creek watershed contribute an economic value of \$9.8 to \$19.7 billion annually to the Pennsylvania and Delaware economies. This report examines that economic value in three different ways:

- 1. Economic value directly related to Brandywine Creek watershed water resources and habitats.** The Brandywine Creek watershed contributes over \$1.16 billion in annual economic activity from water quality, water supply, fish/wildlife, recreation, agriculture, forests, and public parks benefits.
- 2. Value of goods and services provided by Brandywine Creek watershed ecosystems.** Using natural capital as a measure of value, habitats in the Brandywine Creek watershed provide \$560.5 million annually in ecosystem goods and services in 2010 dollars, with a net present value (NPV) of \$18.3 billion calculated over a 100-year period.
- 3. Employment related to Brandywine Creek watershed resources and habitats.** Using employment as a measure of value, natural resources within the Brandywine Creek watershed directly and indirectly support over 28,000 jobs with over \$38.8 million in annual wages.

The purpose of these estimates is to demonstrate that the Brandywine Creek watershed provides real and significant economic benefits to Pennsylvania and Delaware, benefits that are worthy of investment to keep these natural resources healthy and productive. Estimates were made by taking values from existing literature and studies and applying them to the Brandywine Creek watershed using ecological economics and benefits-transfer techniques described in this report. Values are converted to 2010 dollars based on the change in the Northeast Region Consumer Price Index except where noted.

Note that the values in the three categories are not summed because there is some overlap between certain values within each category that could result in double counting. For example, the jobs of fishermen that contribute to employment and wages are also a factor in the economic activity generated from fishing, and the ecosystem values of forests for water-quality benefits may be at least partially captured in the economic value of water supply. Accurately determining (and eliminating) this overlap is difficult within the scope of this analysis.

The estimates presented in this report are as inclusive possible due to a lack of data for some economic sectors. Additionally, they are not meant to be used to compare and contrast uses of the Brandywine Creek watershed's water resources for their value. Some values were not included in these estimates because the data to assess them either are not readily available or do not exist. For example, the full amount of economic activity and jobs associated with the industries that rely on the Brandywine Creek watershed for their processes is not included here, as identifying those companies and gathering information on their economic activity is beyond the scope of this analysis.

1. Introduction

Objectives

This report summarizes the economic value of water, natural resources, and ecosystems of the Brandywine Creek watershed in Delaware and Pennsylvania estimated as:

1. Economic activity including market and non-market value of water quality, water supply, fish/wildlife, recreation, agriculture, forests, and public parks benefits.
2. Ecosystem goods and services (natural capital) value provided by habitat such as wetlands, beaches, open water, forests, and farms.
3. Jobs and wages directly and indirectly associated with the Brandywine Creek watershed.

These estimates demonstrate that the Brandywine Creek watershed provides significant economic benefits to the regional economy and are worthy of investment to keep them healthy and productive. Value-transfer techniques were applied by selecting data from published literature and applying them to the Brandywine Creek watershed using ecological economics techniques.

Values in the three categories above are not summed because there may be overlap and double-counting. For example, the ecosystem values of forests for water-quality benefits are at least partially captured in the economic value of water supply. However, each of the above estimates clearly indicates that the Brandywine Creek watershed is an economic engine that contributes between \$38.8 million and 1.16 billion annually to the Delaware and Pennsylvania economies.

The estimates presented in this report can be considered in the low range because the data to assess economic value are not readily available in some categories. For example, the economic activity and jobs associated with companies and industries that rely on the watershed for their processes are not included here. Because some estimates were made by taking values from existing literature, the values for various activities differ greatly in how they were determined and applied to the Creek's water resources, making it difficult to accurately compare values across uses.

History

The Brandywine Creek watershed, otherwise known as the Brandywine Valley, has long been a cultural and economic hub. The earliest inhabitants of the watershed were the Lenni Lenape, a tribe who knew their waterway as *Wawassan*. Over time, these "Delaware Indians," as they were called, were displaced and forced north- and west-wards by European settlers. The last of the Lenape, Indian Hanna, was buried in 1802 at Embreeville at the forks of the Brandywine.

The economic importance of the Brandywine was evident early on during colonial rule. The Swedes, who arrived on the Kalmar Nyckel, founded the first permanent European settlement in the Delaware Valley at the mouth of Brandywine Creek along the Christina River in 1638. The

Quakers established large farms for grain and cattle with mill dams along the waterways of the Brandywine for the grinding of meal and flour. Downstream towards Wilmington, the navigable tidewater waterways boosted the growing agricultural industry as small ships could directly dock at mills to pick up and deliver goods to other ports, both in the colonies and overseas.

Wagons and cattle were ferried across the wide and shallow Brandywine at various fords. At Chadds Ford, PA British defeated the Americans at the largest of the American Revolution on September 11, 1777. Traveling from the south, British troops sought to take Philadelphia and planned to do so through Kennett Square. General George Washington fought to hold ground at Chadds Ford without realizing, until it was too late, that the British General William Howe had outmaneuvered the American troops, crossing the Brandywine further north near Wistar's Ford, PA and flanking from the right. The American troops retreated and attempted to hold ground at the Birmingham Friends Meeting House, but to no avail. General Washington and his units retreated to Chester as General Howe marched on to and took Philadelphia.

After the founding of the nation, the economy of the Brandywine Valley continued to flourish as an important source of mill power. The Dupont company traces its roots back to black powder mills established in what is now known as the Hagley Museum. Chemist Eleuthere Irenee du Pont and his family fled from the French Revolution's "Reign of Terror" and created E.I. du Pont de Nemours & Company, now a chemical and manufacturing company. Du Pont also built the Hagley mills to produce American black powder; this operation continued through the early 1900s. Though the mill is no longer active, it serves as an historic landmark for Delaware and is a reminder of the multibillion dollar company's humble beginnings.

Today, the Brandywine Creek is a natural treasure in Pennsylvania and Delaware as 32,000 acres (15% of the watershed's total area) are protected through land conservation efforts by the Brandywine Conservancy and Brandywine Valley Association. It is the home of such historic towns as Kennett Square and West Chester in Pennsylvania, and Wilmington and Centreville in Delaware.

The Watershed

The Brandywine Creek watershed is the largest watershed in the Christina Basin and drains 324 square miles, with headwaters flowing south from Chester County, Pennsylvania down to Wilmington, Delaware, where the creek empties into the Christina River. Over 90 percent of the watershed is in Pennsylvania. Agriculture is the dominant land use, followed by forest/wetland, and urban areas. The watershed also provides substantial drinking water resources to communities in both states as water is sourced by surface and ground water intakes, in addition to four reservoirs. It serves as the sole source of drinking water for Wilmington, which is Delaware's largest city. In addition, there is significant environmental value associated with the watershed, including:

- Habitat for rare and endangered species (according to the Pennsylvania Natural Diversity Index)

- Designation as a Pennsylvania Scenic River
- Headwaters that have been designated as High Quality Waters
- Designation of the Broad Run subbasin as a Watershed of Exceptional Value

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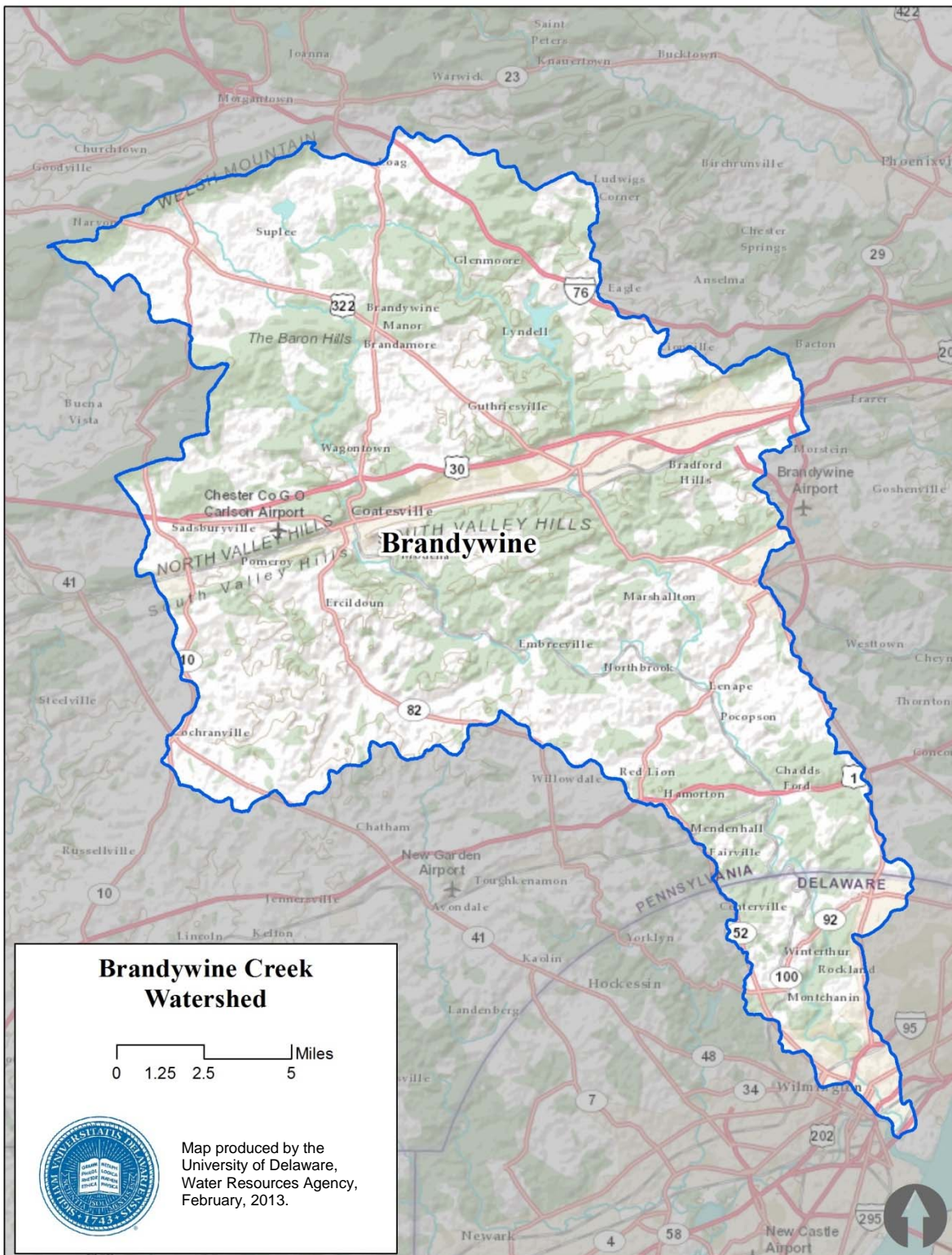


Figure 1. The Brandywine Creek watershed

Land Use

The most dominant land uses in the Brandywine Creek watershed are agriculture and forest, which account for 37% and 41.8% of the watershed's total area, respectively. Less than one quarter of the subbasin (18.5%) is developed land. The remainder of the watershed is covered by freshwater wetlands (1.9%), barren land (0.3%), and as open freshwater (0.5%) (Table 2, Figure 2, and Figure 3).

Table 1. Land use in Brandywine Creek watershed

Ecosystem	Area (mi ²)	% Area
Urban	60	18.5%
Farmland	120	37.0%
Forest land	135	41.8%
Freshwater wetlands	8	2.4%
Total	324	100%

(NOAA CSC 2006)

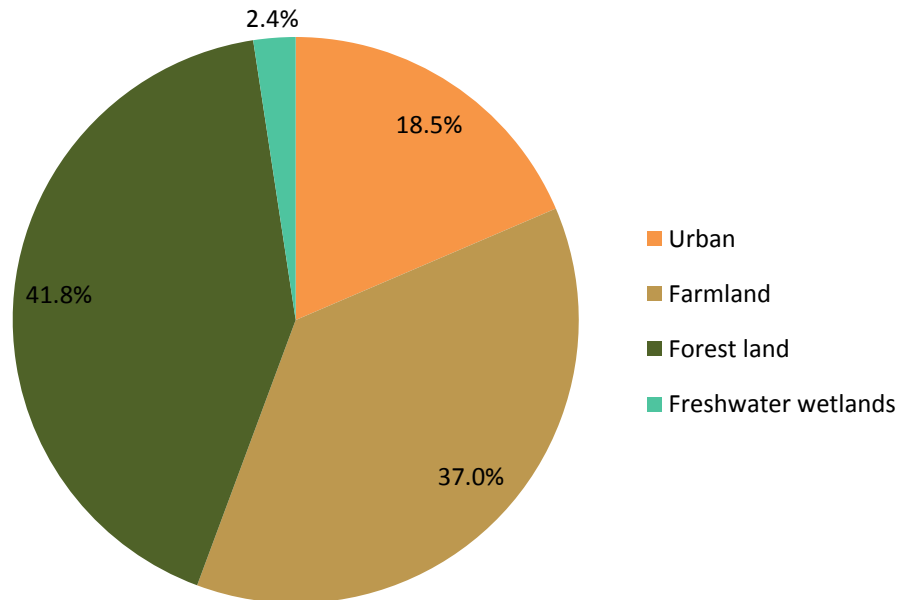


Figure 2. Land use in the Brandywine Creek watershed
(NOAA CSC 2006)

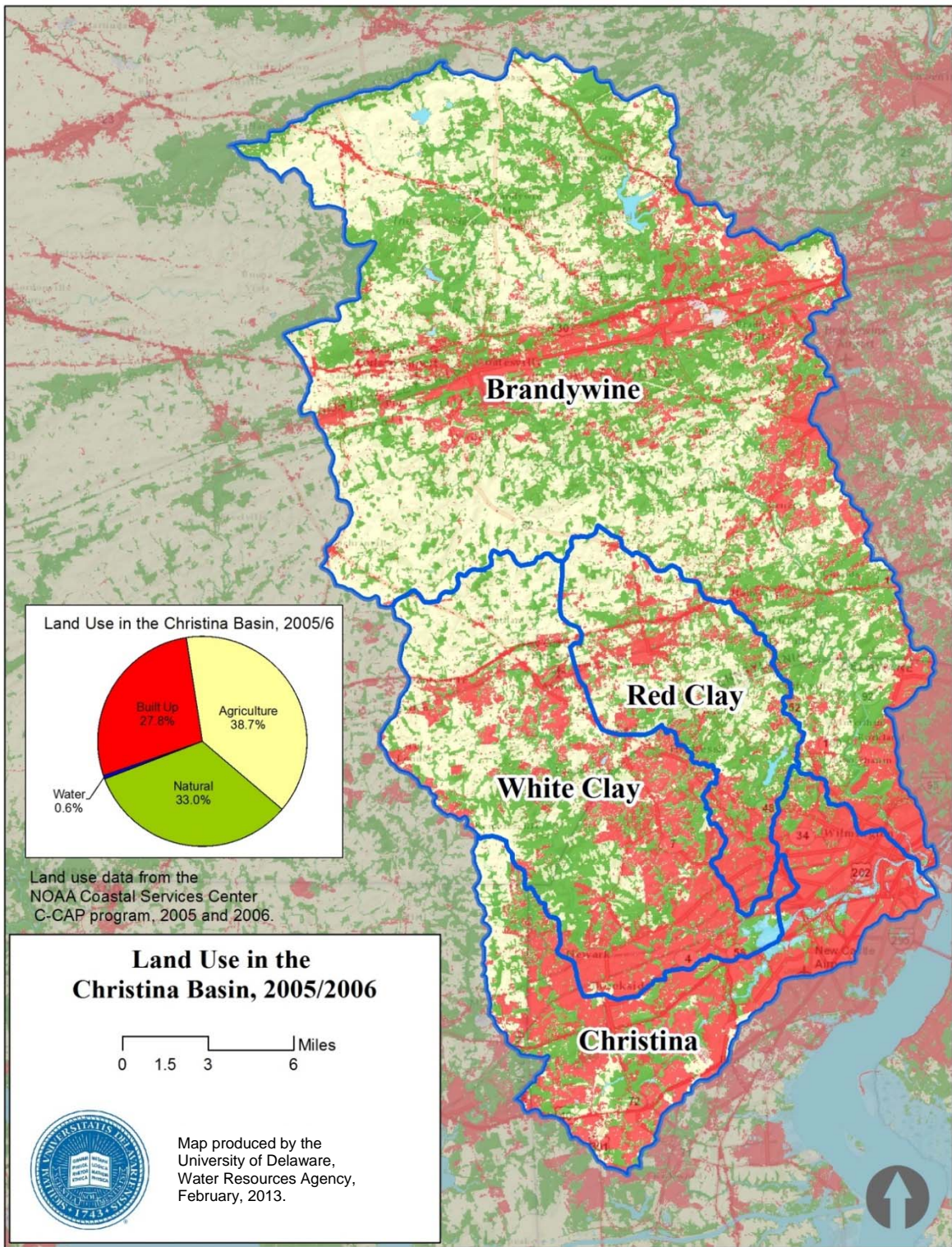


Figure 3. Land cover in the Brandywine Creek watershed (NOAA CSC 2006)

Population

Between 2000 and 2010, the population in the Brandywine Creek watershed population grew by 24,170 (10.9%) from 221,413 to 245,583 (Table 4). The majority of the watershed's spatial extent is within Pennsylvania (301 mi², or 93%), as is the highest population of people (201,496 people). Some 44,087 people reside in the smaller Delaware portion of the watershed (Table 3).

Table 2. Population of Brandywine Creek watershed by state

State	Area (mi ²) ¹	2010 pop. ²	2010 (people/mi ²)
Pennsylvania	301	201,496	669
Delaware	23	44,087	1,917
Total	324	245,583	2,586

1. U.S. Census 2. NOAA CSC 2006

Table 3. Population change in the Brandywine Creek watershed, 2000-2010

Watershed	Area (mi ²)	2000 pop.	2010 pop.	Change	2000 (people/ mi ²)	2010 (people/ mi ²)
Brandywine Creek	324	221,413	245,583	24,170	683	758

U.S. Census 2010

Employment

In 2010, 120,983 people were employed within the Brandywine Creek watershed, with 100,777 employees in Chester County and 21,412 in New Castle County (Table 4).

Table 4. Employment in the Brandywine Creek watershed in 2010

County	County ¹ Population	Watershed ¹ Population	County ² Employment	Watershed ³ Employment
Chester County, Pa.	498,886	201,496	249,515	100,777
New Castle County, Del.	538,479	44,087	261,530	21,412
Total	1,037,365	245,583	511,045	120,983

1. US Census 2010. 2. U.S. Bureau of Labor Statistics 2011.

3. Scaled by ratio of watershed population to county population and multiplied by county employment.

2. Methods

Valuation Techniques

The University of Delaware derived the economic value of the Brandywine Creek watershed from published studies that employed the following valuation techniques:

Avoided Cost: Society sustains costs if certain ecosystems were not present or are lost. For instance, the loss of wetlands may increase economic costs from flood damage.

Replacement Cost: Natural services are lost and replaced by more expensive human systems. For instance, forests provide water-filtration benefits that would be replaced by costly water-filtration plants.

Net Factor Income by Enhancement of Income: Improved water quality is known to enhance fishing productivity and boost fishing jobs/wages.

Travel Cost: Visitors are willing to pay to travel and purchase food and lodging to visit ecosystems and natural resources for tourism, boating, hunting, fishing, and birding.

Hedonic Pricing: Residents may be willing to pay more for higher property values along scenic bay and river coastlines with improved water quality.

Contingent Valuation: Valuation by survey of individual preferences to preserve ecosystems. People may be willing to pay more in fees or water rates to preserve river and bay water quality.

Scope of Work

The University of Delaware established the economic value of the Brandywine Creek watershed according to the following scope of work.

1. Area of Interest: The area of interest is defined as the Brandywine Creek watershed in Chester County, Delaware County, and Lancaster County, Pennsylvania and New Castle County, Delaware. The University of Delaware developed ArcGIS map layers of watersheds, population, ecosystems, habitat, and land use/land cover to perform the analysis.

2. Literature Review: Gather published literature and socioeconomic data relevant to the Brandywine Creek watershed including databases from the U.S. Census Bureau, U.S. Bureau of Labor Statistics, U.S. Department of Agriculture, U.S. Forest Service, and U.S. Fish and Wildlife Service.

3. Annual Economic Value: Estimate the direct (market) and indirect (non-market) economic value of agriculture, water quality, water supply, fishing, hunting, recreation, boating,

ecotourism, and navigation by utilizing population, employment, industrial activity, and land-use data. Total economic activity is the sum of direct and indirect uses, option demand, and non-use values (Ingraham and Foster 2008). Direct-use (market) values are derived from the sale or purchase of natural goods such as drinking water, boating, recreation, and commercial fishing. Indirect (non-market) values are benefits from ecosystems such as water filtration by forests and flood control/habitat protection from wetlands. Option demand is public willingness to pay for benefits from water quality or scenic value of the water resources. Non-use (existence) values are treasured by a public who may never visit the resource but are willing to pay to preserve the existence of the resource. Values are converted to 2010 dollars based on the change in the Consumer Price Index (CPI) in the Northeast Region as reported by the Bureau of Labor Statistics.

4. Ecosystem Services: Tabulate the market value of natural resources (ecosystem services value) in the Brandywine Creek watershed for habitat such as wetlands, forests, farmland, and open water. Ecosystem services (ecological services) are economic benefits provided to society by nature such as water filtration, flood reduction, and drinking water supply. Using ArcGIS, map and tabulate ecosystem areas (acres) using land cover data in the following classifications: (a) freshwater wetlands, (b) marine, (c) farmland, (d), forest, (e) barren, (f) saltwater wetland, (g) urban, (h) beach/dune, and (i) open freshwater. Review published research studies and gather economic value (\$/acre) data for these ecosystem goods and services: (a) carbon sequestration, (b) flood control, (c) drinking water supply, (d) water-quality filtration, (e) waste treatment and assimilation, (f) nutrient regulation, (g) fish and wildlife habitat, (h) recreation and aesthetics. Compute ecosystem services value by multiplying land-use area (acres) by ecosystem value (\$/acre).

Ecosystem services are estimated using value (benefits) transfer where published data and literature from similar watersheds are reviewed and applied to the resource in question. Value-transfer techniques include selecting data from published literature from another watershed or study area and applying the dollars-per-acre values to Brandywine Creek watershed land-use areas. While primary research data from the area in question is preferable and is used in many cases in this report, value transfer is the next best practical way to value ecosystems, especially when, in the absence of such data, the worth of ecosystems have previously been deemed zero.

5. Jobs and wages: Obtain employment and wage data from the U.S. Department of Labor, U.S. Census Bureau, National Ocean Economics Program, and other sources. Estimate direct/indirect jobs by North American Industry Classification System (NAICS) codes such as shipbuilding, marine transportation/ports, fisheries, recreation, minerals, trade, agriculture, and others. NAICS data were supplemented with farm jobs data from the USDA Agricultural Statistics Bureau, U.S. Fish and Wildlife Service ecotourism jobs data, and jobs provided by water purveyors and watershed organizations.

6. Report: Prepare a report and GIS mapping that summarizes (1) annual economic value of activities related to the Brandywine Creek watershed, (2) ecosystem goods and services (natural capital), and (3) jobs and wages directly and indirectly related to the bay and watershed in 2010 dollars.

3. Economic Value

Hodge and Dunn (1992) illustrated the total economic value of water resources based on use and non-use values (Figure 4). Use values include direct values, such as market goods from sales of crops, fish, and timber; unpriced benefits from recreation and aesthetic view sheds; and ecological-function values (ecosystem services) from flood control, water storage, and waste-assimilation services of wetland and forest habitat. Non-use values include future-option values such as future drug discoveries from wetland plants and future recreation, existence values from satisfaction that a water resource exists but may never be visited, and bequest values such as preserving water quality for future generations.

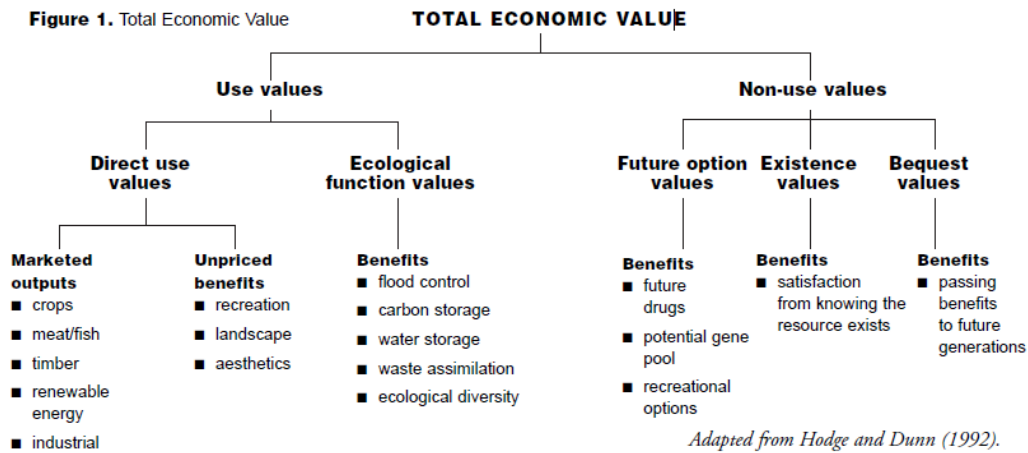


Figure 4. Economic value of water resources (Hodge and Dunn 1992)

The annual economic value of the Brandywine Creek watershed from water quality, water supply, fish/wildlife, recreation, agriculture, forests and public parks benefits exceeds \$800 million (Figure 5 and Table 5).

Water Quality	\$419 million
Water Supply	\$143 million
Fish/Wildlife	\$33 million
Recreation	\$133 million
Agriculture	\$260 million
Forests	\$102 million
Public Parks	\$70 million
Total	> \$1.1 billion

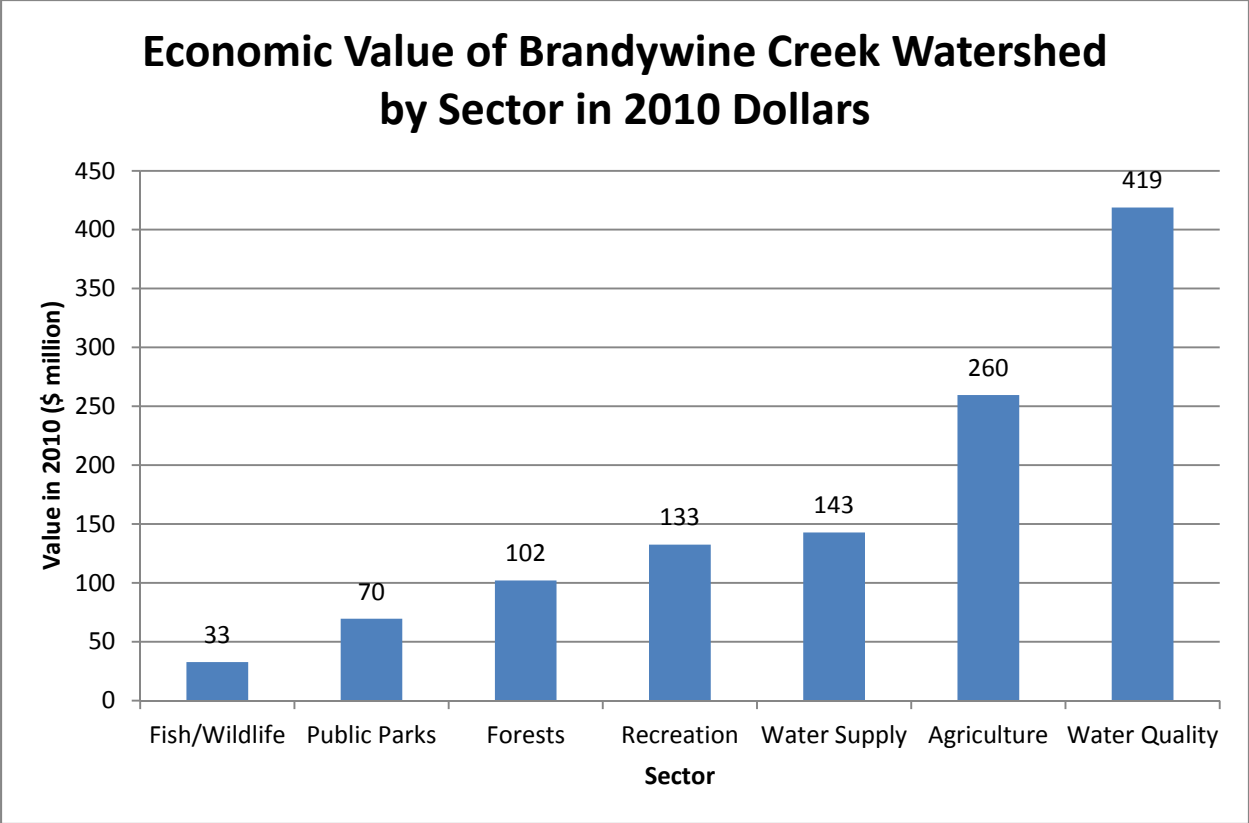


Figure 5. Annual economic value of the Brandywine Creek watershed by sector

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Table 5. Annual economic value of the Brandywine Creek watershed

Sector	Activity	2010 (\$ mil)	Source
Water Quality	Boatable (WTP=\$13.20)	3	University of Delaware (2003)
	Fishable (WTP=\$13.22)	3	University of Delaware (2003)
	Swimmable (WTP=\$112.75)	28	University of Delaware (2003)
	Increased Property Value (+8% over 20 years)	360	EPA (1973), Brookings Institute (2010)
	Water Treatment by Forest (\$76/mgd)	2	Trust for Public Land, AWWA (2004)
	Wastewater Treatment	23	DNREC (2010), UDWRA
Water Supply	Drinking Water Supply (\$7.85/1,000 gallons)	137	UDWRA, CCCD, CCWRA
	Reservoir Storage	2.6	NJWSA (2011)
	Irrigation Water Supply (\$300/acre-foot)	1.3	Resources for the Future (1996), USDA (2007)
	Industrial Water Supply (\$200/acre-foot)	1.6	Resources for the Future (1996), USGS (2005)
Fish/Wildlife	Fishing	10	U.S. Fish and Wildlife Service (2008)
	Hunting	11	U.S. Fish and Wildlife Service (2008)
	Wildlife/Bird-watching	11	U.S. Fish and Wildlife Service (2008)
Recreation	Outdoor Recreation (241,020 participants)	110	Outdoor Industry Foundation (2006)
	State Parks (\$53/visit, 8,374 acres)	22.5	PA DEP and Penn State
Agriculture	Crop, poultry, livestock value (\$3,482/acre)	260	USDA Census of Agriculture 2007 (2009)
Forests	Carbon Storage (\$827/acre)	71	U.S. Forest Service, Del Ctr. Hort. (2008)
	Carbon Sequestration (\$29/acre)	3	U.S. Forest Service, Del Ctr. Hort. (2008)
	Air Pollution Removal (\$266/acre)	23	U.S. Forest Service, Del Ctr. Hort. (2008)
	Building Energy Savings (\$56/acre)	5	U.S. Forest Service, Del Ctr. Hort. (2008)
	Avoided Carbon Emissions (\$3/acre)	0.3	U.S. Forest Service, Del Ctr. Hort. (2008)
Public Parks	Health Benefits (\$9,734/acre)	52	Trust for Public Land
	Community Cohesion (\$2,383/acre)	13	Trust for Public Land
	Stormwater Benefit (\$921/acre)	5	Trust for Public Land
	Air Pollution Control (\$88/acre)	0.5	Trust for Public Land
Total for Watershed		1158.8	

Note: Total economic value is rounded down to avoid double-counting.

Water Quality

Improved Water Quality

Helm, Parsons, and Bondelid (2003) measured the economic benefits of water-quality improvements to recreational users in the New England states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut and found per person willingness to pay (WTP) for good water quality ranged from \$8.25 for boating, \$8.26 for fishing, and \$70.47 for swimming use support in 1994 dollars. Adjusting to 2010 dollars based on the change in the Consumer Price Index (CPI) in the Northeast Region as reported by the Bureau of Labor Statistics, per person WTP is estimated at \$13.20 for boating, \$13.22 for fishing, and \$112.75 for swimming uses (Table 6).

In 2010, the Brandywine Creek watershed population reached 245,583 (U.S. Census 2010). Based on value transfer data from the study in six New England states, annual WTP for improved water quality in the Brandywine Creek exceeds \$34 million in monetary value. The greatest WTP value comes from a swimmable quality level, at \$27.7 million followed by fishable quality and boatable quality at \$3.2 million each (Table 6).

Table 6. Annual WTP for water quality benefits in the Brandywine Creek watershed

Quality Level	WTP per person ¹ (\$1994)	WTP per person ² (\$2010)	Watershed Population	WTP (\$2010)
Boatable	8.25	13.20	245,583	3,241,696
Fishable	8.26	13.22	245,583	3,246,607
Swimmable	70.47	112.75	245,583	27,689,483
Total	86.98	139.17	245,583	34,177,786

1. Helm, Parsons, and Bondelid (2003). 2. Adjusted to 2010 based on change in Northeast Region CPI (BLS). 3. WTP based on Brandywine Creek watershed population.

Increased Property Value

Studies along rivers and bays in the U.S. indicate that improved water quality can increase shoreline property values by 4% to 18% (Table 7). The EPA (1973) estimated improved water quality can raise property values by up to 18% next to the water, 8% at 1,000 feet from the water, and 4% at 2,000 feet from the water. Leggett et al. (2000) estimated improved bacteria levels to meet water quality standards along the western shore of the Chesapeake Bay in Maryland could raise property values by 6%. Poor et al. (2007) studied 1,377 residential property sales in the St. Mary's River watershed on the western shore of Chesapeake Bay and concluded that a 1 mg/l increase in dissolved inorganic nitrogen reduced the average (\$200,936 property value of a house by \$17,642 or 8.8%. Austin et al. (2007) from the Brookings Institution projected that investing \$26 billion to restore the Great Lakes would increase shore property values by 10%.

Table 7. Increased property value resulting from improved water quality

Study	Watershed	Increased Property Value
EPA (1973)	San Diego Bay, Calif.	
- Next to water	Kanawha, Ohio	18%
- 1000 ft from water	Willamette River, Ore.	8%
- 2000 ft from water		4%
Leggett et al. (2000)	Chesapeake Bay	6%
Poor et al. (2007)	Chesapeake Bay	9%
Brookings Institute (2007)	Great Lakes	10%

With improved water quality, property values within 2,000 feet of the Brandywine Creek and its tributaries are estimated to increase by 8%, which is the adjusted midpoint between 18% next to the water and 4% at 2000 ft from the water. The Brandywine Creek and its tributaries flow for 632 stream miles. If the median property value in the Brandywine Creek is \$293,550/acre, based on housing data from the U.S. Census, then properties within 2,000 feet of the creek have an estimated value of \$22.5 million. Property values within 2,000 feet of the water would increase by 8% (or \$7.2 billion) due to improved water quality (Table 8). Since increased property value is a one-time benefit, the annual value over a 20-year period is estimated at \$360 million.

Table 8. Added property value due to improved water quality in Brandywine watershed

Stream Length (miles)	Stream Length (ft)	Area 2,000 ft of Stream (ac)	Property Value @ \$293,550/ac (\$)	Increased Value @ 8% (\$)	Annual Value 20 years (\$)
632	3,336,960	306,424	89,950,836,364	7,196,066,909	359,803,345.45

Water Treatment by Forests

The Trust for Public Land and American Water Works Association (2004) found that for every 10% increase in forested watershed land, drinking water treatment and chemical costs are reduced by approximately 20% (Table 11). If the public drinking water supply is 54.5 mgd and forests cover 86,400 acres (135 mi² or 42%) of the Brandywine Creek watershed, then loss of these forests would increase drinking water treatment costs by \$83 per mgd (\$139/mgd @ 0% forested minus \$56/mgd @ 42% forested), which is equivalent to \$4,856/day or \$1.8 million/year (Table 9).

Table 9. Drinking water treatment costs based on percent of forested watershed

Watershed Forested	Treatment Costs (\$/mg)	Change in Costs
0%	139	21%
10%	115	19%
20%	93	20%
30%	73	21%
40%	58	21%
50%	46	21%
60%	37	19%

Wastewater Treatment

There are 20 permitted surface-discharge-sewage-treatment plants in the Brandywine Creek watershed, only one of which is located in the Delaware portion of the watershed (EPA TMDL Report).

The NPDES wastewater dischargers in Pennsylvania and Delaware possess Federal and state water-quality permits to treat and discharge 15.8 mgd to the Brandywine Creek watershed. An analysis of wastewater utilities conducted by WRA computes that the average wastewater rate in the watershed is \$4.00 per 1,000 gallons, which, for an average residence of four people (at 50 gpcd), is a fee of \$290 per year. The total market value based on treated-wastewater rates in the Brandywine Creek watershed is \$63,093 per day (approximately \$23 million per year) (Table 10).

Table 10. Value of Sewage-Treatment Plants' Discharge in the Brandywine Creek Watershed

NPDES ID	Sewage Treatment Plant	Discharge (mgd)	\$/day	\$/Year
			(\$4.00/1,000gal)	
<i>Main Stem</i>				
DE0021768	Winterthur	0.025	\$100	\$36,500
PA0055476	Birmingham TSA/Ridings at Chadds Ford	0.04	\$160	\$58,400
PA0244031	Chadds Ford Township Harvey Run	0.15	\$600	\$219,000
PA0030848	Unionville - Chadds Ford Elem. School Ring Run	0.01	\$25	\$9,198
PA0031097	Radley Run C.C. Radley Run Municipal Small STP	0.02	\$68	\$24,820
PA0053449	Birmingham Twp. STP Radley Run Municipal STP	0.15	\$600	\$219,000
PA0057011	Thornbury Twp./Bridlewood Farms STP Radley Run	0.08	\$309	\$112,858
PA0036200	Radley Run Mews Plum Run Municipal Small STP	0.03	\$128	\$46,720
<i>East Branch</i>				
PA0026018	West Chester Borough MUA/Taylor Run	1.8	\$7,200	\$2,628,000
PA0043982	Broad Run Sew Co. EB Brandywine Creek	0.4	\$1,600	\$584,000
PA0026531	Downingtown Area Reg. Authority EB Brandywine Cr.	7.5	\$30,000	\$10,950,000
PA0054917	Uwchlan Twp. Municipal Authority Shamona Creek	0.48	\$1,900	\$693,500
PA0027987	Eaglepoint Dev. Assoc. TB Marsh Creek STP	0.02	\$60	\$21,900
PA0050458	Little Washington Drainage Co. Culbertson Run	0.05	\$212	\$77,526
PA0050547	Indian Run Village MHP Indian Run Municipal STP	0.04	\$150	\$54,750
<i>West Branch</i>				
PA0029912	Embreeville Hospital WB Brandywine Creek STP	0.1	\$400	\$146,000
PA0036897	South Coatesville Borough WB Brandywine Creek	0.39	\$1,560	\$569,400
PA0026859	Coatesville City Authority WB Brandywine Creek	3.85	\$15,400	\$5,621,000
PA0036412	Tel Hai Retirement Community TB-WB Brandywine	0.06	\$220	\$80,300
PA0044776	NW Chester Co. Municipal Authority WB Brandywine	0.6	\$2,400	\$876,000
Total		15.77	\$63,093	\$23,028,872

Water Supply

Drinking Water Supply

The streams and wells of the Brandywine Creek watershed provide over 61.7 million gallons per day (mgd) of public drinking water. The annual value of public water supplies in the Brandywine Creek watershed is \$137 million per year or \$128 million from surface water and \$9 million from groundwater.

Surface waters in the Brandywine Creek watershed provide over 58.5 mgd of drinking water in both Chester County, Pennsylvania and Wilmington, Delaware (Table 11). The watershed is served by the following public water systems: Pennsylvania American Water Company, Downingtown Municipal Water Authority, Aqua Pennsylvania, and Wilmington, Delaware. At the water rates charged by the water utilities, the annual value of 58.5 mgd of treated surface water in the Brandywine Creek watershed is \$128 million, which exceeds \$350,000 per day.

Table 11. Public surface water withdrawals

State	County	Purveyor	Capacity ¹ (mgd)	Water Rate ² (\$/1,000 gal) ²	Value/day (\$)	Value/year (\$)
PA	Chester	PA American Water Co.	6	9.21	55,260	20,169,900
PA	Chester	Downingtown MUA	2.5	7.65	19,125	6,980,625
PA	Chester	Aqua PA	6	10.27	61,620	22,491,300
DE	New Castle	City of Wilmington	44	4.88	214,720	78,372,800
			58.5		350,725	128,014,625

1. Phase I & II Report Christina River Basin, Water Quality Management Strategy, May 1998. UDWRA 2012.

The community public water supply wells in the Brandywine Creek watershed provide approximately 3.2 mgd of drinking water to the region. These wells serve as drinking water sources for northern Delaware and southeastern Pennsylvania. The value per year of treated water supply from 3.2 mgd community public water supply wells is \$9 million (Table 12).

Table 12. Community Public Water Supply Wells in the Brandywine watershed

Owner	Capacity ¹ (mgd)	Water Rate ² (\$/1,000 gal) ²	Value/day (\$)	Value/year (\$)
Appleville MHP	0.01	7.85	79	28,653
PSW Beversrede	0.032	7.85	251	91,688
PSW B & E Water System	0.034	7.85	267	97,419
Brandywine Terrace MHP	0.02	7.85	157	57,305
Caln MHP	0.002	7.85	16	5,731
Carriage Crest System	0.003	7.85	24	8,596
Church Farm School	0.013	7.85	102	37,248
Chester County Prison	0.158	7.85	1,240	452,710
Chester County Pocopson Home	0.021	7.85	165	60,170
Devereaux School	0.017	7.85	133	48,709
Downingtown I & A School	0.012	7.85	94	34,383
PSW Friendship Co.	0.034	7.85	267	97,419
Glenview MHP	0.002	7.85	16	5,731
Gregory Courts MHP	0.09	7.85	707	257,873
Hickory House	0.007	7.85	55	20,057
Highland MHP	0.004	7.85	31	11,461
Hilltop MHP	0.017	7.85	133	48,709
Honeybrook Borough Authority	0.189	7.85	1,484	541,532
Icedale MHP	0.024	7.85	188	68,766
Imperial MHP	0.008	7.85	63	22,922
Indian Run Villange MHP	0.042	7.85	330	120,341
Keystone MHP	0.011	7.85	86	31,518
Kimberwick Community	0.011	7.85	86	31,518
Lazy Acres MHP	0.009	7.85	71	25,787
Lincoln Crest MHP	0.024	7.85	188	68,766
Little Washington System	0.064	7.85	502	183,376
Loags Corner MHP	0.008	7.85	63	22,922
PSW Locust Knoll	0.022	7.85	173	63,036
Maplewood MHP	0.004	7.85	31	11,461
Marshallton Manor System	0.01	7.85	79	28,653
Mount Idy MHP	0.005	7.85	39	14,326
PSW Pocopson	0.057	7.85	447	163,319
Springton MHP	0.003	7.85	24	8,596
PSW Spring Run	0.072	7.85	565	206,298
St. Mary of Providence Home	0.006	7.85	47	17,192
Stonehedge System	0.022	7.85	173	63,036
Taylor's MHP	0.007	7.85	55	20,057
Tel Hai Retirement Community	0.036	7.85	283	103,149
PSW Uwchlan Twp.	1.684	7.85	13,219	4,825,081

Valley Springs Water Company	0.033	7.85	259	94,553
West Chester Area Authority	0.065	7.85	510	186,241
West Whiteland System	0.335	7.85	2,630	959,859
Woodbrooke Water Authority	0.006	7.85	47	17,192
Total	3.233		25,379	9,263,353

Wells use the \$7.85 average.

Reservoir Storage

Public water supply reservoirs store over 6.6 billion gallons of water in the Brandywine Creek watershed (Table 13). The New Jersey Water Supply Authority delivers untreated water to public water purveyors from the Raritan River reservoir system at an estimated market price of \$0.394/1,000 gallons (NJWSA 2011). Given the raw water storage value \$0.394/1000 gallons, the annual value of reservoir storage in the Brandywine Creek watershed is \$2.6 million.

Table 13. Economic value of reservoir storage in the Brandywine Creek watershed

Reservoir	Storage (MG)	Value (\$0.394/1000 gal)
Chambers Lake	350	137,900
Rock Run	200	78,800
Struble Lake	100	39,400
Hoopes	2,000	788,000
Marsh Creek	4,000	1,576,000
Total	6,650	2,620,100

Irrigation Water Supply

In a study of the economic value of freshwater in the United States, Resources for the Future (Frederick et al. 1996) estimated the median value of irrigation water withdrawals was \$198/ac-ft in 1996 dollars, which is equivalent to \$300/ac-ft (\$0.92/1,000 gal) in 2010 dollars, adjusting for change in the CPI (Table 14). In 2007, 76,800 acres of cropland (37% of the Brandywine Creek watershed) were cultivated and 1,509 acres were irrigated (USDA 2009). Annual irrigation-water needs from June through September are 9 inches for corn, soybeans, and grain (2,600 gpd/ac for 1,090 irrigated acres, or 2.4 mgd). In the Brandywine Creek watershed, the annual value of irrigating 1,509 acres with 9 inches of water at a use value of \$0.92/1,000 gal is \$1.3 million /yr.

Table 14. Freshwater-use values in the United States

Use	1996 Median ¹ (\$/ac-ft)	2010 Median ² (\$/ac-ft)	2010 Median (\$/1,000 gal)
Navigation	10	15	0.02
Irrigation	198	300	0.92
Industrial Process	132	200	0.61
Thermoelectric Power	29	44	0.14

1. Frederick et al. 1996.

2. Adjusted to \$2010 based on change in Northeast Region CPI (BLS).

Table 15. Value of agriculture irrigation in the Brandywine Creek watershed

County	Farmland by County ¹ (ac)	Irrigation by County ¹ (ac)	Farmland in Watershed (ac)	Irrigation in Watershed (ac)	Irrigation @ 2,600 gpd/ac (gpd)	Value of Irrigation @ \$0.92/1,000 gal (\$/day)	Value of Irrigation (\$/yr)
Chester	117,145	1,659					
Lancaster	326,648	5,366					
Delaware	1,646	36					
New Castle	51,913	2,711					
Total	497,352	9,772	76,800	1,509	3,923,400	3,610	1,317,478

1. Census of Agriculture, 2007, (USDA, 2009)

2. Frederick et al., 1996

Industrial Water Supply

In 2005, the USGS estimated that industrial-water withdrawals totaled 7.0 mgd in the Brandywine Creek watershed. The median market value of industrial withdrawals is \$132/ac-ft in 1996 dollars (Frederick et al. 1996) or \$200/ac-ft. (\$0.61/1,000 gal) in 2010 dollars based on the change in CPI. The value of industrial-water withdrawals (7.0 mgd) in the Brandywine Creek watershed is \$4,271 per day, or \$1.6 million/year (Table 16).

Table 16. Industrial Water Supply-Use in the Brandywine Creek watershed

Industry	Industrial ¹ Water Supply (mgd) ¹	Use Value ² (\$/1,000 gal)	2010 Value (\$/day)	2010 Value (\$/yr)
West Branch Lukens Steel	4.76	0.61	2,904	1,059,814
West Branch Sealed Air Corporation	0.28	0.61	170	61,897
East Branch Sonoco Products	1.32	0.61	805	293,898
East Branch Milestone Materials	0.62	0.61	378	138,043
East Branch Brandywine Paperboard	0.02	0.61	15	5,344
	7.00	0.61	4,271	1,558,995

1. USGS, 2003. 2. Frederick et al. 1996 converted to 2010 dollars based on the change in CPI.

Fish/Wildlife

Fishing, Hunting, and Bird/Wildlife Watching

The U.S. Fish and Wildlife Service (2008) conducted a survey of the 2006 annual economic value of recreational fishing, hunting, birding and wildlife-associated activities in the U.S. The annual economic value of recreational fishing, hunting, birding and wildlife-associated activities was \$4,343 million in Pennsylvania and \$269 million in Delaware in 2006 dollars. Using these state-wide totals and adjusting for percentage of the state in the Brandywine Creek watershed, the annual economic value of the recreational fishing, hunting, birding and wildlife-associated activities for the Basin was \$32.7 million (Table 17).

Table 17. Value of wildlife recreation in Brandywine Creek watershed

Activity	PA ¹ (\$2006)	PA in watershed ² (\$2006)	DE ¹ (\$2006)	DE in watershed ² (\$2006)	Brandywine Cr. Watershed ³ (\$2006)
Fishing	1,291,211,000	8,780,235	96,775,000	1,141,945	9,922,180
Hunting	1,609,045,000	10,941,506	41,381,000	488,296	11,429,802
Wildlife/Birding	1,442,582,000	9,809,558	130,832,000	1,543,818	11,353,375
Total	4,342,838,000	29,531,298	268,988,000	3,174,058	32,705,357

1. USFWS, Survey conducted in 2006, report issued 2008.

2. Scaled by the percentage of each state that is in the Brandywine Creek watershed (0.0089 PA, 0.08 DE).

3. Sum of scaled values.

Recreation

Outdoor Recreation

The Outdoor Industry Foundation (2006) concluded there were 16.3 million participants in recreation activities such as bicycling, camping, fishing, hunting, paddling, hiking, and wildlife viewing in the mid-Atlantic region (NJ, NY, PA) who contributed \$18.3 billion (\$15.6 billion in gear/trip sales) and 216,396 jobs to the regional economy. Given the total population of the 3 states – 40.9 million (NJ 8.8 million, NY 19.4 million, and PA 12.7 million) – , by proportion outdoor recreation activity in the Brandywine Creek watershed (pop. 245,583) contributes \$110 million and 1,299 jobs to the economy (Table 18).

Table 18. Outdoor recreation activity in the Brandywine Creek watershed

Recreation	Activity	Mid-Atlantic Region ¹	Brandywine Creek ²
Bicycling	Gear Trip/Sales/Contributions	\$3,372,000,000	\$20,247,087
	Participants	2,496,000	14,987
	Jobs	40,121	241
Camping	Gear Trip/Sales/Contributions	\$7,513,000,000	\$45,111,616
	Participants	1,874,000	11,252
	Jobs	89,384	537
Fishing	Gear Trip/Sales/Contributions	\$1,768,000,000	\$10,615,911
	Participants	1,890,000	11,348
	Jobs	17,195	103
Hunting	Gear Trip/Sales/Contributions	\$731,000,000	\$4,389,271
	Participants	450,000	2,702
	Jobs	7,234	43
Paddling	Gear Trip/Sales/Contributions	\$784,000,000	\$4,707,508
	Participants	1,586,000	9,523
	Jobs	9,331	56
Hiking	Gear Trip/Sales/Contributions	\$2,411,000,000	\$14,476,788
	Participants	3,048,000	18,302
	Jobs	28,686	172
Wildlife Viewing	Gear Trip/Sales/Contributions	\$1,756,000,000	\$10,543,857
	Participants	4,990,000	29,962
	Jobs	24,445	147
Total	Gear Trip/Sales/Contributions	\$18,335,000,000	\$110,092,037
	Participants	16,334,000	98,077
	Jobs	216,396	1,299

1. Outdoor Industry Foundation 2006.

2. Scaled by population of the Brandywine Creek (245,583) to mid-Atlantic region population.

State Parks

The Brandywine Creek watershed has two state parks – one in Pennsylvania and one in Delaware – which cover approximately 2,638 acres (4.12 mi²) within the watershed. In 2012 the Pennsylvania Department of Conservation and Natural Resources and Penn State reported that visitors to Marsh Creek State Park spent \$18,210,000 on their trips to the park in 2010. This report indicates Marsh Creek State Park had 340,771 visitors in 2010. Using these numbers, \$53.44 spent per visitor was estimated for the state park. Based on visitor data from the Brandywine Creek State Park, approximately 80,000 visitors visit Brandywine Creek State Park annually. Assuming the \$53.44 multiplier from Marsh Creek State Park can be applied to the Brandywine Creek State Park, it can be said that its 80,000 annual visitors spend approximately

\$4.3 million dollars on their visits, totaling \$22.5 million dollars in visitor value between both the Brandywine Creek and Marsh Creek state parks (Table 19).

Table 19. State Park Usage in the Brandywine Creek Watershed

State	Park	Acreage	Total visitors (per year) ^{1,2}	Spending/visitor (\$) ³	Estimated \$ spent per year (2010) ^{1,4}
PA	Marsh Creek	1,705	340,771	53.44	18,210,000
DE	Brandywine Creek	933	80,000	53.44	4,275,200
Brandywine (Total)					22,485,200

1. PADCN and Penn State 2012
2. Values for Brandywine Creek from staff at the Brandywine Creek State Park
3. Estimated using the report: Summary of Economic Significant for White Clay Creek and Marsh Creek, individual reports
4. Brandywine Creek values estimated using PA spending /visitor (at \$53/visit)

Agriculture

In 2007, the USDA National Agricultural Statistics Service (2009) estimated the annual market value of agricultural products sold in Chester, Lancaster, and Delaware counties in Pennsylvania and New Castle County, Delaware was \$1.7 billion. Scaling by the area of farmland in the Brandywine Creek watershed, the value of crops in the watershed is \$260 million (Table 20).

Table 20. Value of Cropland and Agriculture in the Brandywine Creek watershed

County	Farmland by County ¹ (ac)	2007 Value by County ¹ (\$ million)	Farmland in Watershed (ac) ²	2007 Value in Watershed (\$ million)
Chester	117,145	553		
Lancaster	326,648	1,072		
Delaware	1,646	10		
New Castle	51,913	46		
Total	497,352	1,681	76,800	260

1. USDA 2009. 2. NOAA CSC 2006

Forests

The U.S. Forest Service (Nowak et al. 2008) estimated that forests provide environmental benefits such as carbon storage of \$5.9 million (\$827/acre) and air-pollution removal of \$1.9 million (\$266/acre/year). Applying these multipliers, 86,400 acres (135 mi²) of forests in the Brandywine Creek watershed have benefits of carbon storage (\$71.5 million), carbon sequestration (\$2.5 million), air-pollution removal (\$23 million), and building-energy savings (\$0.26 million). Forests in the Brandywine Creek watershed provide environmental benefits by regulating climate change, cooling, and air-emissions control. The latter includes 3.5 million

tons of carbon-storage capacity, 120,960 tons of carbon sequestration, 3,456 tons of air-pollution removal, and 12,096 tons of avoided carbon-emissions capacity (Table 21).

Table 21. Forest benefits in the Brandywine Creek watershed

Forest Benefits	Forests New Castle County ¹		Forests Brandywine Creek ²	
	Environmental (tons/acre)	Economic (\$/acre)	Environmental (tons)	Economic (\$)
Carbon Storage	40	827	3,456,000	71,452,800
Carbon Sequestration	1.4	29	120,960	2,505,600
Air Pollution Control	0.04	266	3,456	22,982,400
Energy Savings		56		4,838,400
Avoided Carbon Emissions	0.14	3	12,096	259,200
Total			3,592,512	102,038,400

1. Nowak et al. (2008).

2. Computed for 86,400 acres of forest in the Brandywine Creek watershed.

Public Parks

The Trust for Public Land (2009) found the 444-acre Wilmington park system provides annual economic value and savings to the public from:

- Health benefits from exercise in the parks (\$4,322,000 or \$9,734/ac),
- Community-cohesion benefits as people socialize in the parks (\$1,058,000 or \$2,383/ac),
- Water pollution–mitigation benefits in treating stormwater (\$409,000 or \$921/ac),
- Air pollution–mitigation value from tree and shrub absorption (\$39,000 or \$88/ac).

Presuming the data gathered for the City of Wilmington study are appropriate for benefits transfer, the 5,303 acres of public parks within the Brandywine Creek watershed (Table 22) provide health benefits (\$51,619,402), community cohesion benefits (\$12,637,049), clean-water benefits (\$4,884,063), and air-pollution-mitigation value (\$466,664) for a total of \$70 million.

Table 22. Value of public parks in the Brandywine Creek watershed

State	Parks in Watershed (acres)	Health Benefits (\$9,734/acre)	Community Cohesion (\$2,383/acre)	Stormwater Benefit (\$921/acre)	Air Pollution (\$88/acre)	Total (\$)
PA	4,108	39,987,272	9,789,364	3,783,468	361,504	53,925,716
DE	1,195	11,632,130	2,847,685	1,100,595	105,160	15,686,765
Total	5,303	51,619,402	12,637,049	4,884,063	466,664	69,612,481

4. Ecosystem Services

Ecosystem services (natural capital) are the sum of goods (commodities like water, crops, and timber that can be sold) and services (functions like flood control, water filtration, and fisheries habitat) provided by watershed habitat, such as wetlands, forests, farms, and open water. The following studies were examined to estimate ecosystem-services values for the Brandywine Creek watersheds:

- Cecil County green infrastructure study by the Conservation Fund, Annapolis, Md. (2007)
- New Jersey Department of Environmental Protection with the University of Vermont (2007)
- Ecosystem services value of forests by the Wilderness Society (2001)
- Ecosystem services value of Peconic Estuary watershed by University of Rhode Island (2002)
- U.S. National Wildlife Refuge System by University of Maryland and the Nature Conservancy (2008)
- Economic value of ecosystem services in Massachusetts by the Audubon Society (2003)

Related Research

Ecosystem services include air filtration, water filtration, recycling nutrients, soil conservation, pollinating crops and plants, climate regulation, carbon sequestration, flood/stormwater control, and hydrologic-cycle regulation. Ecological resources provide marketable goods and services such as timber, fish and wildlife recreation, hiking, and boating/kayaking.

The N.J. Department of Environmental Protection (2007) partnered with the University of Vermont and estimated the value of New Jersey's natural capital at \$20 billion/year in 2004 dollars with a net present value (NPV) of \$681 billion. NPV takes the value of a dollar today and projects it into the future summed annually over a lifetime (say 100 years) given the annual value is discounted by a rate (3%) due to inflation based on the Consumer Price Index (CPI).

Others have calculated the value of natural capital in ecosystems along the Atlantic seaboard and across the United States. Weber (2007) from the Conservation Fund found the largest ecosystem services values in Cecil County, Maryland are from stormwater/flood control, water supply, and clean water functions. The Wilderness Society (Krieger 2001) concluded that forest ecosystem services for climate regulation, water supply, water quality, and recreation benefits totaled \$392/ac in 1994 dollars or \$631/ac in 2010 dollars based on change in the Northeast Region CPI. A contingent value study by University of Rhode Island economists found that natural resources values in the Peconic Estuary watershed in Suffolk County on Long Island New York ranged from \$6,560/ac for wetlands to \$9,979/ac for farmland in 1995 dollars (Johnston et al. 2002). The University of Maryland studied the U.S. National Wildlife Refuge System and determined that ecosystem values of freshwater wetlands and forests are \$6,268/ac and \$845/ac, respectively (Ingraham and Foster 2008). The Audubon Society found the economic value of ecosystems in Massachusetts ranged from \$984/ac for forests to \$15,452/ac for saltwater wetlands (Breunig

2003). The USDA Census of Agriculture (2009) reported in 2007 the market value of agricultural products sold from 4,423 acres of cropland in Ocean County was \$11.5 million (\$9.3 million crops and \$2.2 million livestock/ poultry) or \$2,600/ac.

Table 23 compares ecosystem services values from other watersheds. Data from the NJDEP study and crop value of Chester County agriculture are used for value transfer to the Brandywine Creek watershed as the study area shares similar ecosystems (forests/wetlands), climate (humid continental at 40°N latitude), and physiographic provinces. NJDEP ecosystem-services values are lower than Cecil County’s for wetlands and forests and MassAudubon’s for wetlands. NJDEP estimates are higher than the Wilderness Society’s for forests and U.S. Wildlife Refuge values for freshwater wetlands and forests.

Table 23. Comparison of ecosystem goods and services values from various studies

Ecosystem	Cecil Co., Md. 2006 (\$/ac/yr)	NJDEP 2007 (\$/ac/yr)	Wilderness Society 2001 (\$/ac/yr)	Peconic Estuary 1995 (\$/ac/yr)	U.S. Wildlife 2008 (\$/ac/yr)	Mass. Audubon 2003 (\$/ac/yr)	USDA Census ¹ 2007 (\$/ac/yr)
Freshwater wetland	43,685	11,802			6,268	15,452	
Marine		8,670					
Farmland		6,229		9,979		1,387	3,315 ¹
Forest land	12,033	1,714	641		845	984	
Saltwater wetland	28,146	6,269		6,560		12,580	
Undeveloped				2,080			
Urban		296					
Beach/dune		42,149					
Open freshwater		1,686			217	983	
Riparian buffer	52,765	3,500					
Shellfish areas				4,555			

1. Value of natural goods only measured by crops, livestock, and poultry sold in Chester County (USDA 2009).

Watershed Ecosystem Services

Ecosystem goods and services in the Brandywine Creek watershed using the NJDEP and USDA farm-good values are worth \$560 million (2010 dollars) or \$18.2 billion (NPV), which are conservatively in the lower end of the range (Table 24). If lower per-acre estimates of ecosystem services from other studies were used instead of the NJDEP values, ecosystem services in the Brandywine Creek watershed would be \$200 million or NPV = \$6.5 billion (Table 25). If higher per-acre estimates from other studies were used, the value of ecosystems in the Brandywine Creek watershed would be \$2.0 billion or NPV = \$65.0 billion (Table 26).

<u>Estimate</u>	<u>PV (\$ million)</u>	<u>NPV (\$ million)</u>
Low	199.9	6,500
NJDEP	560.5	18,200
High	2,000	65,000

Ecosystem-services areas within the Brandywine Creek watershed are composed of forests (41.8%), farmland (37%), freshwater wetlands (1.9%), and open water (0.5%). Roughly 19 percent of the land in the Brandywine Creek watershed is urban (Figure 6).

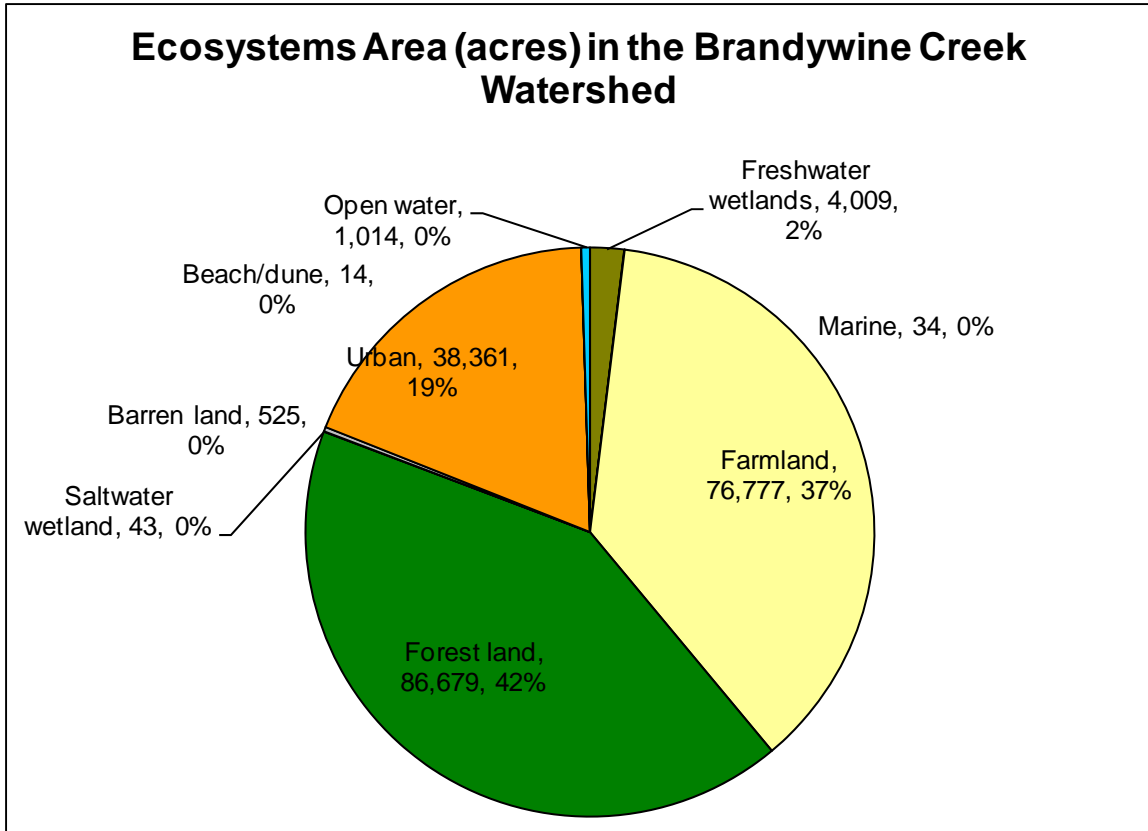


Figure 6. Ecosystem Service Areas in the Brandywine Creek Watershed

Table 24. Value of Ecosystem Goods and Services in the Brandywine Creek watershed

Ecosystem	Area (acres)	\$/acre/yr	PV \$	NPV \$
Freshwater wetlands	4,009	13,621	54,600,951	1,774,530,897
Marine	34	10,006	343,552	11,165,455
Farmland	76,777	4,124	318,045,787	10,336,488,092
Forest land	86,679	1,978	171,461,731	5,572,506,255
Saltwater wetland	43	7,235	313,934	10,202,852
Barren land	525	0	0	0
Urban	38,361	342	13,104,693	425,902,536
Beach/dune	14	48,644	665,605	21,632,156
Open water	1,014	1,946	1,972,881	64,118,646
Total	207,456	2,702	560,509,135	18,216,546,889

Table 25. Low range of ecosystem services in the Brandywine Creek watershed

Ecosystem	Area (acres)	\$/acre/yr	PV \$	NPV \$
Freshwater wetlands	4,009	6,268	25,126,436	816,609,174
Marine	34	8,670	297,681	9,674,616
Farmland	76,777	1,387	106,489,018	3,460,893,082
Forest land	86,679	641	55,561,214	1,805,739,458
Saltwater wetland	43	6,269	272,017	8,840,542
Barren land	525	0	0	0
Urban	38,361	296	11,354,923	369,034,983
Beach/dune	14	42,149	576,732	18,743,778
Open water	1,014	217	220,019	7,150,622
Total	207,456	964	199,898,039	6,496,686,255

Table 26. High range of ecosystem services in the Brandywine Creek watershed

Ecosystem	Area (acres)	\$/acre/yr	PV \$	NPV \$
Freshwater wetlands	4,009	43,685	175,119,394	5,691,380,307
Marine	34	8,670	297,681	9,674,616
Farmland	76,777	9,979	766,152,783	24,899,965,442
Forest land	86,679	12,033	1,043,007,939	33,897,758,032
Saltwater wetland	43	28,146	1,221,276	39,691,481
Barren land	525	0	0	0
Urban	38,361	296	11,354,923	369,034,983
Beach/dune	14	42,149	576,732	18,743,778
Open water	1,014	1,686	1,709,457	55,557,367
Total	207,456	9,638	1,999,440,185	64,981,806,006

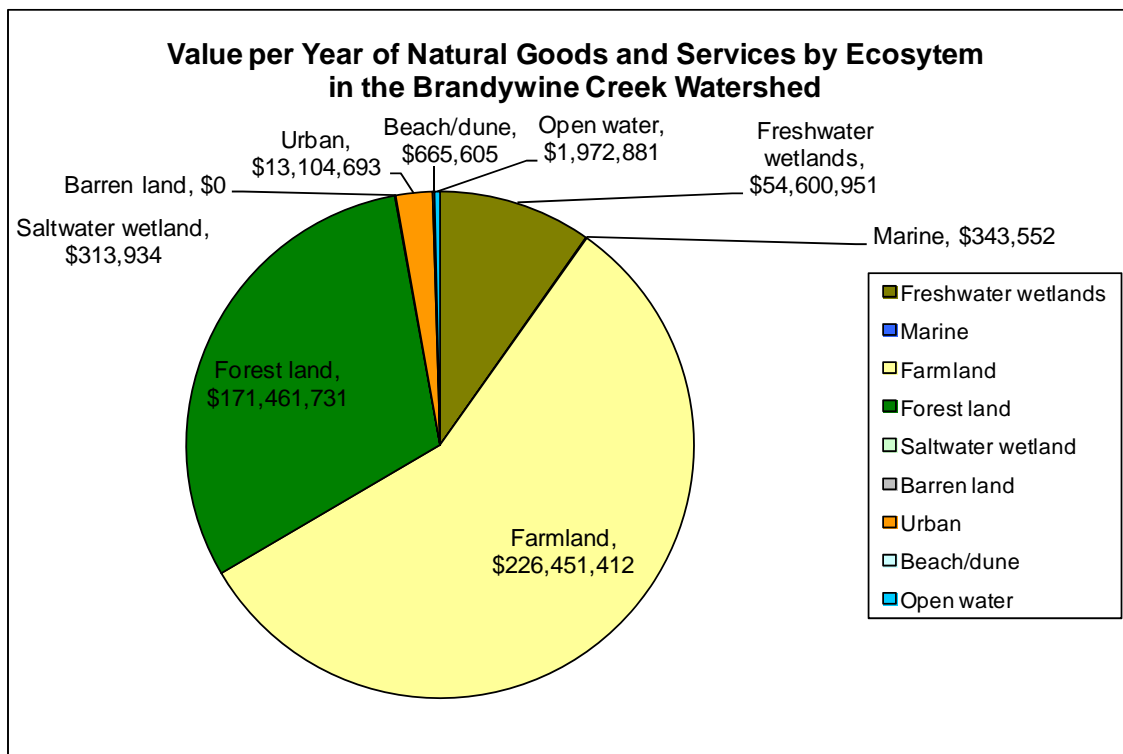


Figure 7. Value of Natural Goods and Services by Ecosystem in the Brandywine

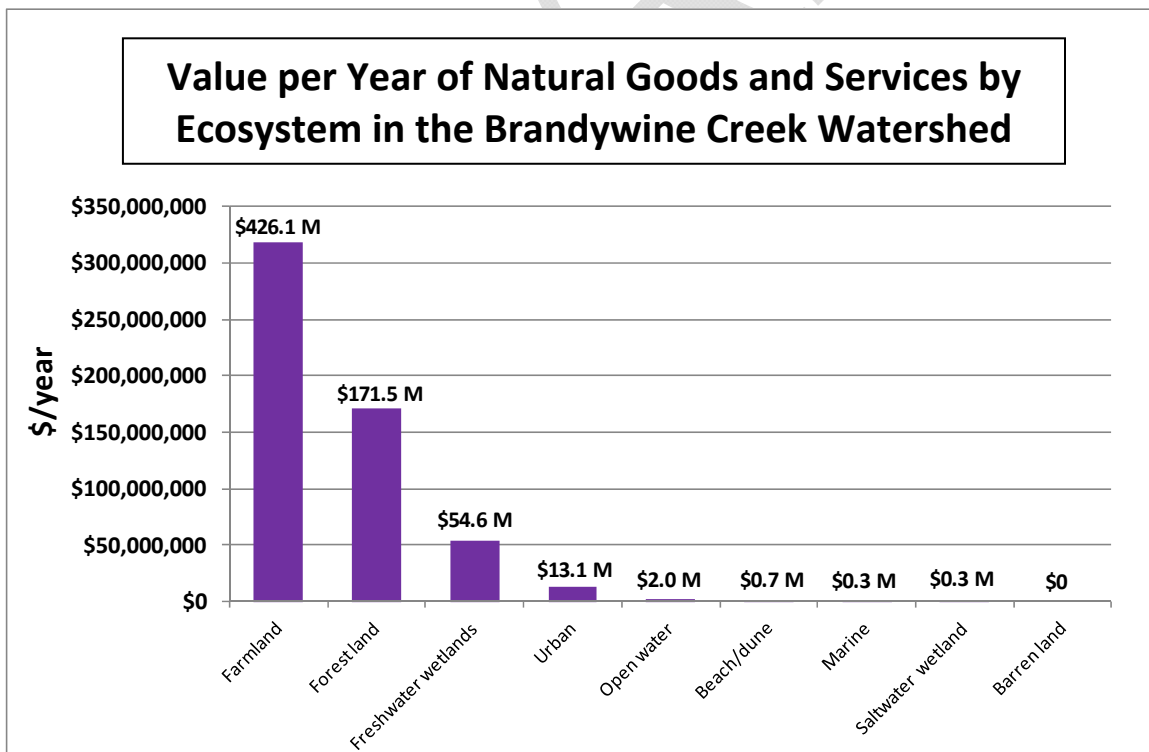


Figure 8. Ecosystem Service Value (2010 dollars) in the Brandywine Creek watershed

5. Jobs and Wages

The Brandywine Creek watershed contains water resources and habitats that support over 50,000 direct and indirect jobs and over \$69 million in annual wages in the coastal, farm, fishing/hunting/birding, watershed organization, and water supply/wastewater industries (Table 27).

Table 27. Jobs and wages directly and indirectly related to the Brandywine Creek watershed

Sector	Jobs	Wages (\$)	Data Source
Direct Watershed-Related	23,208	1,205,450,000	U.S. Census Bureau (2010)
Indirect Watershed-Related	27,850	964,360,000	U.S. Census Bureau (2010)
Coastal	781	15,615,496	National Coastal Econ. Program (2009)
Farm	3,453	2,427,461	U.S. Dept. of Agriculture., (2007)
Fishing/Hunting/Birding	1,121	36,810,167	U.S. Fish and Wildlife Service (2008)
Watershed Organizations	124	5,952,000	WRA and DRBC (2010)
Water Supply Utilities	175	9,723,929	Delaware Tourism Office (2008)
Public Wells	47	2,595,707	WRA and DRBC (2010)
Wastewater Utilities	58	2,322,400	WRA and DRBC (2010)
Total	51,136	69,855,273	

The total of jobs and wages have been rounded down to avoid double counting.

Direct and indirect jobs and wages in the Brandywine Creek watershed watersheds were obtained from U.S. Census Bureau (2010) databases. Note the NAICS database does not include jobs for certain known water-related industries, such as commercial fishing and boat building; therefore the columns are left blank. Hence, watershed-related jobs are likely undercounted. Brandywine Creek watershed-related jobs are tabulated for three categories: (1) total jobs in the Brandywine Creek watershed, (2) direct Brandywine Creek watershed jobs, and indirect watershed jobs.

The U.S. Census Bureau (2010) indicates there were 120,983 nonfarm jobs in the Brandywine Creek watershed (Table 28).

Table 28. Employment in the Brandywine Creek Watershed in 2010

County	County ¹ Population	Watershed ¹ Population	County ² Employment	Watershed ³ Employment
Chester County, Pa.	498,886	201,496	249,515	100,777
New Castle County, Del.	538,479	44,087	261,530	21,412
Total	1,037,365	245,583	511,045	120,983

1. US Census 2010. 2. US Bureau of Labor Statistics 2011

3. Scaled by ratio of watershed population to county population and multiplied by county employment.

Direct Brandywine Creek watershed-related jobs such as water/sewer construction, living resources, maritime, tourism/recreation, ports, environmental services, and water/wastewater management were determined for each NAICS code in the Brandywine Creek watershed. Industries directly associated with the Brandywine Creek watershed (such as water/sewer construction, water utilities, fishing, recreation, tourism, and transportation) employed 23,280 people with \$1.2 billion in wages (Table 29).

Indirect jobs and wages funded by purchases of goods/services by direct jobs earners are estimated by a multiplier of 2.2 for direct jobs and 1.8 for direct wages (Latham and Stapleford, 1990). The United Nations Environment Programme (2011) estimates each tourism job generates 1.5 indirect jobs. For this report, we assume that each direct watershed job funds 1.2 indirect jobs and a dollar in direct wages funds \$0.80 in indirect wages. Indirect jobs in the watershed (based on multipliers of 2.2 for jobs and 1.8 for salaries) employed 27,850 people with \$964 million in wages (Table 29).

Table 29. Direct and indirect watershed-related jobs in the Brandywine Bay watershed, 2009

Sector	North American Industry Classification System (NAICS)	NAICS code	Direct Jobs ¹	Direct Wages ¹ (x\$1000)	Indirect Jobs ²	Indirect Wages ² (x\$1000)
Construction	Water and sewer construction	23711	96	5,491	116	4,393
Living Resources	Agriculture and forestry	115	188	6,868	226	5,495
	Wineries	31213				
	Fish and seafood wholesalers	42446				
	Nursery, garden center, farm	44422	127	4,372	153	3,498
	Fish and seafood markets	44522	2	45	3	36
	Fruit and vegetable markets	44523	24	529	29	423
Minerals	Mining, quarrying, extraction	21	39	2,177	47	1,742
	Electric power generation	2211				
Tourism/ Recreation	Sporting/recreational goods	42391	28	1,282	33	1,026
	Sporting goods stores	45111	216	4,414	259	3,531
	Recreational goods rental	532292				
	Commercial water transport.	532411				
	Recreational vehicle dealers	44121				
	Boat dealers	441222	8	317	10	254
	Museums, historical sites	712	60	1,763	72	1,410
	Amusement parks and arcades	7131	37	238	45	191
	Amusement arcades	71312	35	213	42	170
	Amusement/recreation	7139	1,587	28,414	1,905	22,731
	Golf courses/country clubs	71391	531	15,105	637	12,084
	Marinas	71393		55		44
	Fitness/recreational sports	71394	943	11,135	1,132	8,908
	Amusement/recreation	71399	11	1,538	13	1,231
	Accommodation	721	618	13,555	741	10,844
	Hotels and motels	72111	577	12,396	692	9,917
	Bed-and-breakfast inns	721191		0		
	Recreational vehicle, camps	7212	22	824	26	659
	Full-service restaurants	7221	3,405	51,044	4,086	40,835
	Limited-service restaurants	722211	2,125	25,626	2,550	20,501
Snack/beverage bars	722213	330	4,571	396	3,657	
Food service contractors	72231	829	19,656	995	15,724	
Caterers	722320	207	4,807	248	3,846	
Transportation	Water transportation	483		1,521		1,217

	Inland water transportation	4832		0		
	Scenic/sightseeing transportation	487	1	67	2	53
	Scenic/sightseeing transportation, water	4872	1	67	2	53
	Support activities for water transportation	4883	42	1,712	50	1,369
	Marine cargo handling	488320	36	1,394	43	1,115
Environmental	Architectural, engineering	541	10,280	949,966	12,336	759,973
	Environmental, conservation	813211	66	4,428	79	3,543
	Civic and social organizations	8134	245	4,539	294	3,631
Water/ Wastewater	Water, sewage systems	2213	27	1,909	33	1,527
	Waste management services	562	463	23,412	556	18,730
SUM OF ALL INDUSTRIES			23,208	1,205,450	27,850	964,360

1. Direct jobs/wages are those directly related to the Brandywine Creek watershed.

2. Indirect jobs/wages are derived from purchases of goods and services by direct jobs earners by multipliers of 2.2 for jobs and 1.8 for wages.

US Census Bureau 2010

National Coastal Economy

The National Ocean Economic Program (2009) published a report that summarized the coastal economy in the United States for the following industrial sectors: Marine Construction, living Marine Resources, Mineral Extraction, Ship and Boat Building, Tourism and Recreation, and Transportation. According to the NOEP (2009), coastal counties in the Delaware portion of the Brandywine Creek watershed contributed 781 coastal jobs, representing over \$15.6 million in annual wages and \$30 million toward the state GDP (Table 30).

Table 30. Coastal employment in the Brandywine Creek watershed

Economic Sector	Establishments	Employment	Wages (\$)	GDP (\$)
Construction	2	9	456,564	743,994
Living Resources	1	10	318,431	726,009
Minerals	D	D	D	D
Ship & Boat Building	D	D	D	D
Tourism & Recreation	40	670	10,715,732	22,307,844
Transportation	2	89	3,988,835	5,776,135
All Ocean Sectors	45	781	15,615,496	30,006,273

NOEP 2009

Based on 2010 Delaware and New Castle County, DE population estimates

D = Disclosure issues prevent this data from being presented.

Farm Jobs

The USDA 2007 Census of Agriculture indicates that the agricultural industry contributes about 3,453 farm jobs in the Brandywine Creek watershed and \$2.4 million in wages (Table 31).

Table 31. Jobs from farms in the Brandywine Creek Watershed

Region	Farmland (ac)	Farm Jobs	Wages
PENNSYLVANIA			
Chester County	166,891	7,708	\$5,047,000
Brandywine Creek Portion	74,308	3,432	\$2,247,168
DELAWARE			
New Castle County	66,981	565	\$4,892,000
Brandywine Creek Portion	2,469	21	\$180,293
Watershed Total	76,777	3,453	\$2,427,461

USDA 2007

Fishing/Hunting/Bird and Wildlife Recreation Jobs

A 2007 study by the NJDEP estimated the average annual salary per ecotourism job is \$32,843, based on figures from the 2001 U.S. Fish and Wildlife Service report on fishing, hunting, and wildlife-associated recreation (NJDEP 2007). Using this wage multiplier, fishing, hunting, and bird/wildlife-associated recreation in the Brandywine Creek watershed account for 1,121 jobs, a value of \$36 million in annual economic activity in 2010 dollars (Table 32). While this estimate of ecotourism jobs is not exact, it provides a reasonable estimate of the jobs provided by fishing, hunting, and bird/wildlife-associated recreation in the Brandywine Creek watershed.

Table 32. Jobs from wildlife recreation in the Brandywine Creek watershed

Recreation Activity	Recreation Value ¹ (\$2010)	Jobs ² in 2010 Dollars
Fishing	11,167,501	340
Hunting	12,864,343	392
Wildlife/Birding	12,778,324	389
Total	36,810,167	1,121

1. USFWS 2008

2. Scaled by the percentage of each state that is in the Brandywine Creek watershed (0.0068 PA and 0.0118 DE)

3. Jobs estimated at \$32,843 average salary.

Outdoor Recreation

The Outdoor Industry Foundation (2006) concluded that 16.3 million people participated in watershed-based recreation activities such as bicycling, camping, fishing, hunting, paddling, hiking, and wildlife viewing in the mid-Atlantic region (New Jersey, New York, and Pennsylvania), contributing to 216,396 jobs. Given the population of the three states total 40.9 million (NJ 8.8 million, NY 19.4 million, and Pa. 12.7 million), by proportion outdoor recreation activity in the Brandywine Creek watershed (population 245,583) contributes 1,299 jobs (Table 33).

Table 33. Outdoor recreation jobs in the Brandywine Creek watershed

Activity	Mid-Atlantic Region ¹	Brandywine Creek ²	Total Wages Earned
Bicycling	40,121	241	7915163
Camping	89,384	537	17636691
Fishing	17,195	103	3382829
Hunting	7,234	43	1412249
Paddling	9,331	56	1839208
Hiking	28,686	172	5648996
Wildlife Viewing	24,445	147	4827921
Total	216,396	1,299	42,663,057

1. Outdoor Recreation Foundation 2006.

2. Scaled by population of watershed to Mid-Atlantic region population. Brandywine Creek: 245,583

Watershed Organization Jobs

Sixteen nonprofit watershed and environmental organizations employ at least 124 staff to work on programs to protect the Brandywine Creek watershed (Table 34). Assuming that the average salary of an environmental scientist/specialist is \$61,700 (Bureau of Labor Statistics), these watershed organization jobs account for \$5.95 million in annual wages.

Table 34. Watershed organization jobs in the Brandywine Creek watershed

Watershed Organization	Town	Jobs	Salaries (\$)
PENNSYLVANIA			
Brandywine Conservancy ¹	Chadds Ford	7	336,000
Brandywine Valley Association ¹	West Chester	2	96,000
Delaware Nature Society	Hockessin	20	960,000
Stroud Water Research Center	Avondale	45	2,160,000
Total for Pennsylvania		74	3,552,000
DELAWARE			
Delaware Audobon Society	Wilmington	1	48,000
Delaware Center for Horticulture	Wilmington	18	864,000
Delaware Chapter of the Sierra Club	Wilmington	0	\$0
Delaware Greenways	Wilmington	6	288,000
Friends of Lums Pond	Bear	0	\$0
Green Delaware	Wilmington	-	-
League of Women Voters of Delaware	Wilmington	5	240,000
Nature Conservancy - Delaware Chapter	Wilmington	2	96,000
Partnership for the Delaware Estuary	Wilmington	16	768,000

Sierra Club	Wilmington	0	\$0
Urban Environmental Center	Wilmington	1	48,000
Widener Environmental and Natural Resources Law Clinic ²	Wilmington	1	48,000
Total for Delaware		50	2,400,000
Total for Watershed		124	5,952,000

Water Supply Jobs

Public and private water utilities withdraw over 58.5 mgd of drinking water from surface-water and groundwater supplies in the Brandywine Creek watershed. According to the American Water Works Association, the average salary of a water-system employee is \$55,407. The total number of jobs provided by water utilities in the Brandywine Creek watershed is 176, with annual wages of \$9.7 million (Table 35).

Table 35. Jobs from public water utilities in the Brandywine Creek watershed

Water Purveyor	State	Withdrawal (mgd)	Jobs	Salaries (\$)
PA American Water Co.	PA	6.0	18	997,326
Downingtown MUA	PA	2.5	7.5	415,553
Aqua PA	PA	6.0	18	997,326
City of Wilmington	DE	44.0	132	7,313,724
Total		58.5	175.5	9,723,929

Wastewater Utility Jobs

Twenty wastewater utilities discharge over 15.8 million gallons per day of treated wastewater to the Brandywine Creek watershed. The wage information is computed using the assumption that the average wastewater utility salary is \$40,000/year. These wastewater utilities employ 58 employees who earn over \$2.3 million in wages annually (Table 36).

Table 36. Wastewater treatment jobs in the Brandywine Creek watershed

NPDES ID	Sewage Treatment Plant	Discharge (mgd)	Jobs	Salaries
<i>Main Stem</i>				
PA0055476	Birmingham TSA/Ridings at Chadds Ford TB Harvey Creek Municipal Small STP	0.04	1	40,000
PA0244031	Chadds Ford Township Harvey Run	0.15	1	40,000
PA0030848	Unionville - Chadds Ford Elem. School Ring Run Municipal Small STP	0.01	1	40,000
PA0031097	Radley Run C.C. Radley Run Municipal Small STP	0.02	1	40,000
PA0053449	Birmingham Twp. STP Radley Run Municipal Small STP	0.15	1	40,000
PA0057011	Thornbury Twp./Bridlewood Farms STP Radley Run	0.08	1	40,000
PA0036200	Radley Run Mews Plum Run Municipal Small STP	0.03	1	40,000
DE0021768	Winterthur	0.025	1	40,000

<i>East Branch</i>				
PA0026018	West Chester Borough MUA/Taylor Run Taylor Run Municipal Large STP	1.8	5	216,000
PA0043982	Broad Run Sew Co. EB Brandywine Creek Municipal Large STP	0.4	1	48,000
PA0026531	Downingtown Area Regional Authority EB Brandywine Creek Municipal Large STP	7.5	23	900,000
PA0054917	Uwchlan Twp. Municipal Authority Shamona Creek Municipal Eagleview CC STP	0.48	1	57,600
PA0027987	Eaglepoint Dev. Assoc. TB Marsh Creek Municipal Small STP	0.02	1	40,000
PA0050458	Little Washington Drainage Co. Culbertson Run Municipal Small STP	0.05	1	40,000
PA0050547	Indian Run Village MHP Indian Run Municipal Small STP	0.04	1	40,000
<i>West Branch</i>				
PA0029912	Embreeville Hospital WB Brandywine Creek Municipal Large STP	0.1	1	40,000
PA0036897	South Coatesville Borough WB Brandywine Creek Municipal Large STP	0.39	1	46,800
PA0026859	Coatesville City Authority WB Brandywine Creek Municipal Large STP	3.85	12	462,000
PA0036412	Tel Hai Retirement Community TB-WB Brandywine Creek Municipal Small STP	0.06	1	40,000
PA0044776	NW Chester Co. Municipal Authority WB Brandywine Creek Municipal Large STP	0.6	2	72,000
Total for watershed		15.77	58	2,322,400

Appendix - Employment Codes by Industry, 2009

(U. S. Bureau of Labor Statistics)

Industry	NAICS Code
Agriculture, Forestry, Fishing and Hunting	11
Crop Production	111
Animal Production	112
Aquaculture	1125
Forestry and Logging	113
Fishing, Hunting and Trapping	114
Fishing	1141
Support Activities for Agriculture and Forestry	115
Mining, Quarrying, and Oil and Gas Extraction	21
Oil and Gas Extraction	211
Mining (except Oil and Gas)	212
Nonmetallic Mineral Mining and Quarrying	2123
Support Activities for Mining	213
Utilities	22
Utilities	221
Electric Power Generation, Transmission and Distribution	2211
Natural Gas Distribution	2212
Water, Sewage and Other Systems	2213
Construction	23
Construction of Buildings	236
Residential Building Construction	2361
Nonresidential Building Construction	2362
Heavy and Civil Engineering Construction	237
Land Subdivision	2372
Highway, Street, and Bridge Construction	2373
Other Heavy and Civil Engineering Construction	2379
Specialty Trade Contractors	238
Manufacturing	31
Food Manufacturing	311
Seafood Product Preparation and Packaging	3117
Beverage and Tobacco Product Manufacturing	312
Textile Mills	313
Textile Product Mills	314
Apparel Manufacturing	315
Apparel Knitting Mills	3151
Leather and Allied Product Manufacturing	316
Wood Product Manufacturing	321
Paper Manufacturing	322
Petroleum and Coal Products Manufacturing	324
Chemical Manufacturing	325
Basic Chemical Manufacturing	3251
Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing	3252

	Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	3253
	Pharmaceutical and Medicine Manufacturing	3254
	Paint, Coating, and Adhesive Manufacturing	3255
	Soap, Cleaning Compound, and Toilet Preparation Manufacturing	3256
	Other Chemical Product and Preparation Manufacturing	3259
	Plastics and Rubber Products Manufacturing	326
	Nonmetallic Mineral Product Manufacturing	327
	Cement and Concrete Product Manufacturing	3273
	Lime and Gypsum Product Manufacturing	3274
	Other Nonmetallic Mineral Product Manufacturing	3279
	Primary Metal Manufacturing	331
	Fabricated Metal Product Manufacturing	332
	Machinery Manufacturing	333
	Computer and Electronic Product Manufacturing	334
	Computer and Peripheral Equipment Manufacturing	3341
	Communications Equipment Manufacturing	3342
	Audio and Video Equipment Manufacturing	3343
	Semiconductor and Other Electronic Component Manufacturing	3344
	Navigational, Measuring, Electromedical, and Control Instruments Manufacturing	3345
	Manufacturing and Reproducing Magnetic and Optical Media	3346
	Electrical Equipment, Appliance, and Component Manufacturing	335
	Transportation Equipment Manufacturing	336
	Motor Vehicle Manufacturing	3361
	Motor Vehicle Body and Trailer Manufacturing	3362
	Motor Vehicle Parts Manufacturing	3363
	Aerospace Product and Parts Manufacturing	3364
	Railroad Rolling Stock Manufacturing	3365
	Ship and Boat Building	3366
	Other Transportation Equipment Manufacturing	3369
	Furniture and Related Product Manufacturing	337
	Miscellaneous Manufacturing	339
Wholesale Trade		42
	Merchant Wholesalers, Durable Goods	423
	Merchant Wholesalers, Nondurable Goods	424
	Wholesale Electronic Markets and Agents and Brokers	425
Retail Trade		44
	Motor Vehicle and Parts Dealers	441
	Furniture and Home Furnishings Stores	442
	Electronics and Appliance Stores	443
	Electronics and Appliance Stores	4431
	Building Material and Garden Equipment and Supplies Dealers	444
	Food and Beverage Stores	445
	Health and Personal Care Stores	446
	Gasoline Stations	447
	Clothing and Clothing Accessories Stores	448
	Sporting Goods, Hobby, Book, and Music Stores	451
	General Merchandise Stores	452
	Miscellaneous Store Retailers	453

	Nonstore Retailers	454
Transportation and Warehousing		48
	Air Transportation	481
	Scheduled Air Transportation	4811
	Nonscheduled Air Transportation	4812
	Rail Transportation	482
	Rail Transportation	4821
	Water Transportation	483
	Deep Sea, Coastal, and Great Lakes Water Transportation	4831
	Inland Water Transportation	4832
	Support Activities for Water Transportation	4883
	Truck Transportation	484
	General Freight Trucking	4841
	Specialized Freight Trucking	4842
	Transit and Ground Passenger Transportation	485
	Urban Transit Systems	4851
	Interurban and Rural Bus Transportation	4852
	Taxi and Limousine Service	4853
	School and Employee Bus Transportation	4854
	Charter Bus Industry	4855
	Other Transit and Ground Passenger Transportation	4859
	Pipeline Transportation	486
	Pipeline Transportation of Crude Oil	4861
Information		51
	Publishing Industries (except Internet)	511
	Motion Picture and Sound Recording Industries	512
	Broadcasting (except Internet)	515
	Telecommunications	517
	Data Processing, Hosting, and Related Services	518
	Other Information Services	519
Finance and Insurance		52
	Monetary Authorities-Central Bank	521
	Credit Intermediation and Related Activities	522
	Securities, Commodity Contracts, and Other Financial Investments and Related Activities	523
	Insurance Carriers and Related Activities	524
	Funds, Trusts, and Other Financial Vehicles	525
Real Estate and Rental and Leasing		53
	Real Estate	531
	Rental and Leasing Services	532
	Lessors of Nonfinancial Intangible Assets (except Copyrighted Works)	533
Professional, Scientific, and Technical Services		54
	Professional, Scientific, and Technical Services	541
	Management, Scientific, and Technical Consulting Services	5416
	Scientific Research and Development Services	5417
Management of Companies and Enterprises		55
	Management of Companies and Enterprises	551
Administrative and Support and Waste Management and Remediation Services		56
	Administrative and Support Services	561

	Travel Arrangement and Reservation Services	5615
	Waste Management and Remediation Services	562
Educational Services		61
	Educational Services	611
	Colleges, Universities, and Professional Schools	6113
	Technical and Trade Schools	6115
	Educational Support Services	6117
Health Care and Social Assistance		62
	Ambulatory Health Care Services	621
	Hospitals	622
	Nursing and Residential Care Facilities	623
	Social Assistance	624
Arts, Entertainment, and Recreation		71
	Performing Arts, Spectator Sports, and Related Industries	711
	Museums, Historical Sites, and Similar Institutions	712
	Amusement, Gambling, and Recreation Industries	713
	Other Amusement and Recreation Industries	7139
Accommodation and Food Services		72
	Accommodation	721
	Traveler Accommodation	7211
	RV (Recreational Vehicle) Parks and Recreational Camps	7212
	Rooming and Boarding Houses	7213
	Food Services and Drinking Places	722
Other Services (except Public Administration)		81
	Repair and Maintenance	811
	Personal and Laundry Services	812
	Religious, Grantmaking, Civic, Professional, and Similar Organizations	813
	Social Advocacy Organizations	8133
	Business, Professional, Labor, Political, and Similar Organizations	8139
	Private Households	814
Public Administration		92
	Executive, Legislative, and Other General Government Support	921
	Justice, Public Order, and Safety Activities	922
	Administration of Human Resource Programs	923
	Administration of Environmental Quality Programs	924
	Administration of Housing Programs, Urban Planning, Community Development	925
	Administration of Economic Programs	926
	Space Research and Technology	927
	National Security and International Affairs	928

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