Economic Value of Stormwater in Delaware

Final Draft Report
September 2011

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prepared for:

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Dover, Delaware

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Executive Summary

The National Academy of Sciences (2009) concluded: *"Stormwater runoff from the built environment remains one of the great challenges of modern water pollution control, as this source of contamination is a principal contributor to water quality impairment of waterbodies nationwide."*

Introduction

Objectives: The Delaware DNREC proposes to submit legislation to the General Assembly during Spring 2011 to consider revisions to the Delaware Stormwater & Sediment Control Regulations. The objective of this regulatory review is to quantify the economic costs/benefits of the proposed stormwater regulation revisions according to Title 29, Ch. 104 of the Delaware Regulatory Flexibility Act.

Green Stormwater Management: After the 100-year floods of Tropical Storm Henri (Sep 2003) and Tropical Storm Jeanne (Sep 2004), the Governor's Task Force for Surface Water Management (2005) recommended revisions to the Delaware Stormwater & Sediment Control Regulations that call for innovative green stormwater practices such as:

Infiltration Technologies
Green Roofs
Permeable Surfaces
Bio-Swales
Filter Strips
Rain Gardens

Bioretention Systems
Constructed Wetlands
Infiltration Basins & Trenches
Detentions Basins
Wet Ponds

Green stormwater practices can provide the following benefits to Delaware communities (WERF 2009):

- Higher property values (increased sales, higher sale/resale prices, shorter on-market time)
- Increased tax revenue
- Decreased flood damage that increases property values in the 100-yr floodplain
- Public infrastructure cost savings through reduced size of stormwater pipes and culverts
- Reduced pollution and water treatment costs
- Improved water quality
- Increased tourism and recreation

The Delaware stormwater regulations evolved from the following legislative framework:
1987 - Congress revises Clean Water Act and charges EPA to control NPDES stormwater discharges.
1990 - EPA passes Phase I stormwater regulations for municipal separate storm sewer systems (MS4).
1991 - Governor/General Assembly adopt Delaware Stormwater and Sediment Control Regulations.
1999 - EPA passes Phase II municipal separate storm sewer regulations in cities <100,000 in population.
2003 - Tropical Storm Henri (100- to 500-yr flood) causes over $45 million in flood damage in Delaware.
2004 - Tropical Storm Jeanne (100-yr flood) causes over $6 million in flood damage in Delaware.
2005 - Delaware Task Force for Surface Water Management issues report to Governor.
2006 - Governor /General Assembly amend Delaware Stormwater and Sediment Control Regulations
2009 - EPA issues Federal Register Notice seeking input on federal stormwater regulations.
2010 - DNREC releases Stormwater Runoff Reduction Guidance Document
Feb 2011 – DNREC issues timeline to promulgation/revisions to Delaware Stormwater Regulations
May 2011 - Public workshop on proposed revisions to Delaware Stormwater Regulations
Sep 2011 - Public Hearing/ Public Comment on proposed revisions
Jan 2012 - Effective date of proposed revisions to Delaware Stormwater Regulations

Delaware Regulatory Flexibility Act: Title 29, Chapter 104 requires that prior to any new regulation, an agency shall consider whether it is feasible to exempt individuals/small businesses or whether the agency may promulgate a regulation which sets less stringent standards for individuals and small businesses.

1. Estimated cost of preparation of reports by individuals/small business to comply with the new rule.
2. Estimated costs of investments required by individuals/small businesses in complying with the rule.
3. Estimated cost of legal, consulting, accounting services which individuals/businesses would incur.
4. Ability of individuals/small businesses to absorb costs without suffering economic harm and without adversely affecting competition in the marketplace.
5. Cost to agency of administering rule which sets lesser standards for individuals/small business:
6. Impact on public interest of setting lesser standards of compliance for individuals/small businesses.
7. Accommodations made in regulations to address individual/small business concerns identified above?

Population: In 2009, 885,122 people lived in Delaware on 1,954 sq mi of land with a population density of 1,000 p./sq mi. Over 398,000 people were employed in Delaware in 2009. Between 2000 and 2009, Delaware population grew by 101,565, an increase of 13%. During this decade, the population of Kent County and Sussex County grew by 23% and 24%, respectively,. By 2030, the population in Delaware is projected to grow by 159,000 (18%) to just over a million people.

Land Use: In Delaware (2007), 39% is agriculture, 17% is forest, 17% is saltwater/freshwater wetland, 15% is urban, 8% is marine, and 3% is open freshwater. Delaware is drained by four Whole Basins; the Piedmont, Delaware Estuary, and Inland Bays Basins flow east and Chesapeake Bay Basin flows west.

The Combined 305(b) Report and 303(d) List (2010) classifies Delaware waterways as follows:

- 25 miles of ocean coastline
- 841 square miles of bay
- 2,509 miles of rivers and streams
- 2,934 acres of lakes and ponds.
- 86% of Delaware rivers/streams impaired for swimming due to high bacteria
- 97% of Delaware rivers/streams do not meet fish and wildlife water quality standards.
- 44% of Delaware ponds and lakes do not meet swimming uses.
- 89% of ponds and lakes do not support fish and wildlife uses.
- >100 miles of waters have fish consumption advisories from high PCBs, metals, and pesticides.

Flood Damages: In the last decade, 3 historic storms flooded Delaware causing $90 million in damages:

Sep 15, 2003 - Tropical Storm Henri,	$46 million damages
Sep 18, 2003 - Tropical Storm Isabel,	$40 million damages
Sep 28, 2004 - Tropical Storm Jeanne	$ 4 million damages

The FEMA National Flood Insurance Program indicates New Castle County, Del. registered $12.9 million in repetitive flood damage losses at 51 properties between 1978 and 2008. New Castle County property owners filed the 5th highest flood damage claims of all counties in the 4-state Delaware Basin.

Delaware Floodplain: Situated on the Delmarva Peninsula between the Delaware and Chesapeake bays, Delaware is the lowest state in the U.S. with a mean elevation of 60 feet above sea level. Over 331 square miles or 17% of Delaware's land lie within the 100-year floodplain. Over 621 miles of roads run through the Delaware 100-yr floodplain. Over 18,000 structures lie in the 100-yr floodplain including:

- New Castle County 2,431 structures in the floodplain
- Kent County 1,853 structures in the floodplain
- Sussex County 13,760 structures in the floodplain

Watersheds with the most extreme floods include Shellpot Creek in New Castle County (1,161 cfs/sq mi), Duck Creek (Smyrna River) in Kent County (327 cfs/sq mi), and Indian River (52 cfs/sq mi). During the last quarter century, the largest floods in Delaware occurred on:

- Jul 8, 1989 (July 4th storm)
- Sep 16, 1999 (Hurricane Floyd)
- Sep 15, 2003 (Tropical Storm Henri)

Benefits of Green Stormwater Management

The proposed revisions to the Delaware Stormwater & Sediment Control Regulations call for innovative green stormwater practices that have tangible economic benefits according to watershed groups throughout the U.S. and Canada.

American Rivers reports:

- In California, 1,000 trees reduce stormwater runoff by 1 million gallons and saves $7,000.
- The Delaware Valley tree canopy saves $2 per cubic foot for stormwater volume control.
- Montgomery, Ala. forest has a stormwater infrastructure replacement value of $454 million.
- Albuquerque, NM tree canopy provides 150 MG of storm water services worth $123 million.
- In Denver, 0.1 ac bioretention pond cost $75,976, 17% less than traditional stormwater pond.
- New York City invested over $1.5 billion to protect and restore Catskill reservoir watersheds, rather than spending up to $9 billion on filtration plants, a benefit cost ratio of 6:1.

The City of Philadelphia (2009) reported the Green City - Clean Waters Program is designed to:

- Create 2 dollars in benefits for every dollar invested.
- Provide $500 million in economic benefits and employ 250 green jobs per year.
- Save $400 million from 1.5 million pounds of carbon dioxide emissions avoided or absorbed.
- Improve water quality from 5 - 8 billion gallons of CSO avoided per year.
- Restore 190 acres of wetlands and 11 miles of streams.
- Reduce 6 million Kw-hr of electricity and 8 million kBTU of fuel per year.

Earth Economics (2010) reported instead of constructing conventional curb/gutter and storm sewers:

- The Portland, Ore. Museum of Science Museum constructed vegetated swales and saved $78,000.
- Grayslake, Ill. Prairie Crossing saved $2.7 million using swales, native landscaping, and wetlands.

The USEPA (2010) in a guidance document for the Chesapeake Bay watershed found:

- Middlesound, N.C., low impact development stormwater design gained 4 lots worth over $1 million in new home yield, reduced storm water pipe costs by 89%, avoided $1.5 million in fill material.
- State of Washington, low impact development storm water design reduced site construction costs $22,000 to $761,000 or by 15% to 80% compared to conventional stormwater design.
- St. Paul, Minn. Capitol Region Watershed District constructed infiltration facilities/rain gardens saving $0.5 million capital costs on $2.5 million project infiltrating 2 million cf of runoff at $0.03/cf.
- Portland, Oregon conducted an analysis that indicates a 40,000 sf green roof would provide a net benefit of $404,000 ($2008) over a 40-year life when compared to a conventional building roof.
- In Seattle, green grid streets cost $280,000 per block compared to traditional local street stormwater management at $425,000 per block, a savings of $145,000 per block.

The Wisconsin Department of Natural Resources estimated the mean municipal cost of implementing stormwater programs to comply with MS4 provisions of the Clean Water Act is $162,900 or an average per capita cost of $9.00.

Belanger (2009) conducted a cost-benefit study of urban stormwater economics in Toronto and found:
- A 12,300 acre green roof saved $313 million initially and $37 million annually.
- Conventional concrete pavement cost $11.50/sf vs. permeable pavement at $6.50/sf, saving $4.50/sf.
- A concrete stormwater pipe costs $24/ft versus $5/ft for a green grass swale.

The Center for Watershed Protection (2000) summarized the economics of watershed protection:
- In the Chesapeake Bay watershed, a 12.2 acre commercial office park saved $160,469 when an innovative stormwater design was used instead of a conventional storm sewer design.
- Replacing conventional curb & gutter and storm sewers with water conservation BMPs like landscape bioswales saved $4,000 for a 0.2 acre residential site and $78,000 for a 6-acre commercial parking lot.
- Narrow streets, bioswales, rain gardens, forest buffers, and filter strips instead of conventional curb & gutter & storm sewers saved $1.4 million per residential subdivision or up to $7,458 per lot.
- LID narrow streets, bioswales, rain gardens, natural buffers, filter strips, and forested depressions instead of curb & gutter & storm sewers saved $564,000 per commercial site or up to $13,000 per ac.
- From 1856 to 1873, Frederick Law Olmsted measured a $209 million increase in property value on land adjacent to Central Park in New York City.
- Open space stormwater design at Remlik Hall Farm cost $594,000 or $600,000 (50%) less than a conventional stormwater design approach for this 490-acre cluster development (Table ES1).

Table ES1. Conventional versus cluster stormwater design approach for Remlik Hall Farm

Parameter	Scenario A Conventional Plan	Scenario B Cluster Plan
Engineering Costs	$79,600	$39,800
Road Construction Costs	$1,012,500	$487,500
Sewage and Water	$25,200	$13,200
Contingencies	$111,730	$54,050
Total	**$1,229,030**	**$594,550**
Total Developed Land	287.4 ac	69.4 ac
Roads/Driveway	19.7 ac	11.7 ac
Turf	261.1 ac	54.0 ac
Buildings	6.6 ac	3.9 ac
Total Undeveloped Land	202.7 ac	420.6 ac
Forest	117.6 ac	133.0 ac
Wetlands	11.5 ac	11.5 ac
Total Site Area	**490.2 ac**	**490.2 ac**
Impervious Cover	5.4%	3.7%
Nitrogen	2,534 lb/yr	1,482 lb/yr
Phosphorus	329 lb/yr	192 lb/yr

The American Planning Association (2002) found green stormwater management saves:
- $1,100 for each commercial parking space eliminated or $7,000 per space over life time.
- $150 for each foot of road shortened with reduced pavement, curb/gutter, storm sewer needs.
- $25 to $50 for each foot of roadway narrowed.
- $10 for each foot of sidewalk eliminated.

The Ontario MOE (2003) found the following benefits from green stormwater management:

- Reduced downstream flooding that can increase floodplain property values by up to 5%.
- Reduced energy cooling costs by 33%-50% from increased natural vegetation in Davis, Cal.
- Retrofitting of Seattle's greenstreets BMPs added 6% to the neighborhood value of properties.
- Improved water quality can increase property value by 15% along the water body.
- Bioretention instead of storm sewers saved $250,000 along Anacostia River in Washington, DC.
- Replacing curb & gutter & storm sewers with roadside swales saved $70,000/road mile or $800/lot..
- Lots in LID neighborhoods sold for $3,000 more than lots in competing areas.

American Forests (2006) calculated billions of dollars of stormwater infrastructure would have to be built to replace lost water quality/quantity benefits of urban forests in the U.S. and Canada (Table ES2).

Table ES2. Avoided stormwater construction costs due to tree canopy as measured by American Forests.

Urban Area	Avoided Costs ($ billion)
Vancouver, Can.-Portland, Ore.	$20.2
Metro Puget Sound, Wa.	$5.9
Washington, D.C.-Metro	$4.7
Atlanta, Ga.	$2.4
San Antonio, Tex.	$1.3
Houston, Tex.	$1.3
Chesapeake Bay Region	$1.1
New Orleans, La.	$0.7
Detroit, Mi.	$0.4
San Diego, Cal.	$0.2

Value of Stormwater Management in Delaware

The annual economic value of green stormwater management in Delaware approaches $1 billion if innovative practices are implemented based on benefits from:

- Increased Property Value
- Water Treatment
- Stormwater Detention
- Stormwater Runoff
- Improved Water Quality
- Small Property Owner Benefits

Table 26. Annual economic value of stormwater management in Delaware

Activity	Value ($2010/year)	Source
Water Quality Benefits		
Improved water quality increases stream-side property value by 8%.	$784,000,000	Leggett, et al. (2000), EPA (1973), Brookings Institute (2007)
Water treatment by forests @ $41/mgd	$1,496,000	Trust for Public Land and AWWA (2004)
Benefits of stormwater management to achieve Delaware water quality standards.	$153,000,000	Carson and Mitchell (1993).
Small property owner (1 acre site) benefits of green stormwater management	$8,600/ac	National Green Values™ Calculator at http://greenvalues.cnt.org/national/calculator.php
Flood Control Benefits		
Stormwater detention improves downstream floodplain property value by 2% to 5%.	$42,000,000 - $105,000,000	Braden and Johnston (2004), University of Illinois
Green stormwater mgmt. in Del.can save $17 billion (42.6 billion gal runoff @ $0.35 gal).	$17,000,000	Bélanger (2009), City of Toronto
Total	**≈$1 billion/yr**	

The annual benefits from stormwater management to meet improved boating, fishing, and swimmable water quality standards in Delaware is $141 million with a 2010 willingness to pay of $438 per household (Table ES1 and Fig. ES1).

Table ES3. Annual benefits from stormwater management and improved water quality in Delaware

Water Quality Use Support	2010 Population[1]	2010 Households[1]	2010 WTP[2] ($/hh)	WQ Benefits ($)
Boating	868,000	322,232	$168	$54,134,976
Fishing	868,000	322,232	$127	$40,923,464
Swimming	868,000	322,232	$141	$45,434,712
Total	**868,000**	**322,232**	**$438**	**$141,137,616**

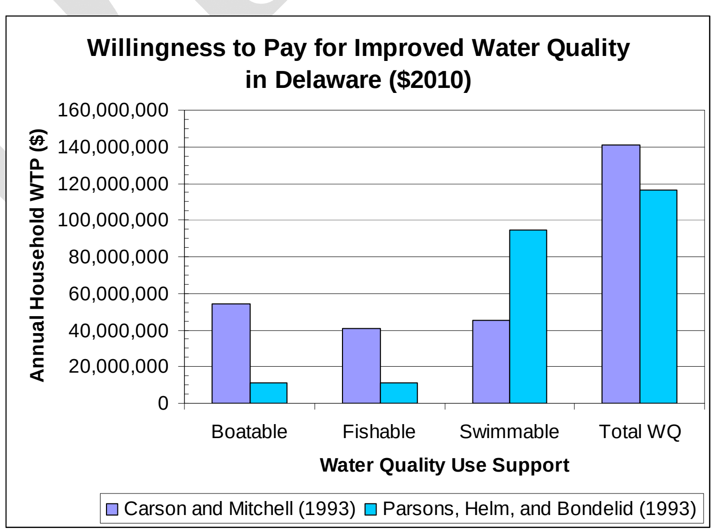


Figure ES1. Willingness to pay for improved water quality in Delaware

Total benefits of municipal ($141 million) and construction site ($11 million) stormwater management to achieve boatable, fishable, and swimmable water quality standards in Delaware are $153 million per year. Annual costs to implement municipal stormwater programs and construction site erosion and sediment controls in Delaware is $11 million. The benefit -cost ratio of innovative green stormwater management to achieve water quality standards in Delaware is 14:1.

According to the National Green Values™ Calculator, a one acre property proposed for development in Delaware will generate 94,160 cf of runoff for predevelopment conditions, 88,307 cf for conventional stormwater design, and 85,067 cf for green stormwater design. Compared to conventional stormwater design, green stormwater design reduces runoff from a one acre site by 3,240 cf or $74,520 using the Center for Watershed Protection value of $23/cf for stormwater treatment. The Center for Watershed Protection recommends the Delaware DNREC adopt an in-lieu fee of $23/cf of stormwater treatment volume not managed on-site.

Watershed Ecosystem Services

The estimated value of natural goods and services provided by ecosystems in Delaware watersheds (2,368 sq mi or 1,515,263 ac) is $6.7 billion ($2010) with a net present value (NPV) of $216.6 billion (Table ES4). Ecosystem services areas within Delaware watersheds are comprised of farmland (39%), forests (18%), freshwater wetlands (12%), marine (8%), and saltwater wetlands (5%). Just over 15% of watershed land in Delaware is urban/suburban. Freshwater wetlands, farms, marine habitat, forests, and saltwater wetlands provide the highest ecosystems goods and services values.

Table ES4. Value of ecosystem good and services in Delaware watersheds

Ecosystem	Area (ac)	$/ac/yr	PV $	NPV $
Freshwater wetlands	178,632	13,621	2,433,081,000	79,075,132,489
Marine	124,879	10,006	1,249,541,955	40,610,113,531
Farmland	590,150	2,949	1,740,640,688	56,570,822,374
Forest land	265,476	1,978	525,143,567	17,067,165,922
Saltwater wetland	71,001	7,235	513,691,702	16,694,980,313
Urban	229,827	342	78,511,742	2,551,631,623
Beach/dune	588	48,644	28,579,665	928,839,116
Open water	48,253	1,946	93,891,133	3,051,461,812
Delaware	**1,515,263**		**6,663,081,452**	**216,550,147,179**

Ecosystem services are provided by the following Whole Basins in Delaware:

- Delaware Estuary $2.4 billion
- Chesapeake Bay $2.0 billion
- Inland Bays $2.0 billion
- Piedmont $197 million

Delaware basins with the highest value of annual ecosystem services per acre include:

- Inland Bays $6,147/ac
- Chesapeake Bay $4,562/ac
- Delaware Estuary $3,878/ac
- Piedmont $1,694/ac

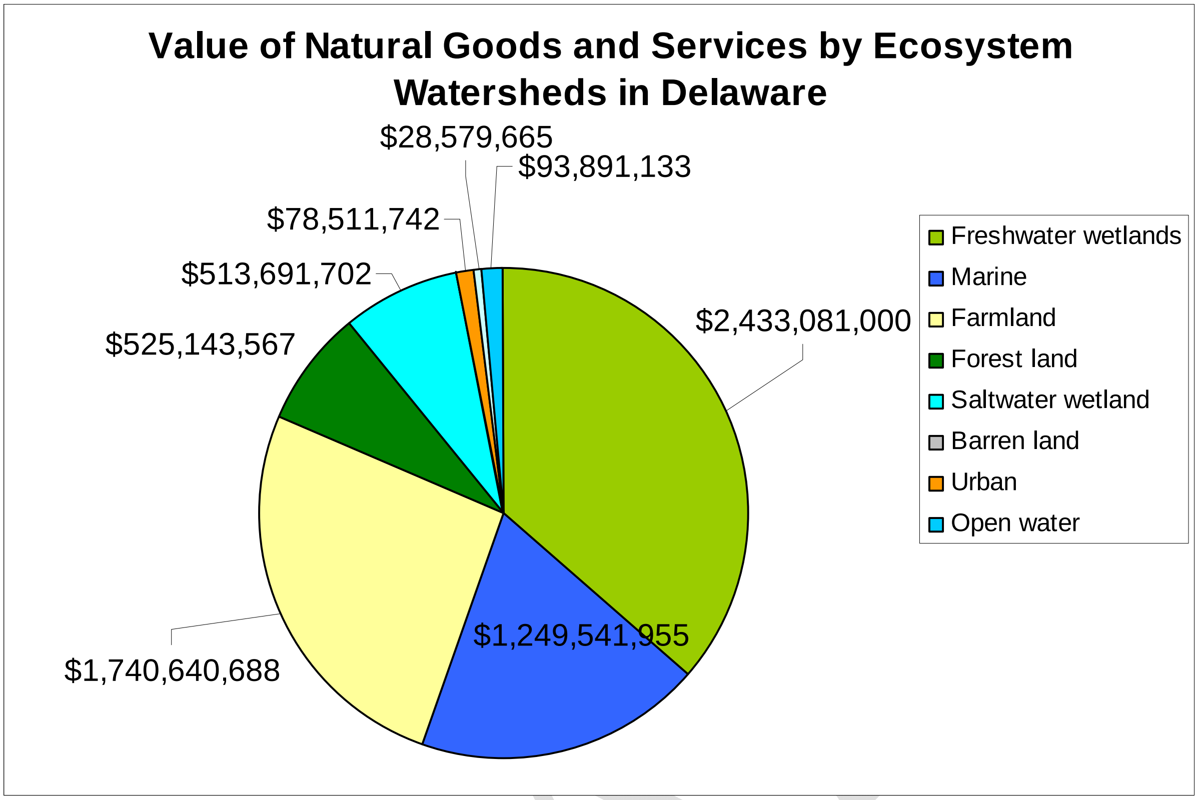


Figure ES4. Value of natural goods and services by ecosystem within Delaware watersheds

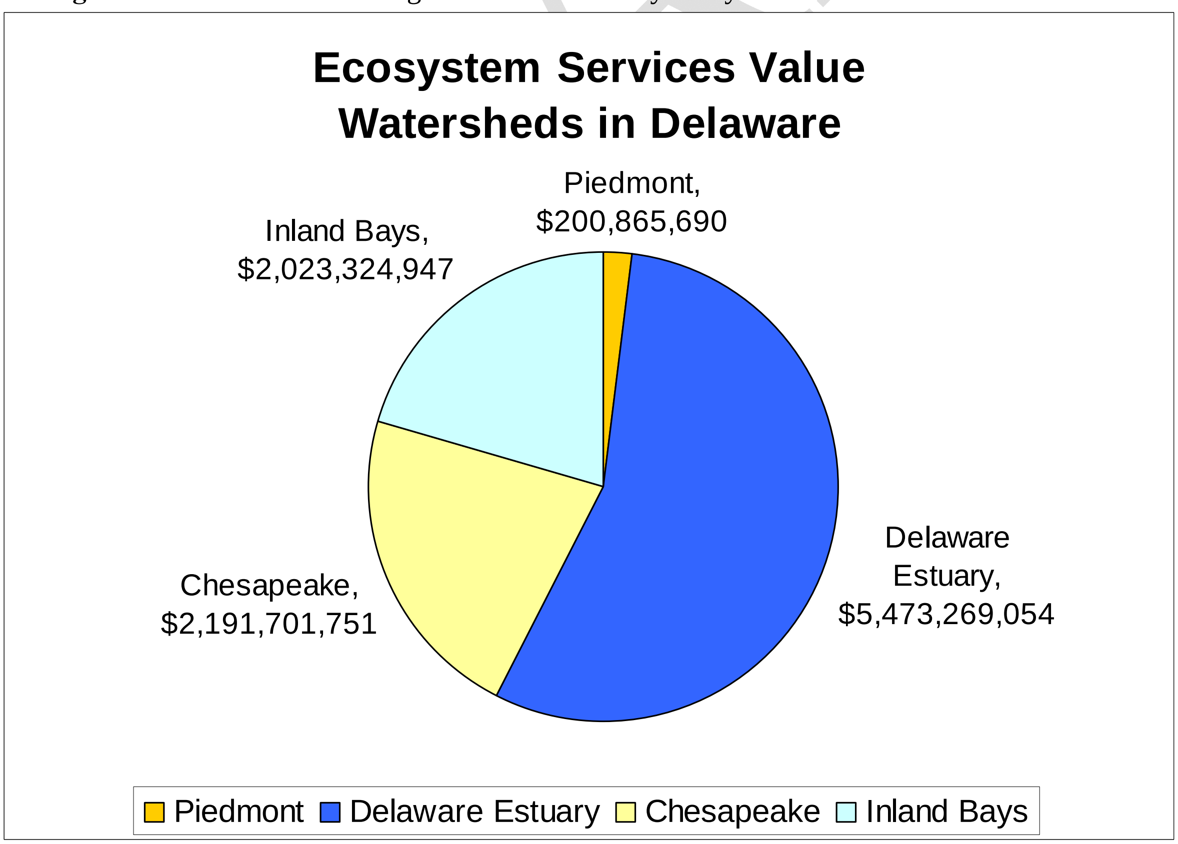


Figure ES5. Value of natural goods and services by watershed within Delaware

1. Introduction

The National Academy of Sciences (2009) concluded:

"Stormwater runoff from the built environment remains one of the great challenges of modern water pollution control, as this source of contamination is a principal contributor to water quality impairment of waterbodies nationwide."

Objectives

The Delaware DNREC Division of Watershed Stewardship proposes to submit legislation to the General Assembly during Spring 2011 for consideration to revise the Delaware Stormwater and Sediment Control Regulations. The proposed stormwater regulation revisions were recommended by the April 2005 Delaware Task Force on Surface Water Management. The University of Delaware Water Resources Agency has prepared the following report to quantify the economic costs and benefits of the proposed stormwater and sediment control legislation.

The objectives of this report and regulatory review are to quantify the economic costs and benefits of proposed revisions to the Delaware stormwater and sediment control regulations particularily with respect to the Title 29, Chapter 104 of the Delaware Regulatory Flexibility Act.

Introduction

After the back-to-back 100-year floods of Tropical Storm Henri (Sep 2003) and Tropical Storm Jeanne in (Sep 2004), the Governor appointed a Task Force for Surface Water Management to overhaul stormwater and floodplain management in Delaware. The task force committee recommended the following revisions to the Delaware Stormwater and Sediment Control Regulations:

- Stormwater management for 2 inch water quality storm for 2-yr, 10-yr, and 100-yr design events.
- Regulatory storm events for 1-yr (Resource Protection), 10-yr (Conveyance), and 100-yr (Flooding).

Instead of conventional curb/gutter, storm sewer, and detention pond practices, the proposed stormwater regulation revisions call for implementation of innovative and green stormwater practices such:

- Infiltration & Retention Technologies
- Green Roofs
- Permeable Surfaces
- Bio-Swales
- Filter Strips
- Rain Gardens
- Bioretention Systems
- Constructed Wetlands
- Infiltration Basins & Trenches
- Detentions Basins
- Retention Ponds (Wet Ponds)

Green stormwater practices can provide the following benefits to communities (WERF 2009).

- Higher property values (increased sales, higher sale/resale prices, shorter on-market time).
- Increased tax revenue.
- Decreased flood damage that increases property values in the 100-yr floodplain.

- Public infrastructure cost savings through reduced size of stormwater pipes and culverts.
- Reduced pollution and water treatment costs
- Improved water quality
- Increased tourism and recreation.

Legislative Framework

Proposed Delaware Stormwater & Sediment Control Regulations evolved have evolved over two decades:

1987 - U.S. Congress revises Clean Water Act authorizing EPA to control NPDES stormwater discharges.

1990 - EPA passes Phase I stormwater regulations for municipal separate storm sewer systems (MS4).

1991 – Governor/General Assembly adopt Delaware Stormwater and Sediment Control Regulations

1993 – Governor/General Assembly amend Delaware Stormwater and Sediment Control Regulations

1999 - EPA passes Phase II municipal separate storm sewer regulations in cities <100,000 in population.

2003 – Tropical Storm Henri (100- to 500-yr flood).

2004 – Tropical Storm Jeanne (100-yr flood).

2005 – Surface Water Management Task Force issues report and recommendations to Governor.

2006 - Governor /General Assembly amend Delaware Stormwater and Sediment Control Regulations

Dec 2009 - EPA issues Federal Register Notice seeking stakeholder input to help shape program to reduce stormwater impacts and expand the area subject to federal stormwater regulations such as:
- Establish requirements to control stormwater discharges from new development and redevelopment
- Develop a single set of consistent stormwater requirements for all MS4s
- Require MS4s to address stormwater discharges existing areas by retrofitting the sewer system.

Jun 2010 - Delaware DNREC releases Stormwater Runoff Reduction Guidance Document concluding:
- Benefits of controlling stormwater runoff volume is well documented and accepted in field.
- Infiltration practices have been used for years to mitigate impacts from increased stormwater runoff.
- Rain events between 0.35 and 3.0 in are responsible for 80% of the total annual runoff volume.
- The median runoff event is 1.25 in or about the 90th percentile rainfall event for Delmarva region.

Feb 2011 – DNREC issues timeline to revised Delaware Sediment/Stormwater Regulations (Table 1).

Table 1. Proposed timeline to promulgation/revisions to Delaware Sediment and Stormwater Regulations

Date	Step
Feb 8, 2011	Tech. Subcommittee Meeting
Mar 8, 2011	Tech. Subcommittee Meeting
Mar 19, 2011	Full RAC Meeting
May 19, 2011	Public Workshop
Sep 2011	Public Hearing/ Public Comment
Jan 2012	Effective Date

Regulatory Flexibility Act Compliance

Title 29, Chapter 104 of the Delaware Regulatory Flexibility Act requires that prior to any new rule or regulation, an agency such as DNREC shall consider whether it is lawful, feasible and desirable for the agency to exempt individuals and small businesses from the effect of the rule or regulation or whether the agency may and should promulgate a rule or regulation which sets less stringent standards for compliance by individuals and/or small businesses.

- The nature of any reports and the estimated cost of their preparation by individuals and/or small business to comply with the new rule.

- The nature and estimated costs of measures or investments that would be required by individuals and/or small businesses in complying with the rule:

- The nature and estimated cost of legal, consulting, and accounting services which individuals or businesses would incur in complying with the rule.

- The ability of individuals and/or small businesses to absorb the costs estimated under questions 1, 2 and 3 of this form without suffering economic harm and without adversely affecting competition in the marketplace:

- The additional cost to the agency of administering a rule which exempts or sets lesser standards for compliance by individuals and/or small business:

- The impact on the public interest of exempting or setting lesser standards of compliance for individuals and/or small businesses.

- What accommodations, if any, have been made in the regulations to address individual or small business concerns identified above?

Administrative Policy D1006

Administrative Policy D1006 – Regulatory Development Process revised September, 2008 outlines the following 25-step process to enact final regulations.

1. Prepare Start Action Notice. Submit copy for Division Director signature. Submit to DNREC Registrar.

2. DNREC Registrar distributes SAN to Divisions for two week comment period.

3. The Secretary shall approve, modify, or reject the SAN.

4. If Secretary approves SAN, DNREC Registrar shall notify the following:

- Division Director
- Responsible staff member
- Public Affairs
- House and Senate Natural Resource/Environ. Management Committees
- Governor's Office
- Persons requesting notice of all SAN's

- The State Registrar of Regulations
- DNREC Hearing Officers

5. Division sends copy approved SAN to interested parties, groups, or persons.

6. Establish list of persons expressing interest in the specific action known as "Interested Persons List."

7. Division lists progress of regulatory processes as attachment to Division's weekly Governor's Report.

8. Conduct optional regulatory workgroup meetings. Post min. 7 days notice w/ agenda, date, time, and location. Notify DNREC Public Affairs. Post on DNREC web site and Public Meetings calendar.

9. Submit draft regulation to Legal Office or Division Paralegal to ensure it is clear and concise, and is enforceable through appeal or litigation in the courts.

10. Schedule/hold optional public workshop(s) on draft regulation. Advertise notice in two Delaware newspapers 20 days prior to workshop. Contact DNREC Public Affairs about press release.

11. Make changes to draft regulation from public comments. Draft regulation now a proposed regulation and ready for public hearing. Submit proposed regulation to Legal Office or Division Paralegal for review.

12. After consultation with DNREC Hearing Officer, schedule a public hearing.

- Reserve meeting place to anticipate large numbers of the public.
- Acquire Court Reporter for hearing, in conjunction with State contract.
- Ensure that federal requirements more stringent than Delaware statutory requirements are followed (e.g. length of public notice periods).
- Advertise time, date and location of public hearing in two Delaware newspapers at least 20 days prior to hearing. Ensure public hearing notice is on DNREC web site and state Public Meetings calendar.

13. Submit proposed regulation to Division Director. Electronically transmit to DNREC Registrar the full text of proposed regulations and Register Notice.

14. Fill out Regulatory Flexibility Act analysis and submit with Register Notice.

15. DNREC Registrar electronically transmits Register Notice and full text of proposed regulation to State Registrar before close of business on the 15th.

16. Secretary directs memorandum to members of House and Senate Natural Resources Committees advising of opportunity to comment through public hearing process on the individual and small business aspects of the regulation as outlined in the Regulatory Flexibility Act (29 Del C. Chapter 104).

17. Conduct scheduled public hearing in accordance with statutory requirements. Public comment (i.e. the "record") shall be open for minimum of 30 days after proposal is published in Register of Regulations.

18. Prepare Hearing Officer's Report with recommendation for Secretary. Hearing Officer prepares draft Order adopting, amending, or repealing regulation.

19. The Secretary shall adopt, modify and adopt, or reject the draft Order after consideration of the Hearing Officer's Report and Recommendation.

20. The Secretary's Office assigns an Order Number to the Order implementing the Secretary's decision, and returns the original Order to the Hearing Officer.

21. The Hearing Officer shall insert number into Order and transmit original signed Secretary's Order and copy of Hearing Officer's Report. The Hearing Officer shall also transmit electronic copies to DNREC Registrar, staff member, Division Paralegal, and Division Director.

22. As final version of regulation is complete, and no later than receipt of signed Order, staff member shall ensure that clean hard copy of the final regulation is transmitted to the DNREC Registrar and electronically submit the following:

- A clean version of the final regulation (including the effective date)
- A marked up version using underlines and strikeouts
- A summary of regulatory changes may be submitted in lieu of entire regulation.

23. Staff member or paralegal forwards hard copy of final regulation to Attorney General for judgment whether proposed action represents taking of property without compensation by 29 Del. C. §605.

24. DNREC Registrar electronically transmits to State Registrar, before COB on 15th of month, copy of Secretary's Order and marked up final regulation or clean version if marked up version not required.

25. Upon expiration of appeal period, DNREC Registrar distributes copies of newly promulgated regulation:

- Legal Office - 1 hard copy
- Secretary's Office - 1 electronic copy
- Chair of NREC Committees & interested members of the General Assembly
- DNREC Public Affairs - 1 electronic copy
- Governor's Office - 1 hard copy

Scope of Work

The University of Delaware Water Resources Agency conducted this analysis according to the following scope of work.

1. Conduct a literature review and review Federal, state, and local reports and publications pertaining to the economic value of stormwater management and proposed revisions to the Delaware stormwater and sediment regulations. This analysis integrates the following stormwater guidance issued by EPA, National Academy of Sciences and other agencies:

- EPA Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act
- EPA Guidance for Federal Land Management in the Chesapeake Bay Watershed
- EPA survey of owners of developed/redeveloped sites, NPDES permitting authorities, and owners/operators of federally regulated municipal separate storm sewer systems (MS4s)
- National Academy of Sciences report: Urban Stormwater Management in the United States,

2. Estimate the economic costs and benefits of stormwater management in Delaware.

3. Transmit a report to the Delaware DNREC summarizing the economic with recommendations whether individuals and small businesses should receive exemptions from the proposed stormwater regulations.

2. Demographics

Demographics

In 2009, 885,122 people live in Delaware on 1,954 sq mi o f land with a population density of 1,000 p./sq mi (Table 2). Just over 398,510 people were employed in Delaware in 2009. Between 2000 and 2009, Delaware population grew by 101,565. an increase of 13% (Table 3). The population of Kent County and Sussex County grew by 23% and 24%, respectively, during this decade. By 2030, the population in Delaware is projected to grow by 159,000 (18%) to just over a million people (Table 4).

Table 2. Land area, population, and employment in Delaware

County	Area (sq mi)	Population 2009	Employment 2009
New Castle	426	534,634	277,797
Kent	590	157,741	49,983
Sussex	940	192,747	61,058
Total	**1,954**	**885,122**	**389,510**

Table 3. Population change in Delaware, 2000-2009

County	Population 2000	Population 2009	Change	Change (%)
New Castle	500,272	534,634	34,362	6.9%
Kent	126.704	157,741	31,037	24.5%
Sussex	156,581	192,747	36,166	23.1%
Total	**783,557**	**885,122**	**101,565**	**13.0%**

(Delaware Population Consortium Annual Population Projections, October 28, 2010)

Table 4. Population projections in Delaware, 2010-2030

County	Population 2010	Population 2020	Population 2030	2010-2030 (change)	2010-2030 (%)
New Castle	538,170	567,764	589,267	51,097	9%
Kent	160,058	178,817	192,853	32,795	20%
Sussex	196,945	235,341	272,511	75,566	38%
Total	895,173	981,922	1,054,631	159,458	18%

(Delaware Population Consortium Annual Population Projections, October 28, 2010)

In Delaware in 2007, 39% of the land is agriculture, 17% is forest, 17% is saltwater/freshwater wetland, 15% is urban, 8% is marine, and 3% is open freshwater (Table 5). Delaware is drained by four Whole Basins; the Piedmont, Delaware Estuary, and Inland Bays basin flow east and the Chesapeake Bay basin flows west (Fig. 1)

Table 5. Land use in Delaware watersheds

Ecosystem	Piedmont	Delaware Estuary	Chesapeake Bay	Inland Bays/ Atlantic Ocean	Total
Freshwater wetlands	4,732	58,390	81,130	34,379	178,632
Marine	799	16,274	233	107,573	124,879
Farmland	9,588	254,143	245,509	80,910	590,150
Forest	32,189	95,346	102,306	35,635	265,476
Saltwater wetland	919	61,617	353	8,111	71,001
Barren land	234	2,305	844	3,076	6,459
Urban	67,357	123,048	17,019	22,403	229,827
Beach/Dune	42	256	74	216	588
Open freshwater	575	14,056	1,780	31,842	48,253
Total	116,435	625,435	449,248	324,145	1,515,263
Ecosystem	**Piedmont**	**Delaware Estuary**	**Chesapeake Bay**	**Inland Bays/ Atlantic Ocean**	**Total**
Freshwater wetlands	4.1%	9.3%	18.1%	10.6%	11.8%
Marine	0.7%	2.6%	0.1%	33.2%	8.2%
Farmland	8.2%	40.6%	54.6%	25.0%	38.9%
Forest	27.6%	15.2%	22.8%	11.0%	17.5%
Saltwater wetland	0.8%	9.9%	0.1%	2.5%	4.7%
Barren land	0.2%	0.4%	0.2%	0.9%	0.4%
Urban	57.8%	19.7%	3.8%	6.9%	15.2%
Beach/Dune	0.0%	0.0%	0.0%	0.1%	0.0%
Open freshwater	0.5%	2.2%	0.4%	9.8%	3.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

The State of Delaware is drained by 4 basins and 45 watersheds. The State of Delaware (2010) Combined 305(b) Report and 303(d) List has classified:

- 25 miles of ocean coastline
- 841 square miles of bay
- 2,509 miles of rivers and streams
- 2,934 acres of lakes and ponds.
- 86% of Delaware rivers/streams impaired for swimming due to high bacteria
- 97% of Delaware rivers/streams do not meet fish and wildlife water quality standards.
- 44% of Delaware ponds and lakes do not meet swimming uses.
- 89% of ponds and lakes do not support fish and wildlife uses.
- >100 miles of waters have fish consumption advisories from high PCBs, metals, and pesticides.

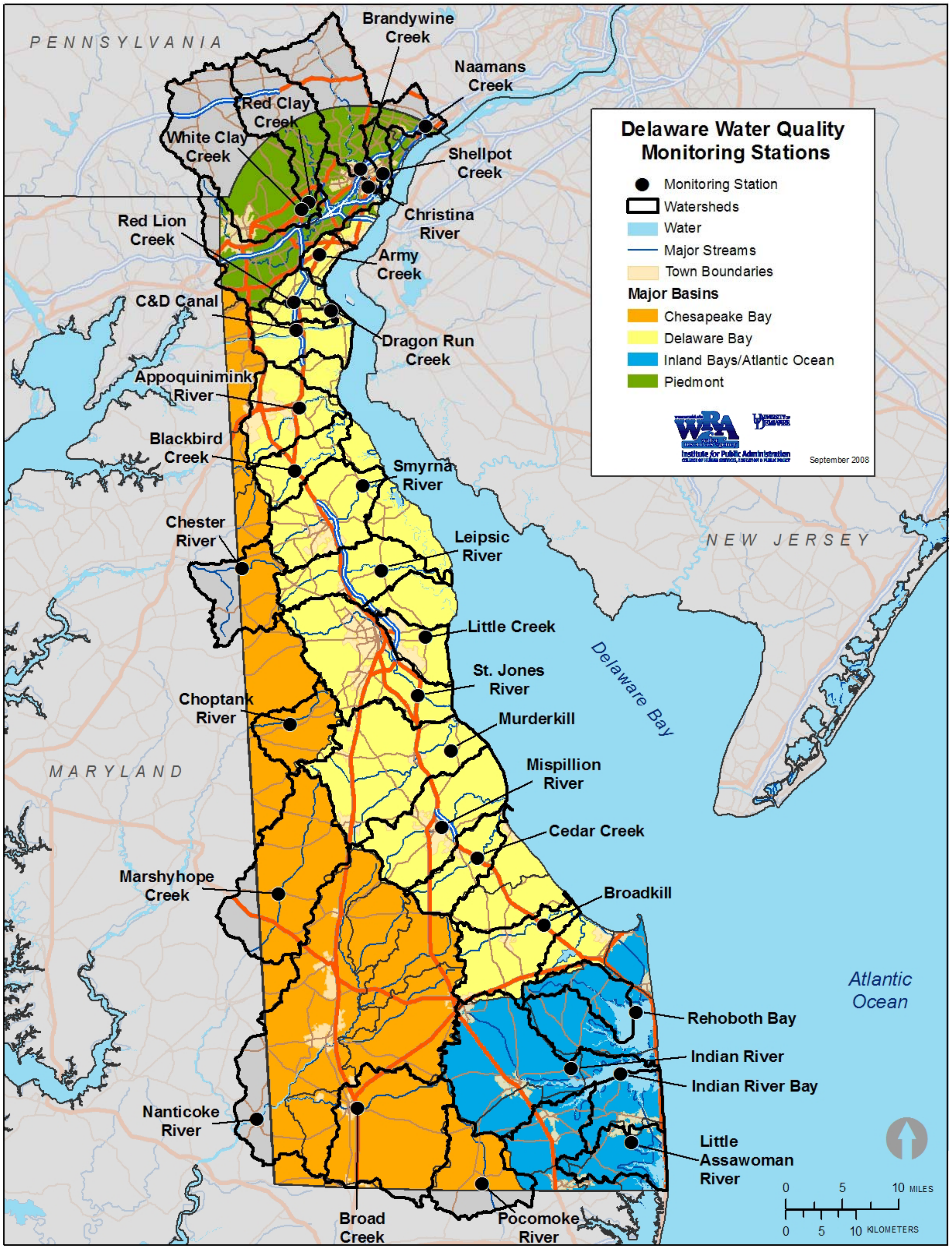


Figure 1. Delaware watersheds

The Great Lakes Coalition (2010) concluded investment in watershed restoration and stormwater management creates good paying jobs and leads to economic benefits while restoring the environment (Table 6).

Table 6. Jobs and salaries created by watershed restoration work
(Great Lakes Coalition (2010) from U. S. Bureau of Labor Statistics)

Job	Mean Salary	Job	Mean Salary
Wetland scientist	$45,730	Fisheries Biologist	$60,670
Research scientist	$45,730	Archeologist	$57,230
Construction manager	$93,290	Operating Engineer	$44,180
Biologist	$69,430	Environmental Engineer	$80,750
Toxicologist	$70,000	Hydrogeologist	$92,710
Chemist	$72,740	Environmental Planner	$64,680
Geologist	$58,000	Plumber/Pipefitter	$9,870
Helicopter Pilot	$90,000	Carpenter	$43,640
Information Technology	$70,930	Electrician	$50,850
Admin. Staff	$32,990	Truck Driver	$39,260
Mechanics	$37,000	Concrete Workers	$39,410
Excavator	$38,540	Dredge Operator	$38,330
Landscape Architect	$65,910	Conservation Scientist	$61,180
Civil Engineer	$81,180	Biological technician	$41,140
General Laborer	$33,190	Pile Drive Operator	$51,410

3. Flooding

Historic Storms

Over the last decade, 3 historic storms have flooded Delaware and caused over $80 million in damages (Table 7):

- Tropical Storm Henri (Sep 15, 2003)
- Tropical Storm Isabel (Sep 18, 2003)
- Tropical Depression Jeanne (Sep 28, 2004)

On Sep 15, 2003, Tropical Storm Henri dumped 10 inches of rain on the Red Clay Creek watershed in New Castle County, Delaware, damaged 194 homes in the Glenville neighborhood in Stanton, and caused $16.1 million in immediate flood damages in Delaware. The once in 500-yr flood included a flood wave that rose 5 feet in an hour and damaged a bridge in Hockessin, wiped out six Wilmington & Western Railroad bridges, and caused $5 million in damages along Red Clay Creek. The historic Greenbank Mill (ca. 1760) experienced $450,000 in damages in the worst flooding in over 2 centuries since the mill was built. Just 8 months after the storm, the State of Delaware, New Castle County, Delaware Department of Transportation, and FEMA allocated over $30 million in funds to acquire and demolish 172 flood damaged homes located within the 100-year floodplain in the Glenville neighborhood along the Red Clay Creek. The Glenville flood acquisition project was the largest housing purchase by State and County governments in Delaware's history due to storm damage. President George W. Bush declared New Castle County a Federal disaster area. Henri caused $46 million in total flood damages including the purchase and relocation of damaged homes in the Glenville neighborhood.

A few days later on September 18, 2003, Tropical Storm Isabel passed over the Delmarva Peninsula as the first major hurricane to threaten the mid-Atlantic since Hurricane Floyd in September 1999. Isabel caused $40 million in flood damages in Delaware leading the Governor to declare a State of Emergency.

Just a year later on September 28, 2004, Tropical Depression Jeanne dumped over 7 inches of rain and spawned the first tornado in New Castle County in 15 years, ripping trees from the ground and severely damaging residential and business structures. Jeanne also initiated a buyout of flood-damaged Newkirk Estates and Glendale communities along the White Clay Creek. State and County governments spent over $34 million in two years to purchase and relocate storm and flood damaged properties due to Tropical Storms Henri and Jeanne.

Table 7. Recent tropical storms and flood damages in Delaware

Tropical Storm	Date	Rainfall (in)	Damages ($ million)
Henri	Sep 15, 2003	>10	$46
Isabel	Sep 18, 2003	>5	$40
Jeanne	Sep 28, 2004	>7	$4

Flood Damages

FEMA National Flood Insurance Program data indicates New Castle County registered $12.9 million in repetitive flood damage losses at 51 properties between 1978 and 2008. During this period, New Castle County property owners filed the 5th highest flood damage claims among all counties in the 4 states of the Delaware River Basin (Table 8 and Fig. 2).

Table 8. Repetitive flood damage claims in the Delaware River Basin, 1978-2007

County	Watersheds	Properties	Flood Losses ($ million)
Bucks, Pa.	Delaware R., Neshaminy Cr.	590	$76.0
Montgomery, Pa.	Schuykill R., Perkiomen Cr.	252	$26.8
Northampton, Pa.	Delaware R., Lehigh R.	193	$25.9
Warren, NJ	Delaware, Pequest, Paulinskill	192	$19.8
New Castle, Del.	Red Clay, White Clay,Christina R.	51	$12.9
Hunterdon, NJ	Delaware R.	156	$12.7

(FEMA National Flood Insurance Program)

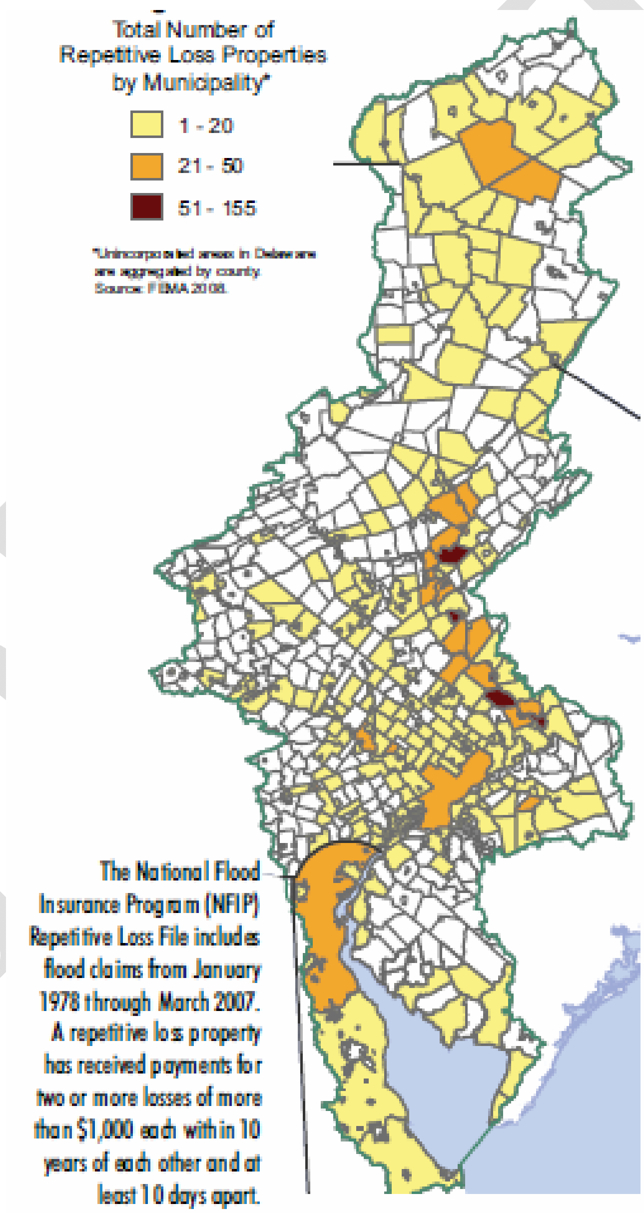


Figure 2. Flood damage claims in the Delaware Basin, 1978-2007
(FEMA National Flood Insurance Program and DRBC)

The Delaware Floodplain

Situated on the Delmarva Peninsula between the Delaware and Chesapeake bays, Delaware is the lowest state in the U.S. with a mean elevation of just 60 feet above sea level. Vulnerable to flooding from rising sea levels and ocean-fueled tropical storm systems, coastal Delaware is one of only three states on a peninsula surrounded on three sides by water. Delaware floods originate from hilly, rocky Piedmont streams in northern New Castle County and tidal influences along the bays and Atlantic Ocean.

Over 331 square miles or 17% of Delaware's land mass are within a FEMA mapped 100-year floodplain. The distribution of floodplain area in the three Delaware counties is similar ranging from 16% to 18% of the land (Table 9).

Table 9. Area of 100-year floodplain in Delaware counties

County	100-yr Floodplain (sq mi)	% of County
New Castle	67	16%
Kent	94	16%
Sussex	170	18%
Total	**331**	**17%**

(UDWRA and FEMA National Flood Insurance Program)

Roads and Structures in Floodplain

Over 621 miles of roads run through the 100-yr floodplain in Delaware (Table 10). New Castle, Kent, and Sussex counties have 128, 75, and 418 road miles in the 100-yr floodplain, respectively. Watersheds with the largest mileage of floodplain roads include the Christina River in New Castle County (44 mi), Murderkill in Kent County (16 mi), and Indian River Bay (106 mi).

Over 18,000 structures lie in the 100-yr floodplain in Delaware with 2,431 structures in New Castle, 1,853 structures in Kent, and 13,760 structures in Sussex counties. Fig. 4 depicts watersheds with most structures in the 100-yr floodplain include the Christina River in New Castle County (1,007 structures), St. Jones River in Kent County (567 structures), and Indian River Bay (3,856 structures).

Flood Discharge

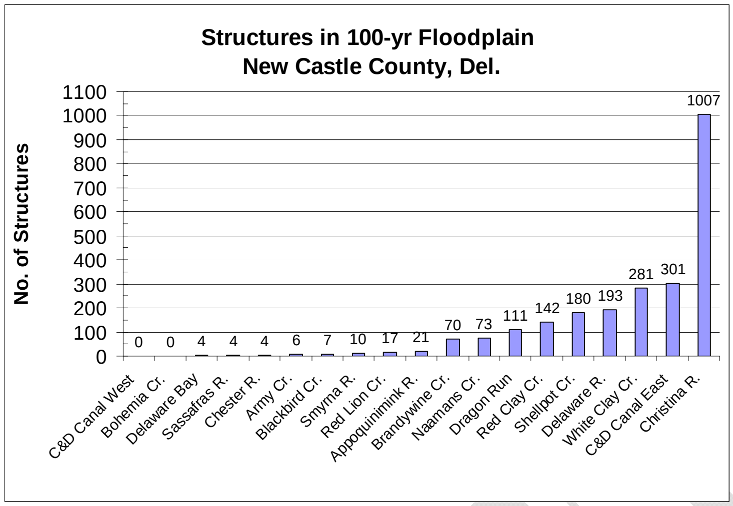
Watersheds with the most extreme floods based on highest unit 100-yr discharge (cfs/sq mi) include Shellpot Creek in New Castle County (1,161 cfs/sq mi), Duck Creek (Smyrna River) in Kent County (327 cfs/sq mi), and Indian River (52 cfs/sq mi) as depicted in Table 11 and Fig. 5. During the last quarter century, the largest floods in Delaware occurred on July 8, 1989 (July 4th storm), September 16, 1999 (Hurricane Floyd), and September 15, 2003 (Tropical Storm Henri) as listed in Table 11.

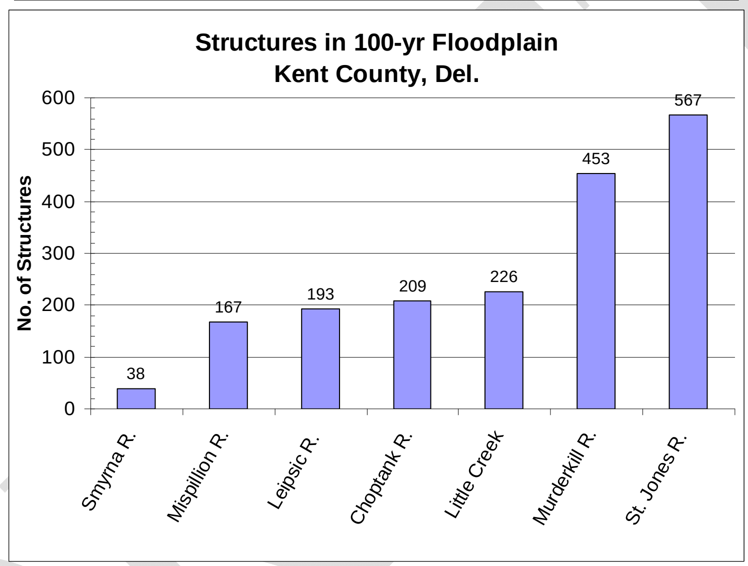
Floodplain Mapping

UDWRA prepared interactive GIS floodplain maps posted at http://brandywine.dgs.udel.edu/flood. The mapping overlays 2007 State of Delaware orthophotography and parcel boundaries with FEMA 100- and 500-year floodplains (Fig. 6). Delaware citizens and governments may access the mapping to determine flood insurance, flood warning, and flood response needs.

Table 10. Area, roads, and structures in the 100-yr floodplain in Delaware

Whole Basin	Watershed	Area (sq mi)	Roads (mi)	Structures (#)
New Castle County		**67.2**	**128**	**2,431**
Chesapeake Bay	Bohemia Creek	0.2	0	0
	C & D Canal West	0.6	1	0
	Chester River	1.4	1	4
	Elk Creek	0.0	0	0
	Perch Creek	0.0	0	0
	Sassafras River	0.4	0	4
Delaware Bay	Appoquinimink R.	7.8	4	21
	Army Creek	1.3	1	6
	Blackbird Creek	6.8	2	7
	C & D Canal East	13.3	16	301
	Delaware Bay	6.9	2	4
	Delaware River	1.7	10	193
	Dragon Run Creek	1.5	3	111
	Red Lion Creek	1.8	1	17
	Smyrna River	5.7	4	10
Piedmont	Brandywine Creek	1.3	13	70
	Christina River	9.5	44	1,007
	Naamans Creek	0.6	3	73
	Red Clay Creek	1.3	5	142
	Shellpot Creek	1.3	6	180
	White Clay Creek	3.8	12	281
Kent County		**94.0**	**75**	**1,853**
Chesapeake Bay	Choptank River	5.4	5	209
Delaware Bay	Leipsic River	28.9	12	193
	Little Creek	3.7	8	226
	Mispillion River	19.9	16	167
	Murderkill River	17.0	16	453
	Smyrna River	5.0	3	38
	St. Jones River	14.1	15	567
Sussex County		**170.4**	**418**	**13,760**
Chesapeake Bay	Broad Creek	6.2	8	252
	Deep Creek	8.7	5	122
	Gravelly Branch	3.1	2	68
	Gum Branch	6.4	8	126
	Marshyhope Creek	10.3	14	184
	Nanticoke River	16.2	20	800
	Pocomoke River	0.0	0	0
Delaware Bay	Broadkill River	26.0	39	957
	Cedar Creek	16.7	20	350
	Mispillion River	19.9	16	126
Atlantic Ocean	Assawoman	0.2	1	84
	Buntings Branch	0.4	3	63
	Indian River	4.9	3	131
	Indian River Bay	17.4	106	3,856
	Iron Branch	1.1	1	46
	Lewes-Rehoboth Canal	6.2	24	662
	Little Assawoman	12.6	89	3,680
	Rehoboth Bay	14.1	59	2,253
State of Delaware		**311.7**	**605**	**18,044**





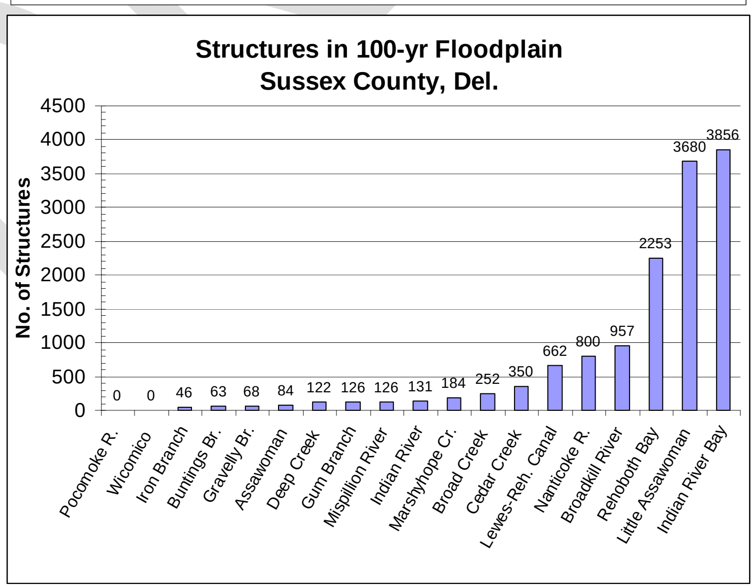


Figure 3. Structures in the 100-yr floodplain in Delaware

Table 11. 100-yr flood discharge in Delaware watersheds

Watershed	100-yr Discharge (cfs)	Watershed Area (sq mi)	Unit Discharge (cfs/sq mi)
New Castle County			
Brandywine Creek	25,600	314.0	82
Christina River	27,600	234.0	118
White Clay Creek	21,500	162.0	133
Red Clay Creek	10,200	54.1	189
Mill Creek	4,400	12.0	367
Pike Creek	3,010	6.3	478
Naamans Creek	7,640	14.0	546
Little Mill Creek	5,800	9.5	611
Dragon Creek	2,817	4.5	622
Shellpot Creek	8,590	7.4	1,161
Kent County			
Choptank River	5,486	94.7	58
Marshyhope Creek	5,312	63.8	83
Liepsic River	3,752	39.1	96
St. Jones River	8,201	38.1	215
Duck Creek	7,400	22.6	327
Sussex County			
Nanticoke River	211	5,120	24
Broadkill River	1,283	45.4	28
Mispillion River	1,110	39.3	28
Broad Creek	3,900	116.1	34
Indian River	5,360	102.0	52

(FEMA Flood Insurance Studies, New Castle Co.(2007), Kent Co.(2008), Sussex Co. (2005), Delaware)

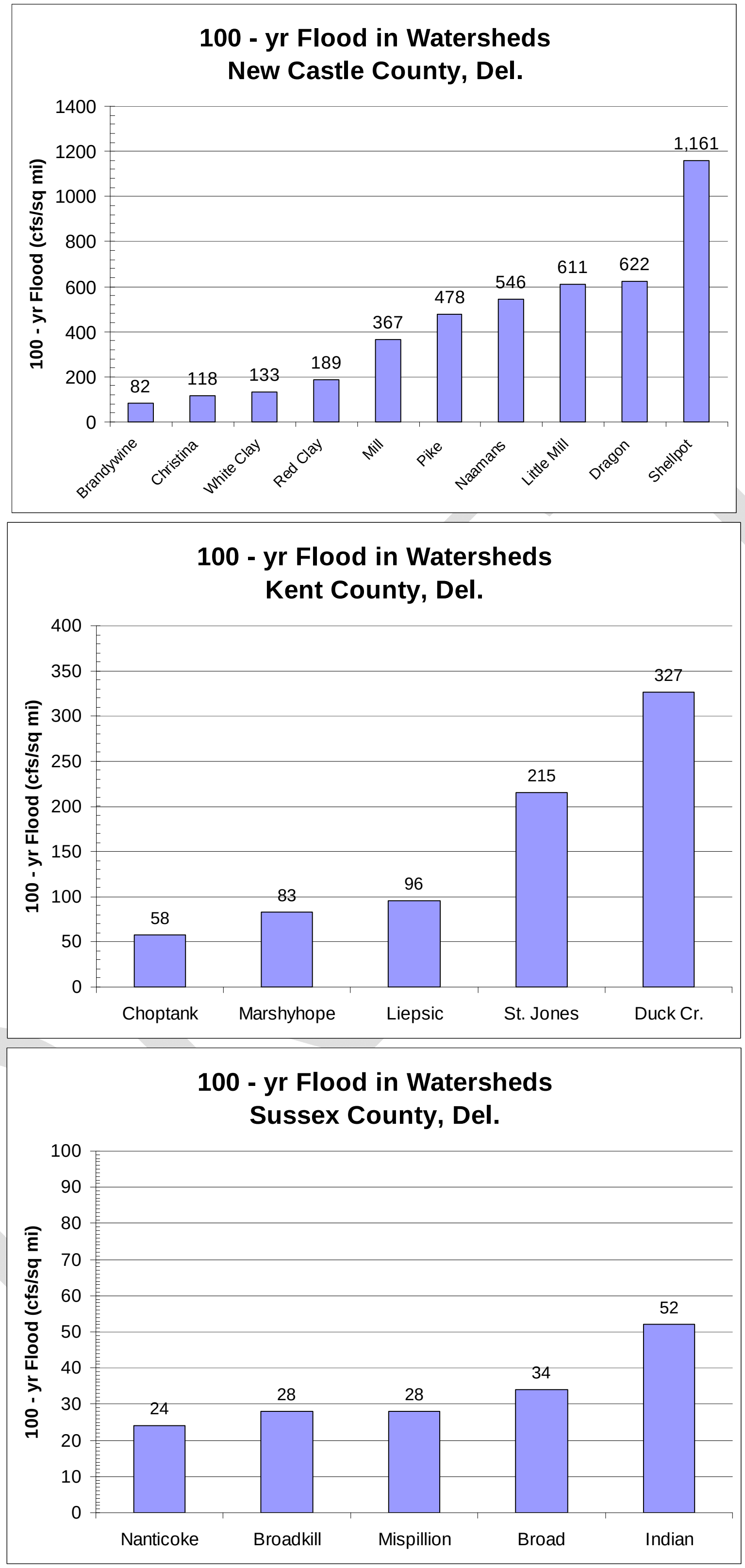


Figure 4. 100-yr flood discharge per area in Delaware watersheds

Table 12. Top 5 floods in Delaware watersheds

Watershed/USGS Gage	Date	Peak (cfs)	Frequency	Probability
New Castle County				
Shellpot Creek at Wilmington, Del.	7/05/89	8,040	100 yr	1%
	9/13/71	6,850	50 yr	2%
	8/27/67	4,650	25 yr	4%
	9/16/99	4,460	25 yr	4%
	7/31/85	4,390	25 yr	4%
Christina River at Cooches Bridge, Del.	9/16/99	7,050	>100 yr	<1%
	7/05/89	5,530	100 yr	1%
	9/28/04	5,430	100 yr	1%
	5/01/47	4,330	50 yr	2%
	6/22/72	3,320	25 yr	4%
White Clay Creek near Newark, Del.	9/16/99	19,500	>100 yr	4%
	9/15/03	13,900	100 yr	1%
	7/05/89	11,600	50 yr	2%
	1/19/96	9,150	25 yr	4%
	7/22/72	9,080	25 yr	4%
Red Clay Creek at Wooddale, Del.	9/15/03	16,000	>500 yr	<0.2%
	9/28/04	8,280	100 yr	1%
	9/16/99	7,650	50 yr	2%
	6/28/06	5,490	25 yr	4%
	7/21/75	5,010	10 yr	10%
Brandywine Creek at Wilmington, Del.	6/23/72	29,000	>100 yr	<1%
	9/17/99	28,700	>100 yr	<1%
	1/25/79	22,400	50 yr	2%
	9/13/71	21,300	50 yr	2%
	9/29/04	20,800	50 yr	2%
Blackbird Creek at Blackbird, Del.	9/16/99	789		
	6/22/72	712		
	7/12/04	694		
	12/14/96	334		
	9/12/60	510		
Kent County				
St. Jones River at Dover, Del.	9/13/60	1,900	25 yr	4%
	2/24/98	1,400	25 yr	4%
	2/26/79	1,340	10 yr	10%
	8/26/58	1,260	10 yr	10%
	6/23/72	996	5 yr	20%
Choptank River near Greensboro, Md.	8/04/67	6,970	>100 yr	<1%
	9/17/99	6,420	100 yr	1%
	2/26/79	6,110	100 yr	1%
	6/17/01	5,240	50 yr	2%
	12/14/96	5,120	50 yr	2%
Sussex County				
Pocomoke River near Willards, Md.	8/20/89	2,820		
	1/29/98	1,970		
	2/26/79	1,870		
	3/23/00	1,480		
Nanticoke River near Bridgeville, Del.	2/26/79	3,020	50 yr	2%
	8/05/67	2,360	25 yr	4%
	8/26/58	2,300	25 yr	4%
	3/03/94	1,970	10 yr	10%
	9/17/99	1,760	10 yr	10%
Marshyhope Creek near Adamsville, Del.	7/13/75	3,700	50 yr	2%
	9/17/99	3,340	50 yr	2%
	8/05/67	3,060	25 yr	4%
	7/30/84	2,800	25 yr	4%

(Sources: www.usgs.gov and FEMA Flood Insurance Study, New Castle County 2007)

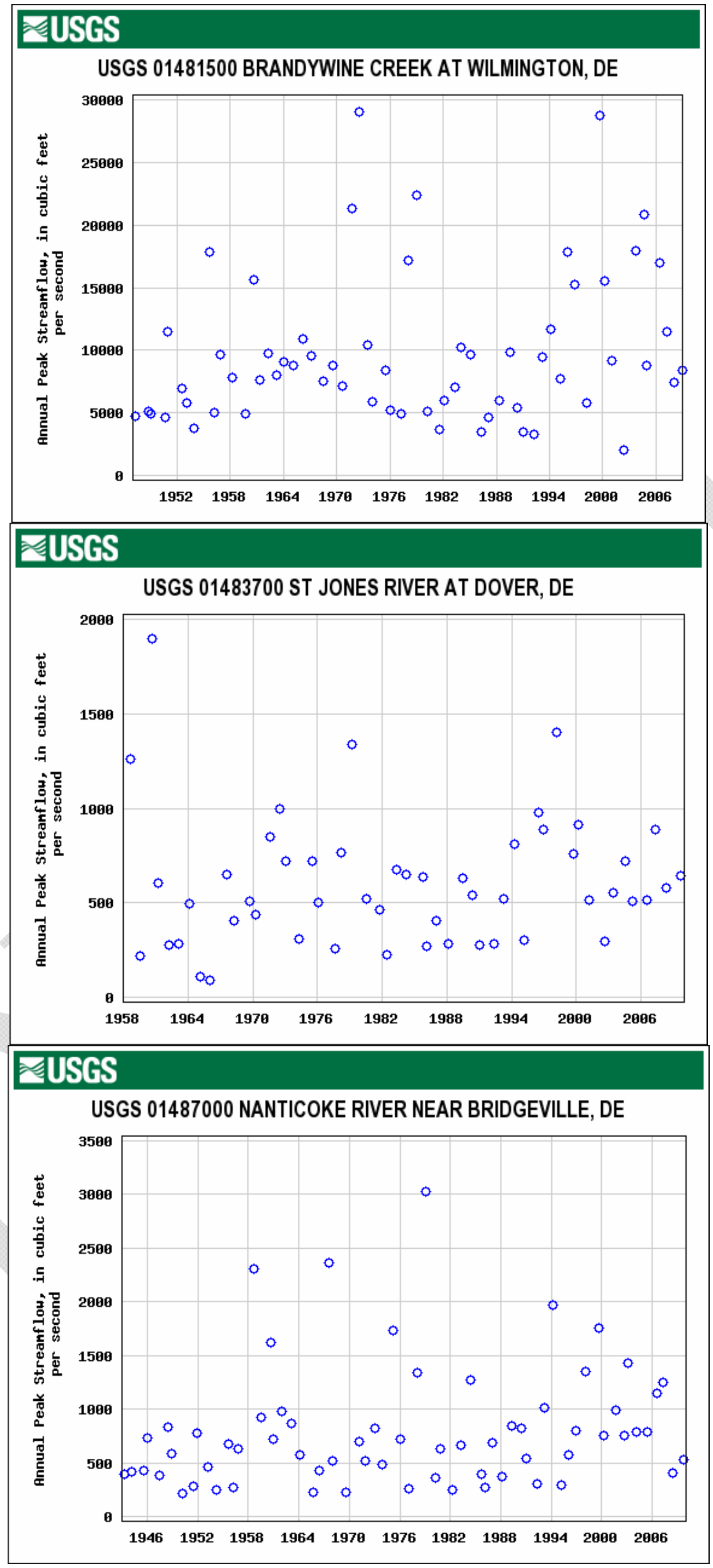
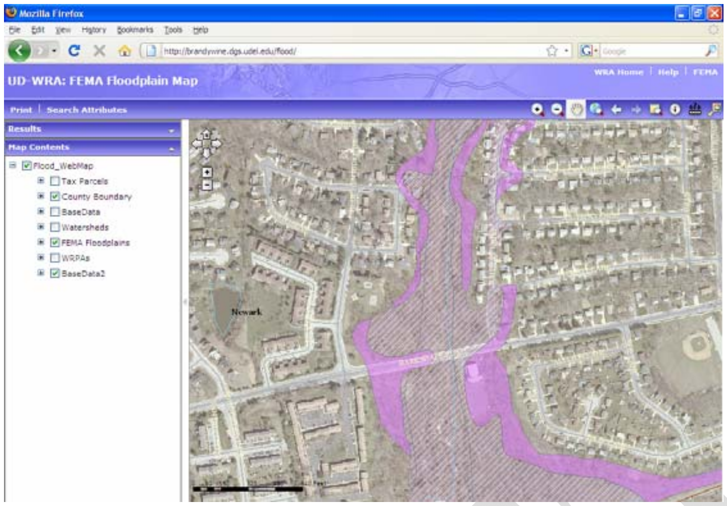
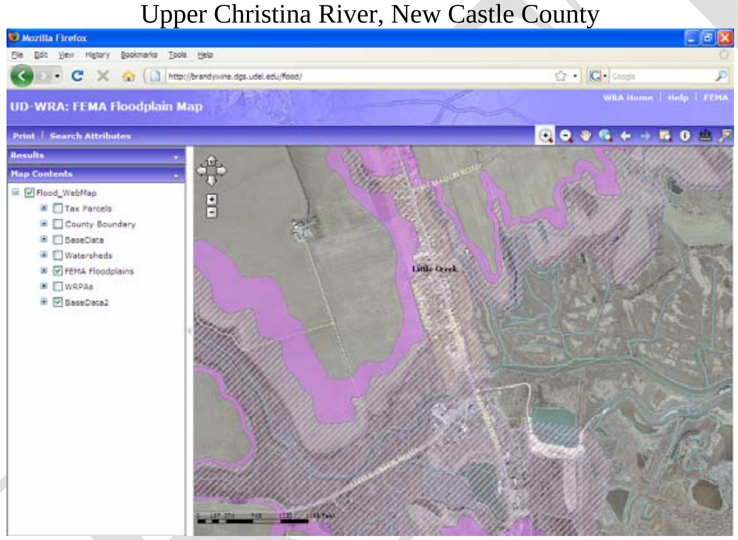


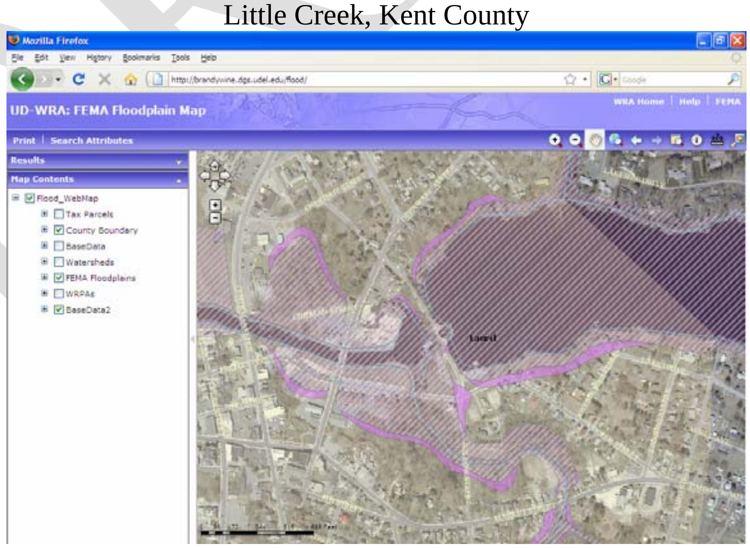
Figure 5. Highest annual peak flows in Delaware watersheds (www.usgs.gov)



Upper Christina River, New Castle County



Little Creek, Kent County



Broad Creek, Sussex County

Figure 6. Floodplain mapping in Delaware
(FEMA and UDWRA)

4. Literature Review

Water Resources Value

Fig. 7 illustrates the total economic value of water resources computed from use and non-use values (Hodge and Dunn 1992). Use values include direct values such as market goods from the sales of crops, fish, and timber; unpriced benefits from recreation and aesthetic viewsheds; and ecological function values (ecosystem services) from flood control, water storage, and waste assimilation services of wetland and forest habitat. Nonuse 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.

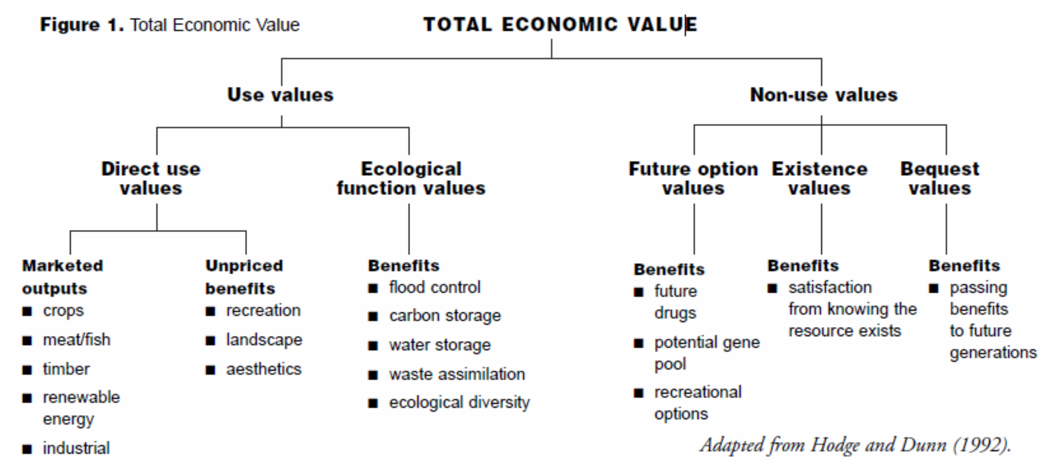


Figure 7. Economic value of water resources (Hodge and Dunn 1992)

American Rivers

American Rivers quantified the economic benefits of stormwater BMPs (K. Baer undated):

- In California, 1,000 trees reduce stormwater runoff by 1 million gallons and saves $7,000.
- The Delaware Valley tree canopy saves $2/cf for stormwater and $52/cf for CSO control.
- The University of Pennsylvania found closeness to urban trees increases home prices by 9%.

American Forests compiled typical stormwater management benefits provided by forests:

- Montgomery, Ala. - The storm water retention capacity of the forest that covered 34% of the City in 2002 was 1.7 billion gallons with an infrastructure replacement value of $454 million.
- In Albuquerque, NM, the tree canopy in 2007 provided 150 million gallons in stormwater detention services worth $123 million.
- In North Carolina, land and construction costs of a stormwater wetland is $2,050/ac of treated watershed.
- In Denver, Col., the cost of a 0.1 acre bioretention pond was $75,976 or 17% less than a traditional stormwater control structure.

City of Philadelphia

In Philadelphia, stormwater is valued through a triple bottom line benefits analysis involving:

- Economic - traditional cost analyses
- Environmental - air, water quality, recreation
- Social – human health, heat stress reduction, quality of life, reduced social costs

Planting or greening 25% of the City with vegetation and trees can:
- Avoid and absorb CO_2 emissions by 10,000 million tons.
- Provide $1,000,000 in health benefits due to improved air quality.
- Result in 6,500,000 recreational new-user days.
- Improved water quality and habitat public willingness to pay of $7.5 million.
- Reduce annual heat related deaths by 3.5.

The City of Philadelphia (2009) reported the Green City - Clean Waters Program is designed to:
- Create 2 dollars in benefits for every dollar invested.
- Provide $500 million in economic benefits and employ 250 green jobs per year.
- Save $400 million from 1.5 million pounds of carbon dioxide emissions avoided or absorbed.
- Provide air quality benefits leading to 1-2 avoided premature deaths, 20 avoided asthma .attacks, and 250 fewer missed days to work or school.
- Improve water quality from 5 - 8 billion gallons of CSO avoided per year.
- Restore 190 acres of wetlands and 11 miles of streams.
- Reduce 6 million Kw-hr of electricity and 8 million kBTU of fuel per year.

Puget Sound

Earth Economics reported on stormwater benefits in the Puget Sound Basin (Batker et al. 2010),:
- The Oregon Museum of Science and Industry in Portland constructed vegetated swales instead of conventional storm sewers and saved $78,000.
- Prairie Crossing subdivision in Grayslake, Illinois saved $2.7 million by using swales, native landscaping, and wetlands instead of conventional curb and gutter stormwater conveyance.

In the Puget Sound watershed near Seattle, stormwater management can cost up to $100 per person per year in a typical year, but per capita costs can increase sharply in floodprone years (Booth et al. 2006).

USEPA

The USEPA (2010) in a guidance document for the Chesapeake Bay watershed found that construction sites contribute 10 to 20 times more sediment than agricultural lands. Conservation design approaches are more cost-effective than conventional stormwater management such as storm sewers and curb and gutter.

In Middlesound, North Carolina, low impact development stormwater design:
- gained 3 to 4 additional lots worth over $1 million in new home yield.
- reduced storm water pipe costs by 89%.
- decreased road width by 9%.
- eliminated 9,000 ft of concrete curb and gutter.
- eliminated 5 infiltration basins.
- avoided $1.5 million in fill material.

Low impact development (LID) storm water design reduced construction costs by 15% to 80% compared to conventional stormwater design in the State of Washington (Table 13).

Table 13. Comparison between conventional and LID stormwater designs in State of Washington

Project	Conventional Development ($)	Low Impact Development ($)	Difference ($)	%
2nd Ave SEA St.	868,803	651,548	217,255	25%
Auburn Hills	2,360,385	1,598,989	761,396	32%
Bellingham City Hall	27,600	5,600	22,000	80%
Gap Creek	4,620,600	3,942,100	678,500	15%
Garden Valley	324,400	260,700	63,700	20%
Laurel Springs	1,654,021	1,149,552	504,469	30%

USEPA 2010

Lenexa, Kansas saved over $300,000 using low impact stormwater design approaches (Table 14)

Table 14. Savings from low impact development in Lenexa, Kansas

Development	Dwelling Units	LID Cost Savings
Single Family	221	$118,420
Multi-family	100	$89,043
Commercial/Retail	57	$168,898
Warehouse/Office	356	$317,483

The Capitol Region Watershed District near St. Paul, Minnesota constructed an infiltration facility, rain gardens, and infiltration trenches in the Como Lake subwatershed that saved $0.5 million in capital costs on a $2.5 million project that infiltrated over 2 million cubic feet of stormwater runoff at $0.03/cf.

Portland, Oregon conducted an analysis that indicates a 40,000 sf green roof would provide a net benefit of $404,000 ($2008) over a 40-year life when compared to a conventional building roof (Table 15).

Table 15. Life-cycle cost and benefits of green roofs in Portland, Oregon

Focus	Cost One-time	Cost Annual	Benefit One-time	Benefit Annual	Net Benefit 40-year
Stormwater Volume Reduction				$1,330	$45,866
Energy Cooling Demand Reduction				$680	$19,983
Energy Heating Demand Reduction				$800	$23,509
Eco-Roof Construction	($230,000)				($230,000)
Avoided Stormwater Facility Cost			$69,000		$69,000
Increased Eco-Roof O&M Cost		($600)			($20,677)
Roof Longevity			$600,000		$474,951
HVAC Equipment Sizing			$21,000		$21,000
Total Costs and Benefits	($230,000)	($600)	$690,000	$2,810	$403,632

Stormwater practices save up to 69.60 per pound of sediment in Charlotte, North Carolina (Table 16).

Table 16. Cost-effective stormwater management practices in Charlotte-Mecklinburg, NC

Stormwater BMP	Sediment Saved ($/lb)
Extended Detention	$69.60
Wetland	$50.33
Wet Pond	$35.15
Sand Filter	$24.43
Rain Garden	$19.55
Filter Strip	$6.23
Vegetated Swale	$3.89
Pond Retrofit	$1.88
Major Stream Restoration	$1.02
Minor Stream Restoration	$0.60

In Seattle, green grid streets cost $280,000 per block compared to traditional local street stormwater management at $425,000 per block, a savings of $145,000 per block (Table 17).

Table 17. Cost of stormwater management alternatives in Seattle, Washington

Street Type (330 LF)	Cost per Block ($)
Local Street Traditional	$425,000
Broadview Green Grid	$280,000

Stormwater bioretention projects cost $14,000 to $41,000 per acre for design and $104,000 to $214,000 per acre for construction (Table 18)

Table 18. Design and construction costs of stormwater bioretention projects

Bioretention Project	Design ($/ac)	Construction ($/ac)
Prince Georges Co, Md.	14,000	104,000
Montgomery Co., Md.	17,000	112,000
Portland, Ore.	41,000	214,000

Wisconsin

The Wisconsin Department of Natural Resources estimated the average municipal cost of implementing stormwater programs to comply with the MS4 provisions of the Clean Water Act is $162,900 with an average per capita cost of $9.00. The average stormwater management cost to achieving 40% reduction in total suspended sediment in 15 municipalities in Wisconsin ranged from 1,380,000 ($34/capita) for small cities to $9,200,000 ($26/capita) in large cities (Earth Tech 2008).

Table 19. Stormwater costs to meet 40% reduction in TSS in Wisconsin municipalities

Population	No. of Cities	Avg. Cost ($)	Min. Cost ($)	Max. Cost ($)	$/capita /yr ($)
5,000-10,000	5	1,380,000	425,000	2,800,000	34
10,000-50,000	6	4,600,000	2,700,000	9,200,000	35
50,000-100,000	4	9,200,000	7,000,000	12,500,000	26

(Earth Tech 2008)

American Public Works Association (APWA)

Treadway amd Reese (2000) reported that conventional stormwater management programs cost $15 to $150 per acre depending on the level of water quality and flood control services.

According to a 1999 USEPA report, maintenance costs for retention basins and constructed wetlands were estimated at 3% to 6% of construction costs, whereas maintenance costs for swales and bioretention practices were estimated to be 5% to 7% percent of construction costs.

City of Toronto

Bélanger (2009) conducted a cost-benefit study of urban stormwater economics in Toronto and found:

- A 12,300 acre green roof saved $313 million initially and $37 million annually.
- A conventional concrete stormwater pavement cost $9.50 - $11.50/sf compared to a permeable pavement at $4.50 - $6.50/sf, a net savings of $3.00 - $4.50/sf.
- A concrete stormwater pipe costs $24/ft versus $5/ft for a green grass swale.

Center for Watershed Protection

The Center for Watershed Protection (2000) summarized the economics of watershed protection:

In the Chesapeake Bay watershed, a 12.2 acre commercial office park saved $160,469 when an innovative stormwater design was used instead of a conventional design (Table 20).

Table 20. Comparison of conventional vs. innovative stormwater design

Costs	Conventional Stormwater Design ($)	Innovative Stormwater Design ($)
Infrastructure	856,242	631,164
Stormwater Technology	88,441	153,859
Afforestation	4,217	3,409
Total	948,900	788,432
Savings		(17%) 160,469

Replacing conventional curb and gutter and storm sewer design with water conservation design BMPs such as landscaped bioswales can save between $4,000 for a 0.2 acre residential development to $78,000 for a 6-acre commercial parking lot (Table 21).

Table 21. Cost comparison of conventional stormwater design vs. water conservation design

Case Study	Savings ($)
6-ac commercial parking lot	$78,000
2-ac light industrial site	$10,000
3.2 ac office and parking Lot	$24,000
2.2 ac educational facility	$21,000
0.2 ac residential development	$4,000
5 ac residential development (31 homes)	$21,000
1 ac Parking Lot	$10,000

Low impact development (LID) such as narrow streets, bioswales, rain gardens, natural buffers, filter strips, and forested depressions instead of conventional curb and gutter and storm sewers saves $1.4 million per residential subdivision or up to $7,458 per lot (Table 22).

Table 22. Residential site cost savings from green LID vs. conventional stormwater design

Development	Location	Savings/ Development ($)	Savings/ Lot ($)
Prairie Crossing	Grayslake, Ill.	$1,375,000	$3,798
Somerset Community	Prince Georges Co,, Md.	$916,382	$4,604
Pembroke Woods	Frederick County, Md.	$420,000	$6,000
Medium Density Residential.	Stafford Co, Va.	$300,547	$2,783
Gap Creek	Sherwood, Ark.	$200,021	$4,819
Circle C Ranch	Austin, Tex.	$185,000	$1,250
Poplar St. Apartments	Aberdeen, NC	$175,000	
The Trails	Lexana, Kan.	$89,043	
Kensington Estates	Pierce County, Was.	$86,800	$843
Garden Valley	Pierce County, Was.	$60,000	$1,765
Madera Community	Gainesville, Fla.	$40,000	$500
SEA Street Retrofit	Seattle, Was.	$40,000	
Meadow on the Hylebos	Pierce County, Was.	$34,000	
Woodland Reserve	Lexana, Kan.	$18,420	
Low Density Residential.	Wicomico Co., Md.	$17,123	$2,140

In commercial developments, low impact development such as narrow streets, bioswales, rain gardens, natural buffers, filter strips, and forested depressions instead of conventional curb and gutter and storm sewers saves up to $564,000 per development or up to $13,000/acre (Table 23).

Table 23. Commercial site cost savings from green LID vs. conventional stormwater design

Commercial Development	Location	Savings/ Development ($)	Savings/ Acre ($)
Parking Lot Retrofit	Largo, MD	$15,000	
Old Farm Shopping Center	Frederick, MD	$36,230	$3,986
270 Corporate Office Park	Germantown, MD	$27,900	$2,180
OMSI Parking Lot	Portland, OR	$78,000	$13,000
Light Industrial Parking Lot	Portland, OR	$11,247	$5,623
Office Warehouse	Lexana, KS	$317,483	
Retail Shopping Center		$36,182	$4,020
Commercial Office Park		$160,468	$12,344
Tellabs Corporate Campus	Naperville, IL	$564,473	$10,263
Vancouver Isl. Tech Park	Saanich, BC	$530,000	

- New urban stormwater strategies provide life cycle cost benefits and added value:
- Stormwater regulations add 10%-17% in real estate value.
- Forest conservation on residential sites adds 6%-15% in property value.
- Tree cover increases residential energy savings by 20%-25%.
- Land setback from floodplains have $10,427/acre in added property value.
- Permeable surfaces, retention areas, and infiltration zones provide 33% to 50% reduction in subdivision capital cost by reducing length of concrete storm sewer piping .

- From 1856 to 1873, Frederick Law Olmsted tabulated a $209 million increase in property value on land adjacent to Central Park in New York City.

Open space stormwater design at Remlik Hall Farm cost $594,000 or $600,000 (50%) less than a conventional stormwater design approach for this 490-acre cluster development(Table 24).

Table 24. Conventional versus cluster stormwater design approach for Remlik Hall Farm

Parameter	Scenario A Conventional Plan	Scenario B Cluster Plan
Engineering Costs	$79,600	$39,800
Road Construction Costs	$1,012,500	$487,500
Sewage and Water	$25,200	$13,200
Contingencies	$111,730	$54,050
Total	**$1,229,030**	**$594,550**
Total Developed Land	287.4 ac	69.4 ac
Roads/Driveway	19.7 ac	11.7 ac
Turf	261.1 ac	54.0 ac
Buildings	6.6 ac	3.9 ac
Total Undeveloped Land	202.7 ac	420.6 ac
Forest	117.6 ac	133.0 ac
Wetlands	11.5 ac	11.5 ac
Total Site Area	**490.2 ac**	**490.2 ac**
Impervious Cover	5.4%	3.7%
Nitrogen	2,534 lb/yr	1,482 lb/yr
Phosphorus	329 lb/yr	192 lb/yr

American Planning Association

By decreasing impervious cover, builders can save costs (APA 2002) by:
- $1,100 for each parking space eliminated in a commercial parking lot, with a lifetime savings of $5,000-$7,000 per space when future parking lot maintenance is considered
- $150 for each foot of road shortened with reduced pavement, curb/gutter, storm sewer needs.
- $25 to $50 for each foot of roadway narrowed.
- $10 for each foot of sidewalk eliminated.

Ontario Ministry of the Environment

Homeowners realize the following benefits from green stormwater management (Ontario MOE 2003):
- Reduced downstream flooding that can increase floodplain property values by up to 5%.
- Reduced energy cooling costs by 33%-50% from increased natural vegetation in Davis, Cal.
- Retrofitting of Seattle's BMP "greenstreets" added 6% to the neighborhood value of properties.
- Improved water quality can increase property value by 15% along the water body.
- Bioretention instead of storm sewers/sand filters saved $250,000 along Anacostia River in Washington, DC.
- Replacing curb, gutter, and storm sewers with roadside swales saved one developer $70,000 per road mile, or $800 per residence.
- Lots in LID neighborhoods sold for $3000 more than lots in competing areas.

American Forests

American Forests (2006) calculated urban forests provide $20 billion in avoided stormwater construction costs in the U.S. and Canada. Billions of dollars of stormwater infrastructure would have to be built to replace lost water quality and quantity benefits of trees (Table 25)

Table 25. Avoided stormwater construction costs due to trees as measured by American Forests.

Urban Area	Avoided Costs ($ billion)
Vancouver, Can.-Portland, Ore.	$20.2
Metro Puget Sound, Wa.	$5.9
Washington, D.C.-Metro	$4.7
Atlanta, Ga.	$2.4
San Antonio, Tex.	$1.3
Houston, Tex.	$1.3
Chesapeake Bay Region	$1.1
New Orleans, La.	$0.7
Detroit, Mi.	$0.4
San Diego, Cal.	$0.2

Environmental Defense Fund

The Environmental Defense Fund found (Scarlett 2010):

- The City of New York invested over $1.5 billion to protect and restore the Catskill Mountain watershed, rather than spending up to $9 billion on filtration plants, a benefit cost ratio of 6:1.

- Using ecosystem services concepts, Portland, Oregon achieved a 95% flow reduction through bioretention, and Seattle reduced the volume of runoff by 98% in one neighborhood with extensive use of “green infrastructure” that cost 25% less than traditional alternatives.

- Chicago’s Green Alleys Program repaved 3,500 acres of impermeable alleys with permeable pavers, using ecosystem services concepts to reduce stormwater.

5. Value of Stormwater Management

Total annual economic value of green stormwater management in Delaware approaches $1 billion (Table 26) based on:

- Increased Property Value
- Water Treatment
- Stormwater Detention
- Stormwater Runoff
- Improved Water Quality
- Small Property Owner Benefits

Table 26. Annual economic value of stormwater management in Delaware

Activity	Value ($2010/year)	Source
Water Quality Benefits		
Improved water quality increases stream-side property value by 8%.	$784,000,000	Leggett, et al. (2000), EPA (1973), Brookings Institute (2007)
Water treatment by forests @ $41/mgd	$1,496,000	Trust for Public Land and AWWA (2004)
Benefits of stormwater management to achieve Delaware water quality standards.	$153,000,000	Carson and Mitchell (1993).
Small property owner (1 acre site) benefits of green stormwater management	$8,600/ac	National Green Values™ Calculator at http://greenvalues.cnt.org/national/calculator.php
Flood Control Benefits		
Stormwater detention improves downstream floodplain property value by 2% to 5%.	$42,000,000 - $105,000,000	Braden and Johnston (2004), University of Illinois
Green stormwater mgmt. in Del.can save $17 billion (42.6 billion gal runoff @ $0.35 gal).	$17,000,000	Bélanger (2009), City of Toronto
Total	**≈$1 billion/yr**	

Valuation Methods

The value of stormwater management in Delaware is estimated from published literature that employ the following economic valuation methods:

- Avoided Cost - Society sustains costs if certain ecosystems are not present. For instance, loss of wetlands and forests may increase flood damages.

- Replacement Cost - Natural services are lost and replaced by more expensive human systems. Forests provide water filtration benefits that would be replaced by stormwater detention ponds.

- Net Factor Enhancement of Income - Improved water quality enhances tourism and fishing industries.

- Travel Cost - Visitors are willing to pay to travel and visit ecosystems and natural resources for tourism, boating, hunting, fishing, and birding recreation.

- Hedonic Pricing - People willing to pay more for higher property values along bay and river coasts.

- Contingent Valuation - Valuation by survey of individual different preferences to preserve ecosystems. People may be willing to pay more for preserved and improved bay water quality.

Increased Property Value

Studies along rivers and bays in the U.S. indicate improved water quality can increase shoreline property values by 6% to 25% (Table 27). The EPA (1973) estimated improved water quality can raise property values by up to 18% next to the water, 8% at 1000 feet, and 4% at 2000 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, Maryland could raise property values by 6%. The Brookings Institute (2007) projected $26 billion invested to restore the Great Lakes would increase shore property values by 10%.

Table 27. Increased property values resulting from improved water quality

Study	Watershed	+ Value
EPA (1973)	San Diego Bay, Cal.	
- Next to water	Kanawha, Oh.	18%
- 1000 ft from water	Willamette R., Ore.	8%
- 2000 ft from water		4%
Leggett, et al. (2000)	Chesapeake Bay	6%
Brookings Institute (2007)	Great Lakes	10%

Property values within 1000 feet of the shore are estimated to increase by 6% due to stormwater management that improves water quality to meet bacteria standards in Delaware watersheds. About 86% of the 2,509 miles of Delaware streams or 2,158 miles are impaired for bacteria. If the median property value in Delaware is $25,000 per acre, then properties within a 1000 feet corridor along 2,158 impaired stream miles in Delaware have an estimated value of $13.1 billion. Property values within 1000 feet of the water would increase by 6% or $784 million due to water quality improvements in Delaware watersheds (Table 28).

Table 28. Added property value due to improved water quality in Delaware watersheds

Impaired Streams[1] (mi)	Streams (ft)	Area within 1000 ft of Stream (ac)	Property Value @ $25,000/ac	Increased Value @ 6%
2,158	11,394,240	523,000	$13,075,000,000	$784,000,000

1. Impaired streams for bacteria as per DNREC Sec. 303d Report 2010

Water Treatment

Forests provides significant stormwater water quality and water treatment benefits. The Trust for Public Land and American Water Works Association (2004) found for every 10% increase in forested watershed land, drinking water treatment and chemical costs are reduced by approximately 20% (Table 29). If the public drinking water supply is 100 mgd and forests cover 265,476 acres (414 sq mi) or 18% of Delaware watersheds, then loss of these forests would increase drinking water treatment costs by $41 per mgd ($139 per mgd @ 0% forested minus $98 per mgd @ 18% forested) or $4,100/day or $1,496,000/year.

Table 29. Drinking water treatment costs based on percent of forested watershed (Trust for Public Land and AWWA 2004)

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

Stormwater Detention

Braden and Johnston (2004) from the University of Illinois estimate on-site stormwater detention provides flood mitigation and water quality protection services totaling 2% to 5% of property value on average for all properties in the flood plain. If 211,840 ac (331 sq mi) or 17% of Delaware's land mass are within a FEMAM - mapped 100-year floodplain and the average value of floodplain land is $10,000 per acre, then the total value of floodplain land in Delaware is $2.1 billion. On-site stormwater detention increases downstream property values by 2% to 5% and there provides $42 to $105 million in economic benefits to downstream floodplain property owners in Delaware.

Stormwater Runoff

The Purdue University THIA model calculates annual stormwater runoff quantity and quality based on precipitation, land use/land cover and hydrologic soil group. Land use (2007) in Delaware watersheds is 40% agriculture, 26% water/wetlands, 18% forest, and 16% residential/urban (Fig. 8). The Purdue model indicates 60 billion gallons per year (8.0 billion cf) of stormwater runoff flows from residential/urban land on Delaware watersheds (Fig. 9 and Table 30) or enough water to cover a football field 2.5 miles high. If residential/urban land were in a predeveloped condition (forest), then the amount of predevelopment runoff would be 17.5 billion gallons per year (2.3 billion cf). The volume of stormwater management needed is 5.7 billion cf to control runoff from residential/urban land in Delaware

Post Development Runoff Volume	8.0 billion cf
- Pre Development Runoff Volume	2.3 billion cf
Required Stormwater Runoff Volume	5.7 billion cf

Bélanger (2009) in a study of City of Toronto urban stormwater economics concluded green streets and urban forests cost less ($0.07/gal) than conventional stormwater storage tanks ($0.42/gal) as summarized in Table 31. If 5.7 billion cf (42.6 billion gallons) of runoff flows from residential/urban land in Delaware based on post development urban/residential minus predeveloped forest condition, then the cost of stormwater treatment using conventional storage tanks is $20 billion (42.6 billion gal x $0.42/gal). The cost of stormwater treatment in Delaware using urban forests and green streets is $3 billion (42.6 billion gal x $0.07 gal), a savings of $0.35/gal or $17 billion.

Table 30. Benefits of stormwater practices ($/gal) Belanger 2009

Technology	gal/$1,000	$/gal
Conventional storage tanks	2,400	0.42
Rain Barrels	9,000	0.11
Urban Forests	13,170	0.08
Green Streets	14,800	0.07

Stormwater runoff from residential and urban land contributes 22 million pounds of pollutants per year to Delaware watersheds. Over 20 million pounds of sediment, or enough dirt to cover a football field a yard deep flows to Delaware waterways in a year.

Pollutant	lb/yr		
Nitrogen	900,000	Fecal Coliform	40,000,000 #
Phosphorus	300,000		
Suspended Solids	20,000,000		
Lead	5,000		
Zinc	40,000		
Oil & Grease	800,000		
Total	22,000,000 lb/yr		

Table 31. Post development annual stormwater runoff from Delaware watersheds (2007)

Land Cover	Area (ac)	Runoff Volume (ac-ft)	Runoff Volume (billion gal)	Runoff Depth (in)
Water/Wetlands	374,512	0	0	0.0
Agriculture	590,150	371,776	121.1	7.6
Forest	265,476	61,476	20.0	2.8
Barren/Grass	6,459	2,031	0.7	3.8
High Density Resid.	119,827	130,287	42.4	13.1
Low Density Resid.	110,588	53,971	17.6	5.9
(2,292 sq mi)	1,467,012	619,541	201.9	33.2

source: Purdue University Runoff Model

Table 32. Pre development annual stormwater runoff from Delaware watersheds (2007)

Land Cover	Area (ac)	Runoff Vol. (ac-ft)	Runoff Volume (billion gal)	Runoff Depth (in)
Water/Wetlands	374,512	0	0	0.0
Agriculture	590,150	371,776	121.1	7.6
Forest	265,476	61,476	20.0	2.8
Barren/Grass	6,459	2,031	0.7	3.8
High Density Resid. (Forest)[1]	119,827	27,960	9.1	2.8
Low Density Resid. (Forest)[1]	110,588	25,804	8.4	2.8
(2,292 sq mi)	1,467,012	489,047	159.3	

1. Assumes urban pre-developed land was forest in Delaware.

Table 33. Annual stormwater pollutant loads from Delaware watersheds

Land Cover	Nitrogen (lb)	Phosphorus (lb)	Susp. Solids (lb)	Lead (lb)	Zinc (lb)	Oil/Grease (lb)	Fecal Coliform (mil #)
Water/Wetlands	0	0	0	0	0	0	0
Agriculture	4,457,039	1,316,852	108,387,092	1,519	16,207	0	119,713,866
Forest	117,251	1,675	167,501	837	1,005	0	152,274
Barren/Grass	3,875	55	5,535	27	33	0	5,032
High Density Resid.	646,081	202,344	14,554,572	3,194	28,399	603,482	32,271,778
Low Density Resid.	267,637	83,820	6,029,187	1,323	11,764	249,990	13,368,486
Total	5,491,883	1,604,746	129,143,887	6,900	57,408	853,472	165,511,436

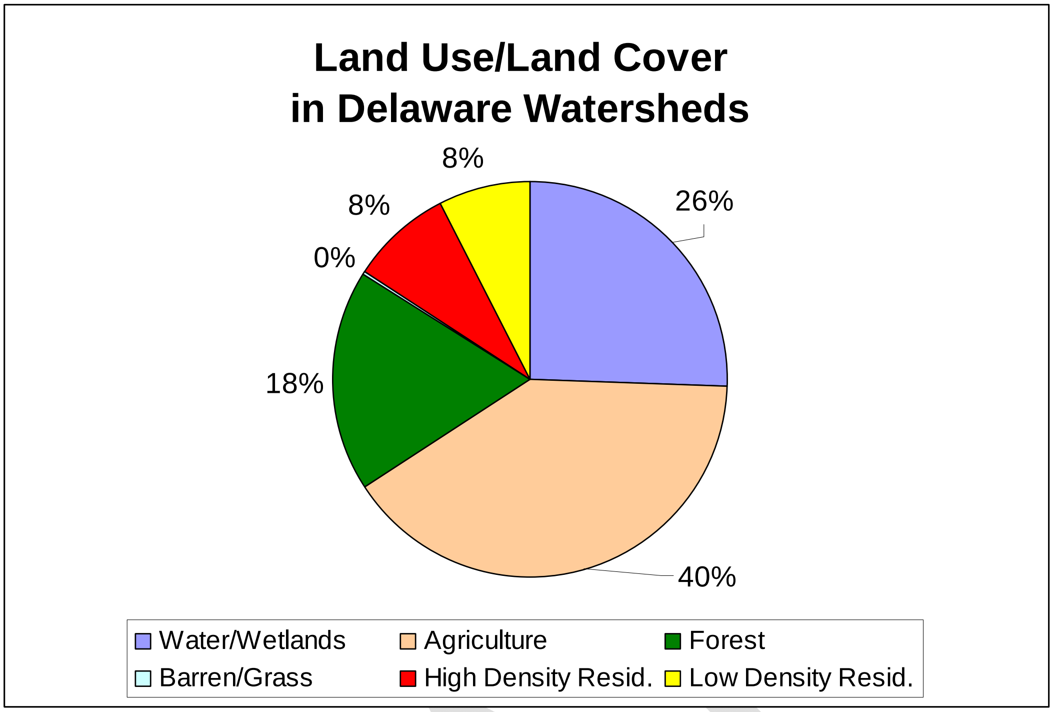


Figure 8. Land use/land cover in Delaware watersheds, 2007
(source: Purdue University Runoff Model)

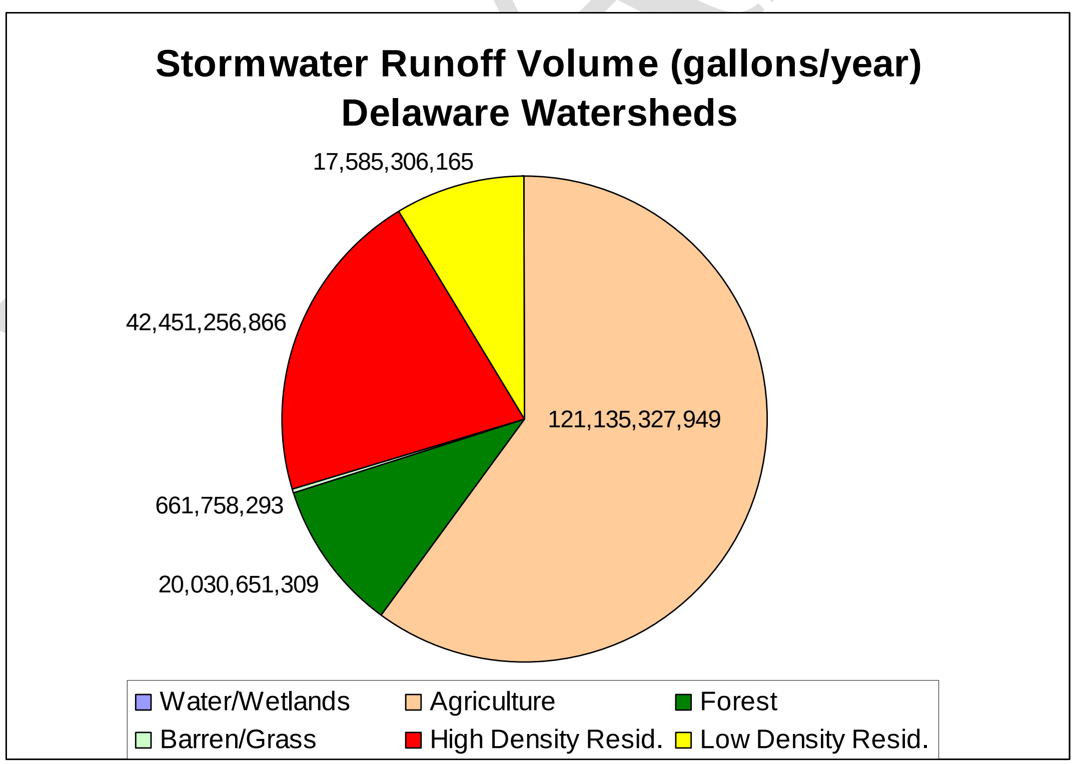


Figure 9. Annual stormwater runoff volume from Delaware watersheds
(source: Purdue University Runoff Model)

Improved Stream Water Quality

Costs

The estimated annual costs in Delaware to implement municipal stormwater programs and construction erosion and sediment controls is $11 million. The economic benefits of stormwater management in Delaware are estimated based on procedures used by USEPA for the NPDES Municipal Phase II Stormwater Permit Program required by the Federal Clean Water Act.

1. Municipal - Estimate the annual per household program cost to implement stormwater management as $9.16 (National Association of Flood and Stormwater Management Agencies, 1998). Convert household cost of $9.16 in $1998 to $13.06 in $2010 based on annual discount rate of 3%. Multiply number of Delaware households (332,198) according to the Delaware Population Consortium (2010) by the 2010 per household compliance cost ($13.06) to determine an annual estimated stormwater management cost of $4,338,506.

2. Construction - EPA estimates the average administrative cost plus BMP costs for construction-related stormwater management to be $4,534 per construction start in 1998. Convert the construction stormwater cost of $4,534 in $1998 to $6,464 in $2010 based on annual discount rate of 3%. Multiply number of Delaware construction starts (1,000) in 2010 by the per site cost ($6,464) to determine an annual estimated construction stormwater management cost of $6,464,000.

3. Administrative - In 1998, EPA estimated annual incremental Federal and State administrative costs for stormwater program compliance to be $5.3 million or $0.19 per person. Converting to $2010 at an annual rate of 3%, the stormwater administrative cost is $0.27 per person. Multiply number of people (895,173) according to the Delaware Population Consortium (2010) by per person cost ($0.27) to determine total annual Delaware stormwater administrative cost of $242,000.

Table 35 summarizes the annual costs in Delaware to implement municipal stormwater programs and construction site erosion and sediment controls as $11 million.

Table 34. Potential annual costs for storm water management Regulation

Stormwater Program	Delaware Universe	Unit Cost ($)	Costs ($2010)
Municipal	332,198 households	$13.06/ household	$4,338,506
Construction/Soil Erosion & Sediment	1,000 construction starts	$6,464/ start	$6,464,000
Federal/State Administration	895,173 people	$0.27/ person	$242,000
Total			**$11,044,506**

Benefits

The economic benefits of stormwater management to improve water quality is estimated by comparing reduced pollutant loadings from municipal and construction site controls that result in changes in water quality classifications between the following uses:

- Non support (Impaired)
- Boatable

- Fishable
- Swimmable

Carson and Mitchell (1993) conducted a contingent value (CV) study to estimate the national benefits of freshwater pollution control to meet the goals of the Clean Water Act. The study surveyed people's preferences or willingness to pay (WTP) for improved water quality to achieve instream, withdrawal, aesthetic, ecosystem use benefits and vicarious consumption and stewardship nonuse benefits (Table 36). They found mean annual household WTP to go from non-supported (polluted) to improved water quality ranged from $93 for boatable, $70 for fishable, $78 for swimmable, to $242 for total use support in $1990. Adjusting for inflation at 3% annually, mean annual household WTP in $2010 ranges from $168 for boatable, $127 for fishable, $141 for swimmable, to $438 for total use support (Table 2). The major policy implications from this willingness to pay research indicates the American public is willing to pay up to $438 per year for watershed and stormwater management controls to achieve boatable, fishable, and swimmable water quality in freshwater rivers and streams.

Table 35. Typical benefits from improved freshwater quality

Benefit	Category	Examples
Use	Instream	Recreational (fishing, swimming, boating)
		Commercial (fishing, navigation)
	Withdrawal	Municipal(drinking water, waste disposal)
		Agriculture (irrigation)
		Industrial/commercial (waste treatment)
	Aesthetic	Near water recreation (hiking, picnicking, photography)
		Viewing (commuting, office/home views)
	Ecosystem	Hunting/bird watching
		Ecosystem support (food chain)
Nonuse	Vicarious	Significant others (relatives, friends)
		American public
	Stewardship	Inherent (preserving remote wetlands)
		Bequest (family, future generations)

Source: Carson and Mitchell 1993.

Table 36. Adjusted annual household values for national water quality benefits

Water Quality Use Support	Mean WTP[1] $1990	Standard Error of Mean ($)	95% Confidence interval ($)	Mean WTP[2] $2010
Boatable	93	8	77-109	168
Fishable	70	6	58-82	127
Swimmable	78	9	60-96	141
Total	**242**	**19**	**205-279**	**438**

1. Carson and Mitchell 1993. 2. Adjusted to $2010 for inflation at 3% annually.

In Delaware, the freshwater benefits of municipal stormwater management to achieve water quality goals ranges from $54 million/year for boatable, $41 million for fishable, $45 million for swimmable, and $141 million for total boatable, fishable, and swimmable water quality uses.

1. Estimate the number of households impacted by water quality changes in proximity to the stream reaches in question. If 97% of waterways in Delaware are impaired according to the Delaware Section 303d report (DNREC 2010) and Delaware's 2010 population is 895,173 and number of

households is 332,198 (DPC 2010), then 868,000 people in 322,232 households are affected by impaired stream water quality in Delaware.

2. Estimate household WTP for incremental water quality improvements from non-supported to boatable to fishable to swimmable stream uses. Carson and Mitchell (1993) estimated household WTP for improved water quality as $93 for non-support to boatable, $70 boatable to fishable, $78 fishable to swimmable, and $242 to achieve total uses in $1990. WTP accrues to $168, $127, $141, and $438, for boatable, fishable, swimmable, and total use support, respectively, when adjusted to $2010 at 3% annually to account for inflation, cost of living increases, and increased public attitudes toward clean water.

3. Estimate the total annual benefits of stormwater management in Delaware as $141 million by multiplying the population (868,000) or households (332,232) affected by impaired water quality by household WTP for boatable, fishing, and swimmable uses (Table 38).

Table 37. Annual benefits from stormwater management and improved water quality in Delaware

Water Quality Use Support	2010 Population[1]	2010 Households[1]	2010 WTP[2] ($/hh)	WQ Benefits ($)
Boating	868,000	322,232	$168	$54,134,976
Fishing	868,000	322,232	$127	$40,923,464
Swimming	868,000	322,232	$141	$45,434,712
Total	**868,000**	**322,232**	**$438**	**$141,137,616**

1. Population and households impacted by impaired streams. About 97% of Delaware streams are impaired (DNREC 2010). 2. Carson and Mitchell 1993, adjusted to $2010 for inflation at 3% annually.

Parsons, Helm, and Bondelid (2003) measured the economic benefits of water quality improvements to recreational users in the northeastern states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut. They found per person WTP for good water quality ranged from $8.25 for boating, $8.26 for fishing, and $70.47 for swimming uses in $1994. Adjusting to $2010 at 3% annually, per person WTP is estimated at $13.20 for boating, $13.22 for fishing, and $112.75 for swimming uses. In Delaware, mean household density is 2.6 people per household, therefore 2010 household willingness to pay from Parsons, Helm, and Bondelid is $34.32 for boating, $34.37 for fishing, and $293.15 for swimming uses (Table 38)

Table 38. Annual willingness to pay for water quality benefits in six northeastern states

WQ Use Support	WTP per person[1] $1994	WTP per person[2] $2010	WTP per household[3] $2010
Boatable	8.25	13.20	34.32
Fishable	8.26	13.22	34.37
Swimmable	70.47	112.75	293.15
Total	**86.98**	**139.17**	**361.84**

1. Parsons, Helm, and Bondelid 2003. 2. Adjusted to $2010 for inflation at 3% annually. 3. Delaware household density of 2.6 p./hh in 2010.

Table 39 compares annual household WTP for improved water quality adjusted to $2010 from Carson and Mitchell (1993) and Parsons, Helm, and Bondelid (2003). Multiplying household WTP by the number of households (97%) in Delaware affected by impaired water quality indicates total WTP ranges from $141 million per year from Carson and Mitchell (1993) national survey data to $116 million per year from Parsons et al. (2003) survey of the six northeastern states. Total WTP in Delaware from both studies are in close agreement ($141 million vs. $116 million) with higher WTP for swimmable uses ($94 million) from the northeastern states data compared to $45 million for the national survey.

Table 39. Comparison of annual willingness to pay for water quality benefits

WQ Use Support	2010 DE Population	2010 DE Households	WTP per household[1] $2010	WTP per household[2] $2010	WQ Benefits[1]	WQ Benefits[2]
Boatable	868,000	322,232	168	34	54,134,976	10,955,888
Fishable	868,000	322,232	127	34	40,923,464	10,955,888
Swimmable	868,000	322,232	141	293	45,434,712	94,413,976
Total	**868,000**	**322,232**	**438**	**361**	**141,137,616**	**116,325,752**

1. Carson and Mitchell 1993. 2. Parsons, Helm, and Bondelid 2003. WTP adjusted to $2010 for inflation at 3% annually.

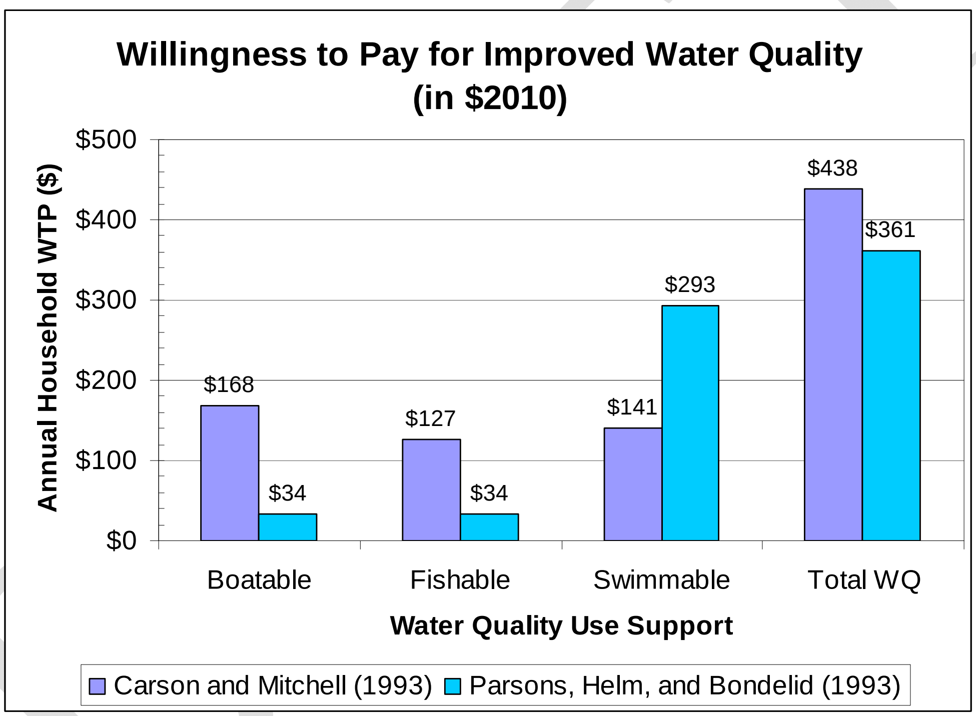


Figure 10. Annual household willingness to pay for improved water quality in $2010.

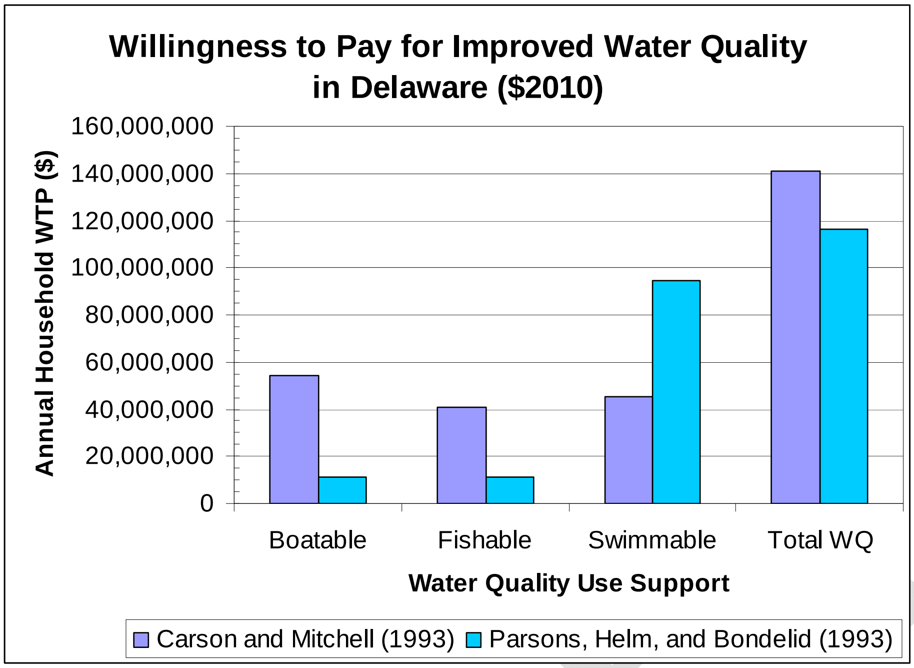


Figure 11. Willingness to pay for improved water quality in Delaware

The benefits of the Delaware stormwater and sediment control program for construction sites is estimated as follows.

1. Estimate household WTP for erosion and sediment controls as $25 per year in $1998 based on a survey in North Carolina (Paterson et al. 1993). Convert household WTP to $36 in $2010 based on 3% discount rate annually.

2. Multiply 2010 household WTP ($36) by number of households in Delaware (332,198) to estimate annual benefits of construction soil erosion and sediment control as $11,959,128.

Table 40 indicates the total benefits of municipal and construction site stormwater management to achieve water quality standards in Delaware are $153 million per year.

Table 40. Benefits of stormwater management to achieve Delaware water quality standards

Stormwater Program	Annual WTP ($2010)
Municipal	$141,137,616
Construction Site	$11,959,128
Total	**$153,090,000**

Benefit/Costs

Total benefits of municipal and construction site stormwater management to achieve boatable, fishable, and swimmable water quality standards in Delaware are $153 million per year. Annual costs to implement municipal stormwater programs and construction site erosion and sediment controls in Delaware is $11 million. The benefit -cost ratio of stormwater management to achieve water quality standards in Delaware is 14:1.

Small Property Owner Benefits

The National Green Values™ Calculator at http://greenvalues.cnt.org/national/calculator.php is used to compare performance, costs, and benefits of green stormwater infrastructure to conventional stormwater practices for small property owners in Delaware. Conventional stormwater practices include concrete curb and gutter storm sewers, and fertilized lawns. Green stormwater infrastructure include rain gardens, cisterns/rain barrels, roadside bioswales, and permeable pavement/sidewalks.

On a one acre parcel, green stormwater practices are compared to conventional stormwater devices to capture the design storm of 2 inches in accordance with the proposed Delaware Stormwater and Sediment Control Regulations. Green stormwater BMPs decrease site impermeable area by 19% and capture 36% of the required runoff volume (Table 41). Compared to conventional practices, green stormwater practices will decrease total life cycle construction/maintenance costs by 5% (net present value) and save $8,600 in construction costs and $13,900 in total life cycle costs due to annual operations and maintenance (Tables 42, 43, 44).

Table 41. Volume control for green stormwater practices on one acre site in Delaware

Parameter	Metric
Volume captured from 2" precip. over site (ft^3)	7,260
Volume Captured by current BMPs (ft^3)	1,880
Rain Garden (ft^3)	500
Cisterns/Rain Barrels (ft^3)	13
Roadside Swales (ft^3)	1,200
Permeable Pavement/Sidewalks (ft^3)	167
Required Volume Captured by BMPs (%)	26
Decrease in Impervious Area (%)	19

Source: National Green Values™ Calculator

Table 42. Coefficients and runoff for green stormwater practices on one acre site in Delaware

	Predevelopment	Conventional	Green	Predevelopment to Conventional Difference (%)	Conventional to Green Difference (%)
Average Annual Rainfall					
Total Runoff (in)	25.94	24.33	23.44	-6%	-4%
Total Runoff Volume (ft^3)	94,160	88,307	85,097	-6%	-4%
Cumulative Abstractions (in)		3.85	4.54		17.97
90% Storm					
Total Runoff (in)	0.09	0.01	0	-89%	-99%
Total Runoff Volume (ft^3)	321	37	0	-89%	-99%
Cumulative Abstractions (in)		0.21	0.03		-87.83
CN	78	69	65		
Initial Abstractions (in)		0.89	1.08		21.58

Source: National Green Values™ Calculator

Table 43. Land use or conventional and green stormwater practices on one acre site in Delaware

	Conventional Area (ft²)	Green (Using BMPs) Area (ft²)
Conventional Roof	3,000	3,000
Green Roof	0	0
Parking Lot	0	0
Permeable Parking Lot	0	0
Swales in Parking Lot	0	0
Streets	4,800	4,000
Reduced Street Width	0	0
Roadside Swales	0	800
Driveway and Alleys	800	800
Permeable Driveway and Alleys	0	0
Sidewalks	1,000	0
Permeable Sidewalks	0	1,000
Lawn	33,960	24,720
with Amended Soil	0	0
Native Vegetation	0	8,240
Rain Garden	0	1,000
Filter Strips	0	0
Planter Boxes	0	0
Trees	0	0
Total Impervious	**9,600**	**7,800**
Total Pervious	**33,960**	**35,760**

source: National Green Values™ Calculator

Costs

	Construction Cost ($)				Annual Maintenance Cost ($)				Life Cycle Cost ($, NPV)			
	Conventional	Green	Difference	%	Conventional	Green	Difference	%	Conventional	Green	Difference	%
Concrete Sidewalk	$5,190	$0	$-5,190	-100%	$29	$0	$-29	-100%	$7,237	$0	$-7,237	-100%
Concrete Driveway	$4,152	$4,152	$0	0%	$23	$23	$0	0%	$5,789	$5,789	$0	0%
Curbs and Gutters	$3,450	$0	$-3,450	-100%	$30	$0	$-30	-100%	$5,150	$0	$-5,150	-100%
Street	$20,784	$17,320	$-3,464	-17%	$264	$220	$-44	-17%	$33,666	$28,055	$-5,611	-17%
Conventional Stormwater Storage	$83,853	$62,139	$-21,714	-26%	$218	$161	$-56	-26%	$108,976	$80,756	$-28,220	-26%
Standard Roof	$22,500	$22,500	$0	0%	$150	$150	$0	0%	$32,142	$32,142	$0	0%
Permeable Pavement-Pavers	$0	$7,100	$7,100	0%	$0	$36	$36	0%	$0	$9,784	$9,784	0%
Turf	$7,132	$5,191	$-1,940	-27%	$3,056	$2,225	$-832	-27%	$105,531	$76,818	$-28,713	-27%
Native Plants	$0	$824	$824	0%	$0	$412	$412	0%	$0	$14,058	$14,058	0%
Rain Garden	$0	$7,000	$7,000	0%	$0	$340	$340	0%	$0	$19,295	$19,295	0%
Roadside Swales	$0	$12,000	$12,000	0%	$0	$96	$96	0%	$0	$17,650	$17,650	0%
Downspout Disconnection	$0	$70	$70	0%	$0	$1	$1	0%	$0	$101	$101	0%
Rain Barrels	$0	$109	$109	0%	$0	$0	$0	0%	$0	$133	$133	0%
Total	**$147,061**	**$138,405**	**$-8,656**	**-6%**	**$3,770**	**$3,664**	**$-107**	**-3%**	**$298,492**	**$284,581**	**$-13,911**	**-5%**

Table 44. Costs of conventional vs. green stormwater management practices

The Center for Watershed Protection recommends that the Delaware DNREC adopt an in-lieu fee of $23/cf of stormwater treatment volume not managed on-site. Table 45 provides a summary of sources used to derive this figure. This proposed in-lieu fee amount was supported by data for the DELDOT Middletown Yard bioretention cost estimate.

According to the National Green Values™ Calculator, a one acre property proposed for development in Delaware will generate 94,160 cf of runoff for predevelopment conditions, 88,307 cf for conventional stormwater design, and 85,067 cf for green stormwater design. Compared to conventional stormwater design, green stormwater design reduces runoff from a one acre site by 3,240 cf or $74,520 using the Center for Watershed Protection value of $23/cf for stormwater treatment.

Table 45. Sources of stormwater construction treatment costs

Source	Construction Costs[1] ($/cf)
Weiss (2007)	18.39 [2]
City of Raleigh, NC (2010)	15.15 [3]
WEG (2010)	14.65 [3]
Chavez (2007)	8.86
CWP (2007)	8.35[2]
Brown & Schueler (1997)	7.45[2]
Wossink & Hunt (2003)	5.45[2]

[1] Costs are provided in units of 2010 dollars per cubic foot of treatment or water quality volume.
[2] Construction costs include present value of long term (20 year) O & M. Cost formula solved using WQv from Simple Method with 1 ac. drainage area; Rv =.95; 100% impervious, P = 1 in.
[3]Construction costs ($/sf) for a typical cross section to determine the treatment volume capacity in cf.

6. Ecosystem Services

Data from the following studies were used to estimate ecosystem services values for Delaware watersheds.

- Cecil County Green Infrastructure Plan by the Conservation Fund, Annapolis, Md.
- New Jersey Department of Environmental Protection with the University of Vermont
- Ecosystem Services Value of Forests by the Wilderness Society
- Ecosystem Services Value of Peconic Estuary watershed by University of Rhode Island.
- U.S. National Wildlife Refuge System by Univ. of Maryland and Nature Conservancy
- Economic Value of Ecosystem Services in Massachusetts by the Audubon Society.

Other Studies

Ecosystem services include air filtration, water filtration, recycling nutrients, soil conservation, pollinating crops and plants, climate regulation, carbon sequestration, flood and stormwater control, and hydrologic cycle regulation (Table 46). These ecological resources provide marketable good and services such as timber, fish and wildlife recreation, hiking, and boating/kayaking. A Cecil County, Md. study found the largest ecosystem services values result from stormwater/flood control, water supply, and clean water functions (Weber 2007).

Table 46. Ecosystem services values for Cecil County (Weber 2007)

Ecosystem Service	Upland Forest ($/ac/yr)	Riparian Forests/ Wetlands ($/ac/yr)	Nonriparian Wetlands ($/ac/yr)	Tidal Marsh ($/ac/yr)
Carbon sequestration	31	65	65	65
Clean air	191	191	191	
Soil and peat formation	17	946	450	1,351
Stormwater/flood control	679	32,000	32,000	1,430
Water supply	8,630	8,630	8,630	
Clean water	1,100	1,925	1,100	11,000
Erosion/sediment control	151	3,418	151	12,700
Water temperature regulation		4,450		
Pest control	50	50	50	
Pollination	75	75	75	
Wood products	142			
Recreation, fish, wildlife habitat	486	534	534	544
Community services savings	439	439	439	439
Increase in property values	42	42		
Total	**12,033**	**52,765**	**43,685**	**28,146**

The New Jersey Department of Environmental Protection (2007) partnered with the University of Vermont and estimated the value of New Jersey's natural capital was $20 billion/year plus or minus $9 billion/year in $2004 with a net present value of $681 billion based on a discount rate of 3% calculated in perpetuity (over 100 years in the future). Natural capital is the sum of goods (commodities like water, crops, and timber that can be sold) and services (functions like flood control, water filtration, and wildlife/fisheries habitat) provided by watershed ecosystems such as wetlands, forests, farms, and open water. In addition to these direct benefits, ecosystems also provide indirect benefits such as ecotourism by hunters, fishermen, boaters, and hikers that spend money to visit natural sites and realize value from improved water quality and habitat. An analysis for the Wilderness Society (Krieger 2001) concluded forests ecosystem services values for climate regulation, water supply, water quality, and recreation benefits totaled $392/ac in $1994 or $631/ac in $2010 at 3% annually (Table 47).

Table 47. Forest ecosystem service values for U.S. temperate forests (Krieger 2001)

Ecosystem Good or Service	1994 Value ($/ac)	2010 Value[1] ($/ac)
Climate regulation	57.1	91.9
Disturbance regulation	0.8	1.3
Water regulation	0.8	1.3
Water supply	1.2	1.9
Erosion and sediment control	38.8	62.5
Soil formation	4.0	6.4
Nutrient cycling	146.1	235.2
Waste Treatment	35.2	56.7
Biological Control	0.8	1.3
Food Production	17.4	28.0
Raw Materials	55.8	89.8
Genetic Resources	6.5	10.5
Recreation	26.7	43.0
Cultural	0.8	1.3
Total	392.1	631.3

1. $2010 computed at 3% annually.

A contingent value study by University of Rhode Island economists found 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 (Johnston et al. 2002). The University of Maryland studied the National Wildlife Refuge System and determined 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).

According to the 2007 USDA Census of Agriculture (2009) the total market value of agricultural crops sold from 510,253 acres of farm land in Delaware was $1,083 billion ($210.6 million in crops and 872.4 million in poultry and livestock) or 2,122 per acre.

Table 48 compares ecosystem services values ($/acre) from other studies. Data from the NJDEP/University of Vermont study are used for value transfer since the Delaware watersheds are similar to New Jersey ecosystems and the two adjacent states in the watershed share a similar climate (humid continental) at 40 degrees north in latitude, similar physiographic provinces (Piedmont/Coastal Plain) and similar aquifers, soils, and ecosystems. Cecil County, Maryland occupies a small sliver of the Delaware

Estuary watershed and utilized higher ecosystem values on a per acre basis for forests and wetlands than the other studies.   The NJDEP ecosystem service estimates ($/ac) are lower than Cecil County values for wetlands and forests and MassAudubon values for wetlands but higher than Wilderness Society values for forests and U. S. Wildlife Refuge values for freshwater wetlands and forests. Values from previous studies were adjusted to $2010 based on 3% annually. Net present values were calculated based on an annual discount rate of 3% in perpetuity (over 100 years in the future).

Table 48. Comparison of ecosystem service value studies

Ecosystem	Cecil Co. Maryland 2006 ($/ac/yr)	New Jersey DEP 2004 ($/ac/yr)	Wilderness Society 2001 ($/ac/yr)	Peconic Estuary 1995 ($/ac/yr)	US Wildlife Refuge 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	2,388[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			

- Value of goods only as measured by agricultural crops, livestock, and poultry sold.

Watershed Ecosystem Services

The estimated value of natural goods and services provided by ecosystems in Delaware watersheds (2,368 sq mi or 1,515,263 ac) is $6.7 billion ($2010) with a net present value (NPV) of $216.6 billion (Table 49). NPV is based on an annual discount rate of 3% over a perpetual life time (over 100 years). Natural goods are commodities that can be sold such as water supply, farm crops, fish, timber, and minerals). Natural services are ecological benefits to society such as stormwater/flood control by wetlands, water filtration by forests, and fishery habitat by beach and marine areas. Ecosystem services areas within Delaware watersheds are comprised of farmland (39%), forests (18%), freshwater wetlands (12%), marine (8%), and saltwater wetlands (5%). Just over 15% of watershed land in Delaware is urban/suburban (Fig. 12).

Freshwater wetlands, farms, marine habitat, forests, and saltwater wetlands provide the highest total ecosystems goods and services values (Fig. 13). The Delaware Estuary ($2.4 billion), Chesapeake Bay ($2.0 billion), Inland Bays ($2.0 billion), and Piedmont (197 million) watersheds provide the highest values of annual ecosystem services (Fig. 14). Delaware watersheds with the highest value of annual ecosystem services per acre include the Inland Bays ($6,147/ac), Chesapeake Bay ($4,562/ac), and Delaware Estuary ($3,878/ac) watersheds as these systems have high combined amounts of forests, marine, and wetlands habitats (over 75%).

Table 49. Value of ecosystem good and services in Delaware watersheds

Ecosystem	Area (ac)	$/ac/yr	PV $	NPV $
State of Delaware	**1,515,263**		**6,663,081,452**	**216,550,147,179**
Freshwater wetlands	178,632	13,621	2,433,081,000	79,075,132,489
Marine	124,879	10,006	1,249,541,955	40,610,113,531
Farmland	590,150	2,949	1,740,640,688	56,570,822,374
Forest land	265,476	1,978	525,143,567	17,067,165,922
Saltwater wetland	71,001	7,235	513,691,702	16,694,980,313
Barren land	6,459	0	0	0
Urban	229,827	342	78,511,742	2,551,631,623
Beach/dune	588	48,644	28,579,665	928,839,116
Open water	48,253	1,946	93,891,133	3,051,461,812
Piedmont	**116,435**		**197,222,250**	**6,409,723,112**
Freshwater wetlands	4,732	13,621	64,452,985	2,094,722,008
Marine	799	10,006	7,994,818	259,831,575
Farmland	9,588	2,949	28,279,693	919,090,039
Forest land	32,189	1,978	63,673,833	2,069,399,557
Saltwater wetland	919	7,235	6,649,002	216,092,568
Barren land	234	0	0	0
Urban	67,357	342	23,010,027	747,825,890
Beach/dune	42	48,644	2,043,051	66,399,165
Open water	575	1,946	1,118,840	36,362,310
Delaware Estuary	**625,435**		**2,423,972,072**	**78,779,092,340**
Freshwater wetlands	58,390	13,621	795,317,362	25,847,814,257
Marine	16,274	10,006	162,840,906	5,292,329,460
Farmland	254,143	2,949	749,590,681	24,361,697,130
Forest land	95,346	1,978	188,605,634	6,129,683,090
Saltwater wetland	61,617	7,235	445,802,585	14,488,584,028
Barren land	2,305	0	0	0
Urban	123,048	342	42,034,778	1,366,130,274
Beach/dune	256	48,644	12,429,832	403,969,529
Open water	14,056	1,946	27,350,295	888,884,572
Chesapeake Bay	**449,248**		**2,049,307,983**	**66,602,509,460**
Freshwater wetlands	81,130	13,621	1,105,045,825	35,913,989,309
Marine	233	10,006	2,327,602	75,647,066
Farmland	245,509	2,949	724,127,218	23,534,134,598
Forest land	102,306	1,978	202,373,653	6,577,143,722
Saltwater wetland	353	7,235	2,556,702	83,092,815
Barren land	844	0	0	0
Urban	17,019	342	5,813,781	188,947,882
Beach/dune	74	48,644	3,599,662	116,989,004
Open water	1,780	1,946	3,463,540	112,565,064
Inland Bays	**324,145**		**1,992,579,147**	**64,758,822,267**
Freshwater wetlands	34,379	13,621	468,264,828	15,218,606,915
Marine	107,573	10,006	1,076,378,629	34,982,305,430
Farmland	80,910	2,949	238,643,096	7,755,900,607
Forest land	35,635	1,978	70,490,448	2,290,939,552
Saltwater wetland	8,111	7,235	58,683,412	1,907,210,902
Barren land	3,076	0	0	0
Urban	22,403	342	7,653,156	248,727,577
Beach/dune	216	48,644	10,507,121	341,481,418
Open water	31,842	1,946	61,958,457	2,013,649,867

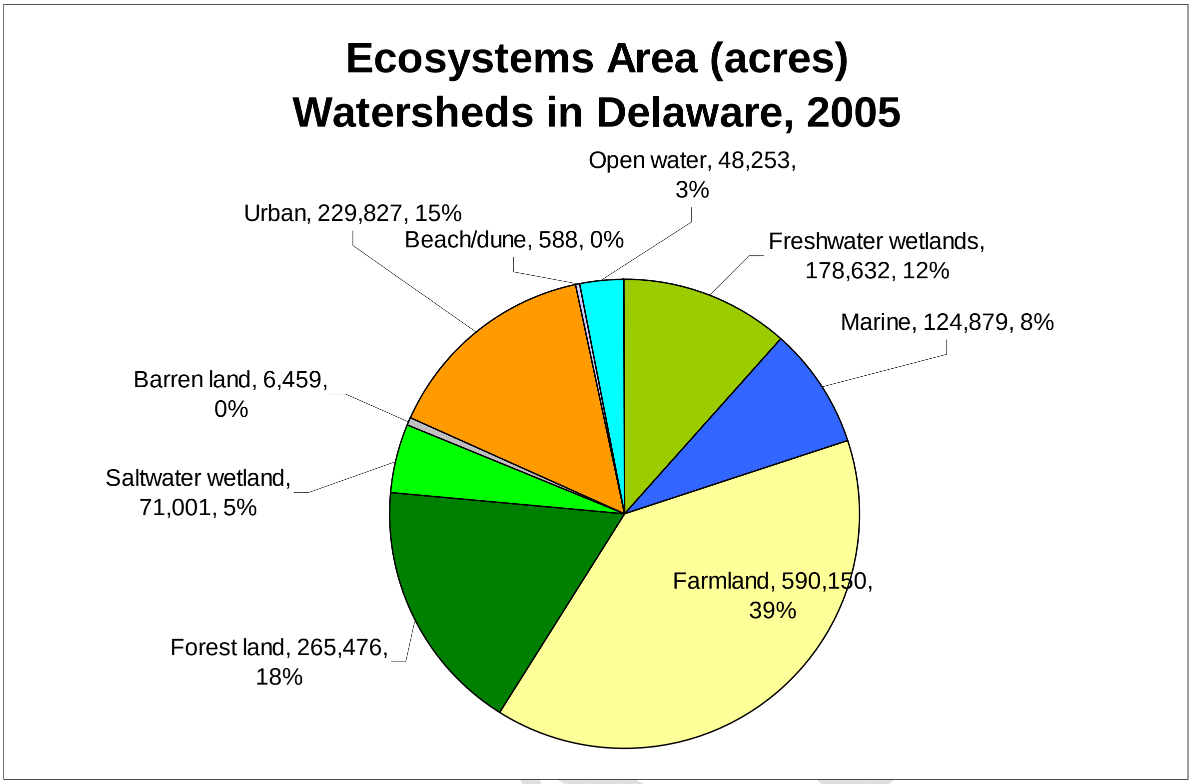


Figure 12. Ecosystem service areas within Delaware watersheds

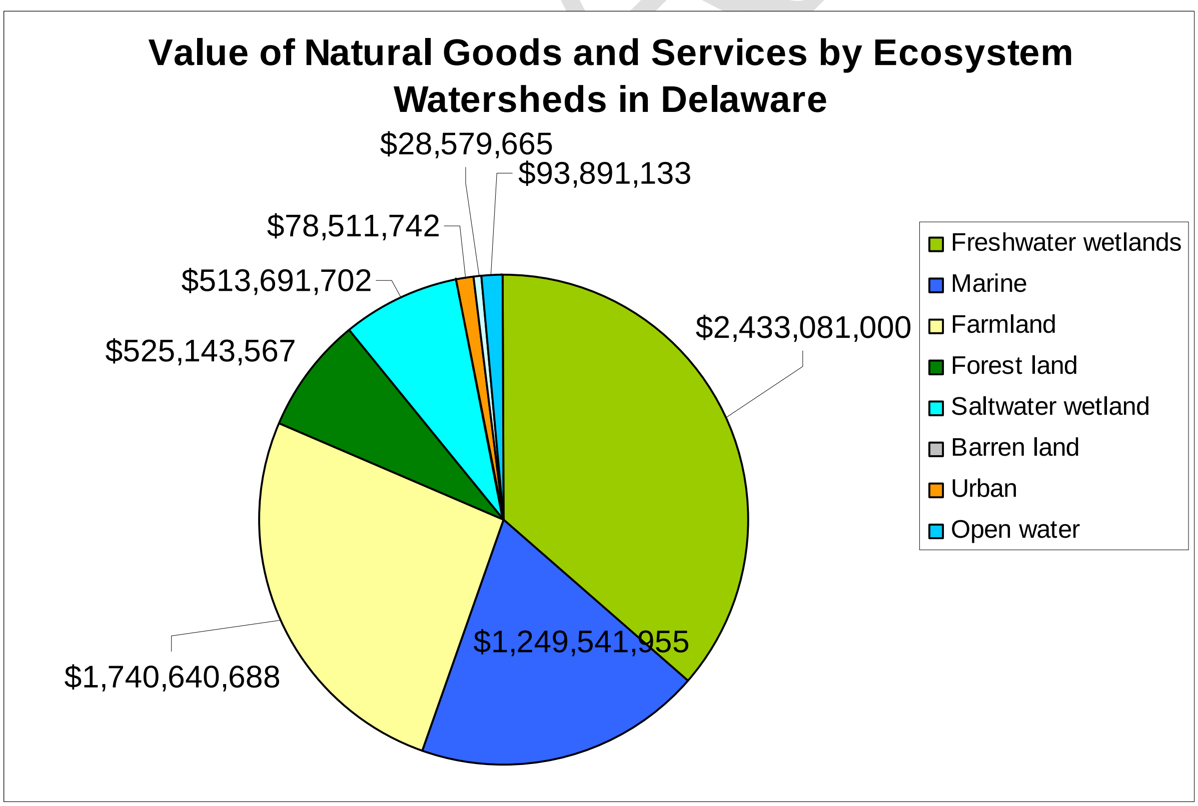


Figure 13. Value of natural goods and services by ecosystem within Delaware watersheds

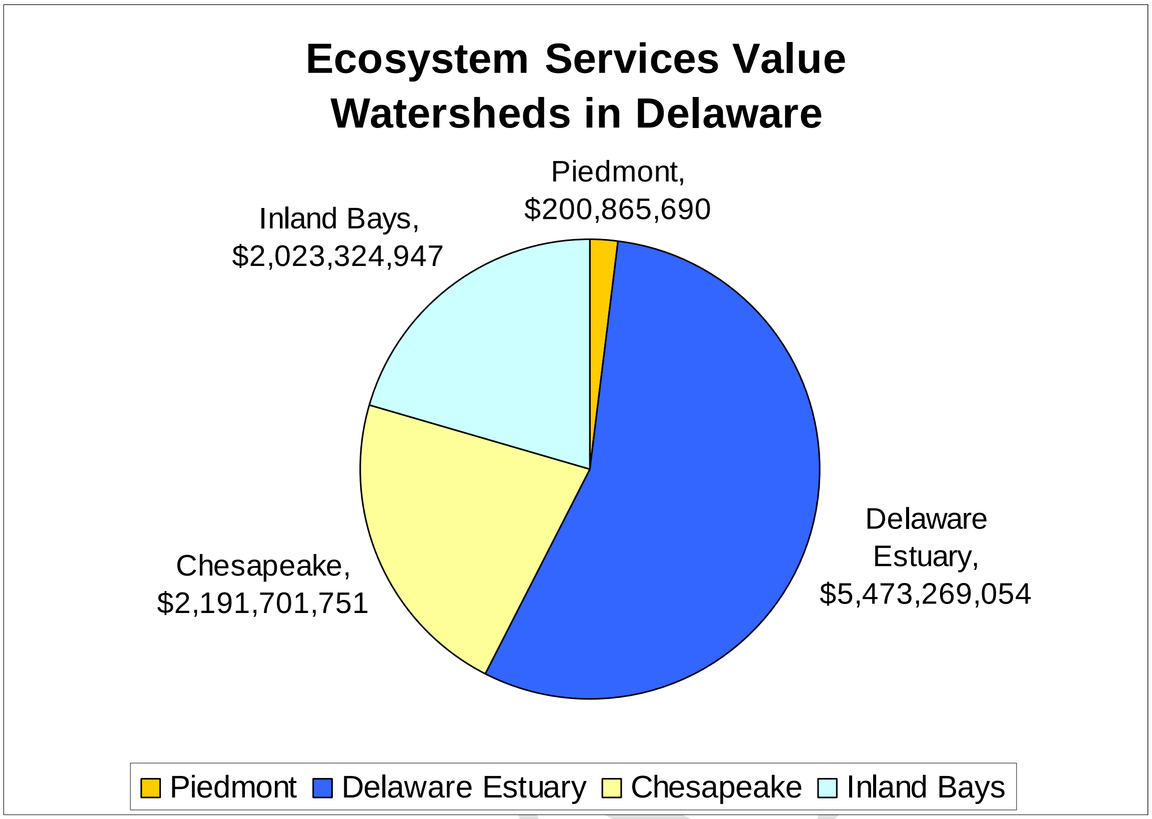


Figure 14. Value of natural goods and services by watershed within Delaware

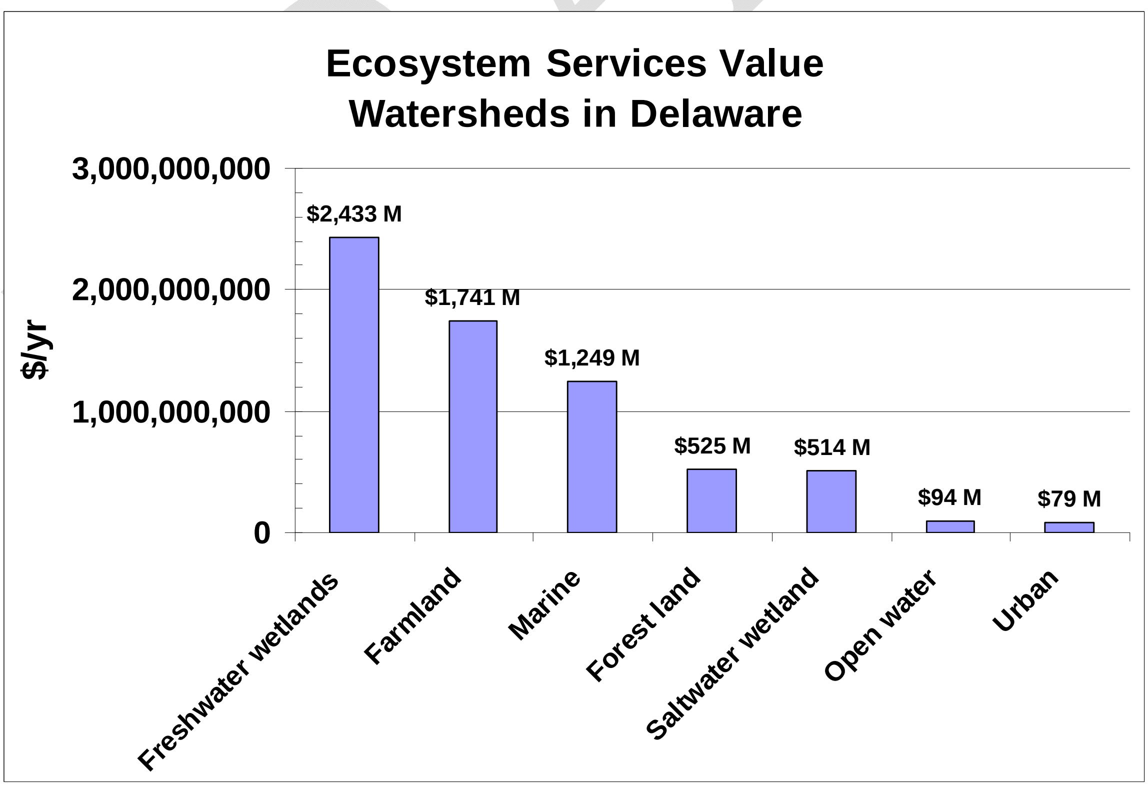
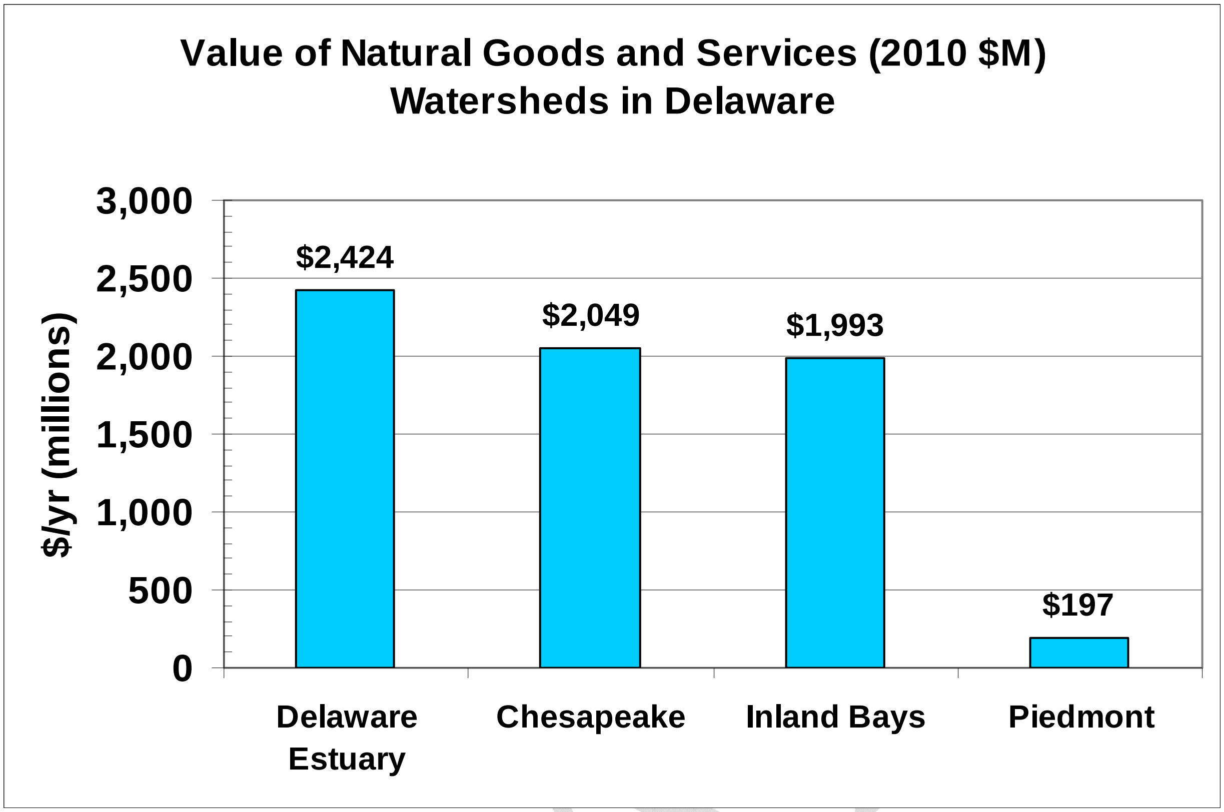


Figure 15. Ecosystem service values ($2010) within Delaware watersheds



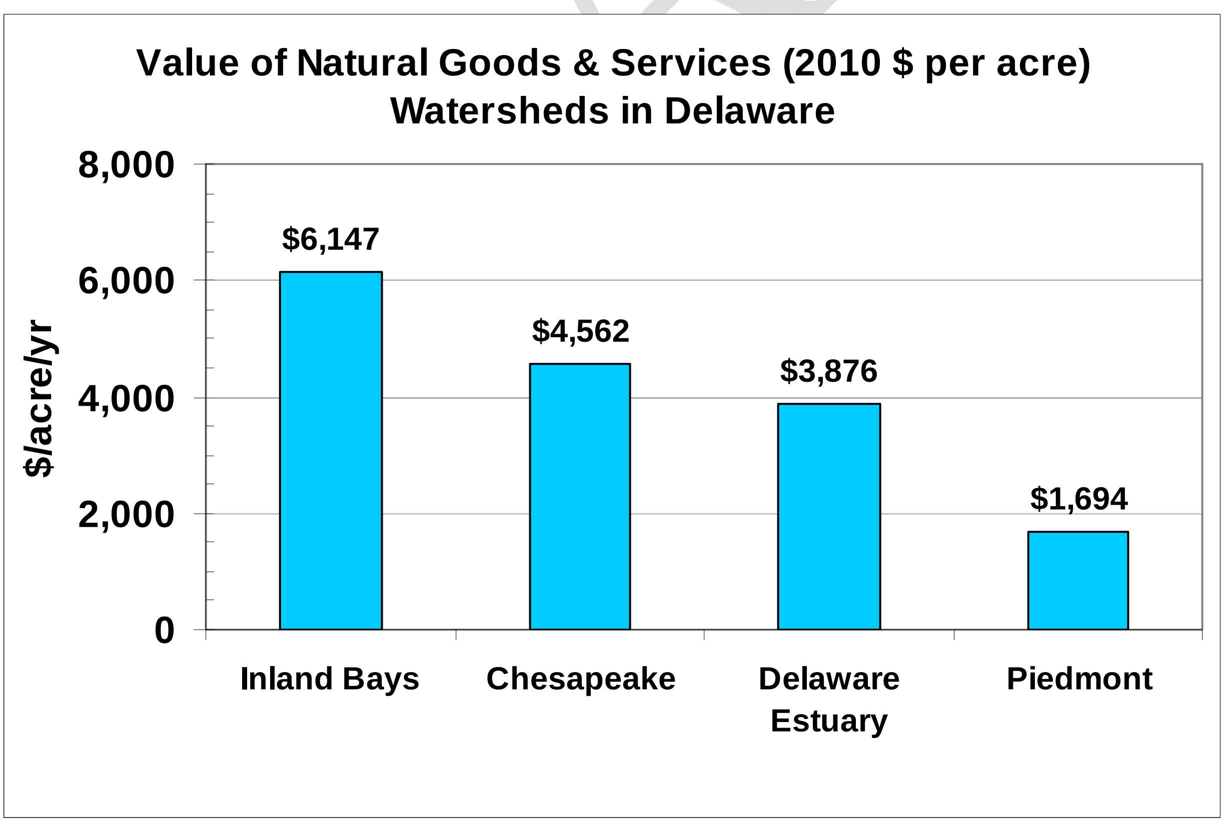


Figure 16. Value of natural goods and services by watershed within Delaware

Estimates of ecosystem services within Delaware watersheds using the NJDEP/University of Vermont values ($6.7 billion in $2010 or NPV of $216.6 billion) are conservative and in the lower end of the range compared to values from other studies. If lower per acre estimates of ecosystem services value from other studies were used instead of the NJDEP values, the total value of natural resources in Delaware watersheds would be $3.7 billion or NPV = $121.5 billion (Table 50). If higher per acre estimates of ecosystem services value from other studies were used, the total value of natural resources within watersheds in Delaware would be $20.1 billion or NPV = $654.6 billion (Table 51).

Estimate	PV ($B)	NPV ($B)
Low	3.7	121.5
NJDEP	6.7	216.6
High	20.1	654.6

Table 50. Low range of ecosystem services Delaware watersheds

Ecosystem	Area (ac)	$/ac/yr	PV $	NPV $
Freshwater wetlands	178,632	6,268	1,119,662,818	36,389,041,588
Marine	124,879	8,670	1,082,700,043	35,187,751,414
Farmland	590,150	1,387	818,538,139	26,602,489,502
Forest land	265,476	641	170,169,833	5,530,519,578
Saltwater wetland	71,001	6,269	445,102,324	14,465,825,530
Barren land	6,459	0	0	0
Urban	229,827	296	68,028,662	2,210,931,501
Beach/dune	588	42,149	24,763,638	804,818,235
Open water	48,253	217	10,470,901	340,304,283
Total ac	**1,515,263**		**3,739,436,358**	**121,531,681,631**
sq mi	**2,368**			

Table 51. High range of ecosystem services within Delaware watersheds

Ecosystem	Area (ac)	$/ac/yr	PV $	NPV $
Freshwater wetlands	178,632	43,685	7,803,521,093	253,614,435,509
Marine	124,879	8,670	1,082,700,043	35,187,751,414
Farmland	590,150	9,979	5,889,107,487	191,395,993,323
Forest land	265,476	12,033	3,194,467,399	103,820,190,465
Saltwater wetland	71,001	28,146	1,998,380,924	64,947,380,025
Barren land	6,459	0	0	0
Urban	229,827	296	68,028,662	2,210,931,501
Beach/dune	588	42,149	24,763,638	804,818,235
Open water	48,253	1,686	81,354,558	2,644,023,135
Total ac	**1,515,263**		**20,142,323,803**	**654,625,523,607**
sq mi	**2,368**			

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