

IMPERVIOUSNESS: A PERFORMANCE MEASURE OF A DELAWARE WATER RESOURCE PROTECTION AREA ORDINANCE¹

Gerald J. Kauffman, Martha B. Corrozi, and Kevin J. Vonck²

ABSTRACT: The New Castle County Resource Protection Area Technical Advisory Committee (RPATAC) requested that the University of Delaware utilize impervious cover estimates to evaluate the performance of the Water Resource Protection Area (WRPA) ordinance. This 1991 ordinance was the first in Delaware to protect the quantity and quality of drinking water supplies by limiting new development in WRPAs – such as areas of ground water recharge, wellhead protection, drainage above reservoirs (reservoir watersheds), and limestone aquifers – to a maximum 20 percent impervious cover. The research used geographic information system (GIS) techniques to evaluate the effectiveness of the ordinance in attaining its objective. The analysis indicated that 138 new developments were proposed in WRPAs since the ordinance was approved in 1991. The composite impervious cover of the 231 square kilometers of WRPAs in New Castle County is 15 percent, less than the 20 percent code requirement, ranging from 7 percent in recharge areas to 41 percent in several wellhead protection areas. To further protect drinking water supplies, the study results indicate, New Castle County should discourage code variances for applications in the more developed WRPAs, those where impervious cover already exceeds 20 percent, and should acquire parks and open space to protect the healthier WRPAs where impervious cover is currently less than 20 percent.

(KEY TERMS: impervious cover; watershed management; source water protection; land use planning; aquifers; water policy.)

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INTRODUCTION

This paper presents an evaluation of the performance of the New Castle County, Delaware, WRPA ordinance. The intent of the ordinance is to protect ground and surface water supplies by limiting impervious cover to 20 percent for new development within recharge, wellhead, reservoir watershed, and limestone aquifer areas. This research investigates the following questions. How many new development applications were submitted in WRPAs since the ordinance was adopted in 1991? What is the current percent impervious cover within the WRPAs? Does the ordinance limit the impervious cover of new development below the 20 percent threshold in WRPAs? What are the policy considerations regarding the existing level of protection provided by the water resource protection area ordinance?

Researchers from the University of Connecticut have recommended incorporating impervious cover indices in zoning, subdivision, and land planning ordinances to protect water resources (Arnold and Gibbons, 1996). Base zoning regulates the density and intensity of development according to the nature of land uses such as residential, commercial, manufacturing, or institutional. Overlay zoning districts are commonly used to protect water and other environmental resource features in municipal or county zoning and land use codes (Maryland Department of the Environment, 2000). The Federal Interagency Stream Restoration Working Group recommends that local governments establish watershed-based zoning districts that set an overall impervious cover threshold for the district (FISRWG, 2001).

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In Delaware, the New Castle County Unified Development Code (New Castle County, 1997) superimposes overlay zoning districts over base zoning to conserve environmental features such as floodplains, steep slopes, aquifer recharge, wellhead, and reservoir watershed protection areas. The Unified Development Code is intended to protect water resource protection areas by limiting the amount of impervious cover of new development to no more than 20 percent of the parcel area. The Unified Development Code defines impervious cover as the amount of pavement and roof area that prevents infiltration in a water resource protection area or watershed.

Representatives of the University of Delaware Institute for Public Administration Water Resources Agency serve on the New Castle County RPATAC, a group of planners, scientists, and geologists that meets monthly to review new development applications within WRPAs and assist New Castle County in administering the water resource protection area ordinance. The RPATAC requested that the University of Delaware conduct research to evaluate the performance of the water resource protection area ordinance since it was adopted in 1991.

New Castle County is the northernmost and most populous of Delaware's three counties. The county is situated along the Atlantic seaboard in the Delaware River Basin midway between Baltimore, Maryland, and Philadelphia, Pennsylvania (Figure 1). The streams and aquifers in New Castle County provide drinking water for more than a half-million people, or over 60 percent of Delaware's population (Kauffman *et al.*, 2003). The impervious cover threshold of 20 percent is based on water budget models reviewed by the New Castle County RPATAC that indicated that the volume of recharge diminishes rapidly once the percent impervious cover exceeds 10 percent to 20 percent of a particular site. The ordinance employs the overlay zoning district approach to protect the following water resource protection areas during development (Minni, 2001): Floodplains – 100-year floodplain as defined by hydrologic models or flood prone soils; Erosion Prone Slopes – steep slopes usually greater than 15 percent, contiguous to floodplains; Cockeyville Formation – area directly underlain by Cockeyville marble and limestone formation; Cockeyville Drainage Area – watershed tributary to the Cockeyville formation; Hoopes Reservoir – watershed tributary to the Hoopes Reservoir; Recharge Areas – soils having excellent recharge potential, usually soils with over 90 percent sand and gravel; Class A Wellhead – area within a 91.5 meter radius of a public water supply well; Class B Wellhead – zone of influence around a field of public water supply wells delineated by a hydrogeologic computer model based on five-year time of travel; and Class C

Wellhead – zone of influence around a field of public water supply wells delineated by interpretation of hydrogeologic reports and maps. Table 1 summarizes the maximum impervious cover thresholds for new development proposed in WRPA overlay zoning districts according to the New Castle County Unified Development Code.

New development requires construction of impervious area, which reduces the amount of ground water recharge as compared to natural ground cover. For instance, a typical water budget model shows that infiltration decreases from 50 percent of total precipitation for a natural ground cover condition to 35 percent infiltration for a ground cover with 35 to 50 percent impervious cover (USEPA, 1993). Table 2 summarizes the decrease in infiltration with increased impervious cover from the USEPA water budget model.

A growing body of literature indicates that ground water recharge and stream base flow measurably decrease with increasing impervious cover. Numerous studies throughout the United States indicate that recharge and base flow are noticeably reduced when impervious cover exceeds a threshold of 10 percent to 20 percent (Kauffman and Brant, 2000). Research in the Maryland Piedmont indicates that stream base flow decreased as impervious cover increased (Klein, 1979). Stream base flow levels, which originate from ground water, were 20 to 85 percent lower after development in urbanized watersheds in Long Island, New York (Simmons and Reynolds, 1982). A study from the State of Washington indicates that increases in percent impervious cover directly result in decreases in percent infiltration (recharge), while runoff increases (City of Olympia, 1995). A hydrologic study in the Gwynns Falls watershed near Baltimore reaffirms the existence of a threshold by concluding that the runoff ratio changes dramatically when the watershed impervious cover exceeds 20 percent (Brun and Band, 2000). Summer base flow was low in 11 Vancouver streams where impervious cover was 40 percent or greater (Finkenbine *et al.*, 2000). In the Accotink Creek watershed in Virginia, a “statistically significant change ($p < 0.05$) in streamflow response occurred between the 13 percent (1963) and 21 percent (1971) impervious surface” (Jennings and Jarnagin, 2002, p. 487). An article in *Impacts of Impervious Cover on Aquatic Systems* concludes that urbanization causes increased impervious cover in a watershed whereby “dry weather flow in streams may actually decrease because less ground water recharge is available” (Center for Watershed Protection, 2003, p. 25). In the Des Moines Creek watershed in the State of Washington, the impervious cover was raised approximately 50 percent and the summer base flows declined in the creek (Booth *et al.*, 2002).

Delaware River Basin

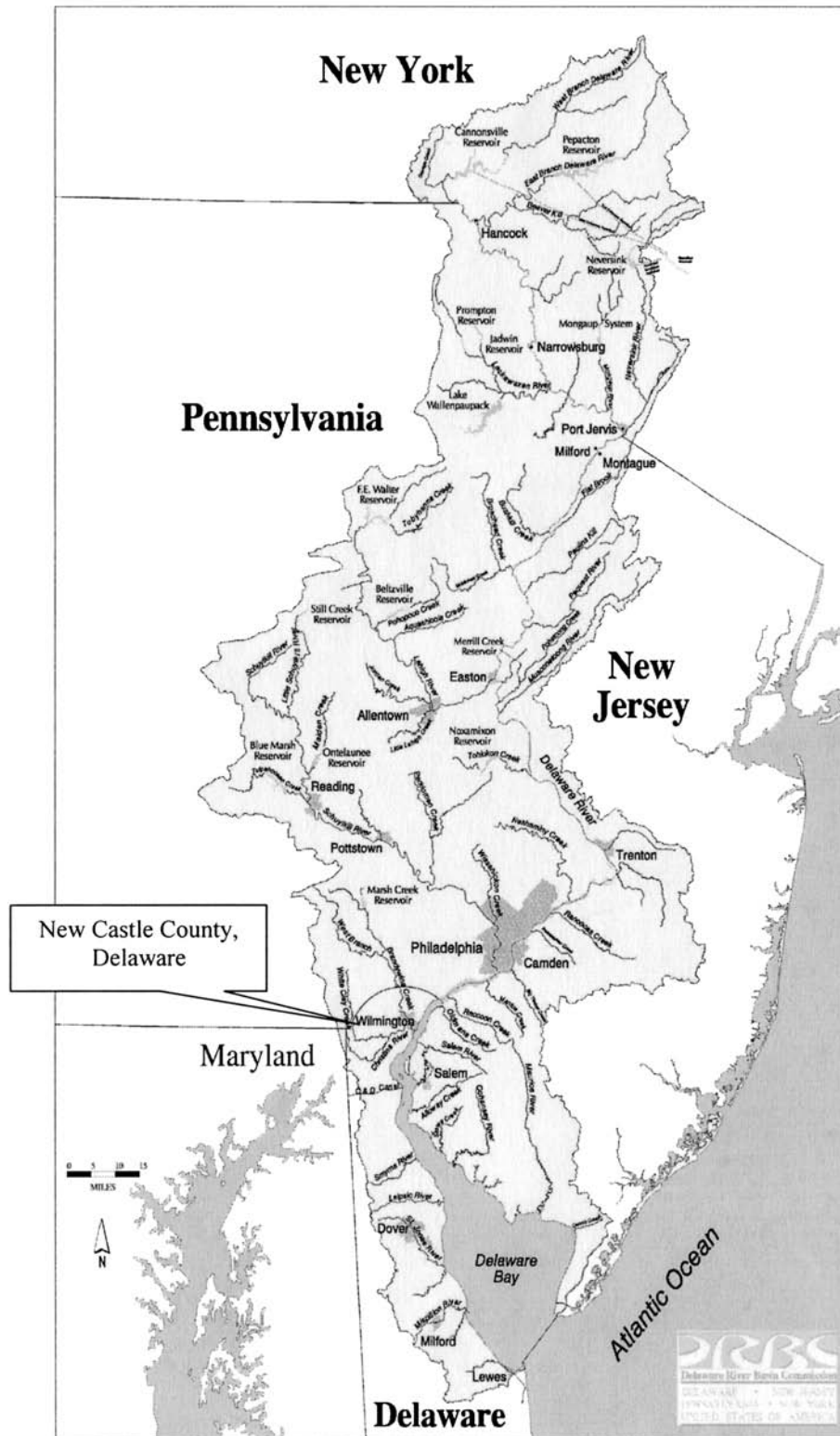


Figure 1. Location of New Castle County, Delaware, Within the Delaware River Basin.

TABLE 1. Maximum Impervious Cover Thresholds in New Castle County, Delaware, Water Resource Protection Areas.

Land Use	Cockeysville (percent)	Floodplain (percent)	Recharge (percent)	Wellhead (percent)	Reservoir (percent)
Single-Family Residential	20	0	20	20	10
Townhouse/Apartment	20	0	20	20	10
Nonresidential	20	0	20	20	10

TABLE 2. Water Budget Model Relating Infiltration to Impervious Cover.

Ground Cover	Infiltration (percent)	Runoff (percent)	Evapotranspiration (percent)
Natural	50	10	40
10 to 20 Percent Impervious	42	20	38
35 to 50 Percent Impervious	35	30	35
75 to 100 Percent Impervious	15	55	30

Source: USEPA, 1993.

In the Brandywine Creek above Wilmington watershed in Delaware and Pennsylvania, the record low daily mean streamflow during drought dropped 35 percent, from 102 million liters per day in 1966 to 76 million liters per day in 2002, while the watershed population doubled, from 90,000 in 1966 to 186,000 by 2002 (G.J. Kauffman, S. Wozniak, and K.J. Vonck, unpublished). During the same time frame, impervious cover in the Brandywine Creek watershed increased from 5 percent in 1966 to 13 percent in 2002.

METHODS

The University of Delaware Water Resources Agency used Arc View® (ESRI, 2002) GIS to determine the number of new developments since 1991 and calculate existing impervious cover ratios within WRPAs in New Castle County. Estimates of impervious cover prior to 1991 are difficult to obtain due to lack of GIS land use data from that era. Impervious cover estimates within WRPAs were derived according to the following methods.

Mapping Water Resource Protection Areas

WRPAs in New Castle County were mapped using existing GIS files (V. Svatos, University of Delaware Water Resources Agency, personal communication, May 2003). Figure 2 delineates the WRPAs, which cover 231 square kilometers or 21 percent of the New

Castle County, Delaware, land area. Figure 3 delineates floodplain, wellhead, and recharge areas near Bear, Delaware, a community approximately halfway between Newark, Delaware, and Wilmington, Delaware.

Delineating New Developments

Using “heads up” digitizing and “create a theme” capabilities of the GIS, the boundaries were delineated of new development applications submitted in WRPAs since the Unified Development Code was adopted in 1991. Statistics were compiled such as number and acreage of new developments in the WRPAs.

Computing Land Use in WRPAs

With 1997 land use data (Delaware DataMIL, 2000) updated to 2000 through field methods, GIS was used to compute the area of each of these land uses within a WRPA: Single Family Residential (SFR), Multi-Family Residential (MFR), Office/Commercial (OC), Industrial (IND), Transportation/Utility (TU), Institutional (INS), Public Open Space (POS), Wooded (WOD), Agriculture (AGR), Water/Wetlands (WW), and Vacant (VAC).

The land use and WRPA files were merged and the coverages clipped so that land use statistics could be computed for each water resource protection area. Figure 4 shows the merger of land use and WRPA files for the Hoopes Reservoir Watershed and

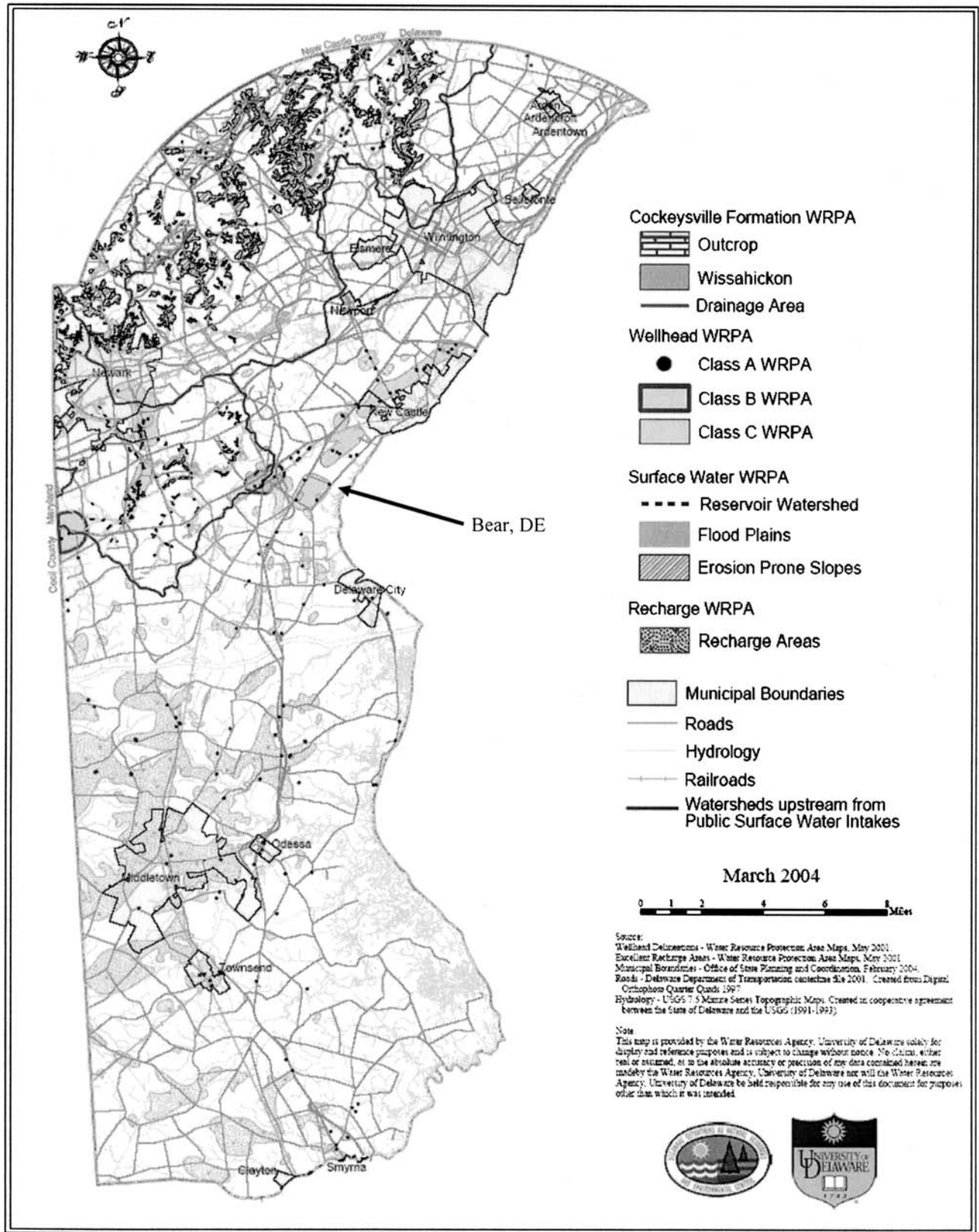


Figure 2. New Castle County Water Resource Protection Area (WRPA) Map.

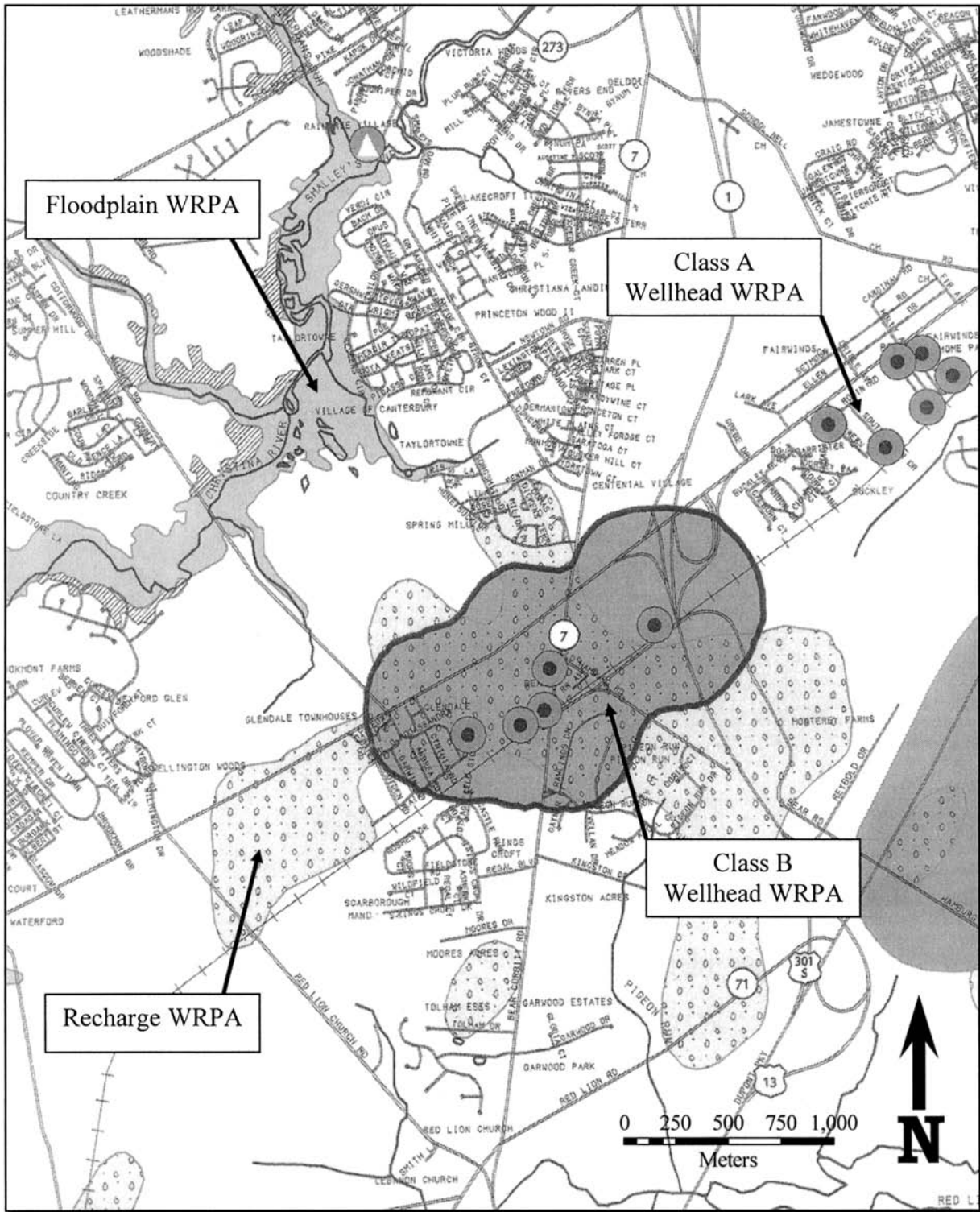


Figure 3. Floodplain, Recharge, and Wellhead Water Resource Protection Areas Near Bear, Delaware.

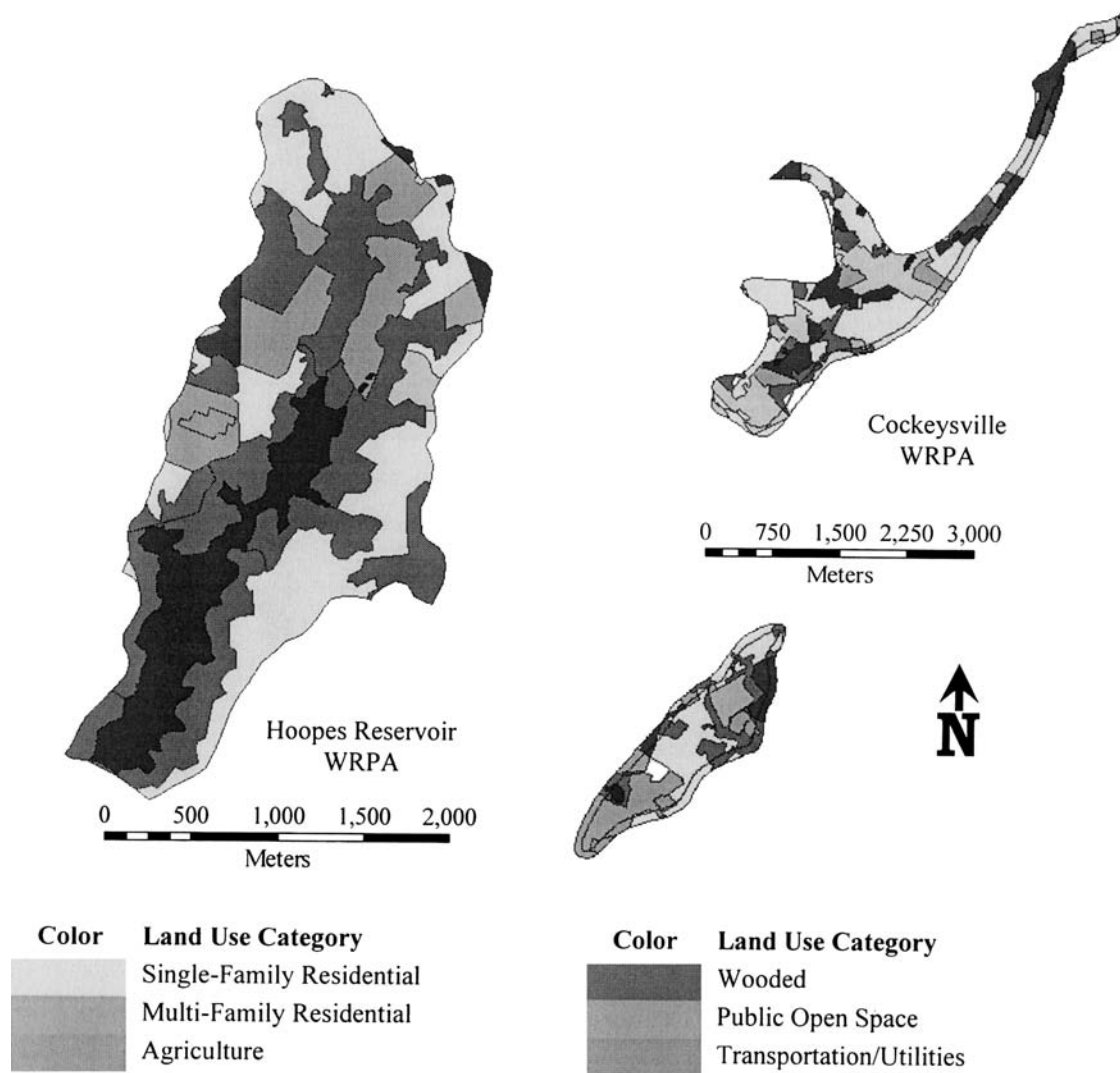


Figure 4. Land Uses Within the Hoopes Reservoir Watershed and Cockeyville Water Resource Protection Areas.

Cockeyville Formation Water Resource Protection Areas.

Computing Impervious Cover

The composite impervious cover of each WRPA was computed using a spreadsheet model and characteristic impervious cover values developed for the Christina River Basin (Greig *et al.*, 1998) according to the formula

where % Imp is the composite impervious cover of an individual water resource protection area (%); SFR Area is the area of single family residential land use within WRPA (ha); MFR Area is the area of multifamily residential land use within WRPA (ha); OC Area is the area of office and commercial land use within WRPA (ha); IND Area is the area of industrial land use within WRPA (ha); TU Area is the area of transportation and utility land use within WRPA (ha); INS Area is the area of institutional land use within WRPA (ha); POS Area is the area of public open space

$$\begin{aligned}
 \% \text{ Imp} = & [(SFR \text{ Area})(30\% \text{ Imp}) + (MFR \text{ Area})(65\% \text{ Imp}) + (OC \text{ Area})(60\% \text{ Imp}) + (IND \text{ Area})(72\% \text{ Imp}) \\
 & + (TU \text{ Area})(90\% \text{ Imp}) + (INS \text{ Area})(85\% \text{ Imp}) + (POS \text{ Area})(0\% \text{ Imp}) + (WOD \text{ Area})(0\% \text{ Imp}) \\
 & + (AGR \text{ Area})(0\% \text{ Imp}) + (WW \text{ Area})(0\% \text{ Imp}) + (VAC \text{ Area})(0\% \text{ Imp})] / \text{WRPA Area}
 \end{aligned}
 \tag{1}$$

RESULTS AND DISCUSSION

land use within WRPA (ha); WOD Area is the area of wooded land use within WRPA (ha); AGR Area is the area of agriculture land use within WRPA (ha); WW Area is the area of water and wetlands land use within WRPA (ha); VAC Area is the area of vacant land use within WRPA (ha); and WRPA Area is the total area within a particular water resource protection area (ha). Table 3 lists values of the characteristic impervious cover of land uses in New Castle County, Delaware.

TABLE 3. Characteristic Impervious Cover of Land Uses in New Castle County, Delaware.

Land Use	Impervious Cover (percent)
Single-Family Residential	30
Multifamily Residential	65
Office/Commercial	60
Industrial	72
Transportation/Utility	90
Institutional	85
Public Open Space	0
Wooded	0
Agriculture	0
Water/Wetlands	0
Vacant Land	0

For example, the impervious cover of a 100 ha recharge water resource protection area, with 20 ha single-family residential, 10 ha multifamily residential, 10 ha office/commercial, 30 ha wooded, and 40 ha agriculture would be computed as

$$\begin{aligned} \% \text{ Imp} &= [(20 \text{ ha})(30\%) + (10 \text{ ha})(65\%) \\ &+ (10 \text{ ha})(60\%) + (30 \text{ ha})(0\%) + (40 \text{ ha}) \\ &(0\%)]/100 = [600 + 650 + 600 + 0 + 0]/100 \\ &= 18.5\% \end{aligned}$$

Estimates of imperviousness can vary depending on assumptions of characteristic impervious cover based on the intensity and density of land use. For instance, if the formula were recomputed assuming a characteristic impervious cover of 20 percent for single-family land use (instead of 30 percent), the composite impervious cover of the recharge WRPA would be 16.5 percent. These estimates are considered to be precise to the range of the nearest 5 percent. The above calculation of 18.5 percent is precise within the 5 percent range of 15 to 20 percent.

According to the GIS database, 138 development applications were submitted within water resource protection areas in New Castle County between 1991, when the ordinance went into effect, and 2001. Approximately 14 applications per year were submitted for review over the 10-year period. More than 3,053 ha (30.6 square kilometers) of new residential and nonresidential land use applications were filed in water resource protection areas. By comparison, the land area of New Castle County is 1,112 square kilometers (New Castle County Department of Planning, 1997). The mean parcel area of the subdivisions that triggered a WRPA review is 44 ha.

Table 4 summarizes the results of the GIS-based analysis of land use and impervious cover within New Castle County WRPAs. Table 5 summarizes the impervious cover calculations. The water resource protection area ordinance protects 231 square kilometers, or 21 percent of the land area in New Castle County. The largest of the WRPAs are the recharge areas that protect 109 square kilometers, or almost 10 percent of New Castle County. The smallest WRPAs are the Hoopes Reservoir watershed, Class A wellhead (defined by a 91.5 m radius around the well), and Class B wellhead (a zone of influence around a collection of wells) areas, which each occupy approximately five square kilometers, or 0.4 percent of the land mass in New Castle County.

The composite impervious cover of the 231 square kilometers of water resource protection areas in New Castle County is 15 percent, or less than the 20 percent threshold set on new development by the ordinance. The WRPAs covered with the most intensive development pressure are the Class A wellhead, Class C wellhead, and Cockeysville limestone formation in Hockessin at 41, 36, and 35 percent imperviousness, respectively. The WRPAs covered with the least amount of development are the River Road Class C wellhead, recharge areas in southern New Castle County, and Hoopes Reservoir watershed at 6, 7, and 8 percent impervious, respectively.

The composite impervious cover of the floodplain water resource protection areas is 12 percent, appreciably less than the 20 percent impervious threshold set by the ordinance. The Christina River floodplain is the least developed, at 10 percent impervious due to the large proportion of undeveloped riparian land protected under the City of Newark, Delaware, stream valley zoning designation.

The composite imperviousness of the erosion prone slopes area is 13 percent, less than the 20 percent code threshold. The Brandywine Creek erosion prone slopes WRPA is the least developed, at 10 percent

TABLE 4. Area and Percent Impervious Cover of New Castle County Water Resource Protection Areas (WRPA).

Water Resource Protection Area	Area (sq. km)	Percent of NCC	Percent Impervious Cover (2000)
Floodplain WRPA			
Red Clay Creek	6.14		15
White Clay Creek	10.22		11
Brandywine Creek	3.58		11
Christina River	8.35		10
Subtotal	28.29	2.5	12
Erosion Prone Slopes			
Red Clay Creek	8.81		13
White Clay Creek	10.92		14
Brandywine Creek	5.85		10
Christina River	2.38		18
Subtotal	27.96	2.5	13
Cockeysville Formation			
Hockessin	3.25		35
Pleasant Hill	1.54		19
Drainage Basin	25.71		24
Subtotal	30.50	2.8	29
Hoopes Reservoir			
	5.07	0.4	8
Recharge Areas			
North of the C & D Canal	13.70	1.0	30
South of the C & D Canal	96.33	8.5	7
Subtotal	110.03	9.5	10
Wellheads Class A			
Public Community Wells	2.68		27
Transient, Noncommunity Wells	0.91		31
Nontransient, Noncommunity Wells	1.30		41
Subtotal	4.89	0.4	31
Wellheads Class B			
Glendale	2.00		
Eastern State	2.58		
Subtotal	4.58	0.4	25
Wellheads Class C			
New Castle	4.55		36
Newark Piedmont	2.11		11
Newark South Wellfield	4.81		30
Army Creek	3.15		24
River Road	2.60		6
Newark Dupont	2.11		18
Subtotal	19.33	1.7	24
<hr/>			
New Castle County WRPA Total	231.00	20.7	15
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TABLE 5. Impervious Cover Calculations for Water Resource Protection Areas in New Castle County, Delaware.

WRPA	ha	Land Use (ha)										Percent Impervious Cover													
		SFR	MFR	OC	IND	TU	INS	POS	WOD	AGR	WW	VAC	SFR	MFR	OC	IND	TU	INS	POS	WOD	AGR	WW	VAC	%IC	
Floodplains	2,818	382	187	75	9	39	7	109	1,304	195	440	50	30	65	60	72	90	85	0	0	0	0	0	0	12
Brandywine Creek	357	44	34	8	0	0	0	9	135	58	69	0	30	65	60	72	90	85	0	0	0	0	0	0	11
Red Clay Creek	611	119	67	21	0	1	0	26	226	29	113	2	30	65	60	72	90	85	0	0	0	0	0	0	15
Christina River	891	86	29	19	6	25	2	4	402	40	172	39	30	65	60	72	90	85	0	0	0	0	0	0	10
White Clay Creek	1,018	133	58	27	3	13	5	71	541	68	86	9	30	65	60	72	90	85	0	0	0	0	0	0	11
Erosion Prone Slopes	2,785	704	163	41	2	8	23	121	1,456	210	445	25	30	65	60	72	90	85	0	0	0	0	0	0	13
Brandywine Creek	582	87	27	17	0	0	7	23	379	34	3	0	30	65	60	72	90	85	0	0	0	0	0	0	10
Red Clay Creek	878	257	44	8	0	0	0	32	436	96	436	1	30	65	60	72	90	85	0	0	0	0	0	0	13
Christina River	237	64	14	7	2	7	2	3	84	23	5	16	30	65	60	72	90	85	0	0	0	0	0	0	18
White Clay Creek	1,088	295	78	8	0	1	13	62	556	57	0	7	30	65	60	72	90	85	0	0	0	0	0	0	14
Hoopers Reservoir	505	141	10	5	0	0	5	0	198	71	76	0	20	65	60	72	90	85	0	0	0	0	0	0	8
Cockeysville	604	225	87	74	0	0	15	5	100	79	7	12	30	65	60	72	90	85	0	0	0	0	0	0	29
Cockeysville (Hookessin)	387	154	68	74	0	0	0	5	55	17	5	8	30	65	60	72	90	85	0	0	0	0	0	0	35
Cockeysville (Pleasant Hill)	217	71	18	0	0	0	15	0	45	62	2	4	30	65	60	72	90	85	0	0	0	0	0	0	19
Cockeysville Drainage Area	2,562	1,416	172	102	0	0	34	8	392	373	11	49	30	65	60	72	90	85	0	0	0	0	0	0	24
Recharge Areas	10,958	1,979	111	184	159	191	78	76	514	7,018	403	244	30	65	60	72	90	85	0	0	0	0	0	0	10
Recharge Areas (North of Canal)	1,361	378	59	79	104	117	48	11	94	414	8	49	30	65	60	72	90	85	0	0	0	0	0	0	30
Recharge Areas (South of Canal)	9,597	1,602	52	105	55	74	30	65	420	6,605	395	195	30	65	60	72	90	85	0	0	0	0	0	0	7
Class A Wellheads	487	138	52	53	6	25	28	25	60	84	13	15	30	65	60	72	90	85	0	0	0	0	0	0	31
Community Wells	287	96	23	19	1	11	11	4	32	57	6	8	30	65	60	72	90	85	0	0	0	0	0	0	27
Nontransient/Noncommunity	130	21	13	13	6	6	13	15	23	11	7	3	30	65	60	72	90	85	0	0	0	0	0	0	31
Transient/Noncommunity	91	20	15	20	0	8	4	6	5	16	0	5	30	65	60	72	90	85	0	0	0	0	0	0	41
Class B Wellheads	456	123	10	50	0	43	0	2	76	82	33	35	30	65	60	72	90	85	0	0	0	0	0	0	25
Class C Wellheads	1,921	475	170	173	14	54	70	42	270	472	38	141	30	65	60	72	90	85	0	0	0	0	0	0	24
New Castle	452	200	49	56	0	10	51	19	16	34	0	17	30	65	60	72	90	85	0	0	0	0	0	0	36
Newark Piedmont	208	32	0	17	4	0	0	0	113	33	9	1	30	65	60	72	90	85	0	0	0	0	0	0	11
Newark South Wellfield	479	131	95	27	10	15	8	15	37	136	0	6	30	65	60	72	90	85	0	0	0	0	0	0	30
Army Creek	312	92	25	39	0	8	0	0	45	19	14	70	30	65	60	72	90	85	0	0	0	0	0	0	24
River Road	260	2	0	15	0	7	0	8	30	157	4	39	30	65	60	72	90	85	0	0	0	0	0	0	6
Newark/DuPont	209	19	1	19	0	15	11	0	30	94	11	8	30	65	60	72	90	85	0	0	0	0	0	0	18
New Castle County WSPA	23,094	5,584	962	758	191	361	259	387	4,370	8,585	1,465	571	30	65	60	72	90	85	0	0	0	0	0	0	15

impervious due to the protection provided by Brandywine Park in Wilmington, the Brandywine Creek State Park, and adjacent conservation land managed as open space by the Woodlawn Trustees.

The Hoopes Reservoir watershed WRPA is suitably protected at 8 percent impervious due to the Valley Garden Park system acquired by the City of Wilmington after the construction of the reservoir in 1931 and zoning in the DuPont “chateau” country north of Wilmington for large lot country estates.

The overall impervious cover of the Cockeyville limestone formation is 29 percent, which results from the suburban growth that occurred near Hockessin prior to passage of the ordinance in 1991 (Figure 5). The Cockeyville area in Pleasant Hill is less intensively developed, at 19 percent impervious. The Cockeyville area in Hockessin has been under more intensive development pressure, at 35 percent impervious, which appreciably exceeds the WRPA ordinance threshold of 20 percent.

Data from aerial photographs in 1989 (two years before the adoption of the 1991 WRPA ordinance) indicate that land use in the Cockeyville formation drainage area was 44 percent urban/suburban, 31 percent pasture/crops, and 25 percent forest, which calculates to 16 percent impervious overall (Woodruff and Plank, 1995). According to the GIS analysis presented herein, 2000 land use in the Cockeyville formation drainage area was 67 percent urban/suburban, 14 percent pasture/crops, and 19 percent forested, which calculates to 24 percent impervious overall, an increase of 8 percent impervious cover since 1989. Due to lack of land use data for 1991, it is difficult to determine how much of this development or impervious cover occurred between 1989 and 1991, when the WRPA ordinance was adopted.

Regarding recharge areas, the southern New Castle County component is more protected, at 7 percent impervious cover, than the northern New Castle County component, at 30 percent impervious. Much of

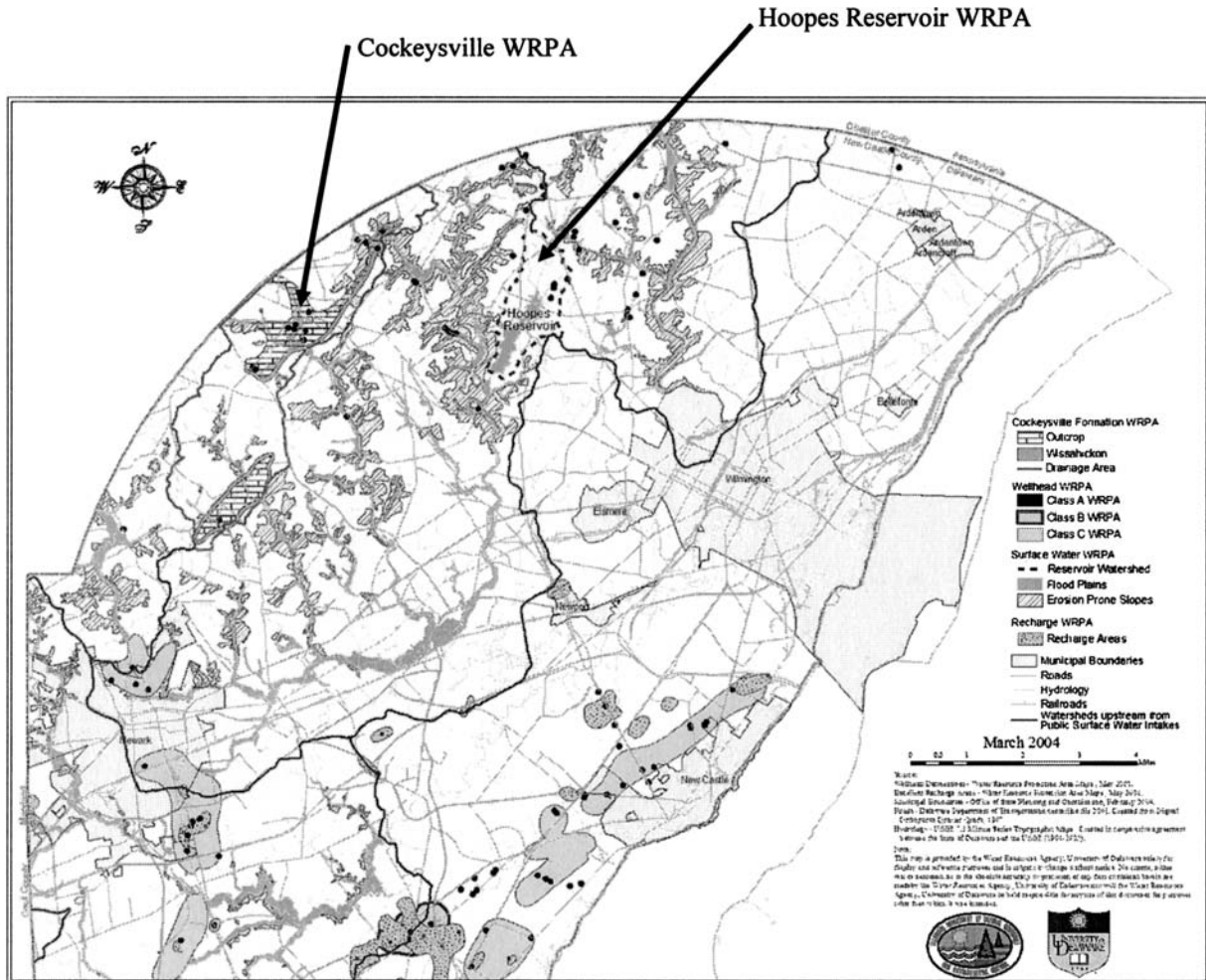


Figure 5. Water Resource Protection Areas in Northern New Castle County, Delaware.

the area north of the Chesapeake and Delaware Canal along the Interstate 95 corridor between Wilmington and Newark, Delaware, is almost built out. Development pressure in southern New Castle County is expected to be heavy, putting these southern recharge areas at risk.

The areas closest to the wells, the Class A wellhead areas where no development is permitted, exhibit some of the highest impervious cover ratios. The Class A wellhead areas, the area within a 91.5 m radius of the well, measure at 31 percent impervious. Drilling records indicate that over 90 percent of the public water supply wells were drilled prior to 1991 and thus were not under the development restrictions set by the WRPA ordinance. The Class A wellheads delineated when wells were drilled after 1991 are free from development except for facilities such as pump houses associated with the wells themselves.

The Glendale and Eastern States Class B wellhead areas along the growing Route 40 corridor are at 25 percent impervious, above the 20 percent threshold. These wellheads can be considered at risk due to projected future intense development along the Route 40 growth corridor.

The Class C wellhead areas average 24 percent impervious, ranging from 6 percent impervious at the River Road wellhead area to 36 percent impervious at the New Castle wellhead. The Newark South wellfield (30 percent impervious) and Army Creek wellhead (24 percent impervious) are both above the 20 percent impervious threshold set by the ordinance and are considered to be at risk from future land development.

Overall, the impervious cover of water resource protection areas is at 15 percent, which is less than the impervious threshold on new development set by New Castle County Unified Development Code. Areas that exceed the 20 percent impervious ordinance threshold are considered to be at risk due to land use pressures. These areas include the Cockeysville, recharge north of the C and D Canal, Class A wellhead, Class B wellhead, and New Castle, Newark South, and Army Creek Class C wellheads. Healthy water resource protection areas, at less than 20 percent impervious cover, are the floodplain, erosion-prone slope, Hoopes Reservoir, recharge area south of the C and D Canal, and Newark Piedmont, River Road, and Newark Dupont Class C wellheads.

CONCLUSIONS

Overall, water resource protection areas included as overlay zoning districts by the New Castle County ordinance are largely protected at 15 percent impervious, less than the code threshold set for new development. However, certain sectors of the WRPA, such as the Cockeysville limestone area in Hockessin and recharge areas north of the C and D Canal, can be considered at risk, exceeding the threshold, due to existing imperviousness from intense development pressure. Much of the development in those areas occurred before the WRPA ordinance was adopted in 1991. On the other hand, the floodplain, erosion-prone slope, Hoopes Reservoir, and southern New Castle County recharge areas are well protected, with impervious cover less than 10 percent, significantly below the ordinance threshold.

It is recommended that the New Castle County RPATAC review future WRPA land development applications with the findings of this analysis in mind and especially scrutinize applications in developed WRPAs that already exceed 20 percent impervious cover and discourage variances or exceptions to the code in these areas. For the more protected WRPAs, where existing impervious cover is less than 20 percent, the RPATAC should focus development outside of these protected areas to further shelter the ground and surface water supplies in New Castle County. The county should target land for parks acquisition and conservation easements in the WRPAs with low imperviousness, such as the southern New Castle County recharge areas, to protect these sensitive lands from further development.

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