

THE NATIONAL WILD AND SCENIC RIVERS ACT AND ENVIRONMENTAL QUALITY: A CASE STUDY IN THE RED CLAY CREEK AND WHITE CLAY CREEK WATERSHEDS

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ABSTRACT *This study evaluates the effectiveness of National Wild and Scenic Rivers Act (NWSRA) federal designation. To assess the effectiveness of designation, the White Clay Creek watershed in southeastern Pennsylvania was compared with an adjacent similar watershed, the Red Clay Creek, which received no federal designation. Significance testing was conducted on water quality parameters (temperature, dissolved oxygen, pH, specific conductance, and total dissolved solids) pre- and post- designation. Results showed a significant decline in water quality in both watersheds over time. This underscores the importance of local watershed management organizations, and that designation through the NWSRA is not a guarantee for stable or improved water quality.*

Keywords: *cooperative federalism, watershed management, White Clay Creek Wild and Scenic River, Pennsylvania*

INTRODUCTION

The location, availability, quality, and control of water have always shaped patterns of human geographic location across the natural landscape (Barham 2001). In the United States, technology allows humans to control the location and availability of water, but our water resources are in constant danger of alteration, endangerment, and pollution due to human activities like agriculture, transportation, and industry (Dunne and Leopold 1978). The early 1970's formation of the Environmental Protection Agency (EPA) and the Clean Water Act established national water quality standards for states and local governments to follow. Around the same time, Congress passed the National Wild and Scenic Rivers Act (NWSRA) of 1968, which preserves state- and federal-nominated rivers and watersheds.

These natural features do not align with the jurisdictions of human municipalities. Rivers and watersheds cross political boundaries across which the methods and priorities for management vary. Planning choices are made to reflect the concept of ecosystem management, and watersheds are thought of as definitive boundaries which represent ecosystems (Randolph 2004). Mirroring the change of perspective from traditional methods– which don't reference watersheds and the ecosystem– to ecosystem management, the planning process for planners, politicians, and other decision makers has also shifted to a more holistic viewpoint that takes multiple variables into account (Clark et al. 2005; Gaden et al. 2008). This shift is in response to the acknowledgement of global environmental challenges such as global population increase, natural resource depletion, climate change, and declining biodiversity (Barham 2001). It has become necessary with these changes to examine how collaboration among multiple environmental preservation groups should function in order to yield the best results.

This study questions the effectiveness a federally-controlled approach to watershed management, specifically the use of National Wild and Scenic Rivers Act (NWSRA) designation as a local watershed management tool. We conduct a comparative analysis of two watersheds in southeastern Pennsylvania, the site of the first and sole watershed designated under the NWSRA. In this case, we defined an effective designation as having significant improvements in water quality, stream-impairing, and stream-improving land use activities have occurred in the federally designated watershed, and that these improvements are significantly greater compared to the stream without federal designation.

We consider the following research questions:

- (1) Have there been significant changes in water quality over time in the White Clay Creek (WCC) and Red Clay Creek (RCC) watersheds?
- (2) Did water quality significantly change in the WCC watershed after federal designation as a National Wild and Scenic River (NWSRA)?

(3) Have there been changes in stream impairing vs stream improving activities over time in the WCC and RCC watersheds?¹

The first two questions address changes in instream water quality measures, and due to past successes of federal involvement, we hypothesized that there would be significant positive changes over time (Babbitt 2005; Sirianni 2006; Kauffman et al 2009). The last question addresses changes in land use/land cover over time, again assuming positive change due to past successes of federal involvement. Many studies acknowledge the correlation between land use and water quality (e.g., Megan et al. 2007; Zampella et al. 2007; Dodds and Oakes 2008; Rothenberger et al. 2009; Ou and Wang 2011), as well as the specific effects of various chemicals on water quality and water ecosystems (Environmental Studies Board 1972; Murphy 2007). These research questions address the potential impact of watershed management practices and Federal designation as an effective environmental planning technique.

NATIONAL WILD AND SCENIC RIVERS ACT

The National Wild and Scenic Rivers Act (NWSRA) of 1968 is a federal solution to the problem of managing rivers across multiple municipal borders. Congress passed the Act to protect and enhance rivers and river corridors with outstandingly remarkable values, so that those natural resources remain in the same state for future generations to enjoy and benefit. Through the NWSRA, rivers are nominated by federal or state governments for either state-administered or federal-administered preservation. The federal government develops a management plan designed to heavily involve local stakeholders. The plan is implemented by different possible government agencies: the National Park Service, the Forest Service, the Bureau of Land Management, the state government, or local management organizations. After a river is added to the National System, the federal government steps back, allowing state and local stakeholders to foster a more stable collaboration level (Burce 2008). As of October 2011, 20,273 km of rivers and streams have been preserved under the act (FWS 2012).

In the United States, federal involvement in local matters may result in conflict rather than the fostering of collaboration, but it may also mediate conflicting relationships between states in the case of issues which span political borders. Successful examples of federal involvement include the Endangered Species Act to prevent urban sprawl and preserve land, the Clean Water Act to control pollution in the Chesapeake Bay Watershed, and preservation and establishment of the Everglades National Park through local, state, and federal cooperation) (Babbitt 2005). Federal involvement is also uninfluenced by competition between states, so the interests of the watershed take precedence over business concerns between states (Burce 2008). For this reason cooperative federalism – the balance of power and relationship between the federal government and other entities such as state and local governments – is worth examining whenever government agencies are involved in partnership or collaboration with local stakeholders (Burce 2008). In the case of the National Wild and Scenic Rivers Act (NWSRA), the success of the act relies on the success of the relationship between the federal government and all other stakeholders (Burce 2008). In the case of the Skagit River Watershed, the Forest Service and State Department of Natural Resources did not effectively regulate logging activities and development following the NWSRA designation which led to increased flooding and decreased number of fish (Anonymous 1991).

BRANDYWINE-CHRISTINA WATERSHED

The Brandywine-Christina Watershed encompasses southeastern Pennsylvania, Delaware, and a small portion of Maryland (EPA 2012a). The watershed is located within the mid-Atlantic ecoregion, about 55 kilometers west of Philadelphia. The area faces issues such as the impacts of runoff, the declining fish population, environmental restoration, and invasive plant and animal species (Stroud Water Research Center 2012). Developmental pressures have also challenged planners to protect water quality from the impacts of increased waste disposal, such as septic tanks and wastewater treatment plants, which release phosphorus, nitrogen, and dissolved solids into the stream water system (Dunne and Leopold 1978).

Historically, the Brandywine Watershed was the subject of research by Dunne and Leopold (1978) in their landmark book, *Water in Environmental Planning*. The Brandywine Valley Association developed the first watershed management organization in the United States in 1945. Today, several groups are invested in the preservation of the waters, including the Chester County Parks and Planning Departments, the Brandywine Valley Planning Association,

¹ Stream impairing activities would include an increase in impervious surface cover, while stream improving activities would include the creation of riparian buffers.

the Brandywine Conservancy, the Stroud Water Research Center, as well as numerous watershed management organizations and land trusts (UD 2012). In addition, each township has developed citizen-elected open space boards and a water resources management boards and governs its own land use. In Pennsylvania, the Brandywine-Christina watershed is located within Chester County and intersects over 20 townships.

There are four sub-basins located within the Brandywine-Christina Watershed: the Brandywine Creek Watershed, the White Clay Creek Watershed, the Red Clay Creek Watershed, and the Christina River Watershed (EPA 2012c). In 2001, the White Clay Creek Watershed (WCC) achieved the National Wild and Scenic River designation, becoming the first and only watershed in the United States to be preserved under the National Wild and Scenic Rivers Act (FWS 2012). The WCC was preserved for recreation because of its location, and access to the watershed by the urban populations of Wilmington, Newark, and Philadelphia (Figure 1). The watershed was also preserved for its biodiversity, especially given its proximity to extensive suburban and urban development (Barscz 2012). Approximately 35% of the waters are impaired (CCWRA 2012).

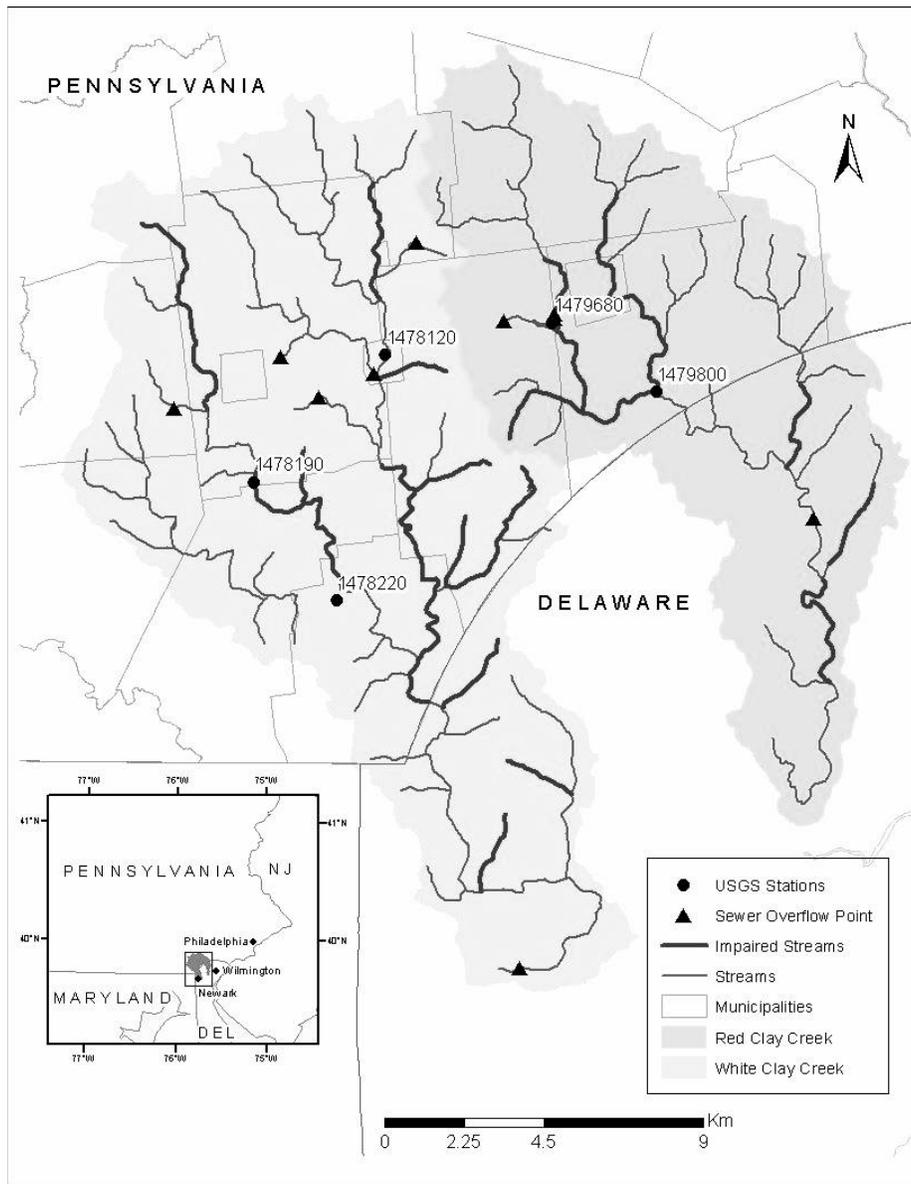


Figure 1: Study Area Watersheds (Sources: EPA 2012b; PSIEE 2012; USGS 2012).

The Red Clay Creek and White Clay Creek Watersheds

The WCC watershed management plan was developed with the federal leadership of the National Park Service (FWS 2012). All other watersheds within the Brandywine-Christina are managed at the municipal level, however Chester County has developed watershed management plans for the subwatersheds (UD 2012). In Pennsylvania, the municipalities govern land use, so several municipalities have control over land use practices within their portion of the watershed. In addition, each township is required by law to have developed a stormwater management plan, which prioritizes stream water quality (PDCED 2003). The WCC watershed is the site of four total maximum daily loads (TMDLs) listed (CCWRA 2012). The WCC's TMDLs were developed because of polychlorinated biphenyl (PCBs), excess nutrients and low dissolved oxygen (DO) at times of low or high flow, and bacteria and sediment at high flow (CCWRA 2012).

The Red Clay Creek (RCC) is a subwatershed of the Brandywine-Christina, and lies east of and adjacent to the WCC (Figure 1). Sixty seven percent of streams located in the RCC are classified as impaired (CCWRA 2012). The land uses in the watershed are similar to the WCC, largely urban and agricultural, with an increase in urban uses since 2001 (Figure 2) (DVRPC 2012). According to the EPA, there are two Superfund sites located in this watershed,

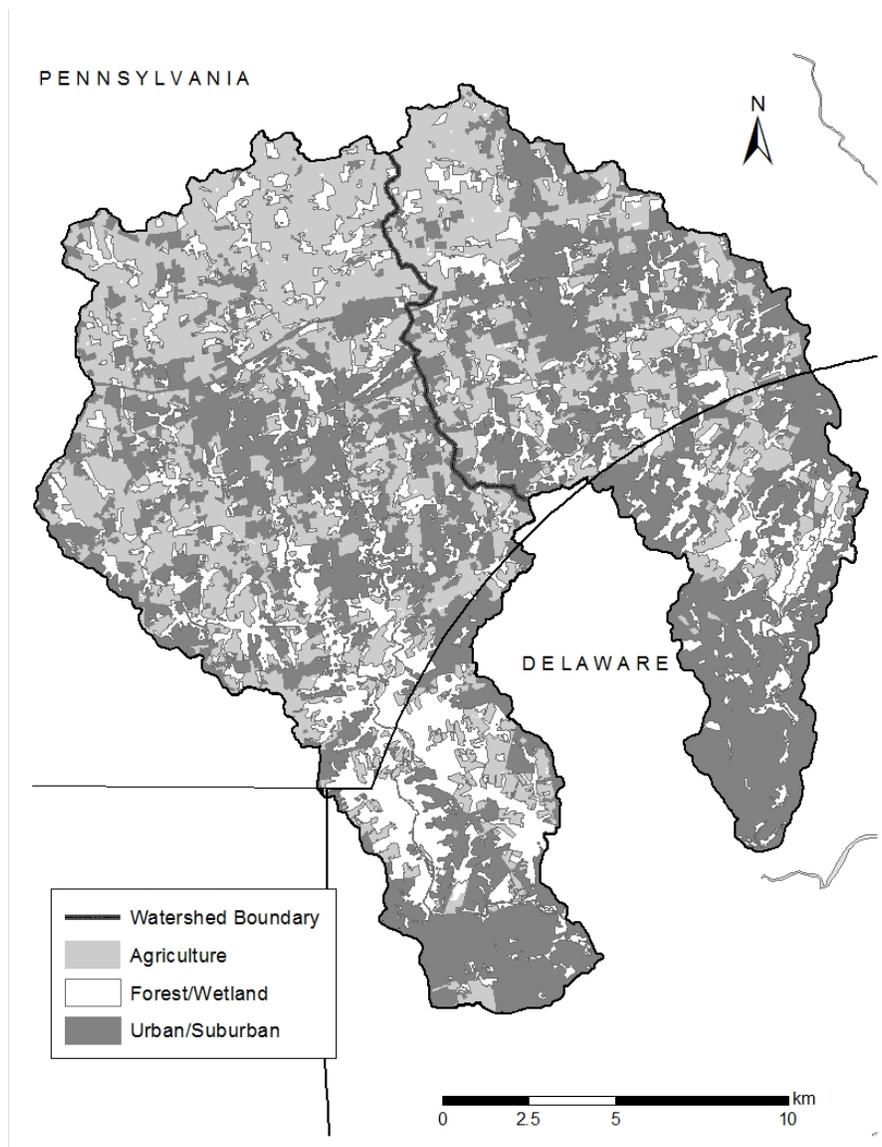


Figure 2. Land Use/Land Cover in the White Clay Creek and Red Clay Creek Watersheds, 2010 (Source: DVRPC 2012 and USGS 2012).

although none are severe enough to be listed on the National Priority List (EPA 2012c). The watershed is managed at the municipality level, but several watershed organizations operate within the RCC Watershed. Thriving mushroom production located in the headwaters of the RCC watershed is a point source of pollution located within the watershed. The national demand for local mushroom products influences the watershed's political context (Bissix and Rees 2001). The watershed is the site of five TMDLs, listed because of PCBs, excess nutrients and low dissolved oxygen at times of low or high flow, and bacteria and sediment at high flow (CCWRA 2012).

Surface water and ground water in both the WCC and RCC watersheds are used for residential, commercial, industrial, and drinking purposes. In urbanized areas, the public water supply uses surface water sources such as reservoirs to supply the urban population. The wastewater is transmitted through sewers to water treatment plants, which discharge into streams. Many residential properties in rural areas draw water from ground wells. These rural properties are sources of wastewater infiltration into groundwater due to leaks in septic systems. Studies have linked impaired stream water quality and changes in stream flow rate with wastewater treatment facilities, industrial discharge, and septic systems (Senior and Koerkle 2003). Many sewer overflow points are also located in the headwaters of the two watersheds (see Figure 1).

DATA AND METHODS

In order to quantify changes in water quality over time in the White Clay Creek and the Red Clay Creek watersheds for Research Questions 1 and 2, we examined water quality data collected by the USGS. For Research Question 3, we analyzed land use/land cover as indications of changes in stream impairing and stream improving activities.

There are 3 water quality monitoring stations in the White Clay and 2 stations in the Red Clay (see Figure 1), all located in Pennsylvania (USGS 2012)². Each USGS sample was examined for over 30 different water quality parameters. Not all variables were measured during each sample and those that were not consistently gathered were eliminated. The following variables were included: temperature, specific conductance (SpCd), dissolved oxygen (DO), pH, and total dissolved solids (TDS). USGS sample data was collected once a year in late October or early November.

The paired sample t-tests compared six pairs of data sets to determine the presence of significant differences in water quality in the WCC and in the RCC pre- and post-designation. Distinctions were made only pre and post the NWSRA federal designation (1970-2000 and 2001-2011 respectively). The mean and Pearson correlation of each dataset were also computed.

The percent change for each water quality parameter at each of the five stations over 1, 2, 3, 5, and 10 year intervals were calculated and graphed. For both watersheds, the station which was monitored over the entire study period was included and assumed to be indicative of water quality in that watershed. For the RCC, USGS station 01479800 was used, and station 014798120 was used for the WCC.

Pennsylvania orthophotos were downloaded from Pennsylvania Spatial Data Access (PASDA) for the years 2000, 2005, and 2010 (PSIEE 2011). ArcGIS v10.0's Editor was used to create a vector polygon layer of riparian buffers at a scale of 1:3000 for each year (ESRI 2011). TIFF files of impervious cover for the entire study area were downloaded from NOAA for the years 2001 and 2006 (NOAA 2012). The files were imported into ArcGIS v10.0 and exported as raster data. The raster value ranges represent the percent of impervious cover in a raster grid cell. Python coding of the "GreaterThan" command was used to calculate the areas where the density of impervious cover increased. Python coding of the "LesserThan" command was used to calculate the areas where the density of impervious cover decreased. The rasters were converted to vector polygon data layers, and the Calculate Geometry command calculated the total areas of impervious cover change.

RESULTS AND DISCUSSION

The initial research question asked if there had been significant changes in water quality over time in the White Clay Creek (WCC) and Red Clay Creek (RCC) watersheds. The first step was to determine if WCC and RCC

² The USGS monitors data stations infrequently, thus only USGS stations with the number of collection dates greater than 20 were chosen, to assure that enough data points were available for statistical analysis. In addition, monitoring stations within one mile of each other were eliminated. While it was acceptable for monitoring to stop before the NWSRA designation, at least one station in each watershed was monitored from 1970-2011.

streams had similar water quality before the NWSRA designation. Similar conditions would establish a basis for watershed level comparison since population proportion, land use, and population change are also similar. Pre-designation, there was a significant difference between the RCC and the WCC for temperature, specific conductance, and total dissolved solids (Table 1). Water quality indicators were statistically better in the WCC than in the RCC.

Table 1: T-test Results of Water Quality Parameters in the White Clay Creek and Red Clay Creek Watersheds, Pre- NWSRA Designation.

Parameters	Watershed	Mean	SD	Significance
Temp	RCC	5.8	1.06	0.00*
	WCC	5.1	0.76	
SpCd	RCC	289.0	72.66	0.00*
	WCC	236.1	74.77	
DisOxy	RCC	13.4	1.76	0.82
	WCC	13.0	0.63	
pH	RCC	7.4	0.61	0.41
	WCC	7.3	0.30	
TDS	RCC	192.3	35.40	0.00*
	WCC	137.4	35.20	

* indicates significant difference at the 0.10 level.

All variables in both watersheds stayed within the Pennsylvania mandated requirements. Mean water quality conditions statistically significantly worsened in the RCC over time (Table 2). Temperature, specific conductance (SpCd), and total dissolved solids (TDS) increased, while dissolved oxygen (DisOxy) decreased over time. Pre- and post-designation in the WCC, mean values significantly changed and water quality decreased. Temperature, specific conductance, pH, and total dissolved solids all increased, and dissolved oxygen decreased (Table 3).

Table 2: T-test Results of Water Quality Parameters in the Red Clay Creek Watershed, Pre-and Post- NWSRA Designation.

Parameters	Time Period	Mean	SD	Significance
Temp	1970-2000	5.8	1.06	0.00*
	2001-2011	9.1	2.60	
SpCd	1970-2000	289.0	72.66	0.01*
	2001-2011	380.8	58.49	
DisOxy	1970-2000	13.4	1.76	0.08*
	2001-2011	12.2	1.55	
pH	1970-2000	7.4	0.61	0.40
	2001-2011	7.5	0.31	
TDS	1970-2000	192.3	35.40	0.02*
	2001-2011	225.6	13.22	

* indicates significant difference at the 0.10 level

We conclude that there were significant changes in water quality over time. Changes in water quality parameters indicated worsened water quality and in no case did water quality improve. The null hypothesis, H1₀, that there was no significant change in water quality measures between the watersheds over the time period of 1970-2010,

was rejected. The alternative hypothesis, H₁, that there was a significant improvement over the time period of 1970-2010 was also rejected.

The second question asked if water quality significantly changed in the WCC watershed after federal designation as a NWSRA. The t-test results indicate that post-designation water quality declined in the WCC (Table 3). A comparison of the RCC and WCC after NWSRA designation indicates that the WCC had a higher average temperature and pH (Table 4), but specific conductance and total dissolved solids are no longer statistically different between the two watersheds (Table 1, 4). This differs from the numbers pre-designation, in which the RCC values were higher for all parameters and the RCC overall had poorer water quality (Table 1). It appears that water quality significantly changed in the WCC post-designation through the NWSRA, and unfortunately this change may not have been in the form of improved water quality.

Table 3: T-test Results of Water Quality Parameters in the White Clay Creek Watershed, Pre-and Post- NWSRA Designation.

Parameters	Time Period	Mean	SD	Significance
Temp	1970-2000	5.1	0.76	0.00*
	2001-2011	11.3	2.34	
SpCd	1970-2000	236.1	74.77	0.00*
	2001-2011	382.9	25.38	
DisOxy	1970-2000	13.0	0.63	0.00*
	2001-2011	11.8	1.59	
pH	1970-2000	7.3	0.30	0.00*
	2001-2011	7.9	0.32	
TDS	1970-2000	137.4	35.20	0.00*
	2001-2011	221.3	9.10	

* indicates significant difference at the 0.10 level

Table 4: T-test Results of Water Quality Parameters in the White Clay Creek and Red Clay Creek Watersheds, Post- NWSRA Designation.

Parameters	Watershed	Mean	SD	Significance
Temp	RCC	9.1	2.60	0.00*
	WCC	11.3	2.34	
SpCd	RCC	380.8	58.49	0.89
	WCC	382.9	25.38	
DisOxy	RCC	12.2	1.55	0.47
	WCC	11.8	1.59	
pH	RCC	7.5	0.31	0.01*
	WCC	7.9	0.32	
TDS	RCC	225.6	13.22	0.39
	WCC	221.3	9.10	

* indicates significant difference at the 0.10 level

An analysis of land use/land cover showed that there was 6.53km² in 2000, 6.42 km² in 2005, and 6.16 km² in 2010 of riparian buffers. Since 2000, the WCC and the RCC combined lost 0.37 km² of riparian buffer, a percent

change decrease of 5.6% (Table 5). The impervious cover analysis revealed a gain of 1.8 km² of impervious cover throughout the study area (Table 5). The same analysis revealed that impervious cover did not decrease from 2001-2006 in any area, supporting the conclusion that no riparian buffer areas were developed in either watershed since the NWSRA designation.

The WCC and RCC watersheds have experienced similar changes in population, population density, and land use/land cover change (Table 5). The two watersheds are not the exact same size, but are proportionally populated. The population of both watersheds has increased along with a gain of urban and suburban land, and a loss of lands devoted to agriculture, forests, and wetlands (Kauffman et al. 2010). The spatial data analysis concluded that impervious cover increased, while riparian buffers decreased. There is no evidence to support that the WCC watershed has had an increase in stream improving activities or a reduction in stream impairing activities, especially in comparison to the RCC watershed.

Table 5: Changes in Development in the White Clay Creek (WCC) and Red Clay Creek (RCC) watersheds.

	Area (km²)	2000 Pop/km²	2010 Pop/km²	Pop Increase (%)	Urban/ Suburban LULC (%)	Agriculture LULC (%)	Forest/ Wetland LULC (%)
RCC	140	305	345	+10	+7.4	-3.9	-1.1
WCC	277	428	446	+4.2	+5.7	-4.2	-1.3

(Source: Land cover/land use data (Kauffman et al. 2010) Population and Density (U.S. Census Bureau 2012).

The inconsistent monitoring of all water quality parameters from the USGS suggests that additional data from other sources may yield a more complete and detailed understanding of the environmental impacts of the NWSRA in the future. The lack of data to examine nitrogen means that the agricultural impact on water quality was not evaluated. The mushroom farms located in the southeastern region of the county represent the majority of the region’s agricultural products (CCADC 2011). Agriculture can produce high levels of nitrogen and phosphorus, sediments which cause eutrophication in streams and degrade water conditions so uses such as drinking, recreation, and aquatic life are no longer supported (Dodds and Oakes 2008).

Future studies of NWSRA effectiveness on water quality could use this study as a model to assess water quality parameters at regular intervals, perhaps every 5-10 years. This would yield more information about trends over time, shedding light as to whether a significant difference occurs as the study area experiences more urban/suburban development. Also, paired with impervious cover data throughout the entire timeframe of the study, correlation between percent impervious cover and water quality parameters could be evaluated.

CONCLUSIONS

Although Kauffman et al. (2010) found that that the average temperature in the Brandywine-Christina watershed did not increase over the last 15 years, we found that water temperature has significantly increased over the 40 year period in both the RCC and the WCC, an increase that is harmful to aquatic life such as cold water fish and macroinvertebrates (Murphy 2007). The presence of the temperature increase in both watersheds suggests that a temperature increase may have occurred throughout the larger Brandywine-Christina watershed, in spite of NWSRA designation. Since temperature affects other water quality parameters in the study, the degradation of other water quality parameters (specific conductance, DO, and TDS) in both watersheds is not unexpected.

Many sewer overflow points are located in the headwaters of the two watersheds; if an overflow occurred at the time the USGS data were collected, specific conductance and TDS were affected by the overflow into the streams (see Figure 1). Sewer overflow adds additional sediment and debris to streams, increasing parameters which involve measuring sediment. Specific conductance significantly increased in both watersheds over the total time period. TDS is related to specific conductance, but there was no significant change in the RCC over time. However, there was a significant increase in the WCC over the total time period, and the WCC is the watershed with six documented sewer overflow points, as opposed to the RCC’s four points. The greater number of sewer overflow points could have contributed to the significant negative change in TDS numbers in the WCC. Since TDS are a measurement of the amount of solids dissolved in filtered water, the parameter is also influenced by storm water runoff and nonpoint

source pollution. If the streams were sampled during or after a storm, increased levels of sediment would be present in the water. However, the large number of data points negated the influence of any storm-influenced data points during statistical analysis. Although no federally recorded sources of nonpoint pollution lie within the two watersheds, localized sources are likely to exist.

The NWSRA designation did not result in improvement or maintenance of water quality pre-designation levels. Water quality parameters worsened over time, but population density, urban/suburban land use, and impervious cover have also increased since 1970. Without NWSRA designation in the WCC, water quality parameters would likely have worsened at a more severe rate. On the other hand, the NWSRA may not be an effective tool for water quality management at the watershed scale: at the rate that water quality values are worsening, the NWSRA will likely not keep water quality parameters within recommended ranges indefinitely. When WMOs develop a watershed management plan, the interests, needs, and locations of humans in the landscape are ecosystem variables as well as water quality or soil type (Barham 2001). The larger area of the WCC means that more management efforts are necessary, more stakeholders exist, and therefore more complicated collaboration structures exist. WMOs operating in the WCC were aware of but not constricted by the NWSRA. Because many organizations operate within the study area, the competition for grant money and space necessitates cooperation to maximize the impact of separate projects.

Based upon the results of this research, federally led management is not necessarily more effective than municipality controlled management in improving water quality at the watershed scale in the study area. The RCC is home to 6 townships, while the WCC is home to 11 townships (Figure 1). The increased number of townships in the WCC likely is an additional challenge to adequate watershed management. Approximately 35% of the waters in the WCC are impaired, compared to approximately 67% of waters in the RCC (CCWRA 2012), yet water quality conditions are similar in terms of specific conductance, dissolved oxygen and total dissolved solids.

Future studies of NWSRA effectiveness should assess water quality parameters every 10 years instead of only pre- and post-designation. This would yield more detailed data about trends over time, shedding light as to whether a significant difference occurs as the study area experiences more urban/suburban development. An exploration of the watershed management plans in all stages of revision from 1970-present would reveal the strengths and weaknesses of different implementation techniques. Lastly, since much of the land use in the study area is zoned residential, interpretation of water quality data would benefit from the inclusion of septic tank numbers and locations. To maintain and improve water quality in streams, watershed management organizations should develop management priorities that reflect conditions in the entire watershed, while questioning federal designation as a useful management tool.

This study underscores the importance of local watershed management organizations, especially in light of the failure of the NWSRA to consistently improve water quality conditions through federal management. Management priorities that reflect conditions in the entire watershed should be developed to maintain and improve water quality in streams. The study also provides validation in the eyes of local stakeholders to implement stream improvement activities such as riparian buffer establishment. The study may be referenced by WMOs when developing and updating water resources management plans, when applying for funding or grants, and when gaining political support for proposed implementation activities. The study may also facilitate discussion among local WMOs concerning future collaboration opportunities at the Brandywine-Christina watershed scale. A continuance of this study twenty and then thirty years after the NWSRA designation will yield more information about the changing water quality parameters. The results indicate that if the National Wild and Scenic Rivers Act is to be a successful example of cooperative federalism and improvements in water quality, then the relationship, support, and resources of the federal government may need to be further developed. It also appears that simply receiving a NWSRA designation is not enough to improve or maintain water quality over time, but should be viewed as one tool of environmental planning to reduce the negative impacts of development and human settlement patterns.

REFERENCES

- Anonymous. 1991. Wild and scenic river suffers from logging. *National Parks*. 65(11/12):14.
- Babbitt, B. 2005. *Cities in the wilderness: a new vision of land use in America*. Washington, D.C.: Island Press.
- Barham, E. 2001. Ecological boundaries as community boundaries: the politics of watersheds. *Society and Natural Resources* 14:181-191.

- Barscz, C. 2012. Conservation and outdoor recreation: Pennsylvania segment. National Park Service. <http://www.nps.gov/nrcr/programs/rtca/nri/states/pa.html> (last accessed 14 April 2012).
- Bissix, G. and J. A. Rees. 2001. Can strategic ecosystem management succeed in multiagency environments? *Ecological Applications* 11(2): 570-583.
- Burce, S. B. 2008. Wild rivers and the boundaries of cooperative federalism: the wild and scenic rivers act and the Allagash wilderness waterway. *Environmental Affairs* 35: 77-110.
- Chester County Agricultural Development Council (CCADC). 2011. *Mushroom data sheet 2011*. West Chester, PA: Chester County. <http://www.chesco.org/agdev/lib/agdev/pdf/mushroomdatasheet.pdf> (last accessed 14 July 2012).
- Chester County Water Resources Authority (CCWRA). 2012. Water quality improvement. West Chester, PA: Chester County. <http://www.chesco.org/water/cwp/view.asp?a=3&Q=653754&PM=1&waterNav=|>. (last accessed 14 April 2012).
- Clark, B. T., N. Burkardt, and M. D. King. 2005. Watershed management and organizational dynamics: nationwide findings and regional variation. *Environmental Management* 36(2): 297-310.
- Delaware Valley Regional Planning Commission (DVRPC). 2012. Home Page. Philadelphia, PA: Delaware Valley Regional Planning Commission. <http://dvrpc.org/> (last accessed 14 April 2012).
- Dodds, W. and R. M. Oakes. 2008. Headwater influences on downstream water quality. *Environmental Management* 41: 367-377.
- Dunne, T. and L. Leopold. 1978. *Water in environmental planning*. San Francisco: W. H. Freeman and Co.
- Environmental Protection Agency (EPA). 2012a. My WATERS mapper. Washington, DC: EPA. <http://watersgeo.epa.gov/> (last accessed 25 May 2012).
- . 2012b. Watershed assessment, tracking, and environmental results: geospatial data downloads. Washington, DC: EPA. <http://www.epa.gov/waters/data/downloads.html#303%28d%29ListedImpairedWaters> (last accessed 23 March 2012).
- . 2012c. Catalog of watershed groups. Washington, DC: EPA. <http://water.epa.gov/action/adopt/network.cfm> (last accessed 10 April 2012).
- Environmental Studies Board. 1972. *Water quality criteria 1972*. National Academy of Sciences and National Academy of Engineering. Washington, DC: US Government Printing Office.
- Environmental Systems Research Institute (ESRI). 2011. ArcGIS Desktop: Release 10. Redlands, CA: ESRI, Inc.
- Fish and Wildlife Service (FWS). 2012. National wild and scenic rivers system. Burbank, Washington: Fish and Wildlife Service. <http://www.rivers.gov> (last accessed 6 March 2012).
- Gaden, M., C. Krueger, C. Goddard and G. Barnhart. 2008. A joint strategic plan for management of great lakes fisheries: a cooperative regime in a multi-jurisdictional setting. *Aquatic Ecosystem Health & Management* 11 (1):50-60.
- Kauffman, G. J., A. C. Belden, K. J. Vonck, and A. R. Homsey. 2009. Link between impervious cover and base flow in the white clay creek wild and scenic watershed in Delaware. *Journal of Hydrologic Engineering* 14 (4):324-334.
- Kauffman, G. A. Homsey, M. Narvaez, S. Chatterson, E. McVey, and S. Mack. 2010. *Christina basin trends, 1995-2010*. Newark, DE: Water Resources Authority, Institute for Public Administration, University of Delaware. <http://www.ipa.udel.edu/publications/ChristinaBasinTrends.pdf> (last accessed 28 April 2012).

- Megan, M. H., M. S. Nash, A. C. Neale, and A. M. Pitchford. 2007. Biological integrity in mid-Atlantic coastal plains headwater streams. *Environmental Monitoring and Assessment* 124: 141-156.
- Murphy, S. 2007. Boulder area sustainability information network: basin water quality terminology. Boulder, CO: Boulder Community Network. <http://bcn.boulder.co.us/basin/natural/wqterms.html>
- Ou, Y. and X. Wang. 2011. GIS and ordination techniques for studying influence of watershed characteristics on river water quality. *Water Science & Technology* 64 (4): 861-870.
- National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. 2012. National land cover database percent developed impervious surface. Charleston, SC: NOAA. <http://www.csc.noaa.gov/digitalcoast/data/nlcd-impervious/download> (last accessed 1 May 2012).
- Penn State Institutes of Energy and the Environment (PSIEE). 2011. Pennsylvania spatial data access (PASDA). University Park, PA: The Pennsylvania State University. <http://www.pasda.psu.edu> (last accessed 28 June 2012).
- Pennsylvania Department of Community and Economic Development (PDCED). 2003. *Pennsylvania municipalities planning code (Act of 1968, P.L. 805, No. 247)*. Harrisburg, PA: General Assembly of the Commonwealth of Pennsylvania.
- Randolph, J. 2004. *Environmental land use planning and management*. Washington, D.C.: Island Press.
- Rothenberger, M. B., J. M. Burkholder, and C. Brownie. 2009. Long-term effects of changing land use practices on surface water quality in a coastal river and lagoonal estuary. *Environmental Management* 44: b505-523.
- Senior, L. A., and E. H. Koerkle. 2003. US Department of the Interior and US Geological Survey. Simulation of streamflow and water quality in the Christina River subbasin and overview of simulations in other subbasins of the Christina River basin, Pennsylvania, Maryland, and Delaware, 1994-98. *Water-Resources Investigation Report 03-4193*. New Cumberland, PA: USGS. <http://pa.water.usgs.gov/reports/wrir03-4193.pdf> (last accessed 20 April 2012).
- Sirianni, C. 2006. Can a federal regulator become a civic enabler? Watersheds at the U.S. environmental protection agency. *National Civic Review* 95(3): 17-34.
- Stroud Water Research Center. 2012. Stroud water research center. Avondale, PA: Stroud Water Research Center. <http://www.stroudcenter.org>
- U.S. Census Bureau. 2012. State & county quick facts. Washington, DC: United States Census Bureau. <http://quickfacts.census.gov>.
- U.S. Geological Survey (USGS). 2012. Water quality standards for HUC=02040205. Baltimore, MD: USGS. <http://nwis.waterdata.usgs.gov/usa/nwis/>.
- University of Delaware (UD). 2012. Christina Basin Clean Water Partnership. Newark, DE: University of Delaware. <http://www.wra.udel.edu/publicservice/regionalwatershedmanagement/christinabasinpartnership>
- Zampella, R. A., N. A. Procopio, R. G. Lathrop, and C. L. Dow. 2007. Relationship of land-use/land-cover patterns and surface-water quality in the Mullica river basin. *Journal of the American Water Resources Association* 43 (3):594-604.