

Timothy F. Tresohlavy. STORMWATER RUNOFF IN NORTH CAROLINA'S TAR-PAMLICO RIVER BASIN: ANALYZING THE POTENTIAL FOR RUNOFF AND STAKEHOLDER PERCEPTIONS OF URBAN STORMWATER RULES. (Under the direction of Dr. Thomas W. Crawford) Department of Geography, April, 2006.

This research examines urban stormwater runoff in the context of its potential for degrading water quality. The purpose of this analysis is two-fold, to visualize the spatial pattern of indicators for stormwater runoff in the Tar-Pamlico River Basin, and to collect primary data of attitudes and perceptions from stakeholders relating to state-mandated urban stormwater rules. Analyzing the spatial pattern of stormwater indicators involves a multi-criteria evaluation (MCE), a geographical information system (GIS)-based method to create index scores for four secondary data layers. The index was aggregated at five levels of analysis, including both human-imposed and natural boundaries. A survey instrument was developed, and a directed sampling method was employed, to gather perspectives from diverse stakeholders of stormwater regulation in the basin. Interviews with public and private sector stakeholders contribute qualitative data to the survey and provided unexpected findings relating to economics and leadership.

Results from the MCE indicate that areas of greater stormwater runoff potential are associated with large urban areas, and few smaller municipalities located adjacent to major thoroughfares. Results from the survey and interviews suggest that stakeholder attitude and perceptions of stormwater vary spatially and demographically. Locations with greatest potential for stormwater runoff are not necessarily linked with unified perceptions of urban stormwater program regulation. Major findings from interviews with stakeholders suggest that the goal of more and better local government planning has yet to be realized because of perceptions relating to a lack of leadership roles.

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RIVER BASIN: ANALYZING THE POTENTIAL FOR RUNOFF AND
STAKEHOLDER PERCEPTIONS OF URBAN STORMWATER RULES

A Thesis
Presented to
the Faculty of the Department of Geography
East Carolina University

In Partial Fulfillment
Of the Requirements of the Degree
Master of Arts in Geography

by
Timothy F. Tresohlavy
April, 2006

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by

Timothy F. Tresohlavý

APPROVED BY:

DIRECTOR OF THESIS: _____



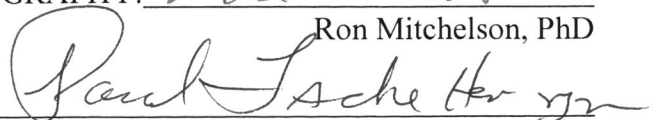
Thomas W. Crawford, PhD

CHAIR OF THE DEPARTMENT OF GEOGRAPHY: _____



Ron Mitchelson, PhD

DEAN OF THE GRADUATE SCHOOL: _____



Paul Tschetter, PhD

DEDICATION

To my daughter, Madison Marie Tresohlavy

Experiencing the most precious moments of your life have been my inspiration for enduring the enormity of labor and sacrifice required for my graduate degree program.

Without your endless love and enduring faith in me, this process may have seemed unattainable. This product is unconditionally dedicated to you, from father to daughter.

Beyond question, you will remain the most cherished person of my life. You are my daily passion and inspiration. Thank you for your ever-present smile.

ACKNOWLEDGEMENTS

Much appreciation is extended to the faculty of the Geography Department at East Carolina University, who have individually and collectively helped to form and shape my character into a candidate who is worthy of this degree.

My fellow graduate student colleagues also deserve acknowledgement for sharing in my experience, and allowing me to contribute to theirs. Thank you for the support and love that you've shown me.

Many thanks are extended to my coworkers at the Pitt County Planning Department, whom I've worked with throughout the entirety of my graduate school program.

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1.0. Introduction

This thesis identifies areas within the Tar-Pamlico basin that possess characteristics relating to increased stormwater runoff potential. This research also analyzes attitudes and perceptions of stormwater regulation from public and private sector stakeholders. A clarification of the problems associated with stormwater runoff is necessary to provide a contextual background prior to the presentation of research questions that have guided this study.

1.1. The problem of stormwater

Rainfall that does not infiltrate into the ground will follow the path of least resistance downslope, and is referred to as stormwater runoff. Impervious surfaces across the urbanized landscape reduce the amount of natural infiltration, and directly affect the generation of stormwater. The total amount of impervious surfaces increases as an urban area further develops, as does the volume of stormwater generated by a typical rain event. Development pressure resulting from an uncontrolled growth pattern contributes to the stormwater problem by constructing excessive impervious surfaces and allowing their placement in environmentally-sensitive areas, such as flood-prone areas near existing stream channels. In summary, impervious surfaces of urban environments and population growth will generate additional quantity (or volume) of stormwater runoff.

The flow of water across impervious surfaces of an urban landscape mobilizes pollutants from parking lots, roadways, and sidewalks, routing them into the storm sewer collection network. This system consists of curb and gutter inlets (Figure 1-1), and is

designed to quickly remove stormwater from parking lots, which further exacerbates stormwater problems by directly discharging polluted runoff into a nearby water body without treatment. The constant addition of pollutants that have been mobilized by stormwater runoff degrades the quality of surface waters, which is necessary for aquatic health, ecological integrity, and human use. North Carolina's seafood industry is dependent upon the quality of its water resources, not to mention the fact that municipal drinking water is withdrawn from surface waters across the state. Additionally, water-based recreation is an important aspect of the economy for Coastal North Carolina and the Outer Banks region, and is also dependent upon the quality of its waters for human use. In summary, pollutants carried by stormwater runoff degrade water quality (or purity), which we depend on for varying human and ecological purposes.

Figure 1-1: Typical curb inlet



Regulating stormwater runoff requires multi-tiered legislation from the federal, state, and local governments in order to protect water quality for an entire river basin. A review of water quality legislation is provided in the literature review section, and the scaled approach to stormwater regulation in the Tar-Pamlico basin is discussed further in

this thesis. Administrating stormwater regulations in the Tar-Pamlico (and other) basin(s) is made more problematic because the natural hydrologic boundaries do not align with human-imposed political boundaries. Therefore the jurisdiction of stormwater rules involve governments of varying size (town, city, county), some of whom may be located in different states depending upon scale (catchment, subwatershed, watershed, subbasin, basin). In summary, strategies for mitigating stormwater-related impacts are strained by coordination problems with multiple jurisdictions, and at multiple scales. The issue of scale is further discussed in this research by conducting a five-level, GIS-based, analysis of a multivariate stormwater runoff potential index.

The State of North Carolina recognizes that non-point source pollution of streams by stormwater runoff across urban landscapes has been, and will continue to be, a leading threat to water quality degradation. The state has created a non-point source planning unit of the Division of Water Quality, and administers the North Carolina State Storm Water Program for coastal areas and areas of high-quality/outstanding resource waters. The state has passed urban stormwater requirements for 11 local governments in the Tar-Pamlico basin, however, the remaining portions of the basin are unregulated. Basinwide water quality monitoring of each stream in the Tar-Pamlico basin is ongoing as required by the Federal Clean Water Act. Additionally, monitoring of nutrient loading (a significant stormwater pollutant) to the Pamlico Sound (located at the mouth of the Tar River) is continuous, the results of which have helped to shape the requirements of stormwater rules in the basin. This analysis of stormwater runoff potential is important and unique

because it identifies and ranks areas that possess the characteristics of increased runoff, thereby suggesting locations where future upstream monitoring should take place.

Varying attitudes with regard to state-mandated stormwater regulation in the Tar-Pamlico basin may contribute to unequal commitment and involvement with the success of the program. A high-level of commitment to the stormwater regulations on behalf of some public sector administrators may strengthen the awareness and perception of the stormwater problem for other stakeholders in the area, and contribute to the overall success of the program. The survey analysis component of this research collects primary data to discover whether stakeholder attitudes and perceptions are geographically and/or demographically related. Surveying the perceptions of these influential actors has yet to be attempted for this study area. Findings could further suggest locations within the basin where administering a local-government stormwater program may be more challenging due to variation in attitudes and perceptions of stakeholders. Interviews conducted with public and private sector stakeholders contribute to this analysis by gathering data relating to why stakeholders may disagree, and what common ground issues they may share. Geographically linking the potential for runoff with stakeholder perceptions has, likewise, yet to be attempted for the study area, and further demonstrates the need for this research.

1.1.1. Research questions

The specific research questions that have guided this study are:

- (1) What is the spatial pattern of indicators for stormwater runoff *potential* in the Tar-Pamlico basin?;
 - a. How does this pattern vary between human-imposed versus natural boundaries of scale?;
- (2) Do attitudes and perceptions on stormwater regulation issues vary geographically and/or demographically in the basin?;
 - a. Are areas of greater stormwater runoff *potential* in the Tar-Pamlico basin linked with unified perceptions on stormwater regulation?

Answering the first research question through a GIS-based analysis may lead to a better understanding of the indicators of stormwater runoff in the study area, and have policy implications to appropriately monitor and regulate stormwater runoff. Answers to this question also contribute to the analysis of stakeholder attitudes and perceptions by identifying areas where greater concern for stormwater runoff may exist.

Any such scale-dependent analysis is subject to the modifiable unit area problem, further explained in the methods section. Conducting this analysis at varying natural and human-imposed levels (municipal, block group, hydrologic unit code (HUC), county, and subbasin) will mitigate the scale and aggregation problems. Lee and Heaney (2003) conducted an analysis at five levels of detail to demonstrate the cost-effectiveness of GIS modeling of impervious areas for local government applications. A multi-criteria evaluation (MCE) weighted linear combination (WLC) method is selected to formulate a multivariate index of stormwater potential in much the same manner as Robbins and Birkenholtz (2003), and Stone (2004), who also evaluate imperviousness. It is my

hypothesis that the spatial pattern of runoff potential for this relatively rural basin will identify the few large urban centers such as the cities of Greenville and Rocky Mount. The remaining areas of the basin will more than likely be indistinguishable because of their present-day rural-agricultural characteristics. This fact did not escape the rule-makers for the Tar-Pamlico Urban Stormwater Rules, who mandated these requirements to only 11 of the total 72 local governments in the basin. I further expect to find significant variation between analysis scales, due to the problems associated with aggregating data to larger units of observation.

Answers to the second research question will be important for establishing a barometer for stormwater program success. Identifying demographic characteristics or geographic locations where stakeholder attitudes and perceptions vary could inform state policy makers as to which groups or areas are in need of additional resources (financial or information varieties). The state stormwater educational outreach coordinator will most likely be interested in the findings of this survey in order to coordinate campaign strategies to increase awareness. Existing surveys of stormwater awareness generally involve the attitudes and beliefs of private citizens, and findings suggest that many citizens are misinformed or simply unaware of the stormwater problem. A 2005 survey of North Carolina residents found that 38% of respondents knew that stormwater is untreated, while 29% incorrectly believed that it receives some form of treatment. The survey also found that activities such as washing a car on the street, improperly disposing of used motor oil, over-fertilizing lawns, and failing to remove pet's waste from impervious surfaces were common practices and relatively unrelated to stormwater

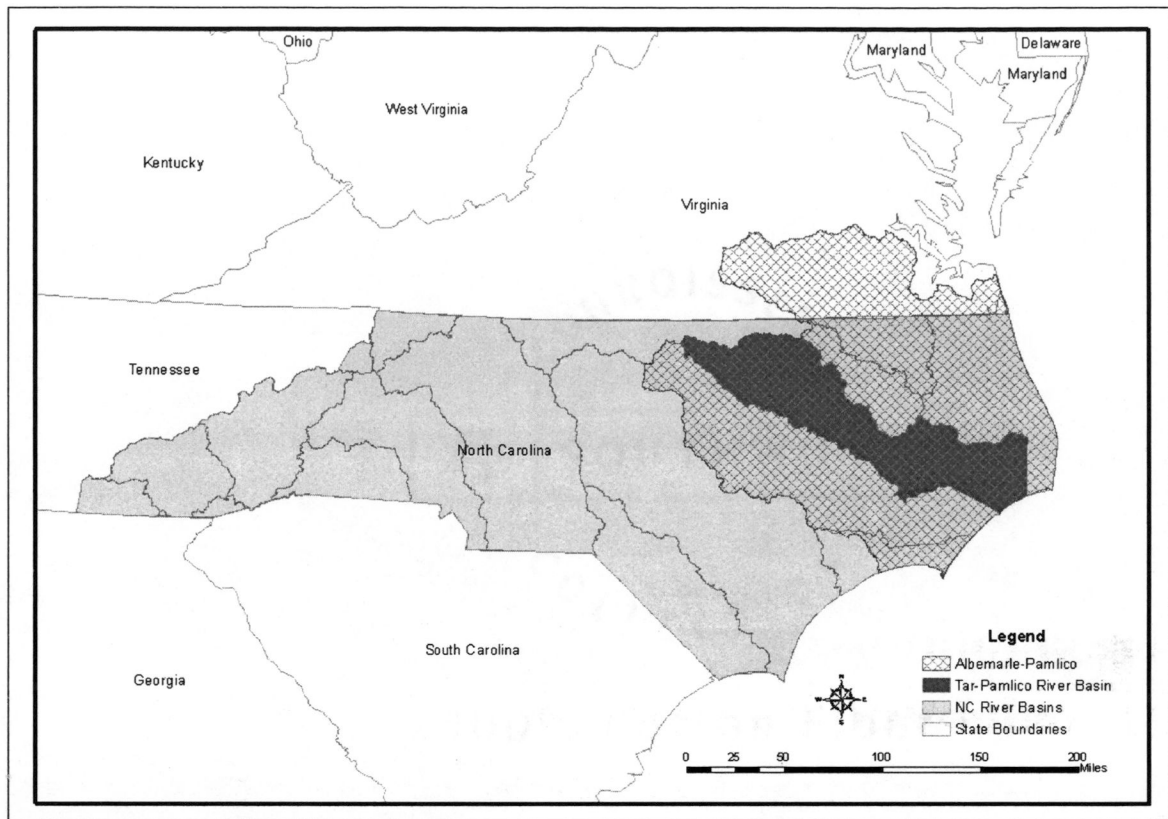
problems. Lastly, the aforementioned survey of North Carolina residents did not find correlations between increased stormwater awareness and demographics such as education level, gender, or age. Because of these and similar findings relating to a lack of citizen awareness, this research focuses on the attitudes and perceptions of informed stakeholders of the Tar-Pamlico Urban Stormwater Rule. Norton (2005) surveyed stakeholders of the North Carolina Coastal Area Management Act (CAMA) requirements, just as I am surveying stakeholders of the urban stormwater rules. Findings from Norton's study indicate that the concept of 'more and better local planning' is unrealized because local government administrators are more likely to complete the state-mandated minimum requirements rather than adopt local development strategies. I expect to find similar perceptions on behalf of the stormwater stakeholders. Furthermore, I expect to find attitudes and perceptions with little variation between age demographics, however, I anticipate significant variation between employment sector demographics (public versus private sector). I also expect to find geographic variation between stakeholders located near a rapidly developing urban area such as Greenville, versus stakeholders located in areas that are not experiencing growth. Interviewing stakeholders provide an opportunity to inquire *why* attitudes and perceptions may vary. A content analysis will be conducted from these interviews to add a qualitative component to the quantitative survey trends. I anticipate that interviews with public sector stakeholders will focus on the optimistic side of the stormwater regulations, whereas the private sector stakeholders will focus more on the pessimistic aspects of these regulations.

1.2. Study area

This section presents some of the human and natural assets of the Tar-Pamlico basin as well as a background of characteristics that demonstrate its value to the citizens of the region. The intent is to provide a context for the study area and explain why protection of its resources is important.

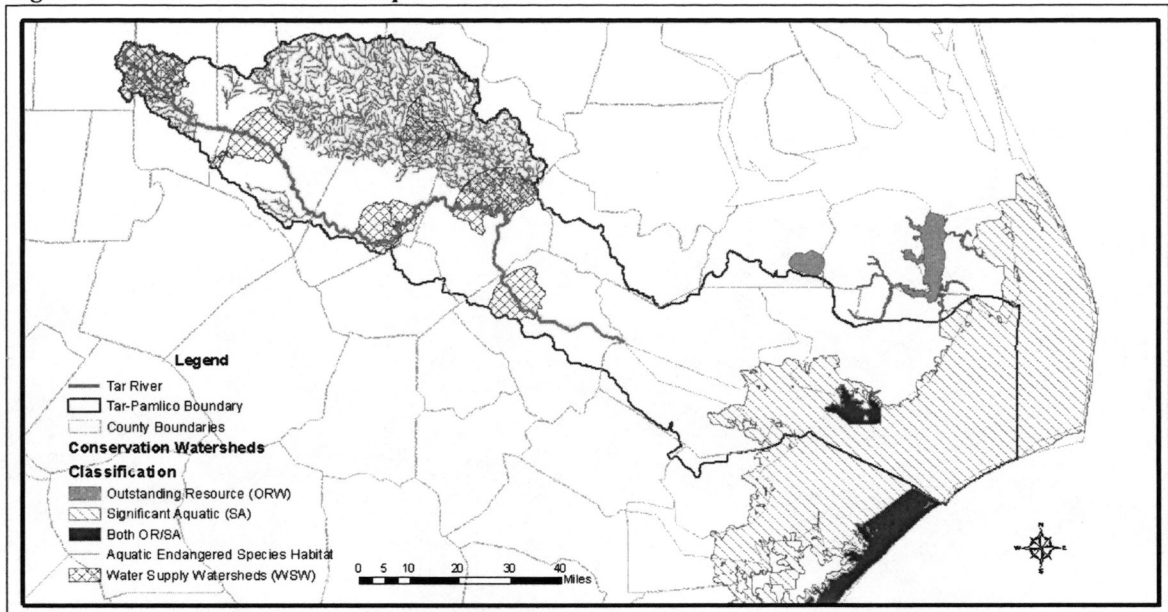
The Tar River begins in the northeast section of North Carolina's piedmont region, and flows 180 miles southeast to the Pamlico Sound (US Geological Survey, 1985; North Carolina, 2002). The basin includes 2,335 miles of streams that are part of the larger Albemarle-Pamlico Estuary (Figure 1-2), which is the second largest estuary system in the United States (North Carolina, 2002), behind the Chesapeake (including the states of NY, PA, WV, MD, and VA). The Tar River supplies freshwater to the highly productive Pamlico Sound, the source of 90% of all commercial seafood harvested in the state (North Carolina, 2002). Protecting the sound involves limiting potential sources of pollutants from any and all upstream locations, which is a fundamental concept in watershed protection, yet often overlooked. Figure 1-3 displays the location of significant water resources in the basin, which includes classified outstanding resource (OR) waters, significant aquatic (SA) waters, endangered species habitats, and watersheds associated with municipal drinking water supply watersheds (WSW). To recap, the Tar-Pamlico basin is a part of a larger estuary, and is productive for harvesting seafood, which is a significant portion of the state economy.

Figure 1-2: The Albemarle-Pamlico Estuary & Tar-Pamlico River Basin



There are additional resources that help make this river basin unique and valuable, such as state and federally protected lands and species. Three designated National Wildlife Refuges: Lake Mattamuskeet, Pocosin Lakes, and Swan Quarter, lie partially or entirely within the Tar-Pamlico basin. There are also a total of 14 public conservation lands, and more than 100 listed natural areas according to the North Carolina Natural Heritage Program (NCNHP, <www.ncnhp.org/index.html>; North Carolina, 2004). These features contribute to the heritage of the region, and reflect the relative ecological health of its waters.

Figure 1-3: Tar-Pamlico Basin Aquatic Resources



Land Cover

Another unique characteristic of the Tar-Pamlico basin is its rural-agricultural setting. According to the North Carolina Center for Geographic Information and Analysis (CGIA), the forest or wetlands land cover is predominant (43.5 percent) in the Tar-Pamlico study area, however agriculture comprises just under one-quarter (23 percent) of the region (Table 1-1). This explains why the state's largest tobacco-producing county (Pitt) and the largest producer of corn, wheat, and sorghum (Beaufort) are both located within the Tar-Pamlico river basin (North Carolina, 2002). Five percent of the basin falls under the urban/developed land cover classification (including roads, highways, and interstates) as of 2001. In summary, agriculture has been a predominant industry for the region, however land cover changes (Table 1-1) indicate that forest/wetlands, and cultivated cropland are declining while the urban land cover type increasing.

Table 1-1: USGS & NC CGIA Land Cover Categories for the Tar-Pamlico River Basin			
	USGS MLRC	NC CGIA*	USGS MLRC
Land Cover Classification	% of 1992	% of 1993-1995	% of 2001
Urban	1.8	1	5.4
Cultivated Cropland	25.2	22	23.0
Pasture/Managed Herbaceous	0.0	3	8.5
Forest/Wetland	52.7	54	43.5
Water	19.3	20	19.2
Other	1.0	0	0.3
Data sources: USGS Land Cover Inventory (MRLC Consortium); *As displayed in North Carolina (2004)			

Population

There are 414,242 residents *entirely within* the basin as of 2000 Census (North Carolina, 2004). An additional 321,074 citizens reside within counties of the Tar-Pamlico basin (Table 1-2), however not within the basin itself because political boarders do not follow these natural (hydrologic) boundaries. There are a total of 18 counties that lie partially or entirely within the basin. Population estimates for these counties are projected to increase by 23% (735,316 to 906,058 citizens) by 2020 (North Carolina, 2004). Population growth trends according to hydrologic boundaries are displayed in Table 1-3, which show that the relatively rural Tar-Pamlico basin has already grown by 13.5% between 1990 and 2000. This population growth has, and will continue to, impact both drinking water supplies and wastewater discharges. The Tar River is the drinking water supply for the cities of Rocky Mount (56,309 residents), Tarboro (10,841 residents), and Greenville (67,499 residents) (US Geological Survey, 1985; population estimates from 2004 NC Office of State Planning <http://demog.state.nc.us/>). There are a total of 51 registered surface water withdrawals from the basin as of 2004 (North Carolina, 2004). These withdrawals are primarily made for municipal (drinking water) and agricultural

(irrigation) purposes. Previous and projected growth estimates indicate that the urbanization process is occurring in this rural basin, which have ramifications for stormwater runoff pollution and degraded water quality.

Table 1-2: Tar-Pamlico River Basin Counties*					
County Name	Location	2004 Pop	2000 Pop	Growth	% Growth
<i>Beaufort</i>	Lower	45,860	44,958	902	2.0
Craven	Lower	91,980	91,523	457	0.5
Dare	Upper	34,248	29,967	4,281	14.3
<i>Edgecombe</i>	Upper	53,916	55,606	-1,690	-3.0
<i>Franklin</i>	Upper	52,882	47,260	5,622	11.9
Granville	Upper	52,942	48,498	4,444	9.2
Halifax	Upper	56,476	57,370	-894	-1.6
Hyde	Lower	5,642	5,826	-184	-3.2
Martin	Lower	24,702	25,546	-844	-3.3
<i>Nash</i>	Upper	90,712	87,385	3,327	3.8
Pamlico	Lower	13,074	12,934	140	1.1
Person	Upper	36,985	35,623	1,362	3.8
<i>Pitt</i>	Lower	141,508	133,719	7,789	5.8
Tyrell	Lower	4,174	4,149	25	0.6
Vance	Upper	43,829	42,954	875	2.0
Warren	Upper	20,074	19,972	102	0.5
Washington	Lower	13,480	13,723	-243	-1.8
Wilson	Upper	76,414	73,811	2,603	3.5
<i>Total</i>		<i>858,898</i>	<i>830,824</i>	<i>28,074</i>	<i>2.6</i>
* No county is <i>entirely</i> within the Tar-Pamlico Basin					
<i>Italics</i> denote a county involved in the Tar-Pamlico (Nutrient Strategy) Stormwater Rule					
Data source: NC Office of State Planning (http://demog.state.nc.us/)					

Table 1-3: North Carolina River Basin Statistics									
Basin	Area (mi ²)	1990 Pop	Rank	2000 Pop	Rank	% Pop Change	Rank	% of total pop	Pop density (per mi ²)
Broad	1,513	169,001	10	230,864	9	36.6	3	2.9	153
Cape Fear	9,419	1,465,451	1	1,833,701	1	25.1	6	22.9	200
Catawba	3,285	1,033,347	3	1,170,512	4	13.3	13	14.6	356
Chowan	1,378	62,474	13	61,034	13	-2.3	15	0.8	44
French Broad	2,830	357,932	6	392,906	6	9.8	14	4.9	139
Hiawassee	644	26,723	15	331,271	15	17.0	10	0.4	49
Little	1,797	67,083	12	79,493	12	18.5	9	1.0	44
Lumber	3,336	259,539	8	298,296	8	14.9	11	3.7	89
Neuse	6,235	1,015,511	4	1,353,617	3	33.3	4	16.9	217
New	752	53,662	14	49,653	14	-7.5	16	0.6	66
Pasquotank	3,635	97,215	11	118,912	11	22.3	8	1.5	33
Roanoke	3,503	263,691	7	335,194	7	27.1	5	4.2	96
Savannah	172	3,950	17	11,482	17	190.7	1	0.1	67
Tar-Pamlico	5,571	364,862	5	414,242	5	13.5	12	5.2	74
Watauga	205	16,083	16	23,676	16	47.2	2	0.3	115
White Oak	1,264	193,813	9	150,501	10	-22.3	17	1.9	119
Yadkin/ Pee-	7,221	1,193,353	2	1,463,535	2	22.6	7	18.3	203
<i>Totals</i>	<i>52,760</i>	<i>6,643,690</i>		<i>8,018,889</i>		<i>27.0</i>		<i>100.2</i>	<i>121</i>
Data sources: As displayed in NC Basins Stats (NCDENR-DWQ); NC CGIA: basin area estimates; NC Office of State Planning (http://demog.state.nc.us/): population estimates									

Urbanization

The relatively rural Tar-Pamlico basin has experienced positive population growth since 1990, and the degradation of water quality resources is inherently linked to economic and developmental growth because of the stormwater runoff process (section 1.1). Studies have shown that urbanization negatively affects stream ecology by allowing direct transportation of non-point source pollutants by stormwater runoff, resulting in water quality problems (EPA, 2000; Wang, 2001). Stormwater runoff is a primary source of nutrient pollution to streams, lakes, and estuaries. Rainfall that does not infiltrate because of the existence of impervious surfaces will mobilize nitrogen and phosphorus from indiscrete locations. The Tar and Neuse rivers of eastern North Carolina have received high levels of nutrient loadings for decades through the stormwater process, and were categorized as ‘nutrient-sensitive’ by the North Carolina Environmental Management Commission (NCEMC) (Mallin et al., 2000) in 1989. Conditions of low dissolved oxygen levels, in part due to excessive algae growth stimulated by the presence of these nutrients, and numerous fish kill events (Table 1-4), are evidence of nutrient sensitive waters. These indicators are commonly observed in these two basins (Stow et al., 2001; Whitall et al., 2003), suggesting that stormwater runoff in this rural landscape has affected aquatic and ecological health. Additional sources of water quality pollutants (bacteria, viruses and heavy metals) are attributed to wastewater treatment plants (Andreen, 2004) that are overwhelmed by rapid population growth or a lack of facility upgrades. A significant problem of the rural Tar-Pamlico basin also includes nutrient pollution resulting from runoff across agricultural and animal feeding operations.

Table 1-4: North Carolina Fish Kill Events per Basin (1996-2004)

Basin	Area (mi ²)	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
Broad	1,513	0	0	0	1	0	0	0	0	0	1
Cape Fear	9,419	21	16	23	14	12	5	8	3	1	103
Catawba	3,285	0	3	1	3	2	4	1	0	1	15
Chowan	1,378	2	2	1	1	0	1	2	2	1	12
French Broad	2,830	0	2	3	1	0	0	1	1	0	8
Hiawassee	644	0	0	0	0	0	0	0	0	0	0
Little Tennessee	1,797	0	0	0	0	0	0	0	0	0	0
Lumber	3,336	4	3	5	0	2	0	0	2	1	17
Neuse	6,235	14	12	8	16	23	37	9	21	8	148
Pasquotank	3,635	10	2	8	2	0	1	6	2	0	31
Roanoke	3,503	2	0	1	0	0	0	0	2	1	6
Savannah	172	0	0	0	0	0	0	0	0	0	0
Tar-Pamlico	5,571	3	6	5	11	14	23	8	6	2	78
Watauga/New	957	0	0	0	1	0	0	0	2	0	3
White Oak	1,264	3	3	1	3	3	3	3	0	0	19
Yadkin-Pee Dee	7,221	1	10	2	1	2	3	8	2	3	32
<i>Annual Total</i>	<i>52,760</i>	<i>60</i>	<i>59</i>	<i>58</i>	<i>54</i>	<i>58</i>	<i>77</i>	<i>46</i>	<i>43</i>	<i>18</i>	<i>473</i>
Data sources: NCDENR-DWQ Fish Kill Reports (http://www.esb.enr.state.nc.us/Fishkill/fishkillmain.htm)											
NC CGIA: basin area estimates											

Collectively the characteristics of the basin discussed above (land cover and population change, as well as urbanization) suggest that the Tar-Pamlico basin is on the verge of more large-scaled growth. This growth potential will definitely increase the amount of impervious surfaces in the basin and likely contribute to the problem of stormwater runoff. This thesis addresses research questions that will aid in the pro-active management of stormwater runoff for this relatively rural basin.

1.3. Outline of thesis

Chapter two of this research reviews the scaled-approach to water quality legislation from the federal, state, and local governments. This chapter also provides additional context for stormwater runoff dynamics, structural best management control structures, and non-structural planning strategies that reduce the generation of stormwater. Chapter three introduces the methodology behind the multi-criteria

evaluation (MCE) GIS-based runoff *potential* index, and addresses the considerations for scale issues. Chapter three also presents the creation, administration, and analysis of the survey instrument to gather data from stakeholders, as well as the interview content analysis. Chapter four presents the major findings from the MCE, which suggest that development pressure from Raleigh is influencing development areas within the basin. This chapter also presents the impact of scale on the analysis of stormwater potential. The next portion of chapter four addresses the *disconnect* between the goals of stormwater regulation and the application of the state-mandated Tar-Pamlico Urban Stormwater Rules. This disconnect must be overcome in order for the stormwater program to be successful. Increased local-government leadership and a redefinition of ordinance administration for the purposes of reconnecting the varying stakeholders are proposed.

2.0. WATER QUALITY & STORMWATER LITERATURE REVIEW

2.1. Existing legislation

Protecting the quality of water for all surface waters of the United States is certainly a daunting task, one that must maximize individual freedoms while restricting activities that contribute to degradation. Strict regulation of direct pollutant sources is necessary, as is the ability of the law to remain flexible across differing landscapes and political climates. This is precisely what was provided through the Federal Clean Water Act, which crafted the mechanism for national-, state-, and local-scaled water quality protection strategies. This section introduces scaled water quality protection programs in North Carolina that stem from this single piece of legislation.

Federal CWA

The Federal Water Pollution Control Act Amendments of 1972, commonly referred to as the Clean Water Act (CWA), nationalizes the business of water quality protection (Andreen, 2004). The goal of the CWA is to protect and/or restore all surface waters to fully support aquatic life and human use, such as recreational swimming, fishing, or commercial harvesting. A significant program created under authority of the CWA involves the regulation of certain point source dischargers, known as the Federal NPDES Permitting Program.

NPDES Permitting Program

The National Pollutant Discharge Elimination System (NPDES) program was created in 1972 from authority granted by the Clean Water Act. The purpose of this program is to establish permit requirements for public (municipal wastewater treatment plants) and private (industry and agricultural operations) surface water discharges (refer to Table 2-1 for the number of permits per NC river basin). Strategies for lowering the pollution contents of wastewaters involved mandating the use of an industry's 'best-available technology,' which is a technique referred to as command-and-control regulation. The requirements set forth in each discharge permit were crafted to provide minimum standards for water quality while allowing for more stringent standards of a local river or lake (if they exist) to be enforced. Thus it can be said that the NPDES program infused "technology-based limitations and environmental quality-based standards" to protect and restore water quality (Andreen, 2004).

The design of this federal program, however, required its delegation to the state-level, where additional programs are created in support of the CWA goal. The Division of Water Quality (DWQ), which is a section of the Department of Environment and Natural Resources (NCDENR), is the delegated agency for administration of the NPDES program for North Carolina since 1975 (Eaker, 1994). The DWQ is the primary state agency with respect to water quality protection in North Carolina, although other NCDENR divisions administer programs that can protect water quality, such as the Division of Land Resources (DLR), and the Division of Coastal Management (DCM).

Table 2-1: North Carolina NPDES Permits per Basin			
Basin Name	# of Permits	Area (mi²)	2000 Population
Broad	44	1,513	230,864
Cape Fear	260	9,419	1,833,701
Catawba	207	3,285	1,170,512
Chowan	11	1,378	61,034
French Broad	133	2,830	392,906
Hiawassee	10	644	31,271
Little Tennessee	40	1,797	79,493
Lumber	51	3,336	298,296
Neuse	149	6,235	1,353,617
New	16	752	49,653
Pasquotank	34	3,635	118,912
Roanoke	81	3,503	335,194
Savannah	16	172	11,482
Tar-Pamlico	67	5,571	414,242
Watauga	28	205	23,676
White Oak	47	1,264	150,501
Yadkin- Pee Dee	231	7,221	1,463,535
<i>Totals</i>	<i>1425</i>	<i>52,760</i>	<i>8,018,889</i>
Data sources: NC CGIA BasinPro 8 (2004); NC Office of State Planning			

2.1.1. Scaled approach

There have been a variety of water quality programs created and administered by NCDENR over the past three decades. These programs address specific water quality issues, such as soil erosion and sedimentation control, drinking water supply protection, or stormwater management for nutrient control. Each set of rules is applied for different jurisdictions across the state, and administered by different divisions of the NCDENR (Eaker, 1994; NCDENR website <http://h2o.enr.state.nc.us/>). This jurisdictional fragmentation makes the already daunting task of water quality protection even more challenging. This sub-section introduces five of these programs, which are presented chronologically. The recurring theme of these programs is the governmental scale approach taken, whereby the federal initiative is translated to state programs, and often to local government

administration at the county and municipal level. The Tar-Pamlico Nutrient Strategy – Urban Stormwater Rule is one such program relevant to the study area of this research.

Sedimentation & Pollution Control Act

The North Carolina Sedimentation and Pollution Control Act (SPCA) of 1973 is a state-initiated program that directly involves the CWA's goal of fully supportive waters. The preamble of this act states that sedimentation from construction sites and road maintenance is a "major pollution problem" for the state. Continuing development of this nature, the preamble explains, will only intensify this pollution, which is characterized as a threat to public health and welfare (North Carolina General Statute, 1973). The SPCA requires minimum control standards for land-disturbing activities greater than one acre in size. The requirements include prior approval of a soil erosion and sedimentation control plan, which outlines the sequence of construction in relation to strategies aimed at limiting on-site soil erosion and eliminating off-site sedimentation by way of stormwater runoff.

The SPCA is administered by the Land Quality Section of the Division of Land Resources (DLR), which is a sector of the NCDENR. The act establishes guidelines for the adoption of a local government ordinance so that the minimum state requirements can be administered locally. This delegation allows for improved administrative efficiency, and flexibility of the program, while supporting federal clean water goals.

Coastal Area Management Act

The Federal Coastal Zone Management Act authorized North Carolina's Coastal Area Management Act (CAMA) of 1974. This state legislation applies *only* to the 20 designated 'Coastal Counties' in North Carolina (Figure 2-1). The goals of the CAMA are to preserve and manage the natural coastal environment (including estuaries, dunes, and beaches), while maintaining the "orderly and balanced use of coastal resources on behalf of the people of North Carolina and the nation" (North Carolina General Statute, 1973; Norton, 2005). The Act established a permitting system to enforce requirements on proposed developments that may affect areas of environmental concern, such as estuaries, the ocean, groundwater supplies, dunes, channels, and numerous other coastal features.

This act is administered by the Division of Coastal Management (DCM), another sector of NCDENR, albeit separate from the Division of Water Quality (DWQ) or Division of Land Resources (DLR). The CAMA does not include guidelines for local government administration however, since there are only 20 coastal counties that fall under its jurisdiction.

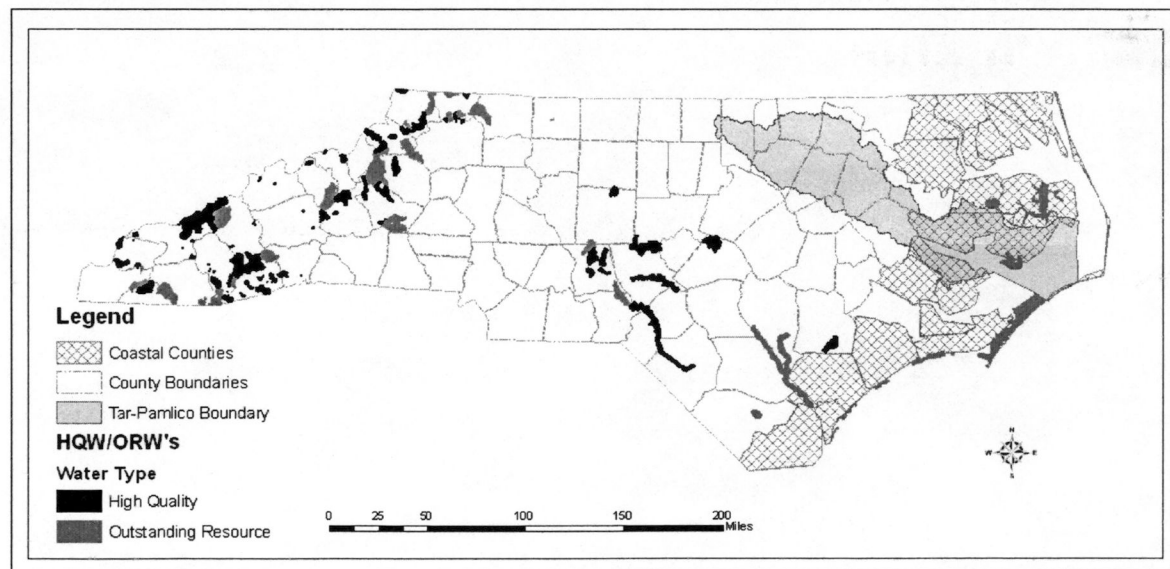
The State Stormwater Management Program

The North Carolina Environmental Management Commission (EMC) created the State Stormwater Management Program (SSWMP) in the 1980s to unify the SPCA and CAMA regulations for environmentally sensitive waters. This program establishes guidelines for future development in (1) each of the twenty coastal counties, and/or (2) watersheds of classified Outstanding Resource Waters (ORW) or High Quality Waters

(HQW) (Figure 2-1). Projects that require either a soil erosion and sedimentation control permit or a CAMA major permit *and* are located in one of the above mentioned areas (coastal counties or ORW/HQW) are subject to low-density development requirements (Eaker, 1994). Percent of impervious surface is a primary component of these restrictions because stormwater quantity and surface water quality is largely affected by local imperviousness (Schueler, 1994; Miltner et al., 2004). The maximum allowable percentage of impervious surface (12-30% of total project area) is flexible depending upon the water quality classification of the receiving stream.

The DWQ administers this program across North Carolina. As with the CAMA, there are no guidelines for a local government stormwater management program because there are relatively few territories dispersed across the state that are subject to these requirements.

Figure 2-1: Jurisdiction of the State Stormwater Management Program (SSWMP)



Tar-Pamlico Nutrient Strategy

Nutrient-related water quality issues in the Tar-Pamlico basin, discussed previously, led to its classification as nutrient sensitive waters by the North Carolina Environmental Management Commission (EMC). A strategy to reduce inputs of nutrients (nitrogen and phosphorus) was developed for the basin as a result. The EMC initially contemplated applying a technology-based standard for nutrient reduction, similar to the protocol of the CWA. An alliance of dischargers and two environmental groups (the Environmental Defense Fund, and the Pamlico-Tar River Foundation) approached the state soon after, proposing an innovative point source/non-point source trading program. In 1989, an agreement was reached between the DWQ, the environmental groups, and the discharger's association to reduce nutrient loading to the Pamlico estuary. This reduction allowed for two methods of reduction, (1) set an annually reducing cap for nutrient loading; or if the cap could not be reached, (2) pay funds into the existing state Agricultural Cost Share Program, which reduces non-point source pollution loadings through the use of agricultural best management practices (BMPs). This flexibility allowed the private sector dischargers to utilize their most cost-effective alternative while meeting a basinwide goal of total nutrient loading reduction (NCDENR website <http://h2o.enr.state.nc.us/nps/tarpam.htm>).

Phase I of the DWQ's Tar-Pamlico Nutrient Strategy began in 1991, and lasted until 1994. The program is said to be successful in that the nutrient cap was never exceeded, and the reduction in nitrogen fertilizer losses from agricultural operations were

greater than expected (45%). All the while, cost-effective trading under the nutrient cap has occurred between dischargers (Wolman, 2003).

Phase II of this strategy lasted from 1995 until 2004, and addressed non-point source (nps) nutrient pollutants as well as point sources. The emphasis for Phase II was the establishment of a non-point source pollution plan that addressed nitrogen and phosphorus loading. This nps plan was voluntary until 1998, when it was determined through in-stream modeling at the Pamlico estuary to be inadequate at producing the goal of 30% reduction in nitrogen loading. Mandatory controls in the form of Tar-Pamlico basinwide rules for (1) riparian buffers, (2) nutrient management, (3) urban stormwater, and (4) agriculture, resulted from this determination. The urban stormwater rules required the development and administration of local government stormwater management programs for only six municipalities and the unincorporated areas of five counties within the Tar-Pamlico basin (Figure 2-2; Table 2-2). Smaller municipalities such as Louisburg (Franklin County) and Nashville (Nash County) are exempt from the urban stormwater rules. Digital copies of these local government plans are available on the NCDENR webpage (http://h2o.enr.state.nc.us/nps/Tar-Pamlico_Nutrient_Trading_Program_files/Tar-PamlicoLocalStormwaterPrograms00.htm).

In-stream measurement samples taken again in 2002 indicate that nutrient loading to the Pamlico estuary have dropped by 18% for nitrogen, and 33% for phosphorus from 1991 levels. These values are encouraging, however the nitrogen loading goal has yet to be reached.

Figure 2-2: Tar-Pamlico Urban Stormwater Rule Jurisdiction

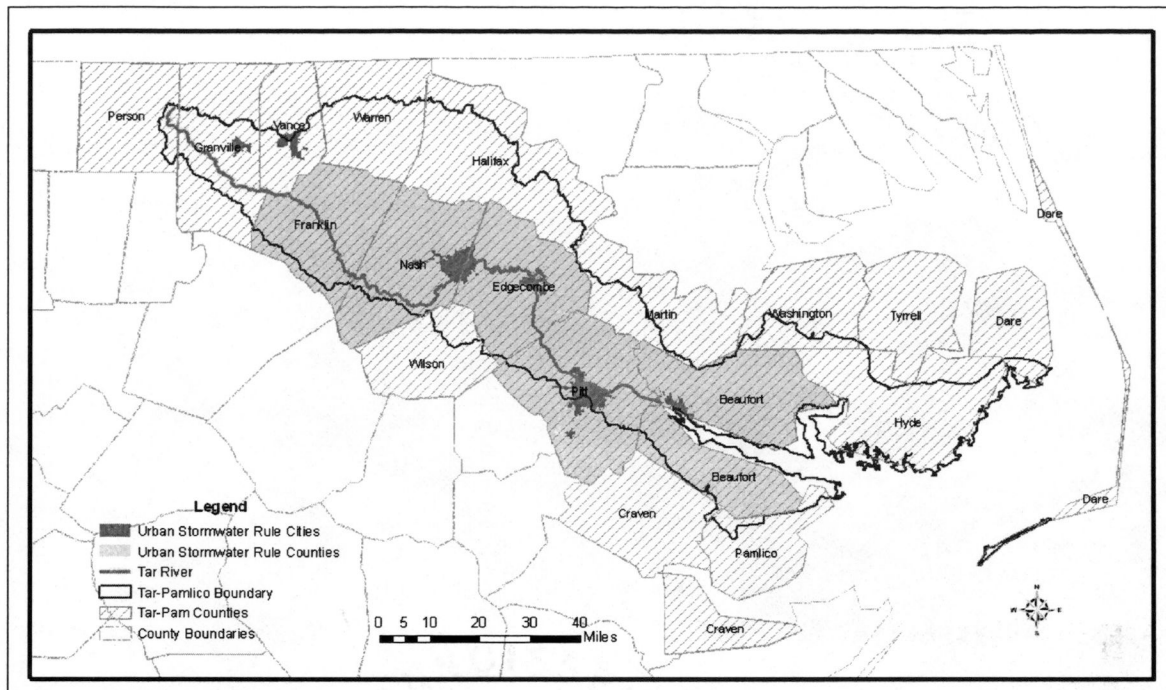


Table 2-2: Jurisdiction of the Tar-Pamlico Urban Stormwater Rule

Municipality	2000 Pop	2004 Pop	Growth	% Growth
Greenville	61,209	67,499	6,290	10.3
Henderson	16,095	16,445	350	2.2
Oxford	8,338	8,562	224	2.7
Rocky Mount	55,977	56,309	332	0.6
Tarboro	11,138	10,841	-297	-2.7
Washington	9,619	9,817	198	2.1
County	2000 Pop	2004 Pop	Growth	% Growth
Beaufort	44,958	45,860	902	2.0
Edgecombe	55,606	53,916	-1,690	-3.0
Franklin	47,260	52,882	5,622	11.9
Nash	87,385	90,712	3,327	3.8
Pitt	133,719	141,508	7,789	5.8
<i>State of NC</i>	<i>8,046,813</i>	<i>8,541,263</i>	<i>494,450</i>	<i>6.14</i>
Data source: NC Office of State Planning (http://demog.state.nc.us/)				

NPDES Phase I & II program for stormwater

An initial permitting program strictly dealing with stormwater discharges began in 1990 for North Carolina. Phase I of this federal program applies to (1) industrial facilities that fall into one of 10 categories, (2) construction activities greater than five acres, and (3) municipal separate storm sewer systems (MS4s) that serve more than 100,000 people (as of the 1990 census). This program requires subject facilities or projects to obtain a permit prior to commencement of operations. A major component of this permit for industrial facilities is the development and implementation of a site-specific comprehensive stormwater pollution prevention plan (SPPP). This plan must detail efforts made to reduce potential sources and prevent accidental discharges.

As previously mentioned, any construction site disturbing more than one acre is required to develop and implement a site-specific soil erosion and sedimentation control plan (SESC program). These SESC plans are required by the Sedimentation and Pollution Control Act to minimize quantity and velocity of stormwater runoff during phases of land disturbing activities. Sites that disturb more than five acres are required to apply for this NPDES Phase I permit in addition to the creation of a soil erosion and sedimentation control plan.

There are six municipalities in North Carolina that are subject to the NPDES Phase I permitting program (Charlotte, Durham, Fayetteville/Cumberland County, Greensboro, Raleigh, and Winston-Salem). These municipalities are required to develop and implement individual local stormwater management programs under Phase I. The major components of this program include (1) storm sewer and land use mapping, (2)

detection and elimination of illicit discharges, (3) public education, and (4) monitoring. These components are similar to those required by local governments under the Tar-Pamlico Nutrient Strategy - Urban Stormwater rules, as presented in the previous section.

Because of the potential for degraded water quality in areas that are rapidly developing, Phase II of the NPDES program was initiated in 1999. Municipalities that own and/or operate a MS4 within a census-designated urbanized area (rather than a threshold population) are subject to the Phase II stormwater rules. These rules are a continuation of the Phase I requirements ((1) mapping; (2) illicit discharge detection & elimination; (3) public education; (4) monitoring), for additional (smaller) municipalities.

Table 2-3 below displays the varying water quality programs across varying levels of government in chronological order. As mentioned previously, each set of rules is applied to different jurisdictions and administered by separate divisions of the NCDENR or local governments.

Table 2-3: Government Scaled Water Quality Protection Regulations				
Year	Title of Legislation/Program	Gov. Level	Jurisdiction	Key Attributes
1972	Federal Water Pollution Control Act Amendments	Federal		All US waters to support recreation and habitat function
1972	National Pollutant Discharge Elimination System (NPDES)	Federal	Point Source Dischargers	National permitting program delegated to states
1973	Sedimentation and Pollution Control Act (SPCA)	State	> 1 acre construction projects	Permitting program for construction (non-agricultural, non-forestry); Addresses #1 pollutant by volume in NC
1974	Coastal Area Management Act (CAMA)	State	20 Coastal Counties, >1 acre construction projects	Permitting program; Protects beach resources for non-residents
1980's	North Carolina State Stormwater Management Program (SSWMP)	State	20 Coastal Counties, OR ORW/HQW (Figure 2-1)	Protection of certain critical locations (fragmented)
1989	North Carolina Water Supply Watershed Protection Act	State	Surface water intake watersheds	Low density standards for development
1989	Tar-Pamlico Nutrient Strategy – Phase 1 (1991-1994)	State	Tar-Pamlico River Basin	Regulated nutrient discharges; Trading cap for dischargers; Coalition formed
	Tar-Pamlico Nutrient Strategy – Phase 2 (1995-2004)	State	Tar-Pamlico River Basin (Figure 2-2)	Non-point source pollution controls for (1) Riparian buffers; (2) Nutrient management; (3) Urban stormwater ; & (4) Agriculture
	Tar-Pamlico Nutrient Strategy – Phase 3 (2004-2009)	Local	Tar-Pamlico River Basin	Local government administration of stormwater programs for <i>nutrient</i> control
1990	NPDES – Phase I program for stormwater discharges	Federal	Industry; or >5 acre construction projects; or MS4's > 100,000	Point source pollution addressed. Population threshold as jurisdiction
	NPDES – Phase II program for stormwater discharges (1999)	Federal	MS4 in census-designated urbanized area	Non-point source pollution addresses; Urbanized area as jurisdiction
1993	North Carolina Basinwide Water Quality Plans	State	Each of the 17 river basins	Basinwide approach to coordinate efforts
2004	Local Government Stormwater Ordinances for Nutrient Control	Local	11 local governments within Tar-Pamlico (Figure 2-2)	(1) Reduce nitrogen loading by 30%, hold phosphorus; (2) Illicit discharge detection & elimination; (3) Retro-fit best management practices (BMPs); (4) Educational outreach

2.2. Stormwater quantity and mitigation

The dynamics of stormwater and its role in degrading surface waters is perceived as the leading threat to water quality in urbanized areas (Arnold, 1996; Barrett et al., 1998; Berke et al., 2003; Huang and Xia, 2001). This section explains urban imperviousness impacts on the quantity and quality of stormwater runoff generated from a storm event (Bledsoe & Watson, 2001; Bledsoe, 2002; Goonetilleke et al., 2005; Miltner et al., 2004; Tsihrintzis and Hamid, 1997; Wang, 2001), as well as the amount of stream discharge. Traditional best management practices (BMPs) have been engineered in order to address the quantity and (to some degree) the quality of the increased runoff. The uncertain long-term effectiveness of these measures has prompted a more recent trend of non-structural planning strategies that limit or eliminate the generation of stormwater (Bledsoe, 2002; Bracmort et al., 2004). Each of these elements, urban imperviousness, best management practices, and non-structural planning strategies are further discussed in this section.

Urban imperviousness

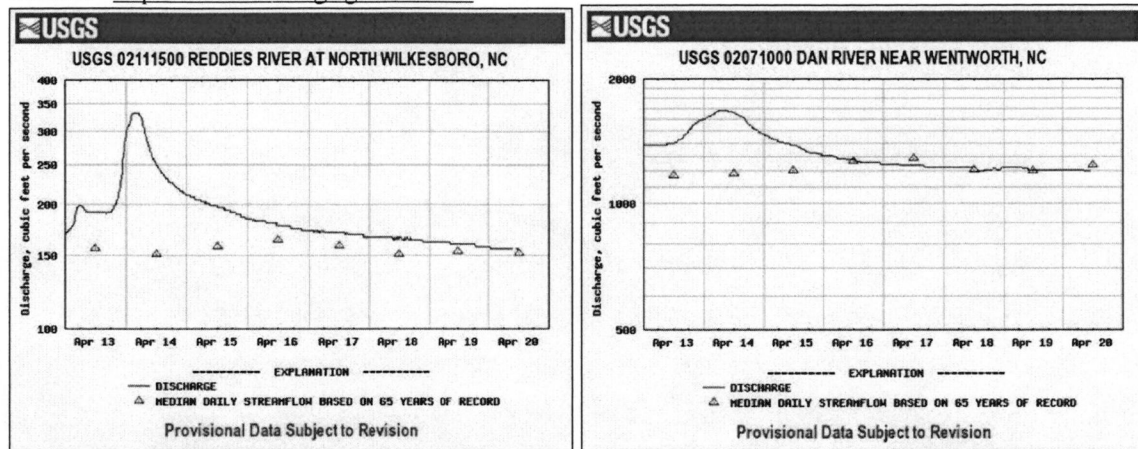
An urban environment is a diverse landscape, one that is full of buildings, roads, sidewalks, parking lots, and other constructed surfaces that impede the infiltration of rainfall. Runoff from these areas travels at a much greater velocity due to the relatively smooth surface of asphalt or concrete. Drop inlets and catch basins collect and route stormwater through concrete pipes that allow for unrestricted flow. This quantity of water will eventually discharge into the nearest stream, where it collects with stormwater runoff

that has been generated from areas upstream. In short, the process of urbanization has four primary hydrologic impacts, (1) infiltration of rainfall decreases, (2) evapotranspiration rate decreases, (3) impervious surface coverage increases, and (4) modification of streams increase. The first three impacts directly generate a greater volume of stormwater runoff, the latter is a consequence of both greater runoff volume, and population pressure to develop in urban areas.

A stream discharge hydrograph displays the volume of water that travels within a stream through time. A typical hydrograph from a rural landscape resembles a bell-shaped curve that is skewed (the tail points) to right (Figure 2-3 A & B). The initial rise in stream discharge occurs gradually after the initial rainfall, and rises to a peak before gradually decreasing back to base flow level. A hydrograph of a stream that is located in an urban landscape is observably quicker to respond following the initial rainfall. The rise towards peak flow is faster, and the peak is generally higher (Bledsoe & Watson, 2001). The descent back to base flow on this hydrograph is also much faster than that of a more rural landscape. Base flow water level between storm events is generally lower for urban streams because of the lack of groundwater infiltration, which constantly recharges streams during relatively dry periods of time. When comparing the same storm event from differing locations, the length of time for rise and fall of stream discharge is usually much shorter for urban areas, however, the amount of rainfall is the same. This temporal difference is a human-engineered result of greater velocity and volume of stormwater runoff for urban landscapes. In short, we have willingly constructed hydrologic ‘highways’ that allow for faster drainage from urban areas.

Figure 2-3 (A & B): Typical Discharge Hydrographs for the Same Storm Event (April, 2005)

Source: <<http://waterdata.usgs.gov/nc/nwis>>



A.) Hydrograph from an urbanized watershed

B.) Hydrograph from a non-urbanized watershed

Best Management Practices (BMPs)

Structural best management practices (BMPs) have traditionally been constructed to control the quantity of stormwater flow from newly developed land. The most common BMPs include wet (Figure 2-4) or dry (Figure 2-5) detention ponds, or stormwater wetlands, all of which address the peak flow discharge from a site (Bledsoe, 2002; McCuen, 2003). Goonetilleke (2005) found that the effectiveness of structural BMPs is not universal across varying landscapes. The state of North Carolina is currently soliciting public comment on its draft stormwater BMP design manual (http://h2o.enr.state.nc.us/su/documents/NCDENR_BMP_Manual_FINAL_July2005.pdf) to gather input regarding measures to address such diversity.

Figure 2-4: Stormwater Wet Detention pond, Greenville, NC



Photography by: Timothy Tresohlavy, April, 2005

The emphasis for these control structures is on reducing the post-construction runoff-rate to pre-construction levels. Detaining stormwater temporarily (releasing it over a longer time period) or retaining stormwater onsite (allowing for infiltration) addresses downstream flooding and mitigates water quality degradation. Retention also helps to save capital improvement expenditures, such as continually replacing undersized bridges, culverts, and other infrastructure (Braden and Johnson, 2004). Bledsoe (2002) shows how traditional detention facilities often fail to prevent stream channel erosion, even at relatively low discharge rates. Findings suggest that stream channel erosion may occur largely due to the increased volume of stormwater generated, rather than its velocity.

Figure 2-5: Stormwater Dry Detention Pond, Greenville, NC



Photography by: Timothy Tresohlavy, April, 2005

The construction and maintenance of stormwater management BMPs is often viewed simply as an additional expense incurred by the developer. This additional cost is transferred to the homeowner through increased lot prices. Sample (2003) evaluates BMP cost effectiveness to develop a method to assign cost to individual parcels within a mixed-use development, thereby quantifying the approximate increase in total lot price that can be expected. Alternatives to structural control BMPs are preferable over raising total project costs. Some of these strategies are discussed briefly in the following section.

2.2.1. Smart Growth planning strategies

Non-structural approaches to stormwater quantity control emphasize the reduction of minimum residential street widths and commercial parking lot sizes (required by traditional local government ordinances). Wetland and riparian buffer conservation, as well as conservation easements, are additional methods that indirectly mitigate the need for structural stormwater controls by displacing impervious surfaces from hydrologically sensitive areas. Strategies of this nature are referred to as Smart Growth planning, which aims at providing livable areas that are more balanced with the natural landscape (McCuen, 2003). These strategies include: the new urbanism movement, greenway corridor planning, and low impact developments (L.I.D.), each is discussed further.

New Urbanism

New urbanism is one such planning strategy that attempts to reduce environmental impact and protect natural areas (Pollard, 2001). New urbanism promotes

(1) mixed-use developments (land uses such as: residential, commercial, and professional) rather than segregation of uses; (2) smaller lots with additional parks and open space; and (3) transit-oriented neighborhoods that are walkable. Figures 2-6 (A & B) provide an example of smaller residential lots with sidewalks, and located within the central business district of Raleigh, NC. A public transportation bus stop is located within the community park, just 2 blocks away. On-street parking is encouraged, however a one-way alley services each house along the block for more private automotive parking.

Figure 2-6 (A): Example of a New Urbanism Development, Raleigh, NC



Photography by: Timothy Tresohlavy, July, 2005

Figure 2-6 (B): Example of a New Urbanism Development (adjacent side of roadway), Raleigh, NC



Photography by: Timothy Tresohlavy, July, 2005

Opponents argue that new urbanism is simply social engineering of architectural design (Gordon and Richardson, 1998) by adding front porches and sidewalks, and

accomplishing very little to support environmental health (Berke et al., 2003; Gordon and Richardson, 1997). Berke (2003) studied 54 pairs of developments (new urbanism and traditional) within five southeastern states to test whether the characteristics of new urbanism translated into actual protection or restoration of hydrologically sensitive areas. The results indicate that new urbanism projects located on ‘greenfield’ sites (new development) were more effective at incorporating watershed protection techniques, however, the same could not be said for ‘infill’ sites (re-development) in urbanized areas.

Greenway corridor planning

Greenway trails are linear pathways (paved or compacted) through urban, suburban and/or rural areas that serve a variety of recreational, conservation, and hydrological functions. A greenway trail system that is regional in scale provides an excellent opportunity for the combination of stormwater mitigation and recreation. Conserving natural areas that surround surface waters will buffer polluted stormwater runoff, increase infiltration of runoff, enhance local wildlife diversity, provide needed recreational opportunities, and accommodate structural stormwater management facilities (Conine et al., 2004; Arendt, 1994; McGuckin and Brown, 1995; Fabos, 2004). Searns (1995) describes greenway corridors as adaptive urban landscapes that have evolved through three generations, (1) axes, boulevards, and parkways; (2) nature-inspired corridors; and finally (3) multi-objective greenway trails. Modern greenways mitigate and counterbalance losses of our natural landscape that regularly result from increasing urbanization (Searns, 1995) by conserving these hydrologically sensitive areas.

Incorporating a regional (multi-jurisdictional) system of greenways according to river basin boundaries will mitigate non-point source pollution by conserving land for infiltration, and reducing the necessity of structural stormwater control BMPs.

Low Impact Development (L.I.D.)

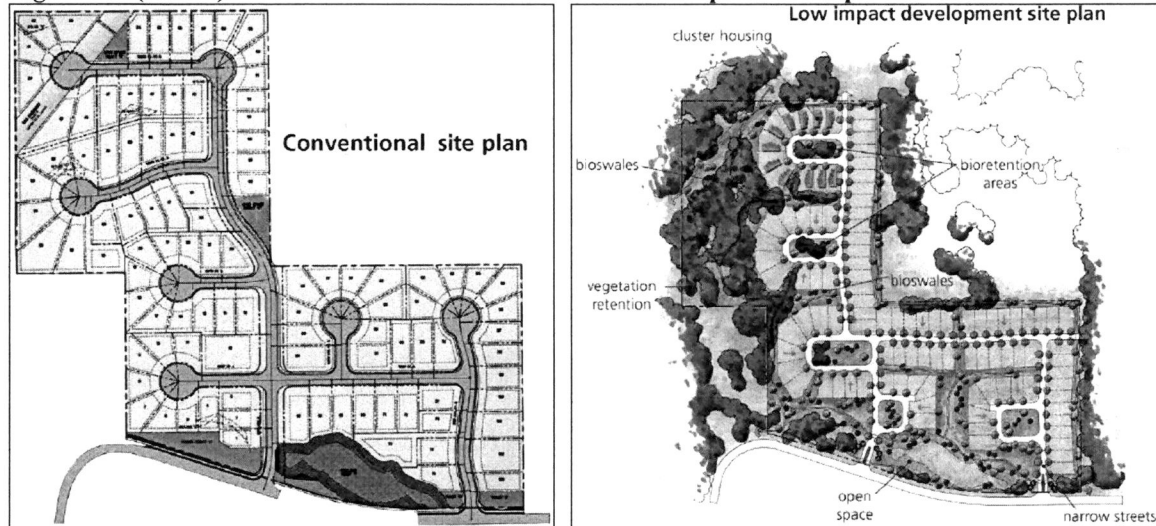
Large structural BMPs that detain stormwater runoff for an entire development are costly to design, construct, and maintain, as well as impractical for some site conditions. A more cost-effective alternative is the utilization of LID measures that address site specific stormwater runoff. Examples of LIDs include bioretention (such as grassy swales, or rain garden areas), permeable pavements, rain barrels, or vegetated rooftops (Figure 2-7). The emphasis for LIDs is to more closely mimic the pre-development hydrology of an area through conservation and small-scale hydrological controls (PSAT, 2005; Figure 2-8 (A & B)). These practices are site-specific, meaning that individual homeowners may implement these design strategies on individual lots to address local stormwater quantity and quality. State-level resources for LIDs are provided by the stormwater engineering group of NC State University's Cooperative Extension Service (<http://www.bae.ncsu.edu/stormwater/>), which directs the Home-A-Syst program that helps to install LID measures for homeowners. Federal-level resources include the US EPA (2000), which provides a literature review of LIDs (<http://www.epa.gov/owow/nps/lid/lid.pdf>), finding that (among others) vegetated rooftops can reduce annual runoff as much as 50%, while general maintenance of any measure is a primary issue.

Figure 2-7: Example of a Green Rooftop, Goldsboro, NC



Photography by: Bill Hunt, NC State University Biological & Agricultural Engineering

Figure 2-8 (A & B): Site Plans for Traditional versus Low Impact Development



(A) Traditional development site plan

(B) Low Impact Development (LID) site plan

Image Source: Puget Sound Action Team Low Impact Development Manual

2.2.2. GIS-based analysis of stormwater

Modeling stormwater, for the purpose of identifying areas of increased generation and quality of runoff *potential*, is not a recent trend (Epsy et al., 1966; Stankowski, 1972; Graham et al., 1974). The computing power available from a geographic information system (GIS), however, has increased the complexity of contemporary stormwater modeling. Tsihrintzis and Hamid (1997) provides 13 examples of non-point source

models commonly used by governmental agencies, and compares their capabilities for a variety of uses (land use, hydrology, water quality, data needs, and time modeling).

Chandler (1994) presented four case studies involving the complexity of stormwater models. Results indicate that a more parsimonious model (fewer variables) can be just as accurate at modeling annual non-point urban pollutant loadings as a more complicated model. Chandler also comments that the applicability of a model is a function of the accuracy and variability of its data. Local governments that fall under the Tar-Pamlico Nutrient Strategy – Urban Stormwater Rule and NPDES Phase I & II (Table 2-3) permitting system are mandated to identify areas for retrofit structures. GIS-based approaches may assist in ranking certain locations over others, and provide a method to satisfy this mandate.

Indicators

Existing literature identifies landscape imperviousness as the single-most important indicator of stormwater runoff generation (ASCE, 1975; Schueler, 1994; Pauleit & Duhme, 2000; Lee & Heaney, 2003). Arnold & Gibbons (1996) present imperviousness as an integrative and measurable indicator and argue for local government planners to utilize this “feasible and cost-effective vehicle for addressing water pollution.” The concept of a *threshold* of percent imperviousness, at which aquatic health begins to decline, is addressed in this article. A threshold of 10% is indicated for the effects of imperviousness to be measurable, as well as a threshold of 30% at which degradation occurs. These values are a reflection of the three imperviousness levels (1-

10%, 11-25%, and 26-100%) presented by Schueler (1994), whose publication is a product of the US Environmental Protection Agency (EPA) Center for Watershed Protection. The 10% effective impervious area threshold is again utilized by Booth & Jackson (1997), Bledsoe & Watson (2001).

The concept of an imperviousness threshold is not confined to planning and management, however, as researchers interested in aquatic and terrestrial ecology are modeling stormwater runoff (Robbins & Birkenholtz, 2003; Stone, 2004; Mitchell, 2005). Miltner (2004) finds that 13.8% imperviousness is the lower threshold at which their Biotic Integrity Index indicates that a stream is declining in ecological health. The study also finds that water quality begins to fall below standards set forth by the Clean Water Act at 27.1% imperviousness, indicating a similar upper-bound threshold of imperviousness. Goonetilleke (2005) studied the relationship between water quality and six categories of land uses. These land uses (rural residential (2%); forest (9%); detached housing (47%); urban residential (55%); town homes (70%); and duplexes (70%)) were characterized by different estimated impervious areas (shown in parentheses). This study finds that “as the level of urbanization increases, even low-intensity rainfall will produce polluted runoff, and hence pollutant loadings.”

Secondary indicators of stormwater runoff generation include land cover (Stone, 2004; Pauleit & Dehume, 2000), transportation infrastructure (Lee & Heaney, 2003), and population density (Stankowski, 1972; Jones & Clark, 1987). Land cover classifications are often made in relation to the degree of imperviousness, such as a forest/wetland cover versus urban category. Brabec (2002) argues that there is ‘considerable variation’ of

imperviousness within cover classes, which can lead to over-generalized modeling of stormwater. The same can be said for using population density as an indicator of stormwater runoff generation. Studies have evaluated imperviousness from census data for decades (Stankowski, 1972; Graham et al., 1974; Gluck & McCuen, 1975; Jones & Clark, 1987, Miltner, 1997), however, the variation of data within aggregation groupings is problematic unless analysis occurs at multiple scales (discussed further in methods section).

Modeling the potential for stormwater runoff generation within the Tar-Pamlico basin is useful for identifying areas that should receive priority for planning and mitigation projects, and addresses the first research question. Evaluating attitudes, behaviors, and perceptions (especially those of citizens) with regard to stormwater awareness is further useful for local government planning.

2.3. Stormwater awareness

Bartlett (2005) surveyed one thousand North Carolina homeowners to determine stormwater knowledge, attitudes, and behaviors. Findings suggest that stormwater is not only largely misunderstood, but exacerbated by the everyday activities of unaware residents. Thirty-eight percent of residents in North Carolina know that stormwater flows (untreated) to the nearest stream, while 29% incorrectly believed that stormwater received some type of treatment. A similar survey of Delaware residents revealed that 48% of residents know that stormwater flows directly to the nearest stream, while 21% believe that it receives treatment (DEDNREC, 2004). Common activities such as mowing

lawns, applying fertilizer, washing an automobile or changing its oil, and even neglecting to pick up pet wastes may all contribute to non-point source stormwater nutrient pollution. Bartlett found that 0.026% of respondents (26 of 1,000) dispose of used oil by dumping it directly into storm drains, and an equal share (0.027%) by dumping it on their lawns. Another 14 respondents (0.014%) dispose of grass clippings by blowing or raking them into the storm drain. Additional surveys on stormwater awareness and public behaviors are available on the US EPA's website for non-point source pollution outreach (<http://www.epa.gov/nps/toolbox/beta/surveys.html>).

Public awareness surveys such as these are an indication that the general public is simply unaware of the water quality impacts resulting from their daily activities. This finding is troubling to local government administrators in the Tar-Pamlico basin who are charged with public education and outreach as part of the Nutrient Strategy – Urban Stormwater Rule, and NPDES Phase I & II requirements.

3.0. DATA & METHODS

3.1. Mapping stormwater potential in the Tar-Pamlico basin

Identifying areas within the Tar-Pamlico basin with significant stormwater runoff potential, and mapping these locations, addresses the first research question, “What is the spatial pattern of indicators of stormwater runoff *potential*.” A GIS-based methodology that aggregates both direct and indirect indicators of stormwater generation at varying political and hydrologic scales is described below. The four data layers utilized were (1) impervious surface; (2) land cover change; (3) density of roadways; and (4) population change (Table 3-1). Sources of these data are further discussed later in this section.

3.1.1. Indicators of stormwater potential

Literature suggests that the amount of impervious surfaces across a landscape is directly related to the generation of stormwater runoff (Schuler, 1994; Arnold & Gibbons, 1996; Lee & Heaney, 2003). The distribution of impervious surfaces throughout the Tar-Pamlico river basin, however, is not uniform and has yet to be incorporated into an index of stormwater runoff potential at multiple political and hydrologic scales.

Urban areas are likely to be associated with high runoff potential because of their high density of built surfaces, however, rural areas with much lower impervious surfaces are (to a lesser degree) also associated with stormwater runoff potential. Suburbanization is the conversion of rural agricultural or forested lands surrounding urban centers into low-density single-family residential developments. This process increases the local percentage of impervious surfaces through the construction of additional homes,

driveways, sidewalk, garages, as well as new interior subdivision roads to access these homes. Therefore, indirect indicators of increased stormwater potential include changes of land cover type, the density of roadways (Lee & Heaney, 2003), and population changes (Stankowski, 1972). An indexing model using multi-criterion evaluation (MCE) is developed to characterize the spatially varying nature of stormwater runoff potential across the study area.

MCE Analysis

Multi-criterion evaluation (MCE) is a term used to describe the spatial indexing of several attributes for a common unit area. The weighted linear combination (WLC) method was selected for this analysis because it is arguably the most common approach to a MCE (Malczewski, 2000). Assigning appropriate weights to indicators is a critical element of the WLC method. The weighted importance is assigned relative to an attribute's potential for generating stormwater runoff quantity. A review of literature has guided the selection of appropriate weights. Impervious surfaces directly influence runoff by replacing the porous landscape with asphalt or concrete that will not allow infiltration of rain water. Because impervious surface is the only direct indicator of the four, this attribute received a majority of the weighted importance (0.60 of 1.00). The remaining three data layers are all indirect indicators, receiving the remaining 0.40 of the weighted importance. Land cover change (0.15) and roadway density (0.15) received equal portions of the remaining weighted importance because they correspond to specific 2-dimensional locations on the landscape. Population change (0.10) is a more indiscrete

measure of stormwater runoff potential, and therefore received a slightly lower weighted importance.

Table 3-1: Indicators for Stormwater Runoff Potential

Attribute Layer	Expressed as	Range	Values	Scores	Standardized by	Indicator Type	Weighted Importance (w_i)
Impervious Surface (2001)	Percentage (%)	0-100	Ex. value 82%; score 82		Linear transformation (0.0 to 1.0)	Direct	0.60
						Indirect	0.15
Land Cover Changes (1992-2001)	Classification Group	0-100	Urban (Ur)	100			
			Cultivated Cropland (CC)	25			
			Pasture/Managed Herbaceous (PMH)	20			
			Other (Ot)	15			
			Forest/Wetland (FW)	10			
			Water (Wa)	0			
Roadway Density (2000)	Density (ft^2/mi^2)	Varies	Ex. value 31,152 (ft^2/mi^2); score 31,125				0.15
Population Change (1990-2000)	Percentage (%)	Varies; Some are (-)	Ex. value 35.6%; Score 35.6				0.10

Impervious surface percentage was expressed as a whole number (for each 30 m grid cell) and attribute values were averaged for an entire aggregation level. Values ranged from 0 to 100 percent imperviousness, meaning that standardization involves dividing by 100. For example, a grid cell with an assigned impervious value of 30 was standardized to 0.30.

Assigning values to qualitative land cover classifications was two-step process of assigning numeric values to land cover types from both the 1992 and 2001 inventory, and then computing the difference between the two layers. Each of the six classifications

Roadway density was calculated as the length of a road segment multiplied by its average width, as provided by the NCDOT District Engineer for Eastern North Carolina (D. Taylor, pers. comm.), and shown in Table 3-3. The area (ft²) of roadways were summed for an entire analysis level (i.e., block group, HUC, etc.), and then divided by the total area (within the basin) for each respective aggregation level (mi² per: municipality, block group, HUC, county, or subbasin).

Table 3-3: Average Road Widths	
Road Type	Width (ft)
Major Highways & Connectors	28
Highways	24
Major Roads	20
Local & Minor Roads	20
Special Roads	20
Ramps	18
Private Roads	16
Data Source: Danny Taylor, P.E., NCDOT	
Road density calculated as: [(width x length) / (area of aggregation level)]	

Census block points from 1990 and 2000 were spatially joined and summarized according to the boundaries of the five levels of analysis (municipalities, block groups, HUCs, counties, subbasins). This process created five separate files with population estimates assigned to the desired units of analysis. Population change was computed as $(((\text{Pop00} - \text{Pop90}) / (\text{Pop90})) \times 100)$ using simple table operations. Population change percent was computed at each aggregation level, allowing for drastically different values (-95% for a single block group, and as high as 468% for another).

Standardization

Using MCE, data values are commonly standardized according to a linear-transformation (percent of total) to form a hierarchy of scores from 0.0 to 1.0 (Chang, 2004). The minimum original value is standardized to 0.0 and the maximum value is standardized to 1.0. The typical formula used for linear-transformation is as follows.

$$S_i = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

Where, S_i is the standardized value, X_i is the original value, X_{min} is the smallest original value, and X_{max} is the highest original attribute value. Observations with negative population change, the only variable (of the four) with negative values, were adjusted to 0.0.

The sum of all weighted criterion scores for a particular area is the index value for stormwater runoff potential. The indexing formula is as follows:

$$I = \sum (w_i * x_i) / \sum (w_i)$$

Where, I is the index value, w_i is the associated weight for each category of indicator, and x_i is the standardized score at the specific location. The computation of the index score from four actual HUCs is provided below. The attributes for the lower-right hand corner cell are as follows: mean 4.443 percent impervious surface; mean land cover change value of 14.93; roadway density of 0.534 ft²/mi²; and a population change of - 22.7 percent.

<u>Original Attributes</u>								
Data layer	Impervious Surface		Δ Land Cover		Road Density		Δ Population	
	0.500	0.259	7.819	6.649	0.306	0.065	0.654	1.506
	0.436	4.443	8.644	14.93	0.056	0.534	62.01	-22.7
<u>Standardized Values (x_i)</u>								
	0.023	0.011	0.243	0.200	0.139	0.084	0.004	0.008
	0.020	0.221	0.274	0.507	0.117	0.308	0.345	0.000
Weights (w_i)	0.60		0.15		0.15		0.10	
<u>Index Values (I)</u>								
	0.0715		0.05					
	0.10515		0.25485					

The computation for the lower-right corner cell is as follows:

$$I = \frac{(w_{ImpSurf} * x_i) + (w_{\Delta LandCov} * x_i) + (w_{RoadDen} * x_i) + (w_{\Delta Pop} * x_i)}{(w_{ImpSurf}) + (w_{\Delta LandCov}) + (w_{RoadDen}) + (w_{\Delta Pop})}$$

$$I = \frac{(0.60 * 0.221) + (0.15 * 0.507) + (0.15 * 0.308) + (0.10 * 0.000)}{(0.60) + (0.15) + (0.15) + (0.10)}$$

$$I = 0.25485$$

Because of the standardization method, which converts all attributes to a 0.0 to 1.0 scale, the computed index score (0.25485) is merely a *relative* value for a *single* observation at a *particular* aggregation level. The final index scores are only interpretable when presented in relation to other locations throughout the basin, and at varying scales, as discussed in the following section.

3.1.2. Multiple scales of analysis

The modifiable areal unit problem (scale and aggregation effects) is a well-established limitation of any fixed-scale analysis of continuous geographical data (Openshaw, 1984; Malczewski, 2000). Data from the US Census are averaged for the entire aggregation level to provide anonymity of residents, however the attributes are not evenly distributed throughout the individual areal units (municipalities, block groups, and counties) (Johnston, 1994). In an attempt to limit this type of error, the MCE was conducted at five scales (Table 3-4) throughout the study area to address *scale* effects. The effect of scale has been discussed by Openshaw (1984), finding that two variables are (on average) found to be more closely correlated at larger units of aggregation. The five levels include (from broad to fine scale) subbasins, county-level, hydrologic units, census block groups, and municipal-level. Municipalities were the most fine-scale unit because there are relatively small towns such as Castalia, which occupies a single block group, as well as larger cities such as Greenville, occupying 46 block groups. Additionally, the 54 municipalities do not provide continuous coverage of the basin (as the remaining four levels do), which further contributed to the decision to treat municipalities as the most fine-scale level of analysis.

Both hydrologic (or natural) boundaries and human-imposed political boundaries were utilized for aggregation in an attempt to mitigate *aggregation* effects related to the modifiable area unit problem. Political boundaries, such as municipalities, block groups, and counties, have been strategically created by humans according to characteristics relating to population, development density, transportation networks, and other human-

influenced conditions. Hydrologic boundaries such as 14-digit HUCs or 6-digit subbasins are based upon the drainage of stream networks and topography, which are relatively arbitrary boundaries in comparison to political boundaries. Aggregation effects are mitigated, not eliminated, by utilizing these two types of aggregation levels.

Table 3-4: Varying Levels of Political and Natural Boundary Aggregation

Political Boundary	# of Divisions	Scale	Natural Boundary	# of Divisions	Scale
Municipalities	54	Fine	Hydrologic Units (14-digit)	167	Fine
Block Groups	353		Subbasins (6-digit)	8	Broad
Counties	18	Broad	Tar-Pamlico Basin	1	Study Area

3.1.3. Data sources & limitations

ArcGIS software was used to create the stormwater index, aggregate values at various scales, and create a series of maps and ranked tables that characterize the patterns of stormwater runoff potential for the study area. This is intended to identify and rank areas where the *conditions* most and least conducive to stormwater runoff exist, using secondary data. This analysis **did not** identify areas where *actual* stormwater runoff is problematic, as there are no comprehensive empirical observations (to date) to evaluate this reality. Any number of structural or non-structural mitigation strategies may already be in place that limit or eliminate this empirically derived stormwater potential. Structural best management practices (discussed previously in literature review section) such as wet or dry detention ponds, stormwater wetlands, or bio-retention rain garden areas are examples of such controls that are commonly used to mitigate stormwater runoff. There are also a number of non-structural planning strategies, such as minimizing street widths

and parking lot standards, promoting New Urbanism developments, and conserving lands for greenway corridor planning, that further mitigate stormwater runoff potential.

USGS MRLC Consortium

Data sets for land cover and impervious surface estimates (Table 3-5) were obtained from the Internet, at the US Geological Survey (USGS) Multi-Resolution Land Characteristics (MRLC) Consortium (<http://gisdata.usgs.net/website/MRLC/>). The 1992 and 2001 land cover datasets were created from existing data collected by the Landsat Thematic Mapper at a resolution of 30 m grid cells. There data originally are classified into 21 land cover types, however this analysis condensed land cover into six categories to coincide with land cover classes set forth by in the Tar-Pamlico River Basinwide Water Quality Plan (North Carolina, 2004). Each category of land cover (urban, cultivated cropland, pasture/managed herbaceous, other, forest/wetland, and water) was assigned a score depending upon its potential for producing runoff from a review of literature. Changes in land cover classification between 1992 and 2001 represented a total of 31.42% of the study area, a majority of which is related to the addition of the pasture/managed herbaceous category in 2001, which occupies 8.5% of the total study area. To recap, the *change* of land cover is captured by subtracting the two scores ['01 - '92], which were assigned to each land cover class based on a review of literature. Negative scores that were most likely due to classification error were adjusted to their respective 2001 score. For example, a grid cell that was urban (1.00) in 1992 and cultivated cropland (0.25) in 2001 resulted in a -0.75 score, which was adjusted back to

its current score (0.25). If the reverse land cover change occurred (cultivated cropland to urban) the score was +0.75, and was retained. Table 3-1 displays the input data layers and scores associated with them; Table 3-2 provides examples of the methodology behind land cover change for this study.

NCGIA BasinPro 8

Hydrologic data layers (Table 3-5) were obtained from the North Carolina Center for Geographic Information and Analysis (NCCGIA) BasinPro 8 product (<http://cgia.cgia.state.nc.us/cgia/>). The NCCGIA is North Carolina's authoritative agency for geographic information, and is also responsible for launching the NC OneMap program, which is a (free) web-based data distribution site for seamless geographic information (NC CGIA, 2006 <www.nconemap.com>).

The following are examples of data layers from the BasinPro product that were utilized for this study: (1) hydrologic unit code (HUC) and subbasin boundaries, (2) political boundaries such as municipalities, block groups, and counties, (3) major and minor streams, (3) discharge sites associated with the National Pollution Discharge Elimination System (NPDES, see literature review section), and (4) Federally designated Natural Heritage Program sites. The boundary layers served as the analysis levels for the MCE, and the hydrologic features were utilized for mapping and presentation purposes.

The BasinPro dataset was released in 2004, as a resource tool for local and regional governments across the state of North Carolina. Replication of methods from this stormwater runoff potential research (on a more fine-scale) by municipal and county

governments is expected because of the widespread acceptance of the BasinPro product and the availability of (free) web-based data.

ESRI

The link between stormwater runoff potential and population change characteristics has been established through previous research (Stankowski, 1972; Jones & Clark, 1987; Miltner, 1997). The density of paved roadways (ESRI StreetMap, 2004) and changes in population (ESRI Census Demographics, 2004) are indicators of development pressure and local economic growth. Growth of this nature is an indirect indicator of stormwater runoff potential because of the increases in impervious surfaces that are associated with new construction (houses, driveways, and new subdivision streets). Because their data provide an *indirect* link to stormwater runoff potential, street density and population change were utilized for this study, however weighted less heavily (15% of the total index for roadway density and 10% for population change).

Table 3-5: Datasets Utilized for the MCE of Stormwater Runoff Potential

Dataset	Product	Source	Acquired	Released	Characteristics
Impervious Surfaces	National Land Cover Data (NLCD)	USGS MRLC	Online	2001	Raster grid layers of Landsat imagery at 30m resolution
Land Cover	National Land Cover Data (NLCD)	USGS MRLC	Online	1992 & 2001	Raster grid layers of Landsat imagery at 30m resolution
Roadways	StreetMap USA	Environmental Systems Research Institute (ESRI)	CD/DVD Product	2004	Vector attribute data with descriptives for road class (width)
Demographics	TIGER boundaries, with Census population	Environmental Systems Research Institute (ESRI)	CD/DVD Product	2004	Vector attribute data at various scales (tract, block, block group)
Hydrologic	BasinPro 8	NC CGIA	CD/DVD Product	2004	Vector attribute data of streams, hydrologic boundaries, and basin resources

3.2. Surveying stakeholder attitudes and perceptions

The second research question, analyzing the environmental attitudes and perceptions of stakeholders, can be achieved through a directed sampling survey and interview process. This combined method collects relevant quantitative data from informed participants of the stormwater regulation process, and provides a more in-depth qualitative analysis of related issues. Directed (sometimes also referred to as ‘purposeful’) sampling is a method that capitalizes on a researcher’s experience and first-hand knowledge of the targeted audience for a particular study area, accounting for limitations in accessibility (DeMers, 2005). This type of sampling is preferred for this research because of the limited number of influential stakeholders in the (rural) Tar-Pamlico basin, and the gained experience (more than two years) of the researcher at the county-government level. Professional credibility of the researcher most likely assisted with increased willingness of stakeholders to participate. An undirected (purely random) sampling method (arguably) does not ensure that stakeholders are well-informed or active in the development process that involves stormwater regulation. Furthermore, difficulty in defining a sampling frame made this latter approach unfeasible.

3.2.1. Targeted audience

Individuals who are directly involved with the creation and implementation of development projects and plans in the Tar-Pamlico River Basin (subject to the urban stormwater rules) were the targeted population for the sampling strategy of this study. These stakeholders included, but were not limited to, (1) professional engineers (P.E.),

(2) professional licensed surveyors (P.L.S.), (3) local-government administrators (planning, public works and/or engineering departments), and (4) environmental non-governmental organizations. Homeowners were excluded from this analysis because it has been shown that a majority of North Carolina residents are unaware of stormwater (Bartlett, 2005), nor are they informed participants in the process of regulating stormwater runoff from development projects.

The study area includes portions of 18 North Carolina counties, some of which have a majority of their jurisdictional boundaries within adjacent basins (Pasquotank, Roanoke, and/or Neuse). There are four cities in the Tar-Pamlico basin with populations greater than 10,000 (Table 2-2), and growth rates are modest (below 3%), if not declining for all but one city (Greenville: 10.3%). These characteristics imply that development projects, and therefore the majority of stakeholders, are distributed throughout the region but still concentrated near Greenville, within Pitt County.

Local government stormwater regulations are not universally applied to all portions of the study area. There are specific political jurisdictions (county and municipal governments) that are required to regulate stormwater runoff, as well as areas without such requirements. The Tar-Pamlico Nutrient Strategy – Urban Stormwater Rule, which is the governing legislation for stormwater regulation in the basin, applies to only five counties and six municipalities that are specifically named by the document (Table 2-2 and Figure 2-2 of the literature review section). Administering the stormwater program is usually a task designated to a single environmental planner or engineer for each of these 11 local governments. The fragmented jurisdiction of these specific nutrient strategy

stormwater rules, and the structure of local government departments, further limits the number of public sector stakeholders. Because of the limited audience, the emphasis for this directed sampling survey was *quality* of responses with a goal of sufficient quantity to effectively describe and analyze attitudes and perceptions of the Tar-Pamlico Nutrient Strategy – Urban Stormwater Rule.

3.2.2. Survey design

An estimate for the approximate number of public and private stakeholders (65-100 individuals) within the Tar-Pamlico basin is provided by the current Tar-Pamlico Non-point Source Pollution Coordinator (J. Huisman, pers. comm.), in agreement with the former coordinator's estimate. This estimate includes state, city, and county government administrators, as well as professional engineers and licensed surveyors. Maximizing stakeholder participation is imperative given their limited number for this study area. Surveys for this analysis are designed to be brief (fit onto one page, front and back), and uniform to accommodate participant time demands (Appendix). Responses are in the form of Likert-scale responses, which indicates the relative degree to which a participant agrees or disagrees with a generalized statement (<http://dictionary.reference.com/>) concerning stormwater planning and regulation. The scale is as follows: 1- strongly disagree; 2- disagree; 3- moderately disagree; 4-moderately agree; 5- agree; 6- strongly agree. The 1-6 scale eliminates the possibility of a neutral response. A more detailed survey design with additional questions would potentially discourage participation, which would have been detrimental due to the limited number of stakeholders. For this reason

only 17 questions, addressing three topics (environmental quality, state and local program administration, and available best management practices) are asked according to the common Likert-scale. These three sections address different aspects of stormwater regulation for the study area. The first places the importance of water quality in relation to the economy. The second asks whether stakeholders support the state-mandated program as delegated to local governments. The final section evaluates whether the availability of control measures are adequate or too costly, and therefore inappropriate. Each of these sections is further explained below, with the actual survey questions provided at the end of each section.

Environmental Quality

The first section of the survey gathers perspectives that relate to the protection of water quality versus the importance of the economy. This tradeoff (economic versus environmental) is common when dealing with resource conservation issues because it balances individual and societal well-being. Questions are posed with a relative measure included in the statement, such as, ‘the quality of the economy is *more* important than the quality of the environment’ and ‘stormwater regulations impose *unnecessary* limitations on development.’ This format avoids the psychological tendency of participants to respond according to what *they believe* the researcher would desire. One can assume that a question phrased ‘the quality of the environment is important to me’ would received high agreement from nearly every participant because it lacks a relative comparison to something else that may be important. The remaining three questions from this section

address the protection of water quality resources for different purposes, (1) future generations, (2) intrinsic (or non-human) value, or (3) regardless of reason (ethical reasons).

1.	Protecting water quality, <i>regardless</i> of reason, is important to me					
	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
2.	Stormwater regulations impose <i>unnecessary</i> limitations on the development process					
	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
3.	Protecting water quality for the next generation is <i>very</i> important to me					
	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
4.	Protecting water quality for its intrinsic value (valuable without human use) is <i>very</i> important to me					
	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6
5.	The quality of our local/state economy is <i>more</i> important than the quality of our environment					
	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6

State & Local Program

The second section addresses the state and local government program that has been constructed to address water quality concerns, and nutrient pollution in the Tar-Pamlico basin. The first issue is whether participants believe that the Clean Water Act goal of protection and propagation of fish, wildlife, and human recreation has been appropriately transferred to the state and local government stormwater program. For example, many stakeholders believe that each municipality should be given the flexibility of adopting unique stormwater standards, while others believe that the regulations should be basinwide for the sake of equality. Still others may believe that the state government should administer the varying stormwater programs rather than individual local

governments. Two primary components of the state-mandated stormwater rules requirements are the environmental education outreach component, and the goal of 30% reduction in nitrogen loading to the Pamlico Sound. These are the final two questions of the state and local program section.

6. The model local-government ordinance crafted by the State of North Carolina *appropriately* balances the goal of the Clean Water Act and the needs of development

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

7. Each municipality within a river basin is unique, and therefore each should be allowed the flexibility to adopt *different* standards for stormwater runoff

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

8. I believe *local-government* administration of stormwater regulations is essential because the state government of North Carolina does not have the necessary resources (i.e., work-force, funding, time)

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

9. Environmental education and community outreach will serve an *essential* role in the success of stormwater regulation

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

10. I believe that 30% reduction in nitrogen loading, as set by the State of North Carolina, is too stringent and therefore restricts development

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

Best Management Practices

The third section of the survey addresses the availability of best management practices (BMPs) that have been approved (by the state of North Carolina) for use by project engineers. As discussed in the literature review section, there are a variety of structural and non-structural practices that address both point source and non-point source stormwater pollution. By posing the questions ‘reducing non point source pollution is equally as important as reducing point source pollution’ and ‘structural

stormwater control BMPs unnecessarily raise the cost of development projects' the survey again asks participants to make tradeoffs between economic costs and pollution reduction. Many believe that addressing non point sources pollution (from unidentifiable sources) is less cost effective than limiting more obvious sources. A final question addresses the perceptions of stakeholders as they relate to the long term maintenance of any structural BMPs by homeowners associations, which are legally and financially responsible for all repairs.

11. Reducing non point-source pollution (diffuse runoff from non-identifiable sources) is *equally* as important as reducing point-source pollution (conveyed through a storm drain pipe)

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

12. Non-structural, smart growth planning techniques (such as reducing road widths, minimizing curb & gutter use, mixed land use, and greenway trail design) do **NOT** help resolve stormwater issues

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

13. Structural stormwater control BMPs (such as bio-retention rain gardens, or detention ponds) *greatly* reduce nutrient loading from stormwater runoff

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

14. Structural stormwater control BMPs (such as bioretention rain gardens, or retention ponds) *should* be aesthetically designed to enhance the landscape's appearance

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

15. I would be willing to have a structural stormwater control BMP installed (without cost) on my property

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

16. Structural stormwater control BMPs *unnecessarily* raise the cost of development projects

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

17. I believe that a homeowners association is sufficient to undertake the long-term maintenance of structural BMPs

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

Private sector confidentiality

Anonymity of participating stakeholders is especially critical in this survey process. The role of a researcher is to avoid reporting any link between responses and names. This was accomplished by coding surveys prior to their entry into a database format (.dbf). Participants were reminded, prior to taking the survey, that their participation was optional, as was providing their name. They were also reminded that there are no ‘right’ or ‘wrong’ responses to survey questions, only unique perspectives.

Demographic questions

A section that categorizes participant demographics is provided at the end of the survey, which served two purposes, (1) the survey concluded with a set of simple questions that establishes a positive disposition towards the research, and (2) the participant may decide whether to include their name and contact information *after* answering the survey questions, rather than prior. Interviewing participants who did not include their contact information was therefore impossible, which was a potential source of bias. The attitudes and perspectives of stakeholders who generally disagree with stormwater regulation are equally as important, yet could not be collected if they indicate that they are unwilling to be interviewed.

Employment is broken into public and private sectors. The public sector is further delineated into state and local government scale. City versus county government is likewise differentiated. The survey options for the private sector include professional

engineers, licensed professional surveyors, development contractors, and a category for other (NGOs).

Reverse (or negative) questions

Survey questions for each of the three sections (environmental quality, state and local program, best management practices) were initially constructed so that high scores (6) translated to an ecocentric (environmental) perspective. The anthropocentric perspective is one in which the participant perspectives are human-related, for example the quality of the economy being more important than the quality of the environment. Select questions were reversed prior to administering the survey to limit the subjective bias that naturally exists between the researcher and private sector participants. The perception of neutrality on the part of the researcher is essential to gain acceptance from private sector stakeholders who may already know me as an environmental regulator for the Pitt County Planning Department. I have held this position with the county for more than two years, and have made many professional contacts during this time who qualify as stakeholders for this survey. Gaining their participation for this stormwater survey and continuing our professional relationship is important, and helped to emphasize the need for neutrality.

The reversal of questions also served to maintain participant focus throughout the survey by limiting mindless sequential 'box-checking,' which can plague quantitative surveys. I received a comment from an initial survey participant in regard to the reversal of questions. This participant stated "I had to stay on my toes" because the questions kept

“switching.” Reversing some of the survey questions therefore had the desired effect on participants.

3.2.3. Survey administration

There were two versions of the survey, a paper-copy and a Microsoft-Word version to be emailed to participants. Providing two versions satisfied three objectives, (1) maximizing confidentiality of respondents by allowing them to anonymously return a survey by mail, (2) improving response time for those who respond by email, and (3) saving money from postage and supplies. No less than 91 separate emails (many to multiple recipients) were sent between December 2005 and February 2006. An additional 19 private sector companies and six governmental offices were visited for paper distribution of surveys. The total number of paper surveys distributed was approximately 65, with 50 completed surveys returned by mail. Some of these 50 were originally emailed and returned by standard mail service.

There are potential limitations of any approach that involves email however, such as the establishment of a digital- or technological-divide. A digital-divide is a condition under which unequal access to the Internet may disadvantage certain participant groups. A technological-divide is similar in that participants with less familiarity of computer technologies could be excluded from the survey process. Considering the survey audience (governmental administrator, private sector engineers/surveyors) and the degree of education needed to gain these employment positions, it is reasonable to assume that these survey limitations were negligible. The targeted population will most definitely

have access to the Internet, as well as a fundamental knowledge of downloading attached documents from an email. Regardless of familiarity with the Internet, paper copies of the survey were circulated by email and in person to further mitigate any potential limitation.

Contact & networking

Enrolling stakeholders across the entire Tar-Pamlico basin is a challenging task, especially for research of a potentially controversial topic. Email was a useful tool that helped to increase the networking capabilities of this survey, allowing additional stakeholders to be contacted through a web of participants and their professional contacts. For example, one particular email to a governmental administrator in the state capital (Raleigh) produced an additional seven, and allowed the survey to ‘snowball’ throughout the department.

The same snowballing process transpired through emails to the private sector. I capitalized on the number of professional contacts made during employment with the Pitt County Planning Department who willingly passed along the survey to additional stakeholders within their respective companies. Telephone calls to private sector development companies also established credibility and provided the opportunity to network.

Personal visitations to private sector companies may not have *substantially* increased participation however, as most engineers and land surveyors were either working in the field, or unable to speak with the survey administrator directly. Instilling trust with the receptionists, on the other hand, helped to return surveys more quickly.

Additional effort, therefore, was made to communicate the difficulties of surveying a diverse population to these administrative assistants.

Interviews

Interviews with stakeholders provided open-ended topics in order to gauge the importance of key issues with respect to the NC stormwater regulations, and added a qualitative component for analysis. Forty-eight survey participants indicated a willingness to be interviewed, however, interviewing all of these individuals was unfeasible for the following reasons. Participation in the survey portion was unevenly distributed across the public and private sector, as anticipated. Governmental administrators on both the state and local government level play the role of civil servants. As such, they are generally available and more willing to devote the time needed to participate. Private sector stakeholders, on the other hand, were busy serving the needs of their multiple clients (i.e., remaining productive at all times). Interviews with private sector stakeholders (in particular) provided necessary qualitative perspectives that enriched the quantitative survey results. Body language (for face-to-face interviews), tone, and selection of words on the part of interviewees helped to identify components of stormwater regulation that are received with the most or least hostility. The frequency of topics discussed also contributed to the formulation of perceived themes (grouped issues) with respect to stormwater rules.

The interview process took place after participants had completed the survey, and indicated that they were willing to be interviewed (58% or 48 of the 83 survey

participants). A total of 21 interviews were conducted (14 from the public sector, 7 from the private sector). Scheduling conflicts and the physical distance between the researcher and interviewee's required four of the 21 interviews to be conducted over the phone. Additional issues and potential questions that were unrelated to the scope and purpose of this research were identified and discussed during interviews. Identifying topics for further research on stormwater regulation are additional benefits from the interview process.

3.2.4. Analysis of results

The analysis of survey results compares mean responses between demographic and geographic categories (i.e., employment sector, age groups, location within the basin). Survey responses have been coded for anonymity and converted to database format for analysis. The database may be opened using both Microsoft Excel and Statistical Package for the Social Sciences (SPSS) software. The intention is to have this dataset available for future researchers, as opposed to retaining only the original paper survey documents.

ANOVA

A formal analysis of variance was conducted using each of the 17 survey questions as dependent variables. A comparison of mean scores for varying demographic groups was made for each question. An F-test statistic was calculated to test whether the population means for location, employment sector, and age groups are equal (null

hypothesis). The F-statistic is a ratio of the variance between grouped observations compared to the total variance of all observations. The F-statistic is calculated as follows.

$$H_0 : \sigma^2_1 = \sigma^2_2 = \sigma^2_3 = \sigma^2_4 \dots \sigma^2_k$$

$$F = \frac{BSS / (k-1)}{WSS / (N-k)}$$

(k-1) = degrees of freedom for numerator
(N-k) = degrees of freedom for denominator
Between Sum of Squares $BSS = \sum n_j (X_{+j} - X_{++})^2$
Within Sum of Squares $WSS = \sum (n_j - 1) * s^2_j$

Age categories were condensed into three groups, ages 25 to 39, 40 to 49, and above 50 years old. Locations within the Tar-Pamlico basin were determined according to the participant's county of employment. Counties within the Tar-Pamlico are shown in Table 1-2, as were their respective designation within the basin (i.e., upper or lower portion).

Content analysis

Topics discussed during interviews were recorded on paper during the event, and transcribed shortly thereafter. The decision to take notes on paper, rather than tape record, supported the research intent to collect data from diverse stakeholders while providing anonymity. Interviews were open-ended discussions of attitudes and perceptions of stormwater rules from diverse stakeholders who may fervently disagree with each other. I desired to have the interviewee as comfortable as possible in order to gain their unique perspective, and so the use of a tape recorder was avoided.

Common topics discussed during interviews were grouped into themes, and a content analysis was conducted on the transcription (and reviewed by the original interview notes). The purpose of this content analysis was to identify the underlying substance from the discussions with stakeholders, such as increased total project cost, or additional administrative tasks, and record the frequency with which they were discussed by members of the public and private employment sector. From this analysis we can evaluate whether a theme is universally perceived by stakeholders, or whether each sector emphasizes different themes.

4.0. RESULTS

4.1. Stormwater runoff potential

The first research question asks for the spatial pattern of *potential* for stormwater runoff in the Tar-Pamlico basin. Indicators of runoff derived from a MCE were aggregated at varying scales of analysis to form an index of runoff potential. Visualizing the pattern of index values across the basin indicated that the greatest potential is located near the few urban areas and along major highway corridors within the study area because existing impervious surfaces are located there. Results further indicate that land cover and population change in the Tar-Pamlico basin is occurring in less developed (rural) areas adjacent to urban centers, indicating a trend towards suburban sprawl for this portion of North Carolina.

A great deal of variation exists, as expected, for the stormwater potential index depending upon the scale of aggregation. For example, block group-level aggregation indicates that areas of high runoff potential are all located *within* urban center boundaries, whereas HUC-level aggregation indicates additional areas of high runoff potential located *beyond* the political boundaries of these cities. Each level of analysis is presented later in this section, however, the mean index values and frequency distribution are first presented below.

4.1.1. Index results

Descriptives and Frequencies

Mean values for each input data layer are reported in Table 4-1, which indicates a general increase as the level of aggregation increases from fine to broad scale. This trend is expected, and reinforces the modifiable areal unit problem described previously (data and methods section). The municipal level is the exception to the trend, possibly because these areas only provide a small proportion of total coverage for the entire basin.

Minimum and maximum index scores are also displaying the same increasing trend as the level of aggregation becomes broader.

Table 4-1: Descriptive Statistics per Analysis Level				
Mean Scores				
Level	Input Data Layers			
	Imp Surf	Δ Land Cover	Roadway Density	Δ Pop
Municipal	0.23282	0.08729	0.05624	0.01637
Block Group	0.06911	0.02574	0.02763	0.00378
HUC	0.03987	0.03852	0.02391	0.01035
County	0.17774	0.08174	0.08066	0.03556
Subbasin	0.22349	0.09702	0.09175	0.03782
Min, Mean, and Max INDEX Scores				
Level	Min INDEX	Mean INDEX	Max INDEX	Skewness
Municipal	0.0	0.39273	0.76504	-0.026
Block Group	0.0	0.12625	0.78216	1.610
HUC	0.00030	0.11265	0.84906	3.889
County	0.02560	0.37570	0.92073	0.672
Subbasin	0.03439	0.45008	0.99367	0.534

Distribution of index scores are normal for the municipal, county, and subbasin-level, but skewed for the block group (1.610) and HUC-level (3.889). This finding suggests further that the index for stormwater runoff potential is unevenly distributed across the basin and influenced by the selected level of analysis. Frequency histograms of index scores are included in each of the following subsections to visualize this pattern.

Municipal-level

Of the 54 municipalities within the study area, the highest index values are associated with urban areas having the greatest population and therefore the most development. Five of the six most populated cities (Greenville, Rocky Mount, Henderson, Washington, and Oxford) are among the top ten index values because they possess the top five impervious surface scores (Table 4-2). The city with the fourth largest population (Tarboro) has the 23rd highest index rank (out of 54), primarily because of its 15th highest impervious surface score. The spatial pattern of index scores and their sample distribution at the municipal-level are presented in Figures 4-1 and 4-2 respectively.

Less populated towns (shown in Table 4-2 in gray shading) such as Franklinton (Index rank: 11), Kittrell (15), Louisburg (14), and Youngsville (12), have high total index scores because of greater land cover change, street density, and/or population change. These four towns are all located off of highways (US 1, US 401) in Franklin and Nash County. These highways connect with nearby Raleigh, indicating that the development pressure of this city may be extending across both political and hydrological boundaries (Raleigh is located in the Neuse river basin) to reach these suburban areas. An article from the Raleigh News & Observer (Price, 25 March 2006) supports this notion, citing that a new 124 lot subdivision in Franklin County will price homes between \$900,000 and \$3 million, while only two existing homes in the county are currently valued above \$1 million.

Table 4-2: Index Rankings at the Municipal-level

Municipality	Class	2000 Pop	Area (mi ²)	Imp Surf	Δ Land Cover	Roadway Density	Δ Pop	INDEX	Index Rank
Henderson	city	16,095	8.24	1	11	27	44	0.7650420	1
Washington	city	9,583	6.70	2	10	16	25	0.7145280	2
Greenville	city	60,476	25.80	3	9	30	12	0.6891040	3
Robersonville	town	1,731	1.20	6	5	2	28	0.6849070	4
Sharpsburg	town	2,421	0.89	12	27	10	1	0.6352900	5
Warrenton	town	811	0.88	4	12	12	36	0.6322140	6
Nashville	town	4,309	2.87	9	3	19	11	0.6151040	7
Oxford	city	8,338	4.46	5	25	13	21	0.6141030	8
Enfield	town	2,347	1.20	8	24	3	29	0.6063900	9
Rocky Mount	city	55,893	35.82	7	8	20	22	0.5826230	10
Franklinton	town	1,745	1.10	10	38	6	32	0.555320	11
Youngsville	town	651	0.92	16	1	46	5	0.5368250	12
Washington Park	town	440	0.26	28	2	1	14	0.5191970	13
Louisburg	town	3,111	2.35	14	23	14	37	0.5152720	14
Kittrell	town	148	0.20	22	7	4	30	0.5147060	15
Scotland Neck	town	2,362	1.22	13	22	25	43	0.5007380	16
Spring Hope	town	1,261	1.40	18	6	21	24	0.4993000	17
Elm City	town	1,165	0.71	20	29	7	33	0.4987160	18
Bethel	town	1,681	1.04	23	20	5	31	0.4915120	19
Littleton	town	692	0.95	11	21	36	27	0.4857610	20
Chocowinity	town	733	1.01	21	4	26	17	0.4856560	21
Pinetops	town	1,419	1.01	24	16	8	34	0.4763880	22
Tarboro	town	11,138	9.66	15	33	29	26	0.4748210	23
Belhaven	town	1,968	1.80	19	32	18	40	0.4695490	24
Conetoe	town	365	0.37	26	26	22	9	0.4386980	25
Bunn	town	357	0.53	25	18	15	38	0.4360390	26
South Henderson	CDP	1,220	1.93	17	42	32	46	0.4208870	27
Simpson	village	464	0.37	34	30	11	13	0.3880190	28
Whitakers	town	799	0.81	31	34	9	35	0.3838370	29
Princeville	town	940	1.58	27	13	24	42	0.3828940	30
Macclesfield	town	458	0.51	29	31	17	39	0.3750770	31
Norlina	town	1,107	1.12	30	28	41	15	0.3368710	32
Middleburg	town	162	0.56	32	39	44	10	0.3267900	33
Macon	town	115	0.45	33	14	49	52	0.2990990	34
Grimesland	town	440	0.52	36	35	23	41	0.2943650	35
Aurora	town	583	1.04	37	19	28	45	0.2921640	36
Centerville	town	99	0.28	35	15	40	50	0.2878380	37
Everetts	town	179	0.45	40	37	31	8	0.2758690	38
Castalia	town	340	0.71	42	45	35	6	0.2496220	39
Hobgood	town	404	1.03	38	41	34	47	0.2379180	40
Falkland	town	112	0.23	44	17	33	23	0.2271400	41
Beargrass	town	53	0.27	39	36	37	48	0.2262360	42
Pantego	town	170	0.62	43	40	39	18	0.2064630	43
Bath	town	275	1.06	47	51	45	3	0.2041350	44
Momeyer	town	291	1.12	50	48	47	2	0.2031040	45
Dortches	town	809	7.71	51	47	43	4	0.1970110	46
Fountain	town	533	0.93	41	44	53	16	0.1918040	47
Parmele	town	290	1.14	46	43	42	51	0.1581740	48
River Road	CDP	4,094	7.29	48	46	48	20	0.1398880	49
Leggett	town	77	0.69	45	50	50	53	0.1228750	50
Speed	town	70	0.28	52	49	38	49	0.1189230	51
Ocracoke	CDP	769	9.56	49	52	51	19	0.1136780	52
Red Oak	town	2,723	19.48	53	53	52	7	0.1085920	53
Hassell	town	72	0.27	54	54	54	54	0.0000000	54

Rankings out of 54 total municipalities within the study area

Bold indicate municipalities involved in the Tar-Pamlico Nutrient Strategy – Urban Stormwater Rule

Gray shading indicate municipalities located off of US 1 and US 401, near Raleigh, NC

Figure 4-1: Municipal-level Stormwater Runoff Potential

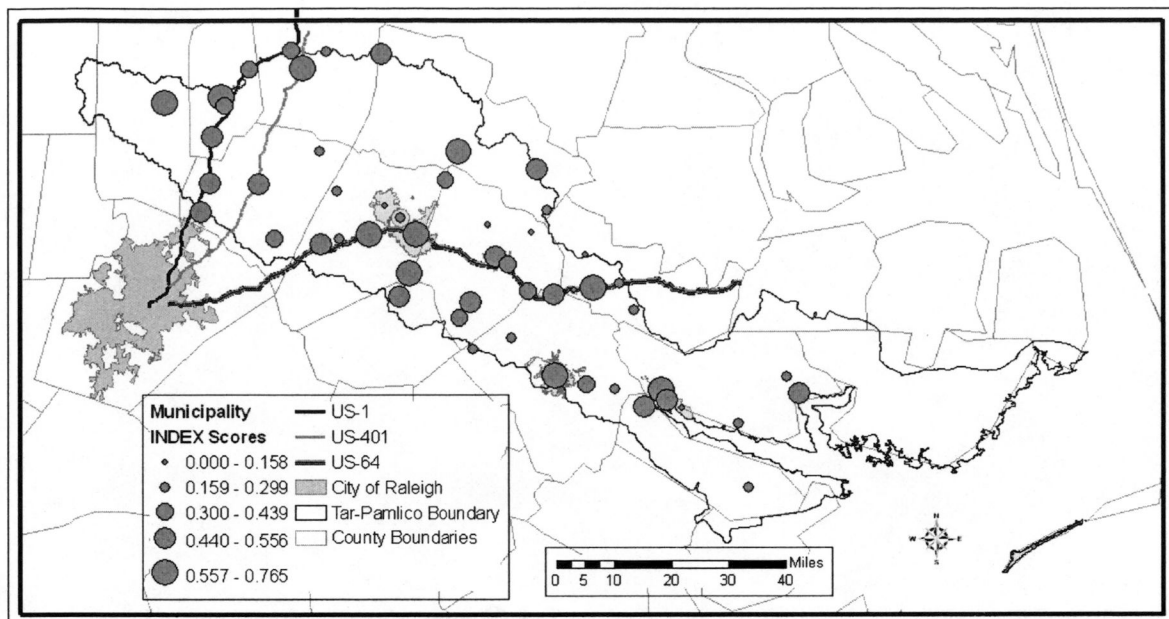
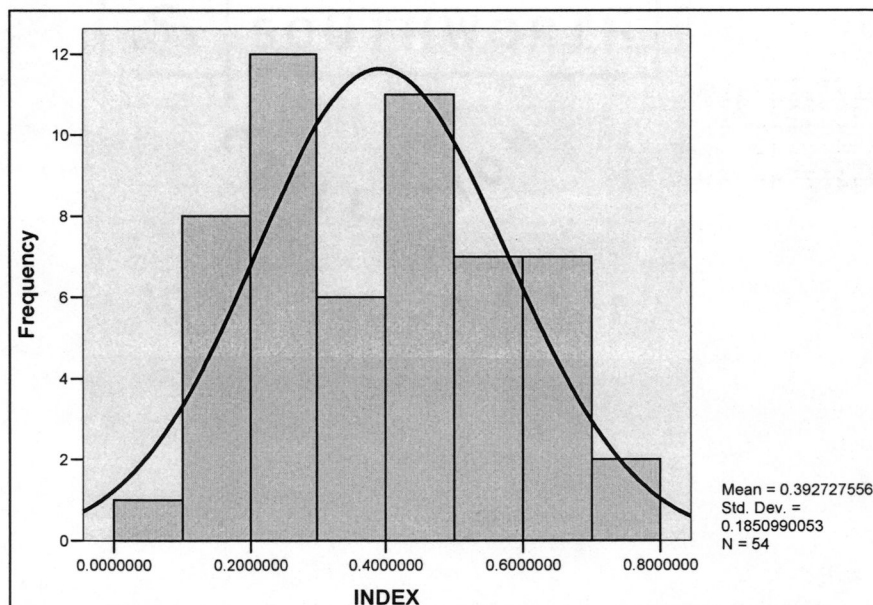


Figure 4-2: INDEX Scores at the Municipal-level



Block group-level

Block groups with higher index values are located within the major urban centers Rocky Mount, Greenville, Henderson, Tarboro, Washington, and Oxford (these six are regulated by the Tar-Pamlico Nutrient Strategy – Urban Stormwater Rule). Additional block groups that possess high index values include those that lie within the towns of Franklinton and Louisburg (Figure 4-3, circled).

Block groups with high total index values are not necessarily those with a high score for land cover change or population change. Many high ranking block groups have negative population growth rates, and were scored 0.0. This finding suggests that population growth is occurring *from* more urban block groups (with higher impervious surface and street density scores) *to* smaller and more rural area (with lower scores for impervious surface and street density). The distribution of sample index scores at the block group-level is presented in Figure 4-4.

Figure 4-3: Block Group-level Stormwater Runoff Potential

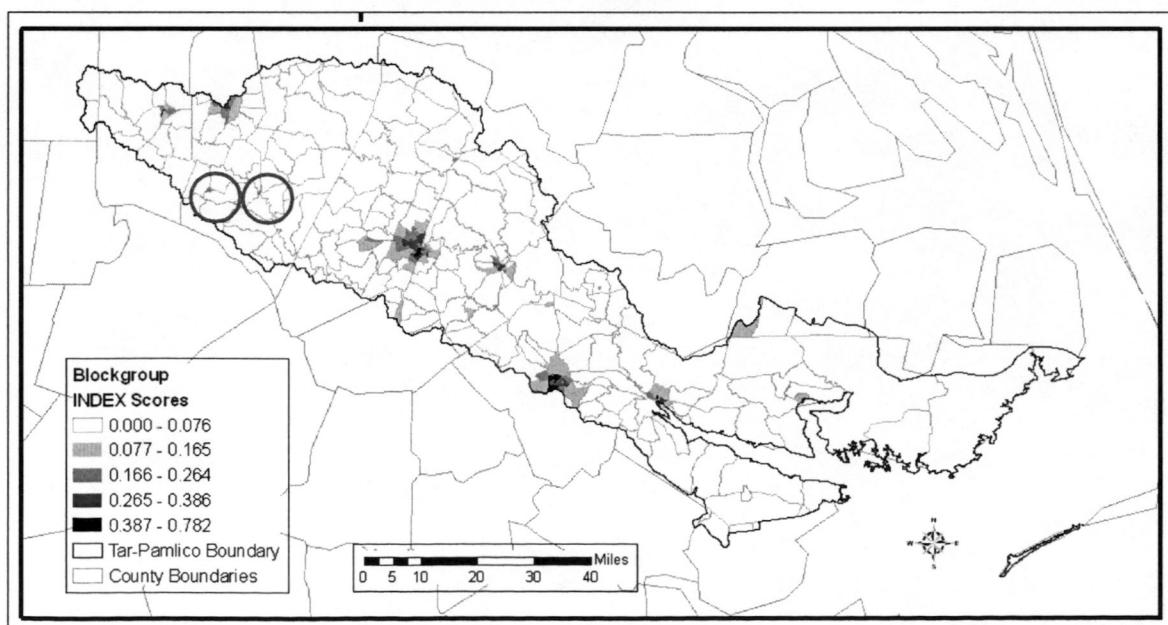
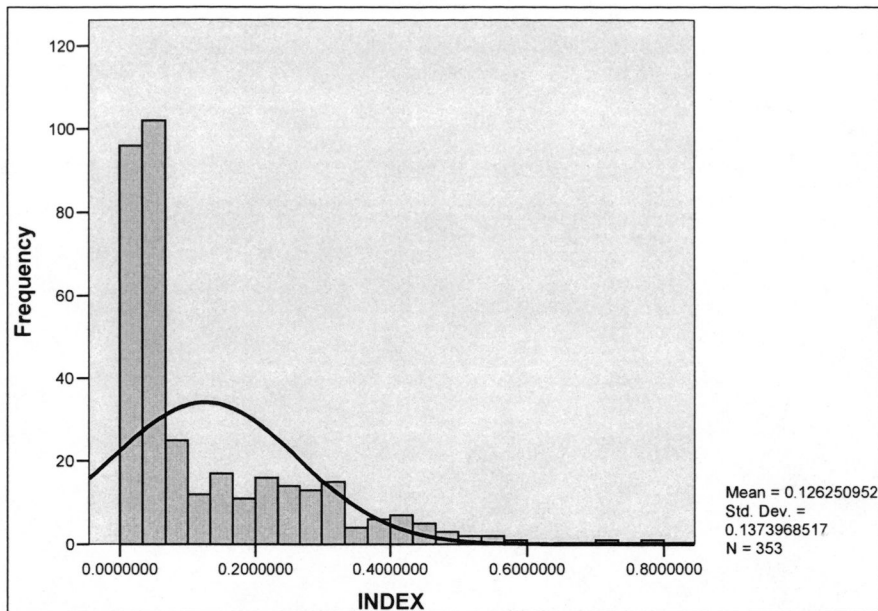


Figure 4-4: INDEX Scores at the Block Group-level

Hydrologic Unit Code (HUC)-level

Highest index scores are again found near large urban centers when scores are aggregated at the hydrologic unit code level (Figure 4-5). Similar to the block group-level, the highest index HUCs do not score high for population change. Development along US Highway 64, traveling from Raleigh northward through Rocky Mount and then eastward through Tarboro and on to the Outer Banks, may be responsible for the moderately-high index values for HUCs across this region. These portions of Nash and Edgecombe County form a distinct corridor that traverses the landscape.

The HUC for Ocracoke Island, part of North Carolina's Outer Banks, possesses the 25th highest index score (of the 161 HUCs) in part because of its moderately high indicator scores: impervious surface (19th); land cover change (29th); street density (20th); population change (82nd). This location has a low index value for all other analysis levels

(municipal, block group, county, or subbasin). The distribution of sample index scores for the HUC-level is presented in Figure 4-6.

Figure 4-5: HUC-level Stormwater Runoff Potential

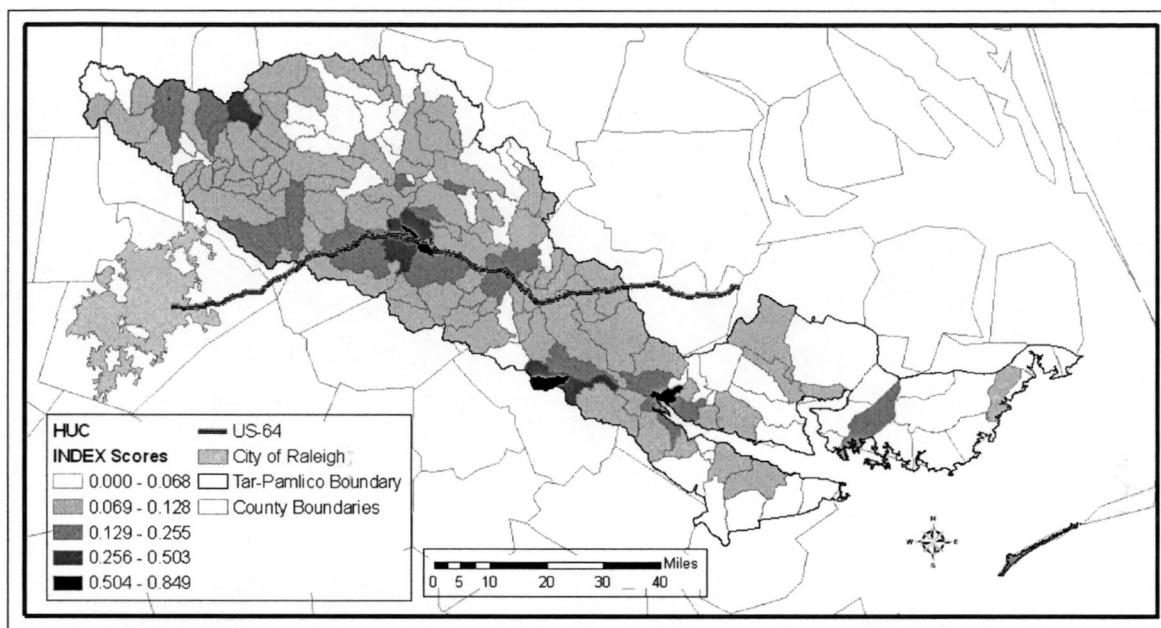
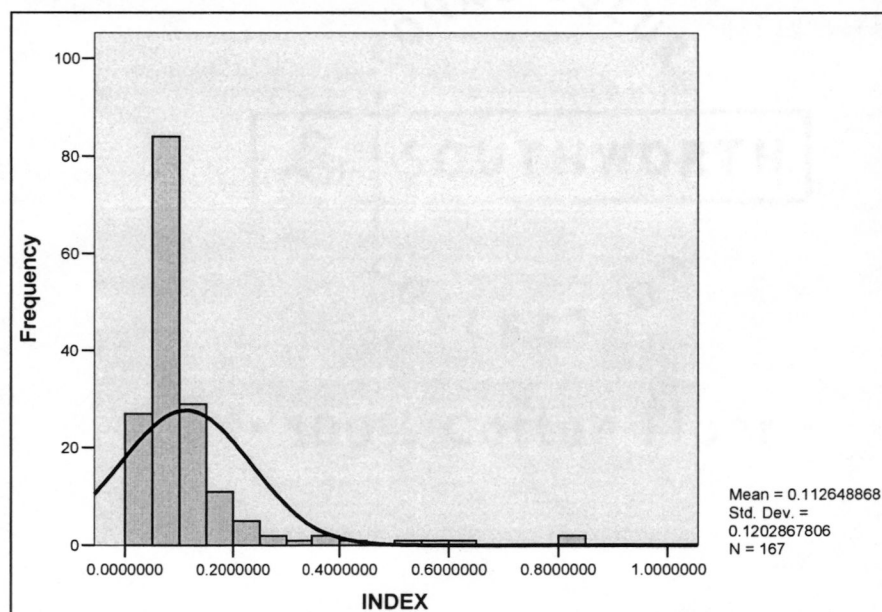


Figure 4-6: INDEX Scores at the HUC-level



County-level

None of the 18 counties associated with the study area are *entirely* within the hydrologic boundaries of the basin. Only the portions of North Carolina counties that fall within the basin have been included in this analysis, meaning that counties with a substantial percentage of their total area located outside of the basin (Table 4-3) are subject to an unavoidable study-area bias. Counties with the highest index values are located in the upper portion of the basin (western), with the exception of Pitt County (the fastest growing county in the basin). Counties to the north and east have much lower index scores, which is visualized in Figure 4-7. Major cities such as Greenville and Rocky Mount, as well as major highway corridors I-95, US 64, and US 264 are located within these highest scoring counties. The distribution of sample index scores for the county-level are displayed in Figure 4-8.

Table 4-3: Index Rankings at the County-level

County	2000 Pop	% Out of Tar-Pam Basin	Input Data Layers				INDEX	Index Rank
			Imp Surf	Δ Land Cover	Roadway Density	Δ Pop		
Vance	42,954	50.11	1	2	1	9	0.9207320	1
Nash	87,420	19.77	2	1	2	7	0.8280970	2
Pitt	133,798	43.65	3	4	3	4	0.7824840	3
Granville	48,498	57.13	4	7	7	5	0.5036550	4
Wilson	73,814	83.84	5	3	4	11	0.4788620	5
Franklin	47,260	12.27	8	8	5	1	0.4745630	6
Edgecombe	55,606	0.81	6	5	6	12	0.4392570	7
Martin	25,593	73.76	7	6	9	13	0.3808800	8
Beaufort	44,958	12.08	9	9	8	10	0.3532720	9
Warren	19,972	37.55	10	11	11	6	0.3321030	10
Person	35,623	92.60	12	12	12	3	0.3123070	11
Halifax	57,370	37.59	11	10	10	14	0.2643990	12
Washington	13,723	78.70	14	13	14	2	0.2523130	13
Hyde	5,826	25.60	13	14	13	8	0.2107540	14
Craven	91,436	99.59	17	15	16	16	0.0900090	15
Pamlico	12,934	87.88	16	16	15	15	0.0857750	16
Tyrrell	4,149	99.56	18	17	17	17	0.0275510	17
Dare	29,967	93.52	15	18	18	18	0.0255980	18

Rankings out of 18 total counties within the study area. No county is entirely within the Tar-Pamlico basin

Bold indicate counties involved in the Tar-Pamlico Nutrient Strategy – Urban Stormwater Rule

Gray shading indicate counties located adjacent to Raleigh, NC

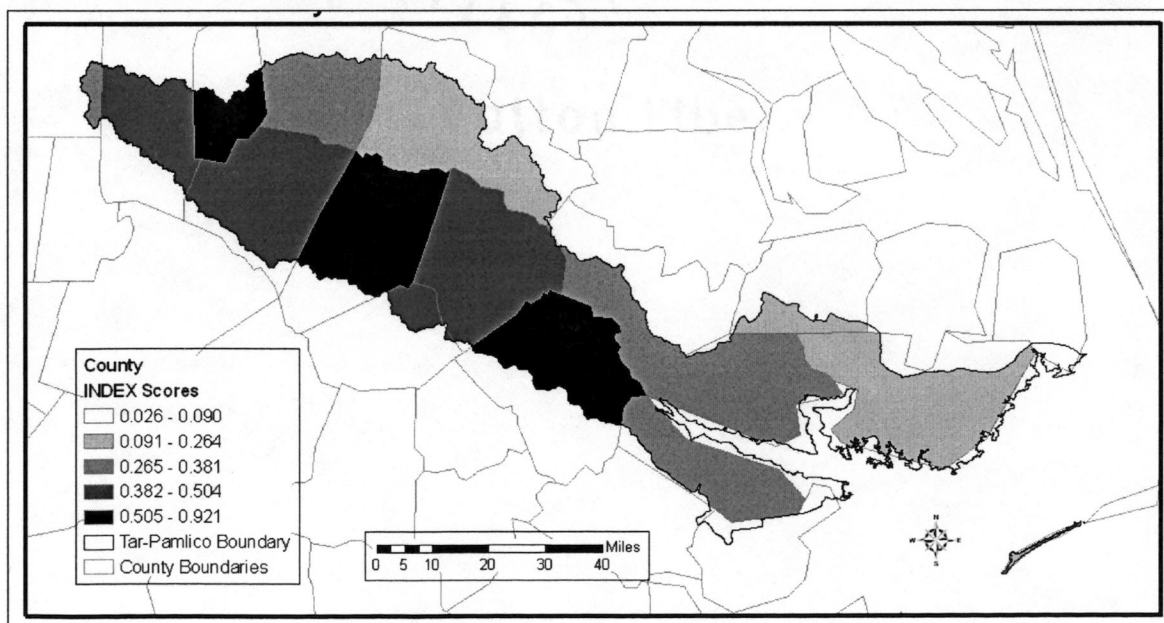
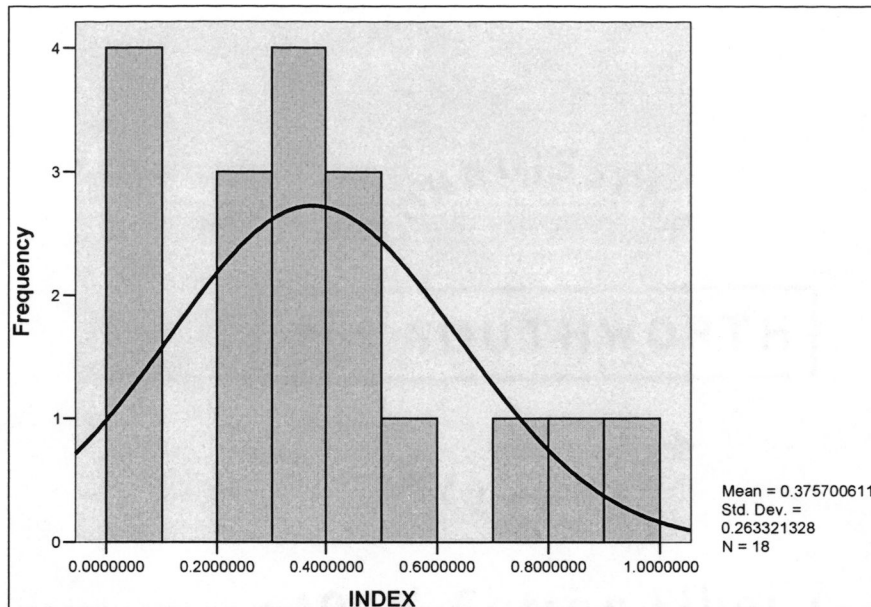
Figure 4-7: County-level Stormwater Runoff Potential

Figure 4-8: INDEX Scores at the County-level



Subbasin-level

The pattern of stormwater runoff potential for the subbasin level (8 divisions) is remarkably similar to that of the county-level (18 divisions). Highest index scores (Table 4-4) are located in the upper portions of the basin (northwest), and lowest index scores located in the lower portion (Figure 4-9). Subbasin #5 is the exception to this generalization, which is almost exclusively within the Pitt County political boundary. This subbasin is ranked 1st (of the 8 subbasins) for impervious surfaces and population change, as well as 2nd for land cover change and roadway density. These scores are explained by Pitt County being home to the City of Greenville, which is the fastest growing urban center in the basin, adding more than 6,000 residents between 2000 and 2004. The distribution of sample index scores at the subbasin-level is presented in Figure 4-10.

Table 4-4: Index Rankings at the Subbasin-level

Subbasin	Approx. Location	% Open Water	Input Data Layers				INDEX	Index Rank
			Imp Surf	Δ Land Cover	Roadway Density	Δ Pop		
TAR5	Pitt	0.0	1	2	2	1	0.9936660	1
TAR2	Nash	0.0	2	1	1	3	0.7926817	2
TAR1	NW	0.0	4	5	3	2	0.5237274	3
TAR3	Central	0.0	3	4	4	8	0.4667546	4
TAR6	Martin	0.0	5	3	5	6	0.4087676	5
TAR4	Northern	0.0	7	6	6	5	0.2023827	6
TAR7	Beaufort	12.8	6	7	7	7	0.1782741	7
TAR8	SW	65.1	8	8	8	4	0.0343860	8

Rankings out of 8 total subbasins within the study area

Bold indicate *approximate* locations for the Tar-Pamlico Nutrient Strategy – Urban Stormwater Rule

Gray shading indicate subbasins located adjacent to Raleigh, NC

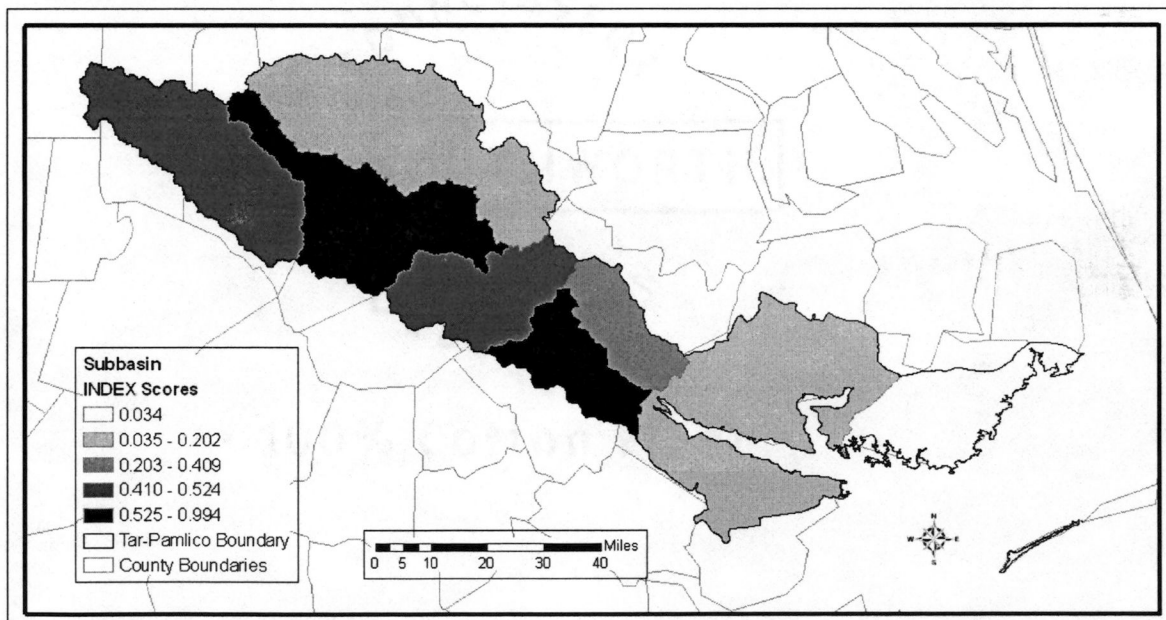
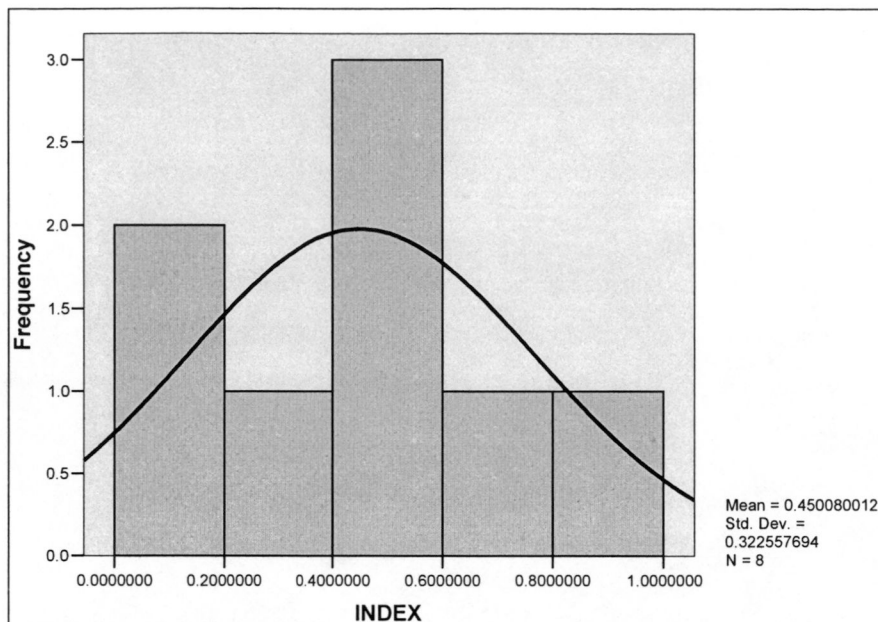
Figure 4-9: Subbasin-level Stormwater Runoff Potential

Figure 4-10: INDEX Scores at the Subbasin-level



The important findings from this MCE analysis of stormwater runoff are, (1) locations near the few urban areas and major highway corridors of the Tar-Pamlico basin are associated with greater potential for runoff; and (2) a trend towards suburban sprawl is observed for areas adjacent to urban centers, as indicated by higher rankings for land cover and population change in more rural locations. The remaining portion of this section presents results from a survey of stakeholders regarding their attitudes and perceptions of the Tar-Pamlico Nutrient Strategy – Urban Stormwater Rule (the second research question). Collectively, the two research questions address whether there are locations with increased potential for stormwater runoff *and* more unified stakeholder perceptions relating to stormwater regulation.

4.2. Stakeholder perspectives

The second research question asks whether stakeholder attitudes and perceptions are geographically or demographically similar across the Tar-Pamlico basin, and if these locations are linked to the runoff potential index. A directed survey and interview process was selected to gather data. An analysis of variance and content analysis was conducted to test the null hypothesis, (H_0 : the variation of mean scores between groups is equal; $H_0 : \sigma^2_1 = \sigma^2_2 = \sigma^2_3 = \sigma^2_4 \dots \sigma^2_k$). Results show that different attitudes and beliefs exist between the public and private sector, as well as among varying locations of employment within the basin. Mean scores differed for a majority of the environmental quality questions, indicating that preconceived notions of water quality are varied. Much less variation exists for questions related to the established state and local stormwater program, however, questions relating to available stormwater best management practices are again highly varied among stakeholders.

Frequencies and Demographics

Table 4-5 displays the frequency of survey participant characteristics. There were a total of 33 surveys returned by email, and the remaining 50 were mailed, for a grand total of 83 surveys. Sixty-four participants (77%) identified themselves as male, and most respondents (49%) were between the ages of 25 and 39. Land owners constitute 86% of the total participants; forty-nine (59%) participants were parents.

The location of survey participants is displayed in Figure 4-11. Employment zip code was used to identify the location of surveys because fewer participants were willing

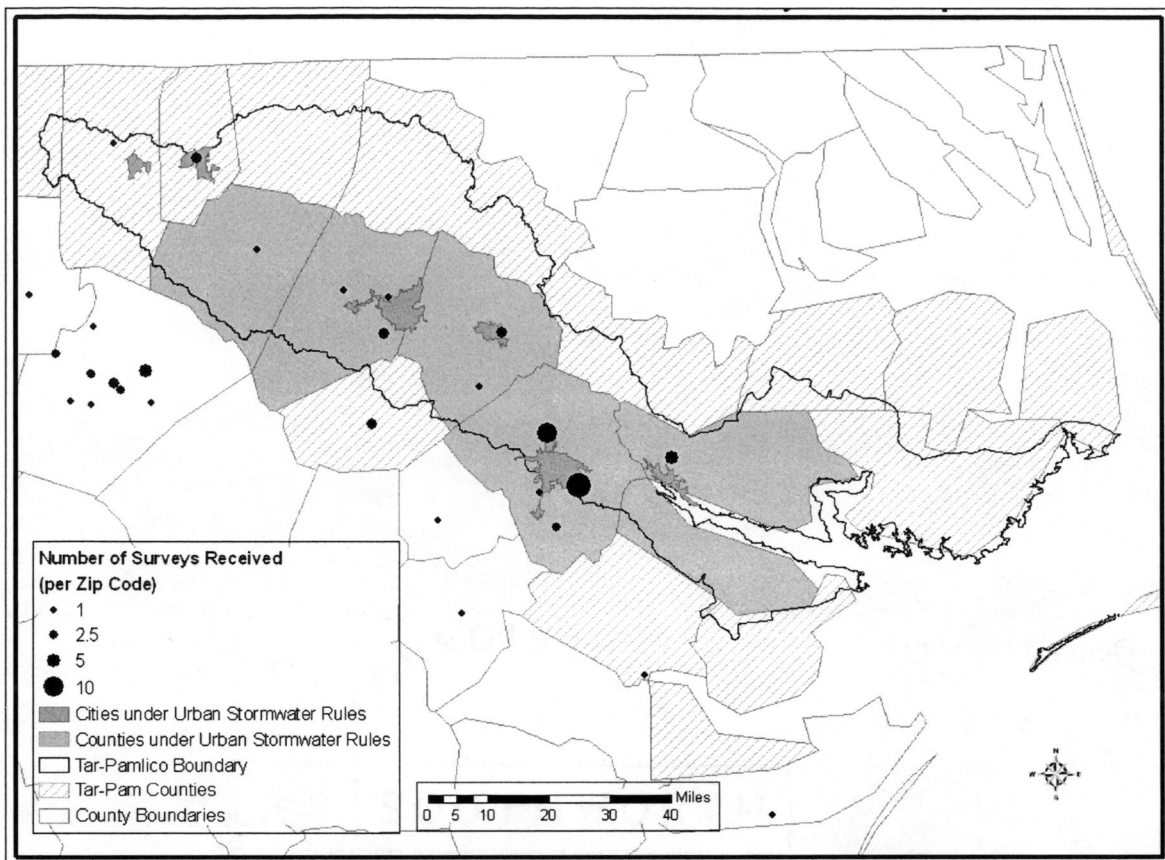
to provide their residential zip code (12 entries left blank). Nearly two-thirds of the 83 surveys were from Pitt County. Forty-three percent were from the lower Tar-Pamlico basin (Pitt & Beaufort Counties), 37% from outside the Tar-Pamlico (most of which are from the NCDENR-DWQ office in Raleigh, Wake County), and the remaining 19% were from the upper basin (Granville, Vance, Nash, Edgecombe Counties).

The public sector (state and local government) accounted for one-half of the total sample. Fifteen surveys were received from the state government, and 24 from local governments (11 city, 11 county, 2 regional). Forty percent of the total stakeholders were from the private sector. Twenty-one were engineers and/or land surveyors, 12 fell under the ‘development’ occupation category (land owners/developers). The remaining 11% of total participants were self-identified as the ‘other’ occupation category (non-governmental organization [NGO], retired, or environmentalist) (Table 4-5).

Slightly more than half (58%) of all respondents were willing to be interviewed. Twenty-eight (of the 41) were public sector employees, 14 (of the 33) were from the private sector, and 6 (of the 9) from the ‘other’ sector.

Table 4-5: Survey Demographics					
Characteristic	Frequency	% of Total	Characteristic	Frequency	% of Total
Survey format			Gender		
Email	33	39.8	Female	19	22.9
Paper	50	60.2	Male	64	77.1
Age*			Parents		
25-39	40	48.8	<no response>	7	8.4
40-49	23	28.0	No	27	32.5
50+	19	23.2	Yes	49	59.0
Landowners			Pitt County		
No	11	13.3	Out of Pitt County	53	63.9
Yes	72	86.7	In Pitt County	30	36.1
T-P Location			Employment Sector		
Lower**	36	43.4	Other	9	10.8
Out	31	37.3	Private	33	39.8
Upper	16	19.3	Public	41	49.4
Occupation Category			Willing to be Interviewed		
State	17	20.5	No / < no response>	35	41.0
Local	24	28.9	Yes	48	57.8
Development	36	43.4			
NGO	6	7.2			
*: One <no response>, not included					
**: Lower Tar-Pamlico basin includes only the counties of Pitt and Beaufort					

Figure 4-11: Distribution of Stormwater Survey Participants



4.2.1. Survey & interview results

Mean scores were computed for varying demographic categories and displayed in Table 4-6. The scale is 1-6, meaning that a mean score of 3.5 indicates a neutral response. Disagreement with survey statements are indicated by mean scores below 3.5, and agreement with a statement is indicated by a mean greater than 3.5. Questions that involved agreement between stakeholder categories (for example, question # 1 from Table 4-6) had mean scores that all fall on the same side of the 3.5 neutral line. Comparatively, questions that involved disagreement among stakeholder categories had mean scores on opposite sides of the 3.5 neutral line (for example, question # 2), and are shown in bold.

Statistically significant variation (@ $p = 0.01$) between stakeholder groups was computed using an F-test statistic. T-test and F-test statistics are identical for a two-case sample (i.e., gender, landowners, and Pitt County location demographic categories), therefore the F-test statistic was used for consistency. The results of this one-way analysis of variance are displayed in Table 4-7 below.

Results from a content analysis of interviews are displayed in Table 4-8. Discussion topics received a score between zero and three for each interviewee, depending upon whether they: mentioned the issue (1), discussed the issue (2), or emphasized the issue (3). A total of 42 points is possible for each discussion topic with the public sector (14 interviews x 3 possible points = 42 total possible points). A total of 21 points is possible for each discussion topic with the private sector (7 interviews x 3 possible points = 21 total possible points). The content analysis (Table 4-8) displays the percentage of total points for each discussion topic $[(\text{actual points} / \text{total possible points}) \times 100]$.

The following three sections are presented in a similar order: (a) statements of agreement between stakeholders, (b) statements of disagreement between stakeholders (shown in bold for Table 4-6), (c) statements with statistically significant (@ $p = 0.01$) variance (shown in grey shading for Tables 4-6 and 4-7), and (d) content analysis scores.

Table 4-6: Survey Statement Mean Scores

Mean Scores	Survey Statements																
	Environmental Quality					State & Local Program					Best Management Practices						
Characteristic	1	2*	3	4	5*	6	7	8	9	10*	11	12*	13	14	15	16*	17
Gender																	
Female	5.11	4.74	5.53	5.05	4.74	3.81	3.79	4.33	5.32	4.68	5.05	5.26	4.50	5.05	5.37	4.72	2.74
Male	4.86	4.30	5.36	4.86	4.27	3.73	4.10	4.43	5.28	4.08	4.70	4.59	4.55	4.84	4.29	4.17	3.21
Total	4.91	4.40	5.40	4.90	4.38	3.74	4.02	4.41	5.29	4.22	4.78	4.74	4.54	4.89	4.54	4.30	3.10
Age																	
25-39	5.00	4.45	5.43	4.98	4.38	3.82	4.59	4.38	5.25	4.22	4.48	4.85	4.62	5.00	4.70	4.36	2.95
40-49	4.91	4.18	5.26	4.70	4.26	4.00	4.05	4.45	5.26	4.00	4.86	4.68	4.36	4.64	4.45	4.09	3.33
50+	4.68	4.47	5.53	4.95	4.53	3.35	3.00	4.50	5.37	4.39	5.26	4.53	4.50	4.89	4.21	4.37	3.26
Total	4.90	4.38	5.40	4.89	4.38	3.77	4.06	4.43	5.28	4.20	4.77	4.73	4.52	4.88	4.52	4.29	3.13
Landowners																	
No	5.27	5.00	5.73	5.36	4.82	4.40	4.45	4.45	5.18	4.82	4.91	5.55	4.91	4.82	4.82	4.73	3.09
Yes	4.86	4.31	5.35	4.83	4.31	3.65	3.96	4.40	5.31	4.13	4.76	4.62	4.48	4.90	4.49	4.23	3.10
Total	4.91	4.40	5.40	4.90	4.38	3.74	4.02	4.41	5.29	4.22	4.78	4.74	4.54	4.89	4.54	4.30	3.10
Parents																	
<No response>	4.86	3.86	5.29	5.14	3.86	3.43	4.43	3.83	4.86	4.00	4.43	4.14	4.29	4.57	4.57	3.86	4.14
No	5.26	5.04	5.56	5.30	4.85	4.12	4.33	4.41	5.52	4.63	5.15	5.19	4.89	5.30	5.04	4.89	2.93
Yes	4.73	4.12	5.33	4.65	4.20	3.59	3.79	4.48	5.22	4.02	4.63	4.58	4.37	4.71	4.25	4.02	3.04
Total	4.91	4.40	5.40	4.90	4.38	3.74	4.02	4.41	5.29	4.22	4.78	4.74	4.54	4.89	4.54	4.30	3.10
Pitt County																	
Out of Pitt	5.13	4.98	5.64	5.21	4.63	3.94	3.94	4.49	5.55	4.74	5.13	4.87	4.71	5.06	4.98	4.85	3.21
In Pitt	4.53	3.40	4.97	4.37	3.93	3.39	4.17	4.27	4.83	3.28	4.14	4.52	4.21	4.59	3.72	3.25	2.90
Total	4.91	4.40	5.40	4.90	4.38	3.74	4.02	4.41	5.29	4.22	4.78	4.74	4.54	4.89	4.54	4.30	3.10
T-P Location																	
Lower	4.63	3.74	5.09	4.60	4.17	3.38	4.03	4.09	4.83	3.71	4.41	4.65	4.34	4.71	3.91	3.70	2.94
Out	5.33	5.27	5.77	5.16	4.67	4.14	3.77	4.62	5.74	5.06	5.39	5.03	4.68	4.90	5.29	4.90	3.07
Upper	4.76	4.24	5.35	5.06	4.29	3.76	4.47	4.71	5.41	3.71	4.41	4.41	4.65	5.24	4.41	4.35	3.47
Total	4.91	4.40	5.40	4.90	4.38	3.74	4.02	4.41	5.29	4.22	4.78	4.74	4.54	4.89	4.54	4.30	3.10
Employment Sector																	
Other	5.78	5.78	6.00	5.78	5.22	4.00	3.00	3.13	5.33	5.89	5.78	5.78	5.25	5.33	5.56	5.78	2.78
Private	4.52	3.30	5.00	4.36	3.85	3.35	4.33	4.61	4.91	2.94	4.09	4.37	4.22	4.84	3.84	3.29	3.44
Public	5.05	5.00	5.59	5.15	4.62	4.00	4.00	4.50	5.59	4.85	5.10	4.80	4.65	4.83	4.85	4.73	2.90
Total	4.91	4.40	5.40	4.90	4.38	3.74	4.02	4.41	5.29	4.22	4.78	4.74	4.54	4.89	4.54	4.30	3.10
Occupation Category																	
State	5.31	5.87	5.88	5.29	4.94	4.44	3.19	4.44	5.71	5.59	5.41	5.65	4.94	4.82	5.25	5.24	2.75
Local	4.88	4.50	5.38	5.04	4.46	3.78	4.22	4.42	5.50	4.37	4.92	4.29	4.48	4.92	4.50	4.46	2.96
Development	4.58	3.44	5.08	4.47	3.89	3.41	4.42	4.57	5.00	3.17	4.23	4.43	4.29	4.86	4.03	3.47	3.43
NGO	6.00	5.83	6.00	5.83	5.33	3.60	3.17	3.33	5.00	5.83	5.67	5.83	5.17	5.17	5.67	5.67	2.67
Total	4.91	4.40	5.40	4.90	4.38	3.74	4.02	4.41	5.29	4.22	4.78	4.74	4.54	4.89	4.54	4.30	3.10

1-6 scale; Mean score of 3.5 indicates the neutral response boundary

Bold mean scores indicate disagreement with statement (mean scores above and below 3.5)

Gray shading indicate statistically significant variance between groups @ p = 0.01

* Mean scores have been reversed for uniformity; high scores indicate an ecocentric (pro-environmental) response

Table 4-7: One-Way Analysis of Variance																	
F-Statistic	Survey Statements																
	Environmental Quality					State & Local Program					Best Management Practices						
Characteristic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Gender	0.928	1.294	0.797	0.458	3.180	0.069	0.614	0.074	0.018	2.391	1.076	4.073	0.033	1.057	8.595	1.943	1.367
Age	0.661	0.281	0.746	0.508	0.647	1.579	9.117	0.064	0.097	0.345	2.522	0.410	0.457	1.568	0.732	0.261	0.522
Landowners	1.698	2.145	2.756	2.299	2.436	3.759	1.058	0.016	0.150	2.029	0.122	5.044	1.804	0.106	0.460	1.083	0.000
Parents	2.622	4.187	0.987	3.411	4.833	2.022	1.446	0.651	1.50	1.509	1.694	2.772	2.683	6.165	2.554	3.496	1.834
Pitt County	7.693	30.14	21.31	13.11	10.13	4.104	0.440	0.554	11.41	22.18	12.40	1.363	4.783	7.234	16.14	28.90	0.771
T-P Location	4.807	11.10	9.206	2.488	2.052	3.463	1.215	1.950	8.634	9.469	6.052	1.419	1.021	2.687	8.472	6.003	0.669
Sector	7.638	27.43	12.43	9.661	10.98	3.003	2.976	4.781	4.744	41.38	10.12	4.519	4.296	1.636	7.717	19.80	1.302
Occupation	5.452	22.32	7.98	4.779	7.952	3.064	3.624	1.584	2.772	23.06	5.088	7.056	2.594	0.310	4.299	10.30	1.026
<i>Italics</i> indicate significant at 0.05. Grey shading indicates significant at 0.01 The t-statistic and F-statistic are the identical for a two-case sample, and therefore the F-test statistic is reported for consistency																	

Table 4-8: Interview Content Analysis		
Public Sector	Discussion Topics	Private Sector
n = 14		n = 7
Environmental Quality		
26.2	Water is an asset worthy of protection through stormwater regulations	19.0
14.3	Political will of citizens in necessary prior to mandating stormwater regulations	23.8
9.5	Citizens resists change and additional governmental regulations	23.8
21.4	Stormwater regulations should emphasize quantity or volume of runoff	33.3
16.7	Stormwater regulations should emphasize quality or purity of runoff	23.8
State & Local Program		
28.6	Stormwater rules are mandated from Federal to State to Local governments	47.6
4.8	The science involved in nutrient loading calculation is lacking/confusing	38.1
5.6	The stormwater rules should include more room for local interpretation	19.0
28.6	Administration of stormwater regulations at the local government level is essential	14.3
4.8	Leadership of stormwater programs is lacking at the state and local government level	19.0
28.6	Science and water quality expertise of local government administrators is lacking	23.8
9.5	County & City governments are staffed differently, making administration of stormwater regulations difficult	0.0
14.3	The illicit discharge identification and removal requirement will be challenging	14.3
7.1	Cooperation of all stakeholders is needed for success of stormwater regulations	33.3
38.1	Education component of stormwater programs is critical to success	33.3
14.3	The fragmented jurisdiction of the stormwater rules is confusing, and unjust	38.1
14.3	Stormwater requirements must be basinwide	23.8
11.9	Regulating stormwater runoff from new developments ONLY is unwise	19.0
7.1	Exemptions from stormwater requirements for agricultural operations are unfair	14.3
Best Management Practices		
23.8	The state must provide more flexibility with respect to selection of BMPs to limit runoff	47.6
11.9	The state process involved in certifying an alternative BMP is too long and difficult	28.6
4.8	Locations in the basin should have different stormwater requirements	14.3
Economics		
14.3	Total cost of development is a primary issue with respect to additional stormwater rules	71.4
16.7	The motivation of a developer is to make a profit, not reduce stormwater runoff	52.4
0.0	The requirement of structural control BMPs results in loss of land and therefore profit	33.3
16.7	Stormwater rules discourage development in economically-depressed areas	9.5
23.8	The nutrient loading buy-down option is an important alternative to BMP installation	14.3
26.2	Long term maintenance of BMPs is a major concern	28.6
19.0	Conservation easements are more cost-effective alternatives to structural BMPs	0.0
Each discussion topic is scored between 0 and 3 points for <i>each</i> interview		
Total of 14 public sector interviews (14 x 3 = 42 total possible points)		
Total of 7 private sector interviews (7 x 3 = 21 total possible points)		
Values are computed as % of total: [(((sum of points per discussion topic) / (total possible points)) x 100)]		
Grey shading indicates unanticipated emphasis topics of Economics and Leadership		

Environmental Quality

Total mean scores (tms) for statements one, three, and four are all above the 3.5 neutral line (Table 4-6), indicating that stakeholder categories *agreed* that protecting water quality is important: (a) regardless of reason (q. #1, tms = 4.91); (b) for the next generation (q. #3, tms = 5.40); and (c) for its intrinsic value (q. #4, tms = 4.90).

Stakeholders further agreed that the quality of the economy is *not* more important than the quality of the environment (q. #5, tms = 4.38).

Means scores fell on both sides of the neutral line, and therefore indicated disagreement between stakeholders when asked whether stormwater regulations impose unnecessary limitations on development (q. #2). For example, the mean score (for q. #2) for survey stakeholders in Pitt County is 3.4, whereas the mean score for surveys outside Pitt County was 4.98. This finding suggests the statement on stormwater regulations imposing *necessary* limitations on the development process is potentially more controversial than other survey statements, and may contribute to difficulty in stormwater regulation in Pitt County.

Statistically significant variation among occupation groups and employment sectors (F-test statistics, shown in Table 4-7) are reported for each of the five environmental quality questions. The same magnitude of variation cannot be reported for questions regarding the remaining two sections (state and local program or best management practices). These results indicate that perceptions of environmental quality are highly varied between stakeholder groups.

Findings from the content analysis suggest that the public sector emphasizes water quality as an asset to the public, and is therefore worth regulation on their behalf, more often than the private sector (26.2% versus 19% of total points). The private sector discussed and emphasized the need for citizens to generate political willpower prior to mandating stormwater regulations to protect water quality (23.8% versus 14.3%).

State and Local Program

Mean scores indicate that stakeholder groups are in agreement (tms = 5.29) that environmental education and community outreach will be essential in the success of stormwater regulation (q. #9). This is the only question from the state and local program section in which mean scores are above 3.5, indicating agreement with the statement.

Mean scores indicate stakeholder disagreement with the statement, “the model local-government stormwater ordinance is an appropriate balance between the Clean Water Act goals and development needs” (q. #6). The difference between mean scores among stakeholder groups, however, is not statistically significant. Mean scores further indicate disagreement with regards to the 30% reduction in nutrient loading, as set by the state of North Carolina (q. #10, Table 4-6).

Variation between stakeholder groups, with respect to the 30% reduction limit (q. #10) is statistically significant for multiple demographic and geographic categories (Pitt County, Tar-Pam location, employment sector, and occupation category). Although mean scores for question #9 (“environmental education is essential...”) are all above 3.5, the variation between groups is statistically different (Table 4-7).

Interviews with private sector stakeholders emphasized the fact that stormwater rules should allow for interpretation and flexibility despite the fact that they are state-mandated. The private sector as a whole also discussed the belief that the science behind quantifying nutrient loading may be lacking (38.1% of total possible points). This notion is primarily in reference to articles dealing with the flux of atmospheric deposition of nitrogen, which may counterbalance any net effects of reduced loadings from stormwater (Whitall et al., 2003).

The public sector discussed and emphasized the need to have the stormwater regulations administered at the local government level for improved efficiency and oversight. Although both sectors discussed the fragmented jurisdiction of stormwater regulation, the private sector emphasized this issue more often. A fragmented jurisdiction is in reference to (1) the urban stormwater rules (6 municipalities and 5 counties); (2) the NPDES Phase II program (census-designated urbanized areas); and (3) the State Storm Water Program (SSWP, coastal counties or HQW/ORW). Each of these programs is administered by different governmental agencies, and involves different locations within the basin.

Best Management Practices (BMPs)

Mean scores above 3.5 from Table 4-6 suggest that stakeholders agree: (a) “Reducing non-point source pollution is equally as important as reducing point source pollution” (q. #11, tms = 4.78); (b) “Structural stormwater control BMPs greatly reduce nutrient loading” (q. #13, tms = 4.54); (c) “Structural stormwater control BMPs should be

aesthetically designed to enhance the landscape's appearance" (q. #14, tms = 4.89); and (d) they would be "willing to have a structural stormwater control BMP installed without cost" on their property (q. #15, tms = 4.54) (Table 4-6).

When asked if "structural control BMPs unnecessarily raise the cost of development projects" (q. #16), mean scores indicate agreement and disagreement between stakeholder groups similar to the scores from question #2 (whether stormwater regulations impose unnecessary limitations on the development process). This finding suggests that additional costs of installing BMPs may contribute to the perception of stormwater regulations as unnecessary.

Four of the seven questions relating to BMPs indicate statistically significant sample variation between stakeholder groups (Table 4-7), despite the fact that mean scores are above 3.5 (agreement with the statement) for six of these questions (Table 4-6). This finding suggests that perceptions of best management practices are varied among *individual* stakeholders, yet groups of stakeholders do not vary to the same degree.

Interviews with the private sector emphasized the need for more alternative BMPs to be included in the state's approved BMP manual (28.6% of total possible points). The private sector also mentioned the need for differing BMP structures available for upper versus lower basin area (14.3%, Table 4-8), citing that the quantity of water to be detained is much greater in the lower portions of the basin. One private sector interview disagreed with the notion that different BMPs should be available for differing locations.

4.2.2. Economic issues

Because economic considerations were (unexpectedly) more-heavily emphasized from both sectors, a separate topic titled ‘Economics’ has been synthesized and displayed in the content analysis (Table 4-8). The stormwater survey instrument did not explicitly address economic issues, and therefore mean score data on this topic was not gathered. These findings suggest that the economics is of primary importance for both the private and public sector. More specifically, the private sector emphasized profits lost due to additional stormwater requirements, while the public sector emphasized the availability of alternatives to meet the stormwater requirements.

Cost of development projects were a primary issue for the private sector (71.4% of total possible points). The topic of profit being the motivation for developers also scored heavily (52.4%). Lastly, the private sector discussed how required structural stormwater control BMPs resulted in the loss of profit because these structures occupy large portions of the land to be sold. This issue received a score of 33% of total possible points for the private sector. The public sector interviewees also discussed economics, including the belief that stormwater rules may discourage development in economically-depressed areas (16.7% of total possible points). Further economic discussion topics from the public sector centered on cost-effective alternatives to installing structural stormwater control BMPs, such as the buy-down option (23.8%) and the designation of conservation easements (19%). The nutrient loading buy-down option is a component of the Tar-Pamlico Nutrient Strategy – Urban Stormwater Rule that allows developers to pay a fine in lieu of failing to meet stormwater runoff requirements for nitrogen and phosphorous

loading. An additional cost-effective alternative to installing a structural stormwater control BMP involves the designation of conservation easements. Lands that would have been subdivided into residential lots and sold, are permanently retained as public open space and owned by the development's homeowners association. This option assists developers in meeting the stormwater runoff requirements for nitrogen and phosphorus loading by limiting impervious surfaces in hydrologically-sensitive areas.

5.0. DISCUSSION

The first research question has two parts, and asks ‘What is the spatial pattern of stormwater runoff potential in the Tar-Pamlico basin?,’ and ‘How does this pattern vary between human-imposed versus natural boundaries of scale?’ Results from the MCE reveal the following spatial trends, (1) areas of greatest potential for runoff are located in close proximity to urban centers, and areas of lowest potential for runoff are located farthest from urban centers; (2) upper portions of the study area have a greater number of high runoff potential than lower portions; (3) scale has a great impact for human-imposed block group versus natural HUC boundaries, however, this impact is not as apparent for human-imposed county versus natural subbasin boundaries; and (4) the frequency distribution of index scores at the block group and HUC-level are skewed, which indicate that a relative few of these observations have a large potential to generate runoff, while the majority have low potential for runoff.

The total index scores are composed of four indicators (impervious surface, land cover change, roadway density, and population change). There is a fundamental distinction between the spatial pattern of existing impervious surfaces that directly generate urban stormwater, and the pattern of indirect indicators of land cover and population change. Existing impervious surface in the study area is concentrated within urban centers, at the intersection of railroads and major highways (US-1, US-64, US-264, and I-95). Indirect indicators of stormwater runoff potential are highest for areas located *beyond* the boundaries of existing urban centers. This pattern is observed for the municipal, block group and HUC-level analysis, however, not visible for scales larger

than the HUC. Therefore, an important and unanticipated finding from this analysis is that the components relating to urban sprawl (land cover and population change in rural areas) can be observed at fine-scales in the Tar-Pamlico basin, most notably for areas in proximity to the City of Raleigh. This phenomenon is further discussed below.

5.1. 'Raleigh –sprawl'

The development pressure influence of Raleigh is observed at the municipal-level analysis, where the relatively small towns of Franklinton, Kittrell, Louisburg, and Youngsville, surrounded by major highways that connect with nearby Raleigh, are (1) experiencing greater land cover change; (2) have high roadway density scores; and (3) have moderately high population change. At the block group-level this influence is not as visually distinct from inspection of data scores and the skewed histogram distribution, indicating that the level of data aggregation may have a pronounced effect. When aggregation is broadened to hydrologic unit codes (HUCs), the spatial pattern of Raleigh-influence is visible upon inspection of the index maps, however, the histogram distribution for the HUC-level is also skewed. Lastly, counties and subbasins in the upper portions of the study area (and adjacent to Raleigh) display high runoff potential scores as well, despite only having moderate population change index scores. Distribution of observations for the county and subbasin levels of analysis is more normal.

Policy & planning implications

Data layers utilized by this MCE were free to obtain from the Internet, and ArcGIS software was utilized for because it is the industry standard for most planning departments. These decisions were made in the hope that local governments subject to the Tar-Pamlico Nutrient Strategy – Urban Stormwater Rule may choose to adopt this type of MCE to similarly visualize the pattern of stormwater runoff potential for their jurisdiction. An analysis of stormwater runoff potential will assist staff with the selection and prioritization of areas for retro-fit locations, which is a requirement set forth by the stormwater rule. Additionally, quantifying the amount and direction of both land cover and population change over time has planning implications. The geographical component (i.e., ‘Where is development moving?’) has implications for the allocation or redistribution of infrastructure resources to provide services to a changing population. Redistributing resources, such as providing water and sewer connections or establishing minimum lot size requirements, should be aimed at reducing this empirically-derived runoff potential by containing the symptoms of sprawl. The approach taken by this study has limitations, as discussed below.

5.1.1. Methodological considerations

The results from this GIS-based multi-criteria evaluation (MCE) are unavoidably influenced by issues of (1) data availability, and (2) methodology, such as (2a) weighted importance, and (2b) scoring of land cover changes.

Data availability

A more fine-scale (parcel-level) analysis, using more recent local data for individual counties or municipalities will undoubtedly increase the precision of locating stormwater runoff potential for a smaller study area. Data used to derive impervious surface scores was provided by the USGS (2001), as was land cover data from 1992 and 2001. The street density index uses 2000 data, and population change was calculated from 1990 and 2000 US Census data. These layers for the entire Tar-Pamlico basin were free to obtain, making them ideal for the purposes of this basinwide research, yet potentially inappropriate for most city or county planning departments. Replication of this analysis for an individual planning department would require the use of more recent, local data, possibly at the parcel-level. Study area (i.e., basinwide, countywide, or citywide) should help to determine the appropriate type of data to be obtained (Landsat, aerial photography, or tax parcel data). Utilizing parcel-level data for this basinwide analysis of stormwater runoff potential would have likely proven computationally inefficient. For example, the study area included portions of 18 counties, each of which may have between 30,000 and 80,000 individual parcels to be aggregated at each of the five analysis levels.

Weighted importance

The assignment of weighted importance is a relatively subjective, but not arbitrary, methodological consideration. Any adjustment of weights will alter the computation of total index scores. This analysis uses the following weighting scheme

derived from existing literature, (1) impervious surface = 0.60; (2) land cover change = 0.15; (3) roadway density = 0.15; (4) population change = 0.10. Impervious surface was the only direct indicator of stormwater runoff potential, and was therefore weighted more heavily. The remaining three are all indirect indicators, and therefore weighted less-heavily, with population change receiving the least weight. This research attempted to visualize the spatial pattern of stormwater runoff potential. An analysis that focuses on future development trends would therefore assign weights more-heavily to the land cover and population change data layers.

Land cover change scoring

Attribute values were also subjectively, and not arbitrarily, assigned to qualitative land cover classifications. Different attribute values for land cover (Urban = 100; Cultivated Cropland = 0.25, etc.) or an alternative scoring method to indicate *change* ('01 value – '92 value; negative scores adjusted to '01 value), would yield differing results for each of the five units of analysis. Land cover change for this study involved the change in land cover between 1992 and 2001 for 30x30 m grid cells. Attribute values were determined for each of the six land use categories (see Methods section) using references from existing literature. Specific land cover changes, such as cultivated cropland to urban, or forest/wetland to urban could be more heavily scored for a similar study that specifically aimed at identifying the process of suburban sprawl.

Increasing the number of generalized land cover categories from six to the full 21 could theoretically increase the precision of this analysis. Justification of scores for each

of the 21 categories would be no more accurate than an educated guess, however, because existing studies utilize fewer variables for a more parsimonious analysis. Furthermore, distinctions between runoff potential from a ‘deciduous’ versus ‘evergreen’ forest, or a ‘hay’ versus ‘grain’ cropland, may not be quantifiable, and therefore including all 21 categories may not be necessary for most research.

5.2. Stormwater program disconnect

The second research question asks, ‘Do attitudes and perceptions on stormwater regulation issues vary geographically and/or demographically in the basin?,’ and ‘Are areas of greater stormwater runoff potential in the Tar-Pamlico basin linked with unified perceptions on stormwater regulation?’ Results from the analysis of variance indicate that significant differences of means scores are reported between stakeholder *locations* within the basin (Pitt County, non-Pitt County; upper, lower, and out of the basin), as well as between *demographics* such as employment sector (public, private, and other) and occupation category (state, local, development, and NGO). These differences of attitudes and perceptions contribute to a general *disconnect* between stormwater *policy* and *application* of the Tar-Pamlico urban stormwater rules. Most stakeholders agreed that stormwater is problematic, and that characteristics of urban development contribute to the problem. Stakeholders did not agree across disparate groups with regard to survey statements associated with the state-level stormwater program. Mean scores of stakeholders geographically located outside of Pitt County indicated a stronger agreement (more ecocentric perspective) for these statements than those stakeholders within Pitt

County. The MCE analysis identified subbasin #5 (almost exclusively within Pitt County) as the highest ranking subbasin for stormwater runoff potential, followed by subbasins located in the upper portion of the basin (near Raleigh). This finding answers the second part of research question number two, specifically ‘Are areas of greater stormwater runoff potential spatially linked with more unified perceptions on stormwater regulation?’ Mean scores from state and local program statements indicate that Pitt County stakeholders, in fact, agree to a lesser extent with the state-mandated stormwater regulations than stakeholders outside of Pitt County.

Mean scores of survey participants from the state occupation category indicated stronger agreement than those of local government and the development category, meaning that the state employees were more likely to agree with their own state-mandated regulations. This was logically anticipated of course, however, the state mean scores were trumped by the ‘other’ employment sector and NGO occupation stakeholders, which indicated that these activists more strongly agreed with statements concerning the state and local program.

Survey questions on the topics of environmental quality and best management practices yield (statistically-significant) different mean scores, however, little disagreement (mean scores above 3.5 for one group and below 3.5 for another group) between stakeholders is observed. Questions dealing with the state and local program, conversely, involve a greater amount of disagreement between stakeholder groups, indicated by different mean scores that straddle the mid-point value (3.5) of the Likert

scale. This research finds that the theoretical disconnect between the state, local, and private sector may be founded (more specifically) on the basis of program administration.

5.2.1. Proposition

Administration of a stormwater program at the local government level is a distinct characteristic of the Tar-Pamlico Urban Stormwater Rule, making it unique compared to many (but not all) remaining North Carolina water quality regulations (refer to literature review section). The public and private sector discussed the importance of local (rather than state) government administration during interviews. The public sector emphasized increased efficiency of administration by those who live and work locally, while the private sector emphasized the need for stronger program leadership. This finding is another unexpected, yet intriguing topic for discussion. The issue of leadership roles is further discussed below, followed by a proposition for advancement of local government environmental planning programs to accommodate the need for leadership.

Local government leadership

The need for dependable leadership on behalf of the local government administrators is a repeated conversation topic from private sector engineers and development contractors, and may be a limiting factor for sustained stormwater program success. The purpose for mandated stormwater rules is agreed upon and viewed as necessary from both perspectives as indicated by survey mean scores and interviews, however, there appears to be insufficient leadership direction as perceived by the private sector.

A lack of available resources, in the form of printed design standards to limit stormwater, or case studies on successful projects, may be contributing factors to the limited leadership as identified by the private sector. Interviewees from the private sector mentioned the lack of a clearly defined leadership role on the part of local governments, and attributed it to a lack of available resources. On the other hand, local government administrators responded positively when asked about the availability of such printed technical resources, workshops, and administrative support supplied by the state government (see the NCDENR Stormwater and Runoff Pollution webpage <<http://www.ncstormwater.org/>>). Public sector interviewees were satisfied with the availability of resources. These same local government administrators were more concerned with their own general lack of ecological expertise, frequently citing that they are planners and/or public works employees, and not water quality technicians. I agree that the plethora of materials available is sufficient, however, I observed a general lack of commitment and enthusiasm for local-level administration of the stormwater program

from local government stakeholders. It is my finding that the perception of a general lack of ecological expertise would be mitigated by immersing themselves in the wealth of available ecological information provided by the Internet. This research tool is the most powerful of our generation, and should be more heavily used by local government stormwater program administrators. In doing so, they can more adequately fill the perceived leadership void by fulfilling the multiple roles of: (1) administrator and regulator of the stormwater requirements; (2) liaison between the state government and private sector (who disagree with respect to many survey questions); (3) arbitrator of local development issues; and (4) provider of technical information to the development community. By fulfilling these roles, the local government officials will also accomplish the increased efficiency sought after by administration of the stormwater program at a local government level.

This sentiment is reflected by Norton (2005), who presents the need for “more and better local planning” under the North Carolina CAMA rules. Norton’s findings suggest that local governments are more willing to complete the minimum state-mandated standards than to implement a local regulatory system that could be tailored to meet their unique needs. This research uncovers the same phenomenon, local government planners and administrators are willing to accept state-mandated stormwater regulations, yet they appear to be unprepared to entirely commit to the program’s successful administration at the local level. In effect, the Tar-Pamlico basin local governments are looking for leadership from the state government in much the same way that the private sector perceives a lack of leadership from the local government. This is a paramount and

unanticipated conclusion synthesized from interviews with stakeholders in the Tar-Pamlico basin.

Redefining ordinance administration

Taking the next step and moving forward with the notion of leadership on behalf of the local government, it may be necessary to reorganize the structure of environmental planning. Governmental planning is conducted according to long-range master plans, which outline problems and goals, choose strategies to meet these goals, and methods to implement such strategies. Traditional local-government planning departments are divided into (1) zoning and land use, (2) subdivision and development regulation, and (3) environmental planning. Each section addresses a different component of the development process, through the administration of separate ('stand-alone') ordinances. Stormwater planning involves a myriad of tradeoffs that coordinate with varying site conditions according to natural and man-made processes. Because of the complexity involved in environmental planning, basinwide water quality protection strategies that extend beyond the jurisdictional boundaries of the local government are necessary. A stand-alone ordinance (or 11 such ordinances in the Tar-Pamlico basin) for stormwater runoff would be largely ineffective for *basinwide* water quality protection. Findings of this research challenges local government planners in the Tar-Pamlico basin to combine their technical and financial resources to form and participate in a regional-scale unified watershed development committee based on the ecological principals of Smart Growth and water quality protection. To do so, I propose an initial reconnection with the state-

mandated stormwater program to address the perceived (and now quantified) disconnect between stakeholders.

5.3. Stormwater program reconnection

Reconnecting the policy goals of basinwide stormwater regulation and their application at the local government level falls upon the capable shoulders of varying city and county professional planners of the Tar-Pamlico basin. State-mandated requirements are passed down through a hierarchal chain of governments and development professionals such as engineers to individual land owners who are generally unaware of the problems associated with stormwater runoff. The message that is delivered to these individuals resembles a highly-restrictive government that requires additional controls and expenses to accommodate stormwater runoff. The theory behind *why* these policies are necessary, or *how* new development projects contribute to basinwide water quality protection, are simply lost during the process, contributing to the perceived disconnect.

The process of reconnecting theory and application of stormwater rules requires that (1) the philosophical realignment of political boundaries to coordinate with hydrologic boundaries; and (2) available resources and expertise be combined and shared among all municipalities. The Albemarle-Pamlico National Estuary Program (APNEP, 2006 <<http://www.apnep.org/>>) is an existing organization that is dedicated to the protection and enhancement of this region. The APNEP combines the resources and requirements of the North Carolina Department of Environment and Natural Resources (DENR) and the U.S. Environmental Protection Agency (EPA) in cooperation with the Virginia

Department on Conservation and Recreation (DCR). More locally, the Pamlico-Tar River Foundation (PTRF, 2006 <<http://www.ptrf.org/>>) is a small non-profit non-governmental organization (NGO) serving as an advocate for resource protection of the basin. These two organizations, however, are lacking local-government involvement that would add needed credibility and authority to their conservation efforts.

The major research findings of this thesis are:

- The spatial pattern of stormwater runoff potential is clustered near urban centers in the Tar-Pamlico basin;
- The direct and indirect indicators of this stormwater potential have differing spatial patterns across the Tar-Pamlico basin, with land cover and population changes influenced by the characteristics of sprawl from the nearby City of Raleigh;
- The spatial pattern of all indicators is scale-dependent;
- Stakeholder groups disagree with statements regarding the state-mandated local stormwater program;
- Both geographic and demographic variation of stakeholders characteristics contribute to varying attitudes and perceptions of stormwater regulations in the Tar-Pamlico basin;
- Economic issues are equally shared by stakeholders of both sectors, although for they are viewed pessimistically for the private and optimistically for the public sector;

- Leadership issues and the commitment of local government planners and administrators to the stormwater program are primary obstacles for overall success at the local level;
- A reconnection with the stormwater program requires the realignment of political jurisdictions with hydrologic boundaries.

Important policy implications stemming from these findings are that local governments must combine stakeholders for the purpose of uniting local efforts under an existing (funded) program. Through this organization, local governments can transform state-mandated stormwater requirements into local-level programs that promote and protect valuable resources. Theory and application of stormwater rules under a new local program will more appropriately translate to local developers as to *why* policies are necessary, and *how* new development contributes.

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APPENDIX

Survey Instrument (Front)

Perspectives on North Carolina Stormwater Regulations in the Tar-Pamlico River Basin

Informed Consent Statement: The East Carolina University (ECU) geography department is attempting to gather perspectives of NC stormwater regulation stakeholders. Please note: all surveys will be coded, in compliance with the ECU Institutional Review Board.

ECU Code: _____

Environmental quality: The following series of questions evaluates the degree to which you agree with a generalized statement about environmental quality. Please answer the questions based on a 1-6 scale, where 1- *strongly* disagree; 2- disagree; 3- *moderately* disagree; 4- *moderately* agree; 5- agree; 6- *strongly* agree.

1. Protecting water quality, *regardless* of reason, is important to me
☐1 ☐2 ☐3 ☐4 ☐5 ☐6
2. Stormwater regulations impose *unnecessary* limitations on the development process
☐1 ☐2 ☐3 ☐4 ☐5 ☐6
3. Protecting water quality for the next generation is very important to me
☐1 ☐2 ☐3 ☐4 ☐5 ☐6
4. Protecting water quality for its intrinsic value (valuable without human use) is *very* important to me
☐1 ☐2 ☐3 ☐4 ☐5 ☐6
5. The quality of our local/state economy is *more* important than the quality of our environment
☐1 ☐2 ☐3 ☐4 ☐5 ☐6

State & Local Program: Again, please answer the questions based on a 1-6 scale, where: 1- *strongly* disagree; 2- disagree; 3- *moderately* disagree; 4- *moderately* agree; 5- agree; 6- *strongly* agree.

Background: The 1972 federal Clean Water Act (CWA) goal involved "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water." The State of NC (NCDENR) has adopted basinwide water quality management plans to help achieve this goal. The State of NC has also created a model stormwater ordinance for local governments (counties of Beaufort, Edgecombe, Franklin, Nash and Pitt within the Tar-Pamlico basin).

6. The model local-government ordinance crafted by the State of North Carolina *appropriately* balances the goal of the Clean Water Act and the needs of development
☐1 ☐2 ☐3 ☐4 ☐5 ☐6
7. Each municipality within a river basin is unique, and therefore each should be allowed the flexibility to adopt *different* standards for stormwater runoff
☐1 ☐2 ☐3 ☐4 ☐5 ☐6
8. I believe *local-government* administration of stormwater regulations is essential because the state government of North Carolina does not have the necessary resources (i.e. work-force, funding, time)
☐1 ☐2 ☐3 ☐4 ☐5 ☐6
9. Environmental education and community outreach will serve an *essential* role in the success of stormwater regulation
☐1 ☐2 ☐3 ☐4 ☐5 ☐6
10. I believe that 30% reduction in nitrogen loading, as set by the State of North Carolina, is too stringent and therefore restricts development
☐1 ☐2 ☐3 ☐4 ☐5 ☐6

(Survey continues on back page...)

Participant feedback is essential & therefore encouraged:

Timothy Treshlavy, treshlavy@gmail.com

Department of Geography, Brewster A-236, East Carolina University, East Fifth Street, Greenville, NC 27858

Survey Instrument (Back)

Best Management Practices (BMPs): Please answer the questions based on a 1-6 scale, where: 1- *strongly* disagree; 2- disagree; 3- *moderately* disagree; 4- *moderately* agree; 5- agree; 6- *strongly* agree.

11. Reducing non point-source pollution (diffuse runoff from non-identifiable sources) is *equally* as important as reducing point-source pollution (conveyed through a storm drain pipe)

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

12. Non-structural, smart growth planning techniques (such as reducing road widths, minimizing curb & gutter use, mixed land use, and greenway trail design) do **NOT** help resolve stormwater issues

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

13. Structural stormwater control BMPs (such as bio-retention rain gardens, or detention ponds) *greatly* reduce nutrient loading from stormwater runoff

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

14. Structural stormwater control BMPs (such as bioretention rain gardens, or retention ponds) *should* be aesthetically designed to enhance the landscape's appearance

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

15. I would be willing to have a structural stormwater control BMP installed (without cost) on my property

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

16. Structural stormwater control BMPs *unnecessarily* raise the cost of development projects

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

17. I believe that a homeowners association is sufficient to undertake the long-term maintenance of structural BMPs

☐1 ☐2 ☐3 ☐4 ☐5 ☐6

If responses from the survey require a further explanation please fill out the following

Question #: _____

Question #: _____

Demographic questions

Name: _____ (optional)

Gender: ☐M ☐F

Age category: ☐18-24 ☐25-29 ☐30-39 ☐40-49 ☐50-64 ☐65+

Which NC County do you live in? _____

Zip code: _____

Do you own any land here? ☐Yes ☐No If Yes, approximately how many acres? _____ (acres)

Do you have any children? ☐Yes ☐No # _____

Which NC County do you work in? _____

Zip code: _____

For the purposes of this survey, what is your occupation category?

Public Sector

☐Local government employee/administrator

☐City ☐County

☐Local government board member/commissioner

☐City ☐County

☐State government employee/administrator

Private Sector

☐Development contractor

☐Professional engineer (P.E.)

☐Professional licensed surveyor (P.L.S.)

☐Other, please specify: _____

Are you willing to participate in a formal interview on NC stormwater regulation?

☐Yes ☐No How may I best contact you? _____

Participant feedback is essential & therefore encouraged:

Timothy Treshlevy, treshlevy@gmail.com

Department of Geography, Brewster A-236, East Carolina University, East Fifth Street, Greenville, NC 27838