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BENEFITS OF QUALITY IMPROVEMENTS IN NORTH CAROLINA'S WATER RESOURCES

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Abstract

This project uses revealed preference methods to assess the monetary benefits to recreation users of ambient water quality improvements in North Carolina, focusing in particular on conventional nutrient pollutants. Specifically, data from a 1994 survey describing recreation use of water resources throughout the state of North Carolina are used to estimate a multinomial logit model of site choice. Sites in this application are defined to be 8-digit hydrological unit watersheds in the state. Linked to these watersheds are measures of water quality obtained from the EPA's Index of Watershed Indicators as well as from the STORET data repository. Results provide considerable evidence that water quality affects recreation site choice, and that users of North Carolina's water resources attach significant value to water quality improvements. Per visit benefits of significant reductions in nutrients in the Neuse River basin are estimated to be $1.97, while similar improvements in the Cape Fear basin are estimated at $2.25 per visit. These figures translate to roughly $29 million and $33 million in annual benefits, respectively.

(Keywords: revealed preference, water quality, benefits estimation, random utility models)

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Summary and Conclusions

This study uses econometric revealed preference methods to assess the monetary benefits to recreation users of water quality improvements in North Carolina. Observed visits to water resources are used to indirectly assess the value to users of the state's waterways. The emphasis is on modeling the impact of conventional nutrient pollution on water recreation site choice. Specifically, data from a 1994 survey of water recreation use are combined with two sources of quality data to estimate a multinomial logit model of water recreation site choice. Recreation sites for this study are defined to be the 8-digit hydrological units in the state, also known as watersheds. Watersheds are defined to be surface water units that include a common drainage area, such that the characteristics of the watershed are approximately homogeneous across its expanse. Significant variation exists in watershed quality across the state. This choice set uses this variation to capture the effects of water quality on recreation decisions while abstracting from factors affecting the choice of a specific destination within the watershed.

Two structural models are estimated, one relying on water quality data from the EPA's Index of Watershed Indicators web site and the other relying on data from the STORET water quality data repository. A characterization of recreation users' preferences for water quality is estimated. From this an understanding of the importance of different pollutants in the decision process is gained. In each case chemical measures of water quality such as acidity, dissolved oxygen, nitrogen, phosphorous, and chlorophyll a are found to significantly affect recreation site choice, with users choosing to visit watersheds with better water quality.

The preference characterizations can be used to measure the benefits to recreation users of quality improvements. Benefits are measures in income equivalents and should be interpreted as a budget-constrained willingness to pay for the improvements. For example, reducing levels of ammonia to 0.1 mg/l in surface waters across the state is found to produce a per trip benefit of \$0.24, while raising levels of dissolved oxygen to 5.0 mg/l produced a per trip benefit of \$0.94. Rough calculations of aggregate annual benefits of these policies are \$3.52 million and \$13.8 million, respectively. Still larger aggregate benefits (\$154 million) are found for similar phosphorous reductions. For the case of improvements in individual river basins, significantly reducing levels of multiple nutrients in the Neuse and Cape Fear basins produce annual aggregate benefits of \$29 million and \$33 million, respectively. These benefits estimates should be interpreted as conservative, since they include only value held by active recreation users of water resources.

Recommendations

Water quality provides benefits to individuals and hence has value. Because it is not traded in the market a price does not exist from which this value can be compared to other goods. Related to this, water quality values cannot be directly examined for the purpose of comparison to the costs of water pollution prevention. Alternative methods are therefore needed to assess this value for policy purposes.

Using revealed preference methods this research finds convincing evidence that water quality matters in the choice of recreation site and that users of North Carolina's water resources would receive significant benefits from water quality improvements. Qualitatively, the results demonstrate that efficiency gains can be obtained from efforts to improve water quality and suggest that policies designed to reduce non-point source pollution provide positive net benefits and should continue, perhaps to a greater extent than is currently under way. Quantitatively, the models estimated in this study can be used to compute the benefits of potential polices for the purpose of comparing benefits to costs resulting from the regulation. For example, the Neuse river basin estimates can be compared to the costs of similar pollution prevention efforts.

The innovative aspects of this study include the use of 8-digit HUCs in the definition of the statewide recreation choice set. This strategy appears well suited for understanding the role of water quality in recreation decisions. Further research may expand on this idea, increasing the spatial resolution by defining smaller hydrological units (i.e. 14-digit HUCs) for the statewide choice set. This would further strengthen the assumption that water quality is homogenous within a given site and allow a more precise understanding of how differences in water quality affect choices. Additional research may also seek to better understand how available water quality data, which usually takes the form of chemical measures, can be better linked to factors which directly affect recreation behavior.

I. Introduction

The 1972 Clean Water Act established ambitious goals for protecting and enhancing the quality of the nation's surface waters. When the legislation was written, the goal of the Act was to provide essentially zero levels of pollution discharge by the mid-1980's. While nearly three decades of regulation have obviously failed to meet this unrealistic goal, there have nonetheless been substantial improvements in surface water quality. These improvements have primarily been the result of technology standard regulations aimed at traditional point sources of pollution such as industrial and municipal sources, resulting in large decreases of toxic and organic chemical loading. To further address water quality issues in the country attention is now being turned to the more difficult problems of ambient water quality regulation and, along with this, the problem of non-point source pollution (Boyd 2000). In 1998, policy makers articulated a shift in national water quality policy to more directly address the non-point problem (Ribaudo, et al. 1999). Agriculture and urban runoff are the largest contributors of non-point source pollutants, which primarily include nutrients, sediments, and pathogens. Nutrients such as nitrogen and phosphorous are the leading cause of quality impairment in lakes and estuaries, and the second leading cause in rivers (Ribaudo, et al. 1999).

As is well known, policies to deal with non-point source pollution are substantially more difficult to design and implement than their point-source counterparts. This stems from the difficulty in identifying and quantifying the numerous and diffuse sources of pollution, as well as the fact that random events such as weather affect pollution runoff. Furthermore, contributors to non-point source pollution tend to be farmers, small businesses, and individual households, upon whom society has in the past been hesitant to impose the costs of pollution prevention. Nonetheless thirty years of regulations aimed at point-sources suggests that the cost-effective possibilities for further water quality improvements likely lie in the regulation of non-point sources. Society is therefore now faced with difficult choices about the benefits and costs of the politically more difficult regulation of non-point sources of water pollution.

The story in North Carolina is similar to that at the national level. Because the state has both a large agriculture sector and fast growing urban areas, non-point sources of pollution, particularly nutrients such as nitrogen and phosphorous, are the largest threat to water quality in the state. Clearly, water quality is very much in the public eye, as evidenced by the prominence of the debate over the future of the state's swine industry in political races and the emotional responses to news of fish kills on the coast. Specific concerns have been voiced over health issues associated with water quality in the state, as well as the effects on tourism and recreation of diminished water quality. In response to these concerns there is a menu of potential policies that could be implemented to improve water quality. These include policies aimed at agricultural operations such as the use of Best Management Practices in cropping activities or the search for replacement technologies for animal waste handling systems. It may also include policies aimed at urban sources of pollution, such as development restrictions and open space initiatives.

Nearly the entire debate on water quality has focused on the costs of implementing the various types of regulations and policies and upon whom they should fall. The costs, however, represent only half the story. What has received much less attention is discussion of the benefits, in terms of income equivalents, of water quality improvements stemming from the additional regulation.

In the economic sense, water and water quality are "goods" consumed by individuals for various purposes. These include obvious uses such as drinking and bathing, but may also include more general uses such as water recreation, wildlife habitat provision, and parks and conservation uses. As with any scarce good, water quality is costly to provide and provides benefits when consumed. Unlike most goods that we are used to thinking about, water quality is not bought and sold in a market and hence has no price from which we can infer its value and weigh this value against other uses. Thus, water quality is a "non-market" good. The invisible hand of the market, which for typical goods can be depended on to deliver the correct quantity, fails in the case of non-market goods; regulation is therefore needed to ensure the "correct" level of water quality. Only a careful comparison of costs and benefits can help policy makers determine the correct level of regulation to be implemented, particularly for the case of difficult non-point source pollution policies, where an understanding of the benefits is critical in justifying additional new regulations.

As previously noted, the benefit side of designing effective regulation has received less attention in the North Carolina. Existing benefits studies have tended to focus on the benefits of water quality on the coast and in the estuaries. What has been lacking is an examination of water quality benefits in the state as a whole, including not only coastal but also inland water resources.

II. Purpose and Objectives

The purpose of this study is to fill this void by examining a component of the benefits of water quality improvements at the state level. As noted above, water quality benefits can be described for many diverse uses of water. In this study, the focus is on the recreational benefits of improved water quality. In particular, the relationship between the recreational use of the state's water resources and ambient water quality is examined. Attention is focused on pollutants such as nitrogen, phosphorous, acidity, low dissolved oxygen, and chlorophyll a to best characterize the effects of non-point source pollution problems in the state. Specifically, data from a national survey of water recreation use conducted by the EPA is combined with water quality data from two sources to estimate an econometric model of recreation site choice. The model characterizes recreation choice as a function of ambient water quality and other site characteristics. This model can then be used to quantify the dollar benefits of various water quality improvement plans. To summarize, the specific objectives of the study include:

- Characterize water recreation choice in the state as a function of ambient water quality data and other characteristics.
- Calculate the benefits of various water quality improvements, such as the reduction of nitrogen and phosphorous levels to consensus criteria levels, which can then be used for comparison with the costs of proposed policies.

The remainder of this report is organized as follows: Section III outlines procedures that will be followed, while section IV provides a brief review of related literature. Moving towards the specifics of the study, section V discusses the available data and section VI the model specification and results. Finally, section VII provides discussion and conclusions.

III. Procedures

The purpose of this study is to assess the dollar value of improvements in water quality. It is worthwhile to be clear at the outset that we are interested in dollar values held by individuals as measured by their willingness and ability to pay out of household income for these improvements. This economic concept of value is distinct from measures such as increased revenues to the tourism industry from water quality improvements, which is less grounded in theory as a measure of value. Since water quality is a non-market good, no price is available for comparative valuation, and alternative methods must be examined. Economists have in general used two approaches for valuing non-market goods such as water quality, stated (direct) preference and revealed (indirect) preference techniques. Stated preference techniques rely on surveys to solicit from individuals directly their value of a resource. For example, a survey may describe for an individual a program, which would change levels of water quality in an area. Each individual in the sample would then be asked if they would be willing to pay a certain amount for that change. Responses of individuals can then be used to calculate the resource value. Stated preference techniques are convenient in that they are flexible enough to be used in a wide variety of areas, from valuing clean drinking water to preserving wildlife habitat. Stated preference methods are often criticized, however, for the hypothetical nature of respondents' answers, and some economists are therefore suspicious of benefits estimates from this technique.

Revealed preference techniques, by contrast, rely on observing individuals interacting with the good of interest to indirectly infer the value of the resource. One such approach is the travel cost model. The travel cost model attempts to characterize the demand for an environmental service (e.g. water quality) by examining recreation trips to the resource for the purpose of "consuming" the environmental service. For example, an individual may travel to a lake or river to enjoy a day of swimming or fishing. By engaging in the activity, the individual is "consuming" water quality. By purchasing a recreation trip, the person is in essence "purchasing" the water quality that goes with it. While we do not typically think of purchasing a recreation trip, there are nonetheless costs associated with taking a trip-- vehicle operation costs and the value of time spent in travel chief among them. Calculation of these costs allows us to specify an implicit price for taking a recreation trip, which can then be used to estimate a demand relationship between recreation trips to a site of interest and the implicit price associated with taking a trip. All things being equal, because travel is costly and travel time valuable and scarce, we expect that people would visit recreation sites closer to their home, since these have a cheaper "price". Recreation sites in general and water recreation resources in particular are not, however, homogenous. Some may have amenities such as boat launch facilities, picnic areas, bathrooms, and beaches with lifeguards. In addition, the environmental quality at sites is likely to differ. Thus, it is not only the implicit price but also site characteristics that are likely to affect visits to a site.[1] A demand equation for trips to a recreation site should therefore include not only the implicit price, but also, to the extent available, variables measuring site characteristics.

Having manufactured a demand relationship between recreation trips and the implicit price of a trip, we can now think of it as a traditional market good for which an estimate of the demand relationship can be used to calculate the benefits to consumers of consumption of the good.

[1] This is not unlike the case for other quality-differentiated goods such as certain types of food, where the choice is not strictly a price-quantity tradeoff, but rather a price-quantity-quality decision.

Economic theory provides tools that can be used to gauge the benefits of price changes and/or site quality changes for users of the resource. The focus on users highlights an important limitation in revealed preference/travel cost models. Because we depend on individuals interacting with the resource to gauge resource benefits, values that may be held by individuals who do not visit the resource cannot be measured by this method. Non-use resource benefits such as existence value, bequest motive, and future-use option value, while potentially recoverable using stated preference methods, are not measured by travel cost models. Benefits estimates from revealed preference models should therefore be thought of as providing a lower bound. A specific type of travel cost model, the random utility model, is to be applied for this study.

A. Random Utility Models

The random utility maximization model (RUM) models the determinants of an individual's recreation decision on a given choice, or trip taking, occasion. It is assumed that on this occasion the individual is faced with an a priori given discrete number of mutually exclusive alternatives (the recreation sites in the typical application), from which he chooses from in order to maximize his well-being, or "utility", on this occasion. On a given trip the individual may choose to visit only one of the alternatives, although the model may include multiple choice situations for the same person. By modeling the choice over a finite number of alternatives that possess different prices and levels of environmental quality, the RUM model captures the effects of the tradeoffs between these in the choice process. The observed individual choice is therefore based on the characteristics of the alternatives, and how important these characteristics are to the person. By observing these choices for many people, we gain an understanding of the general importance of the characteristics of the sites.

To model this situation analytically the analyst specifies a conditional indirect utility function for each of the alternatives. This function provides an ordinal quantification of the well-being received via the choice of a given alternative. The units and magnitude of these functions are meaningless; rather it is the comparison between them that is important. Formally, define the utility function V_j for each of the J alternatives:

$$V_j = V_j(y, p_j, q_j, \gamma), \quad j = 1, \ldots J, \tag{1}$$

where y is income, p_j is the price of a visit to site j (constructed as suggested above from the travel cost and time cost of the trip), q_j is a measure of the attributes at site j, and γ is a vector of parameters. Because the conditional indirect utility function quantifies the benefit to the individual of visiting site j, the model proceeds by assuming that the alternative generating the highest benefit for a given trip will be chosen. Mathematically, the person will choose site j if:

$$V_j > V_i \ \forall \ i \neq j. \tag{2}$$

To construct an econometric model it is assumed that the conditional indirect utility functions are composed of a systematic component that is observable to the analyst, and a component that is random to the analyst but known by the individual. The random component accounts for unobserved heterogeneity in consumer preferences as well as non-modeled characteristics of the available recreation sites. Typically these components are assumed to enter the functions linearly, given by:

$$V_j(y, p_j, q_j, \gamma, \varepsilon) = v_j(y, p_j, q_j, \gamma) + \varepsilon_j, \quad j = 1, ..., J. \tag{3}$$

From the perspective of the analyst the problem is now probabilistic. The probability that an individual will visit a given site for a given trip is the probability that the site has the highest associated utility. Thus, the probability of a visit to site j is the probability that the utility associated with site j is higher than that for any other site:

$$\begin{aligned} prob(j) &= prob(V_j > V_i) \\ &\quad prob(v_j + \varepsilon_j > v_i + \varepsilon_i) \\ &\quad prob(v_j - v_i > \varepsilon_i - \varepsilon_j) \quad \forall i \neq j. \end{aligned} \tag{4}$$

To complete the probabilistic statement it is necessary to specify a particular distribution for the error terms. If it is assumed that the random terms are distributed via the extreme value probability density function, the familiar multinomial logit model of site choice emerges. This is a convenient assumption, since it provides for a closed form for the probability of visiting a site, given by:

$$prob(j) = \frac{e^{v_j}}{\sum_{k=1}^{J} e^{v_k}}, \quad j = 1, ..., J. \tag{5}$$

A probability as in (5) can be specified for each trip observed in the sample and maximum likelihood used to recover estimates of the parameter vector γ.

Estimation of the parameter vector provides a characterization of consumer preferences for the attributes of the sites (up to the unobserved random term) via the conditional indirect utility functions. This characterization can be used to measure the monetary benefits or damages from changes in site characteristics. Compensating variation (CV) is a theoretically consistent measure of these benefits. By definition, compensating variation is the amount of money that would need to be taken away from an individual following an improvement in the resource such that they would be exactly as well-off as they were before the change. Similarly, CV can also be defined as the amount of money that would need to be given to an individual following damages to a resource such that they once again would be exactly as well-off as they were before the change. In more intuitive terms, CV is a dollar measure of consumers' willingness to pay (WTP) for improvements in a resource or their willingness to accept (WTA) compensation for damages to a resource. Thus our measure of value is based on the theoretically valid income equivalent concept, and for values of improvements, is a budget-constrained measure. As noted above, these measures of value are distinct from such concepts as tourist industry revenues or other measures of economic impacts.

Hanemann (1999) shows that for multinomial logit random utility models that are linear in price, the statistical expectation of compensating variation for a change in price or characteristics of a recreation site(s) is given by

$$E(CV) = -\frac{1}{\beta_p}\left[\ln\sum_{j=1}^{J} e^{V_{j0}} - \ln\sum_{j=1}^{J'} e^{V_{j1}}\right], \tag{6}$$

where β_p is the estimated coefficient on price, V_{j0} is the deterministic component of utility with the original value of the characteristics, and V_{j1} is the function with the new values of the characteristics, the change for which we are measuring the welfare effect. Equation (6) can be calculated for each person in the sample and the mean used to provide an estimate of the welfare effect in the population. Note that, since the model is set up to analyze the choice of destination on a given trip, the units on the welfare effect are dollars per trip.

B. Choice Set Definition

The random utility model describes an individual's choice from a discrete set of alternatives on a given choice occasion, or trip in the current application. The approach is particularly well suited for many types of available recreation data and does a good job of modeling the substitutability between recreation sites and their characteristics. Application of the model requires the researcher to specify the choice set from which the individuals choose. Economic theory provides little guidance on what the proper choice set is. Often the choice set definition is based on the best judgement of the researcher, the available data, and the goals of the study.[2]

Most recreation demand studies employing RUMs specify as the choice set a collection of specific recreation sites, such as lakes, rivers, or beaches or some aggregation thereof. For example, studies examining beach visitation might include all public beaches within a certain distance of a person's home. Likewise, studies of marine fishing often specify the choice set based on the location of boat ramps or other facilities. Other studies use some form of aggregation, often based on county or other boundaries. In each of these examples judgement on the part of the analyst is necessary to determine which sites belong in the individual's choice set. In each case there is potential for error if relevant sites are omitted, or conversely, if irrelevant sites are included.

The emphasis of this project is not to study specific recreation sites but rather to model the effects of water quality on choice. To this end the goal is to design a choice set that allows the analysis to capture the effects of water quality on choice while abstracting from factors which may differentiate individual destintations such as boat ramps, beaches, etc. This can be accomplished by grouping together destinations that are expected to have similar water quality characteristics based on their physical hydrology. A potentially attractive strategy to this end is to define as the choice set the 8-digit hydrological unit codes (HUCs) in the state, often referred

[2] A special issue of *Marine Resource Economics* contains a series of articles addressing the challenges of choice set definition for recreation demand studies. See in particular Haab and Hicks (2000) for an overview, and Phaneuf and Herriges (2000) for comments from the author of this study. Apart from this, Peters, Adamowicz, and Boxall (1995) provide the results of experiments in choice set definition when the goal is to value water quality changes.

to as watersheds.[3] Hydrological unit codes were designed by the U.S. Geological Survey to classify surface water drainage, and are organized from the regional level down to the river basin and finally the sub-basin levels, with longer codes used to label the smaller areas being subdivided. Watersheds are defined to include a common drainage area, such that the characteristics of the watershed are roughly uniform across its expanse. According the EPA "...a watershed is the land area that drains to a water body and affects its flow, water level, loadings of pollutants, etc. In both a real and figurative sense, a lake or river is a reflection of its watershed..." (U.S. EPA 1999).

A maintained assumption in this choice set definition is that water quality is approximately homogeneous in a given watershed, and that it is expected to differ significantly between watersheds. We will take advantage of this definition in designing the choice set and interpreting the model results. By choosing a watershed in which to engage in water recreation, the individual is implicitly choosing the level of water quality associated with that watershed, particularly with respect to the diffuse nature of non-point source pollutants that are the primary concern in North Carolina. The choice of destination within that watershed can be thought to be largely orthogonal to this, determined by other factors such as the availability of boat ramps, beaches, other amenities, and individual-specific effects that are assumed to be included in the error term. This strategy appears best suited when the interest is in characterizing preferences for water quality in recreation.

Fifty-eight 8-digit watersheds are associated with North Carolina, either entirely within the state or shared with bordering states.[4] These are shown in Figure 1, labeled by 8-digit HUC, along with the political boundaries of the state. Table 1 provides information linking the numerical HUC labels to the watershed names. In all description that is to follow, these watersheds will serve as the choice set definition. Thus, on a given choice occasion, a participant in water recreation chooses which of the North Carolina watersheds to visit.

C. Linking Behavior to Water Quality

Specification of the RUM model requires inclusion of characteristics of the sites as explanatory variables. The price, or travel cost, of the site should be included along with quantifiable environmental characteristic data. To accomplish this several issues must be addressed. First, water quality monitoring typically produces large amounts of information on chemical measures such as quantities of nutrients present in the water and pH level, which are useful as scientific measures of the health of the waterbody. There is some concern, however, that the values of these parameters may not be what recreation visitors base their behavioral decisions on, since the levels of these ambient water quality measures tend to be invisible to the users. Visible events such as fish kills, alga blooms, and waste spills are closer to the end user and can be expected to have a larger behavioral effect. These episodic events are difficult to quantify and are therefore of little use in specifying recreation demand models. Compromises must be made between the

[3] Von Hafen (1999) suggested this approach for valuing water quality improvements in Pennsylvania's Lower Susquehanna River basin, and the following borrows liberally from his description. In his case, the geographic area considered was smaller, which allowed the use of smaller hydrological units in the choice set definition.

[4] Use of the EPA's Index of Watershed Index web site (www.epa.gov/iwi/) indicates 58 watersheds associated with North Carolina. Data requests to STORET, EPA's repository for water quality data, returned information on only 50 watersheds.

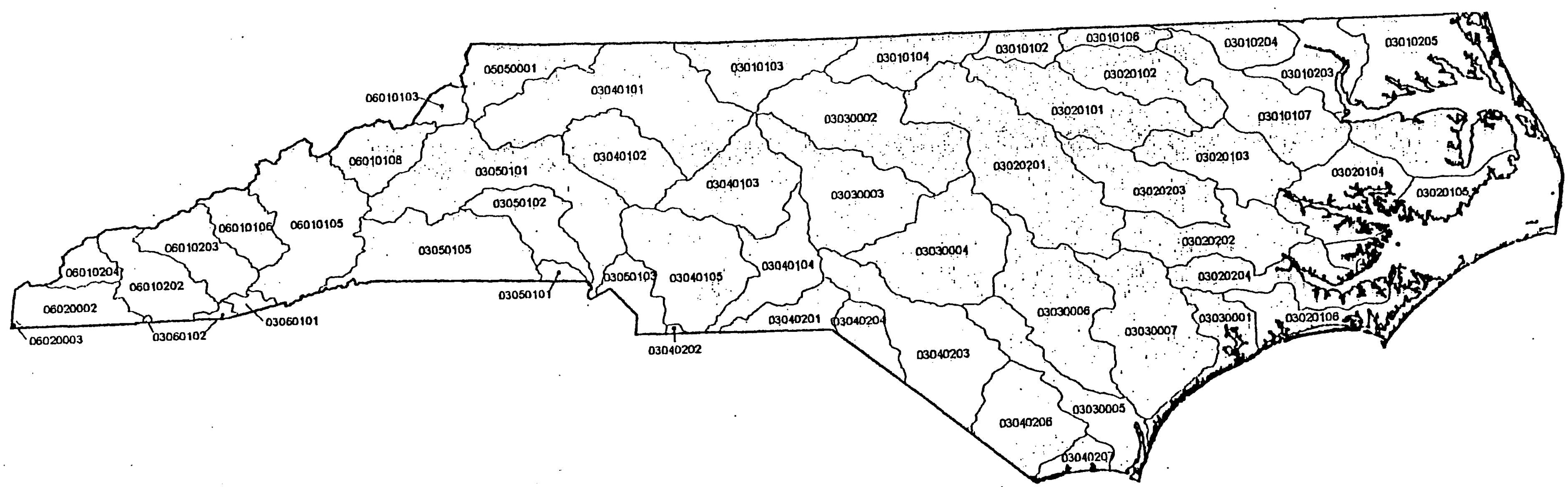


Figure 1: 8-Digit Hydrologic Units in North Carolina

Table 1: Model Choice Set and Summary Statistics

Watershed Name	*8-Digit HUC*	*Visits in Sample*	*Mean Price ($)*	*Standard Deviation Price ($)*
Albermarle	03010205	48	181	115
Black	03030006	0	109	104
Blackwater	03010202	0	164	103
Bogue-Core Sounds	03020106	156	141	128
Carolina Coastal-Sampit	03040207	70	142	104
Chowan	03010203	0	146	106
Contentinea	03020203	0	113	100
Deep	03030003	1	103	92
Fishing	03020102	0	132	99
Haw	03030002	19	111	92
Hiwassee	06020002	2	312	139
Little Pee Dee	03040204	0	113	96
Lower Cape Fear	03030005	12	108	101
Lower Catawba	03050103	22	129	114
Lower Dan	03010104	0	122	89
Lower French Broad*	06010107	0	249	128
Lower Little Tennessee	06010204	0	269	131
Lower Neuse	03020204	34	125	121
Lower Pee Dee	03040201	0	108	98
Lower Roanoke	03010107	0	143	111
Lower Tar	03020103	0	122	110
Lower Yadkin	03040103	35	117	101
Lumber	03040203	1	108	95
Lynches*	03040202	0	134	103
Meherrin	03010204	0	150	103
Middle Neuse	03020202	4	112	112
Middle Roanoke	03010102	1	125	92
New	03030001	213	119	127
Nolichucky	06010108	25	223	124
Northeast Cape Fear	03030007	0	113	112
Nottoway*	03010201	0	158	92
Ocoee*	06020003	0	281	134
Pamlico Sound	03020105	12	136	122
Pamlico	03020104	0	152	117
Pigeon	06010106	0	199	123
Roanoke Rapids	03010106	11	138	96
Rocky	03040105	0	121	107
Saluda*	03050109	0	186	120
Seneca	03060101	3	217	124

Table 1 continued

South Fork Catawba	03050102	0	145	116
South Fork Holston*	06010102	0	213	112
South Yadkin	03040102	0	129	109
Tuckasegee	06010203	1	219	126
Tugaloo*	03060102	0	234	126
Upper Broad	03050105	37	163	122
Upper Cape Fear	03030004	4	105	94
Upper Catawba	03050101	132	156	114
Upper Dan	03010103	12	132	92
Upper French Broad	06010105	18	189	121
Upper Little Tennessee	06010202	6	228	128
Upper Neuse	03020201	3	106	94
Upper New	05050001	2	161	108
Upper Pee Dee	03040104	116	103	99
Upper Tar	03020101	0	117	93
Upper Yadkin	03040101	11	118	97
Waccamaw	03040206	0	117	103
Watauga	06010103	0	201	111
Watts Bar Lake*	06010201	0	276	132

*Watershed not included in models using STORET variables.

use of available data and site quality characteristics that are closer to the individual's perception. The typical assumption is that the chemical measures serve as effective proxies for characteristics that directly affect use decisions. Related to this, water quality policy is typically based on chemical measures of ambient quality. For comparison purposes, benefit measures should also be based on the same criteria. Failing this, a reliable method for converting the benefits of qualitative improvements in water quality into quantitative measures is necessary.

A final issue of concern is the potential divergence between actual water quality conditions and the perception of water quality conditions. McDaniels, Axelrod, and Cavanagh (1998) have documented the possibility of a large divergence between these two. This is of issue for studies such as the current one in that individuals can be expected to base their behavior on personal perceptions that are unobservable to the analyst rather than actual conditions, which the analyst hopes to proxy with chemical data. From a statistical perspective, this is equivalent to an errors in variables problem. That is, the chemical variables are imperfect measures of the true explanatory variables (the subjective measures). This implicitly introduces an additional error term into the model. If the additional error is simply random noise, the coefficient and benefit estimates of the model will still be unbiased, although estimated with less precision than if the actual explanatory variables were available. In other cases, when there is a systematic aspect to the measurement error, or when the errors in measurement in the various explanatory variables are related, the model estimates may be affected. Further discussion on this and other issue concerning the water quality data employed here are described in section V.

IV. Related literature

The ambitious goals of the Clean Water Act have led to the obvious question at the national level as to whether the benefits of regulation continue to be worth the costs. This general question is reviewed and analyzed from a policy perspective by Lyon and Farrow (1995), who provide a good overview of the cost-benefit debate. Ribaudo and Hellerstein (1991) provide an introduction to the basic theoretical and methodological issues associated with estimating water quality benefits, while Bockstael, Hanemann, and Strand (1986) provide a useful, although now somewhat dated, overview of the use of recreation demand models to value water quality. A number of studies have provided empirical estimates of the value of water quality improvements. In the remainder of this section, a sampling of relevant empirical literature at both the general and state level is reviewed.

A. General Literature

The general literature contains varied contributions, from attempts to value localized water quality benefits to large studies intended to capture nationwide benefits. Both stated preference and revealed preference studies have been employed. An example of a stated preference study at the national level, employing the contingent valuation method, is Carson and Mitchell (1993). This study attempts to value the national benefits of freshwater pollution control. Use value benefits such as recreation and aesthetics were examined along with non-use values such as vicarious consumption and stewardship. Rather than linking water quality to specific physical characteristics or chemical measures, or attempting to differentiate point and non-point sources, respondents were asked to value qualitative measures such as changes from boatable to fishable and fishable to swimmable levels of water quality. Results indicate that households would be willing to pay an annual average amount of $106 (in 1990 dollars) to maintain boatable levels of water, an additional $80 to reach fishable levels, and another $89 to reach swimmable levels. In terms of aggregate benefits, the authors' best estimate of the annual nationwide benefits of achieving swimmable waters, from the baseline of non-boatable, is $29.2 billion.

Hayes, Tyrrell, and Anderson (1992) undertook a smaller scale contingent valuation study to value the benefits of water quality improvements in Rhode Island's Upper Narragansett Bay. Similar to the Carson and Mitchell paper benefits for qualitative water quality improvements such as swimmable and shellfishable were estimated. These aggregate estimates ranged from $30-60 million annually for swimmable water and $30-70 million for shellfishable waters in 1984 dollars.

Revealed preference approaches have typically, although not always, valued water quality by linking travel cost models to chemical measures of quality. Revealed preference studies are by definition constrained to include only estimates of use values, since they depend on modeling the interaction of individuals with the resource. Therefore, the non-use values captured in the studies cited above would not be present in studies employing revealed preference techniques. In an early study, Bockstael, McConnell and Strand (1989) apply revealed preference models to the recreational use of Chesapeake Bay. The demand for recreational activities such as beach use, boating, and fishing was estimated using separate use data surveys. Linked to these demand relationships were quality measures such as the multiplication of total phosphorous and nitrogen loadings, and fishing catch rates. As acknowledged by the authors, several limitations are inherent in this study. Nonetheless, for a 20% improvement in the quality variables, the authors find 1987-dollar aggregate benefits of $3.46 million for western shore beach users, $4.7 million for boat users, and $1.3 million for striped bass sport fishing. While not explicitly stated, these can be thought of as benefits from reductions in non-point sources of pollution, since this is the primary issue facing the Chesapeake Bay.

Two more recent studies are closely related to the current project. Tay and McCarthy (1994) examine the effects of water quality on fishing site choice in Indiana, using a portfolio of pollutants that include fecal coliform bacteria, PCB's, oil, phosphorous, and two heavy metals. The choice set includes the entire state, divided into seven in-state aggregate zones and nine out-of-state zones surrounding the state, with average pollution levels in the zones being the explanatory variables. The authors present benefits estimates for a 1% reduction in each of the pollutants, calculating a per trip benefit of $0.22 (1985 dollars) for the phosphorous improvement, and $0.64 per trip for a 1% improvement in all of the included pollutants. Von Haefen (1999) examines the effect of non-source point pollution on water recreation in Pennsylvania's Lower Susquehanna River Basin. Recreation sites are defined by the state's classification of hydrological units into sub-watersheds. Linked to these sites are indicators of pollution based on acidity and degree of eutorphication. These include dummy variables for low pH, high Trophic State Index (TSI), and low dissolved oxygen. The welfare effects of improvements such that all sites have pH levels above six, TSI above 50, and dissolved oxygen above 5.5 mg/l are examined. The willingness to pay per trip for this improvement is estimated to lie between S1.39 and $1.49. Using rough calculations, this translates to approximately $17 million in annual 1994-dollar benefits for the 2.8 million residents of the Lower Susquehanna River Basin.

B. *North Carolina Based Studies*

Existing water quality benefits studies in North Carolina have typically focused on coastal recreation. An example of this is Kaoru (1995), who used a nested RUM to estimate benefits to anglers of quality improvements in the Albemarle and Pamlico Sound area. The choice set is nested such that (after deciding trip length) anglers first chose one of five regions within the sounds to visit, after which they chose the specific site in that region. Included in the attached quality measures are phosphorous and nitrogen discharge at the region level and biochemical oxygen demand and suspended solid at the site level. The author presents the results of numerous potential quality improvements. For example, for a 25% decrease in nitrogen discharges at each of the five regions modeled, per trip benefits estimate of $4.70 (1982 dollars) is reported. In a similar study also examining the use of the sounds for marine angling, Kaoru, Smith, and Liu (1995) report per trip benefits for a 36% reduction in nitrogen loads ranging from $0.76 to $3.95, depending on the level of site aggregation in the choice set definition. In a slightly different approach, Smith, Liu, and Palmquist (1993) investigate how nitrogen loads affect marine sport fishing quality via the resulting effect on fish catch rates. Although no benefits estimates are calculated, the authors report that decreasing nitrogen loadings by 25% will lead to a 1.6% increase in total catch.

Studies addressing water quality in North Carolina have not been limited to revealed preference studies. For example, Smith, Schwabe, and Mansfield (1999) discuss the results of a contingent valuation study designed to assess the benefits to coastal residents of controlling nitrogen loadings via regulations on large hog farms. This study was then used in a benefits transfer framework to roughly assess the monetary value of the state plan to reduce nitrogen loadings in the Neuse by 30%. While acknowledging that the benefits transfer mechanism used is far from perfect, the authors estimate the overall benefits from the plan to be \$29.6 million in 1994 dollars. Another example of a study employing stated preference (combined with revealed preference) data is Whitehead, Haab, and Huang (2000), who also examine the recreation value of the coastal sounds. By combining the two sources of data, the authors are able to assess the welfare benefits of a qualitative improvement in the resource without relying on linking chemical measures of quality to recreation sites. Specifically, the benefits of returning the coastal ecosystem to its pre-1981 state were considered. Fish catches are assumed to increase 60%, and 25% more shellfish beds are opened. Per trip 1995-dolloar welfare improvements for this change are estimated to be \$30, with an estimate per individual per season of \$102. Using rough estimates based on the population of eastern North Carolina (the sample population), the authors estimate seasonal benefits from this quality improvement of \$91 million.

V. Data

In this section the data used for analysis are discussed. Behavioral data used to estimate the site choice model and the quality data that are linked to it are discussed in turn.

A. Behavioral Data

The behavioral data for this study come from the 1994 National Survey of Recreation and the Environment (NSRE), which was a collaborative effort between several federal agencies and consists of four individual components. The Environmental Protection Agency (EPA) administered the National Demand for Water Based Recreation Survey as a component of the overall NSRE. This survey used a random digit dialing population based sample, stratified to ensure adequate representation of each state, to assess the recreation use of water resources in the country. Approximately 16,000 responses are available nationwide. Individuals were asked to report information on boating, swimming, fishing, and viewing or near shore recreation activities. Detailed information on the most recent trip taken for each of these four activities was solicited. This includes the name and location of the water body, the type of water body, whether or not the trip was for a single day, and activity specific information. Furthermore, individuals provided information on the number of trips that they made to this site for this activity during the year. Finally, demographic information is available, including household income, indication of boat ownership, and home location.

To specifically analyze the recreation use of water resources in North Carolina a subset of the nationwide sample was used. To begin with, an observation was selected if the individual was either a resident of North Carolina, or indicated they had made a trip to a North Carolina water body. This provided 551 observations; when observations missing the household's home zip code were eliminated the number was reduced to 541 observations. Of these individuals, 384 reported making a trip in North Carolina and are the focus of the current study. As noted, each individual provided information on their most recent trip for each of the four listed activities. Therefore, each individual could potentially provide information on up to four specific trips, in addition to the number of times during the year they engaged in this activity at this site. From the 384 trip-takers in the state we have available detailed information on 463 North Carolina based water recreation trips (not every respondent participated in each of the four activities). Using this information, combined with information provided on the number of day trips made to this site for this activity, complete data sufficient for RUM estimation are available on 1011 day trips. These data are the basis for this current study, and all the description that follows below is in reference to these trips.

The behavioral data provided information on which body of water the individual visited. To apply this information to the watershed-based choice set definition it is necessary to determine which watershed the destination lies in, in addition to calculating implicit prices for each watershed/site for all individuals. The efforts of staff members at Research Triangle Institute (RTI) aided in the first task. Once the data were collected and cleaned, RTI was contracted to link each of the visited water bodies in the overall sample to the EPA's Reach File 3 (RF3), a system designed to gauge stream flow and water quality at various stream "reaches" in the country. Due to technical challenges in the development of RF3 this has not been completed.

Part of this task, however, involved matching visited water bodies to the 8-digit HUCs in which they lie. We have used this information to match the waterbody the individual visited to the watershed in which it is contained for each trip for which detailed information is available.

The second task of calculating implicit prices required additional effort. Because the choice of visited site from a discrete set is modeled RUMs require characteristic data for each of the available choices for every individual in the sample. In the case of calculating the implicit price, data is needed on the travel distance and travel time between each individual's home and the sites included in the model. To calculate the distance, either latitude/longitude or zip code coordinates are needed for each site and individual home combination. Zip codes for respondent homes were available from the data, while choice set coordinates were obtained in two ways. First, for the specific water bodies visited by individuals the latitude/longitude coordinates for the location were attached to the data during RTI's formatting efforts. Next, latitude/longitude coordinates for each of the 58 N.C. watersheds were obtained via the U.S. Geological Survey's Geographic Names Information Systems web page (U.S. Geological Survey 2000). This web page allows users to enter a city (or other geographical feature) name and obtain in return the latitude/longitude coordinates for that location. For each individual watershed, a city approximately in the center was selected and the coordinates obtained. These coordinates serve as the watershed coordinates for the purpose of calculating distances and travel times.

Travel distances and times were calculated using the software package *PCMiler*. Using zip code and the geo-coordinates, the distance and travel time between each individual's home and each watershed were calculated, along with the distance and time to each of the individual's visited destinations. This information allows calculation of the implicit price of a visit to each of the watersheds. For each individual in the sample, prices are calculated according to:

$$price_j = \$0.22 \times dist_j + \frac{1}{3} \times wage \times time_j, \quad j = 1,\ldots,58, \tag{7}$$

where $dist_j$ is the round trip travel distance, wage is the individuals average hourly salary, and $time_j$ is the round trip travel time in hours to the watershed. The use of \$0.22 per mile for out of pocket costs is a somewhat arbitrary, although reasonable, estimate of the gross vehicle operating costs including fuel and vehicle overhead. More controversial is how the opportunity cost of time is included. There is a large literature examining how the opportunity cost of time should best be included in travel cost models (see Shaw (1992) for a review), with little consensus having been reached. An often-cited article from McConnell and Strand (1981) suggests rational for the use of one-third the wage rate, and this has been adopted for the purposes of this study. In each case, the watershed price is based on the distance to the particular destination visited if the individual visited this watershed, and the price based on the distance to the center of the watershed if it was not visited.

The remaining information in Table 1 presents summary statistics for the 58 watersheds. The third column gives the frequency in the sample of trips to each watershed. The entries in this column therefore add up to 1011, the number of trips for which data is available. The fourth and fifth columns give the mean and sample standard deviation (rounded to the nearest dollar), respectively, of the implicit prices across the sample for each watershed. The large standard deviations in price are illustrative of the fact that the sample is drawn from throughout the state; greater distances are associated with higher prices, providing large variations in price based on location. Other summary statistics of interest are as follows: mean income, $49,600 and percentage of trips in sample where boat ownership is indicated, 26%.

B. Water Quality Data

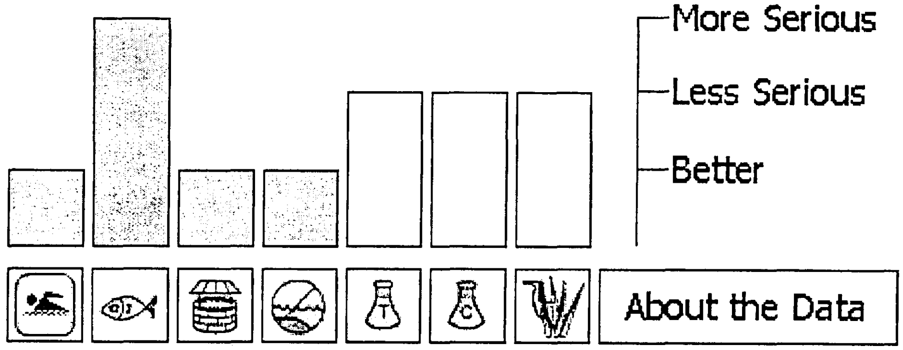
As noted in the procedure section above one challenge with revealed preference approaches to valuing water quality is determining how available measures of water quality may be expected to leave a behavioral footprint that can be detected by analyzing resource use behavior. Further complicating this is the non-point source nature of most of North Carolina's water quality issues. As explicitly demonstrated by McDaniels, et al. (1998), people's perceptions may in fact be different from the conclusions suggested by chemical data indicators. Since behavior is based on perceptions, this is an undeniable concern for revealed preference studies. A pragmatic strategy that was discussed above is to try to specify models that are functions of indicators that come as close as possible to a proxy for the effect on the individual interacting with the resource. In this subsection, the decisions and strategies involved with gathering and linking water quality data are discussed.

There is a vast amount of water quality data available from federal, state, and local sources, with significant overlap in the three. We have chosen to concentrate on two closely related sources of information. The first is based on a relatively new initiative from the EPA to provide web page based information on water quality in a form accessible to the general public. The Index of Watershed Indicators (U.S. EPA 1999) was set up to inform the public on the health of the nation's surface waters at the watershed level. Information is provided in graphical and text format for each watershed, and individuals can quickly locate their home watershed. As shown in Figure 2 (printed directly from the web page) for the example of the Upper Neuse watershed, seven indicators are used to characterize the watershed's condition and eight are used to characterize the watershed's vulnerability. These are then used to calculate the watershed index. Since the primary water quality issue in North Carolina is non-point sources of conventional pollutants, we have specifically examined the conventional pollutant indicator. In Figure 2 the sixth indicator from the left for the condition indicators gauges the effect on watershed health of ambient pollution levels of four conventional pollutants: ammonia, acidity (pH), phosphorous, and dissolved oxygen. The underlying data determining this indicator are available by clicking the icon, from which information on the percentages of monitoring station reading from 1990-97 that are above/below established criteria levels is available.[5] Continuing the Upper Neuse example, the second page of Figure 2 shows the percentages of the monitoring station readings that do not meet criteria for each of the four pollutants, in addition to the number of readings used to establish this percentage. This information was obtained for each of the watersheds listed in Table 1, and provides one source of water quality variables investigated for this project. Columns one through four of Table 2 show summary statistics for the percentages above/below criteria at all 58 watersheds associated with North Carolina. The high sample standard deviations indicate that there is significant variation in these readings across the state. There are advantages and disadvantages to using these variables to represent water quality in the in the choice model.

[5] Acceptable criteria are defined as follows: dissolved $O_2 > 5.0$ mg/l, $6 < pH < 9$, and phosphorous < 0.1 mg/l. Criteria for ammonia is based on formulas which adjust for temperature and pH levels (U.S. EPA 1999).

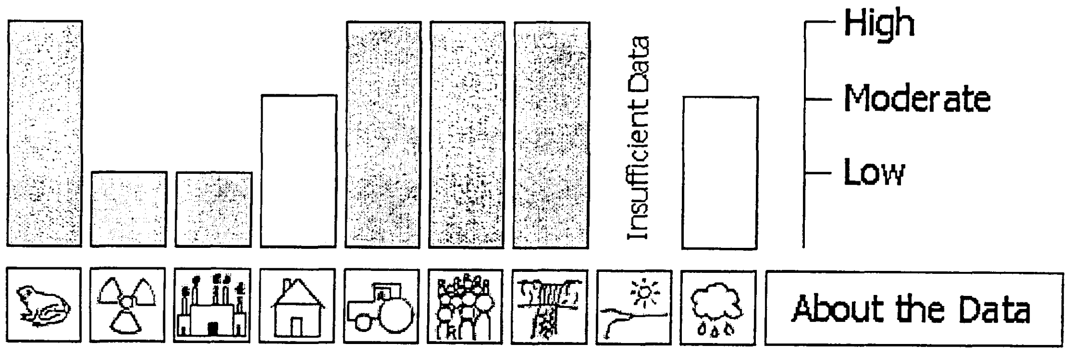
Upper Neuse

The overall IWI score for this watershed is based on the indicators of current condition and future vulnerability. ***Instructions: Move your mouse*** *over the indicator icons below to get descriptions of the indicators and* ***click on the icons*** *to get the indicator score as well as associated data. Please close any other open browsers.*



Condition Indicators

are designed to show existing watershed health across the country. These indicators include such things as waters meeting state or tribal designated uses, contaminated sediments, ambient water quality, and wetland loss.



Vulnerability Indicators

are designed to indicate where pollution discharges and other activities put pressure on the watershed. These could cause future problems to occur. Activities in this category include such things as pollutant loads discharged in excess of permitted levels, pollution potential from urban and agricultural lands, and changes in human population levels.

Figure 2: Index of Watershed Indicators - Upper Neuse Example

Ambient Water Quality Data (Conventional)
Upper Neuse - 1990-1998

Total Observations 13768

Phosphorous			pH		
Total Obs.	Observations Exceeding Criteria	Percent Observations Exceeding Criteria	Total Obs.	Observations Exceeding Criteria	Percent Observations Exceeding Criteria
3219	1195	37.12	3817	76	1.99

Dissolved Oxygen			Ammonia		
Total Obs.	Observations Exceeding Criteria	Percent Observations Exceeding Criteria	Total Obs.	Observations Exceeding Criteria	Percent Observations Exceeding Criteria
3794	340	8.96	2938	311	10.59

Figure 2 continued

Table 2: Summary Statistics for Quality Variables

	pH- *IWI* (% over criteria)	DO- *IWI* (% over criteria)	Phos.- *IWI* (% over criteria)	Ammo.- *IWI* (% over criteria)	Ch. A- *ST* (ug/l)	Phos.- *ST* (mg/l)	Ammo.- *ST* (mg/l)	DO- *ST* (mg/l)
Mean	7.58	13.09	28.76	11.48	16.9	0.33	0.187	5.06
Std. Dev.	9.85	11.63	21.10	11.96	11.61	0.59	0.153	2.48

Note: For all variables statistics are calculated over NC watersheds. IWI statistics are based on 58 watersheds while STORET statistics are based on 50. For all STORET variables except DO statistics are for the 90th percent quantile of available monitoring stations readings. For DO statistics are for the 10th percent quantile.

The percentage over criteria variable is an effective way to collapse numerous monitoring station measures into an understandable, useable statistic. Also, since it is measuring the frequency of "bad" readings, it appears to be an effective way to capture the episodic nature of non-point source pollution. That is, watersheds more susceptible to pollution should have a higher percent-over index. Furthermore, since it is based on many observations over multiple years, it should effectively capture the trend for the watershed that may be highly correlated with individual perceptions in addition to events closer to the end user which more directly affect behavior. Finally, use of information from the Index of Watershed Indicators (IWI) is consistent with the purpose of the EPA web page. Although it is likely too early to be the case, the time may come when the information summarized in the IWI is generally known, and it can be expected to affect recreation decisions. The primary disadvantages of the measure is that we are likely not yet at this point where this information affects decisions, and therefore the use of the percentage criteria is currently at best a proxy measure for the events which likely more directly affect behavioral outcomes.

The second strategy used to link water quality data to the sites relies more directly on the chemical measures from monitoring stations. The EPA's STORET database (U.S. EPA 2000) is a national repository for water quality data collected at all levels of government. Numerous parameters are available at widely varying levels of frequency across watersheds. For this project, all North Carolina monitoring station readings (in this case, for 50 individual watersheds) from 1990-98 were obtained for total phosphorous, various nitrogen compounds, water clarity (measured via secchi disk), dissolved oxygen, chlorophyll a, and pH. The number of readings per 8-digit HUC varied widely across the listed parameters, and many lacked sufficient data points to be of use for analysis. Particularly unfortunate was the thin data available on secchi disk readings, a measure of water clarity and an effective proxy for suspended solids. This parameter would perhaps have a strong behavioral footprint associated with it since the effects are readily visible to recreation users of water resources. Also unfortunate was the lack of data available on ambient quantities of total nitrogen (as opposed to other compounds like ammonia), since explicit interest had been expressed in the welfare effects of total nitrogen reductions.

Parameters that were deemed to have sufficient observations available to be of potential use included ammonia compounds (NH_3+NH_4), total phosphorous, dissolved oxygen, and chlorophyll a, although for a small number of watersheds data were not available and interpolation was necessary. Attention was again paid to the episodic nature of non-point source pollution in constructing the appropriate summary statistics for entry into the model. For each individual watershed, the 90th percent and 10th percent quantiles of the monitoring station readings for each of the four pollutants were determined.[6] For ammonia, phosphorous, and chlorophyll the 90th percent quantiles were used as the appropriate watershed explanatory variables, to best capture "spike" events. For dissolved oxygen, spike events are characterized by low readings of the parameter, since higher levels of the parameter are associated with healthier waters. Therefore, the 10th percent quantile was used. Columns five through eight of Table 2 provide summary statistics for these data. As with the IWI data, significant variation exists across watersheds. An advantage of the use of direct chemical measures is that benefits estimates using these variables will be based on the same chemical units used to form water quality policy and gauge the health of water resources. As noted above, the primary disadvantage is that the measures (with the possible exception of chlorophyll a) are a step removed from the recreation user, and therefore are at best a proxy for characteristics that effect behavior.

It is worth noting that by and large the data used to construct the explanatory variables from the IWI and STORET sources are from the same repository of chemical water quality measures. Thus the two strategies for construction of water quality variables in one sense represent a test of the robustness of results to different summaries of the available data. Additional comments on this will be made in the discussion of the estimation results below.

[6] That is, the value of the parameter for which 90% of the readings are lower and the value of the parameter for which 10% of the readings are lower.

VI. Model Specification and Results

In the following section, model specification, estimation results, and welfare analysis are discussed in turn.

A. Specification and Estimation

Specification of the models for estimation involves several challenges. First, since the trip data are divided by activity, there is the opportunity to include specific quality variables as explanatory variables for the specific activities. For instance, one might expect that contact uses of water resources such as swimming might have different variables influencing site choice than more passive uses such as viewing. Furthermore, variables indicative of biological health such as dissolved oxygen may have a greater effect on fishing uses than on say boating. Next, in some cases, particularly for the variables constructed using the raw STORET information, variables may be highly correlated, which can affect the signs and magnitudes of the estimated effects. For instance, the 90% quantiles for ammonia and phosphorous STORET variables have a correlation coefficient of .63 across the N.C. watersheds. This problem is less apparent in the IWI summary of the data, where the same correlation relationship is only .29. Finally, prior beliefs suggest that the pollution variables as defined (with the exception of the STORET dissolved oxygen variable) should have negative effects on site choice. Given these criteria, the following two specifications corresponding to the two quality variable strategies are considered the "full" models for this study.[7]

$$\begin{aligned}
V_{fish,j}^{IWI} &= \beta_1(y-p_j)+\beta_2 Boat+\gamma_1 pH_j+\gamma_2 DO_j+\gamma_3 Phos_j+\gamma_4 Ammo_j+\varepsilon_{fj} \\
V_{boat,j}^{IWI} &= \beta_1(y-p_j)+\beta_2 Boat+\gamma_1 pH_j+\gamma_3 Phos_j+\gamma_4 Ammo_j+\varepsilon_{bj} \\
V_{swim,j}^{IWI} &= \beta_1(y-p_j)+\gamma_1 pH_j+\gamma_2 DO_j+\gamma_3 Phos_j+\gamma_4 Ammo_j+\varepsilon_{sj} \\
V_{view,j}^{IWI} &= \beta_1(y-p_j)+\gamma_2 DO_j+\varepsilon_{vj}, \\
j &= 1,\ldots,58,
\end{aligned} \tag{8}$$

where *IWI* indicates the quality variables are from the Index of Watershed Indicators, y is choice occasion income, the β_k's and γ_k's are coefficients to be estimated, and the ε_j's are unobserved random components. The STORET quality variable model is similarly defined as:

[7] These specifications were arrived at via incrementally adding quality variables to the specification one activity at a time, and following the criteria for model searching discussed above. This included statistical judgements based on likelihood comparisons as well as more subjective judgements. In some cases inclusion of variables for certain activities caused coefficient estimates to be of unintuitive signs (i.e. increased pollution levels increased utility). These specifications were a priori judged inferior. The signs of most coefficients, although not always the magnitudes, were robust to specification changes. The signs of the IWI dissolved oxygen coefficient and the STORET chlorophyll a were the least stable over various specifications. The most difficult activity to parameterize was the loosely defined "viewing". Only dissolved oxygen provided explanatory power of the correct sign.

$$
\begin{aligned}
&V^{ST}_{fish,j} = \beta_1(y - p_j) + \beta_2 Boat + \lambda_2 Phos_j + \lambda_3 Ammo_j + \lambda_4 DO_j + \varepsilon_{fj} \\
&V^{ST}_{boat,j} = \beta_1(y - p_j) + \beta_2 Boat + \lambda_1 Chl\, a_j + \lambda_2 Phos_j + \lambda_3 Ammo_j + \varepsilon_{bj} \\
&V^{ST}_{swim,j} = \beta_1(y - p_j) + \lambda_1 Chl\, a_j + \lambda_2 Phos_j + \lambda_3 Ammo_j + \lambda_4 DO_j + \varepsilon_{sj} \\
&V^{ST}_{view,j} = \beta_1(y - p_j) + \gamma_4 DO_j + \varepsilon_{vj}, \\
&j = 1,\ldots,50,
\end{aligned}
\tag{9}
$$

where ST indicates the quality variables are from STORET, y and β_k are as defined above, and the γ_k's are coefficients to be estimated. These specifications imply that individuals choose the water activity to engage in, in addition to the watershed to visit on a given choice occasion. The full specifications are similar in that for each case the boating indicator variable enters the boating and fishing activities. It is expected that ownership of a boat will increase the probability that an individual will participate in these two activities. Also, in both cases ammonia and phosphorous enter the boating, swimming, and fishing activities. Dissolved oxygen does not enter as an explanatory variable for boating, since this is an invisible measure associated with aquatic health and is unlikely to affect the choice of boating location. Finally, in both cases the viewing activity contains only the dissolved oxygen explanatory variable. In this survey, the viewing activity is loosely defined to be in some sense an "all other activities" category, and may include near shore uses of water resources. Due to the likely heterogeneity across respondents in interpreting this activity it is postulated that a behavioral trace will not be associated with the other variables. As a measure of general water resource health, dissolved oxygen may provide some explanatory power for viewing visits.

The specifications differ in that the IWI model includes acidity as an explanatory variable, while the STORET specification includes chlorophyll a. It has been suggested that chlorophyll a may be a suitable chemical measure for explaining recreation choice, since its effects are visible to the resource users in the way of enhanced alga and plant growth. In the final specification, the measure was included for the swimming and boating activities.

The two full models were estimated using maximum likelihood according to the choice probabilities given in (5), with results presented in the second and third columns of Table 3. A priori, it is expected that the coefficients on income/price and boat are positive and that all quality variables for the IWI model enter negatively (recall these are measures of the percentage of readings that are out of criteria). These signs imply that, all other things equal, individuals would like to choose less expensive sites with higher water quality and that ownership of a boat will result in a higher likelihood of taking boating and fishing trips. Similarly for the STORET model, it is expected that the ammonia, phosphorous, and chlorophyll a variables enter negatively, since higher levels of these are indicative of worse water quality, while the coefficient on dissolved oxygen should be positive, since higher levels of this variable indicate better water quality. For both models, all estimated coefficients are of the expected sign with all estimates significantly different from zero at better than a 1% level.

As noted previously, a potential concern in the interpretation of the coefficients of the STORET model is the high correlation between the ammonia and phosphorous explanatory variables. To address this, the results of two additional, constrained models are presented in Table 3. Column

Table 3 Estimation Results*

Parameter	*IWI Full*	*STORET Full*	*STORET c1*	*STORET c2*
Price (β_1)	0.045 (0.001)	0.044 (0.002)	0.042 (0.001)	0.044 (0.001)
Boat (β_2)	1.01 (0.213)	1.39 (0.21)	1.43 (0.22)	1.40 (0.22)
pH-*IWI* (γ_1)	-4.74 (0.76)	NA	NA	NA
DO-*IWI* (γ_2)	-1.05 (0.45)	NA	NA	NA
Phosphorous-*IWI* (γ_3)	-6.81 (0.29)	NA	NA	NA
Ammonia-*IWI* (γ_4)	-2.53 (0.68)	NA	NA	NA
Chlorophyll a-*ST* (λ_1)	NA	-0.018 (0.003)	-0.016 (0.003)	-0.017 (0.003)
Phosphorous-*ST* (λ_2)	NA	-0.423 (0.145)	-1.54 (0.16)	NA
Ammonia-*ST* (λ_3)	NA	-11.74 (0.82)	NA	-12.8 (0.76)
DO-*ST* (λ_4)	NA	0.13 (0.012)	0.150 (0.01)	0.13 (0.012)

*Standard error given in parenthesis. All coefficients significant at better than a 1% level. Sample size equals 1011 for all models.

c1 contains estimation results for the STORET model when the ammonia variable is left out of the specification, while column c2 contains results when the phosphorous variable is removed. In each case, all remaining estimates are of the expected sign and significantly different from zero at better than a 1% level. As expected, the coefficient estimates are affected, particularly for phosphorous, which increases by a factor of more than three when the ammonia variable is removed. This will have an effect on the estimated benefits of quality changes.

B. Welfare Analysis

Estimation of the site choice model provides a characterization of preferences for water quality that can be used to assess the monetary benefits of potential quality improvements. This requires statement of a quality improvement to be analyzed. As a demonstration of the benefits measures possible from the model, quality improvement scenarios are analyzed for both the IWI and STORET models. First, comparatively large improvements are considered in which it is assumed that water quality throughout the state is generally within the guidelines specified by the attainment criteria used to construct the IWI percentage variables. Following this, we consider a set of statewide smaller quality improvements. Finally, we examine more policy relevant scenarios whereby the benefits of improvements particular river basins are examined.

The first improvements roughly translate to the following specific scenarios for all watersheds for the IWI model:

1. Ammonia: <10% of readings >EPA criteria.[8]
2. Phosphorous: <10% of readings >0.1 mg/l.
3. Dissolved Oxygen: <10% of readings <5.0mg/l.

For the STORET models, the scenarios for all watersheds are defined as:

4. Ammonia: 90th quantile of readings <0.1 mg/l.
5. Phosphorous: 90th quantile of readings <0.1 mg/l.
6. Dissolved Oxygen: 10th quantile of readings >5.0 mg/l.
7. Chlorophyll a: 90th quantile of readings <15 ug/l.[9]

Using the formula in (6), per trip WTP measures were calculated for each of the scenarios, and the mean value across the sample is reported in Table 4. The scenario descriptions in the first column correspond to those listed above. Calculations for the IWI model are presented in the second column, while calculations for the three STORET models are provided in columns three through five.

A number of points are apparent in examination of the results. First, for the IWI model, the WTP for phosphorous improvements is larger than that for ammonia and dissolved oxygen by several orders of magnitude, with the per trip benefit estimated at $10.50 for phosphorous and $0.24 and $0.94 for ammonia and dissolved oxygen respectively. This result is best explained by recalling

[8] Recall that the criteria used by EPA for ammonia is a function of water temperature and acidity.
[9] For the case of ammonia and chlorophyll a in the STORET models, specific criteria numbers were unavailable and the judgement of the researcher was used to determine criteria levels.

Table 4: Welfare Estimation Results: Large Improvements

Scenario	Per Trip WTP ($'s) for Improvement			
	IWI Full	*STORET Full*	*STORET c1*	*STORET c2*
1. Ammonia: *<10% readings above criteria*	$0.24	-	-	-
2. Phosphorous: *<10% readings above criteria*	$10.50	-	-	-
3. DO: *<10% readings below criteria*	$0.94	-	-	-
4. Ammonia: *90^{th} quantile <0.1 mg/l*	-	$4.89	NA	$5.78
5. Phosphorous: *90^{th} quantile <0.1 mg/l*	-	$0.36	$4.67	NA
6. DO: *10^{th} quantile >5 mg/l*	-	$2.07	$2.33	$2.08
7. Chlorophyll a: *90^{th} quantile < 15 ug/l*	-	$0.33	$1.62	$0.72

the summary statistics in Table 2, which indicate a mean percentage over criteria of nearly 29% for phosphorous, with several watersheds having significantly larger figures. Thus, for the case of phosphorous, the scenario represents a much more extreme potential policy intervention than for the other two parameters. For the STORET model results, as expected the correlation between ammonia and phosphorous explanatory variables has a marked effect on welfare estimates. In the full model, the per trip welfare improvement for the phosphorous scenario is only $0.33, while in the model absent the ammonia variable the per trip measures increases to $4.67. The estimates for ammonia ($4.89-$5.20) and dissolved oxygen ($2.07-$2.33) are fairly stable across the different specifications, while the estimates for the chlorophyll a scenario exhibit some variation ($0.33-$1.62).

The scenarios examined above in a few cases represent fairly large improvements from the current quality level. To provide some balance in the statewide analysis, the benefits of more moderate quality improvements were also considered. For the IWI model this includes

1. Phosphorous: <28% of readings >0.1 mg/l.

For the STORET model, the additional scenarios are:

2. Ammonia: 90th quantile of readings <0.18 mg/l.
3. Phosphorous: 90th quantile of readings <0.33 mg/l.

In each case, this involved reducing the level of the explanatory variable to the sample mean for those watersheds with worse than average measures of these parameters. The results of these calculations are presented in Table 5, which should be read and interpreted similar to Table 4. As anticipated the willingness to pay estimates for these more moderate improvements are of smaller orders of magnitude.

Table 6 presents the final set of scenarios examined. These look at improvements in specific river basins. Since actual policies to reduce non-point source pollution are likely to affect multiple parameters, in this case we examine the benefits of improvements in ammonia, phosphorous, and dissolved oxygen in the Neuse and Cape Fear river basin.[10] Specifically, it is assume that policy reduces pollution such that criteria levels of each parameter are met in each watershed in the basin under consideration. For the IWI model the scenarios translate to:

1. Less than 10% of readings for ammonia, phosphorous, and dissolved oxygen are out of criteria for each watershed in the Neuse basin.
2. Less than 10% of readings for ammonia, phosphorous, and dissolved oxygen are out of criteria for each watershed in the Cape Fear basin.

For the STORET models, this implies:

[10] The Neuse basin includes the Upper Neuse, Middle Neuse, Lower Neuse, and Contentinea watersheds. The Cape Fear basin includes Black, Deep, Haw, Lower Cape Fear, Northeast Cape Fear, and Upper Cape Fear.

Table 5: Welfare Estimation Results: Moderate Improvements

Scenario	*Per Trip WTP ($'s) for Improvement*			
	IWI Full	*STORET Full*	*STORET c1*	*STORET c2*
***1. Phosphorous**: <28% readings above criteria*	$2.08	-	-	-
***2. Ammonia**: 90^{th} quantile <0.18 mg/l*	-	$2.80	NA	$3.62
***3. Phosphorous:** 90^{th} quantile <0.33 mg/l*	-	$0.25	$3.73	NA

Table 6: Welfare Estimation Results: River Basin Scenarios

Scenario	*Per Trip WTP ($'s) for Improvement*			
	IWI Full	*STORET Full*	*STORET c1*	*STORET c2*
1. Neuse River basin improvements	$1.97	-	-	-
2. Cape Fear River basin improvements	$2.25	-	-	-
3. Neuse River basin improvements	-	$1.53	$0.81	$1.51
4. Cape Fear River basin improvements	--	$1.91	$1.80	$1.86

3. For ammonia and phosphorous the 90th quantile readings <0.1 mg/l. For dissolved oxygen 10th readings > 5.0 mg/l for each Neuse watershed.
4. For ammonia and phosphorous the 90th quantile readings <0.1 mg/l. For dissolved oxygen 10th readings > 5.0 mg/l for each Cape Fear watershed.

The results of these benefits estimates for each model are reported in Table 6. The magnitudes of these estimates are not comparable to the previous scenarios in that they represent improvements in multiple parameters for a narrower geographical area. These results are perhaps of greatest interest for informing non-point source pollution policy. Abatement strategies such as the use of best management practices are likely to reduce loading of multiple pollutants implying benefits estimates of these multiple reductions are necessary. Using the IWI model, a per trip willingness to pay of $1.97 is estimated for the Neuse basin, and $2.25 for the Cape Fear. The corresponding estimates for the STORET model are $1.53 and $1.91, respectively.

VII. Aggregate Benefits

The welfare results reported in Tables 4, 5, and 6 in many ways highlight the challenges associated with valuing non-market resources. Each of the two strategies described for linking water quality variables has advantages and disadvantages, and it is perhaps no surprise that the two strategies produce different estimates of per trip benefits for similar improvement scenarios. Examining the results as a whole, the highly significant estimation results for both models allows us to confidently conclude that water quality matters in the choice of water recreation, and that participants have a positive WTP for quality improvements. More specific conclusions require a judgement on which quality variable construction strategy is correct. This cannot be anything other than a subjective judgement based on the experience of the analyst. This said, the use of the IWI criteria data appears to have a few advantages over the chemical data measures used in the STORET models. First, correlation among the explanatory variables is a significantly smaller problem, reducing the need to sort through the effects based on an actual behavioral footprint and those based on the relationship of the pollutants. Next, if the goal is to include variables which best proxy effects that directly affect recreation choice, the IWI variables are arguably superior in that the trend in water quality is more readily collapsed, and the units are similar across the various pollution parameters. Finally, while this should not be over emphasized, potential advantages exist in using readily available web-based information that is consistent with EPA's right-to-know initiative. For these reasons, in what follows discussion will focus on the results from the IWI model.

The random utility model provides a theory-consistent estimate of the per choice occasion willingness to pay for a quality improvement. As a choice occasion model the RUM is not as well adapted to providing estimates over an entire season. Typically, however, policy analysis requires estimates of aggregate or annual benefits, since costs are typically of this form. With a number of caveats the per trip estimates can be used to form approximate annual estimates for the policy scenarios discussed, simply by multiplying the per trip estimates by the number of trips taken in a year. Data is currently not available on the total number of water recreation trips taken in North Carolina. The 1996 National Survey of Fishing, Hunting, and Wildlife Associated Recreation (US Department of Interior, et al. 1996) provides aggregate estimates of trips for the activities listed in the title, broken down by state. According to these estimates, 14.7 million angling days were spent in North Carolina in 1996. For lack of better data, this will be used as an estimate of water based trips in the state.[11] Using the per trip benefits estimates from Tables 4 and 5, the aggregate annual benefits for each scenario are estimated as follows:

- Ammonia reduction: $3.52 million.
- Large Phosphorus reduction: $154.3 million.
- Dissolved oxygen improvement: $13.8 million.
- Moderate Phosphorus reduction: $30.5 million.

Since the first three estimates are based on scenarios where only 10% of monitoring station readings are out of established criteria, the estimates can be interpreted as the benefits of

[11] Caution should be exercised in using this figure. First, the statistic is for angling days, while the model predicts trips. Also, only angling days are included, while the model discusses angling, swimming and viewing as well. This figure should likely be interpreted as an underestimate of trips.

returning all waterways in the state to a level where all uses are supported. As noted above, this represents a fairly large improvement from the status quo, particularly for the phosphorous scenario. The fourth figure provides an estimate of the aggregate annual benefits of a more moderate improvement. Similar calculations can be made for the two river basin scenarios reported in Table 6. Again using 14.7 million as a proxy for the number of water recreation trips, the annual benefits of improvements in each watershed such that ammonia, phosphorous and dissolved oxygen are returned to criteria levels are:

- Neuse river basin improvements: $28.95 million.
- Cape Fear river basin improvements: $33.0 million.

As noted, a number of caveats must be stated concerning these estimates. First, the calculation does not allow for an increase in the number of trips taken due to the quality improvement. Thus, these estimates should be interpreted as under estimates of the use value associated with recreational trips. In addition, the limitations of revealed preference methods discussed above apply. These benefits estimates do not include non-use benefits, benefits accruing to people who may use water resources at a later date, and non-recreational benefits of improved water quality.

Direct comparison of benefits studies is difficult due to the differing nature of resources being modeled, and the fact that benefits estimates are presented for improvement scenarios of different magnitudes. Nonetheless even rough comparisons can provide perspective and a few points can be made between the current results and those cited in section IV. The study from Tay and McCarthy (1994) is most similar to the current effort in that water quality in an entire state is being addressed. Estimated benefits of $0.22 per trip for a 1% decrease in phosphorous levels are likely greater than the benefits estimated for comparative improvements in this study. Kaoru's (1995) estimate of $4.70 per trip for a 25% decrease in nitrogen for coastal North Carolina, meanwhile, appears similar to estimates from this model.[12] Von Haefen's (1999) study, bearing similarities in choice set design, produced welfare estimates of similar orders of magnitude for a smaller geographic area. While admittedly anecdotal, these comparisons suggest the current estimates are consistent with (and perhaps conservative compared to) other revealed preference benefits estimates. In contrast, the stated preference estimates tend to be significantly larger, particularly for the case of Carson and Mitchell (1993). This highlights the fact that revealed preference approaches capture only use-value of the resource, ignoring any non-interactive use that may be associated with it. This aspect of the model results should be kept in mind for policy purposes, with aggregate benefits interpreted as a lower bound.

[12] For example, the constrained STORET model in the fourth column of table 3 estimates benefits of $0.05 per trip for a 1% reduction in the 90th percent quantile for phosphorous across all watersheds. The unconstrained model estimates benefits of $2.98 for a 25% reduction in the 90th percent quantile for nitrogen across all sites.

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