

Parcel Prioritization for Drinking Water Protection
in the Upper Neuse River Basin, North Carolina

by
Anna R. Treadway

Date: _____

Approved:

Dr. Carol Mansfield, Advisor

Masters project submitted in partial fulfillment of the
requirements for the Master of Environmental Management degree
in the Nicholas School of the Environment and Earth Sciences of
Duke University

2007

ABSTRACT

The Upper Neuse River Basin spans six counties in the Piedmont region of North Carolina and is the drinking water source for over half a million people. This water resource needs to be protected so that it can meet the growing demand spurred by rapid population growth. Land conservation is one method for drinking water protection. The Upper Neuse Clean Water Initiative (UNCWI) has successfully prioritized parcels for conservation and suggested potential funding sources. However, they did not consider nonpoint source pollutant loads based on parcel landcover and the distance from the parcel to the surface water intakes or costs of acquiring parcels. The objective of this project is to further prioritize the UNCWI high-priority parcels using a parcel-pollutant-weighting model that considers budget constraints. There are four different scenarios of the model run based on area of the watershed and future land use scenarios. The second objective is to provide the model and results to local conservation organizations and county governments. A user-friendly Excel version of the model will be developed so that land conservationists can input their own variables for parcel prioritization to protect water quality.

ACKNOWLEDGEMENTS

I would like to thank Klugh Jordan and the rest of the staff at the Eno River Association for an excellent experience as their intern. It was there that I became familiar with the Upper Neuse Clean Water Initiative. Many thanks also to Lisa Creasman and Rusty Painter at the Conservation Trust of North Carolina for sharing their expertise in land conservation. Chris Dreps of the Upper Neuse River Basin Association was kind enough to provide the data for 2025 population projections. Finally, thanks to Carol Mansfield, my primary advisor, for her guidance.

TABLE OF CONTENTS

| | |
|--|----|
| TABLE OF FIGURES | iv |
| INTRODUCTION | 1 |
| UPPER NEUSE RIVER BASIN | |
| Characteristics | 1 |
| Watershed Stresses..... | 2 |
| <i>Rapid Population Growth</i> | 2 |
| <i>Rural Communities</i> | 3 |
| LAND CONSERVATION FOR DRINKING WATER PROTECTION | |
| Why Conserve Land?..... | 3 |
| Methods for Protecting Land | 3 |
| Conservation Efforts Already Underway..... | 4 |
| UPPER NEUSE CLEAN WATER INITIATIVE | |
| Development of the Initiative | 5 |
| High-Priority Parcels | 5 |
| Funding Sources..... | 6 |
| OBJECTIVE | 6 |
| METHODS | |
| Parcel-Pollutant Weighting Model | 7 |
| Data Collection and Assumptions..... | 8 |
| Running the PPW Model | 18 |
| <i>Normalizing the Data</i> | 18 |
| <i>Scenarios for Running the PPW Model</i> | 18 |
| RESULTS AND DISCUSSION | |
| Scenario 1..... | 20 |
| Scenario 2..... | 22 |
| Scenario 3..... | 23 |
| Scenario 4..... | 24 |
| Comparison of Results..... | 25 |
| Distribution of Data and Results..... | 25 |
| CONCLUSIONS..... | 25 |
| REFERENCES | 28 |

TABLE OF FIGURES

| | |
|--|----|
| Map 1: Upper Neuse River Basin, NC..... | 2 |
| Model 1: Distance from Parcel to Nearest Downstream Surface Water Intake | 9 |
| Table 1: Pollutant Loads by Land Use Type | 10 |
| Table 2: Land Use Reclassification | 10 |
| Model 2: Land Use Reclassification for High-Priority Parcels | 11 |
| Map 2: Population Change by Subwatershed | 12 |
| Map 3: Parcels for Scenario 1 Input | 13 |
| Map 4: Parcels for Scenario 2 Input | 14 |
| Map 5: Parcels for Scenario 3 Input | 15 |
| Map 6: Parcels for Scenario 4 Input | 16 |
| Table 3: Estimated Funding for Conservation in Upper Neuse River Basin..... | 17 |
| Table 4: Budget (M) for Each Scenario..... | 18 |
| Table 5: Summary Statistics of Parcels Chosen for Each Scenario..... | 20 |
| Table 6: Scenario 1 Results Comparison | 20 |
| Map 7: Scenario 1 Results | 21 |
| Table 7: Scenario 2 Results Comparison..... | 22 |
| Map 8: Scenario 2 Results | 22 |
| Table 8: Scenario 3 Results Comparison..... | 23 |
| Map 9: Scenario 3 Results | 23 |
| Table 9: Scenario 4 Results Comparison..... | 24 |
| Map 10: Scenario 4 Results | 24 |

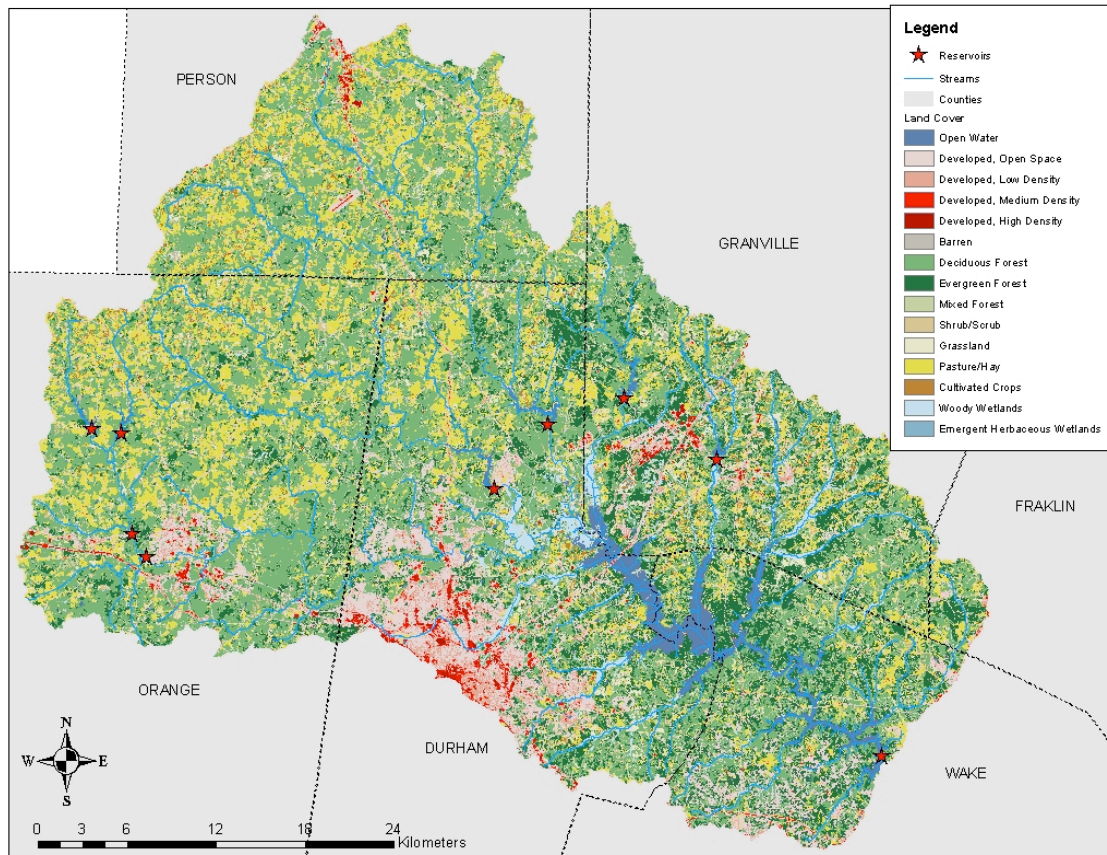
INTRODUCTION

The Upper Neuse River Basin spans six counties in the Piedmont region of North Carolina and is the drinking water source for over half a million people (Hart 2006). This water resource needs to be protected so that it can meet the growing demand spurred by rapid population growth. Population growth also increases development, which can result in increased impervious surfaces and sediment runoff and a decrease in forest cover. There have been some successful efforts to address this issue and protect land in the watershed, but there is a consensus that more coordinated and focused efforts are needed. As a result, environmental organizations and local governments collaborated to form the Upper Neuse Clean Water Initiative (UNCWI) and coordinated a plan to protect the basin's drinking water through land conservation. The UNCWI plan prioritizes parcels for acquisition or to be placed under an easement. These high-priority parcels make up a large area of the basin. This paper uses a Parcel-Pollutant-Weighting Model to further prioritize parcels for land acquisition. Several scenarios are used for the model run to provide examples of ways conservation organizations and local governments can use the model in their prioritization efforts.

UPPER NEUSE RIVER BASIN

Characteristics

The Upper Neuse River Basin covers 770 square miles in Durham, Wake, Person, Orange, Franklin, and Granville Counties in North Carolina. There are nine reservoirs in the basin that are used for drinking water. Lake Michie and Little River Reservoir are in Durham County. Lake Orange, New Hillsborough Reservoir, Lake Ben Johnston, and Corporation Lake are in Orange County. Lake Holt and Lake Rogers are in Granville County. Falls Lake is in Wake County and is the reservoir that the entire upper basin drains into. The current land cover for the basin is as follows: 60% forested, 20% urban, 16% agricultural, and 3% wetlands (Map1).



Map 1: Upper Neuse River Basin, NC

Watershed Stresses

Rapid Population Growth

Raleigh and Durham are two of the top five fastest growing cities in North Carolina (Hart 2006). The current population of one-half million that is receiving drinking water in the basin is expected to double by 2030. This rapid growth leads to increased development. An Upper Neuse River Basin Association study predicts that 13% of the undeveloped land will be developed by 2025 (2003). This will lead to a decrease in forest cover and an increase in sedimentation runoff. Increased sedimentation load in streams decreases storage capacity in reservoirs and increases water treatment costs because sediments can carry pathogens, nutrients, and organic debris. When water picks up and carries contaminants from many different sources, it is called nonpoint pollution. Nonpoint pollution can originate from fertilizer usage in urban areas, improperly managed sediment at construction sites, and many other sources.

Furthermore, urban runoff is the primary source of stream impairment in the Neuse River Basin (Hart 2006).

Rural Communities

In the upper portion of the watershed, there are many rural communities. These areas are trying to find ways to keep their land in private ownership while generating economic growth. This is important to them because most of the land is farmland that has been in the family for generations. The land in this area is also critical to water protection because headwater streams collect a majority of the surface runoff and contaminants (Peterson 2001).

LAND CONSERVATION FOR DRINKING WATER PROTECTION

Why Conserve Land?

The leading cause of water quality degradation is nonpoint source pollution (EPA 2007). These pollutants come from a variety of sources such as fertilizer application, bacteria and nutrients from animal waste, and use of toxic chemicals. Most drinking water suppliers can meet drinking water standards with current technologies. However, treatment has become more difficult and expensive because of a greater diversity of contaminants, increased pollutant loads, and fewer natural barriers (Ernst 2004). Watersheds with pervious land cover naturally filter pollutants. Furthermore, impervious surfaces decrease groundwater recharge. So water is diverted from underground supplies and runs off into surface waters. According to a Trust for Public Land (TPL) and American Water Works Association (AWWA) study, for every 10% increase in forest cover, treatment and chemical costs decrease by about 20%. Also, a 50 to 55% variation in treatment costs can be explained by percentage forest cover in the source area (Ernst 2004). Therefore, land protection is a long-term and cost-effective method for protecting drinking water supplies.

Methods for Protecting Land

There are two different classes of tools that are used to conserve land. Ordinances are examples of regulatory tools that usually restrict development. Development can be

restricted through limits on impervious surface percentages for each lot or even a minimum lot size. Buffer zones are also used to restrict development along waterways. The North Carolina Neuse Nutrient Sensitive Water Rules set a fifty-foot stream buffer along most natural water bodies in the basin. Within this fifty foot buffer, there are two zones. The first zone is 30 feet and does not allow any disturbance. The second zone is an additional twenty feet and allows for some uses, such as driveway crossings, but no building development (NCDENR 2000).

Another tool set for conserving land is voluntary tools. These include best management practices (BMPs) and land conservation. BMPs are methods which prevent or reduce the movement of sediment, nutrients, and other pollutants from the land to water. Land can be permanently conserved through outright land acquisition or conservation easements. In outright land acquisition, landowners voluntarily sell or donate their land to a land trust or the government for permanent protection. A conservation easement is an agreement between a landowner and a land conservation entity that restricts development rights on all or part of the parcel.

Both regulatory and voluntary tools are effective methods for land conservation. However, regulatory tools are not always permanent and can change with the political environment. Land conservation by voluntary means is almost always in perpetuity.

Conservation Efforts Already Underway

In the Upper Neuse River Basin, voluntary land conservation efforts are already underway. Orange County owns land around their reservoirs. The City of Durham and Durham County have developed a greenway system that links riparian corridors. Wake County has an open space plan and watershed management program that target lands for acquisition to benefit water quality. Furthermore, there are many non-profit land conservation organizations that are active in the area. For example, the Eno River Association works to acquire land around the Eno River and transfer it to the Eno River State Park. They have acquired about 5,000 acres so far.

UPPER NEUSE CLEAN WATER INITIATIVE

Development of the Initiative

The Upper Neuse Clean Water Initiative (UNCWI) is a collaboration of conservation organizations and local governments that have developed a plan to protect the basin's drinking water through land conservation. The Trust for Public Land and Triangle J Council of Governments (TJCOG) held a public forum to identify conservation priorities. Then, with the help of a Technical Advisory Team, they developed a Geographic Information Systems (GIS) model that integrated criteria for a Water Quality Protection Scenario and a Parcel Analysis Scenario. The Water Quality Protection Scenario used criteria to spatially represent the objectives of protecting water quality via 1) riparian areas, 2) wetland retention, 3) vertical hydraulic conductance, 4) drinking water source, 5) soil erosion, 6) land use, and 7) headwater catchments. These criteria were weighted based on perceived importance, then aggregated together to come up with a score of 0 to 5 that is spatially distributed. The Parcel Analysis Scenario ranked the parcels using other priorities that included 1) stream frontage, 2) adjacency to protected land, 3) adjacency to significant natural heritage areas, 4) adjacency to natural heritage area element occurrences, and 5) size of parcel. Then the Water Quality Scenario results were aggregated to the parcel level. The number of acres in each parcel that have a score of 3, 4, or 5 were determined. Then, these acres were weighted and averaged together to come up with a water-quality score for each parcel (Hart 2006).

High-Priority Parcels

The results revealed 23,635 high-priority acres, meaning they received a score of 3 to 5 (on a scale of 0 to 5), that are not already protected (Hart 2006). 17,392 parcels were identified as having a weighted-average score of 3 to 5. These 17,392 parcels make up 274,322 acres of the watershed. Since only a portion of most of the parcels is of high-priority, a conservation easement could be placed only on the high-priority area of the parcel. These parcels may also be protected by acquiring the whole parcel, either through purchase or donation.

Funding Sources

Recognizing that there are costs associated with land conservation, the initiative identifies potential funding sources for protection of these parcels. Local funding is recommended as the primary source because competition is greater for state and federal funds. Municipalities and county governments can provide funding through bonds or dedicated revenue streams, such as property taxes and dedicated fees from utility revenue. For example, Raleigh has dedicated a million dollars over the past two years from its water and sewer utility revenue to the UNCWI (Hart 2006). State funding is also a potential source. There are three state trust funds that provide grants for land and water protection. The Clean Water Management Trust Fund (CWMTF) issues grants to local governments, state agencies, and non-profit organizations for projects that "enhance or restore degraded waters, protect unpolluted waters, and/or contribute toward a network of riparian buffers and greenways for environmental, educational, and recreational benefits" (CWMTF 2007). The North Carolina Parks and Recreation Trust Fund (NCPARTF) offers dollar-for-dollar matching grants to local governments for parks and recreational projects, including acquiring land. A maximum of \$500,000 can be awarded yearly to county governments or incorporated municipalities (NCPARTF 2007). The North Carolina Natural Heritage Trust fund (NCNHTF) provides supplemental funding to state agencies for conservation of important natural areas (NCNHTF 2007). Another potential source is the North Carolina Ecosystem Enhancement Program (NCEEP) partners with environmental organizations to help slow the loss of natural areas by using matching funds from their allocated funding from the Department of Transportation (NCEEP 2007). At the federal level, there are stated-directed federal grants and direct federal programs. However, the competition is high for these funds, so they are not a reliable source.

OBJECTIVE

The UNCWI has been successful in prioritizing parcels and suggesting potential funding sources. However, their analysis did not consider nonpoint source pollutant loads based on parcel landcover or the distance from the parcel to the surface water intakes. Landcover and distance are important because they influence the loading of nonpoint

source pollutants. Furthermore, the plan did not consider the amount of funding that would be required to purchase outright or place a conservation easement on the parcels. This project will help funding sources and land trusts by further prioritizing the parcels based on a parcel-pollutant-weighting model that considers budget constraints. A user-friendly Excel version of the model will also be developed so that land conservationists can input their own variables for parcel prioritization to protect water quality.

METHODS

Parcel-Pollutant Weighting Model

The Parcel-Pollutant-Weighting (PPW) Model, from Azzaino et. al (2002), is a binary optimization model that selects parcels based on a parcel index and a weighting of reduced pollutant loads. It is used to select the best parcels for riparian buffers subject to a budget constraint. In other words, it determines the reduction in pollutant load if the parcel was protected versus developed and weights that load by stream frontage or parcel size and distance to where the water is treated. The model then chooses parcels for protection with the best pollutant weight until the total cost of acquiring these parcels is almost as much as or equal to the budget available. The model can be run with up to 100 parcels using the Solver Tool in Excel. It can be run using up to 500 parcels with the purchase of the Premium Solver platform as an add-in in Excel. The PPW model is:

$$\text{Maximize } \sum_{i=1}^I \sum_{j=1}^J (S_i/D_i) W_j (X_{i,j} - X_{i,j}^B) B_i,$$

$B_i = 0, 1$

$$\text{Subject to } \sum_{i=1}^I C_i B_i \leq M$$

Where

- i = the parcel
- J = pollutant with potential water quality problem
- S_i = parcel size or parcel's stream frontage
- D_i = distance to intake
- W_j = weight of the j^{th} pollutant
- $X_{i,j}$ = loading of j^{th} pollutant from i^{th} parcel under current land use
- $X_{i,j}^B$ = loading of the j^{th} pollutant from the i^{th} parcel if an easement is acquired
- B_i => easement has 0=not been purchased or 1=purchased
- C_i = cost of buying an easement on the i^{th} parcel
- M = budget available for land conservation

Data Collection and Assumptions

Parcels (i)

The high-priority parcels that were identified in the UNCWI conservation plan are used for this variable. Since there were 17,392 total unprotected parcels that scored 3 or better out of 5 for water quality protection, based on talks with land trust staff, higher priority is placed on parcels with 2,000 feet or more of stream frontage. This narrowed it down to 2,865 parcels. It also happened to remove the parcels that were smaller than 9.5 acres. 15,655 acres of these parcels received a high priority water quality score.

Pollutants of Concern in Upper Neuse River Basin (j)

The pollutants used in this analysis are phosphorus and nitrogen because they are good indicators of nonpoint pollution. Phosphorus and nitrogen are present in natural waters, but an excess of these nutrients can lead to water quality degradation. These nonpoint pollutants can originate from lawn fertilization, animal waste, and sewage disposal, to name a few. They adversely affect water quality by causing eutrophication in reservoirs. This makes the water treatment process more difficult and expensive.

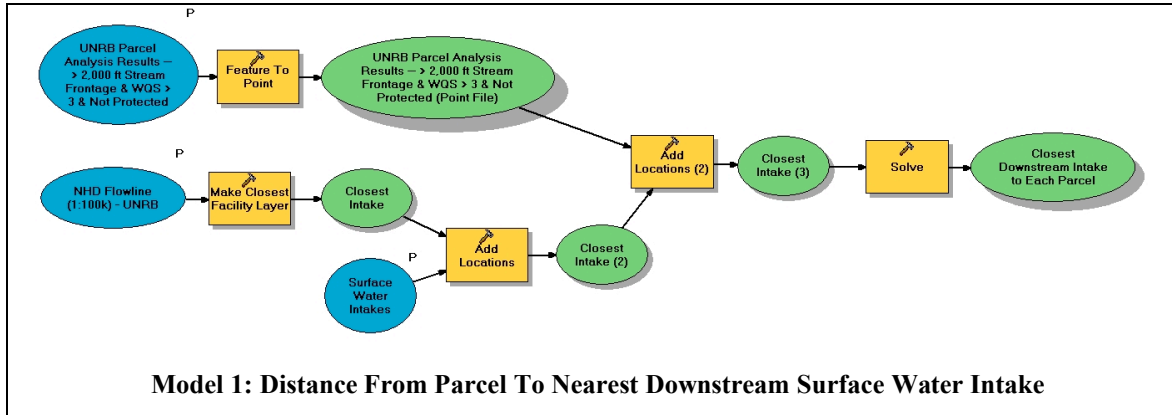
Parcel Size or Stream Frontage (S_i)

The size of the parcel, in acres, and the stream frontage, in feet, is provided by Triangle J Council of Governments in the attribute table for the parcels on the UNCWI Digital Data DVD (TJCOG 2006).

Distance from Parcel To Surface Water Intake (D_i)

The Surface Water Intake shapefile is downloaded from the NC OneMap Geographic Data Source (North Carolina OneMap 2006). This shapefile has all the intakes for North Carolina, so the intakes for the Upper Neuse River Basin are extracted. However, they did not correspond spatially with location of the reservoirs. So the Editing Tool in ArcGIS is used to remove the intake points that were not on lakes and create points for the intakes at Hillsborough Reservoir and Lake Orange. The intake points are placed at the downstream end of the reservoirs.

Then, ArcGIS Network Analyst is used to compute the distance of each parcel to the nearest downstream reservoir intake (Model 1).



Pollutant Weight (W_i)

Nitrogen and phosphorus are each given a pollutant weight of 1. They have the same pollutant weight for this analysis because no data was found on which one contributes more to water quality degradation in the Upper Neuse River Basin.

Pollutant Loading on Protected Parcel (X_{ij}^B)

The average Event Mean Concentrations (in milligrams per liter) in Line et al. (2002) are used for pollutant loading by land use type (Table 1).

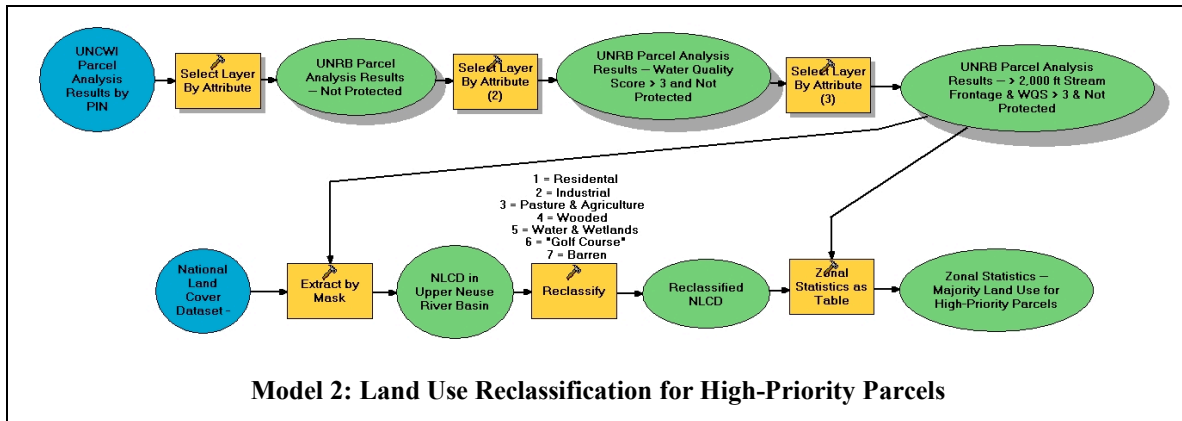
For this variable, current land use data is used to represent what the land use would be if the parcel were protected. The land use raster from the National Land Cover Dataset (NLCD) from 2001 is used to represent current land use (EPA 2001). The NLCD 2001 categories are reclassified to match the land use types for the pollutant loads provided by Line et al. (2002) (Table 2). Then the reclassified land use raster and the UNCWI high-priority parcel shapefile are used to determine the majority land use for each parcel by using the Zonal Statistics Tool in ArcGIS (Model 2).

Table 1: Pollutant Loads by Land Use Type

| Land Use Classification | Total Phosphorus (TP) (mg/L) | Total Nitrogen (TKN) (mg/L) |
|--------------------------------|-------------------------------------|------------------------------------|
| Residential | 0.59 | 5.92 |
| Industrial | 0.27 | 1.39 |
| Pasture & Agriculture | 2.14 | 3.46 |
| Wooded | 0.35 | 3.58 |
| Golf Course | 1.07 | 5.12 |

Table 2: Land Use Reclassification

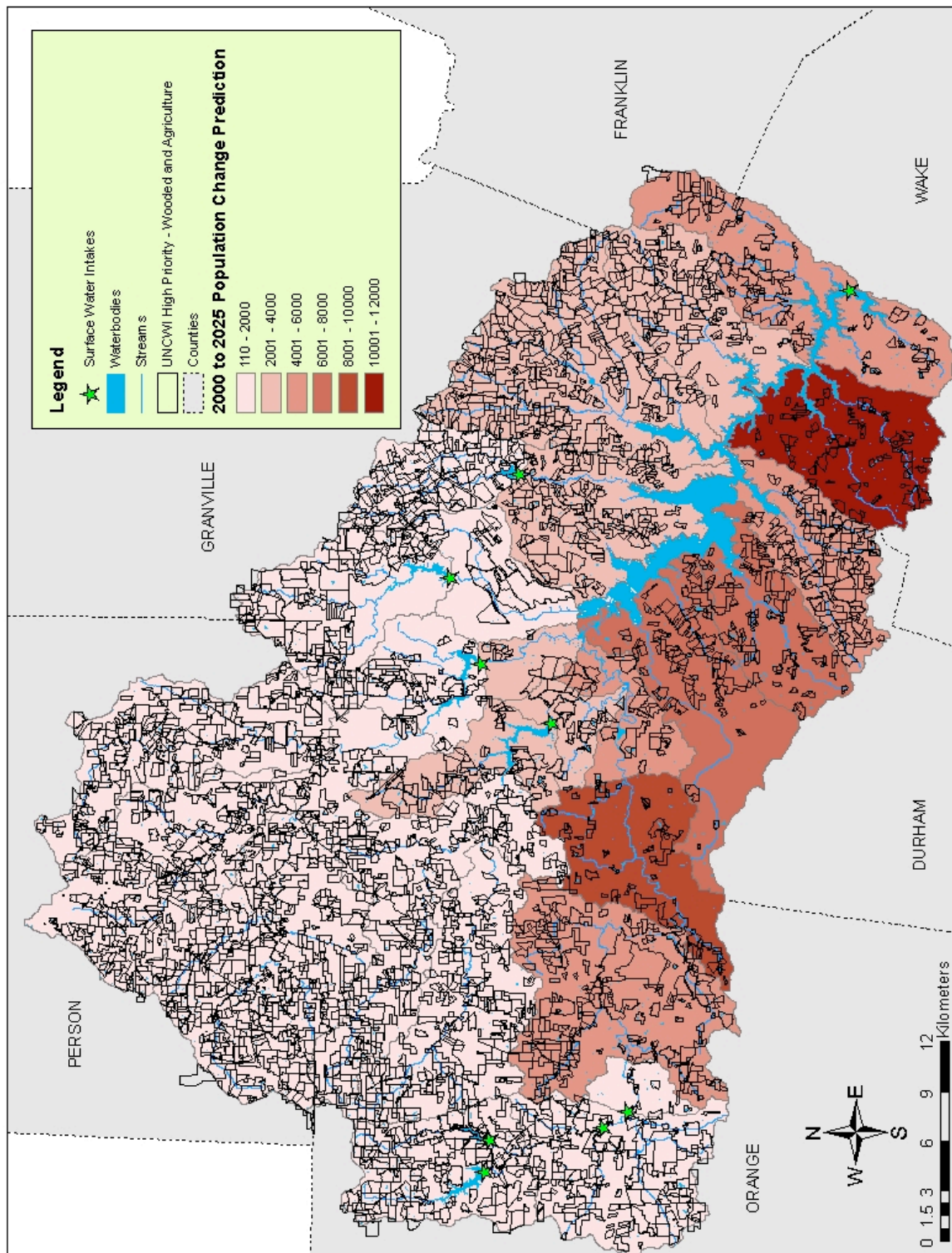
| Land Use Classes | Description of Line et al. Land Use Classes | NLCD Land Use Classes |
|---------------------------|---|-------------------------------------|
| 1 - Residential | 25% impervious | 22 - developed, low intensity |
| | | 23 - developed, medium intensity |
| 2 - Industrial | 65% impervious | 24 - developed, high intensity |
| 3 - Pasture & Agriculture | 0% impervious; moderately to lightly grazed | 71 - grassland / herbaceous |
| | | 81 - pasture / hay |
| | | 82 - cultivated crops |
| 4 - Wooded | mixed pine & hardwoods | 41 - deciduous forest |
| | | 42 - evergreen forest |
| | | 43 - mixed forest |
| | | 52 - shrub / scrub |
| 5 - Golf Course | little impervious surface; few homes; manicured lawns | 21 - developed, open space |
| 6 - Water and Wetlands | n/a | 11 - open water |
| | | 90 - woody wetlands |
| | | 91 - Palustrine forested wetland |
| | | 92 - Palustrine scrub/shrub wetland |
| 7 - Barren | n/a | 31 - barren land |



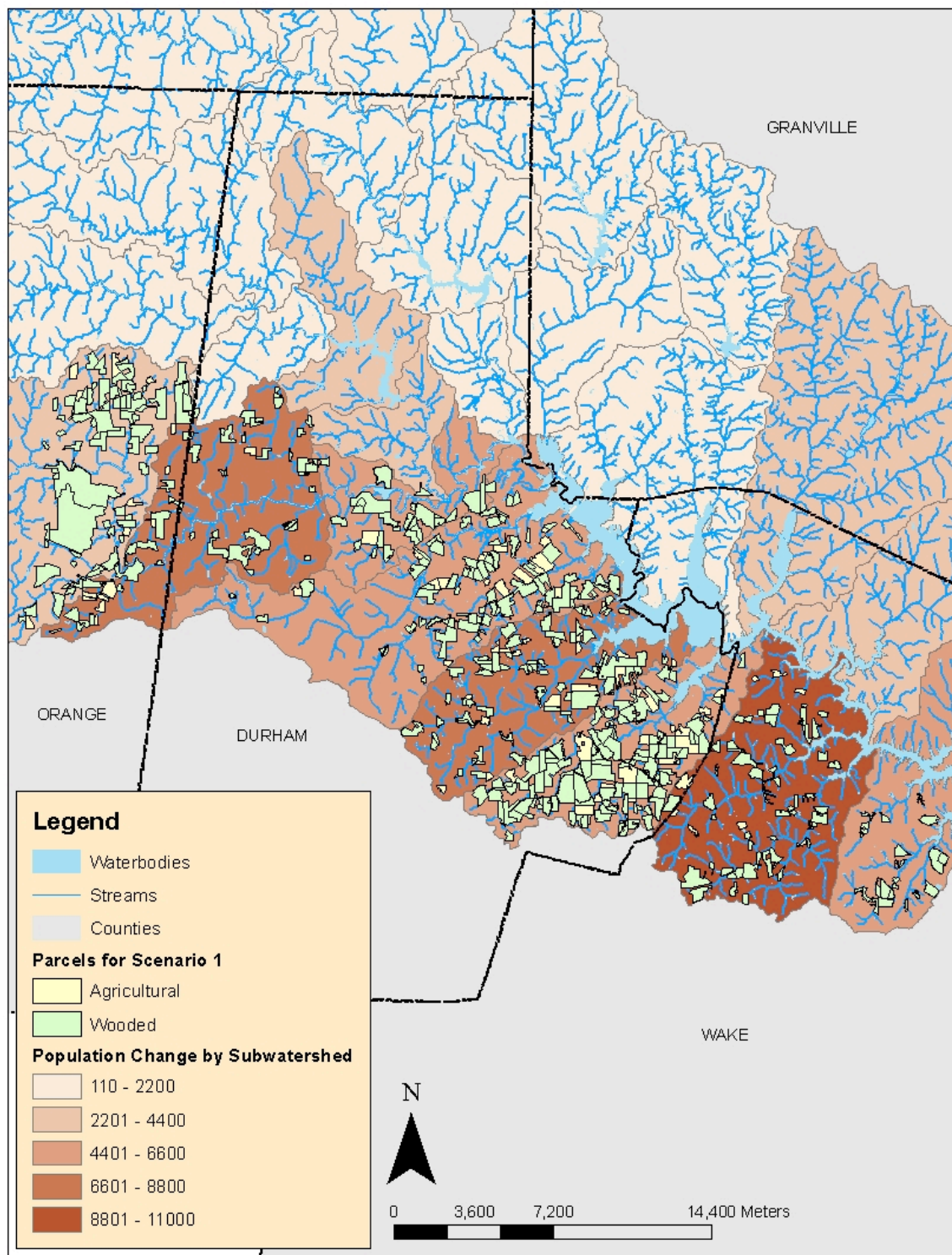
Pollutant Loading if Not Protected (X_{ij})

Future land use projections are used to determine what would happen to a parcel if it was not acquired for conservation purposes. Four different future land use scenarios are used for this variable.

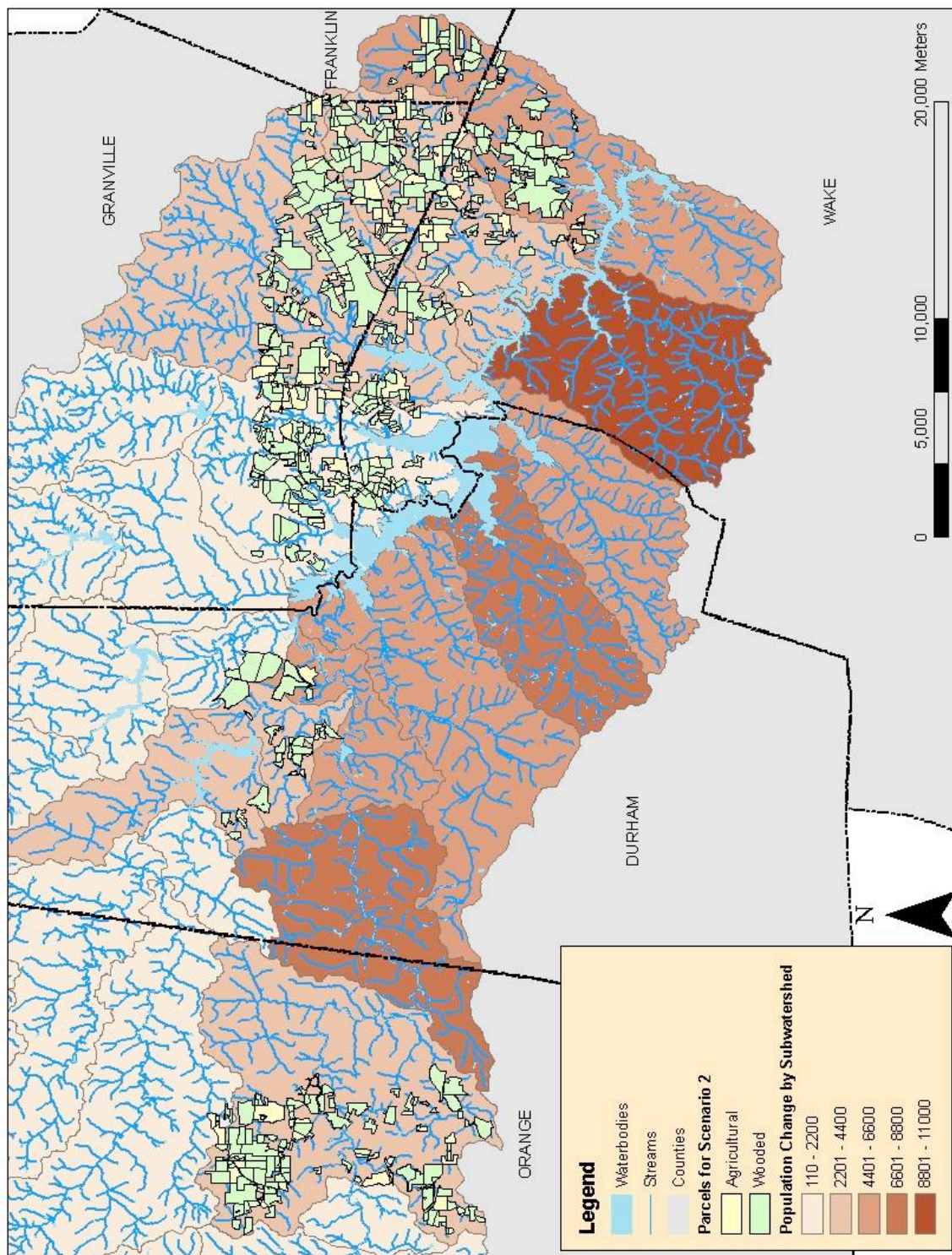
The Upper Neuse River Basin Association (UNRBA) and Tetra Tech, Inc. performed a study in 2000 that projected population in 2025 by subwatershed (UNRBA 2003). The report states that wooded and agricultural parcels will be transformed to residential to account for this population increase. So, the change in population from 2000 to 2025 is calculated for each subwatershed (Map 2). The population change by subwatershed is then divided into equal intervals, and UNCWI high-priority parcels with land use majority of wooded and agriculture are chosen from the subwatersheds with the highest population change. Since the Premium Solver tool in Excel has a limitation of 500 parcels, two different scenarios are used. For Scenario 1, 500 parcels that have been identified as UNCWI high-priority and have a current land use of wooded or agricultural are selected from the subwatersheds with a population change of 4,000 to 12,000 people (Map 3). For Scenario 2, the parcels UNCWI high-priority parcels with current wooded or agricultural land cover remaining in the subwatersheds with a population change of 4,000 to 12,000 people were selected. Then the wooded or agricultural high-priority parcels in the subwatersheds with a population change of 2,000 to 4,000 were selected. A total of 500 parcels were selected for Scenario 2 (Map 4).



Map 2: Population Change by Subwatersheds

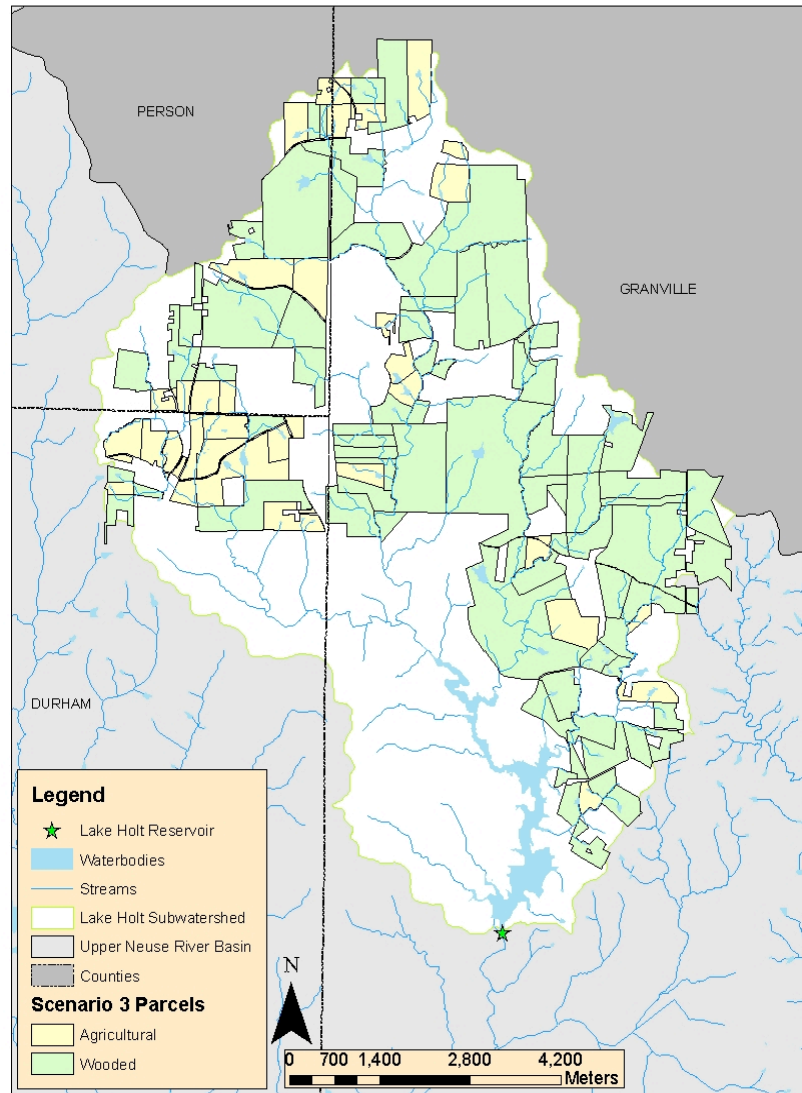


Map 3: Parcels for Scenario 1 Input



Map 4: Parcels for Scenario 2 Input

For Scenario 3, the PPW Model is used to prioritize parcels that are in the Lake Holt Subwatershed. The UNCWI high-priority parcels that are currently wooded or agriculture are assumed to be converted to residential for future land use (Map 5). There are 100 parcels that are of high-priority and wooded or agricultural. These parcels are selected as inputs for the PPW Model.

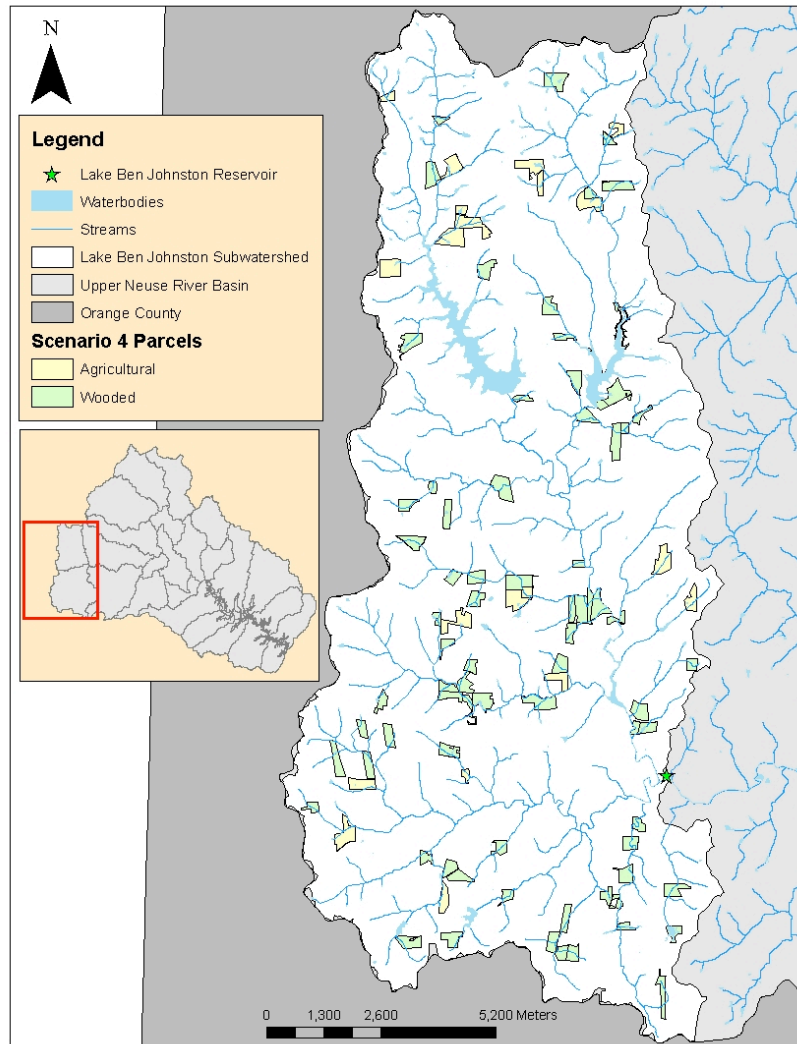


Map 5: Parcels for Scenario 3 Input

Scenario 4 examines the Lake Ben Johnston watershed in Orange County. The UNCWI high-priority parcels that are currently wooded or agriculture and are less than 55 acres are selected for this analysis (Map 6). The smaller parcels are selected because the model is run with less than 100 parcels to show land trusts how they can run the model without having to purchase Premium Solver. There are 90 parcels for the input of this scenario.

Cost of Buying an Easement (C_i)

Assessed land values for each parcel are used for estimating the cost of buying an easement. These land values are provided by the parcel shapefile that each county gave to the UNCWI. Some parcels did not have an assessed value in the attribute table, so the values are found using the register of deeds online databases for each county. If the parcels have no or low assessed value, then they are removed from the analysis.



Map 6: Parcels for Scenario 4 Input

There are no land values for Granville County in the shapefile, so the Granville County parcel shapefile from their GIS department is used. In the Azzaino et al. (2002) paper, the use of assessed land values is justified because they are known to underestimate the actual market value of the whole parcel. So this is regarded as a reasonable estimate of the cost of acquiring a partial easement.

Available Budget (M)

There are no funds appropriated specifically for the Upper Neuse River Basin. However, funding is available through state trust funds and dedicated local funds. For state trust funds, the total appropriation per year can change. Also, conservation efforts in the Upper Neuse River Basin are competing with other efforts in the state. So for an estimate for state funding in the Upper Neuse, the percent area of North Carolina that is the Upper Neuse River Basin is determined. The Upper Neuse occupies an area of about 1.46% of the state of North Carolina. Then the state trust fund appropriations from 2003 are multiplied by 1.46%. The Ecosystem Enhancement Program is relatively new so the 2005-2006 fiscal year data is used for this fund. It is also multiplied by 1.46%. For local funding, estimates are obtained through conversations with county offices. In Orange County, there is a Lands Legacy Program that has spent \$1,157,853.00 on conservation in the Neuse since 2000 (Shaw 2007). So this number is divided by six to obtain a yearly average. In Wake County, there is an open space program, which uses bonds for land conservation. They had \$15 million in 2000 and \$26 million in 2004. About 75% of these bonds go to conservation in the Upper Neuse (Smith 2007). So the two bonds are averaged together and multiplied by 75%. Table 3 shows the end calculations for these funds in the Upper Neuse River Basin. The total is rounded up to \$20,000,000 for this analysis.

Table 3: Estimated Funding for Conservation in Upper Neuse River Basin

| Funding Source | Amount in Upper Neuse River Basin |
|-------------------------------|--|
| State Trust Funds | \$713,436.75 |
| Ecosystem Enhancement Program | \$1,900,548.71 |
| Orange County | \$192,975.50 |
| Wake County | \$15,375,000.00 |
| TOTAL | \$18,181,960.96 |

A value of \$20,000,000 is used as the budget for Scenarios 1 and 2 because the parcels chosen for these scenarios are throughout the basin. For Scenario 3, the state trust funds and the Ecosystem Enhancement Program are potential funding sources. The Lake Holt subwatershed makes up about 3.71% of the Upper Neuse. So the amounts in Table 3 for state trust funds and Ecosystem Enhancement Program are multiplied by 3.71% to

get the budget available for parcel protection in the Lake Holt area. The result is \$97,080.28. This is rounded up to \$100,000 for the M variable for this Lake Holt Scenario.

For Scenario 4, since Lake Ben Johnston is in Orange County, the Orange County budget along with the state trust funds and the Ecosystem Enhancement Program are considered potential sources. The Lake Ben Johnston watershed is 7.92% of the Upper Neuse River Basin. So the state trust fund and Ecosystem Enhancement Program totals from Table 3 are multiplied by 7.92%. Then the Orange County total from Table 3 is added to give a final budget of \$400,057.46. So this number is rounded to \$400,000 for the M variable for Scenario 4. The budget value used for each scenario is in Table 4.

Table 4: Budget (M) for Each Scenario

| Scenario | Budget (M) |
|--------------------------------------|-------------------|
| 1 – Highest Population Change | \$20,000,000 |
| 2 – Second Highest Population Change | \$20,000,000 |
| 3 – Lake Holt | \$100,000 |
| 4 – Lake Ben Johnston | \$400,000 |

Running the PPW Model

Normalizing the Data

To make sure the units of measurement do not influence a parcel's score, acreage, stream frontage, and distance to intake are normalized. The following ratio-scale formula, the same formula used in Azzaino et al. (2002), is used:

$$\text{Normalization of attribute } (\alpha) = \frac{(\text{attribute of } i^{\text{th}} \text{ parcel} - \text{minimum of attribute})}{(\text{maximum of attribute} - \text{minimum of attribute})}$$

Scenarios for Running the PPW Model

The following is a brief description of the scenarios for the PPW model runs. For each scenario, the PPW model is run twice, once for S_i equal to stream frontage and once for S_i equal to size of parcel. When S_i denotes stream frontage, the scenario is referred to

as A. When S_i denotes size of parcel, the scenario is referred to as B. For example, a run of the first scenario with S_i equal to stream frontage is called Scenario 1A. Table 5 displays the summary statistics for the inputs of each scenario.

Scenario 1

The UNCWI high-priority parcels with a current land use of wooded or agriculture in the subwatersheds with the highest population change are selected for this scenario. Of the 500 that were selected, eight parcels did not have accurate assessed land values. Thus, 492 parcels are used for this scenario. A budget of \$20 million is used in this scenario.

Scenario 2

The UNCWI high-priority parcels with a current land use of wooded or agriculture in the subwatersheds with the next highest population change are selected for this scenario. Of the 500 parcels that were selected, thirteen parcels did not have accurate land assessment values. Thus, 487 parcels are used for this scenario. A budget of \$20 million is used in this scenario.

Scenario 3

This scenario is used to focus on smaller watersheds within the basin. Lake Holt is chosen because there are 100 parcels that are currently wooded or agricultural UNCWI high-priority parcels. Therefore, this scenario can be modeled using the Solver tool available in Excel. A budget of \$100,000 is used in this scenario.

Scenario 4

The Lake Ben Johnston scenario is also selected to model a smaller watershed within the basin using the Solver tool. However, this watershed has about 200 parcels that are wooded or agricultural UNCWI high-priority. So parcels with less than 55 acres are chosen to provide a scenario that focuses on smaller parcels. There are 90 parcels that are less than 55 acres. A budget of \$400,000 is used in this scenario.

Table 5: Summary Statistics of Parcels Chosen for Each Scenario

| Scenario | Parcels | Acres | Stream Frontage (ft) | Average Distance to Intake (ft) | Cost (\$) |
|-----------------|----------------|--------------|-----------------------------|--|------------------|
| 1 | 492 | 26,327.46 | 2,370,286 | 136,869.04 | 192,114,998 |
| 2 | 487 | 32,071.22 | 2,570,524 | 127,551.52 | 169,356,444 |
| 3 | 100 | 9,141.75 | 684,858 | 37,721.06 | 15,693,235 |
| 4 | 90 | 2,441.92 | 293,418 | 27,628.97 | 9,397,155 |

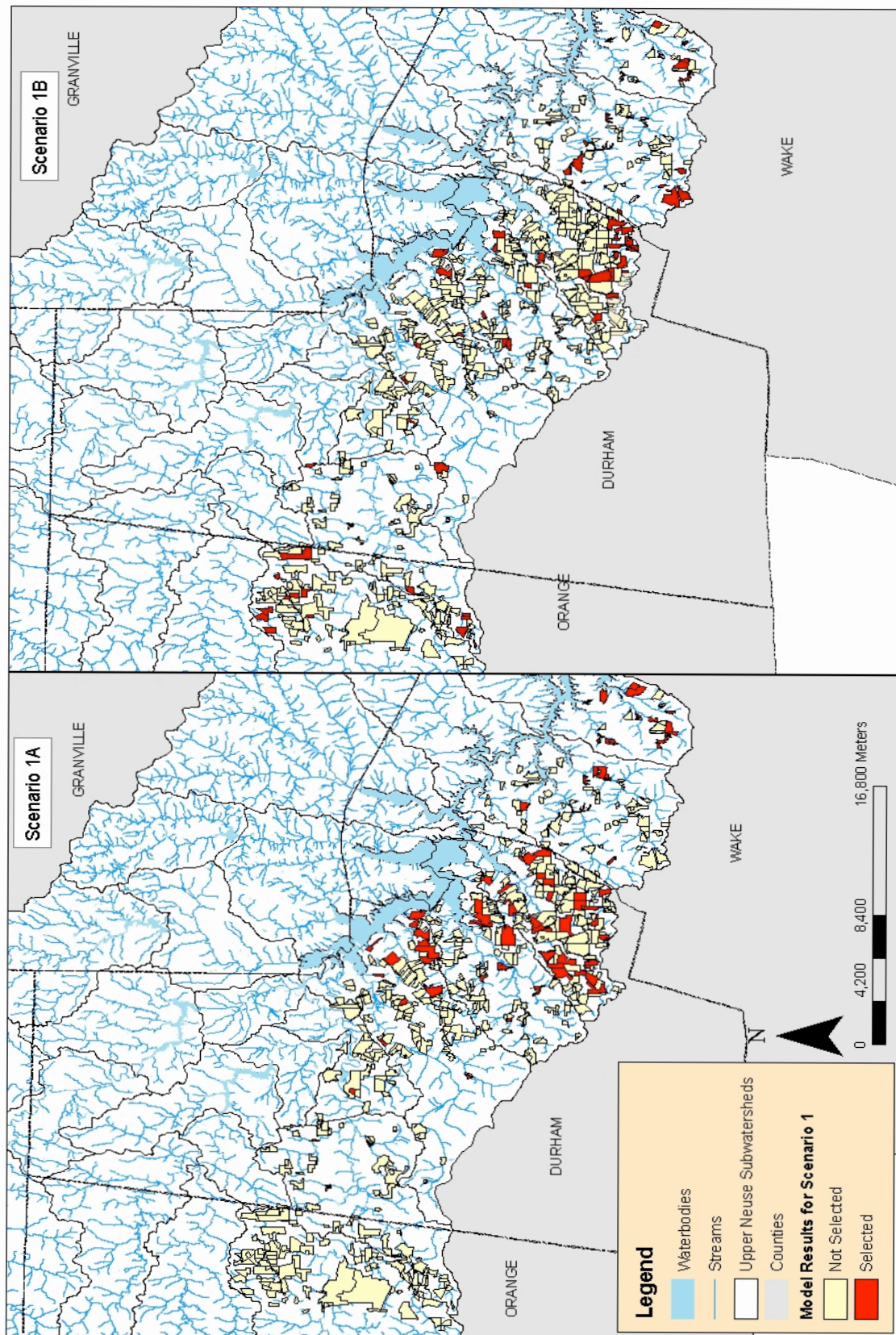
RESULTS AND DISCUSSION

Scenario 1

For the first 2025 future population projection scenario, the PPW Model selected 69 parcels for Scenario 1A (S_i = parcel size) and 58 parcels for Scenario 1B (S_i = stream frontage) (Table 6). Of these parcels, there were 37 in common. Scenario 1A has a greater total parcel-pollutant weight indicating that protection of those parcels will potentially reduce more pollutant loads than the parcels chosen for the stream frontage model. Conservation groups can use these results to narrow their focus to the 37 parcels both of these models selected.

Table 6: Scenario 1 Results Comparison (Wooded & Agriculture in Highest Population Change)

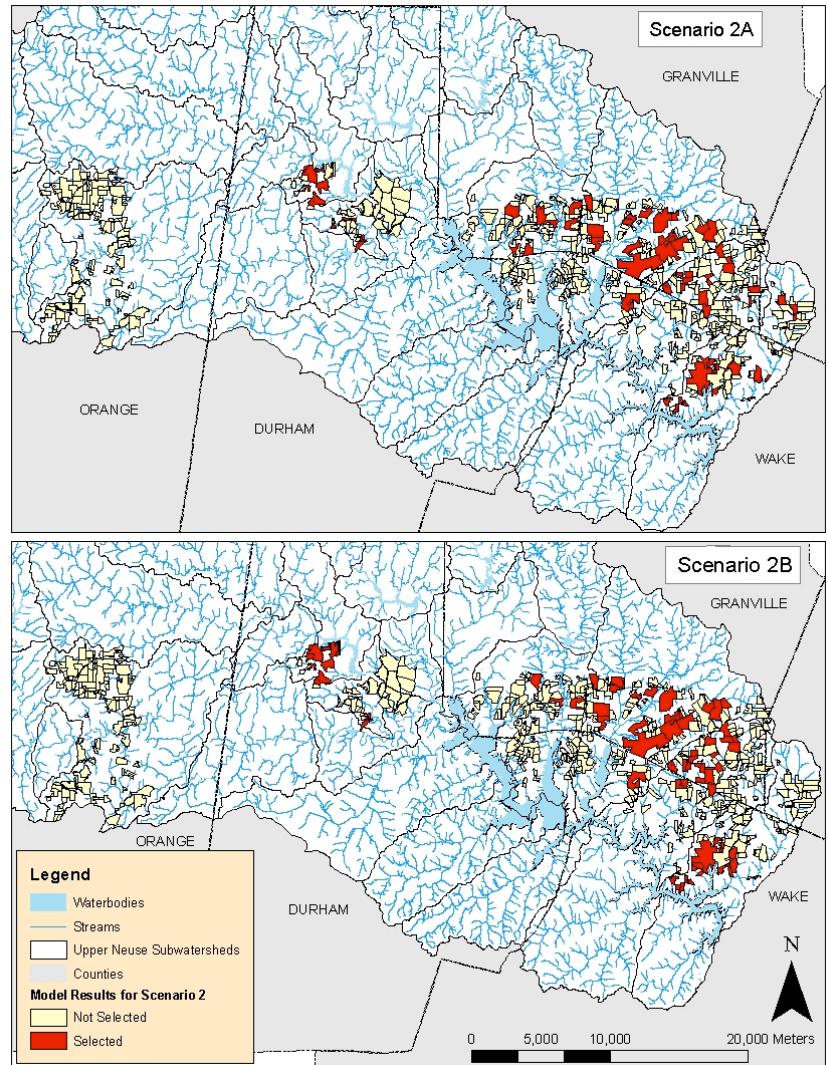
| Scenario | Number of Parcels Selected | Total Acres | Total Stream Frontage (ft) | Average Distance to Intake (ft) | Sum PPW | Total Cost (\$) |
|-----------------|-----------------------------------|--------------------|-----------------------------------|--|----------------|------------------------|
| 1A | 69 | 4,352.22 | 513,876 | 88,766.04 | 133.96 | 19,994,120 |
| 1B | 58 | 4,472.29 | 388,566 | 83,448.39 | 80.46 | 19,998,347 |



Map 7: Scenario 1 Results

Scenario 2

For the second highest 2025 population change by subwatershed scenario, the model chose 64 parcels for Scenario 2A and 63 parcels for Scenario 2B to be protected (Map 8). There are 42 common parcels chosen. The total parcels chosen for each scenario cover about the same amount of area and have similar pollutant weights (Table 7). So in this scenario, the S_i variable does not matter in respect to the total amount of parcels chosen for protection. For this scenario analysis, conservation



Map 8: Scenario 2 Results

groups can focus on the 42 parcels that are commonly selected to see if protection of these parcels matches their conservation goals.

Table 7: Scenario 2 Results Comparison
(Wooded and Agriculture in Second Highest Population Change Subwatersheds)

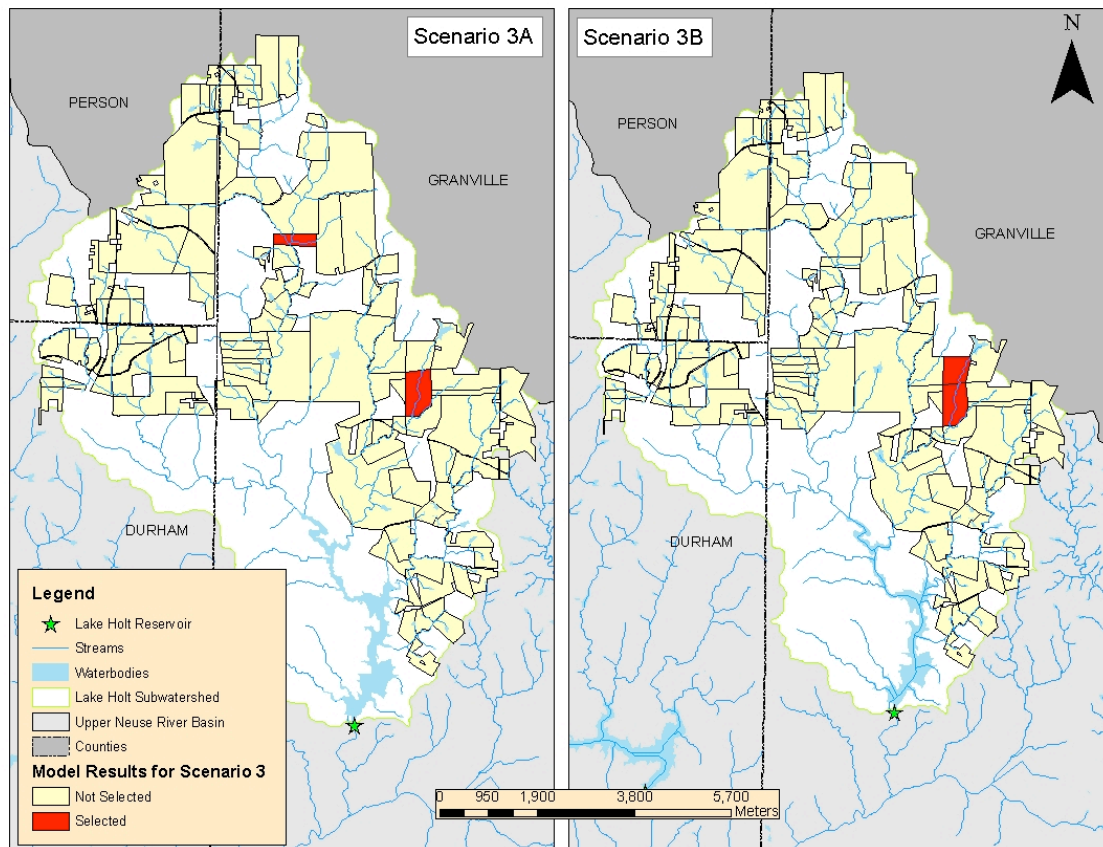
| Scenario | Number of Parcels Selected | Total Acres | Total Stream Frontage (ft) | Average Distance to Intake (ft) | Sum PPW | Total Cost (\$) |
|----------|----------------------------|-------------|----------------------------|---------------------------------|---------|-----------------|
| 2A | 64 | 7,539.73 | 638,758.00 | 88,766.04 | 253.16 | 19,979,289 |
| 2B | 63 | 7,571.83 | 531,236.00 | 80,801.80 | 260.00 | 19,968,662 |

Scenario 3

Both models for Scenario 3 chose 2 parcels (Map 9). There was one parcel in common between the two models (Table 8). The fact that 100 parcels were put into the model and only 2 were selected shows that cost plays an important role in prioritization.

Table 8: Scenario 3 Results Comparison (Lake Holt)

| Scenario | Number of Parcels Selected | Total Acres | Total Stream Frontage (ft) | Average Distance to Intake (ft) | Sum PPW | Total Cost (\$) |
|-----------|----------------------------------|----------------|-------------------------------|--|------------|--------------------|
| 3A | 2 | 152.87 | 17,482 | 36,627.10 | 3.77 | 94,147 |
| 3B | 2 | 182.05 | 16,148 | 33,527.19 | 4.51 | 95,108 |

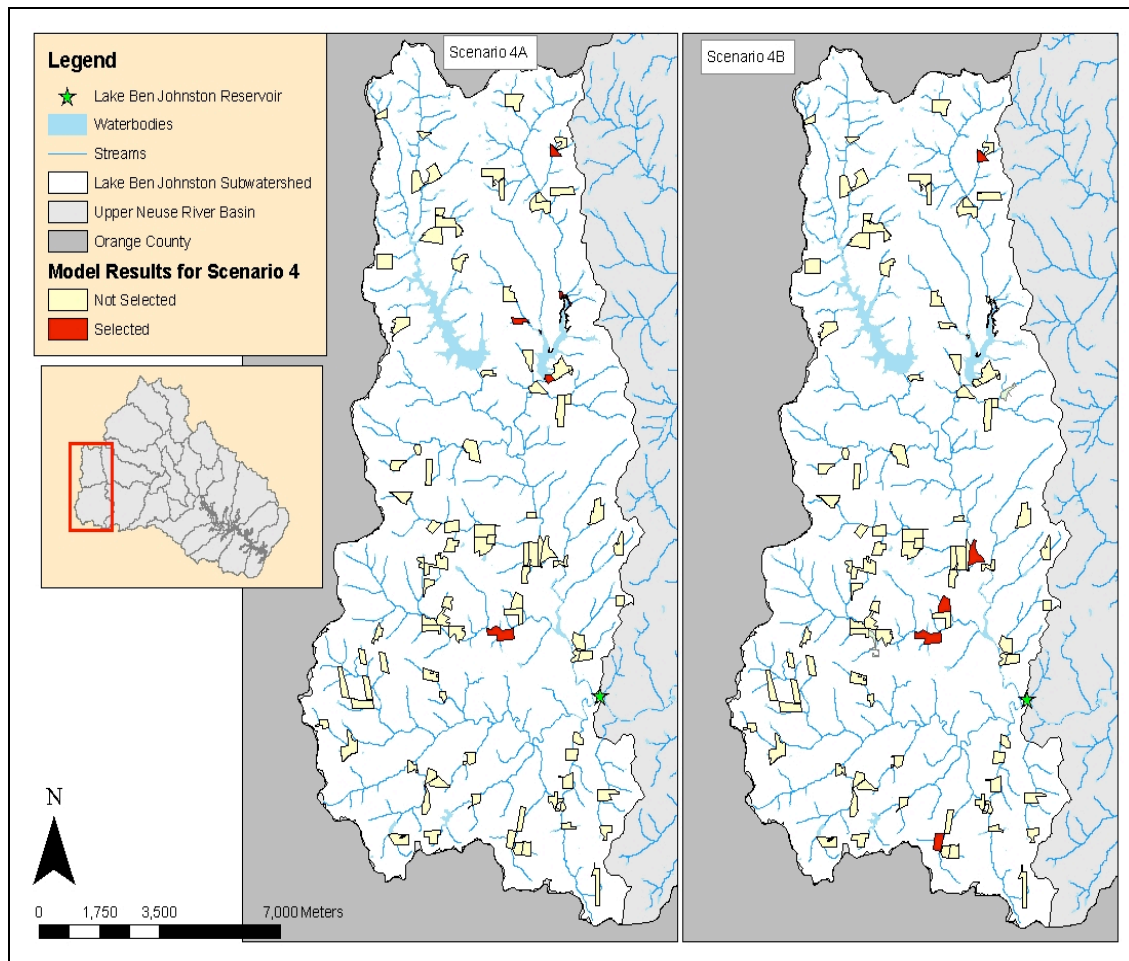


Scenario 4

For the Lake Ben Johnston analysis, the model chose 4 parcels for Scenario 4A 5 parcels for Scenario 4B (Table 9). There are 2 parcels in common between the two model runs. Lake Ben Johnston is located in the Eno River subbasin. So, this model will be helpful for conservation efforts specifically led by Orange County and the Eno River Association.

Table 9: Scenario 4 Results Comparisons (Lake Ben Johnston)

| Scenario | Number of Parcels Selected | Total Acres | Total Stream Frontage (ft) | Average Distance to Intake (ft) | Sum PPW | Total Cost (\$) |
|----------|----------------------------|-------------|----------------------------|---------------------------------|---------|-----------------|
| 4A | 4 | 102.87 | 16,758 | 11,235.70 | 256.67 | 399,244 |
| 4B | 5 | 155.76 | 22,404 | 14,414.55 | 287.46 | 398,755 |



Map 10: Scenario 4 Results

Comparison of Results

For most of the scenarios, the sum of the parcel-pollutant-weight selected by the models was greater when S_i was equal to acreage. However, for Scenario 1, the total parcel-pollutant weight of the selected parcels was greater when S_i was equal to stream frontage. Perhaps this is because the parcels selected by the model in Scenario 1A have almost 130,000 more feet of stream frontage than the parcels selected by the model in Scenario 1B. For all scenarios, the size, amount of stream frontage, and cost of the selected parcels are a large range. This shows that just because a parcel is large or has a large amount of stream frontage does not mean that it is really important for water quality protection, according to this model.

Distribution of Data and Results

The data and results of this analysis will be distributed on a data DVD to local land trusts, governments, and environmental organizations that are interested in land protection in the Upper Neuse River Basin. The PPW Model is set up in Excel in a user-friendly format with detailed instructions. As long as the number of parcels input into the model does not exceed 100, this model can be used without having to purchase add-ins for Excel. Hopefully conservation groups can use this model to prioritize parcels for land conservation based on their objectives and resources.

CONCLUSIONS

The PPW Model is a useful method for predicting the relative contribution of significant parcels to nonpoint point source pollution. By further prioritizing the high-priority parcels from the Upper Neuse Clean Water Initiative, it can better focus the limited amount of resources available for conservation in this area. Furthermore, it can easily be used in an Excel spreadsheet. This is important because land conservation objectives and available data are constantly changing. So, as needed, conservation organizations can input their own variables into the model to prioritize their land protection efforts.

However, there are some caveats for using the PPW model. The Solver tool that is available in Excel can only be used to run 100 parcels or less. For an area the size of

the Upper Neuse, this is a great disadvantage. The Premium Solver platform can be purchased from www.solver.com for \$1,495. This is an add-in for Excel that will allow a model run for up to 500 parcels. However, most conservation organizations do not have the funds for this purchase. Therefore, it might be worth looking into other open-source statistical applications that can run optimization models. However, the disadvantage of using other software is that it is not usually as user-friendly as Excel. Thus, conservation organizations could divide up their area of interest and the available budget. Then run the model for each area, combine the results, and run it again to further prioritize the results. Furthermore, the scenarios used in this analysis consider wooded and agricultural parcels with a wide range of size, stream frontage, and costs. Land trusts could use their own criteria to focus on parcels with certain land use types, sizes, amounts of stream frontage, and costs.

Budget and land values play a large role in prioritization in the model. Therefore, it is important to have an accurate estimation of these variables. The budget variable would be easier to estimate if there was a dedicated source of funding for land conservation in the Upper Neuse or if there was a study on the amount of state, local, and federal funding that is appropriated for this area. Also, the land values used in this project are assessed tax values. These values are usually lower than market values, so they are used to prioritize parcels for conservation easements. Actual market values of the properties can be used in the model to prioritize parcels for land acquisition.

The model can also be improved by determining which nonpoint pollutants are most prevalent in streams and reservoirs in the Upper Neuse River Basin. The cost of treating each pollutant to improve the drinking water quality can also be assessed. Then the results can be used to determine which pollutants to include in the model and what weight to assign to each of them.

Also, future land use is always difficult to predict. The prediction used for these scenarios is only one of many. It may be more useful to focus this model on one particular future scenario, such as a housing development. For example, if there was a proposed development with land use plans in the Eno River basin, the Eno River Association could use the information from the plan to determine the land cover for each parcel in the area and run the model to see which areas of the development could have

significant impacts on water quality. Then they could work with the developers to try to set some Best Management Practices on those priority parcels. The use of this model for land conservation prioritization is a new and useful method for land conservation organizations in the Upper Neuse River Basin.

REFERENCES

Azzaino, Zevi. Conrad, John. Ferraro, Paul. 2002. Optimizing the riparian buffer: Harold Brook in the Skaneateles Lake Watershed, New York. *Land Economics*. 78: 501-14.

[CWMTF] Clean Water Management Trust Fund. 2007. North Carolina's Clean Water Management Trust Fund Fact Sheet 2007. North Carolina: CWMTF.

[EPA] Environmental Protection Agency. National Land Cover Data. 2001.
<<http://www.epa.gov/mrlc/nlcd.html>> accessed 2006 December 10.

[EPA] Environmental Protection Agency. Nonpoint Source Pollution: The Nation's Largest Water Quality Problem. Pointer No. 1. EPA 841-F-96-004A.
<<http://www.epa.gov/owow/NPS/facts /point1.htm>> accessed 2007 January 15.

Ernst, Caryn. 2004. Protecting the Source: Land Conservation and the Future of America's Drinking Water. The Trust For Public Land and American Water Works Association.

Hart, Kelly. 2006. The Upper Neuse Clean Water Initiative Conservation Plan: Protection Land and Drinking Water for the Future. The Trust for Public Land.

[TJCOG] Triangle J Council of Governments. 2006. The Upper Neuse Clean Water Initiative Digital Data DVD.

Line, Daniel E., White, Nancy M., Osmond, Deanna L., Jennings, Gregory D., Mojonner, Carolyn B. 2002. "Pollutant Export from Various Land Uses in the Upper Neuse River Basin." *Water Environment Research*. 74: 100-8

[NCDENR] North Carolina Department of Environment and Natural Resources. 2000. Riparian Buffer Protection rules for the Neuse and Tar-Pamlico River Basins. North Carolina: NCDENR.

[NCEEP] North Carolina Ecosystem Enhancement Program.
<<http://www.nceep.net/pages/ abouteeep. html>> accessed 2007 January 15.

[NCNHTF] North Carolina Natural Heritage Trust Fund. <<http://www.ncnhtf.org/pages/ aboutnhtf.htm>> accessed 2007 January 15.

North Carolina OneMap. <<http://www.nconemap.com/data.html>> accessed 2006 December 5.

[NCPRTF] North Carolina Parks and Recreation Trust Fund.
<<http://www.partf.net/apply.html>> accessed 2007 January 15.

Peterson, Bruce. 2001. Control of nitrogen export from watersheds by headwater streams. *Science*. 292: 86-90.

Shaw, Rich. Orange County Land Resources Conservation Manager.
<rshaw@co.orange.nc.us> 2007 February 13. Land conservation funding question [personal email]. Accessed 2007 February 13.

Smith, Kurt W. Program Manager of Wake County Open Space.
<kwsmith@co.wake.nc.us> 2007 February 16. Land conservation funding question [Personal email]. Accessed 2007 February 16.

[UNRBA] Upper Neuse River Basin Association. 2003. Upper Neuse Watershed Management Plan. North Carolina: UNRBA.