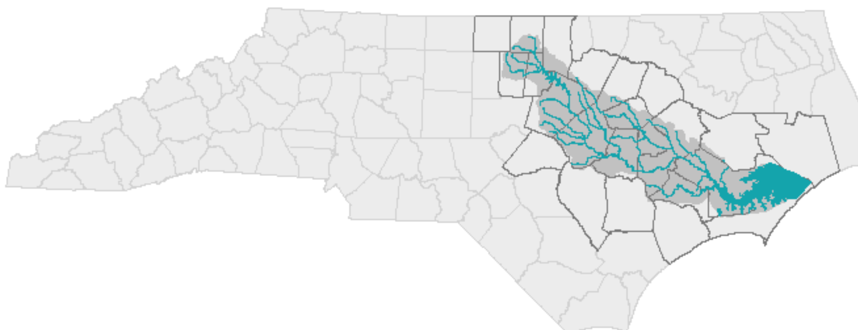
Neuse River Basin
Water Resources Plan



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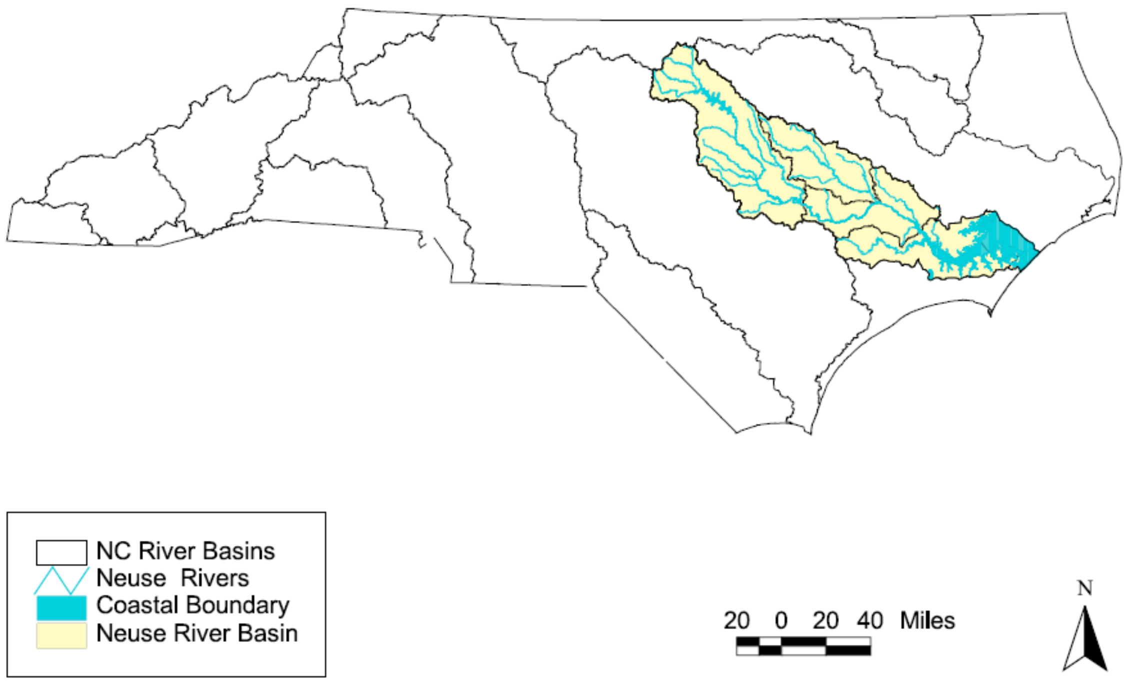


The Neuse River Basin Water Resources Plan provides an evaluation of the water resources of the Neuse River Basin. It describes where existing surface water supplies may not be sufficient to meet future water demands for public water systems, identifies where self-supplied industrial operations may face increased challenges meeting their water needs and provides information on the magnitude of impacts to future recreational opportunities on the basin's major reservoirs.

The analysis is based on evaluations of future water demands in relation to hydrologic conditions that occurred in the basin from 1930 to 2008. These evaluations were conducted using the Neuse River Basin Hydrologic Model - a computer based mathematical model that balances inflows and outflows of surface water at specific locations as it moves downstream. The model covers the basin from the headwaters of the Eno, Flat and Little rivers in Durham and Orange counties, downstream to New Bern, where the Neuse River becomes influenced by the saltwater and tides of the Pamlico Sound.

Future water demands were derived from registered water withdrawers and local water supply plans submitted by public water systems that use water from the Neuse River Basin. Except for required minimum releases from several reservoirs, the model does not provide for water needed in waterways to preserve the ecological integrity of the rivers in the basin.

Neuse River Basin Description

The Neuse River Basin is one of 17 basins designated for planning purposes in North Carolina. It lies entirely within the state. With a drainage area of 6,235 square miles, it is the third largest river basin in North Carolina. The headwater streams merge in Falls Lake Reservoir to form the Neuse River. Below Falls Lake Reservoir the river and its tributary streams flow through the broad flat terrain of the Coastal Plain. The low gradients of the Coastal Plain slow the river as it continues to flow southeasterly toward New Bern, where it changes character. The freshwater flowing downstream becomes brackish as it merges with the tidally influenced saltwater of the estuary and flows into Pamlico Sound. The amount of surface water flowing in the basin is directly related to precipitation, which varies geographically and seasonally. On average, the upper part of the basin receives about 45 inches of rain annually, while the area around New Bern receives about 60 inches a year. Monthly average precipitation throughout the basin is usually higher during the summer months than the rest of the year. However, summer is also the time when vegetation uses more water and high temperatures increase evaporation. The combination of these two factors produces lower streamflows in the summer months when demands for water are usually the highest.

This basin contains areas that have experienced some of the state's fastest growth and supplies water to nearly 1.7 million people living in the 18 counties. The counties with significant area in the basin include Beaufort, Carteret, Craven, Durham, Franklin, Granville, Greene, Johnston, Jones, Lenoir, Nash, Onslow, Pamlico, Person, Pitt, Wake, Wayne and Wilson. If the population continues to grow as it has since 1970, these counties could be home to around three million people by 2050. Most of the communities and water systems in the upper portion of the basin use surface water sources and withdraw water from reservoirs or directly from rivers and streams. The flatter topography of the Coastal Plain is typically not suitable for reservoir development, and most coastal systems use ground water supplies.

The rolling hills of the Piedmont feature several reservoirs that impound surface waters and modify downstream flows. They have been created in the basin's upper watersheds to provide water for water supply and recreational purposes. Falls Lake Reservoir also provides capacity for controlling flood flows. Constructed and operated by the U.S. Army Corps of Engineers, it is the largest reservoir in the basin and holds more than 59 percent of the impounded surface water. Falls Lake Reservoir is the primary source of water for Raleigh and the surrounding communities to whom it supplies water. The analysis in this plan indicates that Raleigh's existing water sources will be insufficient to meet expected increases in demand. The physical characteristics of Falls Lake Reservoir and its operational protocols are discussed in detail within this plan. Likewise, the plan describes the management of the reservoirs on the Eno River watershed. The communities that rely on water from this watershed also face increasing supply shortages as demands increase. However, the Eno River Water Management Plan, supported by local water withdrawers and the Environmental Management Commission, establishes drought management protocols that reduce the negative impacts during periods of low flows.

The Neuse River Basin Water Resources Plan is the result of a series of evaluations that would not have been possible without sufficient data to reconstruct a long-term record of hydrologic conditions in the basin. The 78-year flow record used in this analysis was constructed from historic and real-time streamflow data collected by the U.S. Geological Survey at gaging stations throughout the basin. Key to this work was the data from the seven gaging stations where flows are relatively uninfluenced by human alterations. The 44 years-to-84 years of continuous flow records at these unaltered gaging stations provide vital information on drainage areas from 80 square miles to more than 700 square miles. The data available from this record were critical to the development of the flow record needed to conduct the evaluations necessary for this plan. The flow record, representing conditions from 1930 to 2008, includes high flow events and several drought periods, including 2007, the driest year in the Neuse River Basin.

Process

The Neuse River Basin Water Resources Plan was developed to answer the following question: “Is there going to be enough water in a particular watershed of the basin to sustain all the uses now and into the future?”

Not having realistic estimates of the amount of water needed to protect ecological integrity in the rivers and streams is a serious limitation on the plan’s ability to provide useful answers to this question. Work is currently underway to develop the science-based ecological flows that can be added to future analyses. The modeling and evaluation process developed for this plan provide a solid framework into which target ecological flows can be integrated, when they are developed.

Three levels of water demands were evaluated by comparing the ability of existing water sources to provide withdrawals adequate to satisfy the demands during each of the 78 annual flow patterns in the data record. Current conditions were characterized using 2008 demands and withdrawals. This demand scenario is based on actual water usage in 2008 and provides a point of comparison for changes that may result from increasing water withdrawals to meet increasing water demands in the future.

Future demand scenarios were derived from data submitted by local government water systems and other large community water systems as part of their local water supply plans. Near-term future demands were based on estimated demands for the year 2030. Long-term future demands were based on projected demands for 2050. Therefore, the 2030 demand scenario and the 2050 demand scenario represent estimates of future demands based on the current visions of how these communities may develop.

This analysis does not evaluate conditions in 2030 or 2050. It evaluates two different levels of water demands. In reality, these levels of demand may be reached before these dates, or may not be reached until many years after them. The analysis shows what changes may be seen when these two levels of demand are reached in the basin, based on the other assumptions included in the analysis.

Neuse River Basin Hydrologic Model

The three demand scenarios were evaluated using the Neuse River Basin Hydrologic Model. The model was developed using Operational Analysis and Simulation of Integrated Systems, or OASIS, with Operations Control Language, or OCL™, a generalized computer simulation program designed to characterize water resource systems. The language was developed by HydroLogics, Inc. The Neuse River Basin Hydrologic Model is based on the most practical geographic resolution and calculation time step appropriate for modeling the impacts to the quantities of surface waters in the basin. The model covers the basin from the headwaters of the Eno, Flat and Little rivers in Durham and Orange counties, downstream to New Bern. It is a decision support tool that can be used for multipurpose decision making for surface water resource management and, with additional information, drought management. The Neuse River Basin Hydrologic Model is a mathematical model that balances inflows and outflows of surface water and evaluates changes in quantity as the water moves downstream.

For each demand scenario, the model evaluates water supply withdrawals, wastewater return flows, agricultural withdrawals, and reservoir operating protocols using 78 annual patterns of daily stream flow data. Flows coming into a point of interest and withdrawals from the same point of interest are compared to determine the amount of water available to flow downstream to the next point of interest. The points of interest are called model nodes. There are model nodes designating where water flows in or out of the system, where water is stored in a reservoir, and where calculations are performed to determine how much water is available to send to the next downstream node.

Comparing modeling results with actual conditions in the basin shows that the model does a good job of replicating real world conditions. The model is a useful planning tool that will provide useful information to evaluate water resource management options.

Close examination of conditions in Falls Lake Reservoir in 2007, the driest year on record for the basin, indicates that many of the variations in water levels between real conditions and the model simulations are the result of real-time decision making that is not limited by modeling constraints. Reservoir managers and users made decisions to reduce downstream releases and municipal water withdrawals during the drought, which kept more water in the reservoir than the model predicted would have been there. Including the drought management protocols of the Eno River Water Management Plan, the model produced simulations that did an excellent job of reproducing conditions in the Eno River watershed during 2007.

The model's accuracy during dry periods, when the ability to meet all demands is most likely to be compromised, is critical. The current version of the model produces credible results. The scope of impacts that can be evaluated using the model will increase when target ecological flows are finalized and integrated into the model.

Results

When a scenario simulation is run, the Neuse River Basin Hydrologic Model evaluates hydrologic conditions and produces a set of solutions for each day in the 78-year flow record. If the model indicates water is available at a particular reservoir or river node, then it is allocated to any required downstream releases or withdrawals at that location and the residual amount is passed to the next downstream node. The current version of the model indicates that all of the demands included in the 2008 current conditions demand scenario could be satisfied during the entire range of flows experienced in the Neuse River basin from 1930 to 2008.

Population growth and economic development in the basin are expected to increase demand for water in the future. Modeling of the 2030 demand scenario indicates that Raleigh and Durham may not be able to withdraw the amounts of water specified in the scenario if hydrologic conditions like those experienced in 2007 happen again. This scenario includes average daily demands of 87 million gallons per day for Raleigh and 36 million gallons per day for Durham. Demands in the model vary by month of the year to replicate the seasonal variations in demand experienced by most public water systems. Both of these water systems are evaluating options to increase their water supplies before their demands exceed existing capacities.

The Neuse River Basin Hydrologic Model predicts that six systems may not be able to withdraw the amounts of water needed to fully meet their demands in the 2050 demand scenario under all 78 annual flow patterns contained in the model. These systems include Raleigh and Durham as well as four additional systems - Hillsborough, Orange-Alamance, Piedmont Minerals and South Granville Water and Sewer Authority.

As demands increase, the frequency and duration of supply shortages also increase. Any impacts on target ecological flows would also increase. The long-term, or 2050, demand scenario has higher water demands to support significantly more residents. The long-term demand estimates were derived from information included in water system's local water supply plans. Raleigh anticipates needing 129 million gallons per day to meet demand in 2050, which is a 183 percent increase over 2008 usage. Durham's system is expected to need 41 million gallons per day to meet the expected demand in 2050. The occurrence of shortages for these two systems increases from once in 78 annual flow patterns for the 2030 demand scenarios to 36 of 78 for Raleigh and five of 78 for Durham for the 2050 demand scenario.

If Durham's demand for water reaches the predicted average of 41 million gallons per day with only their current sources of water to meet the need, then the system could expect to experience up to 60 continuous days when demand could not be fully satisfied over the range of flows that have occurred in the basin from 1930 to 2008. If Raleigh's demand reaches the predicted average of 129 million gallons per day with only their current water sources, then the water system could expect to see up to four continuous months when demands could not be fully satisfied. And shortages could occur during 36 of the 78 annual flow patterns seen since 1930.

The other four systems are predicted to face shorter and less frequent shortages compared to Raleigh and Durham. The systems that operate under the Eno River Water Management Plan - Orange-Alamance Water System, Hillsborough, and Piedmont Minerals - could experience up to a month when their modeled demands could not be fully satisfied in two of the 78 annual flow patterns. Recently, Piedmont Minerals made changes in their operations such that they withdraw less water than the volume included in the model. This change may reduce the occurrence of shortages for the other water withdrawers in the Eno River Basin.

The South Granville Water and Sewer Authority also faces supply shortages if their demands reach the projected 10 million gallons per day included in the 2050 demand scenario. If this demand level is reached, the system could face up to 79 continuous days of supply shortages with shortages occurring in 14 of the 78 annual flow patterns in the model.

Except for the systems that operate under the Eno River Water Management Plan, none of the other systems have drought management plans built into the model to alter water demands when supplies become limited. When systems can describe how demands will be reduced during droughts in a way that can be included in the model, it will be possible to refine predictions of the duration and frequency of future shortages.

Drought response plans can help reduce the negative impacts of water shortages. To postpone serious shortages in the future, Durham, Raleigh and South Granville Water and Sewer Authority are encouraged to use their existing water supplies more efficiently and to manage the growth in water demand, while they explore other alternatives. Durham and Raleigh are already evaluating and planning for additional water sources that will help them meet future water demands.

The current version of the Neuse River Basin Hydrologic Model, which does not include target ecological flows in the suite of water demands to be satisfied, does not predict supply shortages for any of the other modeled surface water withdrawers. However, with the same levels of demands used in the projected 2030 and 2050 scenarios, water availability in the basin may not be sufficient to meet all offstream demands and still protect ecological integrity. Until drought response plans are incorporated and the timing and amounts of water needed to protect ecological integrity are clearly defined, it is not possible to determine the magnitude of the potential shortages.

Hydrologic Unit or Watershed Summaries

For this evaluation, the Neuse River Basin is sub-divided into four major watersheds, the Upper Neuse, Middle Neuse, Lower Neuse and Contentnea Creek. The Piedmont terrain of the Upper Neuse watershed and the upper Contentnea Creek watershed contain public water supply storage reservoirs that provide water to some of the most populous areas in North Carolina. In addition, the Upper Neuse watershed contains the majority of controlled flood storage in the basin. Water releases from these reservoirs have a significant influence on the volume of water flowing downstream in the Neuse River, especially when precipitation and tributary stream flows are low.

The Contentnea Creek and Middle Neuse watersheds are much more rural and less populous than the Upper Neuse River. Most public water systems in the Middle Neuse and lower Contentnea Creek watersheds have traditionally relied on ground water to meet their customers' needs. With the implementation of limitations on water withdrawals from the Cretaceous aquifers of the Central Coastal Plain Capacity Use Area, water purveyors are using more surface water resources. Reduced ground water pumping resulting from the use of the Neuse Regional Water and Sewer Authority's new water treatment plant on the Neuse River near Kinston, has already produced measurable improvements in the water levels in underlying aquifers. Substituting surface water sources for ground water sources to protect the integrity of regional aquifers, results in more transfers of water across the basin boundaries used to regulate surface water transfers.

Freshwater flowing into the Lower Neuse hydrologic unit mixes with saltwater and becomes brackish as the river widens into a tidally influenced estuary. The Weyerhaeuser Company withdraws freshwater from this section of river. The amount of freshwater available to this facility can be limited at times due to the movement of the freshwater/saltwater transition zone in the river. The availability of freshwater at the plant has been most limited during droughts when reduced river flows allow saltwater to move upstream. Some public water systems in this watershed are also switching from ground water to surface water sources and increasing transfers of water between regulatory river basins.

The Lower Neuse watershed is particularly vulnerable to the impact of increased fluctuations of climate on water resources. The potential impacts of sea level rise, as well as changes in tropical storms, saltwater intrusion, precipitation and river flow patterns may significantly affect residents and water users in this area. Areas that could be affected by a 2.6 inch and a 12.2 inch sea level rise are shown on maps included in the discussion of this watershed. Sea level rise could change the location of the freshwater/saltwater transition zone in the Neuse River, pushing it farther upstream. This would further limit the ability of the Weyerhaeuser facility to withdraw freshwater at its current intake location that is essential for its operations.

There is a key element missing from the Neuse River Basin Hydrologic Model and, therefore, also missing from the Neuse River Basin Water Resources Plan. At this point, the model does not include criteria to reserve water for ecological flows to maintain the ecological integrity of aquatic habitats. Ecological integrity is "the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to prevailing ecological conditions." Maintaining ecological integrity requires a flow regime that encompasses the appropriate magnitude, timing, frequency, duration, variability and rate of change of stream flows. The state Division of Water Resources, in consultation with the Wildlife Resources Commission and other experts, is in the process of developing a technical approach for scientifically determining the target ecological flow values needed for river basin water resources planning. When a successful process is developed, ecological flow criteria will be integrated into the river basin hydrologic models. The resulting river basin water resources plans will yield more realistic estimates of the amount of water that may be available for offstream uses.

The Neuse River Basin Water Resources Plan provides an overview of the water resources of the basin under current conditions and into the future with projected increases in population and water withdrawals. It identifies the areas of the basin where water systems may not be able to withdraw the quantity of water that they project will be needed to satisfy the demand of their service area. The plan identifies potential alternatives to address these water shortages, which will occur in the future if some of the drought conditions of the past occur again. Future updates of the plan and the hydrologic model will incorporate an approved drought protocol for Falls Lake Reservoir, the details of the individual water shortage response plans, target ecological flows and any modified water resource management plans in the basin.

Chapter 2 - Introduction

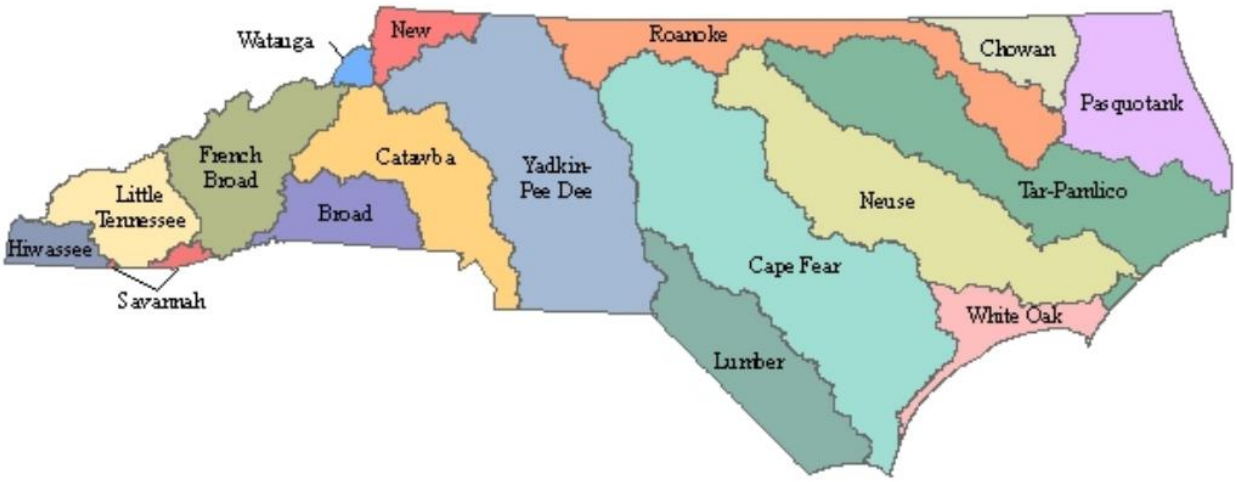
The Neuse River Basin Water Resources Plan describes current and anticipated future uses of surface water in the basin. The effects of withdrawals on the volume of water available throughout the basin are analyzed using a computer-based hydrologic model that evaluates changes to water flows across the range of river flows experienced in the basin since 1930.

Surface water availability at a particular location depends on the amount of precipitation that runs off the watershed contributing drainage to the location of interest. For example, the point of interest could be a municipal water supply reservoir. In that case, the area contributing runoff to the reservoir is referred to as the reservoir's watershed. Moving downstream, the amount of water available at specific locations represents the cumulative contributions from all the watersheds upstream. If the point of interest is the mouth of a river, where it merges with a larger river or the ocean, then the area draining to it is referred to as a river basin.

Since 1974, a multi-digit labeling convention has been used in the United States to catalog drainage areas for water resources planning and data management. Boundaries for the classifications are determined by ridge lines and land contours that define how water flows. The first two digits identify the larger geographical region where the area is located. North Carolina has river systems within three major, multi-state drainage regions: the Ohio, the Tennessee and the South Atlantic-Gulf regions. These larger regions are divided into sub-regions, which are designated by adding two more digits to the region's two-digit code. Sub-regions are subdivided into six-digit accounting units that identify larger river systems within a sub-region. Accounting units are further divided into eight-digit cataloging units. The eight-digit label is a basin's "hydrologic unit code" that identifies a river's drainage basin or a sub-unit of the basin of a larger river. For some purposes, cataloging units are further subdivided by continuing to add pairs of digits to identify smaller drainage areas. Since political boundaries frequently do not follow geographic boundaries, drainage areas commonly encompass multiple governmental jurisdictions, including state, county and local jurisdictions.

For water quality and water quantity planning, North Carolina defines 17 major river basins that are designated by combinations of eight-digit hydrologic units. Several reflect six-digit accounting unit boundaries, but most are defined by combinations of eight-digit hydrologic units that are grouped to facilitate management of North Carolina's water resources.

The N.C. Division of Water Resources is developing a separate river basin water resources plan for each of the state's 17 designated river basins. The analysis presented in each plan will primarily be summarized by the eight-digit hydrologic units contained within the basin. For some basins, an alternative geographic subdivision may be used if it provides a better context for discussions of water management issues.



The following excerpts of the principal policies regulating water withdrawals in North Carolina describe the major legal policies affecting water withdrawals. Additional information on the rules, policies and regulations affecting water resource management can be found on the N.C. Division of Water Resources' website, www.ncwater.org.

The North Carolina Constitution states: "It shall be the policy of this State to conserve and protect its land and waters for the benefit of all its citizenry, ..."[1]

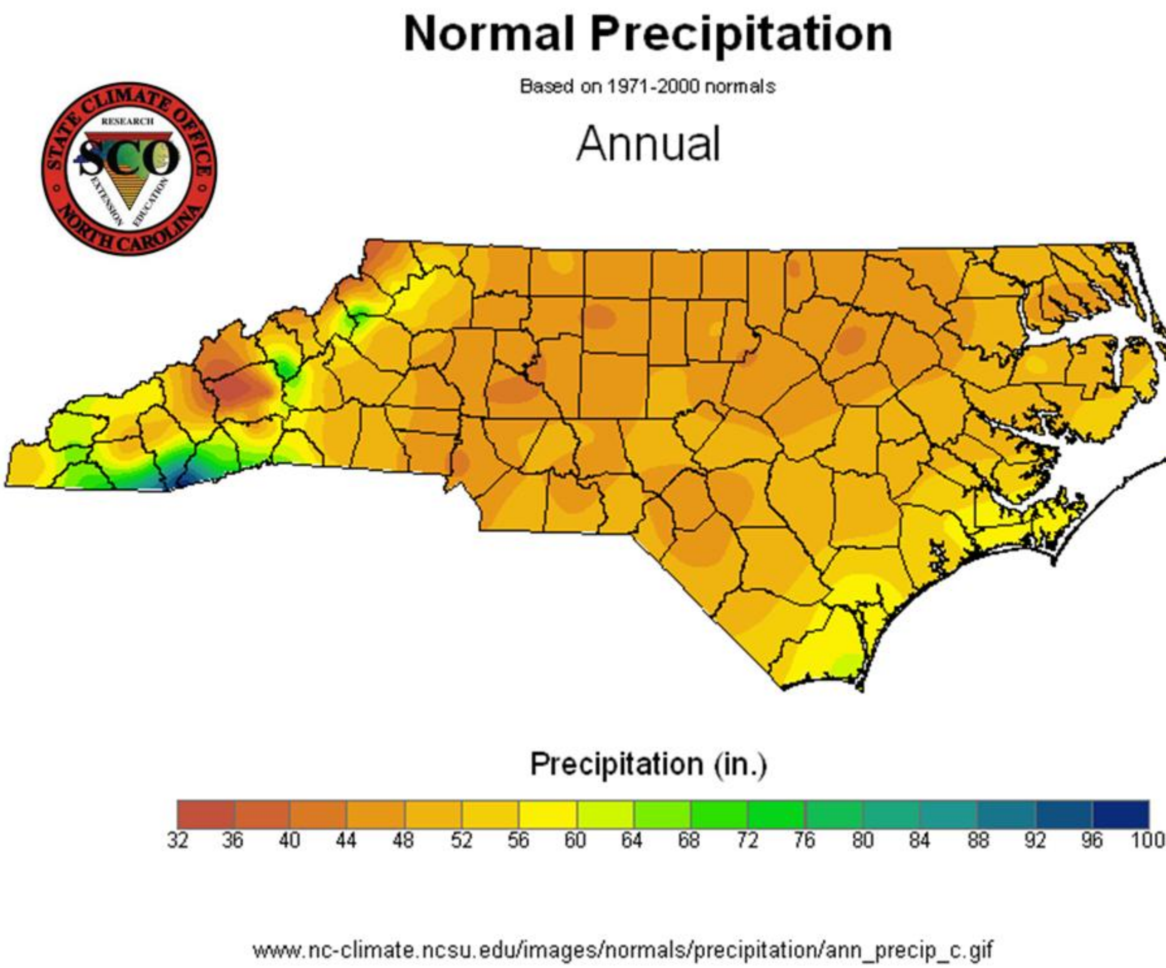
Article 21 of Chapter 143 of the General Statutes of North Carolina, includes the following policy statement: "Recognizing that the water and air resources of the state belong to the people, the General Assembly affirms the State's ultimate responsibility for the preservation and development of these resources in the best interest of all its citizens and declares the prudent utilization of these resources to be essential to the general welfare."[2]

These two statements guide North Carolina water resource management. The waters of the state are managed in trust for the people of North Carolina. The underlying paradigm governing water usage is that we share use of water resources with other current and future residents.

The amount of water available to share varies geographically because precipitation varies across the state. North Carolina generally receives enough precipitation to be thought of as having abundant water resources. On average, most of the state annually receives 45 inches-to-55 inches of precipitation, with lows of 37 inches and highs of more than 80 inches, occurring in some areas of the western mountains. Annual replenishment of the waters of the state has made it possible to develop to our current

[1] NC Constitution Article XIV, Section 5
[2] General Statute § 143-211(a)

levels of population and economic development without adopting a statewide water withdrawal permitting program.



First, let's look at the limitations on the quantity of water that can be withdrawn. With some modifications designed to address specific issues, North Carolina still operates under a riparian rights doctrine established by European colonists. Landowners have the right to the use of water that is adjacent to their property. In the case of surface waters, owning land that is adjacent to a natural body of water makes someone a riparian landowner with a right to reasonable use of the water bordering their land as long as that use does not infringe on the reasonable use of other riparian owners. In the case of ground waters, landowners have the right to use water under their property for use on the overlying parcel. Use of water on the overlying parcel is generally assumed to be reasonable. This approach does not establish a priority among the many uses of water. Conflicts that arise between users are settled by negotiation between parties, or in the cases where the parties cannot come to a satisfactory resolution, they may be settled by the courts.

The General Assembly has established some limitations to the shared beneficial use provisions of the riparian rights doctrine. Exercising its responsibility to preserve and prudently use the waters of the state, the General Assembly adopted the Water Use Act of 1967,[3] which created a protocol for limiting the right to use water. When it becomes necessary to coordinate and regulate water use in an area to protect "the interests and rights of residents or property owners of such areas or of the public interest," the act gives the state Environmental Management Commission the authority to manage water withdrawals to protect the renewal and replenishment of the affected waters. Currently, the 15 counties designated as the Central Coastal Plain Capacity Use Area[4] are the only counties where these provisions apply. In this area, ground water withdrawals are regulated by permits to reduce over-pumping from deep, confined aquifers.[5] To date, this approach has only been used to regulate water withdrawals in limited geographic areas, but there appears to be nothing that limits its application statewide if conditions are warranted.

Even with abundant rainfall, stream flows vary seasonally, and at some times and locations, will be inadequate to meet desired withdrawals. One way to increase the reliability of water supplies is to impound flowing water when it is plentiful for use when it would otherwise be in short supply. This approach provides a reliable supply when natural flows are low. Equal rights to use water in the riparian rights doctrine, is a disincentive to parties who wish to build a reservoir to reduce the risk of a supply shortage. In such a case there is no clear guarantee that impounded water would not be withdrawn by a neighboring riparian owner. In 1971, the General Assembly passed the "Right of Withdrawal of Impounded Water"[6] statute, giving a person who "lawfully impounds water for the purpose of withdrawal" a right to the excess volume of water stored in a reservoir that is superior to other interests in the water. This statute also provides for the transfer of this right to others and for the use of the water in a public water system. Under the rules established to implement the 1967 Dam Safety Law, minimum release requirements[7] may be put in place to protect aquatic habitats below dams. Some of the stored water may have to be used to meet these instream flow requirements.

In addition to the limits on the amount of water that can be withdrawn, there may also be limits on where water can be withdrawn and where it can be used. For instance, owners of lawfully constructed reservoirs can limit use of the impounded water. In addition, permission must be granted by the Federal Energy Regulatory Commission to access water in a reservoir associated with a project licensed under the Federal Power Act. Also, the Tennessee Valley Authority must grant permission for water intakes in the rivers in the mountains that are part of the Tennessee Valley Authority river system.

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[3] General Statute § 143-215.11
[4] www.ncwater.org/Permits_and_Registration/Capacity_Use/Central_Coastal_Plain/
[5] Administrative Code 15A NCAC 02E .0500
[6] General Statute § 143-215.44
[7] Administrative Code 15A NCAC 02K 0500

There may also be limitations designed to protect the public health. Public water supply intakes located downstream of a wastewater treatment plant discharge must be far enough away to allow for assimilation of pollutants before they reach the intake. Similarly, there may be limitations on moving water between river basins.

The General Assembly recognized the potential for environmental harm to river basins if water is withdrawn and used in another river basin, and then is not returned to its basin of origin. In 1993, passage of Senate Bill 875 established a limit on the amount of surface water that could be transferred to another river basin without permission from the Environmental Management Commission and created a procedure to evaluate potential impacts. The original provisions have been amended several times and now require extensive analysis of potential environmental impacts in the river basins as they are defined by the legislature. The current provisions contain an extensive public notification procedure.[8] While this process can increase the expense and time needed to expand water supply sources, it does not prohibit the transfer of water between river basins.

In addition to the regulations and policies noted above, there are two broader environmental review statutes that influence where and how much water can be withdrawn. Projects that use state-derived public funds or public lands are subject to review and modification under the North Carolina Environmental Policy Act.[9] Likewise, federal projects are subject to the National Environmental Policy Act.[10] The provisions of this law are intended “to prevent or eliminate damage to the environment” as well as to stimulate the “health and welfare” of people.

This is by no means an exhaustive review of the water laws in North Carolina. Additional information on the laws, rules and policies guiding water resources management can be found on the Division of Water Resources’ website[11].

[8] General Statute § 143-215.22L
[9] General Statute § 113A-1
[10] Public Law 91-190
[11] www.ncwater.org/Rules_Policies_and_Regulations/

Chapter 3 - Neuse River Basin Description

3.1 General Topography and Hydrology

The Neuse River basin is the third largest river basin in North Carolina and covers 6,235 square miles of drainage area entirely located in the state. The basin includes 3,389 freshwater stream miles, 17,902 acres of freshwater reservoirs and lakes, 143 saltwater miles, and 370,779 estuarine/saltwater acres. The headwaters of the Neuse River are northwest of Durham, where the Eno and Flat Rivers join at a location now inundated by Falls Lake Reservoir in northern Wake County. The river then flows in a southeasterly direction from the Piedmont and into the Coastal Plain regions through Goldsboro and Kinston. Contentnea Creek, a major tributary, flows into the river below Kinston. The river becomes tidally influenced upstream of New Bern, before it finally opens into the estuary leading into the Pamlico Sound. The Neuse River flows approximately 200 miles from its source in Orange and Person counties to its mouth at the Pamlico Sound.

The basin hosts about 1.7 million people living in 18 counties. It includes the Research Triangle, the area encompassing Raleigh, Durham and Chapel Hill and is one of the state's fastest growing regions. The counties completely or partially covered within the basin are Beaufort, Carteret, Craven, Durham, Franklin, Granville, Greene, Johnston, Jones, Lenoir, Nash, Orange, Pamlico, Person, Pitt, Wake, Wayne and Wilson.

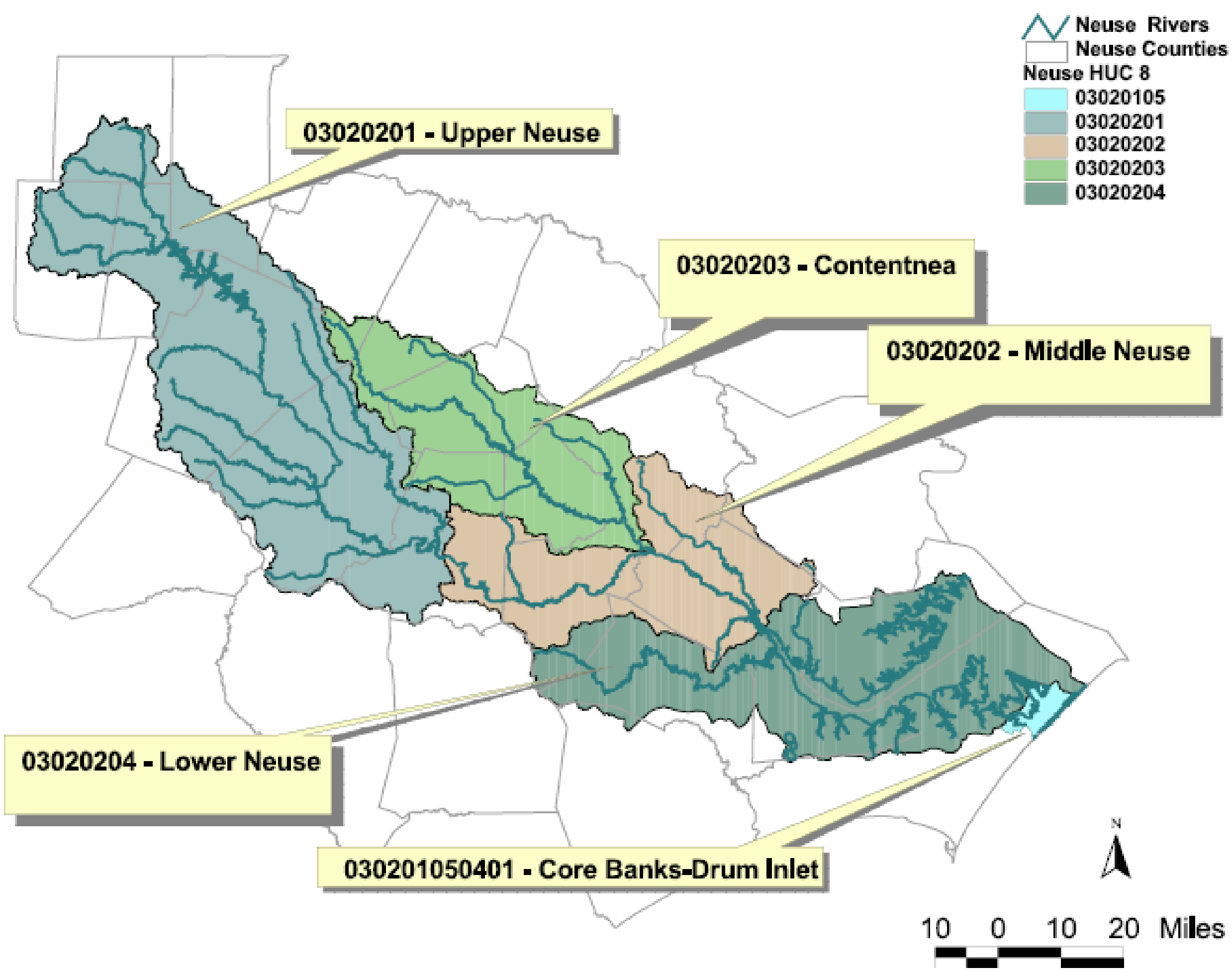
The geographic boundary of the larger Neuse River basin is defined by the six-digit hydrologic unit code, 030202, assigned by the United States Geological Survey, or U.S.G.S. This area is subdivided into four sub-units designated by adding two additional digits to create an eight-digit hydrologic unit code. This protocol of adding more digits to designate smaller sub-units is used nationwide to label geographic drainage areas.

To be consistent with the state Division of Water Quality's river basin designations used for water quality planning, the boundary of the lower Neuse basin for this exercise was extended by adding the Cape Lookout Shoals watershed. This area along the coastal boundary of the Pamlico Sound is designated by a 12-digit hydrologic unit code within a different six-digit hydrologic unit. The resulting sub-units of the Neuse River basin and the constituent watersheds used for this exercise are listed in Table 3-1. The boundaries of each are shown in Figure 3-1.

Table 3-1: Sub-units in the Neuse River Basin

Hydrologic Unit	Major Watersheds	Sub-Watershed Names
03020201	Upper Neuse	Flat River, Little River, Eno River, Upper Falls Lake, Middle Falls Lake, Lower Falls Lake, Crabtree Creek, Milburnie Lake, Swift Creek, Walnut Creek, Middle Creek, Black Creek, Mill Creek, Moccasin Creek, Upper Little River, Lower Little Creek and Falling Creek
03020202	Middle Neuse	Walnut Creek, Bear Creek, Mosley Creek, Clayroot Swamp, Hog Island and Swift Creek
03020203	Contentnea	Buckhorn Reservoir, Toisnot Swamp, Wiggins Mill Reservoir, Black Creek, Nahunta Swamp, Little Contentnea Creek and Contentnea Creek
03020204	Lower Neuse	Upper Trent River, Middle Trent River, Lower Trent River, Upper Broad Creek, Cherry Point - Neuse River, Jones Bay - Bay River, Town of Oriental, Neuse River and Pamlico Sound
030201050401	Core Banks (Drum Inlets)	Core Banks (Drum Inlets)

Figure 3-1: Map of Neuse River Basin hydrologic units



3.2 Major Flow Modifications

The Upper Neuse basin and the upper portion of the Contentnea basin are located in the rolling hills of the Piedmont where the topography provided suitable locations for the creation of reservoirs to impound surface waters. Downstream of the fall line that differentiates the Piedmont from the Coastal Plain, the characteristic flat terrain is not suitable for the development of reservoirs to satisfy water supply demands. However, the accumulated layers of sediments that form the Coastal Plain contain a series of productive aquifers. Many residents of the Coastal Plain depend on groundwater pumped from these aquifers to meet their water needs.

Several reservoirs have been created in the upper basins for water supply, flood control and recreational purposes. Table 3-2 lists the reservoirs and information such as storage capacity, normal water level, estimated yield and location. The map in Figure 3-2 shows that all but one of the existing major reservoirs are located in the Upper Neuse hydrologic unit. Outside of the Upper Neuse watershed, the only major reservoir is Buckhorn Reservoir on the Contentnea Creek.

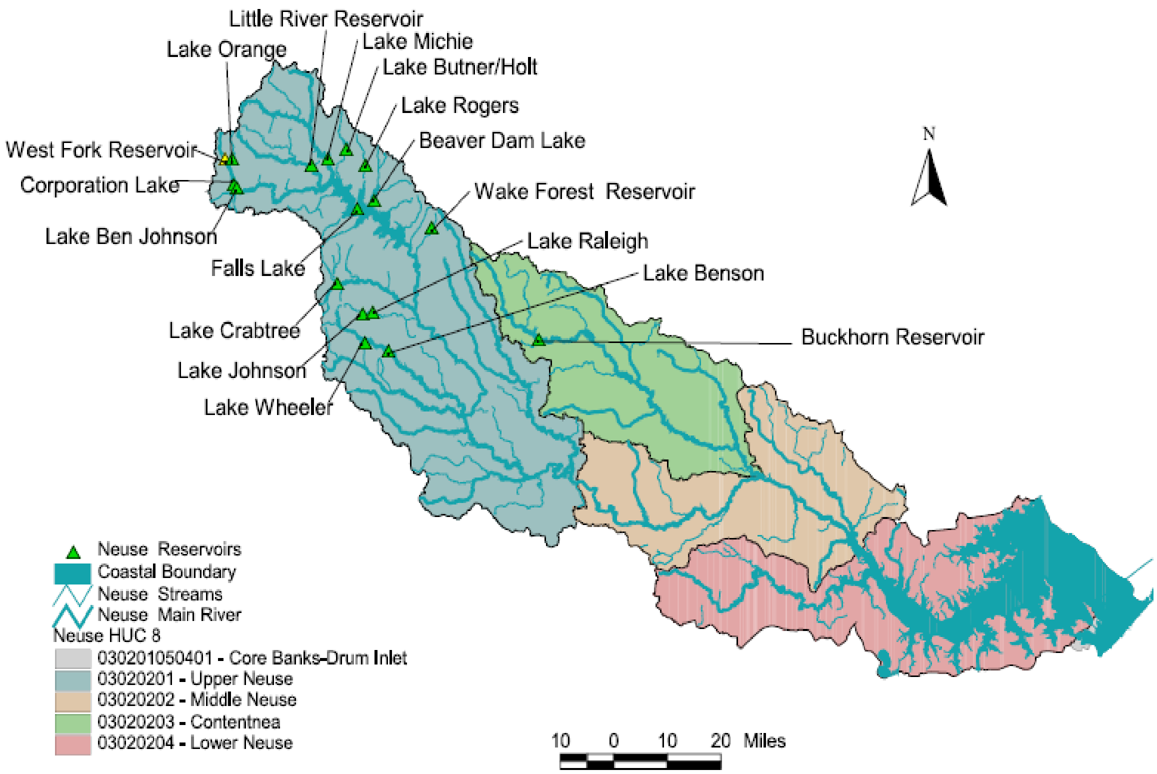
The estimated reservoir yields presented in Table 3-2 and throughout this document are period-of-record yields that are intended for basin planning purposes only. Site specific studies will need to done to support infrastructure investment decisions and regulatory decisions. A period-of-record yield is the amount of water that can reliably be withdrawn from a reservoir without depleting the stored water available, given the flow conditions represented in the data record used for the calculations. Reservoir yields were estimated using the Neuse River Basin Hydrologic Model based on 78 years of hydrologic data from 1930 to 2008, which makes up the period-of-record in the model. The model produces one set of solutions for each day in the period-of-record. To estimate reservoir yields, demand withdrawals were increased until the model indicated there would be one day when the specified demand could not be completely satisfied. The model simulations use current water management policies, including any minimum release requirements from reservoirs and downstream flow targets.

Table 3-2: Major Reservoirs in Neuse River Basin

	Neuse River Basin Reservoirs	Normal Water Level, msl-ft	Useable Storage, ac-ft	Est. Yield, mgd	Streams	Watershed	County
	West Fork Eno Reservoir	633	2,389	3.2	Eno River	Upper Neuse	Orange
	Lake Orange	615	1,255	1.6	Eno River	Upper Neuse	Orange
	Corporation Lake	538	86		Eno River	Upper Neuse	Orange
	Lake Ben Johnston	515	74		Eno River	Upper Neuse	Orange
	Little River Reservoir	355	10,953	15.0	Little River	Upper Neuse	Durham
	Lake Michie	341	8,628	15.4	Flat River	Upper Neuse	Durham
	Teer Quarry Reservoir	265	4,038		Off Stream Reservoir	Upper Neuse	Durham
	Lake Holt	356	5,900	7.5	Knap of Reeds Creek	Upper Neuse	Granville
	Lake Rogers	281	658	1.0	Ledge Creek	Upper Neuse	Granville
	Falls Lake - Beaverdam Conservation Storage Total	251.5	106,322		Neuse River & Beaver Dam Creek	Upper Neuse	Wake
	i. Water Quality		*61,322*				
	Falls Lake [57.7%]		*58,662*				
	Beaverdam Lake [57.7%]		*2,660*				
	ii. Water Supply		*45,000*	65.9			
	Falls Lake [42.3%]		*43,046*				
	Beaverdam Lake [42.3%]		*1,954*				
	Wake Forest Lake	296.8	505	0.8	Smith Creek	Upper Neuse	Wake
	Lake Johnson	343.3	2,218		Walnut Creek	Upper Neuse	Wake
	Lake Raleigh	288	1,950		Walnut Creek	Upper Neuse	Wake
	Lake Wheeler	285	4,552		Swift Creek	Upper Neuse	Wake
	Lake Benson	234	1,824	11.3	Swift Creek	Upper Neuse	Wake
	Buckhorn Reservoir	148	20,641	30.0	Contentnea Creek	Contentnea Creek	Wilson

ac-ft – acre-foot is the volume covered by one foot of water covering one acre. An acre-foot equals approximately 325,900 gallons
Est. Yield – estimated yield based on the flow conditions in the basin since 1930. Estimates are approximate based on Neuse River Basin Hydrologic Model and are intended for basin planning purposes only.
mgd – million gallons per day
msl-ft – mean sea level feet is the elevation in feet above mean sea level

Figure 3-2: Reservoirs in Neuse River Basin



Eno River Basin Reservoirs:

The Eno River originates in Orange County near Hillsborough and flows easterly through Durham County into Falls Lake. This river experiences highly variable flows, which raises concerns about the availability of water to meet water supply uses and instream flow needs. There are four reservoirs and several small ponds located on the Eno River watershed in Orange County. The communities in the watershed rely on the river for water supply. In the mid-1980's, extreme low flows prompted the Environmental Management Commission to investigate the possibility of designating the basin as a capacity use area under the authority of the Water Use Act of 1967. Water withdrawers in the basin worked with the commission to establish a management plan to protect 150 square miles of the Upper Eno River watershed upstream of the confluence with the Little River. The resulting management plan is based on a resolution by the Environmental Management Commission, EMC Resolution 88-13, under the authority of the Water Use Act of 1967, and has benefited from local support since its establishment in 1988. The plan established limits on water withdrawals and targets for reservoir releases during dry conditions. Lake Orange and West Fork Eno Reservoir are operated based on the Eno River Water Management Plan[12]. More specific information on drought management on the Eno River is presented in Chapter 5 of this plan.

[12] www.ncwater.org/Permits_and_Registration/Capacity_Use/Eno_River_Management/

Little River Reservoir and Lake Michie

The Little River Reservoir and Lake Michie, on the Flat River, are managed by the city of Durham to provide water for the city and portions of Durham County. The Lake Michie dam was completed and the reservoir began to fill in 1926. The Little River Reservoir was completed and began filling in 1987. In addition to these reservoirs, Durham uses a former quarry to store water from the Eno River to augment its supply during drought conditions. All three of these impoundments are upstream of Falls Lake.

Lake Holt

Lake Holt Reservoir is the former water supply for the town of Butner. In 2008, the town began using water supplied by the South Granville Water and Sewer Authority to meet its customers' current and future demands for potable water.

Lake Rogers

Lake Rogers is a shallow 175-acre reservoir that formerly served as the city of Creedmoor's primary water supply. In 2008, the city began using water supplied by the South Granville Water and Sewer Authority to meet its customers' current and future demands for potable water.

Falls Dam Project:

Falls Dam, constructed by the U.S. Army Corps of Engineers, or U.S.A.C.E., created the Falls Lake Reservoir, which controls a drainage area of 770 square miles. It is the largest impoundment in the Neuse River basin and holds more than 59.5 percent of the total water volume impounded in the basin. The earthen structure is located in the upper Neuse River in Wake County, about 10 miles north of Raleigh. This project was authorized by the U.S. Congress for flood control, water supply, water quality, recreation and other purposes. The reservoir extends 28 miles up the Neuse River to just above the confluence of the Eno and Flat Rivers. The dam began operation in 1981.

The Beaverdam Creek sub-impoundment and dam are part of the Falls Lake project and the two dams are managed as a single entity by the Corps of Engineers. The Beaverdam Reservoir is a pre-existing impoundment that is completely inundated at normal water levels in Falls Lake. When the water level in both reservoirs drops below 249.6 feet mean sea level, the Beaverdam Creek impoundment is separated from the rest of Falls Reservoir and must be managed separately.

At the normal water level of 251.5 feet mean sea level, the upper 15 feet of water is designated as the conservation pool. The water in the conservation pool serves two main purposes. The city of Raleigh financed the inclusion of water supply storage in the Falls Lake project and controls 42.3 percent of total storage in the conservation pool. The remaining 57.7 percent is designated for maintaining downstream water quality.[13] The space below the conservation pool is reserved to compensate for sediment

[13] EA Falls Lake NC Drought Contingency Plan (Revised 2008).pdf

accumulation. There is 13.3 feet of space above the conservation pool managed for controlled flood storage.

Lake Wheeler and Lake Benson

Both of these reservoirs are located on Swift Creek in southern Wake County. Prior to the completion of Falls Lake they were major sources of water for the city of Raleigh. Raleigh has recently added them back into its regular water supply with the completion of a new water treatment plant that treats water from Lake Benson.

Buckhorn Reservoir

Buckhorn Reservoir, on Contentnea Creek, is the primary water supply for the city of Wilson. The original configuration of the reservoir was completed in 1976 as a supplement to the downstream Wiggins Mill Reservoir and one of several smaller reservoirs that supplied water for the city. In 2002, Buckhorn Reservoir was enlarged and functions now as the primary source of water for the city and portions of Wilson County.

Among the impoundments listed in Table 3-2, 13 are managed as water supply storage reservoirs. Lake Orange, West Fork Eno Reservoir, Little River Reservoir, Falls Lake, Lake Benson and Buckhorn Reservoir are the only impoundments that have minimum release requirements intended to maintain downstream flows.

Storage for Flood Control

One of the main purposes for the construction of Falls Lake Reservoir and the Crabtree Creek impoundments was flood control. Table 3-3 compares the flood control storage capacity to the conservation storage capacity and the vertical height of the dam to impound flood water above conservation levels or normal operation levels at the dam sites. Falls Lake has, by far, the largest flood control storage volume with more than 77 percent of the total flood storage volume in the basin. In the Crabtree Creek watershed, there are a series of several small reservoirs. These smaller reservoirs were built to control and reduce downstream flooding. Collectively, the Crabtree impoundments represent about 23 percent of the total controlled flood storage volume.

Table 3-3: List of Flood Control Reservoirs in Neuse River Basin

Neuse River Basin Reservoirs	Normal Pool Elevation, MSL-ft	Vertical Distance above Normal Pool for Flood Control, ft	Storage Capacity at Normal Pool, ac-ft	Flood Control Storage, ac-ft	Percent of Basin Flood Impoundment	Streams	County
Falls Lake Controlled Flood Storage Total	251.5	13.3	131,395	221,182	77%	Neuse River & Beaver Dam Creek	Wake
Crabtree Creek Impoundments Total			6,399	67,611	23%	Crabtree Creek	Wake

3.3 Hydrology

Surface Water Availability and Reliability

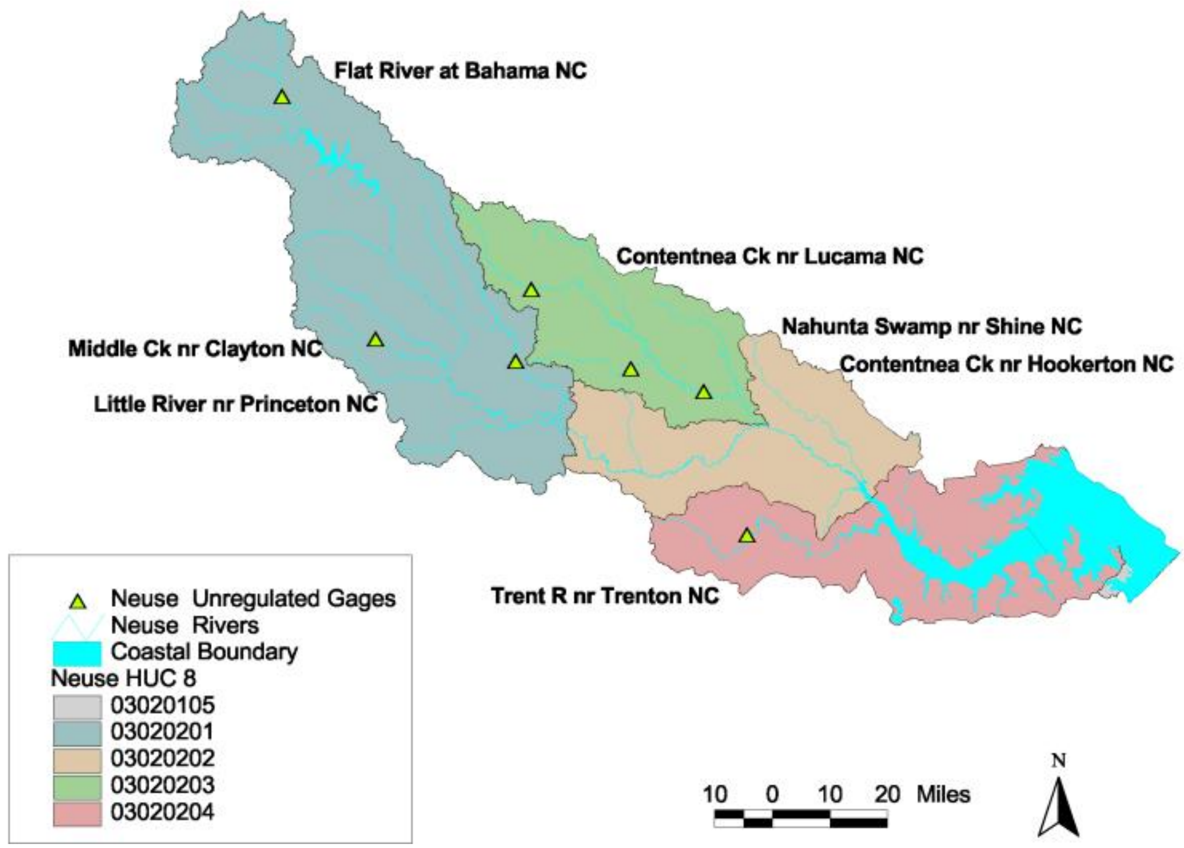
The Neuse River basin stream flows are monitored at 99 U.S. Geological Survey gaging stations. There are seven active gages with long periods of record on relatively unregulated reaches of the river, where impoundments or other man-made alterations have minimal impacts on natural flows. These stations provide valuable flow data for significant drainage areas. Basic information for these gages is listed in Table 3-4 and locations are displayed in Figure 3-3.

Table 3-4: List of Unregulated U.S.G.S. gages in Neuse River Basin

No.	USGS Stations	Station Names	Hydrologic Unit	County	Altitude, msl-ft	Drainage Area, sq-miles	Approx. Period of Records, Years
1	02085500	FLAT RIVER AT BAHAMA, NC	3020201	Durham	346.9	149	84
2	02088000	MIDDLE CREEK NEAR CLAYTON, NC	3020201	Johnston	184.5	83.5	70
3	02088500	LITTLE RIVER NEAR PRINCETON, NC	3020201	Johnston	107.8	232	79
4	02090380	CONTENTNEA CREEK NEAR LUCAMA, NC	3020203	Wilson	116.8	161	44
5	02091000	NAHUNTA SWAMP NEAR SHINE, NC	3020203	Greene	50.74	80.4	54
6	02091500	CONTENTNEA CREEK AT HOOKERTON, NC	3020203	Greene	14.85	733	80
7	02092500	TRENT RIVER NEAR TRENTON, NC	3020204	Jones	19.15	168	58

Period of Records: The number of years U.S.G.S. streamflow historic data is recorded for the stream gage.
msl-ft – mean sea level in feet
sq-miles – square miles

Figure 3-3: Map of Seven Active U.S.G.S. Unregulated Streamflow Gages in Neuse River Basin



Historic streamflow data is available on the U.S. Geological Survey's[14] website. Other sources of water resources data are available on the N.C.Division of Water Resources' website,[15] including weekly, monthly and yearly statistical analyses and plots. A U.S. Geological Survey report on low-flow characteristics of the Neuse River basin can be accessed online at: http://nc.water.usgs.gov/reports/abstracts/wri984135.html.

The monthly average flows are presented for these unregulated gages in Figure 3-4 and Figure 3-5 show plots indicating the percentage of time over the historical record that flow at a stream gage that equals or exceeds a specific value. The graphs are based on daily flow data through December 2009 and show flow in cubic feet per second.

[14] waterdata.usgs.gov/nc/nwis/sw
[15] www.ncwater.org/wrisars/textindex.php

Figure 3-4: Monthly Average Streamflow Plots for Unregulated U.S.G.S. sites in Neuse River Basin

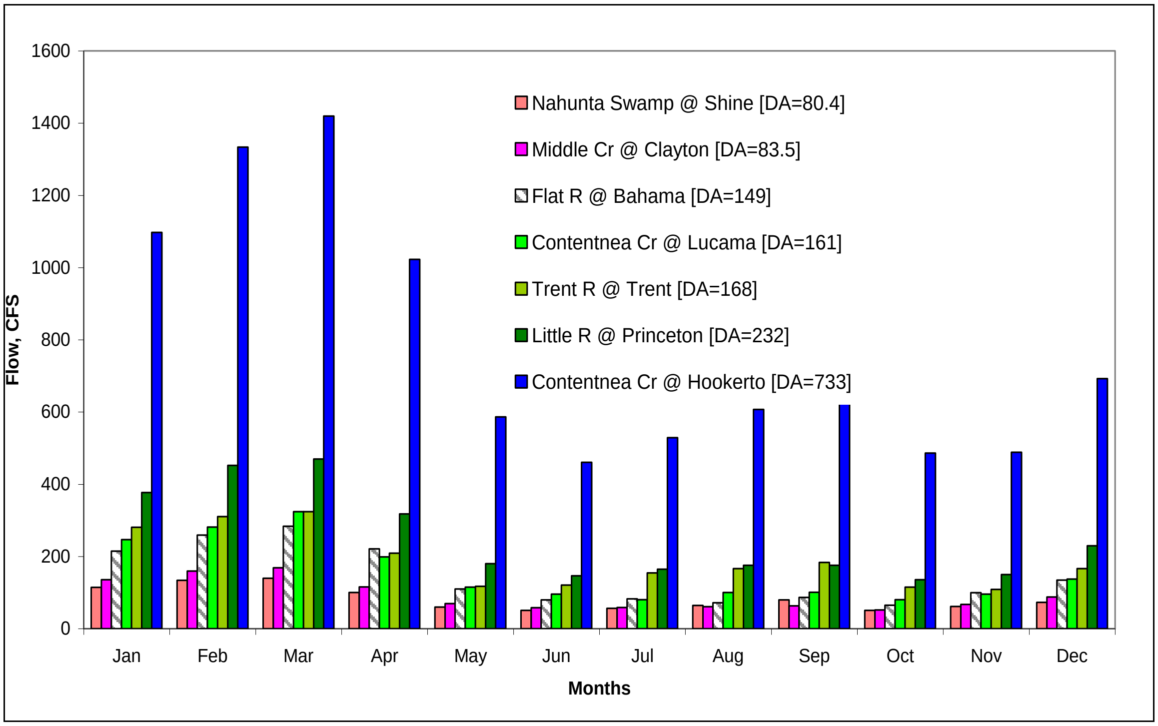
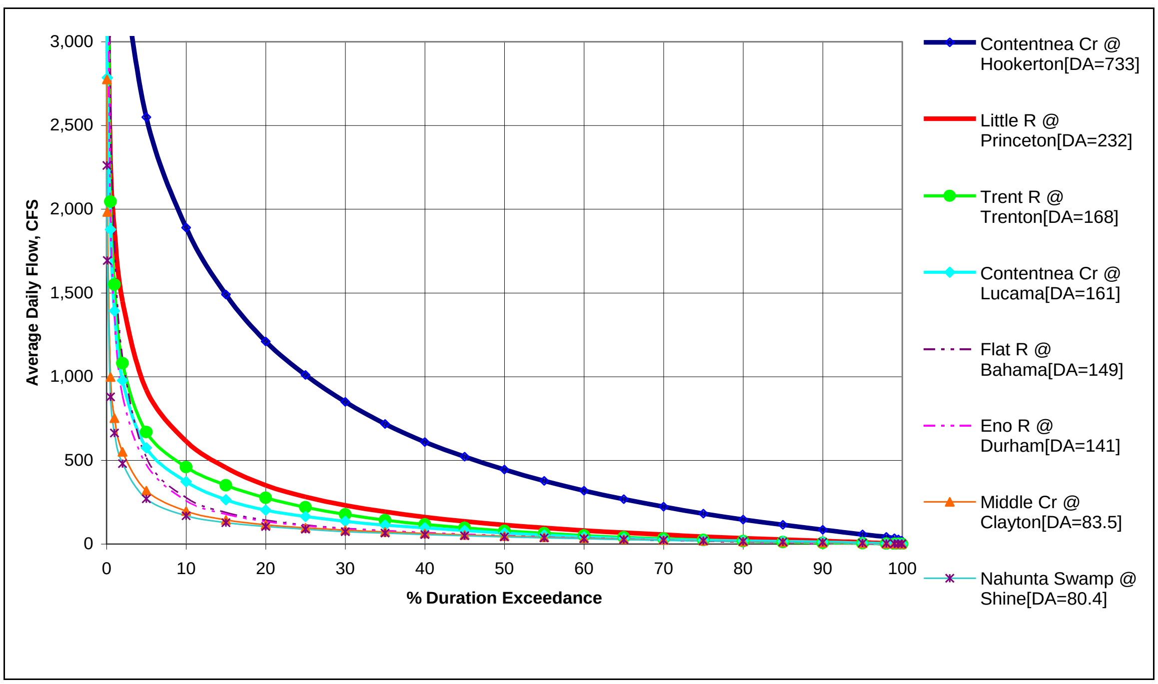


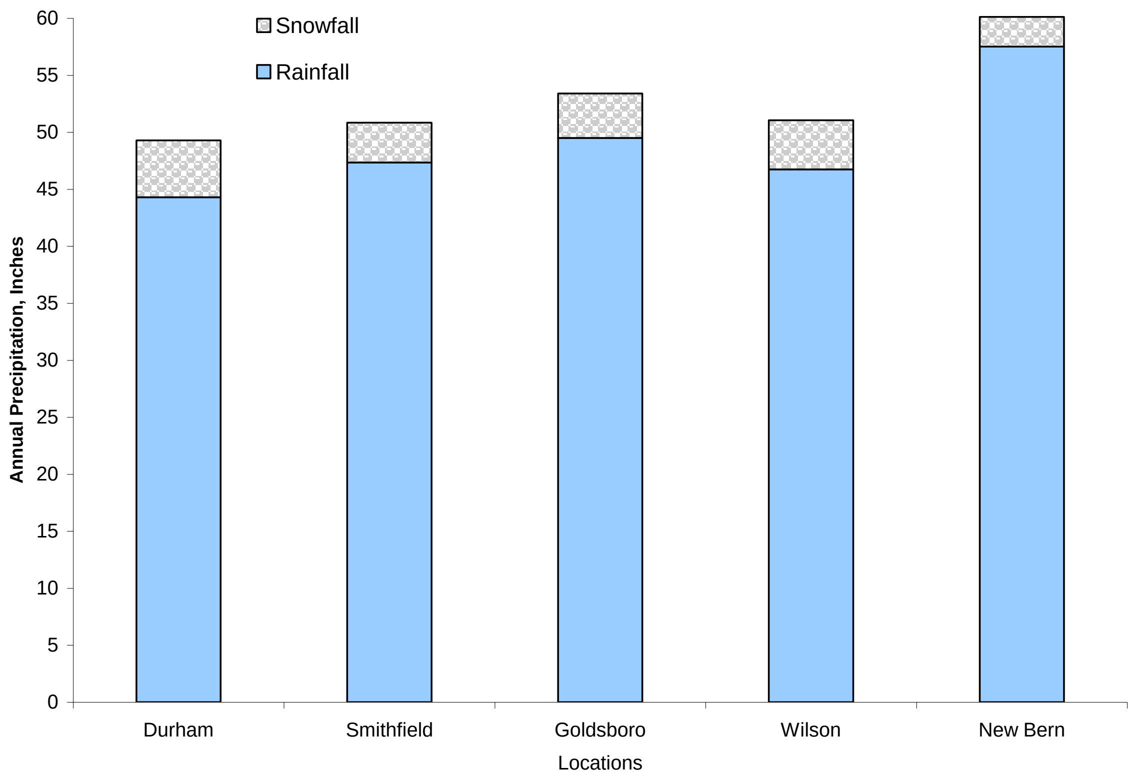
Figure 3-5: Plots of Flow Duration for Unregulated USGS sites in Neuse River Basin



Precipitation

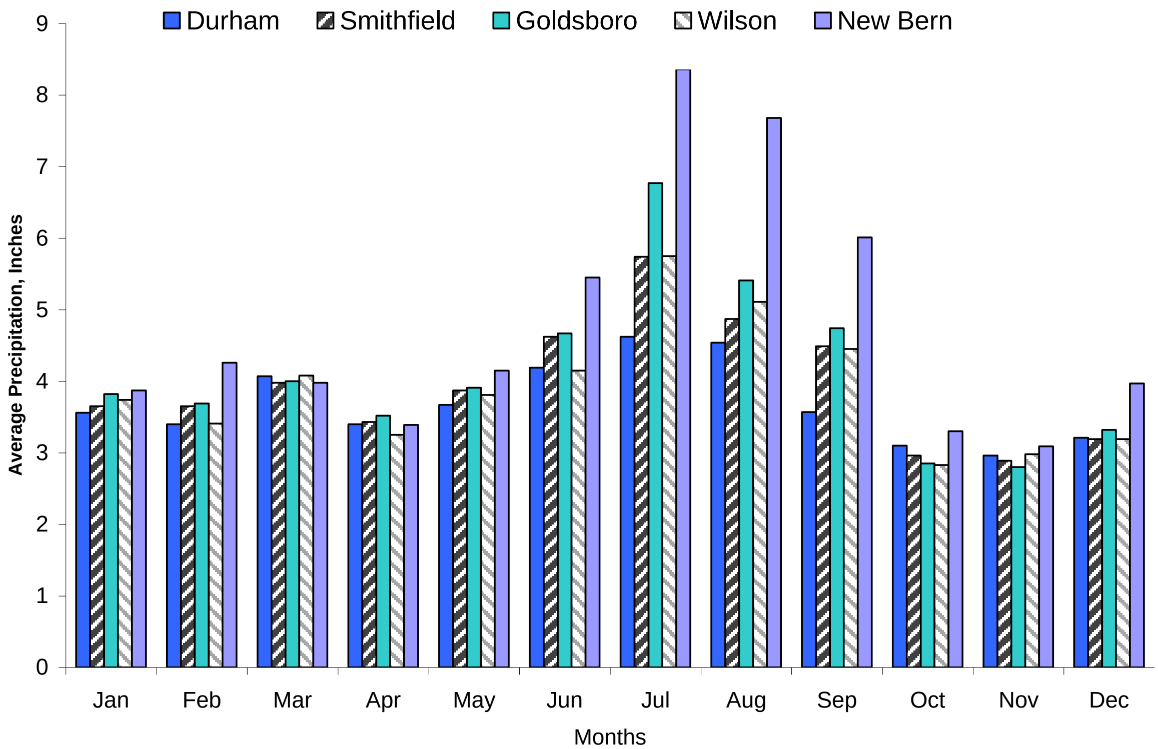
Figure 3-6 shows the annual average rainfall and snowfall in inches for five locations in the basin. New Bern, the closest station to the coast, receives the most rainfall on average at close to 60 inches per year. Durham, in the Piedmont, receives the lowest, at less than 45 inches annually. The same plot also shows the average annual snowfall at these weather monitoring stations. The annual snowfall in the Piedmont is higher than in the Coastal Plain region. July, August and September are the wettest months as shown in the monthly average total precipitation patterns in Figure 3-7. The data for these analyses were collected from the South East Regional Climate Center[16] and updated through December 2009.

Figure 3-6: Annual Average Rainfall and Snowfall in Neuse River Basin



[16] www.sercc.com/climateinfo/historical/historical_nc.html

Figure 3-7: Monthly Average Precipitation in Neuse River Basin



3.4 Neuse River Basin Counties and Municipalities

The Neuse River basin encompasses all or significant portions of 18 counties and 77 municipalities in an area of 6,235 square miles. Fifty-four percent of the basin population lives in 10 percent of the basin land area. The watersheds with the highest population densities are near Raleigh, Durham, Goldsboro, Kinston, New Bern and Wilson. Table 3-5 shows the estimated population in the Neuse River Basin, by county. If the growth trends experienced in these counties between 1970 and 2008 continue, the N.C. Division of Water Resources estimates the population in the basin may increase from the 2008 figure of 1,736,092 to over 3,105,000 people by 2060.

The most populated areas are located in and around Wake County. Counties in the upper basin and along the coast are experiencing high year-round and seasonal population growth that will increase water supply demands and wastewater discharges. The current shift from ground water use to surface water use in the coastal region may also affect water availability in the Neuse River basin.

Table 3-5: County Population Projections based on percent of area in the Neuse River Basin

County	2008**	2020**	2030**	2040**	2050**	2060**
BEAUFORT	645	682	713	745	776	807
CARTERET	357	424	470	515	560	605
CRAVEN	95,797	107,016	115,900	124,785	133,669	142,553
DURHAM	250,111	285,066	320,150	355,233	390,316	425,399
FRANKLIN	5,584	6,402	7,292	8,182	9,072	9,962
GRANVILLE	19,113	21,257	23,733	26,210	28,687	31,163
GREENE	21,205	22,534	24,406	26,278	28,150	30,022
JOHNSTON	160,434	181,237	210,832	240,427	270,022	299,617
JONES	8,618	8,799	9,005	9,211	9,417	9,623
LENOIR	57,208	58,311	58,332	58,352	58,373	58,394
NASH	9,184	10,359	11,304	12,249	13,194	14,139
ORANGE	30,284	35,802	40,307	44,813	49,318	53,824
PAMLICO	7,917	8,922	9,551	10,180	10,810	11,439
PERSON	9,179	10,201	11,029	11,857	12,685	13,512
PITT	42,436	48,388	54,436	60,484	66,532	72,579
WAKE	836,446	979,889	1,155,890	1,331,891	1,507,892	1,683,893
WAYNE	109,383	120,413	127,586	134,759	141,932	149,105
WILSON	72,190	77,602	82,842	88,082	93,322	98,562
Total	1,736,092	1,983,306	2,263,780	2,544,253	2,824,726	3,105,199

**Estimated by DWR using a linear projection of population data for 1970-2008

County and Service Area Population (Water System's Population)

Local governments that provide public water service are required to prepare local water supply plans. These plans contain vital information for planning sustainable use and the allocation of water. The data from each plan is compiled by the state Division of Water Resources and includes water system characteristics, population projections and water demands. Local water supply plans[17] are updated every five years. The 1992, 1997, 2002 and 2007 plans were based on actual water supply and demand conditions on the ground and all included estimates of service population through 2050.

The division's service population projection for 2060 is a linear projection of the population data contained in the plans, from 1992 to 2050. This methodology assumes that population growth will continue in the same pattern as reflected in the plans for that period. Many unforeseeable factors may influence population growth. For instance, if continued growth results in higher costs of living, reduced quality of life or inadequate public infrastructure including water, sewer, school and transportation capacities then the figures in Table 3-6 may overestimate future population. The smaller total population in the basin contained in the plan is explained by a percentage of the population being supplied by ground water. Local water supply plans are only concerned with the population supplied by surface water.

[17] www.ncwater.org/Water_Supply_Planning/Local_Water_Supply_Plan/

Table 3-6 below was generated from water systems information submitted to the N.C. Division of Water Resources and by projections made by the division. This table represents the service area population served by each respective surface water system.

Table 3-6: Population in Neuse River Basin served by a Local Water Supply Plan system.

Population Served by Local Water Supply Plan Systems						
Water Systems	**2008**	**2010**	**2020**	**2030**	**2040**	**2050**
Orange-Alamance	8,281	8,344	8,844	9,344	9,844	10,344
Hillsborough	12,493	13,972	16,778	20,134	24,160	28,992
Durham	232,226	227,054	257,162	288,271	314,127	329,280
South Granville WASA	10,467	13,397	17,149	21,950	28,097	35,964
Raleigh	435,000	485,202	629,255	765,125	926,473	1,060,472
Wilson	50,100	50,500	54,500	59,400	64,700	70,500
Johnston County	88,709	91,011	109,814	126,635	164,321	204,399
Smithfield	11,476	16,617	22,367	28,117	33,867	40,000
Goldsboro	31,665	33,312	35,111	36,726	38,415	40,182
Neuse Regional WASA	53,748	74,571	84,244	94,591	99,825	106,402
Served by Surface Water	934,165	1,013,980	1,235,224	1,450,293	1,703,829	1,926,535
Served by Ground Water	267,964	290,781	334,137	377,850	376,061	418,670
Total Population Served	**1,202,129**	**1,304,761**	**1,569,361**	**1,828,143**	**2,079,890**	**2,345,205**

Source: Division of Water Resources

Water Withdrawals and Waste Water Discharges

Table 3-7 summarizes the estimated surface water withdrawals and Table 3-8 summarizes the wastewater return flows for 2008, 2030 and 2050 demand scenarios modeled for this analysis. All volumes are shown in million gallons per day. In addition to the public water systems that withdraw surface water, two other large surface water users are included in the modeling.

The H. F. Lee Energy Complex, on the Neuse River near Goldsboro, is operated by Progress Energy Carolinas, Inc. The existing coal-fired generating facilities can produce 397 megawatts of electricity. Renovations during the next few years will replace the existing generating units with gas-fired units capable of producing 950 megawatts. The new facilities are expected to use about the same amount of water for cooling as the existing units.

Weyerhaeuser Company operates a pulp mill on the Neuse River near its confluence with the Trent River in New Bern. Surface water withdrawals for this facility are included in the modeling for this analysis.

Table 3-7: Withdrawals represented in millions of gallons per day

Systems	2008 Demand	2030 Demand	2050 Demand
Orange-Alamance	0.161	0.19	0.21
Hillsborough	1.136	2.029	2.76
Durham	24.385	35.826	40.923
South Granville WASA	2.576	5.966	10.006
Raleigh	45.22	86.99	129.23
Wilson	8.92	11.214	13.557
Johnston County	7.201	11.854	19.598
Smithfield	2.988	4.64	5.951
Progress Energy - Lee	7.67	7.67	7.67
Goldsboro	4.645	7.733	9.928
Neuse Regional WASA	6.08	12.58	17.292
Weyerhaeuser	15.37	17.75	17.75

Source: NCDENR, Division of Water Resources

Table 3-8: Wastewater Discharges in Millions of Gallons Per Day Estimated Based on Assumptions in the Model-Wastewater permit number listed for each facility

Systems	2008	2030	2050
Orange-Alamance WWTP NC0082759	0.024	0.028	0.031
Hillsborough NC0026433	0.854	1.522	2.070
Durham WWTP NC0023841	8.61	12.181	13.914
SGWASA WWTP NC0026824	2.145	4.952	8.305
Raleigh WWTP NC 0029033	40.874	83.782	115.946
Raleigh WWTP NC0030759	1.105	2.312	3.199
Raleigh WWTP NC0079316	0.624	1.295	1.792
Cary WWTP NC0048879 to Crabtree Creek	6.530	10.864	10.864
Cary WWTP NC0065102 to Middle Creek	4.790	7.867	7.867
Apex WWTP NC0064050	2.358	8.508	9.851
Fuquay-Varina WWTP NC0066516	0.582	1.405	2.132
Wilson WWTP NC0023906	7.452	9.322	11.275
Stantonsburg WWTP NC0057606	0.249	0.294	0.315
Snow Hill WWTP NC0020842	0.167	0.488	0.622
Farmville WWTP NC0029572	1.373	1.518	3.052
Maury SD WWTP NC0061492	0.131	0.151	0.170
Johnston Co WWTP NC0030716	1.224	2.015	3.332
Clayton WWTP NC0025453	0.936	1.541	2.548
Smithfied Wastewater to Johnston Co WWTP	2.373	3.666	4.701
Johnston Co WWTP NC0030716	3.823	6.052	8.509
Kenly WWTP NC0064891	0.343	0.389	0.488
Princeton WWTP NC0026662	0.109	0.153	0.214
Benson WWTP NC0020389	1.116	1.254	0.550
Goldsboro WWTP NC0023949	7.18	7.733	9.928
LaGrange WWTP NC0021644	0.333	0.401	0.428
NRWASA WTP WW NC0088111	0.458	0.943	1.297

Source: NCDENR, Division of Water Resources

3.5 Water Resource Services

Many of the Piedmont communities of the Neuse River basin rely on surface water withdrawn from reservoirs, a river or a stream. Surface water use comprises two-thirds of the total demand in the basin, while ground water is the major source of water for the communities in the Coastal Plain.

The Neuse River basin provides water to support crop and livestock production, which are the primary land uses in the Coastal Plain counties. Forests and wetlands are prominent in the eastern portion of the basin. Analysis of land cover data based on 1987 satellite imagery provided by the North Carolina Center for Geographic Information and Analysis, reveals that agriculture and forestry comprise more than two-thirds of the basin's total surface area, or 34.7 percent, and 33.9 percent of land area. Wetlands and open water, including the Neuse estuary and large impoundments, comprise more than 20 percent of the surface area (N.C. DENR, DWQ, 2004).

Recreational and commercial fishing are important economic activities in the estuarine waters of the basin. Important fisheries include flounder, blue crabs, shrimp and oysters. The Bogue and Core Sound areas have an abundance of vital fisheries habitats. Next to the Pamlico Sound area, the Core and Bogue Sound areas possess more fish nursery areas than any other portion of the Albemarle and Pamlico Sounds regions.

The estuarine waters include approximately 2,750 acres of primary nursery areas and 1,250 acres of secondary nursery areas, which are essential to the continued sustainability of coastal fisheries. The rivers and streams of the basin provide spawning areas for anadromous fish, such as shad and herring, which are saltwater species that migrate up river to spawn in fresh water. Resident species such as largemouth bass and catfish are important species to recreational fishermen throughout the freshwater rivers and streams of the basin.

As one of only four river basins contained in North Carolina, the Neuse River basin exhibits a rich diversity of habitats as it flows from the Piedmont to the Coastal Plain, from the fractured and weathered igneous and metamorphic rock of the Piedmont to the predominant silt, sand and clay of the Coastal Plain, from fresh to brackish water.

Many habitats in the Neuse River basin are protected by government holdings in parks and refuges. State parks encompass 48,000 acres, or 1.4 percent of the basin. The North Carolina Wildlife Resources Commission holds approximately 110,000 acres, or 3.2 percent of the basin, in gamelands. There are no National Wildlife Refuges in the basin, but almost 58,000 acres or 1.7 percent of the basin is in the Croatan National Forest (N.C. DENR, Water Quality 1993).

The riverine aquatic habitat in the Neuse River basin is a product of water chemistry, temperature, flow and channel characteristics. Changes in aquatic habitat quality, availability and longitudinal distribution may be positively and negatively influenced by changes in river flows as well as changes in adjacent land-use, alterations to water quality, and changes in weather and climate patterns. When diverse aquatic communities are successfully supported by the riverine environment, this indicates that habitat requirements essential for growth and reproduction are being met, and that conditions allow organisms to exhibit resilience in the face of habitat disturbance.

There are current and historic records of endangered species in the Neuse River basin. However, there is no critical habitat areas presently designated for endangered aquatic species in the basin.

In addition to the primary water quality classifications assigned to all surface waters of North Carolina by the state Division of Water Quality, there are supplemental classifications that may be added to provide additional protection for special uses or values. These include High Quality Waters, or HQW, Outstanding Resource Waters, or ORW, Nutrient Sensitive Waters, or NSW, Swamp Waters, or Sw, and Unique Wetlands, or UWL. The NSW supplemental classification is for nutrient management due to susceptibility to excessive plant growth. All waters of the Neuse River basin have a NSW classification. The Sw classification is based on characteristics, such as very low velocities, that distinguish these waters from other streams that drain steeper topography. Waters with the UWL classification have been documented as habitat essential for the conservation of state or federally listed threatened or endangered species. There are no waters in the Neuse River basin presently with the UWL supplemental classification. The HQW and ORW supplemental classifications require an excellent rating based on the Division of Water Quality's water chemistry testing, and fish and aquatic macroinvertebrate sampling. An additional requirement for the ORW classification is a determination by a state wildlife resource agency, such as the Wildlife Resources Commission and the Marine Fisheries Commission that these reaches have outstanding fish habitat and fisheries, or have special ecological or scientific significance. Commercial shellfishing areas, or SA, and pristine public water supply watersheds-WS-I and WS-II, both primary surface water classifications, are also HQW by definition. Primary nursery areas, or PNA, are designated by the Marine Fisheries Commission, not the Division of Water Quality, but are also designated as HQW. Waters with any of these classifications have more stringent stormwater requirements to protect and preserve the water quality necessary for the supplemental classification.

The main factors affecting water quality are related to human activity and include point source discharges from municipal and industrial wastewater treatment plants, small package treatment plants and large urban and industrial storm water systems. Non-point sources are also an important factor and include construction activities, runoff from roads, parking lots and rooftops, failing septic systems, agriculture and timber harvesting activities that do not follow best management practices. For a more comprehensive overview of these issues, visit the Division of Water Quality Neuse River Basin Plan homepage, Chapters 15 and 16.[18]

[18] h2o.enr.state.nc.us/basinwide/Neuse/2008/NeuseRiverBasinPlanDRAFT.htm

Public Lands and Natural Areas

The Neuse River basin contains ecologically significant public lands. The N.C. Division of Parks and Recreation manages areas that include Eno River State Park, William B. Umstead State Park, Cliffs of the Neuse State Park, Mitchell Mill State Natural Area, and Occoneechee Mountain State Natural Area. The N.C. Wildlife Resources Commission manages Butner-Falls of the Neuse Game Land, Caswell Farm Game Land, Cherry Farm Game Land, Goose Creek Game Land, and Neuse River Game Land. State educational institution-owned land includes North Carolina State University's 1,700-acre Hill Demonstration Forest, and Johnston Community College's 2,900-acre Howell Woods Environmental Learning Center. The Camp Butner Training Site, owned by the North Carolina National Guard, is a 4,000-acre training facility composed primarily of pine plantations and some quality natural areas, including Knap of Reeds Creek.

Federally-owned land in the Neuse basin includes both military and natural resource reservations, such as the Cape Lookout National Seashore, which includes Core Banks and Portsmouth Island. The U.S. Fish and Wildlife Service manages Cedar Island National Wildlife Refuge, while the U.S. Department of Defense owns Cherry Point, a Marine Corps Air Station with a number of large significant natural areas. A portion of the Croatan National Forest lies in the Neuse River basin, including most of the 9,000-acre Sheep Ridge Wilderness, and a large part of the 8,000-acre Catfish Lake Wilderness. For a better description of those locations, please visit North Carolina Division of Parks and Recreation[19], the Division of Water Quality Neuse River Basin Plan homepage, Chapter 20[20] and U.S. Fish and Wildlife Service.[21]

[19] www.ncparks.gov/Visit/main.php
[20] h2o.enr.state.nc.us/basinwide/Neuse/2008/NeuseRiverBasinPlanDRAFT.htm
[21] www.fws.gov/refuges/profiles/index.cfm?id=42531

Chapter 4 - Conditions and Management Needs

The Neuse River Basin Water Resources Plan presents the results of an investigation of current and future water quantity related issues focusing primarily on the ability to satisfy expected surface water withdrawals. Information on current and anticipated surface water withdrawals was obtained from existing data submitted to the Division of Water Resources under the Local Water Supply Planning and Water Withdrawal Registration programs. This data was supplemented as needed by additional data collection efforts.

The resulting collection of data on surface water withdrawals was integrated into the Neuse River Basin Hydrologic Model to identify areas in the basin where there may be difficulty satisfying the desired levels of surface water withdrawals. The model is a computer-based mathematical model of water flow in the basin from the headwaters above Falls Lake downstream to New Bern. It is a water quantity model that evaluates changes in water quantity at designated locations in the basin. The points in the model where data enters or where mathematical evaluations of conditions are performed are referred to as model nodes. A model node may represent a withdrawal for an offstream use such as a local municipality, an inflow from a water reclamation facility, a reservoir where water is stored for later release, or water flowing in from a tributary stream, and so on. The result of an evaluation of conditions at one node becomes an input to the equation describing conditions at the next downstream node.

The model is based on 78 years of data describing the hydrologic conditions in the basin. A model run evaluates the mathematical equation describing conditions at each node and produces a set of solutions for each day in the 78 years of the historical record from 1930 to 2008. The range of conditions included in this record encompasses dry, normal and wet conditions, including the recent extreme droughts. Each model run evaluates a particular scenario designed to characterize a specific set of conditions.

This section discusses the results of four water demand scenarios: current conditions based on 2008 water withdrawals and future conditions based on expected withdrawals to meet anticipated demands in 2030 and 2050, and 10 percent of inflows reduction based on the 2050 scenario. The future demand scenarios were designed to determine conditions at two levels of withdrawals anticipated to occur, but which may or may not occur in the specified years. These are all hypothetical scenarios. More detailed information on the model and the assumptions used in each scenario can be found in Chapter 5 of this document. The withdrawals modeled for each of the 13 water supply nodes are summarized in Table 5-1.

Demand nodes may include withdrawals for more than one purpose. The model includes a priority weighting for each withdrawal so that individual demands are satisfied in a manner that reflects, as closely as possible, current protocols. For instance, if a reservoir has a required minimum release or a downstream flow target, the withdrawal to account for this requirement will be satisfied before the withdrawals for municipal water systems. Since basin-wide instream flow needs have not been defined, the current version of the model does not have requirements to meet specific flow criteria, except where minimum releases are required as existing permit conditions. The model will satisfy withdrawal demands at a particular node if there is water available. For withdrawals from reservoirs, demands will be satisfied if there is water available in storage. Otherwise, the desired withdrawal will be only partially met. Similarly, for a withdrawal node on a river segment, demands will be satisfied if there is enough water flow into it from the upstream node. The division anticipates having criteria for instream flows defined for future modeling exercises.

The output from the hydrologic model used for this analysis is dependent upon the data and assumptions included in the current version of the model. Changes in expected demands or changes in the assumptions implicit in the model may produce different output values. The current version of the model does not assume reductions in water withdrawals during drought conditions except for the water users that are parties to the Eno River Water Management Plan. If water withdrawers implement effective demand reduction programs during droughts, the impacts of supply deficits may be reduced. Chapter 5 provides a detailed discussion of the model and the critical assumptions on which it depends.

The model does not include Durham’s Teer Quarry, which is to be used under drought conditions, or Raleigh’s proposed Little River Reservoir, which is still being evaluated. These proposed facilities may help to resolve some of the projected water supply deficits identified in the future demand scenarios.

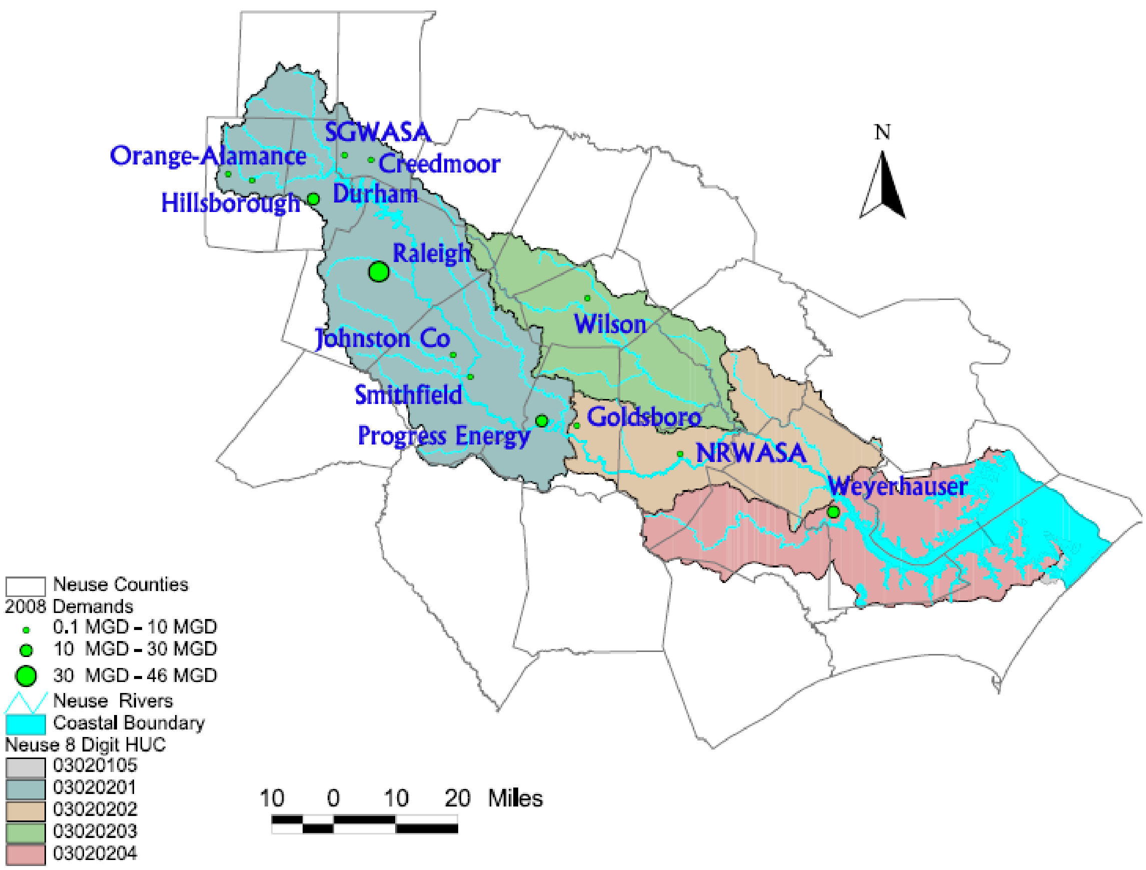
Water demand deliveries were compared to the requested water demands for each of the three demand scenarios. For the 2008 demand scenario, the model predicts that all the desired withdrawals can be met for all days of the 78 years of flow conditions included in the model, as indicated in Table 4-1. In other words, the model predicts that the range of flow conditions experienced in the Neuse River basin since 1930 would be adequate to consistently satisfy the level of withdrawals specified in the 2008 demand scenario. The relative locations of the major demand nodes are shown in Figure 4-1.

Table 4-1: Water Supply Demand & Deficits Predicted for the 2008 Demand Scenario

Systems	Average Daily Demand (mgd)	Deficit (mgd)
Orange Alamance Water System	0.16	0
Hillsborough	1.14	0
Durham	24.37	0
South Granville WASA	2.58	0
Creedmoor	0.30	0
Raleigh	45.22	0
Wilson	8.91	0
Johnston County	7.19	0
Smithfield	2.99	0
Progress Energy – Lee	7.67	0
Goldsboro	4.64	0
Weyerhaeuser	15.38	0
Neuse Regional WASA	6.08	0

WASA – water and sewer authority
mgd – million gallons per day

Figure 4-1: 2008 Major Demand (MGD) Locations



4.1 Near-Term Projected Conditions and Management Needs

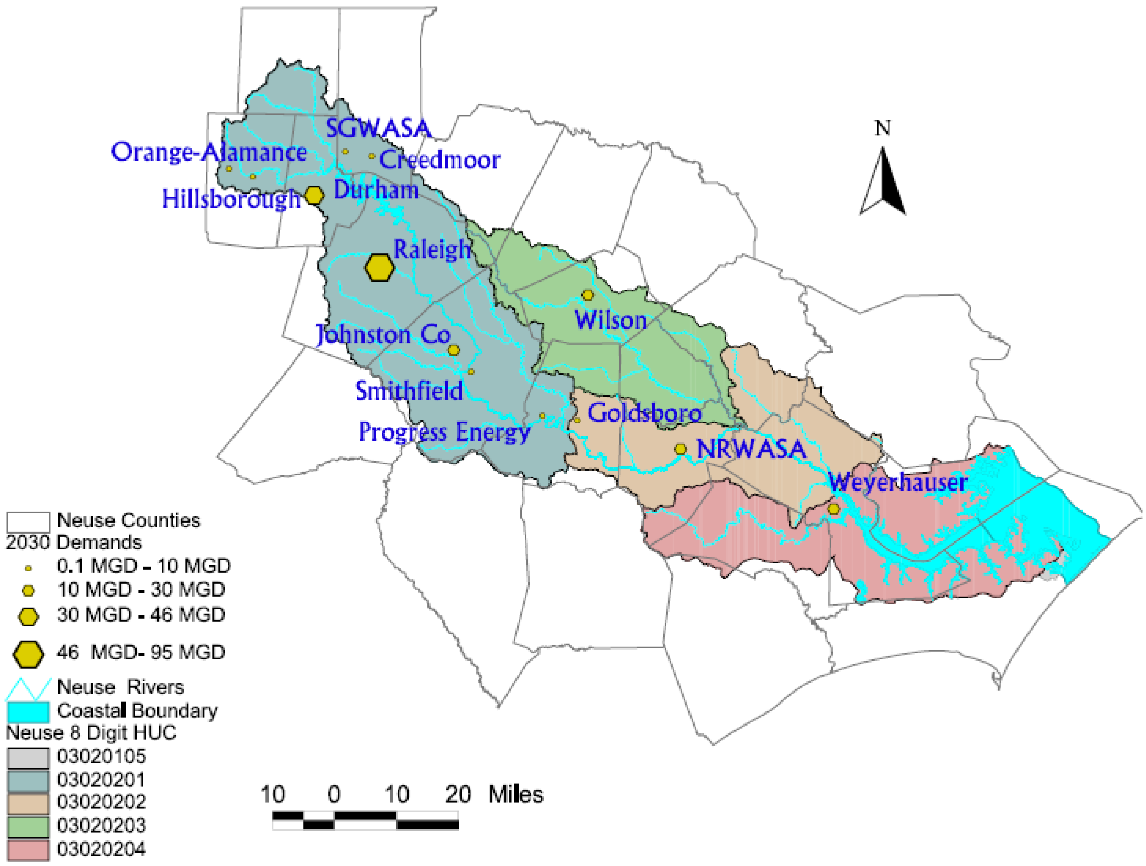
Table 4-2 summarizes the instances in which the model predicts that the full water supply demands may not be satisfied in the 2030 demand scenario. Average deficit is defined here as the average of deficits in days with deficits. The model indicates that in a repeat of the hydrologic conditions experienced in 2007, the cities of Raleigh and Durham may not be able to withdraw the amounts of water specified in this scenario. Table 4-2 shows the demands specified for the model nodes representing these utilities. These annual average use values are adjusted for each month of the year to more realistically represent the seasonal pattern of water usage in each system. For Raleigh, the highest monthly demand in this scenario is 104 million gallons per day. The highest level of demand for Durham is 43 million gallons per day. In the future, when the water demands reach the levels specified in this scenario, and if there is a repeat of the hydrologic conditions seen in 2007, then Raleigh could experience 10 consecutive days when their total demands cannot be met. Under these conditions, Durham could face up to 37 consecutive days with a supply deficit. These two utilities are currently in the process of evaluating options to increase their available supply of water. If supplies are increased before demands grow to the levels specified in this scenario then they may be able to minimize the impacts of predicted shortages with effective water shortage response planning.

Table 4-2: Water Supply Demand & Deficits Predicted by the Neuse River Basin Hydrologic Model, 2030 Scenario

Model Scenario / Water Systems	2030 Average Daily Demand (MGD)	2030 Average Deficit (MGD)	Longest Deficit (Days)	Years Demand Not Fully Met Out of 78
Durham	35.83	30.31	37	1
Raleigh	86.99	44.55	10	1

Longest Deficit (Days) = The greatest number of consecutive days over the entire 78 year record that the full water supply demand may not be met.
Years Demand Not Met = The number of years out of a total of 78 annual flow patterns that the full water supply demand may not be met.

Figure 4-2: 2030 Major Demand Million Gallons Per Day (MGD) Locations



4.2 Long-Term Projected Conditions and Management Needs

In the future, as the population grows and water demands increase, the chances of experiencing water shortages are likely to increase as well. The primary goal of this exercise is to identify when and where water supply shortages may occur. The 2050 demand scenario was chosen to evaluate levels of demand that may develop far enough in the future to allow time to plan for sustainable solutions. Shortages will occur when there is not enough water available to satisfy the desired demands. New water sources, combined with programs to control demand growth, may be needed to control the occurrences of water shortages.

Water withdrawals, modeled in the 2050 demand scenario, are based on demand predictions derived from information contained in local water supply plans and water withdrawal registrations. The Neuse River Basin Hydrologic Model attempts to satisfy the specified level of withdrawal at each model node given the amount of water available over the range of hydrologic conditions seen in the basin between 1930 and 2008.

Table 4-3 summarizes the instances in which the model predicts that the full water supply demand may not be met in the 2050 scenario. Compared with the 2030 scenario, this scenario shows four additional water withdrawers that may experience supply deficits. These are the Orange-Alamance Water System, the town of Hillsborough, Piedmont Minerals and the South Granville Water and Sewer Authority, or South Granville Water & Sewer Authority. The relative locations of the withdrawals for these entities are shown on the map in Figure 4-3.

For the 2050 scenario, Raleigh's annual average demand is 129 million gallons per day, or mgd, which results in a maximum daily demand of about 155 mgd, when the average demand is adjusted for seasonal variations in use. At this level of demand, and existing sources of water, the model predicts that Raleigh may to be able to meet its specified demands in 36 of the 78 annual flow patterns in the model. The model predicts that the longest continuous deficit period could be up to 124 days, with an average deficit of about 86 mgd for those days.

Under the 2050 demand scenario, the Orange-Alamance Water System, Hillsborough and Piedmont Minerals, may have supply deficits if the hydrologic conditions experienced in 2002 and 2008 occur again. The model predicts that they may experience up to 30 consecutive days when they may not be able to withdraw enough water to satisfy their demands. This situation is similar to the conditions predicted by the model for the 2030 demand scenario. These water users are all parties to the Eno River Water Management Plan, which mandates withdrawal reductions during droughts. The drought protocol specified in the management plan is incorporated in the hydrologic model. Therefore, when flow conditions in this portion of the basin trigger the drought protocol, the model automatically reduces the specified withdrawals. These users have adopted water shortage response plans that help their employees and customers reduce their need for water.

In the 2050 demand scenario, the model also predicts that the South Granville Water and Sewer Authority, or SGWASA, will likely experience periods when its modeled demands cannot be fully satisfied from its existing sources. The model shows this system could experience supply shortages with the reoccurrence of 14 of the 78 annual flow patterns in the model. With an average daily withdrawal of 10 mgd, and seasonal withdrawals reaching more than 11 mgd, SGWASA could experience average deficits of more than eight mgd and as much as 79 continuous days of supply shortages.

The model predicts an increase in the occurrence of deficits for the city of Durham also under the 2050 demand scenario. With an average daily demand of 41 mgd and a seasonal demand reaching 49 mgd, Durham could expect to experience water shortages in five of the 78 annual flow patterns in the model. With a reoccurrence of these flow conditions, the model predicts that the average deficit would be 29 mgd, and the longest continuous period of supply deficits to be 60 days. Table 4-3 presents the number of years with water supply deficits, average demand, average deficits, and number of consecutive days with deficits for each of the systems with a deficit under the 2050 scenario.

Table 4-3: Water Supply Demand & Deficits Predicted by the Neuse River Basin Hydrologic Model, 2050 Scenario

Model Scenario / Water Systems	2050 Average Demand (mgd)	2050 Average Deficit (mgd)	Longest Deficit Period (Days)	Years Demand Not Fully Met Out of 78
Orange-Alamance	0.21	0.14	30	2
Hillsborough	2.76	1.84	30	2
Piedmont Minerals	0.25	0.16	30	2
Raleigh	129.23	86.18	124	36
Durham	40.92	29.13	60	5
SGWASA	10.01	8.7	79	14

Longest Deficit (Days) = The greatest number of consecutive days over the entire 78 year record that the full water supply demand may not be met.
Years Demand Not Met = The number of years out of a total of 78 annual flow patterns that the full water supply demand may not be met.
Systems in Red are those for which a deficit is predicted in any scenario seven or more years out of the 78 year record.

Figure 4-3: 2050 Major Demand (mgd) Locations

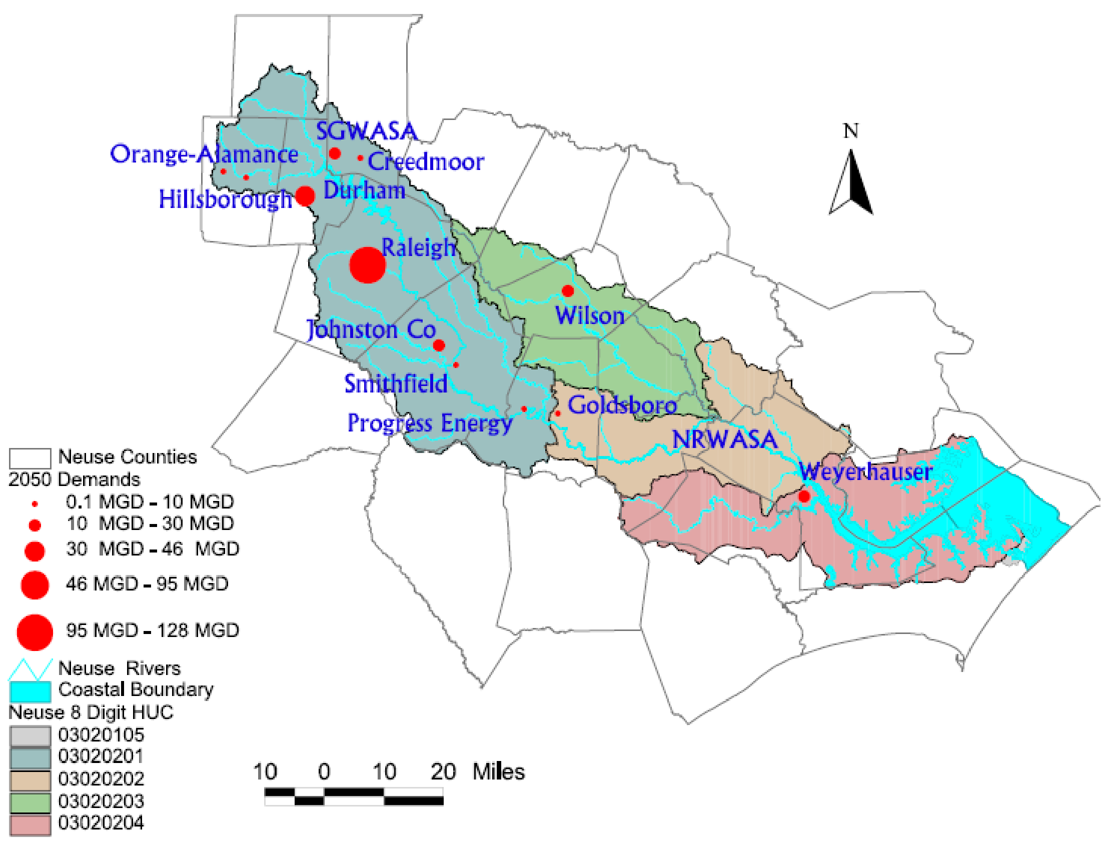
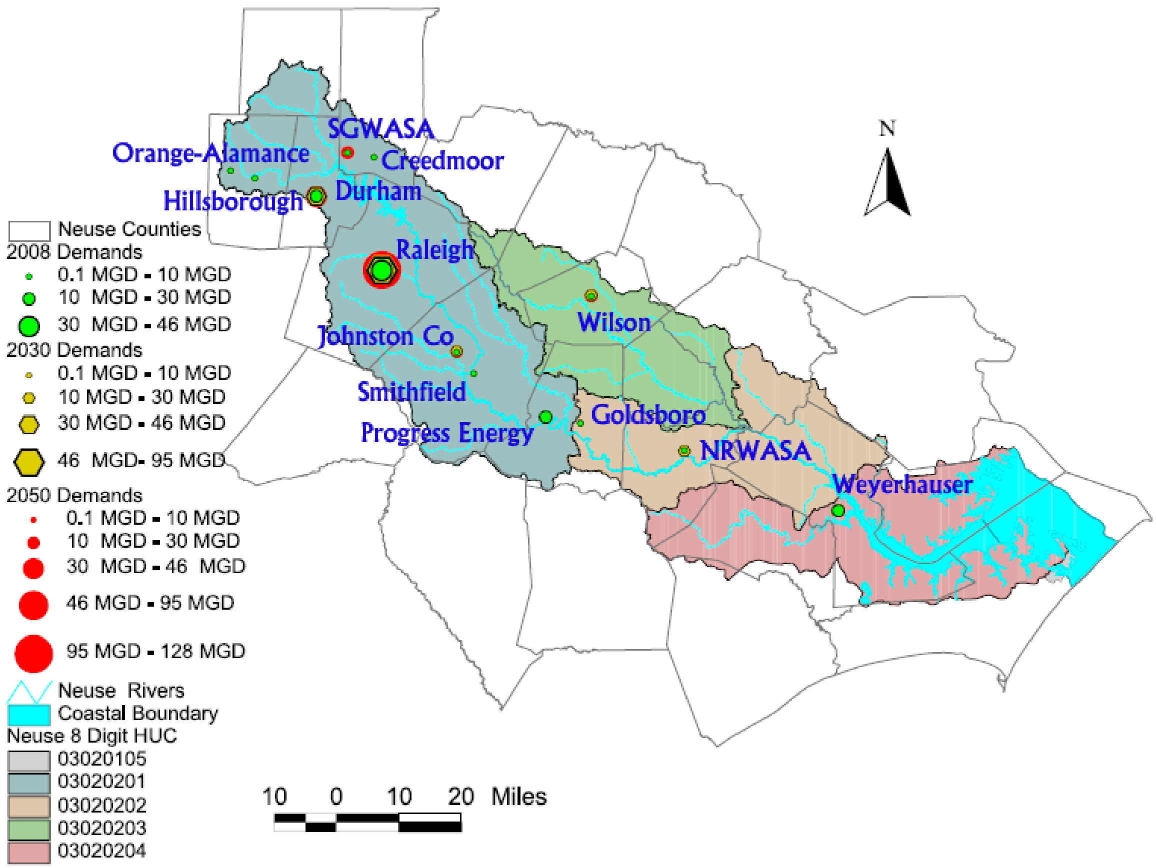


Figure 4-4: Water Demand (MGD) Growth Comparison for Three Plan Scenarios



4.3 Results of the 10 Percent Inflows Reduction, based on the 2050 Scenario

There has been a lot of discussion focused on how historical climate conditions may be changing. At this time, historical data is still the best data available to predict future conditions in the Neuse River basin. The 78 years of flow data used in the model included several significant droughts of varying durations. For this exercise, an additional model scenario was developed to evaluate the potential impacts to water withdrawers if the basin experienced drier conditions than any represented in the historical data record.

This scenario evaluated the 2050 demand levels using a hypothetical set of flows created by reducing all flows in the historical record by 10 percent. All the systems that had deficits under the 2050 scenario were even more negatively impacted, with a 10 percent reduction in historical inflows on all rivers and streams in the Neuse River basin. Under this scenario, the model predicts that Orange-Alamance, Hillsborough and Piedmont Minerals would still face deficits during repeats of the 2002 or 2008 flow conditions. Deficits would increase for the South Granville Water and Sewer Authority, Raleigh and Durham water systems, resulting in a higher number of days and annual flow patterns with shortages, as shown on Table 4-4 below. The increase in the average deficit could be substantial for the Raleigh system where the average deficit increased from 86 million gallons per day in the 2050 scenario, to 90 million gallons per day in the 10 Percent inflows reduction scenario. Under this scenario, Raleigh could expect to experience shortages during 38 annual flow patterns, two more than using the historical record. Also, the longest period of deficit could increase to 130 days, from 124 days, using the historical record.

Table 4-4: Water Supply Demand & Deficits Predicted by the Neuse River Basin Hydrologic Model, 90 Percent Inflows based on the 2050 Scenario

Model Scenario / Water Systems	2050 Average Demand (mgd)	2050 Average Deficit (mgd)	Longest Deficit (Days)	Years Demand Not Fully Met Out of 78
Orange-Alamance	0.21	0.21	36	2
Hillsborough	2.76	1.95	35	2
Piedmont Minerals	0.25	0.24	36	2
Raleigh	129.23	90.46	130	38
Durham	40.90	30.71	61	6
SGWASA	10.01	8.7	103	16

Longest Deficit (Days) = The greatest number of consecutive days over the entire 78 year record that the full water supply demand may not be met.
Years Demand Not Met = The number of years out of a total of 78 annual flow patterns that the full water supply demand may not be met.
Systems in Red are those for which a deficit is predicted in any scenario seven or more years out of the 78 year record.

Chapter 5 - River Basin Hydrologic Model

5.1 Neuse River Basin Model Details

The model used for this analysis, the Neuse River Basin Hydrologic Model, uses Operational Analysis and Simulation of Integrated Systems, or OASIS, with Operations Control Language, or OCL,™ developed by Hydrologics, Inc. OASIS is a generalized simulation program designed to characterize water resource systems. OCL is a proprietary program that facilitates the customization of OASIS for specific applications. The Neuse River Basin Hydrologic Model is a computer- based mathematical model that simulates surface water flows in the Neuse River. It has the capability to take into account a great deal of hydrologic information and water use data. It can be used to evaluate the impacts to water quantity of projected future demands and operational scenarios. The model produces a hypothetical picture of surface water conditions in the basin based on the data and assumptions used to create a modeling scenario.

The Neuse River Basin Hydrologic Model was developed in consultation with the major water withdrawers in the basin and representatives of state and federal resource management agencies. It is intended as a planning tool that will convey trends and as a day-to-day management tool. More information on the model and its development is available at the following link on the state Division of Water Resources' website.[22] The current methodology for developing model data requires a large amount of input data, including understanding the flow impairments from reservoir operations, water supply withdrawals, wastewater returns, agricultural withdrawals and the adjustments necessary for inflows to ensure that the model preserves the known volume of flow at downstream gages. Identifying and adjusting for human induced alterations to natural flows and statistically filling-in missing streamflow data, are the most time-intensive parts of model development when starting with a computer program specifically designed to characterize water resources.

The model balances water coming into with water going out of the river system, subject to the assumptions, goals and constraints built into the model. Each point in the system where inflows and outflows are evaluated is called a model node. At each node, water is allocated to demands based on a modeler-defined set of priorities that reflect operating guidelines and protocols. At the reservoir nodes, water is stored and released subject to user-defined operating rules constructed to simulate real operations. The model operates on a daily time step making one set of calculations for each day using daily average values for each calculation.

In this exercise, the 2008 conditions are used as the base case against which the scenarios of future demands and return flows are compared. Using the model to compare future demand conditions with the base case conditions, provides information

[22] www.ncwater.org/Data_and_Modeling/Neuse_River_Basin_Model/

to identify the possible impacts on reservoir water levels and stream flows at points of interest around the basin due to increasing water withdrawals.

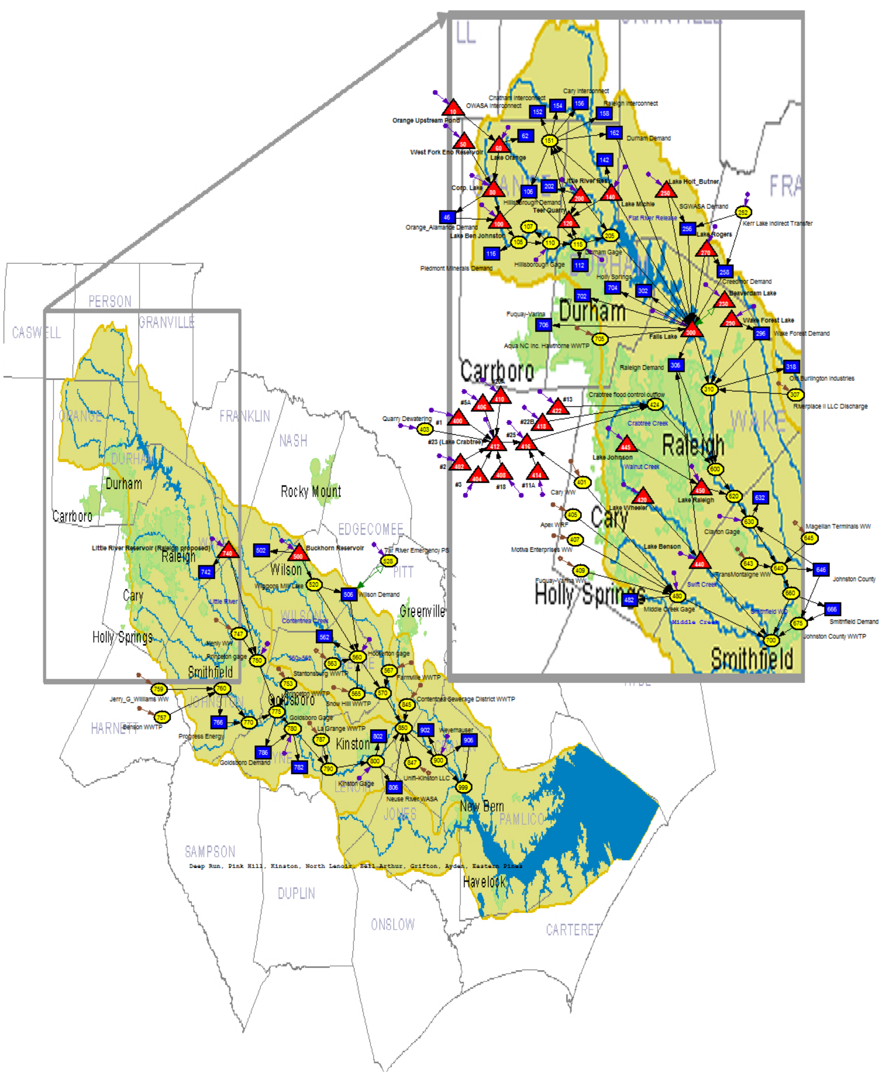
Scope of the Model

The geographic scope of the model extends from the headwaters of the Eno and Flat Rivers, above the Falls Lake Reservoir in northern Wake County, downstream to New Bern, where the river is a tidal estuary. The following schematic map of the basin shows the geographic coverage of the model and the relative location of the various model nodes.

Figure 5-1 shows the complexity of the model. Each of the polygons in the schematic represents a node where the model performs a calculation to sum up the effects of inflows and outflows of water. The squares represent the withdrawal points and the triangles represent the reservoirs.

Figure 5-1: Neuse Hydrologic Model Schematic

NEUSE RIVER BASIN SCHEMATIC



5.2 Model Scenarios Evaluated

For this analysis, four different scenarios were modeled: a characterization of current conditions, two scenarios of future withdrawals and a scenario simulating a condition with increased future withdrawals and decreased inflows.

A scenario based on data for the year 2008 is used to portray current water withdrawal and management conditions. Modeled water withdrawals were estimated using water demands and other data from local water supply plans and additional information received from water systems and other registered water withdrawals. This scenario provides a basis for comparison of other scenarios modeled. In this analysis, three other scenarios were evaluated. The results of the other scenarios are compared to this base case to identify possible changes to flow conditions and water availability due to the projected changes in water withdrawals and return flows.

A scenario based on water demands anticipated for the year 2030 was constructed using local water supply plan data and any updated projections received from water systems. While the levels of withdrawals included in this scenario are based on the estimated demands for 2030, this volume of withdrawals could occur before then, or in some year after 2030. The values used in this scenario are based on expectations in 2008 as to what customer demands may be in 2030. Withdrawals are assumed to follow future water use projections provided to the division by water withdrawers and the water systems that depend on them. This scenario includes Lake Benson and Lake Wheeler in the city of Raleigh's available water supply. However, it does not include the unpermitted new reservoir for Raleigh on the Little River in eastern Wake County. This scenario is intended to provide information on possible conditions for 20 years in the future.

To get a glimpse of possible conditions for 40 years in the future, a scenario based on anticipated demands in 2050 was also evaluated. It is similar to the 2030 scenario, except that the water withdrawals are those expected to be needed to meet customers' water demands in the year 2050. Demand projections are based on information supplied to the division in the local water supply plans and other registered water withdrawals. As with the 2030 scenario, the projected values are based on current understanding of the number of customers expected to be served and their expected demands for water in 2050.

For a picture of possible conditions in the future, an additional scenario was developed. This scenario is based on the concept that our current level of annual precipitation may decrease, and the resulting stream flows may be lower than those experienced in the last 78 years. This scenario used the same withdrawal values as the 2050 scenario, except that the inflows to the system have all been multiplied by 0.9, simulating a 10 percent, across the board, reduction in available water. It is intended to help identify the potential impacts of a long period of decreased inflows to the river system.

Model Components

The Neuse River Basin Hydrologic Model balances water coming in with water going out of the river system, subject to goals and constraints established for each node. Priorities established during model development determine how water is allocated between competing uses at each withdrawal node. At the reservoir nodes, water is stored and released subject to operating rules defined during model development. The model operates on a daily time step, making one set of calculations for each day in the 78-year flow record, using daily average values for each input. Daily average demands for each withdrawer are adjusted within the model to compensate for the fact that in reality, water withdrawals vary throughout the year. Annual average withdrawal amounts are adjusted by a set of user specific coefficients to produce lower withdrawals in months when use is typically below average and to increase withdrawals in the months when the system use is typically above average.

Inputs

The model uses a set of estimated daily natural inflows to characterize the water entering the river system. The inflow dataset was developed using 78 years of flow records adjusted for known withdrawals, discharges, and reservoir operations. The portion of the Neuse River basin covered by the model was subdivided into smaller drainage areas. An average daily inflow was estimated for each drainage area and for each of the more than 28,000 days in the 78 years of flow data. Inflows to the system enter the model at discrete points shown in the schematic in Figure 5-1 as purple arrows.

Water is removed from the system at discrete withdrawal nodes shown as blue boxes on the model schematic. Withdrawals can be for water supply systems, industrial water users, or agricultural water users. Public water supply withdrawals are based on local water supply plan data submitted to the division by local water utilities. Self-supplied industrial water withdrawals were derived from data submitted under the division's water withdrawal registration program. For self-supplied industries, it was assumed that future withdrawals will be the same in the 2030 and 2050 scenarios, as in the 2008 base case scenario, unless additional information was available to justify changes in projections.

Agricultural uses for livestock and irrigation were estimated with the help of county agricultural extension agents and an agricultural extension irrigation specialist. Water use estimates were developed for irrigated crops, taking into consideration variations in planting times in the upper, middle and lower regions of the basin. Livestock water needs are based on animal head counts in each county and the water use factors used by the U.S. Geological Survey in the 1995 estimated water use in North Carolina. Acreage of irrigated crops and number of livestock units were developed for each county in consultation with county agricultural extension agents. The resulting values for each county were proportioned to specific withdrawal nodes based on the proportion of each county's agricultural water use estimated to be in each drainage area. For example, the watershed for Durham's Lake Michie Reservoir is estimated to contribute 31 percent of agricultural water use in Person County and about eight percent of Durham County's agricultural use.

Discharges from wastewater treatment plants and water reclamation facilities constitute inflows into the river system. They enter the model similarly to natural inflows, as water inputs at discrete nodes. They are represented in the schematic as brown arrows. Wastewater return flows, associated with water withdrawn at some other location in the basin, are typically estimated as a percentage of the volume of water withdrawn. The appropriate percentages were determined by evaluating historical data submitted to the department by water purveyors.

At most nodes, the model balances inflows and outflows at each node. Outflows and withdrawals equal inflows on all days for all nodes except reservoir nodes, represented by red triangles in the schematic. In the case of a reservoir node, change in daily storage is considered in the balance equation. Each reservoir in the model has a set of operating guidelines that define such things as the available storage at specific water levels, minimum release requirements and drought management protocols. Five reservoirs in the system have minimum release requirements: Lake Orange, West Fork Eno Reservoir, Little River Reservoir, Falls Lake and Buckhorn Reservoir. Further in this document, some specific results will be shown in the models for the Falls Lake and Eno River reservoirs. Nodes in the model are connected by arcs which define how the model moves water through the system. Arcs are represented in the model schematic by black arrows that define the direction of water movement from one node to the next downstream node.

Outputs
The Neuse River Basin Hydrologic Model can provide a variety of outputs in a variety of configurations. The primary outputs used for this analysis include the following:

1. Daily flows: The model provides estimates of daily water flows into a node, out of a node or through an arc.
2. Daily reservoir levels.
3. Daily reservoir releases.
4. Daily accounting of Falls Lake conservation storage. The model keeps track of how much water is remaining in the water supply storage pool and the water quality storage pool. Storage remaining in the water supply pool and the water quality pool is tracked daily using standard accounting principles. This information is used to determine the release from the reservoir during droughts.

5.2.1 Water Use and Wastewater Discharge

Table 5-1 summarizes the estimated withdrawals. Table 5-2 summarizes the return flows for the base case of 2008, the 2030 and the 2050 demand scenarios for the major water users modeled for this analysis. All volumes are shown in million gallons per day, or mgd.

Table 5-1: Model Demand Withdrawals (MGD)

Systems	2008 Demand	2030 Demand	2050 Demand
Orange-Alamance	0.161	0.19	0.21
Hillsborough	1.136	2.029	2.760
Durham	24.385	35.826	40.923
South Granville WASA	2.576	5.966	10.006
Creedmoor	0.301	0.569	1.162
Raleigh	45.22	86.99	129.23
Wilson	8.92	11.214	13.557
Johnston County	7.201	11.854	19.598
Smithfield	2.988	4.640	5.951
Progress Energy - Lee	7.67	7.67	7.67
Goldsboro	4.645	7.733	9.928
Neuse Regional WASA	6.08	12.58	17.292
Weyerhaeuser	15.37	17.75	17.75

Source: N.C. Division of Water Resources, 2010.

Table 5-2: Model Wastewater Discharge Node Return Flows (MGD)

Systems	2008	2030	2050
Orange-Alamance WWTP NC0082759	0.024	0.028	0.031
Hillsborough NC0026433	0.854	1.522	2.070
Durham WWTP NC0023841	8.61	12.181	13.914
SGWASA WWTP NC0026824	2.145	4.952	8.305
Raleigh WWTP NC 0029033	40.874	83.782	115.946
Raleigh WWTP NC0030759	1.105	2.312	3.199
Raleigh WWTP NC0079316	0.624	1.295	1.792
Cary WWTP NC0048879 to Crabtree Creek	6.530	10.864	10.864
Cary WWTP NC0065102 to Middle Creek	4.790	7.867	7.867
Apex WWTP NC0064050	2.358	8.508	9.851
Fuquay-Varina WWTP NC0066516	0.582	1.405	2.132
Wilson WWTP NC0023906	7.452	9.322	11.275
Stantonsburg WWTP NC0057606	0.249	0.294	0.315
Snow Hill WWTP NC0020842	0.167	0.488	0.622
Farmville WWTP NC0029572	1.373	1.518	3.052
Maury SD WWTP NC0061492	0.131	0.151	0.170
Johnston Co WWTP NC0030716	1.224	2.015	3.332
Clayton WWTP NC0025453	0.936	1.541	2.548
Smithfield Wastewater to Johnston Co WWTP	2.373	3.666	4.701
Johnston Co WWTP NC0030716	3.823	6.052	8.509
Kenly WWTP NC0064891	0.343	0.389	0.488
Princeton WWTP NC0026662	0.109	0.153	0.214
Benson WWTP NC0020389	1.116	1.254	0.550
Goldsboro WWTP NC0023949	7.18	7.733	9.928
LaGrange WWTP NC0021644	0.333	0.401	0.428
NRWASA WTP WW NC0088111	0.458	0.943	1.297

Source: NC Division of Water Resources, 2010.

5.2.2 Future Water Supply Alternatives

Overall, only the Upper Neuse River Basin Hydrologic Unit Code, or HUC 03020201, faces water supply deficits for the 2030 and 2050 future demand scenarios. New water supply sources projected to be available in this HUC area are Raleigh's Benson system and Durham's Teer Quarry, which is to be used under drought conditions.

Some of the water systems in the basin have additional sources of water under development, or in the planning stages. Upon completion, the added water available may help resolve some of the deficits predicted by the model based on currently available sources of water. Raleigh and Durham, the two largest water systems in the basin, have supply expansions under development.

Raleigh has recently completed a new water treatment facility that will use water from lakes Benson and Wheeler south of the city. These reservoirs had been the main sources for the city's water system prior to the completion of Falls Lake in the early 1980's. This additional supply of water is included in the 2030 and 2050 model scenarios. Raleigh has been working for a number of years to construct a new reservoir on the Little River in eastern Wake County. Work is still underway to determine potential environmental impacts of this project. If this project is constructed, it is expected to add almost 14 million gallons a day to Raleigh's available supply.

Durham is also developing additional water sources. Durham currently holds a 10 percent allocation of the water supply pool in Jordan Lake, which is assumed to be able to reliably supply 10 million gallons per day, or mgd, of water. As of May 2010, Durham has access to about four mgd of Jordan Lake water through a connection with the town of Cary's distribution system. Access to the remaining six mpg is expected to be obtained through an additional connection with Cary in the near future. Durham is also developing a site to store water from the Eno River in Teer Quarry, an inactive quarry pit, as a supplemental source for use during droughts. The plan is to divert a portion of flows during high-flow periods to fill the quarry so that water can be withdrawn during low-periods to help meet customer demands.

5.2.3 Management During Drought Conditions

Droughts may be unpredictable, but their occurrence is inevitable. Planning ahead to adjust normal operations when they occur can help reduce the impacts to water resources and minimize disruptions for water withdrawers. Reservoirs in the headwaters of the Neuse River basin buffer drought effects on residents by storing water during high-flow periods for use during low-flow periods. Some of the reservoirs in the model have requirements to release specified amounts of water downstream. When water supplies become diminished during droughts some minimum flow requirements may be reduced to preserve stored water. These reductions must be done with consideration for the needs of downstream water dependent ecosystems and impacts to water quality.

The U.S. Army Corps of Engineers, that operate Falls Lake, are required to release minimum amounts of water from the dam. There are flow targets that must be met at the U.S. Geological Survey stream gage at Clayton that vary seasonally. From November to April, the target is 184 cubic feet per second. From May to October, the target is 254 cubic feet per second. The hydrologic model includes the goals of meeting these target flow levels when evaluating water needs from Falls Lake. During previous droughts, releases from the dam have been reduced to preserve water in the reservoir. However, there is no approved drought management plan in place at this time. A proposed drought management plan for Falls Lake is still under review. Therefore, no drought management protocol for Falls Lake is incorporated into the hydrologic model.

Durham has two reservoirs in the upper Neuse River basin: Little River Reservoir and Lake Michie. There are minimum flow requirements for the Little River Reservoir that are incorporated into the model. However, there is no drought management protocol for Durham's reservoirs. Therefore, none were incorporated into the model.

There are two additional reservoirs represented in the model in the upper Neuse River basin: Lake Orange and West Fork Eno Reservoir. The dam safety permit for the West Fork Eno Reservoir provides for reductions in required minimum releases during droughts if withdrawals have also been reduced. The two reservoirs are managed under a negotiated Eno River voluntary capacity use area agreement. Flow criteria and drought management protocols were established by the Eno River Water Management Plan.[23] The original plan was revised in 2000 to incorporate the newly-constructed West Fork Eno Reservoir. The plan defines six stages of surface water withdrawals, required water releases and instream flow requirements. Stream flows are measured at the U.S. Geological Survey stream gage at Hillsborough. Selection of the appropriate stage is based on the storage condition of Lake Orange[24]. The West Fork Eno Reservoir, or WFER, dam safety permit[25] also established a three-tiered set of minimum release requirements and reductions in water withdrawals from this reservoir based on the remaining storage. The requirements of the Eno River water management plan are incorporated into the hydrologic model, so that when the storage thresholds are met the model adjusts the releases accordingly.

5.2.4 Ecological Integrity

As discussed in the Executive Summary, the N.C. Division of Water Resources is working to develop an approach for quantifying the flows needed to maintain ecological integrity for use in river basin water resources planning. Until this task has been completed for the Neuse basin, ecological flows are an important, although yet-to-be quantified, part of the basin model and plan. A hydrologic stream classification system has been developed for North Carolina for use in determining ecological flows, according to the stream type. Much work remains to be done before a scientifically defensible methodology can be implemented statewide. Output from the Neuse River

[23] www.ncwater.org/Permits_and_Registration/Capacity_Use/Eno_River_Management/
[24] Same as 23
[25] Same as 23

Basin Hydrologic Model can be used to determine stream classifications by using the unimpaired flows at any location.

5.3 Model Validation

The Neuse River Basin Hydrologic Model is based on the most practical geographic resolution and calculation time step appropriate for modeling the impacts to the quantities of surface waters in the basin. It is a decision support tool that can be used for multipurpose decision making for surface water resource management and, with additional information, drought management.

In order for the model to be useful as a decision support tool, it must be capable of approximating real water conditions. How well the model accomplishes this task is determined by comparing the model results to known characteristics and examining the variation. While the ideal situation would be a perfect match, this is highly unusual because of the various time frames and geographic scales over which data are collected, and the need to fill in missing data using approximations from known data. The ultimate goal of any model is to make it useful in the sense that the model addresses the right problems and provides accurate information about the system being modeled. Validation of the model is accomplished by comparing the outputs of the model to comparable historic, observed data. This section will present various graphs comparing simulated model data to historic or observed values.

Key goals of the water supply planning exercise are to determine where and when there may not be enough water available to satisfy instream flow needs and expected water supply withdrawals. Given this focus, the model's accuracy during dry periods, when the ability to meet all demands is most likely to be compromised, is of critical importance. The Neuse River Basin Hydrologic Model is based on historic flow data that captures the range of flows experienced in the basin from January 1930 to April 2008. The 78 years of data constitute the period of record of flow data for this model. Running a model scenario evaluates the effects of withdrawing the specified water demands under the flow conditions experienced in each year in the period of record. Frequently, certain flow conditions may be referred to by referring to the year in the record in which they occurred. Based on this period of record, 2007 was the driest year in the Neuse River basin. The following discussion compares model-predicted conditions to the historical, observed conditions in 2007, for several important locations in the Neuse River basin.

It is important to keep in mind that the model is essentially a long mathematical equation that calculates results strictly based on how the equation is set up. Results are based on the numbers processed at each node with no ability to make compromise decisions, like those that can be made by the human operators of water withdrawal and water control facilities. For the model to function as intended, decision criteria have to be mathematically defined based on characteristics that can be linked to water quantity, such as changes in water levels. However, facility operators are not necessarily constrained to take the same action at the same water level as the model. Therefore, we expect real-time management decisions to result in variations between actual and simulated conditions.

Figure 5-2 through Figure 5-4 compare model-predicted Falls Lake elevations and Clayton gage target minimum stream flow conditions, to the historic and observed similar conditions.

Figure 5-5 and Figure 5-6, on the other hand, do not compare with any historic data, rather show the model's responses in drought conditions for the minimum flow release protocols built in to the model at different drought stages for the West Fork Eno Reservoir and Lake Orange. The plots show how the minimum flow release quantities were reduced as the drought condition deteriorated to higher stages.

Figure 5-2 plots the model-simulated water levels and the observed, historic water levels for Falls Lake during 2007. As expected, the simulated data did not fully match the historic values. The normal water level in the reservoir is 251.5 feet above mean sea level. The year began with water levels at or above normal and then steadily declined as drought conditions worsened. In addition to water lost due to evaporation, water was released to augment river flows downstream and water was withdrawn to supply customers of Raleigh's water system. The model does not include a drought management protocol for Falls Lake. Real-time decision making is not constrained to the options programmed into the model. Therefore, one would expect to see historic water levels differ from the model-simulated water levels as operators adjusted to drought conditions.

The plots in Figure 5-2 show that the simulated data followed the real water level pattern quite closely and the magnitudes of the data point differences are not significant. Falls Lake is Raleigh's primary water supply, and this graphical comparison of conditions in 2007 indicates that this model effectively simulates water level conditions in Falls Lake during low-flow conditions. Figure 5-2 also shows the increased intensity of drought conditions by showing the sequence of drought declarations made by the N. C. Drought Management Advisory Council.

Figure 5-3 shows the percent of time in 2007 that the water level in Falls Lake was at or above certain elevations. As expected, the computed values vary from the actual historic values measured at the reservoir. The benefits of altering operations to respond to drought conditions can be seen in the difference in the two lines in the lower left of the graph. The model, with no built-in drought protocol, predicted that the extreme low elevation reached, could have been a foot, or more, lower than the actual minimum reached. In addition, it predicts water levels could have been below the actual minimum for about 10 percent of the year. The close tracking of these two plots shows the ability of the model to reproduce actual conditions quite well. At the same time, the variation in the plots at low water levels shows the benefits of the changes that reservoir managers made to normal operations in response to worsening drought conditions.

Figure 5-2 : Comparison of Simulated and Historic Falls Lake Elevation

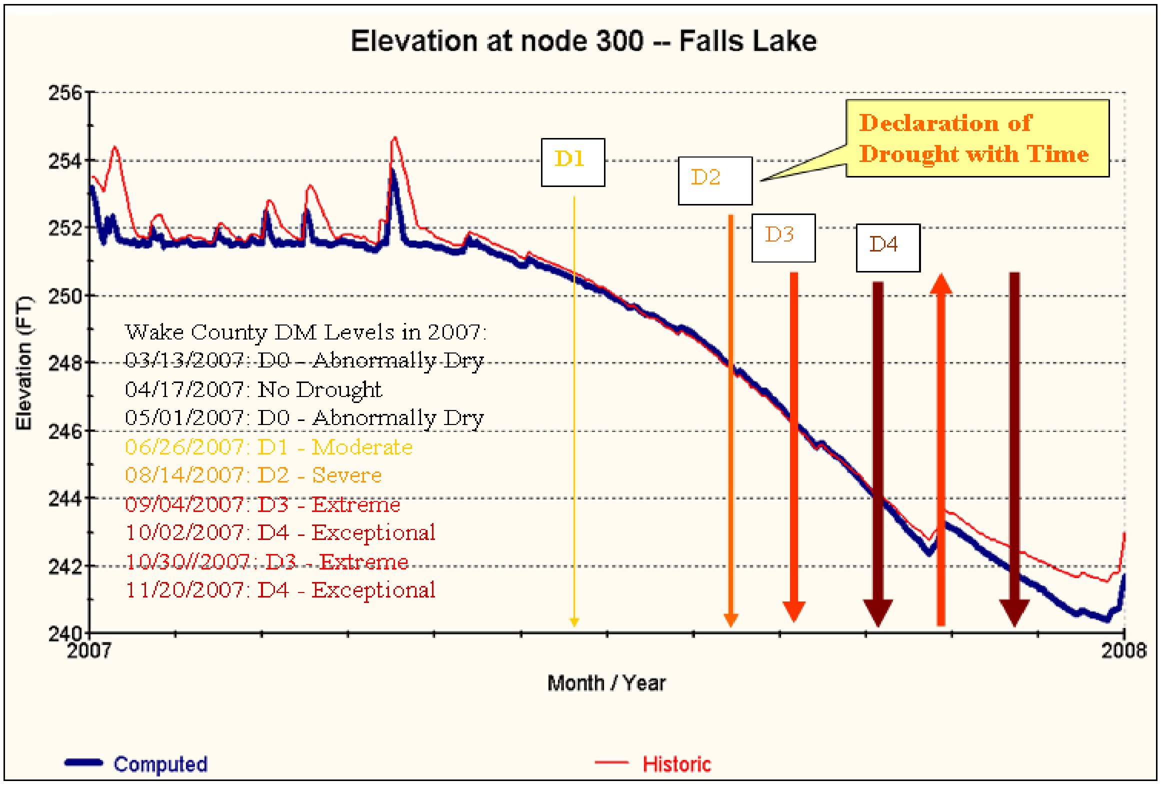
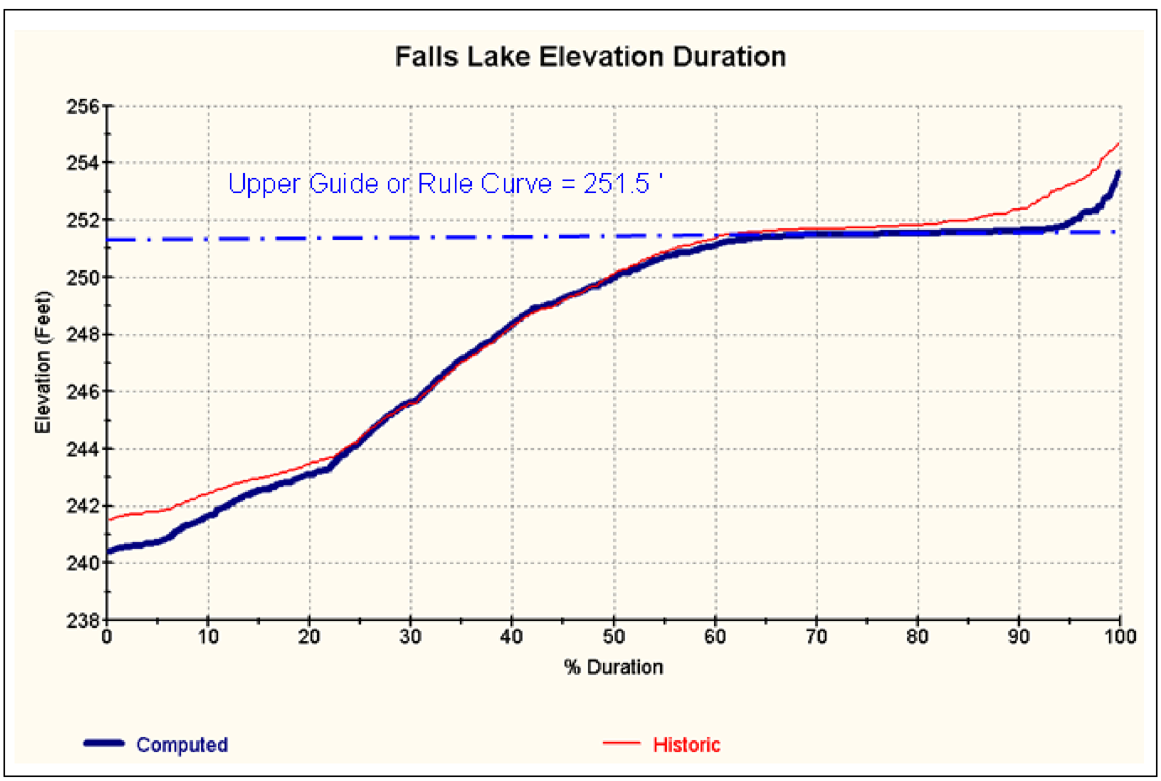


Figure 5-3: Comparison of Simulated and Historic Duration Curve for Falls Lake Elevation



Part of the water stored in Falls Lake is used to supplement downstream river flows. Water is released from the dam to maintain flows above specified target flows in the Neuse River at the U.S. Geological Survey stream gage in Clayton, N.C. Figure 5-4 below shows stream flows below 400 cubic feet per second at the Clayton stream gage. This indicates how well the model characterizes the requirement to keep flows above the specified targets. The model does not include a drought protocol. Therefore, the program does not possess the ability to adjust release requirements in response to drought conditions. Also, the model has the ability to calculate how much water is needed to meet the downstream target and release that amount of water from the reservoir. The operators have to estimate how much is needed in addition to the inflows from the basin between the dam and the gage and consider the time it takes for the water to travel down to the gage.

As noted above, the operators are not constrained by the conditions set in the model and can adjust flow augmentation releases to respond to drought conditions. The results of these adjustments show up in this graph where actual flows at Clayton were consistently below the target levels beginning in mid-year. This indicates a reduction in downstream releases to preserve the supply of stored water. Referring back to Figure 5-2 this reduction in downstream releases shows up in the water level plot where the actual water levels diverge from that predicted by the model, as a result of releasing water necessary to maintain the target flows as shown in Figure 5-4.

Figure 5-4: Comparison of Simulated and Historic Clayton Gage flow and Minimum Flow

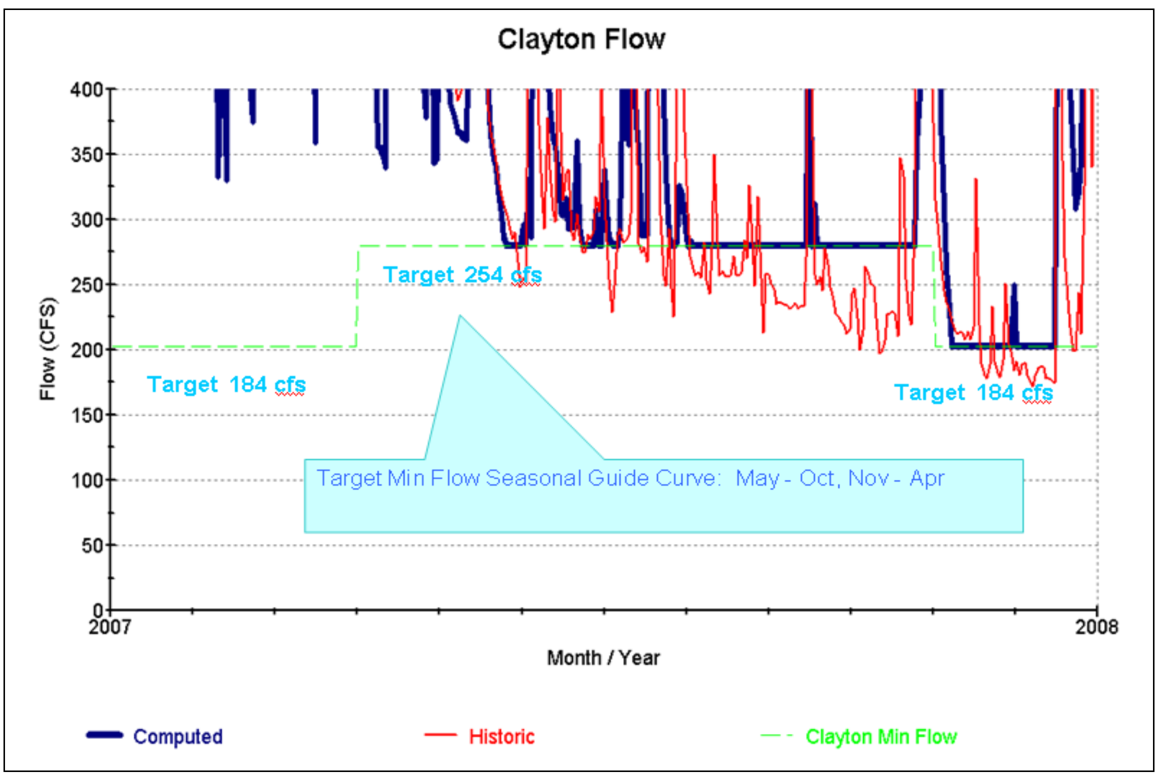


Figure 5-5: West Fork Eno Reservoir Elevation and Flow Fluctuations in 2007

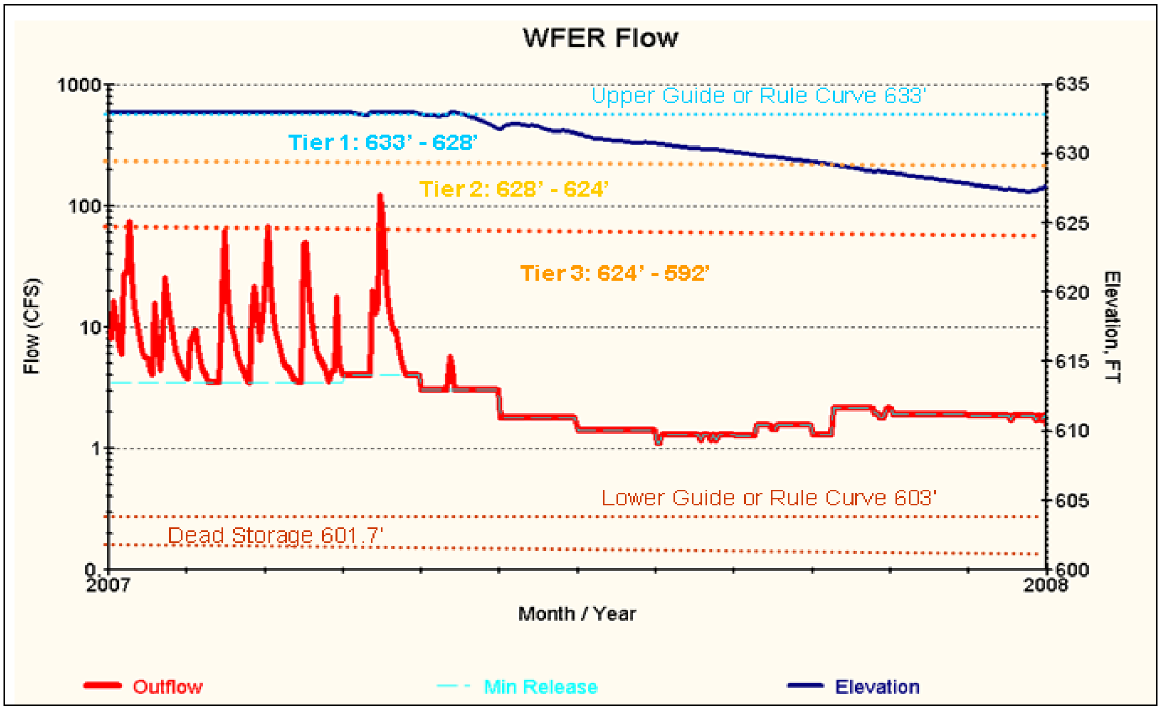
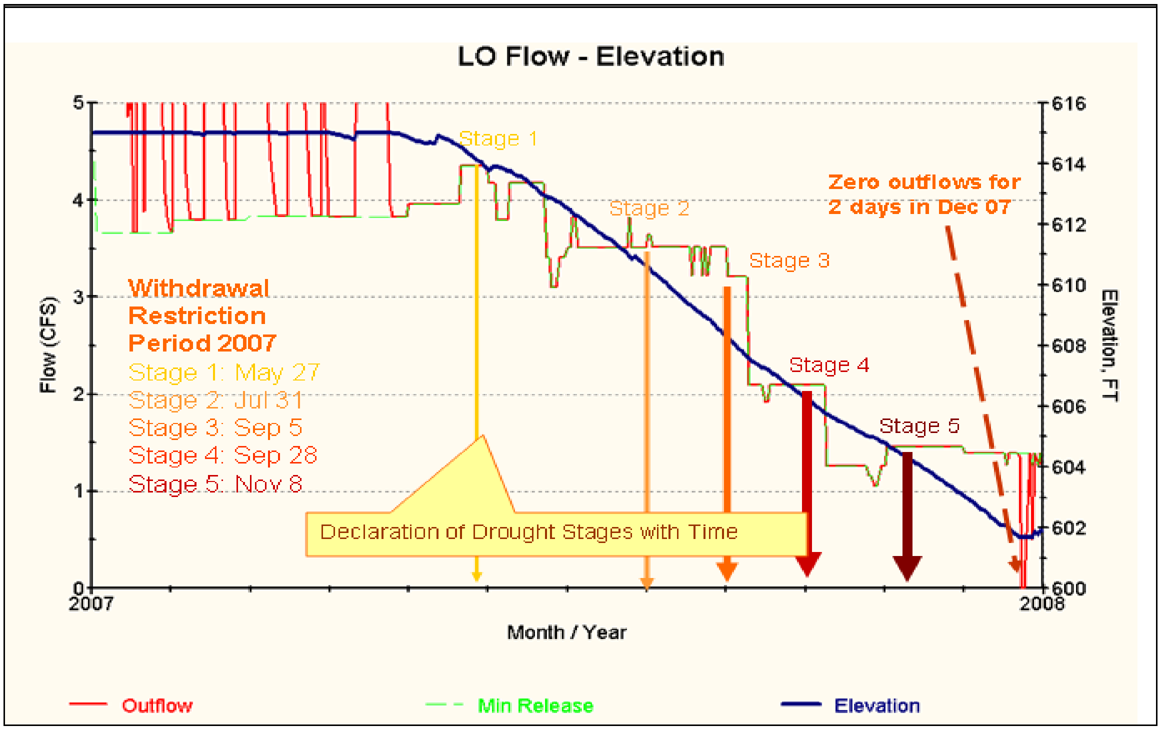


Figure 5-6: Lake Orange Elevation, Drought Stages and Flow Fluctuations in 2007



The validation assumptions and other information from the validation analysis are available online on the Neuse modeling[26] page.

5.4 Changes in Water Availability and Reliability

As discussed in section 5.2.3, Management During Drought Conditions, regarding the simulation of drought management in the model, Falls Lake and Durham's reservoirs do not have drought management protocols to include in the model to simulate operational changes in response to drought conditions. The model does include the drought response criteria specified in the Eno River Water Management Plan, to model withdrawals and releases from Lake Orange and West Fork Eno Reservoir during drought conditions.

The duration plots shown in Figure 5-7 indicate the percentage of days the water level in Lake Orange is at or above certain elevations, over the 78 years of historic flow conditions used in the model. The maximum normal elevation of water in Lake Orange is 615 feet mean sea level, or msl. The lowest operation elevation is 601.7 feet msl. The reservoir's drought operation protocol is implemented based on the amount of storage remaining. The three lines represent the three model scenarios run using historic flow conditions. The results of these scenarios are represented by blue, red and black lines for 2008, 2030 and 2050, respectively. In all three scenarios, the model predicts that water levels could reach the minimum operating level with a repeat of the lowest flow conditions experienced since 1930. The blue line shows the conditions expected with the current levels of water withdrawals. The red and black lines show how conditions could change with the increased withdrawals needed to meet expected demands in the years 2030 and 2050. The 2008 scenario shows water levels about one foot below full pond in about 40 percent of the days. Under the 2030 and 2050 withdrawal scenarios, the model predicts the water level could be about two feet below full pond for 40 percent of the days. Another way to interpret the plot is to look at how often specific water levels are predicted to occur. For instance, under current withdrawal conditions the model predicts water levels to be at or below 608 feet msl, or seven feet below full, about six percent of the time. Under the 2030 and 2050 demand scenarios, the model predicts the water level could be at or below this level about 11 percent of the time. This information should be useful for parties concerned about water levels in Lake Orange and allow them to adjust their expectation about possible future water levels conditions when the reservoir is fully used for the purposes for which it was developed.

The Eno River Water Management Plan defines six levels of allowable water withdrawals and minimum releases from Lake Orange and the West Fork Eno Reservoir. Figure 5-8 illustrates the percent of time that the model predicts Lake Orange storage could be at each of the six levels over the range of flows in the 78-year flow record. This figure can be interpreted similarly to the previous one, by looking at the change in storage predicted to occur for a specific percent of time, or by looking at the

[26] www.ncwater.org/Data_and_Modeling/Neuse_River_Basin_Model/Model_Data/Reports/08_NRHM_Oasis_Validation_Results_Sept09.ppt

change in how long a specific storage condition, or drought management stage, is predicted to occur.

Figure 5-7: Lake Orange Elevation Duration Curve

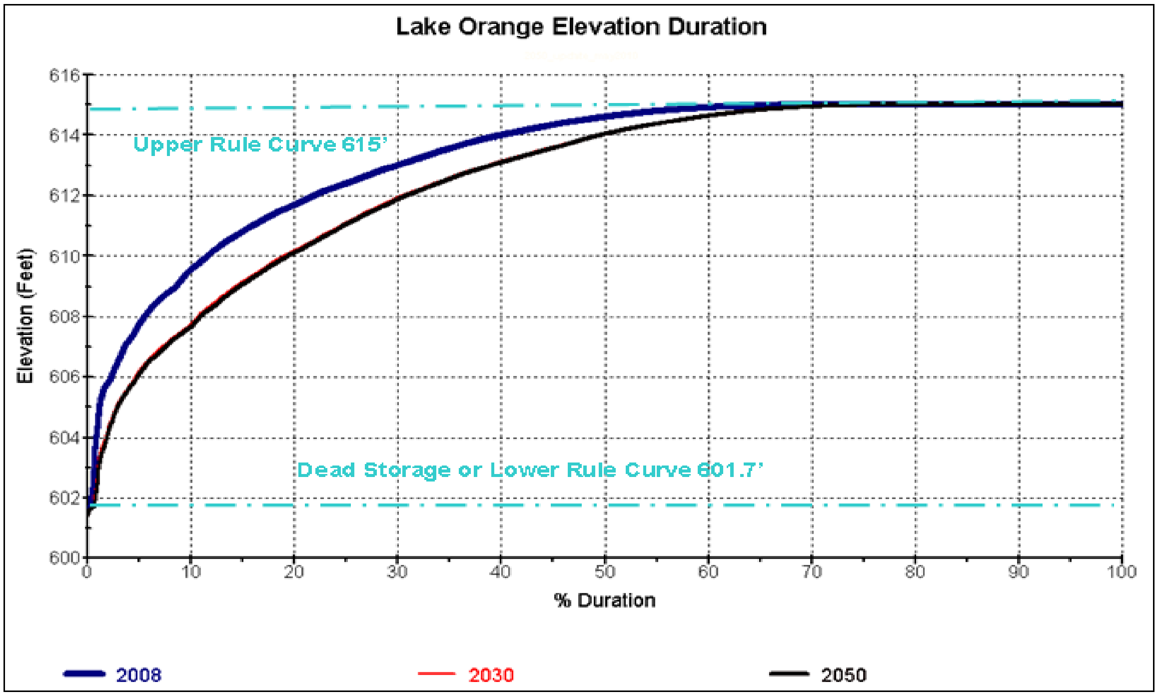
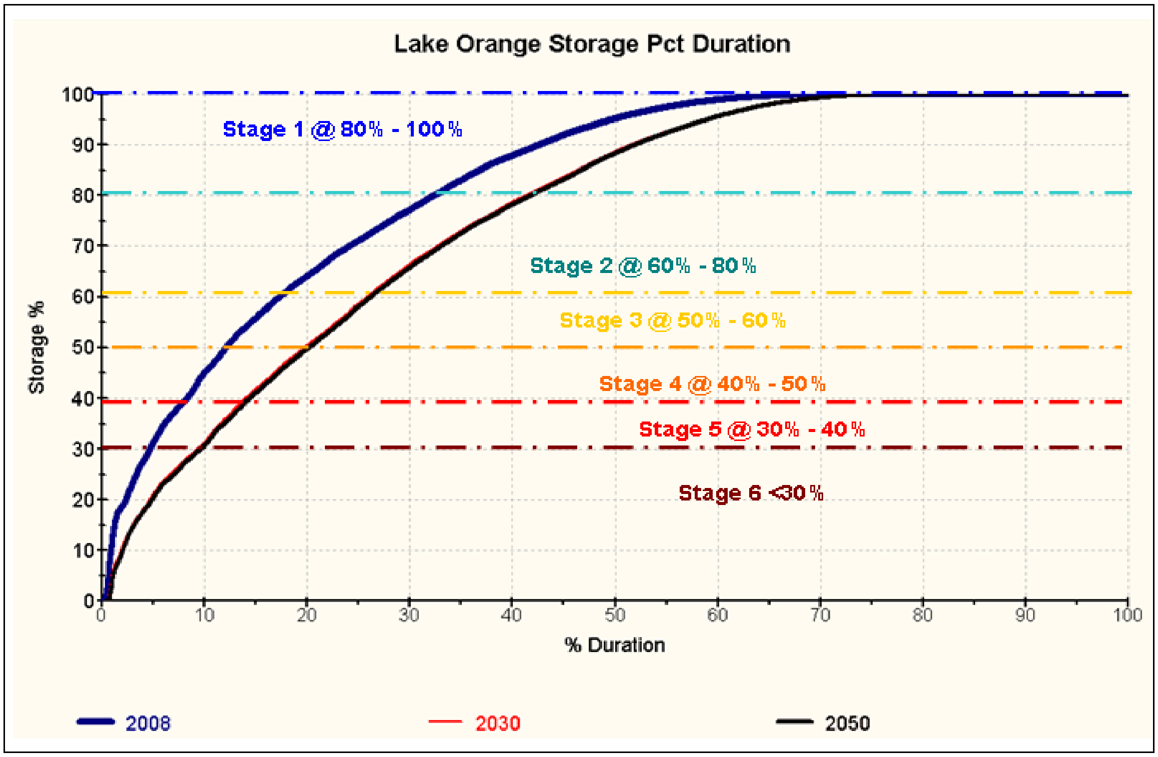


Figure 5-8: Lake Orange Storage Percent Duration Curve



There is an additional set of criteria regulating the minimum releases from the West Fork Eno Reservoir, or WFER, that must also be met. The dam safety permit for this reservoir established a three-tiered minimum release schedule and reductions in water withdrawals based on the amount of water in the reservoir. The model monitors the water level in this reservoir during simulation runs and adjusts downstream releases accordingly. Figure 5-9 shows the percentage of time water levels in the West Fork Eno Reservoir are predicted to be at or below certain elevations and the corresponding management tier specified in the dam safety permit. Tier 3 was not triggered under the 2008 demand scenario. However, if the demands expected in the 2030 and 2050 scenarios actually occur, the model predicts the water levels will be at the Tier 2 and Tier 3 levels for increasing amounts of time as withdrawals increase. Tier 2 was triggered for about one percent of the days in the 2008 scenario and is predicted to increase to around four percent under the 2030 withdrawal scenario. Even though the 2030 and 2050 plots overlapped in Lake Orange, it did not overlap for WFER operation. The reason is that the Eno area withdrawal restrictions from Lake Orange are supplemented by WFER.

Figure 5-9: WFER Elevation Duration Curve

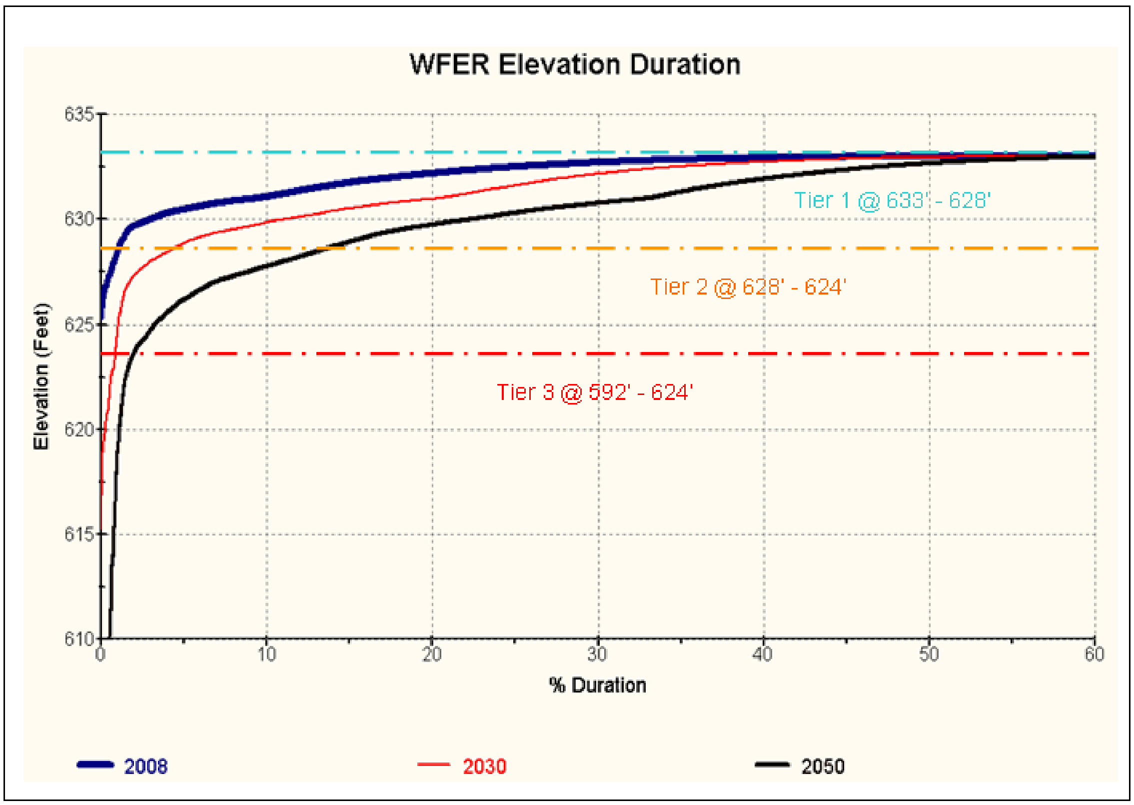


Figure 5-10 and Figure 5-11 compare the predicted frequency and duration of drought response stages specified in the West Fork Eno Reservoir's dam safety permit. The left axes in these plots represent the tier levels one through three, while the red lines indicate the frequency the restrictions are triggered, and the line thickness indicates the duration of an occurrence. Figure 5-10 compares the occurrences under the 2008 withdrawal scenario with the 2030 withdrawal scenario. Figure 5-11 compares the 2008 scenario with the 2050 scenario. These charts clearly predict an increase in the frequency and duration of the implementation of drought response measures as withdrawals increase in the future. For instance, under the 2008 demand scenario, the model predicts the West Fork Eno Reservoir would be in Tier 2 conditions for 108 days with a repeat of the flow conditions experienced in 2002. With the increased withdrawals in the 2030 demand scenario, the model predicts it would be in Tier 2 conditions for 83 days with an additional 114 days in Tier 3 conditions. Under the 2050 demand scenario, the time in Tier 3 increases to 222 days for a recurrence of 2002 flow conditions.

Figure 5-10: WFER 2008 and 2030 Triggered Tiers

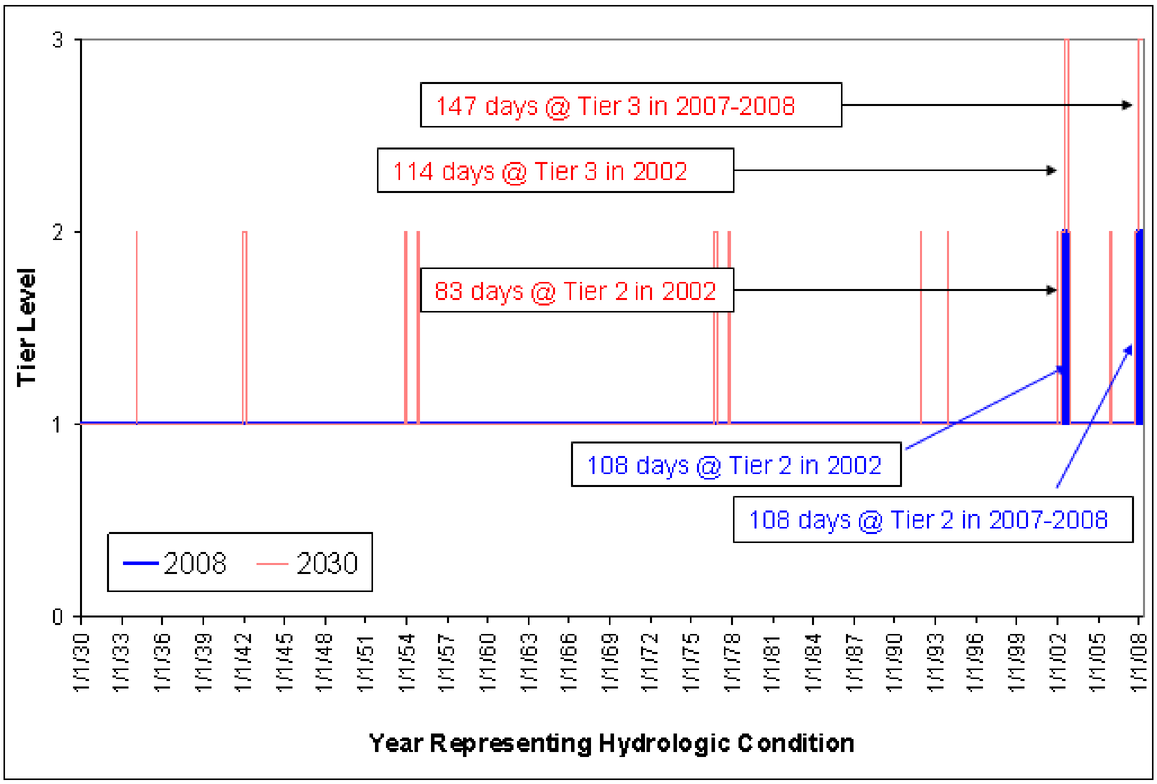
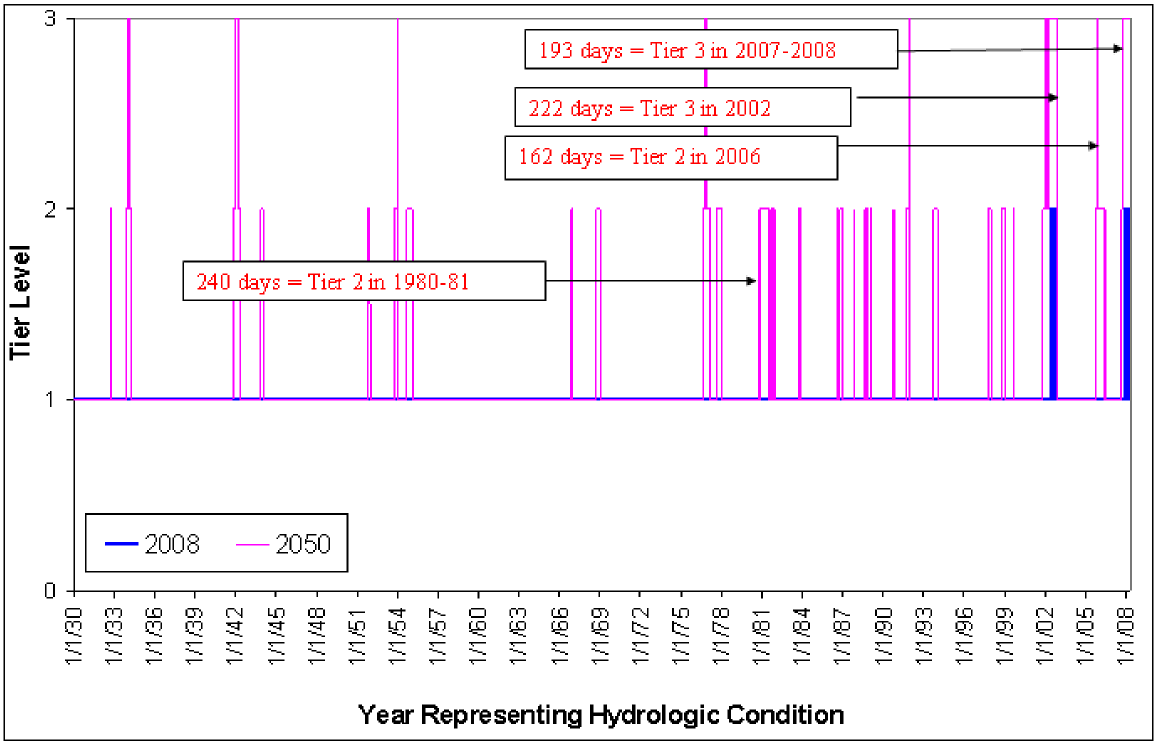


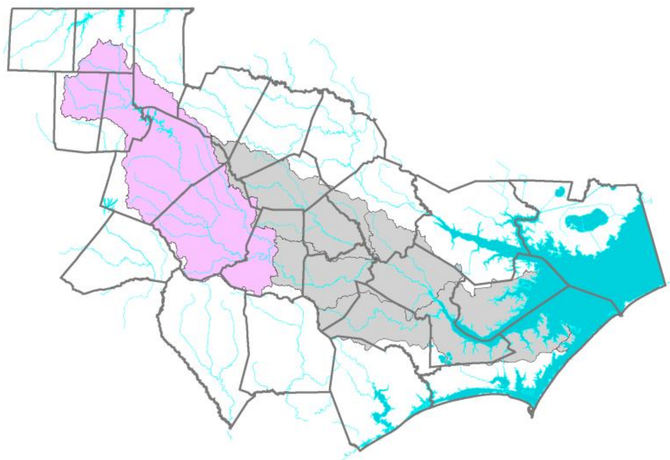
Figure 5-11: WFER 2008 and 2050 Triggered Tiers



Chapter 6 - Hydrologic Unit Summaries

6.1 Upper Neuse River Hydrologic Unit Code (HUC 03020201)

03020201 Upper Neuse – Quick Facts



Regions
Piedmont
Counties
Durham, Franklin, Granville, Johnston, Orange, Person, Wake, Wayne, Wilson
Major Public Water Supply Systems (PWSS)
Butner, Cary, Clayton, Creedmoor, Durham, Garner, Hillsborough, Holly Springs, Johnston County, Knightdale, Morrisville, Orange Alamance, Raleigh, SGWASA, Smithfield, Wake Forest, Wayne WD, Wendell, Zebulon
Major Industrial Withdrawals
Piedmont Minerals, Progress Energy
Population (2000 Census)
931,498

Number of SW Intakes
12
Number of Water Supply Reservoirs /Lakes
17
Number of PWS GW wells
~ 50
Number of Drought Monitoring Wells
2
Number of ECONET/COOP Weather Stations
14
Stream Miles
1698
HUC Total Area
2406 sq-miles
Number of USGS Gages (Regulated/Unregulated)
22/3

Upstream Watersheds:
None
Downstream Watershed
Middle Neuse
Subwatersheds
Flat River, Little River, Eno River, Upper Falls Lake, Middle Falls Lake, Lower Falls Lake, Crabtree Creek, Milburnie Lake, Swift Creek, Walnut Creek, Middle Creek, Black Creek, Mill Creek, Moccasin Creek, Upper Little River, Lower Little Creek, Falling Creek
Recreation Areas
Eno River State Park, Falls of the Neuse State Recreation Area, Hemlock Bluffs Natural Area, Mitchell's Mill Natural Area, William B. Umstead State Park.

The Upper Neuse River hydrologic unit is the upper most watershed of the Neuse River basin. It is located in the piedmont region and its rolling hills create a topography that is favorable for reservoir development. It contains most of the large water supply and flood control reservoirs in the Neuse River basin. Table 3-2 in Chapter 3 lists the reservoirs and their physical characteristics.

The Upper Neuse River watershed is the most populated hydrologic unit of the five in the basin, with 931,498 people living in the 2,406 square mile watershed according to the 2000 census. The number of people depending on water resources from the 17 reservoirs and 1,698 miles of streams in the watershed, increases the importance of efficiently managing water resources, especially during droughts.

6.1.1 Water Use

The Upper Neuse River hydrologic unit, or watershed, provides water to one of the most populated areas of the state. Between now and 2030, the state Demographer's office predicts a more than 50 percent increase in population bringing the number of residents to over two million. Sixty percent of these new residents are expected to be moving into Wake County. Official population projections end in 2030. For the longer planning horizon used in this analysis, staff with the N.C. Division of Water Resources developed population estimates based on the growth trends seen in each county from 1970 to 2008. This approach shows populations in these counties reaching 2.3 million by 2030 and over 3.1 million by 2060. Whatever the actual figures turn out to be, a significant increase in the number of residents is expected to result in a significant increased demand on the regional water resources by the mid-century.

Water withdrawal information used for this analysis comes from several different sources. Owners of facilities that withdraw large quantities of water are required by statute to report water withdrawals to the Division of Water Resources. Under this requirement, agricultural operations must report withdrawals of one million gallons per day, or mgd, or greater and non-agricultural operations report withdrawals of 100,000 gallons per day or greater. Units of local government that supply water to the public and other large community water systems meet this requirement by submitting a local water supply plan. Also, the Department of Agriculture and Consumer Services annually surveys agricultural operations that withdraw 10,000 gallons a day or more. Water systems in the fifteen counties of the Central Coastal Plain Capacity Use Area, or CCPCUA, report water use if they withdraw 10,000 gallons a day or more.

Table 6-1 shows the number of operations and the amount of water withdrawn in 2008 within the Upper Neuse River hydrologic unit. The public water systems that depend on surface water resources from this watershed used the largest percentage of the total water withdrawn. Fourteen of the systems depend on surface water sources. In addition to the 28 community water systems that have submitted a local water supply plan, there are an about 260 smaller community water systems that depend on ground water to meet their customers' demands. On average, the community water systems using water from this watershed withdrew about 114 million gallons per day during 2008. Of the water systems submitting a local plan, nine have a water shortage response plan that meets the division's minimum requirements as of February 2010.

According to available data, 126 agricultural operations in this hydrologic unit withdraw 10,000 gallons per day or more of ground and surface water. During 2008, these facilities withdrew 9.2 million gallons per day on average primarily from surface water sources. The 21 golf courses registering water use in the hydrologic unit used 2.5 mgd on average, primarily from surface water sources. Ten mining operations in the watershed report water withdrawals to the division. During 2008, these operations pumped 3.7 million gallons per day on average to remove water from the mining pits to allow for the operation of mechanical equipment and for other processing purposes. One self-supplied industry in the hydrologic unit withdraws ground water. Other industrial operations depend on public water systems for their water needs. Progress Energy Carolinas operates a thermoelectric generating facility in Wayne County that uses water from the Neuse River for cooling.

Table 6-1: Estimated 2008 Average Day Water Withdrawals in HUC 03030201 in Million Gallons per Day (mgd)

Operations reporting to DWR or DA&CS Agricultural Water Use Survey				
Upper Neuse HUC 03020201	**Operations**	**Ground Water**	**Surface Water**	**Total**
Agriculture/Aquaculture	126	1.397	7.805	9.2
Golf Courses	21	0.111	2.398	2.5
Industry	1	0.113	0	0.1
Mining	10	0.202	3.503	3.7
Public Water Systems	290	25.529	88.157	113.7
Thermoelectric	1	0	7.035	7.0
LWSP Systems	28		Sub-unit Total	136.2
WSRP meeting minimum standard	9			

For the 28 local water supply plan systems using water from this hydrologic unit, water demand for these communities is projected to grow from 105 mgd to more than 170 mgd by 2030, and reach 232 mgd by 2050, the limit of projections in the current plans. Over this period, these systems anticipate the population served will grow from 926,000 in 2008 to 1.42 million in 2030 and 1.89 million by 2050.

Some of the residents of Wake County in this watershed are served by water from neighboring river basins, notably the Haw River and Upper Cape Fear River basins. Four water systems that supply water to Wake County from these basins submit a local water supply plan. Currently, about 169,000 residents receive water from the Haw River basin and about 37,500 receive water from the Upper Cape Fear River basin. The number of persons supplied from these four water systems sources is anticipated to grow to 459,000 by 2030 and 545,000 by 2050.

Combining the information from the 32 local water supply plan systems of the counties in the Upper Neuse hydrologic unit shows that these systems are planning to meet the water demands of about two-thirds of the estimated number of residents of these counties in 2050. If the expectations represented by the population projections and the planned growth in large community water systems materialize, then about one-third of the residents of the nine counties in this watershed will be dependent on small community water systems or individual household wells at mid-century.

Water demand from surface water sources in this watershed is projected to more than double in the next 30 years, from 105 mgd in 2008 to 216.6 mgd in 2050.

Figure 6-1: Map of Public Water Systems and Reservoirs around HUC 03020201

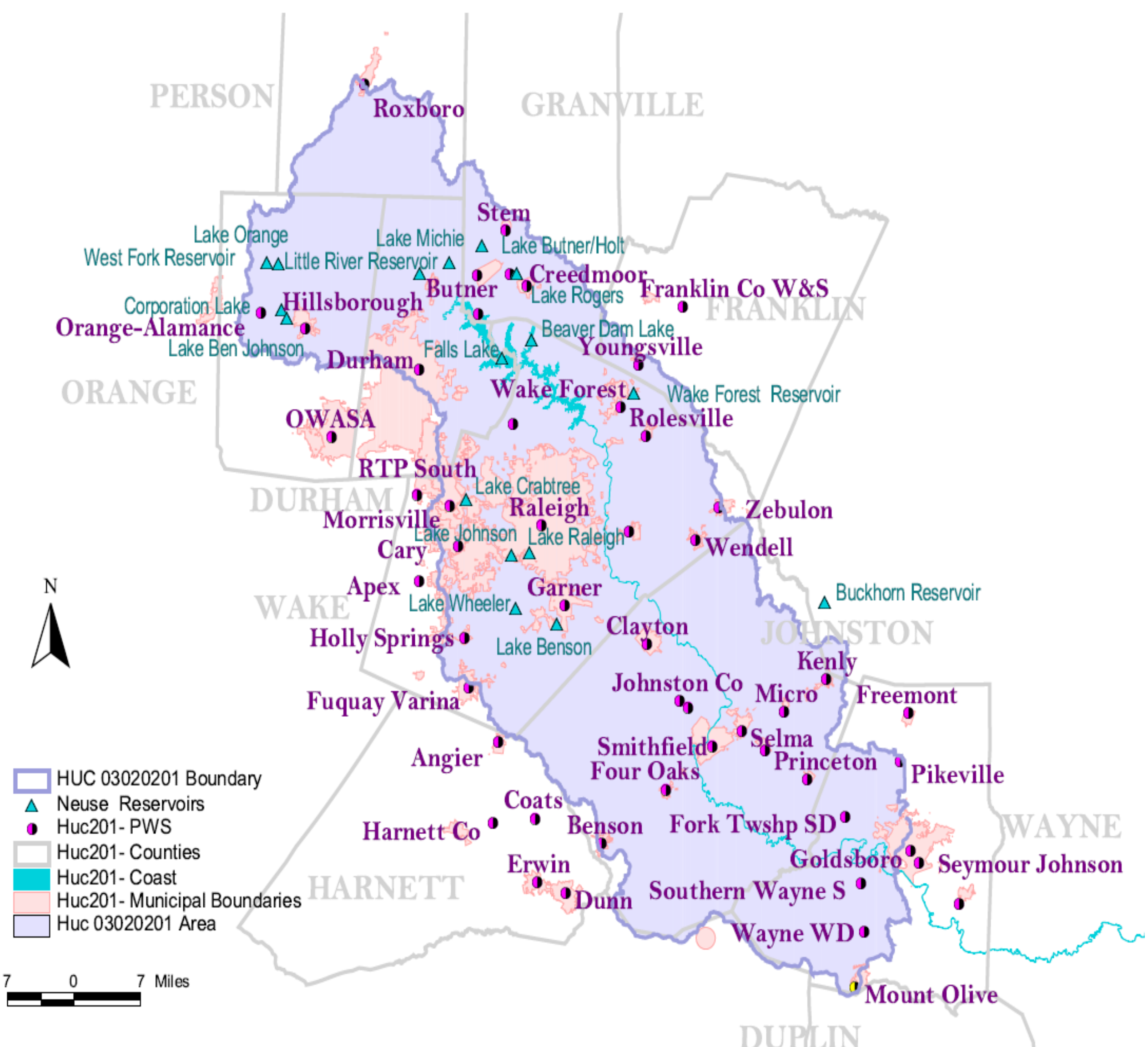


Figure 6-2: Water Sources and Connections for community water systems around HUC 03020201

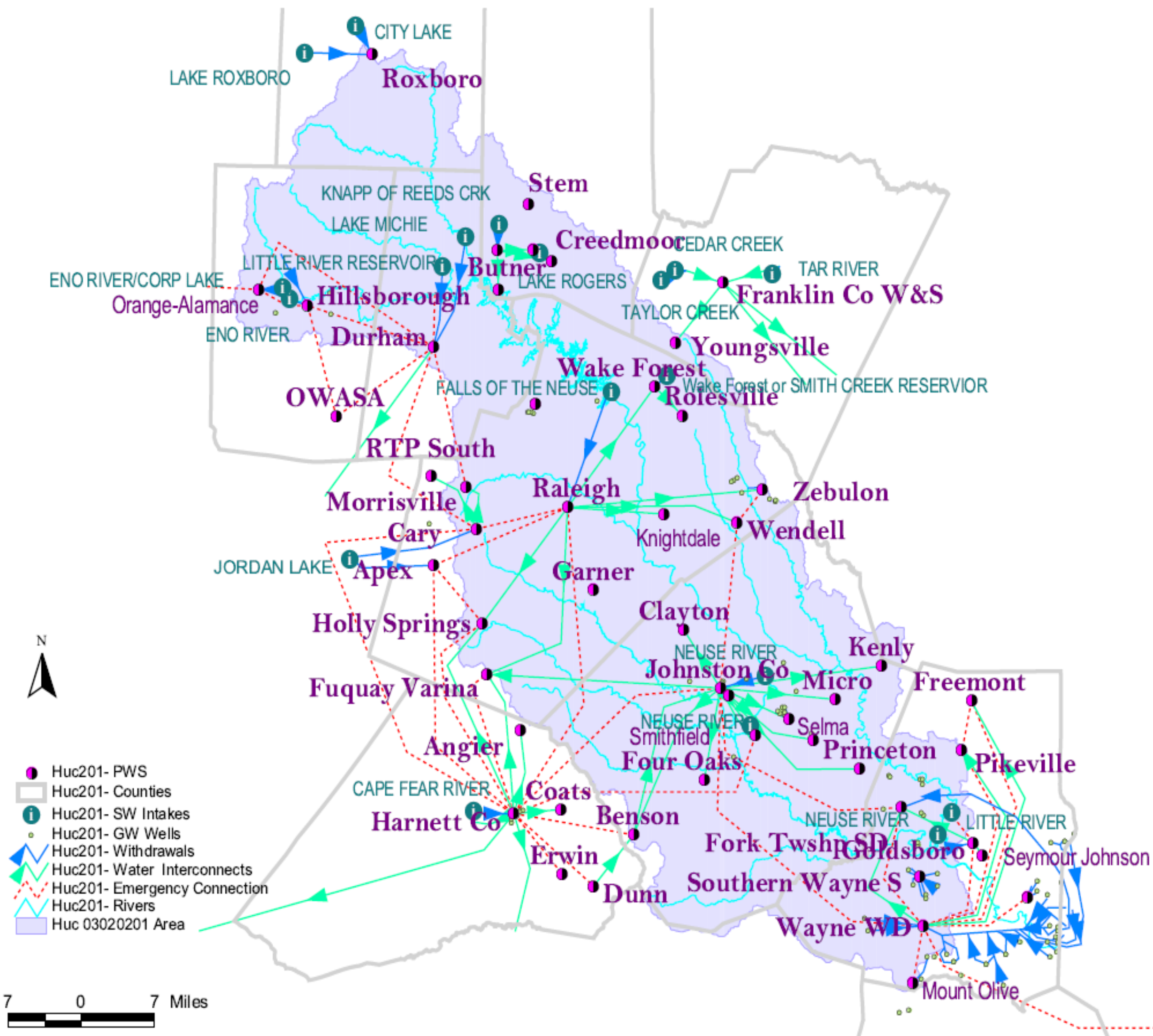
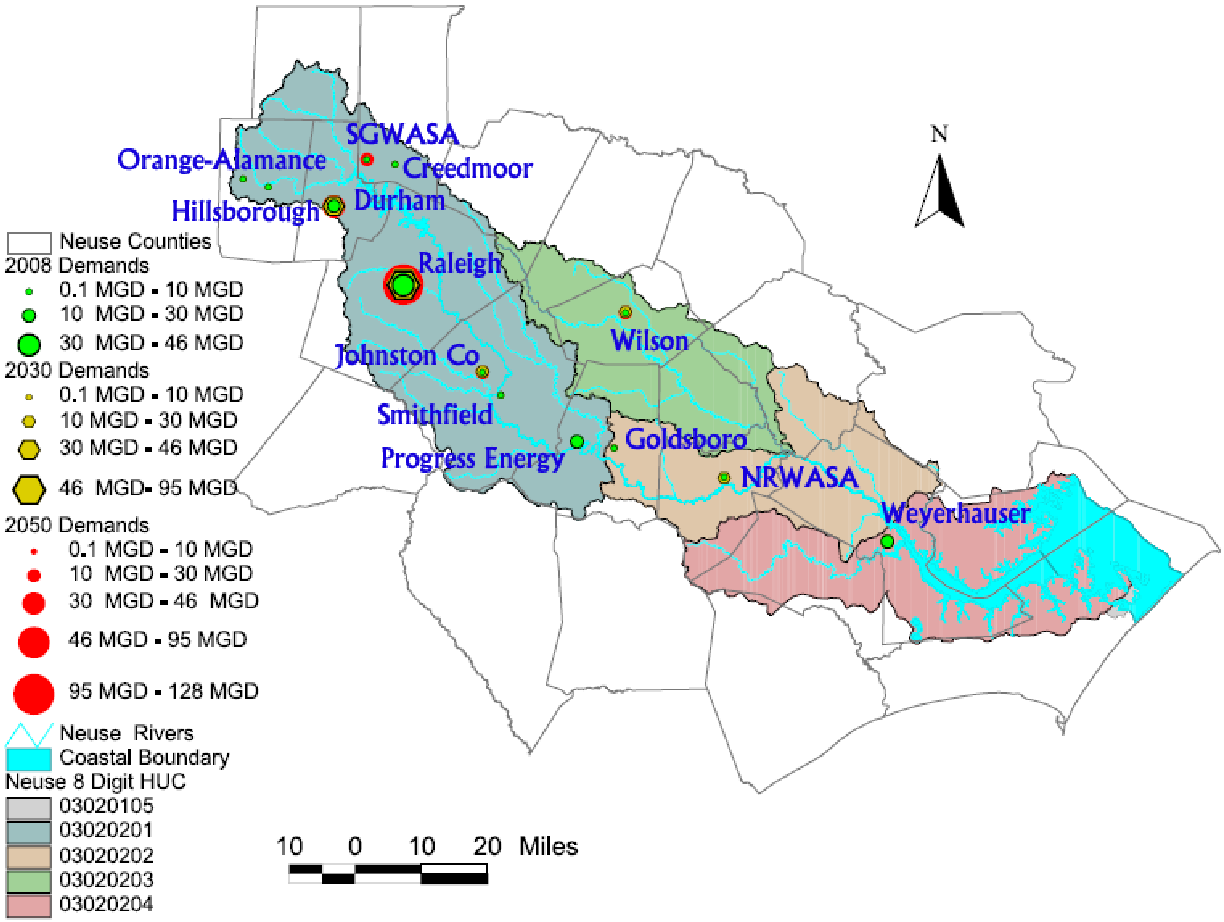


Figure 6-3: Water Demand Increase Comparison for All Three Demand Scenarios



6.1.2 Evaluating Water Supply

Data on current and anticipated surface water withdrawals were compiled from information submitted to the N.C. Division of Water Resources under the local water supply planning and water withdrawal registration programs. These data were supplemented as needed by collecting additional data. Data on surface water withdrawals and expected future water demands were integrated into the Neuse River Basin Hydrologic Model. The model provides a tool to identify areas in the basin where there may be difficulty satisfying the desired levels of surface water withdrawals. The model is a computer-based mathematical model of water flow in the basin from the headwaters above Falls Lake downstream to New Bern. It is a water quantity model that evaluates changes in water quantity at designated locations in the basin. The points in the model where data enters, or where mathematical evaluations of conditions are performed, are referred to as model nodes. A model node may represent a withdrawal for an offstream use such as a local municipality, an inflow such as a discharge from a water reclamation facility, a reservoir where water is stored for later release, or water flowing in from a tributary stream. The model evaluates inflows and outflows at nodes of interest and the result at a node becomes an input to the equation describing conditions at the next downstream node.

The model is based on 78 years of data describing the hydrologic conditions in the basin. A model run evaluates the mathematical equation describing conditions at each node and produces a set of solutions for each day in the 78 annual flow patterns in the historical record from 1930 to 2008. The range of conditions included in this record encompasses dry, normal and wet conditions, including the recent extreme droughts. Each model run evaluates the ability to satisfy the levels of water demands against the amount of water available for each day in each annual flow pattern. The Neuse River Basin Hydrologic Model is designed to replicate water management decisions and operational protocols to realistically mimic water resource conditions in the basin. Chapter 5 of this document describes the model and the modeling process in more detail.

The following sections provide more detailed discussions of the results of this analysis for the major water supply sources in this watershed as well as other existing and potential issues that must be considered when planning for long-term water supply needs.

6.1.3 Falls Lake Reservoir

Falls Lake Reservoir Operation

Falls Lake has been managed by the U.S. Army Corps of Engineers since its completion in 1981. It was authorized by the U.S. Congress to provide for water supply, recreation, flood control, fish and wildlife management, and downstream flow augmentation. Raleigh contracted for the water supply storage in the reservoir and therefore has exclusive use of this portion of the storage. As is typical for multi-purpose reservoirs, the storage volume of the impoundment is divided into individually managed theoretical pools that are delineated by elevation above mean sea level. The normally empty flood control storage lies above the conservation pool, which provides storage for water supply and downstream flow augmentation. The space below the conservation pool is designated as the sediment pool. The storage in the sediment pool is reserved to compensate for volume lost due to the accumulation of sediments over the life of the project.

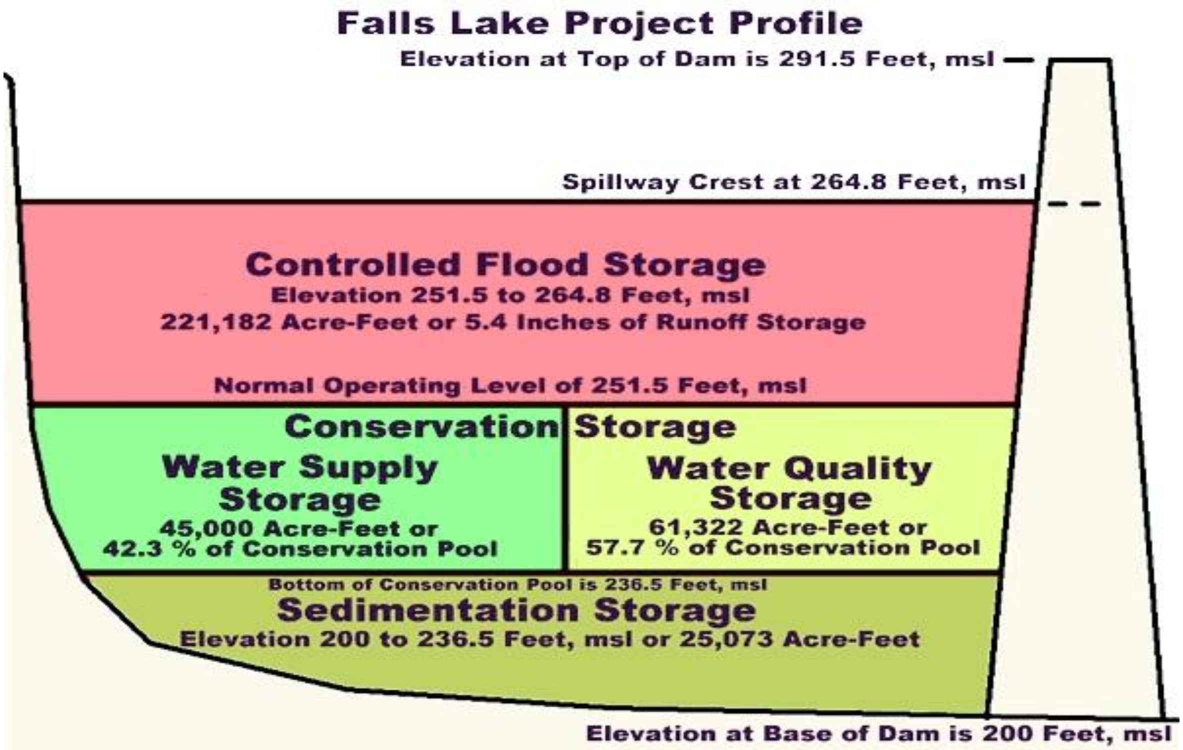
The usual operating level of 251.5 feet above mean sea level defines the top of the conservation pool. The normally empty space above the conservation pool, between 251.5 feet and 264.8 feet, is dedicated to controlled flood storage. It can store 221,182 acre-feet of water, the release of which can be controlled to reduce downstream impacts from flooding. The water level last approached the upper limit of controlled flood storage on October 1, 1999 in the aftermath of a series of tropical storms during August and September. At this upper elevation, the surface of Falls Lake covers 12,410 acres.

The space between 236.5 feet and 251.5 feet is the conservation pool, which contains 106,322 acre-feet of water storage for public water supply and downstream flow augmentation. Raleigh's water supply is 42.3 percent of the water in the conservation pool, and the remaining 57.7 percent is managed by the U.S. Army Corps of Engineers to maintain downstream flows. When full, Raleigh's water supply storage contains about 15 billion gallons of water.

The Corps of Engineers manages water releases from the project to equal or exceed downstream flow targets at the U. S. Geological Survey stream gage at Clayton. Table 6-2 below summarizes these requirements. The flow augmentation pool, sometimes referred to as the water quality pool, can hold an estimated 61,322 acre-feet of water. The volume of water remaining in the water supply pool and the water quality pool is tracked daily using standard accounting principles.

The sediment pool is the portion of the reservoir below the conservation pool between the bottom at 200 feet and 236.5 feet. The amount of storage available in the sediment pool is approximately 25,073 acre feet.

Figure 6-4: Falls Lake Storage Volume Allocation



In general, releases from the lake depend on the amount of water flowing into the river between the dam and the U.S. Geological Survey stream gage at Clayton and the amount of water remaining in the water quality pool. Under normal conditions, water is released, if needed, to meet the ranges of daily average flows shown in the table below.

Table 6-2: Falls Lake downstream target flows

Months of the year	Immediately below Dam	USGS gage at Clayton
Nov -Mar	40-65 cfs, 26-42 mgd	184 cfs, 119 mgd
Apr -Oct	100 cfs, 65 mgd	254 cfs, 164 mgd.

cfs = cubic feet per second
mgd = million gallons per day

If inflows to Falls Lake are not sufficient to replace the water lost through evaporation and removed for water supply and flow augmentation, then the available supply in the conservation pool declines. If dry conditions continue and the conservation pool continues to decline, normal operations may be adjusted to preserve the supply of water. Raleigh will ask its customers to reduce their water use so the utility can reduce withdrawals from the water supply pool. Downstream releases may be reduced if that can be done without producing detrimental effects on downstream water quality. The U.S. Army Corps of Engineers is in the process of reviewing a draft drought management protocol that, if approved, will establish a protocol on how normal operations will be altered during drought periods.

Modeling Falls Lake

The following sections present results of modeling the demand scenarios used in this analysis. The complete results are shown in several different presentation formats to aid understanding and can be found on the division's website, www.ncwater.org.

a) Elevation Profile

This assessment evaluates three demand scenarios over the range of flows experienced in the hydrologic unit from 1930 to 2008. The 2008 demand levels are used to represent current conditions or the base case against which other scenarios are compared. The water withdrawals necessary to meet the estimated demands for water in 2030 and 2050 are modeled to provide information on what near-term and long-term conditions may look like. Figure 6-5 shows how reservoir water levels vary under the three different demand scenarios modeled. As expected, water levels in the reservoir decline further during periods of low inflows, as water withdrawals increase to meet growing customer demands.

The model predicts that the reservoir could reach a minimum water level of about 240 feet, which is under the 2050 demand scenario, during a recurrence of the hydrologic conditions experienced during the 2002 and the 2007-08 droughts. These two periods are the driest on record in this basin. As part of this analysis, hypothetical flow conditions were created to simulate conditions in the future if the basin experiences drier conditions than have occurred in the past. This scenario used the 2050 demand estimates and reduced all inflows by 10 percent. As expected, the model predicted that the reduced water availability would result in lower water levels in Falls Lake during drought conditions.

Figure 6-6 shows modeled water levels in Falls Lake predicted under this 10 percent inflow reduction scenario. The model predicts minimum water levels of about 236 feet if inflows are 10 percent less than the level of inflows during 2002. If inflows were 10 percent less than the 2007-08 drought conditions, then the minimum water level in Falls Lake could reach 238.5 feet above mean sea level.

The current version of the Neuse River Basin Hydrologic Model does not contain a drought protocol that reduces downstream releases and water supply withdrawals in response to declining storage. With no built-in drought protocol the model predicts possible conditions if no accommodations are made for worsening drought conditions. In reality, when storage is being depleted during droughts, Raleigh will implement its water shortage response plan to reduce water withdrawals and the Corps of Engineers, in consultation with state agencies, will reduce releases from the dam. However, at this time and with no approved drought plan, the changes cannot be described mathematically for inclusion in the model.

A draft drought management plan has been developed and is under review by the Corps of Engineers. If a drought protocol is approved, it will be included in the model. Future versions of the model will incorporate, to the extent possible, the individual water shortage response plans adopted by water withdrawers in the watershed. The reader can glean an idea of the potential benefits of a drought management plan by referring to Figure 5-2. This graph plots the actual water levels and the modeled levels in Falls Lake during 2007 and 2008. The higher water levels are the result of the changes to operations made in response to worsening drought conditions. The water levels predicted by the model show what they might have been with no reductions in withdrawals and downstream releases.

Figure 6-5: Falls Lake Elevation Profile for the Three Demand Scenarios

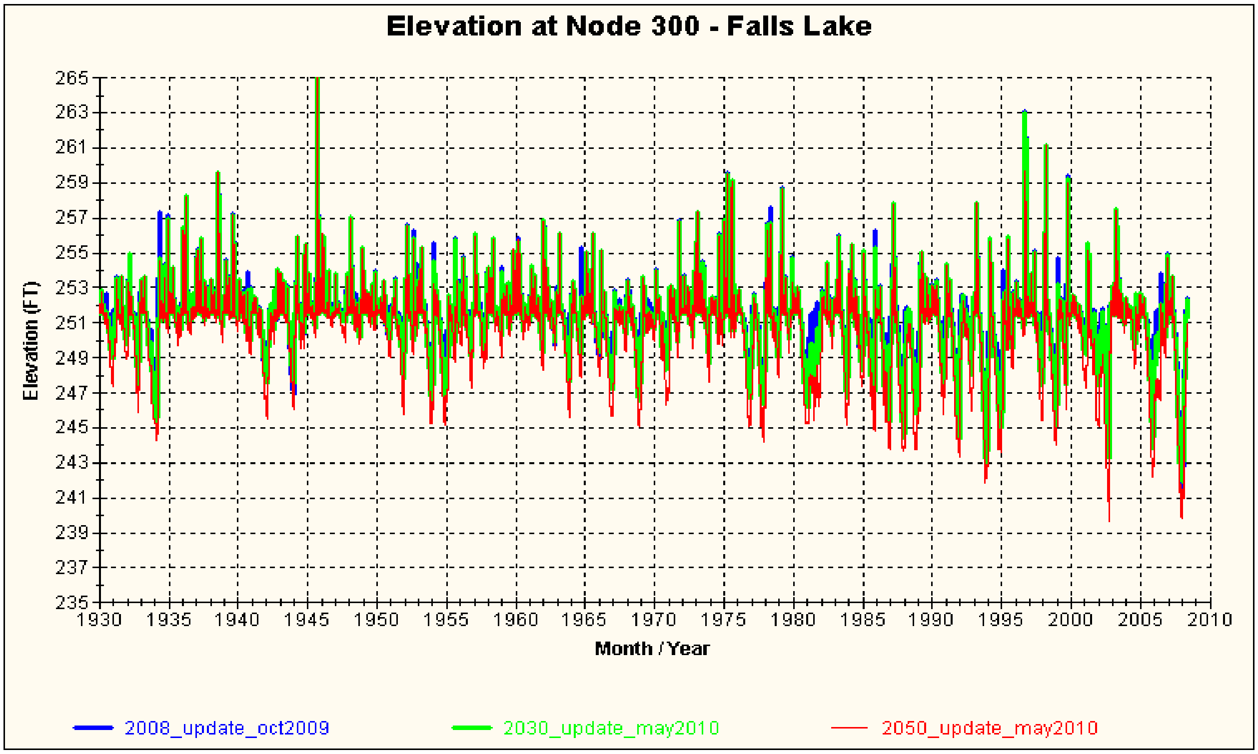
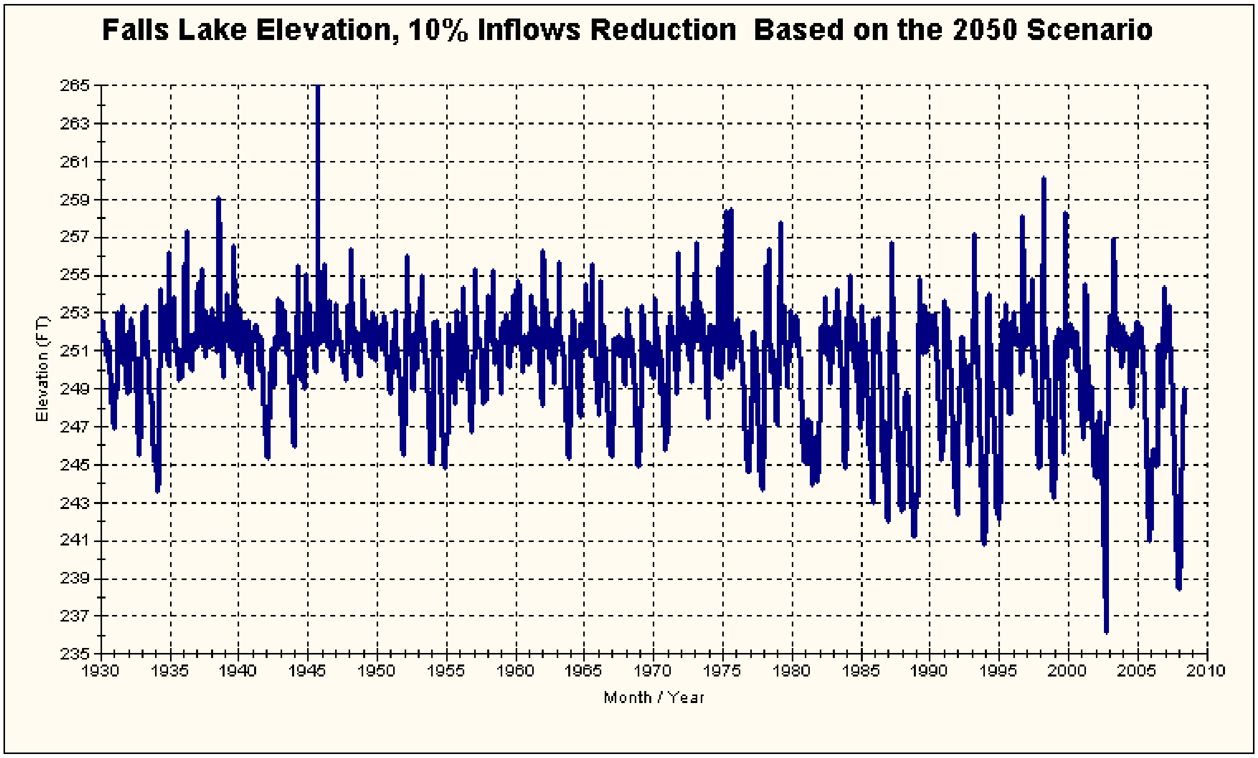


Figure 6-6: Falls Lake Elevation Profile for the Reduced Inflow Scenario



b) Water Supply Pool Profile

Raleigh financed the inclusion of water supply storage during the construction of Falls Lake. Therefore, Raleigh enjoys the exclusive use of the water supply storage, and it is the major water source for the city. In 2010, the city brought online a new 20 million gallons per day, or mgd, water treatment plant that treats water from its former sources on Swift Creek. In the 2008 demand scenario, the base case, Raleigh's average daily withdrawal from Falls Lake is 45 mgd. In the 2030 demand scenario, the average daily withdrawal increases to 92.5 mgd and it grows to 128 mgd in the 2050 demand scenario.

The percentages of storage remaining in the water supply pool, during each of the annual flow patterns, for the water withdrawals specified in the 2008, 2030 and 2050 demand scenarios, are shown in Figure 6-7. As expected, the percent of remaining water supply storage is lower for most annual flow patterns as water-supply withdrawals increase.

For the 2008 demand scenario, the model predicts that the water supply pool could decrease to 30 percent full with a repeat of flow conditions seen during the 2007 drought. Under the 2030 demand scenario, the model predicts that the water supply pool could be depleted during a repeat of the flow conditions experienced in 1936, or in a repeat of the hydrologic conditions experienced during the 2007 drought. The predicted occurrences of total depletion of the water supply pool increase significantly under the 2050 demand scenario. To reduce the occurrences of water shortages in the future, Raleigh will need to use its current supply more efficiently, manage the growth of water demand and probably develop new sources of water.

Figure 6-8 shows that reducing water inflows to 90 percent of the historical inflows under 2050 demands could be expected to impact the water supply pool by reducing it between 2 percent and 10 percent during droughts. Under this scenario, the water supply pool could be depleted more times and for longer periods of time.

Figure 6-7: Falls Lake Water Supply Storage Profile for the Three Demand Scenarios

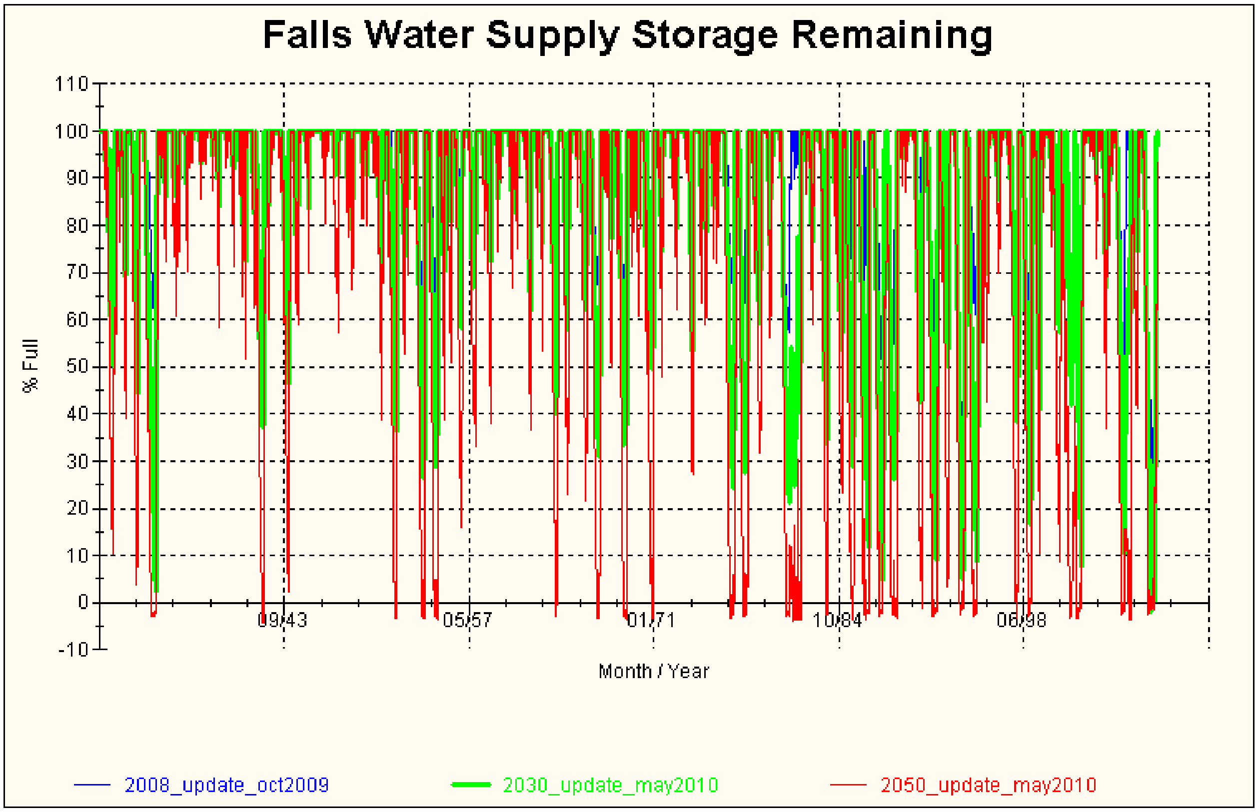
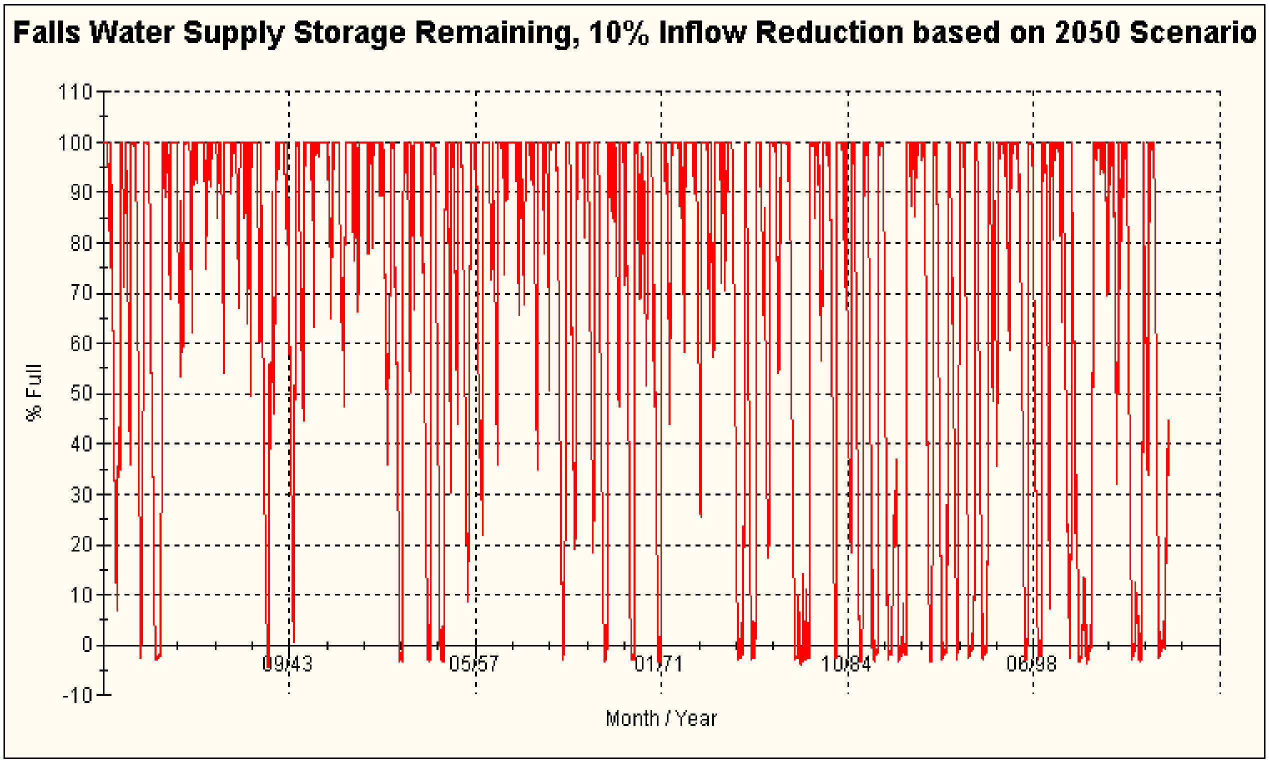


Figure 6-8: Falls Lake Water Supply Storage Profile for Reduced Inflow Scenario

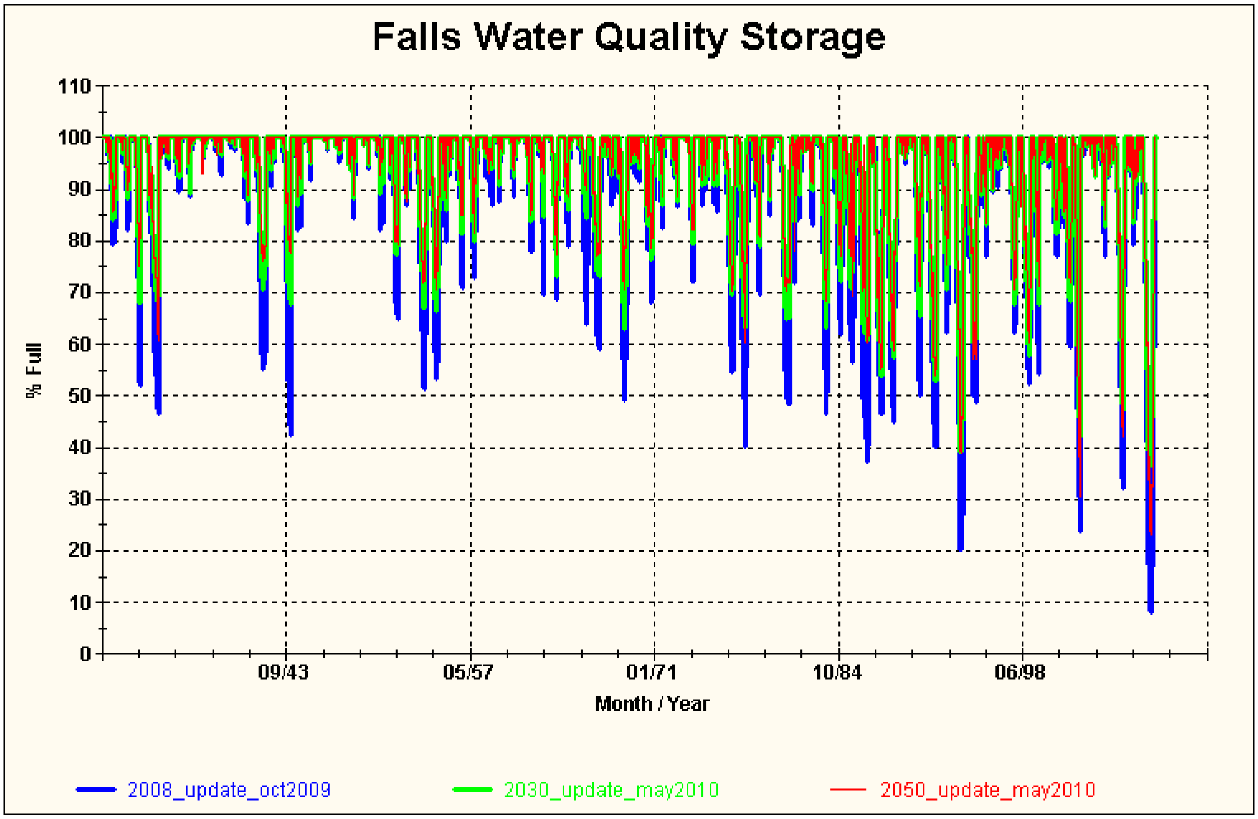


c) Flow Augmentation Pool Profile

Figure 6-9 shows the percentages of storage remaining in the water quality or flow augmentation pool of Falls Lake, over the range of annual flow patterns and the three demand scenarios modeled. The periods when the flow augmentation pool is drawn down the most significantly, do not occur in the 2050 or the 2030 demand scenarios, but rather under the 2008 demand scenario. The lowest expected level predicted by the model is around 9 percent remaining under the hydrologic conditions experienced during the 2002-03 droughts. There were no expected occurrences of the flow augmentation pool being below 20 percent full under the 2030 or 2050 demand scenarios.

Wastewater discharges for Raleigh are expected to increase in the future. Much of the discharged wastewater is expected to flow past the Clayton stream gage and therefore reduce the amount of water that must be released from Falls Dam to meet the target flow at Clayton. Since water released from the dam to meet the Clayton target comes out of the flow augmentation pool, the increased future discharges will relieve stress on the flow augmentation pool. Therefore, as Raleigh uses more water in the future their wastewater discharges are expected to increase. This will reduce the releases from the flow augmentation pool that are required to meet the instream flow target at Clayton during periods of low natural inflows between the dam and the gage.

Figure 6-9: Falls Lake Water Quality Storage Profile for the Three Demand Scenarios



d) Water Level Duration Curves

A duration plot shows the percentage of time the water level will be at or below a certain elevation shown on the left side of the plot. Duration plots provide another way to look at the variations in Falls Lake water levels predicted by the model for the various levels of demands in the 2008, 2030 and 2050 demand scenarios. Duration plots for the three demand scenarios analyzed are shown in Figure 6-10.

The normal operating elevation of Falls Lake is the top of the conservation pool at 251.5 feet. Water stored in the 13.3 feet above this elevation during high flow events can be released in a controlled way. Above 264.8 feet mean sea level, or msl, water flows freely over the emergency spillway into the Neuse River. The plots in Figure 6-11 also show the reservoir elevations below which the use of boat launching facilities on Falls Lake may be limited. Having accurate elevation data for recreational facilities makes it possible to use the model to indentify how the increasing water withdrawals for public water supplies may limit recreational access to reservoirs. Of the nine boat ramps in Falls Lake, model results indicate that the use of those with minimum operating elevations 240 feet above mean sea level may be limited for some percentage of time over the range of flows experienced since 1930. Figure 6-10 and 6-11 show the percentage of time that water levels in the reservoir are at or below specific elevations. Under the 2008 demand scenario, about 30 percent of the time the conservation pool is less than full. For the 2050 demand scenario, the amount of time the conservation pool is not full, increases to about 50 percent of the time and minimum elevation predicted by the model declines an additional two feet.

The model also predicts that the water levels in Falls Lake will be above the normal operations level about 10 percent of the time reflected in the range of flows experienced in the basin since 1930. A major reason for building Falls Lake was to store water during high-flow events so it could be released in a controlled manner to minimize flooding impacts downstream. Figure 6-11 also shows the reservoir elevations below which the use of boat launching facilities on Falls Lake may be limited. Having accurate elevation data for recreational facilities makes it possible to use the model to indentify how the increasing water withdrawals for public water supplies may limit recreational access to reservoirs. Of the nine boat ramps in Falls Lake, model results indicate that the use of those with minimum operating elevations 240 feet above mean sea level may be limited for some percentage of time over the range of flows experienced since 1930. Figure 6-10 indicates that there were hydrologic conditions in the past that could have produced enough flow to completely fill the flood control pool and overflow the emergency spillway. The model predicts that if the hydrologic conditions that occurred in 1945 recur, then Falls Lake's flood control pool may not be adequate to avoid uncontrolled releases into the Neuse River.

Figure 6-10: Falls Lake Elevation Duration Plots up to Normal Elevations for 3 Demand Scenarios

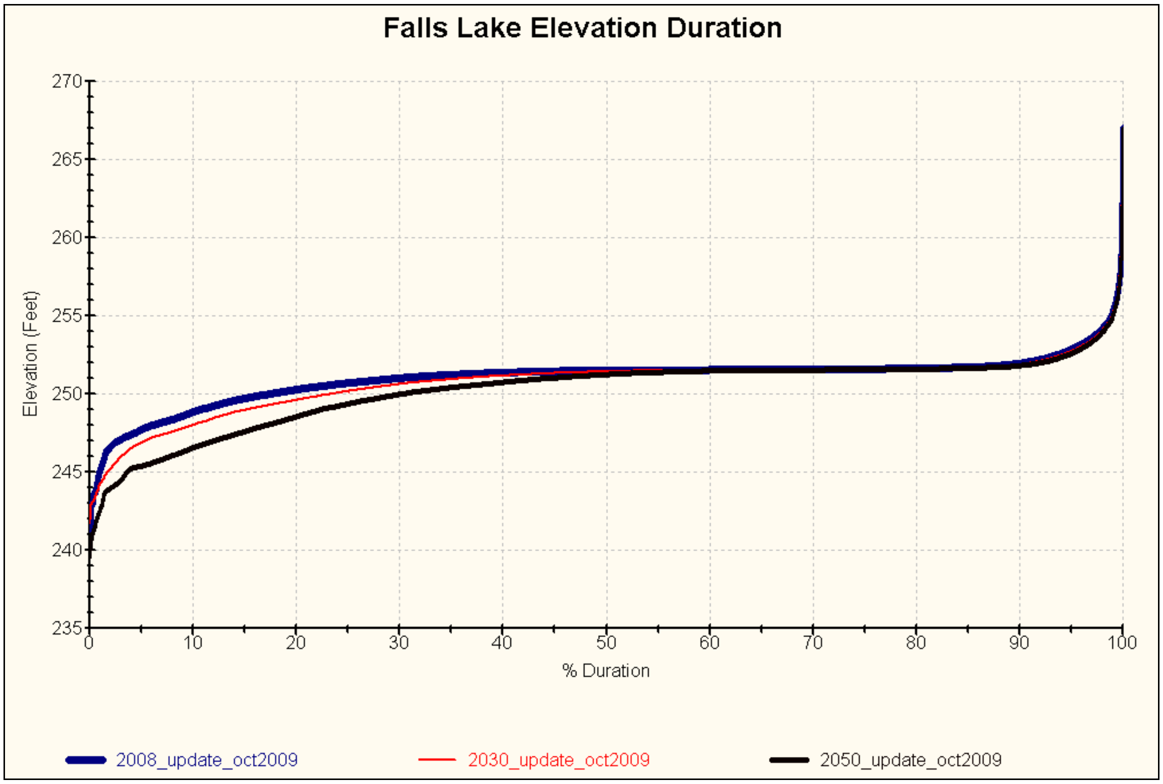
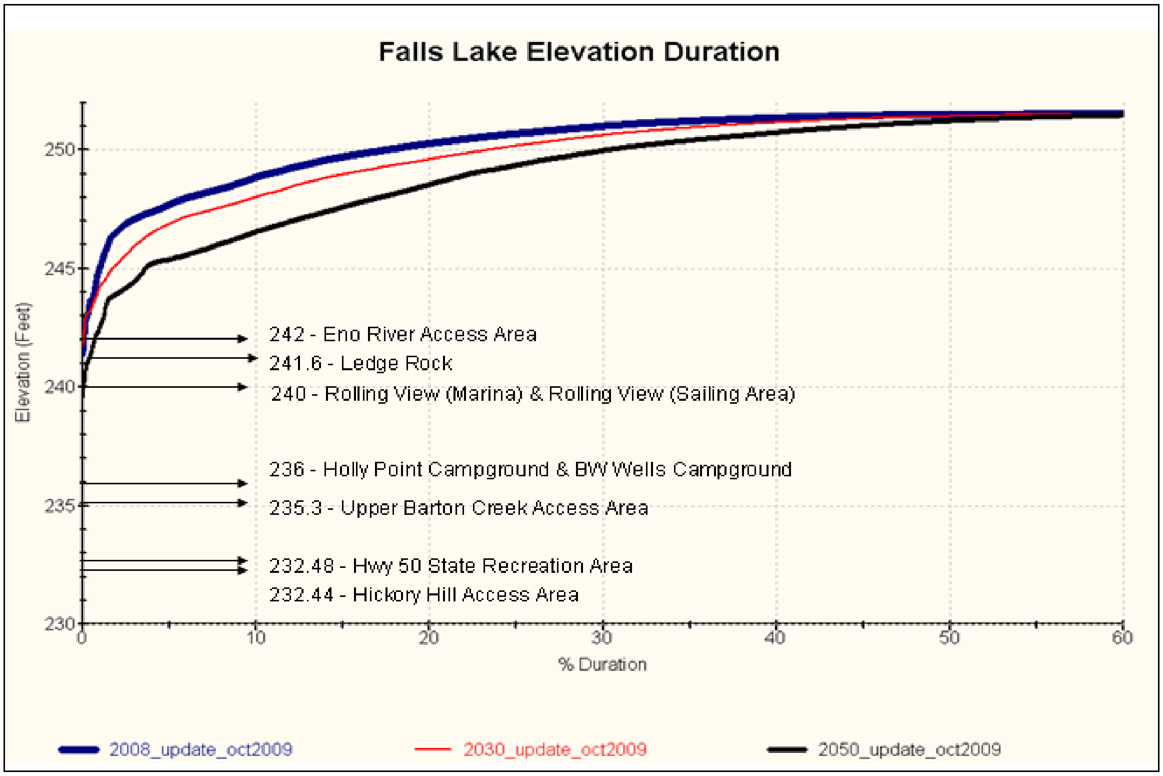


Figure 6-11: Falls Lake Elevation Duration Plots Showing the Impacts on Boat Ramp at Lower Elevations



6.1.4 Modeling the Eno River

Lake Orange and West Fork Eno Reservoir are the major reservoirs on the Eno River watershed. Figure 6-12 below shows the percentage of days in the 78 years of flow records when the predicted water levels for Lake Orange are expected to be at or above the levels marked on the vertical axis of the graph. The model includes the reservoir's drought operation protocol, which is linked to the level of water in the reservoir. Under normal conditions, the water level in the reservoir is maintained at 615 feet above mean sea level; the elevation referred to on the plot as the Upper Rule Curve. The minimum operating elevation or the Lower Rule Curve is at 601.7 feet as shown in Figure 6-12. The three demand scenarios modeled are shown as blue, red and black lines for 2008, 2030 and 2050, respectively. In the three simulation runs, the minimum water level approached the minimum operating elevation. Under the 2008 demand scenario, the model indicates the water level could be below the normal pool elevation about 50 percent of the time. Over the range of historical flows used in the model, for the 2030 and 2050 demand scenarios the model predicts that the water levels could be less than full about 65 percent of the time.

The Eno River Water Management Plan defines minimum releases from Lake Orange and the West Fork Eno Reservoir and limits allowable water withdrawals. It defines a six-tiered protocol that adjusts these quantities based on the volume of water remaining in Lake Orange. Figure 6-13 shows the threshold levels on a duration plot of percent of storage in Lake Orange. It illustrates the percentage of time each of the tiered stages could be experienced under each of the three demand scenarios. The plots show the ranges of the six stages of the water management plan. For example, the model indicates that as water withdrawals increase the time Lake Orange may be in Stage 3 conditions could increase from about 12 percent, under the 2008 demand levels, to around 20 percent under the 2030 and 2050 demand scenarios. In general, it appears that as water withdrawals increase, the water level in the reservoir will spend more time at lower elevations.

Figure 6-12: Lake Orange Elevation Duration Curve

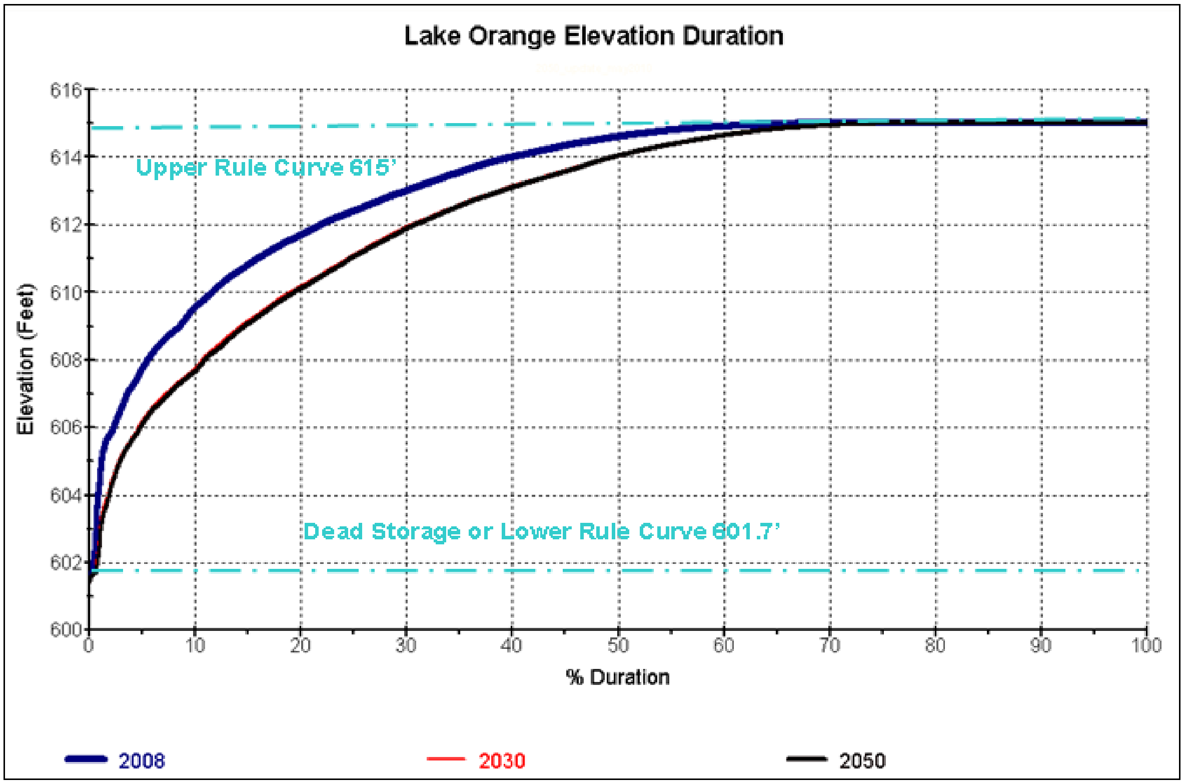
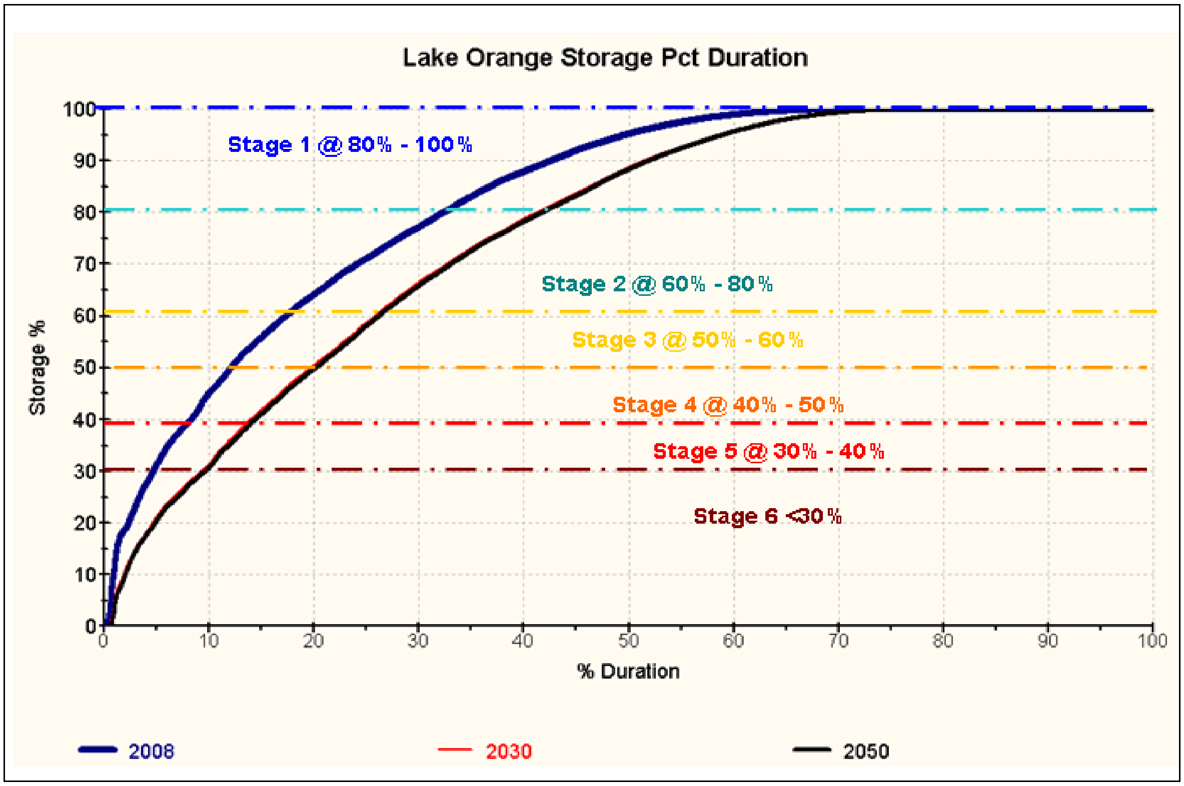
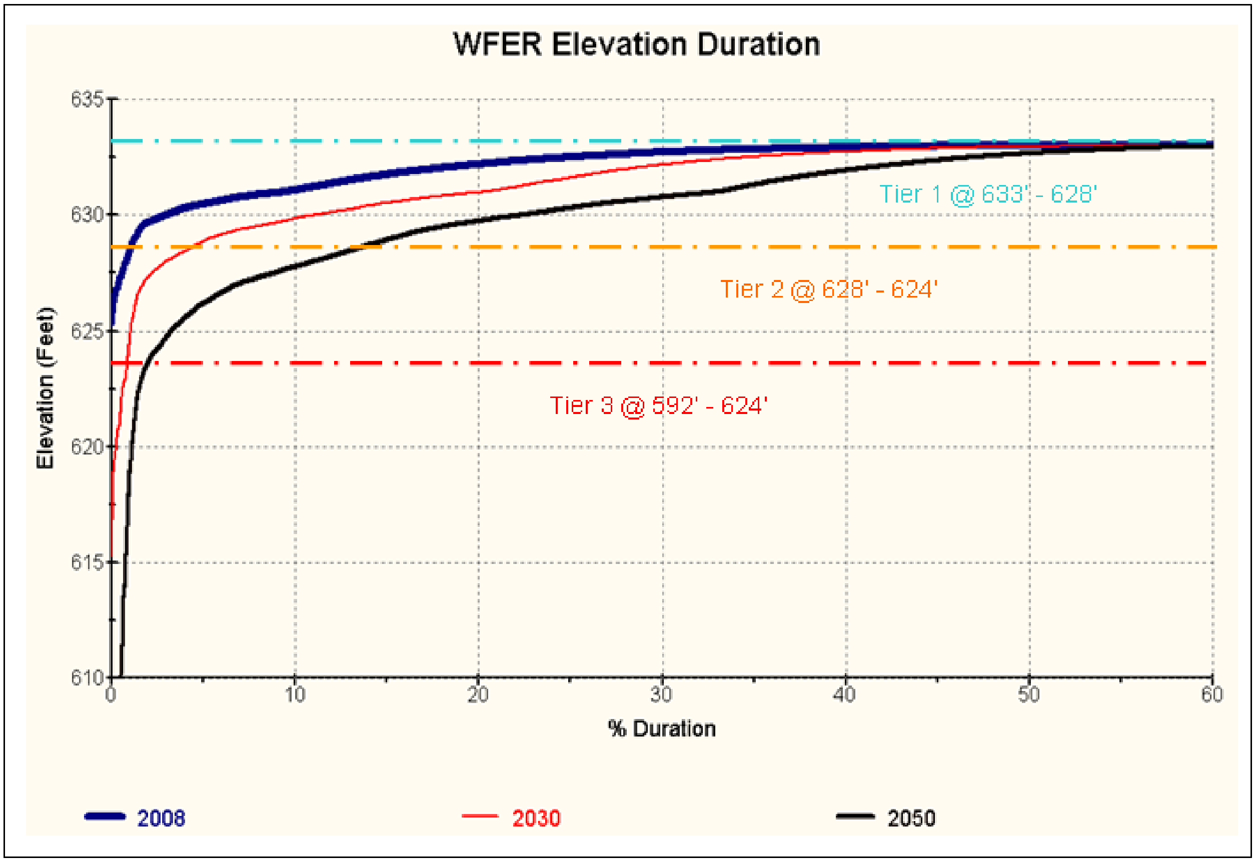


Figure 6-13: Lake Orange Storage Percent Duration Curve



The West Fork Eno Reservoir has required downstream release protocols based on the reservoir water level that is part of the reservoir's dam safety permit. These requirements are built into the model. Figure 6-14 shows how long the model predicts the water levels in the reservoir will be at specific elevations. The figure also shows the amount of time water levels are predicted to be below each of the three trigger elevations of 633 feet, 628 feet and 624 feet for Tier 1, Tier 2 and Tier 3, respectively. At the level of withdrawals specified in the 2008 demand scenario, the model predicted that Tier 2 would be triggered about 1 percent of the time and did not indicate that water levels would reach the Tier 3 threshold. On the other hand, Tier 3 was triggered about 1 percent of the time for the 2030 demands and about 3 percent of the time for the 2050 demands scenario. While these modeled water levels are not definitive, they do provide useful information for parties that may be impacted by changes in water levels in these reservoirs.

Figure 6-14: West Fork Eno Reservoir Elevation Duration Curves



6.1.5 Future Shortages

As was mentioned in Chapter 4, the model predicts that the full water supply demands could not be met from existing sources for the levels of demand in the 2030 demand scenario for the Durham and Raleigh water systems over the range of flows experienced since 1930.

Table 6-3: Water Supply Demand Deficits Predicted by the Model for the 2030 Scenario

Water System	2030 Average Demand (mgd)	2030 Average Deficit (mgd)	Longest Deficit (Days)	Years Demand Not Met Out of 78
Durham	35.83	30.31	37	1
Raleigh	86.99	44.55	10	1

Longest Deficit (Days) = The greatest number of consecutive days over the entire 78 year record that the full water supply demand maybe is not met.
Years Demand Not Met = The number of years out of a total of 78 that the full water supply demand maybe is not met.

The South Granville Water and Sewer Authority, Orange-Alamance Water System, Hillsborough and Piedmont Minerals as well as Raleigh and Durham show supply deficits with the level of withdrawals needed for the 2050 demand scenario. In the 2050 scenario, the model predicts the largest water supply deficit for Raleigh's water system. Given the level of expected demands and existing sources of supply, the model predicts potential deficits in 36 of the 78 annual flow patterns modeled. The South Granville Water and Sewer Authority shows deficits for 14 flow years in the 2050 scenario. With the level of demand specified for Durham's system in the 2050 demand scenario, the model predicts supply shortages in five of the 78 annual flow patterns used in the model.

Table 6-4: Water Supply Demand Deficits Predicted by the Model for the 2050 Scenario

Model Scenario Water Systems	2050 Average Demand (mgd)	2050 Average Deficit (mgd)	Longest Deficit (Days)	Years Demand Not Fully Met Out of 78
Orange-Alamance	0.21	0.14	30	2
Hillsborough	2.76	1.84	30	2
Piedmont Minerals	0.25	0.16	30	2
Raleigh	129.23	86.18	124	36
Durham	40.92	29.13	60	5
SGWASA	10.01	8.7	79	14

mgd – million gallons per day

6.1.6 Durham's Water Sources

Durham's main water sources are Lake Michie on the Flat River and the Little River Reservoir on the Little River. Both are in Durham County northwest of the city. Durham has been treating and distributing water withdrawn from the Flat River since 1917. The dam creating Lake Michie was completed in 1926 to store 4.6 billion gallons of water and increase the reliability of supply from the Flat River. The Little River Reservoir, with a capacity of 4.9 billion gallons, has been supplying water to the city's system since 1988. Both of these reservoirs are managed to satisfy public water supply demands. In addition to its two reservoirs, Durham has the ability to pump water directly from the Eno River to supplement their supply. Recently, the city has added the ability to store water from the Eno River in an unused quarry to supplement its existing sources. The integration of the water stored in the quarry was not complete when the model on which this analysis is based was constructed. Therefore, the ability to use water from the quarry is not included in the model.

In addition to the self-managed water sources discussed above, Durham holds a 10 percent allocation of the water supply pool of Jordan Lake. When the Neuse River Basin Hydrologic Model was being developed, this source was not included in Durham's available supply because the system's access to the water in Jordan Lake was not clear. Since that time, connections with Cary's water system have been put in place that will permit Durham to use water from its Jordan Lake allocation. The water stored in the quarry and water available from Jordan Lake will be included in subsequent revisions of the model.

The discussion of Durham's water supply situation in this document is based on the current configuration of the Neuse River Basin Hydrologic Model in which Durham's available supply of water is limited to the storage in Lake Michie and Little River Reservoir. Current work to expand the city's available supply will reduce the frequency and magnitude of potential shortages identified in this analysis.

Three water demand scenarios were modeled. Current conditions were simulated using 2008 water demand levels. Possible future conditions were characterized using the levels of withdrawals needed to meet estimated water demands in 2030 and 2050. These levels of demands may be reached before or after the specified years. However, using them provides a picture of what conditions could be 20 years in the future and 40 years in the future.

The model predicts that, as water withdrawals increase in the future, the amount of water in Durham's reservoirs will spend more time at lower levels. Figure 6-15 and Figure 6-16 below show the percentage of time the reservoir water levels are predicted to be at the elevations on the vertical scales under the three demand scenarios. These graphs indicate that the model predicts the depletion of available water supply in the reservoirs given the levels of demand used in the 2030 and 2050 demand scenarios.

Figure 6-17 and Figure 6-18 show the impacts of increasing water withdrawals in the context of the percentage of storage remaining in the reservoirs during each of the 78 annual flow regimes experienced in the basin between 1930 and 2008. These graphs clearly show the model predictions that the reservoirs could be depleted if conditions seen in the some of the driest years in the past recur.

Figure 6-15: Lake Michie Water Levels

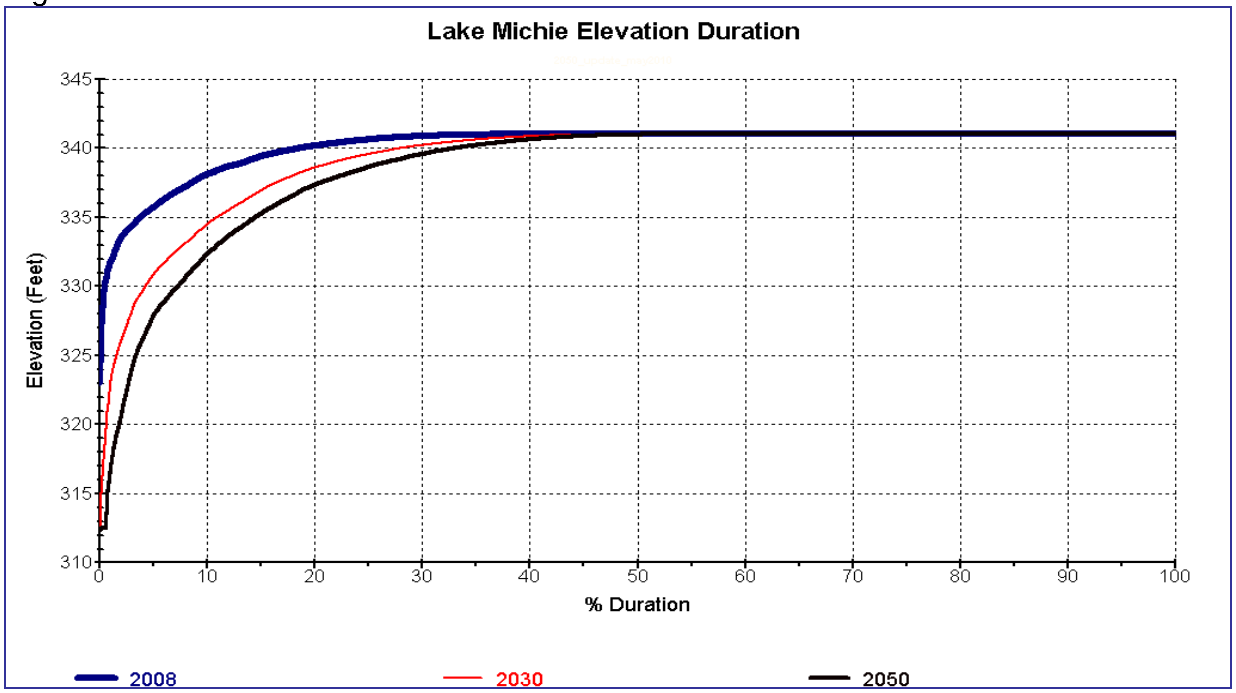


Figure 6-16: Little River Reservoir Water Levels

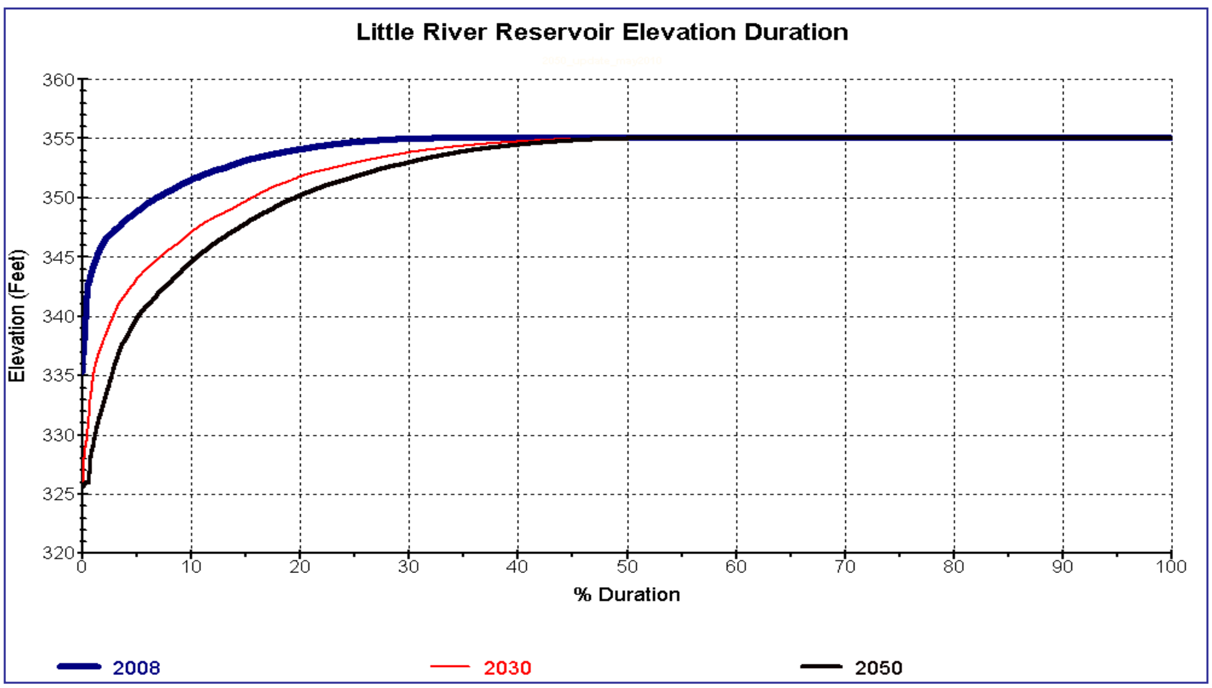


Figure 6-17: Lake Michie Percent of Storage Remaining

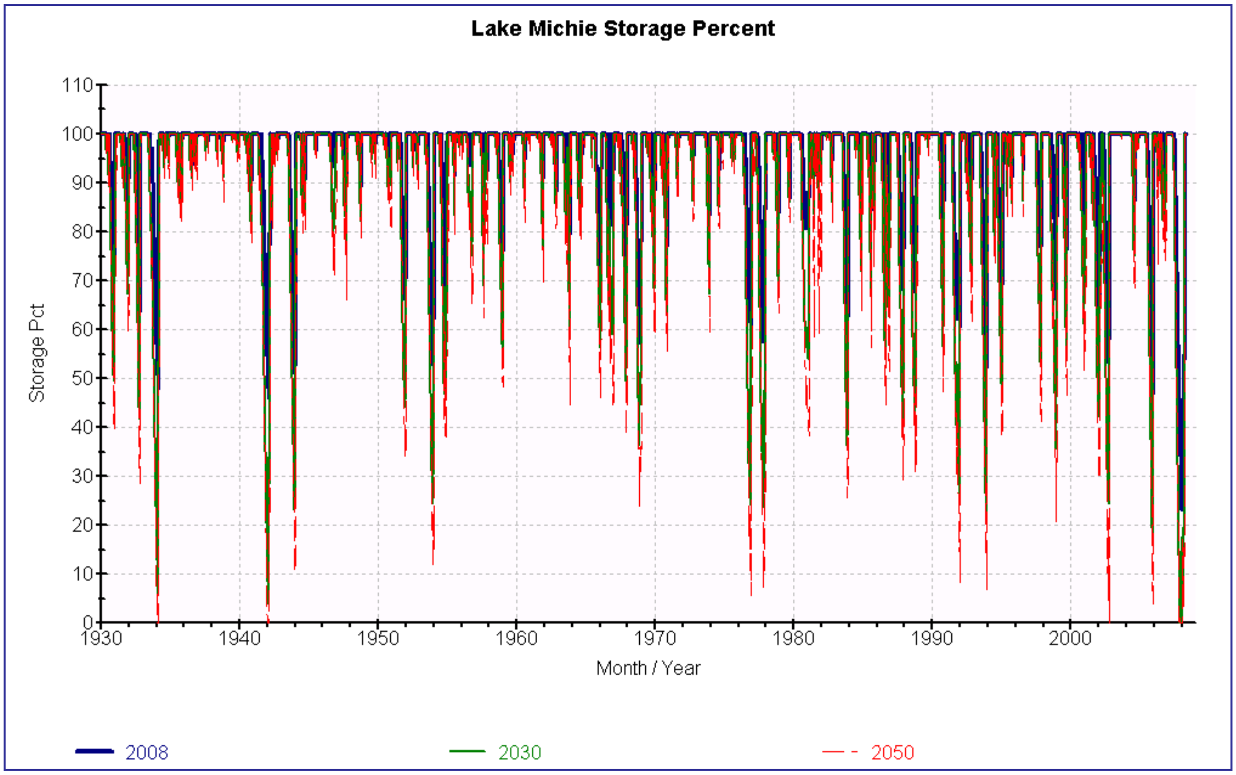
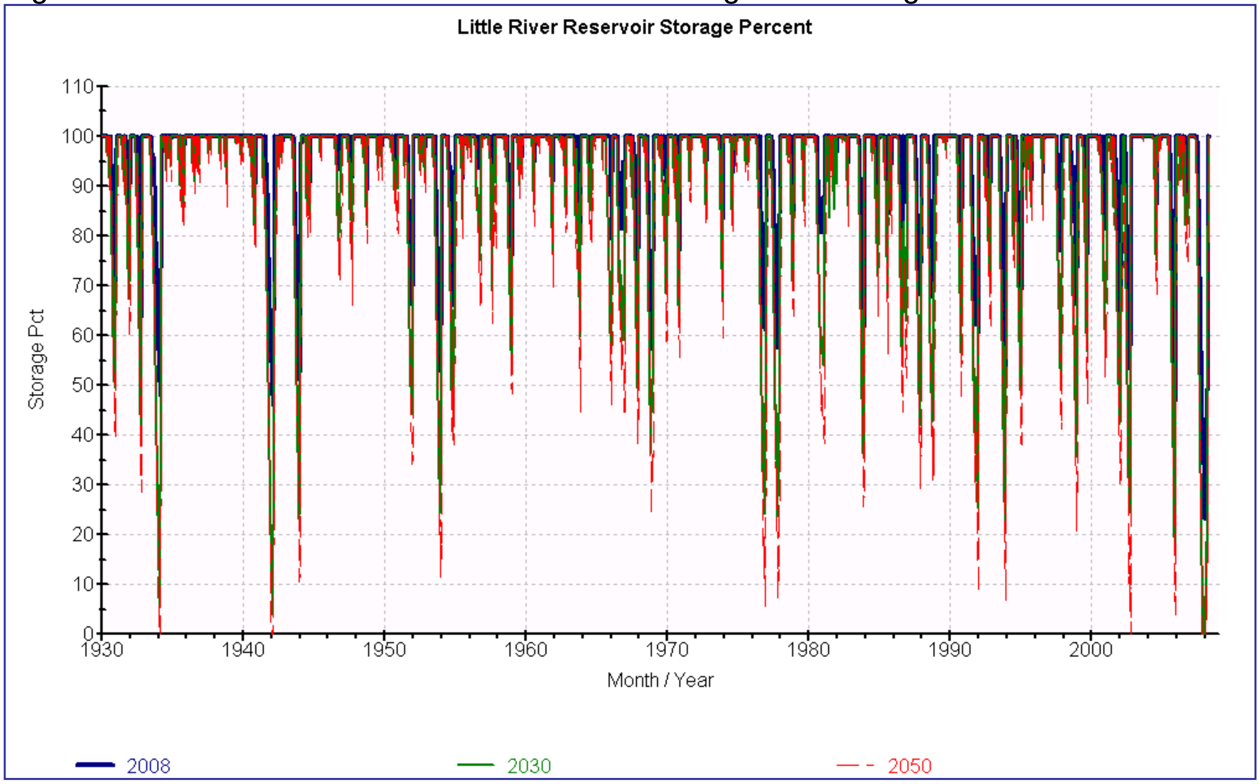


Figure 6-18: Little River Reservoir Percent of Storage Remaining



6.1.7 Surface Water Transfers

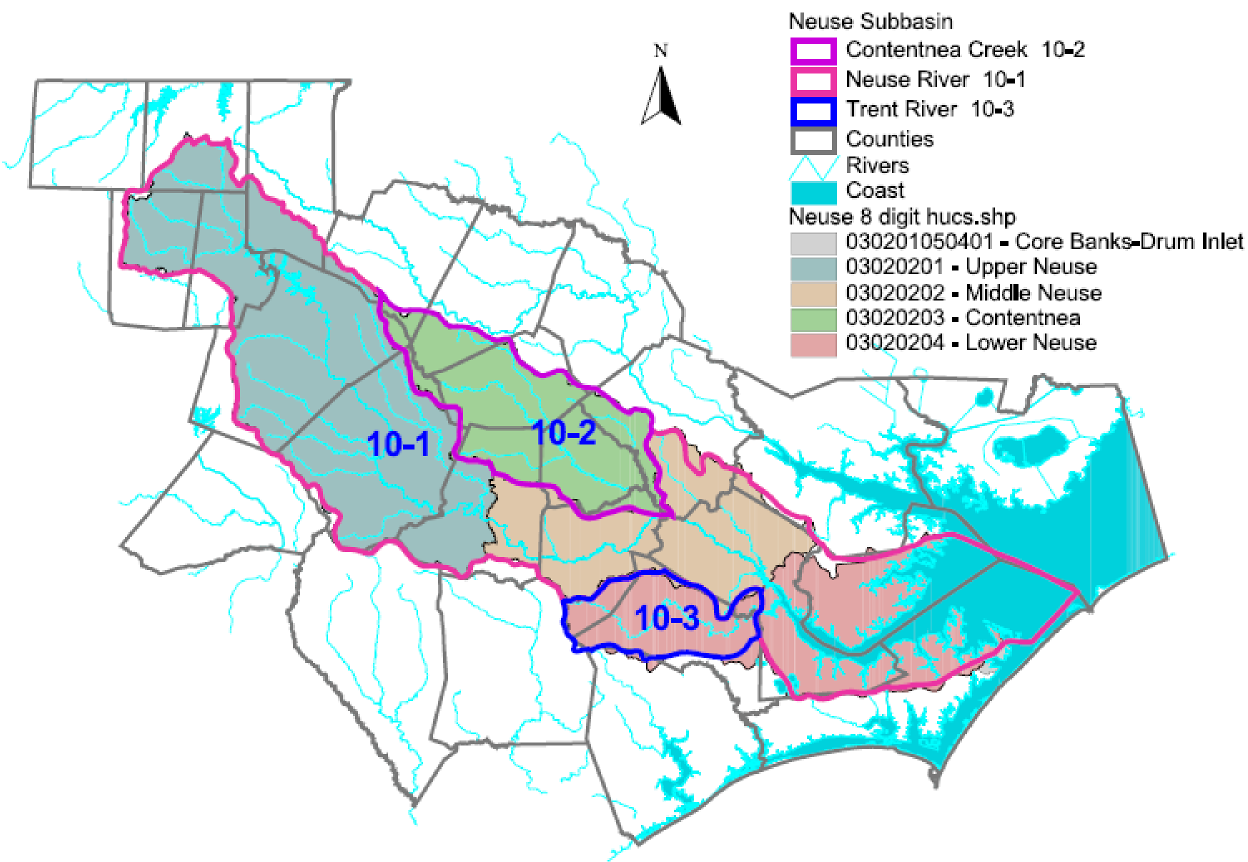
Many cities and towns in North Carolina were originally built along the high ground or ridgelines to avoid floods. As these communities developed, they grew to straddle multiple river basins. A transfer is created when surface water is withdrawn from one river basin and not returned to the basin of origin. As the volume of water transferred increases, the potential for detrimental environmental impacts also increases. In 1993, the General Assembly decided that surface water transfers should not increase to more than two million gallons per day without an evaluation of the associated beneficial and detrimental impacts. Many public water systems straddle river basin boundaries and rely on transferring surface water to provide drinking water to their customers and dispose of their customers' wastewater. As North Carolina's population has grown, many public water systems have merged to control costs, improve operations and improve reliability. Increased reliance on regional rather than local water sources has also resulted in more water systems relying on surface water transfers to meet their customers' water demands.

In 1993, the North Carolina legislature adopted the Regulation of Surface Water Transfers Act (G.S. §143-215.22I). The law regulates large surface water transfers between river basins by requiring approval from the state Environmental Management Commission. The act has been modified several times since it was first adopted, most recently in 2007. In general, certificates are required for new transfers of two million gallons per day or more. Surface water withdrawers are allowed to transfer the full capacity of facilities that existed or were under construction before July 1, 1993 without obtaining a certificate. That capacity to transfer is referred to as the withdrawers "grandfathered" capacity. The statute divides the state into 38 unique river basins that define the geographic boundaries used to calculate transfers with respect to the law's requirements. More information on current interbasin transfers, or IBTs, governing regulations, and the approval process can be found on the N.C. Division of Water Resources' website at www.ncwater.org/Permits_and_Registration/Interbasin_Transfer/

The 38 legislatively defined river basins used to evaluate transfers, under the Regulation of Surface Water Transfers Act, do not correspond to the 17 major river basins used for planning purposes by the N.C. Department of Environment and Natural Resources or the hydrologic units used for the analysis of water resource management issues discussed in this document. Figure 6-19 below shows the river basin boundaries used for evaluation of surface water transfers in relation to the hydrologic units used for this analysis and the larger Neuse River basin that forms one of the17 planning basins. Within the larger Neuse River basin, there are three legislatively defined basins designated for evaluation of surface water transfers. The relationships of the various designations are shown in the table below and the boundaries of the legislatively defined basins are shown in Figure 6-19.

IBT Basin Designation	IBT Basin Name	Hydrologic Unit
10-1	Neuse River	03020201, 03020202, and lower portion of 03020204
10-2	Contentnea Creek	03020203
10-3	Trent River	Upper portion of 03020204

Figure 6-19: Neuse IBT Basin Boundaries over eight-digit HUCs



In the Neuse River basin, several water systems depend on surface water transfers to meet customer's demands. However, most of these systems have a maximum daily transfer of less than two million gallons per day and are therefore not subject to approval by the Environmental Management Commission. Table 6-5 lists the significant water transfers affecting the Upper Neuse watershed. Withdrawers transferring more than two million gallons per day of surface water are discussed in more detail below.

Table 6-5: Surface Water Transfers in HUC 0302020

Hydrologic Units	Water System	Source Basin	Receiving Basin	Maximum Transfer (in mgd**)
03020201	Durham	Neuse River (10-1)	Haw River (2-1)	29.2
03020201	Orange Alamance WS	Neuse River (10-1)	Haw River (2-1)	< 2
03020201 / 03020203	Raleigh	Neuse River (10-1)	Contentnea Creek (10-2)	< 2
03020201	Fuquay-Varina	Neuse River (10-1)	Cape Fear River (2-3)	< 2
03020201	Holly Springs	Neuse River (10-1)	Cape Fear River (2-3)	< 2
03020201 / 03020203	Zebulon	Neuse River (10-1)	Contentnea Creek (10-2)	< 2
03030002 /03020201	Cary/Apex/Morrisville	Haw River (2-1)	Neuse River (10-1)	22.4
03030004 /03020201	Dunn	Cape Fear River (2-3)	Neuse River (10-1)	< 2
03020101 and 03010102 to 03020201	Franklin Co	Roanoke River (15-1)	Neuse River (10-1) and Tar River (14-1)	*

* This water system has requested an interbasin transfer certificate. The certificate has not yet been approved. For more information, please see the division's website at http://www.ncwater.org/Permits_and_Registration/Interbasin_Transfer/

** mgd – million gallons per day

City of Durham

Forty-five percent of Durham's service area is in the Neuse River basin (10-1) with 55 percent in the Haw River basin (2-1). Prior to 1993, Durham's only water sources were in the Neuse River basin, creating a transfer from the Neuse to the Haw River basins. Based on the existing infrastructure in 1993, Durham has a grandfathered transfer capacity of 45.4 million gallons per day.

In 2002, Durham received an allocation of 10 percent of the water supply storage in Jordan Lake. Since this water supply is located in the Haw River basin, it provides Durham with a non-transfer water supply alternative for the portion of its service area in the Haw River basin. Since Durham had a net transfer from the Neuse River basin to the Haw River basin, the water supply from Jordan Lake serves to reduce its surface water transfer. Prior to receiving a Jordan Lake allocation, Durham's interbasin transfer worksheets estimated that the city would need a certificate after 2050. However, access to the Jordan Lake water supply pool will push the threshold further into the future. Based on available information, Durham will not need to apply for an interbasin transfer certificate for the foreseeable future.

Cary/ Apex/ Morrisville/ Wake County

Cary, Apex and Morrisville, and Wake County together hold an interbasin transfer certificate for a combined transfer of 24 million gallons per day from the Haw River basin (2-1) to the Neuse River basin (10-1). This certificate was approved by the state Environmental Management Commission on July 12, 2001. These systems use water from the Cary-Apex intake on Jordan Lake and discharge treated wastewater from their existing wastewater treatment plants located on tributaries of the Neuse River. The towns are required to submit annual reports summarizing their estimated transfers. These reports and the certificate can be found on the division's website at http://www.ncwater.org/Permits_and_Registration/Interbasin_Transfer/.

Franklin County/ KLRWS

The Kerr Lake Regional Water System is a regional provider of drinking water. The system provides water from Kerr Lake in the Roanoke River basin to Henderson and Oxford, and Warren County. These three customers, in turn, provide water to portions of Vance, Granville, Franklin and Warren counties. Currently, a small portion of the water supplied to Franklin County, less than 0.3 million gallons per day, is being transferred to the Neuse River basin. However, the volume of the transfer is projected to grow to more than 2 million gallons per day by the year 2040. In February 2009, the Kerr Lake Regional Water System submitted a notice of intent to request an interbasin transfer certificate from the Environmental Management Commission. In the notice, the Kerr Lake Regional Water System requested an increase from its grandfathered capacity of 10 million gallons per day up to 24 million gallons per day, including a transfer of 2.4 million gallons per day from the Roanoke River basin to the Neuse River basin. These transfer amounts are based on water use projections to the year 2040. More information on the status of this proposed transfer can be found on this division's website at http://www.ncwater.org/Permits_and_Registration/Interbasin_Transfer/.

6.1.8 Central Coastal Plain Capacity Use Area

The Central Coastal Plain Capacity Use Area rules affect the Wayne County portion of the Upper Neuse hydrologic unit. The N.C. Division of Water Resources has five active water use permits in this watershed using 41 wells. Each of these production wells lies west of the declining water level reduction zone and, therefore, the owners are not required to reduce pumping from these sources. The coastal plain sediments get thinner as one moves westward into Wayne County, so many of the permitted wells tap the unregulated Surficial or Bedrock aquifers. Eleven of the 41 wells are constructed to withdraw water from the Cretaceous aquifers.

The Central Coastal Plain Capacity Use Area program has permit conditions that require reporting of daily water withdrawals by production wells and monthly pumping and static water levels.

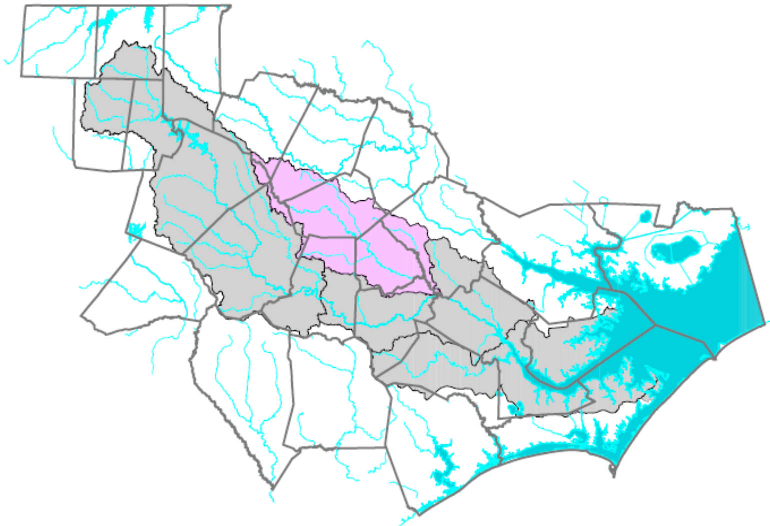
Most of the reported data is available to the public on the N.C. Division of Water Resources' website. The data are regularly used by the division to assess the conditions of regional ground water resources.

6.1.9 Data Management Needs

In general, more monitoring of water resources conditions throughout the state would improve the data available for river basin modeling and planning for sustainable water supplies. There should be adequate monitoring sites to capture surface water conditions at existing surface water intakes and provide drought response triggers. There should be at least one monitoring well in each county that provides reliable information to describe the effects of drought conditions on ground water resources. In addition, ground water monitoring stations are needed to document changes in regional ground water resources. Currently, there are four monitoring stations in this hydrologic unit with a total of five wells. Three wells are in the Piedmont portion of the watershed and a two-well station is located in the Coastal Plain portion. The western boundary of the declining water level zone of the Central Coastal Plain Capacity Use Area runs through Wayne County. Having additional monitoring stations in this county would improve the data needed to characterize regional ground water resources.

6.2 Contentnea Creek hydrologic unit (HUC 03020203)

03020203 Contentnea Creek – Quick Facts



Regions
Piedmont, Central Coastal Plain
Counties
Franklin, Greene, Johnston, Lenoir, Nash, Pitt, Wake, Wayne, Wilson
Public Water Supply Systems (PWS)
Baily, Black Cr, Farmville, Fountain, Freemont, Greene Co, Hookerton, Lucuma, Middlesex, Saratoga, Sims, Snow Hill, S Greene WC, Stantonsburg, Walstonburg, Wilson, Wilson Co.
Major Industrial Users
None
Population (2000 Census)
136,236

Number of SW Intakes used by PWS
2
Number of Water Supply Reservoirs
1
Number of GW PWS wells
~ 60
Number of Drought Monitoring Wells
1
Number of ECONET/COOP Weather Stations
3
Stream Miles
655.5
HUC Total Area
1008 sq-miles

Number of USGS Gages (Regulated/Unregulated)
1/3
Upstream Watersheds:
None
Downstream Watersheds
Middle Neuse
Subwatersheds
Black Creek, Buckhorn Reservoir, Contentnea Creek, Little Contentnea Creek, Nahunta Swamp, Toisnot Swamp, Wiggins Mill Reservoir
Recreation Areas

6.2.1 Water-Use

The Contentnea Creek hydrologic unit or watershed has an area of 1,065 square miles and a 2000 Census population of 136,236 people. While the nine counties comprising this watershed had about 1.5 million residents in 2008, many of them live outside of this hydrologic unit and get their water from other basins. Using the population distribution figures reported for 2000 by the N.C. Division of Water Quality, the N.C. Division of Water Resources estimated the 2008 population in the Contentnea Creek watershed to be 179,000. If population growth in the future follows the trend from 1970 to 2008, then the population in this watershed is estimated to be more than 233,000 by 2030 and about 320,000 by 2060.

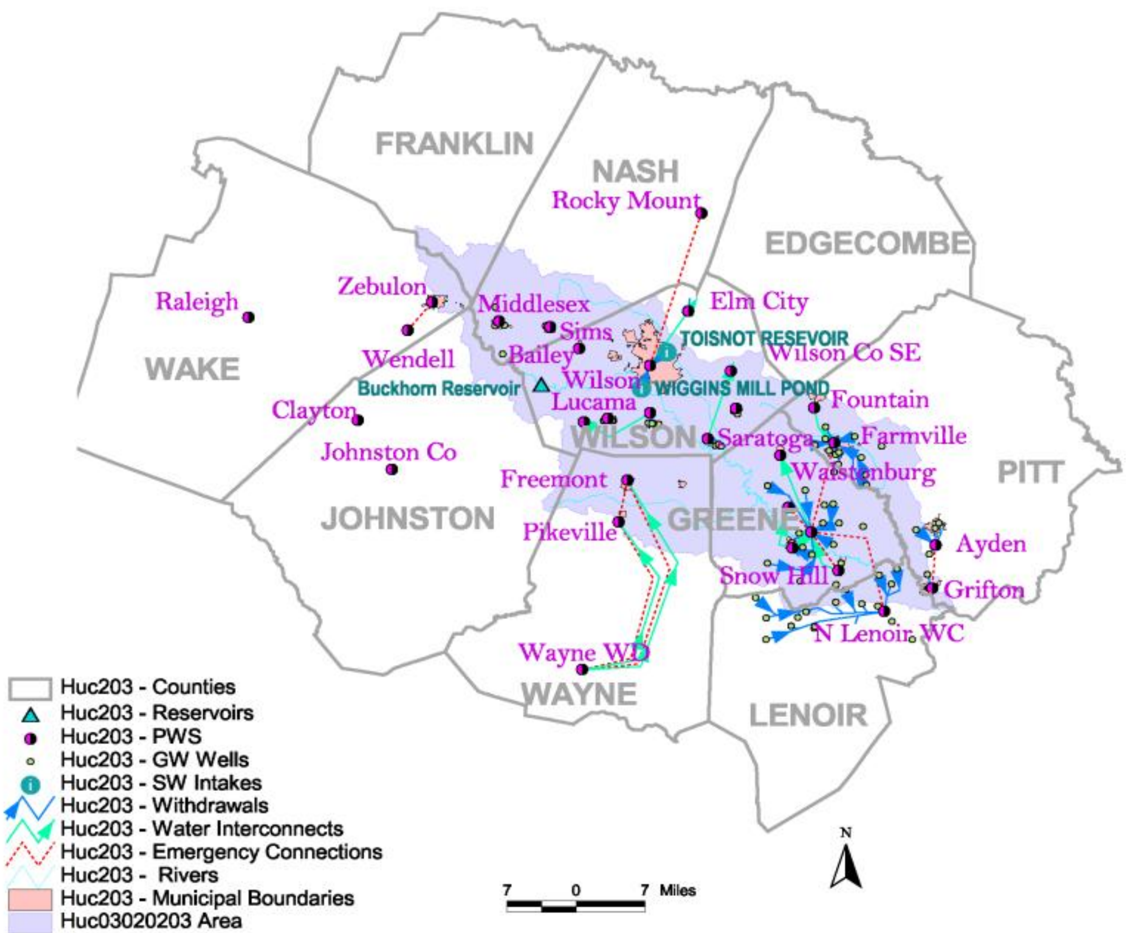
Water withdrawal information used for this analysis comes from several different sources. Owners of facilities that withdraw large quantities of water are required by statute to report water withdrawals to the N.C. Division of Water Resources. Under this requirement, owners of agricultural operations must report withdrawals of one million gallons per day or greater and non-agricultural operations report if their withdrawals are 100,000 gallons a day or more. Units of local government that supply water to the public and other large community water systems meet the reporting requirement by submitting a local water supply plan. Also, the N.C. Department of Agriculture and Consumer Services annually surveys agricultural operations that withdraw 10,000 gallons a day or more. Water systems in the 15 counties of the Central Coastal Plain Capacity Use Area report water use if they withdraw 10,000 gallons a day or more.

Table 6-6 shows the number of operations and the amount of water withdrawn during 2008 in the Contentnea Creek hydrologic unit. Public water systems withdrew the largest portion of water used. The 22 public water systems, for which information is available, used on average just under 13 million gallons per day, most of which came from surface water sources. The 80 agricultural and aquaculture operations in this watershed withdrew 8.9 million gallons per day on average, two-thirds of which was from surface water sources. There are three golf courses withdrawing water in this watershed that reportedly use about 100,000 gallons per day on average. One self-supplied industry in the watershed withdraws ground water. As of February 2010, three of the 21 public water systems in the watershed submitting a local water supply plan and three have a water shortage response plan that meets the minimum requirements for such a plan.

Table 6-6: Estimated 2008 Average Day Water Withdrawals in HUC 03030203 in Million Gallons per Day (mgd)

Operations reporting to DWR or DA&CS Agricultural Water Use Survey				
Contentnea Creek HUC 03020203	**Operations**	**Ground Water**	**Surface Water**	**Total**
Agriculture/Aquaculture	80	2.623	6.239	8.9
Golf Courses	3	0.003	0.065	0.1
Industry	1	0.027	0	0
Mining	3	0.563	0	0.6
Public Water Systems	22	3.734	8.941	12.7
Thermoelectric	0	0	0	0
LWSP Systems	21		Sub-unit Total	22.2
WSRP meeting minimum standard 2-24-10	3			

Figure 6-20: Water Sources and Connections for Public Water Systems around HUC 03020203



6.2.2 Surface Water Transfers

The following table lists the most significant surface water transfers affecting the Contentnea Creek hydrologic unit. Withdrawers transferring more than two million gallons a day of surface water are discussed in more detail below.

Table 6-7: Surface Water Transfers in HUC 03020203

Hydrologic Unit	Water System	Source Basin	Receiving Basin	Maximum Transfer (in mgd)
03020103 to 03020203 and 03020202	Greenville Utilities Commission	Tar River Basin (14-1)	Neuse River (10-1) and Contentnea Creek (10-2)	*
03020202 to 03020204, 03020203, and 03020103	Neuse Regional WASA	Neuse River (10-1)	Trent River (10-3), Contentnea Cree (10-2) and Tar River (15-1_	*

* This water system has requested an interbasin transfer certificate. The certificate has not yet been approved. For more information, please see the Division's website at http://www.ncwater.org/Permits_and_Registration/Interbasin_Transfer/
mgd – million gallons per day

Greenville Utilities Commission

The Greenville Utility Commission has requested an interbasin transfer certificate for an 8.3 million gallons-a-day surface water transfer from the Tar River to the Contentnea Creek basin and four million gallons a day transfer from the Tar River to the Neuse River basin. These proposed transfers would provide water to the communities of Farmville and Winterville as well as the Greene County water system, which are all required to reduce their reliance on current ground water sources by the Central Coastal Plain Capacity Use Area rules. As of May 2010, this transfer request is being considered by the Environmental Management Commission. For more information on the status of this project, please see the division's website at http://www.ncwater.org/Permits_and_Registration/Interbasin_Transfer/.

Neuse Regional Water and Sewer Authority

The Neuse Regional Water and Sewer Authority was formed in 2000 to meet local water supply needs as communities shifted off ground water in response to declining ground water levels and the resulting capacity use area rules. In September 2008, the authority began operating a 15 million gallon-a-day water treatment plant, which withdraws water from the Neuse River. Members of the authority include the towns of Ayden, Grifton and Pink Hill, and the Deep Run, North Lenoir, Bell Arthur and Eastern Pines water corporations.

The Neuse Regional Water and Sewer Authority will need an interbasin transfer certificate in the near future to provide water to the Bell Arthur and Eastern Pines service areas in the Contentnea Creek and Tar River basins and to Pink Hill and the Deep Run service areas in the Trent River basin. The authority plans to file a petition for an Interbasin Transfer Certificate with the state Environmental Management

Commission before the end of 2010. Additional information on this project will be available on the division's website as it becomes available.

6.2.3 Central Coastal Plain Capacity Use Area

Most of the Contentnea Creek hydrologic unit lies within the designated Central Coastal Plain Capacity Use Area, or CCPCUA. The rules associated with the CCPCUA established a permitting program for ground water withdrawers using more than 100,000 gallons per day. As of May 2010, there were 36 active water use permits in this watershed using 105 wells. Users withdraw water from wells in the declining water level zone and de-watering reduction zone of the CCPCUA. Users in these zones are required to reduce their usage of the Cretaceous aquifer wells. The Cretaceous aquifers are comprised of sediment deposited during the Cretaceous Period more than 63 million years ago. The rules require different levels of reductions in ground water withdrawals from these aquifers by 2018 depending on the designated zone. The declining water level zone requires 30 percent reductions and the de-watering zone requires 75 percent reductions in use from each permit holder's approved base rate. The approved base rate is either the 1997 annual use from these aquifers, or the annual usage from August 1, 1999 through July 31, 2000. Sixty-two of the 105 wells are constructed to withdraw water from the Cretaceous aquifers.

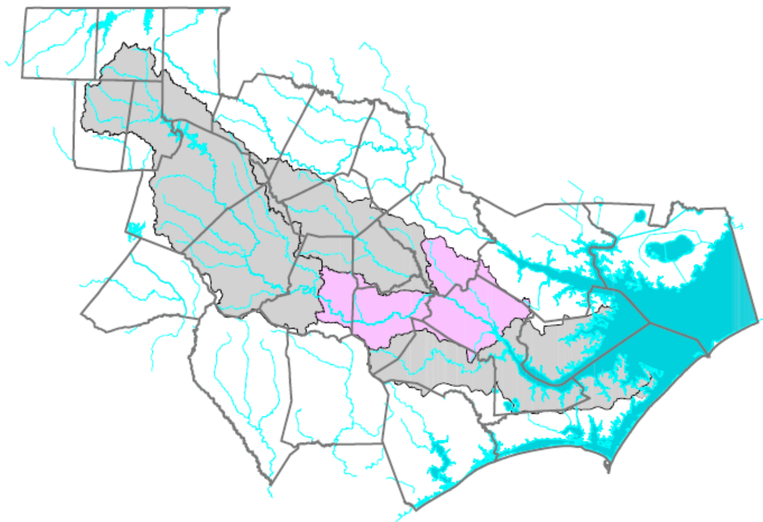
The CCPCUA program has permit conditions that require reporting of daily water withdrawals by production wells and monthly pumping and static water levels. Most of the reported data is available to the public via the division's web pages and is often used by the division to assess the conditions of the ground water resources.

6.2.4 Data Management Needs

In general, more monitoring of water resources conditions throughout the state would improve the data available for river basin modeling and planning for sustainable water supplies. There should be adequate monitoring sites to capture surface water conditions at existing surface water intakes and provide drought response triggers. There should be at least one monitoring well in each county that provides reliable information to describe the effects of drought conditions on ground water resources. The Contentnea Creek watershed has six ground water monitoring stations in the Coastal Plain portion of the basin with a total of 20 wells. Management and planning for this watershed could be improved by adding several monitoring wells and stream gages to monitor drought conditions. The amount of water available from reservoirs is affected by the amount of evaporation that occurs from the water's surface. Having accurate estimates of evaporation in each watershed that hosts a reservoir would improve river basin modeling and improve the accuracy of reservoir yield estimates. Each watershed with a water supply reservoir should have an evaporation monitoring station. Currently, there is no evaporation monitoring station in this watershed.

6.3 Middle Neuse hydrologic unit (HUC 03020202)

03020202 Middle Neuse – Quick Facts



Regions
Central Coastal
Counties
Beaufort, Craven, Greene, Jones, Lenoir, Pitt, Wayne
Public Water Supply Systems (PWS)
Ayden, Cover City, Craven Co., Deep Run WC, Dover, Goldsboro, Grifton, Kinston, La Grange, N Lenoir WC, Seymour Johnson, Vanceboro, Walnut Creek, Winterville
Major Industrial Users
None
Population (2000 Census)
154,049
Number of SW Intakes used by PWS
None
Number of Water Supply Reservoirs
None
Number of GW wells used by PWS
~ 100
Number of Drought Monitoring Wells
2
Number of ECONET/COOP Weather Stations
4
Stream Miles*
340
HUC Total Area
1065 sq-miles
Number of USGS Gages (Regulated/UnRegulated)
0/5
Upstream Watersheds:
Upper Neuse
Downstream Watersheds
Lower Neuse
Subwatersheds
Bear Creek, Clayton Creek, Hog Island, Mosley Creek, Swift Creek, Walnut Creek
Recreation Areas
Cliffs of the Neuse State Park.

* Source: Subbasin Overview Chapters, [DWQ Neuse Basinwide Plan, July 2009]

6.3.1 Water-Use

Middle Neuse hydrologic unit, or watershed, has an area of 1,008 square miles and a 2000 Census population of 154,049 people. This watershed includes areas in seven counties, but most of its area is in Craven, Greene and Lenoir counties. There were about 504,000 residents in the seven counties in 2008, about 35 percent of which were in the three previously mentioned primary counties. Using the population distribution figures reported for 2000 by the state Division of Water Quality, the state Division of Water Resources estimated the 2008 population in the Middle Neuse hydrologic unit at about 202,000. If population growth in the future follows the same trends experienced from 1970 to 2008, then the population in this area is estimated to be about 264,000 by 2030 and about 362,000 by 2060.

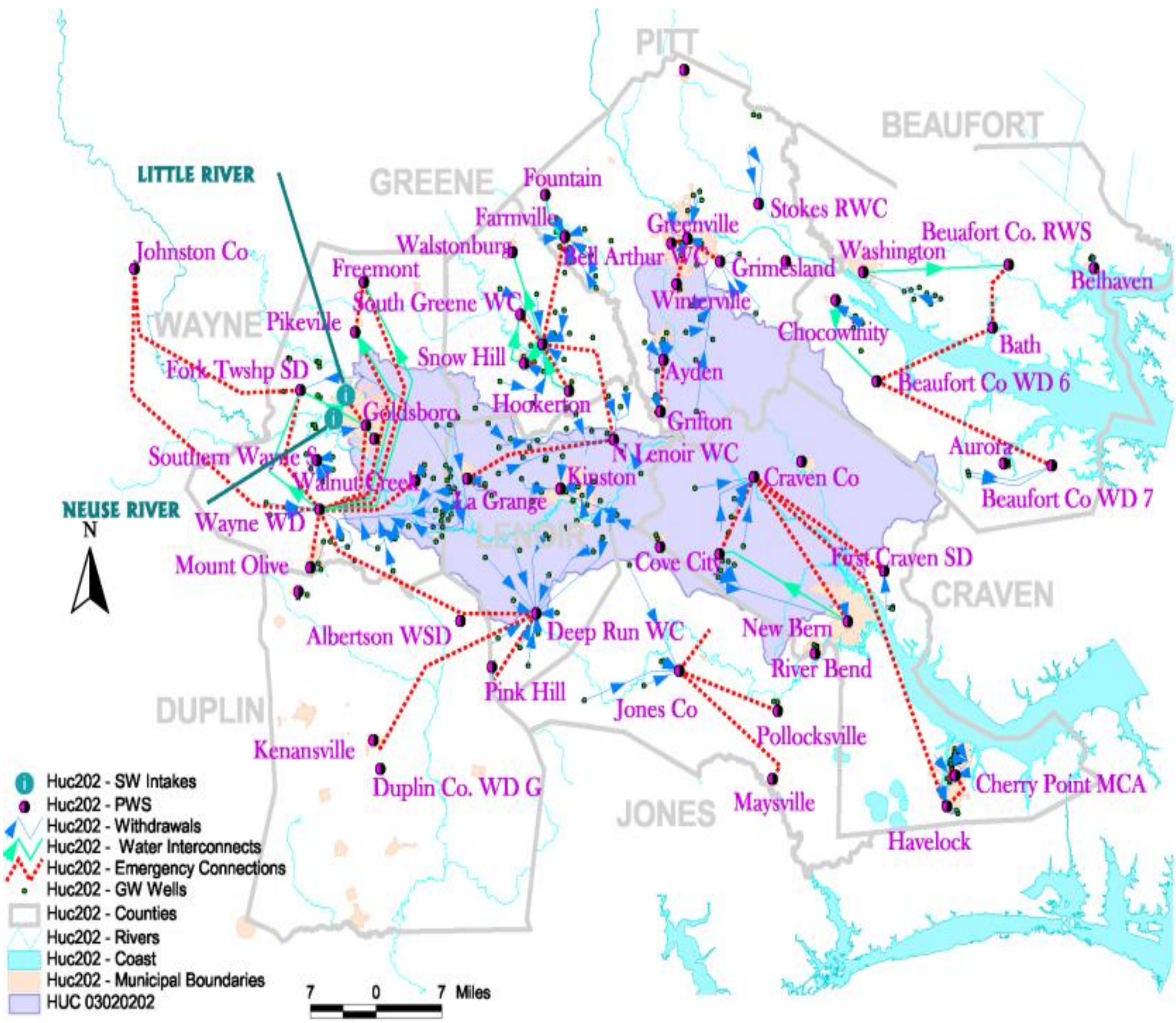
Water withdrawal information used for this analysis comes from several different sources. Owners of facilities that withdraw large quantities of water are required by statute to report water withdrawals to the division. Under this requirement, owners of agricultural operations must report withdrawals of one million gallons per day or more and non-agricultural operations report if their withdrawals are 100,000 gallons a day or more. Units of local government that supply water to the public and other large community water systems meet this requirement by submitting a local water supply plan. Also, the N.C. Department of Agriculture and Consumer Services annually surveys agricultural operations that withdraw 10,000 gallons a day or more. Water systems in the 15 counties of the Central Coastal Plain Capacity Use Area report water use if they withdraw 10,000 gallons a day or more.

Table 6-8 shows the number of operations and the amount of water withdrawn during 2008 in the Middle Neuse watershed. Self-supplied industrial operations withdraw the largest percentage of water. The Weyerhaeuser facility in Craven County uses surface water. The other industrial facilities use ground water. According to available data, 48 agricultural and aquaculture operations in this basin withdraw 10,000 gallons a day or more of ground water or surface water. During 2008, these facilities withdrew 4.3 million gallons per day on average, primarily from ground water sources. Three mining operations in the watershed report water withdrawals to the division. During 2008, these operations pumped 8.6 million gallons per day on average to de-water the mining pits to allow for the operation of mechanical equipment and other processing purposes. There are 13 public water systems reporting water use in this basin. All of them submit local water supply plans to the division. These systems primarily rely on ground water sources to meet their customers’ needs. Two of these systems had a water shortage response plan meeting the minimum requirements as of February 2010.

Table 6-8: Estimated 2008 Average Day Water Withdrawals in HUC 03030202 in Million Gallons per Day (mgd)

Operations reporting to DWR or DA&CS Agricultural Water Use Survey				
Middle Neuse HUC 03020202	**Operations**	**Ground Water**	**Surface Water**	**Total**
Agriculture/Aquaculture	48	4.166	0.098	4.3
Golf Courses	2	0.033	0	0
Industry	6	1.594	15.598	17.2
Mining	3	8.571	0	8.6
Public Water Systems	13	8.344	1.649	10.0
Thermoelectric	0	0	0	0
LWSP Systems	13		Sub-unit Total	40.1
WSRP meeting minimum standard 2-24-10	2			

Figure 6-21: Water Sources and Connections for Public Water Systems around HUC 03020202



6.3.2 Surface Water Transfers

The Middle Neuse watershed lies within the legislatively defined Neuse River, 10-1, basin used for regulation of surface water transfers. The Neuse Regional Water and Sewer Authority distributes water from the Neuse River to member communities that serve customers in several river basins outside of its source basin. Also, the Greenville Utilities Commission will be distributing water from the Tar River to communities with customers in the Neuse River basin, or 10-1.

Table 6-9: Surface Water Transfers in HUC 03020202

HUC8	Water System	Source Basin	Receiving Basin	Maximum Transfer (in mgd)
03020103 to 03020203 and 03020202	Greenville Utilities Commission	Tar River Basin (14-1)	Neuse River (10-1) and Contentnea Creek (10-2)	*
03020202 to 03020204, 03020203, and 03020103	Neuse Regional WASA	Neuse River (10-1)	Trent River (10-3), Contentnea Cree (10-2) and Tar River (15-1_	*

* This water system has requested an interbasin transfer certificate. The certificate has not yet been approved. For more information, please see the Division's website at
http://www.ncwater.org/Permits_and_Registration/Interbasin_Transfer/
mgd –million gallons per day

Greenville Utilities Commission

The Greenville Utility Commission has requested an interbasin transfer certificate for 8.3 million gallons per day to be transferred from the Tar River basin to the Contentnea Creek basin, and a four million gallons per day to be transferred from the Tar River basin to the Neuse River basin. This proposed transfer would serve the communities of Farmville, Winterville and Greene counties. These water systems currently rely on ground water and are all required to reduce their pumping from the Cretaceous aquifers by the Central Coastal Plain Capacity Use Area rules. The Environmental Management Commission is expected to take up this request before the end of 2010. Water transferred to the Neuse River, 10-1, basin will augment current water resources in the Middle Neuse watershed. For more information on this project, please see the division's website at http://www.ncwater.org/Permits_and_Registration/Interbasin_Transfer/.

Neuse Regional Water and Sewer Authority

The Neuse Regional Water and Sewer Authority formed in 2000 to develop a surface water source and treatment facility to meet long-term water needs in the region. Member communities are located within the Central Coastal Plain Capacity Use Area and are required to reduce withdrawals from the underlying Cretaceous aquifers. In September 2008, a new 15 million gallon per day water treatment plant began operation supplying water from the Neuse River to the authority's members. As a result, Ayden, Grifton and Pink Hill and the Deep Run, North Lenoir, Bell Arthur and Eastern Pines water corporations have reduced their withdrawals of ground water producing measurable improvements to the status of regional ground water resources.

The Neuse Regional Water and Sewer Authority will need an interbasin transfer certificate from the state Environmental Management Commission to continue providing water to the Bell Arthur and Eastern Pines areas in the Contentnea Creek, 10-2, and Tar River, 15-1, basins and to Pink Hill and the Deep Run areas in the Trent River, 10-3, basin. The authority plans to file a petition for the commission's consideration before the end of 2010. More detailed information will be posted to the division's website at www.ncwater.org as it becomes available.

6.3.3 Central Coastal Plain Capacity Use Area

The entire Middle Neuse watershed is located within the boundaries of the Central Coastal Plain Capacity Use Area. Therefore, water withdrawers are subject to the monitoring and permitting programs established to manage water withdrawals. The state Division of Water Resources has 36 active water use permits using 161 wells in this watershed. There are production wells in the declining water level, de-watering, and saltwater encroachment reduction zones where cutbacks in use of the Cretaceous aquifers are required. The Cretaceous aquifers are those comprised of sediment deposited during the Cretaceous Period more than 63 million years ago. Water systems that were using these aquifers when the rules were approved were assigned an approved base rate of use that defined the starting point for calculating use reductions. The approved base rate is either the use in calendar year 1997 or usage from August 1, 1999 through July 31, 2000. Reductions in use vary depending on the geographic zone where the wells are located. Water users with wells in the declining water level zone must reduce withdrawals from the Cretaceous aquifers by 30 percent from the approved base rate for wells withdrawing from the Cretaceous aquifers. And water users with wells in the de-watering and saltwater encroachment zones must reduce withdrawals by 75 percent.

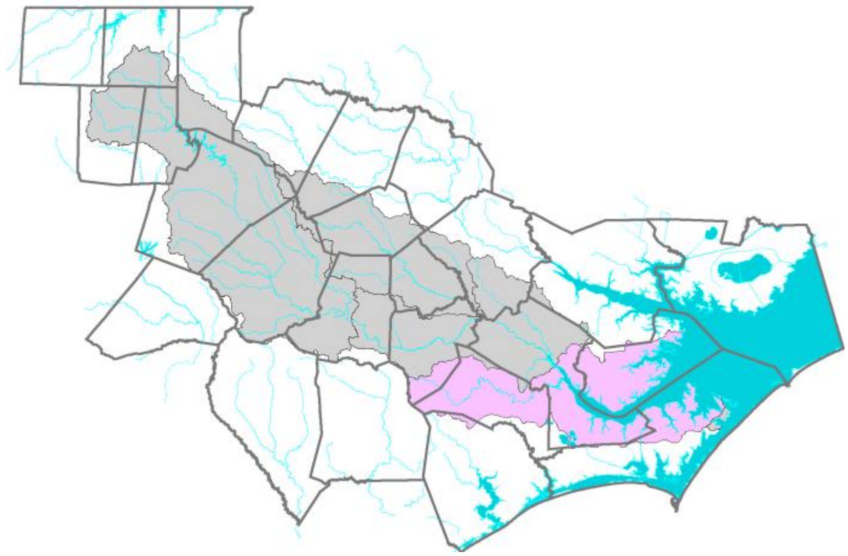
Ninety-nine of the 161 wells are constructed to withdraw ground water from the Cretaceous aquifers. The CCPCUA program has permit conditions that require monthly reporting of daily water withdrawals by production wells and monthly pumping and static water levels. Data submitted to the division by water users in this region provide valuable information for monitoring regional water resource conditions. Most of the data reported are available on the division's website.

6.3.4 Data Management Needs

The Middle Neuse River basin needs additional monitoring to improve the data available for hydrologic analysis. Currently, there are 20 monitoring stations with a total of 73 wells. All of these well stations are in the Coastal Plain. Future modeling of this basin could be improved by adding more stream flow gages.

6.4 Lower Neuse hydrologic unit (HUC 03020204)

03020204 Lower Neuse – Quick Facts



Regions
Central Coastal - Coastal
Counties
Carteret, Craven, Jones, Lenoir, Pamlico
Public Water Supply Systems (PWS)
Cherry Point MCA, First Craven SD, Havelock, Jones Co, Merrimom SD, New Bern, Oriental, Pamlico Co, Pink Hill, Pollocksville, River Bend.
Major Industrial Withdrawer
Weyerhauser Company
Population (2000 Census)
99,006
Number of SW Intakes used by PWS:
None

Number of Water Supply Reservoirs
None
Number of GW wells used by PWS
~ 60
Number of Drought Monitoring Wells
None
Number of ECONET/COOP Weather Stations
9
Stream Miles*
415
HUC Total Areas
1583 **s**q-miles
Estuary Area*
365 acres

Number of USGS Gages (Regulated/Unregulated)
3/1
Upstream Watersheds:
Middle Neuse
Downstream Watersheds
None
Subwatersheds
Cherry Point, Jones Bay, Lower Trent River, Middle Trent River, Neuse River, Pamlico Sound, Town of Oriental, Upper Broad Creek, Upper Trent River
Recreation Areas
Croatan National Forest, Theodore Roosevelt Natural Area, Fort Macon State Historic Park and Recreation Area and Hammocks Beach State Park.

The Lower Neuse hydrologic unit encompasses the areas of the Coastal Plain that drain to the Neuse River below New Bern, including the Trent River watershed. The river widens in the Coastal Plain and becomes estuarine in nature with brackish water. The streams and rivers in this watershed are where the freshwater riverine conditions dominant inland become strongly affected by the tidally driven movement of the salty saline waters of the Pamlico Sound. In this watershed the transition zone, where freshwater becomes salty water, is continuously moving upstream and downstream based on the dynamic relationships between tides, wind and river flows. Below the surface a similar dynamic exists, without the tidal influence, in the ground water aquifers. In this case, it is the boundary between fresh ground water moving seaward from inland recharge areas and saline ground water being pushed inland from the sea. For surface waters, the transition zones fluctuate daily. For ground waters, the transition zones change much more slowly based on changes in water pressures in the fresh and saline portions of the aquifers. Most residents of the Coastal Plain have traditionally relied on ground water to satisfy their water demands. There are no surface water intakes for public water systems in this watershed.

6.4.1 Water-Use

The Lower Neuse watershed has an area of 1,583 square miles and an estimated population in 2000 of 99,006 people. The basin includes lands and waters in five counties. There were almost 242,000 year-round residents, in total, in these counties during 2008. Using the population distribution figures reported for 2000 by the N.C. Division of Water Quality, the N.C. Division of Water Resources estimated the 2008 year-round population in the Lower Neuse hydrologic unit at about 130,000. If population growth in the future follows the same trends, experienced from 1970 to 2008, then the year-round population in this area is estimated to be 170,000 by 2030 and 233,000 by 2060.

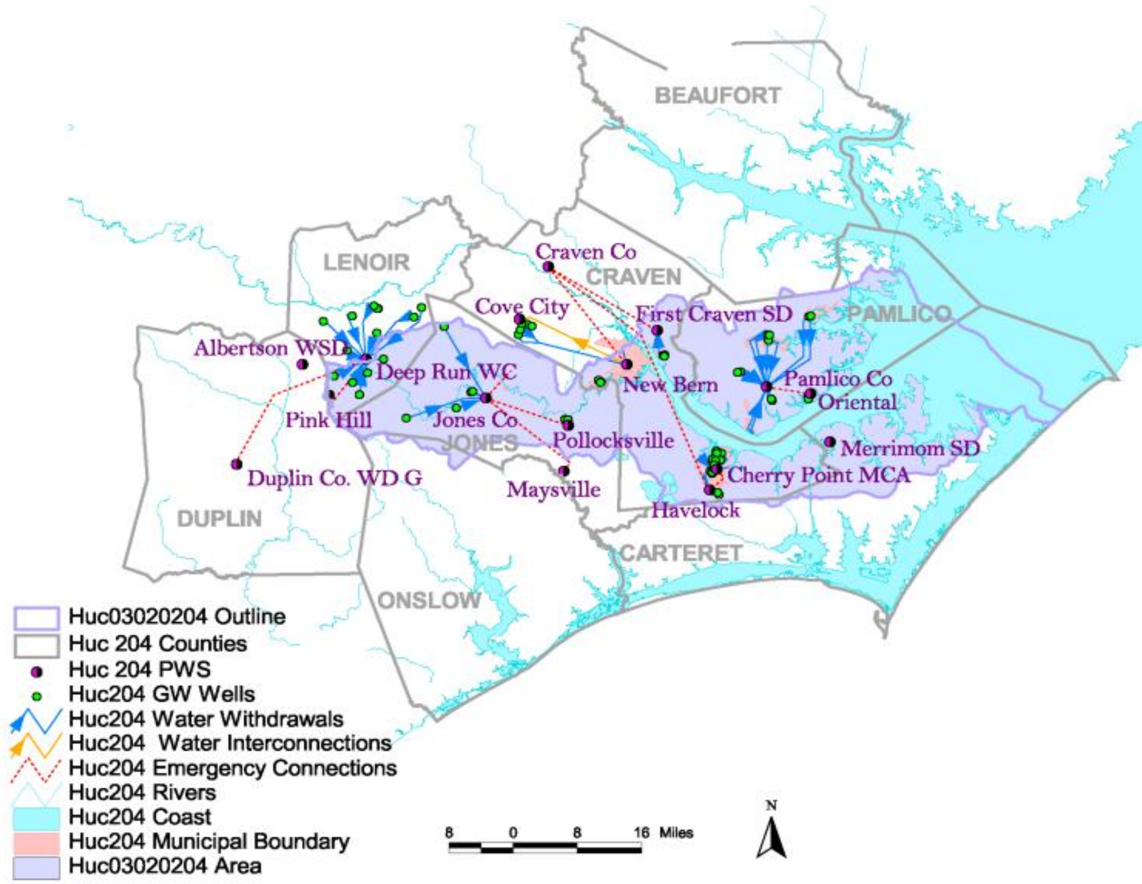
Water withdrawal information used for this analysis comes from several different sources. Owners of facilities that withdraw large quantities of water are required by statute to report water withdrawals to the N.C. Division of Water Resources. Under this requirement, owners of agricultural operations must report withdrawals of one million gallons per day or more and non-agricultural operations report if the withdrawals are 100,000 gallons a day or more. Units of local government that supply water to the public and other large community water systems meet this requirement by submitting a local water supply plan. Also, the N.C, Department of Agriculture and Consumer Services annually surveys agricultural operations that withdraw 10,000 gallons a day or more. Water systems in the 15 counties of the Central Coastal Plain Capacity Use Area report water use if they withdraw 10,000 gallons a day or more.

Table 6-10 shows the number of facilities and the amount of water withdrawn during 2008 in the Lower Neuse watershed. Public water systems withdraw the most water in this basin. The nine public water systems withdrew over 11 million gallons per day of ground water. None of these systems use surface water. According to available data, 20 agricultural operations in this watershed withdraw 10,000 gallons a day or more of ground or surface water. During 2008, these facilities withdrew 1.2 million gallons per day on average. The seven golf courses registering water use in the basin used 0.3 million gallons per day on average, primarily from ground water sources. Three mining operations in the basin report water withdrawals to the division. On average, they pumped 40,000 gallons per day of ground water during 2008. Of the nine public water systems submitting a local water supply plan, two had submitted a water shortage response plan that met the required minimum criteria by Feb. 24, 2010.

Table 6-10: Estimated 2008 Average Day Water Withdrawals in HUC 03030204 in Million Gallons per Day (mgd)

Operations reporting to DWR or DA&CS Agricultural Water Use Survey				
Lower Neuse HUC 03020204	**Operations**	**Ground Water**	**Surface Water**	**Total**
Agriculture/Aquaculture	20	0.436	0.751	1.2
Golf Courses	7	0.227	0.054	0.3
Industry	0	0	0	0
Mining	3	0.04	0	0
Public Water Systems	9	11.147	0	11.1
Thermoelectric	0	0	0	0
LWSP Systems	9		Sub-unit Total	12.7
WSRP meeting minimum standard 2-24-10	2			

Figure 6-22: Water Sources and Connections for Public Water Systems around HUC 03020204



6.4.2 Surface Water Transfers

The Lower Neuse hydrologic unit includes areas designated as the Trent River, 10-3, and Neuse River, 10-1, for regulation of surface water transfers. The Neuse Regional Water and Sewer Authority withdraws water from the Neuse River upstream in the Middle Neuse watershed and delivers potable water to member communities that serve customers in several river basins outside its source basin.

The hydrologic and legislatively defined basins the affect Neuse Regional Water and Sewer Authority water management are summarized in the following table.

Table 6-11: Surface Water Transfers in HUC 03020204

Hydrologic Unit	Water System	Surface Water Transfer Source Basin	Surface Water Transfers Receiving Basin	Maximum Transfer
03020202 to 03020204, 03020203, and 03020103	Neuse Regional WASA	Neuse River (10-1)	Trent River (10-3), Contentnea Cree (10-2) and Tar River (15-1)	Undefined at this time*

* This water system will be requesting an interbasin transfer certificate. For more information, please see the Division's website at http://www.ncwater.org/Permits_and_Registration/Interbasin_Transfer/

Neuse Regional Water and Sewer Authority

The Neuse Regional Water and Sewer Authority, or NRWASA, formed in 2000 to develop a surface water source and treatment facility to meet long term water needs in the region. Member communities are located within the Central Coastal Plain Capacity Use Area and are required to reduce withdrawals from the underlying Cretaceous aquifers. In September 2008, a new 15 million gallon per day water treatment plant began operations supplying water from the Neuse River to the authority's members. As a result, the towns of Ayden, Grifton and Pink Hill, and the Deep Run, North Lenoir, Bell Arthur and Eastern Pines water corporations have reduced their withdrawals of ground water and produced measurable improvements to the status of regional ground water resources.

NRWASA will need an interbasin transfer certificate from the Environmental Management Commission to continue providing water to Pink Hill and the Deep Run water systems that serve customers in the Trent River basin. The authority plans to file a petition with the state Environmental Management Commission before the end of 2010. More detailed information will be posted to the division's website as it becomes available.

6.4.3 Central Coastal Plain Capacity Use Area

The entire Lower Neuse watershed is located within the boundaries of the Central Coastal Plain Capacity Use Area. Therefore, water withdrawers are subject to the monitoring and permitting programs established to manage water withdrawals. The N.C. Division of Water Resources has 31 active water use permits using water from 112 wells in this watershed. There are production wells in both the de-watering and salt water encroachment zones where reductions in the use of the Cretaceous aquifer wells are required. The Cretaceous aquifers are comprised of sediment deposited during the Cretaceous Period more than 63 million years ago. Water systems that were using these aquifers when the rules were approved were assigned an approved base rate of use that defined the starting point for calculating use reductions. The approved base rate is either the usage in calendar year 1997, or the usage from Aug. 1, 1999 through July 31, 2000. Reductions in use vary depending on the geographic zone where the wells are located. Water users with wells in the de-watering and saltwater encroachment zones, must reduce withdrawals from the Cretaceous aquifers by 75 percent from their approved base rates for wells withdrawing from the Cretaceous aquifers.

Ten of the 112 wells are constructed to withdraw ground water from the Cretaceous aquifers. The CCPCUA rules require permit holders to report monthly on daily water withdrawals by production wells and monthly measurements of pumping and static water levels. Data submitted to the division by water users in this region provide valuable information for monitoring regional water resource conditions. Most of the data reported are available on the division's website.

6.4.4 Impacts of Climate Variability on Water Resources

The low-lying terrain of this watershed is susceptible to inundation as relative sea level fluctuates. This is obvious in tidal areas where water levels and the extent of the inundation of land areas fluctuates daily. There is growing evidence that historical climate patterns are changing and that we may see future climate conditions outside of the historical ranges of events. Additional information on how North Carolina may be affected by these changes can be found on the N.C. Department of Environment and Natural Resources' website at www.climatechange.nc.gov. An expected consequence of these changes is a noteworthy rise in relative sea level. As sea level rises, the boundaries between land and water will change, especially in low-lying coastal areas such as the Lower Neuse hydrologic unit. This can displace coastal wetland habitats. During tropical storm events, higher sea levels would likely produce levels of inundation and disruption of services beyond those seen in the historical record. Changes in air and water temperature patterns could change the frequency and intensity of tropical storms.

Studies into the changes in climate variability show potential impacts to water availability and water quality. Existing problems and anticipated future problems due to growing demands on available water resources could be exacerbated by changes in climate variability.

In coastal areas, the intrusion of saltwater could limit the usefulness of regional ground and surface sources. Changes in seasonal precipitation patterns and/or the annual amount of precipitation, could lead to flow conditions in the state's river and streams not seen in the historical records. Changes in flow patterns would likely lead to changes in the location of the transition zones between freshwater and salty water in coastal rivers. Likewise, the transition zones between fresh and saline ground waters can be expected to move inland as sea level rises.

The N.C. Department of Transportation conducted the Sea Level Rise in North Carolina Study in 2005. The maps below were part of the Climate Change Adaptation for Transportation Infrastructure presentation at the N.C. 2010 Climate Change Adaptation Workshop. The maps show the potential impact zones of a 2.6 inch and a 12.2 inch sea level rise along North Carolina's coast.

Figure 6-23: Sea Level Rise in NC 2.6 inches – DOT Study

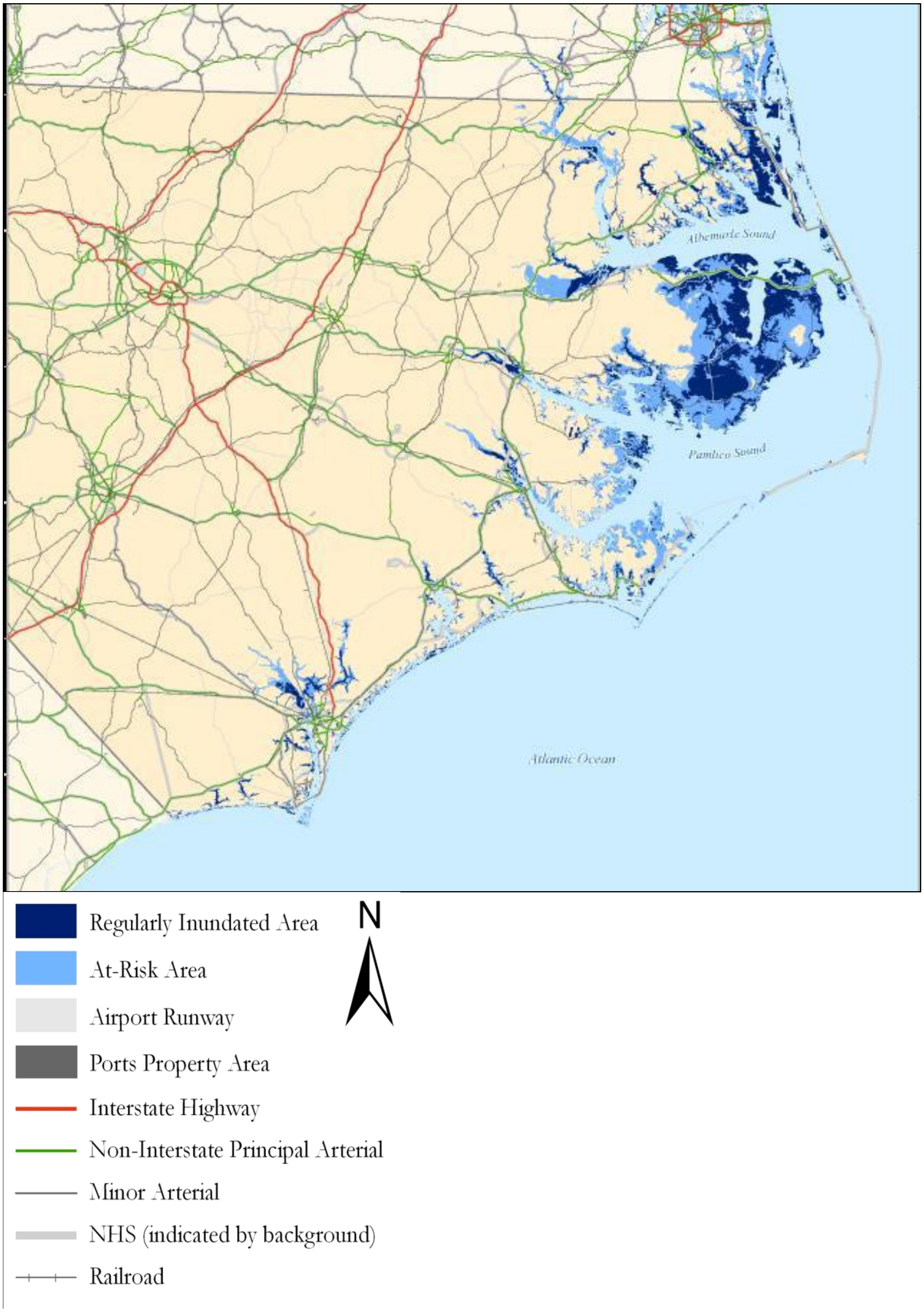
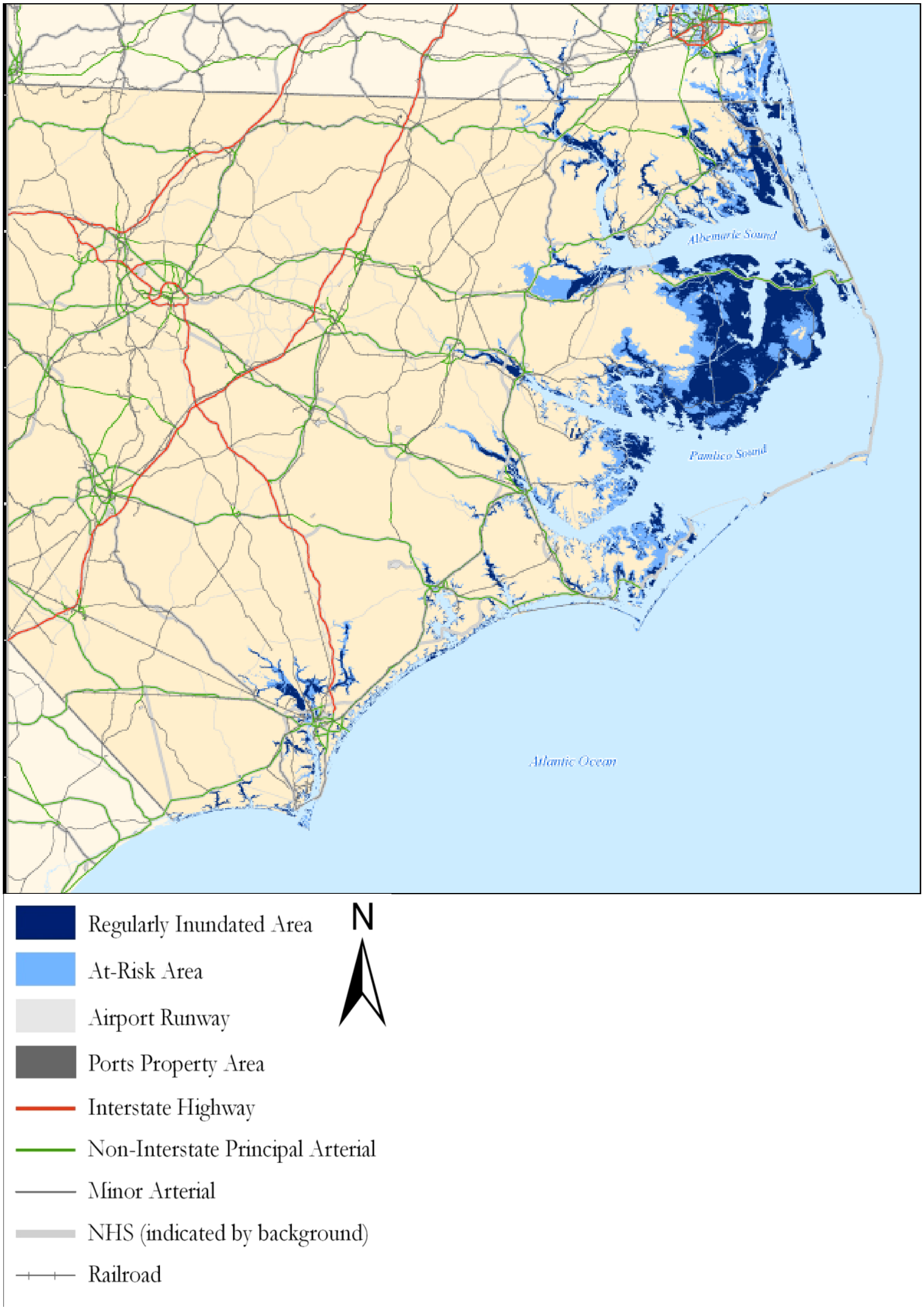


Figure 6-24: Sea Level Rise in NC 12.2 inches – DOT Study



6.4.5 Saltwater Intrusion in Coastal Areas

Saltwater intrusion of the lands and waters of the Lower Neuse watershed may force changes in where and how water can be used, as well as producing changes in coastal habitats. These changes will impact ground water and surface water users in the watershed. For example, consider the potential impacts to one of the region's largest surface water users.

The major industrial surface water withdrawer in the Lower Neuse watershed is the Weyerhaeuser Company's facility near New Bern. In the past, reduced river flows during drought conditions have allowed saltwater from the estuary to move upstream to the vicinity of this facility's water intake. The facility requires fresh water for its production operations. When the freshwater/saltwater transition zone in the river reaches their intake, operations at the plant are impacted. Weyerhaeuser has looked into the duration of periods when saltwater intrusion affects the intake in relation to river flows at Kinston and Streets Ferry. Weyerhaeuser monitored and analyzed this relationship for the period from 1988 to 1999. Table 6-12 quantifies the length of time operations at the Weyerhaeuser facility are impacted at various river flow rates.

Table 6-12 shows that, given the current status of relative sea level, as the flow in the river declines the impacts to operations increase. The location of the freshwater/saltwater transition zone is a function of the balancing the downstream movement of freshwater and the inland movement of saltwater. For any given flow rate in the river, the zone will be pushed upstream with high tides and recede downstream with low tides. If the anticipated increases in relative sea level actually occur then high tides will be higher and push the transition zone further upstream. Understanding how potential increases in climate variability could impact the quality and quantity of water available to water users will allow parties to adapt and prepare for sustainable sources of supply.

Table 6-12: Average number of days affected per week for different river flows

Flow at Kinston (cfs)*	Flow at Streets Ferry (cfs)*	Days Per Week Impacted			Additional Days Threatened		
		Dec-May	Jun-Aug	Sep-Nov	Dec-May	Jun-Aug	Sep-Nov
400	574	0.71	0.35	0.88	0.13	0.14	0.25
350	500	0.85	0.49	1.13	0.40	0.18	0.47
300	427	1.24	0.67	1.60	0.27	0.31	0.49
275	391	1.51	0.98	2.08	0.14	0.05	0.11
250	354	1.65	1.03	2.19	0.09	0.12	0.18
225	318	1.75	1.15	2.37	0.21	0.19	0.33
200	282	1.95	1.35	2.70	0.09	0.12	0.19
175	246	2.05	1.47	2.89	0.11	0.17	0.24
150	210	2.16	1.63	3.13	0.48	0.46	0.78

* cfs = cubic feet per second

A research report from Weyerhaeuser on the background information, analysis and findings prepared in 2002 can be found in the Appendix.

6.4.6 Data Management Needs

In general, more monitoring of water resources conditions throughout the state would improve the data available for river basin modeling and planning for sustainable water supplies. More stream flow gages are needed to improve understanding of the relationship of river flows and movement of saltwater from the estuary. In the Lower Neuse watershed, there are 10 ground water monitoring stations with a total of 40 wells. Several regional effect stations are desired to understand the impacts of water withdrawals on regional ground water resources. As in other watersheds, more wells designed to monitor drought conditions and climate effects are needed in the Lower Neuse.

Chapter 7 - Other Water Resource Management Activities

7.1 Water Resources Development Projects

The N.C. Division of Water Resources coordinates the expenditure of water resource related capital improvement funds in the State. Each year, the North Carolina General Assembly appropriates funds to provide the cost-share match for federal and non-federal water resource projects. On the federal level, the division works with the U.S. Army Corps of Engineers. On the local level, the division administers the Water Resource Development Grant Program, http://www.ncwater.org/Financial_Assistance/, which is designed to provide cost-share grants and technical assistance to units of local government throughout the State. Applications for grants are accepted for seven purposes: general navigation, recreational navigation, water management, stream restoration, beach protection, land acquisition and facility development for water-Based recreation, and aquatic weed control.

Federal Projects in the Neuse River Basin

- Neuse River Basin Investigation
  http://www.saw.usace.army.mil/Neuse-River/main.htm
  Recent water quality and flooding problems in the Neuse River Basin have impacted the lives and livelihood of many residents in the Neuse River Basin. This study focuses on ways to improve water quality and how best to improve aquatic habitats. It has three areas of interest: (1) stream and wetland restoration; (2) removal of obsolete dams and other obstructions; and (3) restoration of oyster habitat and oysters in the Neuse River estuary. Projects recommended by this study may be carried out by the U.S. Army Corps of Engineers, if funding is available, or by the state of North Carolina, if federal funding is not available. This feasibility study is scheduled for completion in 2010 if federal funding is appropriated.

- Gum Thicket Creek Restoration, Oriental, Pamlico County (Section 206).
  This project will protect Gum Thicket Creek, including 180 acres of brackish marsh and associated wetlands under conservation easements. It will stop erosion that is progressively removing the physical and hydrologic barrier between the Neuse River and Gum Thicket Creek, which if not stopped will destroy the natural ecology and hydrology of the area. This project will also provide a net increase in habitat value through the creation, restoration and improvement of the marsh wetlands and estuarine environment. The proposed construction of seven acres of marsh and improved shallow water habitat will replace wetlands lost to recent erosion and restore a more natural hydrology to approximately 180 acres of conservation land including a brackish estuarine creek, and associated coastal marsh and submerged aquatic vegetation. A

3,800-foot long rock sill will be aligned parallel to, and approximately 50 feet away from the shoreline, to facilitate project construction and development, and provide long-term protection from future wave erosion. This project is on hold awaiting federal funding.

<u>Water Resource Development Grant Projects</u>

- Johnston County – Mountains-to-Sea Trail Corridor - The project provides financial assistance to Clayton for planning and the acquisition of lands for the establishment of the Mountains-to-Sea Trail along the Neuse River through its jurisdiction.

- Jones County - Trent River Navigation - The project provides financial assistance to Jones County for Phase 2 of the Trent River Navigation Project. The project will remove small boat navigation hazards from 26 miles of the upper Trent River to facilitate and promote water-based ecotourism in Jones County.

- Wake County - Rocky Branch Restoration - The project provides financial assistance to the North Carolina Sea Grant Program for Phase 3 of the Rocky Branch Restoration Project. Phase 3 of the project will restore 1,090 feet of existing stream channel and uncover an additional 235 feet of former stream channel located on the N.C. State University campus.

- Wayne County - Bear Creek Drainage - The project provides financial assistance to Wayne County Drainage District #1 to repair four outlet structures and stabilize banks on four flood control impoundments along an unnamed tributary to Peters Creek.

7.2 Aquatic Weed Control

The N.C. Division of Water Resources houses the Aquatic Weed Control Program, which implements the Aquatic Weed Control Act of 1991. Details of this program can be found on the division's website, www.ncwater.org.

Invasive species come in many forms, some in the form of aquatic plants. The invasive or "noxious" aquatic plants are non-indigenous species that are known to impose negative environmental and/or economic impacts. The terms invasive and noxious are generally inter-changeable. Non-indigenous, or exotic, plants are abundant in the nursery industry. The public availability of a large assortment of exotic plants is widespread. The development of a global marketplace has facilitated the introduction of foreign plants to new locations. Large amounts of materials are moved from continent-to-continent every day, and a part of this material includes plants and materials to propagate plants. Whether the cargo is intended to be plant material or the plant material is merely "hitchhiking", exotic plants find their way to the Neuse River Basin from far away places. Some of these exotic plants turn out to be quite undesirable. They interfere with our water use demands or alter habitat leading to an unpredictable chain of events. The U.S. Department of Agriculture and the N.C. Department of Agriculture and Consumer Services act as regulatory agencies and maintain a list of prohibited plant species. It is unlawful to import, culture, sell or transport plants included on those lists.

Noxious aquatic weeds that are regulated and appear in the Neuse River basin include hydrilla and creeping water primrose.

The worst noxious aquatic weed that infests the Neuse River Basin is *Hydrilla verticillata*, commonly referred to as hydrilla. A submerged plant native to Eurasia and northern Africa, hydrilla has been termed the “perfect aquatic weed” because of its ability to act particularly weedy. Hydrilla tends to grow and spread very quickly. It typically fills the water column with its vegetative growth in calm aquatic habitats like ponds and lakes. This behavior is undesirable because it impacts carrying capacity, recreation, water quality and habitat functions.

The first appearance of hydrilla in North Carolina happened to be at sites within the Neuse River Basin in 1982. Since then, there has been much effort to eliminate this noxious aquatic weed from the basin. Ongoing hydrilla management has effectively controlled growth and eliminated the plant from some watersheds in the Neuse River basin. Yet hydrilla persists in other areas and continues to show up in “new” sites across the state each year. A few areas of the Neuse River basin infested with hydrilla are: West Fork Eno Reservoir, Eno River, Reedy Creek Lake in William B. Umstead State Park, Lake Raleigh, Lake Benson, Buckhorn Lake and Contentnea Creek. The State’s Aquatic Weed Control Program, housed in the N.C. Division of Water Resources, manages hydrilla at most of these sites with the cooperation of local governments.

Creeping Water Primrose, or *Ludwigia hexapetala*, is another exotic and noxious aquatic plant that has found its way into the waters of the Neuse River basin. Native to South America, this species develops showy yellow flowers during the summer and is a prolific seed producer. Creeping Water Primrose grows in shallow water along shorelines and can produce floating mats as it “creeps” into deeper water. This plant behaves as a perennial in North Carolina, whereas new growth will arise from stems that persist from the previous growing season. Heavy infestations of Creeping Water Primrose can inhibit water withdrawals, interfere with recreational activities, and alter habitat. Water bodies in the basin infested with Creeping Water Primrose include Falls Lake, Brentwood Lake in Raleigh, Beamon Lake in Raleigh, Fox Croft Lake in Raleigh, and Buckhorn Lake in Wilson.

Some plants are designated as noxious aquatic weeds by the N.C. Department of Environment and Natural Resources, but are not regulated by the U.S. Department of Agriculture and the N.C. Department of Agriculture and Consumer Services. These species can be legally imported, cultured and sold, although they are known to have qualities that make them invasive. In many cases, these plants are regulated in other states. Parrotfeather is one of the plants in this group that is found within this basin.

Parrotfeather, or *Myriophyllum aquaticum*, is in the milfoil family. There are a handful of native milfoils that inhabit the waters of North Carolina. Most species in the milfoil family appear similar except for their floral spikes, the uppermost part of the plant that emerges from the water. The name parrotfeather comes from the feather-like appearance of its floral spike. It is also this part of the plant that makes it appealing as an ornamental and thus commonly sold as a water garden specimen. Parrotfeather infests Corporation Lake, an impoundment of the Eno River, Reedy Creek Lake in William B. Umstead State Park and the Little River.

Parrotfeather thrives in calm waters, where it tends to fill the water column. It crowds out native submerged aquatic vegetation and deprives mid-sized and large fish of suitable habitat. Infestations of parrotfeather increase mosquito breeding habitat, which can lead to elevated occurrences of diseases such as malaria, Eastern Equine Encephalitis, West Nile Virus and heartworm in dogs.

7.3 Drought Response Plan and Implementation

7.3.1 Drought Response Legislation

Legislation addressing drought management has been enacted by the North Carolina General Assembly since the drought of the 1980's. The drought that culminated in 2002 was followed by the drought of 2007-2008,[27] which was identified as the worst drought in more than 100 years in North Carolina. Recent drought legislation has included provisions designed to improve water supply planning, enhance the registration and maintenance of water use and water withdrawal data, reduce drought vulnerability and allow for quicker responses to future water shortage emergencies.

The North Carolina Drought Management Advisory Council, or the NC-DMAC,[28] was created by law in 2003. Its predecessor, the Drought Monitoring Council, was an interagency information exchange body created in 1992. Hydrologic conditions in North Carolina are reported each week by a technical team of the NC-DMAC to the compilers of the U.S. Drought Monitor. The USDM, which is defined as the national drought map, usually serves as the drought map for North Carolina as well. The map[29] is updated weekly based on current conditions. A new USDM is released each Thursday. The USDM[30] designates areas of drought using the following categories: D0, or Abnormally Dry; D1, or Moderate Drought; D2, or Severe Drought, D3, or Extreme Drought and D4, or Exceptional Drought.

[27] www.ncwater.org/Drought_Monitoring/dmhistory/?startdate=2000-01-04&label=false&chartType=dmlevel
[28] www.ncdrought.org/
[29] www.ncwater.org/Drought_Monitoring/droughtupdate/
[30] drought.unl.edu/dm/monitor.html

In 2003, legislation required the Environmental Management Commission to develop rules establishing minimum standards for water use during droughts. After several years of work, the resulting rules (15A NCAC 2E .0600) became effective in March 2007. The rules require water systems and users to plan ahead for drought conditions and establish protocols or plans that will adjust water demands to minimize detrimental impacts. Drought legislation enacted by the General Assembly and signed into law on July 31, 2008, includes provisions to improve water use data; reduce drought vulnerability; and allow for quicker response to water shortage emergencies. This law changed some existing water supply and drought planning policies and gave DENR the responsibility to approve local water supply plans and water shortage response plans. Prior to this legislation, these plans were submitted to the N.C. Division of Water Resources and reviewed for consistency with the general requirements contained in the authorizing legislation, but no formal approval was required.

7.3.2 Water Shortage Response Plans

Water systems required preparing and updating a local water supply plan, or LWSP, must also develop a water shortage response plan, or WSRP. A WSRP establishes authority for declaration of a water shortage, defines different phases of water shortage severity, and outlines appropriate responses for each phase. Additionally, all plans must include specific conditions, which trigger implementation of drinking water use reduction measures and movement to more restrictive and less restrictive stages. The triggers used to activate the various water conservation measures vary according to water system supply types, such as reservoirs, run-of-river, ground water, purchase or combination systems. As specified in the legislation, all WSRP's are considered approved upon submission until they are formally disapproved by the N.C. Division of Water Resources.

According to rules governing water use during droughts and water emergencies (15A NCAC 02E. 0607), all systems that must prepare a LWSP are required to submit a WSRP, or they are subject to implementing a set of default rules during periods of extreme or exceptional drought, as designated by the NC-DMAC. This 2008 legislation states that the N.C. Division of Water Resources, acting as an agency of the N.C. Department of Environment and Natural Resources, has the authority to issue civil penalties to water systems for failure to implement these measures when required. This is a new responsibility for the division that will require new monitoring, tracking and enforcement efforts. The 2008 drought legislation also gave the department the authority to require the implementation of more stringent response levels contained in the WSRP's, if necessary to achieve needed water withdrawal reductions. The N.C. Division of Water Resources is mandated to provide the necessary analysis and justification for such actions.

As of March 2010, there are 479 water systems in North Carolina, including 67 systems in the Neuse River Basin that have submitted WSRP's. The WSRP's for the Neuse Basin or for the State are available at:
http://www.ncwater.org/Water_Supply_Planning/Water_Shortage_Response_Plans/plan.

7.3.3 Water System Water Conservation Status

The Division of Water Resources and the regional offices of the N.C. Division of Environmental Health's Public Water Supply Section, have worked together to make possible an online reporting of the status of water conservation requirements by public water systems. This online database provides a consistent way to document and track status of and impacts to public water supply systems. The system is operational and is used to track 656 water systems throughout the state, including 84 systems in the Neuse basin. This information can be accessed at: http://www.ncwater.org/Drought_Monitoring/reporting/index.php.

Table 7-1: Water Shortage Response Plan Summary for Major Water Systems for Neuse River Basin

Water System	Source	Hydrologic Unit	Monitoring	Number of Stages	Trigger	Stages 1	Stages 2	Stages 3	Stages 4	Stages 5
Cary - Apex	Jordan Lake	Upper Neuse	Daily Inflow	4	Supply Remaining, days	120 days	90 days	60 days	30 days	
Clayton	Johnston County	Upper Neuse	Johnston County	4	Johnston County					
Durham	Little River Reservoir + Lake Michie	Upper Neuse	Lake Storage	4	Storage Remaining, Seasonal [May-Oct/Nov-April] % - Additional Source - No Additional Source	75/80 - 40/45	55/60 - 35/40	40/45 - 30/35	30/35 - 20/25	
Goldsboro	Neuse River	Upper Neuse	River Stage	4	Neuse River Stage @ Intake	52 msl	50 msl	49.5 msl + <30% goal	~ Intake Level	
Hillsborough	Lake Orange + West Fork Eno Reservoir	Upper Neuse	Lake storage	3	Supply Remaining, days	180 days	135 days	90 days		
Holly Springs	Harnett County	Upper Neuse	Harnett County	4	Harnett County					
Johnston County	Neuse River	Upper Neuse	Water Use - Supply Monitoring	3	Adequate Supply	Can't be maintained	below adequate supply	serious shortage		
Kenly	Johnston County	Upper Neuse	Johnston County	4	Johnston County					
Kinston	Neuse River	Upper Neuse	H2O Consumption	3	Consumption as % of H2O Production Available for days	>80% for 3 days	>90% for 2 days	>100% for 1 day		
Orange Alamance	Eno River, Lake Orange, O-A Wells, Burlington's Supply	Upper Neuse	Lake storage and wells	3	Supply Remaining, days	180 days	135 days	90 days		
Princeton	Johnston County	Upper Neuse	Johnston County	4	Johnston County					
Raleigh	Falls Lake	Upper Neuse	Water Use Monitoring	2	Supply Remaining, %	<70%	<50%			
Smithfield	Neuse River	Upper Neuse	Water Use - Supply Monitoring	3	Adequate Supply	Can't be maintained	below adequate supply	serious shortage		
SGWASA	Lake Butner	Upper Neuse	Water Use - Supply Monitoring	4	No Formulated Method for Stage Declaration					
Wilson	Buckhorn Reservoir	Contentnea Creek	Lake storage and levels	5	% Storage Remaining + Lake Level below Capacity	<60% + 4'	<43% + 6'	<30% + 8'	<19% + 10'	<10% + 13'

7.3.4 Registration of Water Withdrawals and Transfers

The registration and reporting of water withdrawals and transfers has been required for more than a decade. Recent rulemaking has mandated that registered water users must electronically submit water use information annually to the N.C. Division of Water Resources by April 1 each year.

Information on all water users is important for the establishment and implementation of drought management measures in the river basin. In addition to information contained in local plans, the N.C. Drought Management Advisory Council uses data from registered water withdrawals and surface water transfers between river basins maintained by the division. In general, this registration requirement applies to any non-agricultural water user who withdraws 100,000 gallons or more of ground water or surface water in any day, or who transfers 100,000 gallons or more of surface water in any day from one river basin to another. The registration requirement also applies to any agricultural water user who withdraws 1 million gallons or more in any day of ground water or surface water, or who transfers 1 million gallons or more in any day of surface water from one river basin to another. Units of local government that withdraw water or transfer surface water meet their obligation to register by submitting and regularly updating a local water supply plan. A listing of registered water users and the annual water use data submitted to the division are available at the division's website, www.ncwater.org. This website allows the user to view the water use data by river basin or county.

7.3.5 Drought Response and Drought Proofing Activities

The N.C. Division of Environmental Health's Public Water Supply Section and the N.C. Division of Water Resources have established a list that ranks local water systems in three tiers of vulnerability during drought conditions. Regional engineers in the state public water supply section review and update the drought vulnerability tier list and identify community water systems needing assistance. This ranking is a subjective assessment based on best professional judgment and experience of the state public water supply section's field staff. Systems remain at their highest tier-level until a supplemental water source is available to provide an emergency water supply and reduce the system's vulnerability to drought.

Tier Definitions

Tier-1: systems are considered to be in a crisis mode (or) have less than 100 days of present supply remaining (or) are likely to be in a crisis if conditions persist because they lack interconnections for emergency water supply.

Tier-2: systems are not in crisis now but could be within the next few months.

Tier-3: systems are not yet in a vulnerable position but are subject to change as the drought continues.

During droughts, the list of water systems in Tier 1, 2 and 3 in the state will be available online at: http://www.ncwater.org/Drought_Monitoring/.

Glossary

ABR	Approved Base Rate -- The annual withdrawal rate established during CCPCUA permitting.
Acre-foot (acre-ft)	The volume of water required to cover 1 acre of land (43,560 square feet) to a depth of 1 foot. Equal to 325,851 gallons or 1,233 cubic meters.
Aquifer (confined)	Soil or rock below the land surface that is saturated with water. There are layers of impermeable material above and below it. It is under pressure so that when the aquifer is penetrated by a well, the water will rise above the top of the aquifer.
Aquifer (unconfined)	An aquifer whose upper water surface (water table) is at atmospheric pressure, and thus is able to rise and fall.
Brackish water	A mixture of fresh and saltwater.
CCPCUA	Central Coastal Plain Capacity Use Area -- a 15-county region of the North Carolina Coastal Plain designated by the Environmental Management Commission under the Water Use Act of 1967.
Climate	The average weather or the regular variations in weather in a region for a period of years.
Community Water System	A public water system that supplies water to the same population year-round.
COOP	Cooperative weather station.
Drainage Area	An area or region of land that catches precipitation that falls within that area, and funnels it to a particular creek, stream, river or reservoir.
DWR	N.C. Division of Water Resources.
EMC	Environmental Management Commission.
Estuary (estuarine)	The wide lower course of a river where it meets the sea and the tide flows in, causing fresh and saltwater to mix
GW	Ground water

Hydrologic Unit	A standardized watershed classification system developed by the U.S.G.S. in the mid-1970s. Hydrologic units are watershed boundaries organized in a nested hierarchy by size.
Igneous rock	Rock formed under conditions of intense heat or produced by the solidification of volcanic magma on or below the Earth's surface.
Metamorphic rock	The result of the transformation of an existing rock type in a process called metamorphism, which means "change in form."
MGD	Million gallons per day.
PWS	Public water system.
POR	Period of record.
POR Yield	POR Yield is the annual amount of water that can be withdrawn or taken from a source of supply over a period of years without depleting that source beyond its ability to be replenished naturally.
Public Water System	Provides water for human consumption through pipes or other constructed conveyances to at least 15 service connections or serves an average of at least 25 people for at least 60 days a year.
Regulated Gage	U.S.G.S. gage stations regulated by human activities.
Riparian	Situated along or near the bank of a river, an owner of land along a river.
SW	Surface water
Unregulated Gage	U.S.G.S. gage Stations not regulated by human activities.
USGS	United States Geological Survey.
Watershed	The land area that drains into a particular lake, river, or ocean
Weather	The state of the atmosphere with regard to temperature, cloudiness, rainfall, wind and other meteorological conditions.

APPENDIX

TITLE: **Prediction of salt intrusion to Cowpen Landing based on Neuse River flow at Kinston**

Summary:

1. Salt water migrates into the lower Neuse River during periods of low flow and is typically near or upstream of the city of New Bern during summer-fall months of most years. Rapid upstream movement of salt can occur during wind-driven events.
2. The Neuse River water quality model developed in 1994 (Neuse-WQ) was used to evaluate how the frequency of salt water near Cowpen Landing (mill intake canal) is affected by upstream river flow at Kinston. The model predicts vertical and longitudinal salt water movement with CE-QUAL-W2 (enhanced version 1)
3. Simulations were run at different river flow at Kinston ranging from 150 to 400 ft^3/s (212-574 ft^3/s at Streets Ferry). Other upstream and downstream boundary information was selected to represent recent or typical summer conditions.
4. Variation in water level in the Neuse Estuary at the city of New Bern during the 60-day simulation caused salt intrusion to Cowpen Landing in all flow scenarios tested. The frequency of days with peak conductivity exceeding an acceptable level of <0.5 mS/cm near the mill intake canal at Cowpen Landing increased as flow decreased:

Table 1. Number of days with peak conductivity greater than 0.5, 1.0, or 2.0 mS/cm by location.

Kinston Flow	Streets Ferry Flow	Cowpen Landing		Midpoint: Spr.Gdn to Cowpen		
		>0.5	>1.0	>0.5	>1.0	>2.0
400	574	4	0	6	2	0
350	500	5	2	8	4	0
300	427	7	3	10	5	2
275	391	9	3	11	7	2
250	354	9	4	14	9	3
225	318	10	6	15	10	3
200	282	13	7	16	12	6
175	246	14	9	21	14	8
150	210	17	14	25	15	10

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5. At a Streets Ferry flow of 574 ft^3/s, salt water intrusion to the mill intake canal at Cowpen Landing was predicted to be short-term (hours) on four days during the 60-day simulation.
6. The occurrence of salt intrusion increased to approximately weekly (15% of simulated days), on average, when river flow decreased below 427 ft^3/s at Streets Ferry (300 ft^3/s at Kinston).

Background Information:

- The Neuse River Basin originates in north central North Carolina northwest of Raleigh, with a drainage area of 4040 mi^2 above Streets Ferry Bridge. Flow from approximately 80% of the drainage area is unregulated by impoundment.
- The Neuse River from upstream of the mill intake at Cowpen Landing to Pamlico Sound is influenced by lunar tides. The region of the estuary affected by salt water depends on flow in the Neuse River over the prior weeks to months. Salt water is typically near or upstream of the city of New Bern during summer-fall months of most years (See Figure 1).
- Short-term (hours to days) movement of salt water in the Neuse River system is controlled by wind-driven water level changes in the lower estuary (below Minnesott Beach). The salt wedge also migrates during twice per day lunar tides but to a much less extent than the wind-driven events.

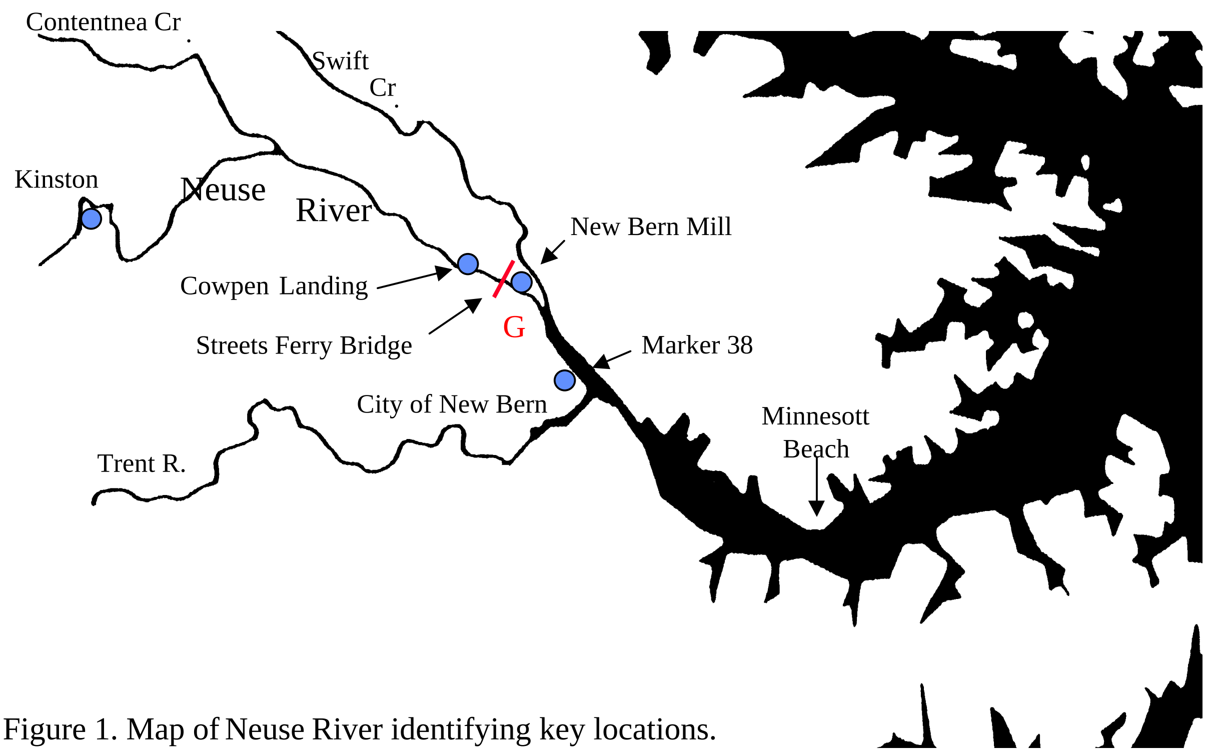
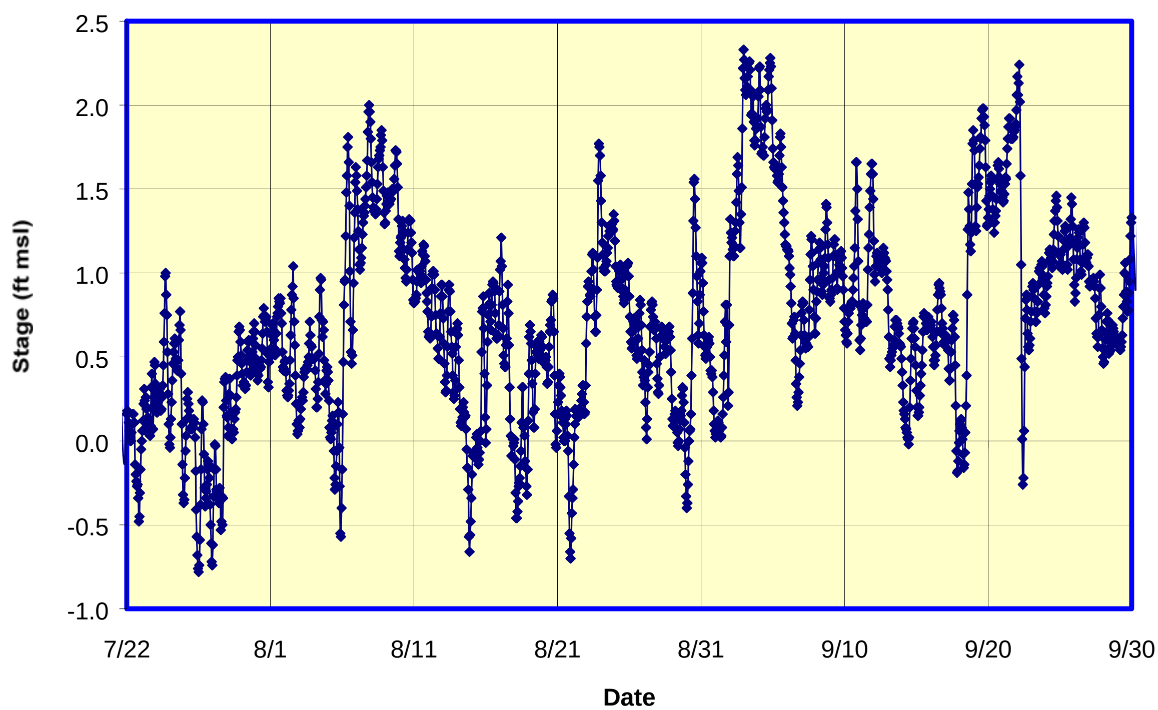


Figure 1. Map of Neuse River identifying key locations.

Salt Modeling Description:

- The Weyerhaeuser New Bern Mill funded development of a water quality model in 1992-94 as a NPDES permit requirement. The model propagates flow in the Neuse River at Kinston downstream to Cowpen Landing (see Fig. 1) with DWOPER, a one dimensional hydrodynamic model, and then simulates hydrodynamics and water quality from Cowpen Landing to the city of New Bern with CE-QUAL-W2 (enhanced version 1) (Beak 1994).
- The model predicts salt water movement in addition to its intended use of evaluating the impact of mill biochemical oxygen demand (BOD) input on river dissolved oxygen.
- The objective of the current salt modeling study was to evaluate the potential frequency of salt intrusion to the head of the intake canal for New Bern Mill at Cowpen Landing. Model runs utilized typical summer conditions for the city of New Bern (conductivity = 25 mS/cm; water temperature = 28°C) at river flows at Kinston from 150 to 400 ft^3/s (Streets Ferry = 210-574 ft^3/s). Flow at Streets Ferry is estimated in the model as 1.242 x $(Flow_{Kinston})^{1.024}$.
- Water level for all simulations was taken from July-September 1994, which provides a period of fluctuating water level at the city of New Bern consistent with periodic wind-driven tide events (see Figure 2).

Figure 2. Neuse River Stage at city of New Bern - 1994



- The model simulation began on July 25 to allow a 7-day spinup period before predictions of salt location were evaluated. Predictions for August 1 through September 29 were evaluated for the number of days on which peak conductivity in bottom waters exceeded 0.5 and 1.0 mS/cm at the mid-way point between Spring Garden and Cowpen Landing (0.6 miles below Cowpen Landing) and/or at Cowpen Landing. A threshold of 2.0 mS/cm was also used for the mid-way location.

Salt Intrusion Predictions:

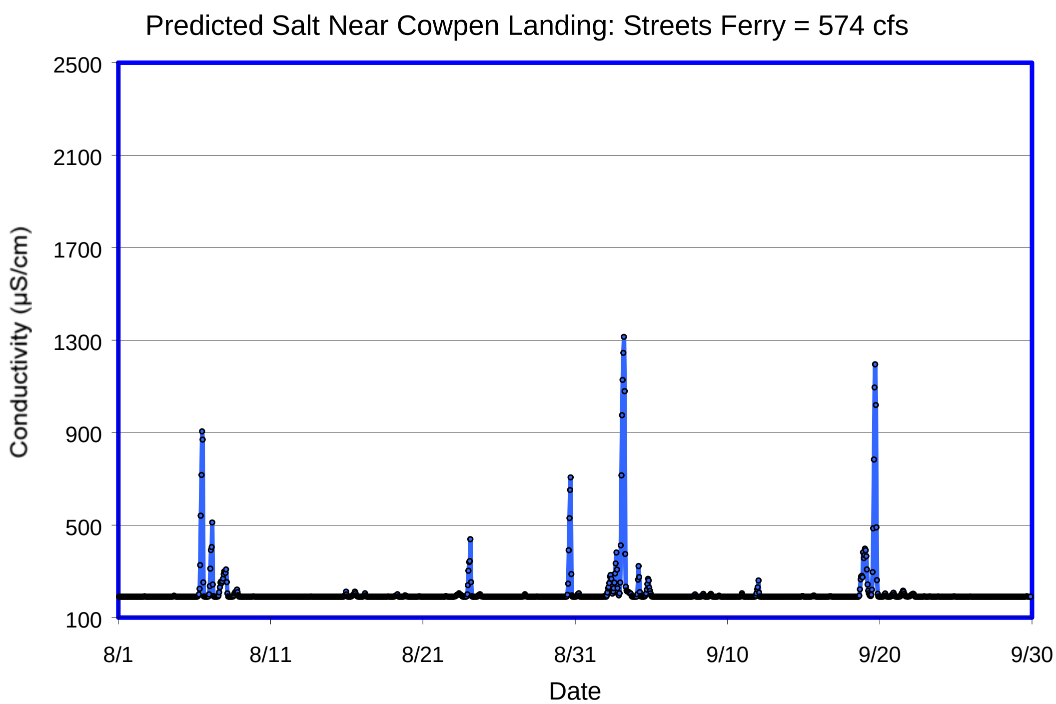
- The key for protection of the freshwater supply to New Bern Mill is to maintain conductivity at the entrance to the intake canal at <0.3 mS/cm. When conductivity is expected to exceed this threshold, the gate to the intake canal is closed, and the Mill goes on shutdown alert. If conditions have not changed in 12 hours then the Mill initiates shutdown procedures. A conductivity of 0.5 mS/cm was used to interpret model predictions as an indication of the location of the leading edge of salt water in bottom waters.
- Table 1 summarizes the number of days during the 60-day simulation period on which peak conductivity at the intake canal (Cowpen Landing) or 0.6 mi downstream (mid-way between Cowpen Landing and Spring Garden) was >0.5, >1.0, and >2.0 mS/cm.

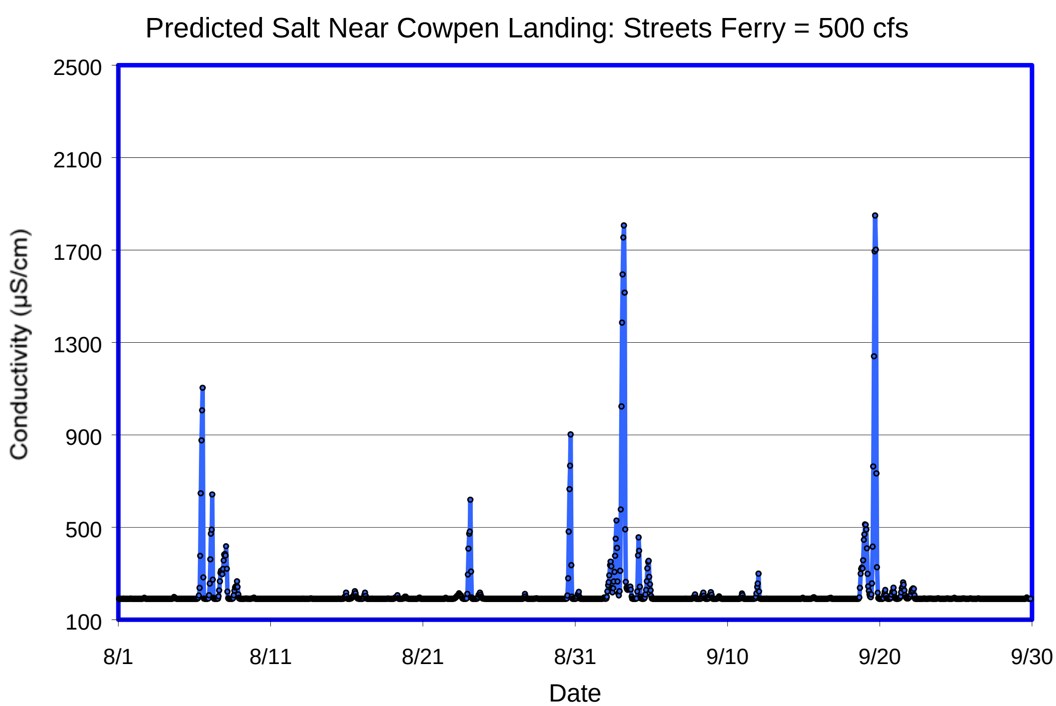
Table 1. Number of days with peak conductivity greater than 0.5, 1.0, or 2.0 mS/cm by location.

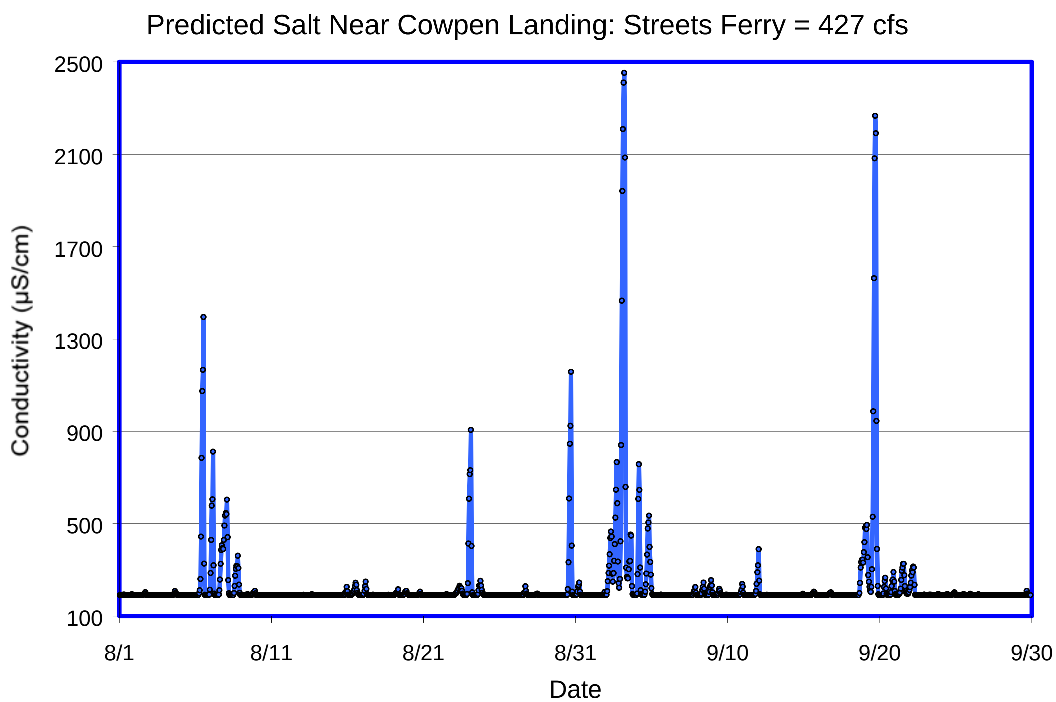
Kinston Flow	Streets Ferry Flow	Cowpen Landing		Midpoint: Spr.Gdn to Cowpen		
		>0.5	>1.0	>0.5	>1.0	>2.0
400	574	4	0	6	2	0
350	500	5	2	8	4	0
300	427	7	3	10	5	2
275	391	9	3	11	7	2
250	354	9	4	14	9	3
225	318	10	6	15	10	3
200	282	13	7	16	12	6
175	246	14	9	21	14	8
150	210	17	14	25	15	10

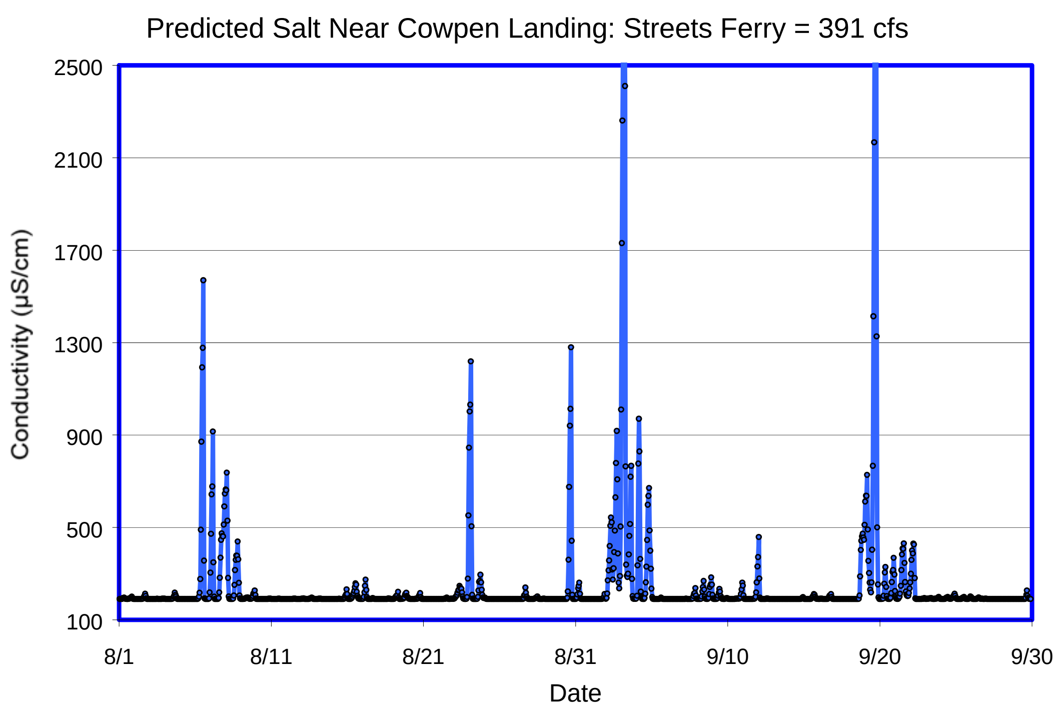
- Mill operations were predicted to be impacted by salt intrusion for all river flows simulated illustrating how wind-driven salt water movement can occur when river flow at Streets Ferry is 574 ft^3/s.
- There was a progressive increase in the number of day on which mill operations would be affected by salt intrusion from four at 574 ft^3/s to 17 at a flow of 210 ft^3/s at Streets Ferry.

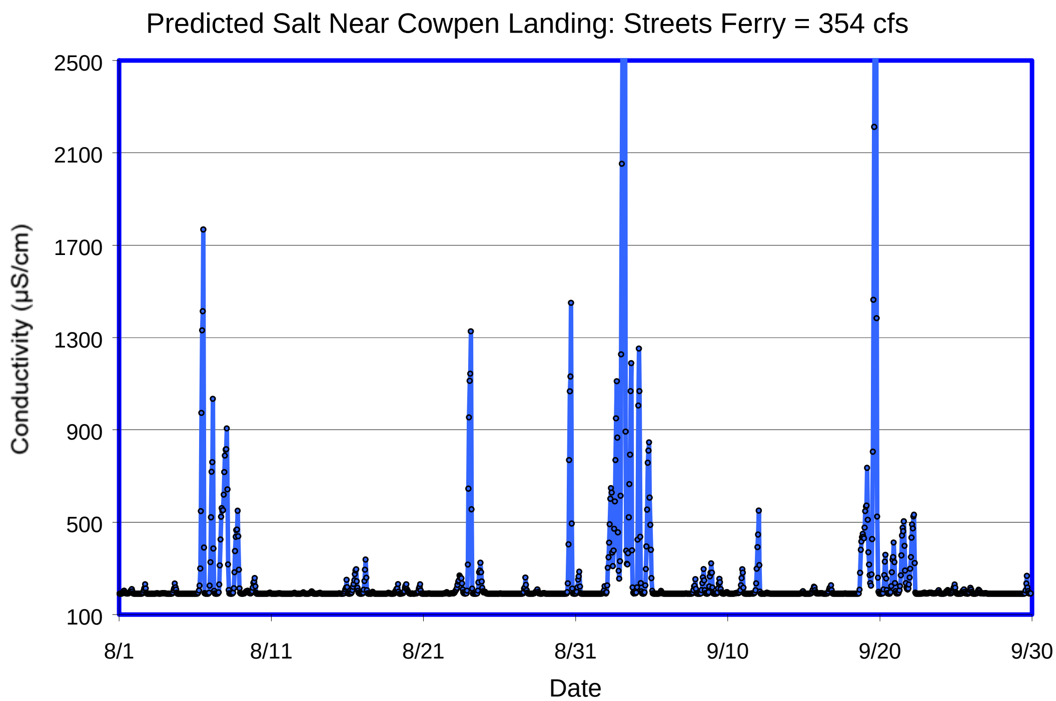
<u>Plots of Modeled Conductivity</u>: Location is between Spring Garden and Cowpen Landing

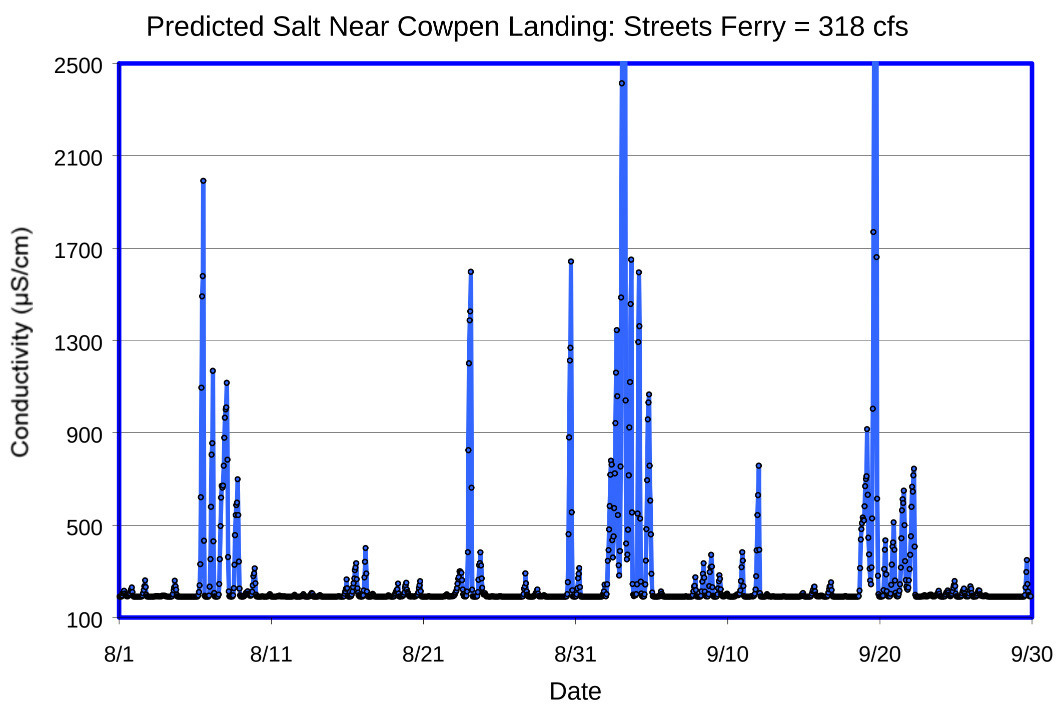


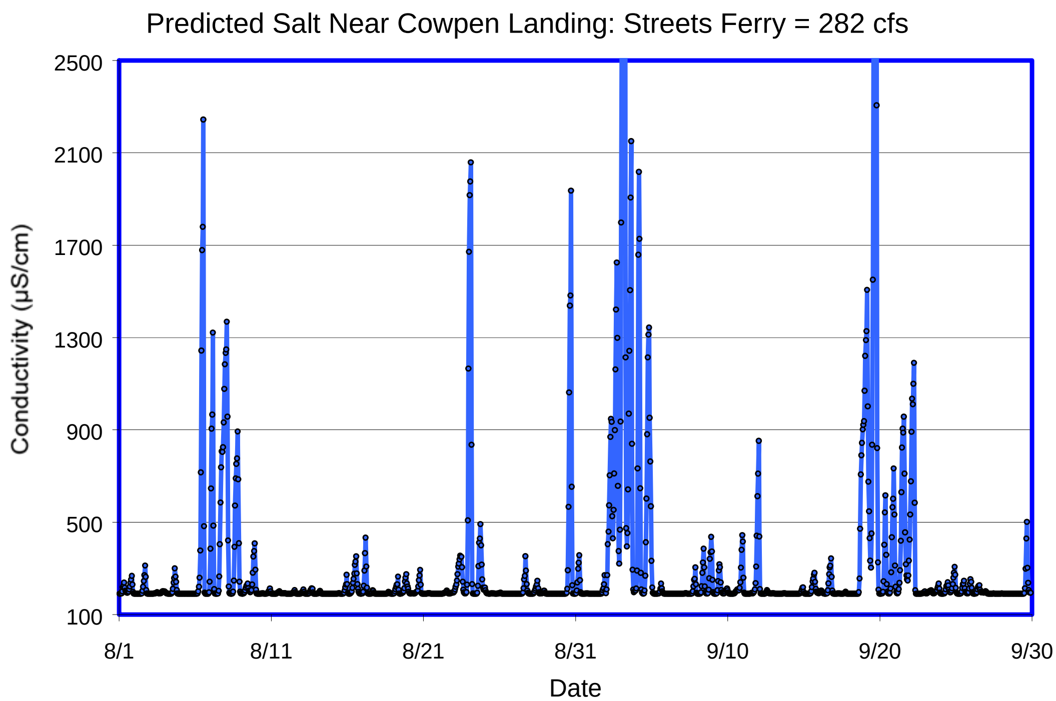


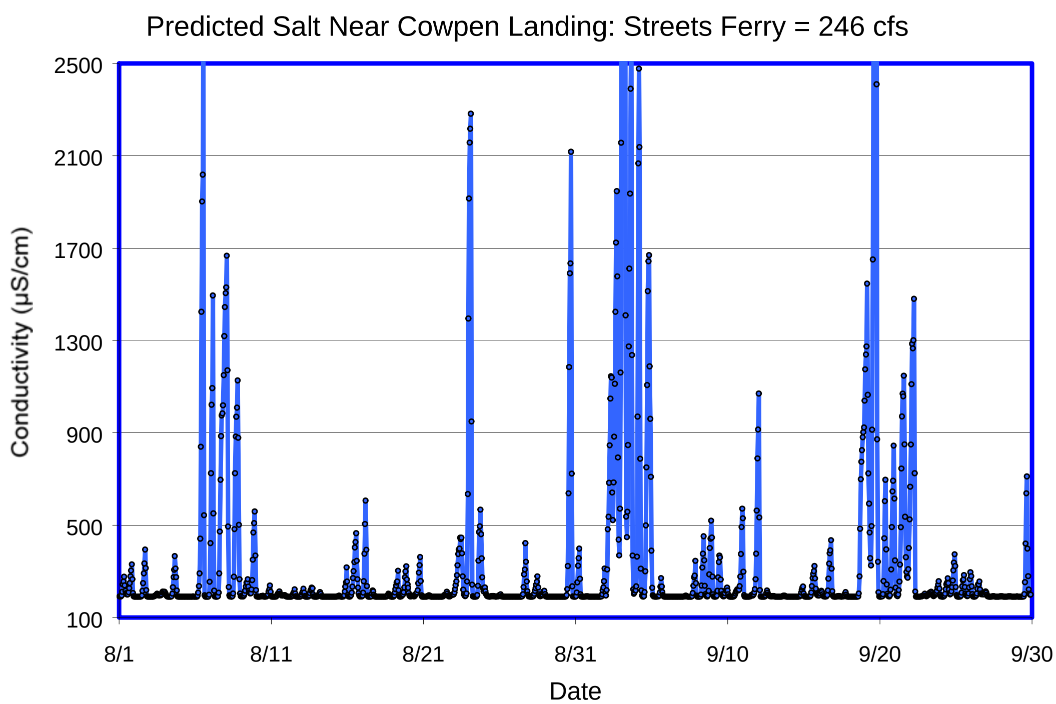

Predicted Salt Near Cowpen Landing: Streets Ferry = 427 cfs
Conductivity (µS/cm)
2500
2100
1700
1300
900
500
100
8/1
8/11
8/21
8/31
9/10
9/20
9/30
Date

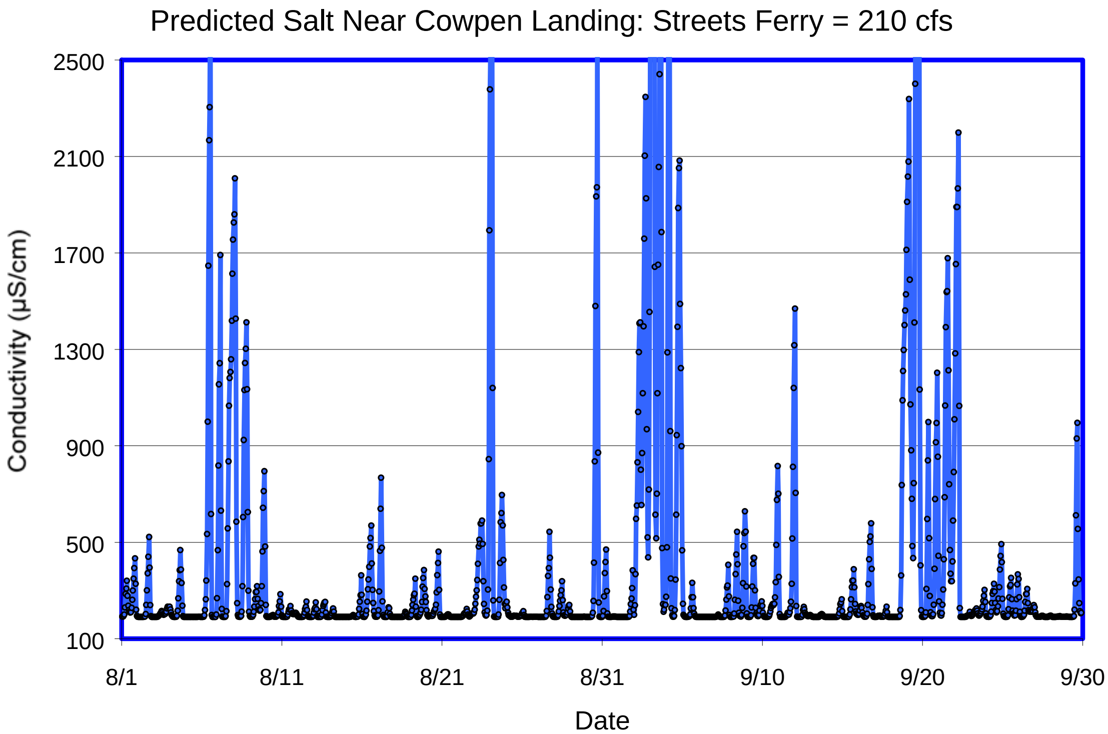

Predicted Salt Near Cowpen Landing: Streets Ferry = 391 cfs
Conductivity (µS/cm)
2500
2100
1700
1300
900
500
100
8/1
8/11
8/21
8/31
9/10
9/20
9/30
Date


Predicted Salt Near Cowpen Landing: Streets Ferry = 354 cfs
Conductivity (µS/cm)
2500
2100
1700
1300
900
500
100
8/1
8/11
8/21
8/31
9/10
9/20
9/30
Date


Predicted Salt Near Cowpen Landing: Streets Ferry = 318 cfs
Conductivity (µS/cm)
2500
2100
1700
1300
900
500
100
8/1
8/11
8/21
8/31
9/10
9/20
9/30
Date


Predicted Salt Near Cowpen Landing: Streets Ferry = 282 cfs
Conductivity (µS/cm)
2500
2100
1700
1300
900
500
100
8/1
8/11
8/21
8/31
9/10
9/20
9/30
Date


Predicted Salt Near Cowpen Landing: Streets Ferry = 246 cfs
Conductivity (µS/cm)
2500
2100
1700
1300
900
500
100
8/1
8/11
8/21
8/31
9/10
9/20
9/30
Date



<u>Literature Cited</u>:

Beak Consultants. 1994. Neuse River Dynamic Water Quality Model. Report to Weyerhaeuser Company, New Bern, North Carolina.