DRAFT

Cape Fear River Basin Water Supply Plan

NC Department of Environment and Natural Resources

March 2009

Division of Water Resources

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Executive Summary

"The river basin is widely acknowledged to be the most appropriate unit area for water resource planning and development because it is a natural, specifically limited area that acts as a unique hydrologic system."

- by Margaret S. Peterson, Hydraulic Engineer, U.S. Army Corps of Engineers, retired.

Overview

The Cape Fear River Basin Water Supply Plan is one in a series of evaluations that are planned to extend the work first presented in the North Carolina Water Supply Plan. As North Carolina's population continues to grow it is important to regularly evaluate water supply conditions. The river basin perspective helps identify the combined impacts of individual communities' projected needs. This approach reveals potential problem areas where it may be difficult to meet projected water demands while maintaining the environmental quality that makes North Carolina a great place to live. The Division of Water Resources (DWR) released the North Carolina Water Supply Plan in 2001 to summarize the best available water use data for all the major river basins in the state. Since that time the Division has had the opportunity to explore ways to describe water availability. The Division has revised its approach to water supply planning to better characterize the relationship between water availability and the projected withdrawals needed to satisfy the demands of water users through 2050.

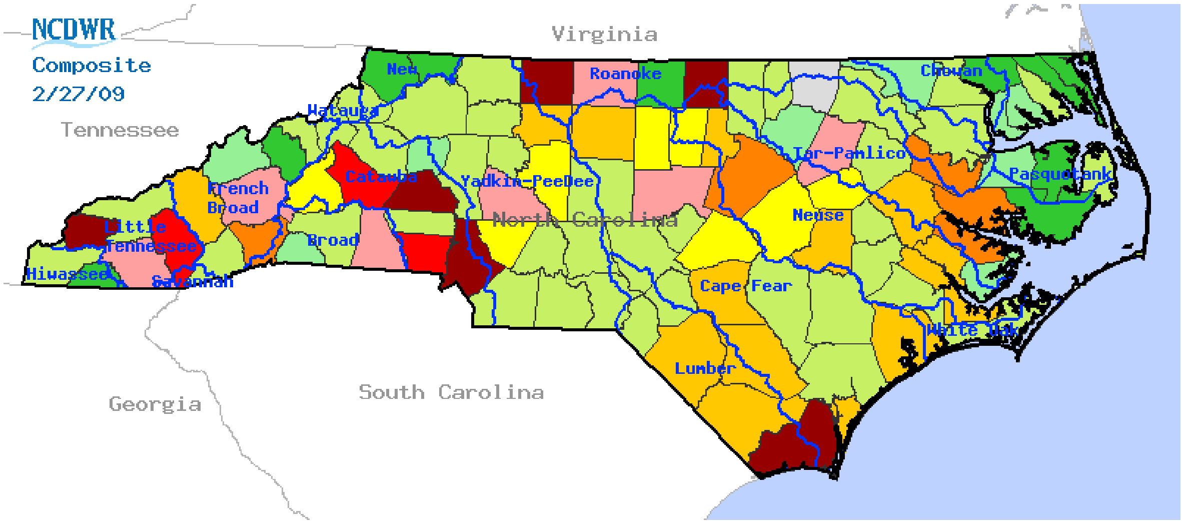
North Carolina has several existing programs that provide valuable information to support this water supply planning effort. Persons that withdraw large quantities of water from the waters of the State must register their withdrawal with the Department of Environment and Natural Resources (DENR). Units of local government that provide water to the public and other large community water systems must prepare and periodically update a Local Water Supply Plan. Registrations and local plans must be updated every five years and all parties subject to either of these requirements must annually report their water usage to the Department.

In addition to these two statewide programs, there are stricter registration and reporting requirements in the fifteen counties of the Central Coastal Plain Capacity Use Area. Permitted withdrawers are required to report their daily water withdrawals to the DWR. Persons that are not required to get a withdrawal permit that use 10,000 gallons per day or more of ground water or surface water are required to register their withdrawal and annually report usage to the DWR.

Combining the data submitted under all of these programs gives the Division a robust database of water withdrawal and use data that makes it possible to do basin wide evaluations such as this one. The Division has also composited data from Central Coastal Plain Capacity Use Area 2007, Local Water Supply Plan 2002, and

Water Withdrawal and Transfer Registration 2004 that contains reported daily water withdrawals, by county. From here it is possible to access water use data by source and by type. The map below, with its legend and data source can be accessed at the Division website.

Map 1: Water Use Data by Source and Type



Geographic Scope

The six hydrologic units that make up the Cape Fear River Basin encompassing almost 9000 square miles form the largest river basin located entirely within North Carolina. As stated by the *Federal Standard for Delineation of Hydrologic Unit Boundaries*,

> "A hydrologic unit is a drainage area delineated to nest in a multi-level, hierarchical drainage system. Its boundaries are defined by hydrographic and topographic criteria that delineate an area of land upstream from a specific point on a river, stream or similar surface waters. A hydrologic unit can accept surface water directly from upstream drainage areas, and indirectly from associated surface areas such as remnant, non-contributing, and diversions to form a drainage area with single or multiple outlet points. Hydrologic units are only synonymous with classic watersheds when their boundaries include all the source area contributing surface water to a single defined outlet point."

The headwaters of the basin begin in the southern parts of Rockingham and Caswell counties and the basin contains more than 1600 miles of rivers and streams. The Cape Fear River flows into the Atlantic Ocean south of Wilmington. The basin contains all or part of twenty-six counties that include the hilly terrain of the Piedmont as well as the relatively flat Coastal Plain. Table - 1 and Figure - 1 show the basin boundaries and hydrologic subunits used in this analysis. This basin delineation is based on recent revisions to the hydrologic unit definitions and is slightly different from that used in prior basin evaluations of water quantity and quality. It does not include the drainage area of the New River in Onslow County or the coastal areas of New Hanover, Pender and Onslow counties that drain directly to the Intercoastal Waterway or the Atlantic Ocean.

The Haw River and Deep River drainage areas with the hilly terrain are characteristic of the Piedmont physiographic region. Twelve of the fourteen water supply reservoirs noted in Table - 2 are in these hydrologic subunits and contain the majority of public water supply storage in the basin, most notably B. Everett Jordan Lake, which is the largest reservoir in the basin.

B. Everett Jordan Dam creates a reservoir capable of holding four million acre-feet of water. The normal operating water level is 216 feet above mean sea level (MSL). Above this elevation there is twenty-four vertical feet of controlled flood storage. Below this elevation, there is storage dedicated to public water supply, downstream flow augmentation, and space set aside for sediment accumulation.

During serious droughts the minimum releases from the dam that protect downstream water quality and aquatic habitat are reduced to preserve the available flow augmentation storage in the reservoir. The water supply storage in the reservoir is allocated by the Environmental Management Commission (EMC). Water supply allocations are assigned as a percent of storage contained in the water supply pool, which is estimated to be able to supply 100 million gallons per day during extreme drought conditions. Sixty percent of the water supply storage is allocated to local governments in the region with about 18% of storage currently being used.

The underlying geology in this portion of the basin is composed of a relatively shallow layer of unconsolidated material overlaying unweathered, fractured bedrock. Wells drilled in this area yield variable quantities of water that typically are only sufficient to provide a dependable supply for individual households and very small community water systems.

The Haw River and the Deep River converge to form the Cape Fear River which flows into the Little River – Cape Fear River hydrologic unit. This area contains the transition from piedmont to coastal plain geology. Water releases from B. Everett Jordan Dam, combined with impoundments in the river, control river flow and water levels downstream to the southern end of Bladen County. Buckhorn Dam, south of State Route 42 near Corinth, creates the first backwater moving downstream of B. Everett Jordan Dam. In the Cape Fear River hydrologic unit south of Fayetteville there are three sets of locks and dams that are operated by the US Army Corps of Engineers to support navigation on the river between Fayetteville and the Port of Wilmington. Lock & Dam #1, the most downstream dam, is the downstream limit of the computer model used to analyze the effects of future surface water withdrawals from the basin. Tidal influences downstream of Lock & Dam #1 make it very difficult to model the effects of upstream withdrawals on this section of the river.

East of the fall line the Coastal Plain's geology is a very complex pattern of sediment layers deposited on the underlying basement rock during cyclic fluctuations of sea level over millions of years. Moving west to east from the fall line to the coast line the sediment layers slope downward and generally become thicker. This stack of sediments is delineated into water-bearing aquifers by confining units made up of sediments that inhibit the movement of water.

The Black River and Northeast Cape Fear River hydrologic units drain 3,300 square miles of the Coastal Plain. The flows from these drainage systems merge with the main stem of the Cape Fear River below Lock & Dam #1 and above Wilmington. Ground water is the primary source of drinking water for communities in this region. The structure of the aquifer system buffers these deeper, high quality water sources from the effects of drought. These aquifers have historically provided a reliable source of water for residents in this area.

The current and future water supply demands evaluated for this report were based on data available to the Division of Water Resources in October 2007. Local Water Supply Plans and water withdrawal registration data submitted to the Division, as well as discussions with major water users, were the primary sources of these data. At the time future demand scenarios were being assembled, local plans for 110 water systems in the basin were reviewed. Twenty-three systems withdraw surface water to provide drinking water to their customers and fifty-five other public water systems. The remainder of the public water systems in the basin depends on ground water to meet their public water supply needs.

There are four major electric generating facilities in the Cape Fear Basin. They are all owned and operated by Progress Energy Carolinas. The Cape Fear Plant, a 317 megawatt (MW) coal fired facility is located at the confluence of the Deep and Haw Rivers. The Cape Fear Plant uses water from the Cape Fear River for cooling water and returns used water to the river downstream at Buckhorn Dam. The Harris Nuclear Plant is a 900 MW facility located east of the Cape Fear Plant in southwestern Wake County. Harris Lake, formed by impounding Buckhorn Creek, provides cooling water for this facility. Buckhorn Creek flows into the Cape Fear River just below Buckhorn Dam in Chatham County. The 398 MW Sutton Plant is a coal fired facility located along the Cape Fear River below Lock & Dam #1 near Wilmington. At the mouth of the river, the Brunswick Nuclear Plant is an 1875 MW facility that uses saline water for cooling. These four facilities produce a total of 3490 MW of electricity for communities throughout eastern and central North Carolina.

River Basin Modeling

The analysis presented in this report is based on combining water use data submitted by water users in the basin and compiled by the DWR staff and consultants with a computer based hydrologic model designed to simulate the effects of water withdrawals on surface water availability. The results of the modeling give a hypothetical representation of changes in water quantity that is limited by data availability and the accuracy of assumptions that have to be made about future conditions. Changes in data availability and quality or changes in the assumptions used will produce different results.

An initial version of a Cape Fear River Basin Model was developed for analyzing the potential impacts of requested increases in water supply allocations from B. Everett Jordan Lake that were approved in 2002. In 2007 the data compiled for the initial model was transferred to an easier to use program platform and the model was updated to extend streamflow data through 2005. The model used for this analysis, *Cape Fear River Basin Hydrologic Model* uses OASIS with OCL ™, developed by HydroLogics, Inc. OASIS is a generalized simulation program designed to characterize water resource systems. OCL, Operations Control Language, is a proprietary program that facilitates the customization of OASIS for specific applications. The *Cape Fear River Basin Hydrologic Model* was developed in consultation with the major water withdrawers in the basin along with representatives of State and federal resource management agencies.

The *Cape Fear River Basin Hydrologic Model* performs a series of calculations that balance inflows and outflows, given the operating constraints and management goals established at user-defined points of interest in the basin upstream of Lock & Dam #1 in Bladen County. Points of interest include reservoirs, surface water withdrawals, stream gages, wastewater discharges, and inflows from tributary streams. Each of these points of interest in the model is referred to as a model "node". The nodes are arranged systematically to mimic the movement of water through the basin. The equation used at each node includes any operational constraints and management protocols that affect decision making at that location and the result of the calculation become an input to the next downstream node.

The *Cape Fear River Basin Hydrologic Model* is based on seventy-six years of streamflow data, capturing the range of flows that have occurred in the basin from 1930 through 2005. The model produces one solution for each of the 27,700 days in the flow data using the daily average for each characteristic considered. Operating protocols, water withdrawals and wastewater discharge as of 2003 were used to characterize current conditions. Estimated demands for 2030 and 2050 were also modeled and compared to current conditions to identify areas where it may be difficult to meet future water demands. Table 6 in the report summarizes the withdrawals and return flows modeled for the surface water withdrawers in the basin. Modeling results indicate that, based on the assumptions used, the water demands at thirty-one of the forty-two water supply demand nodes could be met everyday over the range of flows that occurred in the basin between 1930 and 2005. Modeling anomalies create the shortages at six of the eleven nodes (see Table - **7**), where the model indicates limitations meeting projected demands. These situations are associated with water systems that have multiple sources of water. The model will be updated to more accurately capture how those sources are managed during drought periods. The model indicates water withdrawal demands that are not completely satisfied may face limited-duration shortages. These shortages could be addressed by implementation of demand management and water conservation measures or development of supplemental sources of water.

Reservoir Water Levels and Flow Changes

Variable flows in rivers and streams means the amount of water available at a particular location also varies. Withdrawals will be restricted when flows are low. Reservoirs serve to store captured water for its eventual use at other times in the future. Once constructed, a reservoir has a fixed volume of water available for withdrawers. If withdrawals exceed inflows, a situation that is likely to occur during droughts, the water level in a reservoir will decline. How much the water level declines depends on how much water is being removed, including downstream releases, withdrawals and evaporative losses. Therefore as withdrawal demands increase, water levels are likely to be lower and will be exacerbated during drought conditions.

As expected, the increases in withdrawals predicted in the 2030 and 2050 scenarios produce changes in the patterns of water levels in the reservoirs modeled. Of particular interest are the changes in water storage and elevations shown for B. Everett Jordan Lake. Modeling indicates that increased withdrawals will mean the water levels will be drawn down lower and for longer periods of time than under the 2003 scenario. Normal operating water level for the reservoir is 216 feet MSL. The 2003 demand scenario indicates that water levels would be below 214 feet about 10 percent of the time. Under the 2030 and 2050 demand scenarios water levels are predicted to be below this level about 16 percent and 18 percent of the time, respectively.

Currently, the model does not contain provisions to maintain flows sufficient to protect the ecological integrity of the riverine ecosystems present in the area modeled. If the model indicates that water is available to satisfy an off-stream demand, then the model will allow the withdrawal and deduct that volume of water from the river, regardless of the amount remaining in the waterway. To begin examining how best to integrate ecologic integrity into the model’s management goals, several locations in the basin were selected to compare flow patterns under the estimated unimpaired conditions; the base case scenario; and the 2030 and 2050 demand scenarios.

This approach characterizes the changes in flow regimes by determining how frequently daily flows fall within different brackets over the range of flows represented in the period of record, on a seasonal basis. The percentages within each bracket can then be compared for the unimpaired and three different withdrawal scenarios. For example, modeling indicates that the amount of time when flows in one section of the Deep River would be in the bracket from 10% to 20% of average annual flow increases from the current 27% to 31% under the 2050 demand scenario (during the June through November time frame) . There is not enough information available at this time to determine the possible impacts of the predicted flow changes on aquatic habitat for species in the vicinity of these selected locations.

More information is needed regarding the response of aquatic habitat and organisms to changes in water availability, both in timing and quantity, throughout the river system. The approach used in this analysis is one way to show the range of changes that could be experienced in the future and provides a starting point for discussions about potential impacts.

There are plans to investigate a flow modification threshold using existing instream habitat studies and hypothetical flow regimes generated by river basin hydrologic models. Developing such a threshold would provide a screening approach that could be included in river basin models to make sure adequate flows for ecological integrity are maintained. It should be noted that such a screening approach would be a broad-brush planning tool. It would not necessarily exempt proposed new or expanded large withdrawals from having to conduct site-specific evaluations of impacts on water availability and aquatic habitats.

Surface Water Transfers

Large transfers of surface water between legislatively defined river basins in North Carolina have been regulated for decades. The roots of the current regulatory regime date back to 1991 when legislation was passed establishing grandfathered transfer capacities and requiring new transfers of two million gallons per day or more to receive approval from the Environmental Management Commission (EMC) before commencing. Recent changes to the controlling legislation established stricter decision making and notification requirements.

The analysis for this plan considered water supply demands for 114 water systems that depend on water from the Cape Fear River Basin to meet customer demands. Most of these systems were established many decades ago to provide fire protection and drinking water to expanding communities. The current configuration of the drinking water distribution and wastewater treatment systems are the result of a series of additions to the systems to meet growing demands. When regulatory basin boundaries were defined by the General Assembly the boundary lines divided many water system service areas.

In the Cape Fear River Basin, seventy-eight water systems depend on surface water from the basin to meet customer demands. Twenty-three of those systems have surface water withdrawals and they provide water to the other fifty-five other water systems. Of the seventy-eight water systems that depend on surface water, twenty-nine systems provide water to customers in basins other than the basin that is the source of their water. Eleven of the seventy-eight water systems discharge their treated wastewater to a basin other than the one that is the source of the water.

Most of these systems that transfer surface water have not exceeded their grandfathered capacity [1]or they have not approached the two million gallon per day threshold established by the legislation. Two groups of water systems have received permission from the EMC to transfer large quantities of surface water.

In 1991, under prior legislation, the Piedmont Triad Regional Water Authority received permission to transfer water in conjunction with approvals necessary for the construction of Randleman Reservoir on the Deep River. They are allowed to transfer up to 30.5 million gallons per day from the Deep River Basin to the Haw River Basin and the Yadkin River Basin.

In 2001, the Towns of Cary, Apex and Morrisville along with Wake County, as a group, received permission to transfer, with conditions, up to 24 million gallons per day from the Haw River Basin to the Neuse River Basin. These systems have allocations of water supply storage in B. Everett Jordan Reservoir and get their drinking water from a water treatment plant owned and operated by the Towns of Cary and Apex. One of the conditions included by the EMC requires returning some of their treated wastewater to the Cape Fear River Basin. Work is ongoing to site a new treatment facility and associated discharge to meet this requirement.

As communities in the basin continue to grow more water systems will face the need to get permission from the EMC to transfer water between basins or find alternative ways to meet their system needs. The Brunswick County water system and the systems that depend on it for their potable water currently face this dilemma. The County is proposing to increase an existing transfer from the Cape Fear River to the Shallotte River Basin. The County will hold a series of public scoping meetings in April 2009 in preparation for development of a State Environmental Policy Document to evaluate the impacts and benefits of the proposed increase. The EMC is the decision-making authority for transfers between basins.

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[1] [1] “Grandfathered capacity” is the amount of water that a facility can transfer without needs to get an interbasin transfer certificate. This applies to facilities existing or under construction on July 1, 1993.

1 Existing Water Resources and Water Balances

1.1 Basin Summary

(a) Basin Description

The Cape Fear River basin is the largest river basin in North Carolina. It drains 9,149 square miles from the Piedmont to its mouth at Cape Fear, south of Wilmington, and runs through 6,386 freshwater stream miles including tributaries[2].

The Cape Fear River Basin is composed of six hydrologic sub-units. The 8-digit hydrologic unit codes [HU] assigned by the United States Geological Survey (USGS) for these basin subunits along the major tributaries are listed in Table - 1. The boundaries of each HU are shown in Figure - 1. The basin starts at the headwaters of the Haw and Deep Rivers which together drain about 3120 square miles of the Piedmont physiographic province. These two major tributaries merge to form the Cape Fear River below B. Everett Jordan Dam. The Cape Fear flows southeasterly through the transition from Piedmont to Coastal Plain terrain on its way to the Atlantic Ocean, south of Wilmington. The Black River and Northeast Cape Fear River, which together drain about 3,310 square miles of the Coastal Plain, also flow southeasterly and merge with the Cape Fear upstream of Wilmington.

Table - 1: Cape Fear River Basin HUs

8 Digit HU	**Watersheds**	**Tributaries**
03030002	Haw River	Upper Haw River, Reedy Fork, Stony Creek, Middle Haw River, Big and Little Alamance River, Lower Haw River, New Hope Creek, B. Everett Jordan Reservoir, Morgan Creek, University Lake
03030003	Deep River	Deep River, Muddy Creek, Richland Creek, Cabin Creek, McLendon's Creek, Rocky River
03030004	Little River Cape Fear River	Cape Fear River, Little River, Rockfish Creek
03030005	Lower Cape Fear River	Cape Fear River, Town Creek, Brunswick River
03030006	Black River	South River, Great Coharie Creek, Six Runs Creek, Black Creek
03030007	Northeast Cape Fear River	Northeast Cape Fear River, Goshen Swamp, Rockfish Creek

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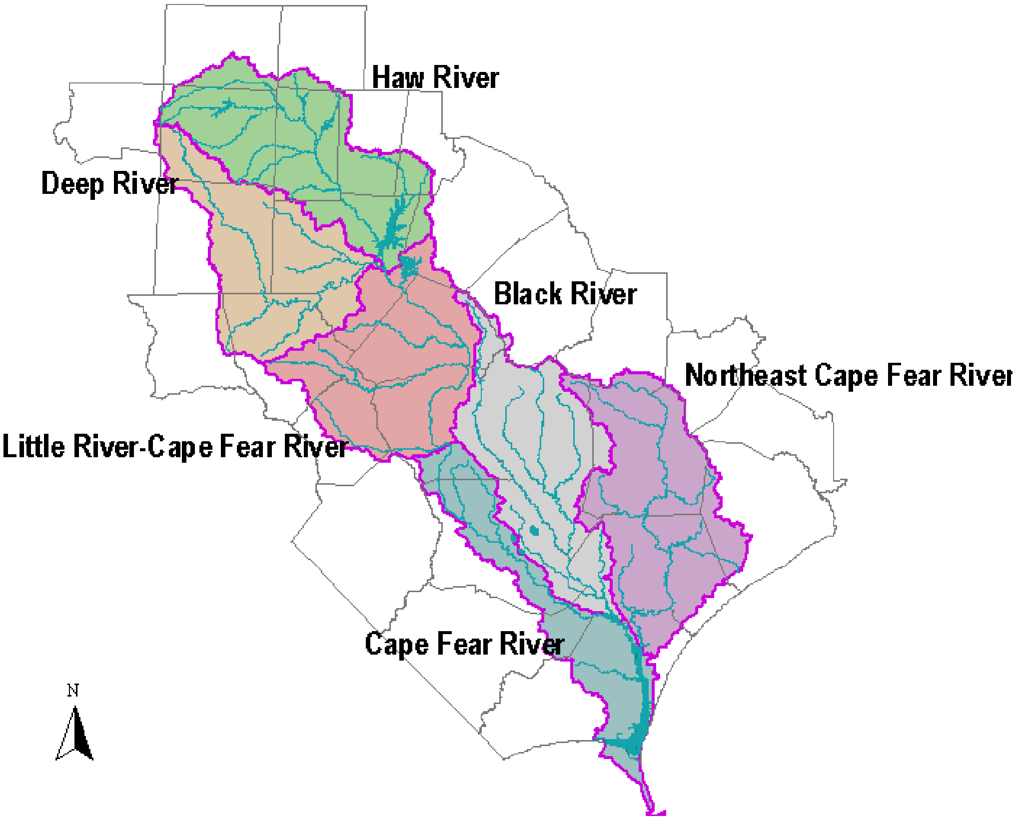
[2] Cape Fear Quick Facts, http://www.ncwater.org/basins/Cape_Fear/

Figure - 1: Map of Cape Fear River Basin HUs



(b) Major Flow Modification

The rolling hills in the Piedmont areas possess suitable locations for the creation of reservoirs by surface water impoundments. The flat terrain characteristic of the Coastal Plain is not suitable for surface water impoundments, however, productive aquifers have been formed by the accumulation of sediment layers.

Several reservoirs have been created in the upper sub basins for water supply, flood control and recreational purposes. The Haw River is impounded by the B. Everett Jordan Dam, just upstream of its confluence with the Deep River, forming the largest multi purpose reservoir within the river basin. Water supply storage in Jordan Lake is controlled by the State of North Carolina and is allocated by the EMC. Table - 2 shows the list of the lakes/reservoirs located in the upper basin.

Table - 2: Cape Fear Water Supply Reservoirs

Water Supply Reservoirs	Max Storage, acre-ft	River	Sub Basin	County
Riedsville Dam	11,416	Troublesome Creek	Haw River	Rockingham
Old Stony Creek Reservoir	3,700	Stony Creek	Haw River	Alamance
Brandt Res	18,391	Reedy Fork Creek	Haw River	Guilford
Lake Jeanette & Townsend	39,504	Richland & Reedy Fork Creek	Haw River	Guilford
High Point Reservoir	3,683	Deep River	Deep River	Guilford
Randleman Reservoir	62,000	Deep River	Deep River	Randolph
Ramseur Reservour	1,221	Deep River	Deep River	Randolph
Graham Mebane Reservoir	15,645	Back Creek	Haw River	Alamance
Mackintosh Reservoir	34,700	Great Alamance Creek	Haw River	Alamance
Cane Creek Reservoir	10,813	Haw River	Haw River	Alamance
Univ Lake	1,320	Morgan Creek	Haw River	Orange
Jordan Lake	4,000,000	Haw River	Haw River	Chatham
Harris Lake	270,000	Buckhorn Creek	Little River Cape Fear	Wake-Chatham
Glenville Reservoir	231		Little River Cape Fear	Cumberland

One acre-foot equals approximately 325,900 gallons.

Besides these water supply reservoirs there are numerous small impoundments for hydroelectric generation which are under the jurisdiction of the Federal Energy Regulatory Commission. A complete list of these dams with their operation status and descriptions is available in the Water Resources section of the 2005 Cape Fear Water Quality Basin Plan[3].

The US Army Corps of Engineers has built and continues to maintain three locks and dams that ensure a minimum channel depth of 8 feet for navigation purposes for 110 miles on the Cape Fear River from Fayetteville to Wilmington. The locations of these locks and dams are shown in Table 3. The furthest downstream of these facilities, Lock & Dam #1 is the downstream boundary of the computer model used for the analysis presented in this plan.

Table - 3: Cape Fear Lock and Dam

Lock and Dam No	Other Name	Location	River Distance
1	Lock and Dam # 1	CF River in Bladen County	39 miles upstream of Wilmington.
2	Lock and Dam # 2	Elizabethtown	2 miles SE of Elizabethtown
3	William O. Huske Dam	Fayetteville	20 miles S of Fayetteville

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[3] [http://h2o.enr.state.nc.us/basinwide/documents/chapter32waterresources_001.pdf].

1.2 Hydrology

(a) Surface Water

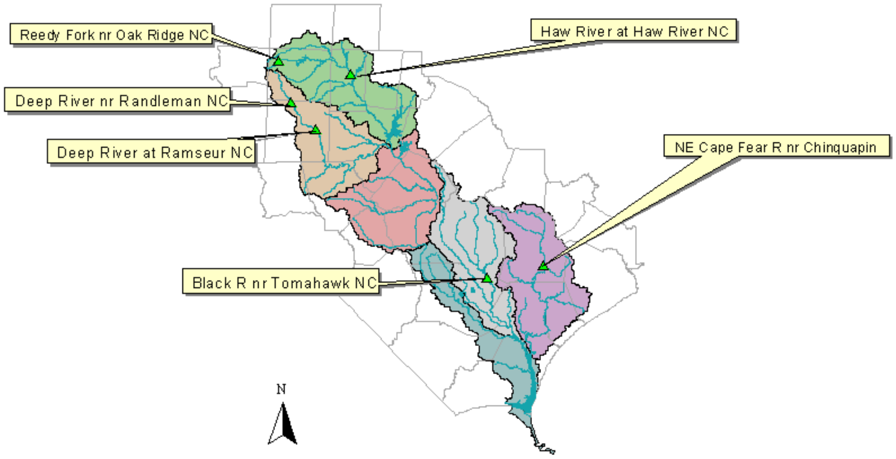
(i) Surface water Availability and Reliability

The Cape Fear stream flows are monitored at 105 United States Geological Survey (USGS) gage stations. Among these, 6 are on unregulated reaches of the river, where impoundments or any other manmade disturbances do not impact the natural flows. These 6 gage stations provide valuable data about streamflows for several significant drainage areas for a considerable continuous time period. Basic gage information for these gages are listed in Table - 4 and locations are displayed on a map in Figure - 2.

Table - 4: List of USGS Unregulated Streamflow Gage Stations

No.	USGS Stations	Station Names	HU	County	Dr. Area, sq-mile	Approx. POR Years
1	02093800	REEDY FORK NEAR OAK RIDGE, NC	3030002	Guilford	20.6	53
2	02096500	HAW RIVER AT HAW RIVER, NC	3030002	Alamance	606	80
3	02099500	DEEP RIVER NEAR RANDLEMAN, NC	3030003	Randolph	125	76
4	02100500	DEEP RIVER AT RAMSEUR, NC	3030003	Randolph	349	85
5	02106500	BLACK RIVER NEAR TOMAHAWK, NC	3030006	Sampson	676	57
6	02108000	NORTHEAST CAPE FEAR RIVER NEAR CHINQUAPIN, NC	3030007	Duplin	599	68

Figure - 2: Map of 6 USGS Unregulated Streamflow Gage Stations



Average daily stream flow values have been analyzed for these 6 stations for each calendar year of the periods of record available for each station. The monthly average of mean, maximum and minimum daily stream flow values are shown in Figure - 3, Figure - 4 and Figure - 5, respectively. Mean values are provided in Figure - 3 with the higher mean flows occurring in the winter and early spring and lower mean flows occurring during the summer months. This variation in seasonal flows illustrates just one of the complications that must be addressed by water systems that choose to use surface water as their source of drinking water. The impacts of flow variation on water systems become even clearer when the minimum flow values shown in Figure - 6 are also taken into account. These minimum flows have occurred during the periods of record for these gages and flows of these levels can be expected to occur in the future.

Figure - 3: Monthly Mean Flow in Cubic Feet per Second

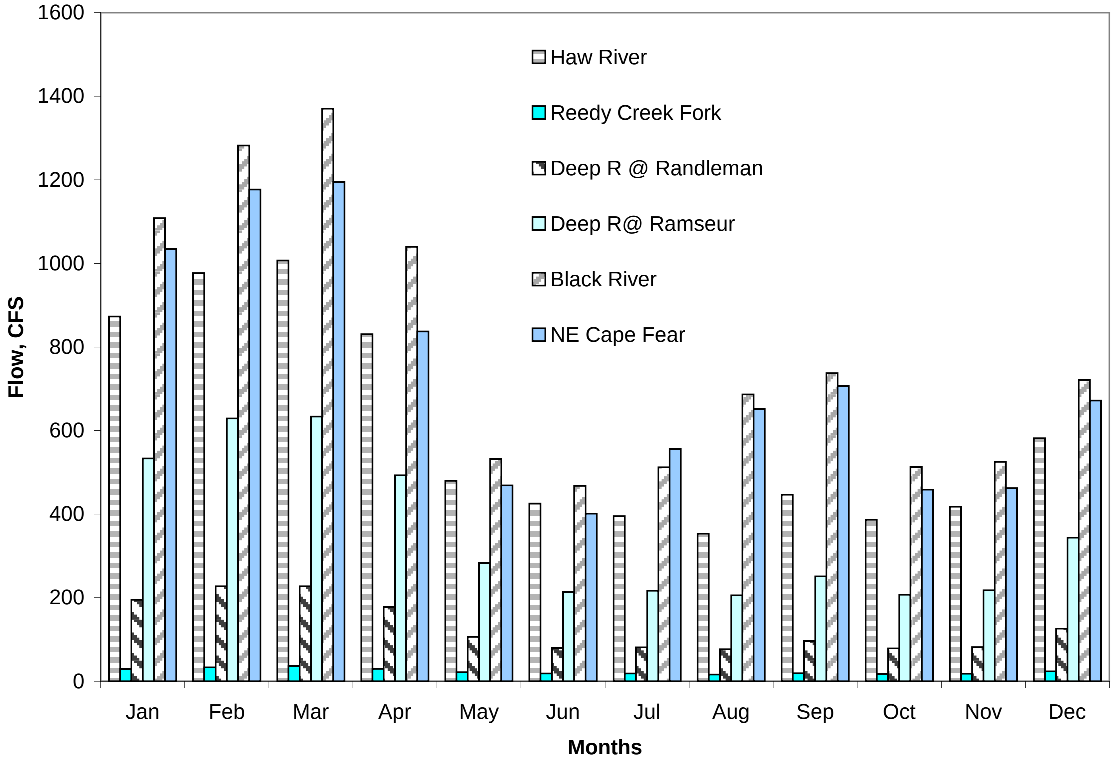


Figure - 4: Monthly Maximum Stream Flow in Cubic Feet per Second

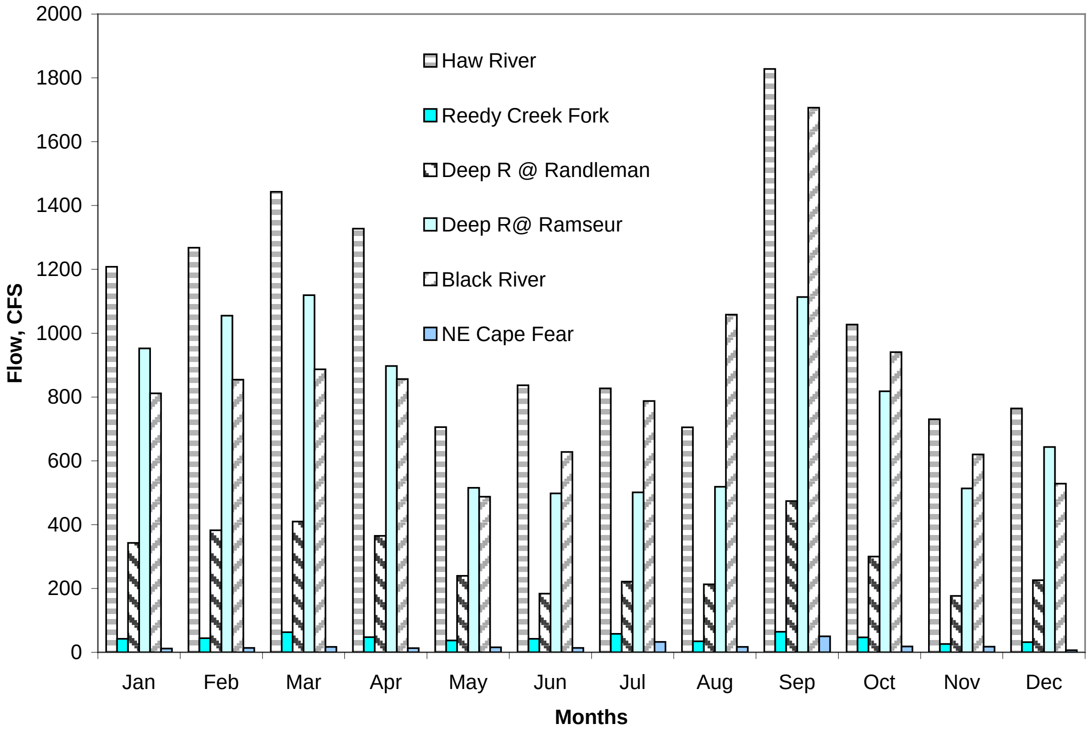
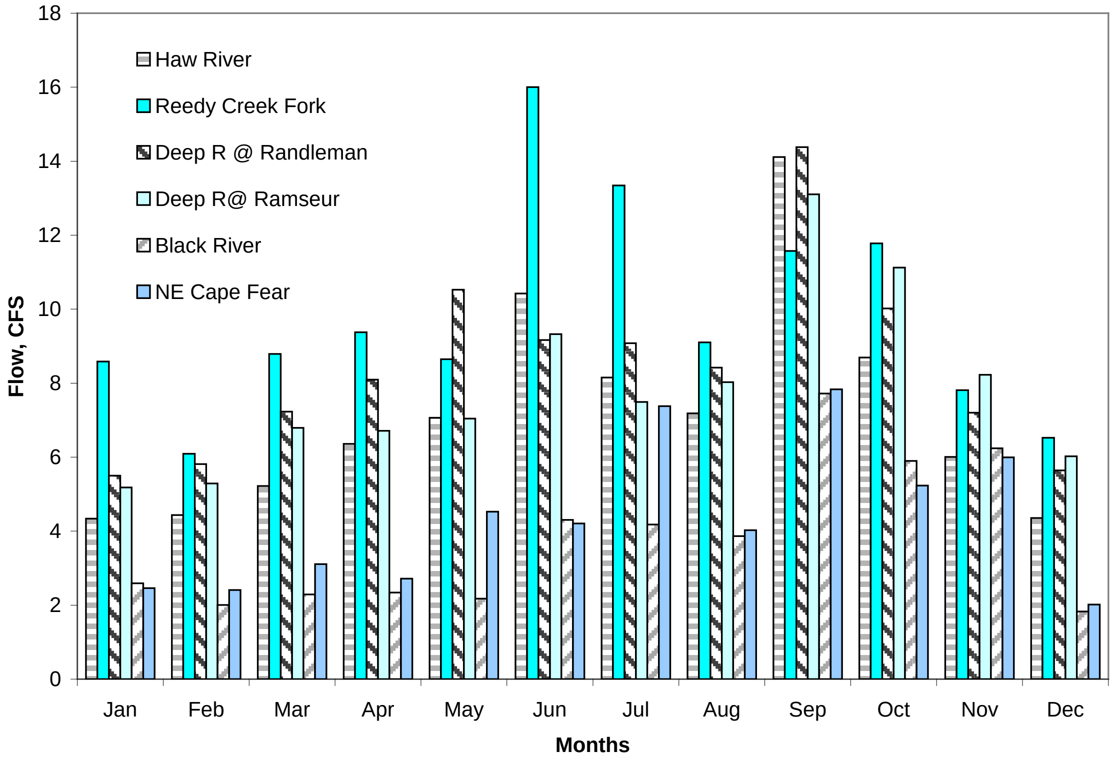


Figure - 5: Monthly Minimum Stream Flow in Cubic Feet per Second



Stream flows are dependant upon the rainfall over the corresponding drainage areas. Thus the drainage area sizes as well as other factors such as geology, topography, vegetation and temperature, have a great influence over the amount of runoff that contributes to streamflows. The yield of a watershed is calculated as the measured streamflow from a unit area. The plots in Figure - 6, Figure - 7 and Figure - 8 show the mean, maximum and minimum unit stream flow measured as cubic feet per second per square mile [CFS/Sq-Mile]] of drainage area for each of the 6 unregulated gages. These unit flow plots are useful for decision making in water resources management. Even though the mean flows shown in Figure - 4 vary substantially between gage sites, the mean unit flows across the basin, as shown in Figure - 6, do not vary to the same degree. Figure - 7 indicates that maximum unit flows vary seasonally as well as by location.

Figure - 6: Unit Mean Flow Statistics in Cubic Feet per Second / Square Mile of Drainage Area

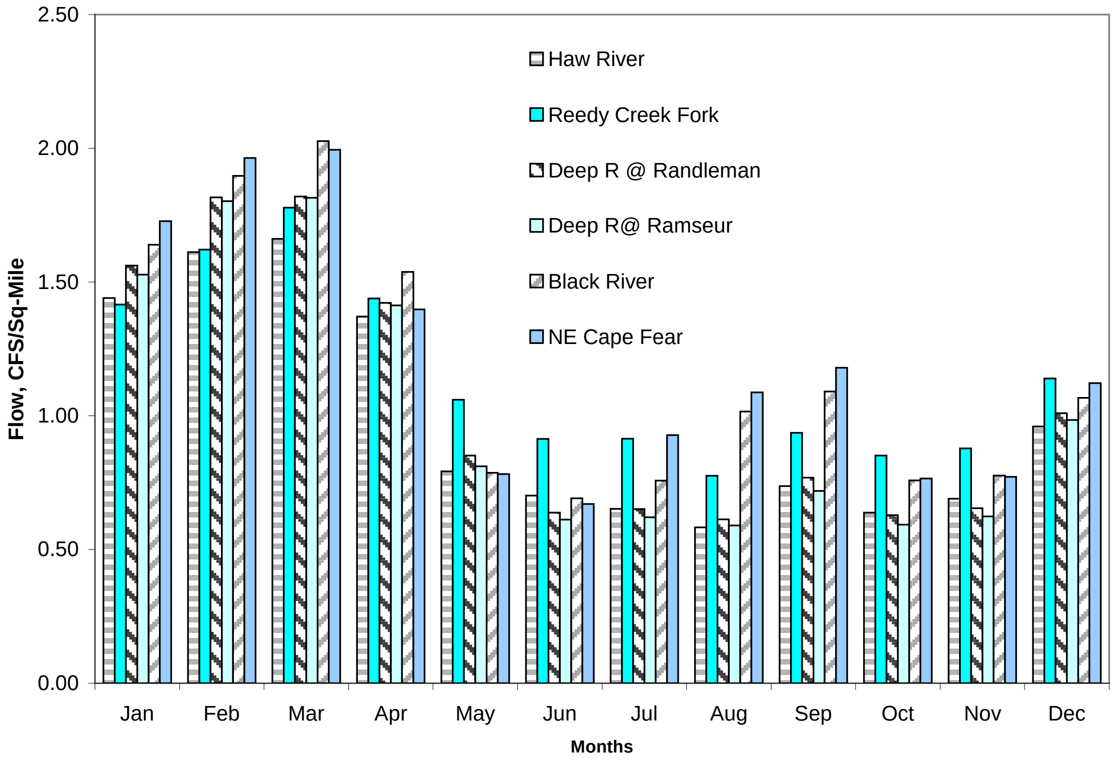


Figure - 7: Unit Maximum Flow Statistics

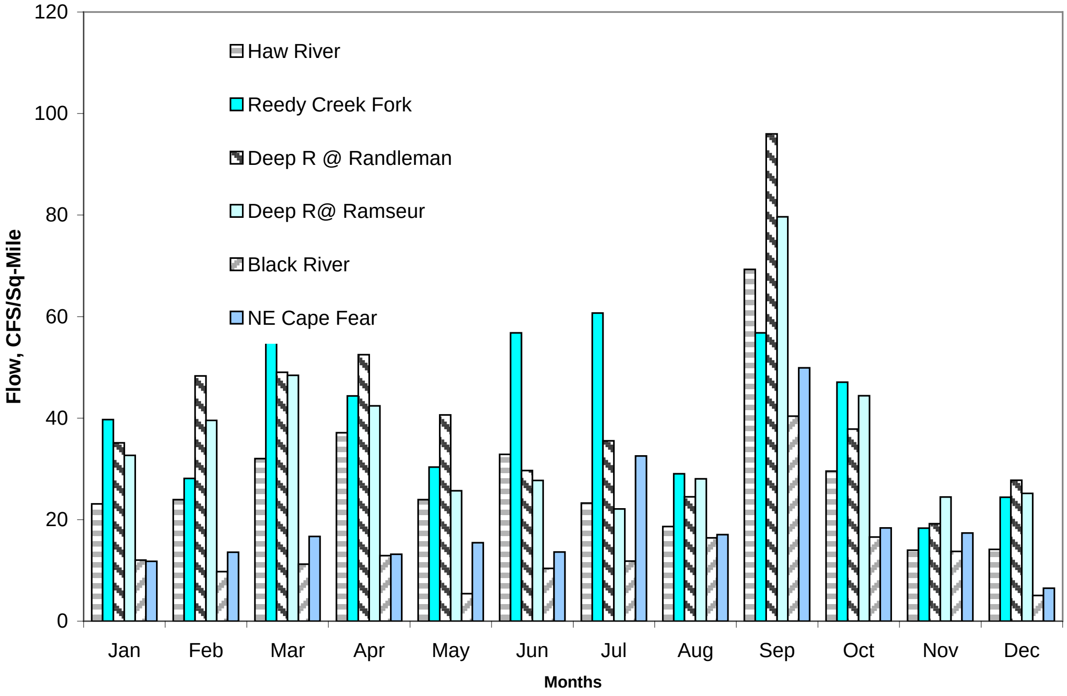
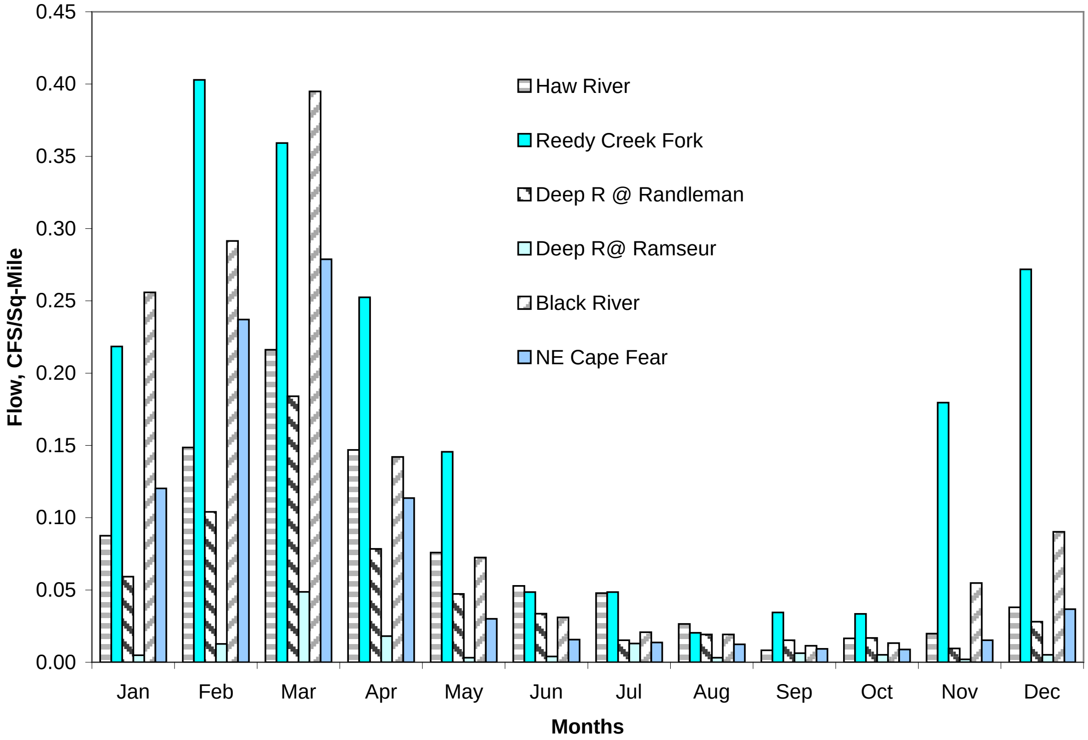


Figure - 8: Unit Minimum Flow Statistics



To supply water to a public water system there must be a balancing of the system’s desired withdrawals and the quantity of water that is reliably available from a water source. For run of the river water sources the availability of water can best be presented by using a duration plot, which shows the percent of time that flow at a gage station will be above a specific value. The stream flow duration plots in log scale and regular scale for the six stations discussed above are shown in Figure - 9 and Figure - 10. These plots indicate that fifty percent of the time the flow varies from 14 cfs to 510 cfs from these drainage areas. Ninety percent of the time flow varies from 6.4 cfs to 103 cfs. Among all these stations, the Haw River station demonstrates more reliability compared to the other stations in the upper basin and 99% of the time the streamflow is at or above 41cfs.

The duration plot for the Deep River at Randleman indicates that over the period of record used for this analysis the flow was 20 cfs or more 85 percent of the time. Conversely, it was less than that for 15 percent of the time. In fact it was less than 13 cfs for 5 percent of the time and less than 9 cfs for 2 percent of the time. This approach provides some parameters for the expected occurrence of various levels of flow. For example, a community hoping to reliably withdraw 15 cfs or about 9.7 million gallons per day would face a significant amount of time where flow at this location would not be sufficient to meet their demand, even without a requirement to maintain a minimum flow below their withdrawal point.

Figure - 9: Flow Duration Plots for Period of Record – Log Scale

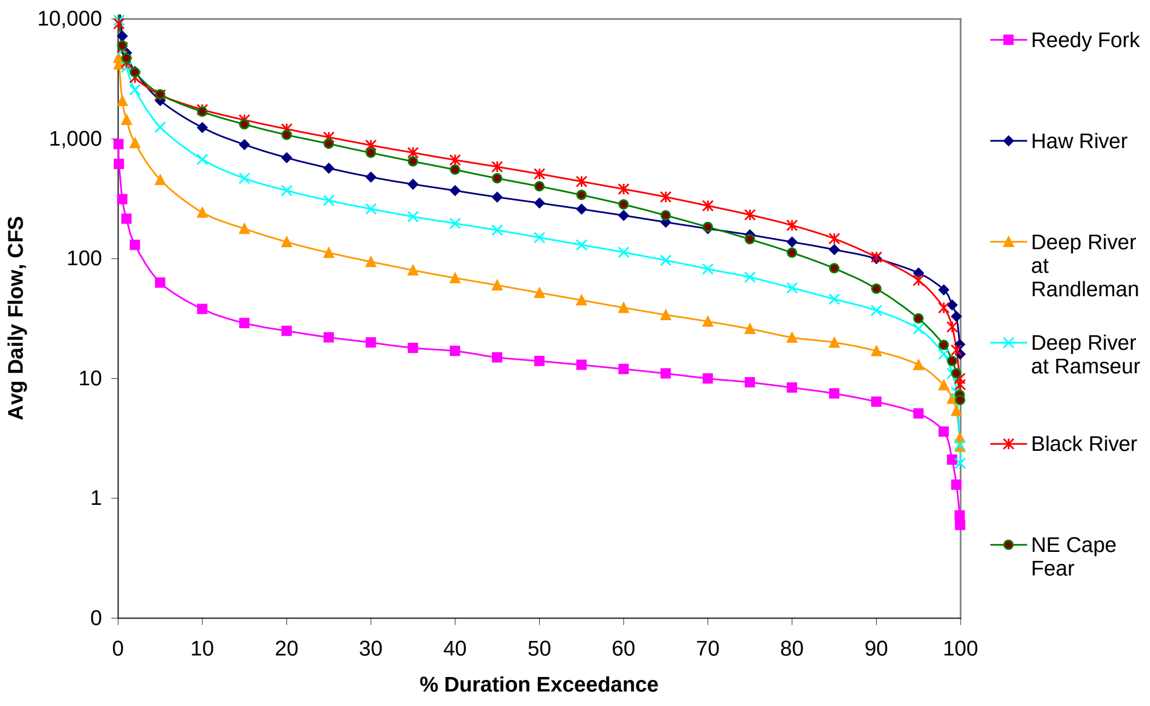
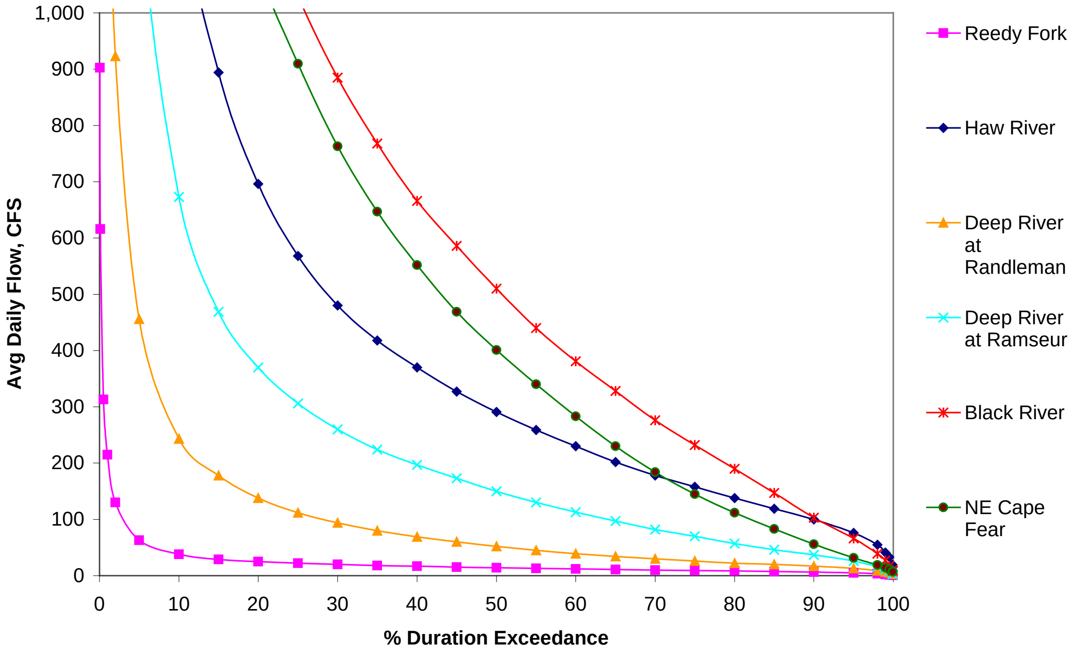


Figure - 10: Flow Duration Plots for Period of Record



(ii) Basin Model Description and Assumptions

The Cape Fear River Basin Hydrologic Model on the Surface Water Assessment and 2008 Analysis

The model used for this analysis, *Cape Fear River Basin Hydrologic Model* uses OASIS (Operational Analysis and Simulation of Integrated Systems), with OCL ™, developed by HydroLogics, Inc. OASIS is a generalized simulation program designed to characterize water resource systems. OCL, Operations Control Language, is a proprietary program that facilitates the customization of OASIS for specific applications. The *Cape Fear River Basin Hydrologic Model* was developed in consultation with the major water withdrawers in the basin along with representatives of State and Federal resource management agencies. More information on the model and its development can be found on the Division's website.

OASIS balances water coming in with water going out at all nodes, subject to the goals and constraints established for each node. The model also assigns weights to each type of water use. This allows the model to make allocation decisions between competing uses. At the reservoir nodes, water is stored and released subject to user-defined operating rules. The model operates on a daily time step making one set of calculations for each day and uses daily average values for each calculation.

In the model, the 2003 demands scenario is used as the base case against which the scenarios of projected future demands and return flows are compared. Using the model to compare future demand conditions with the base case conditions may help to identify the possible impacts on reservoir levels and stream flows at points of interest around the basin due to proposed increases in water supply demands. This Cape Fear Analysis is the most comprehensive analysis that has been done so far using this model.

The DWR began this update to the Cape Fear River Basin Water Supply Plan in October 2007 by meeting with water systems in the basin and requesting that water systems provide the Division with any revised projections of future water supply demands. Except for the twenty water users that submitted additional data in response to this request, the demands modeled were derived from the 2002 Local Water Supply Plans submitted by the water systems. Also at the October 2007 meeting, attendees heard presentations describing several new and expanded withdrawals that are being considered or under development and that have the potential to influence future conditions of the Cape Fear River.

Progress Energy Carolinas is evaluating the possibility of increasing the generating capacity at its Harris Nuclear facility in southwestern Wake County. Also, the Lower Cape Fear Water and Sewer Authority will be developing a surface water intake on the Cape Fear River near Tarheel to supply water to a Smithfield Foods facility and surrounding communities.

Additional information supplied by water withdrawers was integrated into the model and an initial round of modeling was conducted in early 2008. In May 2008 a draft modeling report was released by DWR. While conducting its own review of the modeling results, DWR received comments and suggestions from several other stakeholders. Adjustments were made to the model to more realistically characterize the existing management protocols and the future water demand scenarios were modeled again. In response to comments submitted to DWR, an additional scenario was designed to show the impacts if all of the 100 million gallons per day of water supply storage in B. Everett Jordan Reservoir were withdrawn.

The analysis presented in this document is based on the results of the revised modeling. A detailed report describing the results of the revised modeling was released in October 2008. A copy of the report can be found at the Water Resources homepage.

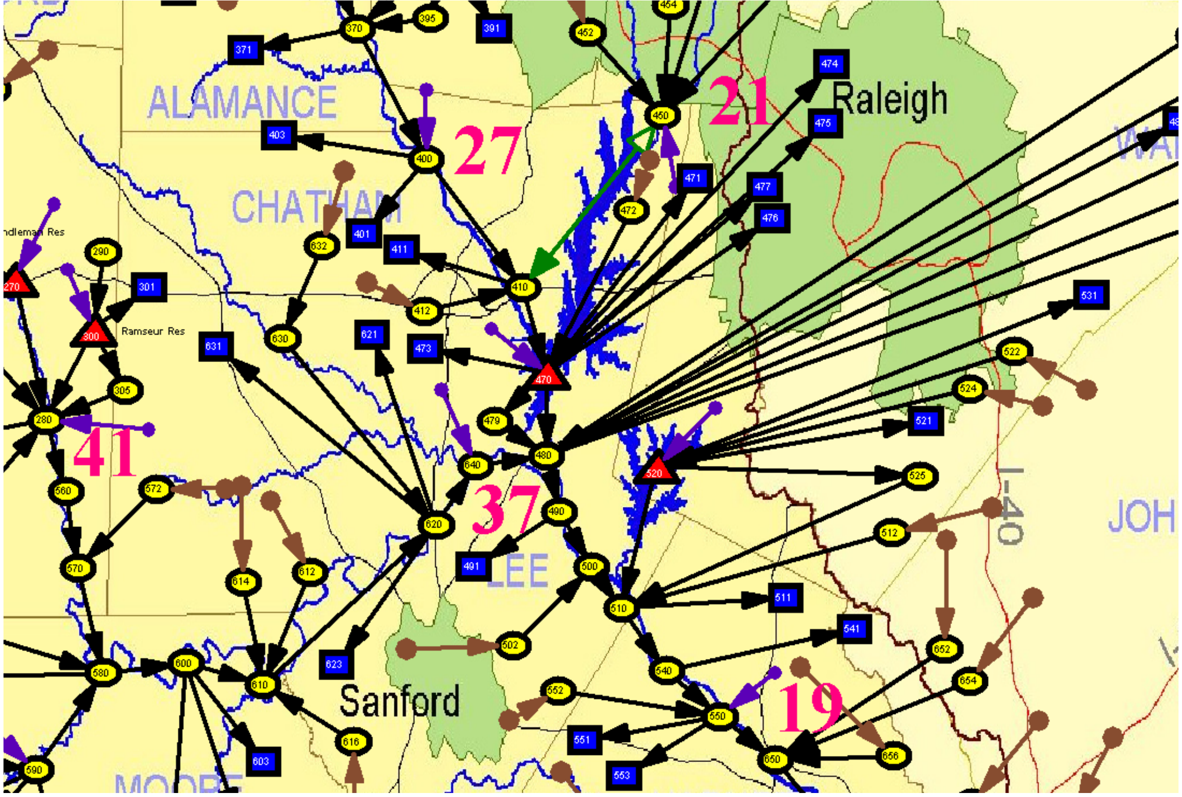
Scope of the Model

The geographic scope of the model includes the drainage areas of the Deep River, the Haw River and the Cape Fear River above Lock and Dam #1 in Bladen County. The model evaluates the quantity of surface water available at various points of interest within this geographic boundary. The schematic map in Figure – 11 shows the geographic coverage of the model and provides some ideas regarding the relative location of the various model nodes.

Each of the polygons in the schematic represents a node where the model performs a calculation to sum the effects of inflows and outflows of water. Figure - 12 provides a more detailed image of the model schematic in the vicinity of B. Everett Jordan Dam and the confluence of the Deep and Haw Rivers.

Figure - 11: Cape Fear Hydrologic Model Schematic

Figure - 12: Cape Fear Hydrologic Model Detailed Schematic



Scenarios Modeled

For this round of modeling six different scenarios were analyzed: a simulation of conditions without any withdrawals discharges or storage impoundments, which is called the Unregulated Flow Scenario; a characterization of current conditions, which is called the 2003 Demands Base Case; and four scenarios of future conditions

i. Unregulated Flow Scenario

This scenario modeled stream flows which are the estimated natural flows in the basin, unaffected by impoundments, water withdrawals, or wastewater discharges. To model this scenario, all demands and discharges were set to zero. All reservoirs were assumed to have zero usable storage, meaning they are modeled to remain full and release exactly the amount of water that flowed into them.

ii. 2003 Demands Base Case

This scenario reflects current conditions. Water demands and return flows were estimated using local water supply plan data and additional information received from water systems and data from other registered water users. The results of the other scenarios were compared to this base case to identify possible changes in impacts due to projected changes in withdrawals and return flows.

iii. 2030 Demands

This scenario modeled the water demands that are projected for the year 2030 using local water supply plan data and any updated projections received from water systems. Jordan Lake water supply withdrawals may, in some cases, be greater than the current approved water supply allocations. These withdrawals were assumed to follow the future water use projections provided by the allocation holders.

iv. 2050 Demands

The 2050 demand scenario is similar to 2030 demand scenario, except that the modeled water demands are those needed to meet water demands projected for 2050 that are contained in the local water supply plans or additional information supplied by water withdrawers.

v. 2050 Demands with Jordan Lake Water Supply Demands set to 100 MGD

This scenario is the same as the 2050 demands scenario except that the total water supply demand from Jordan Lake is set to 100 mgd, which is the estimated maximum safe yield of the water supply pool. Under the previous 2050 demands scenario, a total of 73.5 mgd is modeled as being withdrawn from Jordan Lake for water supply. Under this new scenario, an additional water supply demand node was added to Jordan Lake, and the annual withdrawal at this node was set at 26.5 mgd, bringing the total water supply withdrawal from Jordan Lake to 100 mgd. Note that the additional 26.5 mgd of water withdrawn was assumed to be a 100% consumptive use. None of this additional withdrawal is being returned to the basin. This is a conservative assumption chosen in order to assess the maximum impacts to the Jordan Lake level from the additional withdrawal.

vi. 2050 Demands with 80% of Historic Natural Inflows (Climate Change Scenario)

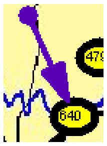
This scenario is the same as the 2050 demands scenario except that all of the natural inflows to the system have all been multiplied by 0.8. The purpose of this scenario is to make an attempt to assess the potential impacts of a long period of increased ambient average temperatures (Climate Change), while meeting the same 2050 demands scenario with 80% of water available.

Model Assumptions

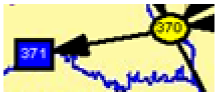
The Cape Fear River Basin Hydrologic Model balances water coming in with water going out at all nodes, subject to goals and constraints designed to characterize current management protocols at each node. Each type of water use is given a user-defined priority at each node which gives the model the ability to make allocation decisions between competing uses. At the reservoir nodes water is stored and released subject to user-defined operating rules. The model operates on a daily time step making one set of calculations for each of the 27,700 days in the historic flow dataset using daily average values for each of the characteristics considered.

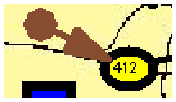
Inputs
Inputs to the model calculations include the following:

1. Estimated Daily Natural Inflows: The model uses a set of daily natural inflows that estimate the water entering the system due to runoff. These inflow data were developed using seventy-six years of flow records and are adjusted for upstream withdrawals, discharges, and reservoir operations. These inflows are modeled as entering the systems at discrete points scattered throughout the watershed. In the schematic, they are shown as purple arrows.



2. Daily Withdrawals: Water is removed from the system at discrete points, represented in the model as withdrawal nodes. These nodes show up as blue boxes on the schematic. These 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 which in some cases were updated to reflect improvements in projections of future demands. Self-supplied industrial water withdrawals were derived from data submitted under the Division's water withdrawal registration program. It is assumed to remain the same in 2030 and 2050 as it is in the base case unless additional information was available to justify changes in projections. Agricultural demands are the same as those used in previous versions of the model. 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 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 USGS in the 1995 Estimated Water Use in North Carolina. Percentages of irrigated crops and livestock in the basin were developed for each county in consultation with county agricultural extension agents. There are individual nodes for agricultural water use in each county in the basin.



3. Daily Wastewater Discharges: 

Return flows from wastewater discharges are modeled similar to natural inflows, as water inputs at discrete nodes. They are represented in the schematic as brown arrows. Inflows from wastewater discharges come from industrial and municipal wastewater treatment plants and water reclamation facilities. The inputs used in the base case were used to calculate the percentage of a facility's water withdrawal that is directly returned to the surface waters of the basin as wastewater return flow. This percentage was then applied to estimated future withdrawals to estimate future wastewater return flows. For example, if a town withdraws 10 mgd on average and returns 6 mgd of treated wastewater, then 60% of the withdrawal is returned directly to the surface waters of the basin. In the 2030 and 2050 scenarios, the assumed wastewater discharge, for this specific example, is again 60% of the withdrawal.

4. Reservoir Operating Guidelines and Data: The model balances inflows and outflows at each node. Inflows equal outflows on all days for all nodes except reservoir nodes, represented by red triangles in the schematic. In the case of a reservoir, the change in daily storage is considered in the balance equation. Each reservoir in the model has a set of operating guidelines. Only two reservoirs in the system have minimum release requirements, Jordan Lake and Randleman Lake. Jordan Lake has a fairly complex set of operating rules, which are explained in a further section of this document on Jordan Lake. Randleman Lake is operated to maintain a minimum release that varies according to reservoir level. The minimum release is assumed in the model as follows:

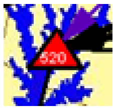


Table - 5: Randleman Lake Releases

Percent Remaining in Storage	Minimum Release at Dam
0-30%	10 cfs
30-60%	20 cfs
60-100%	30 cfs

Outputs

The Cape Fear River Basin Hydrologic Model can provide a variety of model run outputs in a variety of configurations. The primary outputs used for this analysis include the following:

1. Daily Flows: The model outputs daily flows into a node, out of a node, or through an arc. An arc connects two nodes, and is represented in the schematic as a black arrow between two nodes.
2. Daily Reservoir Levels
3. Daily Reservoir Releases
4. Daily Accounting of Jordan 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. This information is used to determine the release from the reservoir during droughts.
5. Drought Stage at Jordan Lake: According to the percentage of storage remaining in water quality storage, the model outputs the daily drought stage.

Withdrawals and Discharges

Table - 6 summarizes the estimated withdrawals and return flows for the 2003 base case and the 2030 and 2050 demand scenarios for the major water users modeled for this analysis. All volumes are shown in million gallons per day (MGD).

Table - 6: Demands and Discharges Assumed in the Modeling (All units are in MGD)

System	Node Description	Node #	Node Type	2003	2030	2050
Angier	NC0082597 (AngiersWW)	654	WWTP Discharge	0.43	0.81	0.90
Archdale	Randleman Lake	904	Withdrawal		1.20	1.20
Asheboro	NC0026123 (AsheboroWW)	282	WWTP Discharge	5.62	7.57	9.94
Broadway	NC0059242 (BroadwayWW)	940	WWTP Discharge		0.11	0.13
Burlington	Lake Mackintosh	341	Withdrawal	10.86	11.73	15.51
	NC0083828 (BurlingtonMackintoshWW)	352	WTP Discharge	0.39	0.41	0.54
	Stoney Creek Reservoir	71	Withdrawal	7.30	5.97	7.91
	NC0023868 (BurlingtonEastWW)	106	WWTP Discharge	0.07	9.87	12.93
	NC0023876 (BurlingtonSouthWW)	362	WWTP Discharge	6.40	9.48	12.48
Carthage	Nicks Creek	701	Withdrawal	0.26	0.59	0.70
Carolina Trace WS	NC0038831 (CarolinaTraceUtilWW)	674	WWTP Discharge	0.25	0.27	0.27
Cary	Jordan Lake	471	Withdrawal	14.02	32.09	34.88
Apex	NC0081591 (CaryApxWW)	472	WTP Discharge	0.69	0.00	0.00
	Western Wake Regional WRF (CaryRegWW)	930	WWTP Discharge		18.40	20.60
Chatham Co North	Jordan Lake	473	Withdrawal	1.03	9.63	15.88
	NC0035866 (NorthChathamWW)	452	WWTP Discharge	0.01	0.05	0.08
Dunn	Cape Fear River	663	Withdrawal	3.49	11.77	17.59
	NC0078955 (DunnWW)	682	WTP Discharge		0.51	0.76
	NC0043176 (DunnWWTP)	692	WWTP Discharge	3.04	9.99	15.35
Durham	Jordan Lake	476	Withdrawal		10.00	10.00
	NC0047957 (DurhamReclamationWW)	462	WWTP Discharge	10.73	11.29	12.90
	NC0026051 (DurhamCtyTriangleWW)	454	WWTP Discharge	4.49	4.02	4.59
Elizabethtown	NC006671 (ElizabethtownWW)	960	Discharge		1.04	1.25
Erwin	Swift Textiles Reservoir	661	Withdrawal	0.65	0.89	1.06
	NC0064521 (ErwinSouthWW)	686	WWTP Discharge	0.95	0.98	1.17
	NC0001406 (BurlingtonIndustriesWW)	684	WWTP Discharge	8.74	0.00	0.00
Fayetteville	Cape Fear River	733	Withdrawal	20.00	69.18	83.11
	NC0076783 (FayettevillePOHofferWW)	744	WTP Discharge	1.23	4.71	5.73
	Little Cross Creek	761	Withdrawal	0.00	0.00	0.00

System	Node Description	Node #	Node Type	2003	2030	2050
	NC0023957 (FayettevilleCrossCreekWW)	742	WWTP Discharge	12.39	31.87	43.24
	NC0050105 (FayettevilleRockfishCreekWW)	774	WWTP Discharge	13.04	24.00	24.00
Fort Bragg	Little Upper River Dam	721	Withdrawal	6.27	0.00	0.00
Franklinville	NC0007820 (FranklinvilleWW)	910	WWTP Discharge		0.04	0.05
Fuquay-Varina	NC0028118 (FuquayVarinayWW)	552	WWTP Discharge	1.01	0.39	1.18
Goldston Gulf SD	Deep River	605	Withdrawal		0.13	1.94
Graham	Graham-Mebane Lake	321	Withdrawal	3.23	6.05	8.11
Mebane	NC0045292 (GrahamMebaneWW)	102	WTP Discharge	0.323	0.60	0.81
	NC0021211 (GrahamCtyWW)	108	WWTP Discharge	1.85	2.46	3.14
	NC0021474 (MebaneWW)	104	WWTP Discharge		1.84	2.63
Greensboro	Lake Townsend	141	Withdrawal	19.65	17.53	23.19
	NC 0081671 (GreensboroLakeTownsendWW)	142	WTP Discharge	12.76	1.56	2.07
	Lake Brandt	121	Withdrawal	11.44	8.77	11.59
	NC 0081426 (GreensboroMitchellWW)	174	WTP Discharge	0.26	0.15	0.20
	Randleman Lake	901	Withdrawal		20.83	27.54
	NC0047384 (GreensboroTZOsborneWW)	182	WWTP Discharge	23.08	26.60	40.34
	NC0024325 (GreensboroNBuffaloCrkWW)	176	WWTP Discharge	1.97	16.00	16.00
	UNC Greensboro (formerly NC0082082) (UNCGreensboroWW)	172	Discharge	0.03	0.00	0.00
Harnett Co	Cape Fear River	551	Withdrawal	7.04	27.47	40.03
	NC0021636 (LillingtonWW)	664	WWTP Discharge		0.43	0.95
	NC0030091 (BuiesCreekWW)	656	WWTP Discharge		0.50	0.50
	NC0031470 (HarnettCoWW)	950	WWTP Discharge		0.40	0.40
High Point	City and Oak Hollow Lakes	221	Withdrawal	13.12	10.58	12.30
	NC0081256 (HighPointWW)	236	WTP Discharge	0.86	0.66	0.77
	Randleman Lake	902	Withdrawal		4.80	5.44
	NC0024210 (HighPointEastWW)	232	WWTP Discharge	15.08	19.06	22.82
Holly Springs	Jordan Lake Release	924	Withdrawal		0.00	0.00
	Cape Fear River	923	Withdrawal		0.00	0.00
	NC0063096 (HollySpringsWW)	522	WWTP Discharge	0.92	4.01	4.83
Jamestown	Randleman Lake	903	Withdrawal		0.67	0.71
Lee County Cumnock Golden Poultry	Deep River	601	Withdrawal	0.65	2.50	2.50
	NC0083852 (LeeCtyWW)	616	WTP Discharge	0.16	0.40	0.40
Lower Cape Fear WSA	Cape Fear River	825	Withdrawal	17.58	21.31	25.70
Moore Co (Vass)	Thagards Lake	711	Withdrawal		0.00	0.00
Morrisville	Jordan Lake	477	Withdrawal	1.5	3.96	3.96

System	Node Description	Node #	Node Type	2003	2030	2050
Orange-Alamance	Jordan Lake	921	Withdrawal		0.00	0.00
Orange Co						
Orange WASA	Cane Creek Reservoir	391	Withdrawal	5.43	4.68	6.90
	University Lake	431	Withdrawal	2.84	3.19	4.70
	NC0082210 (OWASA_WTP_WW)	442	WTP Discharge	0.36	0.40	0.59
	Jordan Lake	922	Withdrawal		5.00	5.00
	NC0025241 (OWASA_MasonFarmWW)	444	WWTP Discharge	8.30	9.94	12.82
Pittsboro	Haw River	401	Withdrawal	0.65	8.14	8.14
	NC0020354 (PittsboroWW)	412	WWTP Discharge	0.45	4.23	4.23
Progress Energy	Shearon Harris	521	Withdrawal	31.41	31.41	31.41
		524	Discharge	19.5	19.5	19.5
Progress Energy	Cape Fear Plant	487	Withdrawal	194.15	194.15	194.15
		512	Discharge	194	194	194
Raeford	NC0026514 (RaefordWW)	772	WWTP Discharge	1.88	3.61	4.10
Ramseur	Sandy Creek	301	Withdrawal	0.58	0.92	1.09
	NC0026565 (RamseurWW)	572	WWTP Discharge	0.27	0.34	0.40
Randleman	Randleman City Reservoir	261	Withdrawal	0.90	0.16	0.55
	Randleman Lake	905	Withdrawal		1.01	1.01
	NC0025445 (RandlemanWW)	252	WWTP Discharge	1.09	1.08	1.45
Randolph Co	Randleman Lake	906	Withdrawal		6.00	6.00
Reidsville	Lake Reidsville	31	Withdrawal	5.75	5.41	5.76
	NC0046345 (Reidsville_WTP_WW)	24	WTP Discharge	0.48	0.46	0.49
	NC0024881 (ReidsvilleWW)	42	WWTP Discharge	3.05	3.46	3.63
Robbins	Brooks	591	Withdrawal	0.26	0.24	0.27
	NC0062855 (RobbinsWW)	582	WWTP Discharge	0.25	0.16	0.19
Sanford	Cape Fear River	491	Withdrawal	6.53	21.06	39.73
	NC0002861 (SanfordWW)	502	WTP Discharge	0.65	2.09	3.93
	NC0024147 (Sanford_WWTP)	612	WWTP Discharge	4.38	12.36	23.67
Siler City	Rocky River	631	Withdrawal	2.97	5.83	6.00
	NC0058548 (SilerCityWW)	632	WWTP Discharge	2.96	4.56	5.40
Spring Lake	NC0030970 (SpringLakeWW)	722	WWTP Discharge	0.90	1.42	1.85
Star	NC0058548 (StarWW)	592	WWTP Discharge	0.16	0.11	0.12
Wake Co - RTP South	Jordan Lake	474	Withdrawal	0.39	2.65	3.82
Wilmington	Cape Fear River	823	Withdrawal	14.80	30.70	39.80

Water Supply Demands vs. Delivery

Note: The results presented in this section are only the three water demands scenarios; the 2003 base case, 2030, and 2050 demands scenarios.

There are 42 modeled water supply demand nodes. In the scenarios, the nodes were individually examined to determine if the projected available quantity for surface water would be sufficient to meet projected demand at each of those nodes. The withdrawal amounts assumed by the model at each water supply node are summarized in the previous section titled “Withdrawals and Discharges”.

For demand nodes on run-of-river sections of streams, the model has a set of weights and goals that determine whether water supply demands can be met. The model uses these weights to prioritize water uses. Simply stated, the weights assign points to each type of use such as a water supply demand, irrigation demand, minimum release from a reservoir, or reservoir storage. The model allocates water by choosing the allocation which maximizes the total weight points. At this time, minimum in-stream flow needs have not been identified and therefore have not been assigned a weight. Using the model to analyze in-stream flows at additional nodes may help identify in-stream flow concerns downstream of water supply withdrawals. In future model runs, in-stream flow targets may be set as needed which may further constrain water supply withdrawals.

For demand nodes from reservoirs, the water supply demand is met if the reservoir has sufficient water remaining in storage. If the model predicts that a demand from a reservoir is not met, this is an indication that the reservoir has been depleted.

Water deliveries were compared to water supply for each of the three demands scenarios. **The model predicts that for 31 of the 42 water supply nodes, the full demand is met for all days for all three water demand scenarios.** However, there are 11 nodes for which the full demand is not met under all three water demand scenarios.

Table - 7 summarizes the 7 nodes for which the model predicts that the full water supply demand would not be met in one or more scenarios for more than one of the 76 years that were modeled. These 7 nodes represent the most significant water supply deficits predicted by the model. They are listed in alphabetical order and divided into systems which have only a single water supply and systems which have multiple water supplies.

The largest water supply deficit predicted by the model is the direct result of how the model was set up to distribute demand among the sources of water available to the Orange Water and Sewer Authority (OWASA). OWASA’s University Lake shows a deficit in 24 of the 76 years in the 2050 scenario. However, this deficit is due not to an actual water supply shortage, but rather how the model deals with the OWASA multi-reservoir water system. In the current model, separate water demands are assigned to each water supply as if they were managed independently. In actuality, these reservoirs are managed as a multi-reservoir system and withdrawals would be taken from another source before University Lake was depleted. However, the model is currently not set up to take this into account. It should be noted that OWASA's Cane Creek Reservoir water supply withdrawals showed no deficits in the 2003 and 2030 scenarios, and only one 2-day deficit under the estimated 2050 demands. This level of supply shortfall could likely be addressed by implementing water conservation measures if this level of demand becomes a reality.

The model shows a deficit for Fort Bragg under the base case scenario in 7 of the 76 years. For decades Fort Bragg has depended on the Little River to meet its water needs. Recent droughts have highlighted the inadequacy of this watershed to reliably meet the recent demands and the base is in the process of switching its source of water. In the future Fort Bragg will get its water from the Cape Fear River through a neighboring water system. This change was included in the model and is the reason that Fort Bragg did not show a water supply deficit in the 2030 and 2050 scenarios.

Among the water systems with only one water supply, deficits were predicted for Ramseur, Randleman, and Robbins. However, only for Ramseur was a deficit predicted in more than two of the 76 years.

The model predicts significant water supply deficits for the Town of Ramseur in all three scenarios. The Ramseur reservoir is small as is Ramseur's projected water supply demand, not expected to exceed 1.1 mgd before the year 2050. Information submitted to DWR since this modeling was completed indicates that the town plans to increase their available water supply beginning in 2015 by purchasing water from Asheboro or Randolph County. These options would likely address the deficits identified in this analysis.

The deficits for Greensboro Townsend Lake and High Point are been solved by future allocation from the Randleman Lake, while Robbins C B Brooks has been planning to make a connection with Montgomery County for an additional source of water. The minor deficit for Randleman could likely be resolved through enhanced water conservation measures during times of water shortages.

Table - 7: Water Supply Demand Deficits Predicted by the OASIS Model

	Model Scenario	2003 Demand (mgd)	Longest Deficit (Days)	Years Demand Not Met Out of 76	2030 Demand (mgd)	Longest Deficit (Days)	Years Demand Not Met Out of 76	2050 Demand (mgd)	Longest Deficit (Days)	Years Demand Not Met Out of 76
Node	**Water Systems**									
	Systems With a Single Water Sources									
301	Ramseur	0.58	34	12	0.9	35	16	1.1	43	20
261	Randleman				0.2	16	2	0.6	15	1
591	Robbins CB Brooks	0.26	33	2	0.24	33	2	0.27	33	2
	Systems With Multiple Water Sources									
721	Ft. Bragg	6.3	12	7						
141	Greensboro Townsend							23.2	36	3
221	High Point - F Ward	13.12	34	5				12.3	16	4
431	OWASA University Lake	2.8	48	7	3.2	7	7	4.7	92	24

# of Days Per Year Demand Not Met = Number of days out of the full 27,394 days of record that the model shows the full demand maybe is not met, divided by 76 (years of record).
Longest Deficit (Days) = The greatest number of consecutive days over the entire 76 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 76 that the full water supply demand maybe is not met.
Systems in Red are those for which a deficit is predicted in any scenario seven or more years out of the 76 year record.

Climate Change Scenario

The increased attention in recent years concerning the potential impacts of climate variability and the possibility of experiencing climate conditions outside the historic range of variability encouraged DWR staff to construct a modeling scenario that could indicate possible impacts from extreme reductions in precipitation. This scenario was designed to show the potential impacts to the water supply pool and the flow augmentation pool as a result of extreme drought in the river basin due to climate variability. The scenario provides one possible example of potential impacts if the regions climate changed to the point that the flows from precipitation and runoff were only 80% of the flows identified for the 76-year period of record used in the model.

For this scenario the 2050 water demands were used and the simulated natural inflows in the model were reduced by 20%. For Jordan Lake, this scenario has 73.5 mgd of water withdrawals. With less flow from tributary streams into the river below the dam, more water would have to be released from the flow augmentation pool to maintain river flows within the target range at the Lillington stream gage. This level of reduction in inflows due to changes in precipitation patterns is thought to be much more drastic than available information indicates would be likely. Therefore, this scenario represents an extreme, but unlikely, future scenario.

From running the 2050 demands with 80% of historic natural inflows scenario we were also able to verify that 15 Water Supply Systems would now encounter difficulty in meeting their 2050 water demand, as shown in Table - 8. Other results of modeling this scenario are also shown in Figure - 17 and Figure - 20.

Table - 8: System Inflows Reduced to 80% of Historical Natural Inflows Under 2050 demands

Node	Water Systems	2050 Demand (mgd)	Longest Defict (Days)	Years Demand Not Met Out of 76
121	Greensboro Lake Brandt	11.60	12	1
141	Greensboro Lake Townsed	23.19	57	6
143	Cone Mills Richland Lake WS	0.71	14	3
221	High Point City and Oak Hollow Lakes	12.28	72	12
261	Randleman Water Supply	0.56	30	5
301	Ramseur Water Supply	1.09	53	25
391	Orange WASA Cane Creek Resorvoir	6.96	19	2
431	Owasa University Lake	4.68	101	35
591	Robbins (Brooks)	0.27	33	2
781	Dupont WS	12.34	1	1
901	Greensboro Demand Randleman	27.59	22	2
903	Jamestown Demand Randleman	0.72	25	1
904	Archdale Demand Randleman	1.20	24	2
905	Randleman Demand Randleman	1.01	24	2
906	Randolph Co Demand Randleman	6.01	25	2

Longest Deficit (Days) = The greatest number of consecutive days over the entire 76 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 76 that the full water supply demand maybe is not met.

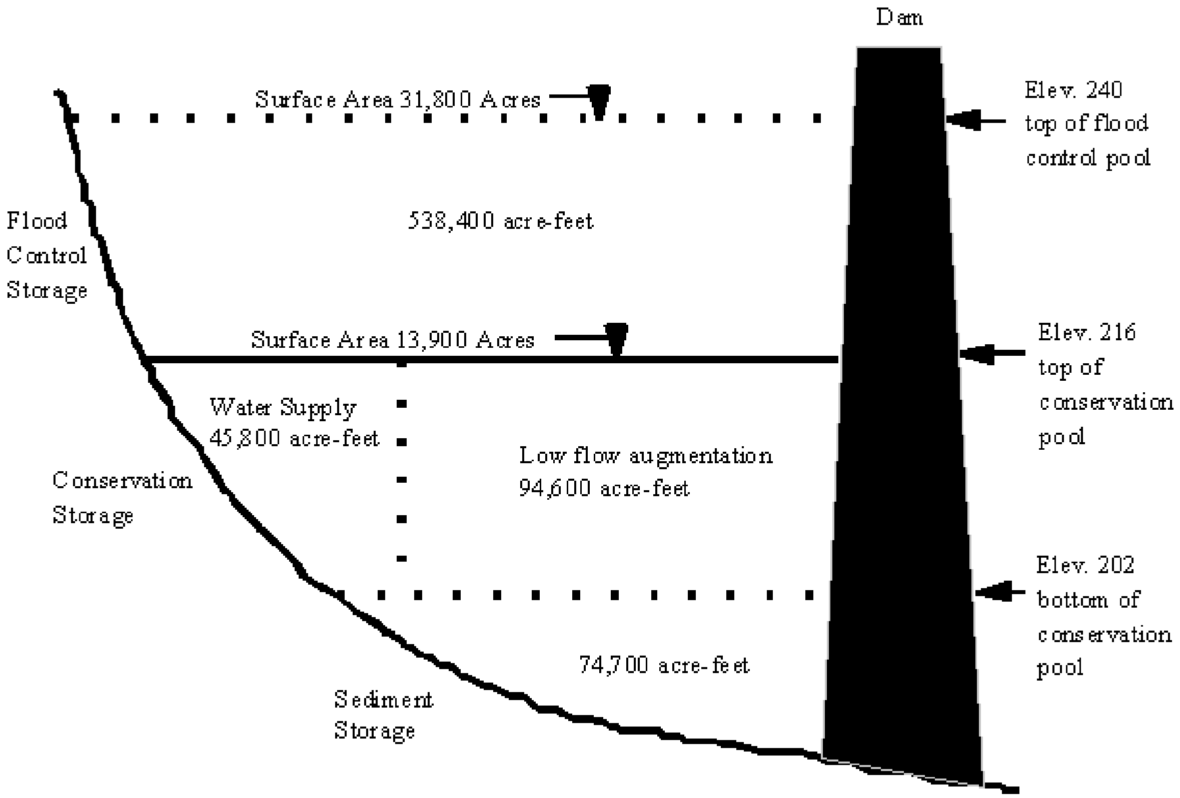
Modeling B. Everett Jordan Lake Reservoir

Jordan Lake Operations

B. Everett Jordan Reservoir is operated by the US Army Corps of Engineers. It was designed to provide for water supply, recreation, flood control, fish and wildlife management, and low-flow augmentation. As is typical for multi-purpose reservoirs, the storage volume of the impoundment is divided vertically into separately managed pools that are delineated by elevation above sea level. The normally empty flood control pool provides about 538,000 acre feet of controlled flood storage above the conservation pool. The conservation pool provides storage for water supply and low flow augmentation. Below the conservation pool, the sediment pool provides space for the accumulation of sediment.

Under normal conditions water level in the reservoir is maintained at the top of the conservation pool at 216 feet above mean sea level (MSL). At this elevation, the reservoir covers 13,900 acres. Usable water in the reservoir at this elevation is approximately 140,400 acre-feet and is referred to as the conservation storage. Approximately 45,800 acre-feet in the conservation pool, or about 15 billion gallons, is designated to provide public water supply, and is called the water supply pool. This amount of storage is estimated to be able to furnish approximately 100 million gallons per day (MGD) during the most severe drought.

Figure - 13: Jordan Lake Storage Volume



In addition to water supply, the reservoir's conservation pool provides 94,600 acre-feet of water for downstream flow augmentation to benefit water quality and economic development. This storage is generally referred to as the flow augmentation or water quality pool. The water quality pool is used to maintain a target minimum flow of about 388 MGD (600 cfs) at Lillington during non-drought periods, and less during droughts. Inflows to and withdrawals from each of these storage pools are accounted-for independently. Therefore, withdrawals from the water supply storage pool do not reduce the amount of water remaining in the flow augmentation pool.

Jordan Lake has more complex operating rules than the other reservoirs in the basin. During droughts, the Army Corps of Engineers operates the reservoir according to a schedule that indicates how releases should be varied as the water quality pool draws down. The Corps is in the process of recommending that these operating rules be approved for permanent inclusion in the operations plan.

In general, releases from the reservoir depend on the amount of water needed to maintain the target flow at Lillington, but releases may be limited based on the amount of water remaining in the flow augmentation pool when the basin is experiencing drought conditions. The operating schedule shown in Table - 9 summarizes the proposed drought management protocol. A more complete explanation is included in the 2008 OASIS Model Assessment.

Table - 9: Jordan Lake Reservoir Operating Rules during Drought

Drought Stage	**% Remaining in WQ Pool**	**Minimum Release (cfs)**	**Lillington Target (cfs)**
0	80-100	40	600
1	60-80	40	450-600
2	40-60	40	300-450
3	20-40	200	None
4	0-20	100	None

Some Modeling Results for Jordan Lake

The following sections present some results of modeling the various scenarios used in this analysis. The complete results are shown in several different presentation formats to aid understanding and can be found at the DWR website.

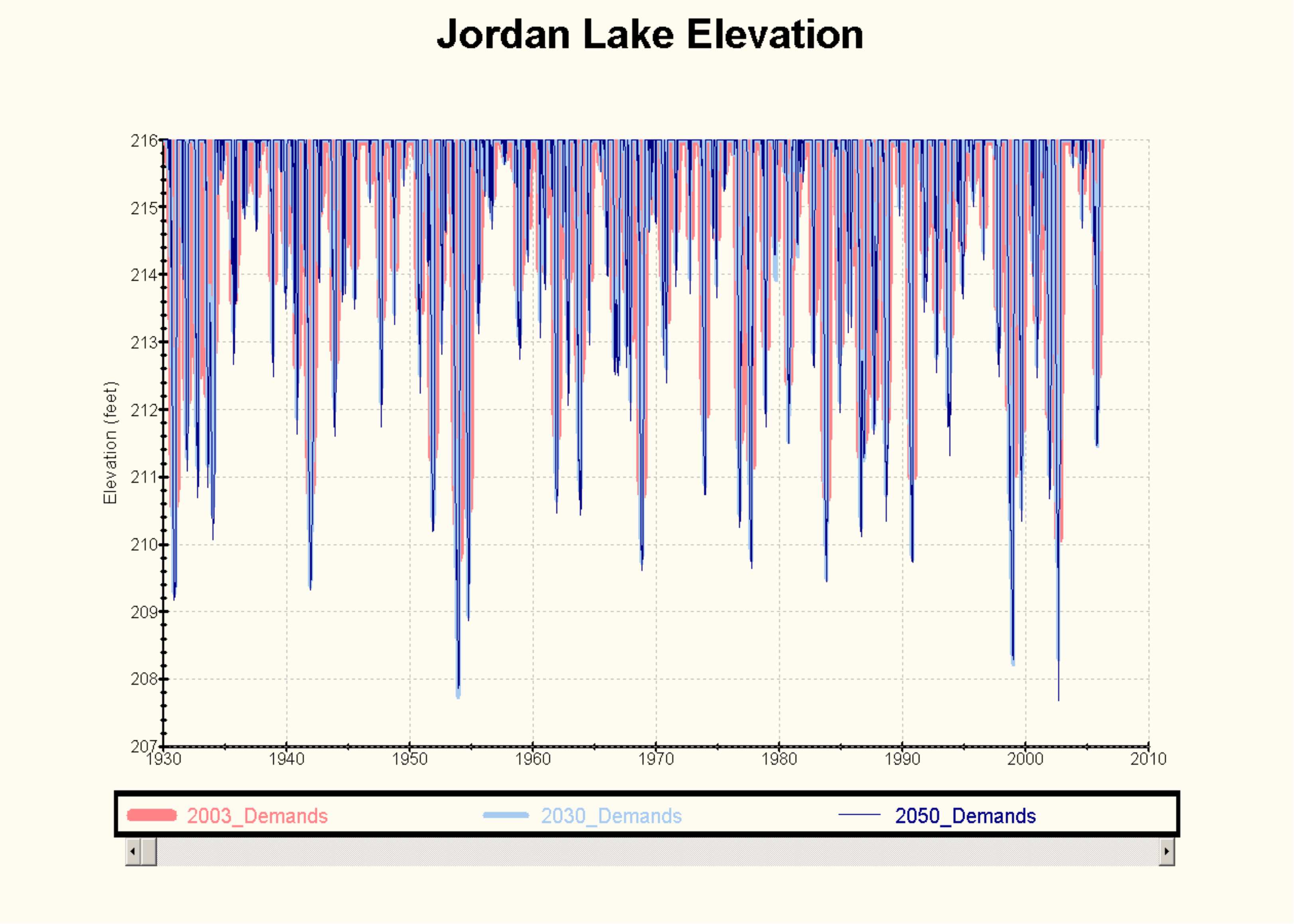
i. Elevation Profile

Elevation profiles show how reservoir levels vary over a specified period of time. They are useful for examining the shorter term fluctuations in reservoir elevation, and in this assessment three demand scenarios are shown for the entire 76-year period of record.

It is of particular interest to notice the behavior of the reservoir elevation during drought periods, when it is drawn down to its lowest levels. The elevation profiles for the three demand scenarios are presented in Figure - 14. During the major droughts on record, Jordan Lake is expected to be drawn down increasingly further as water supply demands increase from the base case to the 2050 demand levels.

The profile shows a minimum lake elevation of about 207.5 feet with the estimated 2050 demands scenario during the 2002 drought. Another deep drawdown occurs during the 1952-53 droughts, drawing the water level down to just below 208 feet. In all scenarios, the reservoir never drops to 202 feet, the elevation that represents a concern for the water systems that rely on Jordan Lake.

Figure - 14: Jordan Lake Elevation Profile



ii. Water Supply Pool Profile

Approximately one-third of the water stored in the conservation pool of the reservoir, referred to as the water supply pool, is dedicated to providing water for public water supply to local governments. The water supply pool is expected to be able to supply 100 mgd of water. Allocations of water are designated as a percentage of the water supply pool storage. Therefore, an allocation of 10 percent of the water supply pool is generally assumed to represent 10 mgd on average.

Table 9 summarizes current water supply allocations and the current and future demand levels modeled for the allocation holders. The combined estimated water supply withdrawals equal 16.94 mgd for the 2003 base case scenario. In the future, combined withdrawals for the allocation holders increase to 63.33 mgd for the 2030 scenario and to 73.54 mgd for the 2050 scenario.

Table - 10: Jordan Lake Allocation (a**ll units in MGD)**

Systems	**Node#**	**% of Storage Allocation**	**2003**	**2030**	**2050**
Cary/Apex	471	32	14.02	32.09	34.88
Chatham Co North	473	6	1.03	9.63	15.88
Durham	476	10	0	10	10
Morrisville	477	3.5	1.5	3.96	3.96
Orange WASA	922	5	0	5	5
Wake Co - RTP	474	3.5	0.39	2.65	3.82
Total Jordan Lake Demand			**16.94**	**63.33**	**73.54**

The water supply pool profiles for the three demands scenarios in Figure - 15 demonstrat that the pool is drawn down increasingly as water supply demand increases from the base case up to 2050 demand levels. The minimum predicted storage remaining in the water supply pool is about 50%, which is reached during a repeat of the 1952-53 drought conditions under the 2050 demands scenario. The graph also shows that the water supply pool would drop below 55% remaining during a repeat of the 2002 drought conditions with the projected 2050 level of demands.

Because of the importance of B. Everett Jordan Dam and reservoir to the satisfaction of water supply needs in the Triangle Region and the augmentation of downstream flows in the Cape Fear River, two additional modeling scenarios were run. Both of which could be considered as possible worst case scenarios for stressing the water storage capability of the reservoir.

One scenario was designed to show potential impacts to water supply storage if the entire water supply pool was allocated and being used. Current rules governing allocation of water supply storage limit allocations of water that would not be returned to the reservoir’s watershed to 50% of water supply pool. To test the ability of the reservoir to provide the total estimated supply of 100 mgd a consumptive use of 26.5 mgd was added to the 73.5 mgd water supply withdrawals in the 2050 scenario. This created a scenario where 100 mgd is being withdrawn from the water supply pool. The impacts to the water supply pool of this scenario are shown in Figure - 16.

The increased attention in recent years concerning the potential impacts of climate variability and the possibility of experiencing climate conditions outside the historic range of variability encouraged DWR staff to construct a modeling scenario that could indicate possible impacts from extreme reductions in precipitation. This scenario was designed to show the potential impacts to the water supply pool and the flow augmentation pool as a result of extreme drought in the river basin due to climate variability. The scenario examines one possible example of the potential impacts of climate change if the flows from precipitation and runoff were only 80% of the flows identified for the 76-year period of record used in the model.

For this scenario the 2050 water demands were used and the simulated natural inflows in the model were reduced by 20%. Furthermore, withdrawals from the reservoir were set at 73.5 mgd. With less flow from tributary streams into the river below the dam, more water has to be released from the flow augmentation pool to maintain river flows within the target range at the Lillington stream gage. This level of reduction in inflows is believed to be more drastic than available information indicates is likely to occur. Therefore, this scenario represents an extreme future scenario. The results of modeling this scenario are shown in Figure - 17 and Figure - 20.

Figure - 15: Jordan Lake Water Supply Pool Profile – Demands Scenarios

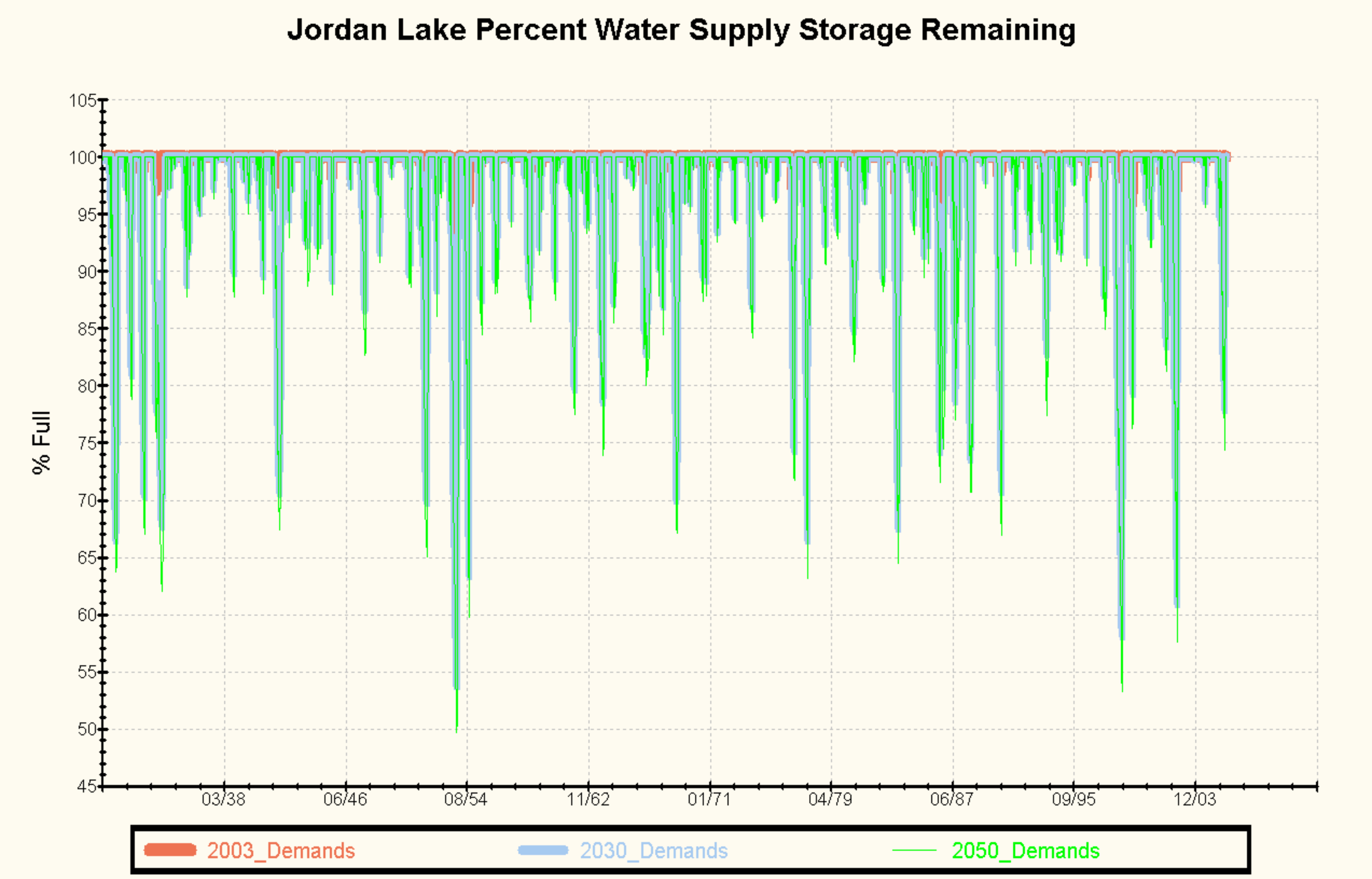


Figure - 16 shows that the water supply pool profile is lowered significantly under the 100 mgd water supply scenario, lowering the pool as low as 20% full in three different droughts over the 76 year period of record. Because the pool was not fully depleted under this scenario, it would indicate that the safe yield of the water supply pool may be slightly higher than 100 mgd.

Figure - 16: Jordan Lake Water Supply Pool Profile – 100 MGD Scenario

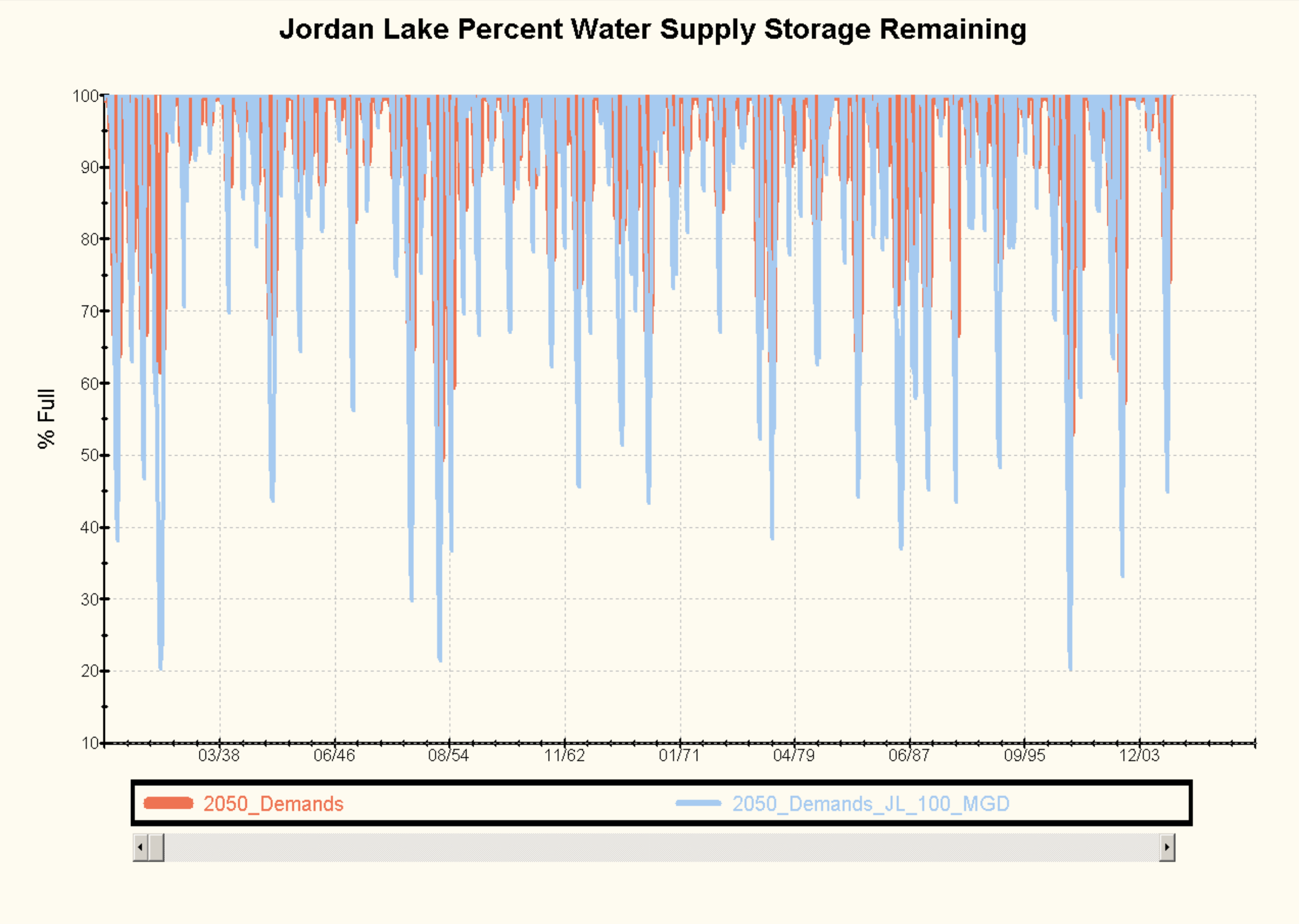
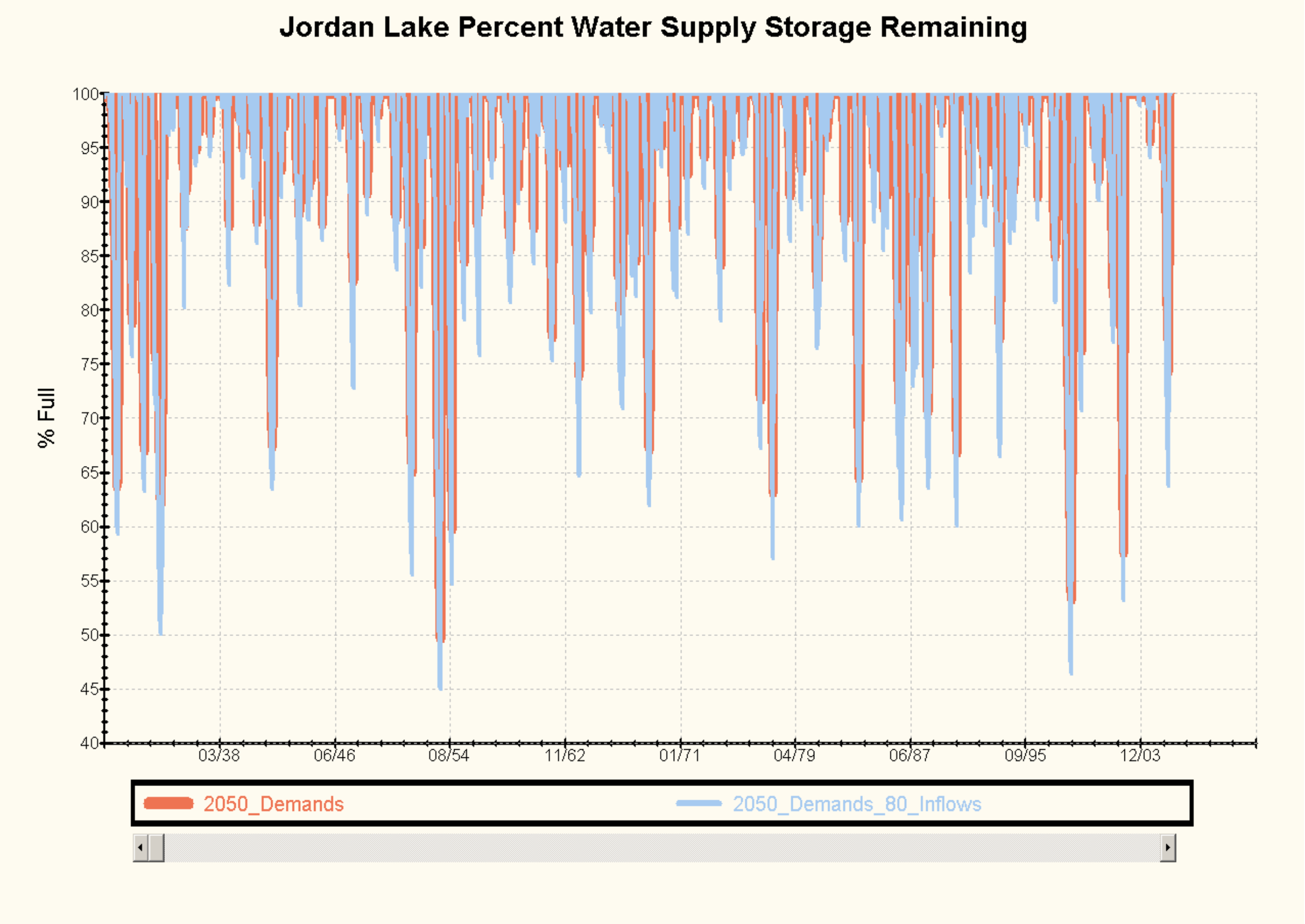


Figure - 17 shows that reducing system inflows to 80% of the simulated historical natural inflows under 2050 demands is expected to impact the water supply pool by drawing it down an additional 2% to 10%. The lowest percent remaining is still predicted to occur during a repeat of the flow conditions during the 1952-53 droughts lowering the available supply an additional 5% to about 45 % full.

Figure - 17: Jordan Lake Water Supply Pool Profile – 80% Inflows



iii. Water Quality (Flow Augmentation) Pool Profile

The water quality (WQ) or flow augmentation pool profile in Figure - 18 shows some interesting and apparently non-intuitive results. However, on closer look, the results are easily explained. An interesting observation is that the periods when the water quality pool is drawn down the most do not always occur under the 2050 demands scenario, but rather sometimes under the base case demand scenarios. The lowest expected level predicted by the model is just above 20% remaining under the base case demands with the inflows that occurred during the 1952-53 drought conditions. There were no expected occurrences of Stage 4 drought (WQ pool below 20%) under any of the demands scenarios. This is an indication that the Corps of Engineers' drought response measures are effective at maintaining the water quality pool storage even during the most severe drought conditions.

It is important to understand why the model sometimes predicts that the water quality pool to draw down further under the base case demands than under the higher 2050 demands. The Town of Cary is currently in the process of developing the Western Wake wastewater treatment plant that is expected to discharge treated wastewater to the Cape Fear River below Jordan Lake and upstream of the Lillington gage. Discharges from this plant will flow by the Lillington gage and therefore reduce the amount of water that must be released from Jordan Dam to meet the target flow at Lillington specified under the drought operating rules. Since water released from the dam to meet the Lillington target comes out of the water quality pool, the increased future discharges from the Western Wake plant will relieve stress on the water quality pool to meet the Lillington in-stream flow target. Therefore, as withdrawals from the water supply pool increase with increasing future water supply demands, releases from the water quality pool that are required to meet the in-stream flow target at Lillington during low flows tend to decrease.

An interesting result of this 2008 assessment is a comparison of the water quality pool profiles for the normal 2050 demands and scenario, and the scenario in which the water supply demands from Jordan Lake are increased to 100 mgd. The results show that increasing water supply demands to 100 mgd have little or no noticeable impact on the water quality pool, as observed in Figure - 19. In another modeling run, the water quality pool profiles for the normal projected 2050 demands scenario are compared to a scenario with the same demand levels but with inflows to the system reduced to 80% of historical inflows. This run shows an impact of an additional 3% to 10% of draw down on the water quality pool for most droughts, as shown in Figure - 20.

Figure - 18: Jordan Lake Water Quality Pool Profile – Demands Scenarios

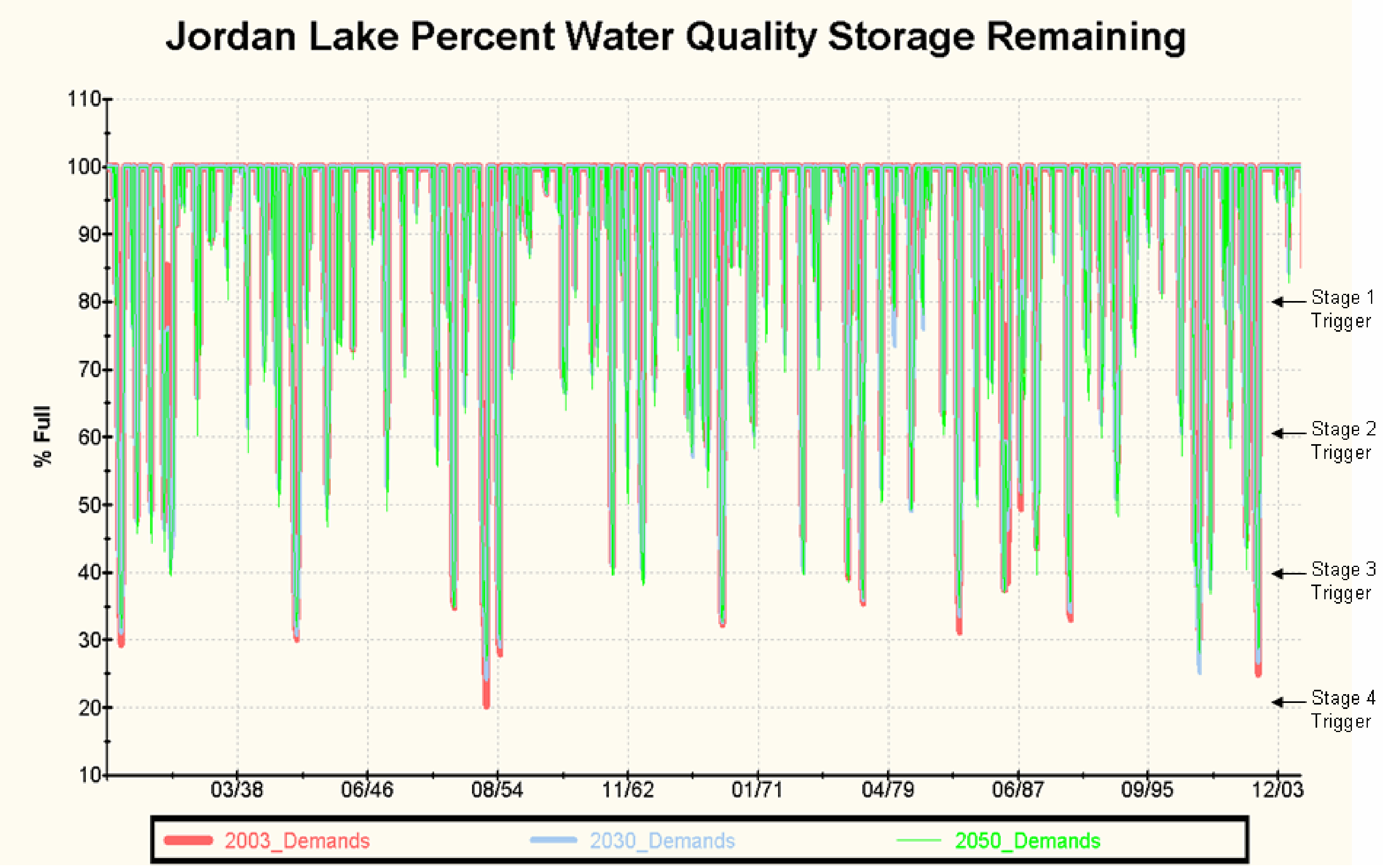


Figure - 19: Jordan Lake Water Quality Pool Profile – 100 MGD Water Supply Demand

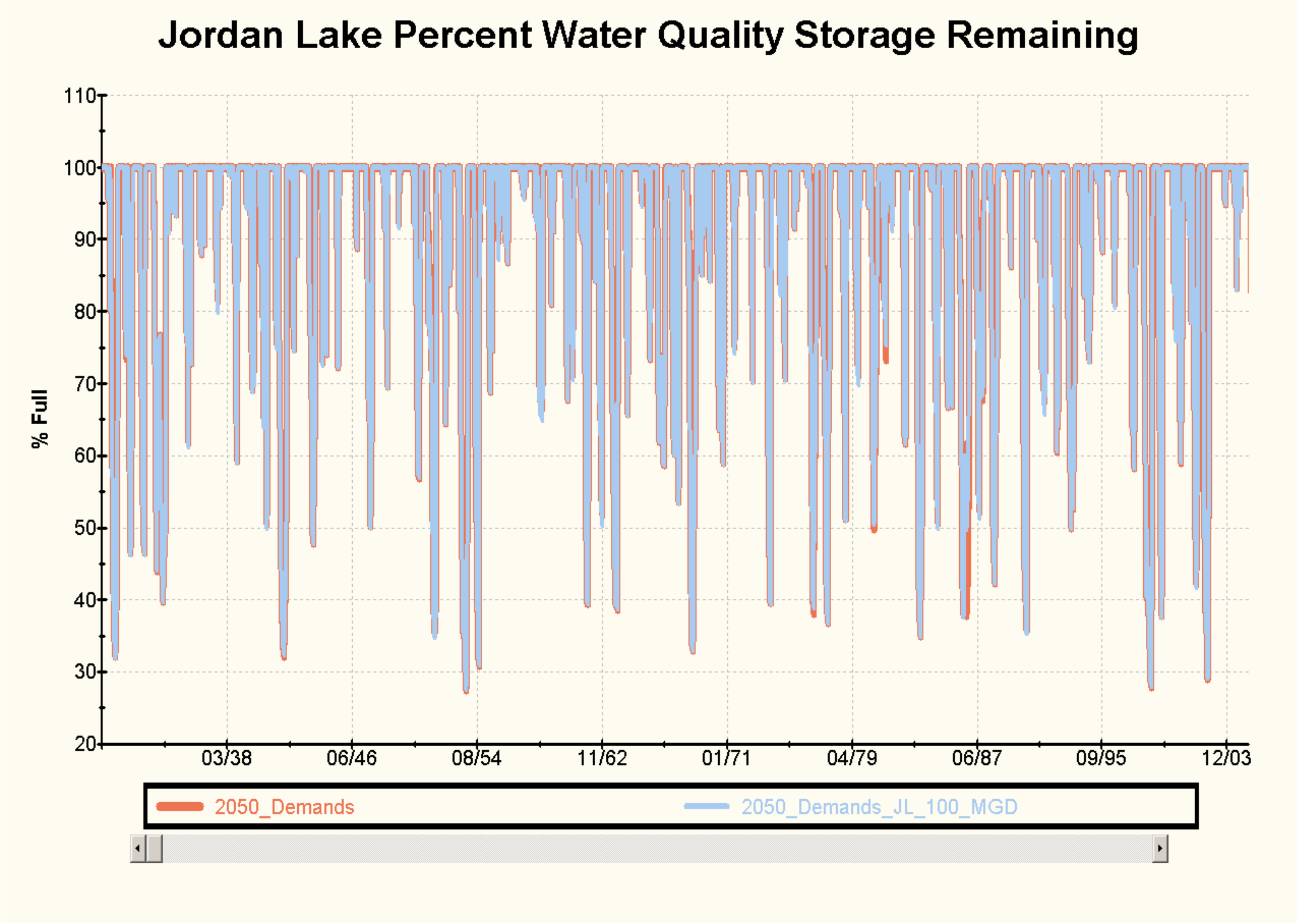
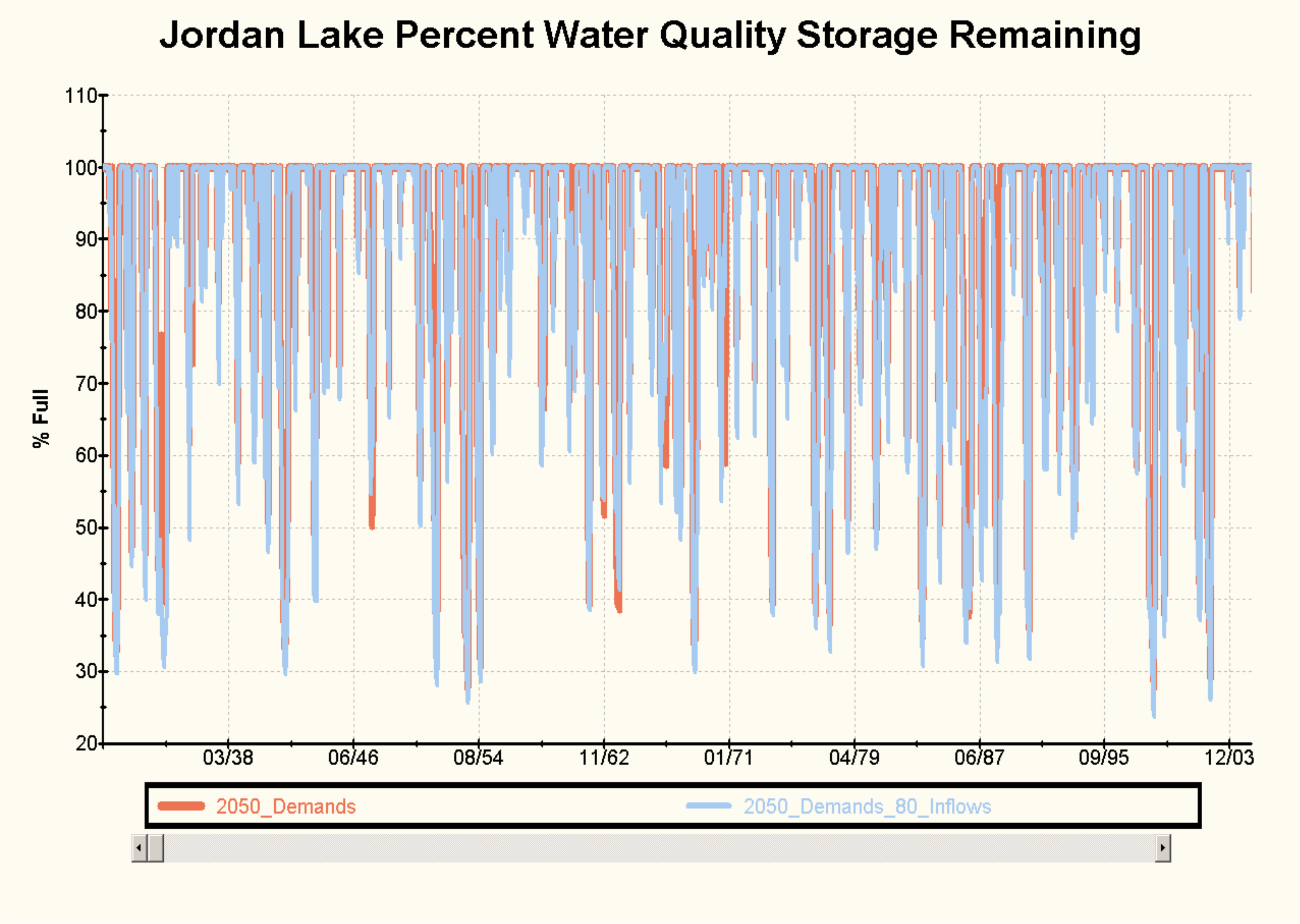


Figure - 20: Jordan Lake Water Quality Pool Profile – 80% Inflow

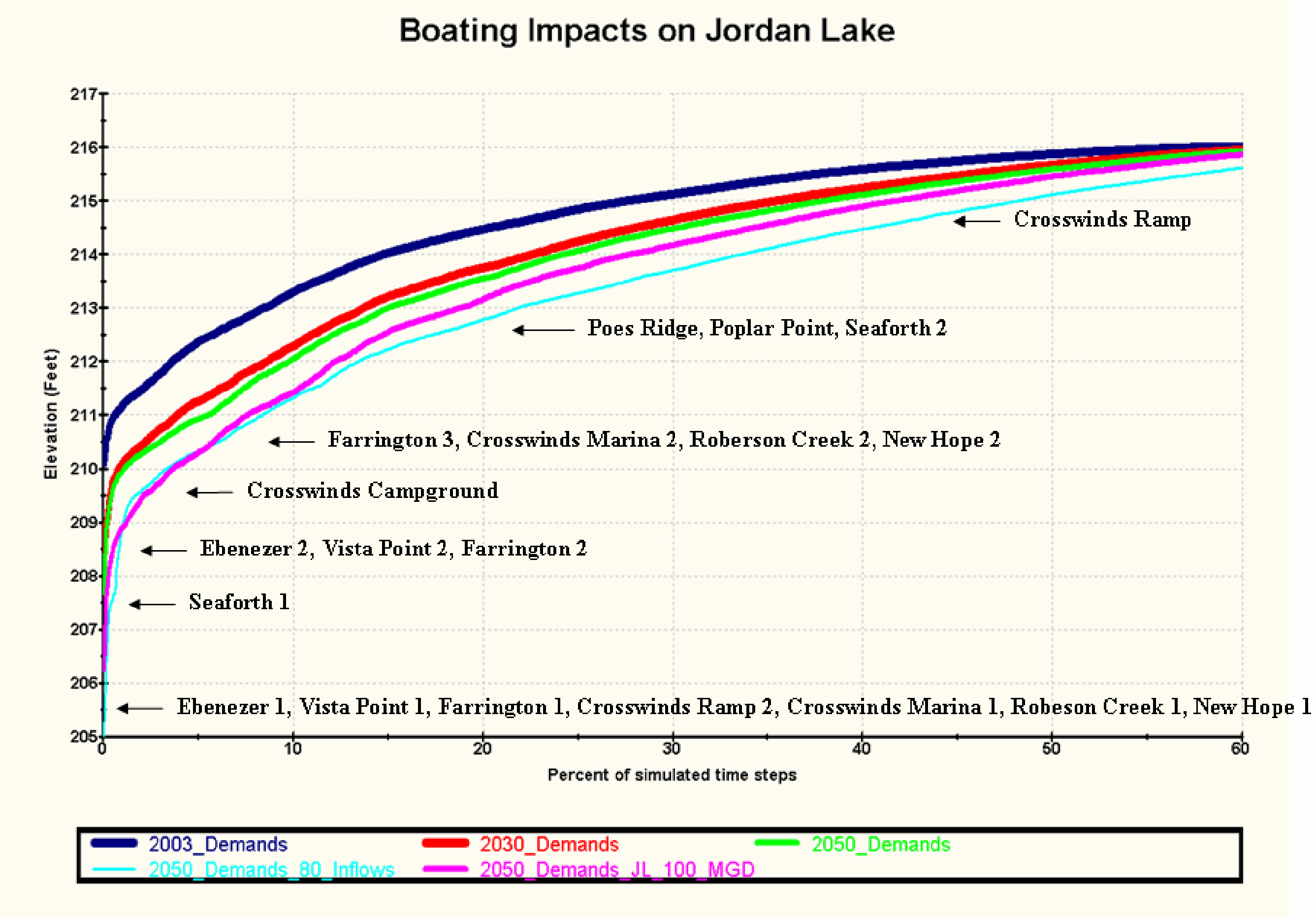


iv. Impacts on Boating at Jordan Lake

Changes in Jordan Lake's water levels predicted by the model could affect other uses of the reservoir besides water supply and flow augmentation. One of the benefits anticipated during development of the reservoir was an increase in recreational opportunities for the region. The changes to water levels in the reservoir predicted by the model will impact these recreational uses also. As an example, Figure - 21 shows the duration curves of water levels for Jordan Lake for the five scenarios modeled in this analysis along with the minimum elevation levels needed for use of the public boat ramps on the reservoir.

This chart shows the percentage of days out of the 27,700 days modeled, when use of each of the boat ramps could be limited over the range of flows in the 76-year period of record. During normal conditions the water level is maintained at 216 feet above mean sea level. The upper line on the graph represents current conditions. As withdrawals increase in the future the model predicts that use of many of the boat ramps could be limited more frequently. With increasing future withdrawals, the duration graph shifts to the right indicating an increase in the percent of time that the water level is below that elevation for boat ramp use, except for the ramps that cluster around 205.5 feet msl.

Figure - 21: Jordan Lake Boating Impacts



(b) Ground Water

Hydrogeologic Setting of the Cape Fear River Basin

To the east of the fall line (the boundary between the Piedmont and Coastal Plain), the geology of the Cape Fear River Basin may be characterized as a gently southeastward dipping, and southeastward thickening wedge of sediments and sedimentary rock ranging in age from Recent through Cretaceous which rests on an underlying basement complex of Paleozoic and earlier aged rocks. The basement surface ranges in elevation between 200 feet above sea level and 1,515 feet below sea level within the coastal plain, and dips southeast at a rate of 40 feet per mile in the northwestern part of the area to 72 feet per mile in the southeast. The sediment wedge is comprised of layers and lenses of sand, clay, silt, limestone, gravel, shell material and combinations thereof which range in total thickness from zero at the fall line to in excess of 1,515 feet in the southern tip of New Hanover County and southeastern-most part of Brunswick County. In a successive manner, older stratigraphic units outcrop immediately west of the up dip limit of the next younger unit. Deposition occurred in cyclic fashion during alternating transgressions and regressions of the Atlantic Ocean, in marine to non-marine environments.

The sedimentary column of the lower Cape Fear River Basin is subdivided into geologic formations and formation members based upon position of layers in the sequence of sediments, lithology, and faunal (fossil) composition. The subdivision of these deposits into aquifers and confining units is based on the delineation of non-permeable versus hydraulically connected permeable units, the boundaries of which sometimes, and sometimes do not, correspond to geologic formation boundaries. Aquifers and confining units are commonly made up of more than one formation, or may include only part of a formation or parts of several formations due to the discontinuous distribution of strata in the lower Cape Fear River Basin.

To the west of the fall line, the upper Cape Fear River Basin is primarily composed of rocks of the Carolina Slate Belt. The Late Proterozoic-Cambrian aged Carolina Slate Belt rocks are interbedded, metavolcanic tuffs, breccias, argillites and flows trending northeastward. This basement rock is intruded by Jurassic aged north to northwest trending diabase dikes and numerous Proterozoic to Paleozoic aged plutons (igneous intrusive rocks). Fault bounded, northeast trending, Triassic aged mudstone, sandstone, conglomerate, and minor coal occur near the boundary between the Piedmont and Coastal Plain just west of the fall line. Jurassic aged diabase dikes also intrude these rocks of the Triassic Basins.

The hydrogeologic system in the lower Cape Fear River Basin, from basement to land surface, consists of six regionally significant aquifers and the intervening confining units that separate them. They are mentioned from youngest to oldest as follows:

The surficial, or water table aquifer, is made up primarily of Quaternary age sediments. It also includes parts of older formations depending on the varying age of underlying sediments and the varying stratigraphic position of the uppermost confining layer.

The Castle Hayne aquifer is comprised primarily of the Eocene age Castle Hayne Formation. The confining unit occurs in the Quaternary age units that overly the aquifer.

The Peedee aquifer is made up of the Peedee Formation. In the southeastern corner of the study area, the aquifer includes all, or part of, the Paleocene age Beaufort Formation. The confining unit is generally present in the Beaufort Formation or upper part of the Peedee Formation.

The Black Creek aquifer corresponds primarily to the Black Creek Formation. In some areas the aquifer includes the upper part of the Cape Fear Formation and the lower part of the Cretaceous Peedee Formation. The confining unit is made up of clay or silt beds in the upper part of the Black Creek or lower part of the Peedee Formations. To the northwest of the pinchout of the Peedee Formation, the confining unit of the Black Creek aquifer may include Pliocene age Yorktown or younger age deposits which directly overly the Black Creek Formation. In this area, the Black Creek aquifer can include permeable beds in the lower part of these younger formations.

The Upper Cape Fear aquifer corresponds to the upper part of the Cape Fear Formation and sometimes the lower part of the Cretaceous Black Creek Formation. The confining unit is composed of clay or silt beds present in the lower part of the Black Creek or upper part of the Cape Fear Formation.

The Lower Cape Fear aquifer is comprised, along with its confining unit, of the lower part of the Cape Fear Formation of Cretaceous age.

Piedmont aquifers are categorized as either fractured basement rock, overlying regolith (saprolite or weathered basement rock, soil and alluvium or recent sedimentary deposits), or Triassic Basin.

General Description of the Ground Water System

Representative hydrogeologic cross sections through the Cape Fear River Basin are shown in Figure - 22 (or a better resolution figure in a PDF format), exhibiting the complexity of ground water flow patterns and salt water interfaces in relation to hydrogeologic units. Ground water flows in a rather complex three dimensional pattern through the subsurface in a multilayered Coastal Plain environment. Flow occurs laterally through aquifers from recharge to discharge areas along flow lines which parallel directions of steepest hydraulic gradient. Flow also occurs vertically upward to discharge areas or downward in recharge areas in response to differences in hydraulic head between aquifers. For a better figure definition view, Figure 23 is also available in a PDF format.

All of the aquifers in the coastal plain contain salt water over regions of varying extent, due to fluctuations of sea level that occurred during deposition of coastal plain sediments. The surficial aquifer contains salt water on the barrier islands along the coast of New Hanover and Pender Counties, as well as along the fringes of the coastline, and other areas where high tides cause natural intrusion of salt water. As recognized by Winner and Coble (1989), the position of fresh water-salt water interfaces within North Carolina Coastal Plain aquifers has a very complex pattern. Sediments were deposited during cyclic fluctuations of sea level over geologic time. The seaward limit of fresh water is unique for each aquifer as governed by variations in hydraulic properties, position and rates of recharge, thickness and hydraulic conductivity of overlying confining beds, and hydraulic gradients. Salt water interfaces are not sharply defined, but occur as transition zones of variable width due to diffusion between salty and fresh water. The movement of fresh ground water through deeper confined aquifers in the coastal plain causes interfaces to retreat slowly seaward over geologic time. However, in areas of heavy ground water pumping and resultant water level declines, saline ground water can move toward pumping centers due to a reversal of hydraulic gradient.

As illustrated by a generalized annual water budget model for the lower Cape Fear River Basin (Figure - 23 a), recharge occurs predominantly through rainfall, which enters the surficial (or water table) aquifer in the inter-stream areas. The lower Cape Fear River Basin receives an average of 50 inches of total precipitation per year based on historical records covering the years between 1971 to 2000 (Southeast Regional Climate Center, Historical Climate Summaries for North Carolina 1971 to 2000, Website). Based on a water budget model developed by the U.S. Geological Survey for Brunswick County (Harden, Fine and Spruill, 2003), and using precipitation data averaged for the area, it was determined that about 8 inches of the 50 inches of total annual precipitation is lost to overland flow to nearby surface water bodies. Another 32 inches are taken up annually through evapotranspiration. Of the 10 inches of water that enters the water table as recharge, 9 inches per year flows from recharge to discharge areas such as the Cape Fear, Lumber, South, and Waccamaw Rivers, associated floodplains, and the Boiling Springs Lakes. One inch or less of ground water per year enters the deeper confined aquifers as recharge. This water budget model assumes steady state conditions in which no pumping from the ground water system is occurring.

Figure - 22: Hydrogeologic Cross Sections in CFRB (vertically exaggerated)

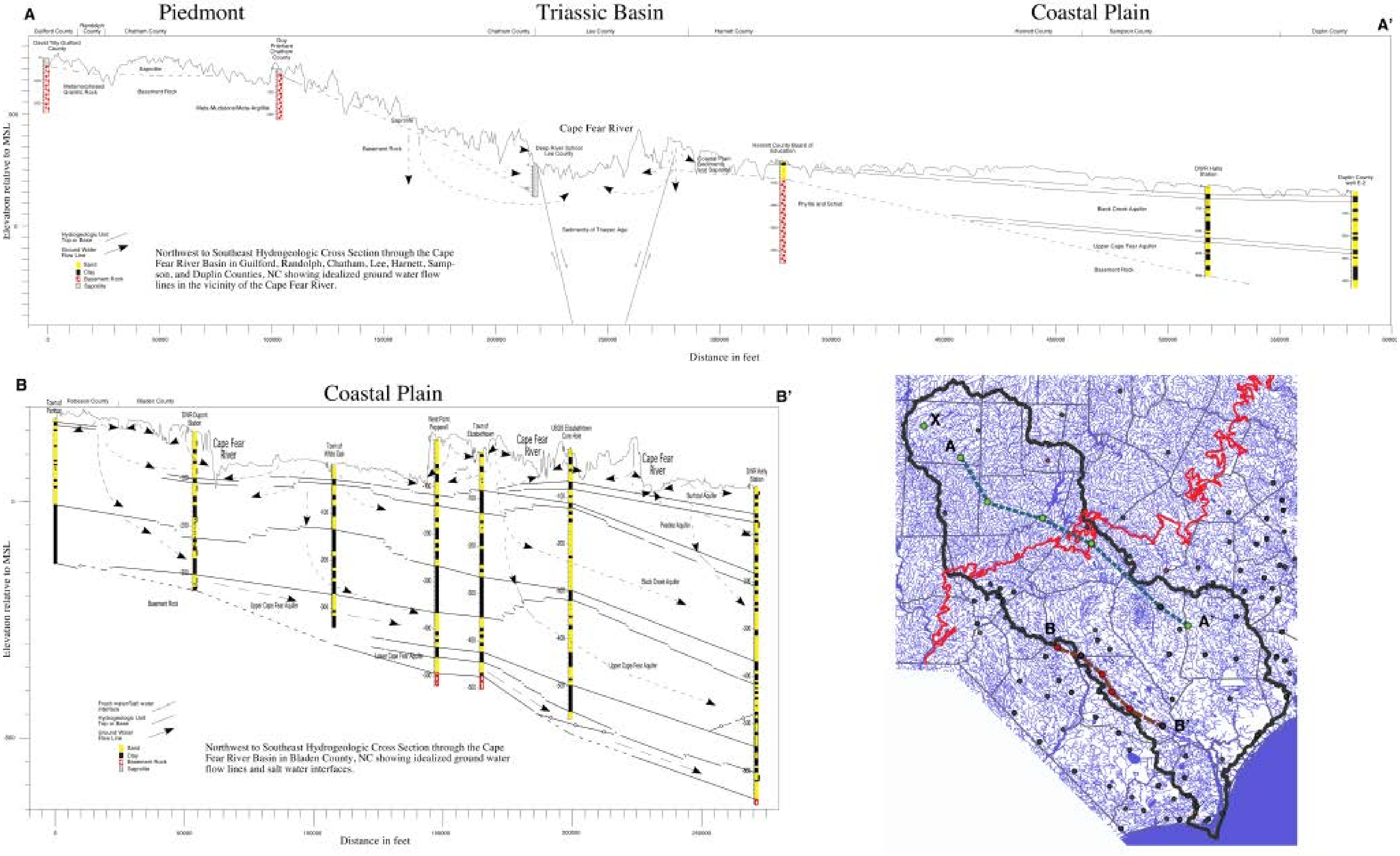
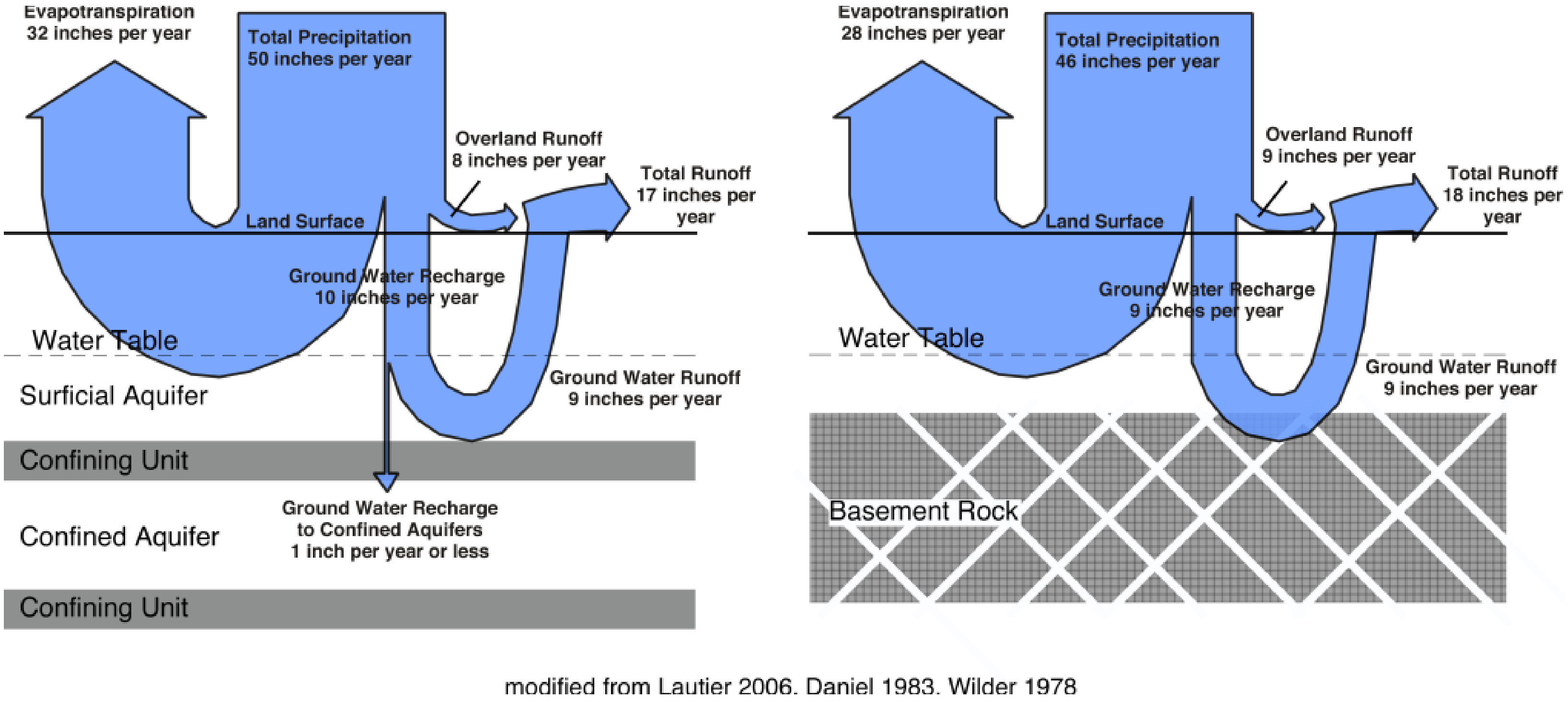


Figure - 23: Typical Water Budgets for the (a)Coastal Plain and (b)Piedmont Portions of CFRB



modified from Lautier 2006, Daniel 1983, Wilder 1978

The Piedmont Cape Fear River Basin water budget (Figure - 23 b) from Daniels and Sharpless (1983) differs slightly from the coastal plain model with differing amounts of average rainfall, evapotranspiration, and runoff. The biggest distinction is the lack of a recharge component to confined aquifers.

Division of Water Resources Monitoring Well Network

The operation of the monitoring well network is an integral part of DWR's mission to ensure that the State has an adequate water supply for its citizens. Information collected quarterly from this well network is used to:

- Evaluate climatic influences on the State's ground water supply, including effects of drought and recharge-discharge relationships;
- Monitor human-induced effects on the State's ground water supply, particularly in the regional aquifer systems of the Coastal Plain physiographic province. These effects include local and regional water level declines as well as migration of the fresh water-salt water interface within various aquifers;
- Provide supporting data for enforcement and creation of current and future ground water usage regulations, such as the Central Coastal Plain Capacity Use Area rules; and
- Provide high quality ground water data to local governments, ground water professionals, and the general public to use in making informed decisions in ground water related issues.

Data collected from the network are available to the public through DWR's internet website, www.ncwater.org. These data include ground water levels, chloride measurements, well construction information, borehole log construction (lithological and geophysical), ground water monitoring station locations, and geophysical/lithological data collection from non-DWR well sites.

The monitoring well network currently consists of 555 wells at 182 monitoring stations (sites). There are 22 wells located in the Piedmont and Mountain physiographic provinces (Piedmont and Mountain) and 533 wells located in the Coastal Plain physiographic province (Coastal Plain). Since the Coastal Plain relies more heavily on ground water supplies than either the Piedmont or Mountain Regions, ground water monitoring and research has been more concentrated in the Coastal Plain.

Hourly water level data are extremely valuable in assessing aquifer recharge, impacts of large storms on ground water conditions, and delineation of aquifer boundaries. DWR typically publishes only the manual water level readings and daily water level data from recorders on the website. Hourly data is available upon request for specific wells.

Recently more resources have been invested in monitoring the Piedmont and Mountain ground water conditions to better understand the impact of drought cycles on ground water supplies and their contribution to surface water flow. Although DWR and USGS have been continually monitoring the well network, the drought network was officially established in 2001 with the development of the DWR drought web page to house the data. There are presently 35 wells within the DWR monitoring well network used to assess drought conditions.

The U.S. Geological Survey (USGS) has also contributed to the monitoring of the State's ground water resources under a cooperative agreement between the State of North Carolina and the Federal government. The cooperative well network consists of 23 monitoring wells, many of which are also part of the DWR statewide network.

There are 88 DWR network wells and two wells operated by the USGS within the Cape Fear River Basin. These wells are screened in eight different aquifers in the Coastal Plain and include three wells in basement rock. Eleven of the DWR & USGS network wells within the Cape Fear River basin have been designated as drought wells. Table - 11 summarizes the network wells in the Cape Fear River Basin.

The distribution of the network wells by aquifer in the basin is as follows: Surficial – 35, Peedee – 11, Upper Cape Fear – 12, Lower Cape Fear – 2, Black Creek – 20, Castle Hayne – 5, Upper Tertiary – 1, basement rock – 3, and regolith – 1. Eleven of these wells are used to monitor drought conditions (one by the USGS and ten by DWR).

The drought indicator well network now stands at 46 wells distributed throughout North Carolina. DWR has established a near term goal of 60 wells associated with that network. Certainly, additional wells in the Cape Fear River Basin will be part of that formula. In order to better assess the hydrogeologic conditions of the entire Cape Fear River Basin, additional well stations need to be installed (especially in counties that currently do not have stations) and existing stations may need additional wells added.

Table - 11: County Summary of Cape Fear River Basin Wells

County	Station Name	No. of Wells	Drought Wells	Total by County
Bladen	Kelly	3	1	
	DuPont	6		
	Smith McNair House	2		
	Dublin	5		Bladen - 16
Brunswick	Maco	2		
	Town Creek	2		
	Boiling Springs RS2	2		
	Boiling Springs RS1	1		
	Southport RS4	3	1	Brunswick - 10
Cumberland	Cedar Creek Fire Tower	4		
	Seabrook School	1	1	
	Bushy Lake	3		Cumberland - 8
Duplin	Pink Hill	4		
	Rose Hill	5	1	
	Chinquapin	3		Duplin - 12
Guilford	Gibsonville	1	1	Guilford - 1
Hoke	Raeford	1		Hoke - 1
Moore	Hog Island	3		
	Southern Pines Water Plant	2		
	Southern Pines 1	2		
	Eastwood	1		
	Weymouth Woods	2		Moore - 10
New Hanover	Wilmington Airport	1	1	
	Fort Fisher	1		New Hanover - 2
Onslow	Folkstone	6		Onslow - 6
Pender	Topsail Beach	4	1	
	Burgaw	2		Pender - 6
Randolph	NC Zoo	1	1	Randolph - 1
Sampson	Halls	3	1	
	Turkey	2		
	Six Runs	6		
	Ivanhoe	3		Sampson - 14
Wake	Fuquay-Varina	1	1	Wake - 1
DWR Total			**10**	**88**
Brunswick	USGS, BR-100	1		
Orange	USGS, NC-126	1	1	
Total			**11**	**90**

Ground Water Assessment Techniques

Because ground water flow in the coastal plain's confined aquifers do not honor the current basin boundaries (ground water flow occurs across basin boundaries), the DWR network wells provide a regional picture of the stress on the aquifers. So, the distribution of wells in the Upper Cape Fear aquifer throughout the coastal plain gives us data to assess the status of that aquifer even though we may not have many wells in that aquifer within the Cape Fear River Basin boundaries. There are two recent examples of where water levels collected from the confined aquifer wells were used to determine who was withdrawing ground water and whether a capacity use area designation would be needed to correct an over-pumping situation.

Peedee aquifer water levels began dropping dramatically in the southeastern portion of Brunswick County during 2003-2004. Three monitoring stations exhibiting this trend were used to pinpoint the location of a new large withdrawal from the aquifer. Cogentrix Inc., north of Southport, was determined to be the new user and they were required to submit a registration of their usage through the state-wide DWR water withdrawal registration program as required by General Statute 143-215.22H.

Upper Cape Fear aquifer water levels began dropping in the early 1990's as a result of withdrawals from Smithfield Foods in Tar Heel, Bladen County and other users. The impact from these withdrawals could be measured into neighboring counties and river basins within a few years based on the monitoring well network data for that aquifer. A 2004 agreement between the Lumber River Council of Governments, the DWR and the EMC convinced Smithfield Foods and other water users to begin planning for use of surface water from the Cape Fear River for their water needs. Planning necessary for the construction of a new intake on the river, called Bladen Bluffs, is well on its way.

Use of the monitoring well network (or an improved network with additional wells and better geographic distribution) for ground water assessment in the coastal plain portion of the Cape Fear River Basin is a valuable method to determine where the confined aquifers are being stressed too heavily or salt water intrusion may become a problem. In addition, the network is clearly a useful tool to estimate the impact of drought conditions on the shallow ground water levels throughout the basin. The monitoring well network has been useful not only for identifying problems of excessive drawdown in Bladen County and Southeastern Brunswick County as previously mentioned, but has allowed the Ground Water Management Section to detect the lateral encroachment of salt water in the Peedee Aquifer in Onslow County. Between October, 1999 and September, 2004, chloride concentrations in the Peedee Aquifer at the DWR, Folkstone monitoring station increased from 35 to 266 parts per million (ppm). Concentrations of greater than 250 ppm chloride are defined by the U.S. Environmental Protection Agency to be salt water. Pumping from the Castle

Hayne Aquifer, in the Onslow County well field apparently affected water levels in the underlying Peedee Aquifer to an extent that the salt water/freshwater interface has migrated westward and affected the DWR Folkstone Peedee monitoring well. The value of the network in identifying problems of this nature is invaluable, as it provides early warning signs of problems that can be corrected before they become more serious. The addition of new monitoring wells or monitoring stations to the DWR network will continue to enhance our capability to identify and manage situations that otherwise would remain unrecognized.

Using the network for more than drought assessment in the Piedmont portion of the river basin is not practical. Aquifers in the Piedmont do not have regional characteristics like in the coastal plain, so a network would require too many wells to gauge local aquifer conditions to be practical.

Other investigators have relied on recharge estimations to the shallow ground water system as a method of defining the capabilities of aquifers. They have established rates of recharge in gallons per day per square mile using water budget models based on base flow determinations from surface water gage data. Those workers assume that discharge from the aquifer system (base flow) equates to the rate of recharge to the aquifer system and an annual rate available for use by wells (or some portion thereof). However, these safe yield type calculations are wrong and impractical. They are wrong because the analysis requires that a balance between withdrawals, recharge, and natural discharge be constant over time which is definitely not the case. A safe yield determined for a county or large portion of a county is impractical because it would require a huge number of wells and access to large areas of land to come close to withdrawing the estimated rate. Use of annual rates of recharge or potential withdrawal rates only highlights areas where ground water is more or less plentiful.

Those types of analyses <u>do not</u> indicate whether a particular ground water withdrawal is sustainable or without conflict with other nearby users. Use of ground water flow models would fall victim to the same limitations of the safe yield determinations. They would also fail to properly imitate the complex nature of flow in the basement rock aquifer of the Piedmont. The current surface water model of the Cape Fear River (although it does not explicitly model ground water flow) does implicitly measure discharges from the ground water system into surface water along the modeled water course. If one could estimate the ground water discharge amounts from this knowledge, it would still be a rate applied to some large area of land and of little use to a ground water management program.

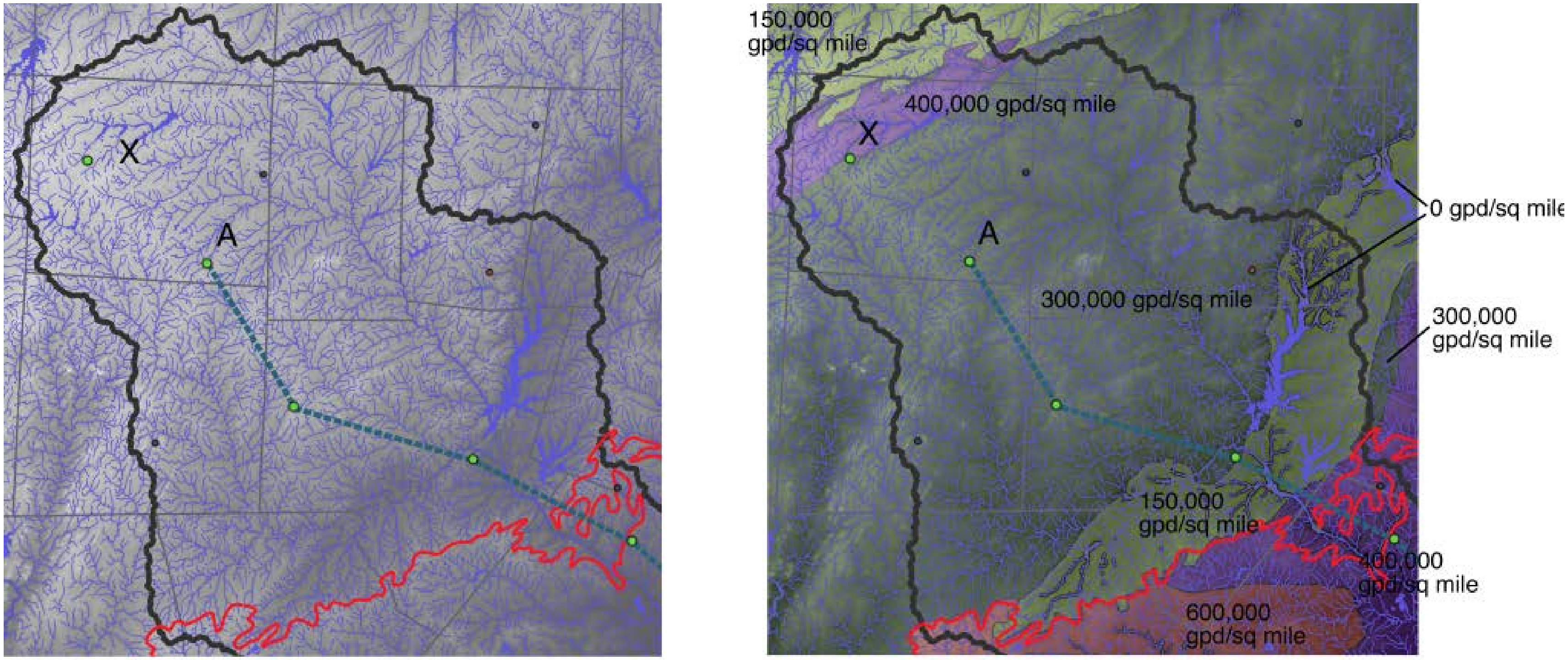
Heath (1994) mapped rates of recharge to the surficial aquifer state-wide. Figure - 24 shows two pictures of the upper Cape Fear River Basin, both with the digital elevation data (lighter shades of gray equate to higher elevations), hydrography, and the fall line. The second picture shows the distribution of Heath's recharge rates as well. The Triassic Basin areas stand out in both pictures as they remain basins today and contain sediments which make it a slowly recharging area (150,000 gallons per day per square mile). There is an area in the northwestern portion of the upper Cape Fear River Basin where basement rock fractures appear to control hydrography. Surface water drainage patterns do not appear as dendritic (or irregularly branched like a tree). Even with estimates of recharge rates as shown on this map, there is not enough information available to discern whether a site is capable of providing enough water or that it will not compete with a neighboring well field.

The dot on Figure - 24 labeled with an “X” in each map identifies an aquifer test done in May 1983 associated with the Daniel and Sharpless (1983) report. At this site, 20 wells were drilled and monitored during the test. A production well was pumped for 62 hours at 38.5 gallons per minute.

Lastly, the total volume of water withdrawn suggested that water stored in the basement rock fractures was untouched by the test – virtually all the water came from storage in the regolith (unconsolidated material above the basement rock). All of this information would not be available without an individual site assessment.

Understanding the sustainability of ground water withdrawals in the Piedmont portion of the Cape Fear River Basin must rely on information derived from a local assessment of resource potential by the user, careful maintenance of existing production wells, and tracking of water level and quality measurements from production wells over time. The same methods work for the Coastal Plain portion of the basin with the added benefit of a monitoring well network to assess the regional stress on confined aquifers.

Figure - 24 Upper CFRB with and without Heath (1994) Recharge Rates



- Digital elevation data (higher elevations equal lighter shades of gray)
- Fall Line (boundary between Piedmont and Coastal Plain physiographic provinces)
- Hydrography
- Cape Fear River Basin boundary

- The recharge rate along hydrography is 0 gpd/sq mile

- Recharge rates are average (lack of rain and addition of impenetrable surfaces like roads, houses and parking lots will reduce recharge rates)

(c) Instream Flow

This chapter includes a general background discussion of instream flow needs and how they are determined and managed (more detail is provided in the Appendix), followed by a description of how instream flow needs have been addressed to date in the Cape Fear Basin Plan.

(i) Instream and Offstream Water Use

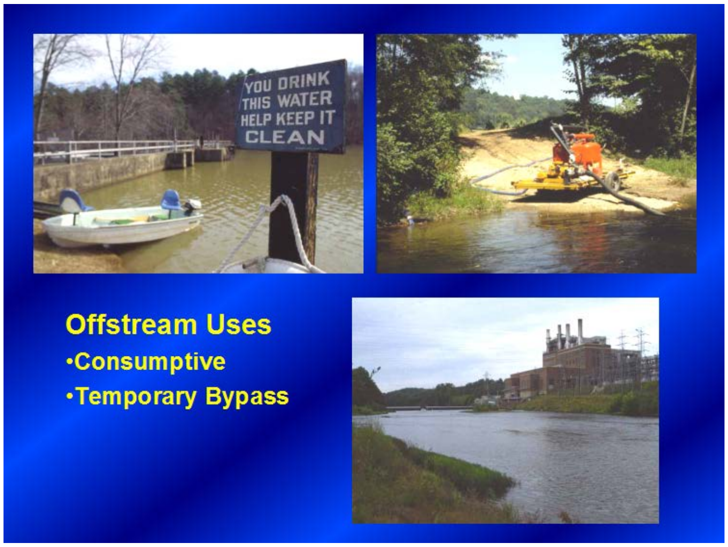
Instream flow needs refer to the amount of water needed to support instream uses - those stream functions that are maintained by water being in the natural channel, including.

- Aquatic Habitat
- Water Quality (e. g. dissolved oxygen, temperature)
- Channel Morphology (stream banks, channel shape, & substrate)
- Wetlands
- Aesthetics

Instream Uses

In contrast to instream uses, offstream uses are those that require removal of water from the natural channel. Offstream uses may remove water temporarily or permanently from the source stream. Permanent removal of water by a withdrawal (i.e. water that is not discharged back to the source stream) is referred to as a **consumptive use**. Examples of offstream uses include:

- Public Water Supply
- Industrial Water Supply
- Agricultural Water Use
- Offstream Recreational Water Use (golf course irrigation, snow making)
- Electric Power Generation



Offstream Uses

- **Consumptive**
- **Temporary Bypass**

Growth in the state's population and economy will be accompanied by pressure to increase withdrawals from surface waters to satisfy offstream demands. At the same time, preserving adequate instream flows is important to maintain the environmental quality that attracts people and business to North Carolina. Increased water supply withdrawals are often accompanied by increased wastewater discharges, and adequate flows for wastewater assimilation can become a critical instream flow issue when the same stream is used for upstream withdrawals and downstream discharges. Peaks in the offstream demand for agricultural and residential irrigation occur during drought - paradoxically the same time that stream flows are in shortest supply - and can lead to potential conflicts between offstream demands and instream flow needs. Awareness of this issue was heightened by experiences during the droughts of 2002 and 2007-08.

Careful management of water resources is necessary to maintain instream flow needs and still meet reasonable offstream demands for water. It is important to include instream flow needs in basinwide water supply modeling and planning, since **leaving instream flow needs out of the equation would not provide an accurate picture of water availability**.

(ii) Quantifying Instream Flow Needs

Determining the quantity of water needed to maintain instream flow needs incorporates:

- Location – site-specific characteristics including habitat and drainage area
- Timing – seasonal hydrologic patterns, organism life cycles
- Measurement – typically measured in cubic feet per second (cfs)

The amount of water used for offstream purposes is generally not difficult to determine. Flows through pipes and pumps can be calculated or measured and public water systems meter usage for billing purposes. Wastewater treatment plants also meter the flow being discharged, and using this information allows the percentage of consumptive loss to be calculated. Knowing the existing use by business, industry and residences allows future demand to be predicted on a per capita basis. Uncertainties about the amount of offstream demand are most often due to difficulties in gathering data, particularly for dispersed, intermittent uses such as irrigation.

The amount of water needed to maintain instream uses can be more difficult to determine. Various evaluation techniques are available, depending on the instream flow need that is being quantified. Some of these techniques are based on flow statistics for the stream in question and are a desktop approach. Other approaches require site-specific field studies that can vary in complexity.

Water Quality Flow Needs – Water quality models can be used to evaluate the effect of a given amount and concentration of effluent on downstream water quality. This approach does not determine the flow needed to maintain water quality, but instead uses a minimum drought flow statistic to determine the amount and degree of treatment of the wastewater discharge that is needed to maintain state water quality standards for relatively short periods under worst case low flow conditions. The drought flow statistic used is the lowest flow that occurs for seven consecutive days, with a recurrence probability of once every ten years – referred to as the 7Q10. The assumption is that water quality standards may not be maintained when flows fall below the 7Q10, but this is a very infrequent, acceptable risk. Therefore, it is very important to realize that the 7Q10 is NOT intended to be the flow that maintains water quality or aquatic habitat for any great length of time.

Recreational Flow Needs – The amount of instream flow needed for recreation depends on the activity and may be seasonal, or vary between weekends and weekdays.

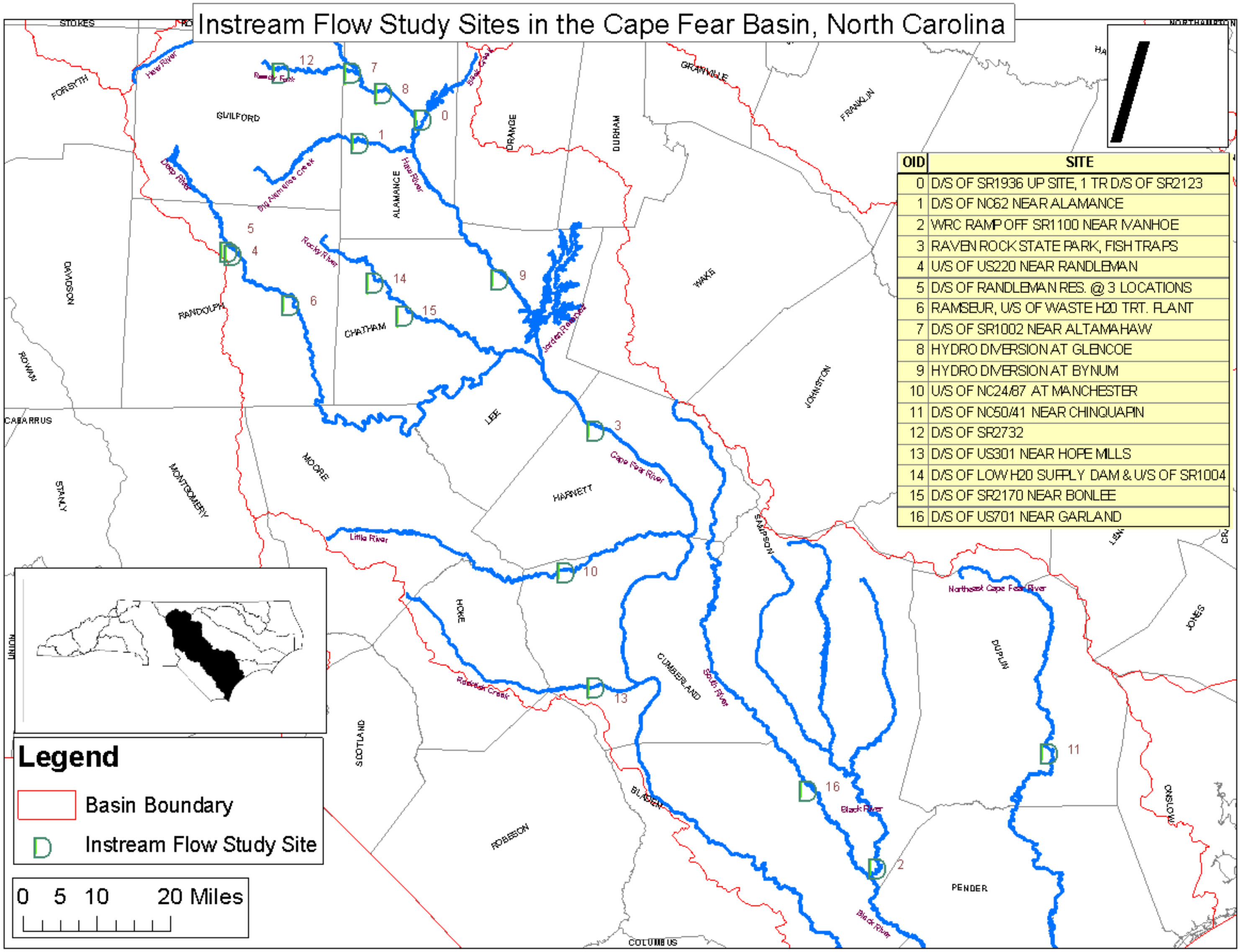
Aquatic Habitat Flow Needs – This instream flow need applies to all streams, throughout the year - unlike recreational flow needs or some other instream uses, which may or may not be applicable to a given stream, or may only be relevant during certain periods. There are a variety of techniques for determining a quantity of instream flow needed to maintain aquatic habitat. These range from desktop approaches that use hydrologic information about the stream to calculate a flow number, to site-specific field study methods with varying degrees of complexity and data needs. More details on the various methods used in North Carolina are included in the Appendix.

For the past 25+ years, two field study approaches have been used in North Carolina to evaluate instream flows needed for aquatic habitat. A wetted perimeter study is the more simplistic of the two, in that it assumes any area of wetted stream channel has the same habitat value, regardless of habitat characteristics. Several wetted perimeter studies were conducted throughout the Cape Fear basin as part of a federally funded water planning study in the early 1980s. A copy of the instream flow report resulting from those studies is included in the Appendix.

In recent years, the field study approach used for instream flow and aquatic habitat studies has shifted primarily to the Instream Flow Incremental Methodology (IFIM). This approach entails more complex data collection and modeling than a wetted perimeter study and evaluates habitat amounts according to quality of habitat.

A map showing the various field studies of instream flow needs for aquatic habitat in the Cape Fear Basin is shown below in Figure - 25. The internet-based version of this report includes an interactive version of this map that can be used to access additional information about each study.

Figure - 25: Instream Flow Study Sites in the Cape Fear River Basin, NC



Instream Flow Study Sites in the Cape Fear Basin, North Carolina

OID	SITE
0	D/S OF SR1936 UP SITE, 1 TR D/S OF SR2123
1	D/S OF NC62 NEAR ALAMANCE
2	WRC RAMP OFF SR1100 NEAR IVANHOE
3	RAVEN ROCK STATE PARK, FISH TRAPS
4	U/S OF US220 NEAR RANDLEMAN
5	D/S OF RANDLEMAN RES. @ 3 LOCATIONS
6	RAMSEUR, U/S OF WASTE H20 TRT. PLANT
7	D/S OF SR1002 NEAR ALTAMAHAW
8	HYDRO DIVERSION AT GLENCOE
9	HYDRO DIVERSION AT BYNUM
10	U/S OF NC24/87 AT MANCHESTER
11	D/S OF NC50/41 NEAR CHINQUAPIN
12	D/S OF SR2732
13	D/S OF US301 NEAR HOPE MILLS
14	D/S OF LOW H20 SUPPLY DAM & U/S OF SR1004
15	D/S OF SR2170 NEAR BONLEE
16	D/S OF US701 NEAR GARLAND

(iii) Maintaining Ecological Integrity

Over the past 10 years, concern has grown amongst aquatic biologists that recommendations for instream flow needs have focused too much on only minimum flows. These threshold flows are intended to maintain aquatic life for relatively short periods of time. The lower the minimum, for example the 7Q10 flow, the more it is suited only to allow survival for brief periods. Ecosystems suffer when the minimum flow becomes THE flow for extended periods. As offstream demands increase, the potential for leaving only the minimum flow in the stream for longer and longer periods also increases.

The goal of protecting instream flows should be to maintain ecological integrity of the stream. 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 that of the natural habitat."[4]

A living system exhibits ecological integrity if, when the system is subject to disruption, it recovers and continues to provide the natural goods and services that normally accrue from that system. Ecological integrity includes biological, chemical and physical components.

If ecosystems are to be maintained in a healthy condition, a "**flow regime**" approach is needed rather than just a minimum threshold flow. This is especially important for streams that have significant existing or projected withdrawals for offstream uses. A flow regime encompasses the magnitude, timing, frequency, duration, and rate of change of stream flows.

A flow regime approach retains some degree of natural stream flow variability, and thus avoids an aquatic population shift towards generalist, lowest common denominator species. One way to implement a flow regime approach is to set aside a percentage of the varying natural inflow for offstream use or storage in reservoirs, leaving the remainder to support a healthy aquatic ecosystem with varying flows downstream of the withdrawal or dam. This represents a change from setting aside only a minimum for the stream and allocating all of the rest for offstream uses. Basinwide hydrologic modeling and implementation of drought protocols can help manage offstream withdrawals and maintain instream flow regimes without degrading ecological integrity.

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[4] Karr, J.R. and D.R. Dudley. (1981). Ecological Perspectives on Water Quality Goals. Environ. Manage. 5: 55-68. See generally http://www.epa.gov/bioiweb1/html/biolref.html

(iv) The Existing Review Process for Instream Flows

For specific proposed projects, the DWR works with other divisions and agencies to evaluate instream flow concerns as part of the preparation of environmental documents and review of permits. Flow requirements have been included in the following:

- Approvals of a Finding of No Significant Impact (FONSI) for Environmental Assessments (EA's) – subject to State Environmental Policy Act (SEPA)
- Conditions of section 401 certificates issued by the NC Division of Water Quality – subject to federal Clean Water Act
- Conditions of section 404 permits issued by the U.S. Army Corps of Engineers – subject to federal Clean Water Act
- Articles in hydropower licenses issued by the Federal Energy Regulatory Commission (FERC)
- Requirements in dam safety permits issued by the NC Division of Land Resources
- Withdrawal permits in designated Capacity Use Areas – subject to NC Water Use Act of 1967

Depending on the nature of the project, a field study to evaluate instream flow needs may be required.

(v) Incorporating Instream Flow Needs in Basinwide Modeling and Planning

For modeling and planning purposes, instream flow needs will need to be quantified at numerous locations throughout the basin in order to evaluate existing and proposed withdrawals and reservoirs that modify stream flows. Ideally, these instream flow amounts would be determined using state-of-the-art field study approaches. However, this is not practical in terms of the time and staff that would be required to achieve basinwide coverage. Therefore, a screening approach is needed that will identify reaches where available water may not be sufficient to satisfy existing or projected offstream uses and still maintain ecological integrity and other instream uses.

It is very important to recognize that a screening approach is NOT intended for use as a tool in setting instream flow requirements. For example, if a screening tool uses “x” percentage of the average flow as an indicator of instream flow concerns, this does NOT mean that “x” percentage of average flow is the only flow that needs to be continually maintained in the stream. A screening tool is only intended to flag stream reaches with potential concerns during the basinwide planning process. Individual water projects will still be subject to site-specific review and evaluation, and watersheds with flagged reaches of concern might require additional instream flow studies for water supply planning purposes.

An initial attempt to develop a screening approach for the Cape Fear Basin Plan used an approach based on the percentage of average annual flow remaining in the stream after flow modifications, as outlined in the table below. The Appendix contains additional description of this approach, called the Tennant Method. The historical average annual flow at each node location was determined using the basin model under the unregulated scenario. At each node, the percentages of flows falling within different ranges of a percentage of average annual flow were calculated for different times of the year. These were then compared for the unregulated flows and existing 2003, projected 2030, and projected 2050 offstream demand flow scenarios (scenarios modeled under section 1.2).

Table - 12: Modified Tennant Method Guidelines for Preliminary Screening of Instream Flow Concerns

	Description of Flow Levels	March to May	June to November	December to February
Level 1	< 10% of QAA*	Severe Degradation	Severe Degradation	Severe Degradation
Level 2	10 - 20% of QAA	Poor or Minimum	Fair or Degrading	Fair or Degrading
Level 3	20 - 30% of QAA	Fair or Degrading	Good	Good
Level 4	30 - 40% of QAA	Good	Excellent	Excellent
Level 5	40 - 50% of QAA	Excellent	Outstanding	Outstanding
Level 6	50 - 60% of QAA	Outstanding	Outstanding	Outstanding
Level 7	60 - 100% of QAA	Optimum	Optimum	Optimum
Level 8	100 - 200% of QAA	Optimum to Flushing	Optimum to Flushing	Optimum to Flushing
Level 9	>200% of QAA	Flushing or Maximum Flow	Flushing or Maximum Flow	Flushing or Maximum Flow

*QAA is the Average Annual Flow

The plots shown in Figure -26 through Figure – 28 are examples of a summary of stream flow levels using the preliminary screening criteria in the table above. Daily stream flows at points of interest throughout the basin were estimated using the basin hydrologic model for the entire 75 years of record. Then the percentage of days during the 75-year period when flows were within each of the various stream flow brackets was calculated. The Cape Fear River Basin 2008 Assessment includes the results for all of the nodes.

While the attempt at a screening process shown in the examples above is a good first step, additional analysis is needed to address the question of what constitutes a significant, undesirable effect on the various instream uses that depend on adequate stream flows. For example, in the third figure shown below the most notable differences are seen between the unimpaired and existing conditions in the first three flow brackets: 0–10%, 10–20% and 20–30% of average annual flow. The key question remaining is: do these shifts in hydrology adversely affect aquatic habitat?

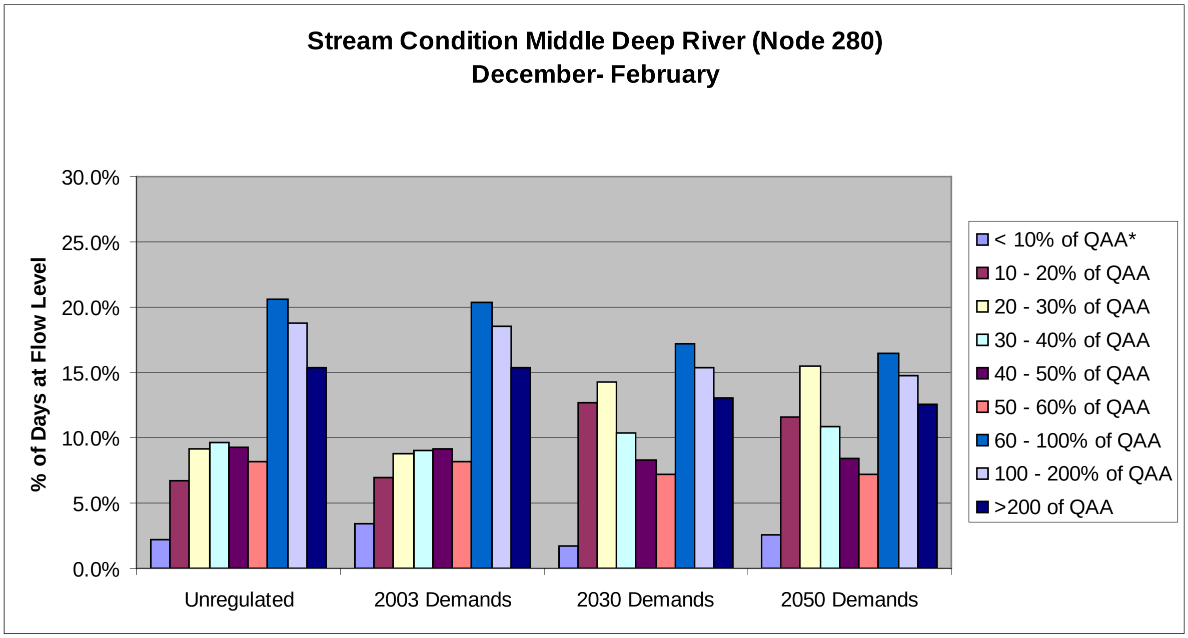
Additional analysis is needed to test this and other possible screening approaches before it is applied further. This analysis will use existing aquatic habitat study sites, with a focus on those sites where the more sophisticated Instream Flow Incremental Methodology field study approach was used to develop a relationship between flow and habitat. The basin hydrologic model will be used to produce flows at these study sites with varying degrees of alteration. Analyzing the effects of these simulated hydrologic alterations on aquatic habitat at the study sites will allow development of a screening tool based on a flow indicator that corresponds to a threshold level of aquatic habitat impact, with a conservative safety margin.

An improved screening process would still only be used for basinwide planning purposes. New or increased water withdrawals would still undergo site-specific instream flow evaluations as part of the environmental review and permitting process.

Modeling and Planning Can Help Prevent This

**… If Instream Flows
and Uses
are Included
in the Equation**

Figure - 26: Stream Condition Middle Deep River, Dec-Feb

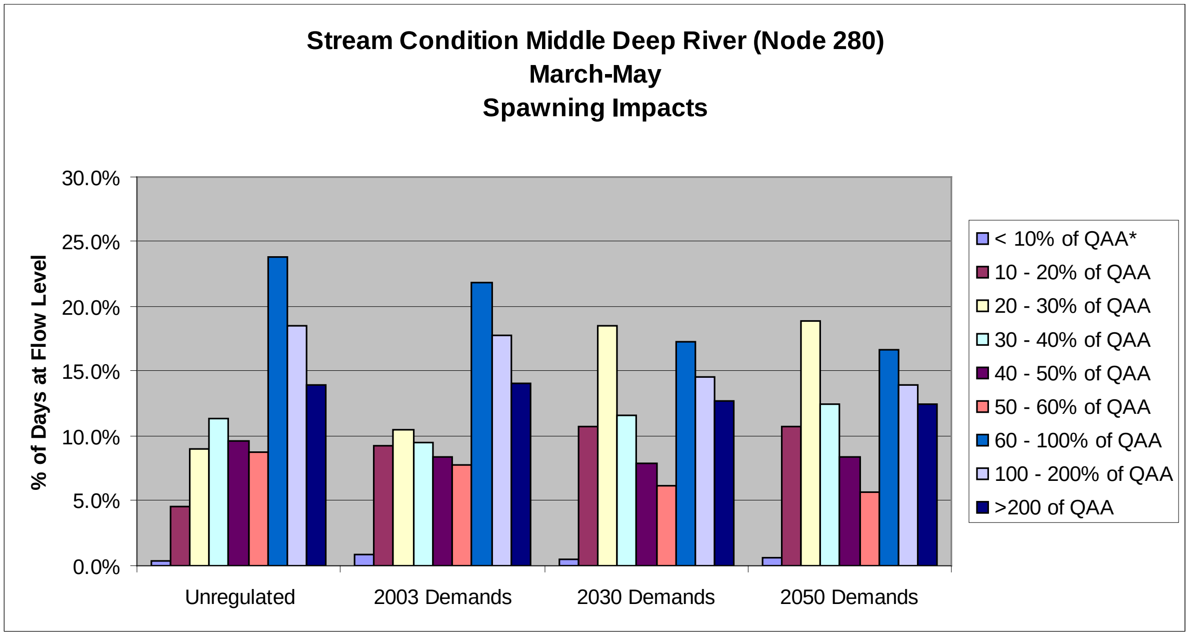


*QAA (average annual flow) at Node 280 = 227 mgd or 351 cfs

Table - 13: Stream Condition: Middle Deep River (Node 280)

Level	**Dec-Feb**	**Unregulated**	**2003 Demands**	**2030 Demands**	**2050 Demands**
1	< 10% of QAA*	2.2%	3.5%	1.7%	2.6%
2	10 - 20% of QAA	6.7%	7.0%	12.7%	11.6%
3	20 - 30% of QAA	9.2%	8.8%	14.2%	15.5%
4	30 - 40% of QAA	9.6%	9.1%	10.3%	10.9%
5	40 - 50% of QAA	9.2%	9.2%	8.3%	8.4%
6	50 - 60% of QAA	8.2%	8.2%	7.1%	7.1%
7	60 - 100% of QAA	20.6%	20.4%	17.1%	16.5%
8	100 - 200% of QAA	18.8%	18.5%	15.4%	14.8%
9	>200 of QAA	15.4%	15.4%	13.1%	12.5%

Figure - 27: Stream Condition Middle Deep River, March-May

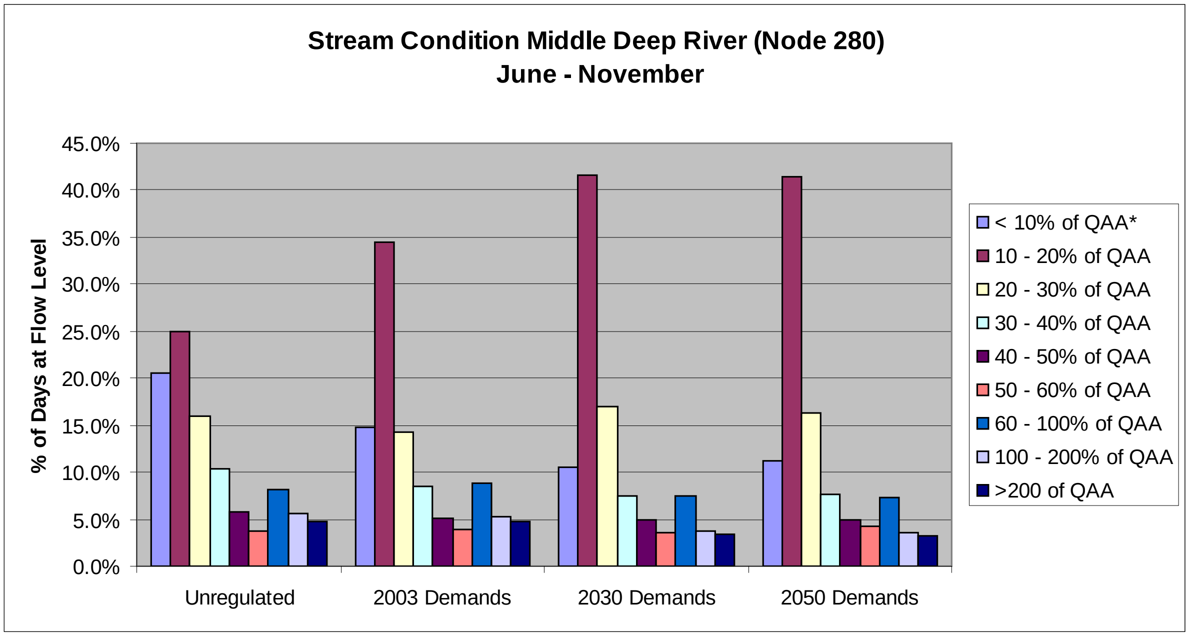


*QAA (average annual flow) at Node 280 = 227 mgd or 351 cfs

Table - 14: Stream Condition: Middle Deep River (Node 280)

Level	**Mar-May**	**Unregulated**	**2003 Demands**	**2030 Demands**	**2050 Demands**
1	< 10% of QAA*	0.3%	0.9%	0.6%	0.6%
2	10 - 20% of QAA	4.6%	9.2%	10.7%	10.8%
3	20 - 30% of QAA	9.1%	10.5%	18.5%	18.9%
4	30 - 40% of QAA	11.4%	9.5%	11.7%	12.5%
5	40 - 50% of QAA	9.7%	8.3%	7.9%	8.4%
6	50 - 60% of QAA	8.8%	7.8%	6.1%	5.7%
7	60 - 100% of QAA	23.8%	21.9%	17.3%	16.6%
8	100 - 200% of QAA	18.5%	17.8%	14.6%	14.0%
9	>200 of QAA	13.9%	14.1%	12.7%	12.5%

Figure - 28: Stream Condition Deep River, Jun-Nov



*QAA (average annual flow) at Node 280 = 227 mgd or 351 cfs

Table - 15: Stream Condition: Middle Deep River (Node 280)

Level	June-Nov	Unregulated	2003 Demands	2030 Demands	2050 Demands
1	< 10% of QAA*	20.6%	14.8%	10.6%	11.2%
2	10 - 20% of QAA	24.9%	34.5%	41.5%	41.5%
3	20 - 30% of QAA	16.0%	14.3%	16.9%	16.3%
4	30 - 40% of QAA	10.3%	8.4%	7.5%	7.6%
5	40 - 50% of QAA	5.8%	5.2%	5.0%	4.9%
6	50 - 60% of QAA	3.8%	3.9%	3.6%	4.2%
7	60 - 100% of QAA	8.2%	8.9%	7.5%	7.4%
8	100 - 200% of QAA	5.6%	5.3%	3.8%	3.6%
9	>200 of QAA	4.8%	4.7%	3.5%	3.3%

1.3 Climatology

The humid subtropical climate of North Carolina consists of long, hot, humid summers and short, mild winters[5]. The spring and autumn seasons provide the most pleasant weather and are the periods most favored by many of the State's residents. On average, annual precipitation across the state ranges from about 38 inches to more than 80 inches. Eastern areas of the Coastal Plain receive between 50-55 inches, primarily because of sea-breeze effects and tropical storms that occur primarily in the late summer and early autumn. Precipitation during the winter tends to be widely distributed, and many areas of the State can receive a substantial amount from a single storm system. Summer rainfall tends to be spotty, resulting from the convective patterns of daily heating and subsequent evaporation that aid in developing thunderstorms. Under typical patterns, much of the moisture delivered to North Carolina comes from the Gulf of Mexico. With a Bermuda high-pressure system that typically resides in the central North Atlantic Ocean, prevailing winds generally come from the south or southwest, thereby enabling the transport of moisture. Additionally, some storms move across the southern tier of the United States and turn northeastward along the eastern seaboard, delivering precipitation in a "wrap-around" effect. More common in the winter, these storms are sometimes referred to as "nor'easters" because of the cool and breezy conditions that accompany them. Some of the heaviest recorded snowfalls in eastern North Carolina resulted from these coastal storms (USGS Report, 2005). Statistical analyses were performed using the observed rainfall, snowfall and temperature data from several weather stations.

(a) Precipitation

The rainfall and snowfall data were collected from the South East Regional Climate Center (SERCC) for five stations. On average one station was selected along the major river with significant rainfall variation for location. The selected stations are at: Greensboro, Siler City, Sanford, Fayetteville and Wilmington. All these stations have long period of records ranging from 35 years to more than 100 years. The map in Figure - 29 shows the locations of the five stations in the river basin.

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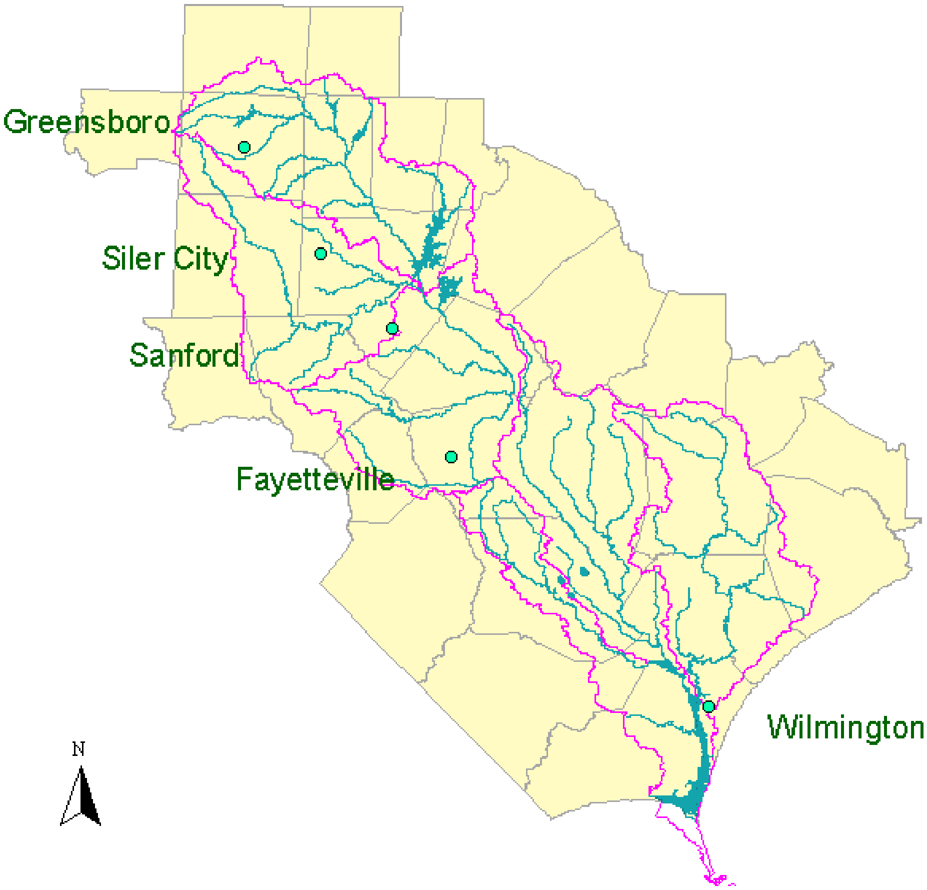
[5] Page 11, http://pubs.usgs.gov/sir/2005/5053/pdf/SIR2005-5053.pdf

Figure - 29: Map of Five SERCC Weather Stations



The average annual precipitation plots for those stations are shown in Figure - 30. This plot shows that the highest average annual rainfall of 54.6 inches was observed at the Wilmington station in the lower basin. The rainfall amounts are relatively lower in the upper basin. In Greensboro, the average is only 43.5 inches. However, the average snowfall accumulation is much higher in Greensboro (8.6 inches) and much lower in other stations. Therefore, more than 52 inches of total annual average precipitations were observed in Greensboro and in Wilmington, whereas the other stations had close to 50 inches.

Figure - 31 shows the monthly average rainfall pattern. Wilmington is located in the highest rainfall producing area in wet months, but the year-round amounts do not vary that much from upper basin to lower basin. The average monthly rainfall varies from 2.7 inches to 7.8 inches across the basin throughout the year.

Figure - 30: Average Annual Precipitation

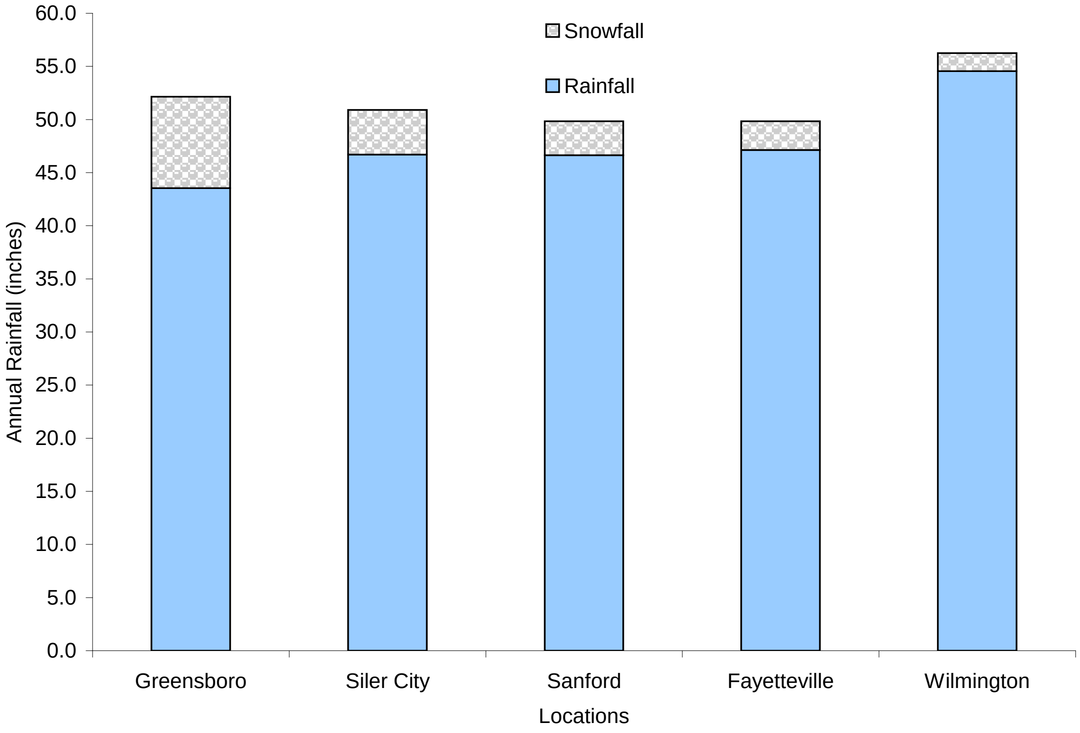
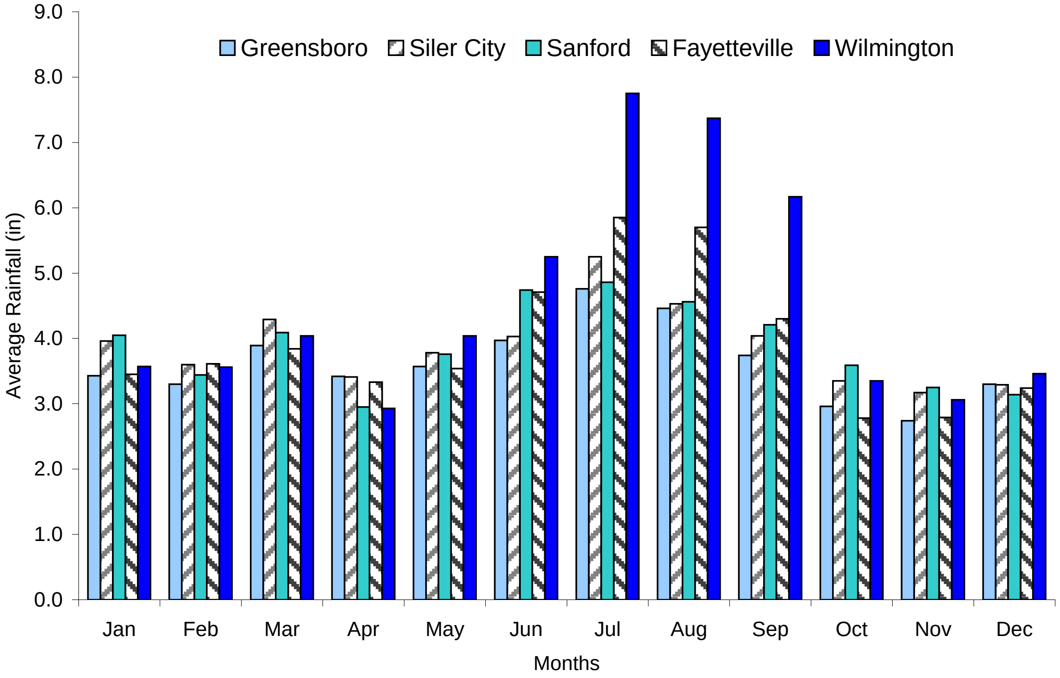


Figure - 31: Average Monthly Rainfall



(b) Temperature

Temperature readings recorded at the same five SERCC weather stations (Greensboro, Siler City, Sanford, Fayetteville and Wilmington) were analyzed. Temperature variations across the basin are relatively small. Figure - 32 and Figure - 33 show the average monthly maximum and minimum temperatures. The maximum temperature varies from upper 40s to lower 90s. The minimum temperature varies from upper 30s to lower 70s. The two plots show that seasonal minimum temperature variation is more than seasonal maximum temperature variation.

Figure - 32: Average Maximum Temperature

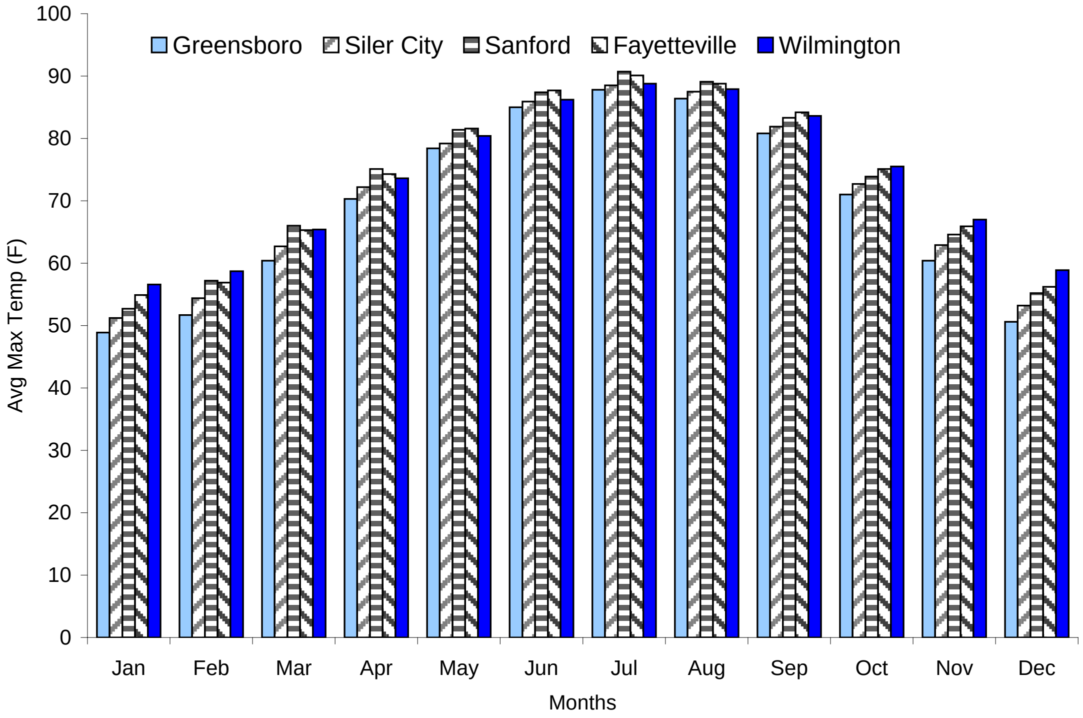
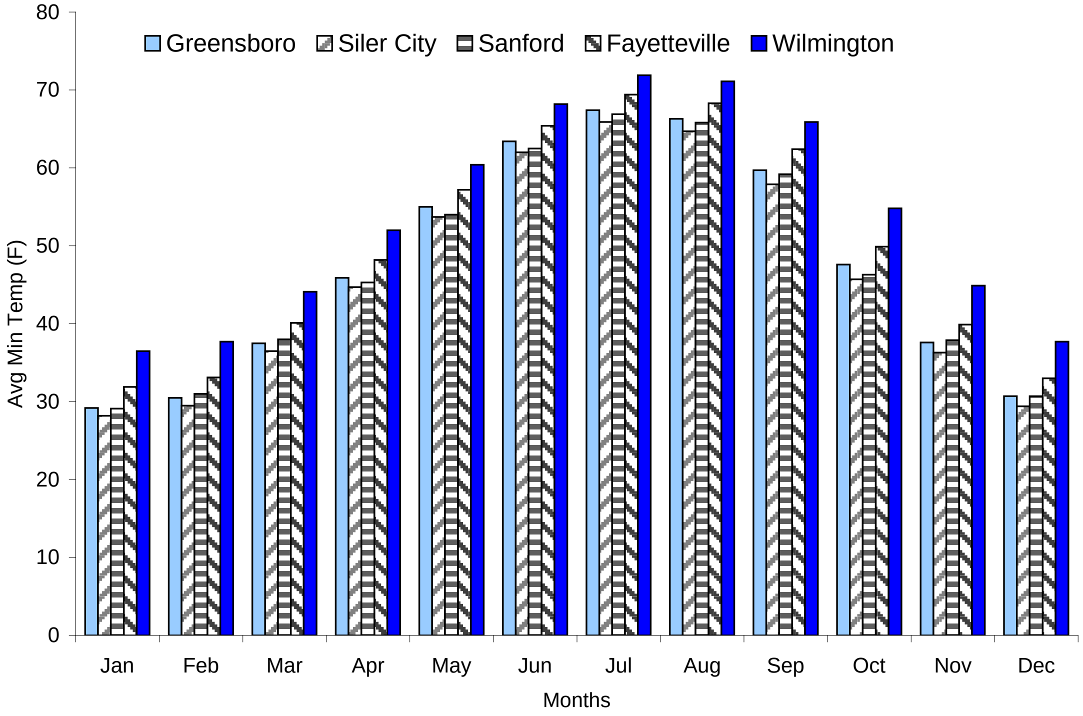


Figure - 33: Average Minimum Temperature



1.4 Water Quality

For complete information on Water Quality in the Cape Fear River Basin, please visit the link to NCDWQ's Cape Fear River Basinwide Water Quality 2005 Plan.

2 Water Management

2.1 Drought Response Plan and Implementations

Drought Response Legislation

Legislation addressing drought management has been enacted by the North Carolina General Assembly since the drought of the 1980's and following droughts. The drought that culminated in 2002 was followed by the drought of 2007-2008, identified as the worst drought in more than 100 years in North Carolina.

During these most recent droughts, water users and community water systems were severely stressed and a number of people experienced economic loss as a result of water shortages. Some communities were dangerously close to running out of water. The experience with the droughts emphasized the importance of proper management of North Carolina's water supplies. 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 (NC-DMAC) was created by law in 2003. Its predecessor, the Drought Monitoring Council, was an interagency coordinating and information exchange body created in 1992. The original council did a creditable job of monitoring and coordinating drought responses in the 2002 drought. Consequently, the General Assembly recognized the Drought Monitoring Council's leadership role by assigning it official statutory authority and changing its name to the Drought Management Advisory Council to reflect the broader role of the council, which encompasses more than just monitoring drought conditions. Local drought conditions in North Carolina are reported each Tuesday by a technical team of the NC-DMAC to the U.S. Drought Monitor (USDM). The USDM, which is defined as the national drought map, serves as the drought map for North Carolina as well. The USDM designates areas of drought using the following categories D0-Abnormally Dry, D1-Moderate, D2-Severe, D3-Extreme, and D4-Exceptional. The map is updated weekly based on current conditions and a new USDM is released each Thursday.

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. For water systems required to prepare and update a Local Water Supply Plan (LWSP), these plans must be included in their LWSP as a Water Shortage Response Plan (WSRP). An effective WSRP should adhere to the guidelines set forth by the water use rules during drought. Water users without a written plan are advised to follow the applicable default water use reduction measures outlined in Section .0614 of the rules during exceptional and extreme drought classification as depicted by the US Drought Monitor of counties in North Carolina. A WSRP establishes authority for declaration of a water shortage, defines different phases of water shortage severity, and outlines appropriate responses for each phase.

The registration and reporting of water withdrawal and transfers have been required for more than a decade. Recent rulemaking has mandated that registered water users must electronically submit water use information annually to the DWR by April 1 of each year.

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. It 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. DWR is presently developing the review and approval process that will be used to accomplish this task. Prior to this legislation, these plans were submitted to DWR and reviewed for consistency with the general requirements contained in the authorizing legislation, but no formal approval was required.

The 2008 Drought Legislation further requires water systems to implement the approved Water Shortage Response Plans, or EMC-adopted default conservation measures, when conditions warrant. This legislation provides DENR with the authority to issue civil penalties to water systems for failure to implement these measures when required. This is a new responsibility for DENR (DWR) that will require new monitoring, tracking, and enforcement efforts. The Session Law also gives DENR the authority to require the implementation of more stringent response levels contained in the WSRPs, if necessary to achieve needed water withdrawal reductions. DWR is mandated to provide the necessary analysis and justification for such actions.

Water Shortage Response Plans for Local Water Supply Systems

Within the Cape Fear River Basin there are a total of 64 public water systems required to prepare Local Water Supply Plans. This group includes community water systems that regularly serve 1,000 or more service connections or 3,000 or more individuals and any unit of local government that provides or plans to provide public water service. According to rules governing water use during droughts and water emergencies (15A NCAC 02E. 0607), these systems are required to submit a water shortage response plan or they are subject to implementing a set of default rules governing water use during periods of extreme or exceptional drought, as designated by the NC-DMAC. As of January 2009, approximately 80 % of these water systems have submitted water shortage response plans to the Division of Water Resources. Plans are viewable on the Division's website.

Table - 16: Water Shortage Response Plan Data

	Number of Local Water Supply Plan Systems	Water Shortage Response Plans Submitted	Percent of Systems with Plans
Cape Fear River Basin	64	51	80%
North Carolina	542	467	86%

Assessments indicate widely varying levels of detail on water shortage protocols included in these plans. Plan review criteria developed from 15A NCAC 02E. 0607 requirements stipulate essential information which must be provided in all water shortage response plans. Key among these are the authority responsible for declaration of a water shortage, the definitions of tiered stages of water shortage severity, and the corresponding responses appropriate to each stage. 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 that are 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. Examples of suitable triggers for each supply type are available on the DWR website. As specified in the legislation, all water shortage response plans are considered approved upon submission until they are formally disapproved by DWR staff

Water System Water Conservation Status

The DWR and Public Water Supply Section (PWSS) regional offices have worked together to make possible the on-line reporting of the status of water conservation requirements by public water systems. This on-line database provides a consistent way to document and track status of and impacts to public water supply systems. The system is operational and in use, and tracks the more than 600 water systems throughout the state. This information can be accessed at: http://www.ncwater.org/Drought_Monitoring/reporting/index.php

Registration of Water Withdrawals and Transfers

Information on all users of water is important for the establishment and implementation of drought management measures in the river basin. In addition to information contained in local plans the NC-DMAC uses data from registered water withdrawals and surface water transfers between river basins maintained by the DWR.

In general terms, this registration requirement applies to any non-agricultural water user who withdraws 100,000 gallons or more in any one day of ground water or surface water or who transfers 100,000 gallons or more in any one day of surface water from one river basin to another. An agricultural water user who withdraws 1,000,000 gallons or more in any one day of ground water or surface water or who transfers 1,000,000 gallons or more in any one 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 on-line on the DWR website. This website allows the user to view the water use data by river basin or by county.

North Carolina Drought Management Advisory Council

The primary function of the NC-DMAC is to provide consistent and accurate information on drought conditions in the state to the USDM, to water users, and the public about drought conditions in the state to help improve the management and mitigation of the harmful effects of drought. The NC-DMAC is required to meet at least once a year and as needed during drought.

A technical team of the NC-DMAC holds a weekly conference call on Tuesday of each week to assess drought conditions in the state. Information gathered in this weekly update is reported to the author of the USDM map that is updated and released each Thursday (www.ncdrought.org).

Weekly drought advisories are issued by the NC-DMAC showing drought conditions by county in North Carolina. Counties under drought advisories are listed each week by drought classification. The drought response actions listed for the counties are based on the county drought classification (www.ncdrought.org).

Drought Response and Drought Proofing Activities

The PWSS and the DWR have established a list that ranks local water systems in three tiers of drought vulnerability. PWSS regional engineers 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 PWSS 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.

The list of water systems currently in Tier 1, 2 and 3 in the state is available online at: http://www.ncwater.org/Drought_Monitoring/reporting/weekstatust123.php

Seven community water systems in the Cape Fear Basin were identified as Tier-1 systems in the 1998-2002 and 2007-2008 droughts: Robbins, Southern Pines, Swepsonville, Greensboro, Carthage, Moore County and Siler City. These systems applied for and received emergency funds to reduce their vulnerability to drought. Projects included new water sources or interconnections with a nearby water system.

Water Audits and Leak Detection

Community water systems have been encouraged to increase their water use efficiency, identify leaks, and examine other areas where water could be saved. DENR has worked with communities to help conduct water system audits. So far twenty-three systems have requested help in conducting water audits of their systems. DWR has contracted with five engineering firms to conduct the water audits and leak investigations and to report their findings to the communities and to DWR. In the Cape Fear Basin, a contract is in place for water audit and leak detection assistance for High Point.

In the Cape Fear Basin, the local supply plans that were submitted in 2002 for 111 water systems indicated that 58 had an unaccounted-for water loss estimate of less than ten percent, 34 systems had an unaccounted-for loss of 10 to 20 percent, and 19 systems recorded unaccounted-for losses greater than 20 percent.

2.2 Interbasin Transfer

Surface Water Transfers in the Cape Fear River Basin
Development of municipal water systems is a responsibility assumed by local governments. In most cases, current public water systems represent the expansions and improvements that have been made to water systems originally established many decades ago. As communities grew in area and population, water systems grew to provide customers with dependable supplies of drinking water and water for other purposes, especially fire fighting. The desire to avoid damage from periodic flooding encouraged community development on the higher ground out of the flood plain where feasible. In some locations this high ground forms the boundary between two different river basins resulting in communities with residents in multiple river basins. As a result of this, drinking water systems supplying these communities must distribute water to multiple river basins. For some communities, choosing the best site for a wastewater treatment facility meant building it in a river basin different from their source of water. Surface water not returned to the source basin by customers in another basin and wastewater discharges in a basin different from the source constitute transfers of water under the legislation regulating the interbasin transfer of surface waters.

Like most river basins in North Carolina, the Cape Fear River Basin has water systems that move water between rivers and hydrologic units within the basin and some that move water out of the basin entirely. A detailed discussion of the regulations related to interbasin transfers of surface water can be found at the DWR website. Basically, moving large quantities of surface water between the river basins requires permission of the EMC. Water systems that had the ability to move water across these basin boundaries when the interbasin transfer legislation was initially enacted are allowed to continue with the transfer up to the maximum capacity that was in place in July 1993. This capacity is referred to as their “grandfathered capacity”. Transfers greater than two million gallons per day or increases in a system’s transfer to more than two million gallons per day, if it is greater than the system’s grandfathered capacity, are not allowed without receiving permission from the EMC.

In the Cape Fear River Basin there are many water systems that depend, to some extent, on moving surface water between the basins defined by the legislation regulating surface water transfers. Two groups of entities using surface water from this river basin have received a formal authorization for an interbasin transfer from the EMC to transfer large quantities of water. In the appendix of this document there is a table summarizing this movement of water in the Cape Fear River Basin.

The Piedmont Triad Regional Water Authority, composed of the municipalities of Archdale, Greensboro, High Point, Jamestown, and Randleman and Randolph County, worked over several decades to develop a new reservoir to supplement existing water sources in the Triad Region. In 1991 the Authority received permission to transfer up to 30.5 million gallons per day from the Deep River Basin to the Haw and Yadkin River Basins to allow for the use of water from the proposed Randleman Lake Reservoir. The reservoir has since been completed although the facilities to withdraw and treat the water are still under development.

The Commission's decision includes requirements for minimum releases from Randleman Reservoir. Under normal conditions 30 cubic feet per second (cfs) of water must be released to the river below the dam. During drought conditions, releases may be reduced based on the amount of water remaining in the reservoir. If the remaining storage drops below 60%, the release may be reduced to 20 cfs and if it drops below 30%, the releases may be cut back to 10 cfs. A copy of the document authorizing this transfer can be found at the DWR website.

In 2001, the EMC gave permission, with conditions, to the Towns of Cary, Apex and Morrisville and Wake County (representing Research Triangle Park – South), as a group, to transfer up to 24 mgd from the Haw River Basin to the Neuse River Basin. All of these systems hold allocations of water from B. Everett Jordan Reservoir and get their drinking water from a water treatment plant co-owned by the towns of Cary and Apex. Likewise, wastewater collected from these systems is treated by water reclamation facilities operated by Cary and Apex. Cary and Apex had an existing approved interbasin transfer of 16 mgd from the Haw River Basin to the Neuse River Basin associated with the permitted wastewater treatment plant discharges.

In its 2001 decision, the Commission stipulated that, after 2010, any water used for other than consumptive purposes in the Neuse Basin in excess of 16 million gallons per day must be returned to the Haw or Cape Fear River basins. This stipulation requires the construction of a new wastewater reclamation facility to treat the wastewater collected in the Neuse River Basin in excess of 16 mgd. The planning, environmental review and permitting of the new facility and associated collection system have not been completed. A final decision on the preferable location for the new facility's discharge has not been made. Due to the nuances of the existing interbasin transfer law, at least one of the possible options would require a certification of another interbasin transfer from the Haw River Basin to the Cape Fear River Basin. This requirement would add significant time and expense to the project and would likely postpone completion to well beyond the 2010 limit established in the existing interbasin transfer certificate. Copies of the application, environmental review documents and the Commission's decision can be found at the DWR website.

Many water systems in North Carolina depend on moving surface water between river basins at volumes below the threshold that triggers the need for the EMC interbasin transfer approval. Water systems are allowed to transfer up to 2 mgd or the limits of their “grandfathered capacity” before they have to seek authorization for an interbasin transfer from the EMC. Most of the water systems that transfer water between basins have not exceeded their grandfathered capacity or transfer less than 2 mgd and therefore the transfers are not subject to approval by the EMC. In the appendix of this document there is a table summarizing this movement of water in the Cape Fear River Basin.

Based on information contained in Local Water Supply Plans there are 114 active water systems that depend on water from the Cape Fear River Basin. Twenty-four water systems withdraw surface water as their source of drinking water. These twenty-four systems provide water to an additional fifty-three water systems. Therefore, there are seventy-seven water systems in the basin that depend on surface water withdrawals to meet some or all of their customers water needs. Of the seventy-seven systems that depend on surface water, either by withdrawing it directly or by purchasing treated surface water, thirteen systems discharge wastewater to a basin different from the source. Twenty-seven of the seventy-seven water systems provide drinking water to customers in a basin different from the source of the water.

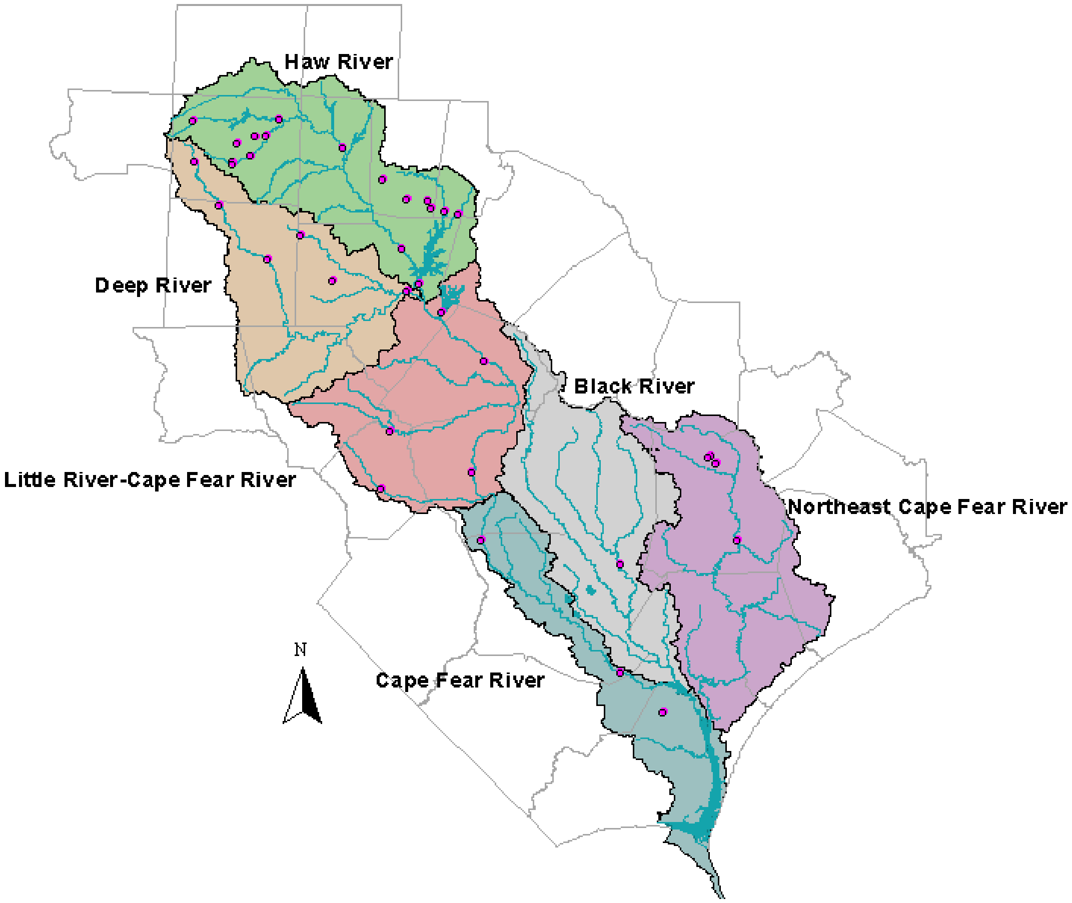
As communities in the Cape Fear River Basin continue to grow and water system service areas expand to provide drinking water to more customers, there will be more communities that will need to petition the EMC for an interbasin transfer certificate. Some of these petitions will be necessary because the water systems are approaching the limits of their grandfathered capacity and others because water systems are contemplating transfers of over two million gallons a day for the first time.

2.3 *Data Management Needs*

Surface Water

The Cape Fear River Basin contains 105 USGS stream flow gage stations; among those there are 42 stations equipped to provide real time monitoring of flows and water levels along with other useful parameters. The distribution of the gages are shown in the map in Figure - 34 As can be seen from the map the gage stations are concentrated in the upper hydrologic units in the basin. There is only one active gage in Black River HU. The addition of more gages in this drainage would significantly enhance water resource data for this area.

Figure - 34: USGS Streamflow Gage Locations in Cape Fear River



Ground Water

The drought indicator well network consists of 46 wells distributed throughout North Carolina. The DWR has established a near term goal of 60 wells associated with that network. Certainly, additional wells in the Cape Fear River Basin will be part of that formula. In order to better assess the hydrogeologic conditions of the entire Cape Fear River Basin, additional well stations need to be installed (especially in counties that currently do not have stations) and existing stations may need additional wells to improve the quality of data collected.

Water Use and Conservation

The DWR has developed two electronic reporting systems to implement the 2008 Drought Legislation (S.L. 2008-143) and its associated water use reporting requirements. These systems report and record the level of water conservation measures that have been implemented by individual water systems. The weekly water use of the various water systems will also be recorded (when this weekly water use reporting requirement has been implemented by DENR).

During times of drought, the Cape Fear water systems' water conservation status and weekly water use reporting (when required) can be found on the DWR website.

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Appendices

Cape Fear River Basin
Water Supply Plan

NC Department of Environment
and Natural Resources

January 2009

Division of Water Resources

Table of Contents

1. County Summary

Counties and Municipalities in the Cape Fear River Basin

By following the Local Governments and Planning Jurisdictions in the Basin, the Cape Fear River basin encompasses all or portions of 26 counties and 115 municipalities, presented in table 1. Twenty-seven municipalities are located in more than one major river basin, and 15 municipalities are located in more than one county.

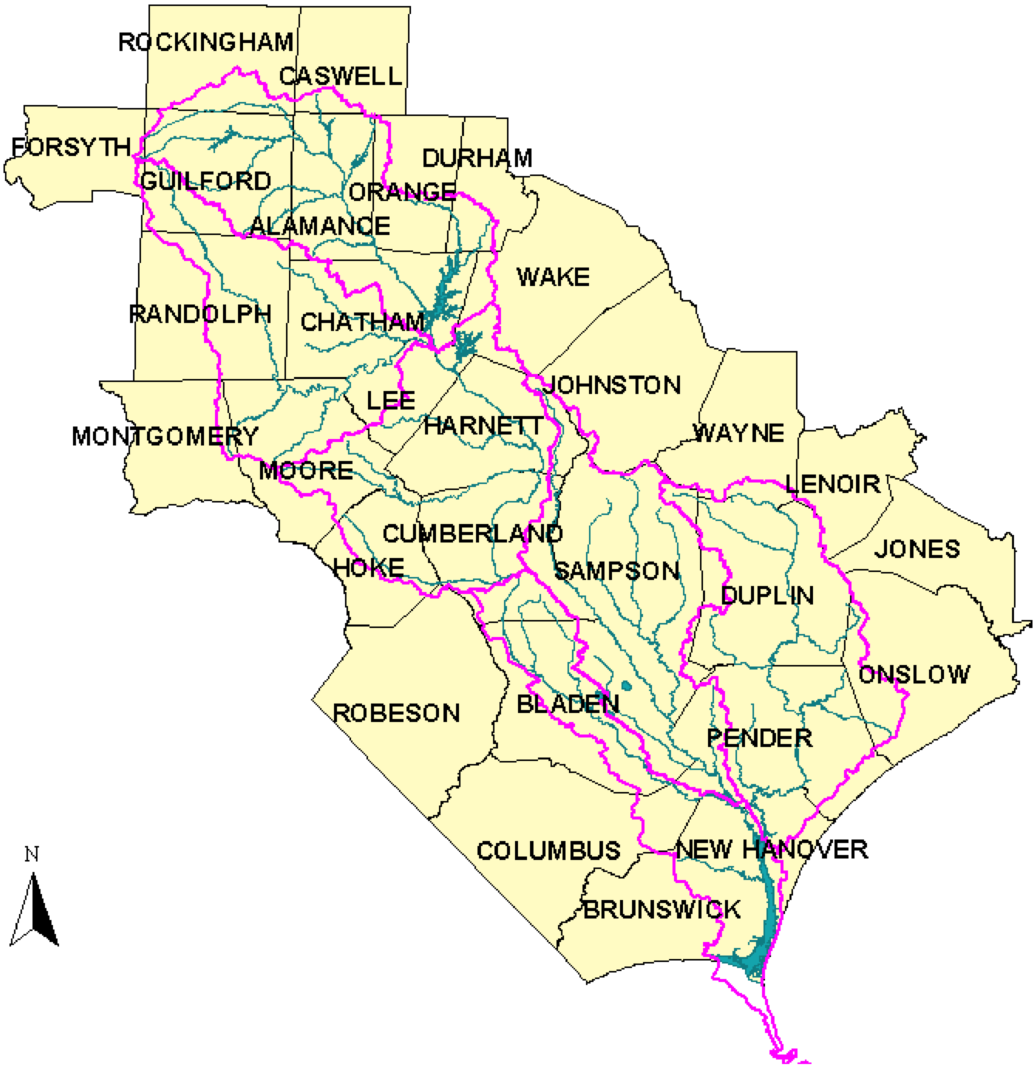
Table 1: Population data from Office of State Planning for municipalities with populations greater than 2,000 persons, located wholly or partly within the basin and represents 53 of the 115 municipalities in the basin.

County	Municipalities
Alamance	Alamance, Burlington, Elon, Gibsonville, Graham, Green Level, Haw River, Mebane, Swepsonville
Bladen	Dublin, East Arcadia, Elizabethtown, Tar Heel , White Lake
Brunswick	Bald Head Island, Belville, Boiling Spring Lakes ♦, Caswell Beach, Leland, Navassa, Northwest, Saint James, Sandy Creek, Southport
Caswell	None
Chatham	Cary, Goldston, Pittsboro, Siler City
Columbus	Bolto, Sandyfield
Cumberland	Falcon, Fayetteville, Godwin, Hope Mills, Linden, Spring Lake, Stedman, Wade
Duplin	Beulaville, Calypso, Faison, Greenevers, Harrells *, Kenansville, Magnolia, Mount Olive, Rose Hill, Teachey, Wallace *, Warsaw
Durham	Chapel Hill *, Durham, Morrisville
Forsyth	High Point, Kernersville
Guilford	Archdale, Gibsonville, Greensboro, High Point, Jamestown, Kernersville, Oak Ridge, Pleasant Garden, Sedalia, Stokesdale, Summerfield, Whitsett
Harnett	Angier, Broadway, Coats, Dunn, Erwin, Lillington
Hoke	Raeford
Johnston	Benson
Lee	Broadway, Sanford
Montgomery	Biscoe, Candor, Star
Moore	Cameron, Carthage, Pinehurst, Robbins, Southern Pines,Taylortown, Vass, Whispering Pines
New Hanover	Carolina Beach, Kure Beach, Wilmington, Wrightsville Beach
Onslow	Holly Ridge, North Topsail Beach, Surf City
Orange	Carrboro, Chapel Hill, Durham, Mebane
Pender	Atkinson, Burgaw, Saint Helena, Surf City, Topsail Beach, Wallace, Watham
Randolph	Archdale, Asheboro, Franklinville, High Point, Liberty, Ramseur, Randleman, Seagrove, Staley
Rockingham	Reidsville ♦
Sampson	Autryville, Clinton, Falcon, Garland, Harrells, Newton Grove, Roseboro, Salemburg, Turkey
Wake	Apex, Cary, Fuquay-Varina, Holly Springs, Morrisville
Wayne	Mount Olive

Source: North Carolina Center for Geographic Information and Analysis (CGIA), 1997.

For a better visualization of the counties, below is the map of the counties in the Cape Fear River Basin

Figure 1: Counties in the Cape Fear River Basin



a. *Demographics*

In the last few decades the population growth in some parts of the Cape Fear River Basin area has being influenced mainly by the availability of jobs, specially in high technology industries, but other facts like cost of living, environmental attractions, weather, education and security has also played their roles. The most populated areas are located in and around the Triad, Triangle, Fayetteville and Wilmington. Those counties in the upper basin and along the coast are experiencing high population growth that will add increased drinking water demands and wastewater discharges.

Population in the Cape Fear River basin has grown from just under 1.5 million to over 1.8 million people from 1990 to 2000 (NC DENR Water Quality, 2005). The overall population of the basin based on 2000 Census data is 1,834,545, with approximately 197 persons/square mile. If this trend continues, the 26 counties with some land area in the Cape Fear River basin are expected to increase population from just fewer than 3 million to over 5 million people (28.9 percent) by 2020. Projections by Water Resources division for the Counties in the Cape Fear River Basin estimates that from 2000 to 2020 will have a population growth of 43% and by 2050 an 106% increase, compared also with 2000 census

b. Local Water Supply Plans, County Populations and Growth Trends

For the purposes of this analysis we assumed that local officials have a better perspective of how their communities will grow than we do. Because, generally, local water systems in their Local Water Supply Plans only provide data up to 2020, we will based our estimations of population growth beyond that on the pattern of their population growth.

The Local Water Supply Plans (LWSPs) are updated every five years with 1992 being the first year on which most plans were based. The 1992 LWSPs are based on actual water supply and demand conditions in calendar year 1992, so are the 1997 and 2002 updates. The 1992 plans, the 1997 and 2002 updates included estimates of service population for 2000, 2010 and 2020. The future population projections for 2030, 2040 and 2050 were based on actual population figures for 1992, 1997 and 2002, and population estimates for 2000, 2010 and 2020. These population projections for 2030, 2040 and 2050 are linear projections and this method assumes that over the period from 2020 to 2050, population growth will continue the same pattern as reflected in the period 1992 to 2020, and it seems reasonable, given the limits of existing information. The 1990 and 2000 are Census data and the other years are projections from Office of State Budget and Management and NCWRD.

Table 2 below contains the total population in each county and it says how much percent of that population is in the basin. The 1990 and 2000 population data is from the Census Bureau while the other data are projections made by the Office of State Budget and Management (OSBM), and the Division of Water Resources at NCDENR.

Table 2: County population Projections and % in the Cape Fear River Basin

County	Percent of County in Basin	1990	2000	2002	2010	2020	2030	2040	2050
Alamance	100	108213	130800	135317	148192	167362	187943	207357	226946
Bladen	69	28663	32278	33001	32556	32583	32471	34180	34947
Brunswick	45	50985	73141	77572	111155	146227	179424	210917	243984
Caswell	10	20662	23501	24069	23453	23416	23234	24444	24930
Chatham	100	38979	49326	51395	62887	77008	91491	103678	116968
Columbus	11	49587	54749	55781	54225	53370	52281	54203	54561
Cumberland	98	274713	302960	308609	317094	333174	346686	367530	384848
Duplin	100	39995	49063	50877	54788	61111	68153	75182	82005
Durham	27	181844	223314	231608	267086	309651	353630	396126	439104
Forsyth	2	265855	306063	314105	352810	401019	451350	494952	541615
Guilford	97	347431	421048	435771	480028	539335	600192	664921	727255
Harnett	100	67833	91085	95735	112513	135239	158751	180900	203494
Hoke	57	22856	33650	35809	47096	61890	78396	90422	104395
Johnston	2	81306	121900	130019	171548	225194	283401	328537	379389
Lee	100	41370	49170	50730	59358	70107	81418	90515	100640
Montgomery	6	23359	26827	27521	27941	29189	30544	32639	34299
Moore	79	59000	74768	77922	87915	100874	113650	127932	141454
New Hanover	100	120284	160327	168336	202411	242460	280977	322414	362748
Onslow	22	149838	150355	150458	174731	183501	189191	203364	214471
Orange	49	93662	115531	119905	131797	145119	156958	175778	191311
Pender	100	28855	41082	43527	54764	67889	80558	93667	106695
Randolph	56	106546	130471	135256	142620	155057	167598	184771	199357
Rockingham	19	86064	91928	93101	91485	90830	89836	92127	92727
Sampson	99	47297	60161	62734	66320	73080	80460	89368	97257
Wake	15	426311	627846	668153	920298	1230382	1560026	1810843	2098690
Wayne	9	104666	113329	115062	116386	120056	123152	128720	133065

Source: Census Bureau, Office of State Budget and Management, NCDENR DWR.

This third table is a little bit different from the previous one, because here the Population Projections represents the percent of population of the county inside the river basin, instead of the total population in each county.

Table 3: Total River Basin Population According to the County Population

County	Percent of County in Basin	1990	2000	2002	2010	2020	2030	2040	2050
Alamance	100	108213	130800	135317	148192	167362	187943	207357	226946
Bladen	69	19777	22272	22771	22464	22482	22405	23584	24113
Brunswick	45	22943	32913	34907	50020	65802	80741	94913	109793
Caswell	10	2066	2350	2407	2345	2342	2323	2444	2493
Chatham	100	38979	49326	51395	62887	77008	91491	103678	116968
Columbus	11	5455	6022	6136	5965	5871	5751	5962	6002
Cumberland	98	269219	296901	302437	310752	326511	339752	360179	377151
Duplin	100	39995	49063	50877	54788	61111	68153	75182	82005
Durham	27	49098	60295	62534	72113	83606	95480	106954	118558
Forsyth	2	5317	6121	6282	7056	8020	9027	9899	10832
Guilford	97	337008	408417	422698	465627	523155	582186	644973	705437
Harnett	100	67833	91085	95735	112513	135239	158751	180900	203494
Hoke	57	13028	19181	20411	26845	35277	44686	51541	59505
Johnston	2	1626	2438	2600	3431	4504	5668	6571	7588
Lee	100	41370	49170	50730	59358	70107	81418	90515	100640
Montgomery	6	1402	1610	1651	1676	1751	1833	1958	2058
Moore	79	46610	59067	61558	69453	79690	89784	101066	111749
New Hanover	100	120284	160327	168336	202411	242460	280977	322414	362748
Onslow	22	32964	33078	33101	38441	40370	41622	44740	47184
Orange	49	45894	56610	58753	64581	71108	76909	86131	93742
Pender	100	28855	41082	43527	54764	67889	80558	93667	106695
Randolph	56	59666	73064	75743	79867	86832	93855	103472	111640
Rockingham	19	16352	17466	17689	17382	17258	17069	17504	17618
Sampson	99	46824	59559	62107	65657	72349	79655	88474	96284
Wake	15	63947	94177	100223	138045	184557	234004	271626	314804
Wayne	9	9420	10200	10356	10475	10805	11084	11585	11976
Total		**1494145**	**1832593**	**1900282**	**2147107**	**2463467**	**2783125**	**3107291**	**3428023**

Source: Census Bureau, Office of State Budget and Management, NCDENR DWR

c. County and Service Area Population (Water System’s Population)

The table 4 below represents the Service Are Population, served its respective system, and the percent of the population that is inside each County.

The Local government that provides water to its public is responsible to prepare Local Water Supply Plan, and this plan contains vital information for sustainable use and allocation of the water. The data from each Water System is compiled in the DWR database. The Local Water Supply Plans provided water system characteristics through the year 2020 and up to 2050 the population projection, water demand and wastewater discharge are estimated by the DWR staff and any information discrepancies is resolved by that staff.

The Local Water Supply Plans (LWSPs) are updated every five years and mostly based on the first one, the 1992. The 1992, 1997 and 2002 LWSPs were based on actual water supply and demand conditions and all included estimates of service population up to 2020.

Our population projections for 2030, 2040 and 2050 are linear projections of the population data presented by each system from the LWSPs, from 1992 to 2020. Our methodology assumes that the population growth will continue the same pattern as reflected in the period of 1992 to 2020. Few of our projections (DWR) for service area population from 2030 to 2050 presented bigger population projection then the total county population and we suppose this was a result of the different approaches applied by different agencies (DWR and some NC Water Systems).

Table 4: Service Area Population

ounty	**Water System**		**1992**	**1997**	**2002**	**2010**	**2020**	**2030**	**2040**	**2050**
Alamance	Burlington	Service Area Population	40369	43200	45480	51151	58976	68406	79443	92085
		% of County Population			33.61%	34.52%	35.24%	36.40%	38.31%	40.58%
Alamance	Graham	Service Area Population	10347	11725	13530	14562	17017	19627	22638	26110
		% of County Population			10.00%	9.83%	10.17%	10.44%	10.92%	11.50%
Alamance	Mebane	Service Area Population	4960	5100	8076	12200	15860	19830	24300	29160
		% of County Population			5.97%	8.23%	9.48%	10.55%	11.72%	12.85%
Alamance	Haw River	Service Area Population	1928	2183	2183	2350	2600	3000	3400	3800
		% of County Population			1.61%	1.59%	1.55%	1.60%	1.64%	1.67%
Alamance	Elon	Service Area Population	4695	5045	6969	8420	10178	11937	13695	15453
		% of County Population			5.15%	5.68%	6.08%	6.35%	6.60%	6.81%
Alamance	Green Level	Service Area Population	1536	1536	2133	2300	2500	2600	2800	3000
		% of County Population			1.58%	1.55%	1.49%	1.38%	1.35%	1.32%
Alamance	Alamance	Service Area Population	259	257	375	328	387	476	513	566
		% of County Population			0.28%	0.22%	0.23%	0.25%	0.25%	0.25%
Alamance	Ossipee SD	Service Area Population	300	300	400	425	450	527	586	644
		% of County Population			0.30%	0.29%	0.27%	0.28%	0.28%	0.28%
Alamance	Swepsonville	Service Area Population				1209	1413	1630	1850	2107
		% of County Population				0.82%	0.84%	0.87%	0.89%	0.93%
		County Population			**135317**	**148192**	**167362**	**187943**	**207357**	**226946**
Guilford	Greensboro	Service Area Population	194000	199000	229634	264598	307007	350196	383767	418306
		% of County Population			52.70%	55.12%	56.92%	58.35%	57.72%	57.52%
Guilford	High Point	Service Area Population	70258	71160	89306	98879	110839	122799	134759	146719
		% of County Population			20.49%	20.60%	20.55%	20.46%	20.27%	20.17%
Guilford	Gibsonville	Service Area Population	3799	3799	4427	5637	7004	8553	10260	12285
		% of County Population			1.02%	1.17%	1.30%	1.43%	1.54%	1.69%
Guilford	Jamestown	Service Area Population	3000	4329	5470	6000	7000	7500	8200	8500
		% of County Population			1.26%	1.25%	1.30%	1.25%	1.23%	1.17%
Guilford	Archdale	Service Area Population	7100	8500	9257	10500	13000	14000	15000	16000
		% of County Population			2.12%	2.19%	2.41%	2.33%	2.26%	2.20%
		County Population			**435771**	**480028**	**539335**	**600192**	**664921**	**727255**

Randolph	Asheboro	Service Area Population	21000	20222	23694	26007	30689	34128	37878	41627
		% of County Population			17.52%	18.24%	19.79%	20.36%	20.50%	20.88%
Randolph	Randleman	Service Area Population	3200	3526	4247	5300	6200	7100	8300	9600
		% of County Population			3.14%	3.72%	4.00%	4.24%	4.49%	4.82%
Randolph	Randolph Co	Service Area Population		83634	90002	195471	108003	121457	144282	152994
		% of County Population			66.54%	137.06%	69.65%	72.47%	78.09%	76.74%
Randolph	Ramseur	Service Area Population	2300	2524	2300	2970	3240	3560	3912	4260
		% of County Population			1.70%	2.08%	2.09%	2.12%	2.12%	2.14%
Randolph	Liberty	Service Area Population	2344	2200	2702	2783	2867	2953	3038	3123
		% of County Population			2.00%	1.95%	1.85%	1.76%	1.64%	1.57%
Randolph	Franklinville	Service Area Population	225	823	1250	1350	1458	1575	1700	1850
		% of County Population			0.92%	0.95%	0.94%	0.94%	0.92%	0.93%
		County Population			**135256**	**142620**	**155057**	**167598**	**184771**	**199357**

Rockingham	Reidsville	Service Area Population	14011	14085	14477	15321	16033	16650	17066	17492
		% of County Population			15.55%	16.75%	17.65%	18.53%	18.52%	18.86%
Rockingham	Rockingham Co	Service Area Population	92	0	204	2082	2085	2294	3347	4052
		% of County Population			0.22%	2.28%	2.30%	2.55%	3.63%	4.37%
		County Population			**93101**	**91485**	**90830**	**89836**	**92127**	**92727**

Bladen	Elizabethtown	Service Area Population	4000	4181	5895	6457	7098	7804	8580	9433
		% of County Population			17.86%	19.83%	21.78%	24.03%	25.10%	26.99%
Bladen	Dublin	Service Area Population	251	447	447	450	450	450	450	450
		% of County Population			1.35%	1.38%	1.38%	1.39%	1.32%	1.29%
Bladen	White Lake	Service Area Population	3400	1010	529	581	640	704	775	850
		% of County Population			1.60%	1.78%	1.96%	2.17%	2.27%	2.43%
Bladen	Tar Heel	Service Area Population	268	204	210	225	240	256	272	288
		% of County Population			0.64%	0.69%	0.74%	0.79%	0.80%	0.82%
Bladen	East Arcadia	Service Area Population			670	700	730	760	790	820
		% of County Population			2.03%	2.15%	2.24%	2.34%	2.31%	2.35%
Bladen	Bladen Co. WD (West & E Arcadia)	Service Area Population	2675	4282	4221	4500	4800	5000	5300	5500
		% of County Population			12.79%	13.82%	14.73%	15.40%	15.51%	15.74%

Bladen	Bladen Co WD (East Bladen)	Service Area Population	432	1240	1925	2100	2250	2400	2600	2700
		% of County Population			5.83%	6.45%	6.91%	7.39%	7.61%	7.73%
Bladen	BLADEN CO WD - E ARCADIA	Service Area Population	62	496	970	1368	1765	2482	3083	3683
		% of County Population			2.94%	4.20%	5.42%	7.64%	9.02%	10.54%
Bladen	Lower Cape Fear WSA	Service Area Population	292178	0	0	0	0	0	0	0
		% of County Population								
		County Population			**33001**	**32556**	**32583**	**32471**	**34180**	**34947**

Chatham	Siler City	Service Area Population	5272	5541	6966	7300	7613	7942	8282	8639
		% of County Population			13.55%	11.61%	9.89%	8.68%	7.99%	7.39%
Chatham	Pittsboro	Service Area Population	2200	2022	2413	3195	4492	6316	8878	12482
		% of County Population			4.69%	5.08%	5.83%	6.90%	8.56%	10.67%
Chatham	Goldston Gulf SD	Service Area Population	1158	1000	1200	1250	1280	1290	1295	1300
		% of County Population			2.33%	1.99%	1.66%	1.41%	1.25%	1.11%
Chatham	Chatham County East	Service Area Population	710	680	835	2286	2862	4323	6425	9526
		% of County Population			1.62%	3.64%	3.72%	4.73%	6.20%	8.14%
Chatham	Chatham County Southwest	Service Area Population	1789	1793	2250	5047	5396	7341	10130	14203
		% of County Population			4.38%	8.03%	7.01%	8.02%	9.77%	12.14%
Chatham	Chatham County North	Service Area Population	3735	5860	7500	13209	40974	61828	93294	98318
		% of County Population			14.59%	21.00%	53.21%	67.58%	89.98%	84.06%
		County Population			**51395**	**62887**	**77008**	**91491**	**103678**	**116968**

Cumberland	Fayetteville	Service Area Population	130000	159225	178200	243160	315840	402480	445140	487800
		% of County Population			57.74%	76.68%	94.80%	116.09%	121.12%	126.75%
Cumberland	Spring Lake	Service Area Population	10500	12050	9565	10065	11575	13310	15310	17605
		% of County Population			3.10%	3.17%	3.47%	3.84%	4.17%	4.57%
Cumberland	Stedman	Service Area Population	777	668	664	744	844	944	1044	1144
		% of County Population			0.22%	0.23%	0.25%	0.27%	0.28%	0.30%
Cumberland	Falcon	Service Area Population	695	695	714	757	807	857	907	957
		% of County Population			0.23%	0.24%	0.24%	0.25%	0.25%	0.25%
Cumberland	Wade	Service Area Population	438	457	477	532	590	595	660	730
		% of County Population			0.15%	0.17%	0.18%	0.17%	0.18%	0.19%
Cumberland	Linden	Service Area Population	465	800	948	1150	1175	1200	1225	1250

		% of County Population			0.31%	0.36%	0.35%	0.35%	0.33%	0.32%
Cumberland	Godwin	Service Area Population		203	238	248	258	268	278	288
		% of County Population			0.08%	0.08%	0.08%	0.08%	0.08%	0.07%
Cumberland	Fort Bragg	Service Area Population		65000	65000	65000	65000	65000	65000	65000
		% of County Population			21.06%	20.50%	19.51%	18.75%	17.69%	16.89%
		County Population			**308609**	**317094**	**333174**	**346686**	**367530**	**384848**

Durham	Durham	Service Area Population	140000	157600	181000	240530	276403	298974	314127	329280
		% of County Population			78.15%	90.06%	89.26%	84.54%	79.30%	74.99%
		County Population			**231608**	**267086**	**309651**	**353630**	**396126**	**439104**

Harnett	Dunn	Service Area Population	9200	9731	9931	10546	11200	11895	12632	13415
		% of County Population			10.37%	9.37%	8.28%	7.49%	6.98%	6.59%
Harnett	Angier	Service Area Population	2265	3010	3505	4114	4810	5500	6432	7246
		% of County Population			3.66%	3.66%	3.56%	3.46%	3.56%	3.56%
Harnett	Coats	Service Area Population	1958	1800	1832	2180	2594	3087	3674	4372
		% of County Population			1.91%	1.94%	1.92%	1.94%	2.03%	2.15%
Harnett	Lillington	Service Area Population	2400	3003	2917	3100	3200	3300	3400	3500
		% of County Population			3.05%	2.76%	2.37%	2.08%	1.88%	1.72%
Harnett	Campbell University	Service Area Population			4000	4400	4600	4800	5000	5000
		% of County Population			4.18%	3.91%	3.40%	3.02%	2.76%	2.46%
Harnett	Erwin	Service Area Population	4400	4265	4537	5300	6000	6546	7183	7821
		% of County Population			4.74%	4.71%	4.44%	4.12%	3.97%	3.84%
Harnett	Harnett Co	Service Area Population	26000	65000	77958	97791	122668	158875	193021	242126
		% of County Population			81.43%	86.92%	90.70%	100.08%	106.70%	118.98%
		County Population			**95735**	**112513**	**135239**	**158751**	**180900**	**203494**

Hoke	Raeford	Service Area Population	3910	3910	3517	4300	4800	5280	5579	5989
		% of County Population			9.82%	9.13%	7.76%	6.74%	6.17%	5.74%
Hoke	Hoke RWS	Service Area Population	752	12700	24900	31900	40650	49400	58150	66900
		% of County Population			69.54%	67.73%	65.68%	63.01%	64.31%	64.08%
		County Population			**35809**	**47096**	**61890**	**78396**	**90422**	**104395**

Johnston	Benson	Service Area Population	2880	4000	2920	3030	3140	3250	3371	3488
		% of County Population			2.25%	1.77%	1.39%	1.15%	1.03%	0.92%
		County Population			**130019**	**171548**	**225194**	**283401**	**328537**	**379389**

Lee	Sanford	Service Area Population	17540	21608	34573	40900	56600	76000	92100	111600
		% of County Population			68.15%	68.90%	80.73%	93.35%	101.75%	110.89%
Lee	Broadway	Service Area Population	1003	1070	1026	1184	1366	1559	1757	1967
		% of County Population			2.02%	1.99%	1.95%	1.91%	1.94%	1.95%
Lee	Carolina Trace WS	Service Area Population			1199	1759	2000	2000	2000	2000
		% of County Population			2.36%	2.96%	2.85%	2.46%	2.21%	1.99%
Lee	Lee Co Water - Sewer District 1	Service Area Population	1935	1870	5240	11912	15044	18176	21308	24440
		% of County Population			10.33%	20.07%	21.46%	22.32%	23.54%	24.28%
Lee	Lee Co Cumnock Golden Poultry	Service Area Population	37	145	150	1	1	1	1	1
		% of County Population			0.30%	0.00%	0.00%	0.00%	0.00%	0.00%
		County Population			**50730**	**59358**	**70107**	**81418**	**90515**	**100640**

Montgomery	Star	Service Area Population		862	830	820	850	875	900	950
		% of County Population			3.02%	2.93%	2.91%	2.86%	2.76%	2.77%
		County Population			**27521**	**27941**	**29189**	**30544**	**32639**	**34299**

Moore	Southern Pines	Service Area Population	11709	12175	13120	15221	17689	20140	22569	24990
		% of County Population			16.84%	17.31%	17.54%	17.72%	17.64%	17.67%
Moore	Robbins	Service Area Population	1400	1950	1226	1728	2008	2286	2410	2615
		% of County Population			1.57%	1.97%	1.99%	2.01%	1.88%	1.85%
Moore	Aberdeen	Service Area Population	3200	3648	3578	3935	4282	4624	5040	5642
		% of County Population			4.59%	4.48%	4.24%	4.07%	3.94%	3.99%
Moore	Carthage	Service Area Population	1610	2175	2114	2400	2600	2800	3000	3200
		% of County Population			2.71%	2.73%	2.58%	2.46%	2.35%	2.26%
Moore	Taylortown	Service Area Population	601		875	918	945	973	1002	1032
		% of County Population			1.12%	1.04%	0.94%	0.86%	0.78%	0.73%
Moore	Cameron	Service Area Population		391	460	524	573	630	693	762
		% of County Population			0.59%	0.60%	0.57%	0.55%	0.54%	0.54%

Moore	Moore Co (Vass)	Service Area Population	678	736	759	796	842	888	934	980
		% of County Population			0.97%	0.91%	0.83%	0.78%	0.73%	0.69%
Moore	Moore Co (Hyland Hills)	Service Area Population	140	267	276	290	308	326	344	362
		% of County Population			0.35%	0.33%	0.31%	0.29%	0.27%	0.26%
Moore	Moore Co (Pinehurst)	Service Area Population	5785	7746	11013	16239	22773	29306	35839	42373
		% of County Population			14.13%	18.47%	22.58%	25.79%	28.01%	29.96%
Moore	Moore Co (Seven Lakes)	Service Area Population	2150	2685	3567	4096	5860	7624	9388	11152
		% of County Population			4.58%	4.66%	5.81%	6.71%	7.34%	7.88%
Moore	Moore Co (The Carolina)	Service Area Population		0	14	24	36	48	60	71
		% of County Population			0.02%	0.03%	0.04%	0.04%	0.05%	0.05%
Moore	Moore Co (Addor)	Service Area Population		0	64	69	74	79	83	88
		% of County Population			0.08%	0.08%	0.07%	0.07%	0.06%	0.06%
Moore	Moore Co (Robbins)	Service Area Population			69	69	69	69	69	69
		% of County Population			0.09%	0.08%	0.07%	0.06%	0.05%	0.05%
		County Population			**77922**	**87915**	**100874**	**113650**	**127932**	**141454**

Orange	Orange WASA	Service Area Population	57900	65000	73700	87400	97200	110000	122900	135700
		% of County Population			61.47%	66.31%	66.98%	70.08%	69.92%	70.93%
Orange	Orange-Alamance	Service Area Population	11000	11500	9074	8742	9742	10742	11742	12742
		% of County Population			7.57%	6.63%	6.71%	6.84%	6.68%	6.66%
		County Population			**119905**	**131797**	**145119**	**156958**	**175778**	**191311**

Wake	Cary	Service Area Population	52403	82700	102965	134000	173000	216000	236000	236000
		% of County Population			15.41%	14.56%	14.06%	13.85%	13.03%	11.25%
Wake	Apex	Service Area Population	5200	12000	26100	48800	74600	100400	102172	102172
		% of County Population			3.91%	5.30%	6.06%	6.44%	5.64%	4.87%
Wake	Holly Springs	Service Area Population	1784	5492	11580	37275	71400	103900	122220	125000
		% of County Population			1.73%	4.05%	5.80%	6.66%	6.75%	5.96%
Wake	Fuquay-Varina	Service Area Population	4300	6249	10335	14510	25188	43724	75898	131750
		% of County Population			1.55%	1.58%	2.05%	2.80%	4.19%	6.28%
Wake	Morrisville	Service Area Population	1751	2200	10028	17750	23900	27000	27000	27000
		% of County Population			1.50%	1.93%	1.94%	1.73%	1.49%	1.29%
		County Population			**668153**	**920298**	**1230382**	**1560026**	**1810843**	**2098690**

Brunswick	Southport	Service Area Population	3660	5124	5124					
		% of County Population			6.61%	0.00%	0.00%	0.00%	0.00%	0.00%
Brunswick	Long Beach Water	Service Area Population	3280	4789	5419	6797	8526	10392	12186	13981
		% of County Population			6.99%	6.11%	5.83%	5.79%	5.78%	5.73%
Brunswick	Oak Island	Service Area Population	785	891	13700	14700	15700	16700	17700	18700
		% of County Population			17.66%	13.22%	10.74%	9.31%	8.39%	7.66%
Brunswick	Shallotte	Service Area Population	1078	1242	1617	2005	2606	3387	4448	5782
		% of County Population			2.08%	1.80%	1.78%	1.89%	2.11%	2.37%
Brunswick	Ocean Isle Beach	Service Area Population	13879	689	426	503	600	721	819	924
		% of County Population			0.55%	0.45%	0.41%	0.40%	0.39%	0.38%
Brunswick	Brunswick Co.	Service Area Population	45748	61959	30175	88792	103047	119590	138790	161071
		% of County Population			38.90%	79.88%	70.47%	66.65%	65.80%	66.02%
Brunswick	Sunset Beach	Service Area Population	591	1908	1946	2024	2105	2189	2277	2368
		% of County Population			2.51%	1.82%	1.44%	1.22%	1.08%	0.97%
Brunswick	Caswell Beach	Service Area Population	500	220	392	436	510	592	692	804
		% of County Population			0.51%	0.39%	0.35%	0.33%	0.33%	0.33%
Brunswick	Holden Beach	Service Area Population	10000	910	815	1200	1700	2000	2482.167	2912.133
		% of County Population			1.05%	1.08%	1.16%	1.11%	1.18%	1.19%
Brunswick	Navassa	Service Area Population	439	520	525	590	685	762	844	926
		% of County Population			0.68%	0.53%	0.47%	0.42%	0.40%	0.38%
Brunswick	N. Brunswick SD	Service Area Population	3464	3484	4600	5000	5500	6000	6500	7000
		% of County Population			5.93%	4.50%	3.76%	3.34%	3.08%	2.87%
Brunswick	Carolina Shores SD	Service Area Population			0	4089	5698	5983	6581	6910
		% of County Population			0.00%	3.68%	3.90%	3.33%	3.12%	2.83%
Brunswick	Boiling Spring Lakes	Service Area Population			695	855	1055	1255	1455	1655
		% of County Population			0.90%	0.77%	0.72%	0.70%	0.69%	0.68%
Brunswick	Northwest	Service Area Population			695	855	1055	1255	1455	1655
		% of County Population			0.90%	0.77%	0.72%	0.70%	0.69%	0.68%
		County Population			**77572**	**111155**	**146227**	**179424**	**210917**	**243984**

Columbus	Riegelwood SD	Service Area Population	320	323	350	400	425	471	513	554
		% of County Population			0.63%	0.74%	0.80%	0.90%	0.95%	1.02%

		County Population			**55781**	**54225**	**53370**	**52281**	**54203**	**54561**
New Hanover	Wilmington	Service Area Population	57213	66686	101600	120600	134000	147400	160800	174100
		% of County Population			60.36%	59.58%	55.27%	52.46%	49.87%	47.99%
New Hanover	Carolina Beach	Service Area Population	4271	4643	4800	5500	6200	6900	7700	8700
		% of County Population			2.85%	2.72%	2.56%	2.46%	2.39%	2.40%
New Hanover	Wrightsville Beach	Service Area Population	2935	3146	2832	3000	3000	3000	3000	3000
		% of County Population			1.68%	1.48%	1.24%	1.07%	0.93%	0.83%
New Hanover	Kure Beach	Service Area Population	6190	1251	1629	2000	2100	2200	2300	2300
		% of County Population			0.97%	0.99%	0.87%	0.78%	0.71%	0.63%
New Hanover	Figure Eight Island	Service Area Population	732	825	976	1098	1220	1426	1602	1779
		% of County Population			0.58%	0.54%	0.50%	0.51%	0.50%	0.49%
New Hanover	Kings Grant	Service Area Population			3408	3608	3608	3608	3608	3608
		% of County Population			2.02%	1.78%	1.49%	1.28%	1.12%	0.99%
New Hanover	Monterey Heights Water Supply	Service Area Population		1095	817	980	1157	1321	1500	1675
		% of County Population			0.49%	0.48%	0.48%	0.47%	0.47%	0.46%
New Hanover	New Hanover Co 421 Water System	Service Area Population	108	187	107	114	121	128	135	142
		% of County Population			0.06%	0.06%	0.05%	0.05%	0.04%	0.04%
New Hanover	New Hanover Co Water System	Service Area Population		7671	14008	16310	19206	21931	24900	27805
		% of County Population			8.32%	8.06%	7.92%	7.81%	7.72%	7.67%
		County Population			**168336**	**202411**	**242460**	**280977**	**322414**	**362748**

Source: Office of State Budget and Management and Local Water Supply Plan, NC DENR, DWR.

2. Basin Specific Issues

a. FERC – Hydropower

The Federal Energy Regulatory Commission (FERC) is responsible for regulating the production and interstate transmission of power in the United States, including hydroelectric power produced with dams. The FERC regulates hydroelectric projects by the terms and conditions contained within a license issued by the FERC to the hydropower producer.

Pursuant to Section 23(b)(1) of the Federal Power Act, 16 U.S.C. 817(1), a non-federal hydroelectric project must (unless it has a still-valid pre-1920 federal permit) be licensed if it: (1) is located on a navigable water of the United States; (2) occupies lands of the United States; (3) utilizes surplus water or water power from a government dam; or (4) is located on a body of water over which Congress has Commerce Clause jurisdiction, project construction occurred on or after August 26, 1935, and the project affects the interests of interstate or foreign commerce. A license is issued for a period between 30 and 50 years.

Those projects that do no meet these requirements are not subject to FERC authority. The non-jurisdictional projects in North Carolina are regulated by the North Carolina Utilities Commission.

Among the terms and conditions included in the project license are requirements to maintain flows below the project to support aquatic habitat, water quality, recreation, and municipal and industrial needs, based on consultation with federal and state agencies. These flow requirements may also be included in a Section 401 certification issued by the applicable state water agency under the authority of the federal Clean Water Act. Flow requirements for non-jurisdictional projects in North Carolina may be included in the Section 401 certification or in the Certificate of Public Convenience and Necessity (CPCN) issued by the Utilities Commission, if the CPCN was issued prior to August, 2007.

Flow requirements may be specific amounts, in cubic feet per second (cfs), based on historical flow statistics or a field study. Other projects may not have a specific amount but are required to operate in a mode known as run-of-river, where inflow into the project equals outflow from the project. A run-of-river requirement is typically requested for projects with little storage capacity and no bypassed reach. A bypassed reach is a section of natural stream channel below the project dam that has reduced flows because water is diverted by a man-made canal or pipe to the powerhouse. The water eventually returns to the natural channel farther downstream below the powerhouse.

Figure 2: Hydropower Projects in the Cape Fear River Basin, NC

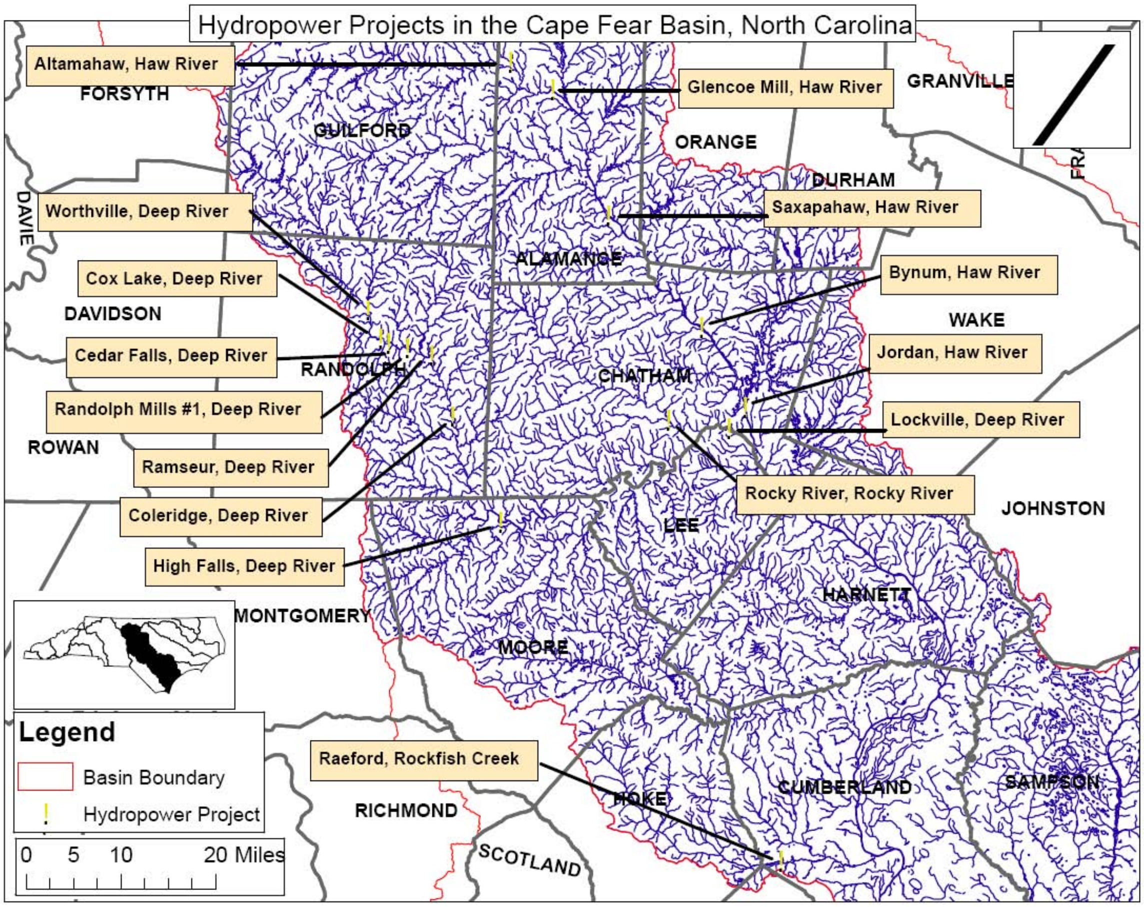


Table 5: Hydropower Projects in the Cape Fear Basin, North Carolina

PROJECT	FERC PROJ #	STREAM	DRAINAGE AREA (mi^2)	LICENSE / CPCN FLOW REQUIREMENT ($ft^3\ sec^{-1}$)
Worthville	P-3156	Deep R.	236.00	Run-of-river (inflow = outflow)
Cox Lake	P-6559	Deep R.	254.00	42.0
Cedar Falls	P-7783	Deep R.	266.00	32.0
Randolph Mills #1	non-jurisdictional	Deep R.	277.00	46.0
Ramseur	P-11392	Deep R.	349.00	45.0
Coleridge	P-7478	Deep R.	401.00	35.0
High Falls	P-7987	Deep R.	792.00	108.0
Lockville	P-6276	Deep R.	1436.00	70.0
Altamahaw	non-jurisdictional	Haw R.	188.00	Run-of-river (inflow = outflow)
Glencoe Mill	P-7404	Haw R.	481.00	57.0
Saxapahaw	P-4509	Haw R.	1016.00	10, or .25 x inflow, whichever is less
Bynum	P-4093	Haw R.	1265.00	80.0
Jordan	P-11437	Haw R.	1690.00	40.0 below dam but 600 at Lillington, NC
Raeford	P-6619	Rockfish C.	179.00	Run-of-river (inflow = outflow)
Rocky River	P-3586	Rocky R.	95.00	Run-of-river (inflow = outflow)

b. The Use of Water Supply on Jordan Lake

The State of North Carolina has been assigned the use of the entire water supply storage in Jordan Lake and, under G.S. 143-354(a)(11), can assign this storage to local governments that has a need for water supply storage. The North Carolina Administrative Code (15A NCAC 2G.0500) describes the specific procedures to be used in allocating the Jordan Lake water supply storage.

Allocations fall into two categories. Level I allocations are made based on 20-year water need projections *and* when withdrawals are planned to begin within five years of receiving the allocation. Level II allocations are made based on longer term needs of up to 30 years.

Initial allocations of water supply from Jordan Lake were made in 1988. At that time, 42 percent of the water supply pool was allocated. There have been two subsequent rounds of allocation and currently 63 percent of the water supply pool is allocated. Note that allocations are actually a percentage of the water supply pool and not a rate of withdrawal. However, for convenience allocations are frequently expressed in MGD, since 100 percent of water supply storage has an estimated safe yield of 100 MGD.

Existing rules limit water supply allocations that will result in diversions out of the Lake's watershed to 50 percent of the 100 MGD total water supply yield. The EMC may review and revise this limit based on experience in managing the Lake and on the effects of changes in the Lake's watershed that affect its yield. Currently, 40 MGD of the 100 MGD yield is approved to be diverted out of the Lake's watershed.

Table 6: Current Allocations

Holder	Level I	Level II	Total
Towns of Cary and Apex	32	0	32
Chatham County	6	0	6
City of Durham	10	0	10
Town of Holly Springs	0	2	2
Town of Morrisville	3.5	0	3.5
Orange County	0	1	1
Orange Water & Sewer Authority	0	5	5
Wake County - RTP South	3.5	0	3.5
Total	**55 mgd**	**8 mgd**	**63 mgd**

For further and better comprehension on Jordan Lake Water Supply Allocation, (North Carolina Administrative Code Section T15A:02G.0500 Allocation of Jordan Lake Water Supply Storage), please visit NCDENR/DWR homepage.

3. Instream Flow Needs

Types of Instream Uses*:*

Aquatic Habitat – Stream flows affect physical habitat conditions such as depth, current velocity, and access to cover, feeding, and spawning areas. Adequate flows are needed to provide the necessary physical conditions for the propagation and survival of aquatic organisms - including fish, mussels, and aquatic insects.

Water Quality – Stream flows are an important factor in a stream's ability to maintain adequate levels of dissolved oxygen. Assimilation of oxygen demanding products from wastewater discharges or non-point source runoff is directly related to the amount of flow, as is the ability of the stream to reaerate. Other water quality parameters such as temperature, salinity, and algal growth are also influenced by stream flows.

Recreation – Depending on the nature of the stream, the amount of stream flow can play a greater or lesser role in the use of the waterway for recreation. High gradient streams with boulders, ledges and other similar channel features may be used for whitewater paddlesports, and this recreational use tends to be flow-dependent. Streams that are low gradient are more placid and deep, with a smooth water surface. Recreational use of this type of stream is often less sensitive to changes in flow.

Channel Morphology – The shape and condition of the stream channel and banks can be greatly influenced by flow patterns over time. High flow events may change channel alignment, alter sand or gravel bars, erode banks, and affect bank vegetation. These effects may be perceived as negative, but high flows are also useful for preventing degradation of the channel by flushing accumulated sediments. In general, the frequency, magnitude, duration, and timing of both low and high flow events affect channel morphology. The stability of a stream channel and its banks is related to the extent to which historic, natural hydrology has been modified.

Wetlands – Some streams, particularly in the eastern piedmont and coastal plain areas, have immediately adjacent wetlands, or braided channels with wetland areas. The ability of these areas to function as wetlands is influenced by flows that maintain adequate surface and subsurface water levels, so that soils and vegetation retain their wetland character. Wetland areas can play a role in groundwater recharge and maintaining base flow in surface waters.

Aesthetics – The aesthetic appeal of a stream is affected by the amount of exposed streambed, the sound and appearance of moving water, the presence or absence of algae, and the clarity and depth of the water. These factors are all related to the amount of flow. Prolonged periods of low flow, in particular, may have undesirable aesthetic impacts.

***Types of Offstream Uses**:*

Consumptive Use: Permanent removal of water by a withdrawal (i.e. water that is not discharged back to the source stream) is referred to as a consumptive use. Often an offstream user will return a portion, but not all, of the withdrawal as treated wastewater. The unreturned portion is considered a consumptive use. The amount of water withdrawn most significantly affects the stream reach between the point of withdrawal and the point of return discharge. The amount of the withdrawal that is a consumptive loss continues to affect the stream beyond the point of the return, until enough additional drainage area and tributary inflow is gained to reduce the effect of lost water.

Public Water Supply – Local water systems operated by government or private entities withdraw water from streams for use by residential, business and industrial customers. If customers are not also served by a wastewater collection system, but instead use an individual non-discharge wastewater disposal system such as a septic tank and absorption drain field, then that portion of the water use is considered a consumptive loss. Water that is ultimately discharged as wastewater in another watershed is also considered a consumptive loss for the source watershed. Water used for outdoor purposes such as lawn watering and car washing is a consumptive use. Water systems may also have some percentage of the total withdrawal that is unaccounted for. This unaccounted amount may be due to leakage in water lines, un-metered connections, use for fire protection and line flushing, or use at the water treatment plant for filter back-washing. Unaccounted for water is also tallied as a consumptive loss, although some unknown quantity of this water may actually be returned to the source stream. The total percentage consumptive use can be determined by comparing the measured withdrawal to the measured wastewater discharge. *A list of local water systems and their individual water supply plans can be found at* http://www.ncwater.org/Water_Supply_Planning/Local_Water_Supply_Plan/

Industrial Water Supply – Some private industries have their own withdrawals from surface waters separate from public water supply systems, and may also have separate wastewater treatment systems. The concepts for determining the amount of consumptive use are the same as for a public water supply system. One noteworthy type of consumptive use for some industrial users is water used for evaporative cooling. Another type of industrial use that is usually consumptive is for quarry operations that use water for dust control or gravel washing. *A list of registered industrial and mining water withdrawals can be found at* http://www.ncwater.org/Permits_and_Registration/Water_Withdrawal_Registration/

Agricultural Water Use – Some agricultural operations use surface water withdrawals for irrigation, livestock watering, or cooling of buildings where animals are raised. Horticultural nursery operations may also use surface water for irrigation. Typically these types of agricultural water use are 100% consumptive. A list of registered withdrawals for agricultural, livestock, and non-agricultural irrigation use can be found at http://www.ncwater.org/Permits_and_Registration/Water_Withdrawal_Registration/

Offstream Recreational Water Use – Some popular outdoor recreational pursuits in North Carolina rely on water withdrawals to support their recreational infrastructure. In particular, irrigation of golf courses and water use for snow making at ski resorts may use surface water withdrawals for these purposes. Because these uses require outdoor application of water to land, they are consumptive, although occasionally catchment basins are used to recycle water from runoff and reduce the withdrawal from the original source stream. A list of registered withdrawals for golf course irrigation and snow making use can be found at http://www.ncwater.org/Permits_and_Registration/Water_Withdrawal_Registration/

Electric Power Generation – The production of electric power may involve instream use, temporary withdrawal, or consumptive use – depending on the type of generation and the configuration of the power plant. A hydroelectric facility where the turbines are located in a powerhouse at the base of the dam does not divert water from the stream to produce power. On the other hand, some hydroelectric facilities divert water through pipes, tunnels or artificial channels that create a bypassed reach between the point of withdrawal and where the water is discharged back into the natural channel. Bypassed reaches at different facilities vary in length from a few hundred feet to several miles. Instream flow needs in a bypassed reach are dependent on the provision of required flows that are not diverted for power production. Fossil fuel and nuclear power plants use water for cooling and steam production. Surface water withdrawals for these purposes include a portion that is a consumptive use, but the amount varies with the type of system. Once-through cooling systems temporarily remove a larger amount of water but return most of it to the stream. Cooling systems that recapture and re-circulate withdraw less water overall, but a much larger portion is lost consumptively.

Instream Flow Needs are a Function of:

Location - A quantified instream flow need is particular to a given location, since instream uses and hydrology are influenced by drainage area, tributary inflow, habitat type, the assemblage of aquatic organisms, and other instream uses that might be relevant.

Timing - Another important variable in determining instream flow needs is time. Recreational activities often have a seasonal component, or vary between weekdays and weekends, and even time of day. Critical periods for certain life stages of aquatic organisms occur during specific months or seasons. The life cycles of aquatic organisms are adapted to variations in flow that occur during a year and instream flow needs often vary accordingly. In North Carolina, stream flows are usually highest in the spring (March in particular), and lowest in the late summer and early fall (September and October). Finally, aquatic ecosystems are also adapted to variations from year to year. Dry years may benefit certain species, while wet years benefit others. Inter-annual variability may be needed to retain the overall system and diversity of habitat and species.

Measurement – Stream flows are typically measured in cubic feet per second (cfs), calculated by multiplying the depth (feet) and width (feet) of a stream cross section times the speed of the current (feet per second). Offstream demands are often measured in million gallons per day (mgd). The conversion between these units is: mgd x 1.546 = cfs.

Methods for Quantifying Instream Flow Needs

Water Quality Flow Needs – Water quality models can be used to evaluate the effect of a given amount and concentration of effluent on downstream water quality. This approach does not determine a water quality flow need, but instead uses a minimum drought flow statistic to determine the amount and degree of treatment of the wastewater discharge needed to maintain state water quality standards. The drought flow statistic used is the lowest flow that occurs for seven consecutive days, with a recurrence probability of once every ten years – referred to as the 7Q10. The assumption is that water quality standards may not be maintained when flows fall below the 7Q10, but this is a very infrequent, acceptable risk. Therefore, it is very important to realize that the 7Q10 is NOT intended to be the flow that maintains water quality for any great length of time. This modeling approach requires additional data and a higher degree of complexity if non-point sources of oxygen demanding products from runoff are also to be considered. Wastewater discharges located downstream of large reservoirs that alter downstream hydrology use the required release from the reservoir (rather than the 7Q10) to model water quality and determine effluent treatment needs.

Recreational Flow Needs – The amount of instream flow needed for recreation depends on the activity and may be seasonal, or vary between weekends and weekdays. One approach uses field measurements to determine flows that provide adequate depths for the reach in question to be navigable for a given type of watercraft. Another approach employs user surveys after recreational activity has taken place at multiple stream flows to determine minimally acceptable flows and optimal flows, based on the quality of the recreational experience.

Aquatic Habitat Flow Needs

What follows is an overview of approaches that have been used in North Carolina to recommend instream flows for aquatic habitat. A more comprehensive discussion of various methods can be found in: *Annear, T., I. Chisholm, H. Beecher, A. Locke, and 12 other authors. 2004. Instream flows for riverine resource stewardship, revised edition. Instream Flow Council, Cheyenne, WY.*

Desktop Approaches

Tennant, or Montana, Method: The Tennant Method was developed in the 1970's by taking photos of multiple streams at a range of known flows, and surveying aquatic biologists for their evaluation of habitat quality at each flow. It uses a percentage of the average yearly flow as an indicator of how well the instream habitat is maintained. Ten percent of the average annual flow is considered a short-term survival flow that provides poor or minimum habitat, while twenty percent is considered a flow for good habitat. Forty percent of the average annual flow is recommended for spring and early summer months to support good habitat for spawning activity.

New England Method: A standard setting approach that uses the lowest median monthly flow as the flow required to maintain aquatic habitat. The median monthly flow is determined by calculating the flow for each month for which half of the daily flows are lower and half are higher – based on stream gauging records. In North Carolina, September is usually the lowest flow month, so the September median value would be used as the aquatic habitat flow following the New England Method approach.

NC Dam Safety Law Rules: In the early 1990's, Division of Water Resources' staff developed a new desktop approach based on a dataset of field study evaluations available up to that point in time. Regression analyses were performed on a database of 33 wetted perimeter studies (see description of this technique below) in the piedmont region. This resulted in two regression formulas that could be used to predict the results of a wetted perimeter study in the piedmont. One formula was for use on ungauged streams, and the other required at least 20 years of daily flow records from a U.S. Geological Survey gauge. Lack of data prevented regression analyses for the mountain or coastal plain regions. This desktop method was incorporated in rules subject to the NC Dam Safety Law that require flows to maintain aquatic habitat in dam safety permits *(15A NCAC 2K.0501-.0504).*

Field Study Approaches

Wetted Perimeter Study: A wetted perimeter study is somewhat simplistic, in that it assumes any area of wetted stream channel has the same habitat value, regardless of habitat characteristics such as depth, bottom substrate or current velocity. Field data are collected at multiple stream cross-sections selected to represent the range of habitat types available. Data collection involves measurements at three significantly different flows, to determine the relationship between flow and the amount of the channel that is submerged at each cross-section. The flow recommended by the wetted perimeter approach is the point of inflection – the point at which additional flow results in much smaller incremental increases in the amount of submerged channel. Flows below the point of inflection would result in incremental dewatering of the stream bottom.

The plots below show an example of instream flow study cross-section, or “transect,” and the output from a wetted perimeter study.

Figure 3: Rocky River, Cross-Section Profile

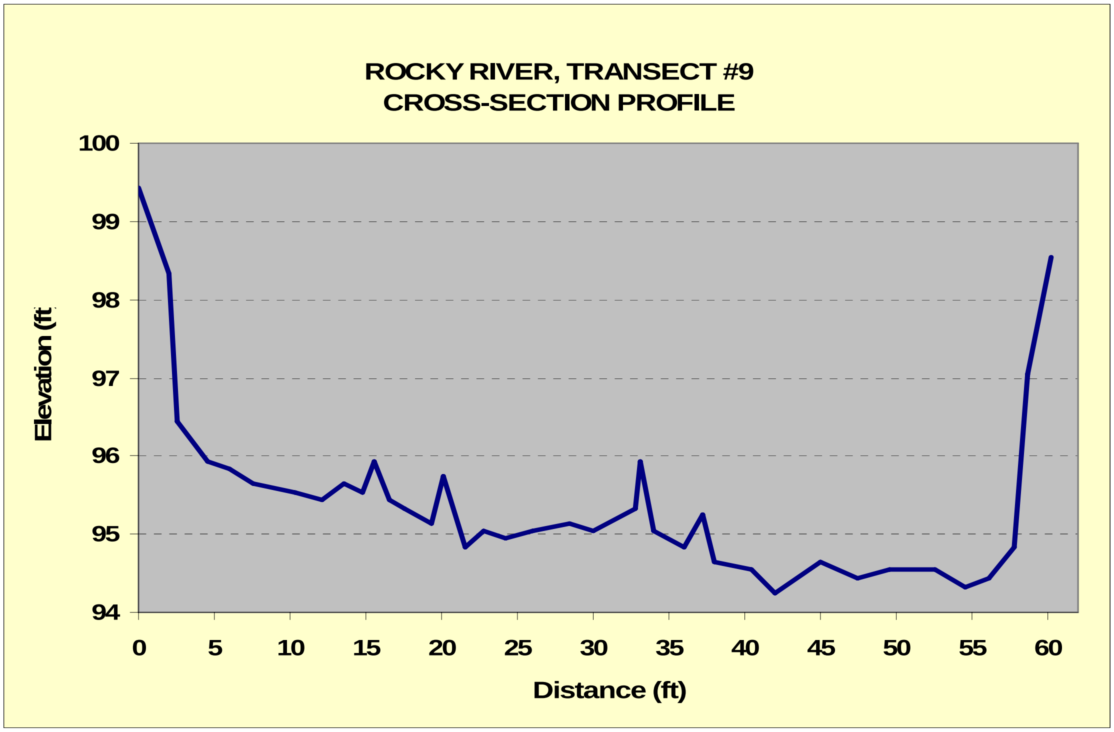
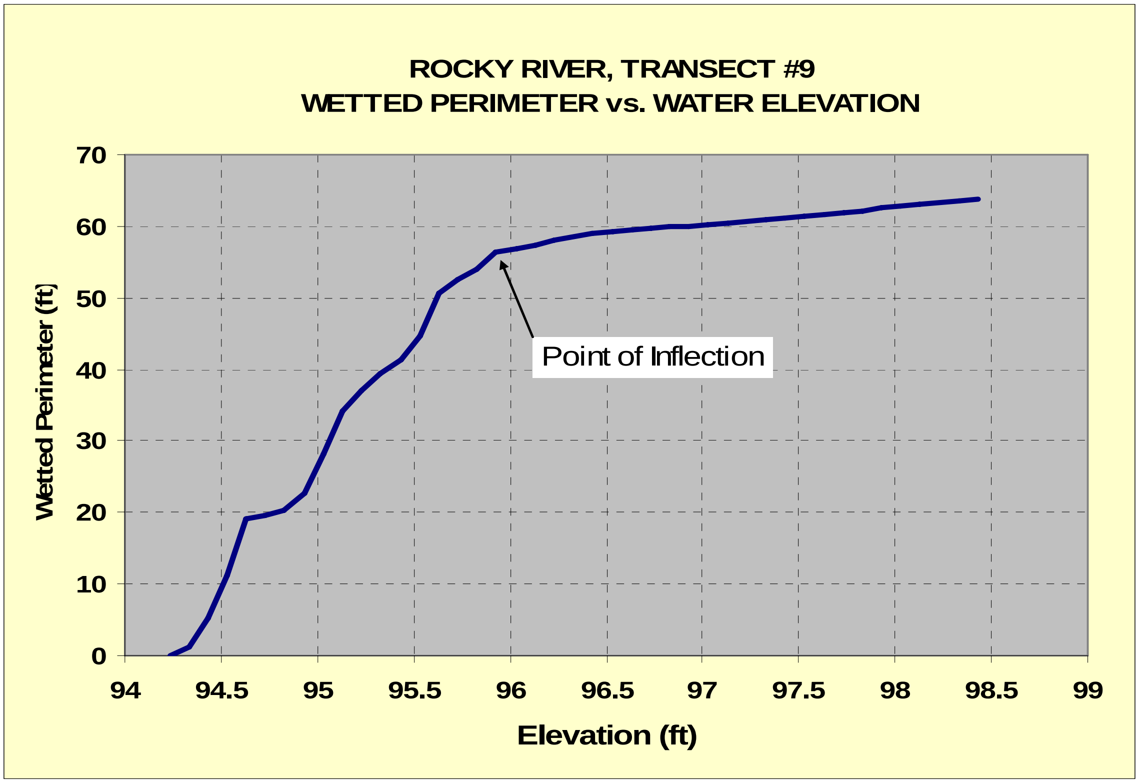


Figure 4: Rocky River, Wetted Perimeter vs. Water Elevation



Instream Flow Incremental Methodology (IFIM): This approach entails more complex data collection and modeling than a wetted perimeter study. Representative stream cross-sections are selected (as with wetted perimeter studies), but IFIM evaluates habitat amounts according to quality of habitat – incorporating information about depths, current velocities, bottom substrate, and cover for aquatic organisms. IFIM has other advantages over wetted perimeter studies. Modeling can target species or types of species that are of particular concern. The model output is a relationship of the amount of aquatic habitat (weighted by quality) to stream flow. This allows comparison of different flow alternatives by using a technique called time series analysis, which entails converting a record of stream flows over time into a record of habitat values over time for each species or group of organisms. Statistical analysis can then be used to compare the time series of habitat values produced by different flow options – including the no-project, “natural,” unimpaired flow record. IFIM, including time series analysis, is well-suited to take advantage of basinwide hydrologic model outputs, by comparing the unimpaired flow record to flows that incorporate existing or projected future water withdrawals, wastewater returns, and operation of upstream reservoirs.

An example of habitat versus flow relationships determined using IFIM is shown in the first plot below. The second plot shows an example of a habitat duration analyses comparison from a time series analysis.

Figure 5: Rocky River, Redbreast Sunfish Habit vs. Discharge

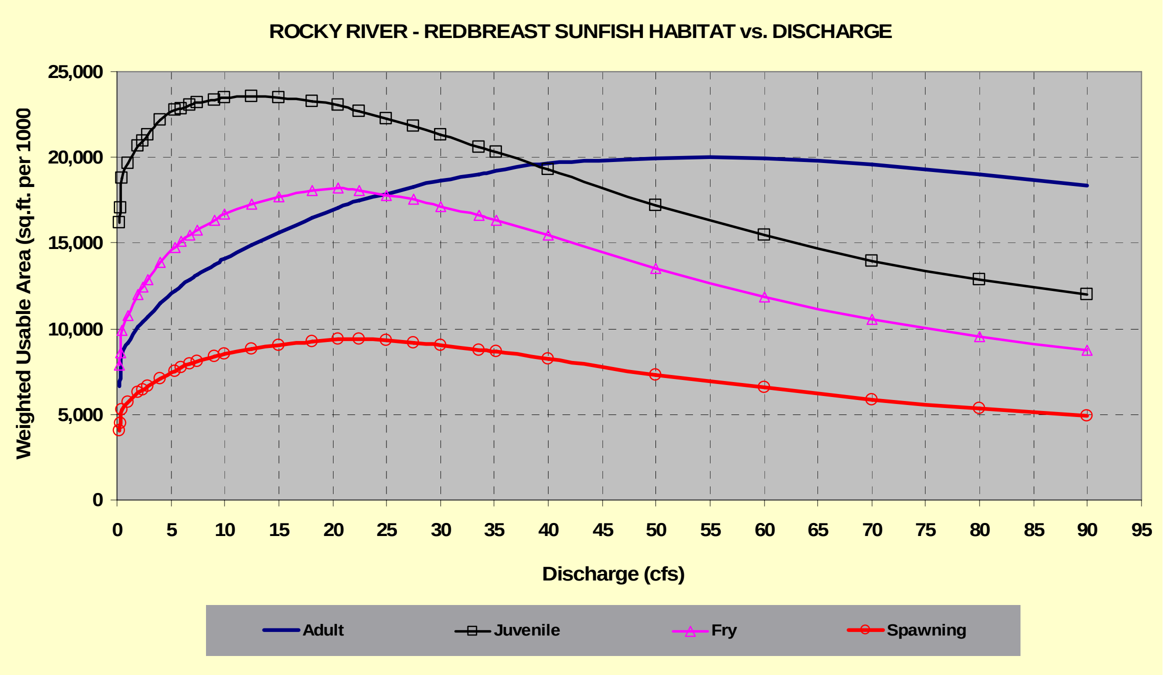
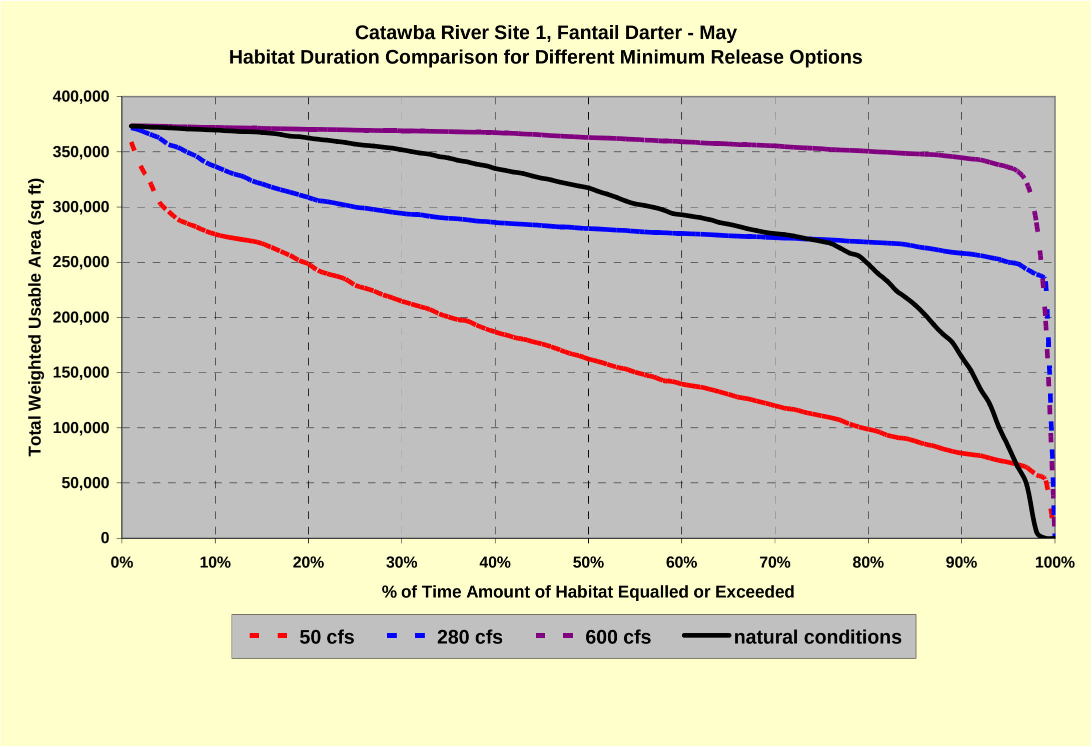


Figure 6: Catawba River, Habit Duration Comparison for Minimum Release



Components of a Flow Regime Recommendation:

Magnitude - the amount of stream flow moving through a geographic location at a particular time - usually measured as a volume per unit of time (for example, cubic feet per second or million gallons per day).
Timing - the occurrence of flows of a given magnitude within the annual hydrologic cycle.
Frequency - the probability that flows of a certain amount will occur.
Duration - the period of time associated with a specific flow condition.
Rate of change - how quickly flows change from one magnitude to another.

4. Drought

- ***Drought Definition and Classification:***

According to Wikipedia, *a drought is an extended period of months or years when a region notes a deficiency in its water supply*. Generally, this occurs when a region receives consistently below average precipitation. This is a normal, recurrent feature of climate. It occurs almost everywhere, although its features vary from region to region. Defining drought is therefore difficult; it depends on differences in regions, needs, and disciplinary perspectives[1]. There are two main drought types from conceptual and operational perspectives. Disciplinary perspective of drought includes meteorological, hydrological, agricultural and socioeconomic types.

No single definition of drought works for all circumstances, so people rely on drought indices to detect and measure droughts. But no single index works under all circumstances, either. That's why we need the Drought Monitor, a synthesis of multiple indices and impacts that represents a consensus of federal and academic scientists. Drought conditions are assessed every week by United States Drought Monitor[2] in collaboration with several federal, state and academic partners in the United States. More information on drought indices is available on the drought monitor webpage[3]. With the synthetic multiple indices, the areas are then categorized as five drought classifications. The Drought Monitor summary map identifies general drought areas, labeling droughts by intensity, with D1 being the least intense and D4 being the most intense. D0, drought watch areas, are drying out and possibly heading for drought, or are recovering from drought but not yet back to normal, suffering long-term impacts such as low reservoir levels. Drought category or classification information is available on the web page[4]. The general information on drought definitions, category and assessment are available on national DM page[5].

The sequence of drought impact with time duration is best described in the chart below from USDM website:

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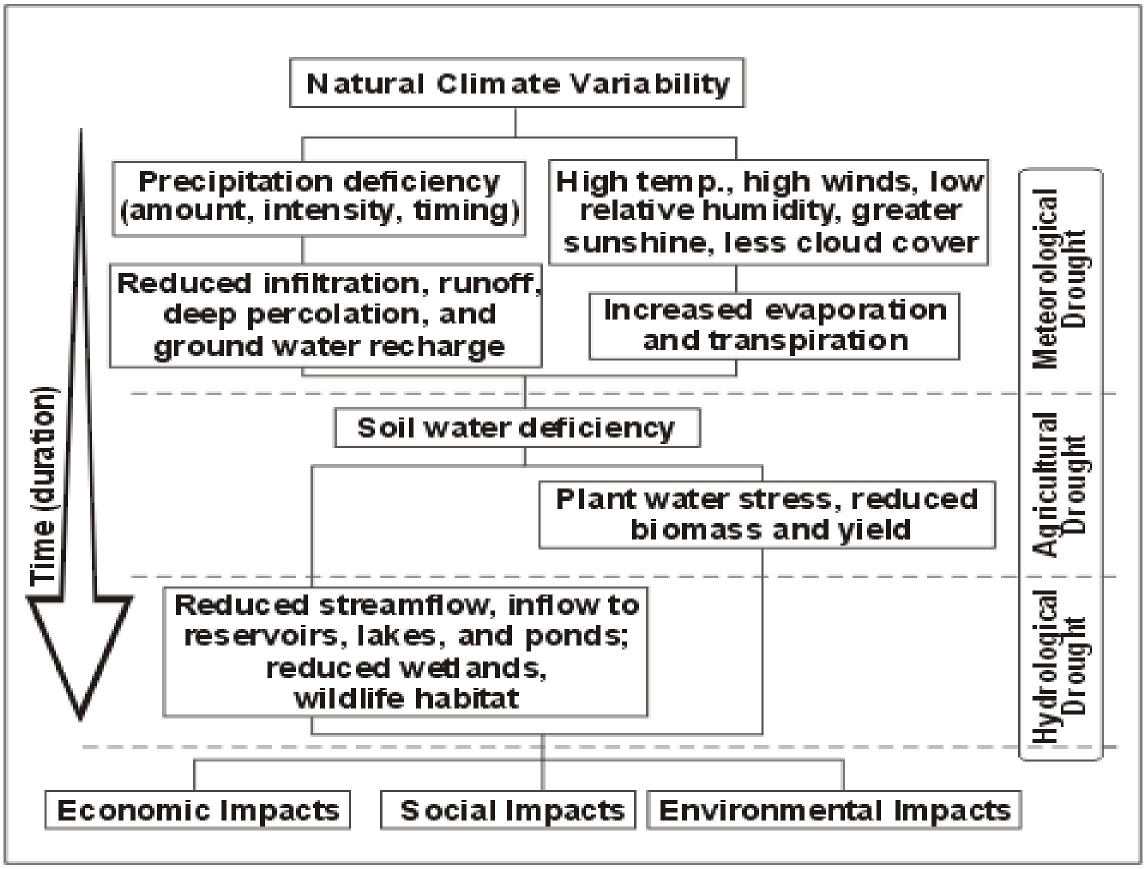
[1] http://drought.unl.edu/whatis/what.htm
[2] http://drought.unl.edu/dm/monitor.html
[3] http://drought.unl.edu/whatis/indices.htm
[4] http://drought.unl.edu/dm/archive/99/classify.htm
[5] http://drought.unl.edu/dm/index.html

Figure 7: Sequence of Drought Impacts



The formation of the North Carolina Drought Management Advisory Council (NCDMAC), and their responsibilities and activities will be discussed in *Drought Management* section in the following chapter of this plan.

- ***Historical Drought Assessment:***

Drought conditions prevailed across much of North Carolina for consecutive years during the past decade. The widespread record low streamflow, groundwater levels, emergency water conservation measure taken by the public water supply systems, and low reservoir storages with major change in reservoir operations indicated that the severe droughts hit the state and prevailed once from 1998 to 2002 (USGS Report 2005[6]), and then second time in 2007 and continued throughout 2008[7]. 2007-2008 drought is believed to be the worst drought in recent years[8,9]. The Cape Fear River basin was no exception; it experienced the severe drought condition for major part of the basin[10]. More information on drought responses taken by the state,

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[6] http://pubs.usgs.gov/sir/2005/5053/pdf/SIR2005-5053.pdf

[7] http://www.ncwater.org/Drought_Monitoring/dmhistory/?chartType=dmmap&enddate=2007-12-11&type=Basin&startdate=2002-08-13&method=awa

[8] http://www.ncwater.org/Drought_Monitoring/dmhistory/?chartType=dmpcnt

[9] http://www.ncwater.org/Drought_Monitoring/dmhistory/?chartType=dmlevel

[10] http://www.ncwater.org/Drought_Monitoring/dmhistory/?chartType=dmlevel&type=Basin&id=Cape%20Fear

local governments and drought press releases released from Governor's office etc. will be discussed in *Drought Management* section in the following chapter of this plan.

The statistics of historical streamflows at some of the USGS gage stations show how severely the drought hit the area in 2007. Haw River near Bynum flow was ranked 1st and 2nd in the dry category for the period of record flows in climatic years 2007-2008 and 2001-2002 respectively. These statistics can be found by clicking on NCDWR's WRISARS database. Reedy Fork near Gibsonville gage flow was ranked 2nd in the dry category for the period of record flows in climatic year 2007-2008 and 3rd in 2001-2002. These statistics can be found by clicking on NCDWR's WRISARS database.

The streamflows in time series and annual plots at some of the USGS gage stations shown in the following few plots also indicate the severity of drought in dry seasons of 2007 and 2008. In annual plots, the yellow band is zero to 10th percentile flows for the period of record flows which represents very dry conditions. The year 2007-2008 flows plotted in black line fall in or just above that band for some part of this drought season. Later half of 2008 flows are towards normal to wet percentiles, indicating beginning of drought relief in terms of streamflows. Other drought indicators also recovered from drought and currently Cape Fear River basin is out of overall droughts as shown in the current drought page.

Figure 8: Ftreamflow in time series at Black River near Tomahawk

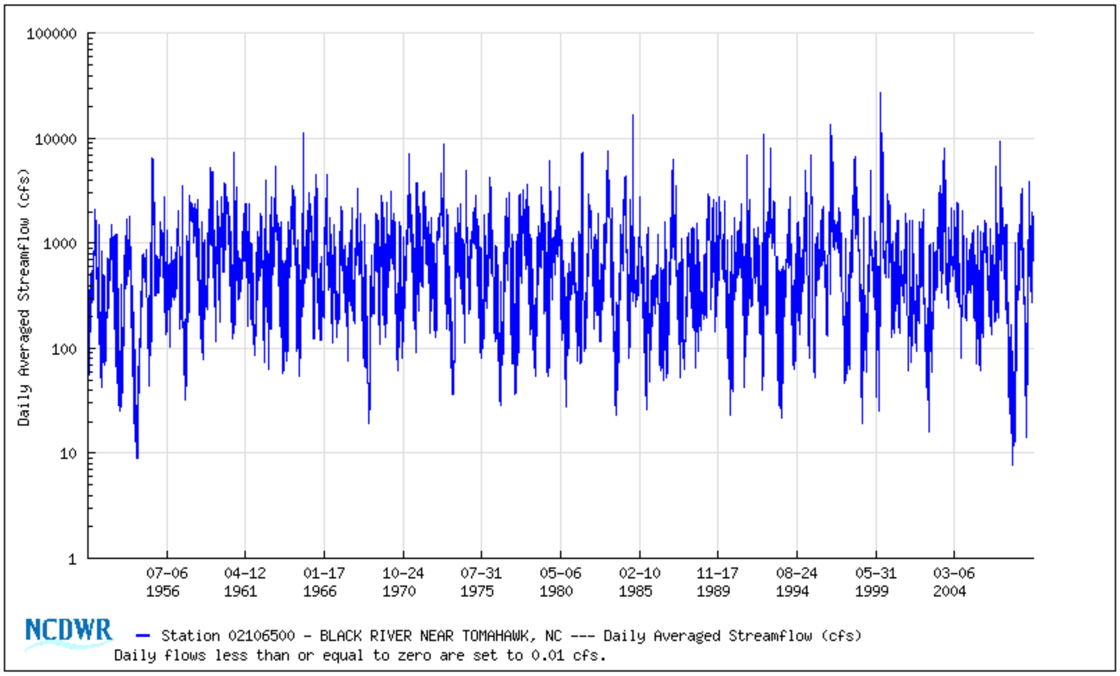


Figure 9: Annual Streamflow at Black River near Tomahawk

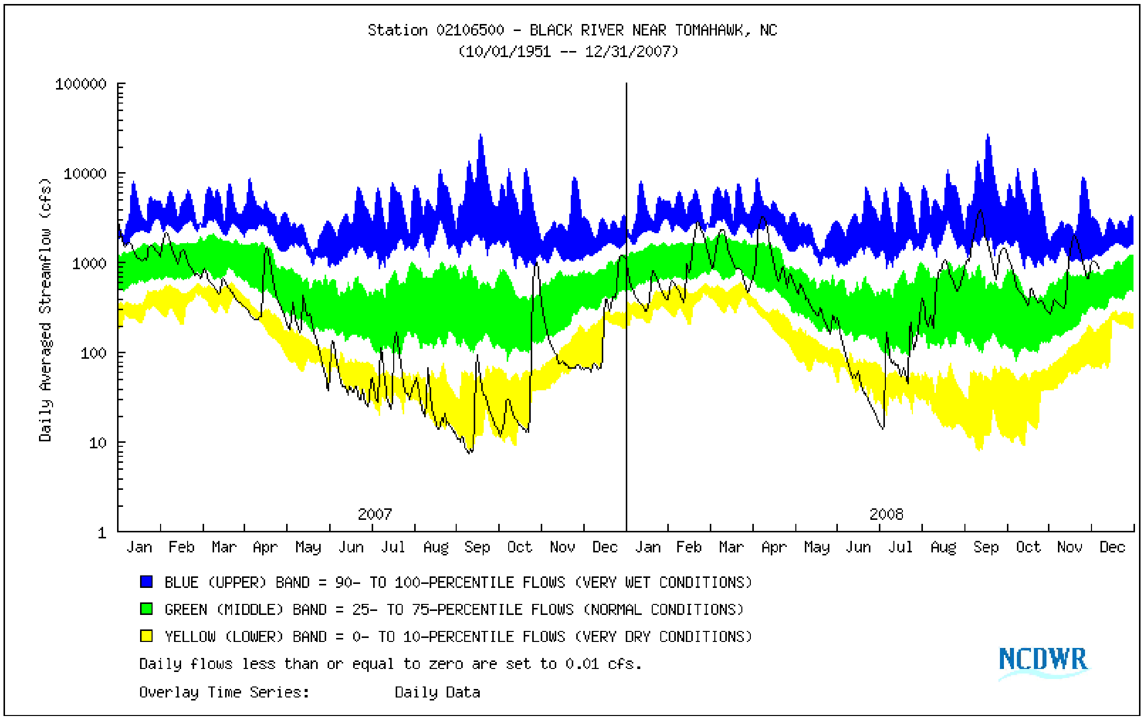


Figure 10: Streamflow in time series at Reedy Fork near Oak Ridge

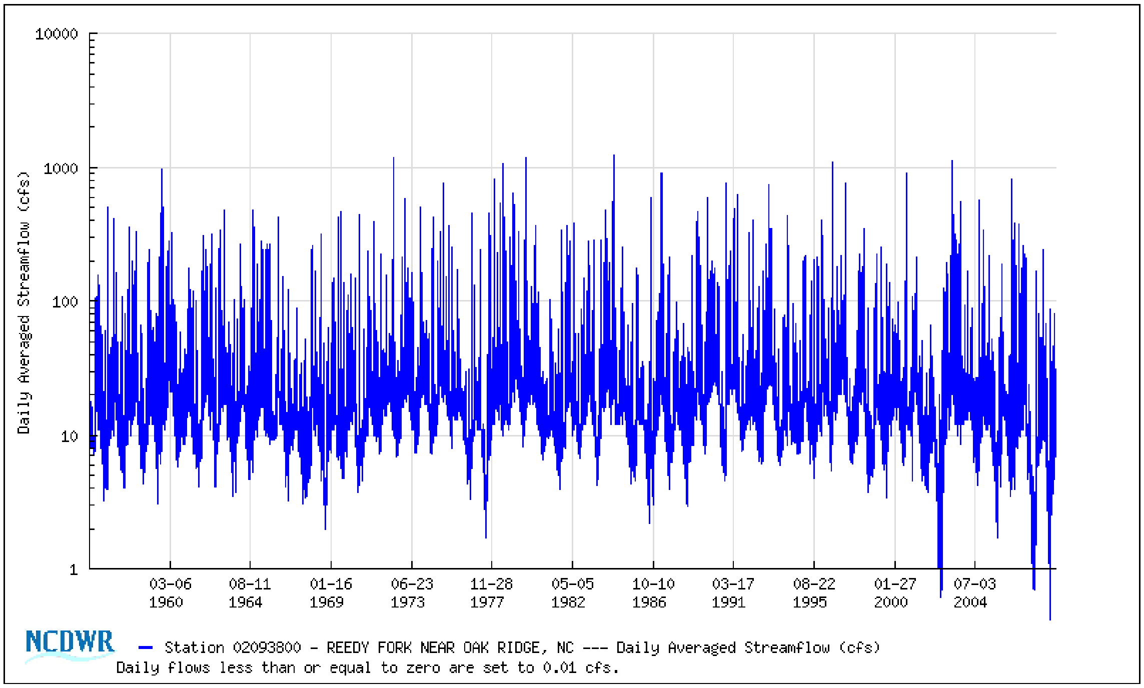


Figure 11: Annual Streamflow at Reedy Fork near Oak Ridge

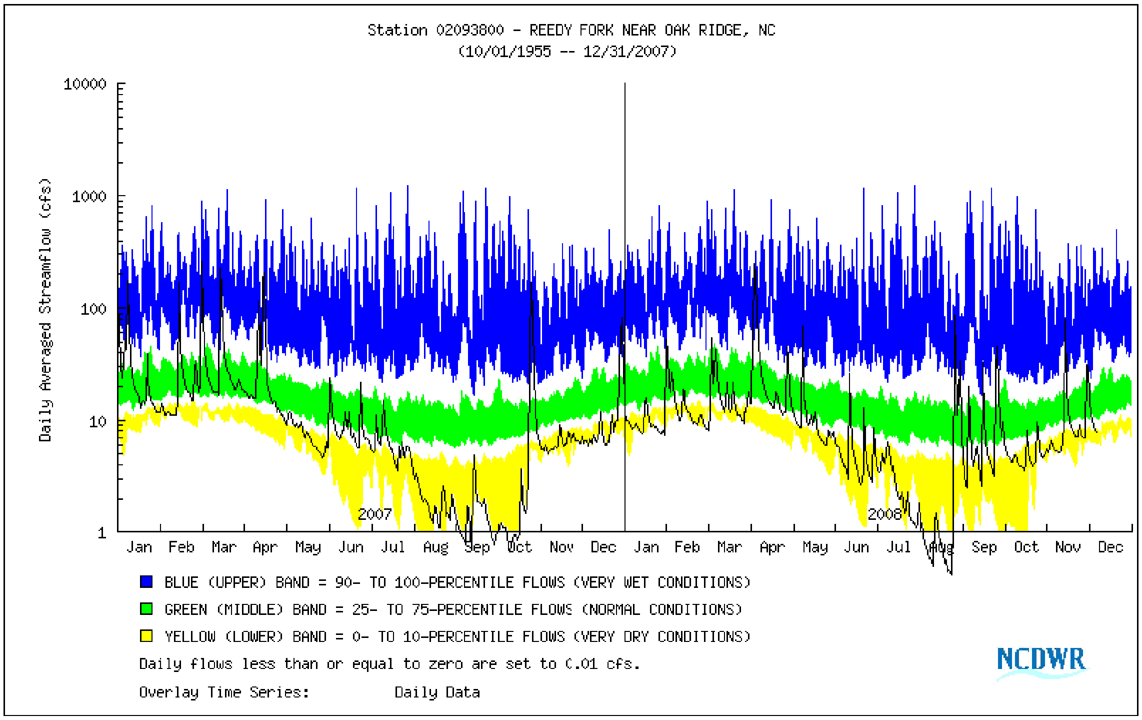


Figure 12: Streamflow in time series at Buckhorn Creek near Corinth

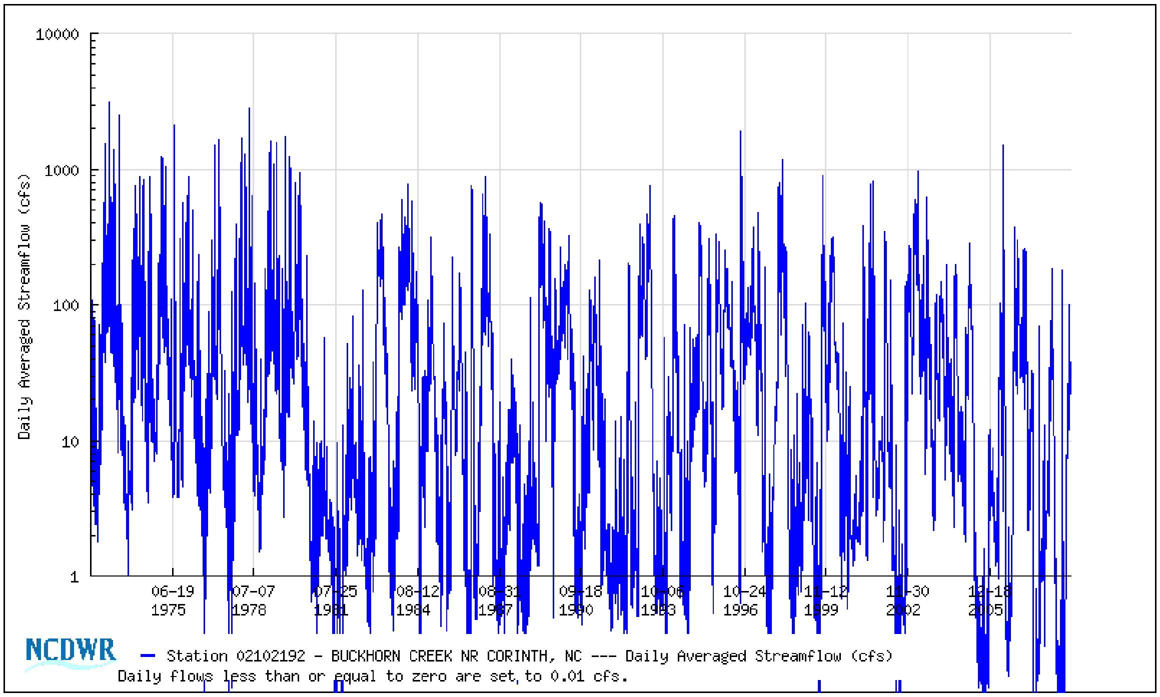
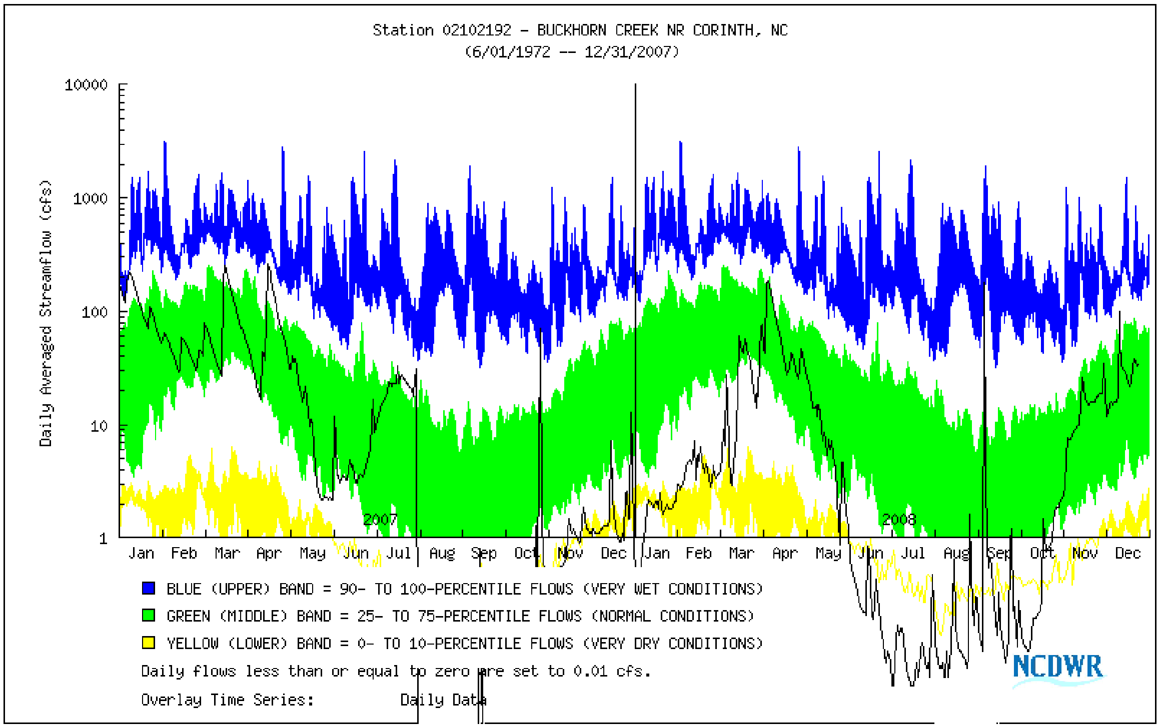
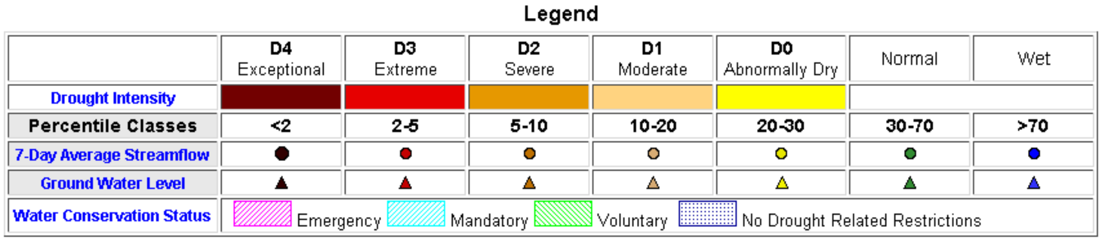


Figure 13: Annual Streamflow at Buckhorn Creek near Corinth



The severity of the droughts in 2002 and 2007 can be portrayed in the following few maps that show the progression of droughts in time in Cape Fear River basin and in North Carolina. The overall North Carolina drought conditions got worse in mid December 2007 when 78 counties out of 100 counties in North Carolina were hit by the highest drought category; maps are available on the NCDrought maps page. These two historical drought conditions are presented in the following few maps. The legends for the maps are provided 1st in the following figure:

Figure 14: Legends used for USDM Maps



Legend

	D4 Exceptional	D3 Extreme	D2 Severe	D1 Moderate	D0 Abnormally Dry	Normal	Wet
Drought Intensity	🟫	🟥	🟧	🟧	🟨		
Percentile Classes	<2	2-5	5-10	10-20	20-30	30-70	>70
7-Day Average Streamflow	●	●	●	●	●	●	●
Ground Water Level	▲	▲	▲	▲	▲	▲	▲
Water Conservation Status	▨ Emergency ▨ Mandatory ▨ Voluntary ▨ No Drought Related Restrictions						

Figure 15: Cape Fear River Basin Drought Coverage on 08-13-2002

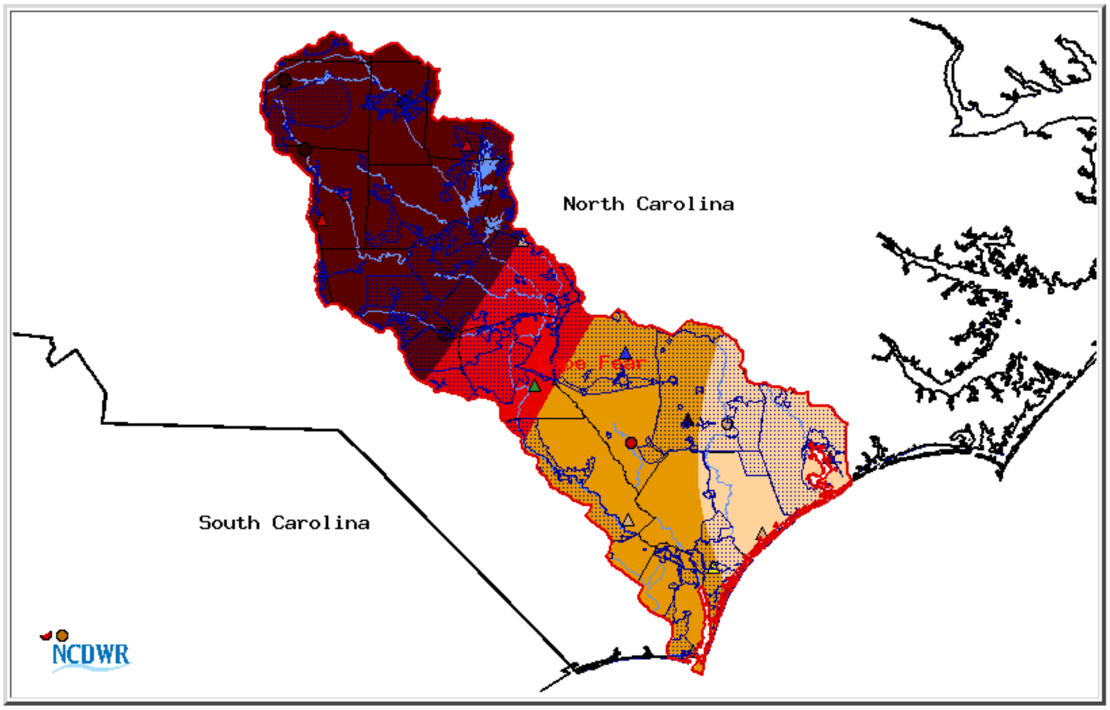


Figure 16: Cape Fear River Basin Drought Coverage on 10-23-2007

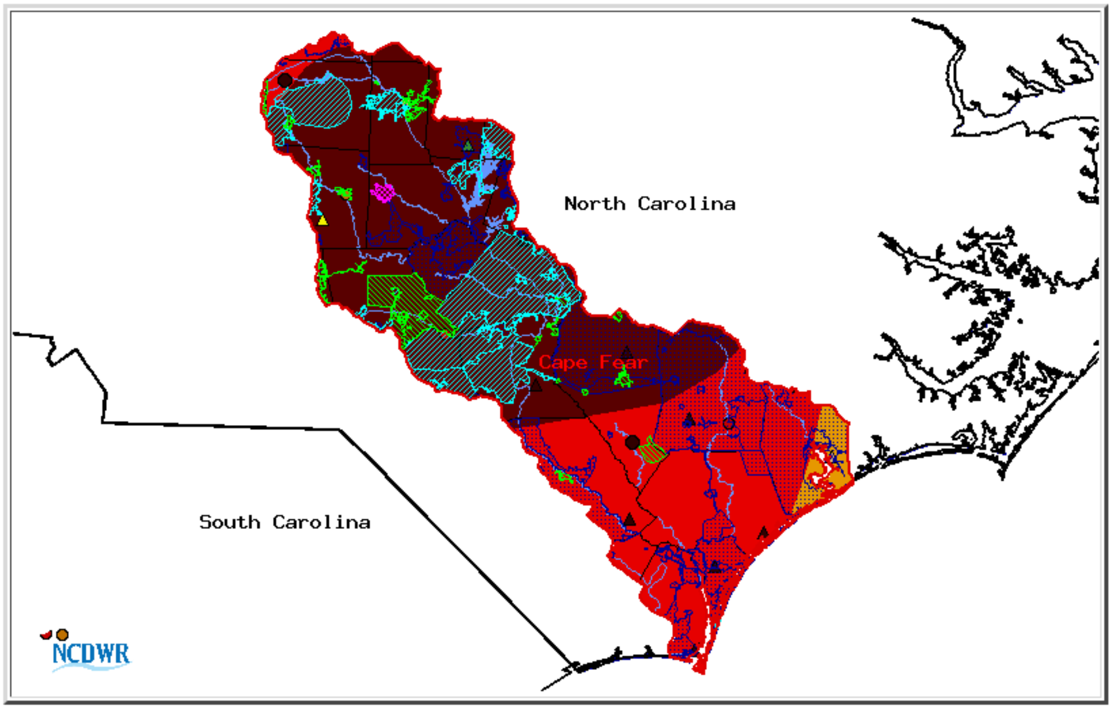


Figure 17: Cape Fear River Basin Drought Coverage on 12-11-2007

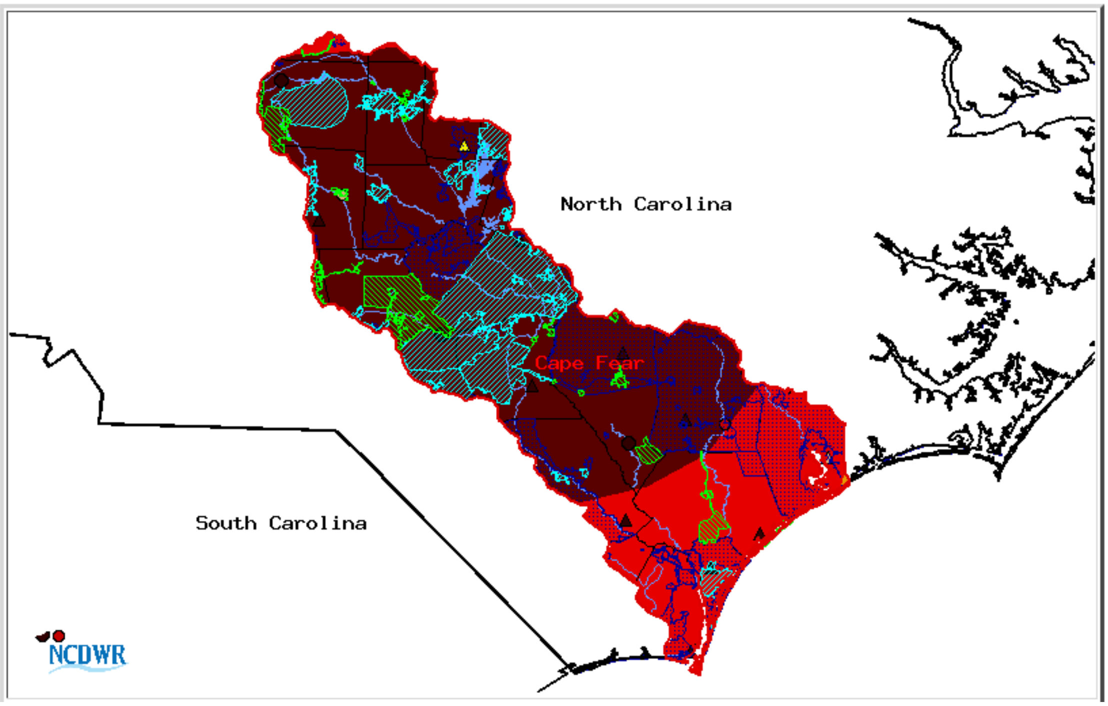
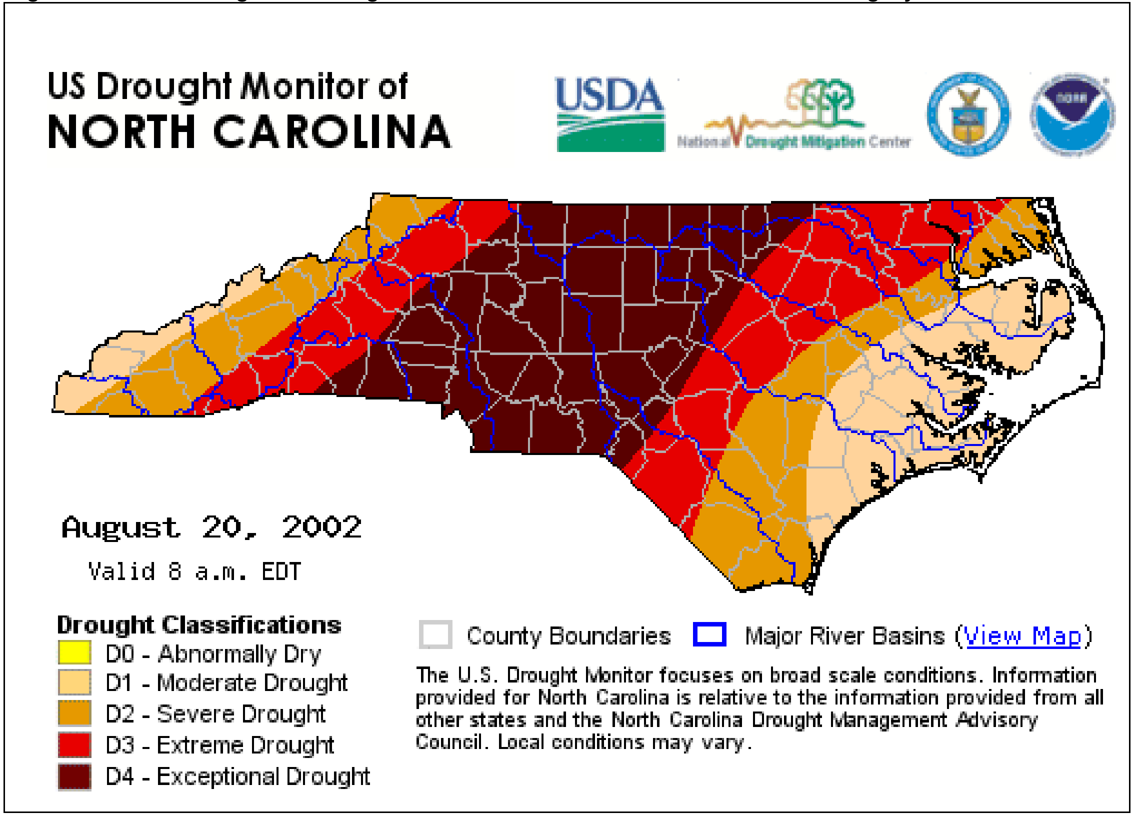
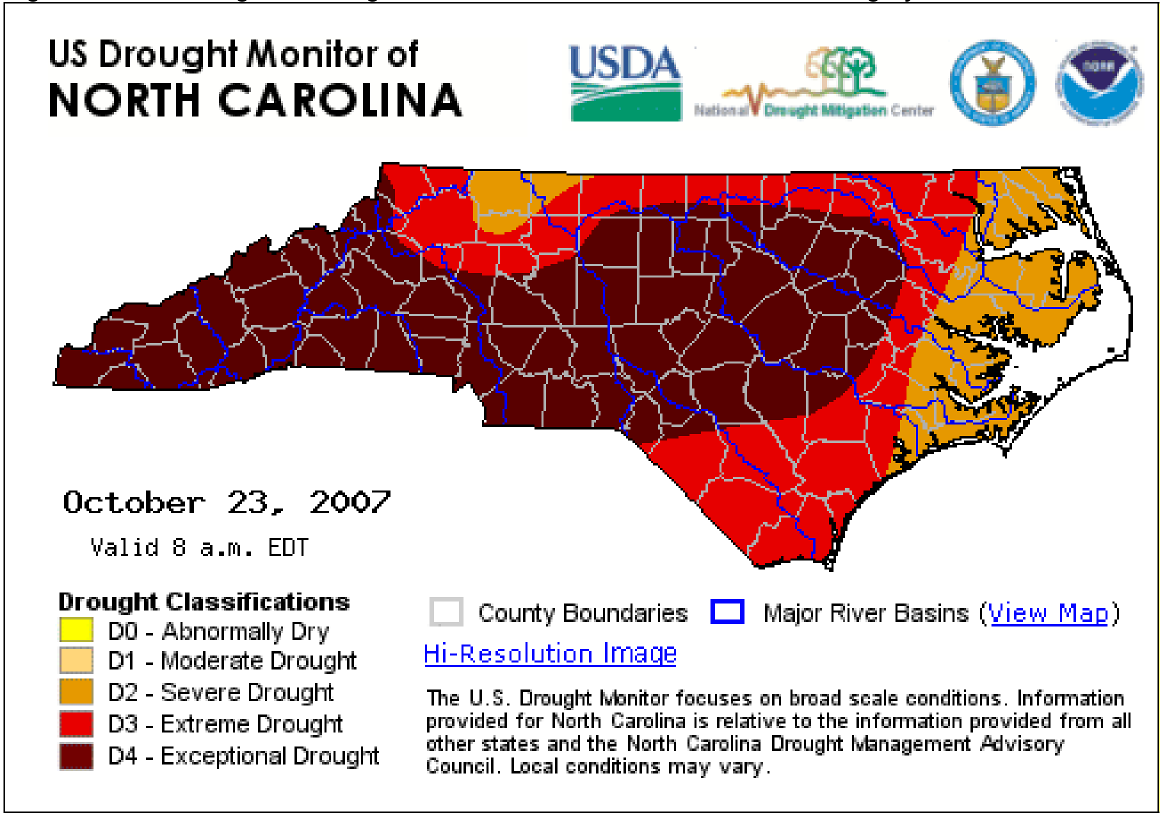


Figure 18: NC Drought Coverage on 08-20-2002: 46 Counties in D4 Category



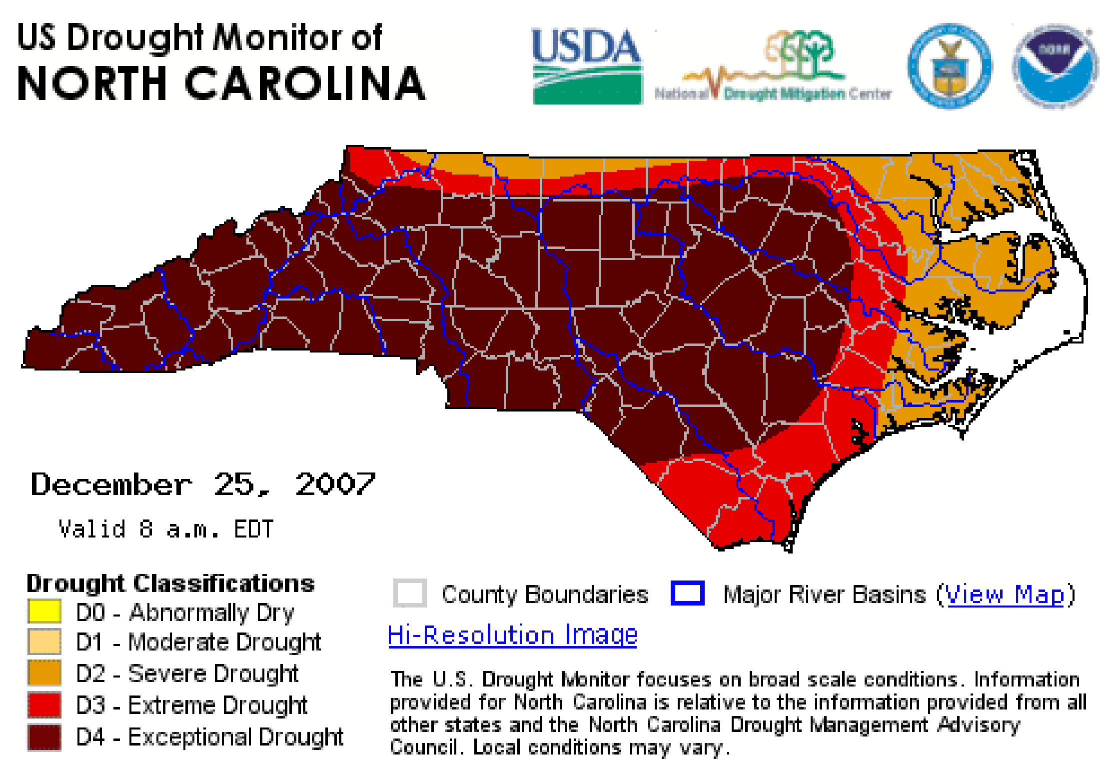
The U.S. Drought Monitor focuses on broad scale conditions. Information provided for North Carolina is relative to the information provided from all other states and the North Carolina Drought Management Advisory Council. Local conditions may vary.

Figure 19: NC Drought Coverage on 10-23-2007: 72 Counties in D4 Category



The U.S. Drought Monitor focuses on broad scale conditions. Information provided for North Carolina is relative to the information provided from all other states and the North Carolina Drought Management Advisory Council. Local conditions may vary.

Figure 20: NC Drought Coverage on 12-25-2007: 78 Counties in D4 Category



The U.S. Drought Monitor focuses on broad scale conditions. Information provided for North Carolina is relative to the information provided from all other states and the North Carolina Drought Management Advisory Council. Local conditions may vary.

5. Ground Water

Hydrogeologic Setting of the Cape Fear River Basin

To the east of the fall line (the boundary between the Piedmont and Coastal Plain), the geology of the Cape Fear River Basin may be characterized as a gently southeastward dipping, and southeastward thickening wedge of sediments and sedimentary rock ranging in age from Recent through Cretaceous which rests on an underlying basement complex of Paleozoic and earlier aged rocks. The basement surface ranges in elevation between 200 feet above sea level and 1,515 feet below sea level within the coastal plain, and dips southeast at a rate of 40 feet per mile in the northwestern part of the area to 72 feet per mile in the southeast. The sediment wedge is comprised of layers and lenses of sand, clay, silt, limestone, gravel, shell material and combinations thereof which range in total thickness from zero at the fall line to in excess of 1,515 feet in the southern tip of New Hanover County and southeastern-most part of Brunswick County. In a successive manner, older stratigraphic units outcrop immediately west of the up dip limit of the next younger unit. Deposition occurred in cyclic fashion during alternating transgressions and regressions of the Atlantic Ocean, in marine to non-marine environments.

The sedimentary column of the lower Cape Fear River Basin is subdivided into geologic formations and formation members based upon position of layers in the sequence of sediments, lithology, and faunal (fossil) composition. The subdivision of these deposits into aquifers and confining units is based on the delineation of non-permeable versus hydraulically connected permeable units, the boundaries of which sometimes, and sometimes do not, correspond to geologic formation boundaries. Aquifers and confining units are commonly made up of more than one formation, or may include only part of a formation or parts of several formations due to the discontinuous distribution of strata in the lower Cape Fear River Basin.

To the west of the fall line, the upper Cape Fear River Basin is primarily composed of rocks of the Carolina Slate Belt. The Late Proterozoic-Cambrian aged Carolina Slate Belt rocks are interbedded, metavolcanic tuffs, breccias, argillites and flows trending northeastward. This basement rock is intruded by Jurassic aged north to northwest trending diabase dikes and numerous Proterozoic to Paleozoic aged plutons (igneous intrusive rocks). Fault bounded, northeast trending, Triassic aged mudstone, sandstone, conglomerate, and minor coal occur near the boundary between the Piedmont and Coastal Plain just west of the fall line. Jurassic aged diabase dikes also intrude these rocks of the Triassic Basins.

The hydrogeologic system in the lower Cape Fear River Basin, from basement to land surface, consists of six regionally significant aquifers and the intervening confining units that separate them. They are mentioned from youngest to oldest as follows:

The surficial, or water table aquifer, which is made up primarily of Quaternary age sediments. It also includes parts of older formations depending on the varying age of underlying sediments and the varying stratigraphic position of the uppermost confining layer.

The Castle Hayne aquifer is comprised primarily of the Eocene age Castle Hayne Formation. The confining unit occurs in the Quaternary age units that overly the aquifer.

The Peedee aquifer, which is made up of the Peedee Formation. In the southeastern corner of the study area, the aquifer includes all, or part of, the Paleocene age Beaufort Formation. The confining unit is generally present in the Beaufort Formation or upper part of the Peedee Formation.

The Black Creek aquifer, which corresponds primarily to the Black Creek Formation. In some areas the aquifer includes the upper part of the Cape Fear Formation and the lower part of the Cretaceous Peedee Formation. The confining unit is made up of clay or silt beds in the upper part of the Black Creek or lower part of the Peedee Formations. To the northwest of the pinchout of the Peedee Formation, the confining unit of the Black Creek aquifer may include Pliocene age Yorktown or younger age deposits which directly overly the Black Creek Formation. In this area, the Black Creek aquifer can include permeable beds in the lower part of these younger formations.

The Upper Cape Fear aquifer, which corresponds to the upper part of the Cape Fear Formation and sometimes the lower part of the Cretaceous Black Creek Formation. The confining unit is composed of clay or silt beds present in the lower part of the Black Creek or upper part of the Cape Fear Formation.

The Lower Cape Fear aquifer, which is comprised along with its confining unit, of the lower part of the Cape Fear Formation of Cretaceous age.

Piedmont aquifers are categorized as either fractured basement rock, overlying regolith (saprolite or weathered basement rock, soil and alluvium or recent sedimentary deposits), or Triassic Basin.

General Description of the Ground Water System

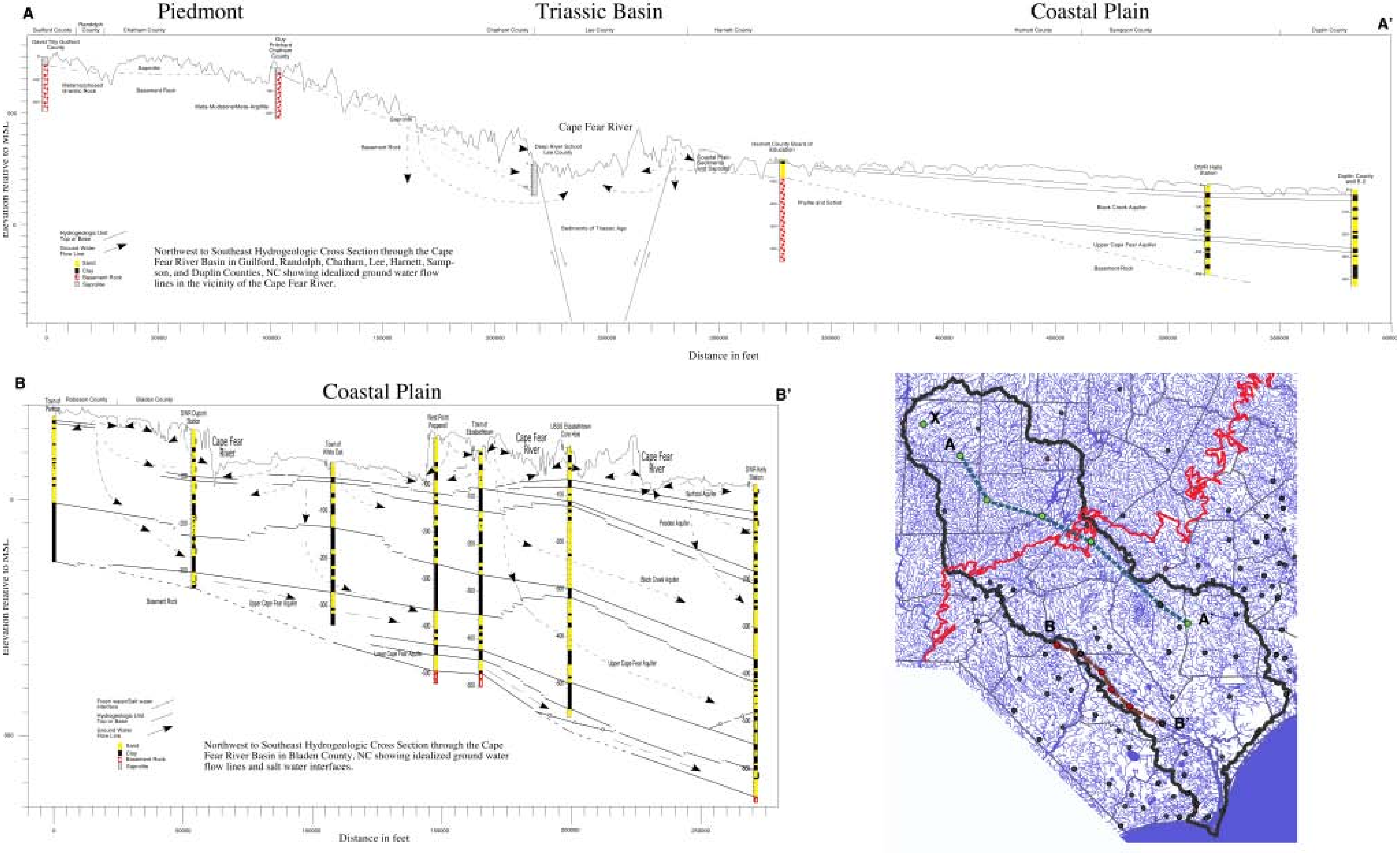
Representative hydrogeologic cross sections through the Cape Fear River Basin are shown in figures 21 and 22**,** exhibiting the complexity of ground water flow patterns and salt water interfaces in relation to hydrogeologic units. Ground water flows in a rather complex three dimensional pattern through the subsurface in a multilayered Coastal Plain environment. Flow occurs laterally through aquifers from recharge to discharge areas along flow lines which parallel directions of steepest hydraulic gradient. Flow also occurs vertically upward to discharge areas or downward in recharge areas in response to differences in hydraulic head between aquifers.

All of the aquifers in the coastal plain contain salt water over regions of varying extent, due to fluctuations of sea level that occurred during deposition of coastal plain sediments. The surficial aquifer contains salt water on the barrier islands along the coast of New Hanover and Pender Counties, as well as along the fringes of the coastline, and other areas where high tides cause natural intrusion of salt water. As recognized by Winner and Coble (1989), the position of fresh water-salt water interfaces within North Carolina Coastal Plain aquifers has a very complex pattern. Sediments were deposited during cyclic fluctuations of sea level over geologic time. The seaward limit of fresh water is unique for each aquifer as governed by variations in hydraulic properties, position and rates of recharge, thickness and hydraulic conductivity of overlying confining beds, and hydraulic gradients. Salt water interfaces are not sharply defined, but occur as transition zones of variable width due to diffusion between salty and fresh water. The movement of fresh ground water through deeper confined aquifers in the coastal plain causes interfaces to retreat slowly seaward over geologic time. However, in areas of heavy ground water pumping and resultant water level declines, saline ground water can move toward pumping centers due to a reversal of hydraulic gradient.

As illustrated by a generalized annual water budget model for the lower Cape Fear River Basin (figure 23), recharge occurs predominantly through rainfall, which enters the surficial (or water table) aquifer in the inter-stream areas. The lower Cape Fear River Basin receives an average of 50 inches of total precipitation per year based on historical records covering the years between 1971 to 2000 (Southeast Regional Climate Center, table 1). Based on a water budget model developed by the U.S. Geological Survey for Brunswick County (Harden, Fine and Spruill, 2003), and using precipitation data averaged for the area, it was determined that about 8 inches of the 50 inches of total annual precipitation is lost to overland flow to nearby surface water bodies. Another 32 inches are taken up annually through evapotranspiration.   Of the 10 inches of water that enters the water table as recharge, 9 inches per year flows from recharge to discharge areas such as the Cape Fear, Lumber, South, and Waccamaw Rivers, associated floodplains, and the Boiling Springs Lakes. One inch or less of ground water per year enters the deeper confined aquifers as recharge. This water budget model assumes steady state conditions in which no pumping from the ground water system is occurring.

Piedmont Cape Fear River Basin water budget (figure 24) from Daniels and Sharpless (1983) differs slightly from the coastal plain model with differing amounts of average rainfall, evapotransporation, and runoff. The biggest distinction is the lack of a recharge component to confined aquifers.

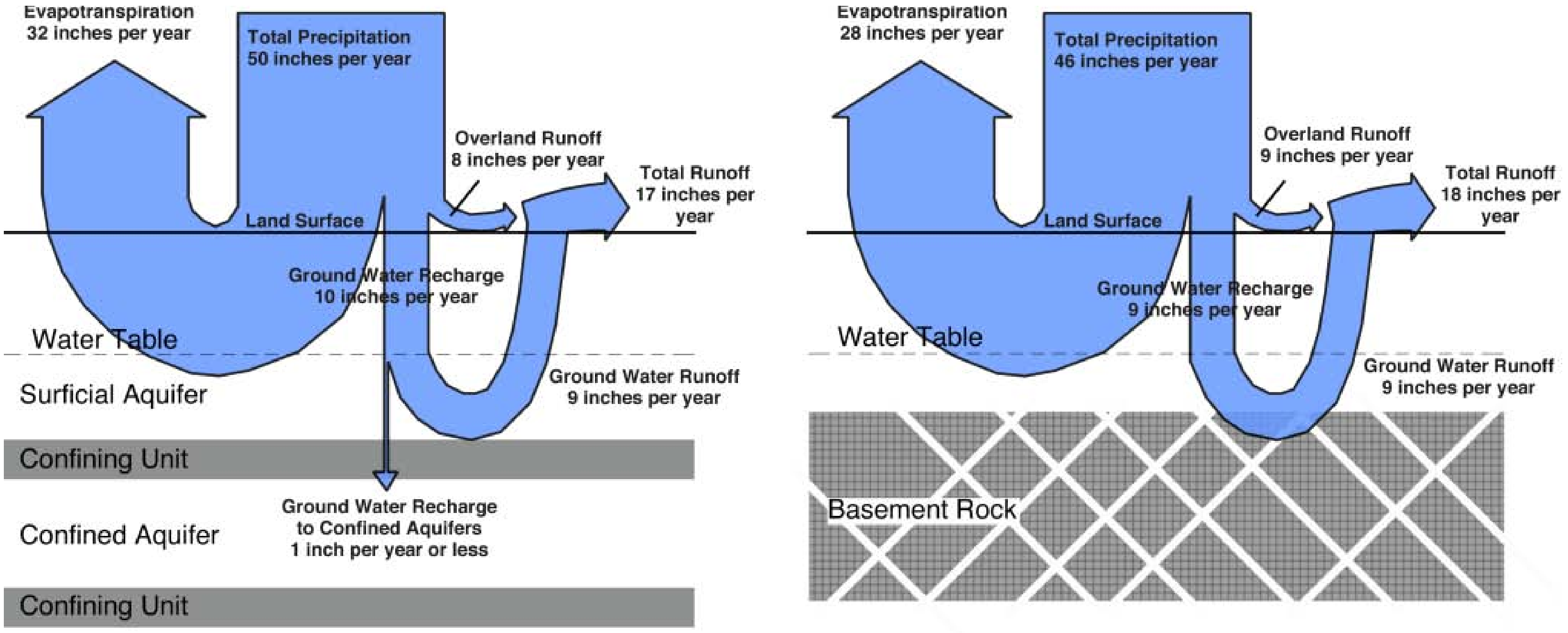
Figures 21 and 22: Hydrogeologic Cross Sections in CFRB (vertically exaggerated)



Northwest to Southeast Hydrogeologic Cross Section through the Cape Fear River Basin in Guilford, Randolph, Chatham, Lee, Harnett, Sampson, and Duplin Counties, NC showing idealized ground water flow lines in the vicinity of the Cape Fear River.

Northwest to Southeast Hydrogeologic Cross Section through the Cape Fear River Basin in Bladen County, NC showing idealized ground water flow lines and salt water interfaces.

Figures 23 and 24: Typical Water Budgets for the (a) Coastal Plain and (b) Piedmont Portions of CFRB



modified from Lautier 2006, Daniel 1983, Wilder 1978

Hydrogeologic Framework of the Cape Fear River Basin

Surficial Aquifer

The surficial aquifer is the uppermost aquifer in the system of aquifers and confining units that comprise the hydrogeologic framework of the lower Cape Fear River Basin. The surficial aquifer is unconfined and thus, the water table is able to fluctuate with changes in ground water storage. It is the first aquifer to receive recharge, storing water as it moves laterally to rivers, lakes and other discharge areas, and downward in small quantities to deeper, confined aquifers. The rate at which recharge occurs in any given area in the study region is dependant on several factors, including:

- differences in precipitation rates from one area to another.
- variations in soil types and their differing infiltration capacities.
- the position of the water table relative to land surface, which varies over time.
- the slope of the land surface.
- evapotranspiration rates, which vary across the region, and over time.

Over the Coastal Plain Section of the Cape Fear River Basin, the surficial aquifer is primarily made up of Quaternary age sands with interbedded silts and clays, but can also be composed of older units depending on the stratigraphic position of the first confining bed and where the various, older units are present in the shallow subsurface.

In the Piedmont section of the Cape Fear River Basin, regolith is classified as the surficial aquifer and the fractured basement rock is either unconfined (a part of the surficial aquifer) or partly confined (see figure 2). The Triassic Basin aquifer, because of the fine grained nature of the sediments, is unusually difficult to use for obtaining ground water. Wells are very low yielding and typically only associated with homeowners, not industry or commercial users. The diabase dikes prevalent in the Carolina Slate Belt and Triassic Basins can make wells in these areas much more prolific because water is drawn from much greater distances along the fractures associated with the igneous intrusive rock. Ground water flows in the porespaces of the regolith and in the openings (joints or fractures) of the metaigneous rocks of the Carolina Slate Belt.

In the Piedmont, ground water flow boundaries are equivalent to the surface water drainage areas. Topographic highs form surface drainage and ground water divides and topographic lows form drainage avenues for both surface and ground water systems. Ground water flow tends to be localized or contained within a watershed. Ground water flow in the Coastal Plain can occur in a regional sense or between surface water basins.

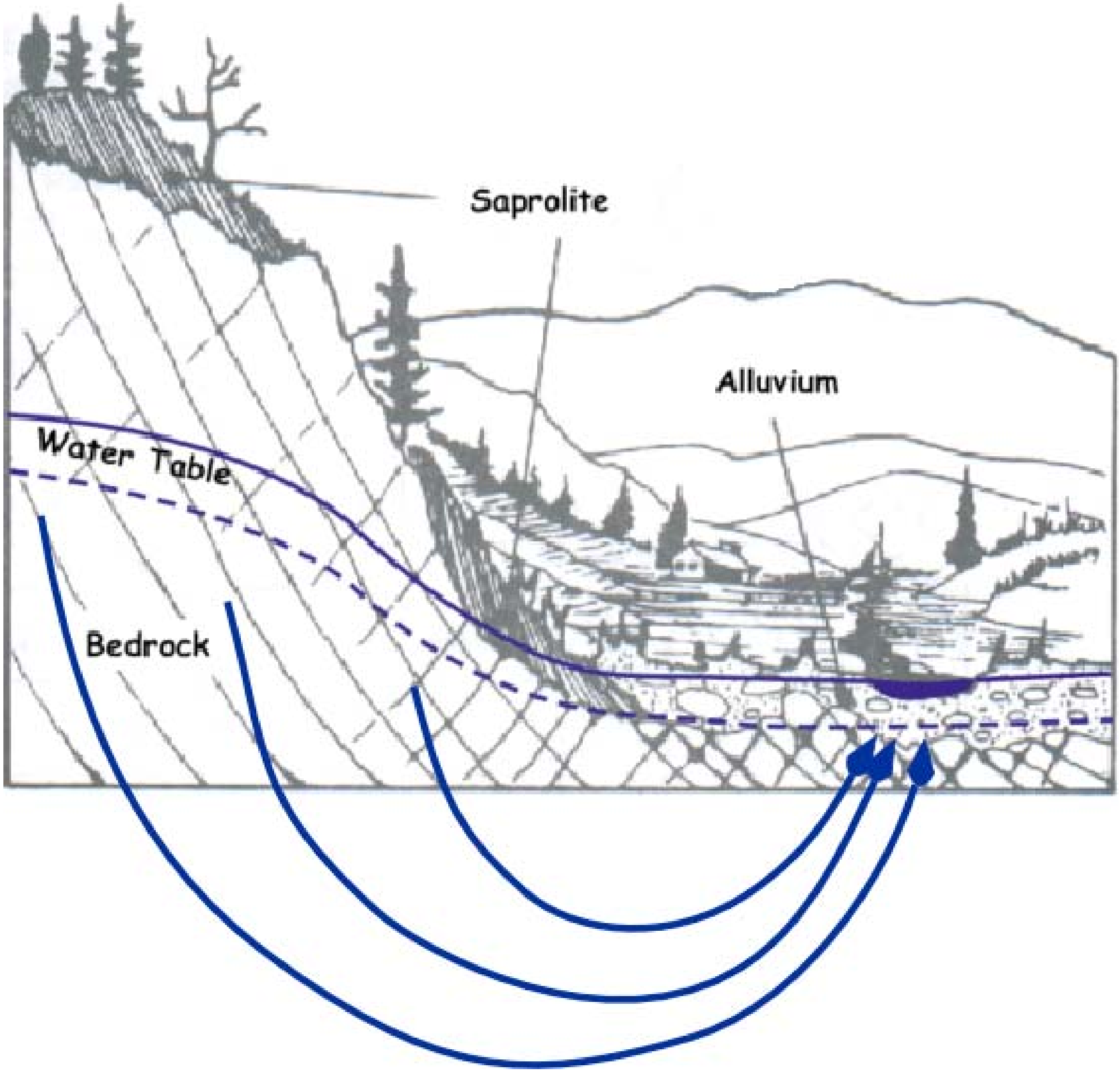
Rainfall infiltrates through regolith and into basement rock fractures. Regolith may be composed of soil horizons, weathered material overlying basement rock (saprolite), or eroded and deposited weathered material (alluvium). Rainfall infiltrates directly into basement rock where it is exposed at land surface. The water table is defined as the depth where the openings in the subsurface materials become saturated. Those openings may be joints or fractures in rock or pore spaces in unconsolidated rock material. The water table is a muted imitation of the topography; it is highest under hills and lowest in stream valleys. However, the water table is also closest to land surface in valleys. Ground water naturally discharges from the subsurface as base flow in streams and at springs (where the water table is higher than land surface). Base flow is the portion of stream flow made up of ground water. It is most easily measured when rainfall is negligible over a significant amount of time. The generalized annual water budget for the upper Cape Fear River Basin is shown in figure 24.

In figure 25, the water table is represented by the solid line (the height water will reach in a well). When rainfall is scarce the ground water is not recharged and the water table declines (dashed line) as it is discharged from the subsurface via surface water drainage. Ground water would naturally follow theoretical flow lines as indicated, but would be restricted to flow through available openings or fractures. In this example, the stream would go dry without current runoff from rainfall into drainage.

In the diagram fractures in the basement rock illustrate some of the pathways in which ground water might flow. Fractures are shown as being more common in the valley and less common below the hill. In most cases topography is controlled by the fracture patterns. More highly fractured rock forms the valleys and draws and less fractured the hills and ridges. Often, fractures form conjugate pairs; fractures that are 60 to 90 degrees apart from one another. In some areas of the Upper Cape Fear River Basin, the fracture patterns are obvious from the distribution and alignment of streams and topography. Ground water flow within saprolite and alluvium occurs through interconnected porespaces or sometimes through relict foliations in saprolite.

Locating wells near lineations in topography or drainage patterns or at the intersection of such features usually increases the well yield. However, yields are dependent on many factors including depth of well, diameter of well, location (hill or valley), degree and orientation of fracturing of the rock unit, degree of weathering of rock (thickness of saprolite).

Figure 25, adapted from USGS Water Resources Investigations 77-65, by M. D.Winner, Jr., figure 2. vertically exaggerated and generalized



Shallow wells, commonly dug or bored wells, tap the shallowest portion of the subsurface above the basement rock. They are usually a few tens of feet deep. They are most susceptible to going dry during drought conditions. Springs are also used for water supplies, but are also susceptible to going dry. Drilled wells are the most common method of extracting ground water. These wells are typically six inches in diameter and more than two hundred feet deep.

The best way to ensure a good yielding well is to drill it where it has the best chance to intersect as many basement rock fractures as possible. Often this is difficult to achieve. One may accomplish this by a review of topography and drainage patterns for the best locations. It is usually the case that a well should not be drilled in the most convenient location. Dug or bored wells should not be used as they are prone to pollution and drying up.

Castle Hayne Aquifer

The presence of the Castle Hayne aquifer is limited to the eastern part of Cape Fear River Basin in eastern Brunswick, New Hanover, Pender, Duplin and Onslow Counties. It is much thinner in the southeastern Coastal Plain than in the central Coastal Plain, achieving a maximum known thickness of 318 feet in Onslow County. The top of the aquifer dips gently from northwest to southeast at a rate of about 12 feet per mile, and ranges in elevation from between 18 feet above sea level to 130 feet below sea level at Carolina Beach in New Hanover County.

The aquifer consists primarily of light gray to white moldic limestones, and bryozoan rich limestones of the Eocene age Castle Hayne Formation, grading downward to calcareous, fine-grained sandstone in the deeper subsurface. It also contains the uppermost part of the Peedee Formation of Cretaceous age in central New Hanover County, the lower part of the River Bend Formation of Oligocene age in southern New Hanover County, and the upper part of the Beaufort Formation of Paleocene age in southeastern Brunswick County. Where these formations are included the aquifer may also contain gray to light brown, silty, fine grained quartz sand, sandy moldic limestone or fine-grained shelly sandstone.

The aquifer is recharged by water moving downward from the surficial aquifer at a rate that varies from place to place over the study region. Rates of recharge are dependent on the thickness and vertical hydraulic conductivity of the overlying confining unit, and how much higher the water table elevation is above the elevation of the Castle Hayne potentiometric surface in recharge areas.

Peedee Aquifer

The Peedee aquifer is present in the southeastern part of the Cape Fear River Basin, pinching out approximately along a line through central Bladen County, the southern tip of Sampson, and into central Duplin County. It dips to the southeast at a rate of 5 feet per mile, increasing to a rate of 24 feet per mile in New Hanover County. The elevation of the top of the aquifer ranges from 38 feet above sea level in southern Robeson County to 219 feet below sea level at Kure Beach in New Hanover County. The top surface of the aquifer is rather hummocky in the central part of the study area, apparently due to an erosional cut and fill surface between Quaternary and Peedee age deposits. The aquifer is generally wedge shaped in profile, thickening toward the southeast to a known maximum of 404 feet in eastern Brunswick County.

The aquifer is primarily composed of the Upper Cretaceous age Peedee Formation, the lithology consists of gray or light brown, silty, fine to very fine grained quartz sand with trace quantities of glauconite, phosphorite, oyster shells, and pyrite. In southeastern Brunswick and north central New Hanover Counties, the Rocky Point Member makes up the uppermost part of the Peedee Formation, consisting of gray, sandy, moldic limestone, grading downward to a very calcareous sandstone. The updip limit of the Peedee aquifer extends in some areas, a few miles further to the northwest than the limit of the Peedee Formation as delineated on the North Carolina Geologic Map. The reason for this is that the aquifer contains some upper sands of the Black Creek Formation and probably some lower sands of Quaternary age that directly overly the Peedee Formation.

Black Creek Aquifer

The Black Creek aquifer is present over most of the coastal plain section of the Cape Fear River Basin, and is made up of alternating beds of sand and clay of the Upper Cretaceous Black Creek Formation. The sands are generally gray to olive gray in color, fine to medium grained, poorly sorted, and contain variable amounts of glauconite, phosphorite, shell fragments, lignite, and traces of mica, pyrite and marcasite. Clays are generally gray to black in color, and lignitic. Individual sand and clay beds generally range between 10 and 20 feet in thickness across the region. The aquifer includes the Middendorf Formation in Hoke, western Cumberland, and Harnett Counties where it interfingers into the Black Creek Formation and appears to be connected hydraulically. Due to a lack of water level data, it is somewhat uncertain as to whether the aquifer is confined in these counties, or part of the surficial aquifer. Correlation of geophysical logs indicates the persistance of clay beds in the upper part of the Middendorf Formation or lower part of the Quaternary. For this reason, the aquifer appears to be confined in the interfluvial areas and under water table conditions in the fluvial valleys where confining beds have been eroded.

The top of the aquifer dips to the southeast at a rate of 8 to 10 feet per mile as exhibited by elevation contours. It ranges in elevation between 318 feet above sea level in northern Hoke County, to 641 feet below sea level at Kure Beach in southern New Hanover County

The Black Creek aquifer is recharged by water moving downward from the Peedee aquifer in the portion of the study area where the Peedee is present. Where the Black Creek is well confined, it is recharged at rates of less than one inch per year (or less than 47,610 gallons per day per square mile). To the northwest of the area where the Peedee aquifer pinches out, the thickness of sediments that overly the Black Creek is reduced, the confining unit is generally thinner, and recharge rates are assumed to be much higher. This depends of course, on the other factors that control recharge to confined aquifers, such as vertical hydraulic conductivity, and hydraulic gradients. In Hoke, Bladen, Cumberland and Harnett Counties, the Black Creek aquifer occurs at a shallow enough level in the subsurface to be incised by the Cape Fear River and its tributaries, allowing direct discharge of ground water (figure 2).

Upper Cape Fear Aquifer

The Upper Cape Fear aquifer is composed of alternating beds of sand, clay, and silt which are part of the Upper Cretaceous Cape Fear Formation. The sands are made up of quartz and feldspar, and are fine to coarse grained, subrounded to subangular, poorly sorted with minor to abundant iron oxide staining. Also present are accessory iron oxide minerals such as pyrite, marcasite, and siderite. Fine gravel is present in some well samples. Clay and silt beds are generally red, pink, to yellowish gray in color.

The top of the aquifer ranges in elevation between 38 feet above sea level to 905 feet below sea level at Kure Beach in southern New Hanover County. The top of the aquifer dips to the southeast at a rate that varies from 5 feet per mile to 29 feet per mile in the eastern part of the Cape Fear River Basin. The unit is wedge shaped in cross sectional profile, thickening generally toward the southeast from a minimum of 44 feet to a maximum of 208 feet in northern New Hanover County.

Combined pumping from the Black Creek and Upper Cape Fear aquifers (1,974 gallons per day) at Smithfield Foods Inc. near Tarheel in Bladen County, and from the Elizabethtown-White Lake area (903,000 gpd) has produced large cones of depression in both the Black Creek and Upper Cape Fear aquifers. Upper Cape Fear water levels at the center of the Smithfield Foods cone of depression have been drawn down to approximately 114 feet below sea level. Due to reductions in the volume of water withdrawn from the Upper Cape Fear aquifer, water levels recovered somewhat at Smithfield Foods between 2001 and 2005, but have stabilized since then.

The Upper Cape Fear aquifer is particularly sensitive to pumping in the Cape Fear River Basin because it is well confined by thick overlying clay beds which highly limit the amount of vertical recharge. The aquifer is also relatively thin in the Tarheel-Elizabethtown area, which limits transmissivity, and large cones of depression are able to form due to relatively low volume pumping. Careful well field design, including adequate spacing between wells is necessary to prevent excessive drawdown in this aquifer.

Lower Cape Fear Aquifer

The Lower Cape Fear Aquifer is lithologically similar to the Upper Cape Fear with the exception that it contains in its lower part, reworked materials from the underlying Paleozoic age basement rock. Sediments that comprise the aquifer are part of the Upper Cretaceous Cape Fear Formation.

According to an elevation contour map, the top of the aquifer dips to the southeast at a rate that varies from 9 feet per mile to 31 feet per mile in the eastern-most section of the study area. The average thickness is 151 feet, with a range between zero where it pinches out, to 430 feet near the town of Southport in Brunswick County. The aquifer is used very little in the study region, due mostly to the fact that it contains salt water over the majority of the area.

Division of Water Resources Monitoring Well Network

The operation of the monitoring well network is an integral part of DWR's mission to ensure that the State has an adequate water supply for its citizens. Information collected quarterly from this well network are used to:

- Evaluate climatic influences on the State's ground water supply, including effects of drought and recharge-discharge relationships;
- Monitor human-induced effects on the State's ground water supply, particularly in the regional aquifer systems of the Coastal Plain physiographic province. These effects include local and regional water level declines as well as migration of the fresh water-salt water interface within various aquifers;
- Provide supporting data for enforcement and creation of current and future ground water usage regulations, such as the Central Coastal Plain Capacity Use Area rules; and
- Provide high quality ground water data to local governments, ground water professionals, and the general public to use in making informed decisions in ground water related issues.

Data collected from the network are available to the public through DWR's internet website, www.ncwater.org. These data include ground water levels, chloride measurements, well construction information, borehole log construction (lithological and geophysical), ground water monitoring station locations, and geophysical/lithological data collection from non-DWR well sites.

The monitoring well network currently consists of 555 wells at 182 monitoring stations (sites). There are 22 wells located in the Piedmont and Mountain physiographic provinces (Piedmont and Mountain) and 533 wells located in the Coastal Plain physiographic province (Coastal Plain). Since the Coastal Plain relies more heavily on ground water supplies than either the Piedmont or

Mountain Regions, ground water monitoring and research has been more concentrated in the Coastal Plain.

Hourly water level data are extremely valuable in assessing aquifer recharge, impacts of large storms on ground water conditions, and delineation of aquifer boundaries. DWR typically publishes only the manual water level readings and daily water level data from recorders on the website. Hourly data is available upon request for specific wells.

More resources have been invested in monitoring the Piedmont and Mountain ground water conditions to better understand the impact of drought cycles on ground water supplies and their contribution to surface water flow. Although DWR and USGS have been continually monitoring the well network, the drought network was officially established in 2001 with the development of the DWR drought web page to house the data. There are 35 wells within the DWR monitoring well network used to assess drought conditions.

The U.S. Geological Survey (USGS) has also contributed to the monitoring of the State's ground water resources under a cooperative agreement between the State of North Carolina and the Federal government. The cooperative well network consists of 23 monitoring wells, many of which are also part of the DWR statewide network.

There are 88 DWR network wells and two wells operated by the USGS within the Cape Fear River Basin. These wells are screened in eight different aquifers in the Coastal Plain and include three wells in basement rock. Eleven of the DWR & USGS network wells within the Cape Fear River basin have been designated as drought wells. Table 7 summarizes the network wells in the Cape Fear River Basin.

The distribution of the network wells by aquifer in the basin is as follows: Surficial – 35, Peedee – 11, Upper Cape Fear – 12, Lower Cape Fear – 2, Black Creek – 20, Castle Hayne – 5, Upper Tertiary – 1, basement rock – 3, and regolith – 1. Eleven of these wells are used to monitor drought conditions (one by the USGS and ten by DWR).

The drought indicator well network now stands at 46 wells distributed throughout North Carolina. DWR has established a near term goal of 60 wells associated with that network. Certainly, additional wells in the Cape Fear River Basin will be part of that formula. In order to better assess the hydrogeologic conditions of the entire Cape Fear River Basin, additional well stations need to be installed (especially in counties that currently do not have stations) and existing stations may need additional wells added.

TABLE 7: County Summary of Cape Fear River Basin Wells

County	Station Name	No. of Wells	Drought Wells	Total by County
Bladen	Kelly	3	1	
	DuPont	6		
	Smith McNair House	2		
	Dublin	5		Bladen - 16
Brunswick	Maco	2		
	Town Creek	2		
	Boiling Springs RS2	2		
	Boiling Springs RS1	1		
	Southport RS4	3	1	Brunswick - 10
Cumberland	Cedar Creek Fire Tower	4		
	Seabrook School	1	1	
	Bushy Lake	3		Cumberland - 8
Duplin	Pink Hill	4		
	Rose Hill	5	1	
	Chinquapin	3		Duplin - 12
Guilford	Gibsonville	1	1	Guilford - 1
Hoke	Raeford	1		Hoke - 1
Moore	Hog Island	3		
	Southern Pines Water Plant	2		
	Southern Pines 1	2		
	Eastwood	1		
	Weymouth Woods	2		Moore - 10
New Hanover	Wilmington Airport	1	1	
	Fort Fisher	1		New Hanover - 2
Onslow	Folkstone	6		Onslow - 6
Pender	Topsail Beach	4	1	
	Burgaw	2		Pender - 6
Randolph	NC Zoo	1	1	Randolph - 1
Sampson	Halls	3	1	
	Turkey	2		
	Six Runs	6		
	Ivanhoe	3		Sampson - 14
Wake	Fuquay-Varina	1	1	Wake - 1
DWR Total			**10**	**88**
Brunswick	USGS, BR-100	1		
Orange	USGS, NC-126	1	1	
Total			**11**	**90**

Ground Water Assessment Techniques

Because ground water flow in the coastal plain's confined aquifers do not honor the current basin boundaries (ground water flow occurs across basin boundaries) the DWR network wells provide a regional picture of the stress on the aquifers. So, the distribution of wells in the Upper Cape Fear aquifer throughout the coastal plain gives us data to assess the status of that aquifer even though we may not have many wells in that aquifer within the Cape Fear River Basin boundaries. There are two recent examples of where water levels collected from the confined aquifer wells were used to determine who was withdrawing ground water and whether a capacity use area designation would be needed to correct an over-pumping situation.

Peedee aquifer water levels began dropping dramatically in the southeastern portion of Brunswick County during 2003-2004. Three monitoring stations exhibiting this trend were used to pinpoint the location of a new large withdrawal from the aquifer. Cogentrix Inc. north of Southport was determined to be the new user and they were required to submit a registration of their usage through the state-wide DWR water withdrawal registration program.

Upper Cape Fear aquifer water levels began dropping in the early 1990's as a result of withdrawals from Smithfield Foods in Tar Heel, Bladen County and other users. The impact from these withdrawals could be measured into neighboring counties and river basins within a few years based on the monitoring well network data for that aquifer. A 2004 agreement between the Lumber River Council of Governments, the DWR, and the Environmental Management Commission pressured Smithfield Foods and other water users to begin planning for use of surface water from the Cape Fear River for their water needs. Planning necessary for the construction of a new intake on the river, called Bladen Bluffs, is well on its way.

Use of the monitoring well network (or an improved network with additional wells and better geographic distribution) for ground water assessment in the coastal plain portion of the Cape Fear River Basin is a valuable method to determine where the confined aquifers are being stressed too heavily or salt water intrusion may become a problem. In addition, the network is clearly a useful tool to estimate the impact of drought conditions on the shallow ground water levels throughout the basin. Using the network for more than drought assessment in the Piedmont portion of the river basin is not practical. Aquifers in the Piedmont do not have regional characteristics like in the coastal plain, so a network would require too many wells to gauge local aquifer conditions to be practical.

Other investigators have relied on recharge estimations to the shallow ground water system as a method of defining the capabilities of aquifers. They have established rates of recharge in gallons per day per square mile using water budget models based on base flow determinations from surface water gage data.

Those workers assume that discharge from the aquifer system (base flow) equates to the rate of recharge to the aquifer system and a annual rate available for use by wells (or some portion thereof). However, these safe yield type calculations are wrong and impractical. They are wrong because the analysis requires that a balance between withdrawals, recharge, and natural discharge be constant over time which is definitely not the case. A safe yield determined for some county or large portion of a county is impractical because it would require a huge number of wells and access to large areas of land to come close to withdrawing the estimated rate. Use of annual rates of recharge or potential withdrawal rates only highlights areas where ground water is more or less plentiful.

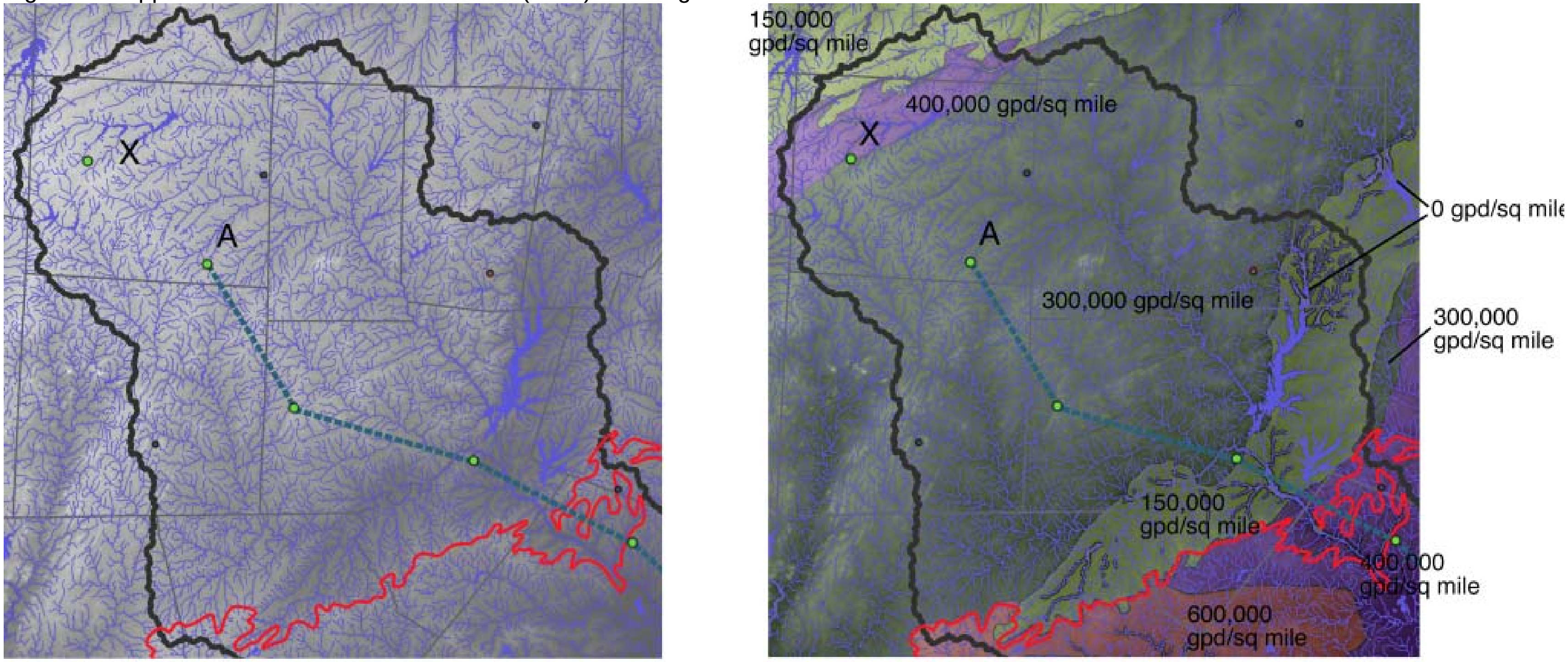
Those types of analyses do not indicate whether a particular ground water withdrawal is sustainable or without conflict with other nearby users. Use of ground water flow models would fall victim to the same limitations of the safe yield determinations. They would also fail to properly imitate the complex nature of flow in the basement rock aquifer of the Piedmont. The current surface water model of the Cape Fear River (although it does not explicitly model ground water flow) does implicitly measure discharges from the ground water system into surface water along the modeled water course. If one could estimate the ground water discharge amounts from this knowledge, it would still be a rate applied to some large area of land and of little use to a ground water management program.

Heath (1994) mapped rates of recharge to the surficial aquifer state-wide. Figure 6 shows two pictures of the upper Cape Fear River Basin, both with the digital elevation data (lighter shades of gray equate to higher elevations), hydrography, and the fall line. The second picture shows the distribution of Heath’s recharge rates as well. The Triassic Basin areas stand out in both pictures as they remain basins today and contain sediments which make it a slowly recharging area (150,000 gallons per day per square mile). There is an area in the northwestern portion of the upper Cape Fear River Basin where basement rock fractures appear to control hydrography. Surface water drainage patterns do not appear as dendritic (or irregularly branched like a tree). Even with estimates of recharge rates as shown on this map, there is not enough information available to discern whether a site is capable of providing enough water or that it will not compete with a neighboring well field.

The dot on figure 26 labeled with an “X” in each map identifies an aquifer test done in May 1983 associated with the Daniel and Sharpless (1983) report. At this site, 20 wells were drilled and monitored during the test. A production well was pumped for 62 hours at 38.5 gallons per minute. The results indicated an area of drawdown associated with the withdrawal which suggested a distance which might be used for spacing of multiple production wells. The pump test also revealed that the area of drawdown was elongated and not symmetrical about the pumping center. Lastly, the total volume of water withdrawn suggested that water stored in the basement rock fractures was untouched by the test – virtually all the water came from storage in the regolith. All this information would not be available without an individual site assessment.

Understanding the sustainability of ground water withdrawals in the Piedmont portion of the Cape Fear River Basin must rely on information derived from a local assessment of resource potential by the user, careful maintenance of existing production wells, and tracking of water level and quality measurements from production wells over time. The same methods work for the Coastal Plain portion of the basin with the added benefit of a monitoring well network to assess the regional stress on confined aquifers.

Figure 26: Upper CFRB with and without Heath (1994) Recharge Rates



- Digital elevation data (higher elevations equal lighter shades of gray)
- Fall Line (boundary between Piedmont and Coastal Plain physiographic provinces)
- Hydrography
- Cape Fear River Basin boundary

- The recharge rate along hydrography is 0 gpd/sq mile

- Recharge rates are average (lack of rain and addition of impenetrable surfaces like roads, houses and parking lots will reduce recharge rates)

6. Interbasin Transfer

Table 8: Local Water Supply Plan Systems Using Surface Water form Cape Fear River Basin

County	Water System using Surface Water	Source of water	Discharge to different hydrologic unit	Estimated Average Daily Discharge (mgd)	Service Area in different hydologic unit	Estimated consumptive use in other hydrologic unit (mgd)
Alamance	Alamance	Burlington				
	Burlington	**Lake Mackintosh, Stoney Creek Reservoir**				
	Elon	Burlington				
	Graham	**Graham-Mebane Lake**				
	Green Level	Graham				
	Haw River	Burlington				
	Mebane	Graham				
	Swepsonville	Graham				
Brunswick	Bald Head Utilities	Brunswick County				
	Boiling Spring Lakes	Brunswick County				
	Brunswick County	Lower Cape Fear WSA	X	0.4	X	2.25
	Caswell Beach	Brunswick County				
	Holden Beach	Brunswick County			X	0.4
	N. Brunswick SD	Brunswick County				
	Northwest	Brunswick County				
	Oak Island	Brunswick County			X	unk
	Ocean Aire Water System	Brunswick County				
	Ocean Isle Beach	Brunswick County	X	0.276	X	0.424
	Shallotte	Brunswick County	X	unk	X	0.449
	Southport	Brunswick County				
	Sunset Beach	Brunswick County			X	0.66
Chatham	Chatham County East	Sanford			X	unk
	Chatham County North	**B. Everett Jordan Lake**				
	Chatham County Southwest	Goldston Gulf SD, Siler City				

	Goldston Gulf SD	**Deep River**				
	Pittsboro	**Haw River**				
	Siler City	**Rocky River, Dobson Lake**				
	St. Lukes Water	Goldston Gulf SD				
Cumberland	Aqua North Carolina, Inc.	Harnett County RWS				
	Brettonwood Hills	Fayetteville PWC				
	Falcon	Dunn			X	0.104
	Fayetteville PWC	**Cape Fear River, Glenville Lake, Big Cross Creek**				
	Godwin	Falcon				
	Kelly Hills	Fayetteville PWC				
	Linden	Harnett County RWS				
	Maxwell Water Company	Fayetteville PWC				
	Old North Utility Services, Inc. (Fort Bragg)	**Little River, Fayetteville PWC, Harnett County RWS**				
	Spring Lake	Fayetteville PWC, Harnett County RWS				
	Stedman	Fayetteville PWC			X	0.045
Guilford	Gibsonville	Burlington				
	Greensboro	**Lake Townsend, Lake Brandt, Lake Higgins, Reidsville, Burlington**	X	3.3		
	High Point	**Deep River (City Lake, Oak Hollow)**	X	3.76	X	unk
	Jamestown	High Point, Greensboro			X	unk
Harnett	Angier	Harnett County RWS				
	Bragg Comm./NTA Water System	Harnett County RWS				
	Coats	Harnett County RWS				
	Dunn	**Cape Fear River**			X	unk
	Harnett County Regional Water System	**Cape Fear River**			X	unk
	Lillington	Harnett County RWS				
Hoke	Hoke County	Fayetteville PWC			X	unk
Johnston	Benson	Dunn	X	unk	X	0.938
	Johnston County	Benson			X	0.063

Lee	Broadway	Sanford				
	Sanford	**Cape Fear River**	X	3.88	X	0.87
	Utilities, Inc. (Carolina Trace)	Sanford				
Moore	Carthage	**Nicks Creek**			X	unk
	East Moore Water District	Harnett County RWS				
	Moore County Public Utilities-Vass	East Moore Water District				
	Robbins	**Cabin Creek, Bear Creek**				
	Skyline Estates	Harnett County RWS				
	Woodlake	Harnett County RWS				
New Hanover	Lower Cape Fear WSA	**Cape Fear River**				
	Wilmington	**Cape Fear River**	X	unk	X	unk
Orange	Orange Water and Sewer Authority	**Cane Creek Reservoir, University Lake**				
	Orange-Alamance Water	Haw River, Town of			X	0.484
Randolph	Archdale	High Point				
	Franklinville	Ramseur				
	Ramseur	**Sandy Creek**				
	Randleman	**Polecat Creek (City Reservoir)**				
Rockingham	Reidsville	**Lake Reidsville, Lake Hunt**			X	unk
	Rockingham County	Reidsville			X	unk
Sampson	Sampson County	Dunn			X	0.616
Wake	Apex	**B. Everett Jordan Lake**	X	2.22	X	unk
	Cary	**B. Everett Jordan Lake**	X	11.66	X	unk
	Feltonsville Community	Apex			X	0.009
	Fuquay Varina	Harnett County RWS	X	unk	X	unk
	Holly Springs	Harnett County RWS			X	0.118
	RDU	Cary			X	0.26