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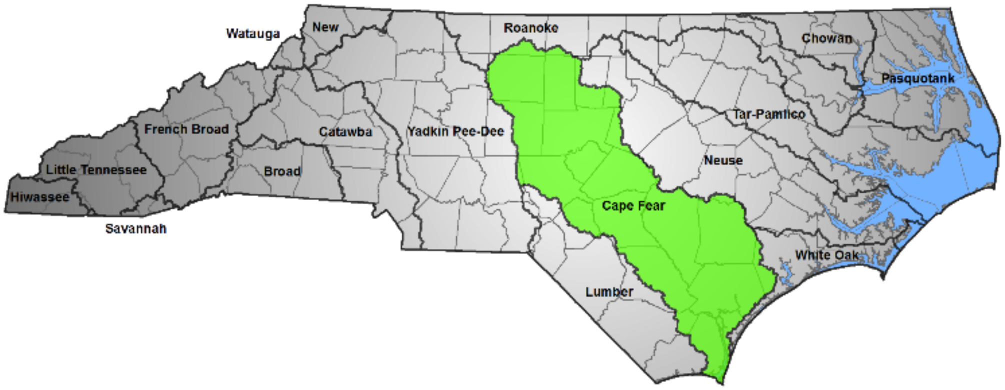
Cape Fear River
Water Supply Evaluation



Prepared by:
North Carolina
Division of Water Resources
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Executive Summary

The Cape Fear River Water Supply Evaluation reviews the long term water needs of public water systems that depend on surface water from the Deep River, Haw River and Cape Fear River subbasins and their ability to meet those needs through 2060. The scope of this analysis is limited to public water systems and self-supplied industrial facilities that use surface water and the neighboring water systems that depend on them. The evaluation is based on information submitted to the Division of Water Resources from community water systems and self-supplied industrial water withdrawers under the local water supply planning and water withdrawal registration programs. Additional details were provided by local governments that submitted applications for allocations of water supply storage from Jordan Lake.

While the driving force for this evaluation is to determine the need for and effects from allocations of water from the water supply pool in B. Everett Jordan Lake, defensible allocation decisions require consideration of the adequacy of other regional water supply sources. Communities in several portions of the basin depend on water from the Neuse River Basin. Likewise, communities in some areas within the Neuse River Basin depend on water from the Haw River and Cape Fear River subbasins. Therefore, this evaluation looks at the interdependency of communities on surface water withdrawals from the Deep River, Haw River, Cape Fear River, Neuse River and Contentnea Creek subbasins with an emphasis on the effects on surface water availability upstream of Lock & Dam # 1 on the Cape Fear River in Bladen County.

Since the early 1990s North Carolina has required persons that withdraw large quantities of water to register their withdrawals.[1] Units of local government and other large community water systems meet this requirement by preparing and updating a local water supply plan. [2] These programs are managed by the Division of Water Resources. Both programs require annual reporting of data on current water sources and use. In addition, the local water supply plans include information on projected water demands through 2060. These two programs provide the foundation of water use data to evaluate water needs from a basin perspective. The Cape Fear - Neuse River Basins Hydrologic model, the schematic of which is shown in Figure ES-2, was calibrated to reproduce known water resource conditions in 2010 providing a representation of current conditions and a point of comparison for changes predicted from model scenarios based on various levels of water withdrawals needed to meet future customer demands. Each model scenario evaluates a specific set of withdrawals and management options over the range of surface water flows that occurred in the Deep River, Haw River, Cape Fear River, Neuse River and Contentnea Creek river subbasins from January 1930 to September 2011. The modeling results are contingent on the specific data and assumptions used in the model. Local governments that submitted applications for allocations of water from the Jordan Lake water supply pool submitted additional details on demand projections and water supply options. The ability of surface water sources to provide enough water to meet water demands at specific intake locations is evaluated using the hydrologic model to look at conditions for each of the 29,858 days in the historic flow data.

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[1] NC GS § 143-215.22H

[2] NC GS § 143-355 (l)

The analysis focuses on the amount of water available from sources used by communities, industry and agricultural operations. While the analysis may show that water is available from a particular source, some water utilities may have to increase the pumping or treatment capacity to deliver the desired amount of water to meet customer demands in 2060. The Cape Fear – Neuse River Basins Hydrologic Model used for this analysis does not reserve water to protect ecological integrity and it does not include water quality data.

The hydrologic model characterizes surface water quantity conditions over the range of flows represented by the 81-year historic record. It characterizes water quantity conditions by evaluating the effects of withdrawals and inflows as water flows downstream from the headwaters to the model's terminal node where streamflows become tidally influenced. Figure ES-1 shows the geographic boundaries and the subbasin designations used in this analysis. The red dots in each basin show the downstream limits of the Cape Fear – Neuse River Basins Hydrologic Model.

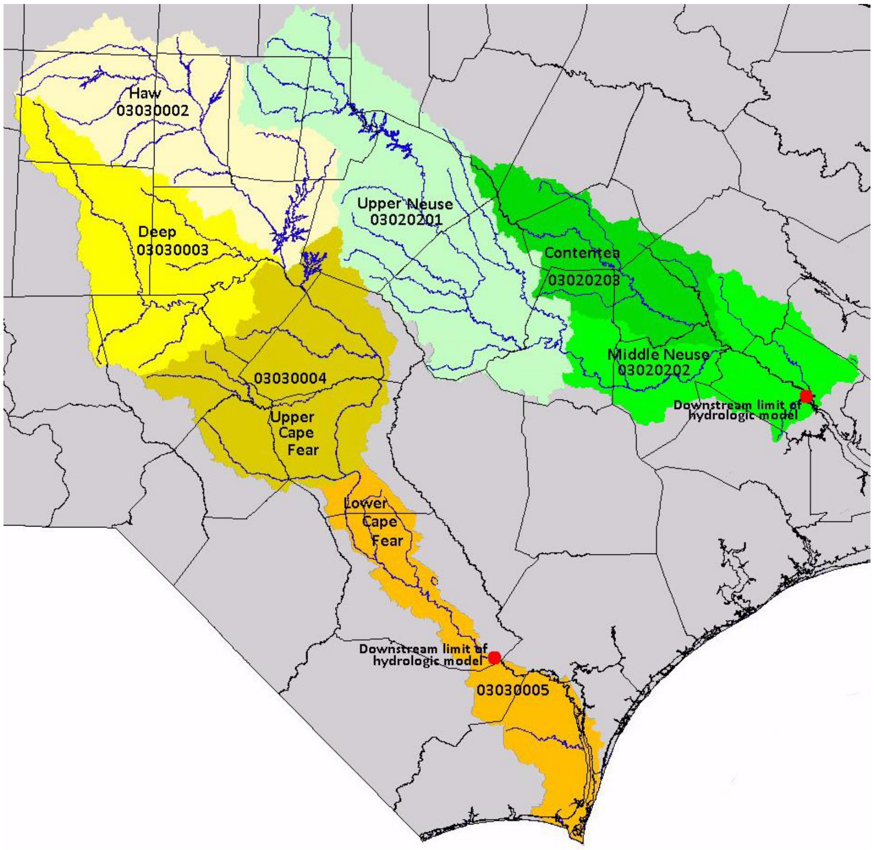
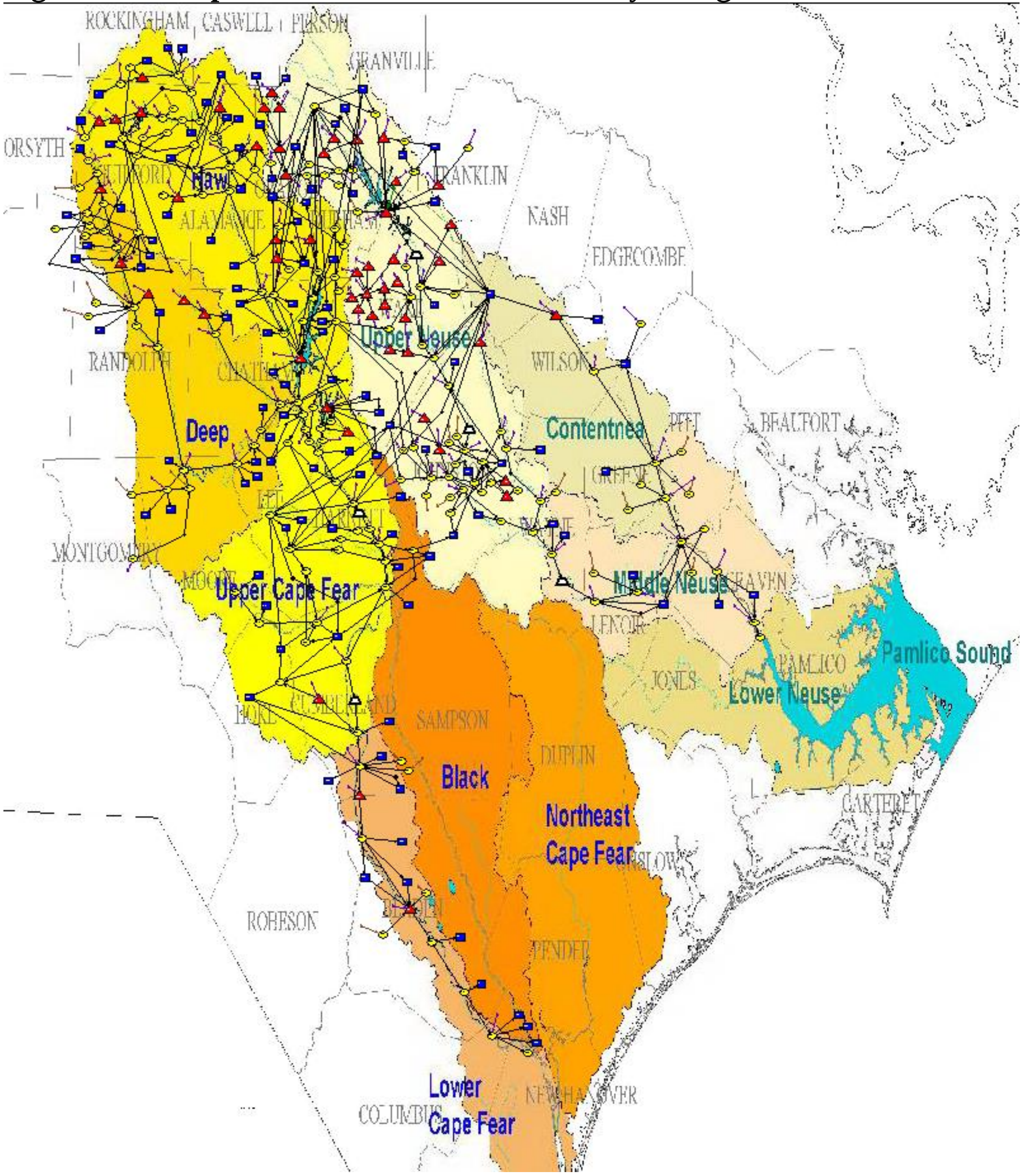


Figure ES-1 Geographic scope of Cape Fear - Neuse River Basin Hydrologic Model

The water utilities included in this analysis are listed in Table 1in the body of this report along with estimates of the number of people currently served and projected to be served in the future. The specific sources and estimated available supply amounts for each utility evaluated in this study are shown in Table 2 and water demand estimates are shown in Table 3. Table 4 presents estimates of future water demands prepared by DWR using service population estimates from the local plans and the calculated gallons per person per day based on usage in 2010, the basecase year of the hydrologic model.

The Cape Fear – Neuse River Basins Hydrologic Model is a computer based tool that evaluates changes in surface water quantities at specific locations based on processing water withdrawal estimates and associated wastewater returns in the context of streamflows that occurred between 1930 and 2011. The schematic presentation of the model structure in Figure ES-2 shows the complexity of water sharing among water utilities in these basins.

Figure ES-2 Cape Fear - Neuse River Basins Hydrologic Model Schematic



B Everett Jordan Dam and Lake

B. Everett Jordan Dam was constructed in response to flooding of the Cape Fear River. The Cape Fear River experienced several significant flooding events prior to the devastating flood of September 1945 which produced an estimated $4.7 million dollars of damage[3] in Fayetteville. The Deep River Subbasin and Haw River Subbasin received about six inches of precipitation during the first week of September that year producing river flows at Lillington,

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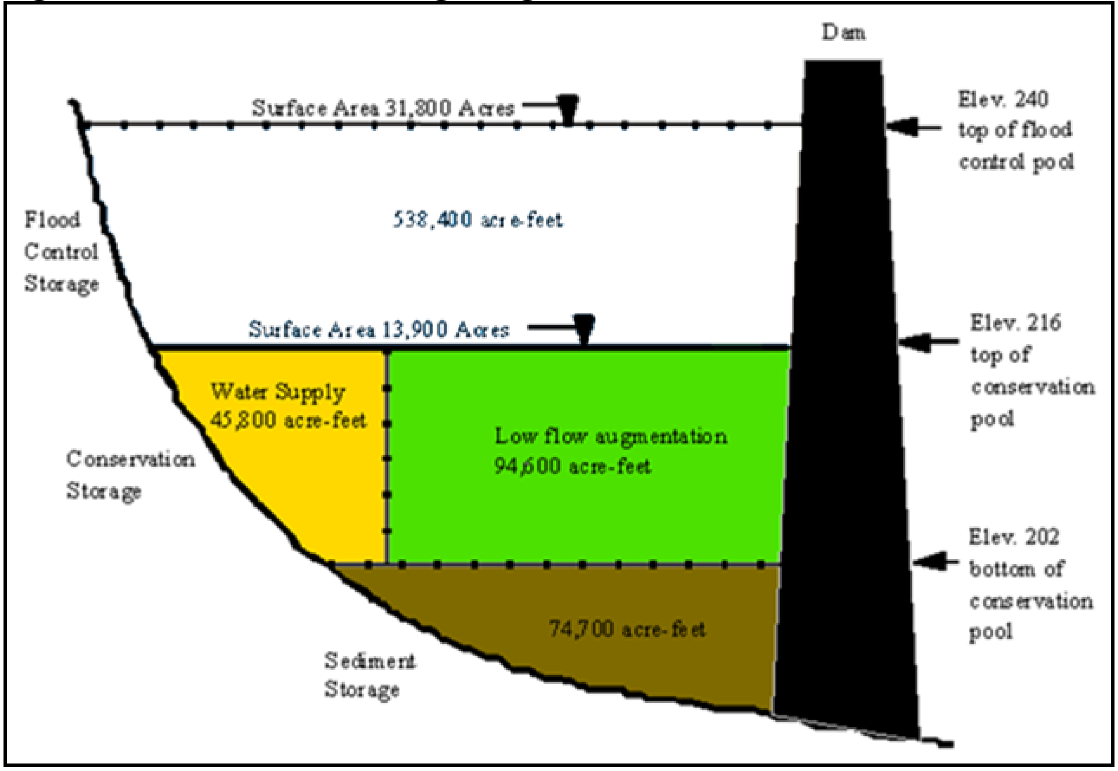
[3] 2007; Carolina Public Health; "The Lake That Almost Wasn't"; Spivey, Angela; Fall 2007

upstream of Fayetteville, of 140,000 cubic feet per second. The citizens of Fayetteville saw the Cape Fear River rise to 68.9 feet above mean sea level, more than 33 feet above flood stage. Shortly after this event the U.S. Congress commissioned the U.S. Army Corps of Engineers to study water resource needs in the basin.

In 1963, based on the results of this study, the U.S. Congress authorized the construction of "New Hope Reservoir" on the Haw River to address issues identified by the USACE. Construction began in 1967. In 1973 the project was renamed in honor of U.S. Senator B. Everett Jordan. "The purposes of B. Everett Jordan Dam and Lake are to provide flood damage reduction, water supply, water quality control, fish and wildlife conservation and outdoor recreation."[4] The reservoir water levels first met normal operating levels in February 1982.

Figure ES-3 Jordan Lake Storage Diagram



B. Everett Jordan Dam can retain the runoff from a six inch rainfall on the reservoir watershed in the 538,400 acre-feet[5] dedicated to flood storage. Water in the flood control pool can be released in a controlled manner to manage flooding impacts downstream. The upper level of controllable flood storage is at 240 feet mean sea level. Above this elevation water flows freely over the spillway.

The project also includes 94,600 acre-feet of storage to provide water for flow augmentation to address water quality issues downstream. During the study the State of North Carolina

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[4] http://www.saw.usace.army.mil/Locations/DistrictLakesandDams/BEverettJordan.aspx

[5] 538,400 acre-feet can hold 175.4 billion gallons of water

agreed to assume financial responsibility for expanding the storage capacity to provide 100 million gallons per day of water to address future water supply needs. Therefore, the project includes 45,800 acre-feet of storage for water supply needs. In addition, 74,700 acre-feet of storage are included to provide the ability to compensate for space lost to the water supply and flow-augmentation pools due to sediment accumulation over the life of the project

When not in flood control mode the reservoir water level is maintained at 216 feet above mean sea level, except during times of low inflows. At this elevation the conservation storage and sediment storage pools are full. The storage between 202 feet mean sea level and 216 feet mean sea level is dedicate to flow augmentation and water supply. Storage below 202 feet mean sea level is reserved to compensate for sediment accumulation in the reservoir.

Withdrawals from the flow augmentation account and the water supply accounts are tracked separately and deducted from the volumes stored for each purpose. Therefore it is helpful to think of them as two separate reservoirs. Water in the flow augmentation account is not used for water supply and water in the water supply account is not used to augment streamflow below the dam.

Flood Risk Management

Since the completion of Jordan Lake the highest water levels in the Cape Fear River at Fayetteville were generated by Hurricane Fran in 1996 when the water level reached 44 feet mean sea level. This was above the minor flooding elevation of 35 feet but well below the 1945 flood elevation of 68.9 feet. Precipitation from Hurricane Fran pushed the water level in Jordan Lake to 233.25 feet mean sea level storing about 341,409 acre-feet (over 111 billion gallons) of water in the flood control pool and moderating water levels in Fayetteville.[6]

The Cumberland County Multi-jurisdictional Hazard Mitigation Plan Update of 2010 includes the following statement. “Although the Jordan Dam and Lake serve multiple purposes, such as water supply, recreation, and flood-control, it is the flood-control purpose that is most important in Fayetteville. For example, it is estimated that this project provided an 8-foot reduction in the 100-year flood stage at the U.S. Geological Survey’s streamflow gage on the Cape Fear River at Fayetteville.”[7]

Flow Augmentation for Water Quality

During the water resources study the U.S. Army Corps of Engineers consulted with the U.S. Public Health Service and received the recommendation that a flow in the range of 600 cubic feet per second would be needed to meet water quality targets given the standards of

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[6] The National Oceanographic and Atmospheric Administration and the U.S. Geological Survey designate an elevation of 58 feet mean sea level in the Cape Fear River at Fayetteville as the indicator of a major flooding event. This water level would be produced by stream flows in the range of 85,000 cubic feet per second. If the 58,000 cubic feet per second of water flow down the Haw River continued downstream rather than being retained in Jordan Lake flows at the Lillington stream gage could have reached over 99,000 cubic feet per second, a level sufficient to push water levels in Fayetteville into the major flood classification.

[7] 2010; Cumberland County Multi-Jurisdictional Hazard Mitigation Plan Update; prepared by: Comprehensive Planning Section of the Cumberland County Planning & Inspections Department and The Fayetteville Planning Department; March 2011

treatment at the time and volumes of wastewater received by the Cape Fear River.[8] The flow augmentation pool of the project was designed to provide enough water to augment river flows to ensure flows of 600 cubic feet per second at the U.S. Geological Survey's stream gage on the Cape Fear River at Lillington. This level of flow is equivalent to 388 million gallons per day. Prior to the completion of Jordan Lake the low flow of record at Lillington was 11 cubic feet per second in October 1954. Since completion of Jordan Lake Dam and initiation of flow augmentations the lowest daily average flow at Lillington was 155 cubic feet per second during drought conditions in August 2002.

Inflows to the reservoir not needed to maintain normal water levels are passed downstream. Since completion of Jordan Lake Dam flows at Lillington have been above the target more than 80 percent of the time. More than 50 percent of the time flows have exceeded 1000 cubic feet per second. Therefore much of the time water does not need to be released from the flow-augmentation pool to meet the target flows downstream. The ability to use water from the augmentation pool is critical to maintaining downstream flows when inflows to Jordan Lake decline between precipitation events and during droughts.

During the drought of 1986 the target flow was temporarily reduced to 450 cubic feet per second to preserve the water remaining in the flow augmentation pool.[9] A follow-up study recommended adjusting the target flow to 600 ± 50 cubic feet per second to provide more management flexibility. Flows in this range are equivalent to 355 to 421 million gallons per day.

Severe drought conditions from 1998 through 2002 again required temporarily reducing flow targets at Lillington to preserve storage in the flow augmentation pool. In 2008 the USACOE adopted a revised drought management plan that prescribes a progressive reduction in the flow target as the flow augmentation pool is depleted. Stepped reductions begin when storage in the flow augmentation pool drops below 80 percent. This protocol is now implemented automatically as storage declines in the flow-augmentation pool. The drought response protocol is described in detail in Appendix A.

Water Supply

The State of North Carolina oversees the allocation of 32.62 percent of the conservation pool dedicated to water supply that was designed to provide 100 million gallons per day of water. Under General Statute § 143-354 (a) (11) the General Assembly authorized the Environmental Management Commission to allocate water supply storage in Jordan Lake to local governments upon proof of need and the commitment to pay the capital, interest,

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[8] 1990; Testimony of John N. Morris, Director, Division of Water Resources: Transcript of Fayetteville Area Chamber of Commerce; The Lower Cape Fear Water and Sewer Authority; the Counties of Bladen, Brunswick, Columbus, New Hanover, Pender and the City of Wilmington; Mike Pleasant, President and the Fayetteville Area Economic Development Corporation; City of Fayetteville, a North Carolina Corporation; and the County of Cumberland v. North Carolina Department of Environment, Health and Natural Resources and the Environmental Management Commission: August 16, 1990: Raleigh, NC: before Beecher R. Gray, Senior Administrative Law Judge.

[9] 1987; NC Department of Natural Resources and Community Development; Draft Report, Jordan Lake Hydrology and Downstream Water Quality Considerations.

administrative and operating costs based on the volume allocated. The allocation rules allow the EMC to make allocations sufficient to meet applicants' water supply needs over a 30 - year planning horizon. For allocation requests where the withdrawal or return flows would be a transfer of surface water requiring an interbasin transfer certificate the review of the application for an interbasin transfer certificate must be coordinated with the review of the allocation request. [10]

Due to the uncertainty of whether the desired water supply demands and flow augmentation requirements could be met as water supply withdrawals increased the allocation rules limited diversions out of the Jordan Lake watershed to 50 percent of the water supply pool yield. This rule did give the EMC the authority to "review and revise this limit based on experience in managing the lake and on the effects of changes in the lake's watershed that will affect its yield".[11] Since 1988 there have been changes on the watersheds above Lillington that have enhanced the reliability of the water supply and flow augmentation pools in Jordan Lake. Table ES-1 shows the current and requested allocations from the Jordan Lake water supply pool.

The Cape Fear - Neuse River Basins Hydrologic Model

The Division of Water Resources uses a hydrologic modeling designed to simulate water resource systems to evaluate surface water availability under various water withdrawal and management scenarios. The hydrologic model creates a hypothetical representation of surface water conditions based on available data and inferences from known data to characterize the relationships between water withdrawals, return flows and management protocols. The basecase model scenario produces a mathematical characterization of surface water volumes and streamflows based on conditions in 2010. The basecase scenario evaluates water usage and existing infrastructure and management protocols over the range of stream flows experienced from January 1930 through September 2011. The model does not project future streamflow conditions. Outputs from the basecase scenario provides information on the magnitude and duration of water shortages that might have occurred during historic flow conditions or that may occur if similar flow conditions occur in the future with water withdrawals to meet the 2010 water demands.

Scenarios based on alternative water withdrawal volumes and management options are compared to the basecase scenario to identify how conditions could vary compared to current conditions represented by the basecase scenario. The alternative scenarios that are the focus of this document are constructed around the water withdrawals expected to be needed to meet customer demands in 2060. This fifty-year planning period is consistent with requests from

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[10] http://www.ncwater.org/?page=297 15A NCAC 02G .0504 (h)

[11] 15A NCAC 02G .0504 (h) To protect the yield of Jordan Lake for water supply and water quality purposes, the Commission will limit water supply allocations that will result in diversions out of the lake's watershed to 50 percent of the total water supply yield. The Commission 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 will affect its yield.

the Environmental Management Commission in previous Jordan Lake Water Supply Allocation processes to look at long-term impacts of allocation decisions.

The geographic scope of the Cape Fear – Neuse River Basins Hydrologic Model is shown in Figure ES-2. For surface water users included in the model estimates of future water demands are derived from local water supply plans and other available data. Corresponding wastewater return flows are estimated as the same percentage of water withdrawals used in the basecase model scenario, unless more specific information is available. The annual average amounts are adjusted to estimate monthly average water and wastewater amounts to capture seasonal variability of water demands. Local government water systems provide data on available water sources, including expected future sources, in the local water supply plans.

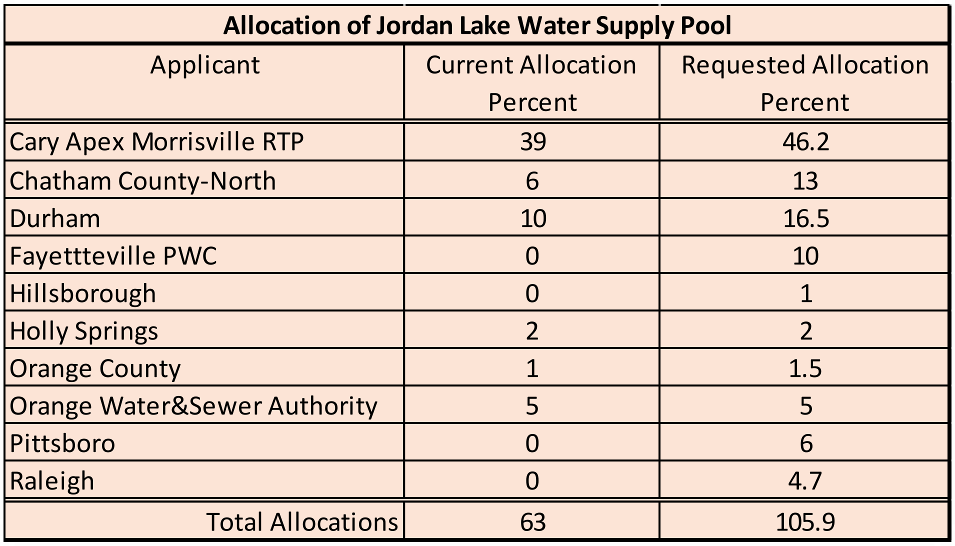
The amount of water available at each surface water withdrawal location is determined within the model based on the historic flow data. For water supply reservoirs water availability is based on reservoir physical characteristics, management protocols, inflows and change in storage. Table 6 in the document lists the annual average withdrawal and wastewater return amounts used in the model scenarios used for this evaluation.

Modeling B. Everett Jordan Reservoir

B. Everett Jordan Reservoir is a multipurpose reservoir built and managed by the US Army Corps of Engineers. It was authorized for flood control, water supply, water quality, recreation, and fish and wildlife conservation. Modeling of Jordan Lake in this evaluation is targeted at identifying the potential impacts to water supply storage, flow augmentation storage, reservoir water levels and streamflows downstream of Jordan Dam as more of the water supply pool is used in the future. The conditions resulting from increased usage of the water supply storage are compared to the conditions generated by the withdrawals needed to meet 2010 demands over an 81-year hydrologic record. Effects on the water supply pool are directly related to water withdrawals by units of local government. Currently 63 percent of the water supply storage is allocated to communities in Chatham, Durham, Orange and Wake counties.

The Division of Water Resources received requests for new or increased allocations totaling 105.9 percent of the water supply pool. Allocation requests are based on anticipated water needs to meet customer demands in 2045. Several model scenarios were constructed to evaluate the ability of surface water withdrawers throughout the Cape Fear River Basin to meet anticipated 2060 demands from existing and planned sources and from two different options of future supplies based on allocation requests. The scenario labels and descriptions are summarized in Table ES-2. Each model scenario evaluates a set of withdrawals needed to meet customer demands based on the current and expected future infrastructure configurations described in the local water supply plans and the Jordan Lake Allocation applications.

Table ES- 1 Current and Requested Water Supply Allocations



Allocation of Jordan Lake Water Supply Pool

Applicant	Current Allocation Percent	Requested Allocation Percent
Cary Apex Morrisville RTP	39	46.2
Chatham County-North	6	13
Durham	10	16.5
Fayettteville PWC	0	10
Hillsborough	0	1
Holly Springs	2	2
Orange County	1	1.5
Orange Water&Sewer Authority	5	5
Pittsboro	0	6
Raleigh	0	4.7
Total Allocations	63	105.9

Table ES-2 Model Scenario Descriptions

Model Scenario Descriptions	
Simbase_Current	This scenario models the baseline current conditons in 2010 based on available water supplies, infrastructure and customer demands at that time
01_LWSP_Dem_2060	**LWSP** indicates this scenario uses demand and supply data from the local water supply plans of all water systems dependent on surface water sources in the model. **Dem_2060** indicates this scenario is modeling the ability to meet the estimated water withdrawals needed to meet 2060 demands.
03_JLA_F_Req2045_Dem2060	**JLA** indicates this scenario uses data from Jordan Lake Water Supply Allocation applications submitted to DWR. **Req2045** indicates this scenario adds the requested Jordan Lake allocations to existing water supplies reported in the LWSPs. The **"F"** indicates this scenario includes the allocation request for all the applicants including Fayetteville PWC. **Dem2060** indicates this scenario evaluates the ability to meet the water withdrawals needed to meet 2060 water demands and the resulting changes to water availability.
02_JLA_Req2045_Dem2060	**JLA** indicates this scenario uses data from Jordan Lake Water Supply Allocation applications submitted to DWR. **Req2045** indicates this scenario adds the requested Jordan Lake allocations to the available water supplies for all applicants. The **lack of an "F"** indicates this scenario does not include the allocation request for Fayetteville PWC. **Dem2060** indicates this scenario evaluates the ability to meet the water withdrawals needed to meet 2060 water demands and the resulting changes to water availability.

Modeling indicates that for at least 60 percent of the days represented in the historic flow record the water supply and water quality pools are at or above 100 percent full and the water elevation in Jordan Lake is at or above the normal operating elevation. Figures ES-4, ES-5 and ES-6 show the 40 percent of time over the historic record when modeling shows storage is less than full and when reservoir water elevations drop below the normal operating elevation of 216 feet above sea level.

The top line in Figures ES-4, ES-5 and ES-6 represents conditions produced by withdrawals to meet 2010 customer demands. All model scenarios are evaluated over the range of flow conditions from 1930-2011. The basecase scenario is used to provide a set of conditions that are likely to be familiar to readers. They provide a baseline against which the effects of future withdrawal levels can be compared. Figure ES-4 shows that as use of the water supply pool increases the percent of storage will be lower for longer periods of time.

Figure ES-4 Jordan Lake Water Supply Storage Duration Graph

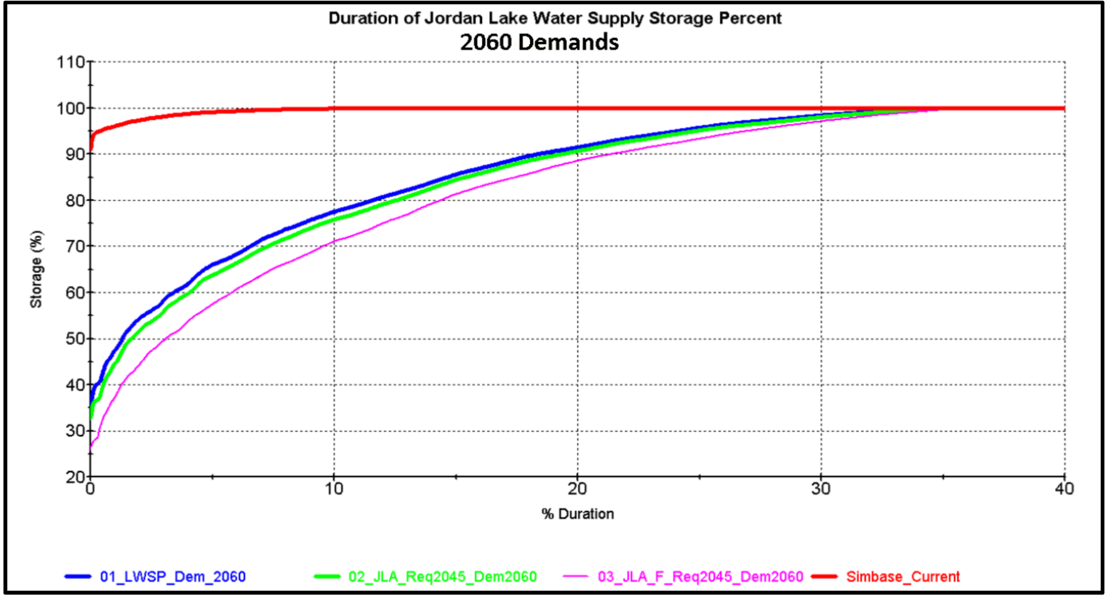


Figure ES-5 shows that the water quality pool will be below full for more time over the flow ranges in the model as surface water withdrawers increase use in the future. The storage for each percent of the flow of the flow record is predicted to be lower in the future compared to the 2010 basecase scenario figures. However, so declines except in the lowest levels reached in each scenario. In the future the minimum water quality pool storage rises to 29 percent from the 21 percent level shown for the 2010 demand scenario.

Figure ES-5 Jordan Lake Water Quality Storage Duration Plot

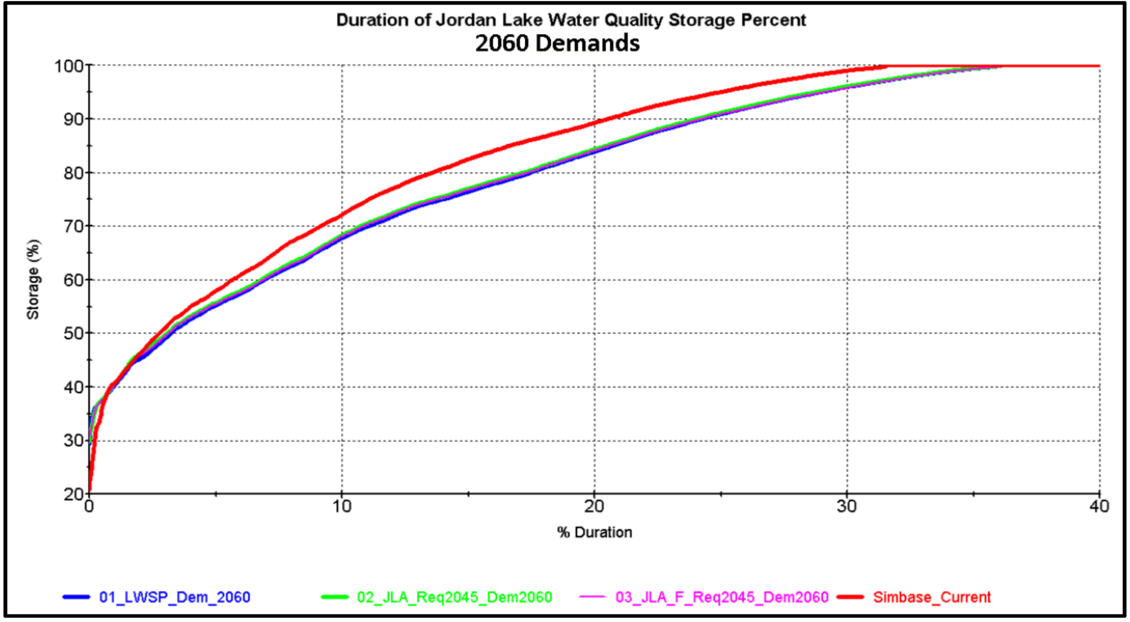


Figure ES-6 Jordan Lake Water Level Duration Graph

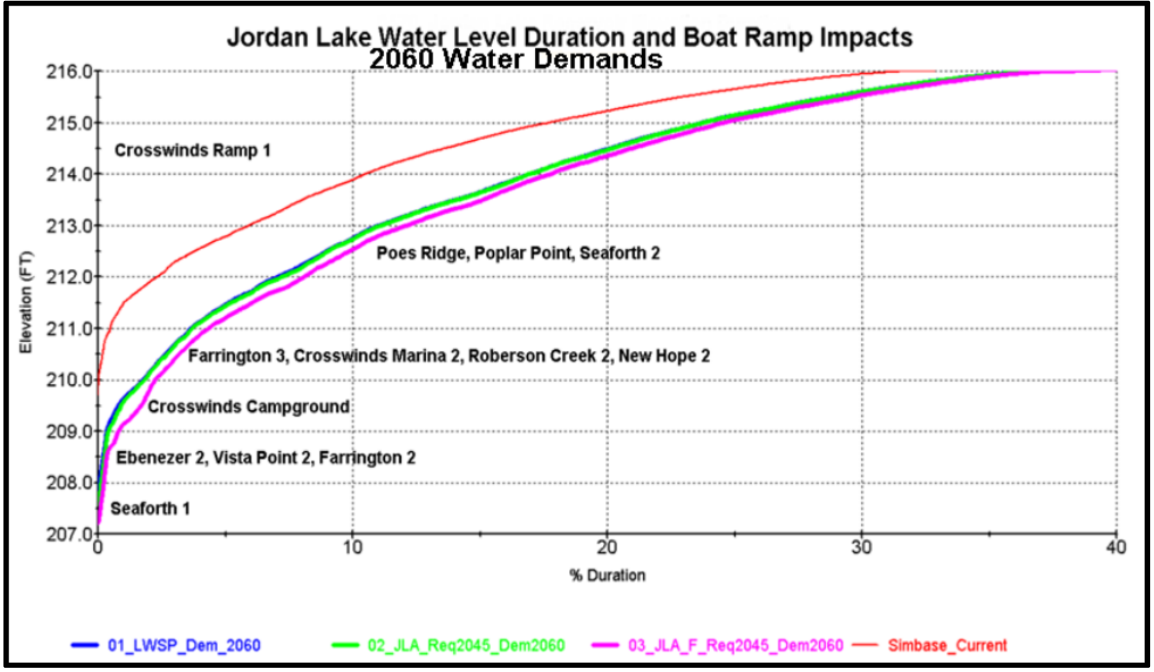


Figure ES-6 shows the combined effects of changes in water supply and water quality storage on water levels in Jordan Lake. It also indicates elevations at which the use of specific boat ramps may be compromised. As use of water from Jordan Lake increases boat launching facilities will be impacted more.

Tables ES-4 and ES-5 show the minimum values reached and when they occurred for the reservoir water levels, water supply and water quality pool storage and streamflows in the Cape Fear River at Lillington for each of the included model scenarios.

Table ES-4 Jordan Lake Minimum Values

Jordan Lake Storage Conditions and Target Flow Summary							
Model Scenario	Jordan Lake Water Level		Jordan Lake Water Supply Pool				
	Minimum Level, ft	Date of Minimum Level	Minimum Water Supply Storage %	Minimum Water Supply Period	Days in Minimum Supply Period	Longest Period Storage < 100%	Days in Critical Period
Simbase-current	209.72	8/30/2002	90.91	7/9/1953 - 12/9/1953	154	7/9/1953 - 12/9/1953	154
01_LWSP_Dem2045	207.99	12/1/1953	42.22	7/7/1953 - 1/15/1954	193	5/17/1933 - 3/4/1934	292
01_LWSP_Dem2060	207.66	10/23/2007	35.73	7/6/1953 - 1/15/1954	194	5/17/1933 - 3/5/1934	293
02_JLA_Req2045_Dem2045	207.82	12/1/1953	38.03	7/6/1953 - 1/15/1954	194	5/17/1933 - 3/4/1934	292
02_JLA_Req2045_Dem2060	207.59	12/1/1953	32.82	7/6/1953 - 1/15/1954	194	5/17/1933 - 3/5/1934	293
03_JLA_F_Req2045_Dem2045	207.37	12/1/1953	28.66	5/17/1934 - 3/5/1934	293	5/17/1934 - 3/5/1934	293
03_JLA_F_Req2045_Dem2060	207.21	12/1/1953	26.09	5/17/1933 - 3/6/1934	294	5/17/1933 - 3/6/1934	294

Table ES-5 Minimum Values J.L. Water Quality Pool and Cape Fear River Flow at Lillington

Jordan Lake Storage Conditions and Target Flow Summary								
Model Scenario	Jordan Lake Water Quality Pool				Lilington Low-Flow*			
	Minimum Water Quality Storage, %	Date of Minimum Storage	Days Water Qualtiy Storage = 0	Events Water Qualtiy Storage = 0	Lowest Daily Flow, cfs	Date of Lowest Daily Flow	Years with Flow < 600 cfs**	Days with Flow < 600 cfs**
Simbase-current	20.82	8/30/2002	0	0	284.55	10/1/2007	61	4,274
01_LWSP_Dem2045	29.53	10/23/2007	0	0	171.12	8/19/2002	64	4,987
01_LWSP_Dem2060	29.29	10/23/2007	0	0	151.80	8/19/2002	66	5,107
02_JLA_Req2045_Dem2045	30.09	10/23/2007	0	0	174.82	8/19/2002	64	4,955
02_JLA_Req2045_Dem2060	29.82	10/23/2007	0	0	157.66	8/19/2002	66	5,071
03_JLA_F_Req2045_Dem2045	30.09	10/23/2007	0	0	174.53	8/19/2002	65	4,974
03_JLA_F_Req2045_Dem2060	29.88	10/23/2007	0	0	155.59	8/19/2002	66	5,108

Note * The flow record used for these model scenarios contains a total of 29,858 days in the period of record.

Note** The flow target at the Lillington streamgage is 600 ± 50 cfs (cubic feet per second). The count in these columns will include periods when flows were estimated to be between 550 and 600 cfs, not technically a violation of the target.

Table ES-6 Jordan Lake Water Supply Yield Analysis Results

Estimated Jordan Lake Water Supply Yield									
Model Set Up	Return Flow Assumption			2010 Basecase Scenario			2060 Demand Scenario		
	Percent of Withdrawal Returned to Jordan Lake Watershed	Percent of Withdrawl Returned Below Jordan Lake Dam	Percent of Withdrawal Out of Basin	Estimated Water Supply Yield (MGD)	Jordan Lake Minimum Elevation (ft-msl)	Minimum Water Supply Storage 2/24/1934 (%)	Estimated Water Supply Yield (MGD)	Jordan Lake Minimum Elevation (ft-msl)	Minimum Water Supply Storage 2/24/1934 (%)
1	0	0	100	104.06	202.65	0.65	112.92	203.03	0.79
2	100	0	0	156.94	204.30	1.07	169.66	204.06	1.18
3	0	100	0	104.98	203.55	0.74	113.84	203.36	1.60
4	50	50	0	125.44	203.88	2.69	136.69	203.67	0.96
5	50	0	50	124.19	202.69	0.86	134.86	203.07	0.87
6	0	50	50	104.00	202.65	0.71	112.92	203.03	0.73
7	25	75	0	114.63	203.70	1.17	124.81	203.50	0.81
8	25	0	75	113.25	202.67	0.73	122.91	203.05	0.85
9	75	25	0	140.31	204.07	0.95	151.45	203.86	0.97
10	0	25	75	103.99	202.65	0.75	112.92	203.03	0.77
11	75	0	25	137.56	202.71	0.89	149.55	203.04	1.02
12	0	75	25	104.00	202.65	0.70	112.92	203.03	0.71

Table ES-6 shows the results of an analysis of the potential yield of the water supply storage pool in Jordan Lake based on where withdrawn water is discharged back to the waters of the state. The 2010 Basecase Scenario values reflect current management protocols. The 2060 Demand Scenario values take into consideration changes to sources, discharge volumes and management protocols upstream of Jordan Lake that are expected to occur by 2060 based on information submitted to DWR. The theoretical yield estimates range from 104 million gallons per day if all the withdrawn water was removed from the Cape Fear River Basin to 157 million gallons per day if all the withdrawn water was returned to the Jordan Lake watershed.

As noted earlier the Cape Fear – Neuse River Basins Hydrologic Model includes surface water dependent utilities in the Deep River, Haw River, Cape Fear River, Neuse River and Contentnea Creek subbasins. It includes 40 surface water withdrawals that provide water for 118 community and industrial water systems. This evaluation looks at the ability of the modeled withdrawers in the Deep River, Haw River and Cape Fear River subbasins to meet estimated withdrawals needed to meet 2060 customer demands. Demand numbers came from data submitted support Jordan Lake water supply allocation requests and from local water supply plans and water withdrawal registrations submitted to DWR for non-applicants. Many, but not all water withdrawers, have a water shortage response plan included in the model. These plans are designed to reduce demands during drought conditions.
This analysis assumes some increased use of water from the water supply pool in Jordan Lake, development of additional supplies and interconnections reported in local water supply plans, and expansion of water treatment facilities for some communities. The analysis depends on several key assumptions built into the hydrologic model of water quantity availability, such as:

- The evaluation focuses on the question, will there be enough water available at specific locations to satisfy estimated future water demands,
- Water is not reserved in rivers and streams to protect aquatic habitat and ecological integrity except to the extent that minimum releases are required,
- Population and demand projections in local water supply plans and Jordan Lake allocation application are the best informed estimates,
- Future water withdrawals will be from the same locations as current withdrawals with the addition of new withdrawal locations specified in the source data,
- Water systems that depend on purchasing water from another water system will continue being supplied by the current seller during the planning horizon of this study,
- Wastewater return flows will continue at the current locations unless additional information is provide,
- Future wastewater return flows will be the same percentage of water use as in the 2010 basecase model scenario unless additional information was provided,
- The model does not predict the future flow conditions, it indicates the effects of withdrawing various volumes of water over the range of streamflow conditions that occurred between 1930 and 2011,
- Agricultural water use is based on estimates developed for previous river basin models and is assumed to be consistent over the planning horizon,
- Water quality is not evaluated,
- Does not evaluate flooding conditions, and

- Does not extend into tidally influenced sections of the Cape Fear River or Neuse River.

Conclusions

Given the assumptions and data used in the Cape Fear – Neuse River Basins Model, the surface water dependent public water systems in the Deep River, Haw River, and Cape Fear River subbasins are not expected to face flow related shortages outside of the ranges that can be addressed if their modeled water shortage response plans are implemented.

Modeling results for Graham, Mebane and Carthage show potential flow related shortages from their existing water sources. However, their local water supply plans indicate the intension for each of these system to upgrade their connections to neighboring water systems in the future to provide additional water. Modeling for Greensboro shows potential supply shortages at demand levels above those shown for 2045. Currently, Greensboro's supply from the Piedmont Triad Regional Water Authority is limited in the model by the existing capacity of the water treatment plant. If water demand grows as predicted in the local water supply plans, there is enough water available from Randleman Reservoir and enough time to increase treatment capacity to address the estimated shortfall.

Introduction

The Cape Fear River Water Supply Evaluation reviews the long term water needs of public water systems that depend on surface water from the Cape Fear River Basin and their ability to meet those needs through 2060. The scope of this analysis of water supply resources in the Cape Fear River Basin is limited to public water systems and self-supplied industrial facilities that use surface water and the neighboring water systems that depend on them. While the driving force for this evaluation is to determine the need for and effects from allocations of water from the water supply pool in B. Everett Jordan Lake, defensible allocation decisions require consideration of the adequacy of other regional water supply sources. Communities in several portions of the basin depend on water from the Neuse River Basin. Likewise, communities in some areas within the Neuse River Basin depend on water from the Cape Fear River Basin. Therefore, the following evaluation will look at the interdependency of communities on surface water withdrawals from both basins with an emphasis on the effects on surface water availability in the Cape Fear River Basin.

The evaluation is based on information submitted to the Division of Water Resources from community water systems and self-supplied industrial water withdrawers. Since the early 1990s North Carolina has required persons that withdraw large quantities of water to register their withdrawals.[12] Units of local government and other large community water systems meet this requirement by preparing and updating a local water supply plan. [13] The Division of Water Resources receives and manages the data submitted under these programs. The local water supply plans include information on projected water demands through 2060 as well as data on current water use and water sources. Other registrations focus on water use and water sources for a particular year and do not include projections of future needs. Data under both of these programs are submitted annually to DWR. These two programs provide the foundation of water use data to evaluate water needs from a basin perspective.

The analysis used for this evaluation focuses on the amount of water available from the source used by each community. While the analysis may show that water is available from a particular source, some communities may have to increase the pumping or treatment capacity to be able to deliver enough water to meet future customer demands. The model used for this analysis, which will be described in more detail later in this document, does not reserve water to protect aquatic habitat. If the evaluation indicates a supply shortage while trying to meet the volume of water needed to meet a given level of demand it is because the model indicates no water is available from the source. The results of analyzing the potential shortages based on modeling results will be discussed in this document.

The Cape Fear – Neuse River Basins Hydrologic Model will be discussed in detail and the various modeling scenarios used for this evaluation will also be described. The adequacy of water supply sources will be discussed. The applications for water supply storage from Jordan Lake will be summarized and the results of modeling several allocation options will be discussed.

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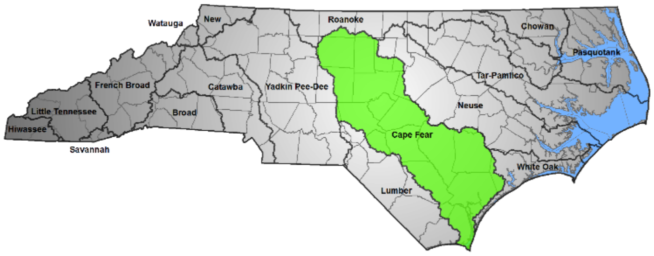
[12] NC GS § 143-215.22H

[13] NC GS § 143-355 (l)

Cape Fear River Basin

Figure 1 Cape Fear River Basin



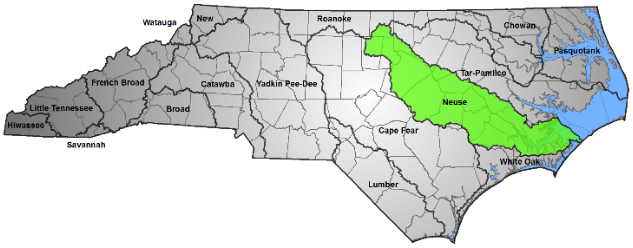
The Cape Fear River Basin is the largest river basin located entirely within North Carolina encompassing 9,200 square miles. Its 1600 miles of rivers and streams begin in the southern parts of Rockingham and Caswell counties and converge to form the Cape Fear River in Chatham County on its way to flow 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. The Haw and Deep river subbasins, with the hilly terrain characteristic of the Piedmont physiographic region, have most of the water supply reservoirs in the basin. B. Everett Jordan Dam, on the Haw River, creates Jordan Lake the largest reservoir in the basin, which is capable of holding four million acre-feet of water. At the normal operating water level of 216 feet above mean sea level the reservoir stores water for public water supply and downstream flow augmentation for water quality. Above this elevation there are twenty-four vertical feet of flood storage capable of retaining 538,400 acre-feet of runoff during high-flow events for controlled release to minimize downstream flooding.

Downstream of Jordan Dam the Haw River and the Deep River converge to form the Cape Fear River. The flow of the river is constrained at four locations below Jordan Lake by dams that do not regulate flow but do create pools in the river with water levels determined by the elevations of the tops of the dams. Moving downstream from Jordan Lake, Buckhorn Dam, south of State Route 42 near Corinth, creates the first such backwater. Below the City of Fayetteville there are three sets of locks and dams in the Cape Fear River 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, near the community of Kelly in Bladen County, is the downstream limit of the evaluation of the effects of surface water withdrawals from Cape Fear River Basin.

Effectively evaluating water supply resources and options in the Cape Fear River Basin also requires evaluating water supply conditions in the Neuse River Basin. Regional water sharing and interconnections between public water utilities are critical to reliably meeting community water needs in both river basins.

Neuse River Basin

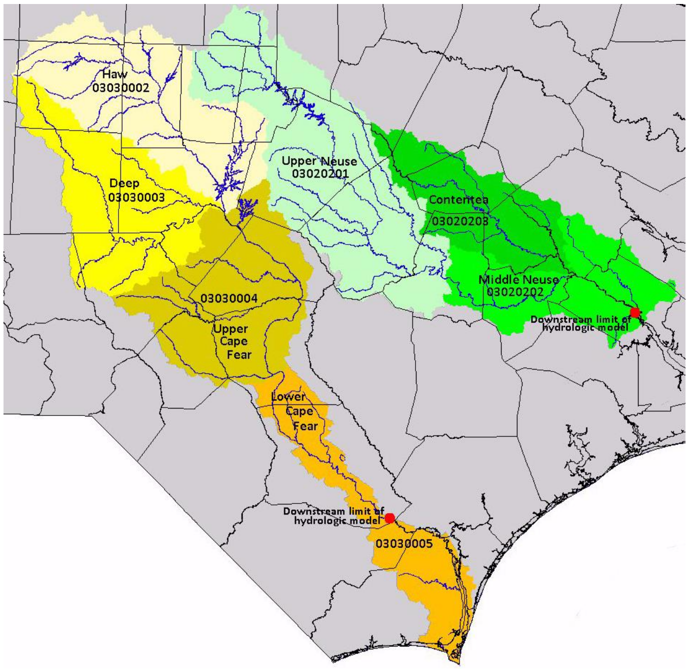
Figure 2 Neuse River Basin



The Neuse River Basin lies entirely within the state draining an area of 6,235 square miles in eighteen counties. It is the third largest river basin in North Carolina. The Eno, Flat and Little rivers merge to form the Neuse River in eastern Durham County in an area now inundated by Falls Lake. Falls Lake, built and operated by the U.S. Army Corps of Engineers, is the largest reservoir in the Neuse River Basin. It is a multipurpose reservoir that provides storage for water supply and flow augmentation as well as flood storage to contain runoff from high-flow events to reduce downstream flooding. Below Falls Lake the Neuse River regains its riverine character as it flows southeasterly through the broad flat terrain of the Coastal Plain to empty into Pamlico Sound.

The Town of Hillsborough and the City of Durham rely on reservoirs on the Eno River and the Flat and Little river watersheds, respectively, to supply water to their water treatment plants. Downstream of these reservoirs, Falls Lake is the primary source of water for the City of Raleigh and the surrounding communities that have partnered with the Raleigh Public Utilities Department. Raleigh also has a water supply source available from the Swift Creek watershed that supplements the available supply from Falls Lake.

Figure 3 Geographic Scope of the Hydrologic Modeling



The quantitative analysis used for evaluating the adequacy of surface water resources is derived from the outputs of a computer-based hydrologic model. The model characterizes surface water quantity conditions, based on historic flow data, by appraising withdrawals and inflows as water flows downstream from the headwaters to the model's terminal node where streamflows become tidally influenced. Figure 3, shows the geographic boundaries and the subbasin designations of the Cape Fear River Basin and Neuse River Basin used in this analysis. The red dots in each basin show the downstream limits of the Cape Fear – Neuse River Basins Hydrologic Model.

This document will review the current and projected service population estimates submitted by water systems in the Cape Fear and Neuse river basins in their local water supply plans. These will be followed by a review of the water utilities' reported available water supplies and projections of future water demands from 2020 through 2060.

Water System: Water Supplies and Demands

Many factors influence how and when a community grows including: road, water and sewer infrastructure; local ordinances, land use controls and development patterns; and availability of jobs. For the purposes of this analysis we assume that local officials have the best perspective on their community growth. This analysis accepts the population projections based on currently available data supplied in the local water supply plans submitted by local officials. Population growth is a key determinant of the future water demands on the public water systems. Table 1 shows the estimated service populations for the water supply systems included in the computer modeling and analysis for this evaluation of water supply conditions. The data provide an insight into the number of people each water system is expecting to serve from its drinking water distribution system in the future. The entries in bold are the local governments that applied for a water supply allocation from Jordan Lake.

Table 1 shows the service population projections for the water systems included in the modeling for this analysis. The data came from local water supply plans for 2010 and 2012. Future projections were taken from the 2012 plans to coordinate with the Jordan Lake allocation applications.

This analysis focuses on the quantity of surface water present at various locations throughout the Cape Fear and Neuse river basins and how the quantity may change as a result of the withdrawals needed to meet future water demands. The amount of water a public water system can provide to meet customer needs is an important factor in assessing the possibility of water shortages. How much water a public water system can provide is a function of the amount available from the source and how much can be pumped and treated to produce potable water. This evaluation looks at how much water is available at the location of water supply intakes. It is important to remember that the analysis for this report only looks at the quantity of water available. There may be water quality concerns associated with a particular source that limit the ability to produce potable water or that limit the amount of water that can be withdrawn because of potential impacts to instream water quality. The amount of water available may also be limited by contractual arrangements, resource management regulations or habitat protection needs.

Ground Water Supply

Some public water systems included in this analysis get their water from ground water and surface water sources. Their surface water demands for this analysis are determined by subtracting the yield of ground water sources from future demand projections based on information in their local water supply plans.

A practical definition of “yield” for a ground water well is the long-term rate at which water can be withdrawn without exceeding the natural recharge capability of the aquifer. In coastal areas withdrawals may be limited to the amount that can be pumped without causing saltwater intrusion into an aquifer. Systems using ground water conduct a drawdown test, at least at initial well construction. The drawdown test determines how much water can be withdrawn from a well without exceeding the natural recharge capability of the associated aquifer. The results of the drawdown test are used to determine the maximum sustainable pumping rate, or yield, for the well. North Carolina requires at least a 24-hour drawdown test to determine well yield for public water supply wells.[14]

The rules governing public water systems require that the combined yield of all wells of a water supply system be adequate to meet the average daily demand in 12 hours pumping time.[15] This requirement ensures that the system can reliably provide adequate water to its customers. The combined 12-hour supply for the wells supplying a water system reported in the local water supply plans is used to determine the adequacy of the existing supplies. If the system needs to pump more than 12 hours a day to meet average system demands, the system administrators face the question of whether to encourage customers to use water more efficiently or to develop additional sources of supply or both.

We used the data on existing 12-hour yields from the Local Water Supply Plans as the available supply from ground water sources for the systems included in this analysis.

Surface Water Supply

Surface water can be withdrawn from a stream or river as it flows past an intake, a run-of-river intake, or it can be withdrawn from an impoundment where flowing water is retained behind a structure that retards its movement downstream. Such an impoundment can be a managed reservoir which can control releases downstream or it can simply be a structure in the channel that creates a pool of water at the height of the structure and allows water to flow unrestricted over the top of the structure. The lock and dam facilities in the Cape Fear River are examples of the latter arrangement.

Managed reservoirs impound water during high flow periods for later use when stream flows would otherwise be insufficient to meet withdrawal demands and management goals. Run-of-river intakes simply withdraw a portion of the water in the stream as it flows by with withdrawals limited by the amount of water in the channel or by limits established to meet environmental management goals.

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[14] 15A NCAC 18C .0402(g)(1)

[15] 15A NCAC 18C .0402(g)(3)

For planning purposes the potential yield or available supply can be estimated for reservoirs and run-of-river intake locations, but the methods for determining the yields are different. The potential yield of surface water sources is the amount of water that can be withdrawn during low flow or drought conditions. The potential yield is determined from data on the amount of water that is likely to be available based on the water that was available during a defined period in the recent past.

Run-of-River Intake

Run-of-river intake systems differ from reservoirs in that they are typically limited by the water flowing in the source stream with no ability to augment water supply during extended dry weather periods. During moderate to high flows this is not a problem. However, during low flow periods this inability to augment flows using stored water can be extremely critical. In some cases, even short-term low flow events can result in water shortages if alternative sources are not available to augment water supplies.

A commonly used estimate of expected low flow levels is a measure of flow called the “7Q10.” The 7Q10 low flow is the lowest average flow for seven consecutive days expected to occur on average once in 10 years based on the historic record. The 7Q10 is not the lowest flow of record, but rather the lowest 7-day average flow with a 10-year recurrence interval. It is also the flow rate used for calculations of wasteload allocations for pollution discharge permits. Low flow conditions with a 10-year recurrence interval have a 10 percent chance of occurring in any year, a high enough probability to warrant advanced planning.

To protect aquatic ecosystems and other users, run-of-river intakes are allowed to withdraw only a portion of the 7Q10 low flow. Limits on run-of-river withdrawals are established by examining the potential impacts of a proposed withdrawal on flows and the aquatic habitat at a particular location based on a site-specific flow study. The local habitat is assessed at various flow levels and a determination is made as to the quality of the habitat and the potential impacts of varying levels of withdrawals. These studies are time consuming and can be expensive. But, they provide a site-specific evaluation of the effects of potential withdrawals and help in designing intakes for conditions at a particular location. An alternative is to use a planning guideline that indicates a withdrawal amount that is unlikely to have serious effects on aquatic habitat during low flow conditions.

In North Carolina the planning guideline that has been used is 20 percent of the 7Q10 flow. If a proposed instantaneous surface water withdrawal, in combination with other withdrawals in the stream reach, will not result in cumulative withdrawals that take more than 20 percent of the 7Q10 flow there has been a general presumption that it will have minimal effects on local aquatic habitat and other users and additional studies have not been automatically required. The 20 percent of the 7Q10 flow is not a limit on withdrawals, but rather a general planning guideline. If there are specific concerns at the proposed site, such as potential impacts on an endangered species, in-depth environmental studies can be required at any level of withdrawal. If 20 percent of the 7Q10 does not provide enough water to meet the expected water demands of a particular system then an instream-flow study will help determine if more water can be withdrawn without harming aquatic habitat.

For water supply systems that withdraw water from streams in the Cape Fear River Basin, results from the Cape Fear-Neuse River Basin Hydrologic Model provide an indication of the limits on water availability at surface water intakes. However, the model does not limit withdrawals to 20 percent of the 7Q10 flow and it does not reserve water for habitat protection. If water is available at a particular location in the model it will be used to satisfy modeled demands. In this arrangement a water supply shortage exists if there is not enough water to satisfy the modeled demands at a particular location.

Reservoir Intakes

Water supply reservoirs impound water during high flow periods for later use when stream flows are not sufficient to meet demands. Stream flows and reservoir storage will determine how much water is available, or how many days of supply are available given a particular daily rate of use. Water can be stored by damming a stream channel or by developing an off-stream storage facility. In either case the historical occurrence of low inflow conditions provides essential data for estimating the potential yield. For any given impoundment the estimated yield is conditioned by the length of the data record used in the calculations.

Reservoir yields are estimated based on the reliability desired for the intended use. A 20-year yield estimates the allowable withdrawal rate based on an expected reliability of 19 out of 20 years. This estimate implies that in any given year there would be a 5 percent risk that the estimated level of withdrawal could not be sustained. Similarly, a 50-year yield estimate defines a withdrawal rate with an expected reliability of 49 out of 50 years having a 2 percent risk that the withdrawal cannot be sustained in any year.

Many surface water systems cannot use the entire amount of their available supply because of treatment and distribution system limitations. In this analysis, we assumed that if water were available from the current source, then systems would invest in the facilities to produce and distribute more potable water when demand approached the limits of existing capacity.

Non-reservoir Impoundments

At several locations on the Cape Fear River water is retained behind an impoundment that creates a pool of water with a surface elevation determined by the height of the impounding structure. Water flowing into the impoundment flows freely over the impounding structure. Water releases from the impoundment are not managed or regulated. These structures provide a relatively constant water depth that provide some of the advantages of a reservoir over a run-of-river intake where water levels are dependent on flow rates and stream channel configurations. More detail on evaluating how much water may be available for communities having a water supply intake in this type of impoundment is provided in Appendix B which discusses conditions above William O. Huske Lock & Dam where Fayetteville Public Works Commission withdraws water.

Purchased Supply

Many water systems buy water from neighboring systems. The Division of Water Resources encourages systems that buy or sell water to develop contracts for the transactions. Contracts make clear to all parties the amount of water to be available and the length of time it will be available. Systems that buy water need to know how much water they can get and for how long. While sellers need to plan to have the committed amount of water available when needed.

Local water supply plans provide information on water sales and purchases as well as contract amounts. Purchase arrangements are assumed to continue over the fifty year planning horizon of this analysis. For water systems for which purchasing water is their only supply, we assumed that their estimated future demands will be met by the current suppliers, regardless of reported contract limits.

Table 2 shows the amount of water available to each of the water utilities analyzed for this report, based on the information reported in their local water supply plans. It indicates the sources available to each utility and the estimated amount of water available from each source in millions of gallons per day. The streams that provide surface water sources are identified and, if applicable, water supply reservoirs are identified. The available supply amounts shown represent the estimated amount of water that is expected to be available from a particular source. Communities may or may not have existing infrastructure sufficient to fully use the listed amount of water.

For water systems that depend on water from another system the selling system is identified and the contract amounts reported in the local water supply plans are shown as the available supplies. The contracts listed in the local plans are of varying lengths and may or may not be capable of being increased if the current contracts prove to be insufficient to meet future demands. These contracts are negotiated directly by the participating utilities.

Local water supply plans are available for review on the Division of Water Resources website at
http://www.ncwater.org/Water_Supply_Planning/Local_Water_Supply_Plan/.
Water demand projections will be discussed in the next section.

Table 1 Estimated Service Populations

Estimated Service Populations base on data from Local Water Supply Plans and Jordan Lake Allocation Requests*									
County	**System ID#**	**Water System**	**2010**	**2013**	**2020**	**2030**	**2040**	**2050**	**2060**
Alamance									
	02-01-035	Alamance	750	955	1,100	1,200	1,320	1,450	1,600
	02-01-010	Burlington	52,000	51,306	56,100	62,896	70,500	79,000	88,600
	02-01-025	Elon	9,419	10,056	11,632	13,884	16,136	18,389	20,641
	02-01-015	Graham	15,043	14,300	17,554	20,246	23,039	25,873	28,460
	02-01-030	Green Level	2,345	2,540	2,873	3,000	3,200	4,144	4,458
	02-01-020	Haw River	2,068	2,309	2,643	3,039	3,495	4,019	4,622
	02-01-018	Mebane	11,393	12,600	15,419	19,445	23,471	27,497	31,523
	30-01-005	Swepsonville	1,154	1,192	1,401	1,751	2,188	2,736	3,419
Bladen									
	03-09-010	Elizabethtown	3,900	3,683	3,612	3,641	3,670	3,699	3,728
	50-09-013	LCFWSA - Kings Bluff (Industrial Use)	0	0	0	0	0	0	0
	50-09-012	LCFWSA - Bladen Bluffs (Industrial Use)	0	0	0	0	0	0	0
Brunswick									
	04-10-130	Bald Head Island Utilities Dept.	200	215	220	230	240	250	260
	04-10-045	Brunswick County	80,000	74,550	96,374	117,025	138,790	158,803	182,622
	04-10-070	Brunswick Regional WSD	18,726	20,269	23,106	27,727	33,272	39,926	47,911
	04-10-055	Caswell Beach	501	600	510	510	510	510	510
	70-10-058	Leland	0	1,240	921	1,183	1,445	1,707	1,969
	04-10-065	Navassa	1,900	747	845	962	1,006	1,115	1,245
	70-10-045	Northwest	882	278	322	386	463	556	667
	04-10-020	Oak Island	8,203	8,595	15,700	16,700	17,700	18,700	19,700
	04-10-025	Shallotte	1,998	3,904	4,000	4,078	4,282	4,496	4,721
	04-10-010	Southport	5,250	5,405	5,500	5,700	6,000	6,600	6,800
Chatham									
	40-19-010	Chatham County Asbury Water System	841	985	1,181	1,371	1,591	1,846	2,143
	03-19-126	***Chatham County North Water System****	***10,200***	***13,120***	***25,900***	***41,600***	***57,300***	***73,400***	***94,000***
	03-19-050	Chatham County Southwest Water System	2,266	2,077	2,601	3,019	3,503	4,066	4,719
	03-19-025	Goldston Gulf SD	1,443	1,370	1,280	1,290	1,295	1,300	1,305
	03-19-015	***Pittsboro****	***3,700***	***4,033***	***24,000***	***58,600***	***79,900***	***87,100***	***96,800***
	03-19-010	Siler City	7,877	8,140	8,547	8,974	9,423	9,894	10,388
Cumberland									
	50-26-027	Eastover Sanitary District	0	6,162	6,200	6,300	6,400	6,500	6,600
	03-26-035	Falcon	720	730	760	820	907	957	1,007
	03-26-010	***Fayetteville****	***199,102***	***203,500***	***254,208***	***316,772***	***384,376***	***412,383***	***440,390***
	03-26-050	Godwin	267	257	258	268	278	288	290
	03-26-045	Linden	1,547	1,605	1,700	1,700	1,700	1,700	1,700
	50-26-019	Old North Utility Services, Inc.	65,000	76,000	78,195	80,150	82,154	84,208	86,313
	03-26-020	Spring Lake	9,000	8,900	9,660	10,670	11,780	13,010	14,370
	03-26-030	Stedman	970	1,061	1,050	1,100	1,150	1,250	1,300
Durham									
	03-32-010	***Durham****	***246,180***	***262,725***	***286,419***	***329,421***	***372,423***	***415,425***	***458,426***
Granville									
	02-39-015	Creedmoor	4,124	4,223	7,475	10,450	13,425	16,400	16,400
	02-39-107	South Granville Water and Sewer Authority	10,467	19,216	20,753	22,828	25,111	27,622	30,385
	40-39-004	Wilton Water and Sewer	0	900	900	900	900	900	900
Guilford									
	02-41-025	Gibsonville	5,980	6,619	8,779	11,864	14,950	18,035	21,121
	02-41-010	Greensboro	260,083	277,080	299,941	339,800	391,874	451,928	521,186
	02-41-020	High Point	101,409	108,285	113,586	123,808	134,950	147,095	160,334
	02-41-030	Jamestown	5,667	5,667	7,000	7,500	8,200	8,500	8,800
	30-76-010	Piedmont Triad Regional Water Authority	0	0	0	0	0	0	0
Harnett									
	03-43-015	Angier	6,545	6,075	8,000	10,000	15,000	20,000	25,000
	50-43-001	Bragg Communities	5,855	5,855	5,855	5,855	5,855	5,855	5,855
	03-43-020	Coats	2,246	2,246	2,302	2,359	2,418	2,479	2,531
	03-43-010	Dunn	9,263	9,263	9,363	9,463	9,563	9,663	9,763
	03-43-045	Harnett County Regional Water System	79,059	90,004	122,909	145,211	167,500	189,778	215,018
	03-43-025	Lillington	3,300	3,269	4,131	4,338	4,554	4,782	5,260

Table 1 (cont.) Estimated Service Populations

Estimated Service Populations base on data from Local Water Supply Plans and Jordan Lake Allocation Requests*

County	System ID#	Water System	2010	2013	2020	2030	2040	2050	2060
Johnston									
	03-51-025	Benson	4,671	3,311	3,625	3,725	3,825	3,925	4,000
	03-51-020	Clayton	15,780	17,635	21,688	29,127	39,118	52,535	70,555
	03-51-195	Flowers Plantation	3,637	4,030	6,059	6,059	6,059	6,059	6,059
	03-51-035	Four Oaks	2,570	2,430	2,701	3,001	3,376	3,832	4,388
	03-51-070	Johnston County	59,800	67,000	79,500	97,000	118,500	144,500	176,500
	03-51-030	Kenly	1,328	1,339	1,407	1,423	1,438	1,451	1,466
	40-51-008	Micro (County Line)	45	15	25	30	40	50	60
	03-51-050	Princeton	1,376	1,201	1,601	2,019	2,536	3,175	4,012
	03-51-010	Smithfield	11,476	11,016	11,093	11,205	11,317	11,431	11,534
Lee									
	03-53-015	Broadway	1,476	1,654	1,848	2,113	2,430	2,795	3,186
	03-53-101	Carolina Trace WS	4,129	4,388	5,220	5,220	5,220	5,220	5,220
	03-53-010	Sanford	40,900	41,967	56,600	76,000	92,200	111,800	135,700
Lenoir									
	04-54-030	Deep Run WC	12,675	12,880	16,413	19,630	23,478	28,080	28,080
	04-54-010	Kinston	27,588	27,500	28,000	28,500	29,000	30,000	30,500
	04-54-025	North Lenoir Water Corp.	14,450	15,647	14,700	15,000	15,250	15,500	15,750
	04-54-020	Pink Hill	955	955	965	980	990	1,000	1,010
Moore									
	03-63-025	Carthage	2,414	2,250	2,600	2,800	3,000	3,200	3,300
	50-63-011	East Moore Water District	3,248	5,200	6,320	6,547	6,783	7,027	7,280
	50-63-021	Moore County Public Utilities-High Falls	11	50	289	300	310	321	333
	03-63-103	Moore County Public Utilities-Hyland Hills	335	294	358	383	410	438	469
	03-63-108	Moore County Public Utilities-Pinehurst	12,450	17,000	17,095	19,511	22,268	25,415	29,005
	03-63-155	Moore County Public Utilities-Robbins	56	100	62	68	74	81	88
	03-63-117	Moore County Public Utilities-Seven Lakes	6,365	5,489	6,443	6,675	6,916	7,165	7,423
	03-63-045	Moore County Public Utilities-Vass	834	1,000	1,087	1,162	1,242	1,328	1,419
	03-63-015	Robbins Water System	1,332	1,108	2,008	2,286	2,400	2,500	2,600
New Hanover									
	04-65-010	Cape Fear Public Utility Authority - Wilmington	169,568	185,000	200,000	233,526	298,636	363,570	380,500
	04-65-015	Carolina Beach	11,900	12,000	13,800	0	0	0	0
Orange									
	03-68-015	***Hillsborough****	***12,216***	***13,565***	***16,800***	***20,100***	***24,200***	***29,000***	***33,800***
	03-68-010	***Orange Water and Sewer Authority****	***79,400***	***80,614***	***92,700***	***107,000***	***121,200***	***135,500***	***149,700***
	03-68-020	Orange-Alamance	8,282	8,456	8,532	8,782	9,032	9,282	9,532
Pitt									
	04-74-025	Ayden	4,861	5,022	5,402	5,973	6,600	7,290	7,390
	04-74-045	Bell Arthur WC	9,000	3,860	9,300	9,300	10,000	10,500	10,550
	04-74-015	Eastern Pines Water Corporation	19,441	19,441	32,160	45,810	45,810	45,810	45,810
	04-74-035	Grifton	2,500	2,854	2,825	3,079	3,356	3,658	3,681
Randolph									
	02-76-030	Archdale	9,700	11,415	13,000	14,000	15,000	16,000	17,000
	02-76-035	Franklinville	1,380	1,164	1,250	1,300	1,400	1,500	1,600
	02-76-020	Ramseur	3,271	3,271	3,240	3,560	3,880	4,230	4,400
	02-76-015	Randleman	4,113	4,150	4,700	5,100	5,500	5,900	6,300
Rockingham									
	02-79-020	Reidsville	14,637	15,000	16,033	16,650	17,066	17,492	18,399
	02-79-050	Rockingham Co	0	818	1,300	1,500	1,700	1,900	2,100
Wake									
	03-92-045	***Apex****	***37,700***	***42,040***	***53,100***	***74,400***	***100,500***	***109,200***	***112,200***
	03-92-020	***Cary****	***144,900***	***166,678***	***176,400***	***208,100***	***230,600***	***247,900***	***248,400***
	03-92-055	Fuquay-Varina	17,937	19,804	27,662	42,162	59,662	77,162	94,662
	03-92-050	***Holly Springs****	***24,700***	***28,320***	***46,710***	***61,920***	***74,821***	***89,041***	***103,261***
	03-92-010	***Raleigh****	***485,219***	***510,000***	***638,500***	***799,100***	***963,200***	***1,134,200***	***1,316,200***
Wayne									
	04-96-060	Fork Township SD	11,100	11,100	11,200	11,450	11,700	12,000	12,300
	04-96-025	Fremont	1,463	1,258	1,324	1,257	1,195	1,135	1,053
	04-96-010	Goldsboro	33,312	37,051	41,356	47,559	54,698	62,902	72,337
	04-96-030	Pikeville	793	714	793	910	1,025	1,135	1,265
	04-96-065	Wayne WD	47,752	47,972	63,037	73,159	85,042	98,692	114,533
Wilson									
	04-98-020	Elm City	1,375	1,454	1,500	1,500	1,500	1,500	1,500
	04-98-010	Wilson	51,000	52,500	54,500	59,400	64,700	70,500	76,800

Table 2 Available Water Supply in Million Gallons per Day

Water System's Estimated Available Supplies reported in Local Water Supply Plans

County	System ID#	Water System	Source	Available Supply (mgd)	Basin
Alamance					
	02-01-035	Alamance	from Burlington	0.50	
	02-01-010	Burlington	Stoney Creek Reservoir	14.60	Haw River (02-1)
		Burlington	Great Alamance Creek/Lake Mackintosh	35.60	Haw River (02-1)
	02-01-025	Elon	from Burlington	1.60	
	02-01-015	Graham	Back Creek/Graham-Mebane Lake	12.00	Haw River (02-1)
	02-01-030	Green Level	from Graham	0.22	
	02-01-020	Haw River	from Burlington	1.50	
	02-01-018	Mebane	from Graham	4.00	
	30-01-005	Swepsonville	from Graham	0.50	
Bladen					
	03-09-010	Elizabethtown	groundwater	0.98	
	50-09-013	LCFWSA - Kings Bluff (Industrial Use)	Cape Fear River	53.00	Cape Fear River (02-3)
	50-09-012	LCFWSA_Bladen Bluffs (Industrial Use)	Cape Fear River	6.00	Cape Fear River (02-3)
Brunswick					
	04-10-130	Bald Head Island Utilities Dept.	from Brunswick County	0.50	
	04-10-045	Brunswick County	from LCFWSA - Kings Bluff	24.00	Cape Fear River (02-3)
		Brunswick County	groundwater	8.88	
	04-10-070	Brunswick Regional (H2GO)	from Brunswick County	1.00	
	04-10-055	Caswell Beach	from Brunswick County	0.30	
	70-10-058	Leland	from Brunswick County	0.50	
	04-10-065	Navassa	from Brunswick County	0.20	
	70-10-045	Northwest	from Brunswick County	0.21	
	04-10-020	Oak Island	from Brunswick County	2.00	
	04-10-035	Ocean Isle Beach	from Brunswick County	1.06	
	04-10-025	Shallotte	from Brunswick County	0.75	
	04-10-010	Southport	from Brunswick County	1.42	
Chatham					
	40-19-010	Chatham County Asbury Water System	from Sanford	0.40	
	03-19-126	Chatham County North Water System	Haw River/B. Everett Jordan Lake	3.00	Haw River (02-1)
	03-19-050	Chatham County Southwest Water System	from Siler City	0.50	
	03-19-025	Goldston Gulf SD	from Sanford	0.25	
	03-19-015	Pittsboro	Haw River	2.00	Haw River (02-1)
	03-19-010	Siler City	Rocky River/ Upper & Lower Reservoirs	4.00	Deep River (02-2)
Columbus					
	04-24-035	Riegelwood SD	CAPE FEAR RIVER	1.00	Cape Fear River (02-3)
Cumberland					
	50-26-027	Eastover Sanitary District	from Dunn	1.00	
	03-26-035	Falcon	from Dunn	0.20	
	03-26-010	Fayetteville	Cape Fear River - 1	42.90	Cape Fear River (02-3)
		Fayetteville	Cape Fear - 2	42.90	Cape Fear River (02-3)
		Fayetteville	Little Cross Creek/Glenville Lake	4.50	Cape Fear River (02-3)
		Fayetteville	Big Cross Creek	0.90	Cape Fear River (02-3)
	03-26-050	Godwin	from Falcon	0.04	
	03-26-045	Linden	from Harnett County RWS	0.25	
	50-26-019	Old North Utility Services, Inc.	from Fayetteville PWC	8.00	
		Old North Utility Services, Inc.	from Harnett County RWS	8.00	
	03-26-020	Spring Lake	from Fayetteville PWC	1.56	
		Spring Lake	from Harnett County RWS	0.50	
	03-26-030	Stedman	from Fayetteville PWC	0.16	
Durham					
	03-32-010	Durham	Eno River	5.00	Neuse River (10-1)
		Durham	Haw River/B. Everett Jordan Lake	10.00	Haw River (02-1)
		Durham	Flat River/Lake Michie	10.50	Neuse River (10-1)
		Durham	Little River Lake	17.40	Neuse River (10-1)
		Durham	Eno River/Teer-Hanson Quarry	5.20	Neuse River (10-1)
Granville					
	02-39-015	Creedmoor	from SGWASA	0.55	
	02-39-107	South Granville Water and Sewer Authority	Knapp of Reed's Creek/RD Holt Reservoir	11.00	Neuse River (10-1)
	40-39-004	Wilton Water and Sewer	from Creedmoor	0.08	
Guilford					
	02-41-025	Gibsonville	from Burlington	2.50	
	02-41-010	Greensboro	Reedy Fork Cr./Lake Townsend	24.00	Haw River (02-1)
		Greensboro	Reedy Fork Cr.Horsepen Cr./Lake Brandt	12.00	Haw River (02-1)
		Greensboro	Brush Creek/Lake Higgins	0.00	Haw River (02-1)
		Greensboro	from PTRWA	6.37	
	02-41-020	High Point	Deep River/Oak Hollow	12.84	Deep River (02-2)
		High Point	Deep River/City Lake	8.60	Deep River (02-2)
		High Point	from PTRWA	2.68	
	02-41-030	Jamestown	from High Point	1.35	
		Jamestown	from Greensboro	0.05	

Table 2 Available Water Supply in Million Gallons per Day (cont.)

Water System's Estimated Available Supplies reported in Local Water Supply Plans					
County	System ID#	Water System	Source	Available Supply (mgd)	Basin
Harnett					
	03-43-015	Angier	from Harnett County RWS	2.02	
	50-43-001	Bragg Communities	from Harnett County RWS	0.80	
	03-43-020	Coats	from Harnett County RWS	0.72	
	03-43-010	Dunn	Cape Fear River	12.00	Cape Fear River (02-3)
	03-43-045	Harnett County Regional Water System	Cape Fear River	68.39	Cape Fear River (02-3)
		Harnett County Regional Water System	from Dunn	1.00	
	03-43-025	Lillington	from Harnett County RWS	2.00	
Johnston					
	03-51-025	Benson	from Dunn	0.95	
		Benson	from Johnston County	0.20	
	03-51-020	Clayton	from Johnston County	2.59	
	03-51-195	Aqua NC / Flowers Plantation	from Johnston County	0.38	
	03-51-035	Four Oaks	from Johnston County	0.24	
	03-51-070	Johnston County	Neuse River	12.00	Neuse River (10-1)
		Johnston County	from Harnett County RWS	2.60	
	03-51-030	Kenly	from Johnston County	0.30	
	40-51-008	Micro (County Line)	from Johnston County	0.50	
	03-51-050	Princeton	from Johnston County	0.13	
	03-51-010	Smithfield	Neuse River	6.20	Neuse River (10-1)
Lee					
	03-53-015	Broadway	from Sanford	0.30	
	03-53-101	Carolina Trace WS	from Sanford	0.29	
	03-53-010	Sanford	Cape Fear River/Yarborough Lake	12.60	Deep River (02-2)
Lenoir					
	04-54-030	Deep Run WC	from NRWASA	0.73	
		Deep Run WC	groundwater	2.603 (0.651)	
	04-54-010	Kinston	from NRWASA	3.07	
		Kinston	groundwater	6.217 (1.437)	
	60-54-001	Neuse Regional Water and Sewer Authority	Neuse River	15.00	Neuse River (10-1)
	04-54-025	North Lenoir Water Corp.	from NRWASA	1.19	
		North Lenoir Water Corp.	groundwater	2.938 (0.735)	
	04-54-020	Pink Hill	from NRWASA	0.15	
		Pink Hill	groundwater	0.13	
Moore					
	03-63-025	Carthage	Nicks Creek/Carthage Reservoir	1.00	Cape Fear River (02-3)
	50-63-011	East Moore Water District	from Harnett County RWS	3.00	
	50-63-021	Moore County Public Utilities-High Falls	from Chatham County SW	0.03	
	03-63-103	Moore County Public Utilities-Hyland Hills	from East Moore Water District	0.05	
		Moore County Public Utilities-Hyland Hills	from Chatham County SW	0.03	
	03-63-108	Moore County Public Utilities-Pinehurst	groundwater	1.37	
		Moore County Public Utilities-Pinehurst	from East Moore Water District	1.00	
		Moore County Public Utilities-Pinehurst	from Aberdeen	0.60	
		Moore County Public Utilities-Pinehurst	from Southern Pines	1.00	
	03-63-155	Moore County Public Utilities-Robbins	from Robbins	0.03	
	03-63-117	Moore County Public Utilities-Seven Lakes	groundwater	0.06	
		Moore County Public Utilities-Seven Lakes	from Moore County-Pinehurst	1.00	
	03-63-045	Moore County Public Utilities-Vass	from East Moore Water District	0.20	
	03-63-015	Robbins Water System	Bear Creek/ CB Brooks Reservoir	0.05	Deep River (02-2)
		Robbins Water System	from Montgomery County	0.25	Yadkin River (18-1)
New Hanover					
	04-65-010	Cape Fear Public Utility Authority - Wilmington	Cape Fear River	53.00	Cape Fear River (02-3)
		Cape Fear Public Utility Authority - Wilmington	groundwater	8.15	
	04-65-015	Carolina Beach	groundwater	2.01	
Orange					
	03-68-015	Hillsborough	Eno River/Lake Ben Johnston	0.68	Neuse River (10-1)
		Hillsborough	West Fork of the Eno Reservoir	1.80	Neuse River (10-1)
		Hillsborough	East Fork Eno River/Lake Orange Reservoir	0.08	Neuse River (10-1)
	03-68-010	Orange Water and Sewer Authority	Cane Creek Reservoir	8.50	Haw River (02-1)
		Orange Water and Sewer Authority	Morgan Creek/University Lake	2.00	Haw River (02-1)
		Orange Water and Sewer Authority	Haw River/ B Everett Jordan Lake	5.00	Haw River (02-1)
	03-68-020	Orange-Alamance	Eno River/Corporation Lake	0.37	Neuse River (10-1)
Pitt					
	04-74-025	Ayden	from NRWASA	0.39	
		Ayden	groundwater	1.091 (0.196)	
	04-74-045	Bell Arthur WC	from NRWASA	0.60	
		Bell Arthur WC	groundwater	1.933 (0.402)	
	04-74-015	Eastern Pines Water Corporation	from NRWASA	1.19	
		Eastern Pines Water Corporation	groundwater	2.722 (0.824)	
	04-74-035	Grifton	from NRWASA	0.14	
		Grifton	groundwater	0.432 (0.108)	
Randolph					
	02-76-030	Archdale	from PTRWA	1.45	
	02-76-035	Franklinville	from Ramseur	0.25	
	30-76-010	Piedmont Triad Regional Water Authority	Deep River/Randleman Reservoir	48.00	Deep River (02-2)
	02-76-020	Ramseur	Sandy Creek Reservoir	6.60	Deep River (02-2)
	02-76-015	Randleman	from PTRWA	1.00	

Table 2 Available Water Supply in Million Gallons per Day (cont.)

Water System's Estimated Available Supplies reported in Local Water Supply Plans					
County	**System ID#**	**Water System**	**Source**	**Available Supply (mgd)**	**Basin**
Rockingham					
	02-79-020	Reidsville	Troublesome Creek/Lake Reidsville	19.00	Haw River (02-1)
		Reidsville	Troublesome Creek/Lake Hunt	0.00	Haw River (02-1)
	02-79-050	Rockingham Co	from Reidsville	0.55	
		Rockingham Co	from Madison	0.20	Roanoke (14-1)
Wake					
	03-92-045	Apex	Haw River/ B Everett Jordan Lake	8.50	Haw River (02-1)
	03-92-020	Cary	Haw River/ B Everett Jordan Lake	30.50	Haw River (02-1)
	03-92-055	Fuquay-Varina	from Harnett County RWS	2.00	
	03-92-050	Holly Springs*	from Harnett County RWS	10.00	
		Holly Springs*	Haw River/ B Everett Jordan Lake	2.00	
	03-92-010	Raleigh	Neuse River/Falls Lake	66.10	Neuse River (10-1)
		Raleigh	Swift Creek/Lake Benson	11.20	Neuse River (10-1)
Wayne					
	04-96-060	Fork Township SD	from Goldsboro	0.50	
		Fork Township SD	groundwater	1.251 (0.645)	
	04-96-025	Fremont	from Wayne WD	0.17	
	04-96-010	Goldsboro	Neuse River	25.85	Neuse River (10-1)
		Goldsboro	Little River	0.65	Neuse River (10-1)
	04-96-030	Pikeville	from Fremont	0.10	
		Pikeville	from Wayne WD	0.15	
	04-96-065	Wayne WD	from Goldsboro	3.20	
		Wayne WD	groundwater	7.85 (6.376)	
Wilson					
	04-98-020	Elm City	from Wilson	0.30	
		Elm City	groundwater	0.15	
	04-98-010	Wilson	Contentnea Creek/Buckhorn Lake	26.70	Contentnea Creek (10-2)
		Wilson	Contentnea Creek/Wiggins Mill Reservoir	1.00	Contentnea Creek (10-2)
		Wilson	Toisnot Swamp/Toisnot Reservoir	0.20	Contentnea Creek (10-2)
		Wilson	Toisnot Swamp/Lake Wilson	1.00	Contentnea Creek (10-2)

Water Demands

This analysis answers the question: is there likely to be enough water available from a particular source to meet the 2060 demands of the public water systems that depend on that source? The results are based on output from the Cape Fear – Neuse River Basins Hydrologic Model a computer modeling platform designed to characterize water resource systems. The details of the model will be discussed in a later section of this document. The model does not reserve water to protect ecological integrity nor does it limit withdrawals to volumes that would not threaten water quality in the vicinity of the withdrawal. Streamflows and water availability estimates generated by the model depend on the wastewater discharge volumes assumed in the model. If the assumptions about the proportions of withdrawals that are discharged as treated wastewater are changed then the flow estimates, and therefore the water availability estimates, will change.

The results of this analysis show that, based on the assumptions in the model, including some increases in water allocations from Jordan Lake reservoir, there appears to be enough water to meet the estimated withdrawals needed to meet 2060 demands, Some communities may have to implement their water shortage response plans during droughts to manage demand and some communities may have to develop additional infrastructure to make use of it. The ability to develop efficient distribution systems and the ability to have additional water available when it is needed depends on factors such as funding and regional cooperation. The demand projections for each water system in this analysis are listed in the Table 3, organized by county.

Table 3 shows the demand estimates compiled from independent projections for residential, commercial, institutional and industrial demands submitted by local officials in their local water supply plans. Table 4 shows demand estimates developed by DWR using the estimated service populations from the local water supply plans and the system-wide per capita water use (gallons per capita day, gpcd) from the 2010 local water supply plans.

Projecting demand strictly on increases in the number of residents served provides a general indication of demand growth. However, overall water system demands can be strongly influenced by industrial and commercial development within a utility's service area. These uses are not necessarily linked directly to the number of residential users.

Table 3 Local Water Supply Plan Water Demand Estimates

2010 Water Use and Estimated Future Water Demands from 2013 Local Water Supply Plans in Million Gallons per Day									
ID#	Water system	Reported Use 2010	Estimated Demand 2020	Estimated Demand 2030	Estimated Demand 2035	Estimated Demand 2040	Estimated Demand 2045	Estimated Demand 2050	Estimated Demand 2060
Alamance County									
02-01-035	Alamance	0.096	0.077	0.083	0.088	0.092	0.097	0.102	0.110
02-01-010	Burlington	9.018	7.652	8.501	8.978	9.454	9.991	10.527	11.739
02-01-025	Elon	0.611	0.634	0.735	0.782	0.829	0.874	0.918	0.999
02-01-015	Graham	1.938	2.461	2.836	3.034	3.231	3.429	3.627	3.988
02-01-030	Green Level	0.080	0.110	0.111	0.113	0.114	0.114	0.114	0.935
02-01-020	Haw River	0.188	0.276	0.290	0.312	0.333	0.358	0.383	0.441
02-01-018	Mebane	1.250	1.833	2.245	2.438	2.631	2.812	2.992	3.332
30-01-005	Swepsonville	0.119	0.114	0.139	0.153	0.167	0.211	0.254	0.307
Bladen County									
03-09-010	Elizabethtown	0.642	0.719	0.775	0.802	0.828	0.862	0.895	0.896
50-09-013	LCFWSA - Kings Bluff (Industrial Use)	2.750	2.627	2.627	2.627	2.627	2.627	2.627	2.627
50-09-012	LCFWSA_Bladen Bluffs		1.450	1.450	1.450	1.450	1.450	1.450	1.450
Brunswick Sounty									
04-10-130	Bald Head Island Utilities	0.206	0.141	0.149	0.153	0.157	0.161	0.165	0.173
04-10-045	Brunswick County	9.586	15.587	17.094	18.319	19.544	20.634	21.723	24.174
04-10-070	Brunswick Regional WSD	1.660	1.639	1.967	2.163	2.359	2.594	2.829	3.394
04-10-055	Caswell Beach	0.145	0.257	0.257	0.257	0.257	0.257	0.257	0.375
70-10-058	Leland	0.243	0.243	0.312	0.347	0.381	0.416	0.451	0.518
04-10-065	Navassa	0.083	0.106	0.113	0.117	0.121	0.128	0.134	0.147
70-10-045	Northwest	0.105	0.233	0.240	0.231	0.222	0.215	0.207	0.215
04-10-020	Oak Island	0.884	0.931	1.346	1.434	1.521	1.622	1.722	1.973
04-10-035	Ocean Isle Beach	0.616	1.085	1.401	1.401	1.401	1.401	1.401	1.401
70-10-057	Sandy Creek		0.013	0.015	0.016	0.017	0.019	0.021	0.024
04-10-025	Shallotte	0.411	0.396	0.416	0.427	0.438	0.449	0.460	0.484
04-10-010	Southport	0.426	1.159	1.390	1.545	1.700	1.780	1.860	2.007
Chatham County									
40-19-010	Chatham County Asbury	0.194	0.184	0.213	0.229	0.245	0.266	0.287	0.330
03-19-126	Chatham County North Water System	1.939	5.968	9.397	11.422	13.447	14.705	15.963	20.442
03-19-050	Chatham County SW	0.328	0.283	0.329	0.355	0.381	0.414	0.446	0.516
03-19-025	Goldston Gulf SD	0.053	0.084	0.088	0.089	0.090	0.092	0.093	0.097
0033-0004	Cape Fear Steam Plant (decommissioned)	5.620	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0383-0001	Performance Fibers	0.201	0.201	0.201	0.201	0.201	0.201	0.201	0.201
03-19-015	Pittsboro	0.623	3.335	7.768	8.928	10.087	10.444	10.801	11.761
03-19-010	Siler City	1.897	1.972	2.070	2.122	2.174	2.228	2.282	2.398
Craven County									
CUR-0052	Weyerhaeuser	14.471	14.471	14.471	14.471	14.471	14.471	14.471	14.471
Cumberland County									
0059-0003	DuPont Company - Fayetteville	10.217	11.170	11.170	11.170	11.170	11.170	11.170	11.170
50-26-027	Eastover SD		0.400	0.402	0.403	0.404	0.405	0.406	0.408
03-26-035	Falcon	0.110	0.061	0.064	0.066	0.067	0.069	0.070	0.075
03-26-010	Fayetteville PWC	25.244	33.700	44.500	50.000	55.500	59.800	64.100	72.500
03-26-050	Godwin	0.015	0.012	0.012	0.012	0.012	0.013	0.014	0.014
03-26-045	Linden	0.145	0.117	0.118	0.119	0.119	0.119	0.119	0.118
50-26-019	Old North Utility Services, Inc.	4.798	4.588	4.702	4.761	4.819	4.879	4.939	5.062
03-26-020	Spring Lake	0.812	1.109	1.177	1.254	1.331	1.414	1.496	1.651
03-26-030	Stedman	0.089	0.091	0.100	0.108	0.116	0.118	0.120	0.124

Table 3 Local Water Supply Plan Water Demand Estimates (cont.)

2010 Water Use and Estimated Future Water Demands from 2013 Local Water Supply Plans in Million Gallons per Day									
ID#	Water system	Reported Use	Estimated Demand	Estimated Demand	Estimated Demand	Estimated Demand	Estimated Demand	Estimated Demand	Estimated Demand
		2010	2020	2030	2035	2040	2045	2050	2060
Durham County									
03-32-010	Durham	25.284	30.669	34.096	36.100	38.100	40.000	41.903	44.401
Granville County									
02-39-015	Creedmoor	0.374	0.472	0.635	0.710	0.784	0.872	0.959	0.959
02-39-107	South Granville Water & Sewer Authorit	3.133	2.707	2.978	3.129	3.279	3.442	3.604	3.964
40-39-004	Wilton Water and Sewer		0.021	0.021	0.021	0.021	0.021	0.021	0.021
Guilford County									
02-41-025	Gibsonville	0.576	0.707	0.924	1.030	1.135	1.238	1.341	1.544
02-41-010	Greensboro	38.535	40.461	45.314	48.485	51.656	55.312	58.967	67.399
02-41-020	High Point	12.186	13.321	15.205	15.891	16.577	17.323	18.068	19.694
02-41-030	Jamestown	0.500	0.570	0.601	0.622	0.642	0.652	0.662	0.681
02-41-030	Jamestown	0.570	0.570	0.601	0.622	0.642	0.652	0.662	0.681
30-76-010	Piedmont Triad RWA (process water)	0.946	0.770	1.110	1.275	1.440	1.830	2.220	2.220
30-76-010	Piedmont Triad RWA (withdrawal)		18.625	19.089	19.331	25.963	26.439	33.304	33.364
Harnett County									
03-43-015	Angier	0.415	0.556	0.720	0.867	1.013	1.192	1.370	1.638
50-43-001	Bragg Comm/NTA Water Sys	0.273	0.270	0.800	0.800	0.800	0.800	0.800	0.800
03-43-030	Campbell University		0.111	0.250	0.250	0.250	0.250	0.250	0.250
03-43-020	Coats	0.145	0.154	0.160	0.163	0.166	0.169	0.172	0.178
03-43-010	Dunn	1.907	1.715	1.747	1.764	1.780	1.797	1.814	1.848
03-43-045	Harnett County Regional Water System	7.988	10.340	12.366	13.450	14.533	15.713	16.893	19.725
03-43-025	Lillington	0.366	0.832	0.871	0.894	0.917	0.939	0.961	1.009
Hoke County									
03-47-025	Hoke RWS	2.215	3.056	3.846	4.341	4.835	5.270	5.705	6.183
03-47-010	Raeford	1.776	2.488	2.535	2.565	2.594	2.630	2.665	2.735
Johnston County									
03-51-025	Benson	0.753	0.854	0.875	0.881	0.886	0.902	0.918	0.939
03-51-020	Clayton	2.244	2.557	3.116	3.459	3.801	4.217	4.633	5.646
03-51-195	Flowers Plantation	0.729	0.416	0.416	0.416	0.416	0.416	0.416	0.416
03-51-035	Four Oaks	0.223	0.281	0.315	0.336	0.357	0.383	0.408	0.469
03-51-070	Johnston County	4.924	6.073	7.331	8.098	8.865	9.849	10.833	13.113
03-51-030	Kenly	0.230	0.231	0.243	0.257	0.271	0.285	0.298	0.313
40-51-008	Micro (County Line)	0.003	0.014	0.016	0.018	0.019	0.020	0.021	0.031
03-51-050	Princeton	0.113	0.132	0.165	0.185	0.204	0.229	0.253	0.315
03-51-010	Smithfield	2.074	2.005	2.165	2.346	2.526	2.712	2.897	4.308
Lee County									
03-53-015	Broadway	0.095	0.118	0.141	0.151	0.161	0.172	0.183	0.209
03-53-015	Broadway	0.095	0.118	0.141	0.151	0.161	0.172	0.183	0.209
03-53-101	Carolina Trace WS	0.214	0.186	0.186	0.186	0.186	0.186	0.186	0.186
0285-0007	Pilgrims Pride	0.929	0.884	0.884	0.884	0.884	0.884	0.884	0.884
03-53-010	Sanford	5.849	7.458	10.563	12.374	14.184	16.710	19.236	23.349
Lenoir County									
04-54-030	Deep Run WC	0.916	1.218	1.457	1.600	1.742	1.914	2.085	2.085
04-54-010	Kinston	3.458	5.874	6.358	6.601	6.843	7.085	7.327	7.811
60-54-001	Neuse Regional Water & Sewer Authorit	0.783	1.233	1.233	1.233	1.233	1.233	1.233	1.233
04-54-025	North Lenoir Water Corp.	0.984	1.181	1.200	1.209	1.218	1.225	1.232	1.246
04-54-020	Pink Hill	0.061	0.070	0.071	0.072	0.072	0.072	0.072	0.072

Table 3 Local Water Supply Plan Water Demand Estimates (cont.)

2010 Water Use and Estimated Future Water Demands from 2013 Local Water Supply Plans in Million Gallons per Day									
ID#	Water system	Reported Use 2010	Estimated Demand 2020	Estimated Demand 2030	Estimated Demand 2035	Estimated Demand 2040	Estimated Demand 2045	Estimated Demand 2050	Estimated Demand 2060
Moore County									
03-63-114	Aqua NC - Woodlake		0.104	0.140	0.140	0.140	0.140	0.140	0.140
03-63-025	Carthage	0.300	0.531	0.567	0.578	0.588	0.589	0.589	0.642
50-63-011	East Moore Water District	0.237	0.332	0.359	0.388	0.416	0.455	0.493	0.556
50-63-021	Moore County Public Utilities-High Falls	0.003	0.005	0.005	0.005	0.005	0.005	0.005	0.005
03-63-103	Moore County Public Utilities-Hyland Hill	0.029	0.024	0.026	0.027	0.028	0.029	0.030	0.032
03-63-108	Moore County Public Utilities-Pinehurst	1.947	2.031	2.317	2.481	2.644	2.831	3.018	3.445
03-63-155	Moore County Public Utilities-Robbins	0.010	0.003	0.003	0.004	0.004	0.004	0.004	0.005
03-63-117	Moore County Public Utilities-Seven Lake	0.457	0.455	0.472	0.481	0.489	0.499	0.508	0.526
03-63-045	Moore County Public Utilities-Vass	0.094	0.084	0.090	0.093	0.096	0.100	0.103	0.111
03-63-015	Robbins	0.166	0.183	0.208	0.214	0.219	0.223	0.228	0.237
New Hanover County									
04-65-010	Cape Fear PUA - Wilmington	19.595	20.648	23.599	25.288	26.977	28.910	30.843	36.715
Orange County									
03-68-015	Hillsborough	1.157	2.320	2.700	2.870	3.040	3.220	3.390	3.700
	Orange County		0.700	1.600	2.000	2.400	2.800	3.200	3.900
03-68-010	Orange Water and Sewer Authority	7.697	8.320	9.680	10.235	10.790	11.325	11.860	12.910
03-68-020	Orange-Alamance	0.648	0.704	0.725	0.735	0.744	0.755	0.765	0.784
Pender County									
70-71-011	Pender County/Rocky Point-Topsail WSD	0.150	2.682	3.576	4.131	4.686	7.320	9.953	12.237
Pitt County									
04-74-025	Ayden	0.446	0.509	0.550	0.575	0.599	0.621	0.642	0.681
04-74-045	Bell Arthur WC	0.655	0.846	0.914	0.991	1.068	1.172	1.275	1.358
04-74-015	Eastern Pines Water Corp.	1.531	2.820	4.020	4.020	4.020	4.020	4.020	4.020
04-74-035	Grifton	0.168	0.166	0.177	0.182	0.187	0.192	0.196	0.202
Randolph County									
02-76-030	Archdale	1.133	1.107	1.128	1.137	1.146	1.157	1.167	1.182
02-76-030	Archdale	1.133	1.107	1.128	1.137	1.146	1.157	1.167	1.182
02-76-010	Asheboro service area demand	4.065	7.553	8.647	9.276	9.904	10.610	11.315	12.387
02-76-035	Franklinville	0.088	0.102	0.106	0.108	0.109	0.111	0.113	0.116
02-76-020	Ramseur service area demand	0.399	0.396	0.426	0.444	0.462	0.478	0.493	0.519
02-76-015	Randleman service area demand	0.969	0.888	0.991	1.059	1.127	1.202	1.277	1.322
Rockingham County									
02-79-020	Reidsville	3.652	3.545	3.683	3.738	3.792	3.840	3.887	4.032
02-79-050	Rockingham Co	0.098	0.134	0.148	0.155	0.161	0.168	0.174	0.188
Wake County									
03-92-045	Apex	2.947	4.890	7.093	8.306	9.519	10.028	10.537	10.754
03-92-020	Cary (inc. sale to RDU, RTP&Morrisville)	17.306	23.400	29.600	31.700	33.800	35.100	36.400	36.600
03-92-055	Fuquay-Varina	1.846	2.554	3.866	4.627	5.388	6.150	6.911	8.456
0033-0011	Harris Nuclear Station	26.448	20.000	20.000	20.000	20.000	20.000	20.000	20.000
03-92-050	Holly Springs	1.601	4.430	5.720	6.230	6.740	6.760	7.740	8.780
03-92-010	Raleigh	50.999	63.251	75.885	84.800	88.601	97.000	99.630	111.556
Wayne County									
04-96-040	Fork Township SD purchases		0.153	0.153	0.153	0.153	0.153	0.153	0.153
04-96-025	Fremont	0.119	0.123	0.119	0.116	0.113	0.111	0.109	0.103
04-96-010	Goldsboro	4.784	5.331	6.015	6.395	6.775	7.204	7.632	8.601
CUR0001	HF Lee Steam Station	15.122	8.077	8.077	8.077	8.077	8.077	8.077	8.077
04-96-030	Pikeville	0.110	0.046	0.063	0.067	0.071	0.075	0.079	0.083
04-96-065	Wayne WD	3.737	4.786	5.555	6.006	6.456	6.974	7.492	8.693
Wilson County									
04-98-020	Elm City	0.157	0.131	0.134	0.136	0.137	0.139	0.140	0.143
04-98-010	Wilson	6.828	8.832	9.971	10.437	10.903	11.415	11.927	12.930

Table 4 Population Based Water Demand Estimates

(Estimated service population from Local Water Supply Plans multiplied by 2010 gallons per capita day water use)

Estimated Water Demands based on Service Populations data from Local Water Supply Plans and Jordan Lake Allocation Requests*								
County	**System ID#**	**Water System**	**2010 gpcd**	**2020 mgd**	**2030 mgd**	**2040 mgd**	**2050 mgd**	**2060 mgd**
Alamance								
	02-01-035	Alamance	128.00	0.141	0.154	0.169	0.186	0.205
	02-01-010	Burlington	173.42	9.729	10.908	12.226	13.700	15.365
	02-01-025	Elon	64.87	0.755	0.901	1.047	1.193	1.339
	02-01-015	Graham	128.83	2.261	2.608	2.968	3.333	3.667
	02-01-030	Green Level	34.12	0.098	0.102	0.109	0.141	0.152
	02-01-020	Haw River	90.91	0.240	0.276	0.318	0.365	0.420
	02-01-018	Mebane	109.72	1.692	2.133	2.575	3.017	3.459
	30-01-005	Swepsonville	103.12	0.144	0.181	0.226	0.282	0.353
Bladen								
	03-09-010	Elizabethtown	89.36	0.323	0.325	0.328	0.331	0.333
	50-09-013	LCFWSA - Kings Bluff (Industrial Use)		1.631	1.631	1.631	1.631	1.631
	50-09-012	LCFWSA_Bladen Bluffs (Industrial Use)		4.039	4.039	4.039	4.039	4.039
Brunswick								
	04-10-130	Bald Head Island Utilities Dept.	1030.00	0.227	0.237	0.247	0.258	0.268
	04-10-045	Brunswick County	119.83	11.548	14.023	16.631	19.029	21.883
	04-10-070	Brunswick Regional WSD	88.65	2.048	2.458	2.949	3.539	4.247
	04-10-055	Caswell Beach	289.42	0.148	0.148	0.148	0.148	0.148
	70-10-058	Leland	100.00	0.092	0.118	0.145	0.171	0.197
	04-10-065	Navassa	43.68	0.037	0.042	0.044	0.049	0.054
	70-10-045	Northwest	119.05	0.038	0.046	0.055	0.066	0.079
	04-10-020	Oak Island	107.77	1.692	1.800	1.907	2.015	2.123
	04-10-025	Shallotte	205.71	0.823	0.839	0.881	0.925	0.971
	04-10-010	Southport	81.14	0.446	0.463	0.487	0.536	0.552
Chatham								
	40-19-010	Chatham County Asbury Water System	230.68	0.272	0.316	0.367	0.426	0.494
	03-19-126	***Chatham County North Water System****	***190.10***	***4.924***	***7.908***	***10.893***	***13.953***	***17.869***
	03-19-050	Chatham County Southwest Water System	144.75	0.376	0.437	0.507	0.589	0.683
	03-19-025	Goldston Gulf SD	36.73	0.047	0.047	0.048	0.048	0.048
	03-19-015	***Pittsboro****	***168.38***	***4.041***	***9.867***	***13.453***	***14.666***	***16.299***
	03-19-010	Siler City	240.83	2.058	2.161	2.269	2.383	2.502
Cumberland								
	50-26-027	Eastover Sanitary District	64.59	0.400	0.407	0.413	0.420	0.426
	03-26-035	Falcon	152.78	0.116	0.125	0.139	0.146	0.154
	03-26-010	***Fayetteville****	***126.79***	***32.231***	***40.163***	***48.735***	***52.286***	***55.837***
	03-26-050	Godwin	56.18	0.014	0.015	0.016	0.016	0.016
	03-26-045	Linden	93.73	0.159	0.159	0.159	0.159	0.159
	50-26-019	Old North Utility Services, Inc.	73.82	5.772	5.916	6.064	6.216	6.371
	03-26-020	Spring Lake	90.22	0.872	0.963	1.063	1.174	1.296
	03-26-030	Stedman	91.75	0.096	0.101	0.106	0.115	0.119
Durham								
	03-32-010	***Durham****	***102.71***	***29.417***	***33.833***	***38.250***	***42.666***	***47.083***
Granville								
	02-39-015	Creedmoor	90.69	0.678	0.948	1.217	1.487	1.487
	02-39-107	South Granville Water and Sewer Authority	299.32	6.212	6.833	7.516	8.268	9.095
	40-39-004	Wilton Water and Sewer	22.22	0.020	0.020	0.020	0.020	0.020
Guilford								
	02-41-025	Gibsonville	96.32	0.846	1.143	1.440	1.737	2.034
	02-41-010	Greensboro	148.16	44.441	50.346	58.062	66.960	77.221
	02-41-020	High Point	120.17	13.649	14.878	16.217	17.676	19.267
	02-41-030	Jamestown	88.23	0.618	0.662	0.723	0.750	0.776
	30-76-010	Piedmont Triad Regional Water Authority		0.000	0.000	0.000	0.000	0.000
Harnett								
	03-43-015	Angier	63.41	0.507	0.634	0.951	1.268	1.585
	50-43-001	Bragg Communities	46.63	0.273	0.273	0.273	0.273	0.273
	03-43-020	Coats	64.56	0.149	0.152	0.156	0.160	0.163
	03-43-010	Dunn	205.87	1.928	1.948	1.969	1.989	2.010
	03-43-045	Harnett County Regional Water System	101.04	12.419	14.672	16.924	19.175	21.725
	03-43-025	Lillington	110.91	0.458	0.481	0.505	0.530	0.583
Hoke Co								
	03-47-025	Hoke RWS	58.68	2.594	3.286	3.638	3.990	4.343
	03-47-010	Raeford	403.64	1.937	2.131	2.341	2.543	2.745

Table 4 Population Based Water Demand Estimates (cont.)

(Estimated service population from Local Water Supply Plans multiplied by 2010 gallons per capita day water use)

Estimated Water Demands based on Service Populations data from Local Water Supply Plans and Jordan Lake Allocation Requests*								
County	**System ID#**	**Water System**	**2010 gpcd**	**2020 mgd**	**2030 mgd**	**2040 mgd**	**2050 mgd**	**2060 mgd**
Johnston								
	03-51-025	Benson	161.21	0.584	0.600	0.617	0.633	0.645
	03-51-020	Clayton	142.21	3.084	4.142	5.563	7.471	10.033
	03-51-195	Flowers Plantation	200.44	1.214	1.214	1.214	1.214	1.214
	03-51-035	Four Oaks	86.77	0.234	0.260	0.293	0.333	0.381
	03-51-070	Johnston County	82.34	6.546	7.987	9.757	11.898	14.533
	03-51-030	Kenly	173.19	0.244	0.246	0.249	0.251	0.254
	40-51-008	Micro (County Line)	66.67	0.002	0.002	0.003	0.003	0.004
	03-51-050	Princeton	82.12	0.131	0.166	0.208	0.261	0.329
	03-51-010	Smithfield	180.72	2.005	2.025	2.045	2.066	2.084
Lee								
	03-53-015	Broadway	64.36	0.119	0.136	0.156	0.180	0.205
	03-53-101	Carolina Trace WS	51.83	0.271	0.271	0.271	0.271	0.271
	03-53-010	Sanford	143.01	8.094	10.869	13.185	15.988	19.406
Lenoir								
	04-54-030	Deep Run WC	72.27	1.186	1.419	1.697	2.029	2.029
	04-54-010	Kinston	125.34	3.510	3.572	3.635	3.760	3.823
	04-54-025	North Lenoir Water Corp.	68.10	1.001	1.021	1.038	1.056	1.073
	04-54-020	Pink Hill	63.87	0.062	0.063	0.063	0.064	0.065
Moore								
	03-63-025	Carthage	124.28	0.323	0.348	0.373	0.398	0.410
	50-63-011	East Moore Water District	72.97	0.461	0.478	0.495	0.513	0.531
	50-63-021	Moore County Public Utilities-High Falls	272.73	0.079	0.082	0.085	0.088	0.091
	03-63-103	Moore County Public Utilities-Hyland Hills	86.57	0.031	0.033	0.035	0.038	0.041
	03-63-108	Moore County Public Utilities-Pinehurst	156.39	2.673	3.051	3.482	3.975	4.536
	03-63-155	Moore County Public Utilities-Robbins	178.57	0.011	0.012	0.013	0.014	0.016
	03-63-117	Moore County Public Utilities-Seven Lakes	71.80	0.463	0.479	0.497	0.514	0.533
	03-63-045	Moore County Public Utilities-Vass	112.71	0.123	0.131	0.140	0.150	0.160
	03-63-015	Robbins Water System	124.62	0.250	0.285	0.299	0.312	0.324
New Hanover								
	04-65-010	Cape Fear Public Utility Authority - Wilmington	115.56	23.112	26.986	34.510	42.014	43.970
	04-65-015	Carolina Beach	121.85	1.682	1.682	1.682	1.682	1.682
Orange								
	03-68-015	***Hillsborough****	***94.71***	***1.591***	***1.904***	***2.292***	***2.747***	***3.201***
	03-68-010	***Orange Water and Sewer Authority****	***96.94***	***8.986***	***10.373***	***11.749***	***13.135***	***14.512***
	03-68-020	Orange-Alamance	78.24	0.668	0.687	0.707	0.726	0.746
Pitt								
	04-74-025	Ayden	91.75	0.496	0.548	0.606	0.669	0.678
	04-74-045	Bell Arthur WC	72.78	0.677	0.677	0.728	0.764	0.768
	04-74-015	Eastern Pines Water Corporation	78.75	2.533	3.608	3.608	3.608	3.608
	04-74-035	Grifton	67.20	0.190	0.207	0.226	0.246	0.247
Randolph								
	02-76-030	Archdale	116.80	1.518	1.635	1.752	1.869	1.986
	02-76-035	Franklinville	63.77	0.080	0.083	0.089	0.096	0.102
	02-76-020	Ramseur	121.98	0.395	0.434	0.473	0.516	0.537
	02-76-015	Randleman	235.59	1.107	1.202	1.296	1.390	1.484
Rockingham								
	02-79-020	Reidsville	249.50	4.000	4.154	4.258	4.364	4.591
	02-79-050	Rockingham Co	96.58	0.126	0.145	0.164	0.183	0.203
Wake								
	03-92-045	***Apex****	***78.17***	***4.151***	***5.816***	***7.856***	***8.536***	***8.771***
	03-92-020	***Cary****	***119.43***	***21.068***	***24.854***	***27.542***	***29.608***	***29.667***
	03-92-055	Fuquay-Varina	102.92	2.847	4.339	6.140	7.941	9.742
	03-92-050	***Holly Springs****	***64.82***	***3.028***	***4.014***	***4.850***	***5.771***	***6.693***
	03-92-010	***Raleigh****	***105.11***	***67.110***	***83.989***	***101.237***	***119.210***	***138.339***
Wayne								
	04-96-060	Fork Township SD	82.79	0.927	0.948	0.969	0.994	1.018
	04-96-025	Fremont	81.34	0.108	0.102	0.097	0.092	0.086
	04-96-010	Goldsboro	143.61	5.939	6.830	7.855	9.033	10.388
	04-96-030	Pikeville	138.71	0.110	0.126	0.142	0.157	0.175
	04-96-065	Wayne WD	78.26	4.933	5.725	6.655	7.723	8.963
Wilson								
	04-98-020	Elm City	114.18	0.171	0.171	0.171	0.171	0.171
	04-98-010	Wilson	133.88	7.297	7.953	8.662	9.439	10.282

The Cape Fear - Neuse River Basins Hydrologic Model

The modeling results are dependent on data availability and the accuracy of presumptions made about future

The analysis presented in this report is based on combining water use data submitted by water users with that compiled by the DWR staff and consultants. The data are evaluated using 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 may occur as surface water withdrawals vary. The results are dependent on data availability and the accuracy of presumptions made about future conditions. Changes in the data used or changes in the presumptions will produce different results.

An initial version of a Cape Fear River Basin Model was developed for analyzing the potential impacts of water supply allocations from B. Everett Jordan Lake that were approved in 2002. In 2007 the data compiled for the initial model were transferred to a different program platform called 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 resulting Cape Fear River Basin Hydrologic Model was developed in consultation with the major surface water withdrawers in the basin along with representatives of State and federal resource management agencies. During the updating process the historic inflow data were updated to extend streamflow data used in the model through 2005.

For the analysis of this fourth round of allocations of water supply storage in Jordan Lake the Cape Fear River Basin Hydrologic Model was combined with the existing Neuse River Basin Hydrologic Model. The combined Cape Fear – Neuse River Basins Hydrologic Model characterizes the effects of surface water withdrawals and water sharing among public utilities in both basins. During the process of merging the two models inflow data were updated to capture flow conditions through September 2011. The basecase of the model processes the range of historical flows through the existing and known future infrastructure and management protocols. Scenarios using expected future water withdrawals are processed to evaluate how resource conditions could vary in the future. The modeling for this analysis evaluates various levels of surface water withdrawals over the range of flows that have occurred in these two basins between January 1930 and September 2011.

The Division of Water Resources uses hydrologic modeling to evaluate surface water availability under various water withdrawal and management scenarios. A hydrologic model creates a hypothetical representation of surface water conditions based on available data and inferences based on known data to characterize the relationships between water withdrawals, return flows and management protocols. Each model produces a mathematical characterization of surface water volumes and streamflows based on conditions defined for a point in time when water withdrawals, wastewater discharges, and water management protocols are fixed and data describing the resultant surface water conditions are available. The model coding is adjusted to closely approximate the known conditions. This primary model scenario captures current conditions at the time of model development, based on conditions up to that time and provides the "basecase" for the model. The basecase scenario provides the benchmark against which the impacts from changes in management regimes and water withdrawals can be compared.

While future demand scenarios are typically designed using withdrawal levels thought to be needed to meet demands some year in the future, the model does not project future surface water flows. It evaluates various water demand quantities against the range of streamflows that have occurred in the historic record. Comparing model scenarios provides information to describe how surface water conditions may differ under the alternative scenarios, from those of the basecase scenario, over the range of flow conditions that historically occurred in the basins.

The basecase scenario is a point in time with which people living and working in the basin had direct experience. In the model used for this analysis the basecase represents conditions in 2010. Looking at the outputs from the basecase of the model provides information on the magnitude and duration of water shortages that might have occurred with the 2010 levels of water demands during historic flow conditions or that may occur if similar flow conditions occur in the future. For instance, what might water resource conditions be like if water withdrawers were trying to meet 2010 water demands during the water availability conditions that existed during the 1953-54 drought?

Modeling the increased withdrawals needed to meet estimated future water demands provides information on how water resource conditions could be affected over the range of historic flow conditions used in the model. Of particular concern are the potential impacts to the ability to meet public water system demands and changes to the magnitude and duration of water shortages as demands increase.

The Cape Fear-Neuse River Basins Hydrologic Model analyzes changes in surface water quantity as water flows downstream. The model includes a sequential set of evaluation locations, referred to as model nodes, which represent locations along the waterways in the Cape Fear and Neuse river basins. The model evaluates the effects of inflows, withdrawals and return flows over the range of flow conditions in these basins from 1930 to 2011. The model balances water coming into the surface water network with water going out of the network at all nodes, subject to the goals and constraints established at each node. Priority among multiple withdrawals at a particular node is regulated by a series of weighting coefficients used to set priority among multiple withdrawals at a node. For example, at reservoir nodes water is stored and released subject to reservoir operating rules. If the reservoir has a required minimum downstream release of water, then that goal is given a higher priority and water is subtracted for that use before water is subtracted for other withdrawals. The model operates on a daily time step. Each model run makes one set of calculations based on daily average values for each of the 29,858 days of flow data in the model.

Future demand projections and the magnitude of water withdrawals needed to meet those demands were derived from data submitted to the division by local officials and water withdrawal managers. In order to keep future demand estimates compatible, future water demand projections for water systems not applying for a Jordan Lake allocation were taken from 2013 local water supply plans to capture all systems expectations of the future needs at a similar point in time to when the applicants were assembling their application data. Public water systems included in the model were asked to review the data included in the model basecase before finalization. Water systems that have reservoirs or multiple sources of water were specifically asked to review the data in the model describing reservoir capacity and how water demands are distributed between multiple sources. Revisions to the data submitted by the water utilities were incorporated into the model before this analysis was completed.

Scope of the Model

The geographic scope of the model is limited by the fact that the model can only handle streamflow moving in one direction, downstream. Therefore the downstream limits of the model are set at a point upstream of where water begins to be tidally influenced and moves upstream as well as downstream in response to tidal actions. The Cape Fear portion of the model includes 5260 square miles of the basin including the drainage areas of the Deep River, the Haw River and the Cape Fear River above Lock and Dam #1 in Bladen County. The Neuse River portion of the model includes 4060 square miles of the basin including the drainage areas of Contentnea Creek and the Neuse River upstream of New Bern.

The model schematic in Figure 6 shows the geographic coverage of the model and shows the relative location of the various model nodes. The nodes on the schematic are not geographically linked to the underlying map. The schematic shows the relative positions where water is withdrawn or added to the streams as it flows downstream. 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 7 provides a more detailed image of the model schematic in the vicinity of Jordan Lake.

Figure 6 Cape Fear – Neuse River Basins Hydrologic Model Schematic

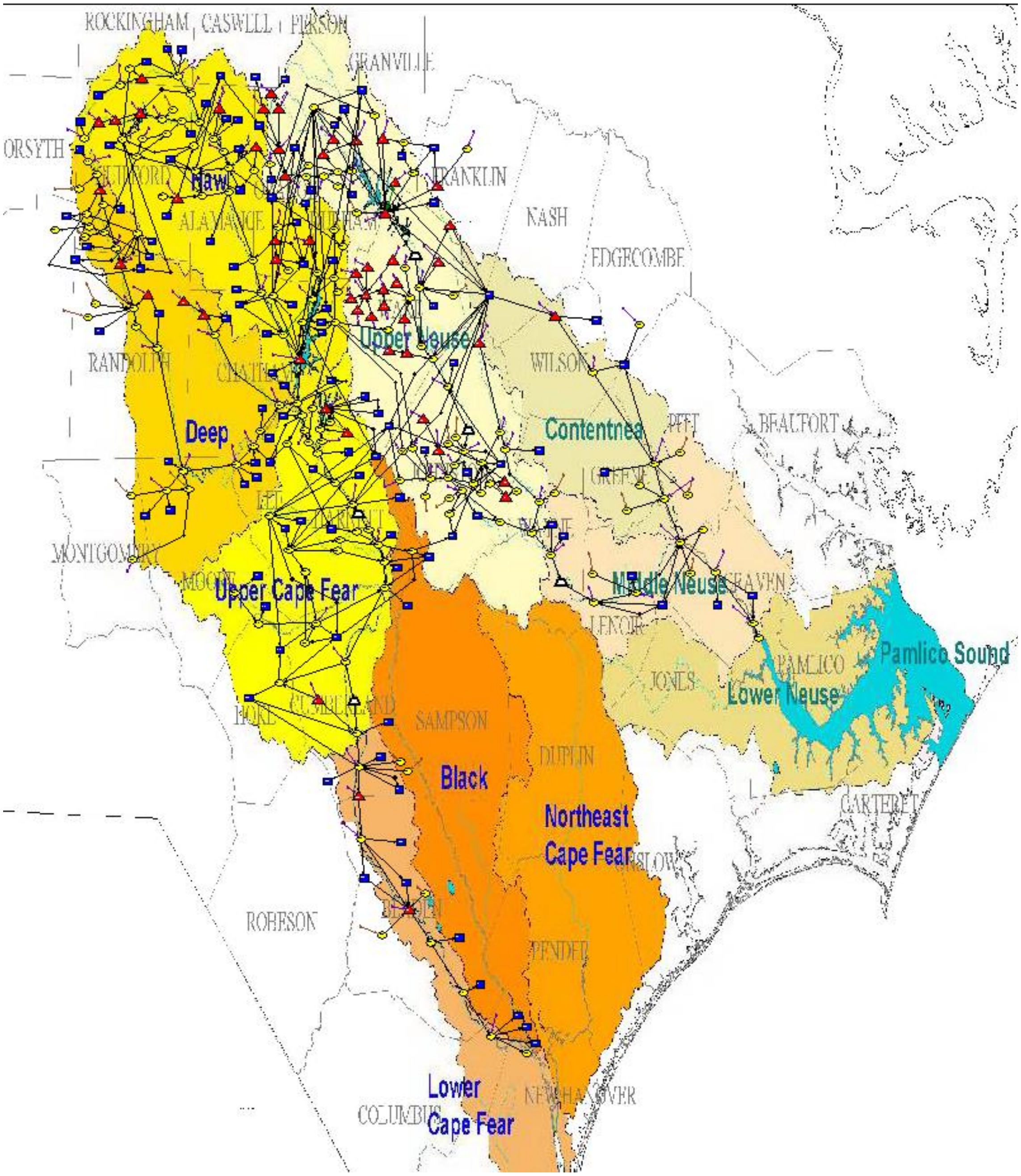
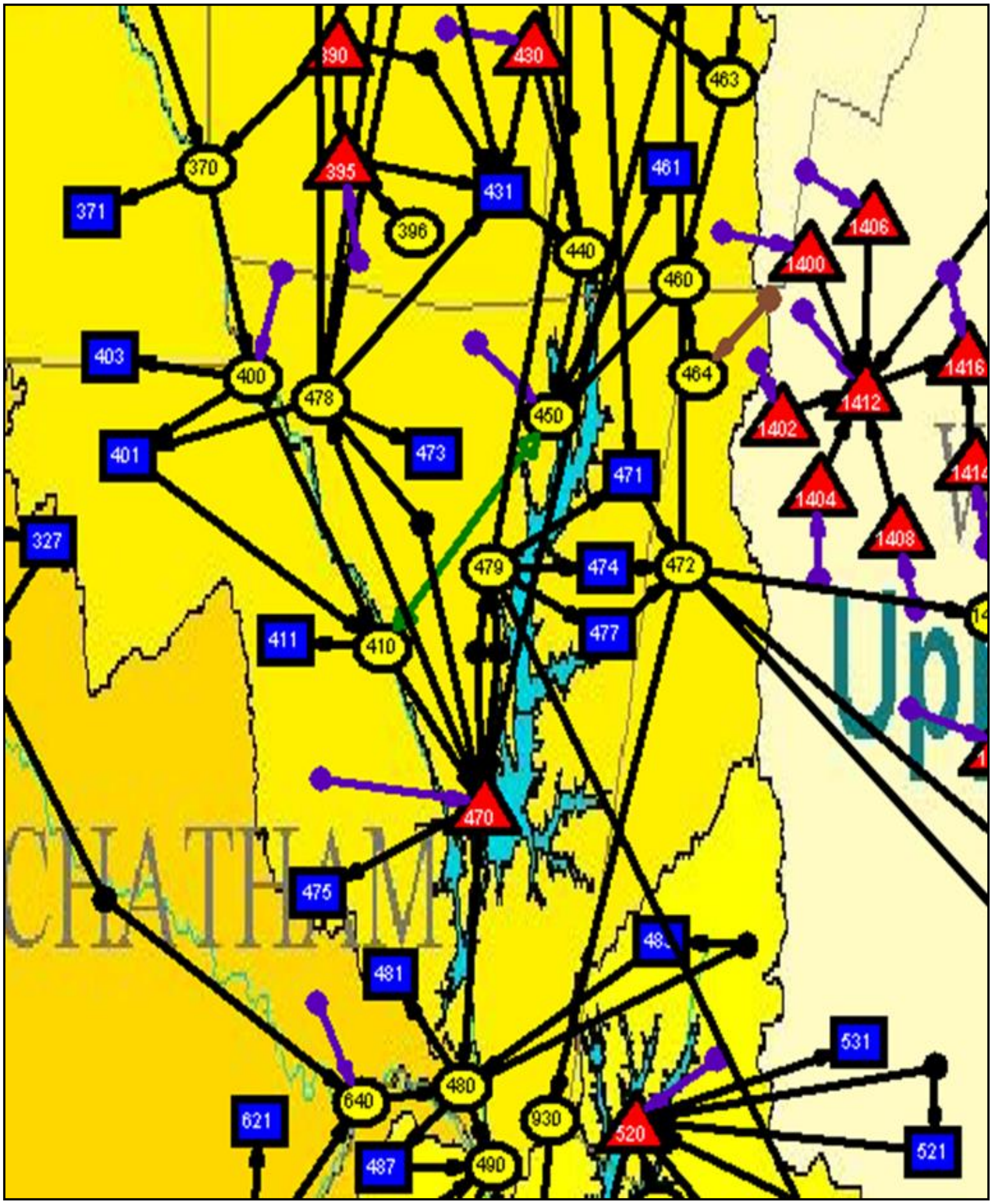


Figure 7 Cape Fear - Neuse River Basins Hydrologic Model Schematic Detail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Modeling the Cape Fear and Neuse River Basins

During each model run the Cape Fear-Neuse River Basins Hydrologic Model balances surface water coming into the streams in the basins with water going out of the streams at all nodes, subject to goals, constraints and management protocols defined for the scenario. Each type of water use is given a priority at each node during model development so that water is apportioned between competing uses to emulate real world conditions. At the reservoir nodes water is stored and released subject to operating rules established in consultation with reservoir managers and users. For each scenario run the model calculates daily average values for the characteristics being considered at each node for each of the 29,858 days in the historic flow dataset.

For future demand scenarios water systems that depend on neighboring water systems for their current water supplies are assumed to continue having their demands met by the same suppliers in the future, unless information is available describing planned changes.

Public water systems that submit a local water supply plan provide estimates of future water demands. The plans do not include estimates of future wastewater return flows. Therefore, for model scenarios other than the basecase scenario wastewater return flows are estimated at the same percentage of water withdrawal or water use as that used in the 2010 basecase scenario, unless additional information is available. The actual amount of treated wastewater returned to the surface waters in these basins will be determined by the utilities' desire and ability to construct the necessary collection systems and treatment facilities as well as the ability to secure the necessary permits.

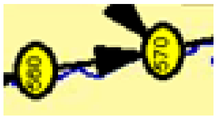
The results of the various modeling scenarios used for this analysis are inextricably linked to the assumptions about how much treated wastewater is returned to the surface waters of the basins. Changes in modeling assumptions will change the model outputs.

The model schematic above represents the workings of the model as a series of lines, or arcs, leading into, out of, or connecting a variety of polygons. The color codes are explained below. The arrows on the arcs show how the model moves water. The polygons show points in the process where a mathematical evaluation is done to determine the cumulative effects of actions represented by the water flowing into or out of that location. The result of that calculation determines the volume of water that is passed downstream to the next node.

Estimated Inflows:

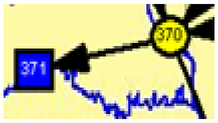
In the schematic watershed inflows are shown as purple arcs. The model uses a set of historic flow data that was adjusted to approximate natural inflows to streams produced by surface water runoff and groundwater discharges. These inflow data were reconstructed using streamflow gage data to create 81years of flow records that were adjusted for historic withdrawals, wastewater discharges, and reservoir operations. The inflows are introduced into the modeling sequence at discrete points throughout the watershed to reflect where the flow enters the actual river system relative to other model nodes.

Flows between nodes:



Water movement between model nodes is indicated by black arcs in the schematic. The direction of the arrows indicates the direction of flow through the arcs. The yellow oval nodes are junction nodes and indicate where a calculation has to be made to adjust for an addition or subtraction of water to the surface water system or a location where a calculation is needed for the analysis for which the model is being used.

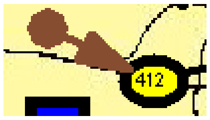
Water Withdrawals:



Arcs leading to a demand node, represented by blue boxes in the schematic, give the location of the withdrawal made to satisfy that demand relative to the locations of other withdrawals and return flows. Water withdrawals are made at discrete nodes to meet demands requested for the associated demand nodes. Withdrawals can be for water supply systems, industrial water users, or agricultural water uses. Public water supply withdrawals are based on local water supply plan data including projections of future demands. Self-supplied industrial water withdrawals were derived from data submitted to the Division under the water withdrawal registration program. Demands for self-supplied industrial users are assumed to remain the same as in the 2010 basecase scenario through 2060 unless additional information is available to justify changes in projections. Agricultural withdrawals represent the estimated agricultural use on the watershed above the point of withdrawal. Agricultural withdrawals are not linked to specific agricultural operations.

Agricultural demands are the same as those used in previous versions of the individual basin models. Agricultural uses for livestock and irrigation were estimated with the help of county agricultural extension agents and an agricultural 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 basins. Irrigation water is withdrawn to make up for precipitation shortfalls to provide optimum crop needs. Livestock water needs are based on animal head counts in each county and the water needs of various animal types. Percentages of irrigated crops and livestock in the basin were developed for each county in consultation with county agricultural extension agents. Agricultural water withdrawals are distributed in the model based on the geographic locations where the water is used.

Wastewater Inflows:



Black arcs leading out of a demand node give the relative location where wastewater from that user is returned to the surface waters of the basin.

Return flows from wastewater discharges that are not linked to a water withdrawal in the model are represented in the schematic as brown arcs and are handled similar to natural inflows, as water inputs at discrete nodes. The sources of this water may be from users that get water from a neighboring subbasin or from groundwater sources. Inflows from wastewater discharges come from industrial operations and municipal water reclamation facilities.

Local water supply plans include estimates of expected future water withdrawals but do not include estimates of the expected portions of used water that may be collected for treatment and discharged to the surface waters being modeled. Assumptions about the magnitude of wastewater return flows are key factors in the hydrologic model. Wastewater discharges linked to a modeled withdrawal are estimated based on the percentage of a facility's water withdrawal that was directly returned to the surface waters of the basin in the basecase scenario. This percentage was then applied to estimated future withdrawals to estimate future wastewater return flows. For example, if a town withdrew 10 million gallons per day on average and returned 6 million gallons per day of treated wastewater in the basecase conditions, then 60 percent of the withdrawal was returned directly to the surface waters of the basin. In other scenarios, the assumed wastewater discharge, for this specific user, is assumed to be 60 percent of the withdrawal. This relationship is used for all wastewater discharges linked to a surface water withdrawal unless more specific information is available.

Wastewater return flows are estimated in the model so that the cumulative withdrawals in model scenarios do not deplete the water resource system. This is a critical assumption in the model. If communities choose not to develop wastewater treatment capacities at these levels or their ability to get permits to discharge the estimated volumes of wastewater modeled are limited by policy or funding then future surface water conditions could be significantly different from those shown in the current modeling.

The results of the various modeling scenarios used for this analysis are inextricably linked to the assumptions about how much treated wastewater is returned to the surface waters of the basins.

Reservoir Operations:

Reservoirs are represented by red triangles in the schematic. The model balances inflows and outflows at each node for each time step in a model run except reservoirs. For reservoirs, the change in storage is included in the balancing equation. Each reservoir in the model has a set of operating guidelines that set the maximum and minimum water levels during normal and extraordinary operating conditions. The largest reservoirs in the model, Jordan Lake and Falls Lake, are multipurpose reservoirs managed by the US Army Corps of Engineers. Both are required to make water releases established to minimize violations of water quality standards downstream. Jordan Lake and Falls Lake have storage dedicated for flow augmentation releases that is managed separately from the storage dedicated to water supply. The management plans for Jordan Lake and Falls Lake can be found at the Corp of Engineer's Wilmington District's website at epec.saw.usace.army.mil.

With the exception of the series of flood control impoundments in the Crabtree Creek watershed in the Neuse Basin the other reservoirs in the model were primarily developed as water supply reservoirs. Some of the water supply reservoirs in the basins have minimum release requirements to maintain streamflows.

For instance, Randleman Lake, which is primarily a water supply reservoir, under normal conditions maintains a minimum release of 30 cubic feet per second downstream of the reservoir. During times when inflows are not adequate to maintain 60 percent or more of usable storage the release requirements are reduced to more closely mimic the downstream flow conditions that would be typical of flow conditions during droughts. When usable storage drops below 60 percent the required minimum release drops to 20 cubic feet per second. If storage drops below 30 percent of usable storage the required release drops to 10 cubic feet per second. For reservoirs that have minimum release requirements the stipulations of the release schedules are built into the model.

Model Scenarios:

Several levels of water demands were evaluated for this exercise. The 2010 base case scenario reflecting current conditions provides the point of comparison for all other model scenarios. Water demands and return flows were estimated using local water supply plan data, additional information received from water systems including Jordan Lake water supply allocation applications and data from other registered water users. The results of the alternative scenarios are compared to the basecase scenario to identify changes to surface water resources due to the variations in withdrawals, return flows and management protocols included in each alternative scenario.

The regulations governing allocation of water supply storage in Jordan Lake limit allocations to the amount estimated to be needed 30 years in the future. A 2045 demand scenario characterizes the water demands expected to be needed in the year 2045 using local water supply plan data and information contained in the Jordan Lake water supply allocation applications. With allocation decisions expected to be finalized in 2015 this scenario gives information on anticipated needs 30 years in the future. The specified levels of demand may actually be reached before or after 2045. The evaluation focuses on the changes in conditions that may occur from the specified levels of demand, whenever they are reached. Modeling the quantity of water to be withdrawn to satisfy estimated 2045 demands provides the analysis used to evaluate requested water supply allocations.

The 2060 demand scenario is based on the water withdrawals expected to be needed to meet 2060 demands as presented in the local water supply plans. It provides a long-range picture of water resource conditions including the effects of the requested water supply allocations. In previous rounds of Jordan Lake water supply allocations members of the Environmental Management Commission asked DWR to provide an analysis over a 50-year planning horizon to identify potential water supply issues beyond the 30-year planning horizon used for allocation decisions.

Withdrawals and Discharges:

Table 6 lists the water supply nodes for the Cape Fear-Neuse River Basin Hydrologic Model and the average annual values used for water withdrawals and the estimated amounts of wastewater that was assumed to be collected, treated and discharged back to the surface waters at the current discharge locations. Some of these withdrawals represent the cumulative demands for multiple water purveyors that depend on water from that source to meet customer demands.

Table 6 Annual Average Surface Water Withdrawals and Wastewater Discharges

Modeled Annual Average Surface Water Withdrawals and Return Flows in Million Gallons per Day (MGD)							
Model Node	Surface Water Withdrawer	Wastewater Proportion	2010 Current Conditions	2035 Estimated Demand	2045 Estimated Demand	2060 Estimated Demand	Estimate Type
31	Reidsville Demand_02-79-020		3.530	4.347	4.459	4.666	Withdrawal
	Reidsville nc0046345 and nc0024881	0.594	2.097	2.582	2.649	2.772	Return
123	Greensboro Total Demand_02-41-010		35.240	48.485	55.312	67.399	Withdrawal
	Lake Townsend nc0081671	0.132	4.652	6.400	7.301	8.897	Return
	North Buffalo Creek nc0024325	0.283	9.973	13.721	15.653	19.074	Return
	Ozborne nc0047384	0.737	25.972	35.733	40.765	49.673	Return
	Mitchell nc0081426	0.02	0.705	0.970	1.106	1.348	Return
223	High Point Service Area Demand_02-41-020		12.640	15.891	17.323	19.694	Withdrawal
	High Point nc0081256 and nc0024210	1.085	13.714	17.242	18.795	21.368	Return
261	City of Randleman Demand_02-76-015		0.400	1.059	1.202	1.322	Withdrawal
	Randleman nc0025445	1	0.400	1.059	1.202	1.322	Return
271	PTRWA Total Withdrawal(supplied to others)		0.000	19.331	26.439	33.364	WW Return
	PTRWA WTP nc0087866	0.107	0.000	2.068	2.829	3.570	Return
301	Ramseur Demand_02-76-020		0.490	0.552	0.589	0.635	Withdrawal
	Ramseur nc0026565	0.343	0.168	0.189	0.202	0.218	Return
321	Graham-Mebane Demand_02-01-015		3.500	6.737	7.965	10.512	Withdrawal
	G-M nc0045292,nc0021211,nc0021474	0.773	2.706	5.208	6.157	8.126	Return
327	Siler City Demand_03-19-010		2.380	2.482	2.647	2.919	Withdrawal
	Siler City nc0026441	0.909	2.163	2.256	2.406	2.653	Return
341	Burlington Demand_02-01-010		15.030	8.978	9.991	11.739	Withdrawal
	Mackintosh nc0023828	0.033	0.496	0.296	0.330	0.387	Return
	East nc0023868	0.335	5.035	3.008	3.347	3.933	Return
	Southside nc0023876	0.483	7.259	4.336	4.826	5.670	Return
401	Pittsboro Demand_03-19-015		0.600	8.410	9.920	11.240	Withdrawal
	Pittsboro nc0020354	0.317	0.190	2.666	3.145	3.563	Return
431	OWASA Demand_03-68-010		7.700	10.240	11.320	12.910	Withdrawal
	OWASA nc0025241	0.955	7.354	9.779	10.811	12.329	Return
471	Cary Apex water supply		18.400	34.800	39.150	41.400	Withdrawal
	Cary Apex return	0.813	14.958	28.290	31.826	33.655	Return
	CarySystem WW (Cary,Apex,Morrisville,RTP)		16.953	33.108	37.090	39.133	Return
	Cary North WRF nc0048879	0.370	6.951	12.250	13.723	14.479	Return
	Cary South WRF nc0065102	0.230	5.255	7.615	8.531	9.001	Return
	Apex WRF nc0064050	0.050	2.543	1.655	1.854	1.957	Return
	Western Wake WRF nc0088846	0.35	0.000	11.588	12.981	13.697	Return
	Durham County Triangle WRF nc0026051		2.204	0.000	0.000	0.000	Return
473	Chatham Co. North Demand		2.200	10.130	13.030	18.120	Withdrawal
	Chatham County - North nc0084093	0.139	0.306	1.408	1.811	2.519	Return
474	RTP Demand		0.600	2.700	3.200	3.300	Withdrawal
	RTP return	0.603	0.362	1.628	1.930	1.990	Return
477	Morrisville demand		1.700	3.320	3.470	3.630	Withdrawal
	Morrisville return	0.961	1.634	3.191	3.335	3.488	Return
483	Performance Fibers Demand		0.200	0.201	0.201	0.201	Withdrawal
	Performance Fibers nc0001899	0.972	0.194	0.195	0.195	0.195	Return

Table 6 Annual Average Surface Water Withdrawals and Wastewater Discharges

Modeled Annual Average Surface Water Withdrawals and Return Flows in Million Gallons per Day (MGD)							
Model Node	Surface Water Withdrawer	Wastewater Proportion	2010 Current Conditions	2035 Estimated Demand	2045 Estimated Demand	2060 Estimated Demand	Estimate Type
487	Cape Fear Steam Station Demand		218.300	0.000	0.000	0.000	Withdrawal
	Cape Fear Steam Station nc0003433	0.989	215.899	0.000	0.000	0.000	Return
491	Sanford Water Supply Demand		6.231	13.029	17.426	24.171	Withdrawal
	Sanford nc0002861 and nc0059242	0.103	0.642	1.342	1.795	2.490	Return
	Sanford nc0024147	0.623	3.882	8.062	10.799	14.998	Return
521	Harris Nuclear Station		20.000	20.000	20.000	20.000	Withdrawal
	Harris Nuclear Station nc0039586	0.616	12.320	12.320	12.320	12.320	Return
551	Harnett County RWS Demand		10.137	30.365	35.015	43.831	Withdrawal
	Total Harnett Co WW	0.575	5.829	17.460	20.134	25.203	Return
601	Pilgrims Pride Demand		0.970	0.884	0.884	0.884	Withdrawal
	Pilgrims Pride nc0083852	0.053	0.051	0.047	0.047	0.047	Return
605	Goldston-Gulf WS PWS 03-19-025		0.000	0.089	0.092	0.097	Withdrawal
654	Angier Demand		0.415	0.867	1.192	1.638	Withdrawal
	Angier WW to Harnett Co RWS	0.883	0.366	0.766	1.053	1.446	Return
663	Dunn Demand		3.410	3.060	3.120	3.215	Withdrawal
	Dunn nc0078955 and nc0043176	0.683	2.329	2.090	2.131	2.196	Return
674	Carolina Trace WS_03-53-101		0.215	0.186	0.186	0.186	Withdrawal
	Carolina Trace nc0038831	1	0.215	0.186	0.186	0.186	Return
701	Carthage Demand_03-63-025		0.300	0.578	0.589	0.642	Withdrawal
	WW sent out of model boundary		0.000	0.000	0.000	0.000	Return
719	Spring Lake WS_03-26-020		0.909	1.254	1.414	1.651	Withdrawal
	Spring Lake nc0030970	0.833	0.757	1.045	1.178	1.375	Return
721	Old North Ut. FBragg Demand_50-26-019		4.800	4.761	4.879	5.062	Withdrawal
	Old North Utilities WW to Harnett Co. RWS	1	4.800	4.761	4.879	5.062	Return
733	FayettevillePWC Demand_03-26-010		26.228	50.721	60.582	73.464	Withdrawal
	Fayetteville PWC nc0076783 and nc 0023957	0.487	12.773	24.701	29.503	35.777	Return
	Fayetteville PWC nc0050105	0.517	13.560	26.223	31.321	37.981	Return
771	Monsanto WS Net Withdrawal		0.000	0.000	0.000	0.000	Withdrawal
781	Dupont WS		11.170	11.170	11.170	11.170	Withdrawal
	Dupont nc0003573	1	11.170	11.170	11.170	11.170	Return
785	LCFWSA_BladenBluff Demand_50-09-012			1.450	1.450	1.450	Withdrawal
	Smithfield Packing-Tarheel Plant nc0078344	1		1.450	1.450	1.450	Return
823	Cape Fear PUA-Wilmington Demand_04-65-010		4.670	20.230	23.128	29.372	Withdrawal
825	LCFWSA_KingsBluff Demand_50-09-013		25.540	23.290	25.852	29.941	Withdrawal
903	Jamestown Demand_02-41-030		0.450	0.622	0.652	0.681	Withdrawal
904	Archdale Demand Randleman_02-76-030		0.700	1.137	1.157	1.182	Withdrawal
	Archdale WW to High Point	1	0.700	1.137	1.157	1.182	Return
906	Randolph Co Demand Randleman		0.000	0.000	0.000	0.000	Withdrawal
921	Orange Co Demand		0.000	2.010	2.810	3.920	Withdrawal
	Orange Co WW to Mebane	0.493	0.000	0.991	1.385	1.933	Return
	Orange Co WW to Durham	0.22	0.000	0.442	0.618	0.862	Return
	Orange Co WW to Hillsborough	0.287	0.000	0.577	0.806	1.125	Return
923	Holly Springs Demand_03-92-050		1.600	6.230	7.240	8.780	Withdrawal
	Holly Springs nc0063098	0.789	1.262	4.915	5.712	6.927	Return

Table 6 Annual Average Surface Water Withdrawals and Wastewater Discharges

Modeled Annual Average Surface Water Withdrawals and Return Flows in Million Gallons per Day (MGD)

Model Node	Surface Water Withdrawer	Wastewater Proportion	2010 Current Conditions	2035 Estimated Demand	2045 Estimated Demand	2060 Estimated Demand	Estimate Type
940	Broadway WS_03-53-015		0.095	0.151	0.172	0.209	Withdrawal
	Broadway nc0059242	0.66	0.063	0.100	0.114	0.138	Return
1046	Orange_Alamance Demand_03-68-020		0.180	0.220	0.226	0.235	Withdrawal
	Orange-Alamance nc0082759	0.092	0.017	0.020	0.021	0.022	Return
1106	Hillsborough Demand_03-68-015		1.160	2.870	3.220	3.700	Withdrawal
	Hillsborough nc0026433	0.644	0.747	1.848	2.074	2.383	Return
1116	Piedmont Minerals Demand		0.000	0.000	0.000	0.000	Withdrawal
			0.000	0.000	0.000	0.000	Return
1162	Durham Service Area Demand		28.230	36.120	39.980	44.370	Withdrawal
	Durham Ellerbe Creek nc0023841	0.329	9.288	11.883	13.153	14.598	Return
	Durham WRF nc0047967	0.375	10.586	13.545	14.993	16.639	Return
	Durham County Triangle WRF nc0026051	0.13	3.670	4.696	5.197	5.768	Return
1256	SGWASA Demand_02-39-107		2.990	3.859	4.334	4.944	Withdrawal
	SGWASA nc0026824	0.624	1.866	2.408	2.704	3.085	Return
1258	Creedmor Demand_02-39-015		0.320	0.731	0.893	0.980	Withdrawal
	Included in SGWASA						Return
1306	Raleigh Demand_03-92-010		52.000	84.760	97.020	115.010	Withdrawal
	Raleigh nc0029033	0.853	44.356	72.300	82.758	98.104	Return
	Raleigh nc0079316	0.014	0.728	1.187	1.358	1.610	Return
	Raleigh nc0030759	0.0244	1.269	2.068	2.367	2.806	Return
	Raleigh presumptive JLA allocation	0.7626	3.584	3.584	3.584	3.584	Return
1506	Wilson Demand_04-98-010		8.960	10.573	11.554	13.073	Withdrawal
	Wilson nc0023906	0.866	7.759	9.156	10.006	11.321	Return
1646	Johnston County Demand_03-51-070		8.560	12.640	15.327	20.252	Withdrawal
	Johnston County nc0030716	0.257	2.200	3.248	3.939	5.205	Return
	Johnston County to Benson	0.015	0.128	0.190	0.230	0.304	Return
	Kenly nc0064891	0.048	0.411	0.607	0.736	0.972	Return
	Clayton nc0064564 and nc0025453	0.263	2.251	3.324	4.031	5.326	Return
1666	Smithfield Demand_03-51-010		2.960	3.370	3.954	5.950	Withdrawal
	Smithfield to Johnston County	0.785	2.324	2.645	3.104	4.671	Return
1706	Fuquay-Varina Demand_03-92-055		1.870	4.627	6.150	8.456	Withdrawal
	Fuquay-Varina to Harnett Co RWS	0.483	0.903	2.235	2.970	4.084	Return
	Fuquay-Varina nc0066516 and nc0066150	0.336	0.628	1.555	2.066	2.841	Return
1756	Benson Demand_03-51-025		0.775	0.881	0.902	0.939	Withdrawal
	Benson nc0020389	0.333	0.258	0.293	0.300	0.313	Return
1766	Progress Lee Steam Plant Demand_CUR0001 (Net)		8.910	8.077	8.077	8.077	Withdrawal
1786	Goldsboro Demand_04-96-010		4.780	6.731	8.071	11.187	Withdrawal
	Goldsboro nc0023949	1.408	6.730	9.477	11.364	15.751	Return
1806	Neuse Regional WASA_60-54-001		7.820	11.979	13.030	14.206	Withdrawal
	NRWASA nc0088111	0.068	0.532	0.815	0.886	0.966	Return
	Kinston nc0024236	0.629	4.919	7.535	8.196	8.936	Return
	Ayden-Grifton WW	0.173	1.353	2.072	2.254	2.458	Return
1906	Weyerhauser Demand_CUR0052		14.470	14.471	14.471	14.471	Withdrawal
	Weyerhauser nc0003191	0.973	14.079	14.080	14.080	14.080	Return

B. Everett Jordan Dam and Reservoir

The Cape Fear River experienced several significant flooding events prior to the devastating flood of September 1945 which produced $4.7 million dollars of damage[16] in Fayetteville. The Deep River Subbasin and Haw River Subbasin received about six inches of precipitation during the first week of September that year producing river flows at the Lillington stream gage, upstream of Fayetteville, of 140,000 cubic feet per second. The citizens of Fayetteville saw the Cape Fear River rise to 68.9 feet above mean sea level, more than 33 feet above flood stage. Shortly after this event the U.S. Congress commissioned the U.S. Army Corps of Engineers to study water resource needs in the basin.

In 1963, based on the results of this study, the U.S. Congress authorized the construction of "New Hope Reservoir" on the Haw River to address issues identified by the USACE. The project was later renamed in honor of U.S. Senator B. Everett Jordan. According to the USACE website "The purposes of B. Everett Jordan Dam and Lake are to provide flood damage reduction, water supply, water quality control, fish and wildlife conservation and outdoor recreation."[17] Jordan Lake first attained its normal operating level in the fall of 1982.

B. Everett Jordan Dam created 538,400 acre-feet[18] of storage to reduce flooding damages downstream. The project provides controlled releases of stored water produced by high flow events in the Haw River Subbasin. The project also includes 94,600 acre-feet of storage to provide water for flow augmentation to address water quality issues downstream. During the study the State of North Carolina agreed to assume financial responsibility for expanding the storage capacity with the goal of providing 100 million gallons per day of water to address future water supply needs. Therefore, the project includes 45,800 acre-feet of storage for water supply needs. In addition, 74,700 acre-feet of storage are included to provide the ability to compensate for space lost to the water supply and flow-augmentation pools due to sediment accumulation over the life of the project

Except during times of low precipitation the reservoir water level is maintained at 216 feet above mean sea level. At this level the flow augmentation, water supply storage and sediment storage pools are full. The storage between 202 feet mean sea level and 216 feet mean sea level is dedicate to flow augmentation and water supply. Storage below 202 feet mean sea level is reserved to compensate for sediment accumulation in the reservoir. Withdrawals from the flow augmentation account and the water supply

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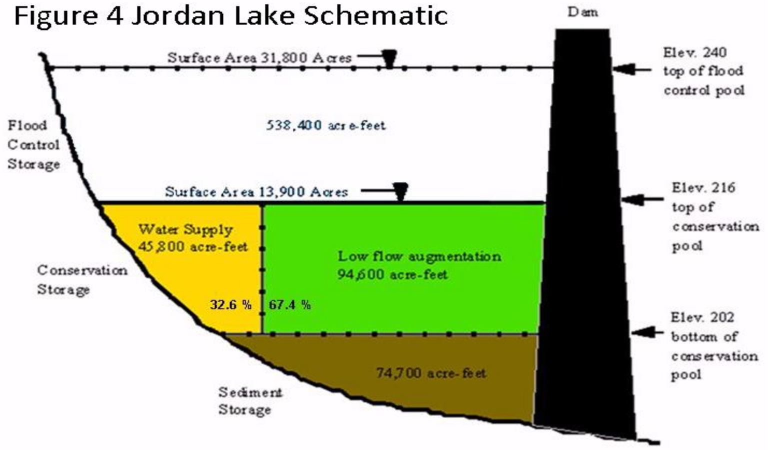
[16] 2007; Carolina Public Health; "The Lake That Almost Wasn't"; Spivey, Angela; Fall 2007

[17] http://www.saw.usace.army.mil/Locations/DistrictLakesandDams/BEverettJordan.aspx

[18] 538,400 acre-feet can hold 175.4 billion gallons of water

accounts are tracked separately and deducted from the volumes stored for each purpose. It is helpful to think of the two storage accounts as two separate reservoirs. Water in the flow augmentation account is not used for water supply and water in the water supply account is not used to augment streamflow below the dam. The upper level of controllable flood storage is at 240 feet mean sea level. Above this elevation water flows freely over the spillway.

Figure 4 Jordan Lake Schematic



The tropical storm that generated flooding in Fayetteville in 1945 deposited about six inches of rain across the Cape Fear River Basin. The headwaters of the Cape Fear River basin are composed of the Deep River Subbasin and the Haw River Subbasin. B. Everett Jordan Dam is located on the Haw River upstream of where it joins the Deep River to form the Cape Fear River. Although usually empty the flood control storage component of Jordan Lake is designed to retain the runoff from six inches of rainfall on the reservoir's watershed. Water in the flood storage pool can be released from the dam in a controlled manner to manage water levels downstream.

Flood Risk Management

The highest flows in Fayetteville since the completion of Jordan Lake were generated by Hurricane Fran in 1996. On September 8th the Cape Fear River elevation at Fayetteville reached 44 feet mean sea level. This was above the minor flooding elevation of 35 feet but below the moderate flooding elevation of 48 feet and well below the 1945 flood elevation of 68.9 feet. The previous day flows in the Deep River near the confluence with the Haw River reached 33,600 cubic feet per second producing flows of 41,400 cubic feet per second at the Lillington stream gage. At the same time Jordan Lake was storing about 58,000 cubic feet per second of water that was flowing down the Haw River above the dam. The water level in Jordan Lake eventually reached 233.25 feet mean sea level storing about 341,409 acre-feet (over 111 billion gallons) of water in the flood control pool and moderating water levels in Fayetteville.[19] The intended flood control benefits of Jordan Lake were demonstrated during this event.

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[19] The National Oceanographic and Atmospheric Administration and the U.S. Geological Survey designate an elevation of 58 feet mean sea level in the Cape Fear River at Fayetteville as the indicator of a major flooding event. This water level would be produced by stream flows in the range of 85,000 cubic feet per second. If the 58,000 cubic feet per second of water flow down the Haw River continued downstream rather than being retained in Jordan Lake flows at the Lillington stream gage could have reached over 99,000 cubic feet per second, a level sufficient to push water levels in Fayetteville into the major flood classification.

The Cumberland County Multi-jurisdictional Hazard Mitigation Plan Update of 2010 includes the following statement. "Although the Jordan Dam and Lake serve multiple purposes, such as water supply, recreation, and flood-control, it is the flood-control purpose that is most important in Fayetteville. For example, it is estimated that this project provided an 8-foot reduction in the 100-year flood stage at the U.S. Geological Survey's streamflow gage on the Cape Fear River at Fayetteville."[20]

Flow Augmentation for Water Quality

While flood control was the primary purpose for initiating the study of water resource needs in the Cape Fear River Basin the issue of water quality arose during the study. The U.S. Army Corps of Engineers consulted with the U.S. Public Health Service for guidance on how much streamflow may be needed to meet water quality targets. The USPHS estimated that a flow in the range of 600 cubic feet per second would be needed to meet water quality targets given the standards of treatment at the time and volumes of wastewater received by the Cape Fear River.[21] The flow augmentation pool of the project was intended to provide enough water to augment river flows to ensure flows of 600 cubic feet per second at the U.S. Geological Survey's stream gage on the Cape Fear River at Lillington. This level of flow is equivalent to 388 million gallons per day. Prior to the completion of Jordan Lake the low flow of record at Lillington was 11 cubic feet per second in October 1954. Since completion of Jordan Lake Dam and initiation of flow augmentations the lowest daily average flow at Lillington reported by the U.S. Geological Survey is 155 cubic feet per second in August 2002.

River flows at Lillington are comprised mainly of the combined flows of the Deep River and Haw River supplemented by the contributions of runoff between the confluence of these rivers and the stream gage. The steam gage at Lillington was set as the compliance point for monitoring flow augmentation releases from Jordan Lake. Releases from Jordan Lake are intended to supplement flows from other sources with the goal of maintaining flows of 600 cubic feet per second (388 million gallons per day) at the Lillington stream gage.

Flows from the Deep River are influenced by the effects of several small hydropower operations on the river. Prior to the drought of 1986 the Army Corps of Engineers was managing downstream releases from Jordan Lake to prevent flows at Lillington from ever dropping below 600 cubic feet per second. Because of the unpredictable nature of

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[20] 2010; Cumberland County Multi-Jurisdictional Hazard Mitigation Plan Update; prepared by: Comprehensive Planning Section of the Cumberland County Planning & Inspections Department and The Fayetteville Planning Department; March 2011

[21] 1990; Testimony of John N. Morris, Director, Division of Water Resources: Transcript of Fayetteville Area Chamber of Commerce; The Lower Cape Fear Water and Sewer Authority; the Counties of Bladen, Brunswick, Columbus, New Hanover, Pender and the City of Wilmington; Mike Pleasant, President and the Fayetteville Area Economic Development Corporation; City of Fayetteville, a North Carolina Corporation; and the County of Cumberland v. North Carolina Department of Environment, Health and Natural Resources and the Environmental Management Commission: August 16, 1990: Raleigh, NC: before Beecher R. Gray, Senior Administrative Law Judge.

flows from the Deep River, releases from Jordan Lake were frequently more than what was needed to meet the target flow at Lillington. During the drought of 1986 water levels in Jordan Lake were drawn down eight feet below the normal pool elevation of 216 feet mean sea level, with no withdrawals for water supply. In order to preserve the water remaining in the flow augmentation pool the target flow was temporarily reduced to 450 cubic feet per second.[22] A follow-up study recommended creating a 50 cubic feet per second buffer on either side of the 600 cubic feet per second flow target to provide more leeway meeting the target and to improve the reliability of the flow augmentation pool. The current flow target is 600 ± 50 cubic feet per second representing a range of flows between 355 and 421 million gallons per day at Lillington.

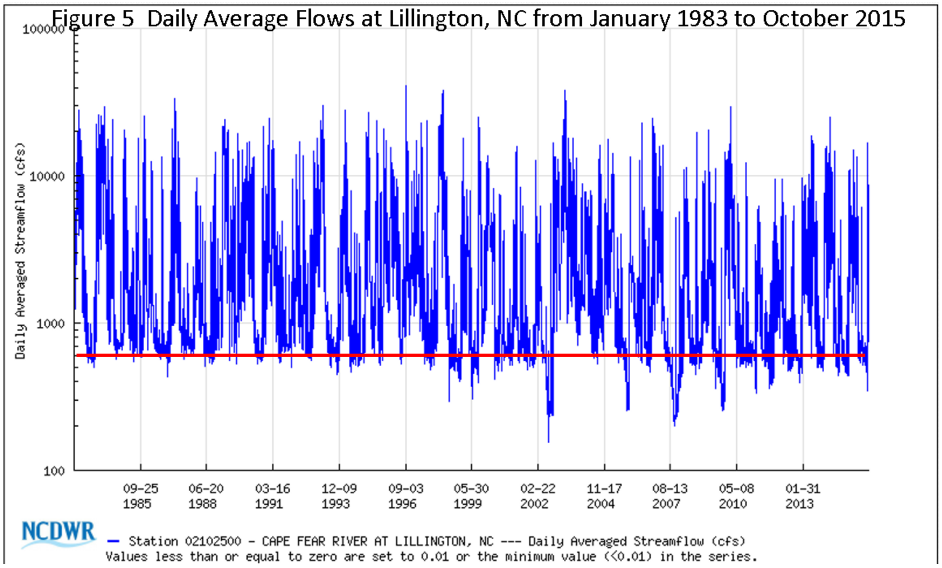

Figure 5 Daily Average Flows at Lillington, NC from January 1983 to October 2015

When water levels in Jordan Lake are at the normal pool elevation of 216 feet mean sea level if inflows to the reservoir are greater than water withdrawals and losses from evaporation the remainder will be released downstream. Therefore much of the time water does not need to be released from the flow-augmentation pool to meet the target flows downstream. Figure 5 shows the daily average streamflows at Lillington since January 1983 with a reference line at 600 cubic feet per second. Over this period flows have been above the target more than 80 percent of the time. More than 50 percent of the time flows have exceeded 1000 cubic feet per second. The ability to use water from the augmentation pool is critical to maintaining downstream flows when inflows to Jordan Lake decline between precipitation events and during droughts.

Severe drought conditions from 1998 through 2002 again required temporarily reducing flow targets at Lillington to preserve storage in the flow augmentation pool. In 2008 the USACOE adopted a revised drought management plan that prescribes a progressive reduction in the flow target as the flow augmentation pool is depleted during periods of low inflows to the reservoir. Stepped reductions begin when storage in the flow augmentation pool drops below 80 percent. This protocol is now implemented automatically as storage declines in the flow-augmentation pool.

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[22] 1987; NC Department of Natural Resources and Community Development; Draft Report, Jordan Lake Hydrology and Downstream Water Quality Considerations.

Water Supply

The State of North Carolina oversees the allocation of 32.62 percent of the conservation pool dedicated to water supply that was designed to provide 100 million gallons per day of water. Under General Statute § 143-354 (a) (11) the General Assembly authorized the Environmental Management Commission to allocate water supply storage in Jordan Lake to local governments upon proof of need and the commitment to pay the capital, interest, administrative and operating costs based on the volume allocated.

The rules allow the EMC to make allocations sufficient to meet applicants' water supply needs over a 30 -year planning horizon designating two levels of allocations based on how soon the allocation will be used. For allocation requests where the withdrawal or return flows would be a transfer of surface water requiring an interbasin transfer certificate the review of the application for an interbasin transfer certificate must be coordinated with the review of the allocation request. [23]

At the time the rules were being formulated Jordan Lake was relatively new and no water was being withdrawn for water supply purposes. Due to the uncertainty of whether the desired water supply demands and flow augmentation requirements could be met as water supply withdrawals increased the rules limited diversions out of the Jordan Lake watershed. Allocations that would result in a diversion out of the watershed were limited to 50 percent of the water supply pool yield, assumed to be 100 mgd. This rule did give the EMC the authority to "review and revise this limit based on experience in managing the lake and on the effects of changes in the lake's watershed that will affect its yield".[24] Since 1988 there have been changes on the watersheds above Lillington that have enhanced the reliability of the water supply and flow augmentation pools in Jordan Lake. Table 5 shows the current status of allocations from the Jordan Lake water supply pool.

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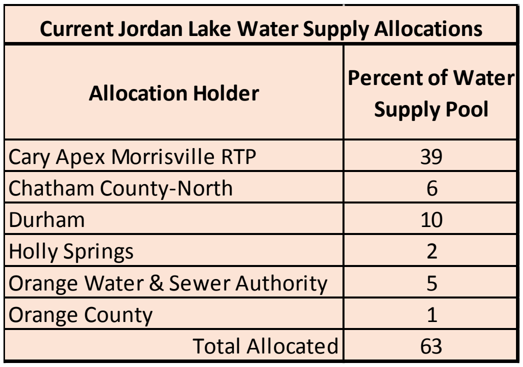
[23] http://www.ncwater.org/?page=297 15A NCAC 02G .0504 (h)

[24] 15A NCAC 02G .0504 (h) To protect the yield of Jordan Lake for water supply and water quality purposes, the Commission will limit water supply allocations that will result in diversions out of the lake's watershed to 50 percent of the total water supply yield. The Commission 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 will affect its yield.

Table 5 Current allocations from the Jordan Lake Water Supply Pool



Current Jordan Lake Water Supply Allocations	
Allocation Holder	**Percent of Water Supply Pool**
Cary Apex Morrisville RTP	39
Chatham County-North	6
Durham	10
Holly Springs	2
Orange Water & Sewer Authority	5
Orange County	1
Total Allocated	63

Modeling B. Everett Jordan Reservoir

Jordan Lake Operations:

B. Everett Jordan Reservoir is a multipurpose reservoir built and managed by the US Army Corps of Engineers. It was authorized for flood control, water supply, water quality, recreation, and fish and wildlife conservation. The storage volume of the impoundment is subdivided based on elevation above sea level. The normally empty space between 216 feet and 240 feet above mean sea level, designated as the flood control pool, can retain the runoff from about six inches of rainfall on the watershed in its 538,000 acre feet of controlled flood storage.

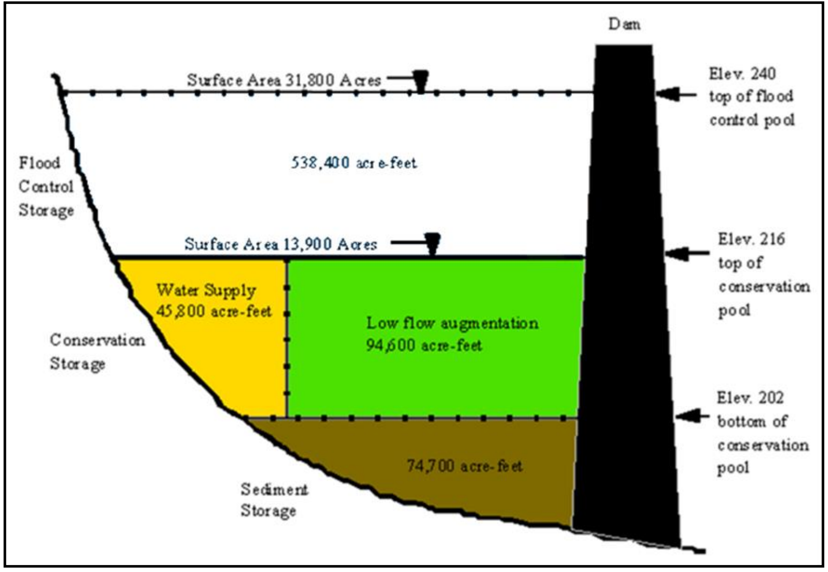
The conservation pool, between 202 and 216 feet above mean sea level, provides storage for water supply and storage for flow augmentation releases to protect water quality downstream. Under normal conditions water level in the reservoir is maintained at the top of the conservation pool. At this elevation, the reservoir covers 13,900 acres. The conservation pool includes approximately 140,400 acre-feet of storage. The conservation pool is managed as two separate pools of water, with separate accounting for each pool. The 74,700 acre-feet of storage below 202 feet mean sea level is reserved to compensate for lost storage volume in the conservation pool due to sediment accumulation.

The 45,800 acre-feet in the water supply pool, reserved for water supply and allocated by the State of North Carolina, contains about 15 billion gallons of water that can reliably supply 100 million gallons per day for local government water systems. The 94,600 acre-feet in the flow augmentation pool is used to supplement downstream river flows. When the releases to maintain water levels at 216 feet mean sea level, in combination with tributary inflows below the dam, are not sufficient to meet the flow target at Lillington water is released from this pool to augment downstream flows.

The flow target of 600 cubic feet per second was the level of flow thought to be needed to meet water quality targets based on treatment protocols, discharge volumes and water quality standards in place when the project was being designed. The target flow at Lillington was recommended by the Federal Water Quality Agency which was part of the U.S. Public Health Service at that time. The recommended target flow provides a significant increase in the amount of water available during low-flow conditions compared to the estimated seven-day average low flow prior to dam construction of 94 cubic feet per second and the historic minimum flow of 11 cubic feet per second prior to operations of Jordan Lake.

Figure 10 shows a generalized representation of the how the storage space behind Jordan Lake Dam is allocated.

Figure 10 Jordan Lake Storage Volume



Based on experiences trying to not violate the specific flow target of 600 cubic feet per second during drought conditions in the 1980s the target was changed to a flow range of 600 ± 50 cubic feet per second. Drought conditions from 1998-2002 required reductions in downstream releases in order to extend the storage in the flow augmentation pool resulting in a minimum daily average flow of 155 cubic feet per second at Lillington during the first week of August 2002. Further studies led to the adoption of a revised drought protocol for the reservoir in 2008. A copy of the "Drought Contingency Plan, Updated May 2008" can be found in Appendix A.

Under the revised drought protocol the Army Corps of Engineers manages the withdrawals from the augmentation pool based on the percent of storage available. Under normal operations there is a minimum release requirement of 40 cubic feet per second from the dam and the goal of maintaining a streamflow of 600 ± 50 cubic feet per second at the Lillington streamflow gage, with the additional goal of maintaining water levels at 216 feet mean sea level. The flow requirements are typically met by releasing inflow to the reservoir to maintain water levels in the reservoir.

When inflows to the reservoir decline during low-flow conditions, and releases to maintain water levels are not adequate to meet the downstream flow target, water is released from the flow augmentation pool to supplement flows below the dam. If the storage in the flow augmentation pool continues to decline then downstream releases are adjusted to meet the adjusted targets outlined in Table 7. The goal of these staged reductions is to extend the usefulness of the water remaining in storage to supplement streamflow as long as possible; protecting water quality and downstream users while at the same time approximating flow reductions that would naturally occur during droughts.

Table 7 Jordan Lake Reservoir Operating Rules during Drought

(Releases and Target values in cubic feet per second)

Drought Stage	**% Remaining in Flow Augmentation Pool**	**Minimum Release (cfs)**	**Lillington Target (cfs)**
0	80-100	40	600 ±50
1	60-80	40	450-600
2	40-60	40	300-450
3	20-40	200	None
4	0-20	100	None

Modeling Results:

The analysis for the Cape Fear River Water Supply Evaluation is based on comparing different levels of estimated future water withdrawals and water supply allocations to current conditions represented by the 2010 basecase model scenario. Data from the local water supply plans, that include estimates of expected water demands through 2060, were used to develop model scenarios.

Future demand estimates were developed by local government water systems and the applicants for allocations of water supply storage in Jordan Lake based on expected customer demands at specific points in the future. Water supply allocations from Jordan Lake are limited by rule to the amount needed within a 30-year planning period. The final decisions on allocations are expected to be made by the Environmental Management Commission in late 2015 therefore some model scenarios evaluate estimated withdrawals expected to be needed to meet 2045 demands. Current river basin planning protocols evaluate water supply conditions for fifty years into the future making 2060, fifty years from the 2010 model simulation basecase, a useful scenario to investigate potential long-range withdrawal needs. This evaluation focuses on the ability of water withdrawers to meet the level of withdrawals anticipate to meet 2060 demands. Table 8 shows the current and requested water supply allocations.

On each of the following graphs and plots a line representing current conditions, labeled as "Simbase_current", provides reference conditions against which alternative scenarios can be compared. In addition to the "Simbase_current" line, three additional plots are included showing the results of alternative scenarios for meeting estimated future demands. On the graphs with "2060 Demands" in the title all the withdrawals compared are based on the estimated withdrawals needed to meet customer demands in the year 2060 at the end of the 50-year planning period. The scenarios vary based on factors that are designated in the line labels on the graphics and described below.

The line designated as "01_LWSP_Dem2060" shows the results of modeling the withdrawals needed to meet the estimated 2060 demands by all surface water withdrawers based on the demands and supplies reported in the local water supply plans.

Jordan Lake allocation requests were based on the amount of water needed to meet demands in 2045 by each applicant. The designation "Req2045" in a plot title indicates that the requested allocation amount was used in the calculation of available supplies for applicants. The line designated as "03_JLA_F_Req2045_Dem2060" shows the cumulative effects of meeting the estimated 2060 demands if all the requested Jordan Lake water supply allocations are granted. DWR received applications from the following applicants: Cary-Apex-Morrisville-Wake County for RTP, Chatham County-North, Durham, Fayetteville Public Works Commission, Hillsborough, Holly Springs, Orange County, Orange Water and Sewer Authority, Pittsboro and Raleigh. The total requests for water supply allocations amounted to 105.9% of the water supply pool.

Table 8 Current and Requested Jordan Lake Water Supply Allocations

Allocation of Jordan Lake Water Supply Pool		
Applicant	Current Allocation Percent	Requested Allocation Percent
Cary Apex Morrisville RTP	39	46.2
Chatham County-North	6	13
Durham	10	16.5
Fayettteville PWC	0	10
Hillsborough	0	1
Holly Springs	2	2
Orange County	1	1.5
Orange Water&Sewer Authority	5	5
Pittsboro	0	6
Raleigh	0	4.7
Total Allocations	63	105.9

Most of the requested allocations would be withdrawn directly from Jordan Lake. Raleigh's and Fayetteville PWC's applications expressed the intention of requesting water from the water supply pool be released from Jordan Lake Dam to be withdrawn downstream. To avoid the potential complication of the resulting surface water transfer, Raleigh proposed withdrawing their allocation and returning treated wastewater at a site on the Cape Fear River in the vicinity of Lillington. Fayetteville PWC would use the existing water supply intakes on the Cape Fear River in the backwater of Lock & Dam #3 downstream of Lillington.

The lines designated as "04_JLA_Req2045_Dem2060" on the following graphs show the results if the requested Jordan Lake allocations of all applicants are approved except for Fayetteville PWC. Fayetteville's withdrawals are modeled as coming from their current water sources without a supplemental release from the water supply pool.

Withdrawals in the model for water utilities not submitting an application for an allocation from Jordan Lake are based on information in their local water supply plans for each model scenario. The withdrawals are set to the levels needed to meet the estimated volumes necessary to meet demands in 2060 for all modeled water utilities.

Jordan Lake Water Storage Evaluation:

The discussions of impacts to water resource conditions that follow rely on a series of graphs and tables to present the variations that occur under different water withdrawal arrangements. This evaluation focuses on the variations in water resource conditions between the volumes of water withdrawals in 2010 and the level of withdrawals expected to be needed to meet demands in 2060. Table 9 provides brief descriptions of the conditions in each of the model scenarios presented in the following graphs. The "Simbase Current" scenario represents the effects of meeting 2010 water demands over the range of hydrologic conditions experienced from 1930 to 2011. The plots for this scenario are shown in red on each graph. The plots for the other scenarios show how conditions may change given the withdrawal levels and management protocols in each scenario.

Table 9 Model Scenarios

Model Scenario Descriptions	
Simbase_Current	This scenario models the baseline current conditons in 2010 based on available water supplies, infrastructure and customer demands at that time
01_LWSP_Dem_2060	**LWSP** indicates this scenario uses data extracted from the local water supply plans of all water systems dependent on surface water sources in the model. **Dem_2060** indicates this scenario is modeling the ability to meet the estimated water withdrawals needed to meet 2060 demands.
03_JLA_F_Req2045_Dem2060	**JLA** indicates this scenario uses data from Jordan Lake Water Supply Allocation applications submitted to DWR. **Req2045** indicates this scenario adds the requested Jordan Lake allocations to the available water supplies for all applicants. The **"F"** indicates this scenario includes the allocation request for all the applicants including Fayetteville PWC. **Dem2060** indicates this scenario evaluates the ability to meet the water withdrawals needed to meet 2060 water demands and the resulting changes to water availability.
02_JLA_Req2045_Dem2060	**JLA** indicates this scenario uses data from Jordan Lake Water Supply Allocation applications submitted to DWR. **Req2045** indicates this scenario adds the requested Jordan Lake allocations to the available water supplies for all applicants. The **lack of an "F"** indicates this scenario does not include the allocation request for Fayetteville PWC. **Dem2060** indicates this scenario evaluates the ability to meet the water withdrawals needed to meet 2060 water demands and the resulting changes to water availability.

If requested allocations from the water supply pool are granted the water withdrawals from Jordan Lake will increase dramatically over the coming decades. Larger withdrawals will produce more fluctuations in the storage in the water supply pool as demands and inflows vary seasonally and from year to year. From a water supply perspective low flow conditions and droughts are critical periods since water shortages can threaten the ability to protect public health. The period from 2000 to 2011 includes two of the driest periods in the Cape Fear River Basin. The two graphs that follow show the storage conditions for the water supply and water quality pools for the four scenarios presented during the flow conditions experienced during these years.

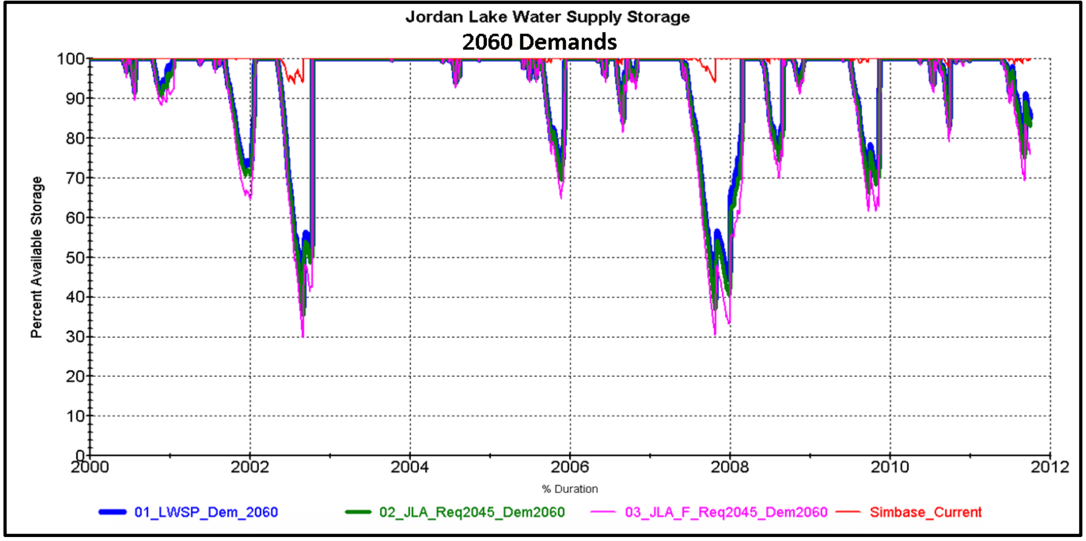
Before looking closely at these plots it may be helpful to remember that reservoirs are intended to retain water when flows are high so that it can be used when flows are low.

During low inflow periods, when water is used from storage, water levels are expected to decline. Without the storage in the reservoir the source stream would not be able to sustain the desired levels of withdrawals needed to meet customer demands. With the larger withdrawals expected in the future the water supply pool in Jordan Lake will be drawn down deeper and longer when the basin experiences low flow conditions. The modeling used for this analysis shows the possible effects of increased withdrawals over the range of hydrologic conditions that have occurred between 1930 and 2011. The graphs below show the effects of each model scenario on the storage pools in Jordan Lake focusing on conditions during recent serious droughts. The red lines on the graphs show the effects on the water supply pool and the flow augmentation pool from withdrawing water to meet the demands in 2010 during the hydrologic conditions experienced from 2000 to 2011.

Figure 5 shows that the model predicts that during the conditions experienced in 2002 and 2007 the water supply pool would likely have been drawn down to about 95 percent of full pool fulfilling the 2010 demands. With larger withdrawals in the future more of the water supply storage will be required to meet customer demands. As expected the graph indicates that during a recurrence of the 2002 or 2007 low inflow conditions meeting the expected water demands for 2060 could reduce water supply storage to about 30 percent of full storage.

An optimistic interpretation of this analysis is that even at the significantly higher levels of withdrawals anticipated in the future the water supply pool appears to be able to meet those demands over the range of drought conditions that have occurred in the Cape Fear River Basin since 1930, with a reserve.

Figure 5 Jordan Lake Water Supply Storage 2000-2011



Under future water demand scenarios the model indicates that conditions of the water quality pool in Jordan Lake will not be drawn down as much as it would be in the 2010 basecase scenario for the period 2000-2011. This is likely due to a couple of factors. Randleman Reservoir, on the Deep River, was not operational in the 2010 basecase scenario. There is a required minimum release of water from the reservoir which is included in the future scenarios. The supplemental input to the Deep River, especially in times of naturally low flows, raises the contribution from the Deep River to the flows in the Cape Fear River at Lillington. Therefore reducing the amount of water required from Jordan Lake to meet flow targets. Also, increased wastewater discharges between Jordan Dam and Lillington reduce the flow-augmentation releases needed from Jordan Lake.

The effects of these changes in the future scenarios can be seen in the Figure 6 where it is most noticeable during the drought conditions in 2002. In the 2010 basecase scenario the model indicates the water quality pool would be drawn down to about 20 percent of available storage while in the future 2060 demand scenarios it would be drawn down to about 35 percent of available storage. The effects are less dramatic in other low-flow periods. In a repeat of the October 2007 hydrologic conditions the difference is less than 5 percent, from about 27 percent remaining storage in the 2010 basecase scenario to about 30 percent in the 2060 demand scenarios. The minimum value variations among the 2060 demand scenarios are in the range of a half of one percent.

According to the modeling done for this evaluation, changes in management and wastewater return volumes projected to occur in the future will likely increase the reliability of the water quality pool, the source of water for flow augmentation, in Jordan Lake. While this analysis is limited to the range of flows that occurred from 1930-2011, the results suggest that the flow augmentation storage in Jordan Lake is likely to be capable of meeting its management goals if flows are outside of this range in the future.

Figure 6 Jordan Lake Water Quality Storage (for flow augmentation) 2000-2011

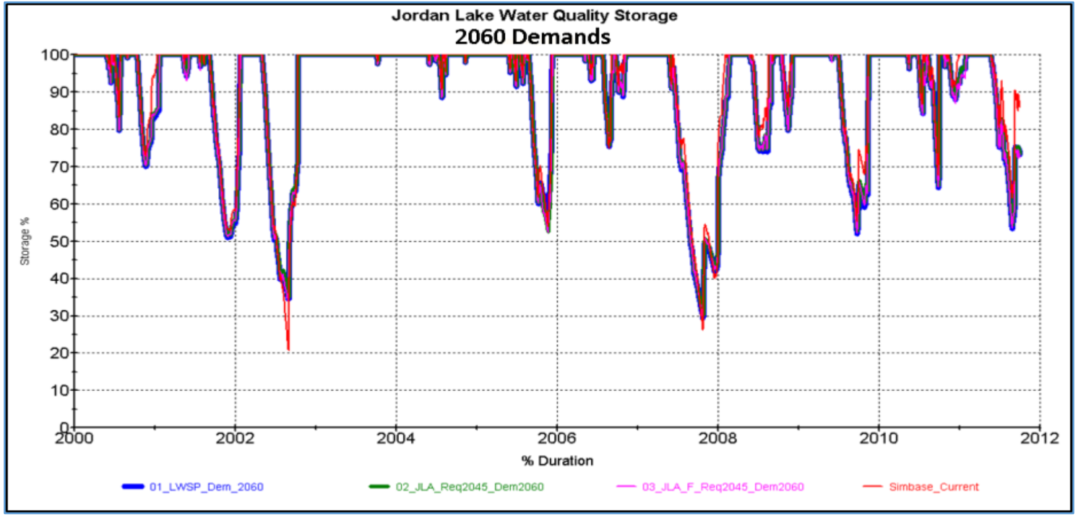
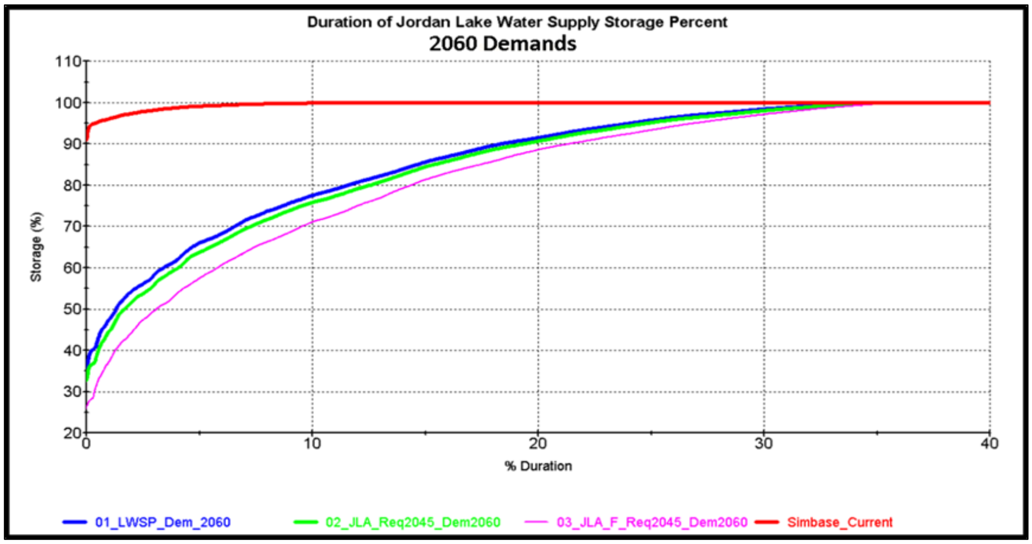


Figure 7 Duration Plot of Water Supply Storage Pool



Figures 7 and 8 show the percent of time the water supply and water quality storage pools are at or below a certain percent of available storage. Note that both graphs show only 40 percent of the entire period of record. For the remaining 60 percent both storage pools are at or above 100 percent full. For water supply storage shown in Figure 7 modeling indicates that the water supply pool is less than 100 percent full about 5 percent of the 29,859 days in the historic flow record for the 2010 basecase demand scenario. The periods when the water supply pool in less than full increases as withdrawals increase in the future. For the 2060 demand scenarios the model indicates that water supply storage is likely to be less than full more than 30 percent of the time, over the range of streamflows in the 81-year flow record. All of the 2060 demand scenarios indicate that for 5 percent of the time water supply storage could be about 65 percent of full, or less.

For the water quality pool the time when storage is less than 100 percent is longer in all the 2060 demand scenarios compared to the 2010 basecase demand scenario. Over most to the range shown in Figure 8 the decline is less than about 10 percent from 2010 demand levels. The maximum drawdown is less in the 2060 demand scenarios than the basecase scenario. In the 2010 basecase demand scenario the minimum storage in the water quality pool over the range of flows in the historic record is 21 percent of full storage. Under the 2060 demand scenarios the minimum water quality storage is about 29 percent of full storage.

Figure 9 shows the magnitude and duration of drought stages that would be triggered under the 2008 Drought Contingency Plan during the flow conditions experienced from 2000 to 2011. Drought responses enter Stage 1 when storage in the water quality pool drops below 80 percent. If storage drops below 60 percent Stage 2 operations are triggered and if storage drops below 40 percent Stage 3 operations are implemented. The effects of the water quality storage declines shown in Figure 6 are reflected in the drought stage designations shown in Figure 9.

Figure 8 Duration Plot of Water Quality Storage Pool (for flow augmentation)

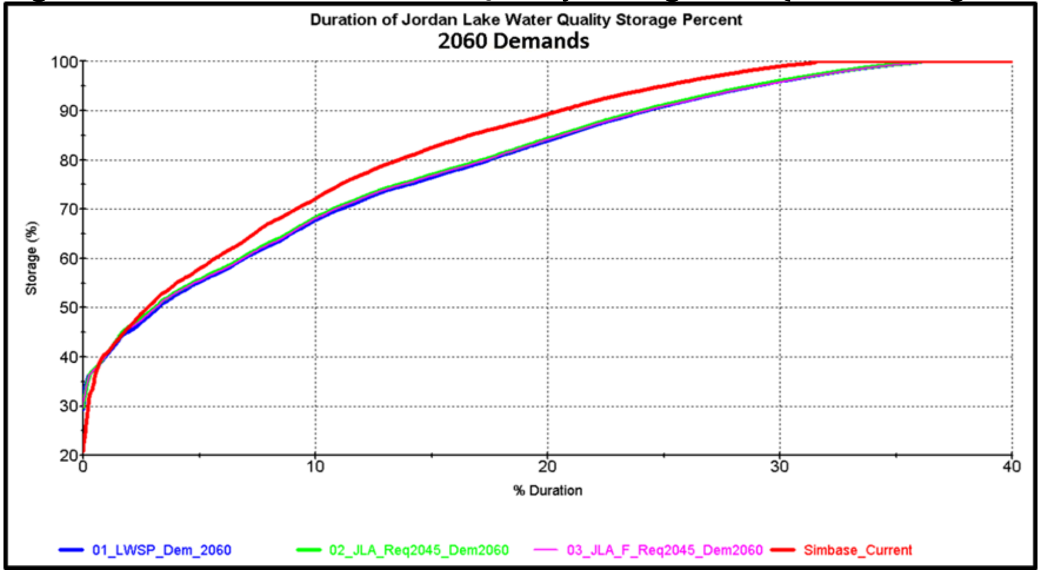
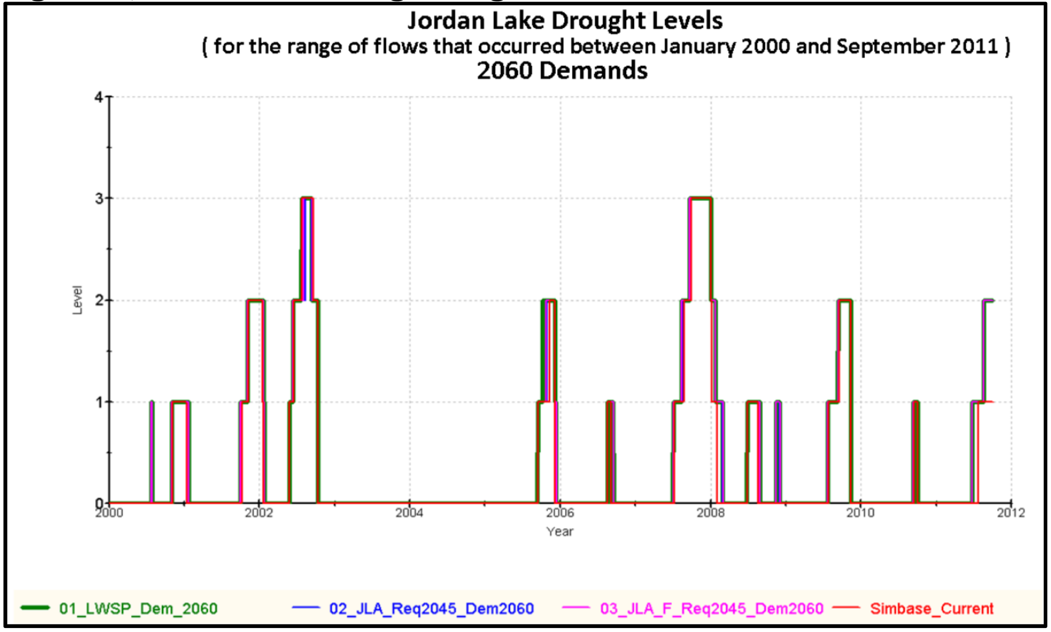


Figure 9 Jordan Lake Drought Stage 2000-2011



Jordan Lake Water Level Evaluations:
The combined effects of the declines in water storage shown in Figures 5 and 6 are reflected in the duration plot of water levels in Jordan Lake shown in Figure 10. As in Figures 5 and 6 Figure 10 shows the 40 percent of time when water levels are below the

normal operating water level for Jordan Lake of 216 feet above mean sea level. At the normal operating level, and above, the water supply and flow augmentation pools are full. During high flow events the water level rises as runoff from the watershed upstream of the reservoir is retained to mitigate flooding impacts to downstream communities. As inflows to the reservoir and downstream high flows decline the water in the flood storage pool is released under controlled conditions until the normal operating elevation of 216 feet mean sea level is regained.

When inflows are sufficient to compensate for evaporation and water supply withdrawals and streamflows are above 550 cubic feet per second downstream at the Lillington streamflow gage the water level will not drop below 216 feet mean sea level. When not in flood control mode, water flowing into the reservoir is credited to the water supply account and flow augmentation account based on the percentage of the conservation pool designated for each, 32.6 percent for water supply and 67.4 percent for flow augmentation. If both of these accounts are full water is released downstream.

When inflows are not sufficient to maintain water levels at 216 feet mean sea level the level of water declines as withdrawals are made for public water supplies and water is released downstream to augment streamflows. The combined effects of the declines in the water supply and flow augmentation pools shown in the graphs above are reflected in Figure 10. Figure 10 shows the model derived water levels during the 40 percent of the time when the water level is predicted to be below the normal operating level over the 81-year flow record. These model results imply that 60 percent of the time the water level is predicted to be at or above the normal operating elevation of 216 feet mean sea level.

With withdrawals sufficient to meet the estimated 2060 demands the hydrologic modeling shows the water level in Jordan Lake will likely be lower for longer than under the 2010 current conditions scenario. The vertical scale on the graphs represents feet above mean sea level. The horizontal scale shows the percent of time of the over 29,000 days in the historic record that the water level may be below specific elevations under four model scenarios.

Recreational opportunities at Jordan Lake are impacted by reservoir water levels. One way to characterize this impact is by looking at how boat launching facilities are affected at various reservoir water levels. Figure 11 includes the elevations at which the use of boat ramps at Jordan Lake may become limited due to water levels. The levels noted on the graph are generally a couple of feet above the bottom of the boat ramp structure. The elevations of the bottoms of the boat ramps on Jordan Lake are listed in Table 3 of the Appendix A, the Drought Contingency Plan. Figure 11 shows that as more of the water supply pool is used in the future boating access will be restricted at more facilities and for longer periods over the historic range of flows than have been experienced in the past.

Figure 10 Jordan Lake Water Elevation

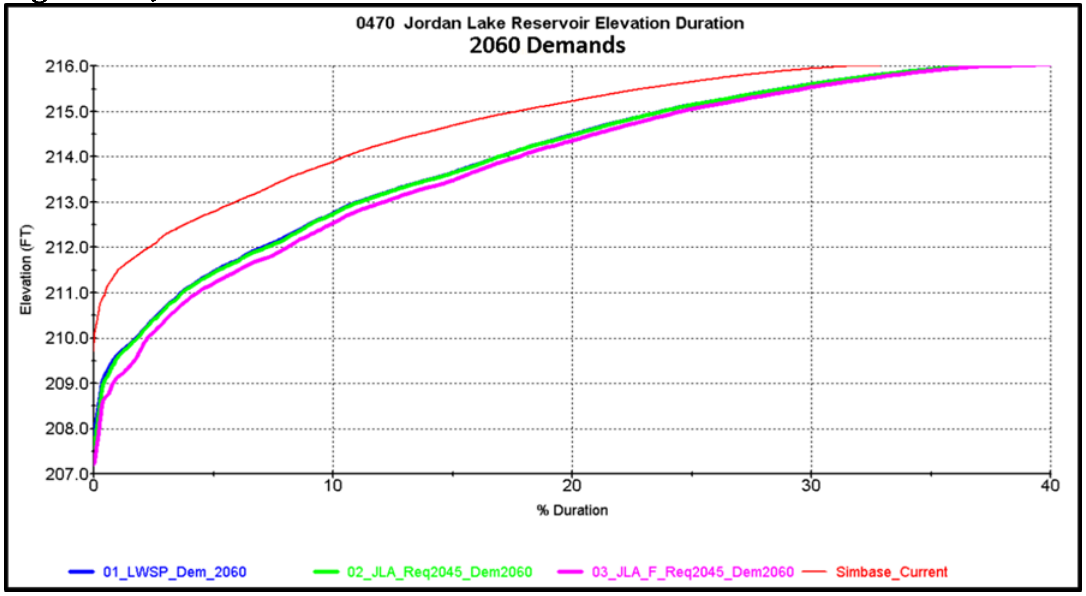


Figure 11 Jordan Lake Boat Ramp Impacts

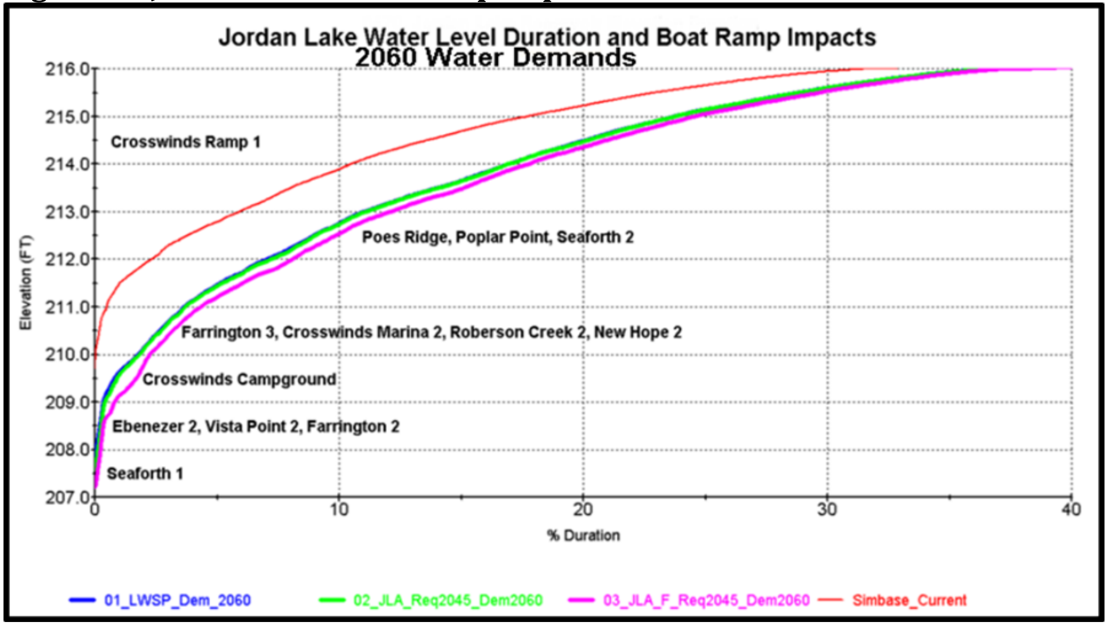
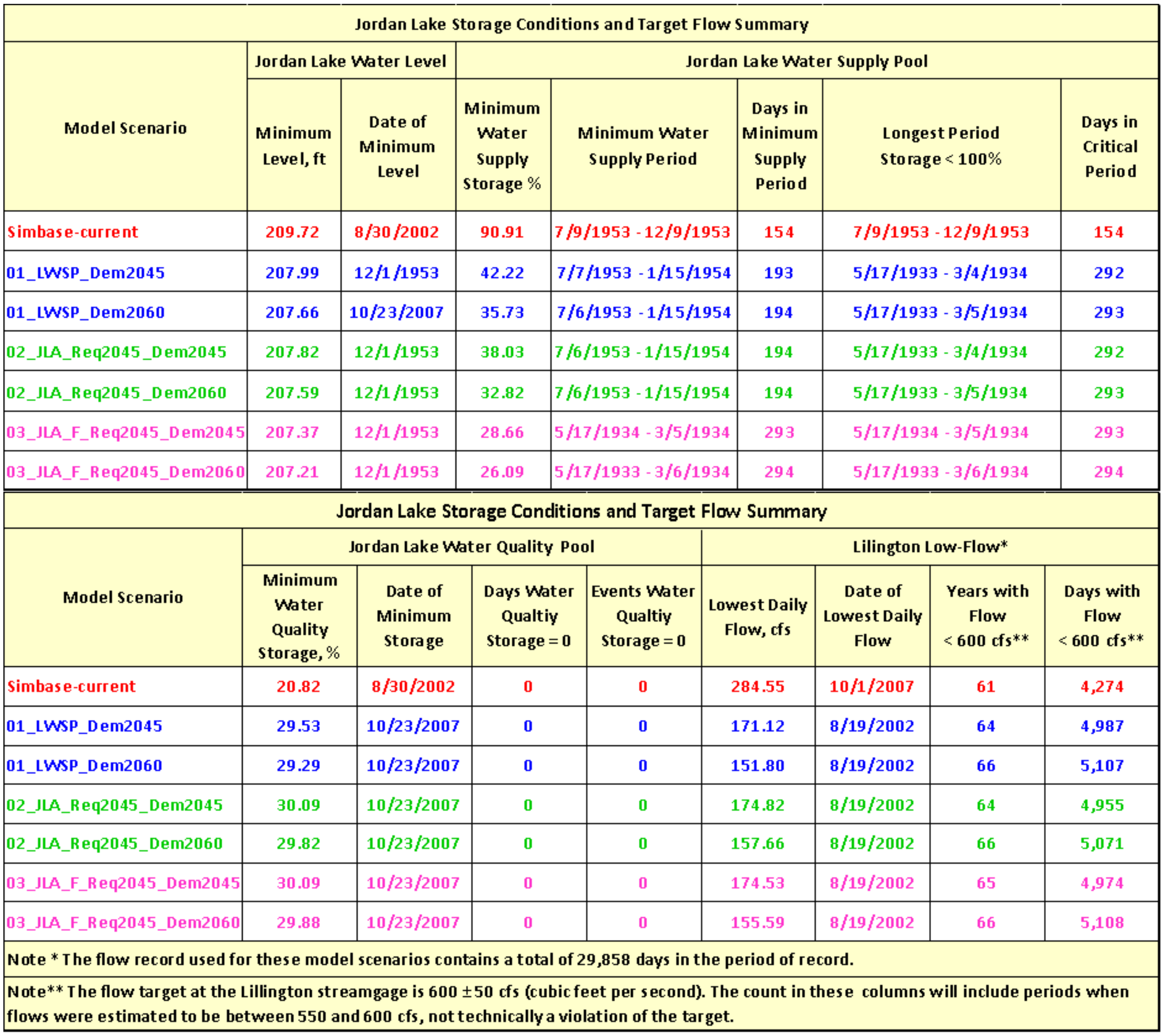


Table 10 shows the model generated minimum values for water level in Jordan Lake, water supply storage, flow augmentation storage in the water quality pool, and the minimum average streamflow at the Lillington streamflow gage for the demand scenarios modeled for this analysis. In addition to the results of the 2060 demand scenarios Table 10 includes results for three 2045 demand scenarios. The”01_LWSP_Dem2045” evaluates water quantity conditions based on local water supply plan data. And, the “03_JLA_F_Req2045_Dem2045” model scenarios evaluates water quantity conditions when withdrawing water sufficient to meet 2045 demands if all the requested Jordan Lake allocations are granted. The "02_JLA_Req2045_Dem2045" model scenario entries show the values if the requested allocations excluding Fayetteville PWC are granted. The dates in the historic flow record when flow conditions produced each of the minimum values are also shown for each scenario.

Table 10 Minimum Value Summary



Jordan Lake Storage Conditions and Target Flow Summary							
Model Scenario	Jordan Lake Water Level		Jordan Lake Water Supply Pool				
	Minimum Level, ft	Date of Minimum Level	Minimum Water Supply Storage %	Minimum Water Supply Period	Days in Minimum Supply Period	Longest Period Storage < 100%	Days in Critical Period
Simbase-current	209.72	8/30/2002	90.91	7/9/1953 - 12/9/1953	154	7/9/1953 - 12/9/1953	154
01_LWSP_Dem2045	207.99	12/1/1953	42.22	7/7/1953 - 1/15/1954	193	5/17/1933 - 3/4/1934	292
01_LWSP_Dem2060	207.66	10/23/2007	35.73	7/6/1953 - 1/15/1954	194	5/17/1933 - 3/5/1934	293
02_JLA_Req2045_Dem2045	207.82	12/1/1953	38.03	7/6/1953 - 1/15/1954	194	5/17/1933 - 3/4/1934	292
02_JLA_Req2045_Dem2060	207.59	12/1/1953	32.82	7/6/1953 - 1/15/1954	194	5/17/1933 - 3/5/1934	293
03_JLA_F_Req2045_Dem2045	207.37	12/1/1953	28.66	5/17/1934 - 3/5/1934	293	5/17/1934 - 3/5/1934	293
03_JLA_F_Req2045_Dem2060	207.21	12/1/1953	26.09	5/17/1933 - 3/6/1934	294	5/17/1933 - 3/6/1934	294

Jordan Lake Storage Conditions and Target Flow Summary								
Model Scenario	Jordan Lake Water Quality Pool				Lilington Low-Flow*			
	Minimum Water Quality Storage, %	Date of Minimum Storage	Days Water Qualtiy Storage = 0	Events Water Qualtiy Storage = 0	Lowest Daily Flow, cfs	Date of Lowest Daily Flow	Years with Flow < 600 cfs**	Days with Flow < 600 cfs**
Simbase-current	20.82	8/30/2002	0	0	284.55	10/1/2007	61	4,274
01_LWSP_Dem2045	29.53	10/23/2007	0	0	171.12	8/19/2002	64	4,987
01_LWSP_Dem2060	29.29	10/23/2007	0	0	151.80	8/19/2002	66	5,107
02_JLA_Req2045_Dem2045	30.09	10/23/2007	0	0	174.82	8/19/2002	64	4,955
02_JLA_Req2045_Dem2060	29.82	10/23/2007	0	0	157.66	8/19/2002	66	5,071
03_JLA_F_Req2045_Dem2045	30.09	10/23/2007	0	0	174.53	8/19/2002	65	4,974
03_JLA_F_Req2045_Dem2060	29.88	10/23/2007	0	0	155.59	8/19/2002	66	5,108
Note * The flow record used for these model scenarios contains a total of 29,858 days in the period of record.								
Note** The flow target at the Lillington streamgage is 600 ±50 cfs (cubic feet per second). The count in these columns will include periods when flows were estimated to be between 550 and 600 cfs, not technically a violation of the target.								

The modeling for this evaluation indicates that even as withdrawals increase in the future there remains significant storage for water supply and flow-augmentation during the worst droughts represented in the historic flow data. With the expected withdrawals needed to meet demands over the next 50 years neither the water supply pool nor the flow augmentation pool are depleted. Both have supply remaining during the driest conditions that have occurred over the 81 years of the historic record. The modeling results indicate that Jordan Lake storage appears to be resilient enough to meet its intended purposes if more extreme drought conditions occur in the future.

The modeling results indicate that Jordan Lake storage appears to be resilient enough to meet the intended water supply and flow augmentation purposes if more extreme drought conditions occur in the future.

Jordan Lake Water Supply Pool Potential Yield

The water supply pool of Jordan Lake was designed to reliably supply 100 million gallons per day. The rules governing allocation of water supply storage required the Environmental Management Commission to limit allocations that would result in *"diversions out of the lake's watershed to 50 percent of the total water supply yield"*. This limitation was included to protect the yield of Jordan Lake for water supply and water quality purposes. The allocation rules allow for revising the 50 percent diversion limit *"based on experience in managing the lake and on the effects of changes in the lake's watershed that will affect its yield"*.

Water supply purposes are met by local government water systems that hold an allocation and withdraw water from the water supply pool. The water quality purposes are met by releasing water from the dam to augment flows in the river downstream. The magnitude of downstream releases are set to maintain a target flow at the USGS stream gage at Lillington.

The reliability of the volume of water available to water withdrawers that use surface water sources is limited by the amount of water available during low-flow conditions. Withdrawers taking water directly from a stream face seasonal variations in streamflows that limit their reliable supply. The purpose of a water supply reservoir is to store water so there is a pool of water available to buffer the effects of seasonal flow variations and thereby increase the reliable supply. The amount of water available to be withdrawn from a reservoir is determined by the storage volume and the amount of inflow available from the watershed contributing drainage to the reservoir. While the drainage area and the physical storage volume are fixed for a specific reservoir the amount of water available is dependent on the water that flows off the watershed into the reservoir, which varies seasonally and from year-to-year.

The yield of a water supply reservoir is determined by estimating how much could be reliably withdrawn over a given record of inflows. The period of record used for this type of analysis is typically 25 years, 50 years or the entire available record of streamflows, depending on the level of risk that is acceptable to the users. The risk of not being able to reliably withdraw the estimated yield during droughts typically decreases as the period of record increases and a broader range of historic flows are used in the analysis.

The Cape Fear-Neuse River Basins Hydrologic Model provides a tool to evaluate the amount of water available to meet the water supply purposes from Jordan Lake. This computer-based mathematical model tracks changes in water volume in the reservoirs and rivers of the basins in response to variations in flows and water withdrawals. To evaluate the potential water supply yield 12 different hypothetical scenarios were constructed to bookend the range of potential yields. The magnitude and location of used water return flows were varied to estimate the reliably of the water supply pool over the range of flows in the 81-year hydrologic record and the assumptions used in the model. Various percentages of water withdrawals are assigned to be returned to three different geographic areas; on the Jordan Lake watershed, in the Cape Fear River between the dam and the Lillington streamflow gage or completely out of the watershed above the Lillington streamflow gage. The yield analysis tool in the model iteratively raises withdrawals from the water supply pool up to the level when the next increase would reduce storage to zero.

The lowest water supply yield estimate occurs when none of the withdrawn water is returned to the reservoir's watershed. The resulting estimated water supply yield is 104 million gallons per day using 2010 water withdrawals for systems not using water from Jordan Lake. Using the 2060 scenario of estimated withdrawals the lowest estimated water supply yield is 113 million gallons per day.

Twelve scenarios of return flow possibilities are summarized in Table 11. Reviewing the data in Table 11, it appears that even if none of the water withdrawn from Jordan Lake is returned to the reservoir's watershed the water supply pool can reliably supply 100 million gallons per day.

Table 11 Jordan Lake Water Supply Pool Yields

Estimated Jordan Lake Water Supply Yield									
	Return Flow Assumption			2010 Basecase Scenario			2060 Demand Scenario		
Model Set Up	Percent of Withdrawal Returned to Jordan Lake Watershed	Percent of Withdrawl Returned Below Jordan Lake Dam	Percent of Withdrawal Out of Basin	Estimated Water Supply Yield (MGD)	Jordan Lake Minimum Elevation (ft-msl)	Minimum Water Supply Storage 2/24/1934 (%)	Estimated Water Supply Yield (MGD)	Jordan Lake Minimum Elevation (ft-msl)	Minimum Water Supply Storage 2/24/1934 (%)
1	0	0	100	104.06	202.65	0.65	112.92	203.03	0.79
2	100	0	0	156.94	204.30	1.07	169.66	204.06	1.18
3	0	100	0	104.98	203.55	0.74	113.84	203.36	1.60
4	50	50	0	125.44	203.88	2.69	136.69	203.67	0.96
5	50	0	50	124.19	202.69	0.86	134.86	203.07	0.87
6	0	50	50	104.00	202.65	0.71	112.92	203.03	0.73
7	25	75	0	114.63	203.70	1.17	124.81	203.50	0.81
8	25	0	75	113.25	202.67	0.73	122.91	203.05	0.85
9	75	25	0	140.31	204.07	0.95	151.45	203.86	0.97
10	0	25	75	103.99	202.65	0.75	112.92	203.03	0.77
11	75	0	25	137.56	202.71	0.89	149.55	203.04	1.02
12	0	75	25	104.00	202.65	0.70	112.92	203.03	0.71

The model provides the ability for evaluating the effects of releasing water from the low flow augmentation pool in Jordan Lake to enhance river flows down steam by tracking the volume of storage remaining during drought conditions. All model scenarios include the drought management protocol for adjusting flow targets based on the percentage of water quality storage remaining in the reservoir. Table Y shows the minimum storage amounts for each of the 12 scenarios evaluated using 2010 and 2060 model scenarios. With the withdrawal levels in the 2010 basecase scenario modeling does not indicate that the water quality pool will be depleted under any of the return flow options. Modeling suggests that as water withdrawals increase in the future, during recurrences of some of the hydrologic conditions that have occurred since 1930, there could be times when the water quality pool may be depleted if none of the withdrawn water is returned to the Jordan Lake watershed.

Table 12 Jordan Lake Minimum Water Quality Pool Storage

Estimated Minimum Water Quality Pool Storage													
	Return Flow Assumption			2010 Basecase Scenario					2060 Demand Scenario				
Model Set Up	Percent of Withdrawal Returned to Jordan Lake Watershed	Percent of Withdrawl Returned Below Jordan Lake Dam	Percent of Withdrawal Out of Basin	Minimum Water Quality Storage (%)	Date of Minimum Water Quality Storage	Number Days Water Quality = 0	Number Events Water Quality = 0	Max Duration days Water Quality = 0	Minimum Water Quality Storage (%)	Date of Minimum Water Quality Storage	Number Days Water Quality = 0	Number Events Water Quality = 0	Max Duration days Water Quality = 0
1	0	0	100	0.02	8/22/2002	0	0	0	0.00	8/9/2002	10	4	4
2	100	0	0	14.04	11/30/1953	0	0	0	9.94	2/24/1934	0	0	0
3	0	100	0	9.15	2/24/1934	0	0	0	4.08	2/24/1934	0	0	0
4	50	50	0	11.94	2/24/1934	0	0	0	7.03	2/24/1934	0	0	0
5	50	0	50	0.21	10/20/2007	0	0	0	0.11	8/22/2002	0	0	0
6	0	50	50	0.08	10/23/2007	0	0	0	0.00	8/21/2002	4	1	4
7	25	75	0	10.75	2/24/1934	0	0	0	5.99	2/24/1934	0	0	0
8	25	0	75	0.08	8/22/2002	0	0	0	0.03	8/22/2002	0	0	0
9	75	25	0	13.63	11/30/1953	0	0	0	8.43	2/24/1934	0	0	0
10	0	25	75	0.02	8/24/2002	0	0	0	0.00	8/14/2002	7	3	4
11	75	0	25	0.35	12/11/2007	0	0	0	0.26	8/29/2002	0	0	0
12	0	75	25	0.12	12/13/2007	0	0	0	0.08	12/11/2007	0	0	0

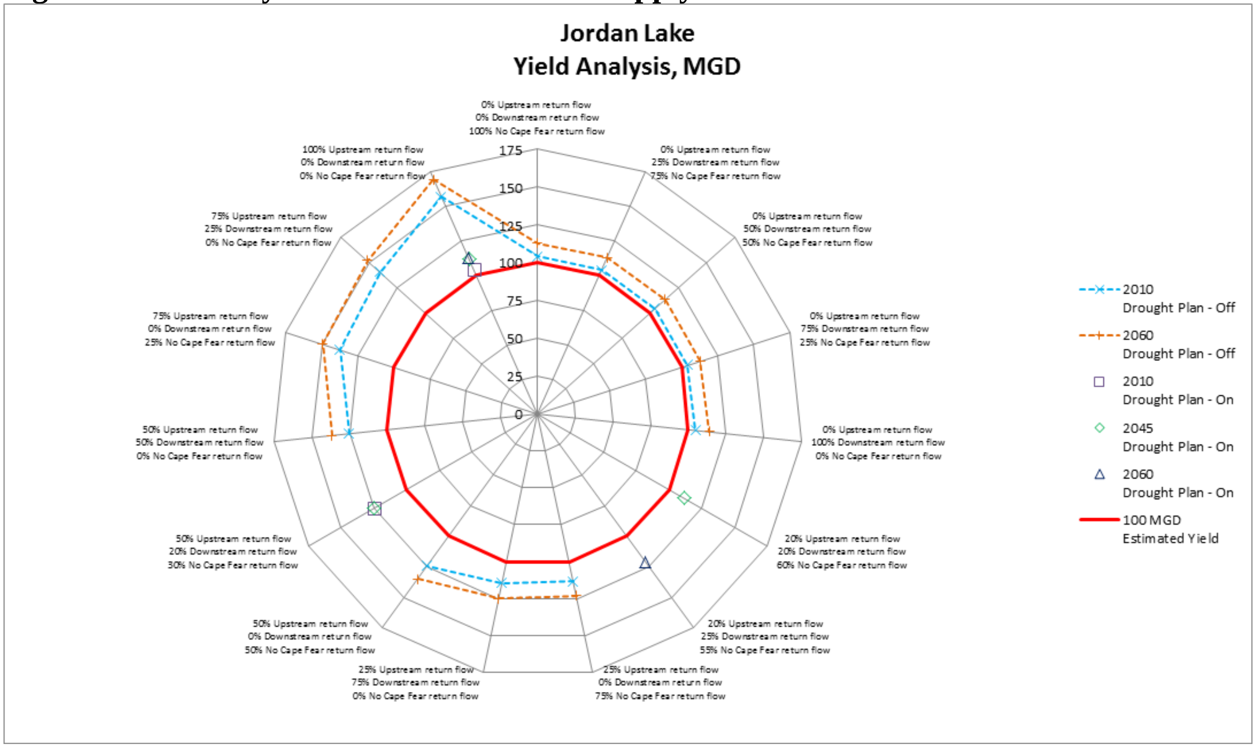
Table 13 presents the lowest daily average flows at the Lillington streamflow gage for each of the return flow configurations. The chart uses the flow value of 600 cubic feet per second as the measure for the flow target. The flow target is currently defined as 600 ±50 cubic feet per second. When storage in the water quality pool declines during droughts the flow target at Lillington is reduced based on the steps defined in the Drought Contingency Plan. Table 13 shows the number of years out of 81 years in the flow record and the number of days out of 29,858 days in the flow record when the model estimates the flows at Lillington to be less than 600 cubic feet per second. The table also shows the date when the minimum flow rate was estimated to occur given the return flow configurations used for the analysis of the water supply yield.

Figure 12 summarizes the results of the suite of analyses that were conducted to determine the reliability of the water supply pool in Jordan Lake. Each spoke on the radial graph shows the result of a different configuration of return flow assignments. The center of the graph represents zero million gallons per day and the outer edge represents 175 million gallons per day. The red band represents the desired yield when the water supply pool was designed, 100 million gallons per day. The graph shows that all of the options of where water withdrawn from the supply pool is used produce potential yield estimates greater than 100 million gallons per day. Even if all the water withdrawn from the water supply pool is removed from the Haw River and Cape Fear River basins the yield estimate exceeds 100 million gallons per day.

Table 13 Cape Fear River Minimum Flows @ Lillington

Estimated Minimum Flows at Lillington Streamflow Gage											
	Return Flow Assumption			2010 Basecase Scenario				2060 Demand Scenario			
Model Set Up	Percent of Withdrawal Returned to Jordan Lake Watershed	Percent of Withdrawl Returned Below Jordan Lake Dam	Percent of Withdrawal Out of Basin	Lillington Lowest daily flow, (cfs)	Date of Minimum	Years with Flow <600 cfs	Days with Flow <600 cfs	Lillington Lowest daily flow, (cfs)	Date of Minimum	Years with Flow <600 cfs	Days with Flow <600 cfs
1	0	0	100	43.36	8/23/2002	23	620	0.00	10/25/1953	14	504
2	100	0	0	600.00	5/2/1930	0	0	600.00	5/2/1930	0	0
3	0	100	0	600.00	5/2/1930	0	0	600.00	5/2/1930	0	0
4	50	50	0	284.56	10/2/1986	7	175	600.00	5/2/1930	0	0
5	50	0	50	119.71	10/21/2007	20	364	0.00	8/22/2002	10	226
6	0	50	50	140.74	10/23/2007	12	214	18.06	8/22/2002	7	169
7	25	75	0	284.56	10/2/1986	6	164	600.00	5/2/1930	0	0
8	25	0	75	71.44	8/23/2002	21	427	0.00	8/12/2002	13	394
9	75	25	0	284.56	10/2/1986	7	182	600.00	5/2/1930	0	0
10	0	25	75	95.47	10/21/2007	11	268	0.00	8/14/2002	12	355
11	75	0	25	233.51	12/12/2007	11	285	105.32	8/28/2002	5	103
12	0	75	25	247.90	12/14/2007	9	172	183.43	12/14/2007	4	84

Figure 12 Summary of Jordan Lake Water Supply Pool Yield Estimates



Water Supply Evaluations

Responsibility for water supply and water infrastructure development are assumed by local governments or non-governmental entities based on specific goals and needs. The primary focus of this exercise is to evaluate the long term water needs of water systems that depend on surface water sources in the Deep River, Haw River and Cape Fear River Subbasins to evaluate allocation requests of water supply storage in Jordan Lake. Because of mutual water sharing relationships an effective analysis also requires consideration of the use of surface water sources and water demands in the Neuse River Basin. Cumulative water demands and water sharing arrangements in the Cape Fear and Neuse River Basins were evaluated over a fifty-year planning horizon using data submitted to the Division of Water Resources. Local water supply plans, prepared by units of local government and other large community water systems, provide water use and water source information as well as estimates of future water demands. The effects of the expected water withdrawals were evaluated using the Cape Fear – Neuse River Basins Hydrologic Model that simulates changes in surface water quantity induced by changes in surface water withdrawals and management protocols in the Cape Fear and Neuse River Basins.

The Cape Fear – Neuse River Basin Hydrologic Model provides DWR staff the ability to evaluate changes to surface water availability that could occur from increases in withdrawals to meet demands at several levels expected to be needed over the next fifty years. The hydrologic model is used to establish a baseline set of conditions by comparing a given year's known withdrawals and management protocols, in this case 2010, to the amount of water available to meet that level of demand in each of 81 years of a reconstructed hydrologic record.

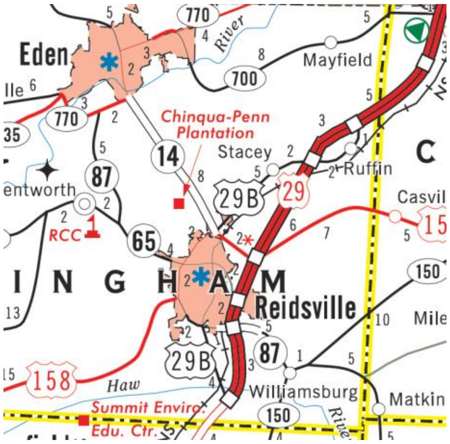
The 81 years of flow records for this model contains several extreme droughts, a couple of which may be familiar to the readers of this report. The 2010 basecase scenario gives an indication of the magnitude and duration of supply shortages that could be expected during a repeat of flow conditions that have occurred in the past given the 2010 levels of water withdrawals and management protocols.

In the analysis for this report DWR staff compiled projections from local water supply plans submitted to the division and created model scenarios based on several levels of water withdrawals expected to be needed to meet customer demands in the future. Comparing the model results of the future demand scenarios with the basecase scenario gives an indication of how the frequency, magnitude and duration of supply shortages may be different during a reoccurrence of conditions similar to historic low flow periods. The goal of these evaluations is to provide water utility managers and local decision makers with data to inform water source and demand management planning and fine tuning of local water shortage response plans.

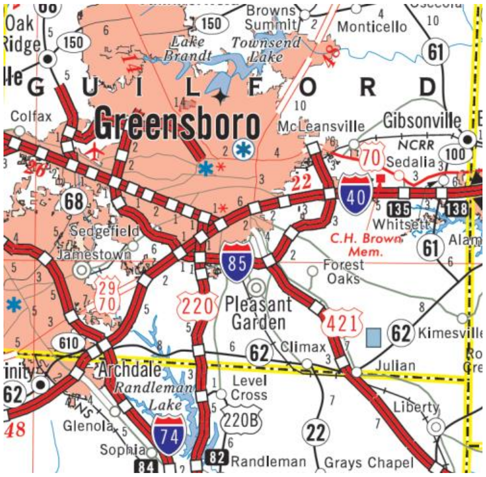
The Cape Fear Basin portion of the model includes the 27 surface water withdrawals in the Cape Fear River and its tributaries above Lock & Dam #1 in Bladen County. These withdrawals support 82 community and industrial water systems in the Cape

Fear and the Neuse River Basin. The Neuse River Basin portion of the model includes the 13 surface water withdrawals in the Neuse River and its tributaries above New Bern. These withdrawals support 36 community and industrial water systems in the Neuse and the Cape Fear River Basin. A schematic of the model is shown in Figure 6.

This section will summarize the potential of flow-related supply shortages for surface water withdrawals in the Haw River, Deep River and Cape Fear River Subbasins based on the Cape Fear-Neuse River Basins Hydrologic Model results. More detail of each of the water system's local water supply plan is available on the division's website at www.ncwater.org/Water_Supply_Planning/Local_Water_Supply_Plan/ .

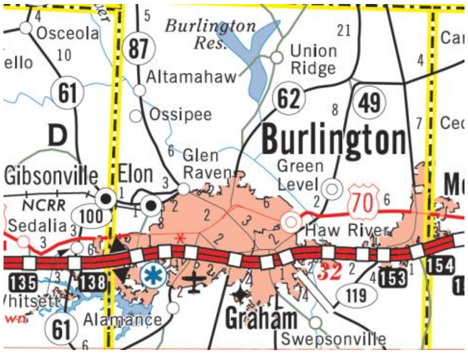


Beginning in the headwaters of the Haw River Subbasin the Town of Reidsville withdraws water from Lake Reidsville on Troublesome Creek supplying water to Greensboro and Rockingham County as well as the town's service area customers. Based on modeling results Reidsville is expected to be able to reliably meet its projected 2060 annual average demand of 5.7 million gallons per day from its current sources without supply shortages.

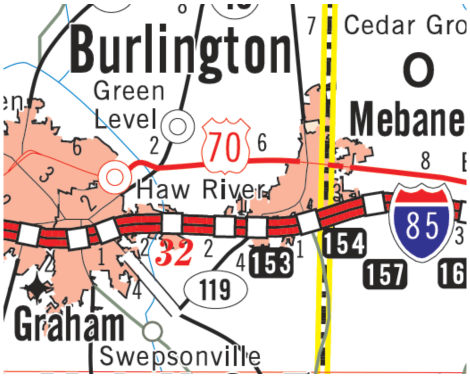


The City of Greensboro has three reservoirs that it manages for water supply, Lake Higgins, Lake Townsend and Lake Brandt. The supply from these sources is supplemented by finished water purchases from Burlington, Reidsville and the Piedmont Triad Regional Water Authority. The PTRWA recently completed construction of the Randleman Reservoir on the Deep River, a regional water supply source. PTRWA operates a water treatment facility distributing drinking water to surrounding communities. Greensboro's multiple sources of water, from different watersheds, provides source redundancy and resilience to low flow conditions. The available capacity in Randleman Reservoir has the ability to cover regional water supply needs for some time to come. The current water treatment plant with a permitted capacity of 12 million gallons per day is not able to fully utilize the estimated available supply of 48 million gallons per day.

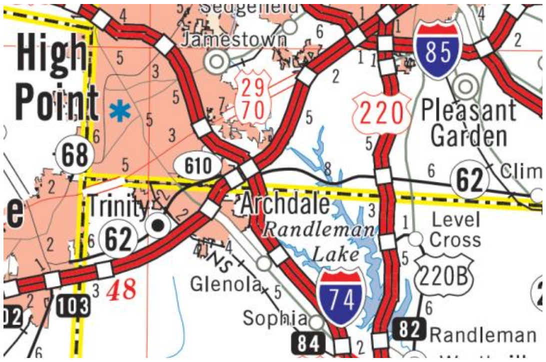
Modeling for this analysis indicates Greensboro could face short periods of supply shortages trying to meet the estimated 2060 demand levels of 65.6 million gallons per day given the treatment limit of PTRWA. As demand increases it will become more practical to invest in water treatment plant expansions to access more water from Randleman Reservoir. In the meantime, modeling does not show any predicted supply shortages from current sources over the range of flows that occurred from 1930 to 2011 while meeting the 2045 estimated annual average demand of about 54 million gallons per day.



The City of Burlington manages two water supply reservoirs in the Haw River Subbasin; Lake Mackintosh on Great Alamance Creek and Stoney Creek Reservoir on Stoney Creek. From these sources Burlington supplies their service customers' demands and regularly provides water to the communities of Greensboro, Elon, Gibsonville, Alamance and Haw River. In turn Haw River passes some of that water on to the Orange-Alamance Water System. The modeling for this report indicates the expected demand needed to meet 2060 customer demands, 26.8 million gallons per day, is likely to be available without any flow-related shortages over the range of historic hydrologic conditions experienced on the watersheds of these reservoirs from 1930 to 2011.

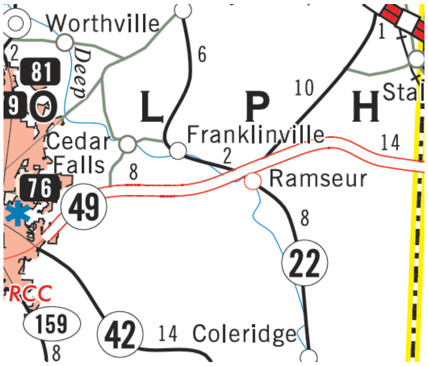


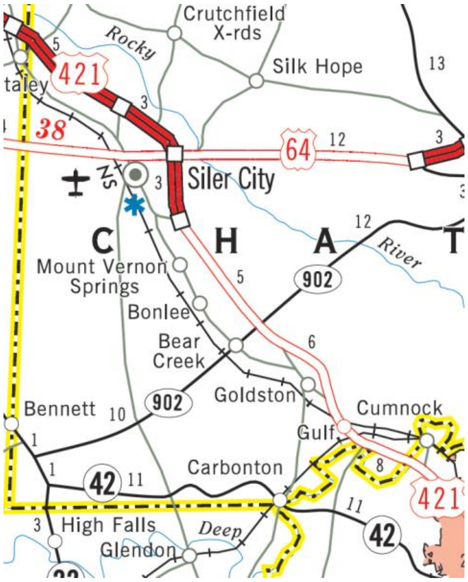
The cities of Graham and Mebane share a reservoir, the Graham-Mebane Lake on Back Creek in Alamance County, and a water treatment plant. Besides the residents of Graham and Mebane the water treatment plant regularly supplies water to customers of the Swepsonville and Green Level water utilities. In the modeling done for this analysis the total demand on this reservoir is estimated to increase from a 2010 level of 3.4 million gallons per day to an estimated 9.5 million gallons per day to meet customer demands in 2060. The modeling predicts that at that future level of demand, with a repeat of the drought conditions seen in 2007-2008 or 1934, the water supply storage in the reservoir could be depleted producing water shortages. No other flow-related shortages were noted in the modeling results for this group of water systems. The existing emergency connection with Burlington may be sufficient to avoid supply shortages.



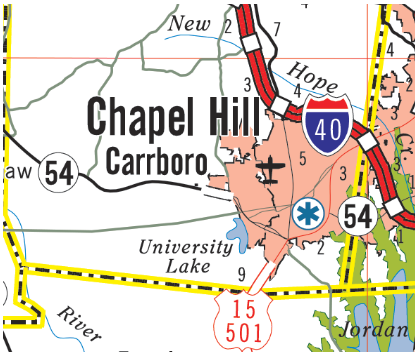
In addition to Greensboro, the communities of High Point, Jamestown, Archdale and Randleman receive water from PTRWA as a sole source or to supplement existing sources. According to the modeling for this analysis flow-related shortages are not an issue for these systems as water demands increase to the amounts expected to be needed to meet 2060 customer demands.

The Town of Ramseur manages the Sandy Creek Reservoir, on a tributary of the Deep River, and operates a water treatment plant supplying water to its service customers and providing the sole source of potable water to the Franklinville water system. According to information in these towns' local water supply plans they are expecting only a modest growth in water demand from now to 2060. Modeling indicates they are likely to be able to withdraw the amount of water expected to be needed to meet 2060 without flow-related shortages.

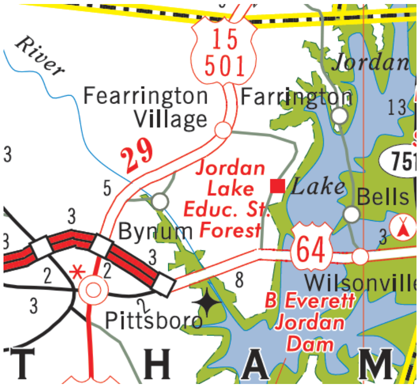




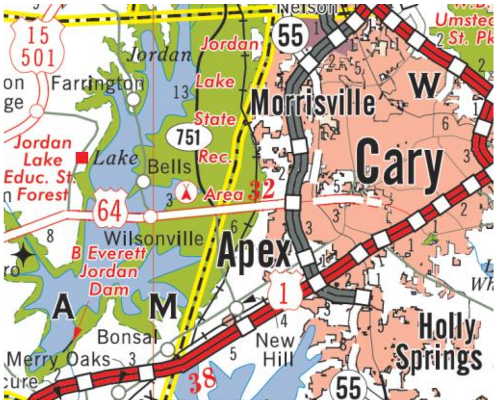
Siler City manages the Rocky River Upper and Lower Reservoirs as a combined system to supply water to its water treatment plant and deliver potable water to the residents and industries in its service area. In addition to its service customers the Siler City water system supplies water to the Moore County Public Utilities-High Falls system and is the sole supplier of potable water to the Chatham County Southwest Water System. The estimated water withdrawal needed to meet 2060 demand in this analysis is 2.1 million gallons per day. The hydrologic model does not indicate any flow-related shortages likely to limit meeting this level of demand from these sources over the range of flows that have occurred on this watershed from 1930 to 2011.



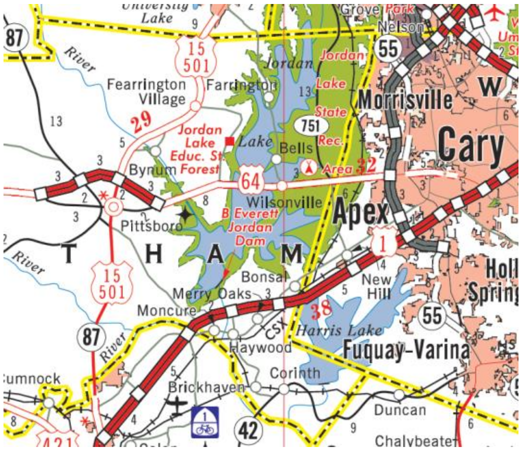
The Orange Water and Sewer Authority provides water and sewer services to residents of Chapel Hill, Carrboro and surrounding portions of Orange County. OWASA manages two reservoirs, University Lake on Morgan Creek and Cane Creek Reservoir, and it currently holds a five percent allocation of the Jordan Lake water supply pool. Water from Jordan Lake provides an alternative source that can be accessed by receiving finished water treated by the Cary-Apex WTP and delivered to OWASA through the Durham distribution system. OWASA's long-term plan includes development of increase supply storage in the quarry, currently operated by American Stone, located on the same watershed as the Cane Creek Reservoir. OWASA has submitted an application to retain a five percent allocation of the water supply pool in Jordan Lake. OWASA is a member of the Jordan Lake Partnership and the consortium working to develop the western Jordan Lake intake and water treatment plant. Modeling indicates the OWASA's current sources including the Jordan Lake allocation is expected to be capable of reliably meeting the expected 2060 demand of 12.9 million gallons per day. The resilience of OWASA's water supplies is enhanced by having a source from the larger watershed and reservoir storage provided by Jordan Lake.



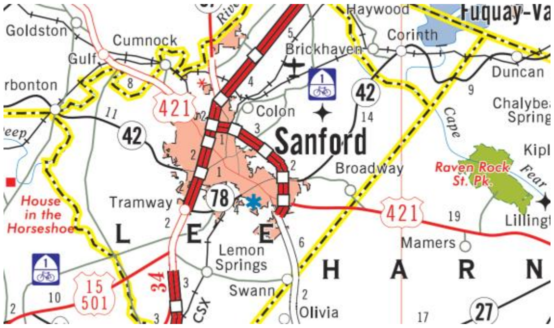
The Town of Pittsboro has an intake in the Haw River upstream of the hydropower dam at Bynum. Currently the town operates a two million gallon per day water treatment plant. With the proposal to develop Chatham Park east of Pittsboro the water utility is expecting to see its customer base grow from 3,700 in 2010 to about 96,800 by 2060 with accompanying growth in water demands. Pittsboro has submitted an application for a six percent allocation of water supply storage in Jordan Lake to supplement an eventual six million gallon per day supply from the Haw River. Pittsboro is a member of the Jordan Lake Partnership and is a member of the consortium of local governments working together to develop an intake and water treatment plant on the western shore of Jordan Lake to allow full utilization of the water supply storage in the reservoir. Modeling indicates that if Pittsboro receives the requested allocation and completes the intended expansions of their withdrawal and treatment capacity from the Haw River there will be enough water available to meet the projected demand of 11.24 million gallons per day.



Currently the only water intake available to access the water supply storage in Jordan Lake is jointly owned and maintained by the towns of Cary and Apex. There are a group of utilities currently holding allocations of water supply storage in Jordan Lake that depend on the Cary-Apex raw water pump station to access their allocations. The Chatham County – North water system has an arrangement with Cary and Apex that allows it to supply water to its water treatment plant from water withdrawn at the Cary-Apex raw water pump station. The Cary-Apex WTP regularly supplies water to RDU Airport, Morrisville and the Wake County portion of the Research Triangle Park. The Town of Holly Springs has an interconnection with Apex that can provide access to its current two percent allocation of water supply storage in Jordan Lake. If these local governments receive their requested allocations their demands will be covered through the allocation planning horizon. Cary has interconnections with OWASA and Durham through which those utilities can access their current Jordan Lake water supply allocations. Modeling shows that if the Cary-Apex, Morrisville and Holly Springs allocation requests are granted these communities will reliably be able to meet currently expected customer demands through 2060.

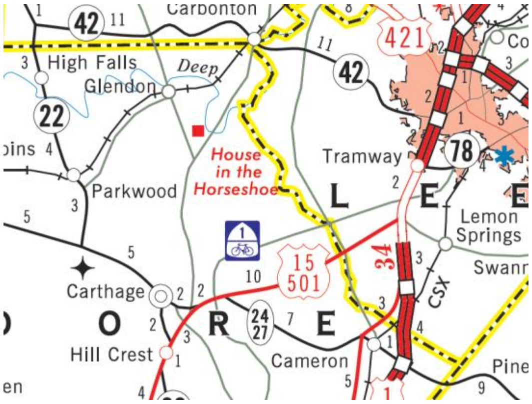


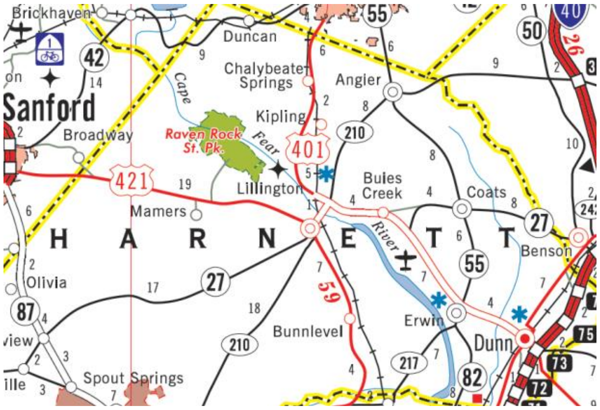
Chatham County provides public water service to areas in the county east of the Haw and Cape Fear rivers not served by Cary or Pittsboro through its Chatham County-North system. The development of Chatham Park, east of Pittsboro, is expected to bring increased development to the surrounding county areas. The Chatham County-North water system is preparing for a service population grow from the 2010 level of 10,200 using 2.16 million gallons per day to 94,000 using 18.1 million gallons per day by 2060. Chatham County currently holds a 6 percent allocation from the Jordan Lake water supply pool and a 3 million gallon per day water treatment plant supplied by the Cary-Apex raw water pump station. Chatham County has requested a 13 percent water supply allocation that will cover there expected demands through 2045. Chatham County is a member of the coalition of systems pursuing the development of the western intake and treatment plant through which its allocation, if granted, will be accessed. If Chatham County receives the anticipated growth associated with Chatham Park it will likely need to find additional sources of water to meet the projected 2060 demand of over 18 million gallons per day.



Below Jordan Lake the City of Sanford withdraws water from an unmanaged impoundment behind Buckhorn Dam on the Cape Fear River known as Yarborough Lake and Buckhorn Dam Lake. In addition to its own customers Sanford also provides water to the Chatham County – East Water System, the Goldston-Gulf Sanitary District, the Town of Broadway and the Utilities, Inc. - Carolina Trace Water System. Sanford discharges about two-thirds of the water it delivers to its service area customers as treated wastewater to the Deep River, upstream of its water supply intake. With this arrangement the effects of Sanford's withdrawals on streamflows becomes the difference between the quantity of the system's water withdrawal and the amount of its wastewater return flow. Modeling results indicate that the water available at Sanford's current intake location is sufficient to meet the cumulative demands of 24.2 million gallons per day estimated to be needed to meet 2060 water demands for this group of water utilities that depend on Sanford's water withdrawals.

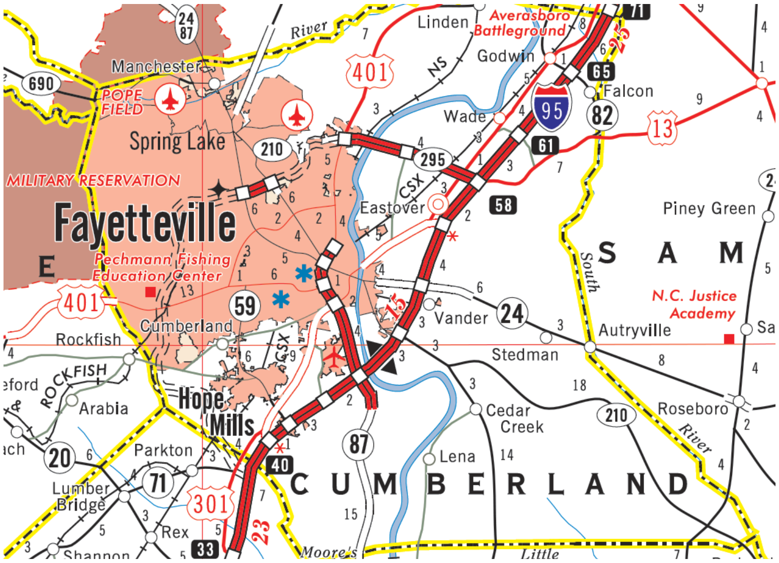
Southwest of Sanford the Town of Carthage withdraws water from Nicks Creek in the headwaters of the Little River watershed, a tributary of the Cape Fear River. The estimated 2060 water demand for this utility is 0.64 million gallons per day. The model does predict the possibility of short-term flow-related shortages from their current surface water source at this level of demand. Carthage's recent local water supply plan indicates the intention to convert an emergency connection with the Town of Southern Pines to a regular source of water. The additional water source has the potential to alleviate flow related shortages at their current source.



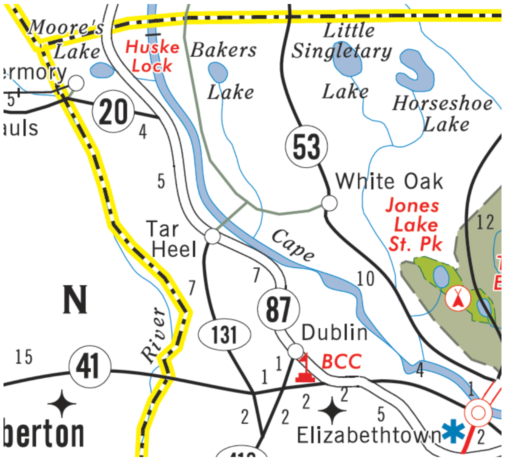


Moving downstream on the Cape Fear River the next surface water intake is the Harnett County Regional Water System facility near the USGS streamflow gage at Lillington. Over the last few decades this utility has become a regional water supplier meeting the needs of communities in Harnett, Moore, Cumberland, Wake and Johnston Counties. Its location downstream of Jordan Lake gives this utility an advantageous position to make use of the reliability of water available from the flow augmentation releases from the reservoir. Modeling results do not indicate any flow related water supply shortages associated with meeting the projected annual average demand of 43.2 million gallons per day estimated to be needed to meet the cumulative demands on this intake in 2060.

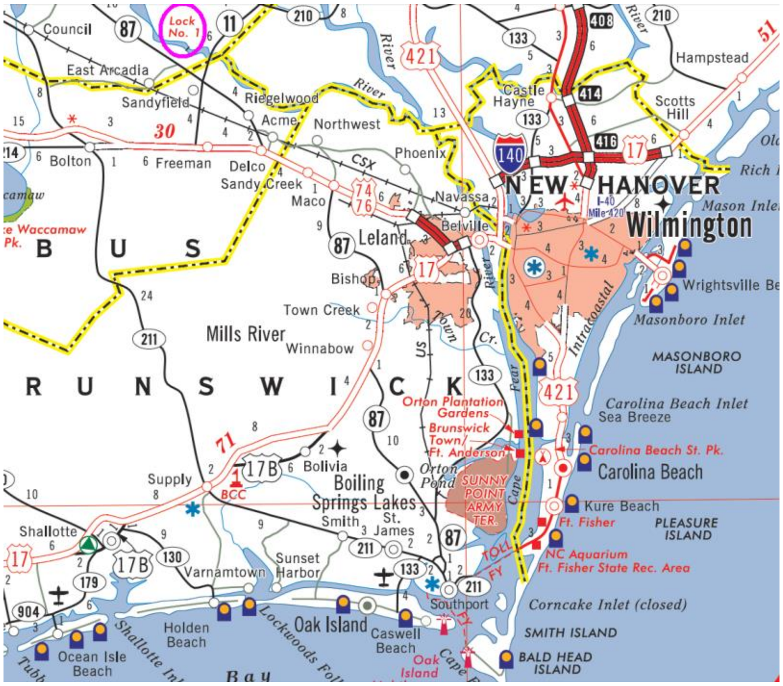
Downstream from the Lillington streamflow gage the City of Dunn (shown on the map above) withdraws water from the Cape Fear River to supply its residents as well as supplying water to the Town of Benson. The estimated 2060 demand for this intake is 3.2 million gallons per day. The model does show potential flow related shortages for this volume of withdrawal at this location. The shortage from the model analysis is the result of the levels of flow chosen as the triggers in Dunn's water shortage response plans combined with a 14-day waiting period to activate demand reductions when the triggers are met. This combination results in several periods of shortages lasting 14 days or less.



Further downstream, the City of Fayetteville's Public Works Commission withdraws surface water from the Cape Fear River providing potable water to customers in its own service area as well as several surrounding communities. Fayetteville PWC maintains two surface water intakes on the Cape Fear River in the backwater of William O. Huske Lock and Dam (Lock & Dam #3) operated by the US Army Corps of Engineers. It also has access to water from Little Cross Creek and Big Cross Creek, tributaries of the Cape Fear River. The lock and dam structure maintains a relatively stable water level in the river above the elevation of the top of the dam for approximately 29 miles upstream as long as there is more water flowing downstream than the net withdrawals and evaporation from the impoundment. Fayetteville PWC's withdrawals are approximately 20 miles upstream of the lock and dam structure and the utility discharges treated wastewater downstream of the water supply intakes and upstream of the dam. The wastewater discharges are generally at a volume approximately equal to 90 percent or more of water withdrawals. Similar to Sanford's arrangement discussed above the magnitude of the effect of Fayetteville's water withdrawals on the flow in the Cape Fear River is best characterized as the difference between the amount of withdrawal and the amount of wastewater return flow. At the current intake location, modeling does not indicate any flow related supply shortages limiting Fayetteville PWC ability to meet its estimated annual average 2060 demand of 78.3 million gallons per day. This analysis assumes the range of flow conditions experienced in the basin from 1930-2011, and the current management and drought protocols for Jordan Lake.



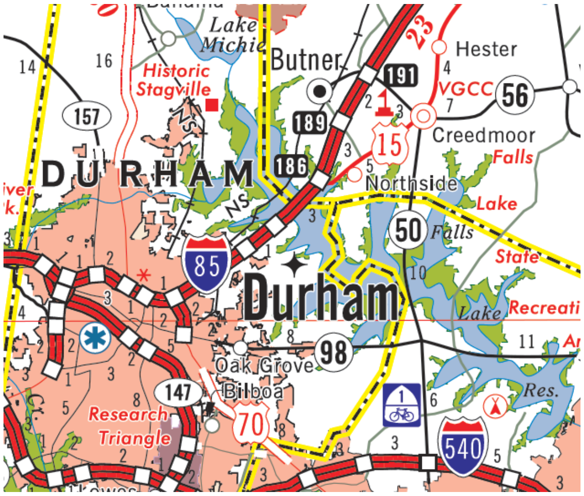
Below Fayetteville, the Lower Cape Fear Water and Sewer Authority withdraws water from the Cape Fear River, at its Bladen Bluffs facility near Tarheel, supplying finished water to The Smithfield Packing Company facility in Tarheel. Based on available information the estimated annual average day demand from this withdrawal in 2060 is 2.3 million gallons per day with approximately the same volume of water returned to the river nearby as treated wastewater. Modeling results do not indicate any flow-related shortages from this volume of withdrawal at this location.



The Cape Fear Public Utility Authority and the Lower Cape Fear Water and Sewer Authority Kings Bluff facility withdraw water from the Cape Fear River in the back water of Lock and Dam #1 near Kelly, N.C. The CFPUA supplies water to Wilmington and surrounding areas of New Hanover County. The LCFWSA Kings Bluff facility supplies raw water to several industrial customers as well as the water treatment plants operated by Brunswick County, Pender County and CFPUA. The estimated combined 2060 surface water demand for CFPUA and LCFWSA is 59.3 million gallons per day. Hydrologic modeling of the Cape Fear River does not indicate the likelihood of flow-related shortages from withdrawing this amount of water at this location. However, none of the water withdrawn is returned to the backwater of the dam, therefore this withdrawal reduces the streamflow below Lock & Dam #1 by the amount of the withdrawal.

Brunswick County's surface water treatment plant, in combination with water from a groundwater treatment plant, provides water to residents and industries throughout the county including those serviced by the following community water systems: Bald Head Utilities, Brunswick Regional (H2GO), Caswell Beach, Holden Beach, Leland, Navassa, Northwest, Oak Island, Ocean Isle Beach, Shallotte and Southport. In addition, the LCFWSA also provides raw water to the Rocky Point – Topsail Water and Sewer District in Pender County.

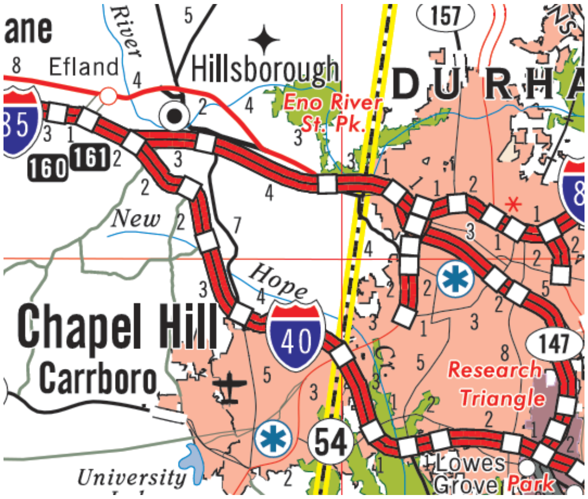
As noted in the introduction to this section, consideration of the water needs and the available supplies of communities in the upper Neuse River Basin are crucial to an accurate understanding and optimum utilization of water supply storage in Jordan Lake. Hillsborough, Durham and Raleigh submitted applications for allocations of water supply storage in Jordan Lake and all depend on water sources in the Neuse River Subbasin.



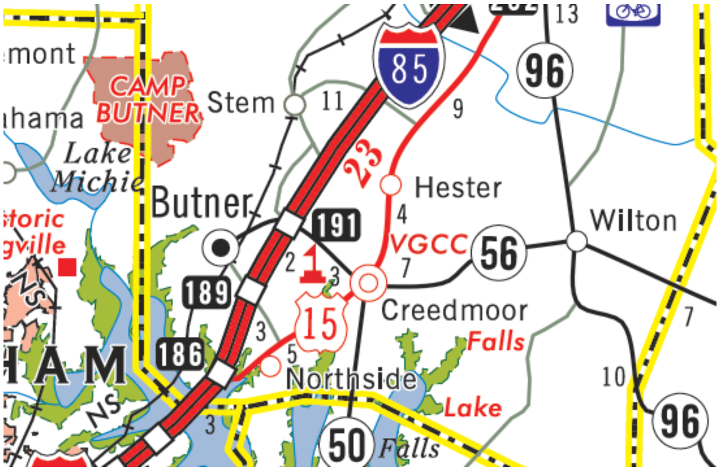
Durham currently has a 10 percent allocation of the Jordan Lake water supply pool which it can receive as finished water through interconnections with Cary's water system. Durham's primary water supply sources are Lake Michie and the Little River Reservoir upstream of Falls Lake in the Neuse River Subbasin. To date Durham has only used its Jordan Lake allocation during drought conditions. Durham's ability to access water from Jordan Lake is likely to become less dependable as the Cary-Apex system requires more of their plant capacity to meet their own demands. Except for its Jordan Lake allocation all of Durham's water supply comes from sources upstream of Falls Lake, which is Raleigh's primary water supply source. Durham has some provisions to pump water from the Eno River, a tributary of Falls Lake, under certain conditions. For some time Durham has been considering the possibility of expanding Lake Michie to increase the amount of water it can provide. Without a reliable source of water outside of the Neuse River Basin all of Durham's options for increasing supply to meet future water demands will impact inflows to Falls Lake.

Durham is a partner with the utilities collaborating on the development of a western intake and treatment plant on Jordan Lake. Durham has indicated in its application that when the water treatment plant comes online it expects to use the full amount of its anticipated 16.5 million gallons a day on a daily basis reducing its withdrawal from the Neuse River Subbasin. Durham currently has mutual aid agreements and emergency connections with Cary, Chatham County – North, Raleigh, Hillsborough, Orange-Alamance Water System and OWASA. Historically about fifty percent of Durham's average daily water use is discharged to the Jordan Lake watershed as treated wastewater.

Durham applied for a 16.5 percent allocation from the Jordan Lake water supply pool, a 6.5 percent increase over their current allocation. Durham's estimated average daily demand in 2060 is 44.37 million gallons per day. Durham's available supply from Lake Michie and the Little River Reservoir is estimated at 34.4 million gallons per day. The modeling done for this analysis does not indicate any flow-related shortages limiting Durham's ability to meet its customer's demands as modified by the utilities water shortage response plans if it receives the requested allocation from Jordan Lake.

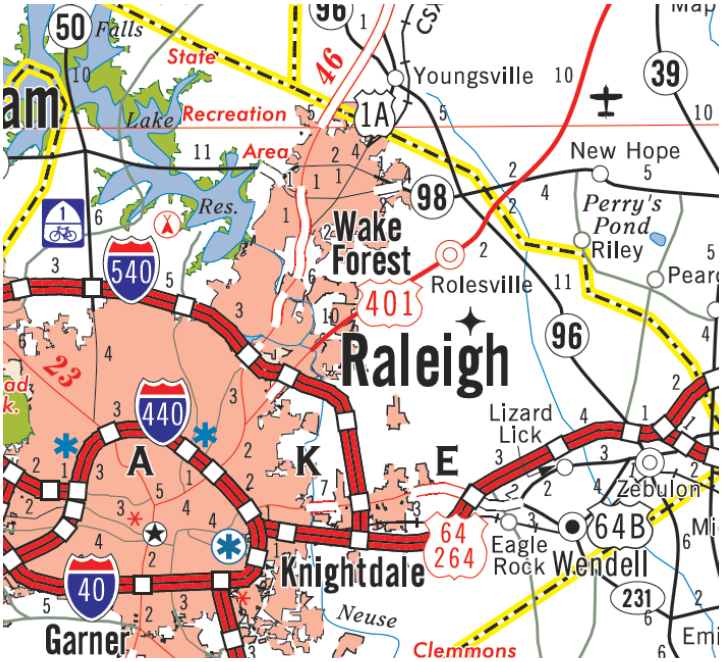


Hillsborough pumps water to its water treatment plant from Lake Ben Johnston, a run-of-river impoundment on the Eno River which receives water from the town's two primary water supplies Lake Orange, on the East Fork of the Eno River, and the West Fork Eno Reservoir. Hillsborough's primary reservoirs both have relatively small drainage areas of nine square miles. In addition, during drought conditions when flows in the Eno River are low, releases must be made from Lake Orange to maintain flows downstream in the Eno River. Hillsborough will soon begin an expansion of the West Fork Eno Reservoir which will increase its water supply storage. The town can receive water from Durham, OWASA and the Orange-Alamance Water System through existing emergency connections. The town can supply water to the Orange-Alamance Water System. Orange County anticipates having the town supply water to economic development zones in the county bordering Hillsborough's current utility service area. Hillsborough applied for a one percent allocation from the Jordan Lake water supply pool to meet its long term water supply needs. Hillsborough's estimated average daily demand in 2060 is 3.7 million gallons per day. The modeling done for this evaluation does not indicate any flow-related shortages limiting Hillsborough's ability to meet their customer's demands as modified by the utilities water shortage response plan.



Also upstream of Falls Lake the South Granville Water and Sewer Authority withdraws water out of R.D. Holt Reservoir on Knapp of Reed's Creek to supply their customers and the Town of Creedmoor. The reservoir has an estimated yield of eleven million gallons per day and the system has an estimated 2060 demand of five million gallons per day.

Modeling does not show any flow related shortages meeting the predicted water demands. SGWASA did not apply for a Jordan Lake water supply allocation.



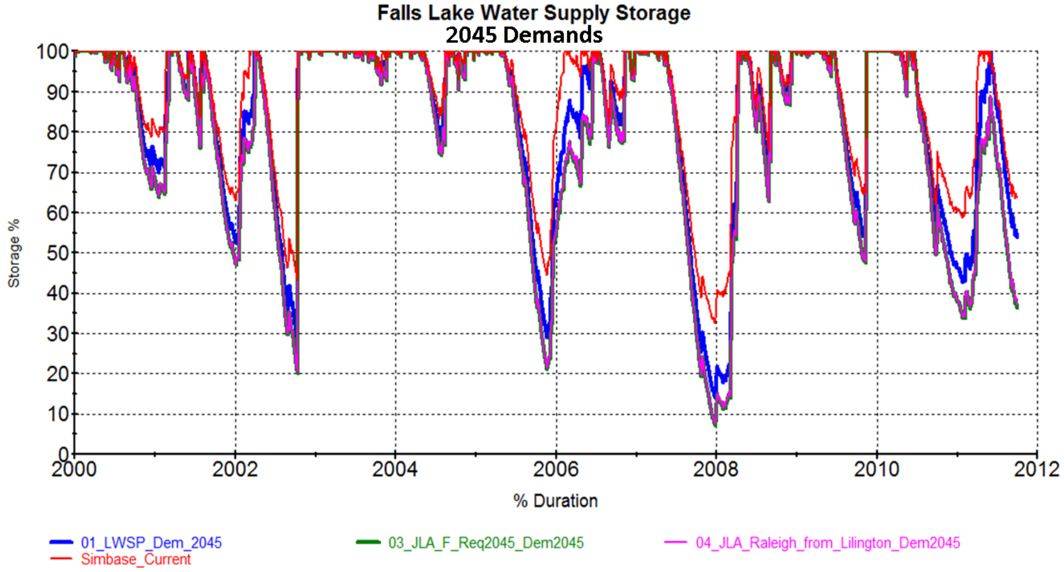
Raleigh depends on the Neuse River Subbasin to supply water to meet its customer's demands. Raleigh's water utility customer base includes the residents of Raleigh, Garner, Knightdale, Rolesville, Wake Forest, Wendell and Zebulon. Raleigh's largest source of water is Falls Lake with an estimated available supply of 66.1 million gallons per day. In addition Lake Wheeler and Lake Benson on the Swift Creek watershed can provide an estimated 11.2 million gallons per day. The combined yield of 77.3 million gallons per day represents an estimate of the reliable supply available during dry conditions. Most of the time inflows to the reservoirs are sufficient to support larger withdrawals. Raleigh's 2035, 2045 and 2060 average daily water demands are estimated to be 85, 97 and 115 million gallons per day, respectively. As water withdrawals increase the stress on water supply sources during dry periods will also increase.

The estimated 2045 demand of 97 million gallons per day on average represents a range of demands from 83 to114 million gallons per day depending on the month of the year. Figure 8 shows the model predictions of the remaining water supply storage for 2010 and 2045 demand levels during the flow conditions experienced from 2000 to 2011. This analysis reflects the restricted demands expected from the water shortage response protocols that Raleigh specified for this modeling effort.

Raleigh has been exploring several options to expand the utility's water supply by increments of 14 to 24 million gallons per day. Each option requires extensive environmental and regulatory review and approval resulting in multi-year permitting periods prior to construction and completion. Raleigh will need additional water supplies to meet the anticipated future customer demands. The 01_LWSP_Dem2045 scenario includes Raleigh's proposed Little River Reservoir which was included as a future option in the local water supply plan. The other two 2045 demand scenarios shown in Figure 10 do not include water from the Little River Reservoir but they include Raleigh's Jordan Lake allocation request of 4.7 million gallons per day from

Jordan Lake in one scenario and from the Cape Fear River near Lillington in the other scenario.

Figure 8 Falls Lake Water Supply Storage



According to the modeling scenarios run for this analysis no flow related supply shortages were noted in the modeling results for other surface water withdrawers downstream of Raleigh on the Neuse River or in the Contentnea Creek subbasin. Appendix C contains tables showing the results of the shortage evaluations for the various model scenarios run for this report.

Summary

Modeling shows that for most public water systems that rely on surface water from the Cape Fear and Neuse River Basins, based on the range of flows that have occurred since 1930, there will likely be adequate quantities of water available to meet anticipated water needs through 2060. Some communities may have to implement their water shortage response plans in order to reduce customer demands during recurrences of historic drought conditions to reliably supply enough water to cover essential water needs. Some communities may be able to cover unrestricted demands even during droughts. This group includes communities that get water from the Cape Fear River below Jordan Lake and the Neuse River below Falls Lake. The flow augmentation releases from these reservoirs improve the reliability of water supplies for downstream communities compared to what would be available without the additional flow releases. The completion of Randleman Reservoir and the Piedmont Triad Regional Water Treatment Facility has significantly improved the reliability of water supplies for communities in the Triad Region by reducing the risk of water shortages. Also, Lake Mackintosh continues to provide reliable water supplies for Burlington and the interconnected surrounding communities.

Water supply reliability is less certain for communities in the Research Triangle Region. Thirteen local government entities in this region formed the Jordan Lake Partnership to investigate options to make optimum use of existing water supplies and to cooperatively plan for additional sources to meet anticipated future needs. The resulting Triangle Regional Water Supply Plan presents the results of the group's work. The TRWSP recommendations included increased allocations from Jordan Lake for several communities to be withdrawn through a newly constructed intake and water treatment plant on the western shore of Jordan Lake. Optimum utilization of the water supply storage in Jordan Lake will require an additional intake facility. The existing raw water intake does not have the capacity to withdraw the 100 million gallons a day of water assumed to be available from the water supply storage.

The TRWSP includes the presumption that Raleigh would continue to pursue the options they were already investigating for expanding water supplies from the Neuse River Basin. Therefore, the TRWSP does not include an allocation from Jordan Lake for Raleigh. The City of Raleigh Public Utility Department did submit an application for an allocation from Jordan Lake to provide a portion of their future needs.

Model scenarios were constructed to characterize options presented in the local water supply plans submitted by communities in the Cape Fear and Neuse River Basins as well as alternative water supply options derived from the allocation applications received by DWR. Additional graphs describing the variations in water supply reservoirs in the model is available in Appendix D. Also, Appendix E presents a discussion and summary tables of the variations in low flow conditions for river nodes in the model for the various model scenarios used for this evaluation.

Conclusions

The Cape Fear River Water Supply Evaluation is based on the water demand, population estimates, and water supply options data available at the time of the study. The cumulative effects of individual surface water withdrawers' expected future water needs from the Deep River, Haw River, Cape Fear River, Neuse River and Contentnea Creek river subbasins are evaluated using a computer-based hydrologic model. The Cape Fear – Neuse River Basins Hydrologic Model is a platform to evaluate the effects of various levels of water withdrawals on water availability in the context of current and known future management protocols over the range of streamflow variability that occurred between 1930 and 2011 in these subbasins.

The model results and subsequent interpretation depends on the following key assumptions and limitations:

- The evaluation focuses on the question, will there be enough water available at specific locations to satisfy estimated future water demands,
- Water is not reserved in rivers and streams to protect aquatic habitat and ecological integrity except to the extent that minimum releases are required,
- Population and demand projections in local water supply plans and Jordan Lake allocation application are the best informed estimates,

- Future water withdrawals will be from the same locations as current withdrawals with the addition of new withdrawal locations specified in the source data,
- Water systems that depend on purchasing water from another water system will continue being supplied by the current seller during the planning horizon of this study,
- Wastewater return flows will continue at the current locations unless additional information is provide,
- Future wastewater return flows will be the same percentage of water use as in the 2010 basecase model scenario unless additional information was provided,
- The model does not predict the future flow conditions, it indicates the effects of withdrawing various volumes of water over the range of streamflow conditions that occurred between 1930 and 2011,
- Agricultural water use is based on estimates developed for previous river basin models and is assumed to be consistent over the planning horizon,
- Water quality is not evaluated,
- The model does not evaluate flooding conditions, and
- The model does not extend into tidally influenced sections of the Cape Fear River or Neuse River.

Given these caveats, the water quantity modeling done for this evaluation suggests that, with several exceptions, the public utilities and other surface water withdrawers in these basins are unlikely to face flow related shortages in the foreseeable future, with an increased use of water supply in Jordan Lake. Some communities will have to make use of their water shortage response plans to protect essential water uses during droughts. The modeling does indicate potential shortages for five water withdrawers, most of which have plans in place to address these concerns as demands increase.

Greensboro’s currently available supply will need to be increased to meet projected 2060 demands. However, the currently available supply is limited by the existing water treatment capacity of the Piedmont Triad Regional Water Authority. PTRWA’s water source, Randleman Regional Reservoir, reportedly has the capacity to support a three-fold increase in the current 12 million gallons per day treatment plant. Prudent expansions of treatment facilities will be able to cover the expected growth in demand.
Modeling for the City of Randleman indicates potential supply shortage from current sources if demands reach the anticipated 2060 levels. As a partner in the PTRWA, Randleman will benefit from future expansions of the authority’s treatment facilities that will address the model-indicated shortages.

The cities of Graham and Mebane, and several surrounding water systems, depend on Graham-Mebane Lake on Back Creek to supply water for their customers. The model indicates a possible three-week shortage meeting 2060 water demands during a reoccurrence of the drought conditions experienced in 2007-2008 or 1934. These water systems have existing connections with the City of Burlington that should be able to cover the potential shortfalls. Modeling of Burlington's supplies and demands do not indicate potential supply shortage over the planning horizon for this evaluation.

The Town of Carthage relies on Nicks Creek for water to meet customer demands. The system also has a long-term contract to purchase water on an emergency basis from the Town of Southern Pines. Modeling of Carthage's 2060 estimated water demands indicate the potential of short-term flow-related shortages during low-flow periods if this demand level becomes reality. The Town's connection with Southern Pines provides a way to address the potential shortages from Nicks Creek.

The Chatham County-North water system anticipates the need to meet annual average day demands of 18 million gallons per days in 2060. Chatham County currently holds a six percent allocation from the water supply pool in Jordan Lake. They have submitted an application request to increase the allocation by seven percent to a total of 13 percent. Under a couple of the allocation options modeled Chatham County-North could face challenges meeting the 2060 estimated demands.

There is no indication this system will face supply shortages over the planning horizon for Jordan Lake water supply allocation decision making, if they receive the requested allocation increase. Chatham County is a member of the consortium of entities proposing to develop a raw water intake and water treatment plant on the western side of Jordan Lake. Their ability to access the requested volume of water is dependent on the construction of these facilities, which is dependent on all members be assured they will have access to Jordan Lake water by receiving their requested allocations.

The City of Raleigh currently depends on water sources in the Neuse River basin to meet water customer needs. It is included in this evaluation because of the water sharing arrangements among water utilities in Haw River, Cape Fear River and Neuse River subbasins. Also, the City of Raleigh Public Utilities Department submitted a request for a 4.7 percent allocation from the water supply pool in Jordan Lake. Raleigh does not currently have an allocation from Jordan Lake. With the water supply pool designed to supply 100 million gallons per day each percent of the pool is generally thought of as representing one million gallons per day. The modeling done for this evaluation shows Raleigh having a potential supply shortage to meet the estimated 2045 demands from their existing water sources in the Neuse River Subbasin. Raleigh's primary water supply source is Falls Lake where the city has access to 42.3 percent of the conservation pool. This source is supplemented by water from the Swift Creek Watershed south of the city. The current available supply from both sources is estimated to be 77.3 million gallons per day.

The model scenarios based on local water supply plan data on current and future available supplies supplements existing supplies with 13.7 million gallons per day from a proposed reservoir on Little River in Wake County. The other modeling scenarios do not include water from the Little River Reservoir in Raleigh's available supply. They do however include a 4.7 million gallons a day supplement to the existing supplies from a source outside of the Neuse River Basin. The City of Raleigh has a very aggressive water shortage response plan included in the model that is triggered by the percent of storage in the water supply pool of Falls Lake. When supply storage declines during low-flow periods implementation of the water shortage response plan reduces customer demands.

Modeling for this evaluation that included the additional supplies discussed above and the water shortage response plan did not indicate potential flow-related shortages related to meeting 2060 demand estimates.

This evaluation indicates that, with the water supply sharing arrangements detailed in the Triangle Regional Water Supply Plan and the local water supply plans submitted by surface water dependent water systems in the Deep River, Haw River, Cape Fear River, Neuse River and Contentnea Creek basins, the quantity of surface water is likely to be sufficient to meet expected 2060 demand levels given the assumptions and limitations of the hydrologic model. The modeling results are dependent on the wastewater return flow assumptions and the limitation that the model does not reserve streamflow to protect aquatic habitats and ecological integrity. This evaluation does not evaluate or predict the quality of water available to public water systems. Delivering drinking water that meets customer expectations may become more challenging as water quality conditions change.

The water elevation variations under the model scenarios discussed above for the reservoirs other than Jordan Lake can be found in the graphs in Appendix D, which also has graphic representations of the flow variations at locations in the Cape Fear River and Neuse River basins.

APPENDIX A

B. Everett Jordan Dam and Lake
Cape Fear River Basin, NC
DROUGHT CONTINGENCY PLAN
Updated May 2008

EXHIBIT B

B. EVERETT JORDAN LAKE
CAPE FEAR RIVER BASIN, NORTH CAROLINA
DROUGHT CONTINGENCY PLAN Updated May 2008

INTRODUCTION

The purpose of this report is to (1) provide a platform from which to make decisions on implementation of water conservation measures during future droughts, (2) review the operational flexibility of the Jordan Water Control Plan in a drought, and (3) address the potential problems associated with an extreme drought. A severe drought in the Cape Fear River basin develops over a fairly long period of time and may have a typical duration of 6-12 months. However, the severe drought which climaxed in 2002 may have begun as early as 1996. Adequate time will be available to plan specific details of a drought operation. Therefore, this plan is an outline of water management measures and coordination actions to be considered when a severe drought occurs. Details of particular water management measures and the timing of their application will be determined as the drought progresses. This plan is part of the Water Control Manual for B. Everett Jordan Dam and Lake.

BACKGROUND

Usually, the demand for water is the greatest when the natural supply is the least. Jordan Lake has been drawn below elevation 210 feet, MSL on four separate occasions since completion of permanent impoundment on February 4, 1982. (Normal level is 216 ft, MSL). During this time period, no water supply withdrawals were made. The only releases were for water quality needs downstream. Table 1 shows the minimum lake elevation for each year since inception of the project.

These elevations indicate that the 1980’s decade was a dry period. The potential for a serious drought did exist in 1983, 1986, and 1988 due to the time of year and the minimum elevation that occurred.

TABLE 1

Minimum Elevation at Jordan Lake since Permanent Impoundment

Calendar Year	Date	Elevation (ft. MSL)
1982	September 28	213.95
1983	October 23	208.85
1984	November 28	212.55
1985	November 3	213.25
1986	November 12	207.85
1987	November 26	210.60
1988	August 29	210.23
1989	September 16	215.63
1990	October 10	209.59
1991	December 26	212.69
1992	October 29	213.80
1993	November 26	210.80
1994	October 13	214.75
1995	August 26	214.87
1996	July 23	215.18
1997	October 18	213.65
1998	December 8	210.31
1999	August 24	212.56
2000	December 15	212.95
2001	December 31	210.89
2002	August 24	209.87
2003	September 14	215.88
2004	March 22	215.76
2005	November 20	212.13
2006	August 30	215.34
2007	October 24	210.19

Historical surface water use (in 1987) by municipalities and industries downstream of Jordan Dam as tabulated by the U. S. Geological Survey is provided in table 2. This table illustrates that the required water supply is significant and will likely continue to increase.

Cape Fear River Basin Water Supply Users below Jordan Dam

Municipality	**Source of Supply**	**Amount of Withdrawal MGD**	**Population (1987) Served**
Vass	Little River	0.14	900
Carthage	Nicks Creek	0.26	1,500
Sanford	Cape Fear River	3.34	18,000
Northeast Metro Water District (Harnett Co.)	Cape Fear River	0.75	5,000
Dunn	Cape Fear River	2.35	9,450
Fayetteville	Cape Fear River	16.25	118,604
Fort Bragg	Little River	7.94	121,828
Wilmington	Cape Fear River	9.72	52,000

Industry	**Source of Supply**	**Average Annual Withdrawal in MGD(1987)**
Chembond Corp.	Haw River	0.22
Honeywell	Haw River	0.32
Moncure Fiberboard Plant	Shaddox Creek	0.34
Sanford Group	Several Ponds	0.08
Elliott Gravel Pit	Several Ponds	0.20
Burlington Industries Erwin Plant	Cape Fear River	2.0
Dupont (Cumberland Co.)	Cape Fear River	9.0
Monsanto (Cumberland Co.)	Cape Fear River	1.3
Cape Fear Feed Products	Cape Fear River	0.05
Federal Paper Board Co.	Cape Fear River	43.25
Wright Chemical Corp	Livingston Creek	0.2
Dupont (Brunswick Co.)	Cape Fear River	7.3
Occidental Chemical Corp.	Cape Fear River	0.29
Dixie Cement	Cape Fear River (2 intakes)	1.2

Lake access is available during periods of low lake levels. This is illustrated in table 3 which gives the bottom elevation of boat ramps at current and future access areas. The top elevation of boat ramps at Jordan Lake is approximately 227 feet MSL. However, operational experience during this period showed that recreational use of the lake began to suffer once the elevation fell below 212-213 feet MSL. Numerous complaints were received at both the Resource Manager's Office and Crosswinds Marina during low elevation periods primarily regarding shoals and navigational hazards within the lake. While the facilities at Crosswinds Marina were designed to function at elevations lower than what occurred, there was very little recreational use observed when Jordan Lake fell below elevation 212 feet MSL. While recreational use of the lake is significantly impacted at elevation 212 feet MSL and below, serious problems are also encountered at Crosswinds Marina once the elevation drops to 205.0 MSL. The problem at Crosswinds Marina is the bracings on the finger pier system which require approximately 6 feet of water to remain in place.

TABLE 3
Bottom Elevation of Public Boat Ramps at Jordan Lake
May 2008

Location	Lanes	Bottom of Ramp Elevation (ft. MSL)
Access Currently Available:		
Ebenezer	2 Lanes	202.0
	4 Lanes	206.0
Vista Point	2 Lanes	202.0
	2 Lanes	206.0
Parkers Creek	2 Lanes	210.0
Farrington	2 Lanes	202.0
	2 Lanes	206.0
	2 Lanes	208.0
Crosswinds Ramp	4 Lanes	212.0
	2 Lanes	202.0
Crosswinds Marina	2 Lanes	202.0
	2 Lanes	208.0
Poes Ridge	4 Lanes	210.0
Poplar Point	4 Lanes	210.0
Seaforth	3 Lanes	205.0
	3 Lanes	210.0
Crosswinds Campground	2 Lanes	207.0
Robeson Creek	2 Lanes	202.0
New Hope Overlook	2 Lanes	202.0
	4 Lanes	208.0

Note: All boat ramps were constructed prior to impoundment of Jordan Lake. The top elevation of all ramps is approximately 227 feet, MSL.

SUMMARY OF EXISTING WATER CONTROL PLAN

The authorized purposes of Jordan Lake are to provide for flood control, water supply, water quality control, recreation, and fish and wildlife conservation. The top of the conservation pool is at elevation 216.0 feet MSL. At that elevation, the mean depth of the lake is 15 feet and the maximum depth is about 66 feet. Allocated storages for Jordan Lake are shown in table 4.

Storage Allocation

	Elevation (Ft. MSL)	**Area (Ac.)**	**Capacity/Jun85 (Ac-Ft)**
Top of flood control pool	240	31,811	753,560
Flood control storage	216-240		538,430
Top of conservation pool	216	13,942	215,130
Bottom of conservation pool	202	6,658	74,700
Conservation pool storage	202-216		140,430
Water Supply			45,810
Water Quality (Low Flow)			94,620
Sediment storage	155-202		74,700

The plan of operation for Jordan Lake project provides for maintaining a normal pool at elevation 216 feet MSL on a year round basis. This is accomplished during periods of normal flow by releasing inflow. During flood periods, releases are based on a combination of downstream flow conditions and lake levels to minimize flood damages downstream. During normal and low-flow conditions, flows are released to maintain a minimum target flow of 600 cubic feet per second (c.f.s.) at the Lillington gage with an allowable range of 550 to 650 c.f.s.. A minimum instantaneous flow of 40 c.f.s. is maintained immediately below the dam. The conservation pool storage is divided with 67.38 percent allocated for water quality releases downstream and 32.62 percent contracted by the State of North Carolina for water supply.

Regulation flexibility is very limited under existing authority. When the lake elevation is in the conservation pool, the project will be operated to meet water supply requirements and water quality low flow releases. The only available flexibility from a regulation viewpoint in this situation would be that the State of North Carolina water quality release requirements and/or water supply withdrawals.

Storage-use flexibility between the conservation and flood control pools is not a viable option within the guidelines authorizing the project. Flexibility within the conservation pool between water supply and water quality would have to be initiated and addressed by the State of North Carolina.

ANALYSIS OF DROUGHT OPERATION

Dry periods occur randomly during any time period. There is no major indicator to distinguish "normal" dry periods from severe droughts during the early stages. Conditions may vary depending on the time of year, length of time the lake is below elevation 216 feet MSL, and water supply and water quality requirements. However, a water budget (which will be generated and maintained by the Wilmington District) outlining water quality and water supply storage remaining will be used to initiate action.

The Drought Management Committee shall consist of the Wilmington District and other Federal agencies as required. Advisors to the committee will be representatives from the State of North Carolina and local governments. Coordination activities shall include but not be limited to initiation of the Drought Contingency Plan, alerting recreation interests within the lake, issuing forecasts of water supply and water quality storage remaining, implementing conservation measures, and making public information releases.

The Division of Water Resources with the Department of Environment and Natural Resources will act as the point of contact for the State of North Carolina, and as the responsible party for notifying all related concerned interests. The Operations Manager for Jordan Lake will be responsible for notifying all related concerned interests within the lake (marina operation, recreation use areas, etc.) of the current status, forecast of drawdown and for performing duties in conjunction with state agencies as described in the "Operational Management Plan" for B. Everett Jordan Lake. Wilmington District Water Management personnel shall prepare a water budget consisting of water supply, water quality storage remaining and a forecast of time remaining at the current usage rate for water quality and water supply. This forecast and water budget shall be updated as needed and furnished to the Operations Manager at Jordan Lake and the Director of Water Resources with the State.

Public press releases shall be made on an "as-needed" basis through the Public Affairs Office (PAO) in the Wilmington District. These statements shall provide the public with a full explanation of drought operations and forecasts of expected conditions in an effort to reduce inquiries from recreation and concerned interests.

A drought situation report for Jordan and other projects within the Wilmington District shall be prepared as appropriate by the Reservoir Regulation Section of the Wilmington District. This report shall provide detailed information on current and forecast situations for informational purposes of District and South Atlantic Division elements.

DROUGHT MANAGEMENT PLAN

This plan may be initiated by the Chief, Coastal, Hydrology and Hydraulics Section of the Wilmington District Corps of Engineers when the elevation at Jordan is below 216 ft., MSL. The Drought Management Plan focuses on waters contained in the conservation pool (202-216 ft, MSL) of Jordan Lake. The said conservation pool contains water to meet congressionally approved water supply and water quality purposes. The Drought Management Plan emphasizes increased coordination and consultation with stakeholders when either water supply or water quality pool storage declines to 80 percent remaining. Due to capacity and outflow requirements, the water quality pool is the controlling entity in management of drought releases.

The Drought Management Committee shall consist of the Wilmington District and other

The drought release schedule from Jordan Dam is listed in table 5 below.

Table 5: Drought Release Schedule

Drought Level	Water Quality Storage Remaining (%)	Jordan Dam Minimum Release* (cfs)	Jordan Dam Maximum Release (cfs)	Lillington Daily Average Flow Target (cfs)
0	>= 80	40+	600	600 +/- 50
1	60 – 80	40+	Lillington target	450 - 600 +/- 50
2	40 – 60	40+	Lillington target	300 - 450 +/- 50
3	20 – 40	40+	200+ *	None**
4	0 – 20	40+	100-200+ *	None**

* Water quality release plus any required downstream water supply releases.
** Lillington flow will be total of Jordan Dam release plus local inflow.

1. A water budget shall be initiated by the Wilmington District (retroactive to the date that the lake first dropped below elevation 216.0 feet MSL). The State of North Carolina shall be updated by the Wilmington District, U.S. Army Corps of Engineers, on a weekly basis regarding water quality and water supply storage remaining. Based on the budget and storage remaining the following operations from BE Jordan Dam and Lake will be taken:

A. Drought level 0: flow target at Lillington remains at 600 +/- 50 cfs
B. Drought level 1: flow target at Lillington ranges from 450 – 600 +/- 50 cfs
C. Drought level 2: flow target at Lillington ranges from 300 – 450 +/- 50 cfs
D. Drought level 3: no flow target set at Lillington. A maximum release rate of 200 cfs from BE Jordan Dam and Lake, plus any required downstream water supply releases.
E. Drought level 4: no flow target set at Lillington. A maximum release rate of 100-200 cfs from BE Jordan Dam and Lake, plus any required downstream water supply releases

Note that for drought levels 0-2, the flow target is a range of flow targets at Lillington. The range of flows result from collaboration and coordination on a variety of parameters such as stakeholder input, short and long term weather outlook, project gate status, influences on stream flows downstream, and local inflows to both Jordan Lake and reaches below the dam. In addition the minimal flows immediately below B. Everett Jordan Dam and Lake is 40 cfs for all drought levels.

Note that for drought level 3 – 4, no flow target is set for Lillington. The flow rate is a mostly constant release set from B. Everett Jordan Dam and Lake. Level 4 releases between 100-200 c.f.s. will be set based on consultation with the state of NC and other stakeholders. Temporary reductions can be made as long as flows at Lillington can be maintained at 300 c.f.s. or greater.

For all release modes listed, in table 5 above, the release operation will be made for a minimum of seven (7) days in conjunction with the monitoring of the river system, made by NCDWQ and other agencies.

Conversely, with increasing water quality storage, the sequence of operation will generally be reversed; however, consideration of limited watershed inflows, precipitation forecasts, or other factors with appropriate stakeholder consultation may warrant continued reduced flow targets at Lillington.

2. Once drought level 4 has passed and no water quality storage remains, the plan of action will depend on decisions that must be made by the State of North Carolina, since all storage within the conservation pool at Jordan Lake has been allocated to water supply and water quality. Potential alternatives available to the State of North Carolina once drought level 4 of the management plan has been met include, but are not limited to, the following:

a. Implement restrictive water use measures for personal and emergency use only (no water for lawns, gardens, pools, car washes, etc.)

b. Temporarily relax State standards for water quality requirements in the river below Jordan Lake to permit continued operation of industrial and municipal waste treatment facilities, and conserve remaining water quality storage.

c. Reallocate any surplus water supply storage for the duration of the drought to supplement water quality storage and/or provide relief in those areas of greatest need.

3. Should the elevation of Jordan Lake fall below lake elevation 202 ft, MSL or all water supply or water quality storage become depleted, potential alternatives include but are not limited to:

a. Emergency reallocation(s) by the Corps under PL 78-534 of remaining storage volume within the Sediment Pool.

b. Declaration by the State of North Carolina of a water emergency as authorized by G.S. 143-355.3. After a water emergency has been declared by the Governor, State of North Carolina, the Secretary, Department of Environmental and Natural Resources, can order emergency diversions to meet the essential water uses of water systems experiencing water shortage emergencies. The Division of Water Resources along with other agencies within the Department of Environmental and Natural Resources will assess water supply problems and recommend actions to the Secretary under this statute.

SELECTED FEDERAL EMERGENCY AUTHORITIES PROVIDING DROUGHT ASSISTANCE

The responsibility for providing an adequate supply of water to inhabitants of any area is basically non-Federal. Corps assistance to provide emergency water supplies will only be considered when non-Federal interests have exhausted reasonable means for securing necessary water supplies, including assistance and support from other Federal agencies.

Assistance may be available from the Corps through PL 84-99 as amended by PL 95-51. Before Corps assistance is considered under PL 95-51, the applicability of other Federal assistance authorities should be evaluated. If these programs cannot provide the needed assistance, then maximum coordination should be made with appropriate agencies in implementing Corps assistance. The applicability of programs administered by the following Federal agencies, as a minimum, will be determined prior to consideration of Corps assistance.

1. Small Business Administration (SBA).

2. Farmers Home Administration (FmHA).

3. Economic Development Administration (EDA).

Corps Authority for Drought Assistance

The Corps authority for Drought Assistance is contained in Chapter 6, "Emergency Water Supplies and Drought Assistance" of Engineering Regulation 500-1-1 Natural Disaster Procedures (1983). Under this authority, the Chief of Engineers, acting for the Secretary of the Army, can construct wells and transport water to farmers, ranchers, and political subdivisions within areas he determines to be drought-distressed.

Appendix B
Cape Fear River Water Availability at Lock & Dam 3

For some time DWR has been suggesting to water utilities with run-of-river intakes to consider 20% of the ten year seven-day low flow[25] as a guideline of how much water it may be possible to withdraw at a specific location for planning purposes, if no better value is available. This value was chosen because it is one of the benchmark criteria in DENR's rules[26] for conforming to the North Carolina Environmental Policy Act.[27] The rules define minor construction activities that may not require the preparation of an environmental document as outlined in the NCEPA.

Specific criteria that must be met for public water supply system projects to be considered minor are "improvements to water treatment plants that involve less than 1,000,000 gallons per day of added capacity and total design withdrawal less than one-fifth of the 7-day, 10-year low flow of the contributing stream."[28] If a proposed increase in the total design capacity for a potable water treatment plant would equal or exceed this amount at the withdrawal location then the preparation of an environmental document is required to evaluate the impact of the proposed project.[29] Using 20% of the 7Q10 flow for planning suggests the amount of water that may be available from a run-of-river intake location without an extensive environmental impact evaluation, if no other NCEPA criteria are triggered by a proposed project. It is not a fixed limit on the withdrawal capacity that may be possible at a specific location. With the proper environmental impact evaluation the utility may be able to withdraw more water.

Estimates of 7Q10 flows are dependent on the historic flow conditions reflected in the data in the period of record used. Water intakes located in free-flowing stream reaches have the potential to significantly impact the river environment and other water users when flows are low. In free-flowing river reaches the amount of water available for all uses is only the amount flowing in the stream channel. If water is withdrawn from a managed reservoir, stored water is available to meet water withdrawal demands and supplement downstream flows to minimize environmental impacts during low flows. Having stored water available increases the reliability of a public water supply source. Having the ability to manage downstream releases provides the ability to compensate for the potential environmental impacts of a withdrawal during low flow conditions by releasing stored water to supplement downstream river flows.

In Fayetteville's case basing the quantity of water available at the intake on the 7Q10 value has limited usefulness. Fayetteville PWC has the capacity to withdraw and treat 57.5 mgd of water through an intake on the Cape Fear River in the backwater of Lock and Dam #3. The lock and dam structure maintains water levels sufficient to reliably keep the intake structure covered to a

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[25] 7Q10,

[26] 15A NCAC 01C .0101 et seq.

[27] NC G.S. § 113A-1

[28] 15A NCAC 01C .0408 (2)(b)(i)

[29] The same section of the rule includes the criteria that if the proposed project would increase treatment capacity by 1,000,000 gallons per day or more the preparation of an environmental document would also be required.

depth sufficient to pump water to the water treatment plants. This arrangement increases the reliability of the source to meet the utility's water needs. L&D#3 is not operated to regulate downstream releases. The water levels behind L&D#3 are typically at or above the top of the spillway creating a pool of water that extends 29 miles upstream. However, unlike a managed water supply reservoir where downstream releases can be tailored to compensate for withdrawals and minimize environmental impacts, L&D#3 does not have the ability to compensate for the cumulative effects of water use from the backwater on downstream river flows. Water flowing into the backwater of L&D#3 flows over the dam with little variation in water levels except during flooding events making it difficult to estimate flow variation within this river reach. The amount of water flowing below L&D#3 is affected by the cumulative use of water from the backwater. Evaluating the potential changes in flows from L&D#3 can be used to consider potential environmental impacts from any proposed increases in water withdrawals in the vicinity of Fayetteville's intake.

The Cape Fear-Neuse River Basins Hydrologic Model can provide flow estimations at L&D#3. Flows downstream from the model node representing L&D#3 can be compared under various withdrawal scenarios to quantify the resulting changes in downstream river flows.
Lock and Dam Number 3 (William O. Huske Lock and Dam) is located at river mile (RM) 95 on the main stem of the Cape Fear River. The estimated upstream limit of the backwater of L&D#3 is RM 124[30]. Within the 29 miles of backwater there are several withdrawals and discharges:

- DuPont intake at RM 96.
- DuPont discharge at RM 95.3.
- City of Fayetteville discharge at RM 109.
- City of Fayetteville discharge at RM 115.5.
- City of Fayetteville intake at RM 117.

The map below, extracted from a Technical Memorandum prepared for Fayetteville PWC by staff at Malcolm Pirnie, shows the location of the features cited above.

The Cape Fear-Neuse River Basins Hydrologic Model characterizes the cumulative effects on surface water conditions of water withdrawals, wastewater returns and water resource management protocols, in the context of over 80 years of surface water flows. The model covers both basins from the headwaters downstream to where flows are tidally influenced. In the Cape Fear River Basin it goes to Lock and Dam #1 and in the Neuse River downstream to a bit above New Bern. A portion of the model schematic showing the nodes associated with the water users in the backwater of L&D#3 is shown below. The locations of inputs and outflows in the model are shown in their relative location to other features in the model. The nodes in the model schematic are not geographically referenced. The schematic represents a very large mathematical equation tracking surface water conditions as water flows downstream. The nodes show where in the sequence water is added to the system from tributary flows, where water is withdrawn for off-stream uses, where used water is returned, where water is stored in a reservoir and where the model compensates for the time-of-travel of water flowing downstream.

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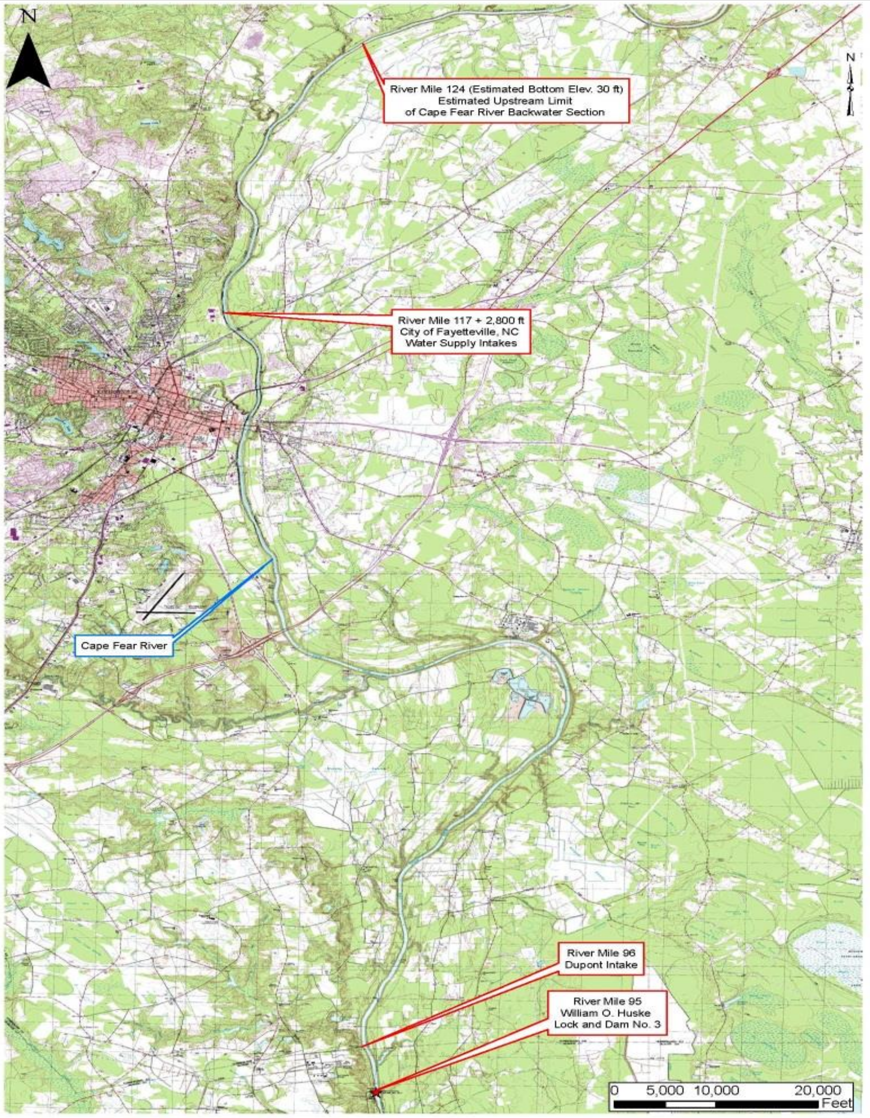
[30] Malcolm Pirnie June 25, 2007 Technical Memorandum – Cape Fear River Safe Yield Evaluation.



MALCOLM PIRNIE

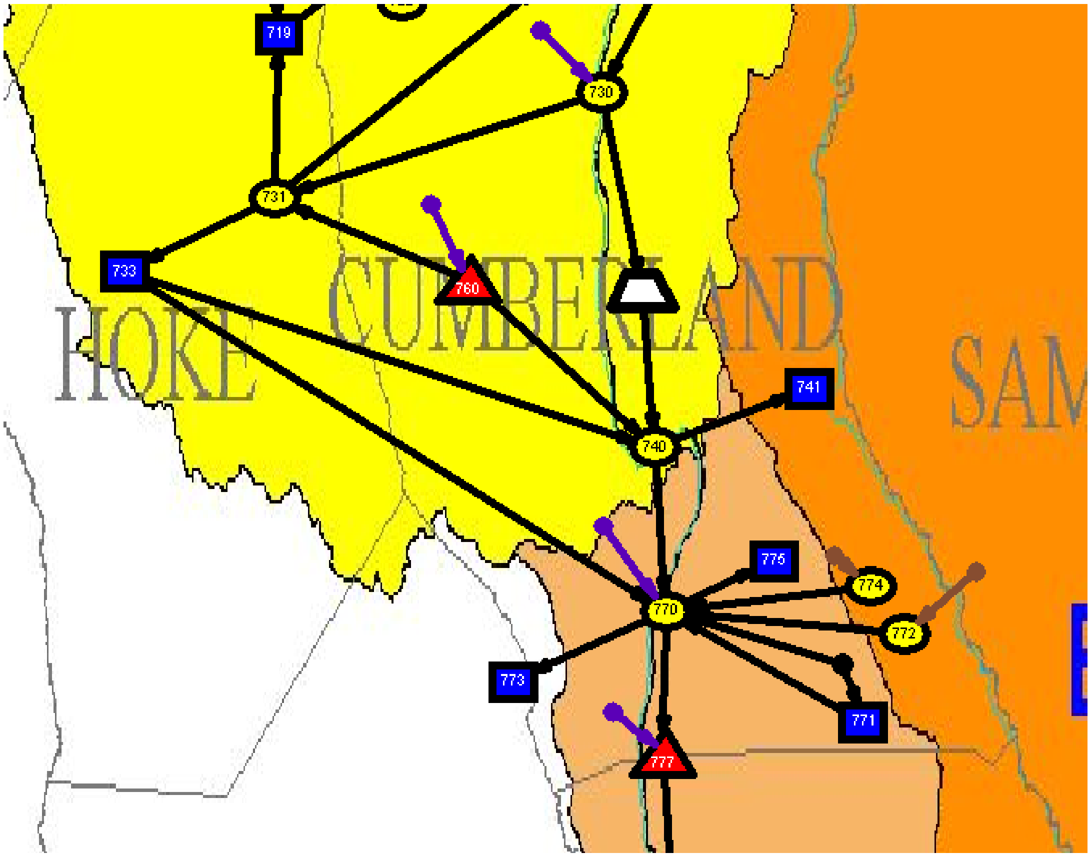
City of Fayetteville, North Carolina
Cape Fear River Safe Yield Evaluation
Backwater Section of Cape Fear River
from Lock and Dam No. 3 to River Mile 124

Figure 2

The relevant model nodes in the combined Cape Fear – Neuse Hydrologic Model are shown below. The arcs between polygons show the direction of water movement. The purple arcs indicate where local inflows are added to the river system.

- Node 777 is Lock and Dam Number 3
- Node 730 is Fayetteville's intake on the Cape Fear River
- Node 731 is Fayetteville's total water withdrawal including water for PWC customers and water supplied to Spring Lake and Old North Utilities
- Node 740 adjusts river flows for the cumulative effects of water flow from node 730, inflow from Glenville Lake, return flow from Fayetteville's Cross Creek WWTP, and agricultural withdrawals in Cumberland County
- Node 760 is Glenville Lake

- Node 770 adjusts river flows for the cumulative effects of water flow from node 740, local inflow, return flow from Fayetteville's Rockfish Creek WWTP, withdrawals to and return flow from the Dupont facility, agricultural withdrawals in Cumberland and Hoke counties, and inflows from two wastewater treatment plants that do not withdraw surface water from the basin.



Data on the elevation, area and volume relationships for the backwater of L&D#3 are not available therefore it is not modeled as a reservoir but as a free-flowing river reach with no accommodations for water storage. The combined basin model was calibrated to sufficiently describe the known surface water conditions experienced in 2010. To evaluate potential changes that may occur due to changes in management, return flows and water withdrawals, various scenarios are developed from the 2010 scenario and modeling results are compared to those from the 2010 scenario. This approach provides a picture of how conditions may change under the alternative scenarios compared to the conditions experienced in 2010, given the assumptions in the model. The hydrologic model produces flow data at river nodes that can be used to estimate various flow statistics, including 7Q10.

There are many factors that will come into play in the evaluation of a proposed expansion of water withdrawal capacity at Fayetteville's intake location. In all likelihood an in-depth environmental impact evaluation will be required regardless of any estimation of the magnitude of the design capacity in relationship to an estimated 7Q10 flow. Potential impacts to river flows due to an increased withdrawal will have to be evaluated. For this analysis DWR staff proposes to use the flow from Lock and Dam #3, as the appropriate measure of impacts to flows from the affected river reach resulting from any increased withdrawal in the backwater of L&D#3. The Cape Fear – Neuse River Basins Hydrologic Model could be used for this analysis by comparing the effects of proposed withdrawal scenarios on outflows from Node 777 representing L&D#3.

Cumulative withdrawals in relation to 7Q10 flow below L&D#3

L&D#3 is not equipped to manage downstream releases. River flows below L&D#3 are the result of spillage over the dam resulting from the cumulative effects of upstream inflows, water withdrawals and return flows in the backwater. The flows coming out of Node 777, representing spillage over the dam, can be used to estimate 7Q10 flows at this location based on the flow record used in the model runs. Changes in outflows from Node 777 under various withdrawal scenarios can be used to evaluate the effects of streamflows that may result from proposed withdrawal increases in the backwater.

Therefore, due to the presence of multiple withdrawals and discharges in the affected reach of Fayetteville's intake, for planning purposes DWR proposes to evaluate the flow impacts of any withdrawal proposals by comparing model outputs at Node 777 to those in the 2010 model scenario that forms the basecase and point of comparison for all modeling scenarios.
The proposed water availability evaluation and flow impact evaluation described above is presented to support water supply planning. Any evaluation associated with a proposed project will be subject to all relevant criteria addressed in the rules[31] guiding conformity with the NC Environmental Policy Act.[32]

In February 2015 DWR staff evaluated the proposed methodology to assess the implications of Fayetteville PWC's 2060 demand projections noted in its Jordan Lake Water Supply Allocation Application. For this evaluation the results of two model scenarios were compared. The 2010 Basecase of the Cape Fear- Neuse River Basins Hydrologic Model and the scenario constructed to evaluate the Jordan Lake allocation requests for 2045 with the estimated water supply withdrawals needed to meet demands in 2060, referred to here as the 2060 scenario. The 2060 scenario did not include Fayetteville PWC's requested allocation from Jordan Lake to see if future demands could be met from the river at the current intake location and to limit the potential effects on flows below L&D#3 to flows in the river and Fayetteville's use of water above L&D#3.

Fayetteville's annual average demand in the 2010 model scenario is 27 mgd with withdrawals ranging from 20 mgd to 35 mgd. For the 2010 scenario the model estimated 7Q10 flow at L&D#3 is 277 mgd. The maximum daily average withdrawal of 35 mgd is about 13% of 277 mgd. The reductions in flows at L&D#3 from Fayetteville's withdrawal is offset by the system's wastewater discharges in the affected reach between the water supply intake and L&D#3. The 2010 model scenario shows the cumulative annual average discharge as 26 mgd with discharges ranging from 25 mgd to 27 mgd. Having the system's wastewater return flows between the withdrawal and first downstream point where flow can be measured suggests that the logical measure of Fayetteville's impact on river flows should be measured as the net withdrawal rather

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[31] 15A NCAC 01C .0101

[32] Additional information of compliance with the NCEPA can be found at: http://portal.ncdenr.org/web/deao/sepa

than the water supply withdrawal. Evaluating the annual average withdrawal of 27.3 mgd, in relation to the annual average wastewater discharge of 25.8 mgd, results in a net withdrawal of 1.5 mgd from the Cape Fear River in the backwater of L&D#3. A 1.5 mgd net withdrawal translates into about 0.5% of the estimated 277 mgd 7Q10 flow. Evaluating the maximum withdrawal (35 mgd) in relation to the minimum wastewater discharge (25 mgd) produces a net withdrawal of 10 mgd; or about 4% of the 7Q10 flow.

The other demand scenario evaluated was for Fayetteville's estimated 2060 water demands. According to Fayetteville's Jordan Lake Water Supply Allocation Application the estimated annual average water demand in 2060 is 75 mgd, ranging from 60 mgd to 90 mgd throughout the year. This demand scenario evaluates water quantity conditions using the estimated 2060 demands for all modeled water withdrawals and the same historic flow data as the 2010 scenario. As expected, increasing withdrawals over the same range of flow conditions reduces river flows below L&D#3 below the levels in the 2010 scenario. The estimated 7Q10 flow below L&D#3 in the 2060 scenario is 246 mgd. Fayetteville's daily average withdrawal of 75 mgd represents 30% of the 7Q10 flow at L&D#3. Fayetteville's estimated 2060 wastewater return flows averages 72 mgd which produces a net withdrawal by Fayetteville PWC of 3 mgd or a little over 1% of the model estimated 7Q10 flow. Estimated wastewater discharges in 2060 range from 69 mgd to 76 mgd. Evaluating the maximum withdrawal estimate (90 mgd) in relationship to the minimum estimated wastewater discharge (69 mgd) gives an estimated net withdrawal of 21 mgd or about 9% of the 7Q10 flow at L&D#3.

Using this approach of assessing net withdrawal by Fayetteville compared to the 2060 7Q10 estimate, based on the water demands and assumptions in the Cape Fear – Neuse River Basin Hydrologic Model, we can estimate the level of withdrawal that may be possible without exceeding 20% of the 7Q10.

2060 Lock & Dam # 3 estimated 7Q10 flow	246 mgd
20% of estimated 7Q10 flow	49 mgd
Fayetteville's	
Estimated 2060 Average Day Demand	75 mgd
Maximum Day Withdrawal	90 mgd
Minimum Wastewater Discharge	69 mgd
Maximum Net Withdrawal	90 – 69 = 21 mgd
Maximum Day / Average Day ratio	90 / 75 = 1.2
Minimum Wastewater / Maximum Withdrawal	69 / 90 = 0.766[33]
Net Withdrawal portion of Maximum Withdrawal	1– 0.766 = 0.234
Net Withdrawal as % of 7Q10	21 mgd / 246 mgd = 8.5 %

Potential Withdrawals relative to 20% of 246 mgd 7Q10

Estimated Maximum Day Withdrawal	49 mgd / 0.234 = 209.4 mgd
Estimated Average Day Withdrawal	209.4 mgd / 1.2 = 174.5 mgd

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[33] 76.6% of the water withdrawn is returned as treated wastewater

Based on these calculations, Fayetteville PWC may be able to withdraw 174.5 mgd from behind Lock & Dam # 3, on an average day basis, without reducing the 7Q10 flow by more than 20 percent. Because this estimate is based on net withdrawals it depends on Fayetteville's ability to maintain a similar ratio of wastewater discharges to water withdrawals in the future. The estimate of potential withdrawal capacity only takes into consideration the water quantity effects of the withdrawal. During the planning and review of a proposed project other factors may be identified that limit the actual withdrawal possible.

When Fayetteville PWC submits a proposal to increase water treatment capacity to supply their customers' estimated future demands, they will in all likelihood be required to prepare an environmental assessment for the project. The methodology described above provides a way to estimate the potential impact to river flows associated with any proposed increase in water withdrawals using the Cape Fear – Neuse River Basins Hydrologic Model. Water demand estimates may need to be reassessed and additional model scenarios developed to capture changes in customers' water use patterns when an expansion project is proposed.

Appendix C

Summary of Model Predicted Water Supply Shortages

Twelve scenarios were developed for the Cape Fear – Neuse River Basins Hydrologic Model for this water supply evaluation. Water delivery shortages were identified for each surface water withdrawal under each scenario. The tables in Appendix C summarize the magnitude and duration of delivery shortages documented using output from the model. The magnitudes of delivery shortages are presented in million gallons per day. The durations of shortages are listed as the number of days. For context when reviewing the duration figures if may be helpful to bear in mind that the 81 years of hydrologic data used in the model results in demands and deliveries being evaluated for 29,858 days for each model scenario.

Three model scenarios evaluate different supply options for three different demand quantities. The demand volumes used in each represent the estimated volumes of water expected to be needed to satisfy water system needs in 2035, 2045 and 2060. These demand estimates represent the amount of water expected to be needed to meet customer demands 20, 30 and 50 years in the future, based on current knowledge.

Two variations on the model basecase scenario are shown. “Simbase_current” is the scenario that captures the 2010 current conditions against which other scenarios are compared. The “Simbase_Dem2045” scenario includes the water sources available to water systems in 2010 with the estimated 2045 customer demands. This scenario shows if there is enough water available from existing sources to satisfy 2045 withdrawal needs. Shortage under this scenario indicate that water systems are likely to need additional water supply sources to meet anticipated future demands. The other ten scenarios were all developed for the Jordan Lake Allocation review process and include “JLA” in the title.

For some systems customer demands are reduced during low flow conditions based on protocols outlined in a water shortage response plan. Some water shortage response plans are triggered by criteria that cannot be captured using the hydrologic model. These systems are designated in the table by the label “Without Water Shortage Response Plan”. The shortage evaluation for these systems does not take into consideration the reduced demands induced by implementing demand reduction protocols during supply shortages.

The table shows three scenarios designated as “01_JLA_LWSP_Dem” followed by 2035, 2045 and 2060. This label denotes a scenario developed for the Jordan Lake Allocation review process using water availability and water demands based on data presented in the Local Water Supply Plans for expected demands in 2035, 2045 and 2060.

The second group of scenarios is designated as “02_JLA_Req2045_Dem” followed by 2035, 2045 and 2060. These scenarios include the requested Jordan Lake allocation amounts to meet demands in 2045 for the applicants that proposed to use water drawn directly from the reservoir. The scenarios include the preferred usage schemes outlined in each allocation application. This set of scenarios does not include Fayetteville PWC’s allocation request in which their allocation would be released from the reservoir to be withdrawn from the Cape Fear River in Fayetteville. These scenarios evaluate the resource changes produced by meeting the 2035, 2045 and 2060 expected demands with the supplies available if the requested allocations are approved by the Environmental Management Commission.

The third group of scenarios is designated as “03_JLA_F_Req2045_Dem” followed by 2035, 2045 and 2060. This set of model scenarios incorporates Fayetteville PWC’s requested allocation and withdrawal scenario into the three scenarios in the previous group.
The twelfth model scenario, designated as “04_JLA_Raleigh_Lillington_Dem2045”, models the outcome if: Raleigh’s requested allocation amount is withdrawn from the Cape Fear River in the vicinity of Lillington, with no water supply release from Jordan Lake; Fayetteville PWC continues to withdraw water from its existing locations with no water supply release from Jordan Lake; and the other applicants withdraw their requested Jordan Lake water supply allocations as described in their applications.

In the tables systems that show a shortage also show a figure for the total number of days out of the flow record that a shortage is indicated by the model, with or without a water shortage response plan. The count of the total days with a shortage is based on over 29,000 days within the historic flow record used in the model. The row indicating the longest average shortage and the longest shortage period suggests the magnitude and duration of shortage these communities may want to address when updating their local water shortage response plan.
Notes:

Greensboro
The shortages shown for Greensboro in the table below appears to be related to the limits on treatment capacity of the Piedmont Triad Regional Water Authority’s water treatment plant. The reported available supply from Randleman Regional Reservoir will support an increase in treatment capacity. As water demand among the member communities increases in the future expanding treatment capacity will become more practical. As envisioned the increase treatment capacity should be adequate to alleviate the potential shortages in by the present modeling.

Randleman
When the model was being developed the City of Randleman depended on the Randleman City Reservoir on Polecat Creek with the expectation of using their share of the Piedmont Triad Regional Water Authority system’s capacity in the future. The current model has Randleman’s supply coming exclusively for PTRWA. The modeling results indicate that, without the benefit of a modelable water shortage response plan, their current available supply from PTRWA is not sufficient to meet projected demands under several future demand scenarios. More recently Randleman has developed an arrangement with Asheboro to purchase water which will likely reduce the indicated shortage magnitude and duration. Also, Randleman’s local officials have the authority to designate a water emergency which is intended to reduce customers’ water demands when supplies are inadequate to meet demands. Implementation of this provision along with the additional water available from Asheboro may be sufficient to avoid the shortages suggested by the modeling for this analysis.

Graham-Mebane

The communities of Graham and Mebane share Graham-Mebane Lake reservoir, on Back Creek, and a water treatment facility. In addition to their own service area customers they regularly supply water to the towns of Swepsonville and Green Level. Current modeling indicates the potential for supply shortages when withdrawals reach the amount currently expected to be needed to meet customer demands in 2060, even with the current water shortage response plan. These communities have a recurring emergency supply arrangement with the City of Burlington which is likely to be able to address the potential shortages indicated in this analysis.

Appendix C Summary of Water System Supply Shortages Under Various Model Scenarios

Cape Fear River Basin

		Model Scenarios											
Model Node Number	Water System / Shortage Measure	01_JLA_LWSP_Dem2035	01_JLA_LWSP_Dem2045	01_JLA_LWSP_Dem2060	02_JLA_Req2045_Dem2035	02_JLA_Req2045_Dem2045	02_JLA_Req2045_Dem2060	03_JLA_F_Req2045_Dem2035	03_JLA_F_Req2045_Dem2045	03_JLA_F_Req2045_Dem2060	04_JLA_Raleigh_Lilington_Dem2045	Simbase-current	Simbase_Dem2045
0031	**Reidsville**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0075	**Haw River**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0077	**Green Level**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0123	**Greensboro**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	37/1	0	0	37/1	0	0	32.9/17
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	21.9/98	0	0	21.9/98	0	0	20.38/98
	Total Days Short	0	0	0	0	0	428	0	0	428	0	0	403
0223	**Highpoint**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0261	**Randleman**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	1.67/31	0	0	1.67/31	1.51/31	0.5/31	1.51/160
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	1.28/214	0	0	1.28/214	1.27/220	0.39/261	1.18/200
	Total Days Short	0	0	0	0	0	13565	0	0	13565	13576	11763	11513
0301	**Ramseur**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0321	**Graham Mebane**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	6.2/22	0	0	6.2/22	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	5.68/22	0	0	5.68/22	0	0	0
	Total Days Short	0	0	0	0	0	50	0	0	50	0	0	0
0327	**Siler City**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0

Appendix C Summary of Water System Supply Shortages Under Various Model Scenarios

Cape Fear River Basin

		Model Scenarios											
Model Node Number	Water System / Shortage Measure	01_JLA_LWSP_Dem2035	01_JLA_LWSP_Dem2045	01_JLA_LWSP_Dem2060	02_JLA_Req2045_Dem2035	02_JLA_Req2045_Dem2045	02_JLA_Req2045_Dem2060	03_JLA_F_Req2045_Dem2035	03_JLA_F_Req2045_Dem2045	03_JLA_F_Req2045_Dem2060	04_JLA_Raleigh_Lilington_Dem2045	Simbase-current	Simbase_Dem2045
0341	**Burlington**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0401	**Pittsboro**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0431	**Orange Water & Sewer Authority**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	5.6/22
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	5.2/22
	Total Days Short	0	0	0	0	0	0	0	0	0	0	0	22
0471	**Cary Apex**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0473	**Chatham County-North**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	12.4/1	0	0	16.9/1	0	0	12.5/24
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	8.9/3	0	0	4.97/33	0	0	10.21/24
	Total Days Short	0	0	0	0	0	3	0	0	152	0	0	136
0474	**Research Triangle Park**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0477	**Morrisville**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0483	**Performance Fiber**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0491	**Sanford**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0

Appendix C Summary of Water System Supply Shortages Under Various Model Scenarios

Cape Fear River Basin

		Model Scenarios											
Model Node Number	Water System / Shortage Measure	01_JLA_LWSP_Dem2035	01_JLA_LWSP_Dem2045	01_JLA_LWSP_Dem2060	02_JLA_Req2045_Dem2035	02_JLA_Req2045_Dem2045	02_JLA_Req2045_Dem2060	03_JLA_F_Req2045_Dem2035	03_JLA_F_Req2045_Dem2045	03_JLA_F_Req2045_Dem2060	04_JLA_Raleigh_Lilington_Dem2045	Simbase-current	Simbase_Dem2045
0521	**Cape Fear Steam Station**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0551	**Harnett County RWS**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0663	**Dunn**	With Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	1.1/6	1.1/14	1.1/14	1.1/6	1.1/7	1.1/14	1.1/6	1.1/6	1.1/14	1.1/14		1.1/14
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0.8/20	0.8/20	0.9/33	0.8/19	0.8/19	0.9/27	0.8/19	0.8/20	0.9/27	0.8/20	0	0.8/27
	Total Days Short	70	81	119	63	71	101	63	71	101	90	0	173
0674	**Carolina Trace**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0701	**Carthage**	With Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0.7/12	0	0	0.7/21	0.7/14	0.3/21	0.7/12
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0.7/12	0	0	0.7/21	0.7/14	0.3/21	0.7/22
	Total Days Short	0	0	0	0	0	72	0	0	72	71	66	71
0719	**Spring Lake**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0721	**Old North Utilities**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0733	**Fayetteville PWC**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0771	**Monsanto**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0

Appendix C Summary of Water System Supply Shortages Under Various Model Scenarios

Cape Fear River Basin

		Model Scenarios											
Model Node Number	**Water System / Shortage Measure**	**01_JLA_LWSP_Dem2035**	**01_JLA_LWSP_Dem2045**	**01_JLA_LWSP_Dem2060**	**02_JLA_Req2045_Dem2035**	**02_JLA_Req2045_Dem2045**	**02_JLA_Req2045_Dem2060**	**03_JLA_F_Req2045_Dem2035**	**03_JLA_F_Req2045_Dem2045**	**03_JLA_F_Req2045_Dem2060**	**04_JLA_Raleigh_Lilington_Dem2045**	**Simbase-current**	**Simbase_Dem2045**
0785	**LCFWSA_Bladen Bluffs**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0823	**Cape Fear Public Utilities**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0825	**LCFWSA_Kings Bluff**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0903	**Jamestown**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0904	**Archdale**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0906	**Randolph**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0921	**Orange County**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	1.77/2	0	0	3.03/26
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	1.13/49	0	0	1.98/59
	Total Days Short	0	0	0	0	0	0	0	0	203	0	0	670
0923	**Holly Springs**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
0940	**Broadway**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0

Appendix C Summary of Water System Supply Shortages Under Various Model Scenarios

Neuse River Basin

		Model Scenarios											
Model Node Number	Water System / Shortage Measure	01_JLA_LWSP_Dem2035	01_JLA_LWSP_Dem2045	01_JLA_LWSP_Dem2060	02_JLA_Req2045_Dem2035	02_JLA_Req2045_Dem2045	02_JLA_Req2045_Dem2060	03_JLA_F_Req2045_Dem2035	03_JLA_F_Req2045_Dem2045	03_JLA_F_Req2045_Dem2060	04_JLA_Raleigh_Lilington_Dem2045	Simbase-current	Simbase_Dem2045
1046	**Orange Alamance Water**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
1106	**Hillsborough**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
1116	**Piedmont Minerals**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
1162	**Durham**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
1256	**South Granville WSA**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
1306	**Raleigh**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	82/10
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	13.3/184
1506	**Wilson**	**With Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
1646	**Johnston County**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
1666	**Smithfield**	**Without Water Shortage Response Plan**											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0

Appendix C Summary of Water System Supply Shortages Under Various Model Scenarios

Neuse River Basin

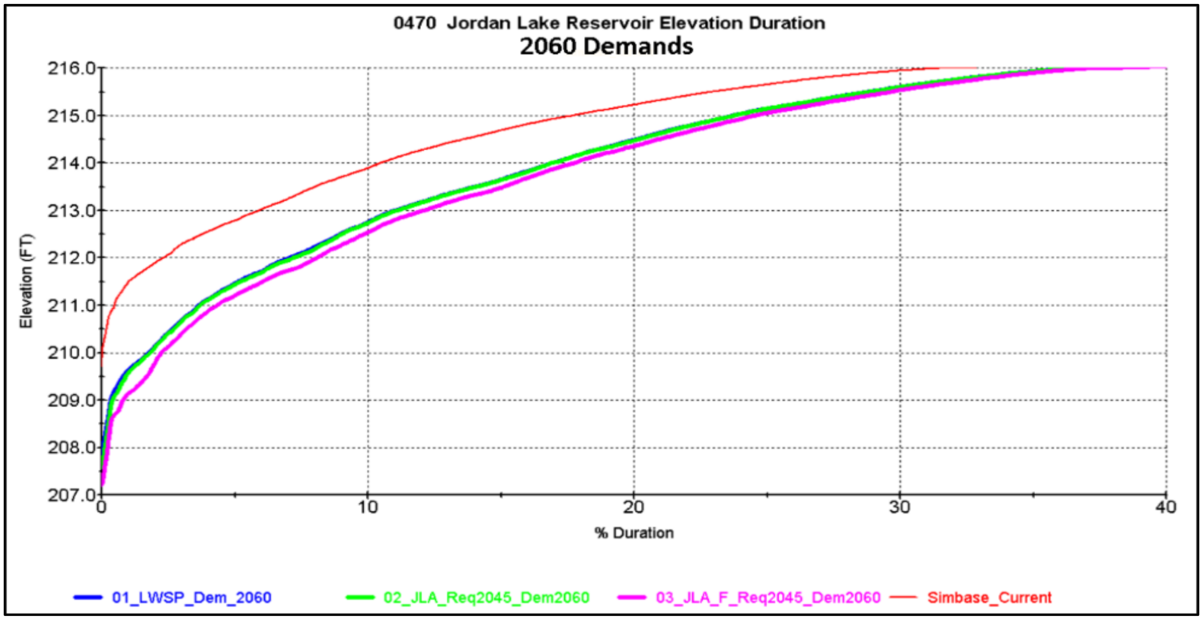
		Model Scenarios											
Model Node Number	Water System / Shortage Measure	01_JLA_LWSP_Dem2035	01_JLA_LWSP_Dem2045	01_JLA_LWSP_Dem2060	02_JLA_Req2045_Dem2035	02_JLA_Req2045_Dem2045	02_JLA_Req2045_Dem2060	03_JLA_F_Req2045_Dem2035	03_JLA_F_Req2045_Dem2045	03_JLA_F_Req2045_Dem2060	04_JLA_Raleigh_Lilington_Dem2045	Simbase-current	Simbase_Dem2045
1706	**Fuquay-Varina**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
1756	**Benson**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
1766	**HF Lee Energy Complex**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
1786	**Goldsboro**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
1806	**Neuse Regional WSA**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0
1906	**Weyerheauser**	Without Water Shortage Response Plan											
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0	0	0	0	0	0	0

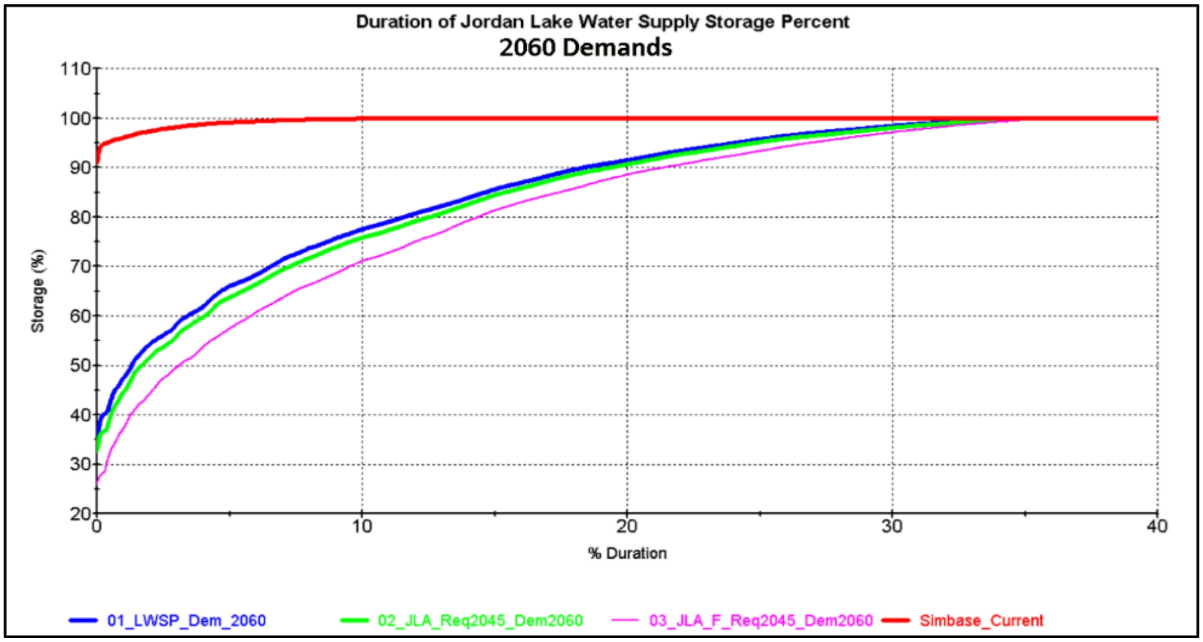
Appendix D: Reservoir and River Flows Status Graphs

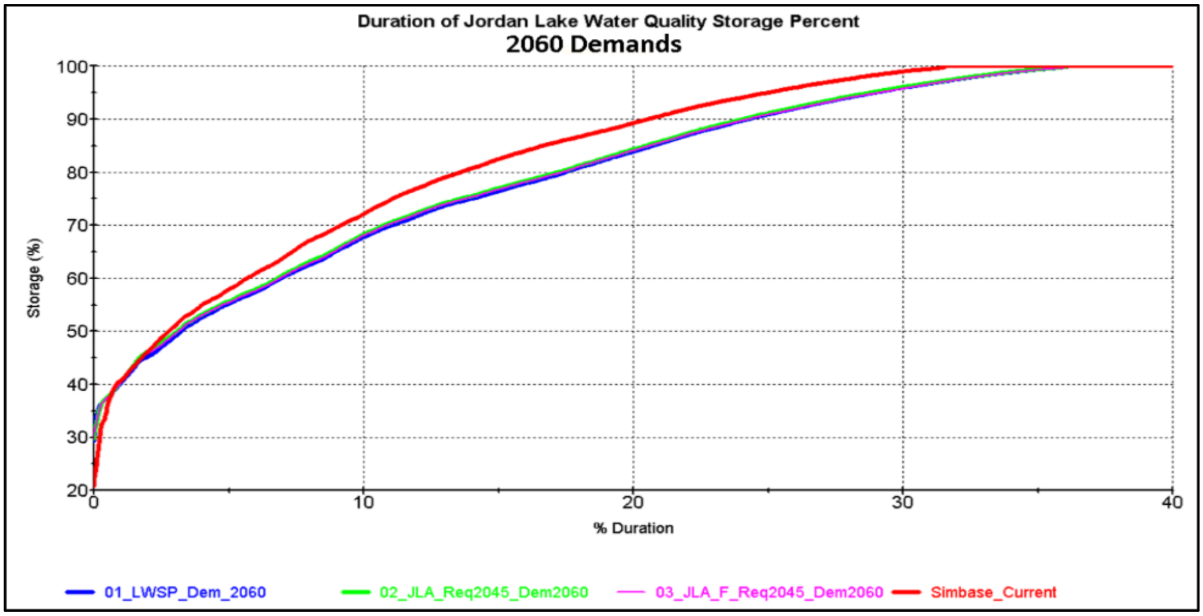
The following graphs show the variation in reservoir conditions across the four model scenarios the form the primary focus of this evaluation. The scenario labeled “Simbase_Current” is a characterization of current conditions based on water use and supplies in 2010. This scenario provides a point of comparison to show how meeting 2060 demands may alter conditions over the range of flows used in the model. The scenario labeled “01_LWSP_Dem_2060” uses the 2060 water demands and available water sources reported in the local water supply plans for all water systems in the model. The scenario labeled “03_JLA_F_Req2045_Dem2060” integrates all the requested allocations from Jordan Lake to the water supply sources to evaluate the effects of meeting estimated 2060 demand levels. The scenario labeled “02_JLA_Req2045_Dem2060” integrates all the requested allocations from Jordan Lake except for Fayetteville Public Works Commission to evaluate the effects of meeting estimated 2060 demand levels.

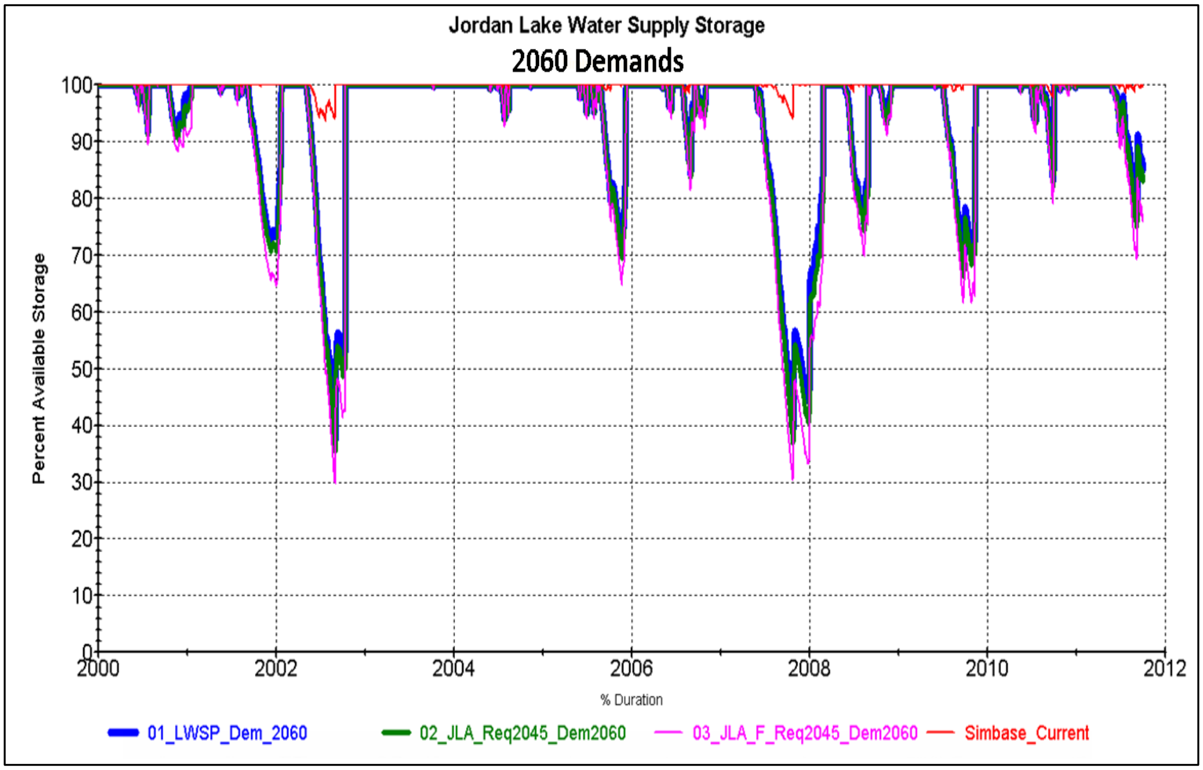
The percent of remaining storage is shown for the water supply and flow augmentation pools in Jordan Lake and Falls Lake for the period from 2000 through 2011. For each of the reservoirs presented the duration plots show the percent of time that water levels are at or below certain elevations of storage percentage. For more differentiation the graphs show the portion of the record when reservoir levels are less than full or when storage is less than 100 percent.

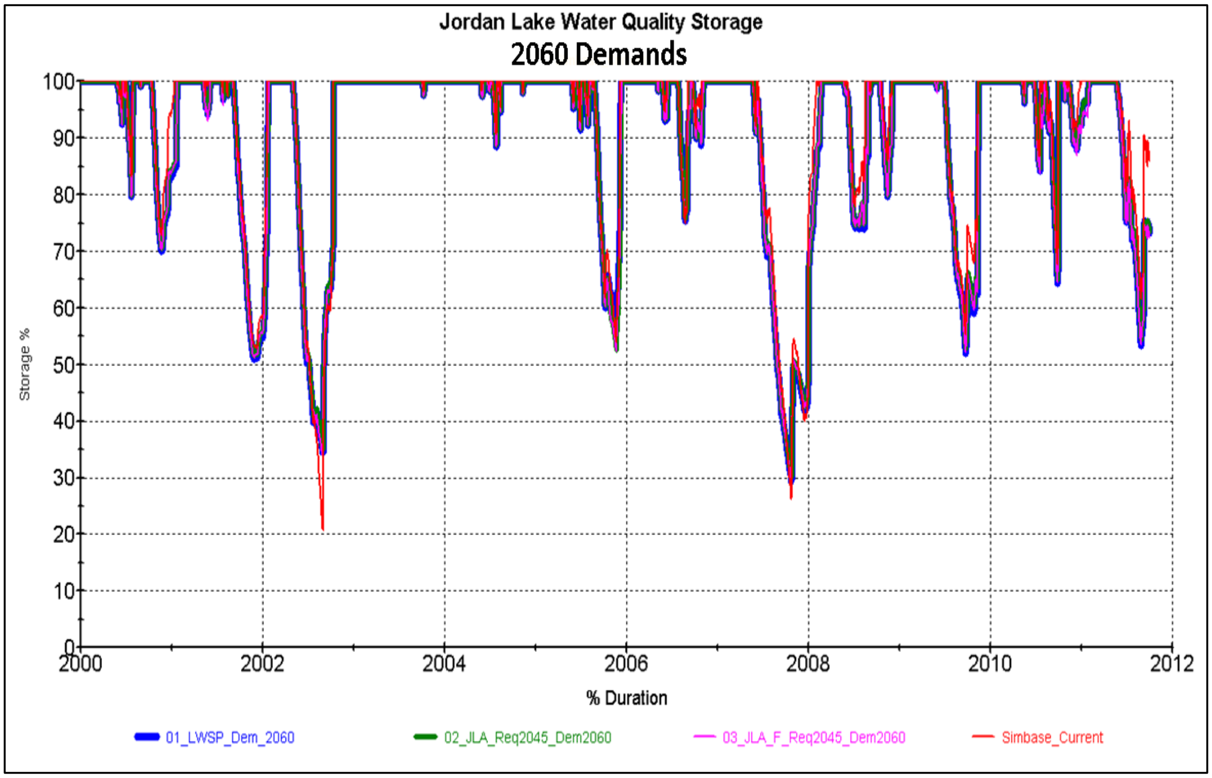
The plots of water levels in the Jordan Lake Reservoir Elevation Duration graph show that the modeling indicates that the water levels are likely to be at or above the normal operating level over 60 percent of the time in the flow record. As a reminder the flow record includes 29,858 days from January 1, 1930 to September 30, 2011. For Jordan Lake the normal operating level is 216 feet above sea level. For the Simbase_Current scenario the shows that the model indicates the water level below 213 feet mean sea level about 6 percent of the time. For the other scenarios the model estimates water levels below 213 feet from 11 to about 13 percent of the days in the flow record.

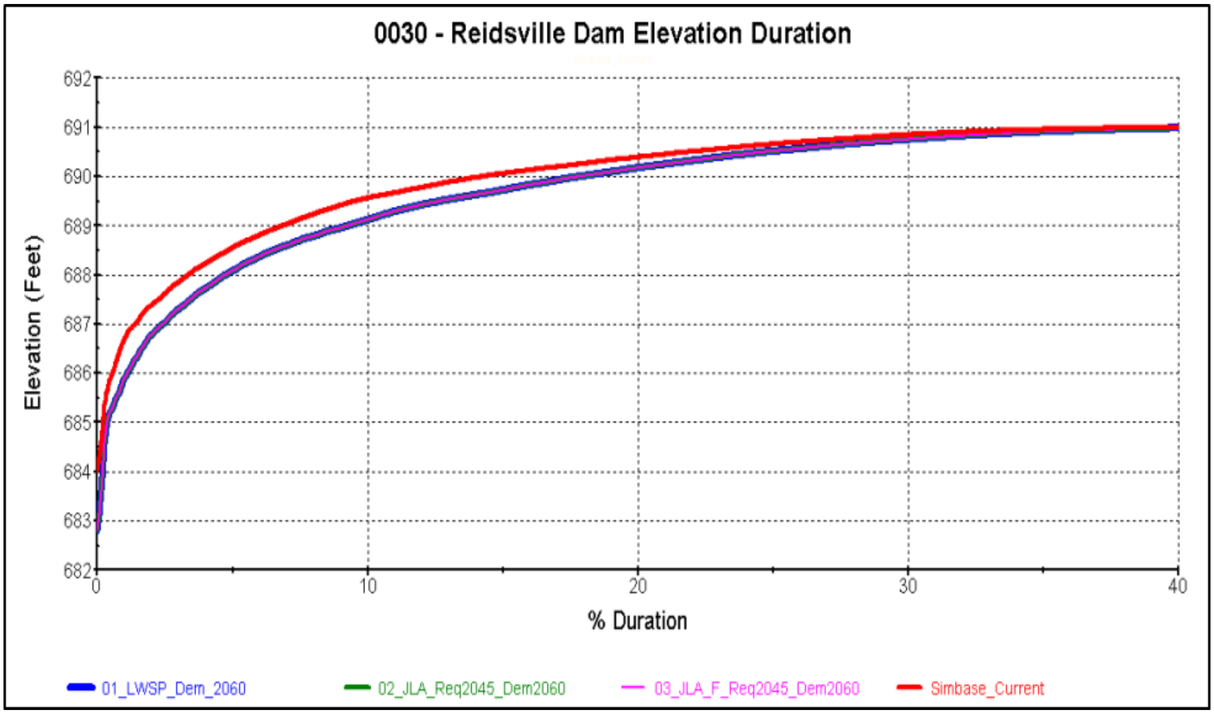


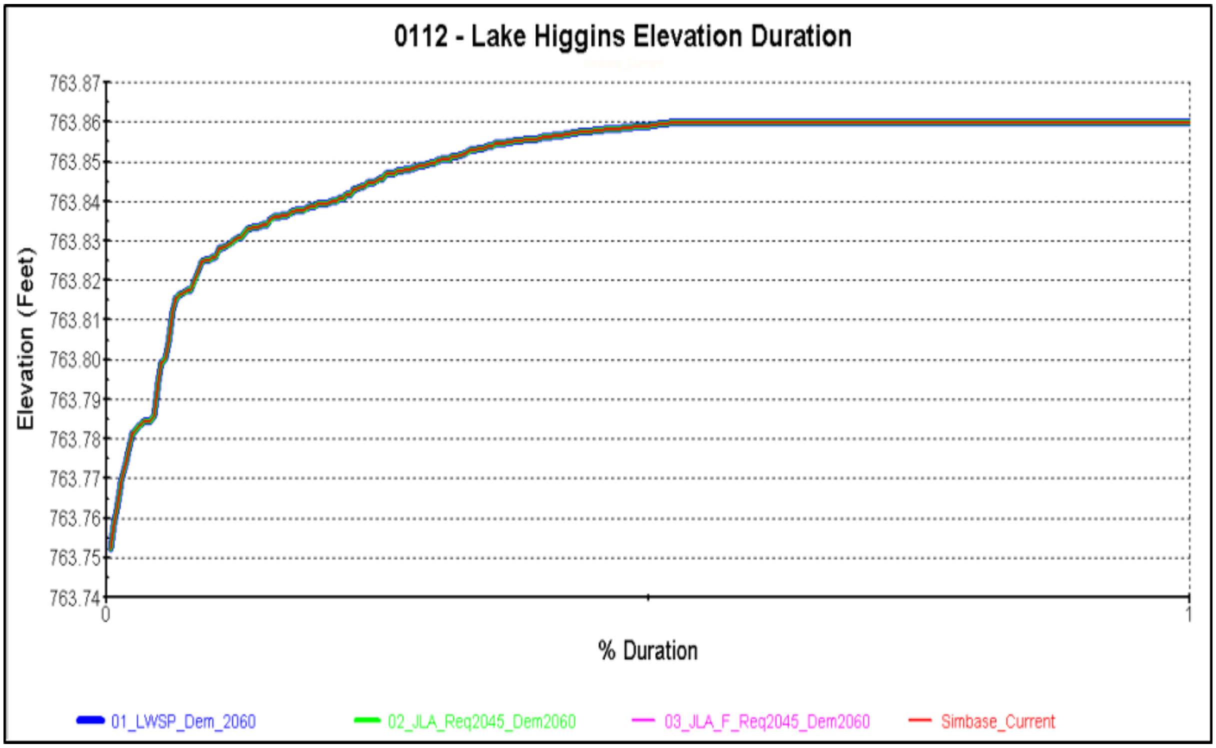

Duration of Jordan Lake Water Supply Storage Percent
2060 Demands
Storage (%)
110
100
90
80
70
60
50
40
30
20
0
10
20
30
40
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

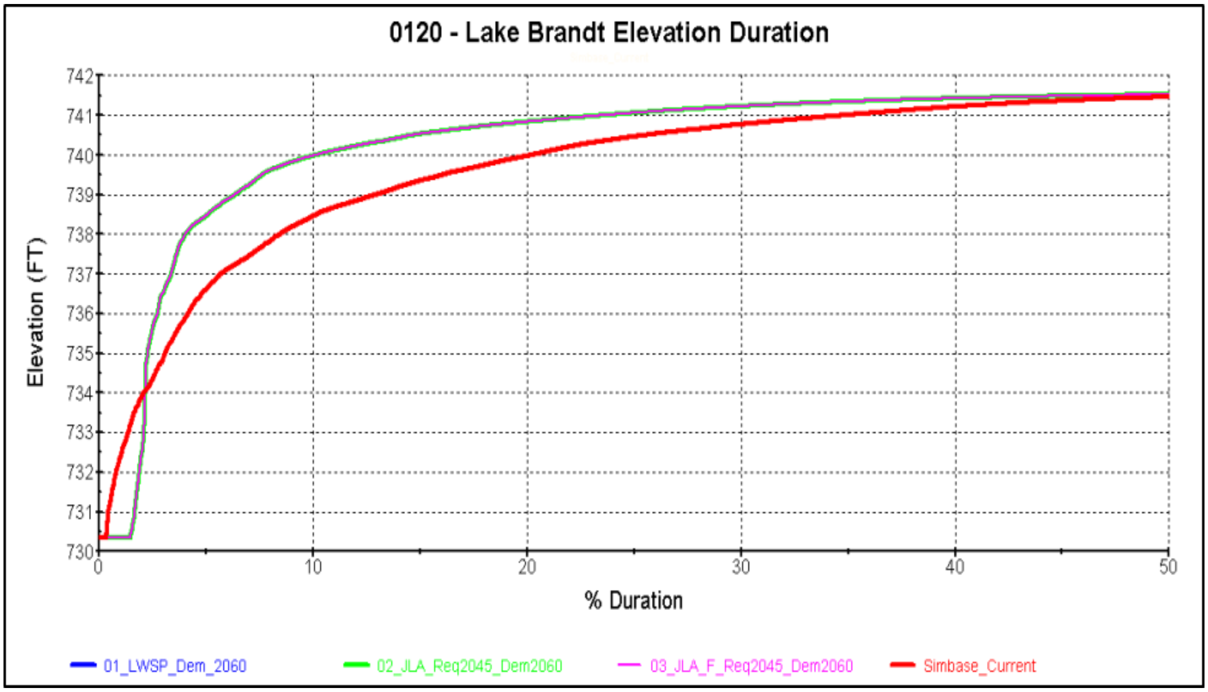

Duration of Jordan Lake Water Quality Storage Percent
2060 Demands
Storage (%)
100
90
80
70
60
50
40
30
20
0
10
20
30
40
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

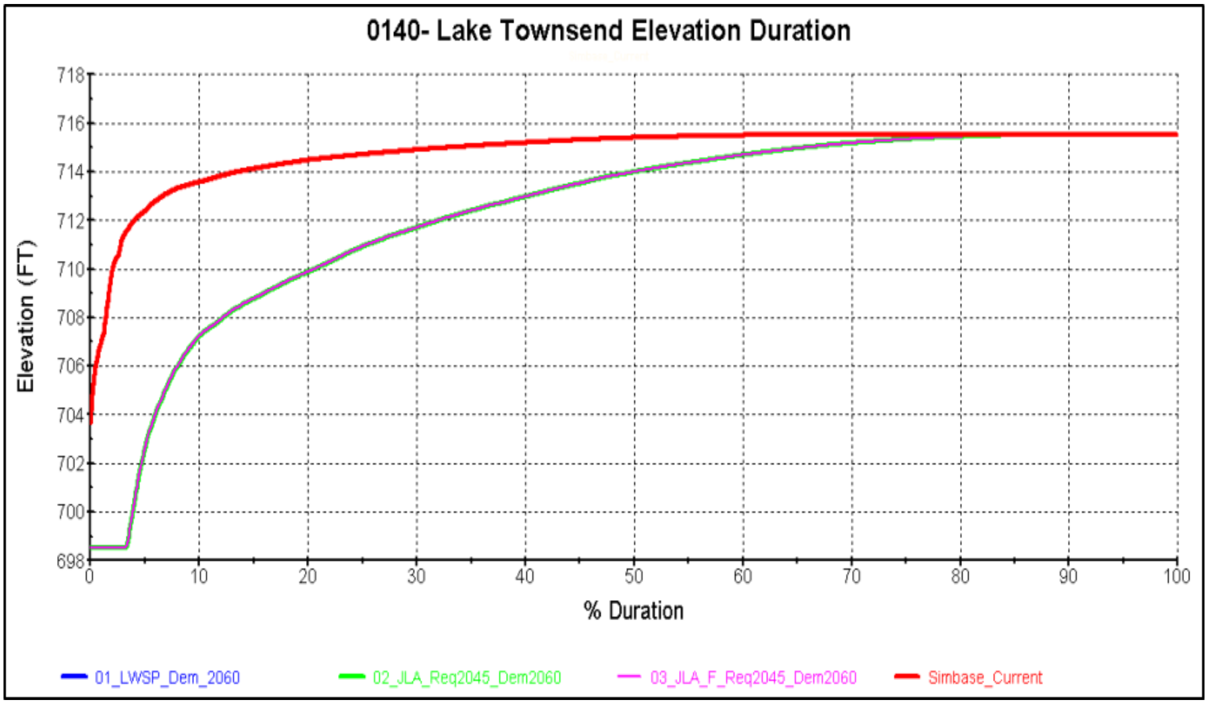

Jordan Lake Water Supply Storage
2060 Demands
Percent Available Storage
100
90
80
70
60
50
40
30
20
10
0
2000
2002
2004
2006
2008
2010
2012
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

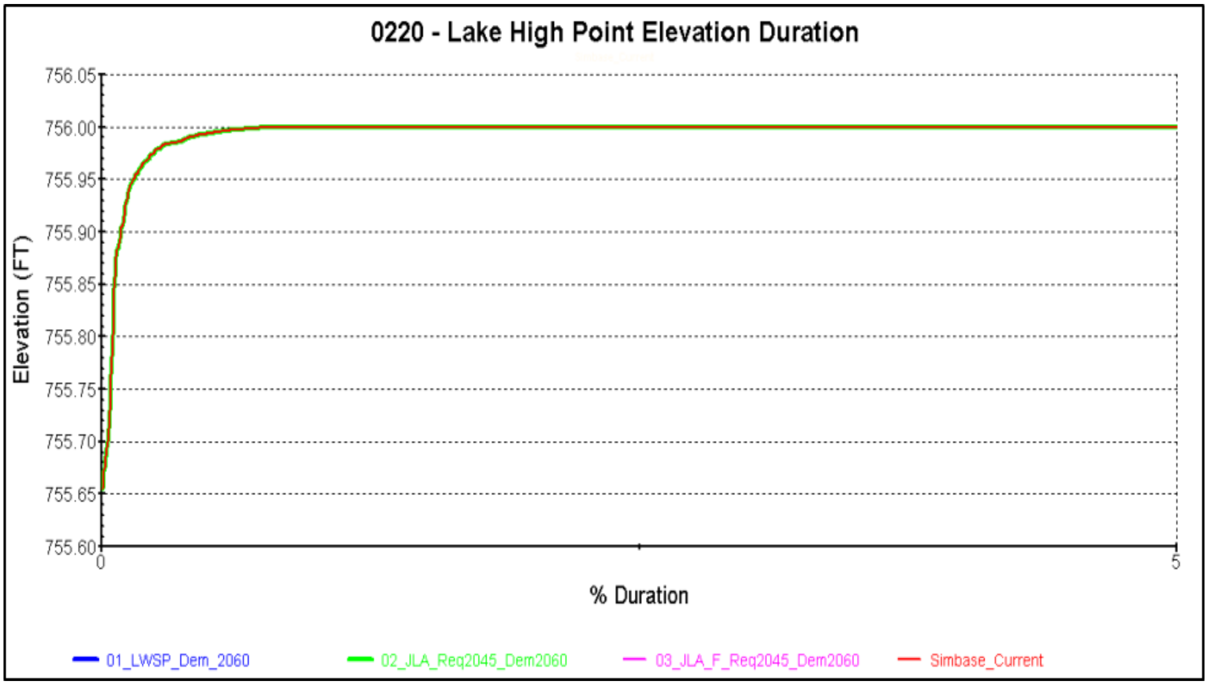

Jordan Lake Water Quality Storage
2060 Demands
Storage %
100
90
80
70
60
50
40
30
20
10
0
2000
2002
2004
2006
2008
2010
2012
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

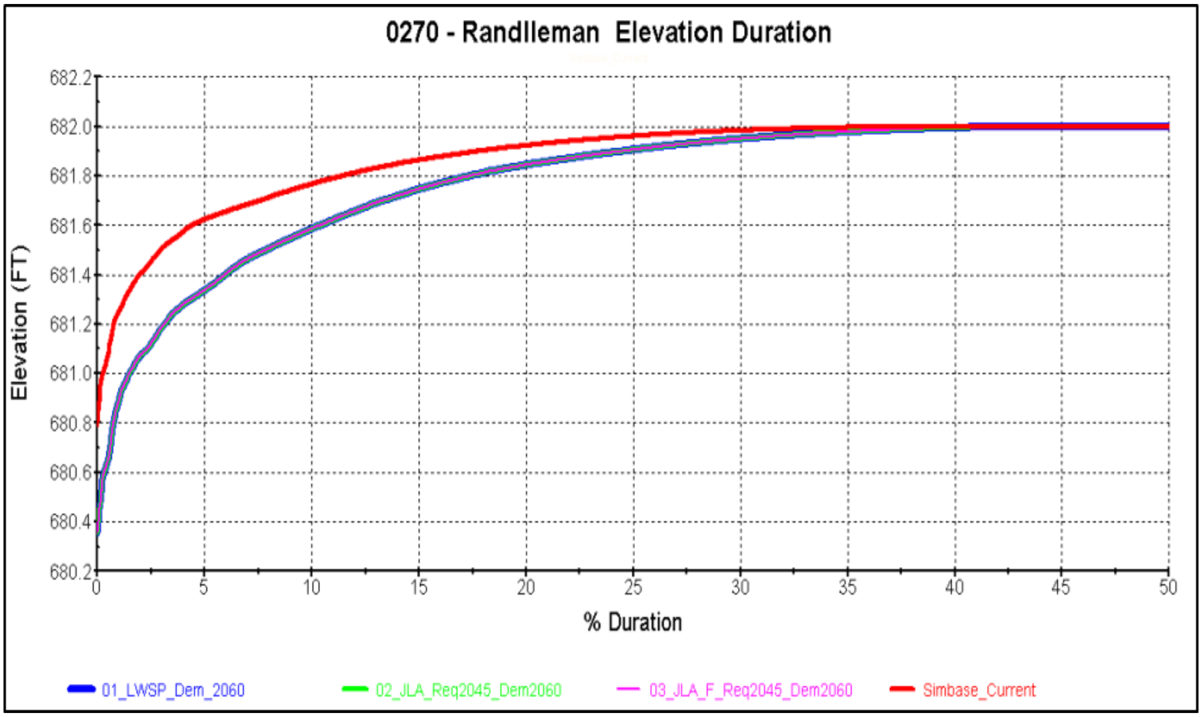

0030 - Reidsville Dam Elevation Duration
Elevation (Feet)
692
691
690
689
688
687
686
685
684
683
682
0
10
20
30
40
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

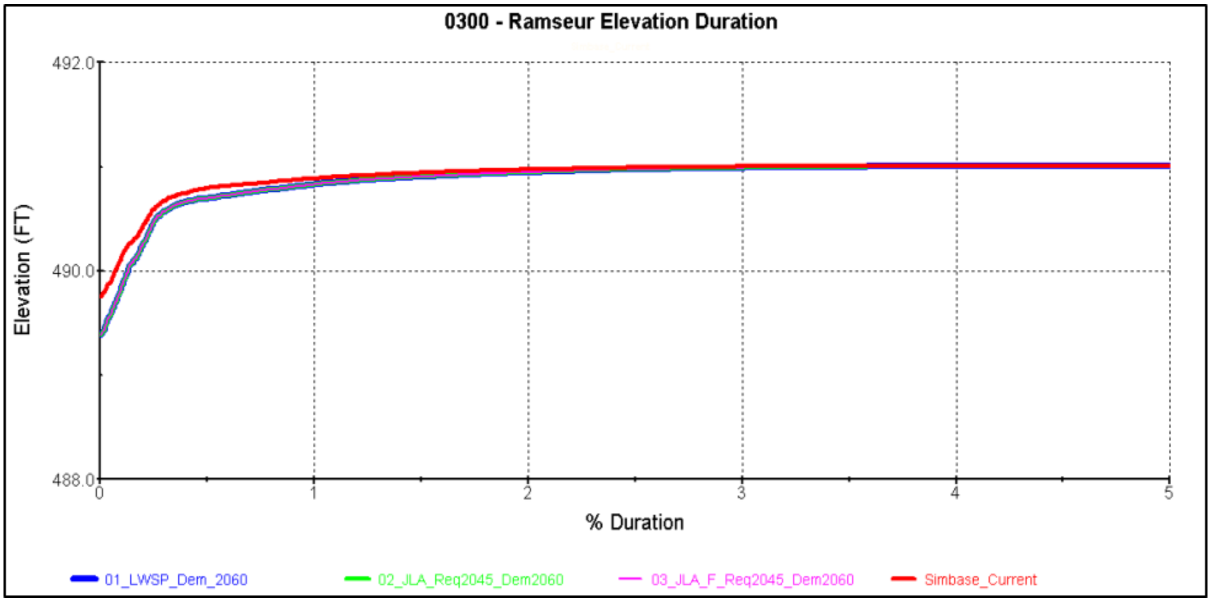

0112 - Lake Higgins Elevation Duration
Elevation (Feet)
763.87
763.86
763.85
763.84
763.83
763.82
763.81
763.80
763.79
763.78
763.77
763.76
763.75
763.74
0
1
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

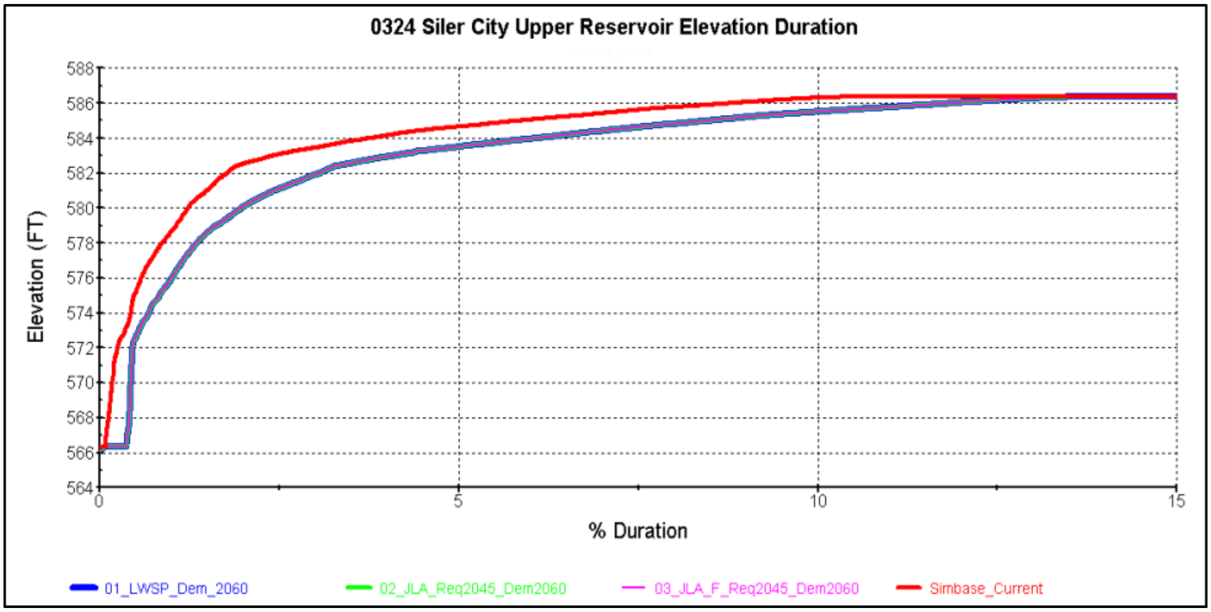

0120 - Lake Brandt Elevation Duration
Elevation (FT)
742
741
740
739
738
737
736
735
734
733
732
731
730
0
10
20
30
40
50
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

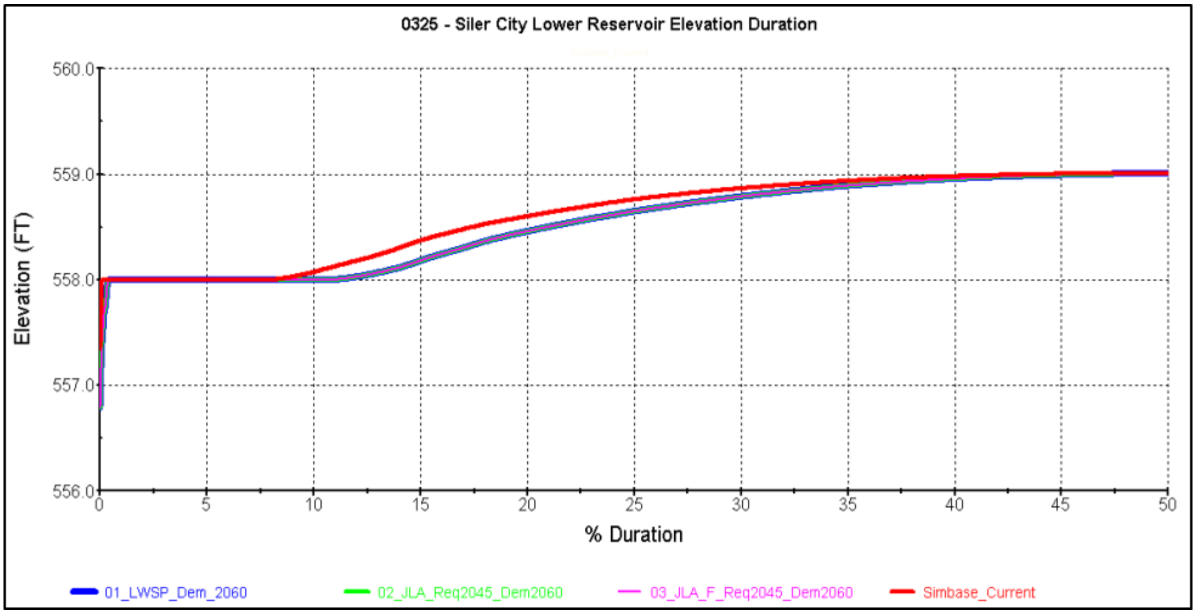

0140- Lake Townsend Elevation Duration
Elevation (FT)
718
716
714
712
710
708
706
704
702
700
698
0
10
20
30
40
50
60
70
80
90
100
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

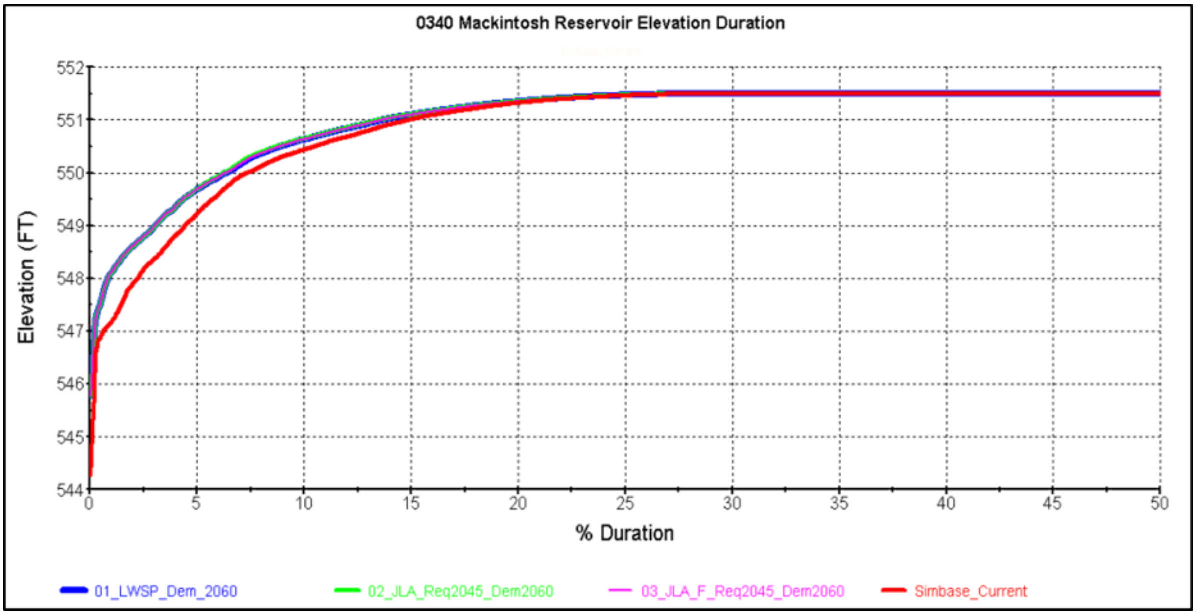

0220 - Lake High Point Elevation Duration
Elevation (FT)
756.05
756.00
755.95
755.90
755.85
755.80
755.75
755.70
755.65
755.60
0
5
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

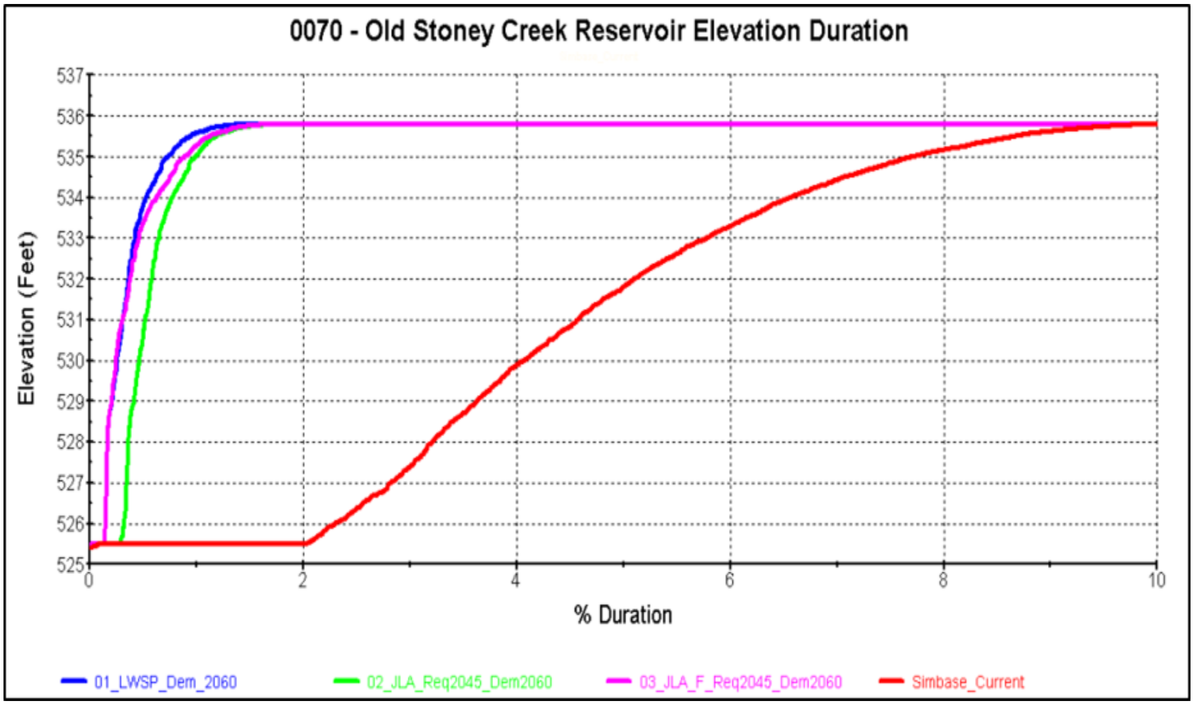

0270 - Randlleman Elevation Duration
Elevation (FT)
682.2
682.0
681.8
681.6
681.4
681.2
681.0
680.8
680.6
680.4
680.2
0
5
10
15
20
25
30
35
40
45
50
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

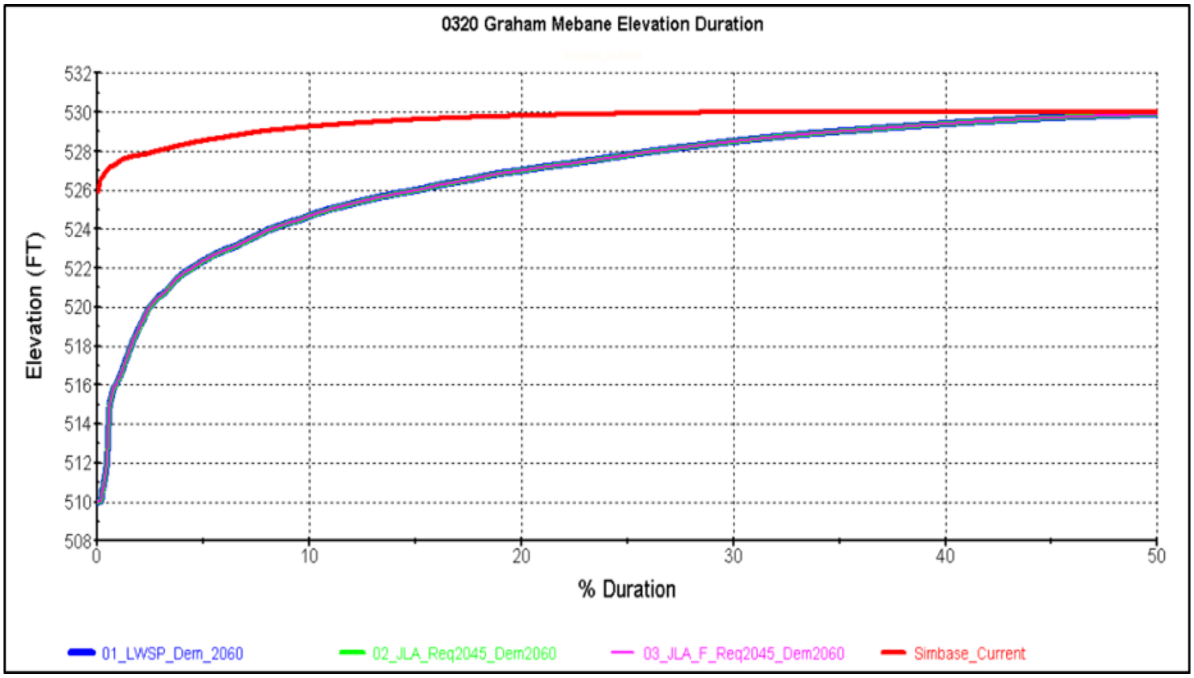

0300 - Ramseur Elevation Duration
Elevation (FT)
492.0
490.0
488.0
0
1
2
3
4
5
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

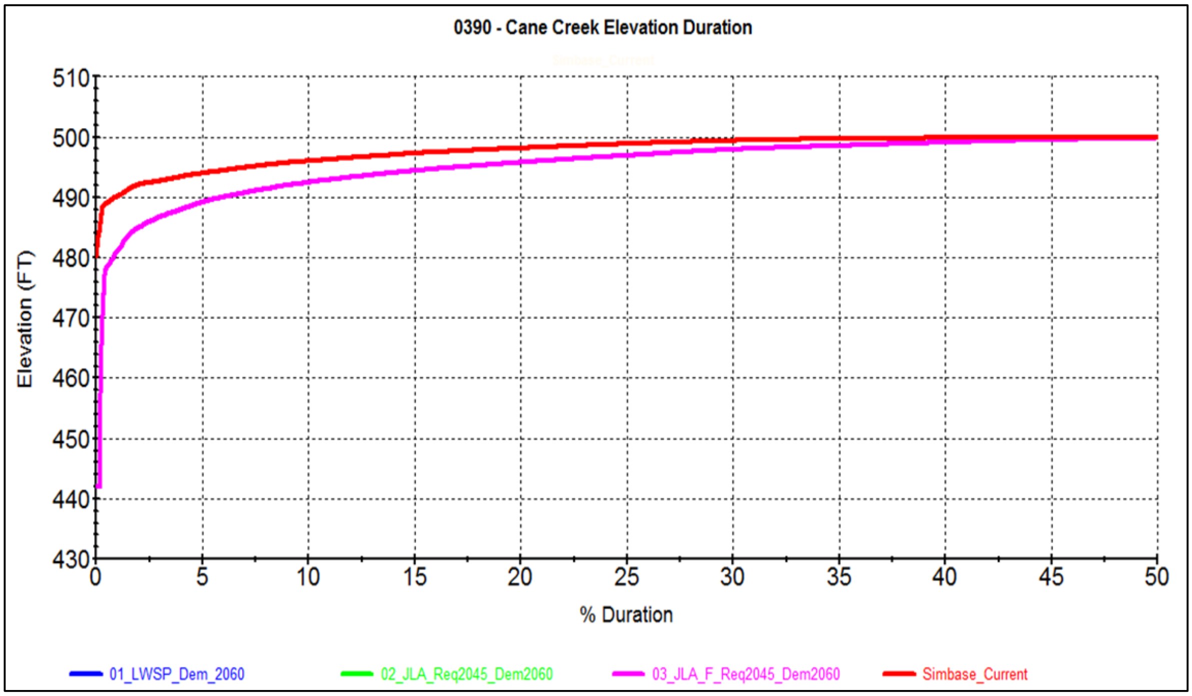

0324 Siler City Upper Reservoir Elevation Duration
Elevation (FT)
588
586
584
582
580
578
576
574
572
570
568
566
564
0
5
10
15
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

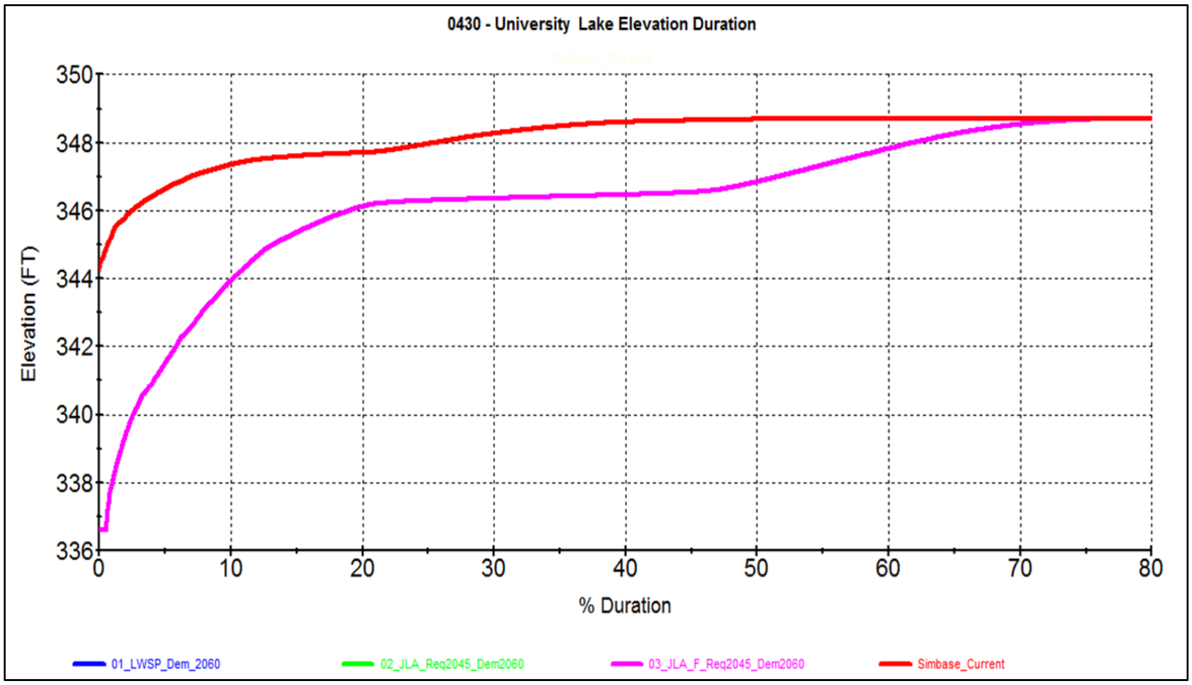

0325 - Siler City Lower Reservoir Elevation Duration
560.0
559.0
558.0
557.0
556.0
Elevation (FT)
0
5
10
15
20
25
30
35
40
45
50
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

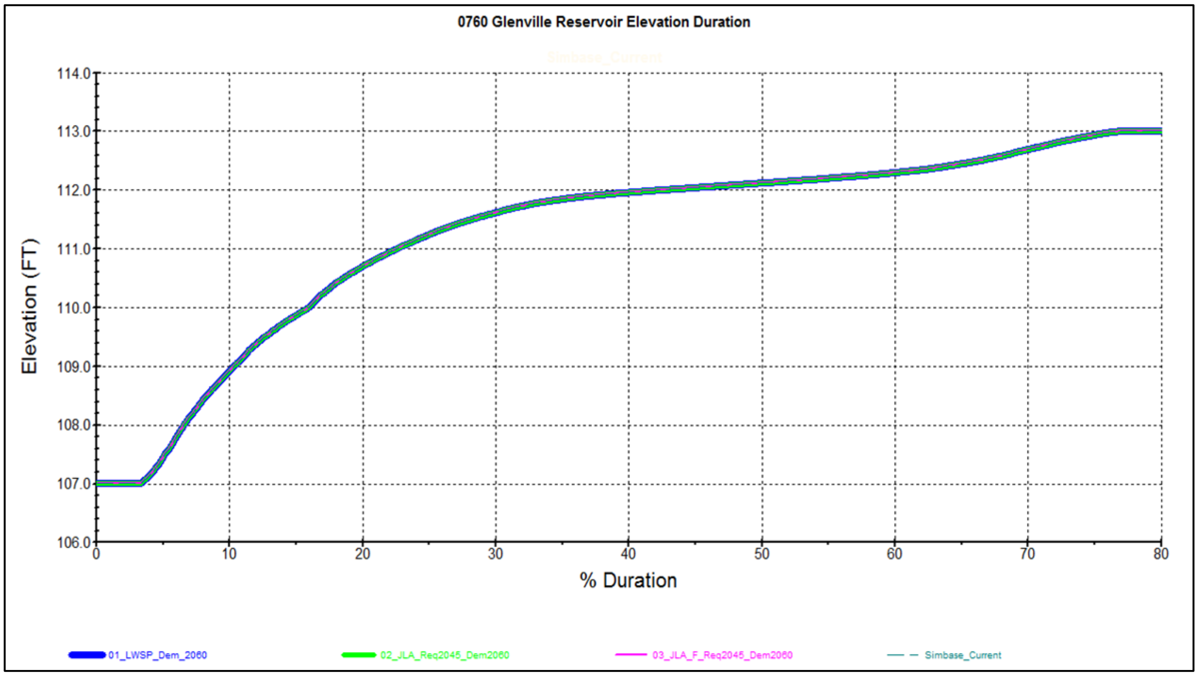

0340 Mackintosh Reservoir Elevation Duration
552
551
550
549
548
547
546
545
544
Elevation (FT)
0
5
10
15
20
25
30
35
40
45
50
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

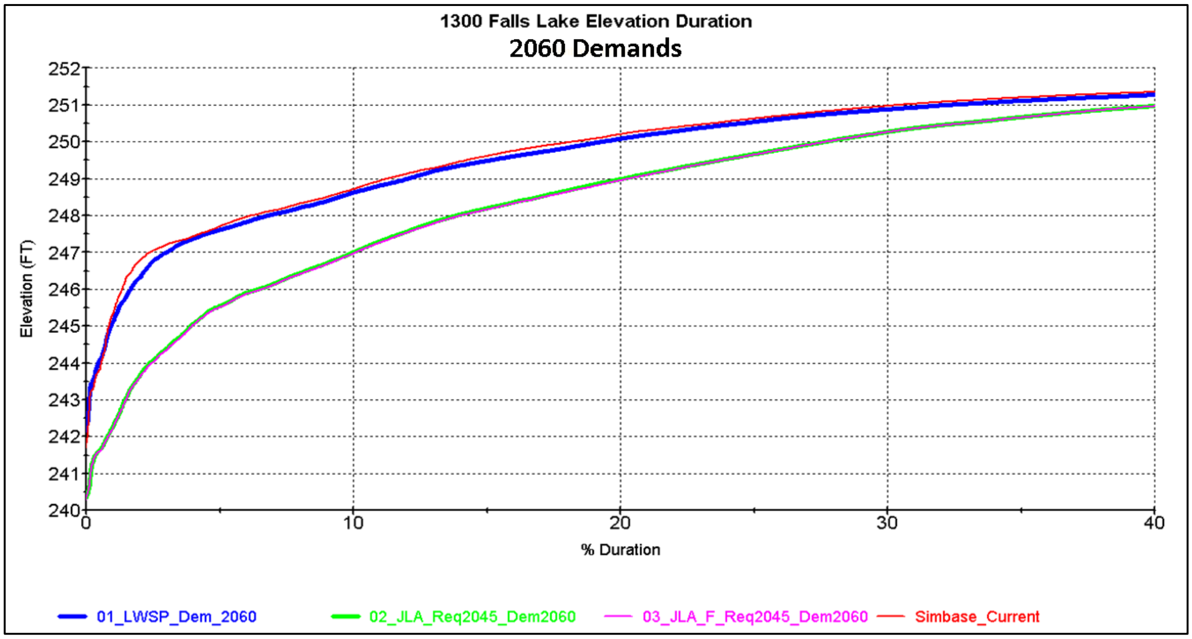

0070 - Old Stoney Creek Reservoir Elevation Duration
Elevation (Feet)
537
536
535
534
533
532
531
530
529
528
527
526
525
0
2
4
6
8
10
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

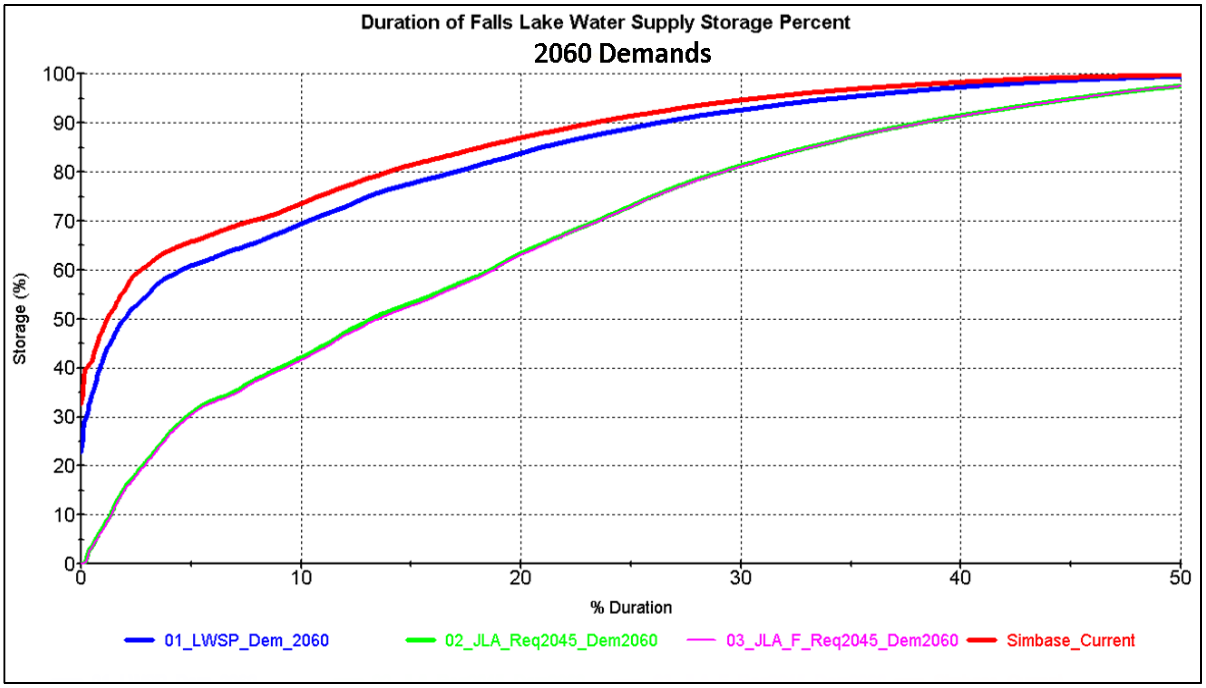

0320 Graham Mebane Elevation Duration
Elevation (FT)
532
530
528
526
524
522
520
518
516
514
512
510
508
0
10
20
30
40
50
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

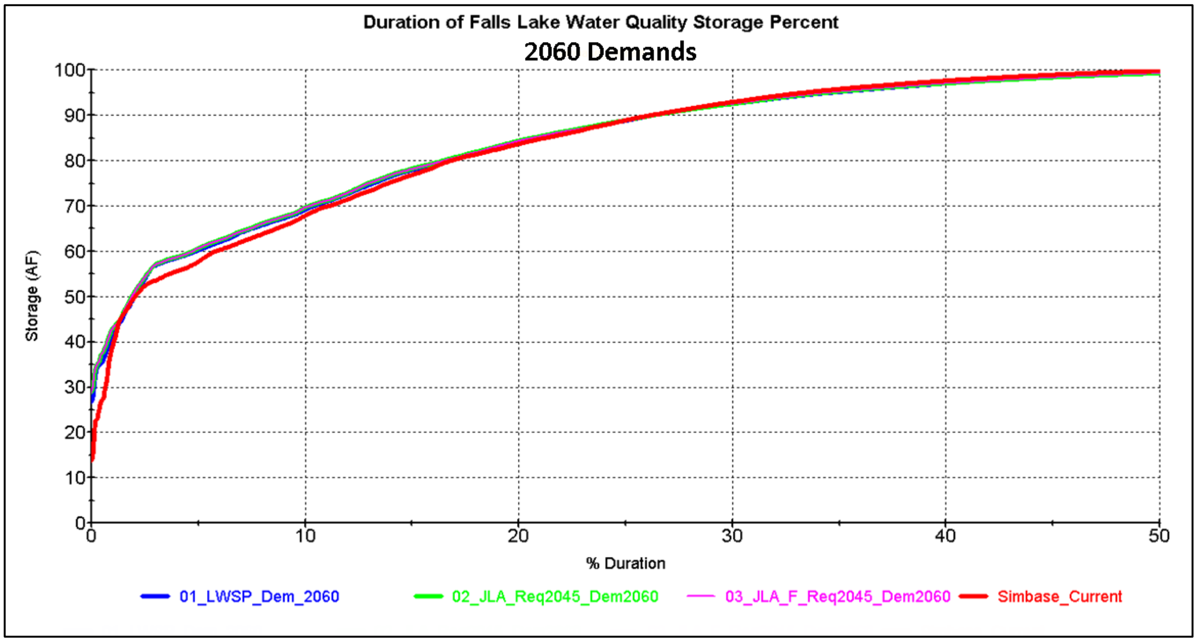

0390 - Cane Creek Elevation Duration
Elevation (FT)
510
500
490
480
470
460
450
440
430
0
5
10
15
20
25
30
35
40
45
50
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

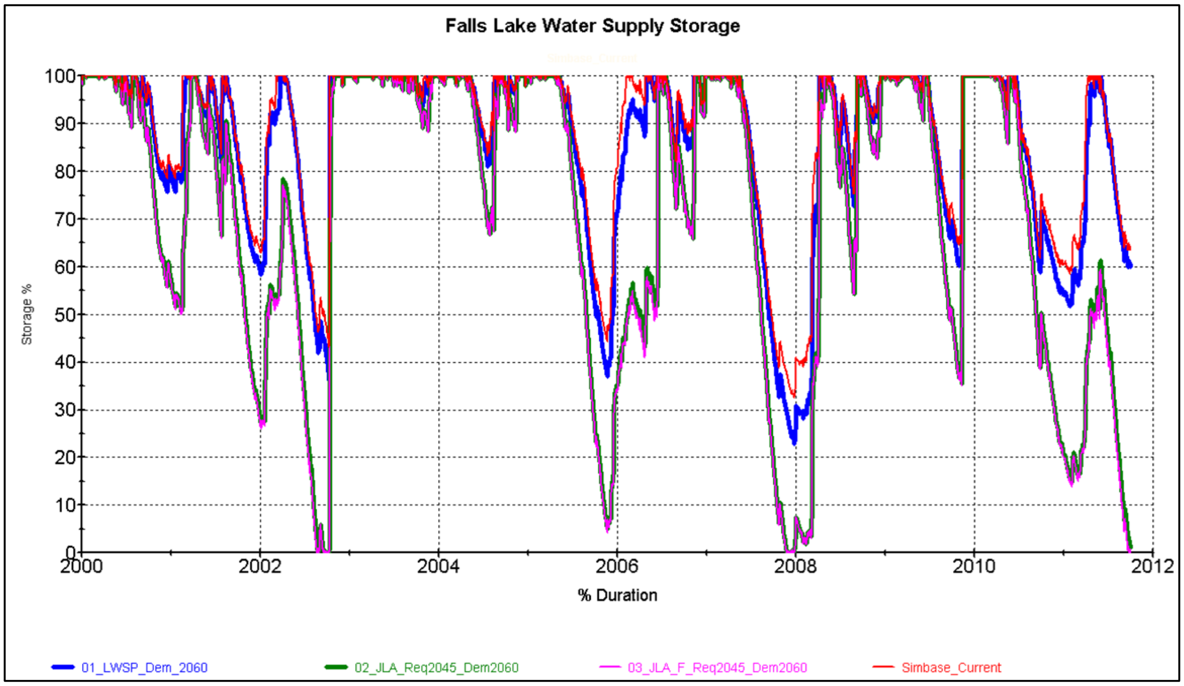

0430 - University Lake Elevation Duration
Elevation (FT)
350
348
346
344
342
340
338
336
0
10
20
30
40
50
60
70
80
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

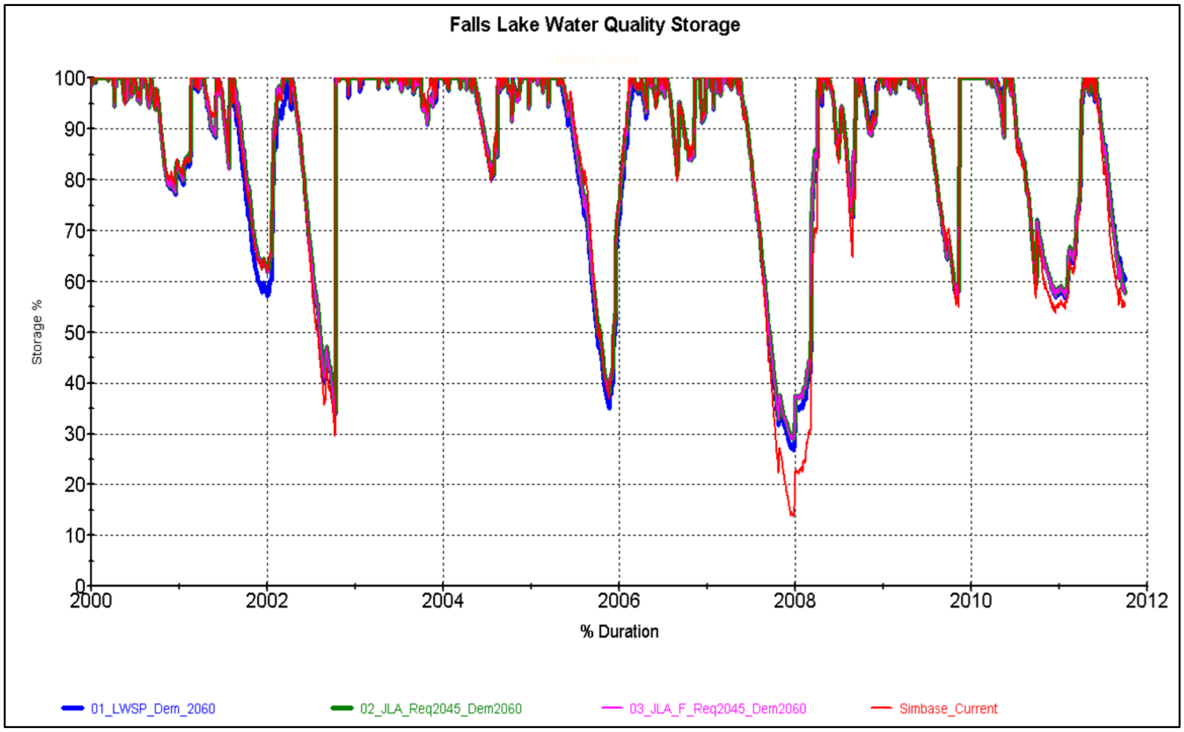

0760 Glenville Reservoir Elevation Duration
Elevation (FT)
114.0
113.0
112.0
111.0
110.0
109.0
108.0
107.0
106.0
0
10
20
30
40
50
60
70
80
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

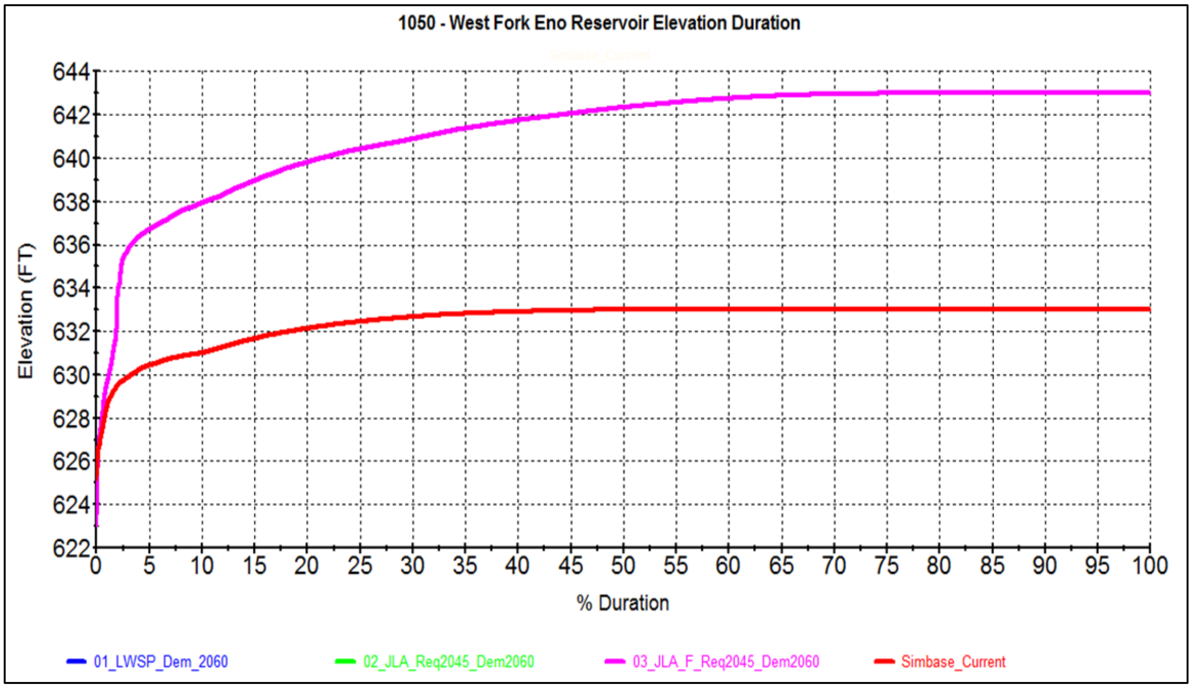

1300 Falls Lake Elevation Duration
2060 Demands
Elevation (FT)
252
251
250
249
248
247
246
245
244
243
242
241
240
0
10
20
30
40
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

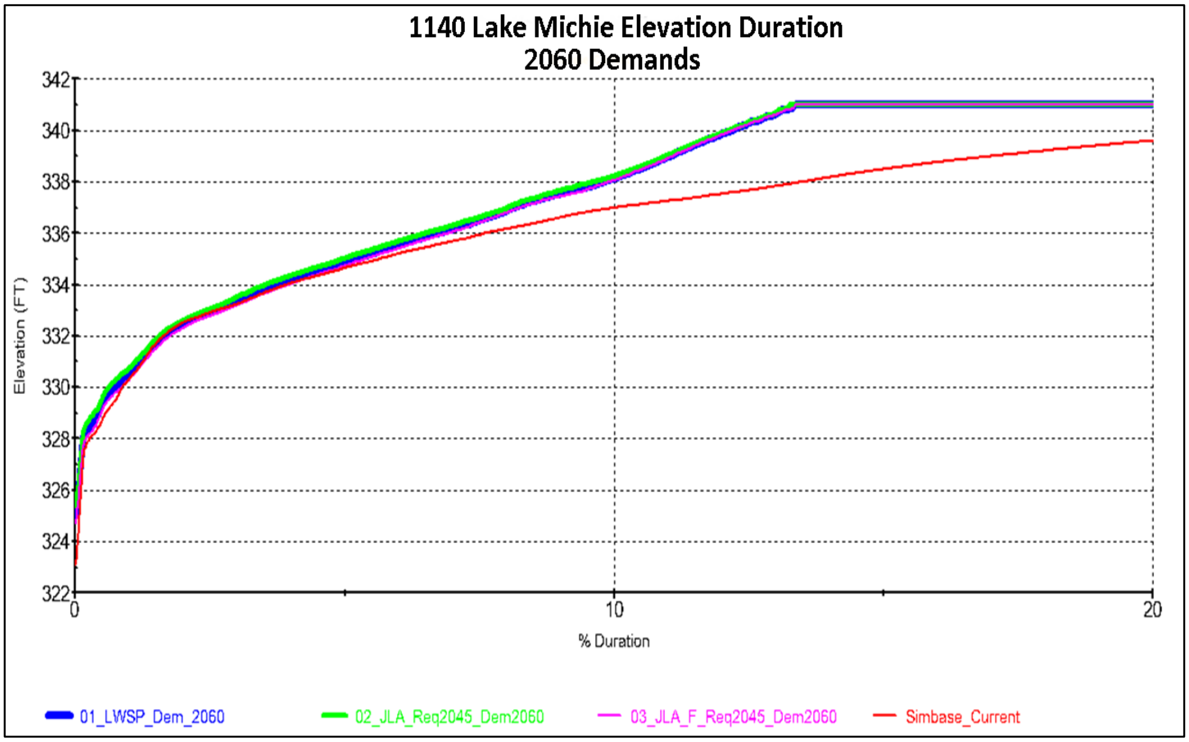

Duration of Falls Lake Water Supply Storage Percent
2060 Demands
Storage (%)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

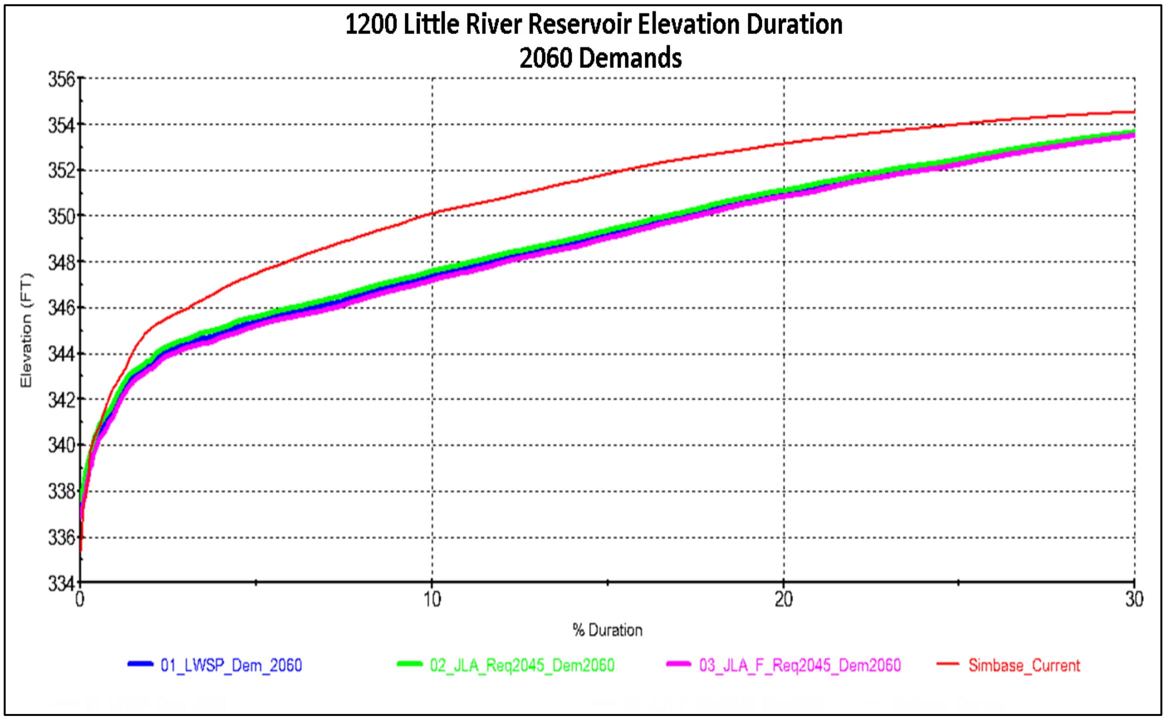

Duration of Falls Lake Water Quality Storage Percent
2060 Demands
Storage (AF)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

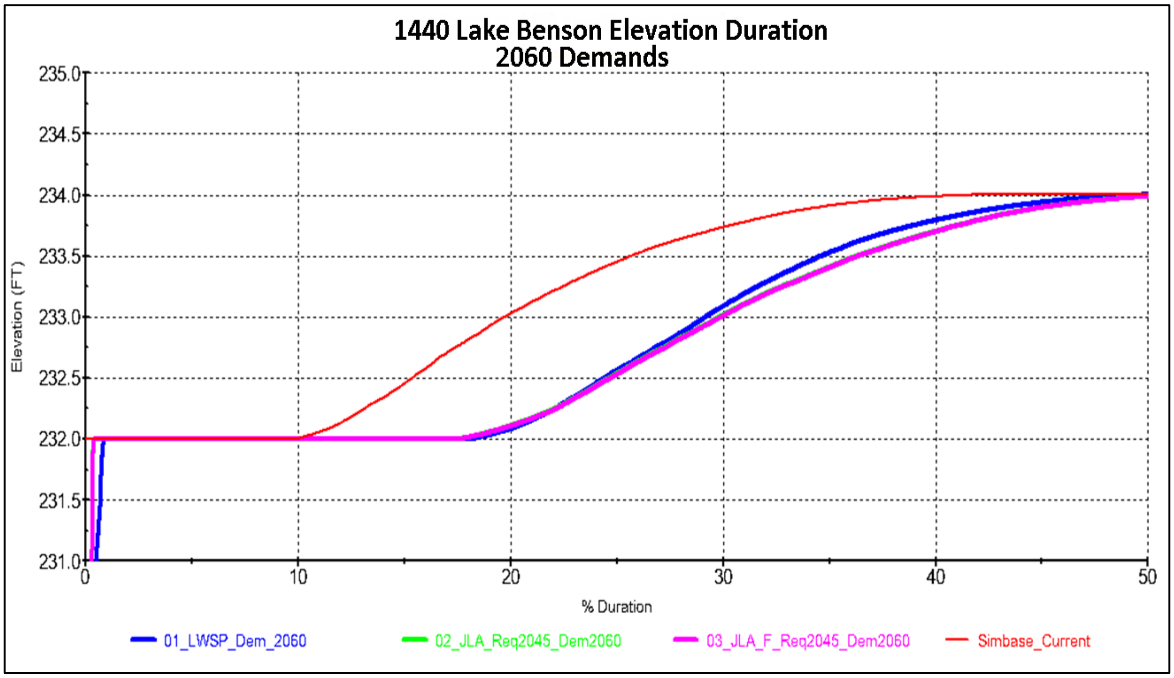

Falls Lake Water Supply Storage

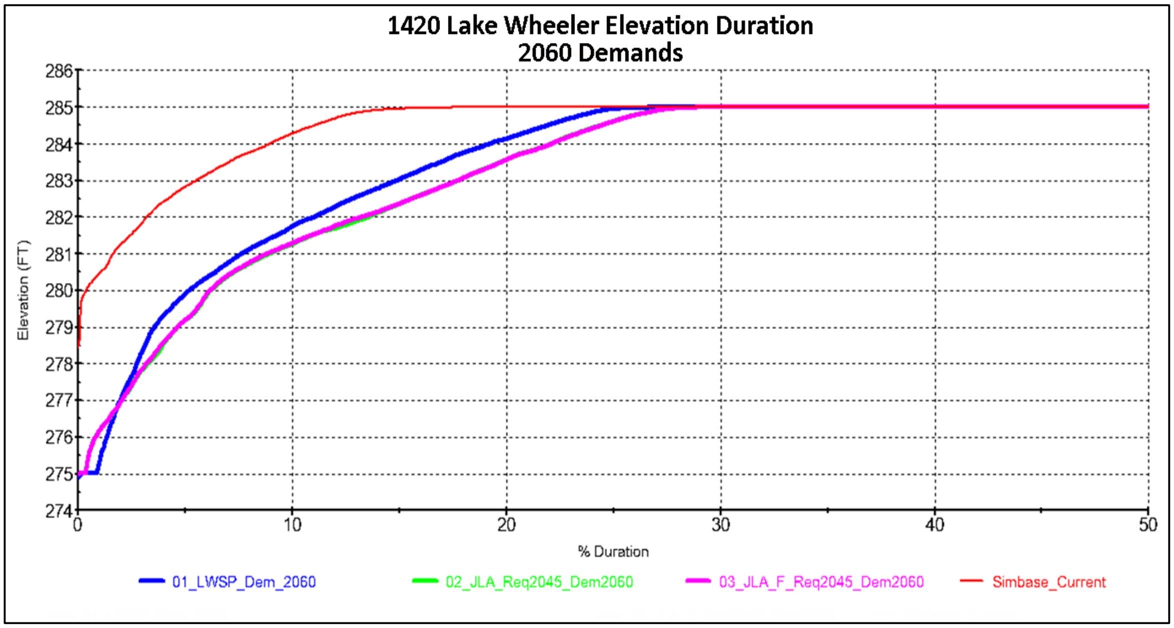

Falls Lake Water Quality Storage


1050 - West Fork Eno Reservoir Elevation Duration
Elevation (FT)
644
642
640
638
636
634
632
630
628
626
624
622
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

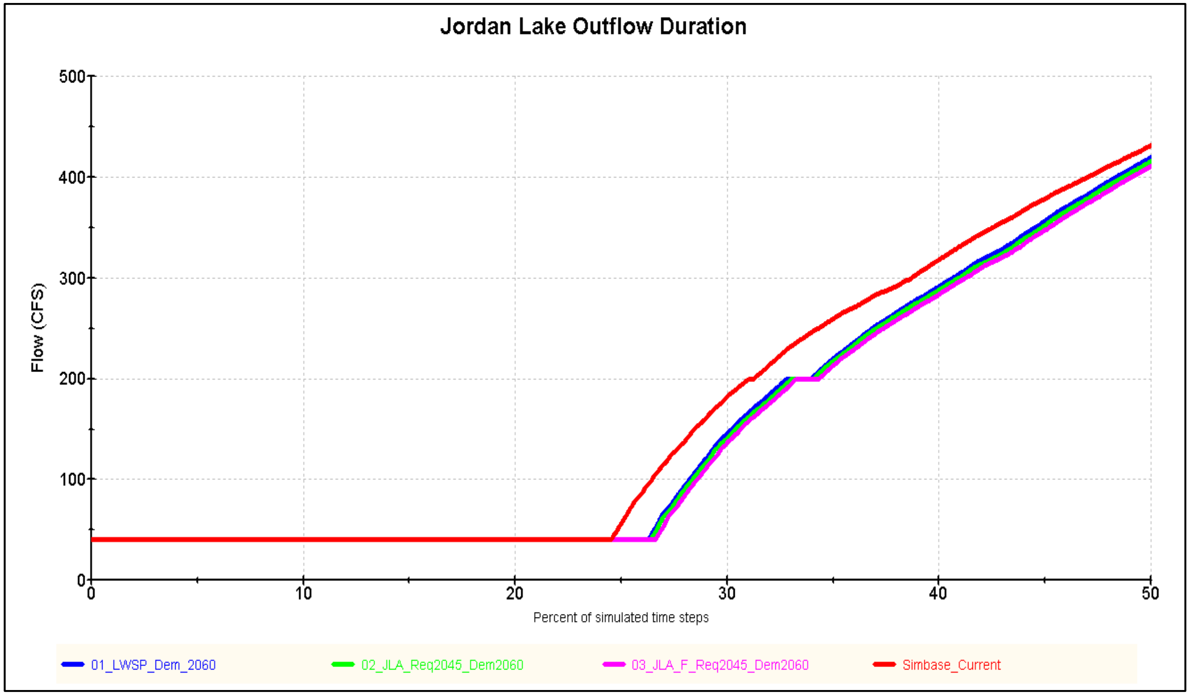

1140 Lake Michie Elevation Duration
2060 Demands
Elevation (FT)
342
340
338
336
334
332
330
328
326
324
322
0
10
20
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

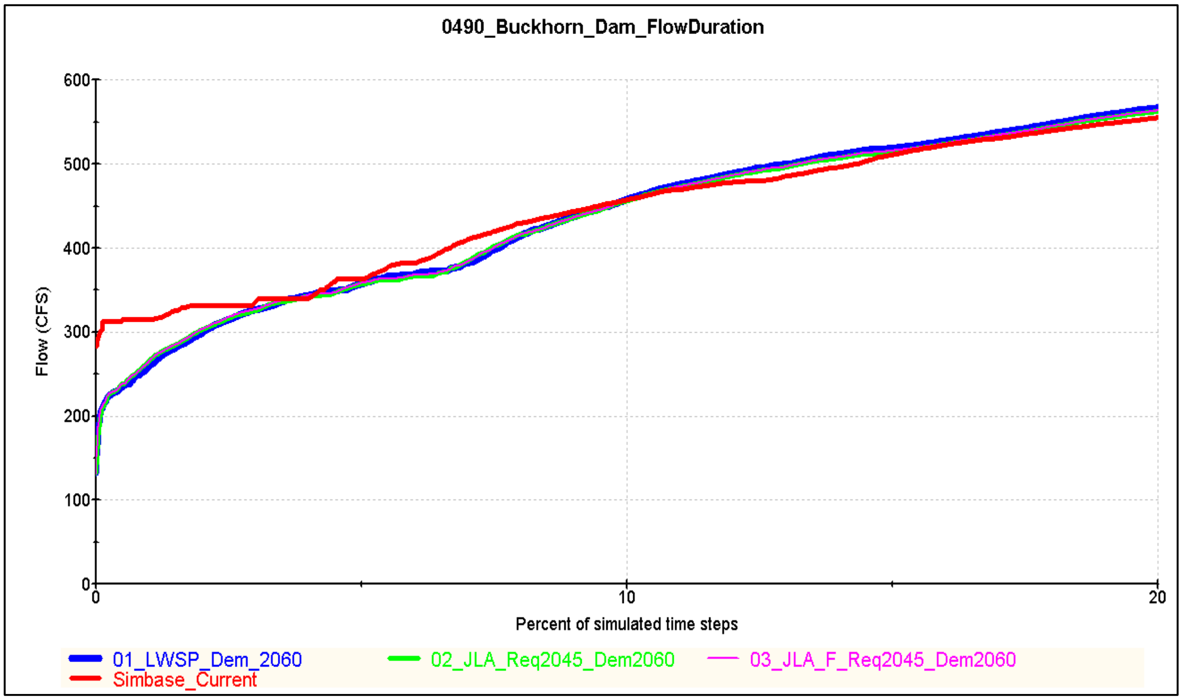

1200 Little River Reservoir Elevation Duration
2060 Demands
Elevation (FT)
356
354
352
350
348
346
344
342
340
338
336
334
0
10
20
30
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

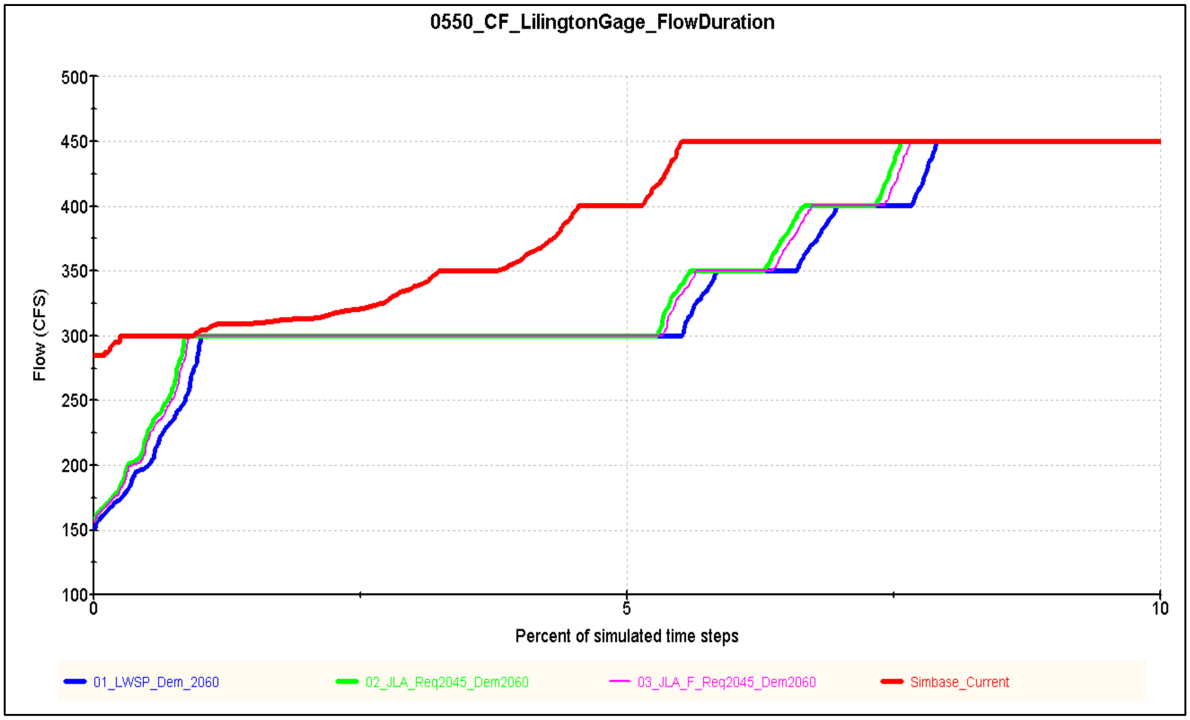

1440 Lake Benson Elevation Duration
2060 Demands
Elevation (FT)
235.0
234.5
234.0
233.5
233.0
232.5
232.0
231.5
231.0
0
10
20
30
40
50
% Duration
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

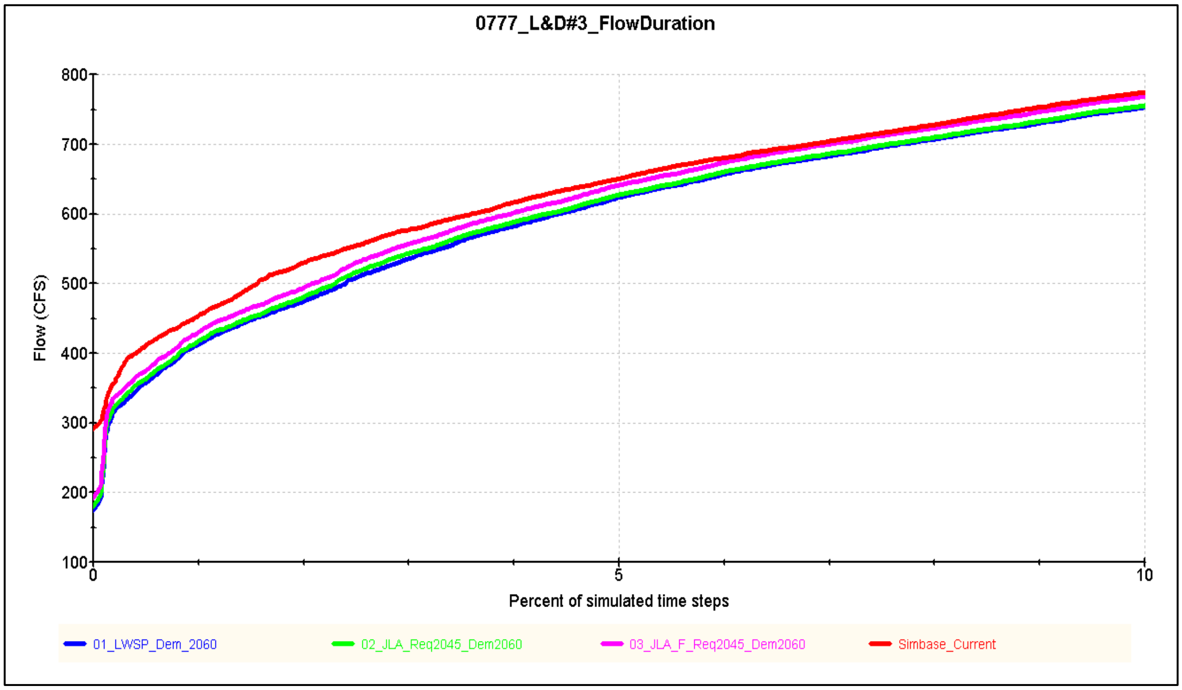


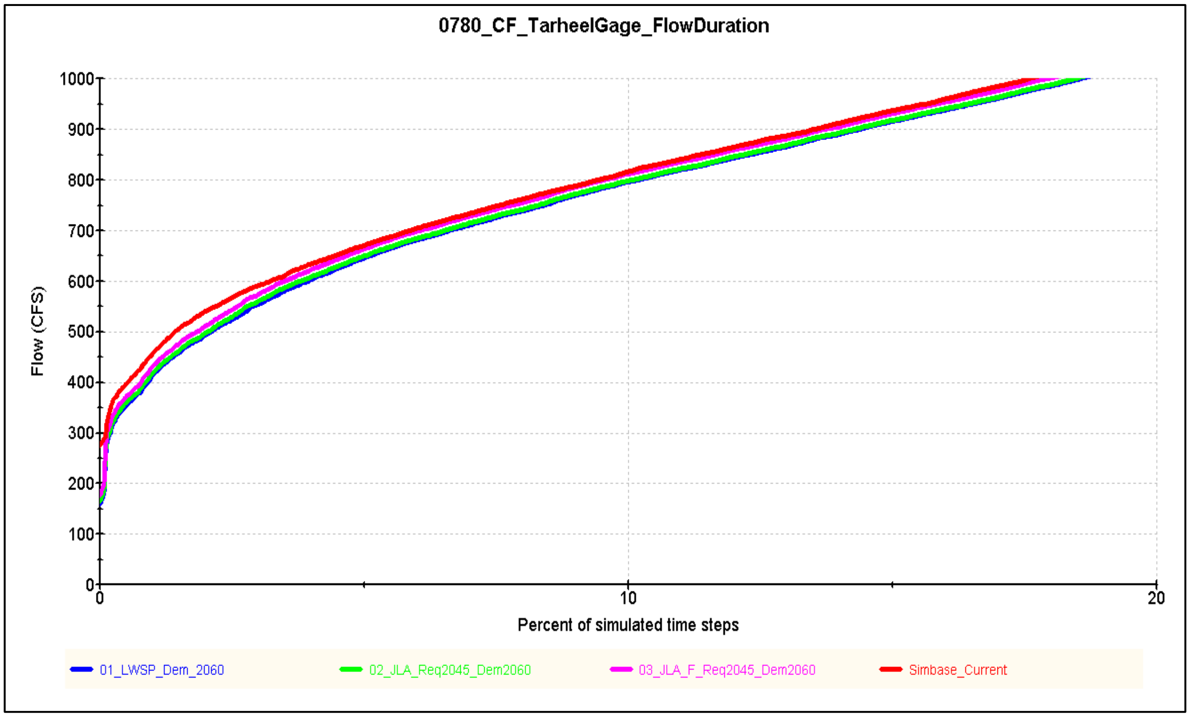
The following flow duration graphs highlight the variations in low flows at each location presented. The vertical scale shows flow rates in cubic feet per second while the horizontal scale shows the percent of simulated time steps in a model run. Using daily time steps when running a model scenario over the 29,858 days in the flow record means there are 29,858 time steps simulated for each model scenario. The flow record used in the model was reconstructed from historic flow records to capture hydrologic conditions from January 1930 to September 2011.

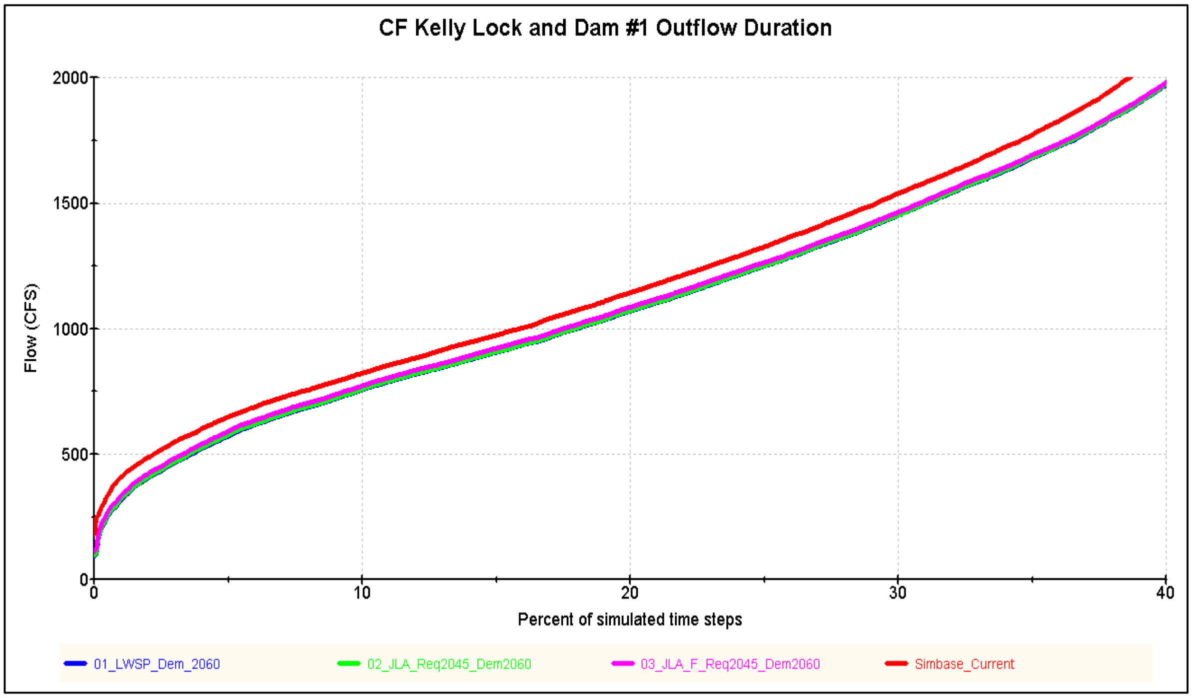



0490_Buckhorn_Dam_FlowDuration
Flow (CFS)
600
500
400
300
200
100
0
0
10
20
Percent of simulated time steps
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

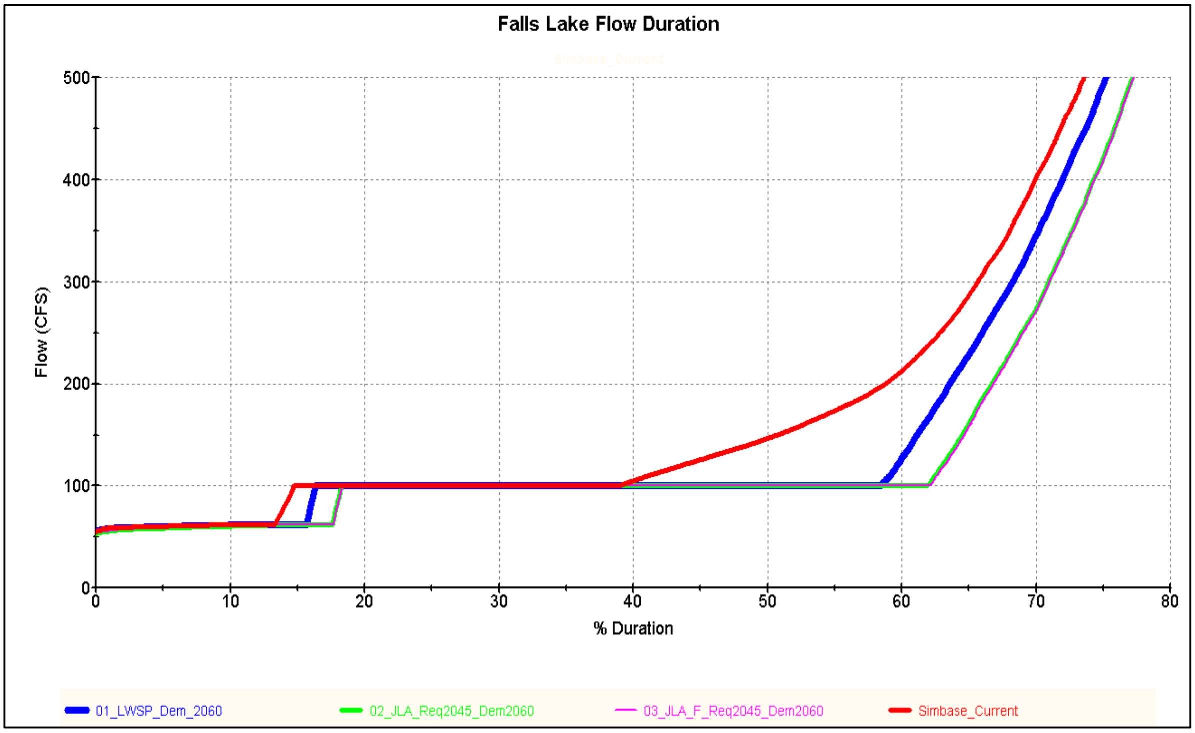

0550_CF_LilingtonGage_FlowDuration
Flow (CFS)
500
450
400
350
300
250
200
150
100
0
5
10
Percent of simulated time steps
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

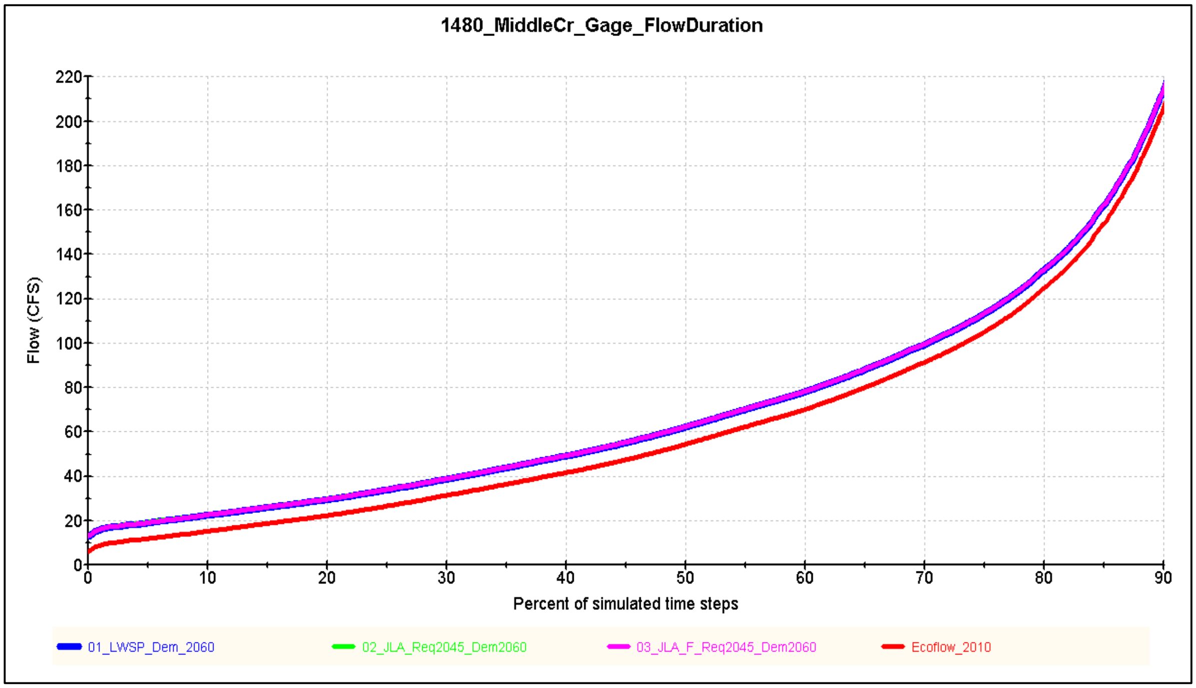

0777_L&D#3_FlowDuration
Flow (CFS)
800
700
600
500
400
300
200
100
0
5
10
Percent of simulated time steps
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

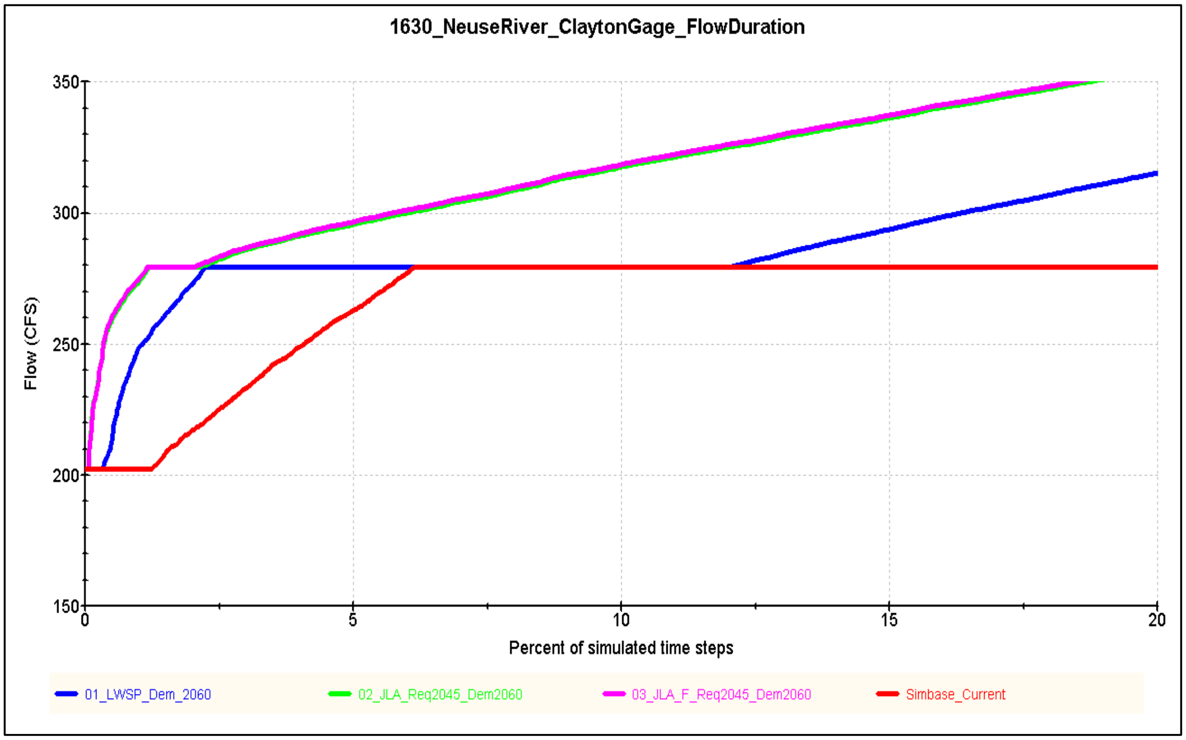

0780_CF_TarheelGage_FlowDuration
Flow (CFS)
1000
900
800
700
600
500
400
300
200
100
0
0
10
20
Percent of simulated time steps
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

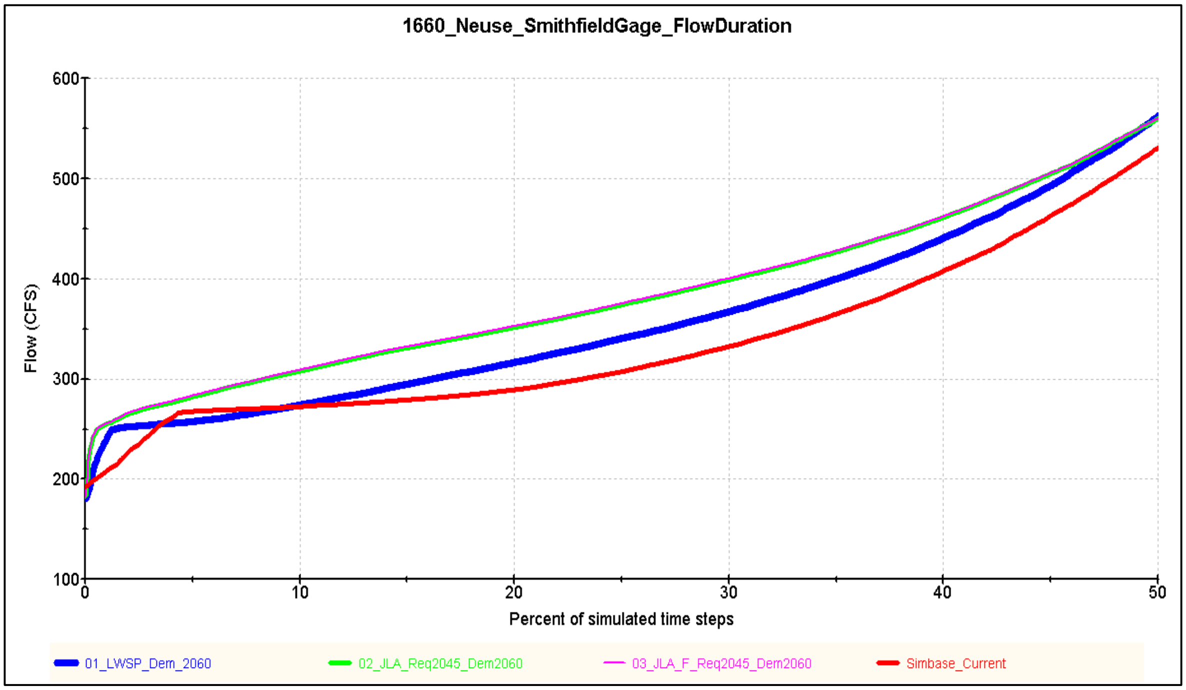


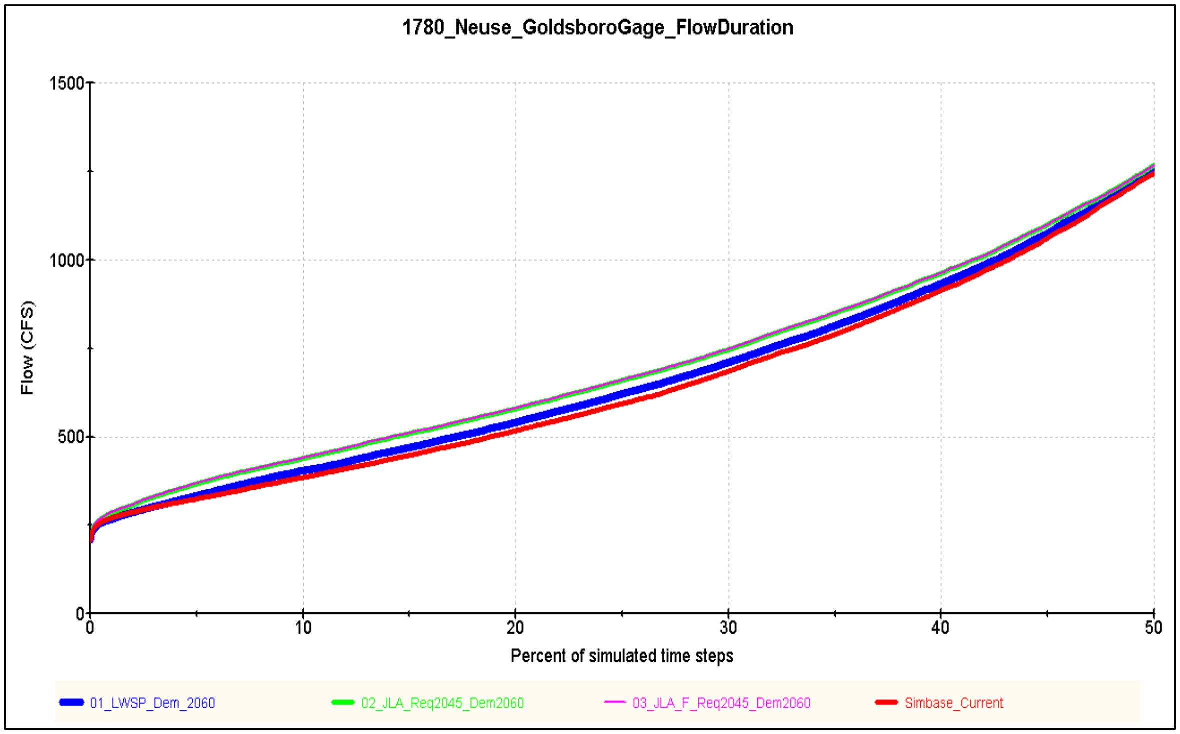
Flow Duration Plots for Falls Lake and Downstream

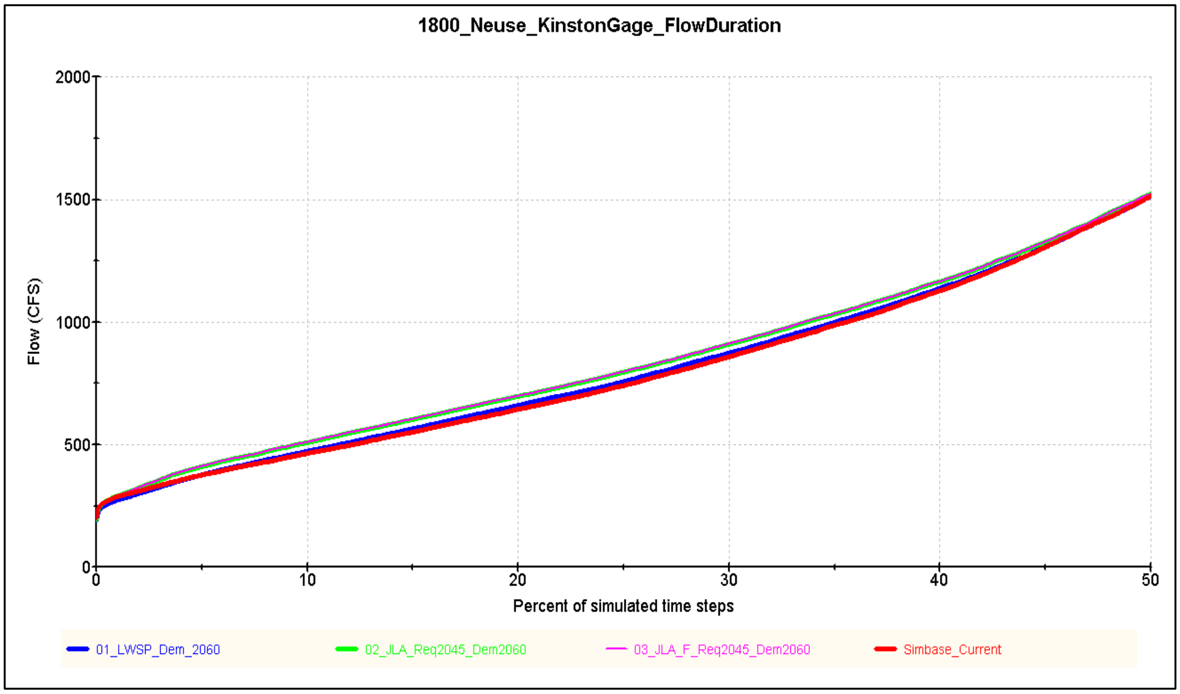


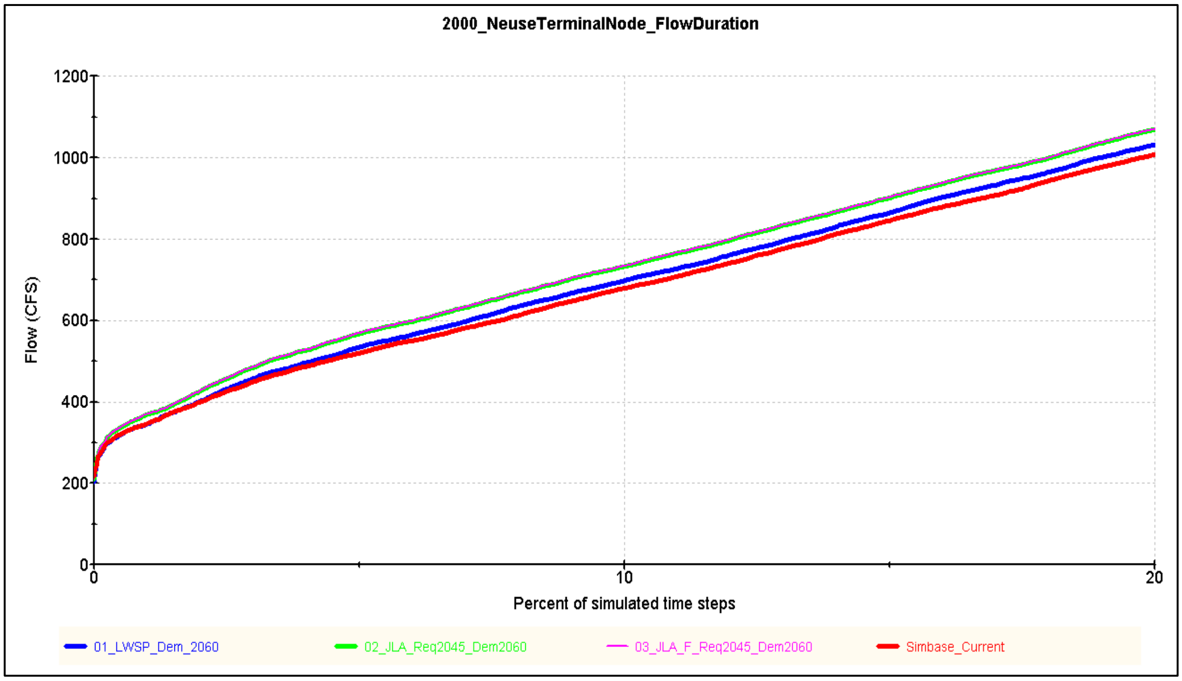

1480_MiddleCr_Gage_FlowDuration
Flow (CFS)
0
20
40
60
80
100
120
140
160
180
200
220
0
10
20
30
40
50
60
70
80
90
Percent of simulated time steps
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Ecoflow_2010


1630_NeuseRiver_ClaytonGage_FlowDuration
Flow (CFS)
150
200
250
300
350
0
5
10
15
20
Percent of simulated time steps
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current


1660_Neuse_SmithfieldGage_FlowDuration
Flow (CFS)
600
500
400
300
200
100
0
10
20
30
40
50
Percent of simulated time steps
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current


1780_Neuse_GoldsboroGage_FlowDuration
Flow (CFS)
1500
1000
500
0
0
10
20
30
40
50
Percent of simulated time steps
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current


1800_Neuse_KinstonGage_FlowDuration
Flow (CFS)
2000
1500
1000
500
0
0
10
20
30
40
50
Percent of simulated time steps
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current


2000_NeuseTerminalNode_FlowDuration
Flow (CFS)
1200
1000
800
600
400
200
0
0
10
20
Percent of simulated time steps
01_LWSP_Dem_2060
02_JLA_Req2045_Dem2060
03_JLA_F_Req2045_Dem2060
Simbase_Current

Appendix E Variations in Stream Flows

When considering how much water is reliably available at a particular location on a river low-flow conditions become the critical measure. Availability may be an issue for determining a potential waste load allocation for a wastewater discharge or it may be an issue for determining the amount of water available for a public water supply withdrawal. A common measure of low flows for these evaluations is what is called the 7Q10 flow. The 7Q10 is a statistically calculated estimate of the lowest 7-day average flow expected to occur once in ten years, based on the historic flow record used in the analysis. The 7Q10 value varies with the length of flow record used and with the beginning and end dates used for defining each year in the record. The calculations that produced the values in the tables below are based on the Climatic Year which encompasses the twelve months between April 1st and March 30th.

The duration of the low flow levels designated by the 7Q10 calculation has the potential to produce negative impacts to resident aquatic species if this level of flow is not considered when determining how much waste load a stream can handle. Similarly it is important when determining how much water can be withdrawn while protecting environmental quality. The 7Q10 flow is estimated to occur once in ten years which means there is a 10 percent chance this level of flow can occur in any year. This level of flow has a high enough probability of occurrence that it has become a benchmark in a variety of flow evaluations to define conditions that happen frequently enough to be considered likely to occur but is not the historic minimum flow.

The numbers in these tables cannot be compared to the 7Q10 calculations derived from the historic streamflow gage data. The model derived calculations are based on the hypothetical situations that are created by passing the 81 years of flow information through the hydrologic model representing the infrastructure and management protocols being used today or expected to be used in the future. For example, the streamflow records for 1955 reflect what actually happened in that year, prior to construction of Jordan Lake. The hydrologic model shows what conditions may be given the current and planned infrastructure and management protocols during the recurrence of the 1955 hydrologic conditions.

Twelve scenarios for the Cape Fear – Neuse River Basins Hydrologic Model were used for this evaluation of impacts to 7Q10 flow estimates. Three model scenario groups evaluate different supply options for each of three different demand quantities. The demand volumes used in each represent the estimated volumes of water expected to be needed to satisfy water system needs in 2035, 2045 and 2060. These demand estimates represent the amount of water expected to be needed 20, 30 and 50 years in the future to meet customer demands, based on current knowledge. The 7Q10 flows for locations in the Cape Fear River and Neuse River Basins from each of the model scenarios are shown in the tables below. Two variations on the model basecase scenario are shown. “Simbase_current” is the scenario that captures the current conditions in 2010 against which other scenarios are compared. The “Simbase_Dem2045” scenario combines the water sources available to water systems in 2010 with the estimated 2045 customer demands. This scenario shows the impacts of withdrawing water sufficient to meet estimated 2045 demands from the sources available in 2010. The other ten scenarios were all developed for the Jordan Lake Allocation review process and include "JLA" in the title.

The tables show three scenarios designated as "01_JLA_LWSP_Dem" followed by 2035, 2045 and 2060. This label denotes a scenario developed for the Jordan Lake Allocation review process using water availability and water demands based on data presented in the Local Water Supply Plans for expected demands in 2035, 2045 and 2060.

The second group of scenarios is designated as "02_JLA_Req2045_Dem" followed by 2035, 2045 and 2060. These scenarios include the requested Jordan Lake allocation amounts to meet demands in 2045 for the applicants that propose to use water drawn directly from the reservoir. The scenarios include the preferred usage schemes outlined in each allocation application. This set of scenarios does not include Fayetteville PWC's allocation request in which their allocation would be released from the reservoir to be withdrawn from the Cape Fear River in Fayetteville. These scenarios evaluate the resource changes produced by meeting the 2035, 2045 and 2060 expected demands with the supplies available if the requested allocations are approved by the Environmental Management Commission.

The third group of scenarios is designated as "03_JLA_F_Req2045_Dem" followed by 2035, 2045 and 2060. This set of model scenarios incorporates Fayetteville PWC's requested allocation and withdrawal scenario into the three scenarios in the previous group. This set of scenarios shows the possible outcomes of approving all the requested allocations.
The twelfth model scenario, designated as "04_JLA_Raleigh_Lillington_Dem2045", models the outcome if: Raleigh's requested allocation amount is withdrawn from the Cape Fear River in the vicinity of Lillington, with no water supply release from Jordan Lake; Fayetteville PWC continues to withdraw water from its existing locations with no water supply release from Jordan Lake; and the other applicants withdraw their requested Jordan Lake water supply allocations as described in their applications.

As water withdrawals increase to meet higher future demands one would expect the residual streamflows and the resulting 7Q10 estimates to decline. However, changes in sources and the magnitude and location of wastewater water returns produce changes in water availability that result in 7Q10 estimates that increase and decrease between model scenarios at locations throughout the basins. The estimated 7Q10 values at fourteen locations in the Cape Fear and Neuse River Basins are presented for each model scenario in the following tables. For each location the lowest value is shown in bold typeface.
The modeling results are products of the data and assumptions used in the Cape Fear – Neuse River Basins Hydrologic Model. Improvements to the data and revisions of the assumptions used will produce different results. A useful way to interpret the data in these tables is to compare the values under the various model scenarios to the "Simbase_Current" scenario values to see how resource conditions may change in the future compared to the current conditions.

Model Estimates of 7Q10 Flows below Jordan Lake in Cubic Feet per Second (cfs)

Scenario Number	Model Scenario	Cape Fear Nodes					
		Buckhorn Dam	Lillington Gage	L&D #3	L&D #2	Above L&D #1	L&D #1
1	01_JLA_LWSP_Dem2035	244	256	390	417	366	295
2	01_JLA_LWSP_Dem2045	**240**	251	385	413	363	283
3	01_JLA_LWSP_Dem2060	242	238	375	404	353	**254**
4	02_JLA_Req2045_Dem2035	243	258	393	420	369	298
5	02_JLA_Req2045_Dem2045	245	254	388	415	364	283
6	02_JLA_Req2045_Dem2060	242	243	381	409	359	260
7	03_JLA_F_Req2045_Dem2035	243	258	407	434	383	313
8	03_JLA_F_Req2045_Dem2045	**240**	253	400	428	378	298
9	03_JLA_F_Req2045_Dem2060	244	241	393	422	372	274
10	04_JLA_Raleigh_Lilington_Dem2045	241	248	382	410	360	280
11	Simbase-current	308	310	428	449	396	348
12	Simbase-Dem2045	**240**	**225**	**365**	**393**	**340**	259

Model Estimates of 7Q10 Flows below Jordan Lake in Million Gallons per Day (mgd)

Scenario Number	Model Scenario	Cape Fear Nodes					
		Buckhorn Dam	Lillington Gage	L&D #3	L&D #2	Above L&D #1	L&D #1
1	01_JLA_LWSP_Dem2035	158	165	252	270	237	191
2	01_JLA_LWSP_Dem2045	**155**	162	249	267	234	183
3	01_JLA_LWSP_Dem2060	157	154	242	261	228	**164**
4	02_JLA_Req2045_Dem2035	157	167	254	271	239	193
5	02_JLA_Req2045_Dem2045	158	164	251	268	235	183
6	02_JLA_Req2045_Dem2060	156	157	246	265	232	168
7	03_JLA_F_Req2045_Dem2035	157	167	263	281	248	202
8	03_JLA_F_Req2045_Dem2045	**155**	164	259	277	244	193
9	03_JLA_F_Req2045_Dem2060	158	156	254	273	240	177
10	04_JLA_Raleigh_Lilington_Dem2045	156	160	246	265	233	181
11	Simbase-current	199	200	277	290	256	225
12	Simbase-Dem2045	**155**	**145**	**236**	**254**	**220**	168

The minimum value at each location is shown in **Bold**

Model Estimates of 7Q10 Flows below Falls Lake in Cubic Feet per Second (cfs)

Scenario Number	Model Scenario	Neuse Nodes							
		Clayton Gage	Johnston Co Intake	Smithfield Gage	HF Lee Energy Complex	Goldboro Intake	NRWASA Intake	Kinston Gage	Weyerhaeuser Intake
1	01_JLA_LWSP_Dem2035	232	228	225	254	255	256	258	297
2	01_JLA_LWSP_Dem2045	244	237	234	258	256	257	260	301
3	01_JLA_LWSP_Dem2060	234	224	217	247	**241**	**244**	**247**	290
4	02_JLA_Req2045_Dem2035	231	227	224	254	253	254	257	295
5	02_JLA_Req2045_Dem2045	242	235	232	258	253	255	258	298
6	02_JLA_Req2045_Dem2060	255	244	238	263	254	259	262	306
7	03_JLA_F_Req2045_Dem2035	231	227	224	254	253	254	257	295
8	03_JLA_F_Req2045_Dem2045	242	235	232	258	253	255	258	298
9	03_JLA_F_Req2045_Dem2060	256	245	238	264	255	260	263	307
10	04_JLA_Raleigh_Lilington_Dem2045	237	231	227	255	251	252	255	296
11	Simbase-current	**203**	**203**	**202**	**245**	250	256	259	**290**
12	Simbase-Dem2045	238	232	229	265	262	262	265	305

Model Estimates of 7Q10 Flows below Falls Lake in Million Gallons per Day (mgd)

Scenario Number	Model Scenario	Neuse Nodes							
		Clayton Gage	Johnston Co Intake	Smithfield Gage	HF Lee Energy Complex	Goldboro Intake	NRWASA Intake	Kinston Gage	Weyerhaeuser Intake
1	01_JLA_LWSP_Dem2035	150	147	146	164	165	165	167	192
2	01_JLA_LWSP_Dem2045	158	153	151	167	166	166	168	194
3	01_JLA_LWSP_Dem2060	151	145	140	160	**156**	**158**	**160**	188
4	02_JLA_Req2045_Dem2035	149	147	145	164	164	164	166	191
5	02_JLA_Req2045_Dem2045	156	152	150	166	163	165	167	193
6	02_JLA_Req2045_Dem2060	165	158	154	170	164	168	170	198
7	03_JLA_F_Req2045_Dem2035	149	147	145	164	164	164	166	191
8	03_JLA_F_Req2045_Dem2045	156	152	150	166	163	165	167	193
9	03_JLA_F_Req2045_Dem2060	165	158	154	171	165	168	170	198
10	04_JLA_Raleigh_Lilington_Dem2045	153	149	147	165	162	163	165	191
11	Simbase-current	**131**	**131**	**130**	**158**	162	165	167	**187**
12	Simbase-Dem2045	154	150	148	171	169	169	171	197

The minimum value at each location is shown in **Bold**