US Army Corps
of Engineers ®
Wilmington District

FALLS LAKE, NORTH CAROLINA

INTEGRATED WATER SUPPLY REALLOCATION
FEASIBILITY STUDY AND
DRAFT ENVIRONMENTAL ASSESSMENT

DRAFT REPORT FOR REVIEW– MARCH 2017

Wilmington District – U.S. Army Corps of Engineers

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1.1 STUDY OVERVIEW AND PURPOSE.

The purpose of this study is to respond to a request from the City of Raleigh, North Carolina, for the reallocation of approximately 12,500 acre-feet of storage (later revised to 17,300 acre-feet) within Falls Lake, a Corps of Engineers multi-purpose project, in order to satisfy future demand for water supply (Attachment 1). Falls Lake provides drinking water for over a half a million people in Raleigh and six other municipalities in eastern Wake County: Garner, Knightdale, Rolesville, Wake Forest, Wendell and Zebulon. Projected population growth, coupled with the lack of additional readily-available water supply and delivery, will lead to unmet demand and water restrictions in coming decades. The City of Raleigh is seeking alternative water supply sources to meet demand for the next 30 years (2016 to 2045).

1.2 Authority.

Authority for this reallocation study is provided by the Water Supply Act of 1958 (43 U.S.C. 390b; P.L. 85-500), as amended. Congress intended for the Corps to use this authority to assume an active role, in conjunction with State and local interests, “in developing [municipal and industrial] water supplies in connection with the construction, maintenance, and operation of Federal navigation, flood control . . . or multiple purpose projects,” i.e., by including storage for water supply in the planning for new Corps projects, or by allowing the use of storage in existing Corps projects for water supply, to the extent it could not already be used for that purpose. 43 U.S.C. 390b(a).

The Corps’ discretionary authority to modify projects without further Congressional approval is limited, according to the Act, as follows:

> Modifications of a reservoir project heretofore authorized, surveyed, planned, or constructed to include storage . . . which would seriously affect the purposes for which the project was authorized, surveyed, planned, or constructed, or which would involve major structural or operational changes shall be made only upon the approval of Congress as now provided by law.

1.3 Project Background.

The Falls Lake project, a multi-purpose facility constructed by the U.S. Army Corps of Engineers (USACE). Authorization of the project was provided through the Flood Control Act of 1965 and the River and Harbor Act of 1965 (P.L. 89-298), substantially in accordance with guidance provided in House Document Number 175, Eighty-Ninth Congress. Construction was initiated in 1978, and completed on February 26, 1981 (allowing limited water supply withdrawals). Permanent, full impoundment was completed in December 1983.

The authorized project purposes of Falls Lake include flood control (flood risk management), water quality, water supply and recreation. Fish and wildlife enhancement was also included as a project purpose based on the Federal Water Project Recreation Act (Public Law 89-72), which required project lands and water areas to be administered for recreation and fish and wildlife enhancement.

The project has been operated for those purposes since completion of construction. The project is constantly operated to maintain water levels near the top of water conservation storage, and to maintain downstream flow targets, through the water quality portion of the water conservation storage. No specific operations are performed for water supply, since the City of Raleigh's water intake is within the lake itself. During periods of high inflow, the project is operated for flood risk management. Flood storage has never been exceeded, and conservation storage has never been fully depleted.

The drainage area upstream of the project is approximately 770 square miles. Falls Lake dam is an earth and rock fill structure with an overall length of 1,915 feet. The top of the dam "as-constructed" is at elevation 291.5 feet above mean sea level (NGVD29). Flood control (flood risk management) storage is managed by the USACE.

1.4 Project Location.

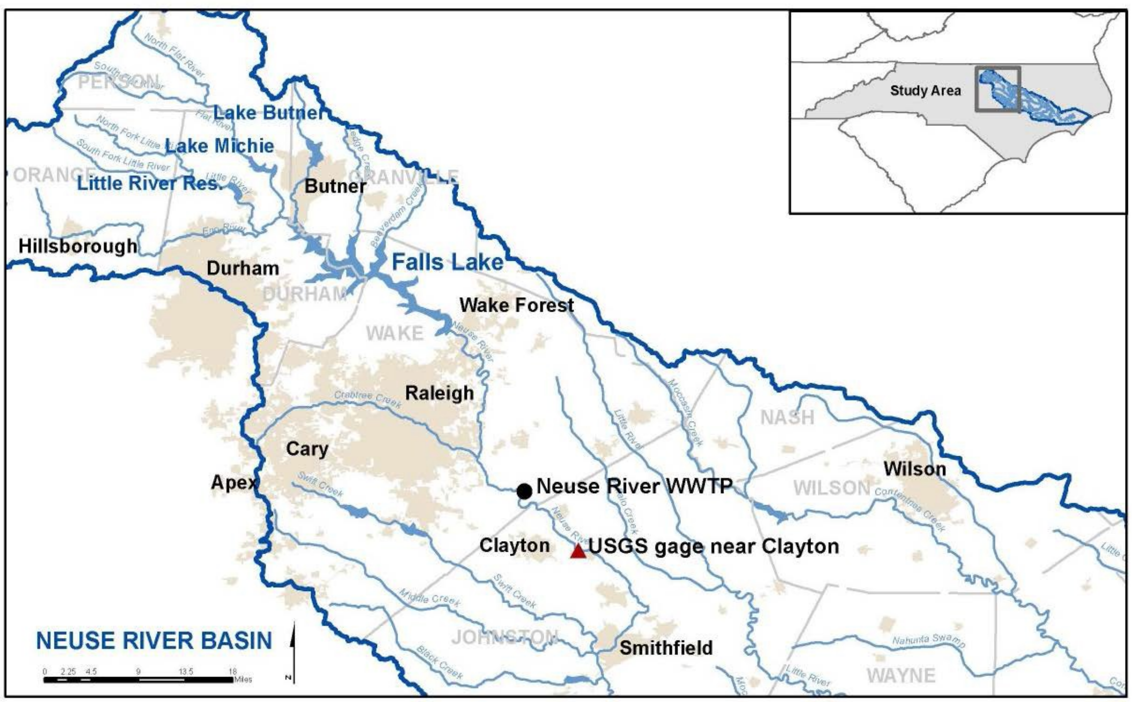


Figure 1.1 - Location of Falls Lake

The existing Falls Lake Project is located on the Neuse River in Wake, Granville, and Durham Counties, North Carolina (Figure 1). It extends from the community of Falls, north of Raleigh, up into the Eno and Flat River watersheds, northeast of Durham, North Carolina.

2.1 HISTORY OF THE PROJECT.

Prior to 1978, flooding of the Neuse River caused extensive damage to public and private properties, including roadways, railroads, industrial sites and farmlands. Falls Lake was constructed to provide flood control (flood risk management); water supply; water quality; and other project purposes, such as recreation. Fish and wildlife enhancement was included as a project purpose based on the Federal Water Project Recreation Act (Public Law 89-72), which required project lands and water areas to be administered for recreation and fish and wildlife enhancement. In 1972, a contract was executed by the United States and the City of Raleigh, which allows for withdrawal of water directly from Falls Lake. This contract obligated the total allocated water supply storage space within the project to the City of Raleigh. A contract for the construction of the dam, spillway, and outlet works was awarded by the Wilmington District on May 18, 1978, and construction was completed on February 26, 1981.

In 1985, a shortage of water storage capacity was discovered, based upon a deficit in reservoir volume due to original survey mapping accuracy. Subsequently, the USACE studied potential solutions for the water storage capacity shortage and prepared a general design memorandum (USACE 1991). Following this study, a concrete barrier was added across the top of the dam by about three feet, as part of modifications, which increased the effective height of the dam to about 294.5 feet (NGVD29). Raising the top of the conservation storage from 250.1 to 251.5 feet (NGVD29), restored all of the 45,000 acre-feet of originally planned water supply storage, and all but 13 percent of the originally planned water quality storage of the lake. None of the originally planned sediment storage and only a minor amount of controlled flood storage capacity was restored, resulting in a sediment storage loss of about 35 percent and a flood storage loss of about nine (9) percent.

Neither the loss of storage in the water quality pool, nor the loss of sediment storage, has turned out to negatively impact water quality commitments or resulted in impacts to other project purposes due to infilling of sediment storage. Because sediment inflow and deposition in the reservoir has been far less than expected, sediment storage since the end of construction has not been significantly depleted. Due to the water quality storage reduction, modifications to the minimum release requirements from the dam were also made in agreement with the State of North Carolina. Minimum instantaneous releases from the dam were increased from 27 cfs year-round to 50-65 cfs during the cold months and 100 cfs during the warm months, and the higher summer downstream flow target of 404 cfs at Clayton was eliminated, leaving only the minimum Clayton flow targets of 184 cfs during the cold months and 254 cfs during the warm months. NPDES wasteload allocations by the State of North Carolina were subsequently based on the Clayton target flow of 254 cfs, not404 cfs. At no time since these operational changes were made has the reduced water quality storage ever been depleted or the water quality flow targets not been met.

At elevation 251.5 feet (NGVD29), which is the top of the conservation storage, the reservoir impounds approximately 131,400 acre-feet of water, covering approximately 12,410 acres. The current capacity, in acre-feet, of the storage at Falls Lake, is presented in Table 2.1, and shown in Figure 2.

Table 2.1 - Falls Lake Storage Volumes (Acre-Feet)

STORAGE	Current (as of 2007)
Controlled Flood Storage	**221,182**
Total Conservation Storage	**106,322**
- Water Supply	**45,000**
- Water Quality	**61,322**
Sediment Storage	**25,073**
TOTAL	**352,577**

Source: U.S. Army Corps of Engineers, Falls Lake Project, Neuse River Basin, NC, Pertinent Data, 27 June 2007.

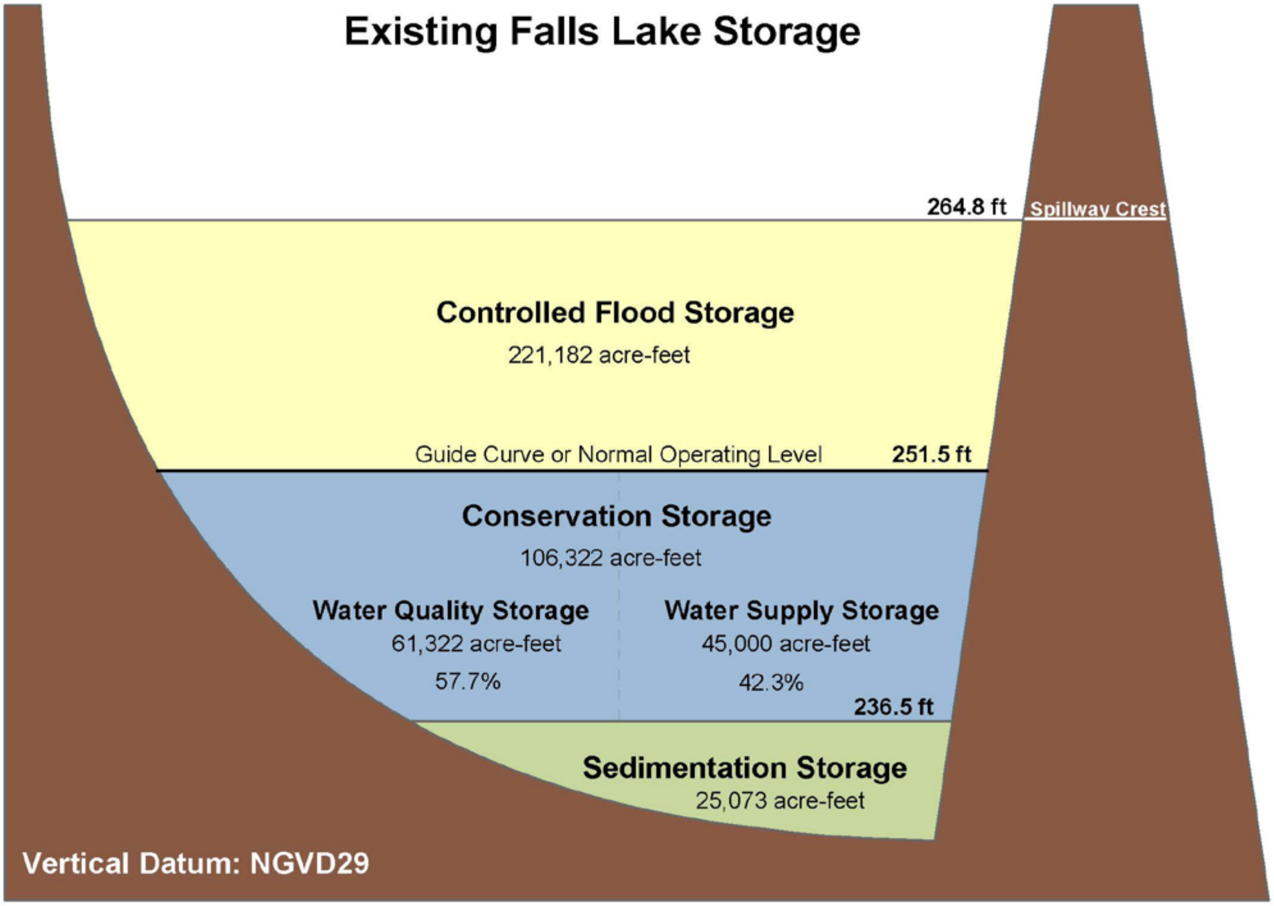


Figure 2 – Existing Falls Lake storage.

2.2 Flood Risk Management Storage (Flood Control Storage).

A primary objective of the Falls Lake project is flood risk management below Falls Lake dam on the Neuse River. Storage of 221,182 acre-feet between elevations 251.5 ft-NGVD29 (top of conservation storage) and 264.8 ft-NGVD29 (spillway crest elevation) is reserved exclusively for the detention storage of floodwaters. An additional 687,400 acre-feet of surcharge storage exists above the free-overflow spillway between elevations 264.8 and 287.1 ft-NGVD29.

The general plan of flood operations provides for maintaining the 251.5 ft-NGVD29 normal storage elevation in Falls Lake by releasing flows that produce non-damaging discharges in the Neuse River downstream of Falls Lake dam, whenever possible. The flood risk management objective is to store water in the controlled flood storage in Falls Lake whenever the Neuse River downstream is, or is forecasted, to exceed the downstream capacity of the channel (i.e., a “bankfull condition”), or reach a depth or condition in which it would cause damage (i.e., “damage stage”). The latter is when flood flows would leave the channel and cause damaging inundation to structures or infrastructure. The United States Geological Survey (USGS) streamgage on the Neuse River near Clayton, North Carolina, is the primary operational flood risk reduction indicator. However, some consideration is also given to river stages farther downstream (such as Goldsboro and Kinston) based on experience during past major flood events. Because of the distance and the lengthy river flow travel time from Falls Lake dam to downstream areas--especially to areas downstream of Clayton--and coupled with runoff from the uncontrolled drainage areas downstream of Falls Lake, releases from Falls Lake dam will sometimes be reduced to near minimum prior to a storm event to prevent discharges from contributing substantially to those uncontrolled floodwaters. Afterwards, when downstream conditions allow, the stored flood waters in the reservoir will be evacuated at a rate that will produce non-damaging stages downstream. Flood releases are based on a tiered release schedule, allowing for increased releases and higher regulated flows at Clayton as lake levels rise higher into the flood storage.

2.3 Conservation Storage (Water Quality and Water Supply Storage)

Conservation storage includes storage for both water quality and water supply. The rights to the entire water supply storage (currently 45,000 acre-feet) are owned by the City of Raleigh, North Carolina. The water quality storage is designed to provide low flow augmentation for downstream water quality, and is managed by the USACE. Minimum releases are required in order to maintain downstream water quality target flows immediately downstream of the dam and at the Clayton, North Carolina gage as shown in Table 2.2. The flow target varies from 184 cubic feet per second (cfs) to 254 cfs, depending on the time of year (USACE, 2007). Releases to maintain minimum average daily flows directly below the dam range from 50-65 cfs (varies based on hydraulic head) to 100 cfs, depending on the time of year.

Table 2.1 - Falls Lake Releases from Water Quality Storage

Release Requirement	Flows (cfs)
Minimum Flow at Clayton	
November through March	**184**
April through October	**254**
Minimum Instantaneous Release	
November through March	**50-65**
April through October	**100**

The severe drought of 2007-08 lead to consideration of the possibility of temporarily allowing the State of North Carolina to access available water in sediment storage if either the water quality or water supply storage within the conservation storage was exhausted. The Wilmington District studied and developed a proposal for using the sediment storage, if needed. The District pursued USACE Headquarters approval, but was never obtained due to lack of policy for emergency (temporary) usage; therefore, no such agreement was ever executed with the State of North Carolina.

Since the early 2000's, the City of Raleigh has been studying alternatives to provide additional water supply to offset growing demand. In 2008, a request was submitted to the Wilmington District, Regulatory Division to impound the Little River (a downstream tributary of the Neuse River) for additional water storage. This downstream Little River is not the same tributary as the upstream Little River tributary, unfortunately with the same name. A public notice was issued by the USACE on 12 September 2008, and a public scoping meeting for drafting the Environmental Impact Statement (EIS) for the proposed project was held on 14 October 2008. Additional scoping, consisting of Project Review Team (PRT) meetings, was conducted in 2009. After resource agency review, it was suggested that the project was apparently neither the least damaging practicable alternative, nor the most cost-effective in terms of construction and mitigation for impacts to streams and wetlands, and the City needed to investigate additional alternatives.

One alternative to the Little River Reservoir involved the potential reallocation of either water quality or sedimentation storage at Falls Lake to water supply storage. Another possibility considered was raising the normal operating level to increase the conservation storage. However, USACE guidance in Engineering Circular ER 1165-2-1156 entitled Water Supply Storage and Risk Reduction Measures for Dam Safety, dictates that any dam with a Dam Safety Action Class (DSAC) rating of 1, 2 or 3 would be prohibited from raising the current normal operating level. Falls Lake dam has a DSAC rating of 3. The DSAC rating is based on a risk analysis driven by life-safety consequences downstream primarily due to projected loss of life should a dam breach occur. The DSAC 3 rating was originally assigned in December 2008 following a Screening Portfolio Risk Analysis completed April 18, 2007, and confirmed with a Periodic Assessment that was completed in June 2012.

Interim discussions on risk reduction and water supply raised the issue of the DSAC rating and its effect on potential water reallocation at Falls Lake. Given that the most likely plans did not involve raising the guide curve, or dam, or affect either flood risk management operations or existing facilities and project features, an exception memo was prepared in February 2015 requesting consideration of water supply reallocation at Falls Lake. Based on this request, Headquarters granted an exception to Engineering Regulation ER 1110-2-1156, Safety of Dams – Policy and Procedures, in March 2015, to study water supply within the existing conservation storage (Attachment 2). The City of Raleigh was notified in writing of the project's DSAC and other points, as required by regulation, on May 19, 2015.

2.4 Existing (Current) Conditions and Existing Operations

The Falls Lake dam is currently operated to provide a normal pool elevation of 251.5 feet NGVD29, which is commonly referred to as the guide curve elevation. The USACE divides its reservoirs into different pools that meet the purposes of the given reservoir. Above the guide curve is the reservoir's flood storage, and below the guide curve is the conservation storage which contains the water supply and water quality storage. The capacity and elevation of these pools are specific to each reservoir and may vary by season based on historic hydrology in the area. The specific storage elevations at Falls Lake are provided in Figure 2.1.

One primary authorized project purpose of Falls Lake is flood risk reduction. This is accomplished by capturing flood waters in the 221,182 acre-feet of controlled flood storage between elevations 251.5 and 264.8 feet NGVD29, within the reservoir, and then later releasing those waters at a controlled, less-damaging rate.

As water supply is also an authorized project purpose, a contract between USACE and the City of Raleigh was signed on February 24, 1972, that allows the City to utilize the entire water supply storage, which has an estimated drought of record safe yield of approximately 64 million gallons per day (mgd) under existing basin conditions and 69 mgd under 2045 basin conditions (based on 2045 basinwide water usage, including increased interbasin transfers into the upper Neuse basin). Meeting the water supply purpose does not normally require special operations by the USACE at the reservoir, since the City of Raleigh withdraws water directly from their intake in the reservoir. During past periods of extreme drought, however, the water supply storage (and other authorized project pools) have been significantly depleted.

The water quality portion of the water conservation storage is allotted to meet the water quality purpose at and downstream of Falls Lake. Releases from the water quality storage are made to meet downstream flow targets immediately below the dam and downstream at Clayton, NC. The Falls Lake Water Control Manual provides guidance on minimum downstream flows that must be maintained throughout the year (Table 2.1). During normal conditions, releases from the reservoir are generally comparable to inflows. However, during periods of low flow, additional releases may be made through the dam to augment and maintain desired downstream flows. Multilevel water quality gates in the dam allow for the release of surface waters during times of the year when the lake is stratified (USACE 1990). During droughts, the Falls Lake Water Control Manual and Drought Contingency Plan provide direction on drought operations and how this storage would be managed whenever the water quality storage remaining drops below 80%.

2.5 Sedimentation and Sediment Storage

The rate of sedimentation within the reservoir is influenced by regional and site-specific conditions, including annual and seasonal precipitation patterns and associated stormwater runoff, as well as shoreline erosion. Sedimentation is an unavoidable problem for reservoirs like Falls Lake, due to steep banks, upstream erosion, erodible soils, and wind and wave action.

Currently, an allocation of 25,073 acre-feet below the elevation 236.5 feet NGVD29 is dedicated for sediment accumulation and storage. This volume is less than the 38,330 acre-feet originally designed for the project to accommodate the predicted sedimentation over a 100-year period (USACE 1981). However, in 1997, a sedimentation resurvey did not indicate any significant loss of storage in the sediment storage. This does not mean that sedimentation is not occurring in portions of the reservoir. There are some select areas in the reservoir that experience higher levels of sedimentation due to shoreline erosion or the pattern of sediment transport through the water. In some cases, these isolated areas of high sedimentation can hinder recreational opportunities. There is, however, no indication that sedimentation has in any way significantly impacted storage in any of the storage pools, nor caused impairment to any operational requirements.

2.6 Recreation

Falls Lake also supports recreation as an authorized project purpose; however, there are no special pool operations for recreation. Recreation opportunities are provided to the maximum extent possible without significant interference with the other purposes described above. Under normal conditions, this operation strives to provide a full conservation pool throughout the year; but, low inflow conditions, combined with seasonally increased water withdrawals/releases commonly result in seasonal drawdowns to some degree beginning in the summer, extending in the fall, and occasionally into the winter months. Additional details on lake operations are provided in the Falls Lake Water Control Manual (USACE 1990).

2.7 Fish and Wildlife Enhancement

Enhancing and protecting fish and wildlife resources *within project lands* is a congressionally-authorized project purpose at Falls Lake. As such, the condition of fish and wildlife resources is a factor in current and future management of Falls Lake. Management of fish and wildlife resources is focused on the protection of native species and the promotion of game species to support recreational fishing and hunting. Hunting and fishing is allowed throughout most of the project lands, in accordance with State and local laws. The North Carolina Wildlife Resources Commission (NCWRC) maintains game lands within the project boundary to support different game and non-game species.

A specific component of USACE's and North Carolina's commitment to enhancing fish and wildlife populations at Falls Lake is the consideration and protection of rare and endangered species and habitats. Within Durham, Granville, and Wake counties, five federally-listed species are known to exist (USFWS 2010). These species and their habitat requirements are described in Section 7 of this report – Affected Environment and Environmental Effects. Additional species of concern that are known to exist in the counties, and may occur on project lands, are also listed in Section 7 of this report.

The last survey of special status species or habitats on project lands was conducted by North Carolina Natural Heritage Program in 1986. The survey identified 13 plant species of special significance, including two populations of smooth coneflower and 13 Registered Natural Areas ranging from 0.5 to nearly 700 acres (USACE 1994).

Wetlands also occur in many of the Falls Lake natural areas and provide quality habitats for many species. In North Carolina, more than 70 percent of the species listed as endangered, threatened, or of special concern depend on wetlands for survival. Many common species of waterfowl, fish, birds, mammals, and amphibians also live in wetlands during certain stages of their lives (NCDENR 2010).

2.8 Information on Previous Allocations and Water Supply Repayment Agreements

The water storage allocation is an authorized project feature and was not accomplished after construction based on a reallocation from other project purposes. The City of Raleigh possesses the only existing water supply storage allocation within the Falls Lake project. A contract between USACE and the City of Raleigh was signed on February 24, 1972, that allowed the City to purchase storage estimated at 45,000 acre-feet within the water supply storage allotment in the reservoir, over a 50-year period. The first year of repayment was made in 1984 based on the year in which water was first withdrawn. The City has made annual payments on that allocation, which will be fully repaid in 2033. The storage volume currently allocated to water supply constitutes 42.3% of the water conservation storage, which consists of the 45,000 acre-foot water supply storage, and the 61,322 acre-foot water quality storage. Annual payments of $679,345.23 have been made each year since 1984. The final year of repayment includes a one-time payment of $3,046,776. In addition to repayment of capital costs, the City of Raleigh also pays an annual portion of project Operations, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R). The City is fully aware of its potential obligations in the future, in regards to their percentage of participation in OMRR&R.

2.9 Information on Prior Water Supply Projects Near or Upstream of Falls Lake.

Falls Lake is the largest of several Neuse River Basin reservoirs, all of which are located in the upper Neuse Basin. Besides Falls Lake and the City of Raleigh's two other smaller reservoirs (Lakes Benson and Wheeler, which will be evaluated in following sections for water supply), there are four municipal water supply reservoirs located upstream of Falls Lake on tributaries to the Neuse River. Two are owned by the City of Durham--Lake Michie on the Flat River and Little River Lake on the (upstream tributary) Little River. The latter is not to be confused with the "Little River Reservoir" considered as an alternative by the City of Raleigh. The "Little River Reservoir" alternative that has been studied involves the construction of a proposed water supply reservoir on a tributary downstream of Falls Lake also referred to as Little River. Two others are owned by the Town of Hillsborough--Lake Ben Johnston and West Fork Eno Reservoir on the Eno River. Durham's lakes are the largest of the four, with an available water supply of about 10.5 MGD for Lake Michie and 17.4 MGD for Little River Lake; however, both of these lakes are fully utilized by the City of Durham for its own water supply needs. Hillsborough's lakes are much smaller with an available water supply of only about 1.2 MGD for Lake Ben Johnston and 1.8 MGD for West Fork Eno Reservoir, with Lake Ben Johnston nearly fully utilized and West Fork Eno Reservoir mostly utilized by 2045. Therefore, from an available supply standpoint, none of these other existing in-basin water supply reservoirs are a viable option for providing additional water supply for the City of Raleigh.

3.1 REALLOCATION FEASIBILITY, INCLUDING ECONOMIC ANALYSIS.

3.2 Introduction to Plan Formulation and Evaluation of Alternatives

The planning process used for this study and detailed in this section was conducted in accordance with detailed guidance contained in the Planning Guidance Notebook (Engineer Regulation 1105-2-100) and the Corps' Water Supply Handbook. This guidance is based on the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies that were developed pursuant to Section 103 of the Water Resources Planning Act (P.L. 89-80) and Executive Order 11747, which was approved by the U.S. Water Resources Council in 1982, and by the President in 1983. A defined six-step process is used to identify and respond to problems and opportunities associated with the Federal objective, and specific state and local concerns. The six steps are as follows:

Step 1: Identify Problems and Opportunities
Step 2: Inventory and Forecast Conditions
Step 3: Formulate Alternative Plans
Step 4: Evaluate Alternative Plans
Step 5: Compare Alternative Plans
Step 6: Select Recommended plan

The process involves an orderly and systematic approach to making evaluations and decisions at each step so that the public and the decision makers can be informed of basic assumptions made, the data and information analyzed, risk and uncertainty, the reasons and rationale used, and the significant implications of each alternative plan. Alternatives were formulated and then screened, evaluated, and compared in an iterative process with increasing levels of detail at each sequence to finally identify the Recommended Plan. Although various analysis parameters may change at each sequence, within each sequence the parameters used to compare alternatives are kept identical. The process concludes with the selection of a Recommended Plan. Specific applications of the process are described in following sections of this document.

3.3 Problems and Opportunities.

The City of Raleigh and its partner agencies are faced with a serious water supply shortfall in the future, as projected population growth exceeds the ability of the City to provide adequate supply, particularly based on a lack of adequate dedicated water supply storage.

The opportunity exists to either use existing storage to provide adequate future supply for the City of Raleigh and its partner agencies, or to create new storage capacity for that eventuality.

3.4 Goals and Objectives

As outlined in the 1983 *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, the Federal objective in water resources planning is to contribute to national economic development (NED) consistent with protecting the Nation's environment. The Federal objective leads to the general overall goal of this study:

Goal

Provide a National Economic Development (NED) Plan for the provision of water supply storage to the City of Raleigh and its partner agencies, based on forecasts of future water demand over a 30-year timeframe (2016 to 2045).

Identifying and considering the problems, needs, and opportunities of the study area in the context of federal authorities, policies, and guidelines resulted in the establishment of the following specific objectives, which are all to be considered over a 30 year period of analysis:

Objectives

1. Identify the least costly water supply storage alternative for the City of Raleigh and its partner agencies that satisfies forecasted water need above existing supply, for the period 2016 to 2045.

3.5 Constraints

The planning process is subject to the limitations imposed by the following general constraints:

- Conformance to USACE policies for the project purpose.
- All applicable Federal laws, regulations, and Executive Orders.
- Current limits of knowledge, information, and predictive ability.

No other specific planning constraints have been identified for this study that would further limit the planning process. Although there are many factors that may ultimately affect the implementability of a particular alternative and be used throughout the screening process, these do not necessarily qualify as planning constraints.

3.6 Formulation and Evaluation Criteria

Alternative plans are evaluated by applying numerous, rigorous criteria. Four general criteria are considered during alternative plan screening: completeness, effectiveness, efficiency, and acceptability.

- *Completeness*: Completeness is the extent that an alternative provides and accounts for all investments and actions required to ensure the planned output is achieved. These criteria may require that an alternative consider the relationship of the plan to other public and private plans if those plans affect the outcome of the project. Completeness also includes consideration of real estate issues, O&M, monitoring, and sponsorship factors. Adaptive management plans formulated to address project uncertainties also have to be considered.
- *Effectiveness:* Effectiveness is defined as the degree to which the plan will achieve the planning objective. The plan must make a significant contribution to the problem or opportunity being addressed.
- *Efficiency*: The project must be a cost-effective means of addressing the problem or opportunity. The plan outputs cannot be produced more cost-effectively by another institution or agency.
- *Acceptability*: A plan must be acceptable to Federal, state, and local government in terms of applicable laws, regulation, and public policy. The project should have evidence of broad-based public support and be acceptable to the non-Federal cost sharing partner.

It should be noted that these criteria may not be fully evaluated at the initial stages of plan formulation in regards to evaluation of measures and preliminary alternatives, but are fully evaluated for the final array of alternatives.

There are also specific technical criteria related to engineering, economics, and the environment, which also will be considered in evaluating alternatives. These are:

Engineering Criteria:

- The design of a safe, efficient, and reliable project that incorporates best engineering principles/practices in support of an NED plan.

Economic Criteria:

- The plan must contribute benefits to National Economic Development.
- Tangible benefits of a plan must exceed economic costs.
- Each separable unit of improvement must provide benefits at least equal to costs.

Environmental Criteria:

- The plan should fully comply with all relevant environmental laws, regulations, policies, and Executive Orders.
- The plan should represent an appropriate balance between economic benefits and environmental sustainability.
- The plan should be developed in a manner that is consistent with the USACE's Environmental Operating Principles (EOPs). (see- http://www.usace.army.mil/Missions/Environmental/EnvironmentalOperating Principles.aspx)

- Adverse impacts to the environment should be avoided. In cases where adverse effects cannot be avoided, then mitigation must be provided to minimize impacts to at least a level of insignificance.

3.7 Inventory of Current and Future Conditions

The inventory of current and future conditions is located in different sections of the report and appendices, in the interest of report brevity. Current and future water availability and demand are discussed in Section 3.7. Current and future environmental conditions under the No-Action and future condition are discussed in Section 7 of this report. Discussion on current and future hydrologic conditions is in the Hydrology and Hydraulics Appendix. Discussion on current and future economic conditions in Sections 4, 5, and 6 of this report, and in the Economics Appendix.

3.8 Water Supply Demand Analysis

Water supply demand for the City of Raleigh service area was forecasted for the period 2016 through 2045 using a spreadsheet-based demand model originally developed by the City of Raleigh for their water supply planning purposes. The demand model was reviewed and revised by USACE Wilmington to ensure reasonableness, accuracy, and adequate documentation. Revision of the demand model, and addition of missing data resulted in a revised 2016-2045 volume of storage from approximately 12,500 acre-feet, to 17,300 acre-feet. The demand model was subjected to review by the USACE Water Supply and Reallocation Center of Expertise, beginning in February 2016. Following contingent approval by the Center, the model was forwarded to the Headquarters Model Review Panel for potential approval for use. Verbal approval for use was received on August 9, 2016.

The water supply demand analysis forecasted a steadily increasing need between years 2016 and 2045, culminating with a 2045 forecast average annual demand of 97.9 mgd, nearly double what actual 2015 demands were, and about 40 mgd greater than what 2015 demands would have likely been under drought conditions. This compares to Raleigh's estimated total system yield (Falls Lake storage plus its existing reservoirs on Swift Creek, a tributary to the Neuse River, near Raleigh) of approximately 84 MGD under 2045 basin conditions, indicating a 2045 water supply shortfall of about 14 MGD. Future forecast demands included shrinking per capita water need due to increased awareness of water supply concerns, increased conservation efforts, and increased water re-use on the part of all parties and partners. Details on the water demand analysis are contained in Appendix A.

3.9 Analysis of Water Supply Benefits - Part 1: Identification, Examination, and Screening of Measures (Formulation, Evaluation, Comparison, and Selection of a Plan)

Many different potential measures were initially considered for addressing the stated problem in regards to future water demand in the Raleigh service area. These measures underwent an initial screening process based on their technical viability and practicality, potential environmental impacts, and a rough order of magnitude (ROM) cost evaluation. Generally, measures were screened out at this stage if they would not be effective in adequately addressing the problem from a technical or implementability standpoint, if they would result in significant adverse environmental impacts, or if another measure could provide equivalent benefits at a significantly lower cost. Initial measures are discussed in more detail in the following subsections. Note that the discussions below are preliminary and appropriate only for this stage of the planning process. Measures that were forwarded on for further consideration undergo additional analysis as it relates to technical viability, environmental impacts, costs, and benefits in a later section of this report. In addition, a "No Action" measure at each location is always carried forward. "No Action" consists of the lack of actions to address the stated problem, and is the basis for comparison for all alternatives.

3.10 Measures and Alternatives

The following section discusses potential measures and preliminary alternatives considered for the purpose of providing adequate water supply to the City of Raleigh and partner agencies, for a projected period of thirty years following implementation (2016 through 2045).

The list of measures and preliminary alternatives contains both structural and non-structural measures. The list is comprehensive; it is not believed that any reasonable/practicable alternatives remain that are not discussed here.

Measures and preliminary alternatives presented below will be discussed and screened in an initial screening process in the following section. Feasible alternatives will then be more fully developed, discussed, evaluated, compared and contrasted, and screened to a single recommended action in a final screening process.

The following is a list of potential measures and preliminary alternatives.

1. **No-Action Plan:** The No-Action Plan is the absence of any measures undertaken to solve the water supply problem facing the City of Raleigh, North Carolina, and environs. The No-Action Plan is the basis to which each measure and alternative are compared. The No-Action Plan assumes that no means are possible to provide storage of water supply necessary to alleviate water supply shortfalls forecast over the year 2016 to 2045 period. The No-Action condition does not include use of water quality storage to make up for lack of water supply.

Population growth for the thirty-year period (as demonstrated in the Water Demand Analysis - Appendix A) is projected to result in an approximate 14 MGD shortfall under 2045 basin conditions and demands, even with implementation of additional and more significant water conservation and recycling actions.

2. **Falls Lake - Reallocation of Storage within the Conservation Storage from Water Quality to Water Supply:** This measure consists of the reallocation of storage from water quality storage to water supply storage. This measure is a reallocation of storage within the same elevation range in the reservoir currently allocated to water quality and water supply. This measure will be evaluated for a range of reallocation volumes to determine the required volume necessary to satisfy 2045 demand.

3. **Falls Lake - Seasonal or Permanent Raising of Normal Pool (reallocate storage from flood storage):** One option under this alternative would consist of seasonal-only raising of the normal (operational) pool, to create additional seasonal storage space for water supply. A second option would consist of permanently raising the normal pool by reallocation of flood control (flood risk management) storage.

4. **Falls Lake - Reallocation of Storage in Sediment Storage to Water Supply Storage:** This measure consists of the reallocation of storage from existing sediment storage to supplement water supply storage. Because water within the reservoir co-mingles, and there are no barriers to flow from one pool to another, this measure would be primarily useful during periods of drought, when this pool could supplement water supply.

5. **Falls Lake - Dredge Lake to Increase Volume:** This measure consists of dredging within the existing reservoir area to increase the volume of conservation storage available for water supply and water quality. This measure would require mechanical removal of material (sediment and/or rock) from the existing pool footprint (bottom of the reservoir), with disposal of dredged sediment off-site.

6. **Falls Lake - Raise Dam to Provide Additional Water Supply Storage:** This measure consists of raising of the operational elevation range of the flood risk management/risk management storage to a higher elevation, by structural means, to create additional storage space for water supply. This measure requires raising of the dam, potential re-design and structural modification to spillway and outlet works, enlargement of the reservoir footprint, and removal of properties along the perimeter of the reservoir, and in downstream areas. This alternative would also require Congressional approval pursuant to the Water Supply Act of 1958.

7. **Construct Middle Creek Reservoir:** This measure consists of the construction of a new dam and reservoir on Middle Creek, a tributary of Swift Creek, which flows into the Neuse River downstream of Falls Lake. This measure will be evaluated for how much storage is possible at one or more sites, as well as its potential costs, technical considerations, its "completeness" in regard to its contribution to water supply over the thirty-year period of

water supply need, and its potential effects, both environmental and societal.

8. **Construct Buffalo Creek Reservoir:** This measure consists of the construction of a new dam and reservoir on Buffalo Creek, a tributary of the Little River, which flows into the Neuse River downstream of Falls Lake. This measure will be evaluated for how much storage is possible at one or more sites, as well as its potential costs, technical considerations, its "completeness" in regard to its contribution to water supply over the thirty-year period of water supply need, and its potential effects, both environmental and societal.

9. **Obtain Additional Water Supply from Lakes Benson and Wheeler (Existing Reservoirs):** This measure consists of creating additional water storage, and thus, water supply, from Lakes Benson and Wheeler, on Swift Creek, a tributary of the Neuse River downstream of Falls Lake. These two existing dam and reservoirs, owned and operated by the City of Raleigh, would need to be raised to create additional storage. These reservoirs are currently operated for water supply purposes to supplement water supply from Falls Lake. Lake Wheeler is also used for recreation.

10. **Neuse River Intake Near Richland Creek:** This measure consists of the construction of a new raw water intake and pumping station on the Neuse River near U.S. 1 downstream of its confluence with Richland Creek.

11. **Construct Offline Storage, Neuse River at Richland Creek:** This measure expands on the Neuse River Intake Near Richland Creek by pumping water skimmed from the river during high flows to an existing quarry site. The quarry would be acquired and converted to a facility for raw water storage.

12. **Neuse River Intake Upstream of City Wastewater Treatment Plant:** This measure consists of construction of a new raw water intake and pumping station on the Neuse River directly upstream of the Neuse River Wastewater Treatment Plant.

13. **Construct Offline Storage Upstream of City Wastewater Treatment Plant:** This measure expands on the Neuse River Intake upstream of the City's Wastewater treatment plant by pumping water skimmed from the Neuse River during high flows to an existing quarry site. The quarry would have to be acquired and converted to a facility for raw water storage.

14. **Convert Existing Quarries to Reservoirs:** This measure consists of the conversion of local quarries to reservoirs, to be used for storage and subsequent release to the Neuse River or its tributaries to reduce releases from Falls Lake. The released water would be credited to the Falls Lake water supply storage. The quarries would have to be acquired and converted to raw water storage facilities.

15. **Development of Groundwater Supplies using Multiple Local Wells:** This measure consists of the development of groundwater using multiple well fields as a source of additional water supply.

16. **Development of Groundwater Supplies by Aquifer Storage and Recovery (ASR):** This measure consists of injecting treated water into an aquifer for later recovery as water supply. During off-peak demand periods excess water would be treated and transferred to the aquifer then extracted when needed to augment the existing water supply.

17. **Development of Groundwater Supplies by using PCS Phosphate-owned Pumped Groundwater:** This measure consists of using ground water pumped by the PCS Phosphate Mining operation, from the Castle Hayne aquifer, for supplemental water supply. The water would have to be purchased from the privately held Eagle Water Resources, as they purchased the rights to the groundwater from PCS Phosphate. This option would reclaim groundwater currently being discharged to the Pamlico River to facilitate the mining operation. The ground water would be treated and pumped approximately 130 miles from Aurora, NC through seven (7) counties for delivery to Raleigh's water distribution system.

18. **Reallocation from John H. Kerr Dam and Reservoir:** This measure consists of potential reallocation of storage in the Corps' existing John H. Kerr Dam and Reservoir project to supplement water supply to the City of Raleigh and associated communities. The Kerr Reservoir project is located in the Roanoke River basin, north of the Neuse River basin, along the Virginia-North Carolina state line (i.e., in a separate river basin).

19. **Obtain Allocation from Jordan Lake:** This measure consists of the potential to provide water supply from the Corps' existing Jordan Dam and Lake (reservoir) on the Haw River, a tributary of the Cape Fear River in the Cape Fear River basin (i.e., in a separate river basin). The reservoir currently serves as the primary water supply for the Towns of Cary, Apex, and Morrisville, and also serves a portion of Chatham County.

20. **Purchase Water from Existing Systems:** This measure consists of use of water from the interconnected water distribution system connecting Wake County to other counties as a source of supplemental water supply for at least portions of Wake County.

21. **Wastewater Reuse from City Wastewater Treatment Plant:** This measure consists of reuse of wastewater from the existing City Wastewater Treatment Plant for the purposes of supplemental water supply.

22. **Water Conservation/Efficiency Measures:** This measure consists of implementation of various water conservation/efficiency measures within the service area, to lessen current and future water need.

3.11 Analysis of Water Supply Benefits - Part 2: Evaluation of Water Supply Measures and Preliminary Alternatives

This section assesses each of the preliminary alternatives, laid out in the previous section, for their ability to provide adequate water supply to the City of Raleigh and partner communities for a projected period of thirty years following implementation (2016 through 2045). Those alternatives that have the capacity to meet the projected demand will also be assessed for their technically viability, environmentally acceptability, and cost-effectiveness to determine if they should be carried forward for further review.

1. **No-Action Plan:** The No-Action Plan is the absence of any measures undertaken to solve the water resource problem facing the City of Raleigh, North Carolina, and environs. Population growth for the thirty-year period as presented in Appendix A is projected to result in a need for approximately 14 MGD of additional water supply by the year 2045, even with implementation of additional and more significant water conservation and recycling actions. Failure to address water supply shortfalls would have significant negative economic, community, and potentially biological effects. This measure has the potential to seriously affect population growth, maintenance of property values, and quality of life for those affected. This measure is technically viable as there is no construction or new infrastructure required for its implementation.

This measure is unacceptable as it does not meet the projected demand and due to its negative impacts to the communities and inhabitants, and economic well-being. However, this alternative will be carried forward in the analysis for comparative purposes and to satisfy Corps of Engineers planning policies.

2. **Falls Lake - Reallocation of Storage within the Conservation Storage from Water Quality to Water Supply:** Falls Lake Conservation Storage serves two of the authorized purposes of the Falls Lake Project; it supplies drinking water for the City (from the Falls Lake Water Supply Storage), and it is used to meet minimum flow requirements below the dam (from Falls Lake Water Quality Storage). This measure consists of the reallocation of storage from

Falls Lake Water Quality Storage to Falls Lake Water Supply Storage, which would provide the City with the required operational yield to meet anticipated demands.

Falls Lake Water Supply Storage is one of two water sources currently used by the City to meet its water demands, and has been estimated to provide a drought of record safe yield of 69 mgd under 2045 basin conditions. The City's other sources of water are Lake Benson and Lake Wheeler in the Swift Creek basin which provide a yield of about 14 MGD during the Falls Lake drought of record. (The drought of record yield for these Swift Creek basin reservoirs is actually closer to 11 MGD; however, its drought of record is not the same as the drought of record for Falls). Accounting for consumptive use the City returns approximately 85% of the water withdrawn from these Neuse River basin source waters to the Neuse River via the Neuse River Wastewater Treatment Plant (NRWWTP).

Analysis of water demand conducted during this phase of study (Appendix A), indicated a projected shortfall by year 2045 of about 14 MGD, which modeling indicates can be met by an additional 17,300 acre-feet of water supply storage in Falls Lake under 2045 basin conditions. This alternative could provide all of that storage shortfall.

The relative location of Falls Lake, the City of Raleigh service area (City of Raleigh Public Utilities District (CORPUD)), the Neuse River Waste Water Treatment Plant (NRWWTP), the USGS gage near Clayton, river flow direction, and withdrawal and return locations are illustrated in Figure 3.1. The minimum release from the dam and the flow target at the Clayton gage are noted in the figure as well. It was recognized that, as the City grows and water demands increase, its wastewater return at the NRWWTP will increase too. The increased wastewater return flows will reduce the burden of meeting the Clayton gage target placed on the Falls Lake Water Quality Pool (FLWQP), (i.e., less water will need to be released from Falls to meet the Clayton target) . By reallocating 17,300 acre-feet (16.4% of the total conservation storage volume, or 28.4% of the current FLWQP volume) from the FLWQP to the FLWSP, and adjusting the inflow apportionment accordingly, the City can expect to meet 2045 system demand of 97.9 MGD during the drought of record conditions.

The reallocation of storage does not require the construction of a new reservoir and minimizes the need for additional infrastructure. The additional wastewater the City is expected to produce as its demand grows would mitigate for much of the lost storage in the FLWQP. Modeling shows that the smaller FLWQP would remain capable of meeting both the minimum release and the Clayton Gage target under all historical conditions.

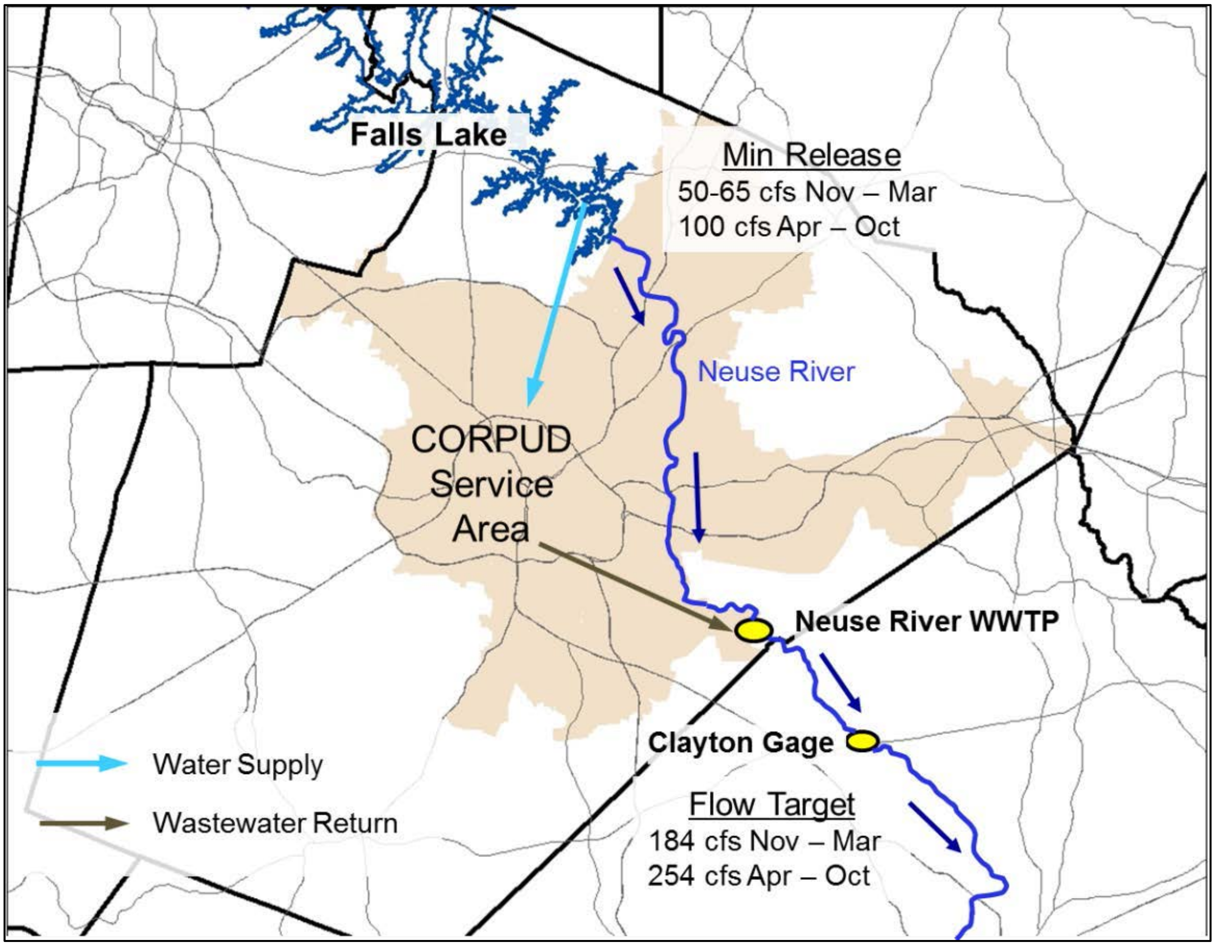


Figure 3.1 - Schematic of Features between Falls Lake and Clayton, NC

CORPUD = City of Raleigh Public Utilities District

This measure appears to be the least cost and have the least environmental impact of the water supply expansion measures available. However, there is some concern by those upstream of the lake that a Falls Lake Reallocation could potentially impact Falls Lake water quality and impede the ability to comply with the Falls Lake Nutrient Management Strategy and Rules.

The reach of the Neuse River between Falls Lake dam and the NRWWTP has a minimum flow regime (noted in Figure 3.1) that would be protected, but this section of the river could experience marginally lower flows, on average, as less water is required from the FLWQP to meet the Clayton Gage target. Nevertheless, the target flows below the dam and at the Clayton Gage can be met under all historical hydrologic conditions.

This measure is technically feasible, meets the projected demand, and is believed to be the least environmentally damaging practical alternative. Consequently, this alternative was carried forward in the analysis for comparative purposes and to satisfy United States Army Corps of Engineers planning policies.

3. **Falls Lake – Seasonal or Permanent Raising of Normal Pool:** (**Reallocation from Flood Storage to Water Supply Storage**): This measure consists of seasonal or permanent raising of the normal (operational) elevation of the conservation storage to create additional storage space for water supply.

Use of the flood risk management storage as a water supply storage option presents numerous difficulties, including: 1) The project has a Dam Safety Action Classification (DSAC) rating of DSAC III, based on potential consequences of failure. Use of flood control storage could result in consequences that include risks to life and safety caused by lack of sufficient storage in the flood pool to properly manage downstream floodflows; 2) The lack of accurate risk-based decision-making criteria required to judge trade-offs between lowered flood storage versus added water supply; 3) The need to provide water supply in storage during the season most likely to fill flood storage (i.e., hurricane season), and 4) the fact that flood storage shortages identified earlier have resulted in an almost 10% reduction in flood storage from that intended. Due to development in the floodplain downstream of Falls Lake, some of which is close to the boundaries of the FEMA 1% chance regulatory floodplain, this option is also not a sound alternative in terms of potentially increasing the number of households paying flood insurance premiums. This alternative possesses considerably more risk than the considerably less risky use of water conservation storage. For these reasons, this alternative was not carried forward for further analysis.

4. **Falls Lake – Reallocation of Storage in Sediment Storage to Water Supply Storage:** This measure consists of the reallocation of storage from existing sediment storage to supplement the water supply storage. Sedimentation is a naturally occurring process in any reservoir and results in the loss of reservoir storage over time. Without dedicated sedimentation storage, sedimentation would diminish the conservation and flood storage over the life of the project, impacting the ability of the project to meet its authorized purposes. Based on sedimentation surveys done to date, the current sediment storage volume of 25,073 acre-feet appears to be more than adequate for the purposes of sediment storage for Falls Lake.

Temporary reallocation of sediment storage to water supply was considered for Falls Lake during the drought of 2007-08. While permanent reallocation from existing sediment storage to water supply storage is not prohibited, it is generally not considered to be a practical long-term storage option. While previous surveys indicate perhaps a surplus of sediment storage, an updated, detailed lake survey to verify/update available storage and sedimentation rates would also be necessary.

With additional survey and technical analysis, this measure is technically and environmentally feasible, and could be a cost-effective means of providing additional water supply in the longer term future. However, given that the sediment storage volume will diminish over time and need to be replaced with another measure, this alternative will not be carried forward for further evaluation within this study. This alternative may prove to be a cost-effective, environmentally-sound, and technically viable alternative in the future, should augmentation of local water supply prove necessary.

5. **Falls Lake - Dredge Lake to Increase Volume:** This measure consists of dredging within the existing reservoir area to increase the volume of storage available within the water supply (water conservation) storage. This measure would require mechanical removal of native material (sediment and/or rock), from the existing storage footprint (bottom of the reservoir), with disposal off-site.

The amount of additional storage needed to provide the required safe yield to meet future demand (at year 2045) is 17,300 acre-feet. Using the sediment accumulation rate of 0.33 acre-feet per square mile of drainage area per year the loss of reservoir storage due to sedimentation in Falls Lake to date is estimated at 8,639 acre-feet. Thus to obtain the required volume a total of 26,039 acre-feet would need to be excavated.

Dredging of Falls Lake would require either mechanical or hydraulic dredging. Mechanical excavation from a barge platform would require the use of an excavator or a crane with a clamshell bucket. The barge would be moved into place and excavated material stored on the barge until it would be towed to shore for material off-loading and off-site disposal. Hydraulic dredging involves pumping sediment and water directly from the lake bottom to an off-site location from the work barge. Dredging would involve construction of one or more temporary drying beds onshore, where the sediment, typically 15-40% of the total volume of dredged/pumped slurry, is allowed to settle. This process generally takes four or more weeks, depending on weather conditions and the composition of sediment. After drying, the sediment is either hauled off by dump truck for disposal in a landfill, or to be spread on land, where available.

Dredging costs vary depending on the lake's bed material, the complexity of the work, availability of a spoils site, and disposal costs for the soil. Assuming an average cost of $17 per cubic yard for hydraulic dredging, the total cost to dredge the 26,039 acre-feet (~42 million cubic yards) would be approximately $714 million. The actual cost is likely to be higher due to the presence of underlying bedrock and coarse soils that would require mechanical dredging to remove.

This measure may be technically feasible and may be environmentally acceptable, although additional survey and technical analysis would need to be performed; however it was determined to not be cost-effective compared to other alternatives, and therefore was not carried forward for additional evaluation.

6. **Falls Lake - Raise Dam to Provide Additional Water Supply Storage:** This measure consists of raising of the normal (operational) elevation of the flood risk management/risk management storage to a higher elevation, by structural means, to create additional storage space for water supply. Implementation of this measure requires raising the dam, re-

designing and structural modifying the spillway and outlet works, raising the raw water intake, enlarging the reservoir footprint, constructing additional slope protection along roadways, and removing properties along the perimeter of the reservoir (to include recreational areas), and in downstream areas. It would also require additional real estate and potentially additional flowage easements in some areas. This measure may create negative impacts to flood risk reduction in downstream areas and around the perimeter of the reservoir, and would therefore, require additional study to offset potential effects, and to understand the level of risk increase (losses to flood risk reduction) created by that action.

Structural modifications to the dam and associated structures would require Congressional approval, pursuant to the Water Supply Act of 1958 (43 U.S.C. 390b; P.L. 85-500), as amended. Given that structural modifications were previously undertaken at Falls Lake dam to address the water storage shortage discovered shortly after Falls Lake went into operation, and the fact that Falls Lake dam is rated a DSAC III dam, this alternative would require very costly study, and potentially extremely costly structural modifications to the Dam, to ensure integrity of the project under higher storage conditions. It would require raising and enlarging the spillway, raising of the embankment, additional and costly real estate acquisitions, and potential relocation of works. Cost of required additional engineering studies and design, along with the construction costs, would be extremely cost-prohibitive compared with the reallocation alternatives on Falls Lake that utilize the existing water conservation storage. Given that there are more cost-effective and practicable means of obtaining water from Falls Lake this measure was not carried forward for further evaluation.

7. **Construct Little River Reservoir:** This measure consists of construction of a new dam and reservoir on the Little River, a tributary of the Neuse River downstream of Falls Lake. The City of Raleigh's long range water resource plan has been tied extensively to the construction of a new reservoir on the Little River. In 1971 a Wake County water and wastewater engineering study (Moore/Gardner, Edwards, Piatt and Wooten Engineers Task Force) identified the Little River as a possible site for a proposed water supply reservoir in eastern Wake County.

The Little River dam and reservoir would be located near the Towns of Wendell and Zebulon, approximately 15 miles east of the City of Raleigh. The normal pool elevation for the proposed reservoir would be 260 feet mean sea level (NGVD29). The proposed reservoir would impound approximately 3.7 billion gallons, which, after adjustments for sedimentation, other losses, and minimum downstream release, would be adequate for the long-term water supply need identified.

The Little River watershed above the proposed dam site encompasses approximately 52.6 square miles of predominantly rural and agricultural land. The watershed is located in the jurisdictions of Wake and Franklin Counties, and includes parts of the Towns of Rolesville and Zebulon. The reservoir would be entirely within Wake County. Regulations are currently in place in these jurisdictions governing density limits, impervious surface limits, runoff control measures, stream and impoundment buffers, retention pond maintenance responsibility, nonresidential uses permitted, and street drainage design. The current WS-II classification (per State of North Carolina Surface Water Classification Program, Water Supply II - Undeveloped) is a key factor that makes this site particularly suitable for water supply development.

This measure would also include a water intake, pumping station, and a water treatment plant with a capacity of 20 mgd. A finished water transmission main would convey treated water to an existing water main at N.C. 97, for distribution to the water systems of the Towns of Knightdale, Wendell and Zebulon, as well as the City of Raleigh and the other municipalities whose utility systems have been merged with the City of Raleigh utility systems.

Studies performed by the City of Raleigh on a potential reservoir on the Little River demonstrate its engineering (technical) feasibility. However, this measure would require considerable environmental mitigation to offset the impacts of inundating 572 acres of wetlands and 7.2 miles of streams. Preliminary cost estimates for this alternative indicate its cost, including potential environmental mitigation, would be in excess of $300 million, making it potentially less cost-effective than other alternatives such as reallocations within the existing Falls Lake project.

While this alternative would have greater environmental impacts and is anticipated to be more expensive than many of the other viable alternatives, it would provide enhanced reliability to the City's water supply system by reducing its degree of dependence on Falls Lake, and thereby mitigate the risk of a shortage if Falls Lake were to be rendered unusable. Together, the Little River Reservoir (13.7 MGD) and the Lake Benson and Wheeler system (11.2 MGD) would be able to provide approximately 28% of the City's total drought of record safe yield, whereas the Lake Benson and Wheeler system alone can only provide 13%.

While there are significant potential environmental impacts and high economic costs associated with this measure, it was carried forward for further evaluation for the following reasons: 1) the resource is in a designated water-supply watershed and should provide a high quality water, 2) this new source of water storage would provide redundancy for the City, and 3) the City has acquired all of the property required to proceed with this alternative. It is worth noting that this alternative was initially the City's preferred alternative, and that while this reservoir is not currently the City's preferred alternative it is still considered to be viable as a longer-term option. This alternative is the next least-costly alternative to reallocation of Falls Lake water conservation storage.

8. **Construct Middle Creek Reservoir:** This measure consists of the construction of a new dam and reservoir on Middle Creek as shown on Figure 3.2. Middle Creek, a tributary of Swift Creek, is located in southern Wake County and northern Johnston County. Middle Creek flows into Swift Creek near its confluence with the Neuse River just west of Smithfield. Although undeveloped at this time, analyses indicate that the potential exists for a water supply reservoir located in its lower reaches, near the Wake-Johnston County border. The Middle Creek alternative would involve construction of a dam and reservoir just upstream of NC 50 in Johnston County. It is estimated that this site would have a drainage area of approximately 82 square miles, and impound approximately 10,700 acre-feet (3.5 billion gallons) of water. Raw water would be pumped from a new raw water pump station located at the reservoir through an approximately 7-mile long raw water transmission main to the D.E. Benton WTP. The D.E. Benton WTP would also need to be expanded for this alternative.

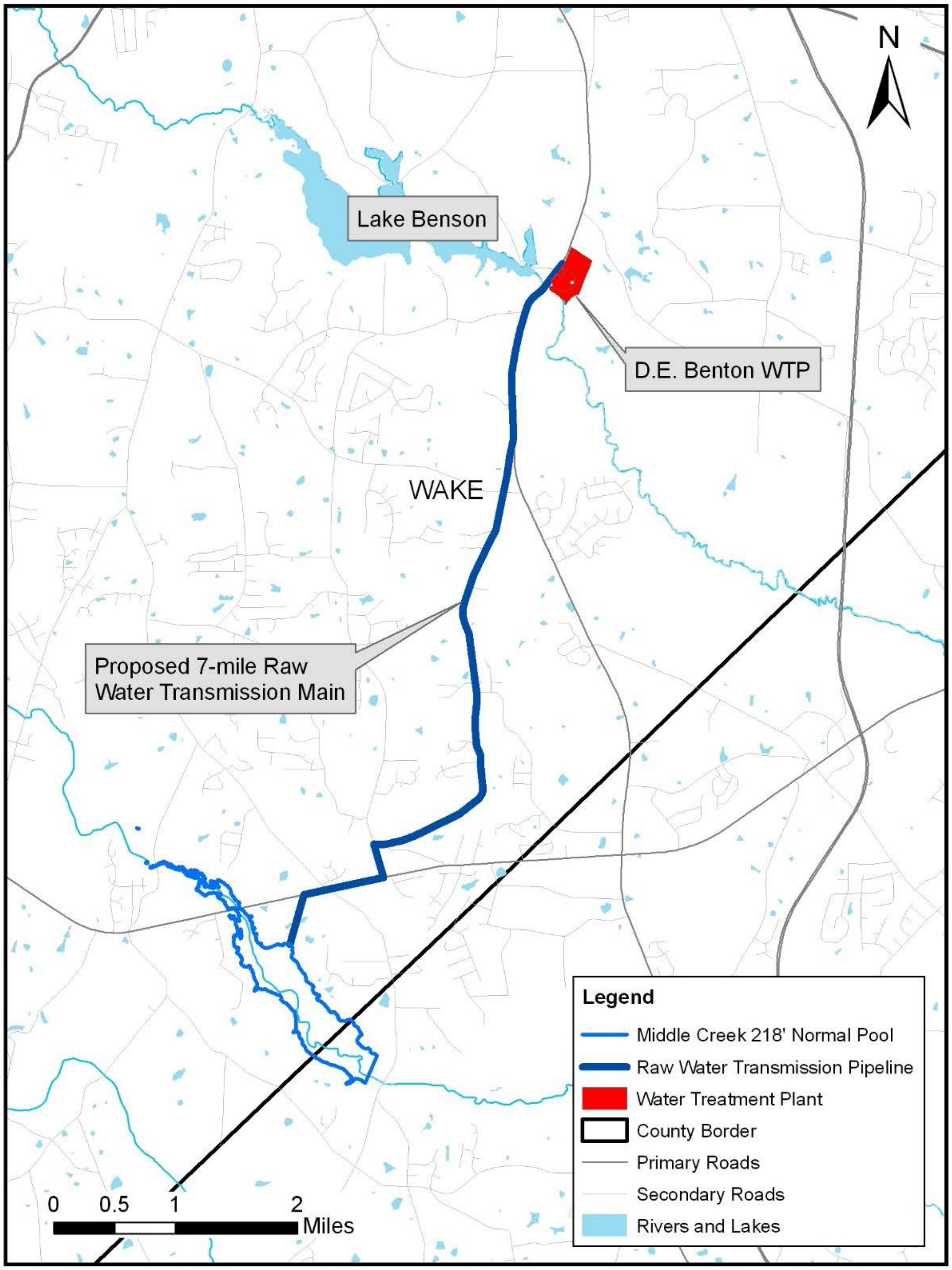


Figure 3.2 - Middle Creek Reservoir

The Apex Water Reclamation Facility and the Town of Cary's South Cary Water Reclamation Facility discharge to Middle Creek. Existing permitted capacity for these plants are 3.6 mgd and 12.8 mgd, respectively. Fuquay-Varina also operates the 1.0-mgd Terrible Creek Wastewater Treatment Plant, which discharges to the Middle Creek basin. This facility is currently being expanded to 6 mgd.

Developing Middle Creek as a water supply and associated permitting will likely prove to be extremely difficult due to the presence of the federally endangered dwarf wedgemussel and several other state and federally-listed species. Some additional obstacles to implementing this alternative include property acquisition, stream and wetland mitigation, and road and bridge relocations. Approximately 560 acres would be inundated, and 1,000 linear feet of state highways and 850 linear feet of secondary roads would be impacted. Existing and anticipated future wastewater discharges make this alternative less desirable from a water quality standpoint. Use of this source would involve acquisition of considerable land area for a reservoir, which would be difficult in what has become an increasingly popular residential area (CH2M Hill, 1998).

This alternative is similar to the Little River Reservoir measure, but more difficult to implement as it requires extensive property acquisitions, has significant impacts to existing roadways, would require establishing a water supply watershed classification (an extremely difficult and perhaps impossible goal), and requires permitting a dam site in Johnston County. This alternative may also not meet projected future demand in and of itself. These difficulties make implementation of this measure unlikely. Due to its similarity to the Little River Reservoir alternative and less favorable circumstances, this measure was not carried forward for further evaluation.

9. **Construct Buffalo Creek Reservoir:** This measure consists of the construction of a new dam and reservoir on the Buffalo Creek. Buffalo Creek is a tributary of the Little River and is located in eastern Wake and Johnston Counties. The Buffalo Creek system is not developed at present, and previous analyses by the City of Raleigh indicate that the potential exists for a water supply reservoir at two locations, one near the Wake-Johnston County border and one just upstream of its confluence with the Little River in Johnston County. The 50-year safe yield is estimated by the City to be approximately 5.4 mgd for the upstream site and 7.2 mgd for the downstream site based on initial evaluations. Construction of the reservoir is expected to cost approximately $300 million.

This measure is technically feasible, but is not likely to be permitted given its location in Johnston County, the number of residents that would have to be relocated, and extensive property acquisitions that would be required. This alternative may also not meet projected future water demand by itself, and would also require establishing a water supply watershed classification. These difficulties make implementation of this measure unlikely, and given its similarity to the Little River Reservoir alternative and less favorable circumstances, this measure was not carried forward for further evaluation.

10. **Obtain Additional Water Supply from Lakes Benson and Wheeler (Swift Creek System):** Lake Wheeler and Lake Benson are located south of Raleigh in Wake County and together make up Raleigh's Swift Creek Water Supply source. Lake Benson served as the principal water supply

for the City of Raleigh until 1986, when construction of the E.M. Johnson WTP at Falls Lake was completed and the former E.B. Bain WTP was taken out of service. The City of Raleigh constructed the D.E. Benton WTP east of NC 50 adjacent to Lake Benson in 2010, and is currently using the Swift Creek system to supplement the water supply from Falls Lake (Figure 3.3).

Lake Wheeler was constructed in 1956 and is located approximately seven miles west of downtown Raleigh. It has a drainage area of approximately 35 square miles. The concrete spillway consists of a triangular crest section with a length of 150 feet. At normal pool, the reservoir impounds approximately 6,410 acre-feet (2.1 billion gallons) of water, covering approximately 524 acres.

Lake Benson is located approximately five miles downstream from Lake Wheeler and was constructed in 1953. The earthen dam has a concrete ogee spillway with a length of 200 feet. At normal pool the reservoir impounds approximately 2,150 acre-feet (0.7 billion gallons) of water, covering approximately 402 acres. The total drainage area for Lake Benson is approximately 66 square miles, which includes the drainage area for Lake Wheeler (Hazen and Sawyer, 1987). The estimated drought of record safe yield of the Swift Creek system, including Lake Wheeler and Lake Benson, is approximately 11.2 mgd.

This measure involves raising the normal pool elevation at both Lake Benson and Lake Wheeler by over 14 feet and could provide a safe-yield of approximately 14 mgd. This would involve constructing new dams at Lake Wheeler and Lake Benson, since raising the normal pool elevation at the existing facilities is not practicable. Diversion of Swift Creek and dam construction would be challenging aspects of this project since both Lake Wheeler and Lake Benson are flanked to the east by major roadways (US 401 and NC 50, respectively). In addition, the construction of a new dam at Lake Benson is anticipated to pose engineering challenges due to the close downstream proximity of the D.E. Benton WTP.

This measure would also involve the expansion of the raw water pump station at Lake Benson, installation of a parallel raw water main to the D.E. Benton WTP, and a 20 mgd expansion of the D.E. Benton WTP.

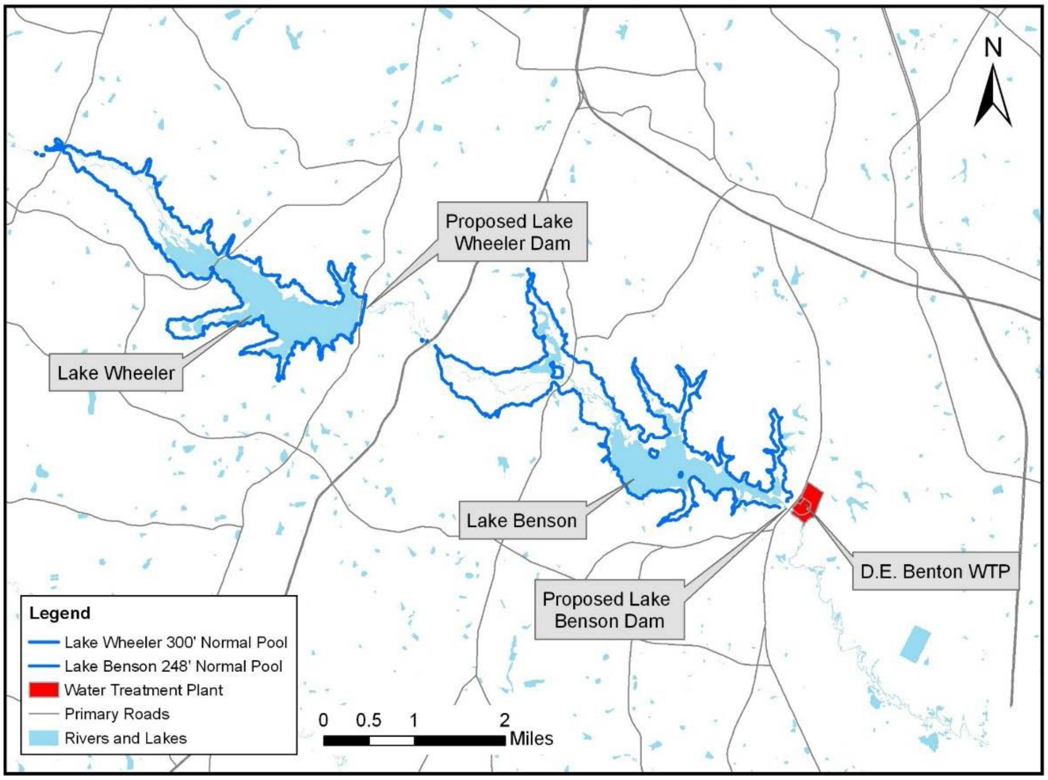


Figure 3.3 - Raising of the Dams at Lake Wheeler and Lake Benson

Some additional considerations for this measure include property acquisition, as both lakes are surrounded by residential communities and parks; stream and wetland mitigation; road and bridge modifications or relocations; and impacts to existing railroad lines (in the case of Lake Benson). At least 500 households, one business, and two parks would be impacted, as well as 14,800 linear feet of state highways, 7,100 linear feet of secondary roads, and 7,400 linear feet of railroad. A total of 2,148 acres of additional property would be inundated.

Finally, further development of the Swift Creek system as a water supply and associated permitting will likely prove to be extremely difficult due to the presence in Swift Creek downstream of Lake Benson of the federally endangered dwarf wedgemussel and several other federally-listed species. Together, these considerations create sufficient concern with this alternative that its implementation is highly unlikely. Consequently, this measure was not carried forward for further evaluation.

11. **Neuse River Intake Near Richland Creek:** This measure consists of construction of a new raw water intake and pumping station on the Neuse River near U.S. 1 downstream of its confluence with Richland Creek, installation of a 3.5-mile raw water transmission main from the proposed intake to the E.M. Johnson WTP, and expansion of the E.M. Johnson WTP. Operation of the new intake would involve pumping from the intake to the E.M. Johnson WTP when the Falls Lake level is less than or equal to an elevation of 251.0 feet (NGVD29), or 0.5 feet below the top of the conservation storage. During these conditions, raw water would be pumped at a

continuous fixed rate of approximately 21 mgd. Pumping is expected to occur on average two times per year, with the frequency of pumping being greater during drought years. When the Falls Lake level is above the elevation of 251.0 feet (NGVD29), raw water would be pumped from Falls Lake to the E.M. Johnson WTP, and no water would be pumped from the new intake. Releases from Falls Lake would be provided to maintain the current target minimum average daily flows directly below the dam of 50-65 cfs or 100 cfs, depending on the time of the year.

This measure would provide a yield adequate for the long-term water supply need identified. However, this alternative would reduce the minimum water quality pool level within Falls Lake during drought conditions. Previous modeling by the City of Raleigh indicates that this alternative would have reduced the minimum water quality storage during the 2007 drought from about 23 percent to about 11 percent of full capacity. This would mean that there would be less water available in the water quality storage during drought conditions to supply additional water as needed for downstream water quality, and there would be a reduction in streamflow from the new intake to the City of Raleigh's Neuse River WWTP.

The Neuse River at the location of the proposed intake is currently classified as WS-IV, Nutrient Sensitive Waters (NSW), Critical Area (CA). The Neuse River from this location to the Falls Lake dam was reclassified for water supply in 2004 in conjunction with a request by Wake Forest to withdraw raw water from the former water supply intake for the Burlington Industries Wake Finishing Plant. As a result of the merger of Wake Forest's utility system with Raleigh's utility system, the Town of Wake Forest discontinued its pursuit of a new intake from the Neuse River. Franklin County has an agreement with Riverplace, LLC, the current owner of the Burlington Industries intake, for reactivation of the intake. Franklin County plans to construct a treatment plant with an initial capacity of 3.5 mgd, and a maximum capacity of 7 mgd, for treatment of raw water from this source to supply finished water to the Franklin County distribution system.

Based on the fact that this alternative would cause a significant reduction in the minimum water quality storage volume during drought conditions, it would be considered a reallocation, and would therefore be similar to the reallocation of storage in the conservation storage to the water supply storage (Alternative 2). Since it would involve more cost for the same yield as Alternative 2, it is not considered a feasible alternative, and was not carried forward.

12. **Construct Offline Storage, Neuse River at Richland Creek:** This measure consists of construction of a new raw water intake and pumping station on the Neuse River near Richland Creek, in the same location as Alternative 11, but pumping to an existing quarry site (Figure 3.4), which would have to be acquired and converted to a facility for raw water storage. This

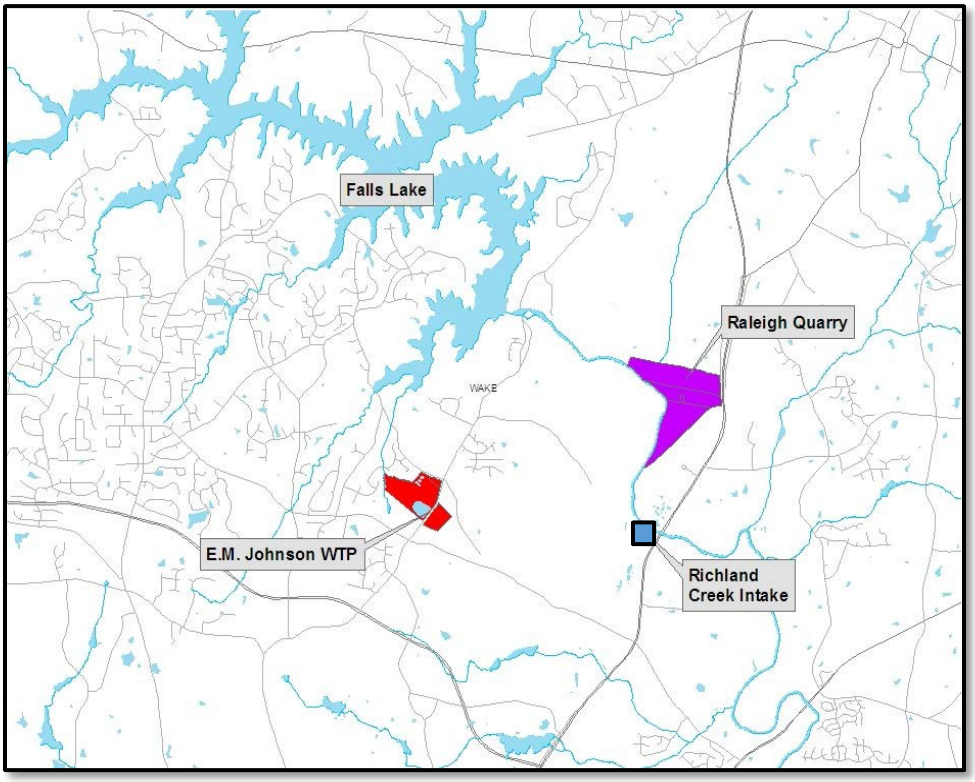


Figure 3.4 - Neuse River Intake with Offline Storage at Raleigh Quarry

alternative involves the construction of a new raw water intake and pumping station on the Neuse River near its confluence with Richland Creek. The existing Raleigh Quarry is adjacent to the Neuse River near Richland Creek. The quarry would be filled/refilled when the Falls Lake level is above the guide curve elevation of 251.5 feet (NGVD29), and the USACE is releasing water from the dam at a rate exceeding the minimum release. Water would be pumped from the intake to the quarry at a rate of up to 50 mgd to refill the quarry. There is little intervening drainage area between the dam and the proposed intake location and it is assumed that maintaining a flow rate below the intake equivalent to the Falls Lake minimum release would be sufficient.

Utilization of the quarry's storage would involve pumping from the quarry to the E.M. Johnson WTP when the Falls Lake level is less than an elevation of 251.0 feet (NGVD29), or 0.5 feet below the top of the conservation storage. During these conditions, raw water would be withdrawn from the quarry and pumped to the E.M. Johnson WTP at a rate of approximately 15 mgd to slow the rate of drawdown of the Falls Lake water supply storage.

At the current estimated usable volume of the quarry, which is about 3 billion gallons (BG) (Figure 3.5), the additional yield expected is on the order of 8 mgd. However, the quarry continues to be mined and the terminal volume of the pit is expected to be about 8 BG. The time frame for completion of quarrying is inexact, but is currently estimated to be 40 to 60 years and therefore, would not be available for use as a water supply facility within the planning period being addressed by this reallocation study. The addition of adjacent land parcels could extend the life of the quarry beyond the already lengthy time horizon suggested. Another possible obstacle to utilizing this source would be the potential pursuit by Duke Energy for quarries across North Carolina for the purpose of coal ash disposal. Storage of coal ash in all or part of the Raleigh Quarry would likely render the site unsuitable for water supply purposes in perpetuity.

In addition to not being able to meet the projected demand in quantity or within the planning study timeframe, this alternative is also cost prohibitive. The quarry is actively mined and with an estimated remaining aggregate volume of 4.6 billion gallons would cost approximately $350 million to purchase (Assumes an aggregate cost of $10/ton, a density of 165 pounds per cubic foot).

While currently not cost-effective, it is technically plausible and potentially environmentally sound. For these reasons this alternative was carried forward for limited further evaluation.

13. **Neuse River Intake Upstream of City of Raleigh's Wastewater Treatment Plant:** This measure consists of construction of a new raw water intake and pumping station on the Neuse River directly upstream of the City of Raleigh's Neuse River Wastewater Treatment Plant (Figure 3.5). This alternative involves siting a new intake along the Neuse River, building a 11.5-mile raw water transmission line to the existing D.E. Benton WTP, and expanding the D.E. Benton WTP from its current 20 mgd capacity to 40 mgd. Locating a new run-of-river intake along the Neuse River just upstream of the Neuse River WWTP offers several advantages over other sites along the river in Wake County, including (1) it provides the ability to utilize an additional drainage area of over 320 square miles below Falls Lake, (2) the City owns the property at the site, and (3) it is upstream of the City's principal wastewater discharge. The intake would require a new pump station and raw water transmission line to move raw water to the D.E. Benton WTP. The withdrawal rate would range as high as 40 mgd.

This alternative has two options, each with the same infrastructure but different operational protocols, dependent upon whether or not an impact on the Falls Lake water quality storage is involved. Option 13a assumes a modest impact on the water quality storage is allowed, while Option 13b assumes no impacts.

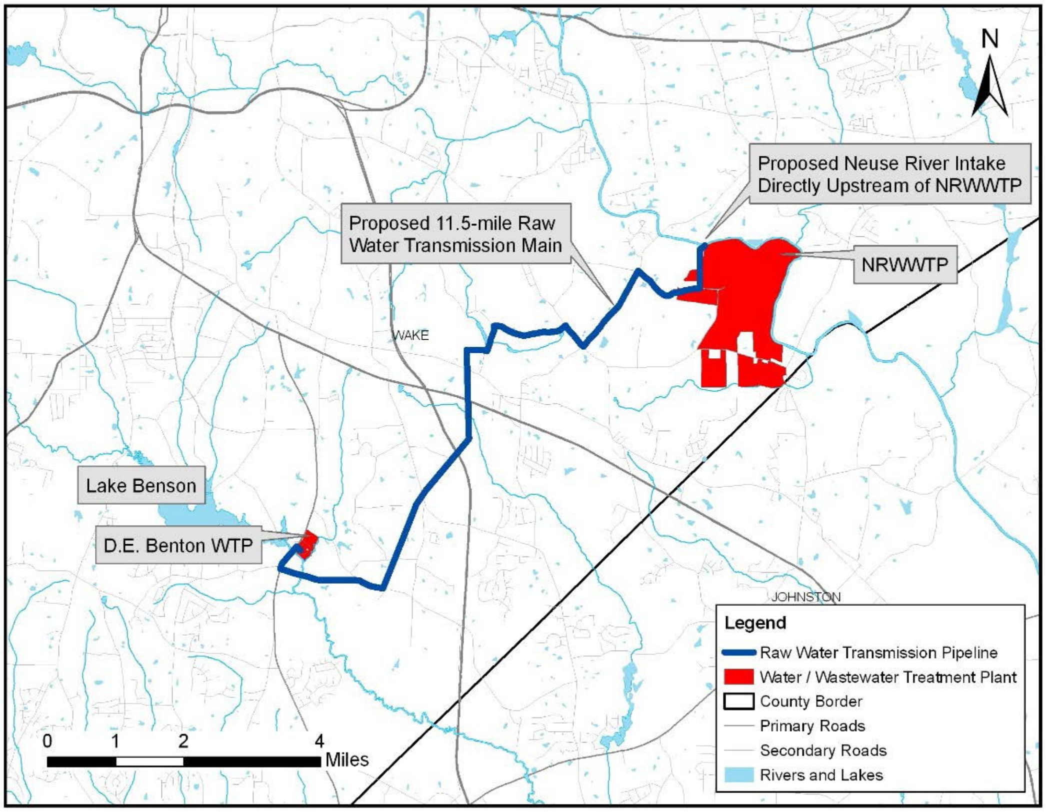


Figure 3.5 - Neuse River Intake Above the NRWWTP

Option 13a – Neuse River Intake Upstream of NRWWTP – Some Impact on Falls Lake Water Quality Storage Allowed: This option would involve continuous operation of the intake during dry conditions. An assumption inherent in all of the Neuse River options is that the flow target at the Clayton gage would continue to be met at all times. Most of the time the minimum release from Falls Lake and the runoff from the intervening drainage area below Falls Lake (including the City's wastewater discharge) is sufficient to meet the Clayton gage flow target. However, during low flow conditions additional releases from Falls Lake Dam would be necessary to accommodate the withdrawal from the river and still provide sufficient flow in the river to meet the Clayton flow target. As a result, water quality storage would be impacted by this option—for example, modeling by the City of Raleigh indicates that during the 2007 drought, the minimum water quality storage would have been about 7 percent under the operational scenario described above. This option would maximize the water supply available for this alternative but would impact the Falls Lake water quality storage. As a result, this option would also be considered a reallocation.

Option 13b – Neuse River Intake Upstream of NRWWTP – No Impact on Falls Lake Water Quality Storage Allowed: This option involves similar infrastructure to that for Option 13a. The main difference between the two options is in the operation of the intake, which would be operated intermittently instead of continuously. Under this scenario, no additional release would need to be made from the Falls Lake water quality storage to accommodate the operation of the intake, and compliance with the downstream Clayton gage flow target would also be maintained. During low flow periods, the withdrawal from the Neuse River Intake would be curtailed, or cease entirely. As a result, the D.E. Benton WTP would not be able to operate continuously at 40 mgd under all conditions, and redundant water treatment capacity would need to be provided at the E.M. Johnson WTP or another WTP serving the City and its merger partners. It is also possible that the City's finished water distribution system would require additional upgrades as compared to Option 13a to provide the flexibility to accommodate passage of finished water that may arrive from the D.E. Benton WTP one day and the E.M. Johnson WTP the next day. The redundant WTP capacity and possible upgrades to the distribution system for Option 13b is the only difference in infrastructure required for Option 13b. Under these optimal constraints, this option could only provide an additional 13 mgd of yield, and would therefore not meet the project need.

Based on previous modeling by the City of Raleigh, the intake would be required to shut down on about 10 percent of the days in the period of record (which includes drought periods), could withdraw more than 5 mgd on 89 percent of days, and more than 20 mgd on 83 percent of the days, while having no impact on the Falls Lake water quality storage. The operation of the Neuse River intake in this manner, without assuming any additional off-stream storage or supplemental supply to the D.E. Benton WTP, would not provide a yield approximately equal to the long-term water supply need identified.

Water Quality Reclassification: The water quality classification of the Neuse River from Falls Lake to the proposed intake is C, Nutrient Sensitive Waters (NSW), and a portion of this reach would require reclassification to WS-IV as shown in Figure 3.6., below. The watershed classification would impact over a third of Raleigh, including much of Raleigh's downtown; a quarter of Garner; and approximately half of Knightdale**.** Furthermore, it is estimated that the water supply watershed reclassification would impact the largest minority populations within the City of Raleigh's service area. It should be noted that the communities of Knightdale and Garner have both expressed significant concerns with the perceived negative impacts on development and redevelopment potential for their respective communities. For these reasons a reclassification was anticipated to be politically and socially impossible, and was dropped from further consideration.

These alternatives would not meet project needs, and were not carried forward.

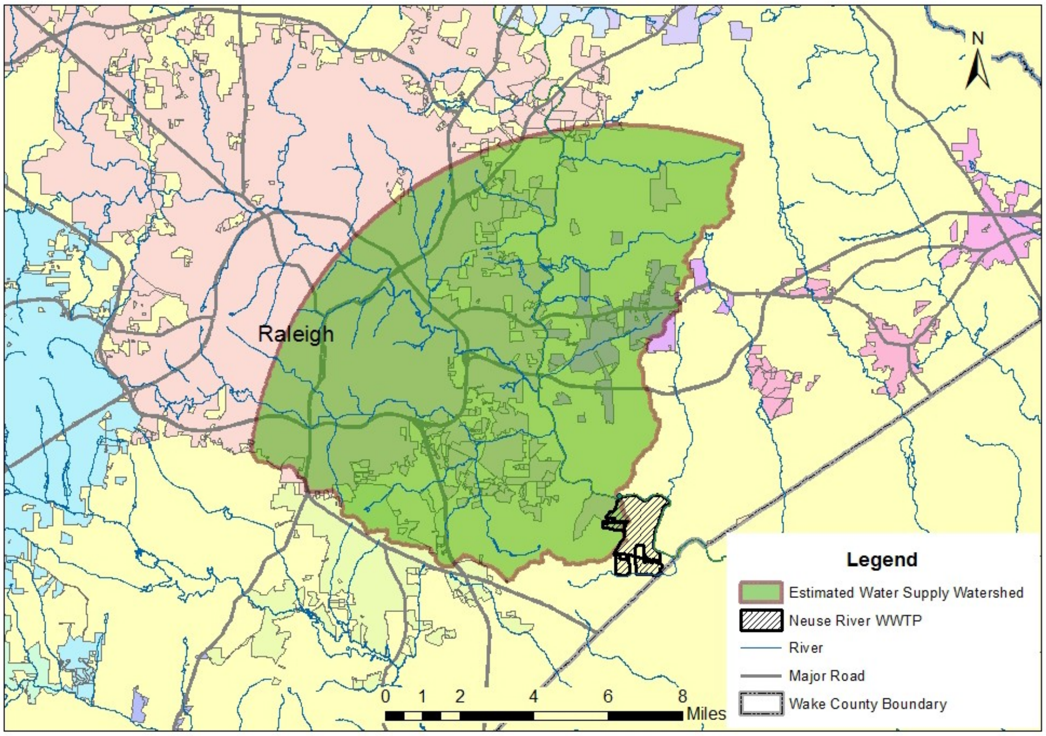


Figure 3.6 - Required Water Supply Watershed Classification for Neuse River Intake

14. **Construct Offline Storage Upstream of City of Raleigh's Wastewater Treatment Plant:** This measure, shown in Figure 3.7 below, consists of the construction of a new raw water intake and pumping station on the Neuse River directly upstream of the Neuse River Wastewater Treatment Plant, but pumping to an existing quarry site which would be acquired and converted to a facility for raw water storage. This alternative involves the construction of a new raw water intake and pumping station on the Neuse River directly upstream of the Neuse River WWTP, in the same location as measure 13. The existing Garner Quarry adjacent to I-40 along E. Garner Road, currently owned and operated by Martin Marietta Materials, would also be acquired and converted to use for raw water storage. A new pumping station would also be constructed at the quarry to allow pumping from the quarry to the D.E. Benton WTP. A new raw water transmission main would be required from the pumping station at the proposed intake to the D.E. Benton WTP. The Garner Quarry is located along the proposed route for the raw water transmission main. A connection at the quarry to the transmission main would be provided to allow raw water to be pumped from the quarry to the D.E. Benton WTP. The D.E. Benton WTP would be expanded from its current 20 mgd capacity to a capacity of 40 mgd.

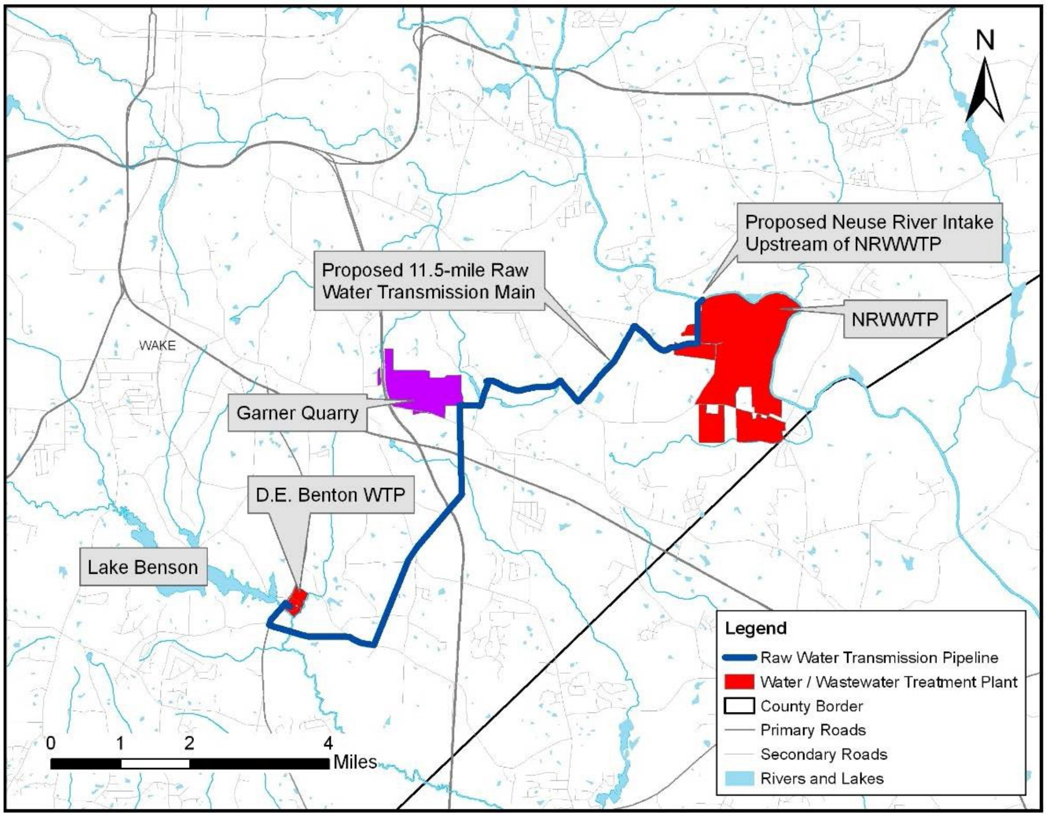


Figure 3.7 - Neuse River Intake Above the NRWWTP with Offline Storage

Operation of the new intake and quarry would involve pumping from the quarry to the D.E. Benton WTP when the Falls Lake level is less than an elevation of 251.0 feet (NGVD29), or 0.5 feet below the top of the conservation storage. During these conditions, raw water would be pumped from the quarry to the D.E. Benton WTP at a rate of 25 to 30 mgd (to meet 2045 demands). Pumping from the intake would not take place until the volume of raw water storage from the quarry is exhausted. At this time, for as long as the Falls Lake level remains less than an elevation of 251.0 feet (NGVD29), raw water would be pumped from the new intake to the D.E. Benton WTP at the same continuous, fixed rate of approximately 25-30 mgd. When the Falls Lake level is above an elevation of 251.5 feet (NGVD29) (the top of the conservation storage), raw water would be pumped from the intake to the quarry at a constant rate of approximately 50 mgd to refill the quarry. As for Alternative 13, releases from Falls Lake would be provided to meet the Clayton gage flow target.

This alternative would provide a yield adequate to meet the long-term water supply need identified and have a positive impact on minimum water quality storage in Falls Lake during droughts, based on modeling by the City.

The Neuse River at the location of the proposed intake is currently classified as C, NSW. As for Alternative 13, the Neuse River and its tributaries from this location to a point five miles upstream of the intake would need to be reclassified as WS-IV waters to enable withdrawal of raw water from this location for water supply. This reclassification would need to be approved by the North Carolina Environmental Management Commission, and the area covered would encompass most of the Town of Knightdale, a portion of the Town of Garner, and a significant portion of the downtown area of the City of Raleigh.

Based on the fact that this alternative would positively influence the minimum water quality storage volume during drought conditions, this alternative would be feasible. However, it would require acquisition of the Garner Quarry for raw water storage. The City has initiated discussions with Martin Marietta to investigate the possibility of purchase of the Garner Quarry for water supply. Currently, Martin Marietta has indicated that the expected useful life of the quarry based on the tonnage remaining is 100 to 150 years. Assuming the City wished to purchase the quarry for water supply at this time, it is expected that the City would have to pay the market value of the property, plus the value of the remaining minerals that could be mined from the quarry. Assuming a quarry life of 100 years, an average quarry mineral output per year of 1.5 million tons, an aggregate cost of $10.00 per ton, and zero inflation, the present worth value of the remaining minerals is estimated at approximately $550 million. Additional costs would be required for the construction of the intake, pump stations and transmission line, along with the expansion of the D.E. Benton WTP. Therefore, based on excessive cost and the need for reclassification of the Neuse River for water supply, this alternative is not presently a feasible alternative and was not carried forward for further evaluation.

15. **Convert Existing Quarries to Reservoirs:** This measure consists of the conversion of local quarries to reservoirs, to be used for raw water storage. This alternative would involve skimming flow from the Neuse River or tributaries of the Neuse River during periods of high streamflow and storing the water in quarry reservoirs. Water would be released from storage and discharged to the Neuse River or its tributaries during low flow periods. Several potential quarry sites could be used, including the Raleigh Quarry referenced previously and the Crabtree Quarry, both currently used for mining operations. None of the existing quarries evaluated have enough storage on their own to meet the long-term water supply need identified.

Major issues for this alternative include coordination of releases from offstream storage with Falls Lake operations, and a mechanism to credit releases from offstream storage to the City's water supply storage in Falls Lake. There would also be a flow reduction in the section of the Neuse River between Falls Lake and the point(s) of discharge from offstream storage to the Neuse River; however, since skimming takes place during higher flow periods, this reduction should not be a significant concern. This alternative could provide additional water supply yield comparable to the projected 2045 need. However, given that mining operations at the existing quarries are still ongoing, the cost would be in excess of $900 million ($550 million for the Garner Quarry, $350 million for Raleigh Quarry, plus cost for the Crabtree Quarry); therefore, based on cost, this alternative is not a feasible alternative at this time and was not carried forward for further evaluation.

16. **Development of Groundwater Supplies using Multiple Local Wells:** This measure consists of the (further) development of groundwater usage as a source of additional water supply. Historically, groundwater has not been used extensively for municipal water supplies in Wake County. Development of groundwater sources has not been viewed as a feasible alternative for municipal water supply as yield is limited in the NC Piedmont and groundwater can be problematic in terms of water quality. Water quality considerations include iron and manganese content, and the presence of chlorides and other chemical constituents. Well yield was examined in the Wake County Comprehensive Groundwater Investigation (CDM, 2003), where driller-reported yields from 2,710 wells were compiled in order to identify locations where yield is expected to exceed 100 gallons per minute (gpm). However, assuming that even one of the areas identified in the report could sustain wells which could dependably produce 100 gpm, approximately 160 individual wells would be required to meet the long-term water supply need identified. The degree of influence between wells and aquifer drawdown would require further study, in addition to the potential impacts of such a well field on private users and community water systems. Based on these factors, development of groundwater supplies is not considered a practicable alternative because of insufficient yield for municipal water supply purposes, and was not carried forward for further analysis.

17. **Development of Groundwater Supplies by Aquifer Storage and Recovery (ASR):** Aquifer storage and recovery (ASR) is the process of injecting water into a groundwater aquifer for storage, and subsequent withdrawal at some later time. Typically, water is introduced to the aquifer when demands are lowest and recovered when demands are high or resources are limited. There are several considerations that must be examined prior to the development of an ASR project. Such parameters include properties of the aquifer, including hydraulic conductivity and productivity, stability of the formation, chemical compatibility of exiting and receiving waters, as well as the chemical makeup of the formation itself and compatibility with receiving waters. At the present time, it is considered that, based on the very fractured nature of the aquifer system in the Piedmont Triassic Basin, the ASR alternative is not feasible because no aquifers are available to accommodate even a small volume of water. This alternative was not carried forward for further analysis.

18. **Development of Groundwater Supplies by using PCS Phosphate-owned Pumped Groundwater:** This measure consists of using water pumped by the PCS Phosphate mining operation for supplemental water supply as shown on Figure 3.8. The PCS Phosphate mining operation is located in Aurora, North Carolina (0ver 100 miles from Raleigh) and is permitted to pump up to 78 mgd from the Castle Hayne aquifer.

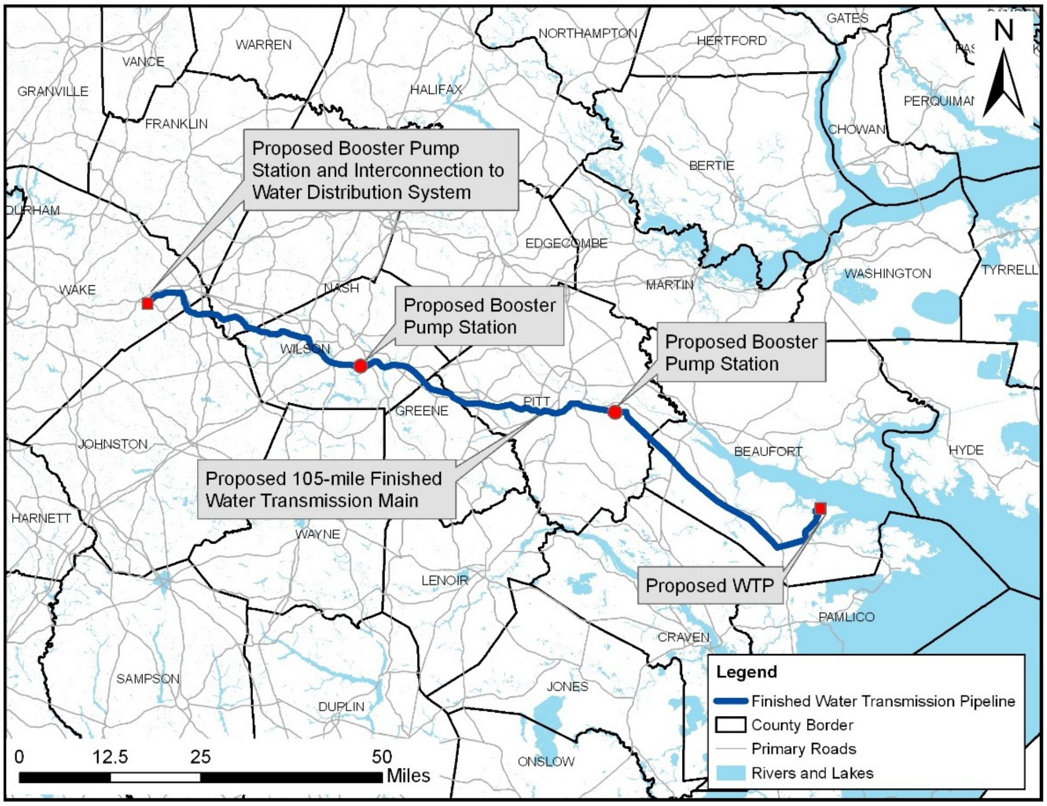


Figure 3.8 - PCS Phospate (Eagle Resources) Groundwater from Aurora, NC

A portion of this water is used for operation of the facility and the remainder is discharged into the Pamlico River just downstream of the estuary.

Eagle Water Company has recognized this discharge as a potential water supply source and has negotiated a contract with PCS Phosphate and obtained a permit from NCDWR for up to 58 mgd of groundwater. In late 2000, Eagle Water Company began searching for public partners to develop a regional water supply system in eastern North Carolina. Potential public partners include cities, counties, county water and sewer authorities, regional water and sewer authorities, or units created by special legislation. A public partner is needed to enable Eagle Water to ensure tax-exempt bonds for the privately-owned portion of the project. The option of using water from the PCS Phosphate mine gained media attention during the 2007 drought with the notion that raw water from the dewatering operations could be used to satisfy water supply needs in the Triangle Region instead of disposing of the water in the Pamlico River. The PCS Phosphate measure would involve construction of a new water treatment facility designed to treat raw water from the Castle Hayne aquifer. Considering the water quality of the Castle Hayne as a source and also the provisions of current drinking water standards, the recommended treatment technology for this water supply is expected to be nanofiltration (or membrane-softening). The use of membranes in water treatment relies on means for the disposal of the reject (or concentrate) stream from the separation process. Hence, locating such a facility in Wake County would prove problematic since the concentrate stream would have to be routed to a wastewater treatment facility for disposal.

Municipal water nano-filtration typically utilizes a 2-stage membrane process and after review of the water quality at PCS, it is estimated a 2-stage plant could achieve 75% product water and 25% concentrate. Three stage membrane processes are available that could increase recovery to 85%, but are usually cost prohibitive for municipal water treatment. This leaves an estimated 43.5 mgd of treated water capacity. Therefore, the City would need to construct, staff, and operate the proposed membrane plant in eastern North Carolina, in proximity of the phosphate mining operations to facilitate the 14.5 mgd concentrate disposal since this reject stream could be diverted to Pamlico Sound.

The PCS Phosphate project also requires the construction of an extensive piping system to convey finished water from the proposed water treatment plant to eastern Wake County. Preliminary investigation reveals that the corresponding finished water transmission main would be approximately 105-miles in length and would cross Beaufort, Pitt, Greene, Wilson, Nash, and Johnston Counties before terminating in Wake County. In addition to a high service pump station to be located at the proposed water treatment plant, at least two additional booster pump stations would be required to pump water from an elevation of approximately 20 feet at the coast to approximately 350 feet in eastern Wake County. A third booster pump station would be required in order to deliver finished water to the City of Raleigh distribution system. It is envisioned that at least one of these booster pump stations would need to provide for rechlorination of finished water to ensure that adequate chlorine residual is maintained in the system. Cost for this alternative is estimated to be approximately $1.2 billion (includes operation and maintenance costs).

Further complicating this alternative is the issue of excess supply. This alternative at 43.5 mgd in and of itself nearly meets all of the City's current water demands (2015 demand was approximately 49 mgd), and would meet projected demands well beyond the 30-year planning horizon. This contributes to the excessive economic cost of this alternative, as the investment in this supply would put a burden on the current rate payers who would be required to pay off the debt. The excess supply also presents significant operational issues as the City would need to suspend or drastically curtail operations at the E.M. Johnson Water Treatment Plant. An additional factor that would have to be further evaluated before this alternative could be implemented is a review of the distribution system. With such a large proportion of the City's water supply coming from the east instead of the west it is possible distribution system modifications would be required.

Hence, due to the extensive nature of facilities required for this option, the logistics associated with operating and maintaining a nanofiltration treatment plant in eastern North Carolina and a 105-mile intrastate finished water transmission main, the excessive cost, and the issue of excess supply, use of water from the PCS Phosphate mining operations is not technically or economically feasible, and was dropped from further consideration.

19. **Reallocation from John H. Kerr Dam and Reservoir:** The John H. Kerr Dam and Reservoir (Kerr Lake) is located at the confluence of the upper Roanoke River and the Dan River along the Virginia-North Carolina state line. Kerr Lake, which covers approximately 50,000 acres, is owned and operated by the USACE and was constructed in the 1950's. The reservoir is one in a series of three impoundments, with the other two, Lake Gaston and Roanoke Rapids Lake, owned and operated by Virginia Power, and located downstream in Virginia and North Carolina. The drainage area upstream of the Kerr project is approximately 7,800 square miles, and the reservoir impounds approximately 1,027,000 acre-feet at 300 feet (NGVD29), the top of the conservation (power) storage. The reservoirs' storage is allocated for a variety of purposes, including flood risk management, power generation, municipal/industrial water supply, pollution abatement, and conservation of fish and wildlife (USACE, 2007).

Water supply was not one of Kerr Lakes' initially authorized purposes. The conservation storage was allocated entirely to power generation. Utilizing the Water Supply Act (WSA) of 1958, portions of the conservation storage have been reallocated to water supply users as summarized in Table 3.1. The Corps' discretionary authority to modify projects without further Congressional approval is limited, according to the Act, as follows:

> Modifications of a reservoir project heretofore authorized, surveyed, planned, or constructed to include storage . . . which would seriously affect the purposes for which the project was authorized, surveyed, planned, or constructed, or which would involve major structural or operational changes shall be made only upon the approval of Congress as now provided by law.

This measure, shown in Figure 3.9, would require the expansion of the existing Kerr Lake Regional Water System intake (or construction of new intake), a new raw water pump station, and a 42-mile long raw water transmission main to the E.M. Johnson WTP. The distance from Kerr Lake to Raleigh and the elevation profile are such that at least one booster pump station would be required along the length of the raw water transmission main. This alternative would also involve expansion of the E.M. Johnson WTP. In addition, this alternative requires the transfer of water between different river basins.

Mitigation of the interbasin transfer from the Roanoke River Basin to the Neuse River Basin is anticipated to require returning all or a portion of the water withdrawn from Kerr Lake back to the Roanoke River Basin. This would be facilitated by construction of an effluent transmission main from the NRWWTP to a tributary of Kerr Lake. Preliminary analysis indicates that an

Table 3.1 - John H. Kerr Water Supply Storage Summary

Municpal & Industrial Water Supply Users	Allocated Acre-Feet	Estimated Yield (mgd)	Percent of Conservation Storage
Kerr Lake Regional Water System (City of Henderson, City of Oxford, Warren County)	10,292	20	1.050
City of Virginia Beach	10,447	20.3	1.066
Virginia Department of Corrections	24	0.047	0.0024
Mecklenburg Co-Generation	617	1.2	0.063
Total	**21,380**	**41.547**	**2.181**

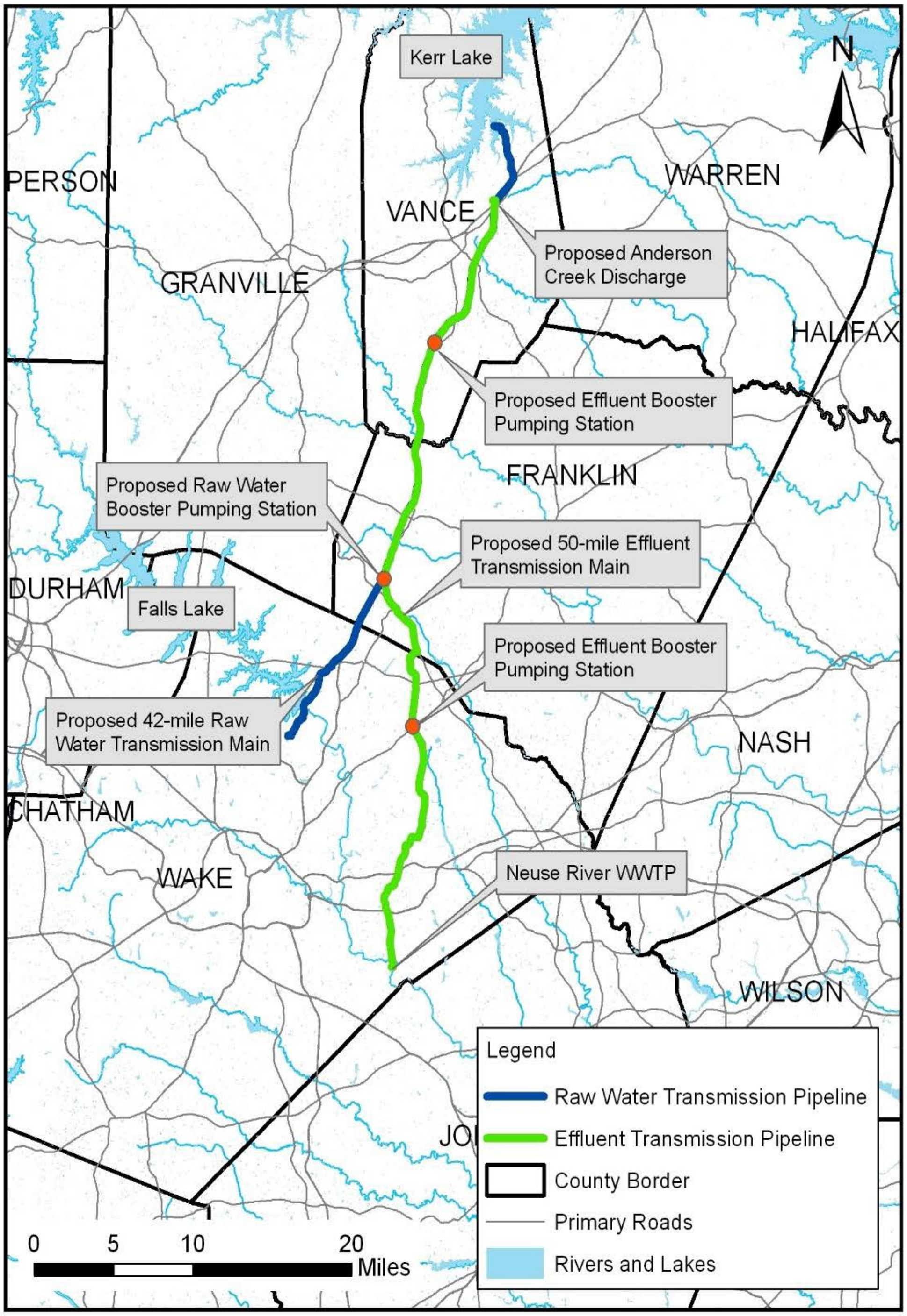


Figure 3.9 - Reallocation from Kerr Lake

effluent pipeline approximately 50 miles long would be required, along with at least two effluent booster stations as shown in Figure 3.9. This alternative is likely to be politically difficult to implement given previously expressed opposition from stakeholders, and the need to obtain property/easments in neighboring Vance County and Franklin County which would require approval from each County's Board of Commissioners.

Therefore, based on cost and the other factors presented above, the implementation of the alternative of using of Kerr Lake as a future water supply source is considered highly unlikely, and was not carried forward for further analysis.

20. **Obtain Allocation from Jordan Lake:** This measure consists of the potential to obtain water supply from Jordan Lake. Jordan Lake is a multi-purpose USACE lake that was impounded in 1981 and is located on the Haw River in the Cape Fear River basin, in eastern Chatham County and southern Durham County. It serves as the primary water supply for the Towns of Cary, Apex and Morrisville, as well as a portion of Wake County (for RTP South). The USACE constructed the B. Everett Jordan Dam on the Haw River, just downstream of its confluence with the New Hope River. The drainage area for the lake is approximately 1,700 square miles. The top of the dam is at 266.5 feet (NGVD29). At 216.0 feet (NGVD29), the top of conservation storage, the reservoir impounds approximately 215,100 acre-feet of water, covering approximately 13,940 acres (USACE, 2007). In addition to water supply, the lake's conservation storage provides approximately 94,600 acre-feet for downstream flow augmentation to benefit water quality and economic development. Minimum releases are controlled to maintain a downstream water quality target flow at Lillington, N.C. of 600 cfs.

The volume of the water supply storage is approximately 45,800 acre-feet, resulting in a projected yield of approximately 100 mgd (USACE, 2007). The State of North Carolina purchased the entire water supply storage in Jordan Lake, and, under G.S. 143-354(a)(11), can allocate this storage to any local government demonstrating a need for water supply storage, with approval of the Secretary of the Army or his designee. The North Carolina Administrative Code (15A NCAC 2G.0500) describes the specific procedures to be used by the State of North Carolina in allocating their Jordan Lake water supply storage.

Under the State's program, water supply allocations from Jordan Lake fall into two categories, and are made based on 20-year water need projections. Level I allocations are for applicants intending to begin withdrawals within 5 years, while Level II allocations reserve the right for withdrawal at a future time, not to exceed 30 years. The current allocations for water supply storage in Jordan Lake are shown in Table 3.2 below. Table 3.2. also shows requested Round 4 allocations currently being considered by the NC Environmental Management Commission (EMC) in accordance with 15A NCAC 2G.0500, including the City of Raleigh's request for 4.7 mgd. The EMC Water Allocation Committee has recommended approval of the City's 4.7 mgd request and the NCDEQ has scheduled the required public hearings for all the requested Round 4 allocations.

Table 3.2 - Jordan Lake Allocations (MGD) with Raleigh using Jordan Lake

Jordan Lake Partner	Current		Total Round 4 Requests	
Apex	**8.5**	**32.0**	**10.6**	**46.2**
Cary	**23.5**		**28.6**	
Morrisville	**3.5**		**3.5**	
Wake County (RTP South)	**3.5**		**3.5**	
Chatham County – N	**6**		**13**	
Durham	**10**		**16.5**	
OWASA	**5**		**5**	
Orange County	**1**		**1.5**	
Holly Springs	**2**		**2**	
Hillsborough	**0**		**1**	
Pittsboro	**0**		**6**	
Raleigh & Merger Partners	**0**		**4.7**	
Sanford	**0**		**0**	
TOTAL JLP	**63**		**95.9**	

If the City is successful in obtaining an allocation, its intended use would be as an emergency water source or a bridging source to provide sufficient supply until a water supply source in the Neuse River Basin is approved and constructed. In addition and in part to assuage concerns of the other Jordan Lake Partners, the City of Raleigh has agreed to relinquish the allocation when the needs of those other Partners exceed their available supply.

The preferred approach to developing the supply would be to work out an arrangement to purchase treated Jordan Lake water from one of the Jordan Lake Partnership (JLP) members shown in Table 3.2 and shown in Figure 3.10. Similarly, if the wastewater from the allocation is required to be returned to the Cape Fear Basin, Raleigh would first approach members of the JLP to see if one of the dual basin JLP members could offset a similar amount of their Neuse Basin discharge and instead return it to the Cape Fear Basin. Alternatively, the City could pump some of its own wastewater to one of the region's WWTPs that discharge to the Cape Fear basin.

Interbasin transfer considerations and the potential for future Jordan Lake allocation requests to exceed available supply are significant issues affecting the City's use of Jordan Lake water. Mitigation of the interbasin transfer from the Cape Fear River Basin to the Neuse River

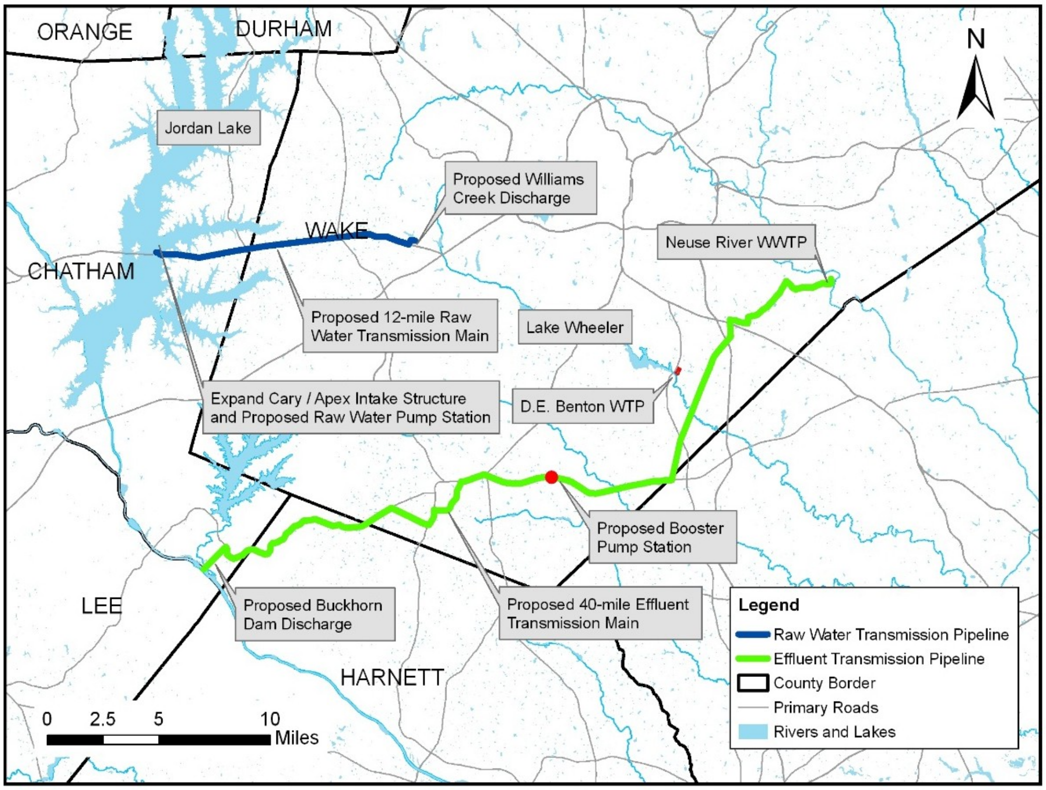


Figure 3.10 - Reallocation from Jordan Lake

Basin could require that all or a portion of the water withdrawn from Jordan Lake be returned to the Cape Fear River. Nevertheless, the City would ask that this interbasin transfer be viewed as a partial offset for the long standing Durham interbasin transfer that is larger and moves water in the opposite direction, from the smaller Neuse Basin to the larger Cape Fear River Basin, and adversely affects the City's primary water supply, Falls Lake.

This measure is technically feasible; however, this measure requires an interbasin transfer and stands to diminish future supply needed by those within the Cape Fear River basin. This measure is also insufficient to meet the projected demand on a permanent basis and is viable as an emergency or temporary bridging source only. For these reasons this measure was not carried forward for further evaluation.

21. **Purchase Water from Existing Systems:** This measure consists of use of water from the inter-connected water distribution systems connecting the City of Raleigh with other municipal water systems as a source of supplemental water supply. Purchasing water from existing systems as a means of meeting the projected growth in demand would require long-term purchase agreements, interconnection and transmission improvements, and increased WTP capacities, as well as addressing interbasin transfer issues. Although connections to the water systems in other counties might provide supplemental sources of water, it is anticipated that

only selected portions of the City's service area would benefit from such arrangements and that available water supply would be relatively small in relation to projected water demands. Raleigh is a party to several emergency sales/purchase arrangements with nearby utilities. There is also one nonemergency commitment to sell 0.75 mgd to Fuquay-Varina. Under their general terms, these agreements provide for the sale of water subject to its availability from the seller. A summary of available water via mutual agreements is as follows:

- Up to 8.5 mgd from the City of Durham
- Up to 9.5 mgd from the Town of Cary
- Up to 1.2 mgd from the Town of Holly Springs
- Up to 2.15 mgd from Johnston County

Water availability under these existing agreements represents only a short-term or emergency supply source for Raleigh and purchase or sales would generally be limited to times of severe drought or periods of special operational need, such as planned/unplanned infrastructure maintenance or other outages. Similar to Raleigh, each of the neighboring municipilaties is also seeking additional water resources to provide for their own long-term water supply needs. Therefore, insufficient water supply available for long-term interlocal sales makes this measure not feasible. This alternative was not carried forward for further analysis.

22. **Wastewater Reuse from City of Raleigh's Wastewater Treatment Plant:** This measure consists of reuse of wastewater from the City's existing Neuse River Wastewater Treatment Plant, for the purposes of supplemental water supply. The City of Raleigh's Reuse Water Master Plan was originally developed in 2007, and is currently in the process of being updated. Currently, the average reuse water demand is approximately 0.4 MGD with more than 20 connections, ranging from three golf courses, a hospital physical plant, and several City of Raleigh facilities. The City also expects to provide reuse water to NC State University's Centennial Campus. In 2013, City staff co-wrote legislation with North Carolina Department of Environment and Natural Resources to allow reclaimed water to be used as a source water under certain conditions. This legislation was signed into law in August 2014. The use of reuse water, in conjunction with water conservation/efficiency, is included in the projections for the water demand analysis for the City of Raleigh, and is therefore not evaluated as a separate water supply measure. This alternative was carried forward as a component of all future conditions.

23. **Water Conservation/Efficiency Measures:** This measure consists of implementation of various water conservation/efficiency measures within the service area, to lessen current and future water need. The City of Raleigh's water conservation programs and efforts have already contributed to the steady decrease in the average gallons per capita day (gpcd) water consumption, which is currently 97 gpcd. The 97 gpcd value compares favorably with any

similarly-sized utility system in the country, and this value is projected to decline further in the future.

A critical factor in maintaining and gradually decreasing per capita consumption rates is the willingness of the system's elected leadership to adopt rate increases as prescribed by utility financial managers. To this end, the Raleigh City Council has continued to implement the recommended rate increases and is expected to support future rate increases as needed. The City of Raleigh Public Utilities Department and the City Council have also committed to the ultimate goal of developing a "full cost of service" rate/fee structure in the future, and this goal is widely understood to not only represent responsible fiscal management, but an additional incentive to decrease water consumption as rates increase.

The cumulative impact of water conservation/customer water use changes, water efficiency measure and reclaimed water use are assumed to deliver 15 million gallons per day in demand savings by 2040. The assumed 15-mgd water conservation/efficiency estimate is included in the projections of water supply need for the City of Raleigh, and is therefore not evaluated further as a separate water supply measure. This alternative was carried forward as a component of all future conditions.

3.11 Analysis of Water Supply Benefits - Part 3: Evaluation, Comparison and Screening of Preliminary Alternatives, and Development of Focused Array of Alternatives.

The evaluation, comparison and screening of alternatives involved the evaluation of the many alternatives and many outcomes created by each alternative, the comparison of each outcome by alternative, and resulting screening of those alternatives that did not meet the objectives of the study, were not technically implementable, would result in unacceptable environmental impacts, or were significantly more costly than alternatives that would result in the same outcome at a much lesser cost. The analysis conducted above lead to the following screening process that led to the Focused Array of Final Alternatives.

Table 3.3 - Falls Lake Reallocation Study - Preliminary Alternatives Summary and Screening

	Water Supply Alternative	Description	Cost*	Feasibility Analysis and Alternative Evaluation and Comparison	Screened/Forwarded
1	No Action			No-Action is the condition to which all alternatives are compared, and assumes no action is taken to address future water demand, other than increased water conservation and re-use. Projected population growth and resultant demand will greatly exceed all conservation and water savings measures, even as individual household demand drops due to more water conservation outreach. Even with additional conservation and water reuse anticipated through 2045, an approximate 70% increase in water demand (based on an anticipated 91% increase in population) is anticipated to occur. Additional storage is not anticipated in No-Action future. No-Action would incur public health and economic consequences associated with the inability to meet future need for clean, potable water.	Carried Forward
2	Falls Lake	Reallocate Storage in Conservation Storage to Water Supply Storage	$142M	*Technically, environmentally and economically feasible. Flow modeling indicates reallocation of up to 5.9 billion gallons (18,000 acre-feet) from the water quality storage to the water supply storage would leave sufficient water to meet downstream flow requirements under all historic hydrologic (drought) conditions based on period 1929-2012. Water demand modeling indicates a need for approximately 17,300 acre-feet of water by 2045. NOTE: Cost includes not only costs of reallocated storage, but also costs of additional transmissions lines, and water treatment facility expansion. Cost includes cost of reallocated storage, plus cost of transmission and treatment of raw water.*	*Carried Forward*
3	Falls Lake	Seasonal Raising of Normal Pool – Reallocation of Flood Storage to Water Supply Storage	>$500M	Not currently technically, environmentally, or economically feasible. Decrease of flood risk management storage would impact volume of flood storage available during hurricane season and could increase downstream flood stage and extent, during certain conditions. Falls Lake dam possesses a Dam Safety Action Class (DSAC) III rating. USACE policy does not permit actions that would raise the normal pool (guide curve) for DSAC I, II, or III dams. Would likely require costly structural modifications and upgrading of the Falls Lake Dam to guarantee adequate flood risk reduction. Raising the guide curve would not meet the projected	Screened

				demand for any reasonable storage raise. Not a cost-effective alternative.	
4	Falls Lake	Reallocate Storage in Sediment Storage to Water Supply Storage	N/A	Technically, environmentally and economically feasible. The sediment storage will diminish as sediment further deposits in the lake, decreasing the yield from this pool over time. With or without future projected sediment inflow, cannot guarantee provision of sufficient volume to meet projected 2045 future need. May allow future supplementation in times of drought. May require additional measures to allow access to this storage, such as pumps or new outlet works.	Screened at this time
5	Falls Lake	Dredge Falls Lake to Increase Volume	$714M+	Technically and environmentally feasible. May not be able to provide sufficient volume to meet projected 2045 water demand due to constraints created by geology and concerns about dam safety. Not economically feasible due to cost. Not a cost-effective alternative.	Screened
6	Falls Lake	Raise Dam to Increase Volume	>$500M	May not be technically, environmentally or economically feasible. Falls Lake dam possesses a Dam Safety Action Class (DSAC) III rating. USACE policy does not permit actions that would raise the normal pool (guide curve) for DSAC I, II, or III dams. Raising the dam may not be technically feasible due to its construction; may require extensive modifications to the existing project. Could require complete drawdown of reservoir. Raising the dam would considerably increase the reservoir footprint, requiring a great deal of real estate and potentially environmental mitigation. Could require new spillway, and potentially all new outlet works. Based on previous USACE studies raising the dam would be 5 to 20 times more costly than measures investigated to reallocate storage in Falls Lake.	Screened

7	Little River Reservoir	New Dam and Reservoir on Little River	~$359M	Technically feasible. Potentially environmentally and economically feasible. May be constructed to meet all of storage required to meet anticipated 2045 need. Could be added to other alternatives at a later time to supplement future need beyond 2045. Would require extensive environmental mitigation. Approximately 26,000 acres of land around the reservoir has a WS-II watershed classification for water supply; the inundated land has been purchased by the City of Raleigh in order to preserve the area for future use. The calculated yield accounts for a minimum release of 3.3 cfs to maintain downstream aquatic habitat, which includes the presence of federally endangered species. Less cost-effective than reallocation at Falls Lake. NOTE: Cost includes not only costs of reallocated storage, but also costs of additional transmissions lines, and water treatment facility expansion.	Carried Forward
8	Middle Creek	New Dam and Reservoir on Middle Creek	>$500M	May not be technically, environmentally or economically feasible. This alternative would be similar to the Littler River Reservoir alternative; however, impacts and cost would be greater given the considerably larger already- developed property acquisition and rezoning required, including property acquisition in Johnston County. On its own, would not provide adequate storage to meet anticipated 2045 demand.	Screened
9	Buffalo Creek	New Dam and Reservoir on Buffalo Creek	>$500M	May not be technically, environmentally or economically feasible. This alternative would be similar to the Littler River Reservoir alternative; however, impacts and cost would be greater given the considerably larger already-developed property acquisition and rezoning required, including property acquisition in Johnston County. On its own, would not provide adequate storage to meet anticipated 2045 demand.	Screened
10	Lakes Benson and Wheeler (Swift Creek)	New Storage at Lakes Benson & Wheeler	>$500M	May not be technically, environmentally, or economically feasible. Lakes are currently at maximum usage. Expansion of this alternative would create high impacts to existing residential areas and major roadways adjacent to the reservoir sites. There are federally-endangered species immediately downstream that could be impacted during low-flow periods. Would not meet anticipated	Screened

				2045 water demand. Would impact other large projects in the area. Would not be a cost-effective alternative.	
11	Neuse River	Neuse River Intake at Richland Creek		Technically, environmentally and economically feasible; however, does not provide storage of flows, thus cannot guarantee provision of future 2045 water demand.	Screened
12	Neuse River	Neuse River Intake near Richland Creek with Offline Storage	>$580M	Technically, environmentally, and economically feasible. Cannot provide anything approaching future 2045 water demand, but could supplement other alternatives to meet that need. Could require less environmental mitigation than other alternatives. Alternative is not as cost-effective as other alternatives; and significantly more expensive than a reallocation alternative. As the volume of the quarry is increased in the future, the offstream storage option becomes increasingly more viable as a future option, particularly as a supplement to other alternatives. NOTE: Cost includes not only costs of reallocated storage, but also costs of additional transmissions lines, and water treatment facility expansion.	Carried Forward
13a	Neuse River	Neuse River Intake upstream of NRWWTP	$166M	Technically, environmentally and economically feasible; however, does not provide storage of flows, thus cannot guarantee provision of future 2045 water demand. May require: 1) watershed reclassification as a water supply watershed, impacting development in large portion of southeast Raleigh, and large portions of Garner and Knightdale; 2) could create a potential environmental justice issue as the portion of the County affected includes a large minority population. 3) Is more costly as it will not be able to take advantage of existing infrastructure available at Falls Lake.	Screened
13b	Neuse River	Neuse River Intake upstream of NRWWTP	$166M	Technically, environmentally and economically feasible; however, does not provide storage of flows, thus cannot guarantee provision of future 2045 water demand. May require: 1) watershed reclassification as a water supply watershed, impacting development in large portion of southeast Raleigh, and large portions of Garner and Knightdale; 2) could create a potential	Screened

				environmental justice issue as the portion of the County affected includes a large minority population. 3) Is more costly as it will not be able to take advantage of existing infrastructure available at Falls Lake.	
14	Neuse River	Neuse River Intake upstream of NRWWTP with Offline Storage	$550M +	Technically, environmentally, and economically feasible. Cannot provide future 2045 water demand, but could supplement other alternatives to meet that need. Could require less environmental mitigation than other alternatives. Alternative is not as cost-effective as other alternatives; significantly more expensive than a reallocation alternative. As the volume of the quarry is increased in the future, the offstream storage option becomes increasingly more viable as a future option, particularly as a supplement to other alternatives.	Screened
15	Quarries	Convert existing quarries for Low Flow Augmentation	$900M +	Technically, environmentally, and economically feasible. Cannot provide future 2045 water demand, but could supplement other alternatives to meet that need. Could require less environmental mitigation than other alternatives. Alternative is considerably less cost-effective than other alternatives; significantly more expensive than a reallocation alternative. Offstream storage option may become increasingly more viable as a future option, particularly as a supplement to other alternatives.	Screened
16	Groundwater	Multiple Local Wells	N/A	Technically, environmentally, and economically feasible, but cannot provide anything approaching future 2045 water demand. Could supplement other alternatives if needed. Could require less environmental mitigation than other alternatives. Would be extremely costly; not a cost-effective alternative.	Screened
17	Groundwater	Aquifer Storage and Recovery	N/A	Not technically, environmentally, or economically feasible; – No aquifers – Piedmont Triassic Basin is a fractured rock aquifer, therefore not feasible for ASR.	Screened
18	Groundwater	PCS Phosphate, Aurora, NC	$1260M	Not technically or economically feasible. Would require a new remote Wastewater Treatment Plant and 105 miles of 36-inch water main, cost prohibitive.	Screened

19	John H Kerr Lake	Reallocation of Kerr Lake	N/A	Not Feasible – Would require double interbasin transfer from the Roanoke River Basin to the Neuse River Basin, and return of treated wastewater flow to the Roanoke River Basin. This alternative also would be politically challenging to implement as Kerr Lake serves both North Carolina and Virginia, with the biggest user of water from Kerr Lake being the City of Virginia Beach, VA.	Screened
20	Jordan Lake	Reallocation of Jordan Lake	N/A	Not Feasible – If an allocation from Jordan Lake was granted it would only be available on a temporary basis, and would serve as a stopgap measure until another water resource can be brought on-line. Jordan Lake is currently fully allocated to other local municipalities. A 4.7 mgd reallocation would not be enough to satisfy the 2045 projected demands. Any allocation over 3 MGD would require an interbasin transfer from NCDEQ for the transfer from the Cape Fear River Basin to the Neuse River Basin, and may require return of flow to the Cape Fear River Basin.	Screened
21	Purchase Water from Existing Systems	Purchase of Water from Other Systems	N/A	Technically, environmentally, and economically feasible; however, existing (and future) systems do not have anything approaching adequate long-term supply to meet required yield.	Screened
22	Wastewater Reuse	Reuse of Wastewater from System	N/A	Technically, environmentally, and economically feasible; however, reuse is already included in the demand projections as an expected future with- and without-project condition.	Assumed
23	Water Conservation/Water Efficiency Measures	Water Conservation and Efficiency Meas	N/A	Technically, environmentally, and economically feasible; however, water conservation/water efficiency measures are included in the demand projections as an expected future with- and without-project condition.	Assumed

3.12 Analysis of Water Supply Benefits - Part 4: Evaluation, Comparison and Screening of Final Array of Alternatives, and Selection of Recommended plan.

Analysis of the final array of alternatives was conducted for technical, environmental and cost-effectiveness criteria, as well as for acceptability, completeness, effectiveness and efficiency. Two alternatives from the preliminary array were carried forward as components of all remaining plans, as they would be implemented under any circumstances: **Alternative 22** - further levels of wastewater re-use, and **Alternative 23** - increasing conservation measures. Three remaining alternatives passed the screening process, **Alternative 2** - Reallocate Storage in Falls Lake Conservation Storage from Water Quality Storage to Water Supply Storage, **Alternative 7** - Construction of a New Dam and Reservoir on Little River, and **Alternative 12** - Neuse River Intake Near Richland Creek with Offline Storage. The following sections provide an analysis of these remaining alternatives, using those evaluation criteria, and provide the rationale for plan selection.

3.13 Economic Benefits Analysis.

National Economic Development (NED) Account: The NED cost includes the costs to implement, maintain, and operate each alternative. The NED account compares the alternatives based on NED cost at FY 2017 price levels and interest rates. NED costs include first costs and Operations, Maintenance, Repair, Rehabilitations and Replacement (OMRR&R) costs; however, unlike financial costs, NED costs typically include interest during construction (IDC) and in this case, potential lost recreation benefits. Annual NED cost, and annual NED benefit were used to determine the NED Plan. Flood risk management benefits (as $0), are not included in the NED account because the hydrologic analysis of the alternatives indicated that no significant differences occur between the alternatives' water surfaces downstream from Falls Lake. Recreation benefits are not included in the annual NED benefit according to Paragraph (1) on Page 3-35 of ER 1105-2-100, which states that the NED water supply benefits are measured by the cost of the alternative (Alternative 7) most likely to be implemented in the absence of the proposed plan (Alternative 2). However, NED recreation benefits lost are considered as part of the cost of reallocated storage in Appendix E of ER 1105-2-100.

For most projects, the NED recreation benefits lost are typically included in the NED costs along with the environmental mitigation and recreation modification costs. In the case of Falls Lake, it was determined that there would be no significant quantifiable economic impact on recreation. The small increment of difference in water surface elevation in times of severe drought, in which case water levels are too low for significant recreation benefit, in a comparison of the without-, and with-project conditions; this small increment of differences in water level for an already low pool, has no net negative effect on recreation activities, thus, for the purposes of NED analysis, there is no quantifiable net loss of benefits to recreation.

To determine NED benefits, comparison was made between the most economical alternative, Alternative 2 - "Falls Lake - Reallocation of Storage in Water Quality Storage to Water Supply Storage" to those of the next least costly alternative, Alternative 7 – "New Dam and Reservoir on Little River". Both alternatives provide the same additional water supply, and amenities. However, because Alternative 2 provides the same level of water supply storage benefits as Alternative 7, but at much lower cost to the nation, State, and local government and taxpayers, Alternative 2 is the NED Plan.

Table 3.4 summarizes the NED account for each of the proposed alternatives. Alternative 12 – "Neuse River Intake near Richland Creek with Offline Storage" is also provided as the following least costly alternative, as an additional point of reference. The difference in costs between Alternatives 7 and 12 would need to decrease by approximately $11 million annually and $23 million annually, respectively before Alternatives 7 and 12 would be equal in cost to Alternative 2. However, based on the costs presented in Table 3.4, Alternative 2 would be most cost-effective for actual implementation, because of its significantly lower cost.

Table 3.4 - Comparison of NED Benefits - Falls Lake Reallocation Alternatives

	Alternative 2 Falls Lake - Reallocate Storage in Conservation Storage to Water Supply Storage (*Federal Plan*)	**Alternative 7** Construction of a New Dam and Reservoir on Little River (*Most-Likely Non-Federal Plan*)	**Alternative 12** Neuse River Intake Near Richland Creek with Offline Storage (*Next Least Non-Fed Cost Plan*)
Total Cost	$142,000,000	$359,000,000	$580,000,000
Total Storage	17,300	<17,300	<17,300
Annual NED Cost	$7,362,283	$18,613,096	$30,071,297
Annual NED Water Supply Benefit	$11,250,813	$--	$--

NOTE: The NED cost includes costs required to implement the alternatives, and includes not only costs of reallocated storage (in the case of Alternative 2), but also costs of additional transmissions lines, and water treatment facility expansion. For Alternative 2 also, includes operation and maintenance costs of $65,766 annually. Interest during construction is also included.

Regional Economic Development (RED) Account: The RED account addresses economic benefits important at a regional level: State, counties, and communities in the broad study area. Items in this account relate to economic activities such as employment and income.

The first component of RED analysis involves benefits to the region created by the action (reallocation). Alternative 2 would provide qualitatively greater RED benefit to the region due to its lower implementation cost. Unquantified RED benefits would also include benefits to the region due to an ensured water supply for additional population inflow, support for water-related municipal and industrial activities, and other contributions. These figures are small compared to the size of the Raleigh-Durham area economy on an annual basis, and would not have a significant effect on the regional economy.

The second component, consisting primarily of construction, does not result in a major outflow or inflow of funds to the regional economy and would not appreciably affect RED any more than a similar expenditure would if the funds are not used for the reallocation activity. In both instances the funds are the responsibility of local sponsors and would be derived from sinking funds, bond sales, and/or income. Given that use of water contained in the reallocated storage would be largely reimbursed through income from municipal and industrial customers, there are no significant disbenefits at an RED scale.

No federal funds would be allocated to this effort. In the event the local sponsors choose to take advantage of federal financing, they pay for reallocated storage over time along with appropriate level of interest (repayment period not to exceed 30 years). In any event, no significant RED impact is considered likely and the cost of an input-output study to better identify the impacts is not believed to be warranted for this analysis.

The National Economic Development (NED) Plan:

The above analyses demonstrate that the NED Plan is the Recommended Plan – Reallocation of Falls Lake Water Quality Storage to the Water Supply Storage, in the amount of 17,300 acre-feet. This plan produces benefits in the amount of $11,250,813, at an annual cost of $7,362,283.00. Costs include $65,766 in annual Operations and Maintenance funding for the project.

Table 3.5 provides a summary of the screening process which led to selection of the Recommended Plan.

Table 3.5 - System of Accounts Analysis and Screening of Final Array of Alternatives

Criteria	No-Action Plan	**Alt. 2 Reallocation of Falls Lake** Reallocate Storage in Conservation Storage to Water Supply Storage	**Alt. 7** Construction of a New Dam and Reservoir on Little River	**Alt. 12** Neuse River Intake Near Richland Creek with Offline Storage
NED Account				
Cost*	No reallocation costs, but eventual costs to residents and businesses due to need to offset water demand by other, more costly means. Lost revenue due to inability of City to serve increased water demand needs and attraction of fewer businesses and residents.	Approx. $142 million (NED cost includes cost of reallocated storage, plus transmission and treatment)	Approx. $359 million (NED cost includes cost of reallocated storage, plus transmission and treatment)	Approx. $580 million (NED cost includes cost of reallocated storage, plus transmission and treatment)
Annual NED Cost	$0	$7,362,283	$18,613,096	$30,071,297
Annual NED Benefit	$0	$11,250,813	$--	$--
Operations & Maintenance Costs	$0	$65,766	$65,766	$65,766
RED Account				
Regional Costs	$0	No significant regional costs	No significant regional costs	No significant regional costs
Regional Benefits	$0	No significant regional benefits	No significant regional benefits	No significant regional benefits

Criteria	No-Action Plan	**Alt. 2 Reallocation of Falls Lake** Reallocate Storage in Conservation Storage to Water Supply Storage	**Alt. 7** Construction of a New Dam and Reservoir on Little River	**Alt. 12** Neuse River Intake Near Richland Creek with Offline Storage
EQ Account				
Environmental Impacts	Lack of future dedicated water storage and water supply may negatively affect local environmental resources	This alternative is not expected to possess any significant negative effects	This alternative could negatively affect hundreds of acres of riparian and open space	This alternative could negatively affect hundreds of acres of riparian and open space, depending on where water storage is sited
Cultural Resources	No effect	This alternative is not expected to possess any negative effects	This alternative would have a currently unknown effect on cultural resources	This alternative would have a currently unknown effect on cultural resources
Air Quality	No effect	This alternative is not expected to possess any negative effects	This alternative could have temporary impacts on air quality during construction	This alternative could have temporary impacts on air quality during construction
Water Quality	No effect	This alternative is expected to have no measurable impacts on water quality	This alternative could have temporary but mitigable impacts on water quality during construction	This alternative could have temporary but mitigable impacts on water quality during construction
Noise Levels	No effect	This alternative is expected to have no measurable impacts on noise levels	This alternative could have temporary impacts on noise levels during construction	This alternative could have temporary impacts on noise levels during construction

Criteria	No-Action Plan	**Alt. 2 Reallocation of Falls Lake** Reallocate Storage in Conservation Storage to Water Supply Storage	**Alt. 7** Construction of a New Dam and Reservoir on Little River	**Alt. 12** Neuse River Intake Near Richland Creek with Offline Storage
EQ Account				
Aesthetics	Lack of future dedicated water storage and water supply may negatively affect local environmental resources, public parks, and landscaping	This alternative would have insignificant effects on aesthetics in the study area by provision of more	This alternative would have insignificant effects on aesthetics in the study	This alternative would have insignificant effects on aesthetics in the study
Sediment and Erosion	No effect	This alternative is expected to have no effects on either sediment or erosion	This alternative could have temporary impacts on sediment and erosion during construction	This alternative could have temporary impacts on sediment and erosion during construction
Flooding	No effect	This alternative is expected to have no effect on flooding	This alternative is expected to have no effect on flooding	This alternative is expected to have no effect on flooding
Aquatic Habitat	No effect	This alternative is expected to have insignificant effects on aquatic habitat	This alternative may have significant effect on aquatic habitat within reservoir footprint	This alternative would affect an unknown amount of aquatic habitat, but would vary significantly depending on siting

Criteria	No-Action Plan	**Alt. 2 Reallocation of Falls Lake** Reallocate Storage in Conservation Storage to Water Supply Storage	**Alt. 7** Construction of a New Dam and Reservoir on Little River	**Alt. 12** Neuse River Intake Near Richland Creek with Offline Storage
EQ Account				
Riparian Habitat	No effect	This alternative is expected to have insignificant effects on riparian habitat	This alternative may have significant effect on riparian habitat within reservoir footprint	This alternative would affect an unknown amount of riparian habitat, but would vary significantly depending on siting
Wetlands	No effect	This alternative is expected to have no negative effects on wetlands	This alternative may have significant effect on wetlands within reservoir footprint	This alternative would affect an unknown amount of wetlands, but would vary significantly depending on siting
Threatened and Endangered Species	No effect	This alternative is expected to have insignificant negative impacts on T&E species	This alternative could have unknown effects on T&E species	This alternative would have unknown effects on T&E species, and would vary significantly depending on siting
Prime and Unique Farmlands	No effect	This alternative is expected to have no negative impacts to prime and unique farmlands	This alternative would have an unknown impact on prime and unique farmlands	This alternative is expected to have no negative impacts on prime and unique farmlands

Criteria	No-Action Plan	**Alt. 2 Reallocation of Falls Lake** Reallocate Storage in Conservation Storage to Water Supply Storage	**Alt. 7** Construction of a New Dam and Reservoir on Little River	**Alt. 12** Neuse River Intake Near Richland Creek with Offline Storage
Corps Criteria				
Acceptability	N/A	Alternative is acceptable in regards to Federal laws, regulations, and guidelines	Alternative is acceptable in regards to Federal laws, regulations, and guidelines	Alternative is acceptable in regards to Federal laws, regulations, and guidelines
Completeness	No-Action is an incomplete solution to the identified problem	This alternative provides a complete solution to the identified problem	This alternative provides an incomplete solution to the identified problem	This alternative provides an incomplete solution to the identified problem
Effectiveness	No-Action is an ineffective solution to the identified problem	This alternative provides an effective solution to the identified problem	This alternative provides a less certain solution to the identified problem	This alternative provides a less certain solution to the identified problem
Efficiency	No-Action is an inefficient use of resources, and not an efficient solution to the identified problem	This alternative provides an efficient use of Federal and non-Federal resources, while providing a cost-effective solution to the identified problem	This alternative provides a less efficient use of non-Federal resources, while also providing a less cost-effective solution to the identified problem	This alternative provides a less efficient use of non-Federal resources, while also providing a less cost-effective solution to the identified problem

NOTE: The NED cost includes costs required to implement the alternatives, and includes not only costs of reallocated storage (in the case of Alternative 2), but also costs of additional transmissions lines, and water treatment facility expansion. For Alternative 2 also, includes operation and maintenance costs of $65,766 annually. Interest during construction is also included.

4.1 DERIVATION OF USER COST.

This section presents the information used to derive the costs that the user will incur over the repayment period to implement the reallocation of storage at Falls Lake only. The user cost does not include costs to extract, transport, treat, or deliver water to end users. User cost also does not include potential repair, or rehabilitation costs, should those costs become necessary.

4.2 Hydropower Benefits Foregone.

The Falls Lake project does not currently possess any hydropower project features, and thus, no hydropower benefits would be foregone as a result of project implementation.

4.3 Flood Control Benefits Foregone.

The Recommended Plan would not include storage reallocated from the flood risk management storage, would not cause changes to storage within the flood risk management storage, and would not cause changes to operations within periods within which the project was operated for flood risk management; thus, no flood risk management benefits would be foregone as a result of Recommended Plan implementation.

4.4 Updated Cost of Storage.

The updated value of the 327,504 ac-ft of usable storage is estimated at $453,423,398 based on the standard method for calculating updated cost of storage. Total usable storage (327,504 AF) is calculated as the Flood Storage (221,182AF; EL 251.5 to 264.8) plus the Conservation Storage (106,322 AF; EL 236.5 to 251.5), excluding Sediment Storage (25,073 AF; EL 200.0 to 236.5). The value of the storage was determined by first computing the cost at the midpoint of construction by using the use of facilities cost allocation procedure as follows:

[Updated Project Joint-Use Cost ($) x Storage Reallocated (AF) / Total Usable Storage (AF)] =
Cost of Reallocated Storage from Water Quality Storage

The cost allocated to the additional storage on this basis is escalated to present day price levels using the estimated 2017 Civil Works Construction Cost Index (CWCCI) System. Computations to determine the value of the 17,300 ac-ft of reallocated storage for Falls Lake are:

[$453,423,398 (FY2017) x 17,300 AF / 327,504 AF] = $23,951,539

The storage cost update for FY2017 for Falls Lake is shown in Table 3.6. These costs will be adjusted to the current rates at the time the water supply agreements are signed and cost indexed to the appropriate fiscal year and interest rate.

Table 4.1 - Updated Project Cost Estimate and Costs of Storage - Falls Lake, North Carolina

UPDATED COST OF STORAGE CATEGORY	JOINT-USE COST*	CWCCI FY 2017 INDEX RATIO	UPDATED JOINT-USE COST
Land & Damages	$ 54,047,166	3.5908	$ 194,073,828
Relocations	$ 33,612,035	3.5643	$ 119,803,376
Reservoir	$ 10,090,287	3.8960	$ 39,311,758
Dams	$ 14,961,635	3.5692	$ 53,401,068
Fish & Wildlife	$ 10,445,255	3.4463	$ 35,997,482
Roads, Railroads & Bridges	$ 698,209	3.5643	$ 2,488,626
Cultural Resources	$ -	3.4518	$ -
Buildings, Grounds & Utilities	$ 1,974,474	3.4518	$ 6,815,489
Perm Operating Equipment	$ 443,760	3.4518	$ 1,513,771
Total	**$ 126,272,821**		**$ 453,423,398**

*Joint-Use Cost is in 1978 dollars, and has been updated to 2016 dollars using CWCCI.

4.5 User's Cost.

The cost to the user (Table 4.2) of the recommended reallocation would be $23,951,539, or $1,151,176 annually over the 30-year repayment period, excluding Operations and Maintenance costs of $65,766 annually. This is based on the updated cost of storage for the entire project ($453,423,398), multiplied by the percentage of storage reallocated from water quality to water supply (0.0528, or 5.28%) as a percent of total usable storage for the project (327,504 total acre-feet of usable storage). It must be noted that the cost of reallocated storage to the customer is estimated to be a total of $36,508,249, unadjusted for inflation in future out-years, including annual O&M costs.

Table 4.2 - Falls Lake Water Supply - Repayment Cost for Additional Reallocated Storage

ITEM	AMOUNT
Storage Required, acre-feet	17,300
Interest Rate, Percent	2.75%
Repayment Period, years	30
Project Storage	
Flood Control	221,182
Water Supply (portion of Water Con Storage)	61,322
Water Quality (portion of Water Con Storage)	45,000
Inactive (Sediment Storage)	25,073
Total	352,577
Total Usable Storage (Above minus Sediment)	327,504
Percent of Additional Usable Project Storage	5.28%
Joint Use Project Cost	
Initial Construction (2017, Price Level)	$453,423,398
Reallocated Water Supply	
Storage Cost	$23,951,539
Annual Cost of Additional Storage	
Investment (Annual)	$1,151,176
O&M (Annual)	$65,766
TOTAL (Annual Payment Unadjusted)	$1,216,942

The total value of the additional 17,300 ac-ft of storage is estimated at $23,951,539 based on the standard method of calculating updated costs of storage. The annual investment for the reallocated portion of the project is $1,151,176; Annual Operations and Maintenance (O&M) for that portion of the project is estimated at $65,766. Total annual cost to the customer, of reallocated storage is estimated at $1,216,942, subject to annual adjustments for inflation.

5.0 TEST OF FINANCIAL FEASIBILITY.

As a test of financial feasibility, the annual cost of storage should be compared to the cost of the most-likely, least-costly alternative that the applicant would undertake in the absence of utilizing the Federal project. This should be an alternative that would provide water of equivalent quality and quantity.

As wells and interbasin water transfer options are not feasible, the most likely alternative to the Federal project is the construction of another reservoir within the same major basin, at a close enough proximity to make distribution economically viable. No other industrial or municipal system within a reasonable distance is known to possess a surplus supply of water adequate to meet the City of Raleigh's needs.

The reallocation of storage has a significant cost advantage over the alternative construction of an additional reservoir within the basin, providing a total cost savings of approximately $217 million over a new reservoir (Table 5.1), and would result in fewer environmental impacts than that of any other alternative.

Table 5.1 - Comparison of Costs and Benefits - Federal and Non-Federal Plans - Falls Lake

	Alternative 2 Falls Lake - Reallocate Storage in Conservation Storage to Water Supply Storage (*Federal Plan*)	**Alternative 7** Construction of a New Dam and Reservoir on Little River (*Most-Likely, Least-Costly Non-Federal Plan*)
Total Cost	$142,000,000	$359,000,000
Total Storage (ac-ft)	17,300	17,300
Annual NED Cost (Annual Cost of Storage)	$7,362,283	$18,613,096
Annual NED Water Supply Benefit	$11,250,813	$--

NOTE: Total cost includes costs required to implement the alternatives, and includes not only costs of reallocated storage in the case for Alternative 2, but in both cases, also costs of additional transmissions lines, and water treatment facility expansion. For Alternative 2, also includes operation and maintenance costs of $65,766 annually. Interest during construction is also included.

6.1 COST ACCOUNT ADJUSTMENTS.

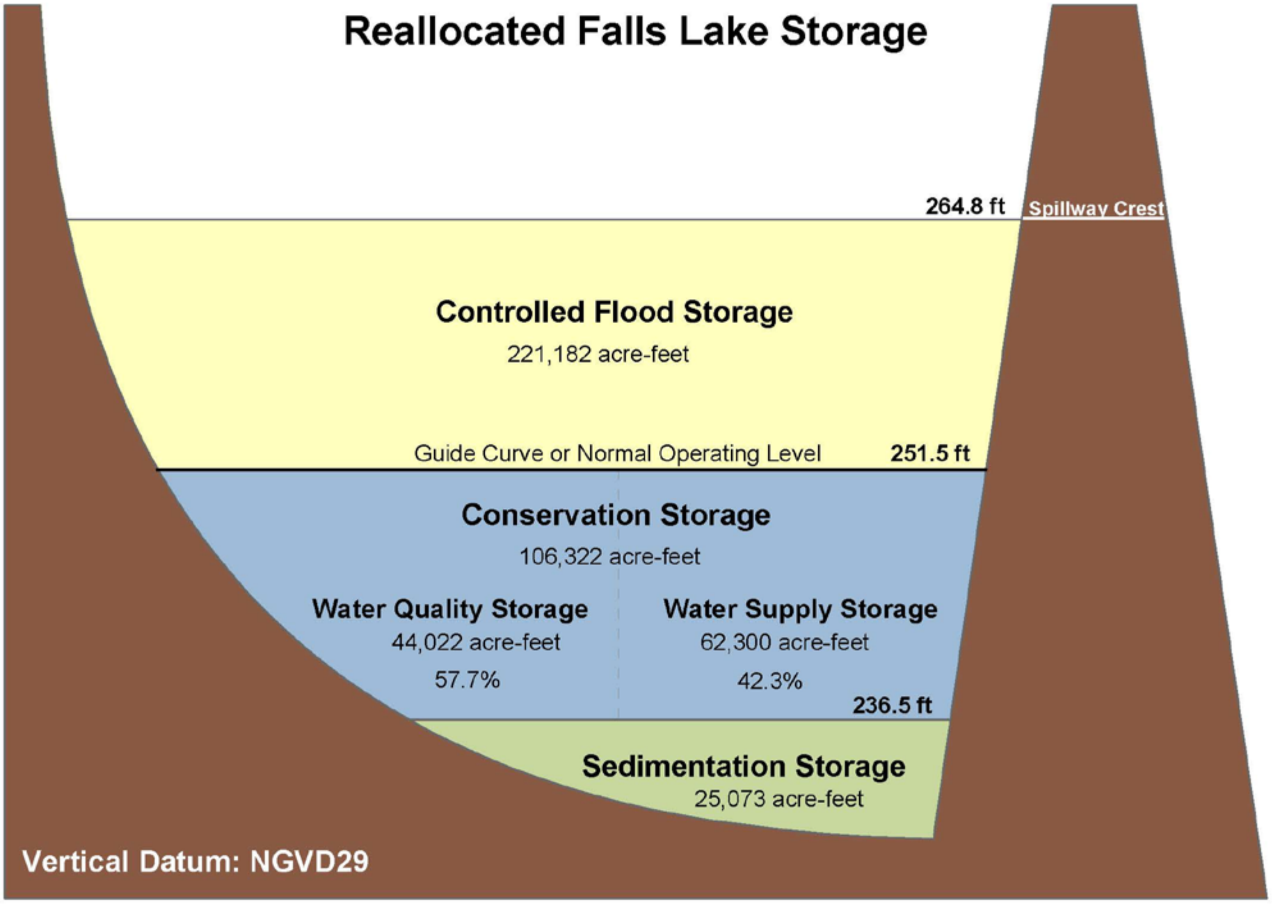
Under the City's existing water supply storage agreement, the repayment plan reaches the end of payments in 2033. The City's intent was that that the reallocated storage will be paid for with Operations and Maintenance (O&M) funds. The City's existing obligation under the water supply storage agreement will be supplemented and/or amended accordingly to include the obligation for any reallocation of storage capacity.

6.2 Existing Allocation.

The current allocation of the Falls Lake reservoir is 221,182 acre-feet in the flood risk management storage; 61,322 acre-feet in the water quality portion and 45,000 acre-feet in the water supply portion of the joint Water Conservation Storage (both totaling in sum 106,322 acre-feet), and a sediment storage volume of 25,073 acre-feet.

6.3 Proposed Future Reallocation.

The proposed future reallocation, which is the Recommended Plan, is for the reallocation of 17,300 acre-feet of storage from the existing water quality storage of 61,322 acre-feet, to the existing water supply storage of 45,000 acre-feet, resulting in a new water quality allocation of 44,022 acre-feet, and a new water supply allocation of 62,300 acre-feet. Future allocation of the Falls Lake project is shown graphically in Figure 6.1.



7.1 AFFECTED ENVIRONMENT AND ENVIRONMENTAL EFFECTS.

This section discusses the resources in the project area and the probable effects or impacts of the proposed project on environmental resources. The Recommended Plan is to reallocate storage in Falls Lake's water quality storage to the water supply storage. The effects discussed can be either beneficial or adverse and were considered over a 30-year period of analysis (2016-2045). Figure 7.1 shows the area of potential effect of the Recommended Plan.

In addition to the Recommended Plan, the impacts of the No Action alternative are addressed in this section. The No Action alternative involves the existing condition of the resources in the project area as well as the future without-project condition of these resources also over a 30-year period of analysis. A future without-project condition would reasonably expect the City of Raleigh to implement programs that reuse wastewater from the system and to incorporate water conservation and efficiency measures. In addition, impacts of the No Action plan are compared to the Recommended Plan in Table 7.1 and are discussed in more detail in the sections following Table 7.1.

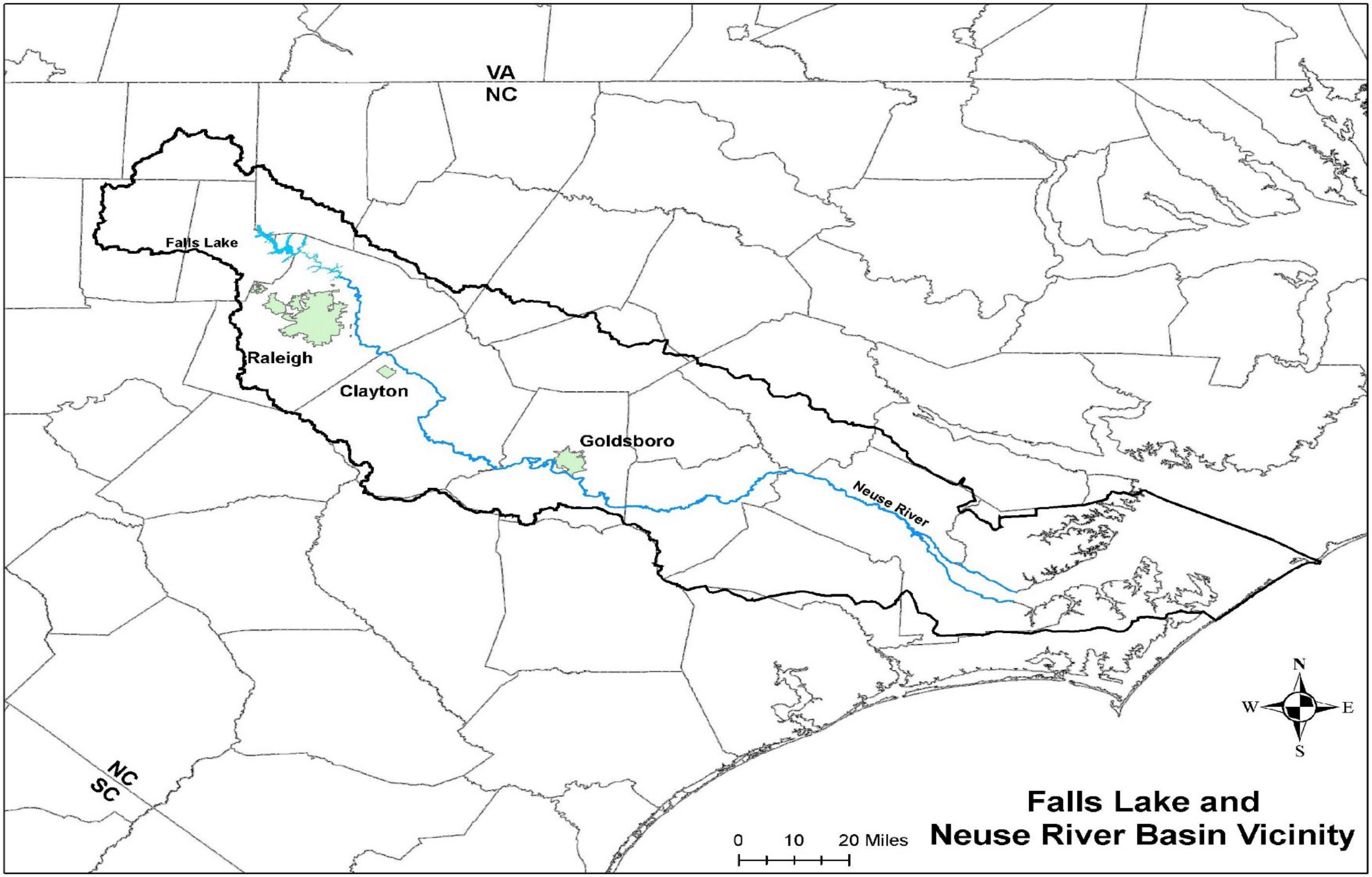


Figure 7.1 - Area of Potential Effect for the Recommended Plan

Table 7.1 - Comparison of Environmental Effects of No Action Alternative vs. Recommended Plan

	Alternative Plans	
Environmental Effect	**No Action**	**Reallocation (Recommended Plan)**
Geology and Sediments	No Change	No Effect
Floodplains	No Change	No Effect
Flood Risk Management	No Change	No Effect
Water Quality	No Change	No significant in-lake water quality effects; possible minor reductions in downstream flows between Dam and Wastewater Treatment Plant
Water Supply	Depletion of the Water Supply storage in 12 of the 30 years modeled for demand (to 2045). Insufficient water supply for industrial and municipal use to approximately 500,000	Reallocation of 17,300 acre-feet of Water Quality storage to Water Supply storage within Falls Lake increases water supply for the area to be served by implementation of the Recommended Plan.
Wetlands	No Change	No Effect
Vegetation	No Change	No Effect
Fish and Wildlife	No Change	No Effect
Endangered Species	No Change	No Effect
Cultural Resources	No Change	No Effect
Socio-economics	No Change	No Effect
Agriculture and Silviculture	No Change	No Effect
Recreation	No Change	No significant effect on downstream recreation including fishing, boating, canoeing and camping. Lake levels for Recommended Plan are slightly lower during droughts, for an already significantly depleted storage, and produces minimal additional negative effects on
Air Quality and Noise	No Change	No Significant Effect
Climate Change	No change on climate change and climate change would have no change on No Action	No effect on climate change and climate change and not expected to have any significant effect on the Recommended Plan.
Hazardous, Toxic and Radioactive Wastes	No change on HTRW and would not result in the production of HTRW.	No effect on HTRW and the Recommended Plan would not result in the production of HTRW.
Aesthetics	No Change	In Reservoir - A minimal decrease due to occasional lower water levels. Downstream aesthetics would have insignificant negative effects from the proposed plan.

7.2 Physical Resources.

7.2.1 Geology and Sediments.

Falls Lake and the upper portion of the Neuse River is underlain by metamorphic and igneous rocks of the Carolina Slate Belt. The Carolina Slate Belt consists mostly of low grade metamorphic (meta-igneous and meta-volcanic) rocks with coarser-grained intrusive granitic rocks. These metamorphic rocks includes slates, phylittes, and schists that are typically fine-grained and platy, and moderately to highly fractured. There are no general development restrictions associated with this geologic terrain.

The rate of sedimentation within the reservoir is influenced by regional and site specific conditions, including annual and seasonal precipitation patterns and associated stormwater runoff, as well as shoreline erosion. Sedimentation is an unavoidable problem for reservoirs like Falls Lake, due to steep banks, upstream erosion, erodible soils, and wind and wave action.

During the construction of the reservoir, an allocation of 25,073 acre-feet below the elevation 236.5 feet NGVD29 was designated for sediment accumulation and storage. This volume was selected based on the predicted sedimentation over a 100 year period (USACE 1981). In 1997, a sedimentation resurvey did not indicate any significant loss of storage in the sediment storage (USACE 1997). This does not mean that sedimentation is not occurring in portions of the reservoir. There are some select areas in the reservoir that experience higher levels of sedimentation due to shoreline erosion or the pattern of sediment transport through the water. In some cases, these isolated areas of high sedimentation can hinder recreational opportunities or natural conditions.

Recommended Plan: This alternative should not have an effect on the geology of the area or to increase or affect sediment inflow or sedimentation in the lake.

No Action: No changes in geology or sedimentation would occur.

7.2.2 Floodplains.

The Neuse River Basin lies wholly within the central and eastern part of North Carolina and drains all or parts of 22 counties. The basin is approximately 180 miles long, a maximum width near its center of approximately 46 miles, and includes about 12 percent of the total land area of North Carolina. It is the second largest river basin (Cape Fear is the largest) lying completely within the State and has a drainage area of 5,598 square miles. The basin is bisected by the “Fall Line”, a belt or zone about 35 miles wide between Benson and Wilson with forms a boundary between the Piedmont Plateau and the Coastal Plain.

At conservation storage elevation, approximately 251.5 feet NGVD29, Falls Lake is 22 miles long with approximately 245 miles of shoreline. This equates to about 12,400 acres of open water surface area. The reservoir receives most of its input from its tributaries during the winter and spring months and occasionally from storms in the summer. The reservoir fluctuates during the summer months; however, flood events and prolonged droughts have and will continue to cause much larger fluctuations in lake levels. These fluctuations have notable implications for recreation, wildlife, vegetation, shoreline erosion, and aesthetics at the project. The Recommended Plan will not cause any significant impacts to floodplains downstream of the dam, with outcomes insignificantly different from the No-Action condition.

Recommended Plan: This alternative will result in very similar flow rates as compared to current rates throughout the project area and therefore will not alter existing hydrology in the floodplain. The Recommended Plan will have no effect on the floodplain.

No Action: The No Action plan will result in no changes to the existing floodplain.

7.3 Water Resources.

7.3.1 Operations and Flood Risk Management.

A primary objective of the Falls Lake project is flood risk management below Falls Lake dam on the Neuse River. Storage of 221,182 acre-feet between elevations 251.5 ft-NGVD29 (top of conservation storage) and 264.8 ft-NGVD29 (spillway crest elevation) is reserved exclusively for the detention storage of floodwaters. An additional 687,400 acre-feet of surcharge storage exists above the free-overflow spillway between elevations 264.8 and 287.1 ft-NGVD29.

The general plan of flood operations provides for maintaining the 251.5 ft-NGVD29 normal storage elevation in Falls Lake by releasing flows that produce non-damage stages in the Neuse River downstream of Falls Lake dam whenever possible. The flood risk management objective is to store water in the controlled flood storage in Falls Lake whenever the Neuse River downstream is at that time, or is forecast in the future, to exceed the downstream capacity of the channel (i.e., a “bankfull condition”), or reach a depth or condition in which it would cause damage (i.e., “damage stage”). The latter is when flood flows would leave the channel and cause damaging inundation to structures or infrastructure. The United States Geological Survey (USGS) streamgage on the Neuse River near Clayton is the primary operational flood stage indicator; however, some consideration is also given to river stages farther downstream (such as Goldsboro and Kinston) based on experience during past major flood events. Because of the distance and the lengthy river flow travel time from Falls Lake dam to downstream areas--especially to areas downstream of Clayton--and coupled with runoff from the uncontrolled drainage areas, releases from Falls Lake dam will sometimes be reduced to near minimum prior to a storm event to prevent discharges from contributing substantially to those uncontrolled floodwaters. Afterwards when downstream conditions allow, the flood risk management space in the reservoir will be evacuated at a rate that will produce up to non-damaging stages downstream. Flood releases are based on a tiered release schedule, allowing for increased releases and higher regulated flows at Clayton as lake levels rise higher into the

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flood storage.

Recommended Plan: There would be no change in normal operating pool levels, no reduction in available flood storage, and no change to operational flood releases associated with this conservation storage reallocation; therefore, no effects to the our flood risk management objective are anticipated.

No Action: No change to flood risk management would be expected.

7.3.2 Water Quality.

Water quality is an authorized purpose of Falls Lake, with 57.7 percent of the conservation storage allocated for this purpose. This storage is used to maintain water quality downstream of the dam in the Neuse River during low-flow conditions by making releases from the lake to meet minimum flow targets immediately below Falls Lake and also farther downstream at Clayton, North Carolina. Augmentation of low-flows in the Neuse River benefits a number of downstream municipal and industrial water systems, as well as the aquatic ecosystem.

Under normal operations at Falls Lake, water quality releases are made to meet a minimum flow target at Clayton, NC, in the months of November through March of 184 cfs (cubic feet per second) and from April through October a daily average flow target of 254 cfs. Additionally, the minimum release at Falls Lake dam is 100 cfs from April through October, and 50-60 cfs from November through March, dependent upon the level of Falls Lake. Flow levels cannot be altered substantially without impacting downstream water quality conditions and water supply intakes in the Neuse River.

The North Carolina Division of Water Quality (now Division of Water Resources) publishes data on water quality throughout the State in its 303(d) Impaired Waters Assessment. The most current 303(d) list available for North Carolina was completed in 2012. The report identifies portions of the Flat River, Ellerbee Creek, Knapp of Reeds Creek, Lick Creek, and Little Lick Creek as they empty into the reservoir, as well as the reservoir itself, as being impaired for supporting aquatic life. This means that these bodies of water do not meet the national water quality criteria established in the Clean Water Act (NCDWQ 2016).

To address this growing problem in the Neuse River Basin, the North Carolina Environmental Management Commission adopted the Falls Lake Rules, a set of permanent rules to implement the Neuse River Nutrient Sensitive Waters Management Strategy. The strategy is based on a set of rules governing riparian areas, agriculture, stormwater, nutrient management, and wastewater. The rules include regulations regarding stormwater management for new and existing development, wastewater discharge, agriculture, and actions by State and Federal entities. The rules also include options for offsetting nutrient loads and fertilizer management (NCDWQ 2016).

The NC Division of Water Resources (DWR) classifies surface waters of the state based on their existing or proposed uses. The primary classification system distinguishes the following three basic usage categories: waters used for public water supply and food processing (Classes WS-I through WS-V), water supply (WS) waters used for frequent swimming or bathing (Class B), and waters used for neither of these purposes (Class C). Class C waters are protected for fishing, boating, aquatic life, and other uses (http://ncdenr.maps.arcgis.com).

Falls Lake is a Class WS-IV Water. Class WS-IV Waters are used as sources of water supply for drinking, culinary, or food processing purposes where a WS-I, II or III classification is not feasible. These waters are also protected for Class C uses. WS-IV waters are generally in moderately to highly developed watersheds or Protected Areas.

The Neuse River from Falls Lake to Clayton is classified as Class WS-IV, Class WS-V and Class C Waters. Class WS-V Waters are protected as water supplies which are generally upstream and draining to Class WS-IV waters or waters used by industry to supply their employees with drinking water or as waters formerly used as water supply.

Dissolved Oxygen (DO) levels in Falls Lake are a concern to some stakeholders. In order to determine the potential effects of the Recommended Plan on DO at Falls Lake, a water quality modeling effort was undertaken as part of this study. Modeling results indicate that any change would be de minimus, or insignificant, as compared to the No-Action Plan. The water quality modeling is discussed in Appendix D to this report.

A frequency analysis of modeled weekly flows was conducted to evaluate differences in 7-day, 10-year (7Q10) annual low-flow statistics for the three modeling scenarios—existing, future with reallocation, and future without reallocation. The annual 7Q10 flow is the annual 7-day minimum flow with a 10-year recurrence interval and is a common water quality-related flow parameter. Table 7.2 below presents the annual 7Q10 flows for each of the modeling scenarios (1) immediately downstream of Falls Lake dam, (2) Neuse River just below Crabtree Creek confluence, (3) Neuse River just above Raleigh's WWTP, and (4) Neuse River at the USGS streamgage near Clayton.

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Table 7.2 - Annual 7Q10 Low Flow Comparisons for All Model Conditions

Downstream Location	Annual 7Q10 Flows (CFS)		
	Existing	Future With Reallocation	Future Without Reallocation
Immediately below Dam	58	54	57
Below Crabtree Creek	106	103	109
Above WWTP	122	121	127
At Clayton Gage	207	258	216

Modeling results show very minor differences in annual 7Q10 flows immediately downstream of the dam, below Crabtree Creek, and above the WWTP for all three scenarios— which comprise the section of river of most concern related to the proposed reallocation. The most notable impact on 7Q10 flows is at the Clayton gage, where model results indicate a 50 cfs increase in future 7Q10 flows with the reallocation compared to existing conditions. This is due to the fact that releases from Falls Lake dam cannot be reduced below its minimum requirement
(50-65 cfs Nov-Mar; 100 cfs Apr-Oct), even if Raleigh's wastewater return flow and downstream local inflows result in flows at Clayton in excess of the flow target (184 cfs Nov-Mar; 254 cfs Apr-Oct). The water quality benefits of these higher 7Q10 flows at the Clayton gage would obviously continue into reaches of the Neuse River farther downstream as well.

Recommended Plan: The Recommended Plan would result in reallocation of 17,300 acre-feet of Water Quality storage to Water Supply storage within Falls Lake. However, the Recommended Plan would not significantly reduce the downstream flow rate between Falls Lake dam and Raleigh's Wastewater Treatment Plant outfall, and water quality flow targets both immediately downstream of Falls Lake and at Clayton, would continue to be met.

No Action: No change in water quality would be expected.

7.3.3 Water Supply.

Water supply is another authorized purpose of Falls Lake. The reservoir is the primary water supply for the City of Raleigh, which also provides water supply to other surrounding communities in Wake County (Figure 7.2). The "water service area" is that area to be served by the Recommended Plan reallocation.

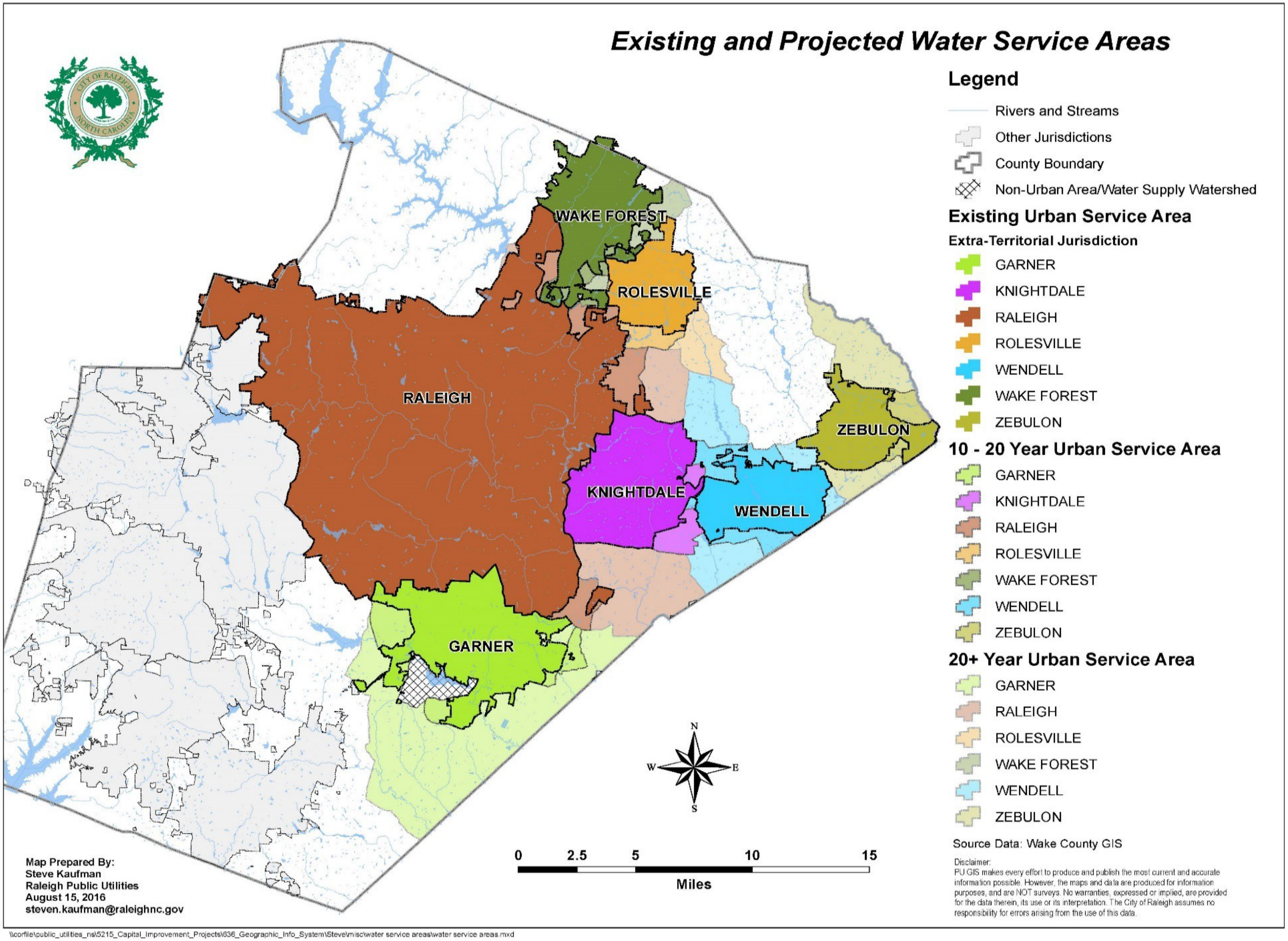

Figure 7.2 - Existing and Projected Water Service Areas

Water supply demand for the City of Raleigh service area was forecasted for the period 2016 through 2045 using a spreadsheet-based demand model originally developed by the City of Raleigh for their water supply planning purposes. The water supply demand analysis forecasted a steadily increasing need between years 2016 and 2045, culminating with a 2045 forecast average annual demand of 97.9 mgd, nearly double what actual 2015 demands were and about 40 mgd greater than what 2015 demands would have likely been under drought conditions. Details on the water demand analysis are contained in Appendix A.

A drought contingency plan was also prepared by the Corps of Engineers, Wilmington District in 2008. The purpose of this plan was to enable the Corps to be more responsive to drought conditions in the Neuse River Basin.

Recommended Plan: This alternative would result in reallocating 17,300 acre-feet of Water Quality storage to Water Supply storage within Falls Lake. The Recommended Plan would provide sufficient water supply to meet projected water demand growth through the period 2016 to 2045.

No Action: As water use increases over time, meeting 2045 demand is not feasible under current conditions. There will be insufficient water supply for projected industrial and municipal demand growth. Water storage would have to be developed through one of the other alternatives described in Section 3.9.

7.4 Biological Resources.

7.4.1 Wetlands.

Wetlands are lands that are wet at least part of the year due to either saturated soils or standing water. A jurisdictional wetland, as defined by the USACE, consists of hydric soils, hydrology, and hydrophytic vegetation. Wetlands include a variety of natural systems, such as marshes, swamps, and bottomland hardwoods (NCDENR 2012). Wetlands are known to exist within all land classifications at Falls Lake.

Wetlands occur in many of the Falls Lake natural areas and provide quality habitats for many species. In North Carolina, more than 70 percent of the species listed as endangered, threatened, or of special concern depend on wetlands for survival. Many common species of waterfowl, fish, birds, mammals, and amphibians also live in wetlands during certain stages of their lives (NCDENR 2012). Typical vegetation found in wetland areas are black gum, water oak, red maple, and sweet gum. Shrubs, like buttonbush and blueberry, and ferns and mosses can also be found surrounding wetlands (Piedmont Habitats, n.d.). As of 2016, approximately 1,063 acres of wetlands exist within 10 miles of Falls Lake (National Wetlands Inventory, n.d.).

Recommended Plan: This alternative would have no effect on wetlands due to the proposed project having limited effect on the lake elevation, and no adverse impacts to adjacent lands.

No Action: This alternative would result in no change to wetlands.

7.4.2 Vegetation.

The land surrounding Falls Lake is primarily deciduous forest with some evergreen forest interspersed. The deciduous forest consists of beech, sweet gum, red maple, sourwood, ironwood, oaks, and many other hardwood trees and understory shrubs and vegetation. The evergreen forest comprises of mostly loblolly pines, but longleaf and several other species of pine trees can also be found, along with American Holly. The shoreline is comprised mostly of native and non-native grasses along the edge. Trees and shrubs are typically found a few feet off of the shoreline, behind the grasses.

Recommended Plan: This alternative would have no effect on vegetation.

No Action: This alternative would result in no change to vegetation.

7.4.3 Fish and Wildlife.

Enhancing and protecting fish and wildlife resources within project lands is a congressionally authorized project purpose at Falls Lake. As such, the condition of fish and wildlife resources is a determining factor in current and future management of Falls Lake. Management of fish and wildlife resources is focused on the protection of native species and the promotion of game species to support recreational fishing and hunting. Some examples of these native fishes are: White Perch, Black and White Crappie, Bluegill, Red-breasted Sunfish, Longnose Gar, Channel, Blue, and Bullhead Catfish, and Striped, Spotted, Largemouth, and White Bass. Common mammals that may be found around Falls Lake are: coyotes, gray squirrels, red and gray foxes, White-tailed deer, rabbits, beavers, and otters. Great white egrets, blue heron, ducks, songbirds, bald eagles, osprey, and cliff swallows are just a few of the bird species that frequent Falls Lake.

The 1981 Master Plan, and other surveys, have noted viable habitat for a variety of waterfowl, other birds, mammals, amphibians, and reptiles. Since the 1981 Master Plan, increasing levels of urbanization around the project have impacted some of these species by limiting available habitat. This development however, has made the relatively undeveloped lands at Falls Lake more important habitat in the region and increasingly valuable to native species.

To document changes in wildlife populations, NCWRC conducts regular inventories of fish resources within Falls Lake. Between 1987 and 1998, the agency stocked the reservoir with striped bass. Stocking was abandoned to focus management efforts on the high quality largemouth bass population found in the reservoir. In 1999, 2005, 2007, 2009, and 2011, NCWRC collected largemouth bass from the lake to determine trends in size. The results of this study found that, although the reservoir supports a quality fishery, the fish are relatively small (less than 16 inches) (NCWRC 2012a).

Since 2000, NCWRC also has collected crappie from the reservoir every other year to determine size and population trends. The studies indicated that the population is slightly overcrowded. This has resulted in the fish showing slowed growth, reduced weights, and large numbers in specific age groups. These findings led NCWRC to recommend that the crappie fishery continue to be harvested without restrictions (NCWRC 2012b).

Similar studies have not been performed on wildlife species, although NCWRC maintains records on the number of game species harvested in different regions of the State. Hunting and fishing is allowed throughout most of the project lands, in accordance with State and local laws. NCWRC maintains game lands within the project boundary to support different game and non-game species.

Falls Lake is authorized to enhance fish and wildlife resources and habitat at Falls Lake. The value of the Falls Lake project lands to fish and wildlife has been further enhanced through the work by USACE, NCWRC, and other partners to develop the wildlife areas and impoundments located throughout the project. These areas were designed to meet the project purpose of enhancing fish and wildlife habitat, fulfilling mitigation agreements between USACE and the U.S. Fish and Wildlife Service (USFWS), as well as providing recreational opportunities for wildlife viewing or hunting. Fish and wildlife resources are managed through habitat enhancement and recreational fishing and hunting, which is allowed in various locations. Habitat enhancement is further supported by the 12 waterfowl sub-impoundments located within the project boundary. USACE also strives to maintain specific water levels during the spring months to promote reproduction of fish and other aquatic species. When feasible, the USACE has worked with NCWRC and U.S. Fish and Wildlife Service to provide downstream flow releases during the spring months that benefit spawning runs of anadromous fish species.

Water releases from Falls Lake Dam are a vital part of the flow regime for anadromous fish such as American shad and striped bass. Some examples of other downstream aquatic resources include various crayfish, shiners, sunfish, and mussels.

Recommended Plan: This alternative will have little to no effect on the lake water quality, and no adverse impacts to adjacent lands and therefore have no effect to Falls Lake fish and wildlife resources. This alternative will result in very similar downstream flow rates as compared to current rates throughout the project area. Therefore, no effects are expected because adequate flows and of suitable water quality will continue to be provided for successful reproduction and growth rates for the American shad, striped bass and other aquatic resources.

No Action: This alternative would have no effect on fish and wildlife.

7.4.4 Endangered Species.

A specific component of USACE and North Carolina's commitment to enhancing fish and wildlife populations at Falls Lake is the consideration and protection of rare and endangered species and communities. Within Durham, Granville, and Wake counties, five Federally-listed species are known to exist (USFWS 2016). These species and their habitat requirements are described below in Table 1.

The last survey of special status species or habitats on project lands was conducted by North Carolina Natural Heritage Program in 1986. The survey identified 13 plant species of special significance, including two populations of smooth coneflower and 13 Registered Natural Areas ranging from 0.5 to nearly 700 acres (USACE 1994).

Table 7.3: Federally-listed Species Known to Occur in the Falls Lake Region

Common Name	Scientific Name	Description	Habitat Requirements
Red-cockaded woodpecker	*Picoides borealis*	A medium-sized bird with black and white coloration.	Optimal habitat is characterized as a broad savanna with a scattered overstory of large pines and a dense groundcover containing a diversity of grasses and shrub species.
Dwarf wedgemussel	*Alasmidonta heterodon*	A small freshwater mussel with a trapezoidal-shaped shell.	Typically found in shallow to deep quick running water on cobble, fine gravel, or on firm silt or sandy bottoms. Other habitats include submerged aquatic plants, and near stream banks underneath overhanging tree limbs.

Table 7.3: Federally-listed Species Known to Occur in the Falls Lake Region			
Common Name	**Scientific Name**	**Description**	**Habitat Requirements**
Michaux's sumac	*Rhus michauxii*	A low growing, densely hairy, dioecious shrub.	Today, many of the Michaux's sumac occurrences are in areas that are artificially disturbed, such as highway and railroad rights-of-way, pine plantations, edges of cultivated fields, and other cleared lands.
smooth coneflower	*Echinacea laevigata*	A perennial herb with smooth stems, few leaves, and pink to purplish flowers.	Occurs primarily in openings in woods, such as cedar barrens and clear cuts, along roadsides and utility line rights-of-way, and on dry limestone bluffs. It usually is found in areas with magnesium- and calcium-rich soils and requires full or partial sun exposure.
harperella	*Ptilimnium nodosum*	An annual herb with slender, erect stems.	Occupies rocky or gravelly shoals of clear, swift-flowing streams and the edges of intermittent pineland ponds or low, wet savannah meadows on the Coastal Plain. In all habitat-types, the species occurs in a narrow range of water depths; it is intolerant of deep water and of conditions that are too dry. However, the plants readily tolerate periodic, moderate flooding.
Northern Long-Eared Bat	*Myotis septentrionalis*	A medium-sized bat with fur color medium to dark brown on the back and tawny to pale-brown on the underside.	During summer, they feed, roost and raise young in forested areas. Some males and non-reproductive females may use caves and mines during the summer. During winter, the northern long-eared bat hibernates in caves and mines.

Table 7.3: Federally-listed Species Known to Occur in the Falls Lake Region			
Common Name	**Scientific Name**	**Description**	**Habitat Requirements**
Tar River spinymussel	*Elliptio steinstansana*	A small freshwater mussel with a brownish rhomboid-shaped shell with up to 6 spines on each valve.	Lives in relatively silt-free uncompacted gravel and/or coarse sand in fast-flowing, well oxygenated stream reaches.
rusty patched bumble bee	*Bombus affinis*	Entirely black heads, but only workers and males have a rusty reddish patch centrally located on the back.	Need areas that provide nectar and pollen from flowers, nesting sites (underground and abandoned rodent cavities or clumps of grasses), and overwintering sites for hibernating queens (undisturbed soil).
Atlantic sturgeon	*Acipenser oxyrhynchus oxyrhynchus*	Grow to approximately 14 feet and can weigh up to 800 pounds, bluish-black or olive brown dorsally with paler sides and a white belly.	Spawning adults migrate upriver in the spring, typically during April and May over hard bottom substrates, are benthic foragers and are relatively sensitive to low dissolved oxygen levels.

There are records for several state threatened mussel species in the Neuse River below Falls Lake in Wake County: Carolina fatmucket, *Lampsilis radiata conspicua;* triangle floater, *Alasmidonta undulata;* eastern lampmussel*, Lampsilis radiata;* and Roanoke slabshell, *Elliptio* *roanokensis*. There are also records in the Wake County portion of the Neuse River for green floater, *Lasmigona subviridis*, which is a Federal Species of Concern and is State Endangered. Maintaining flows during drought conditions is vital for these listed aquatic species and other members of the aquatic community.

The only threatened and endangered species in North Carolina that falls under the jurisdiction of the National Marine Fisheries Service (NMFS) that could be affected by the recommended plan is the endangered Atlantic sturgeon of the Carolina distinct population segment. The numbers of Atlantic sturgeon in this segment are extremely low compared to historic levels and have remained so for the past 100 years (http://sero.nmfs.noaa.gov/protected_resources/sturgeon/).

On June 3, 2016, the NMFS proposed to designate critical habitat for the endangered Carolina distinct population segment of the Atlantic sturgeon. The proposed critical habitat unit that is in the project area is the Neuse (Carolina Unit 3), which extends from Pamlico Sound up to the Milburnie Dam. The four biological features that NMFS identified for essential conservation are: Suitable hard bottom substrate in low salinity water, transitional salinity zones with a gradual downstream gradient, appropriate water depth of at least 1.2 meters, and water quality conditions (temperature and dissolved oxygen).

Recommended Plan: Adequate flows and suitable water quality will continue to be provided and therefore this alternative will have no effect on the any of the state threatened or endangered species mentioned above or the federally endangered Atlantic sturgeon and its proposed critical habitat, endangered dwarf wedgemussel and the endangered Tar River spinymussel.

The endangered Red-cockaded woodpecker, Harperella, rusty patched bumble bee, Michaux's sumac and Smooth coneflower along with the threatened Northern long-eared bat all are located inland and therefore this alternative will have no effect on them.

No Action: This alternative would have no impact on threatened or endangered species.

7.5 Cultural Resources.

Prehistoric period cultural resources identified within Falls Lake range from long-term habitation sites spanning several prehistoric time periods to isolated artifacts and include sites from the Paleo-Indian through Woodland periods (circa 10,000 B.C.-circa 1600 A.D.). Prehistoric sites in the vicinity of the reservoir include lithic scatters, lithic workshops, rockshelters, and short-term habitation sites. Historic period cultural resources include cemeteries, dwellings, dumps, farmsteads, and mills. These sites range from the sixteenth to the twentieth century. Past surveys have recorded both historic and prehistoric sites which document the entire span of human occupation of the area (USACE Master Plan 2013).

Background research, including consultation with USACE archaeologists and the North Carolina State Historic Preservation Office (SHPO), identified a total of 1,128 previously recorded archaeological sites within the boundary of the Falls Lake. Of these sites, a total of 34 archaeological sites are determined eligible for inclusion in the National Register of Historic Places (National Register). Three properties, James Mangum House, Rock Cliff Farm, and Fairntosh, are listed on the National Register and within the boundary of the project, while another, Falls of Neuse Manufacturing Company, is located just outside. In the 1981 Master Plan, Fairntosh is listed as the Bennehan-Cameron Plantation Historic District and includes 6,000 acres with one-third of the plantation on reservoir property. The Falls of Neuse Manufacturing Company property had two elements (dam and raceway) that were within the reservoir boundary. These structures were destroyed during the construction of the Falls Lake Dam.

As part of the 1981 Master Plan, two surveys and evaluations were conducted on project lands. The surveys within the reservoir boundary included large-scale surveys (10,500 and 8,100 acres), medium-scale surveys (350 and 132 acres), architectural surveys, pedestrian surveys, shoreline surveys (48 linear miles), and site-specific investigations to determine the eligibility of both archaeological sites and historic resources for inclusion in the National Register. A total of 281 sites were identified during these surveys. Two sites were recommended for immediate excavations due to potential disturbance by the flood storage and six others were considered significant (USACE 1981). Many other archaeological investigations, as well as the many other efforts, have been conducted prior to and following the 1981 Master Plan.

The 1981 Master Plan includes a description of the probability model developed for most of the Falls Lake project property. The areas were divided into High, Medium, and Low Sensitivity. High Sensitivity areas included areas where known significant sites were present or that they may occur. No development was suggested for these areas. Medium Sensitivity areas are where known moderately sized sites occurred or that may occur. Surveys were suggested before any construction was done. Finally, Low Sensitivity areas are those where no sites occurred or that may have been significantly disturbed. No surveys were necessary in these areas. Using up-to-date information, this model is still applicable for planning future development at Falls Lake.

Recommended Plan: This alternative will have no effect on historic resources. The North Carolina Department of Natural and Cultural Resources (NCDNCR) concurred with this determination by letter dated December 18, 2015.

No Action: No known historic resources would be affected and therefore no changes are expected.

7.6 Socio-Economic Resources.

Recommended Plan: The Recommended Plan would provide sufficient water to meet project demand growth through the year 2045. This would support social aspects within the area provided by the reallocation, shown in Figure 7.2, and support economic growth within those communities.

No Action: The No Action condition would result in insufficient water to provide for future water demand growth for the period 2016 through 2045. This would result in impacts to existing municipal and industrial assets, as water becomes less available. Water shortages would impact economic growth and vitality.

7.6.1 Demographics.

Recommended Plan: Falls Lake provides the drinking water for over half a million people in Raleigh and six other municipalities in eastern Wake County: Garner, Knightdale, Rolesville, Wake Forest, Wendell and Zebulon. The demand is expected to increase with time. This alternative would meet projected water demand for the next 30 years.

No Action: No changes to existing conditions would be expected.

7.6.2 Agriculture and Silviculture.

The land surrounding Falls Lake has been used for agricultural and timbering activities for many generations. Agricultural practices are shown to pre-date the Civil War, with the most important crops during this time being cotton and tobacco. Timber harvests are conducted each year by the NCWRC. The NCWRC manages the forests around Falls Lake by forest thinning, regeneration cuts, and prescribed burns. The amount of timber harvested varies on the stand maturity, resources available, and presence of cultural resources survey data in the proposed harvest areas.

Recommended Plan: This alternative would have no effect on agriculture or silviculture due to the proposed project having limited effect on the lake elevation, and little to no impacts to surrounding lands.

No Action: This alternative would result in no changes to agriculture or silviculture.

7.6.3 Recreation.

USACE provides and manages recreation facilities on the lands it actively manages at Falls Lake. The area immediately surrounding the Visitor Assistance Center, dam, and tailrace includes restrooms, picnic tables, playground equipment, hiking trails, bank fishing access, and trail access to hunters using the adjacent game lands.

The North Carolina Division of Parks and Recreation (NCDPR) operates the majority of developed recreation facilities at Falls Lake as part of the North Carolina State Parks System. Collectively, these facilities comprise the Falls Lake State Recreation Area (SRA). The NCDPR operates a total of eight developed areas around the reservoir, with most of the facilities concentrated in the middle sections of the reservoir. Facilities provide amenities for camping (walk-in, RV, vehicle; some with electric and water hook ups), swim beaches, picnic areas, hiking trails, community building, boat ramps, playgrounds, and mountain biking trails.

Most of the undeveloped lands within Falls Lake are included in North Carolina Wildlife Resources Commission's (NCWRC) Butner-Falls of Neuse Game Land. NCWRC provides four boat ramps at Upper Barton, Ledge Rock, Hickory Hill and Eno River. The boat ramp sites consist of parking areas (paved and unpaved), courtesy docks, and lake access.

In addition to the lake surface area, NCWRC manages hunting within the wildlife areas that comprise the Butner-Falls of Neuse Game Lands within the project. These lands include 12 waterfowl sub-impoundments, around the lake. The sub-impoundments were constructed as part of a mitigation agreement between USACE and USFWS to replace the habitat and hunting opportunities that were lost when the Neuse River floodplain was flooded to create the reservoir. NCWRC lands are multiuse areas open to both the hunting and non-hunting public for purposes of recreation, hunting, trapping, wildlife observation, hiking and mountain biking (on designated trails), and bank fishing. The Falls Lake Trail, part of the Mountains-to-Sea State Trail, crosses through NCWRC and NCDPR-managed lands along the southern shore of Falls Lake, from the Falls Lake dam to Penny's Bend Nature Preserve.

Wake County subleases approximately 244 acres from North Carolina for Blue Jay Point County Park which is located between Lower Barton and Upper Barton Creeks on the southeast area of the lake. Wake County Parks, Recreation, and Open Space's mission at the park is to offer environmental education programming in a natural setting. The park provides approximately three acres of dedicated open space for play fields, playgrounds, an environmental education center, and an overnight lodge. Additionally, the park provides hiking trails, picnic areas, fishing opportunities and demonstration gardens and ponds associated with their education center.

The City of Raleigh operates a canoe launch just downstream of the USACE Tailrace Access Area. The site provides vehicle parking and access to the Falls of Neuse River below the dam.

The City also has leased land from North Carolina and USACE for future development of Forest Ridge Park. The City of Raleigh also subleases approximately 700 acres in Wake County on Falls Lake for Forest Ridge Park, which is currently under construction.

Rolling View Marina is the only commercial marina at the lake and is operated under sublease from North Carolina. The marina provides boat docking, repair services, fuel, and snacks to the visiting public. The marina is directly adjacent to the Rolling View Recreation Area just west of NC 50. The marina has about 200 slips and a public boat ramp.

The North Carolina Botanical Garden Foundation subleases 84-acres from North Carolina for operation and management of Penny's Bend Nature Preserve. The site is located on a peninsula, bounded on three sides by the Eno River as it flows downstream toward Falls Lake. It supports rare plant species, distinctive plant communities, and human sculpted open space.

Falls Lake supports recreation; however, there are no special pool operations for recreation. Recreation opportunities are provided to the maximum extent possible without significant interference with the other purposes described above. Under normal conditions, this operation strives to provide a full conservation pool throughout the year, but summer conditions combined with seasonal water withdrawals/releases commonly result in summer drawdowns to some degree. When water levels are too low or high, USACE, North Carolina, and other management partners must modify recreational offerings to achieve the other goals at the reservoir. Recreational uses in the lake typically start to be impacted when levels fall below 247.0 feet NGVD29 most notably with swim beaches. As the lake levels continue to decrease, impacts also increase. Severe impacts to recreation occur at lake levels 242.5 feet NGVD29 and below due to the unusability of boat ramps. Additional details on lake operations are provided in the Falls Lake Water Control Manual (USACE 1990).

Recommended Plan: The insignificant changes in flow rates that may occur during periods of severe drought would have slight effects on both upstream and downstream recreation, including fishing, boating, canoeing and camping.

During significant droughts, a decrease of lake levels may occur. This decrease may have an impact on the usability of boat docks, boat ramps, fishing piers, marinas, waterfowl impoundments, and swim beaches. Droughts typically occur in the summer and sometimes extend into the fall. The total percentage of time that lake levels would be below 247.0 feet NGVD29 would not be significantly different than the No Action alternative. The percentage of time of significant impacts to lake levels due to water levels being below 242.5 feet NGVD29 is approximately 3.5% versus 1% for the No Action alternative.

No Action: This alternative would result in no change to recreation.

7.7 Other Resources.

7.7.1 Air Quality and Noise.

Falls Lake is located in North Carolina's "Triangle Area", which includes the cities of Raleigh and Durham, as well as Wake, Durham, and Granville counties. The Raleigh-Durham area, which includes Durham and Wake counties, is considered a moderate nonattainment area for carbon monoxide. The region is an attainment area for all other Federal air quality standards (EPA 2011). Despite being in compliance with these standards, portions of the region are subjected to temporary impacts to air quality as a result of activities like large-scale construction projects. Ambient noise levels at the lake are generally low. Noise from recreational activities like motor boats may be occasionally heard.

Recommended Plan: There will be no construction with this alternative so there will be no effect-associated air quality or noise issues. There also will be no effect regarding noise issues associated with implementation.

No Action: This alternative would result in no changes to air quality or noise.

7.7.2 Climate Change.

As concern over the impacts of climate change have heightened in recent years, the need to consider reliability and resilience in the face of long-term change in the Earth's climate is increasingly becoming a requirement for major water resource infrastructure projects. At the same time, the multitude of variables that influence climate and the state-of-the-science understanding of how these variables interact still leave a significant degree of uncertainty regarding the progression of change in climate norms and extremes that will be experienced both globally and regionally. Nevertheless, using the best available science, qualitative and a quantitative analyses were carried out using two US EPA products to evaluate how climate change may influence the ability of the Falls Lake Conservation Pool to achieve its stated purposes once the Conservation Pool reallocation is completed. The first, used in a qualitative analysis, is the US EPA's Climate Resilience Evaluation and Awareness Tool (CREAT). The more detailed quantitative analysis was based upon the US EPA's "Watershed Modelling to Assess the Sensitivity of Streamflow and Water Quality to Climate Change and Urban Development in 20 U.S. Watersheds" study that included a detailed analysis of the Neuse River basin under climate change.

The qualitative evaluation is based on a review of expected changes in temperature and precipitation made available through the US EPA. The EPA provides a summary of the prognostications of numerous climate models categorized into three bins, labeled Hot/Dry, Central, or Warm/Wet depending on predicted changes from present temperature and precipitation characteristics in 2035 and 2060. The evaluation for this study used the EPA data and categorization for eight weather stations in the study area. The central tendency for these weather stations indicates a warmer and wetter future for this region, with the Hot/Dry bin showing only a modest decline in precipitation.

The quantitative evaluation involved the utilization of global and regional climate model results which were run through a rainfall-runoff model under the auspices of the US EPA to produce simulated hydrology for the Neuse River Basin under climate change in the years 2041-2070. Fourteen scenarios were evaluated and the combinations of conditions allowed us to distinguish between the anticipated impacts of climate change and land use change as compared to historical conditions. When the hydrologic output of these scenarios was coupled to the approved-for-use OASIS Cape Fear/Neuse Combined River Basin Hydrologic Model, the results varied from scenarios with very little change in water supply operating yield to scenarios with more than one-third greater operating yield. The median increase in water supply operating yield and annual minimum Water Quality Pool storage are 15% and 7% respectively for scenarios incorporating climate change and anticipated urban development. Both climate change and land use change contributed positively to water quantity availability in most scenarios. While the possibility of a very marginally drier future cannot be ruled out, the magnitude of drying is modest and manageable in the scenarios portraying such a future. The more likely possibility appears to be one of greater hydrologic abundance. Taken as a whole, the quantitative modeling exercise results appear in-line with the qualitative temperature and precipitation trend expectations also compiled by the EPA, providing increased confidence in the value of the conclusion that the best available climate change science at this time does not indicate that climate change is likely to pose a water quantity limitation that would be problematic for the proposed Falls Lake Reallocation. Greater detail on both the qualitative and quantitative analyses are described in Appendix F.

Recommended Plan: This alternative is expected to have no effect on climate change and climate change would have no effect on the Recommended Plan.

No Action: No Action would result in no change to climate change and climate change would result in no change on the No Action condition.

7.7.3 Hazardous, Toxic and Radioactive Waste (HTRW).

The area around Falls Lake contains a mix of natural, residential and commercial areas. A search of EPA's website (https://www3.epa.gov/) on August 11, 2016 produced 92 EPA regulated facilities within two miles around Falls Lake. None of the regulated facilities are on the National Priorities List. The National Priorities List is the list of national priorities among the known releases or threatened releases of hazardous substances, pollutants, or contaminants throughout the Unites States and its territories.

Recommended Plan: This alternative is expected to have no effect on HTRW and the Recommended Plan would not result in the production of HTRW.

No Action: HTRW would have no bearing on known HTRW sites, nor would result in the production of HTRW.

7.7.4 Aesthetics.

The views, vistas, and visual quality of Falls Lake can be defined by its two unique parts of the reservoir. The topography of the eastern half consists of gently rolling hills and ridges with a northeast to southwest trend. Where the project crosses into the Deep River Triassic Basin (west of NC 50), the topography is flatter and the northeast-southwest trending ridges are absent.

Throughout the project, dense stands of pine and hardwood forest provide a canopy over much of the shoreline and, in combination with the gentle topography, limit most long distance views from shore. The twisting reservoir path line and pattern of coves and inlets, further restricts sight distances. Although the forest cover may restrict site distances across the project, these resources also enhance the visual quality of the area by changing with the seasons.

The most notably scenic areas of the lake are around the Holly Point, Shinleaf, and B. W. Wells State Recreation Areas. These areas of the reservoir are located east of NC 50 and north of NC 98. The management areas have numerous rock outcroppings and some of the tallest, prominent rock cliffs in the area which form the "S" curve between the three management areas.

Human development and its presence around Falls Lake have not had noticeable effects on visual quality on much of the shoreline. The vegetation between the edge of the reservoir and the project boundary provides a buffer obstructing most views of private residences and upland road networks into the area. The majority of human built structures in the visual environment are recreation related, including boat ramps, campgrounds, beaches, and picnic areas. Other elements of the human built environment that are visible throughout the project include infrastructure related to the operation of the dam and reservoir.

Recommended Plan: This alternative is expected to have a minor effect on aesthetics due to the potential for a slight decrease in water levels during severe droughts.

No Action: No Action would result in no significant changes to aesthetics, either associated with the reservoir, or downstream of the project.

7.8 Cumulative Impacts.

The Council on Environmental Quality defines *cumulative impact* as "the impact on the environment [that] results from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR 1508.7). Cumulative impacts is a significant issue that should be addressed every time an Environmental Assessment is prepared. The analysis should be commensurate with the project's impacts and the resources affected. For example, small scale projects that have minimal impacts that are of short-duration would not likely contribute significantly to cumulative impacts.

The Recommended Plan will permanently reallocate 17,300 acre-feet of Water Quality storage to Water Supply storage within Falls Lake. As the demand for water grows, the City of Raleigh and the surrounding areas continue to investigate new alternatives to increase water supply. It is anticipated that the City of Raleigh will implement various water conservation and efficiency plans along with water reuse measures to help reduce water needs. Over the large Neuse River Basin area (the 6,235 sq mi) a number of reasonably foreseeable future actions by other Federal, state, and local agencies and by local landowners would be expected to occur. New construction and development would require implementing BMPs to limit the effect of such activities on the aquatic community and in the riparian corridor. The state's Basin-wide water quality planning efforts will continue to evaluate the condition of water quality on a 5-year basis. The state's water quality planning efforts will continue to identify improvement in areas and require reductions in areas not meeting water quality standards. Local municipalities, private dischargers, and landowners will continue to change the way they manage their activities to achieve pollutant reductions until all waterbodies meet water quality standards, including biological integrity.

The Recommended Plan has minimal potential impacts on environmental resources of the basin. Accordingly, the incremental or cumulative adverse effects, effects of the proposed action plus effects of other reasonable foreseeable projects are not greater than those of the No Action alternative alone.

The Recommended Plan would have no significant impacts to the approved, but not yet-funded COE Neuse River Basin Feasibility Study project features, including inland riverine, ecosystem restoration, or coastal wetlands.

The proposed reallocation will have long-term water supply benefits. These benefits will help to address the water supply needs of the City of Raleigh and six other municipalities in eastern Wake County: Garner, Knightdale, Rolesville, Wake Forest, Wendell and Zebulon, for the next 30 years.

In summary, the only impacts from the Recommended Plan is the reallocation of 17,300 acre-feet of Water Quality storage to Water Supply storage within Falls Lake and a minor impact to recreation at the Lake during severe droughts.

7.9 Executive Orders (EO).

7.9.1 Executive Order (E.O.) 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (EO 12898).

This EO requires the federal government to achieve environmental justice by identifying and addressing high, adverse and disproportionate effects of its activities on minority and low-income populations. The EO also states that the impacts of the action would not be disproportionate towards any minority or low-income population. The activity cannot (a) exclude persons from participation in, (b) deny persons the benefits of, or (c) subject persons to discrimination because of their race, color, or national origin. It requires the analysis of information such as the race, national origin, and income level for areas expected to be impacted by environmental actions. It also requires federal agencies to identify the need to ensure the protection of populations relying on subsistence consumption of fish and wildlife, through analysis of information on such consumption patterns, and the communication of associated risks to the public.

The proposed reallocation would provide benefits to the quality of life by improving the water supply to the area residents. No residences or public facilities would be impacted by the proposed action. In public outreach efforts to date, no potential environmental justice issues have been identified. Also appropriate demographic information related to environmental justice was addressed in Section 2.5.1. Therefore the proposed reallocation complies with EO 12898.

7.9.2 Protection and Enhancement of Environmental Quality (EO 11514).

The Federal Government shall provide leadership in protecting and enhancing the quality of the nation's environment to sustain and enrich human life. Federal agencies shall initiate measures needed to direct their policies, plans and programs so as to meet national environmental goals. Environmental quality effects will be insignificant therefore; the proposed reallocation complies with Executive Order 11514.

7.9.3 Protection and Enhancement of the Cultural Environment (EO 11593).

The Federal Government shall provide leadership in preserving, restoring and maintaining the historic and cultural environment of the nation. Federal agencies shall administer the cultural properties under their control in a spirit of stewardship and trusteeship for future generations, initiate measures necessary to direct their policies, plans and programs in such a way that federally owned sites, structures, and objects of historical, architectural or archaeological significance are preserved, restored, and maintained for the inspiration and benefit of the people, and, in consultation with the Advisory Council on Historic Preservation (16 U.S.C. 470i), institute procedures to assure that Federal plans and programs contribute to the preservation and enhancement of non-federally owned sites, structures and objects of historical, architectural or archaeological significance. The proposed water reallocation would have no impact on historic resources and therefore complies with Executive Order 11593.

7.9.4 Floodplain Management (EO 11988).

Executive Order 11988 requires Federal agencies to avoid to the extent possible the long and short-term adverse impacts associated with the occupancy and modification of flood plains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities."

The existing hydrology of the floodplain will not be changed. The proposed water reallocation complies with Executive Order 11988.

7.9.5 Protection of Wetlands (EO 11990).

Executive Order 11990 directs all Federal agencies to issue or amend existing procedures to ensure consideration of wetlands protection in decision making and to ensure the evaluation of the potential effects of any new construction proposed in a wetland. The proposed action would not require filling any wetlands and would not produce changes in hydrology that could affect wetlands.

No wetlands would be affected by the Recommended Plan. The proposed water reallocation complies with Executive Order 11990.

7.9.6 Executive Order 13693 (Planning for Federal Sustainability in the Next Decade)

A new Executive Order (EO) was issued 19 March 2015 (EO 13693 Planning for Federal Sustainability in the Next Decade). Federal Leadership will continue to drive national greenhouse gas reductions and support preparations for the impacts of climate change through a combination of more efficient Federal operations such as outlined in EO 13693. There is an opportunity for agencies to reduce direct greenhouse gas emissions for at least 40 percent over the next decade while fostering innovation, reducing spending, and strengthening the communities where Federal facilities are located. The first priority should be placed on reduction of energy use and cost, and secondly finding renewable or alternative energy solutions. Employing this strategy for the next decade calls for expanded and updated Federal environmental performance goals with a clear overarching objective of reducing greenhouse gas emissions across Federal operations and the Federal supply chain.

The Falls Reallocation project's recommended plan is the least cost, engineeringly sound, environmentally acceptable (Federal Standard) plan for satisfying the future needs of the City of Raleigh and neighboring partner communities. The recommended plan does not require construction or any other activity that will release greenhouse gasses to the atmosphere. The Falls Reallocation project complies with EO 13693 and Wilmington District will continue to implement positive changes to meet the goals outlined in EO 13693.

8.0 PUBLIC AND AGENCY INVOLVEMENT

On November 25, 2015, the USACE sent out a Scoping Letter to interested parties, to identify concerns and issues that might be addressed, and bring them to USACE attention. Commenters included the North Carolina Wildlife Resources Commission, United State Fish and Wildlife Service, the City of Durham, North Carolina, the Falls Whitewater Park (a non-profit corporation working to bring a whitewater park to the Neuse River downstream of Falls Lake), American Rivers, the North Carolina Conservation Network, Sound Rivers, Wake Up Wake County, the North Carolina Department of Natural and Cultural Resources State Historic Preservation Office, the North Carolina Division of Parks and Recreation, the Durham County Manager, and the North Carolina Natural Heritage Program.

Most comments and concerns focused on the perceived lesser volume of water, or reduced flow rates in the channel downstream of Falls Lake dam, and potential impacts to aquatic species. Other concerns included perceived negative impacts to water quality.

In addition, a meeting was held between the appropriate resource agencies, the State, regional governments, and USACE staff, to discuss the planning process, alternatives, and agency concerns. This meeting was successful in providing information the agencies needed as background for upcoming Public (and State and agency) Review of the Draft Report.

The Wilmington District received USACE approval to finalize the Draft Report/draft EA (integrated report) on 25 January 2017. Following finalization of the Draft Report/draft EA (integrated report), it will be circulated for a 30-day Public Review, concurrent with Agency Technical Review, and USACE Policy Review. All comments will be addressed and memorialized, in a Final Report/EA (integrated report).

9.0 CONCLUSIONS.

The analyses conducted during the course of study to-date indicate that Alternative 2 – Reallocation of Storage from Existing Water Quality Storage to Water Supply Storage, is the most technically feasible, cost-effective, and environmentally sound alternative of those evaluated. The detailed evaluation, comparison and screening analysis conducted indicates that Alternative 2 should be adopted as the proposed Recommended Plan. This plan consists of reallocation of 17,300 acre-feet of storage from existing water quality storage to supplement that of existing water supply storage, and would benefit the City of Raleigh and its partner water agencies, as well as all residents within the service area benefitting from this action. By implementing the Recommended Plan, the City and neighboring partner communities would possess a needed storage volume to ensure adequate water supply through the year 2045.

Both water quality and water supply storage are the two existing pools within existing 106,322 acre-foot water conservation storage. Implementation of the Recommended Plan would result in a revised storage volume of 44,022 acre-feet within water quality storage (41.4% of water conservation storage), and a revised storage volume of 62,300 acre-feet within water supply storage (58.6% of water conservation storage).

Since the existing water supply storage is being paid for by agreement with the City of Raleigh under a separate Water Supply Agreement, under a 50-year repayment plan, the Water Supply Agreement will need to be supplemented and/or amended to include the obligations related to the reallocation.

10.0 RECOMMENDATIONS.

It is recommended that the USACE allow the reallocation of 17,300 acre-feet of storage in the Falls Lake Dam and Reservoir Project, from existing water quality storage, to water supply storage, for the long-term benefit of the City of Raleigh, North Carolina, and its partner agencies. I have determined that it is within the discretionary authority of the Chief of Engineers to approve this proposed action, as the Recommended Plan does not include any modifications which would affect the purposes for which the project was authorized, surveyed, planned, or constructed, nor would it involve major structural or operational changes. A draft Finding of No Significant Impact (FONSI) is provided as an attachment to this report. Questions on this Draft Report/draft EA can be directed to Mr. Elden Gatwood, Chief of Planning and Environmental Branch, Wilmington District, at (910) 251-4505, or Ms. Pamela Castens, Project Manager, at (910) 251-4671. Questions on the environmental resources analysis or EA, can be directed to Mr. Eric Gasch, Environmental Resources Specialist, at (910) 251-4553.

Kevin P. Landers, Sr.
Colonel, U.S. Army
District Commander

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City Of Raleigh
NORTH CAROLINA

June 19, 2013

Colonel Steven A. Baker
District Engineer
Wilmington District, USACE
69 Darlington Ave
Wilmington, NC 28403

Dear Colonel Baker:

I am writing to you regarding the Wilmington District of the US Army Corps of Engineers Falls Lake Project. The City of Raleigh would like to have 3.8% (12,582 acre-feet) of the total storage in Falls Lake reallocated from the water quality pool to the water supply pool. To facilitate this request, the City of Raleigh would like to enter into a Memorandum of Agreement to provide funding for reallocation studies. We understand that the current cost estimate for the studies would be approximately $450,000 and that federal funds will not be available to perform the studies.

The City of Raleigh initially has $500,000, which includes the estimated cost of completing the reallocation studies and additional funds for contingency, available for this project, and will not ask to be reimbursed for these expenses at a later date. However, we will need a provision in the MOA providing that if any of these funds remain unspent after the studies are fiscally complete, the unspent funds will be returned to the City. In addition, the City's offer of these funds is dependent on both the City and the Corps of Engineers entering into the Memorandum of Agreement pursuant to which the Corps of Engineers agrees to complete the required studies necessary for a reallocation request to be decided.

The City is making this voluntary contribution of funds with the clear understanding that this contribution will not have any effect on the findings and conclusions of the study. Furthermore, the City understands that the contribution of funds for the reallocation studies will not have any impact on the evaluation and future decision related to any application filed for the City's Little River Reservoir.

We appreciate the efforts of the Corps of Engineers on this important project for City of Raleigh. For further information regarding this work please contact our subject matter experts, Mr. Kenneth Waldroup at 919-996-3489 or Mr. Dan McLawhorn at 919-996-6623. Thank you for your time and consideration of this request.

Sincerely,

J. Russell Allen

J. Russell Allen,
City Manager

cc: John Robert Carman, Public Utilities Director
Kenneth Waldroup, Assistant Public Utilities Director
Daniel F. McLawhorn, Associate City Attorney

DEPARTMENT OF THE ARMY
SOUTH ATLANTIC DIVISION, CORPS OF ENGINEERS
ROOM 9M15, 60 FORSYTH ST., S.W.
ATLANTA GA 30303-8801

REPLY TO
ATTENTION OF

CESAD-RBT

MEMORANDUM FOR COMMANDER, WILMINGTON DISTRICT (CESAW-ECP-E/ GREG L. WILLIAMS)

SUBJECT: Approval of Request for Exception to Perform Water Supply Reallocation Study at Falls Lake Dam, NC (DSAC 3)

1. References:

a. Memorandum, CESAW-ECP-E, 18 February 2015, subject as above.

b. Memorandum, CECW-CE, 25 March 2015, subject as above (Encl).

2. Reference 1.b. provides Headquarters approval for the Wilmington District to conduct a water supply reallocation study at Falls Lake, NC.

3. As stated in reference 1.b., the Wilmington District is required to notify the local sponsor of the Falls Dam dam safety action classification (DSAC) and other items in accordance with paragraph 24.7.6 of Engineering Regulation 1110-2-1156, Safety of Dams – Policy and Procedures. Copies of that correspondence should be forwarded to the Division Dam Safety Officer.

4. If you have any questions regarding this approval, please contact the undersigned at (404) 562-5107.

Encl

CHRISTOPHER T. SMITH, P.E.
Chief, Business Technical Division
South Atlantic Division

CF:
CESAD-PDP/ Wilbert V. Paynes
CESAD-PDC/Kevin J. McCarthy

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

REPLY TO
ATTENTION OF

CECW-CE

MAR 2 5 2015

MEMORANDUM FOR Commander, South Atlantic Division, U.S. Army Corps of Engineers, CESAD-DE, 60 Forsyth Street, Atlanta, GA 30303

SUBJECT: Approval of Request for Exception to Perform Water Supply Reallocation Study at Falls Lake Dam, NC (DSAC 3)

1. References:

a. Memorandum, CESAW-ECP-E, dated 18 February 2015, subject: Request for Exception to Perform Water Supply Reallocation Study at Falls Lake Dam, Raleigh, NC (enclosure 1).

b. ER 1110-2-1156, 31 March 2014, Safety of Dams – Policy and Procedures.

2. The request for an exception to ER 1110-2-1156, Safety of Dams – Policy and Procedures, Chapter 24, to allow a water supply reallocation study to evaluate reallocating water from the water quality pool to the water supply pool within the existing conservation storage at a Dam Safety Action Classification (DSAC) 1, 2, or 3 dam, is approved for Falls Lake Dam, which is classified as DSAC 3.

3. Prior to beginning the study, the district must notify the sponsor, in writing, of the project's DSAC and other points, as required by paragraph 24.7.6 of reference 1.b. Part of that notification should be that the water control plan may change, and effective risk management measures are available and should be implemented by the sponsor/community. Additionally, the sponsor must acknowledge the information in a letter, as described in paragraph 24.7.6 of reference 1.b.

4. HQUSACE does not concur with the statement in paragraph 5 of reference 1.a., "...the only likely way to improve Falls Lake Dam's DSAC rating would be to buy out and relocate thousands of households in the downstream floodplain." Communications with the sponsor must include opportunities to manage consequences through emergency preparedness and risk communication actions, improved warning, and other nonstructural and structural measures.

5. The point of contact is Barbara Schuelke, HQUSACE Dam Safety Program Manager, at (202) 761-4643 or barbara.r.schuelke@usace.army.mil.

Encl

JAMES C. DALTON, P.E., SES
Corps Dam Safety Officer
Directorate of Civil Works

CF:
CECW-CE (Halpin, Schuelke, Webb, Pathak)
CECW-PC (Carlson, Wegner)
CESWL-PE (Plaxco)
CECC-G (Hostyk)
CEMP-SAD-RIT (Brown, Valentin-Meyer)
CESAD-RBT (Smith, Hernandez)
CESAW-DE (Landers)
CESAW-ECP-E (Williams)
CESAW-ECP-EG (Hughes)

US Army Corps of Engineers
WILMINGTON DISTRICT

DRAFT FINDING OF NO SIGNIFICANT IMPACT

FALLS LAKE, NORTH CAROLINA
WATER SUPPLY STORAGE REALLOCATION
INTEGRATED FEASIBILITY REPORT AND ENVIRONMENTAL ASSESSMENT

The U.S. Army Corps of Engineers, Wilmington District (Corps), has conducted an environmental assessment in accordance with the National Environmental Policy Act of 1969, as amended. The Corps assessed the effects of the following action in the Draft Integrated Feasibility Report and Environmental Assessment (EA), dated March 2017, for the Falls Lake Reallocation Study, North Carolina. The final recommendation will be contained in a Directors report dated November 2017. The recommended plan consists of the following:

- Reallocate approximately 17,300 acre-feet of storage within Falls Lake Dam and Reservoir from Water Quality Storage to Water Supply Storage in order to satisfy future demand for water supply

Twenty-three alternatives with varying levels of water supply and reallocation, including the No-Action and the Recommended Plan, were evaluated. The analysis conducted for the Falls Lake Reallocation study indicated that the reallocation of 17,300 acre-feet of storage from the existing water quality pool to supplement that of the existing water supply pool, is the Recommended Plan. Implementation of the Recommended Plan would result in a revised storage volume of 44,022 acre-feet within the water quality pool (41.4% of the water conservation pool), and a revised storage volume of 62,300 acre-feet within the water supply pool (58.6% of the water conservation pool). The recommended plan is the environmentally preferable alternative.

All practicable means to avoid and minimize adverse environmental effects have been incorporated into the recommended plan. The recommended plan would not result in any impacts to federally-listed threatened or endangered species or their designated critical habitat.

The recommended plan will not impact sites listed on or eligible for inclusion on the National Register of Historic Places.

The recommended plan will not result in unavoidable adverse impacts.

Technical, environmental, economic, and cost-effectiveness criteria used in the formulation of alternative plans were those specified in the Water Resource Council's 1983 Economic and Environmental Principles for Water and Related Land Resources Implementation Studies. All applicable laws, executive orders, regulations, and local government plans were considered in the evaluation of the alternatives. It is my determination that the recommended plan does not constitute a major federal action that would significantly affect the quality of the human environment; therefore, preparation of an Environmental Impact Statement is not required.

Date:____________________

____
Kevin P. Landers Sr.
Colonel, U.S. Army
District Commander

US Army Corps of Engineers ®
Wilmington District

FALLS LAKE, NORTH CAROLINA

INTEGRATED WATER SUPPLY REALLOCATION

FEASIBILITY STUDY

APPENDIX A

WATER DEMAND ANALYSIS

CITY OF RALEIGH, NORTH CAROLINA

MARCH 2017

Water Demand Analysis

The population projections, per capita water usage, and resulting water demand projections for the City of Raleigh's through 2045 used in the reallocation study are consistent with the water demand model reviewed and approved earlier in 2016 by the Water Management and Reallocation Studies Planning Center of Expertise.

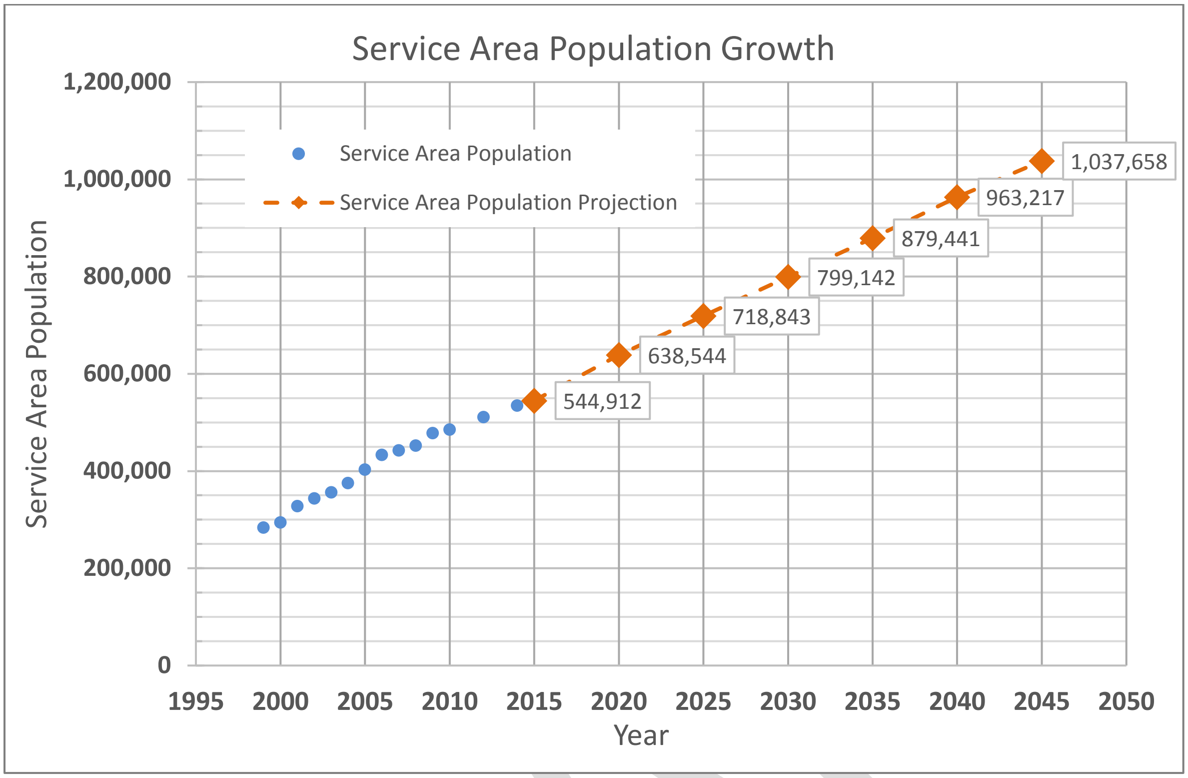
As described below in greater detail, the approach employed in the development of the demand projections was to utilize population projections for the service area from independent government organizations and to combine them with estimates of the service area's unit demand per resident, in gallons per capita per day (gpcd), to estimate water demands for the service area in five year increments. The per resident demand estimate is based in part on current customer behavior in the service area, but also includes adjustments to account for weather-related variability and the expectation of additional water conservation in the future.

Population Projections

The City of Raleigh's service population projections are based on data provided by the federally mandated and federally funded Capital Area Metropolitan Planning Organization (CAMPO). CAMPO publishes population projections by regions known as Traffic Analysis Zones (TAZ). The TAZ data is GIS-based and the TAZ polygons corresponding to Raleigh's service area were aggregated into the overall service area population projection estimates. Current CAMPO population projections do not extend beyond 2040. Therefore, a method to extend the projection from 2040 to 2045 was needed. It was assumed that the population growth rate between 2040 and 2045 would be 1.5% for the service area, which is consistent with the 1.5% growth rate assumption from the NC Office of State Budget and Management (OSBM) population projections for Wake County for the same period. The OSBM data also corresponds well with the US Census Bureau projections of 1.4% for the State of North Carolina.

The census surveys and future projections demonstrate that the area has grown rapidly over the past several decades and is expected to continue to do so. The service area population has grown from around 300,000 in the year 2000 to nearly 550,000 at present. Over the next 30 years the service area population is expect to exceed 1 million people. Figure A-1 illustrates these trends.

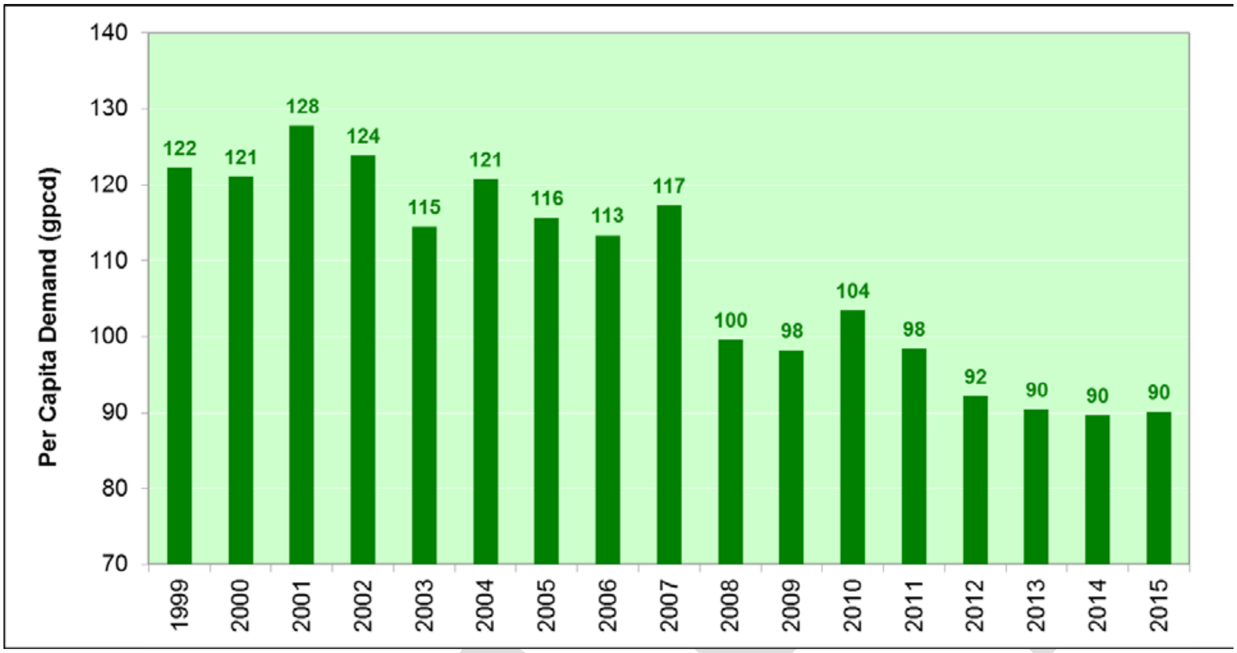
Figure A-1: Service Area Population Growth for City of Raleigh



Unit Demand

Development of the projected water demands is based on an analysis of the City's historical water use and billing records during the period from 1999 through 2014 (See Figure A-2), which are used together to estimate the service area's unit demand in gallons per capita per day (gpcd). The unit demand is calculated by taking the total raw water needed to satisfy the service area's demand divided by service area population. It is not an estimate of residential use in isolation because it includes commercial, industrial, institutional use, process water and non-revenue water. Since the early 2000s, the per capita water demand has been declining and closely mirrors trends observed at other utilities in North Carolina. Much of the decline is assumed to be a product of lasting changes in water use behavior and is reflected as such in the projections (i.e. the projection of unit demand does not rise in the future). The projected unit demand also incorporates anticipated future reductions in the unit demand due to future indoor water conservation measures, reductions in irrigation water use, and the growth of Raleigh's wastewater reuse program. Further, the projections are presented as a range to account for the fact that water demand is subject to year-to-year variations due to weather. More details about unit demand reductions to date, the additional reductions expected in the future, and the weather variability range for demand are described below.

Figure A-2: Historical Per Capita Demand for City of Raleigh



Water Conservation and Efficiency

As illustrated in Figure X-2, the per capita demand for Raleigh's service area has fallen significantly since the turn of the millennium. The per capita demand began dropping in 2002 and 2003 and exhibited another sharp drop after 2007. These declines corresponded with two severe droughts in central North Carolina. However, in contrast to prior droughts the per capita demand has not rebounded to pre-drought levels once mandatory restrictions were lifted. Raleigh's water customer per capita usage is now among the lowest for similar utilities in the U.S. In addition to customer response to severe drought, the reduction in per capita demand from 1999 through 2015 may also be attributed to the factors listed below:

1. The 1994 U.S. Energy Policy Act, which prompted new industrial standards for low-flow plumbing fixtures and building code changes.
2. The development of EPA's WaterSense Program in 2006 which seeks to improve water use efficiency by promoting water-efficient products and services that meet the WaterSense efficiency and performance criteria. Compared to the post-1994 efficiency standard, the WaterSense criteria further reduce flow rates by 20 to 40%.
3. Raleigh's implementation of permanent year-round water conservation measures.
4. Raleigh's implementation of a tiered water tariff structure in late 2010.
5. Wetter than average weather from 2012 through 2015.

It is assumed that the first 4 factors listed above are contributing to more or less permanent reductions in unit demand while the fifth factor (above average precipitation) is producing an additional, but temporary reduction in the unit demand. Adjusting unit demand for weather variability will be discussed further in the next subsection.

The City of Raleigh conducted a Water Conservation and Efficiency analysis to better understand the potential for further reductions in unit demand. Conservation is defined as the water use habits of individual customers (i.e., customer behavior). Efficiency is defined as the minimum water use of plumbing fixtures or water using appliances (i.e., a characteristic of water using devices). The water conservation and efficiency analysis quantified the potential water savings from a range of anticipated consumption reduction measures that were placed into one of four categories. The four consumption reduction mechanisms, or categories, evaluated were: the renovation of existing homes, the adoption of EPA's WaterSense Program (e.g., EPA-initiated voluntary water savings campaign), restrictions on lawn irrigation, and water reuse. The analysis, conducted in 2011, employed customer usage data from 2009 and 2010. The results indicated that by 2045 the unit demand during a hot, dry year like 2010 would be expected to fall from 103.8 gpcd (historically) to 94.4 gpcd. Table X-1 summarizes the reductions that Raleigh expects to achieve by 2045 for each category in the analysis. These additional projected conservation and efficiency savings have been applied uniformly between 2015 and 2045.

Table X-1: Estimated Additional Conservation and Efficiency Savings Through 2045

	Additional Conservation and Efficiency (C&E) by Category	Unit Demand
Baseline per capita water use for 2010		103.8 gpcd
Residential indoor conservation	5 gpcd	
WaterSense residential indoor conservation	1.6 gpcd	
Outdoor (irrigation) conservation	1.2 gpcd	
Water reuse	1.6 gpcd	
Total C&E Savings	9.4 gpcd	
Projected Unit Demand		94.4 gpcd

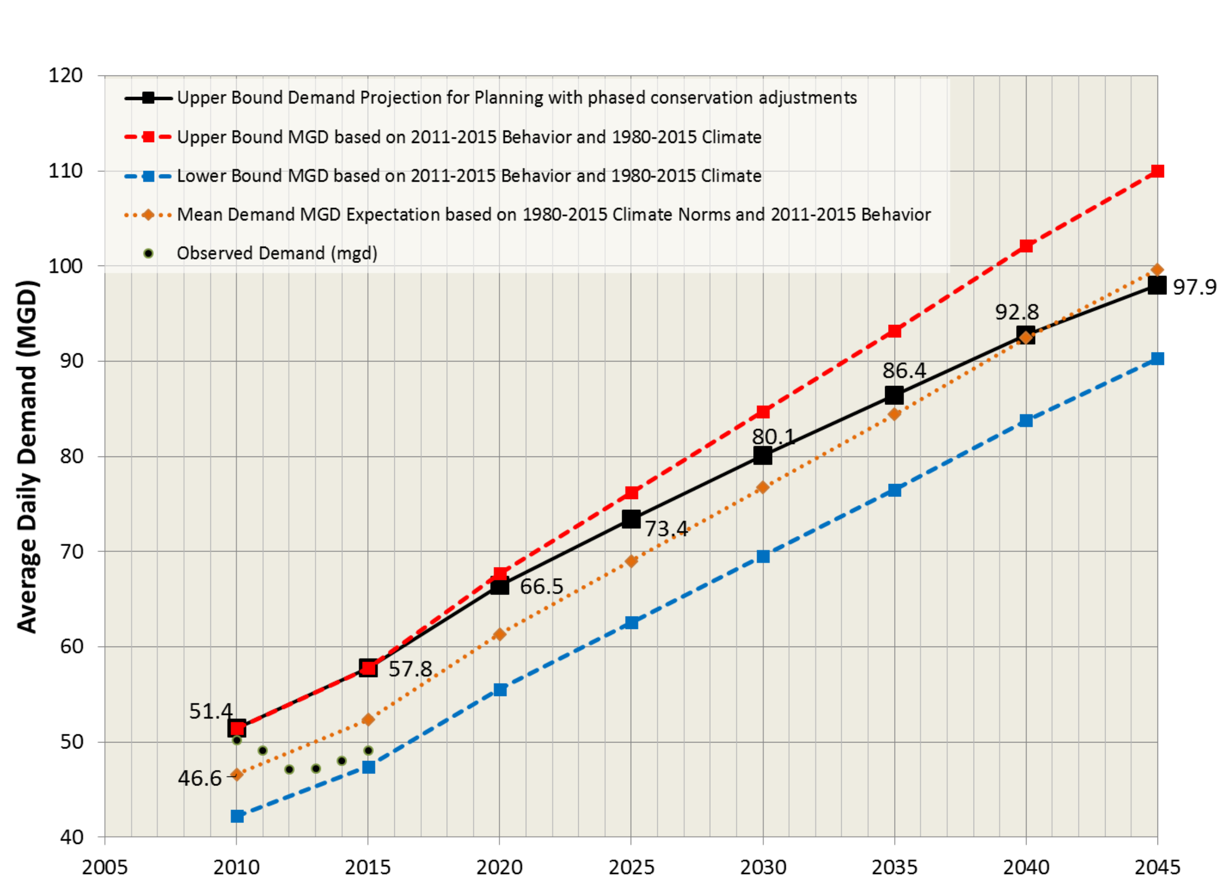
Weather Variability and Demand Fluctuations

Demand can fluctuate significantly from one year to the next due to differences in overall weather patterns. In central North Carolina the weather factor most linked to water demand variability is rainfall and to a lesser extent, temperature. To account for these fluctuations, demand data for recent years (2011-15) was correlated with both weather factors. A regression analysis was performed to correlate the annual unit demand with average high temperature and total precipitation from the months of April through November. The April through November period corresponds to the growing season in central North Carolina and the period during which the vast majority of outdoor water use occurs in this region. The analysis showed that fluctuations in weather from April through November accounted for 90% of the variation in annual average unit demands (r-squared value of 0.9). This relationship was then used to establish a range for expected unit demand (in gpcd) over the broader climatic conditions that prevailed from 1980 to 2015. The results indicate that the upper bound unit demand is expected to be about 106 gpcd on an annual basis with recent customer behavior held constant. This means that in a hot, dry year for this region Raleigh customers would use an average of 106 gpcd over the course of the year. During a very cool and wet year the unit demand could be as low as 87 gpcd. For planning purposes Raleigh needs to procure a sufficient supply to meet the upper bound of this demand range. However, the maximum bound of this range is expected to decline through 2045 in response to additional conservation and greater water reuse by the Raleigh water system as explained in the previous section.

Total Demand Projections

Total demand projections are the product of population projections and unit demand projections for the service area. While unit demand is expected to continue to decline, population growth will drive Raleigh's total demand significantly higher over the next 30 years. The total demand projections are shown in Figure X-3 along with the historical demand for the past 5 years in millions of gallons per day. To account for fluctuations in year-to-year weather conditions consistent with the weather variability analysis described above, an upper and lower bound has been established based on the 106 gpcd and 87 gpcd limits, respectively. The black line in Figure x-3 represents the projected water demands being used in the study, which initially reflects the upper-bound unit demand (represented by the upper dashed red line) but steadily incorporates those previously discussed future reductions in unit demand from additional conservation and efficiency measures. The resulting projected 2045 water demand that Raleigh will need to meet is 97.9 MGD.

Figure X-3: CORPUD Service Area Demand Projections with Weather Variability and Additional Conservation/Efficiency



DRAFT

US Army Corps
of Engineers ®
Wilmington District

FALLS LAKE, NORTH CAROLINA

INTEGRATED WATER SUPPLY REALLOCATION FEASIBILITY STUDY

APPENDIX B

HYDROLOGIC AND HYDRAULIC REPORT

CITY OF RALEIGH, NORTH CAROLINA

MARCH 2017

FALLS LAKE WATER SUPPLY STORAGE REALLOCATION

CITY OF RALEIGH, NORTH CAROLINA

HYDROLOGIC AND HYDRAULIC REPORT

TABLE OF CONTENTS

NOTE: DUE TO PUBLIC FAMILIARITY WITH FALLS LAKE POOL ELEVATIONS RELATIVE TO NGVD29, ALL ELEVATIONS IN THIS REPORT ARE REFERENCED TO NGVD29. TO CONVERT ELEVATIONS TO NAVD88 VERTICAL DATUM. 0.90 FEET SHOULD DEDUCTED FROM NGVD29 ELEVATIONS GIVEN.

LIST OF FIGURES

LIST OF TABLES

ATTACHMENTS

FALLS LAKE REALLOCATION STUDY
HYDROLOGIC AND HYDRAULIC REPORT

1. General

This study investigated the feasibility of a reallocation within the Falls Lake conservation pool from the existing water quality storage to the existing water supply storage that would meet the City of Raleigh's projected 2045 water demands of 97.9 MGD. A comparative analysis of impacts of the reallocation on Falls Lake and downstream flows compared to existing conditions and future conditions without a reallocation was conducted.

No reallocation of flood storage is being evaluated for this study. As described later, a water storage shortage discovered soon after Falls Lake went into operation resulted in a reduction in planned flood storage of about 9%. Therefore, any additional reduction in flood storage is not considered a viable option and was not evaluated. No adverse impacts to flood risk management operations would result from the proposed reallocation of conservation storage.

In addition, no reallocation of sedimentation storage is being evaluated for this study either. Prior sedimentation surveys indicate limited sedimentation thus far; however, more detailed surveys are needed before the District would recommend pursuing reallocation of sediment storage for water supply. Adequate storage appears to be available from within the conservation pool to address the City of Raleigh's water demands through 2045, so reallocation from the sediment pool could possibly be evaluated at some point in the future to meet longer-term future water supply needs.

1.1. Scope of Work

The required storage volume for reallocation from water quality storage to water supply storage was determined. Hydrologic analyses were performed to determine impacts on lake levels, water quality storage, dam releases, and downstream flows for three different conditions: future (2045) conditions with a reallocation, future conditions without a reallocation, and existing conditions.

1.2. Description of Falls Dam and Lake

Falls Lake dam (Lat 35.942, Lon -78.538) is located on the Neuse River about 10 miles north of Raleigh, North Carolina. Falls Dam is located about 32.5 river miles above Clayton, NC and 235 river miles above the mouth of the Neuse River near New Bern, NC. The total drainage area for the Falls Dam watershed is 770 square miles and the watershed of the Neuse River Basin is 5,598 square miles. Falls Dam was authorized for the purposes of flood control, water supply, water quality and low flow augmentation, recreation, and fish and wildlife conservation. Falls Dam was authorized by the 1965 Flood Control Act. Construction began in June 1978 and was complete February 1981. Temporary filling began May 1981 with gates closed in January 1983. The earthen dam is 1,915 feet in length and 92.5 feet in height above the original streambed. The dam crest is 30 feet wide at elevation 291.5 ft-NGVG29 (290.6 ft-NAVD88). In the late 1990s, physical and operating modifications were made to Falls Dam to compensate for a shortage in the design reservoir storage capacity that was discovered shortly after Falls Dam went into operation. The normal pool level (top of conservation pool) was raised from 250.1 to 251.5 ft-NGVD29 (249.2 to 250.6 ft-NAVD88), fully restoring the City of Raleigh's 45,000 acre-feet of water supply storage and restoring all but 13% of the design water quality storage. In addition, two physical modifications were made to the dam to accommodate the higher normal pool elevation and restore all but 9% of the controlled flood storage. A 0.8 feet concrete cap was added to the 100-ft wide uncontrolled spillway, increasing the spillway crest from 264.0 ft to 264.8 ft-NGVD29. Plus, a 3-foot high concrete barrier wall was keyed into and added along the dam crest to provide additional wave run up freeboard protection. Table 1 summarizes the existing physical features and capacities of Falls Dam and Lake.

Table 1. Falls Dam and Lake Physical Features

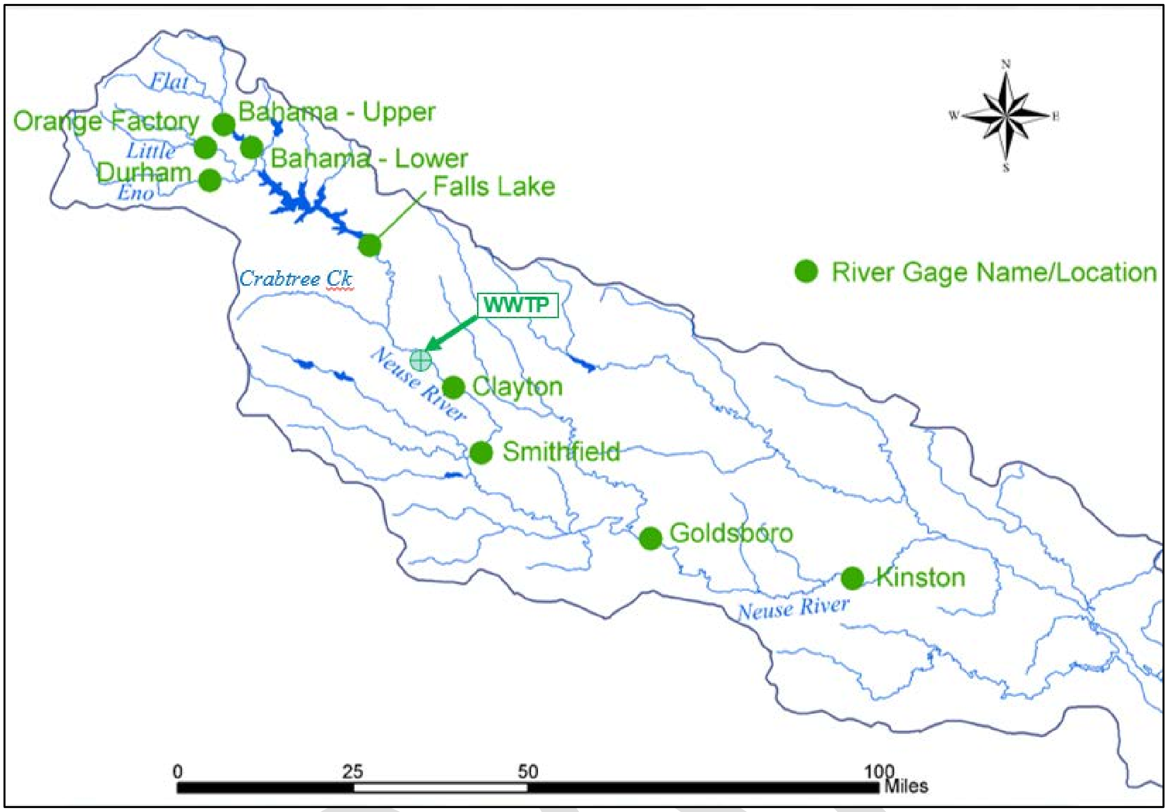
Feature	**Elevation** Ft-NGVD29 (1)	**Storage Volume** (ac-ft)	**Area** (acres)
Top of dam (2)	291.5		
Spillway design flood	287.6	1,040,347	38,811
Top of flood control pool/spillway crest	264.8	352,577	21,427
Top of conservation pool	251.5	131,395	12,410
Top of sediment pool	236.5	25,073	2,600
Base of Dam	200.0	0	0
Total storage		352,577	
Flood control storage	251.5-264.8	221,182	
Conservation storage	236.5-251.5	106,322	
- Water Supply		45,000	
- Water Quality		61,322	
Sediment storage	200-236.5	25,073	
(1) NAVD88 = NGVD29 – 0.90 ft (2) Does not include 3-ft concrete barrier wall			

The 106,322 AF conservation pool is comprised of 61,322 AF of water quality storage and 45,000 AF of water supply storage. The City of Raleigh has a federal water storage agreement for all 45,000 AF of water supply storage and withdraws raw water directly from the lake via a multi-level intake structure. Water from the water quality storage is released from the dam to meet minimum release requirements at the dam and also downstream flow targets at the USGS Neuse River streamgage at Clayton, NC, located about 32.5 river miles below the dam (see Figure 1). Flows at the Clayton gage are comprised of local unregulated inflows between the dam and Clayton and also return flow from the City of Raleigh's wastewater treatment plant located about 10 miles upstream of the Clayton gage. The fact that Raleigh's wastewater is discharged upstream of Clayton and contributes to the water quality flow target at the Clayton streamgage is what makes reallocation of a portion of the water quality pool potentially feasible. Table 2 summarizes the minimum water quality flow requirements at the dam and the Clayton gage.

Table 2. Minimum Water Quality Flow Requirements for Falls Dam Operations

Months	Immediately Downstream of Dam	Neuse River nr Clayton Streamgage
Nov – Mar	50-62 cfs (1)	184 cfs
Apr – Oct	100 cfs	254 cfs
(1) double piggy-back gate release; discharge varies based on hydraulic head		

Figure 1. Neuse Basin Map



1.3 Methods and Procedures

Basic hydrologic data for each modeling condition were computed in order to make the necessary comparisons of the future (2045) with reallocation condition to the future without reallocation and existing conditions. This data was used to develop annual pool elevation frequency and duration, storage durations, and annual and monthly flow durations for dam releases and downstream river points of interest.

2. Hydrologic Analysis

2.1 General

The hydrologic model selected for use in this reallocation study is the OASIS-based Cape Fear/Neuse Combined River Basin Hydrologic Model initially developed by the State of North Carolina Division of Water Resources (NCDWR). OASIS is a patented mass-balance water resources simulation/optimization model. NCDWR has been developing these detailed river basin hydrologic models for all of its river basins over the past decade or so for its long-term water supply planning/management and regulatory decision-making, especially during drought conditions. The original Cape Fear and Neuse River Basin Hydrologic models were developed initially in 2004 and 2008 for separate use in the Cape Fear and Neuse river basins, both of which are wholly within the Wilmington District boundaries. However, recently, these two existing river basin models were consolidated into a combined Cape Fear/Neuse model to better evaluate the unique regional water supply sources in these basins for future demands and impacts of interbasin transfers and also sub-allocation of state-owned water supply storage in another Corps reservoir, Jordan Lake.

The Wilmington District has been involved throughout the development of these models by the State of NC to ensure that they explicitly and adequately capture operations of our Falls Lake and Jordan Lake projects, particularly low-flow operations to ensure that inflow apportionment, storage accounting, and water quality releases are properly handled--however they also handle basic flood operations as well. The Neuse model explicitly handles water withdrawals and discharges for all major water users in the basin and adjoining Cape Fear basin, which is critical since upstream water users can impact inflows into Falls, particularly for future (year 2045) modeling scenarios in regards to upstream interbasin transfers. There are also numerous upstream impoundments that substantially restrict inflows into Falls Lake during droughts that are explicitly modeled. The OASIS model also handles the wastewater return flow associated with Raleigh's water usage that directly affects the water quality releases from the dam and the performance/viability of the water quality storage. In addition, Raleigh also has two other reservoirs in series on a downstream tributary to the Neuse that is fully integrated into the OASIS model that affects their Falls Lake withdrawals.

The District's Neuse River Basin RAS model would not have handled many of these basin elements and conditions as explicitly or as readily as the already-developed OASIS model, such as future system-specific basinwide water use and interbasin transfer impacts, Raleigh's wastewater treatment plant operations and return flow impacts, and operation of Raleigh's two other water supply reservoirs in an adjoining watershed. Based on these significant considerations, the District opted to pursue approval to use the OASIS-based Cape Fear/Neuse Combined River Basin Model developed by the State of North Carolina. The OASIS model has been reviewed and approved for use by the Water Management and Reallocation Studies PCX (see Attachment B-1).

Attachment B-2, *Modeling the Cape Fear and Neuse River Basin Operations with OASIS*, describes how OASIS is used to model the operations of the Cape Fear and Neuse River Basins, including model components, schematics, model input, run configurations, and model output. (This document resides on the North Carolina Division of Water Resources (NCDWR) website at the link provided below and still includes a draft watermark.) Additional appendices detailing static input data and run code, inflow data development, and model weighting descriptions are available on NCDWR website, *http://deq.nc.gov/about/divisions/water-resources/planning/basin-planning/map-page/cape-fear-river-basin-landing/cape-fear-neuse-combined-river-basin-model*.

The geographic extent of the model is much more expansive than is needed for the Falls Reallocation Study, including all water supply intakes and discharges within both the Cape Fear and Neuse basins. [Refer also to Section 2 (Model Components) of Attachment 2 for more detail, along with Flow Charts of Major Nodes in the Upper and Middle Neuse Basin particularly on pages 14-15.] The relevant extents of this model is comprised of the entire upper Neuse Basin above Falls Dam, along with the proximate portion of the Cape Fear Basin involved with interbasin transfers between the two basins (particularly related to the Durham water system demand node and their associated wastewater return arc), and the Neuse River reach extending from Falls Dam downstream to the USGS gage at Clayton (which is our downstream water quality flow target). Raleigh’s wastewater treatment plant is located upstream of the Clayton gage, allowing for that critical return flow to be readily accounted for. The model linkages, inflows, and demands/discharges associated with each of the water users in the relevant extents of the combined model have been accurately set up based on District involvement during early model development. Falls Lake has been explicitly modeled to accurately capture the physical and operational aspects of the project, including proper accounting of inflows, storage accounts, minimum releases, and basic flood ops (however, this is less important for this study since flood storage/operations is not being considered/affected). An unimpaired daily inflow dataset dating back to 1930 was developed for this model, with particular attention paid to preserving the known historical inflows into Falls Lake.

The version of the OASIS model reviewed and approved by the Water Management and Reallocation Studies PCX included some additional enhancements, including:

- creation of additional variables to allow user to more easily specify a reallocation volume and specify adjustments to the conservation pool elevations (this feature was not used) and redefinition of affected variables used for tracking water quality and water supply storage
- enhanced water supply/quality storage accounting to eliminate occasional minor inconsistencies on days when pool elevations were crossing subimpoundment and top of conservation pool elevation thresholds.

Ahead of submitting the OASIS Model for PCX review, the Wilmington District reviewed and verified numerous aspects of the model deemed critical to successful modeling of Falls Lake operations for the Falls Lake Reallocation Study, including:

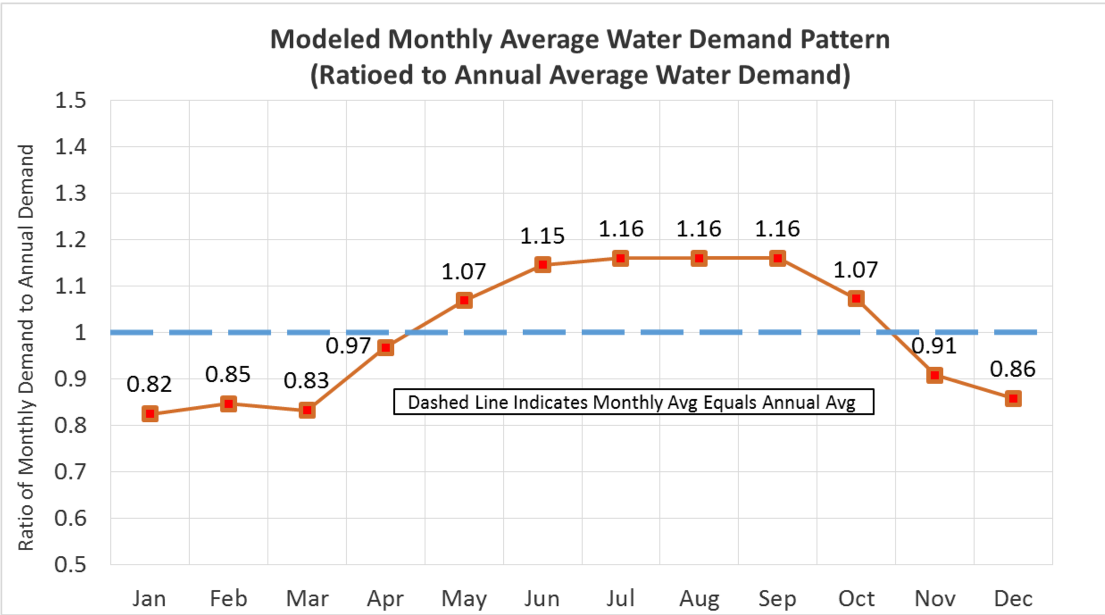
- Storage pool elevations (sediment/conservation/flood)
- Storage volumes by elevation (and surface area by elevation)
- Water Supply and Water Quality storage accounting (volumes, inflow apportionments, etc)
- Minimum release protocols (at dam and at Clayton)
- Routing of flows (travel times, lagging, etc)
- Critical period inflows

Prior to PCX submittal, validation runs were also made to verify that the model was properly accounting for inflows, outflows, lake levels, and changes in storage for the various pools.

Specific conditions modeled include future (2045) basin conditions with a reallocation from the water quality pool to the water supply pool, future (2045) basin conditions without a reallocation, and existing conditions. Future conditions (both with and without reallocation) assume a 2045 water demand of 97.9 MGD for the City of Raleigh and also 2045 water usage throughout the basin by other water systems. Assumptions made about future basin water usage—particularly water users upstream of Falls Lake such as the City of Durham—directly impact inflows into Falls Lake and actually have a bearing on the yield and critical low-flow period. Durham's future (2045) modeled water use from Jordan Lake (which would be an interbasin transfer of water from the Cape Fear Basin into the Neuse Basin) was fairly conservative, with 7 MGD assumed continuously and an additional 3 MGD when they trigger their Stage 2 drought condition—which will partially offset Durham's existing interbasin transfer out of the Neuse Basin to the Cape Fear Basin. These assumptions were consistent between the future with and without model conditions. Future water use by all other systems in the basin was the same as that developed by the State of North Carolina for their OASIS basin modeling. Existing conditions reflect estimated 2015-2016 water usage throughout the basin, with an average annual water demand of 59.5 MGD for Raleigh. Existing water use for all other water users in the basin are averages of the 2010 and 2020 water use data developed by the State of North Carolina for their OASIS basin modeling. Modeling for all conditions also includes Raleigh's two additional water supply reservoirs.

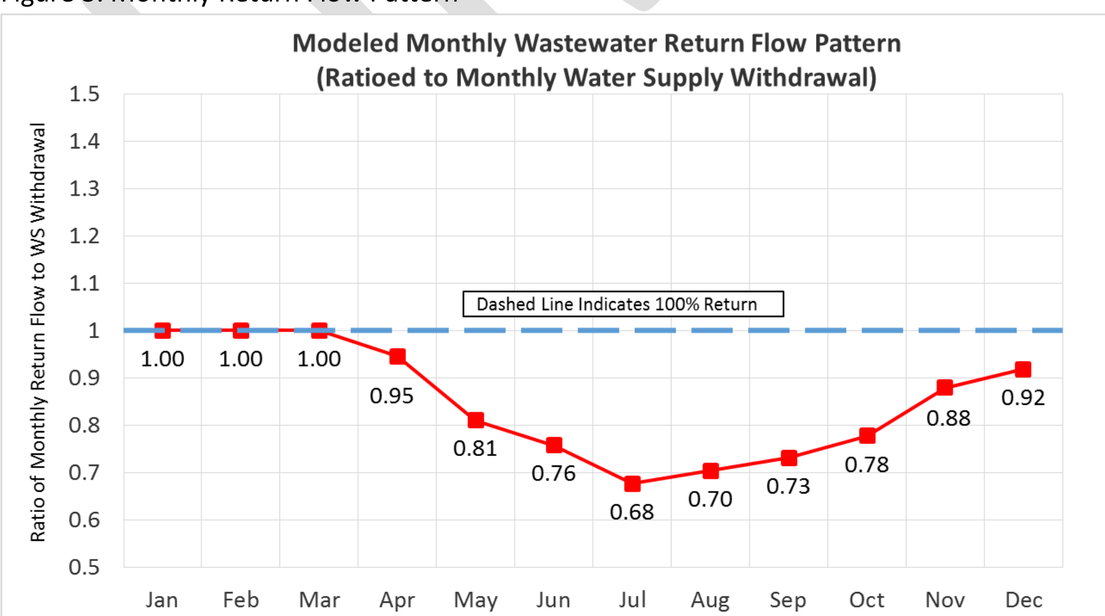
Modeling is done on a daily time-step, with average annual demands converted into daily demand values that vary by month according to a demand pattern based on actual monthly water use by the City of Raleigh. A representative water use pattern based on 2010 water usage was selected for modeling purposes, since it reflected recent water use patterns that are likely to continue and seemed not to have been unduly impacted by overly wet or dry conditions. This monthly pattern is shown in Figure 2.

Figure 2. Monthly Water Demand Pattern



As previously mentioned, also critical to the modeling is properly accounting for Raleigh's wastewater return flow to the Neuse River. Similarly, a monthly pattern of wastewater return flow percentages, also based on 2010 operational data, was developed for modeling purposes (see Figure 3 below).

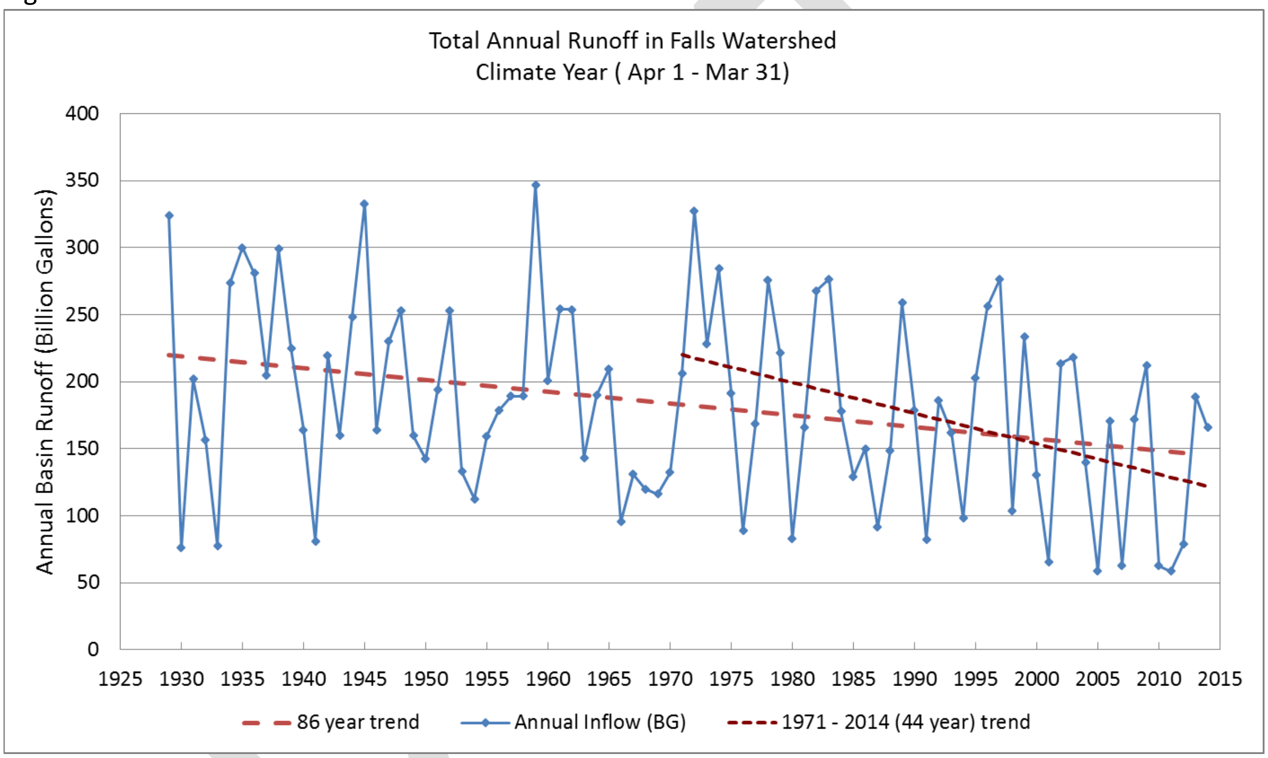
Figure 3. Monthly Return Flow Pattern



2.2 Inflow Modeling Period

While an unimpaired inflow data set dating back to 1930 was developed for the OASIS model, analysis of this data set clearly indicates a declining trend in annual watershed runoff (i.e., inflows into Falls Lake) over the past 40 years or so, compared to the full inflow data set dating back to 1930 (see Figure 4). Whether these trends are due to land use changes, climatic changes, or a combination of multiple causal factors, it was decided to base the reallocation impact analysis on the more recent portion of the inflow data set for a more conservative analysis--especially if these declining inflow trends persist into the future. In addition, modeling of future with reallocation conditions show that 14 of the lowest 15 minimum annual water supply storage amounts occur in the years since 1980, which includes the drought of record. Based on these factors, the inflow data set used in the modeling for the reallocation study extends from April 1, 1980 through March 31, 2015 (35 years).

Figure 4. Falls Watershed Runoff Trends



2.3 Yield-Storage Analysis

The firm yield is the amount of water available for a specific use on a dependable basis during the life of the project. This yield is dependent on the amount of inflows and storage available during the critical low-flow period.

Historically, lake levels and water supply storage reached their lowest recorded levels during actual operations during the 2007-2008 climatic year. However, modeling of 2045 basin conditions for the reallocation volumes being considered in this study shows the critical low-flow period spanning the multiple climatic year period from June 2010 through February 2013.

Inflows for the yield analysis reflect 2045 projected water usage by all systems in the Falls watershed along with interbasin transfers effects due to the City of Durham's projected 2045 Jordan Lake water usage.

Outflows for the yield analysis fully meet the minimum release requirement at the dam and the downstream flow target at Clayton. Raleigh's daily return flow from its wastewater treatment plant upstream of Clayton (averaging almost 84%) partially contributes to the target flow at Clayton, which is taken into account by the model when determining daily water quality releases from the dam.

Because Raleigh also has two other water supply reservoirs (which are explicitly modeled in the OASIS model), both total system yield and Falls Lake yield alone were analyzed to ensure that total system demand was being met. Figure 5 shows these water supply storage-yield relationships for a range of reallocation volumes under 2045 basin inflow conditions. Modeling indicates that an additional 17,300 AF of water supply storage (an increase from 45,000 AF to 62,300 AF) is needed to fully satisfy the 2045 system demand of 97.9 MGD during the critical period. The modeled yield of the 62,300 water supply storage in Falls alone is 84.1 MGD, resulting in a yield-storage ratio of 0.00135. These results are summarized in Table 3.

Figure 5. Falls Lake Water Supply Storage-Yield Relationship

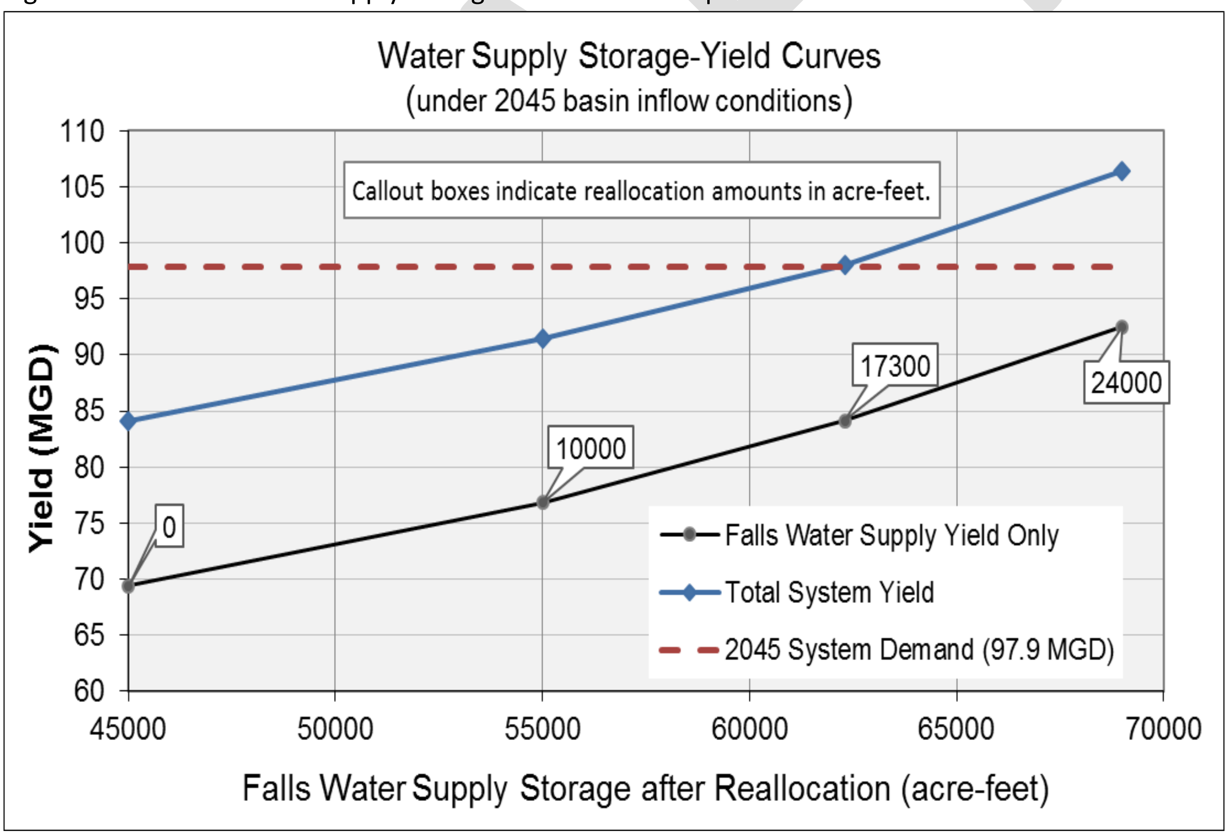


Table 3. Yield and Storage Analysis for Conservation Pool Reallocation at Falls Lake

Water Storage Use	Conservation Pool		
	Existing Storage AF	Proposed Storage AF	Proposed Yield MGD
Water Supply	45,000	62,300	84.1
Water Quality	61,322	44,022	59.4
Total Conservation Storage	106,322		143.5
Yield/Storage Ratio	0.00135		

This reallocation of 17,300 AF wholly within the conservation pool from water quality to water supply reduces the water quality storage from 61,300 AF to 44,022 AF, and therefore its yield. Based on this established yield-storage ratio, the equivalent yield of the remaining water quality storage is 59.4 MGD. However, in reality, the actual performance of the water quality pool is directly influenced and supported by Raleigh's water supply withdrawals from Falls Lake and the subsequent return of most of that water as treated effluent back into the Neuse River downstream of Falls Dam. The more water used/returned by Raleigh, the less water that needs to be released from the dam to meet the downstream water quality flow target at Clayton. Modeling indicates that, during the drought of record under 2045 basin conditions, this reduced water quality pool is still not depleted and actually has about 7906 AF (or 18%) of water quality storage remaining.

2.4 Frequency and Duration Data

Daily pool elevations, conservation storage volumes (water supply and water quality), outflows from dam, and downstream river flows were determined using the OASIS model for existing conditions, future with reallocation conditions, and future without reallocation conditions. Frequency of reservoir drawdown was determined for each modeling condition for comparison. Impacts on frequency of reservoir rise were not evaluated, since there are no changes to normal pool levels or flood operations.

Numerous duration analyses were conducted using the OASIS modeling results, including annual pool elevation duration, annual water quality and water supply storage duration, and annual and monthly dam outflow duration and downstream flow-duration. Dam outflow and downstream flow durations were actually based on 7-day forward moving averages to smooth out some of the daily model variability resulting from strict adherence to release rules and the model's perfect knowledge of inflows and downstream flows. In addition, the OASIS modeling assumes a 10% overshoot of the downstream Clayton flow target to account for the variability and uncertainty with real-time operations to meet an instantaneous minimum flow target at Clayton.

3. Hydraulic Analysis

No hydraulic modeling (HEC-RAS) was necessary for determining water surface elevations along the downstream reaches of the Neuse River for comparison of flood damage impacts since no changes to normal pool levels, flood storage, or flood operations associated with the proposed reallocation.

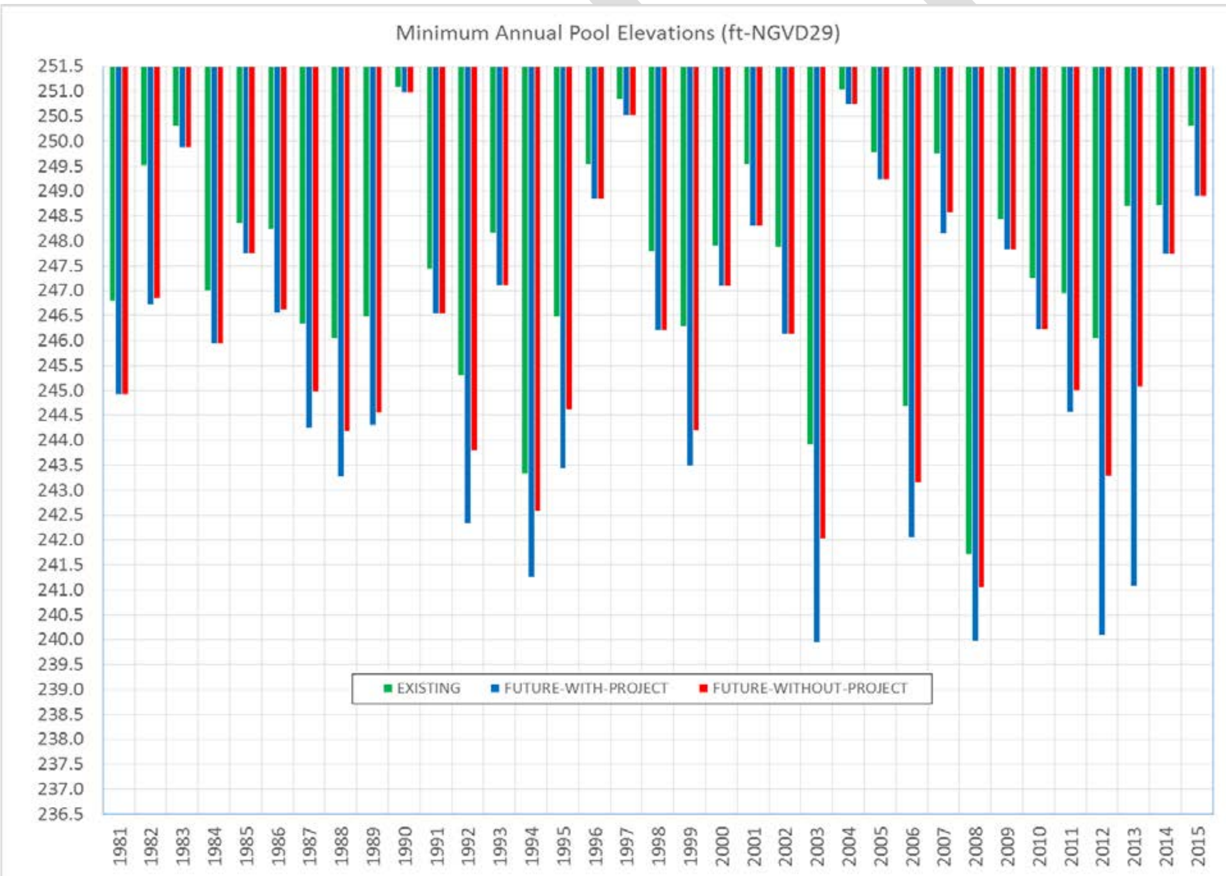
4. Results

4.1 Pool Elevations

Minimum annual pool elevations for Falls Lake for the 1980-2015 modeling period were compared for existing, future with reallocation, and future without reallocation conditions (see Figure 6). Under existing conditions, Raleigh's water supply demands are considerably less (59.5 vs 97.9 MGD), so minimum annual pool elevations are expectedly higher than under future (2045) conditions for all years—with or without the proposed reallocation. Comparing existing to future with reallocation, this difference in minimum annual pool elevation is 1.6 feet or less for half of the years and exceeds 3 feet difference in only about 10% of the years.

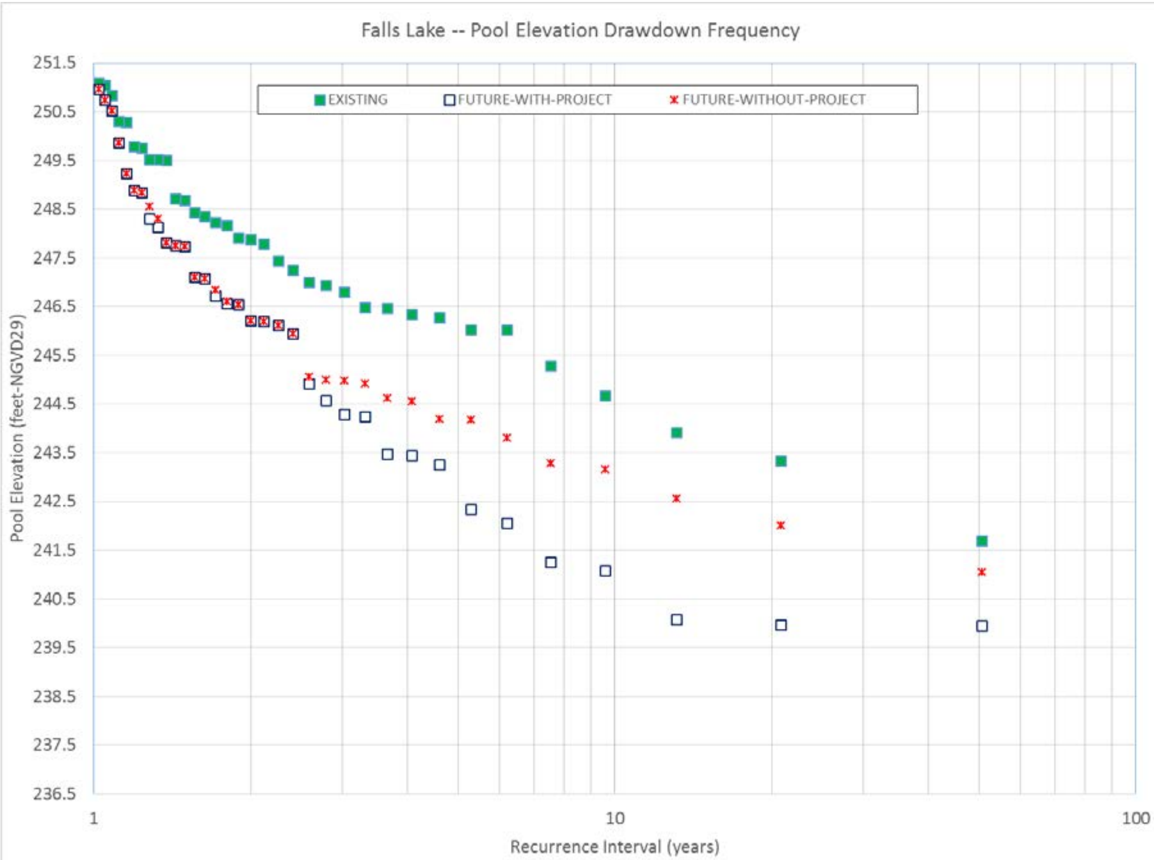
Comparing future (2045) with and without reallocation conditions, the minimum annual pool elevation differences are much less. In half of the years there is no modeled difference and less than 1.5 feet difference in over 90% of the years.

Figure 6. Falls Lake Minimum Annual Pool Elevation for All Model Conditions



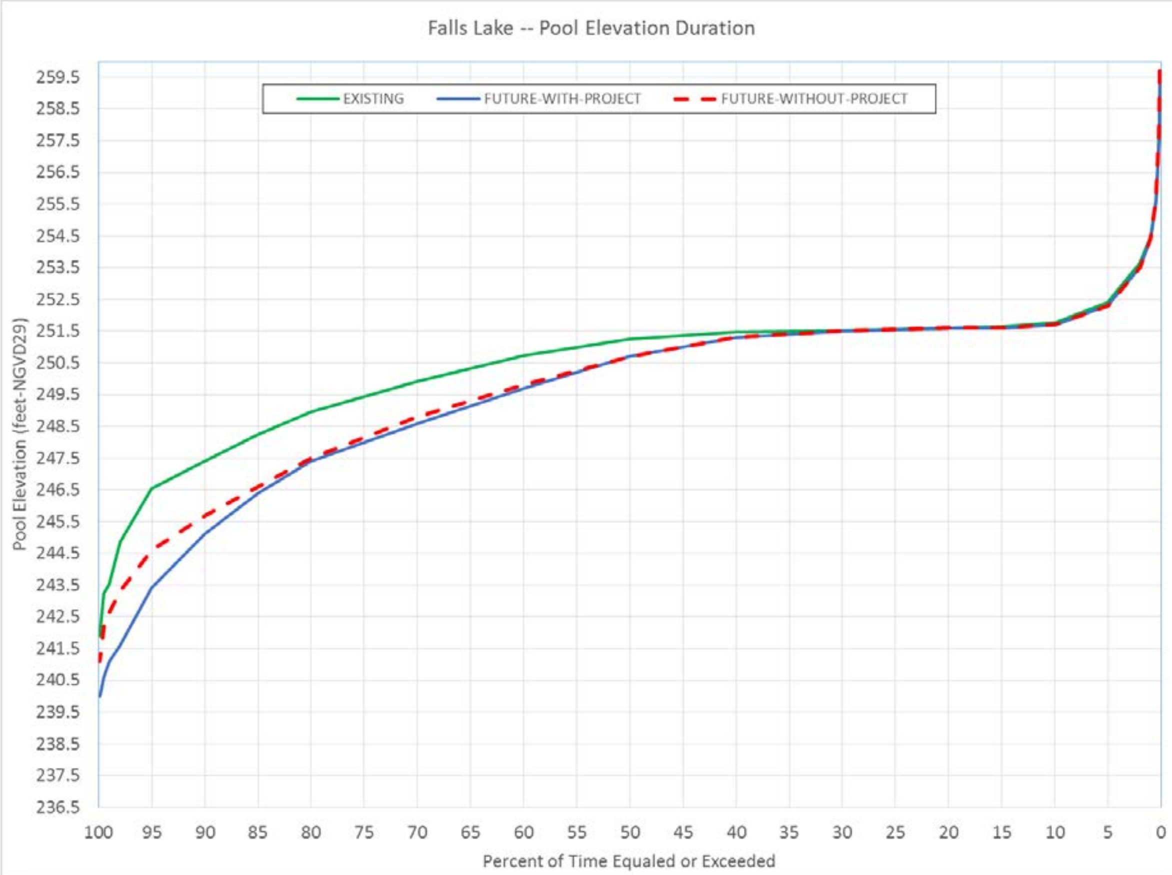
The drawdown frequency analysis (Figure 7) indicates similar relative pool elevation differences between modeled conditions. As expected, drawdowns for a given recurrence interval are less for existing conditions than for future (2045) conditions. For recurrence intervals less than 2.5 years, the pool elevation difference is only about a foot or less between existing and future conditions; however, for greater recurrence intervals, these differences increase to more than 3 feet between existing and future with reallocation. For future conditions, there is essentially no difference in drawdown with or without reallocation for recurrence intervals less than 2.5 years; however, for greater recurrence intervals, that difference increases to as much as 2 feet. Beyond 20-year recurrence intervals, the drawdown differences between all conditions begin to decrease significantly.

Figure 7. Falls Lake Frequency of Reservoir Drawdown for All Model Conditions



The duration plot below (Figure 8) confirms that only pool elevations below the top of conservation pool (251.5 ft-NGVD29) are affected by the proposed reallocation. Under existing conditions, lake levels are expectedly higher in the conservation pool for a greater percentage of the time since water demands are less; however, there is generally no more than a 10% difference in duration for any pool level and less than 5% difference for elevations below 243.5 ft-NGVD29. For example, lake levels are at or above guide curve (elevation 251.5 ft-NGVD29) about 40% of the time under existing conditions, compared to 30% of the time for both future conditions. Lake levels are at or above elevation 247.5 ft-NGVD29 (4 feet below guide curve) about 90% of the time under existing conditions, compared to 80% of the time for both future conditions. Comparing future conditions, there is little or no difference in durations between with and without reallocation modeling results for 85% of the time (at or above elevation 246.5 ft-NGVD29), and for elevations below 246.5, less than a 3% difference in durations between with and without reallocation modeling results.

Figure 8. Falls Lake Pool Elevation Duration for All Model Conditions



4.2 Water Supply Storage

Minimum annual water supply storage for the 1980-2015 modeling period were compared for existing, future with reallocation, and future without reallocation conditions (see Figure 9). For existing conditions of 2015-2016 basin demands and the current 45,000 AF of water supply storage, minimum water supply storage occurred in 2007-2008 climatic year, with approximately 24% of water supply storage still remaining. For future without reallocation conditions, 2045 basin demands were modeled without reallocation of any additional water supply storage, resulting in total depletion in 12 of the 35 years and near-total (<2% remaining) depletion in 2 additional years. For future with reallocation conditions, 2045 basin demands were modeled with reallocation of 17,300 AF of storage from water quality to water supply, avoiding depletion in all years but with only 500 AF remaining during the 2010-2013 drought of record.

The duration plot for the water supply storage (Figure 10) further demonstrates the inadequacy of the existing water supply storage to meet Raleigh's future (2045) water demands and the adequacy of the proposed reallocation to avoid depletion. In the 12 years that water supply storage would be depleted under future without reallocation conditions, water supply shortages would occur a total of 534 days (or about 45 days per shortage year), which corresponds to about 4% of the 35-year modeling period.

Figure 9. Falls Lake Minimum Annual Water Supply Storage for All Model Conditions

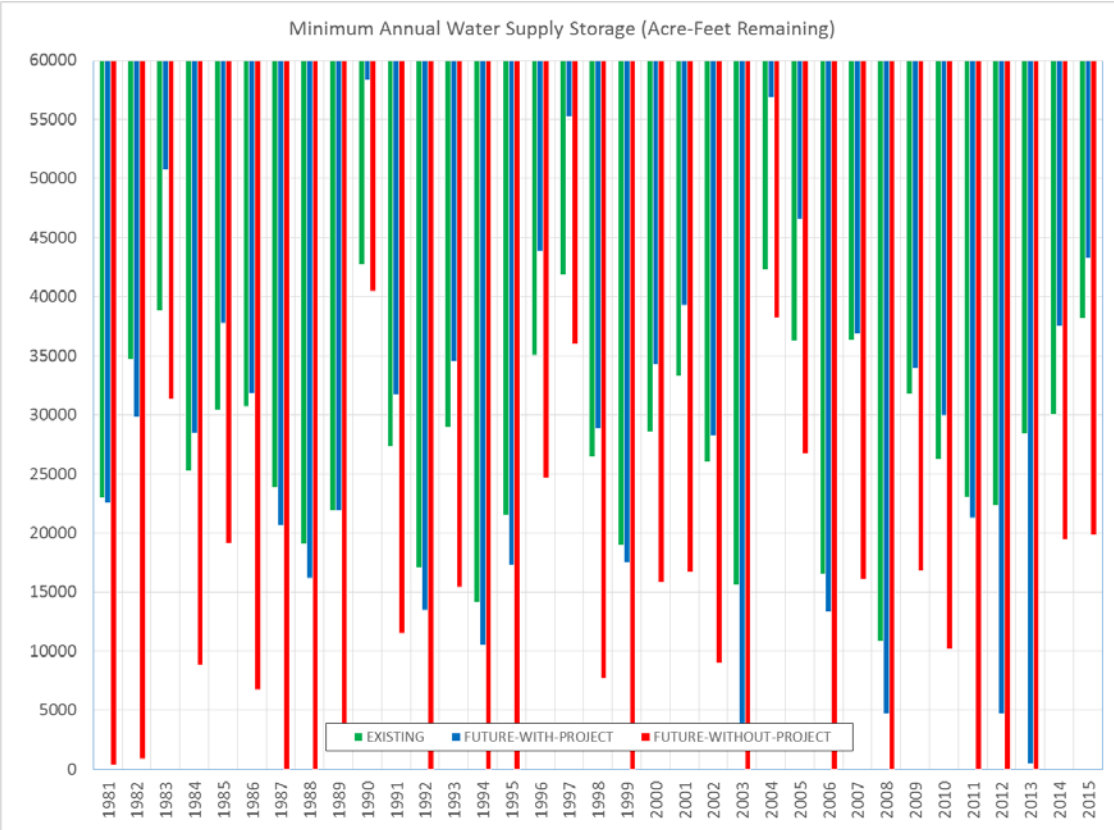
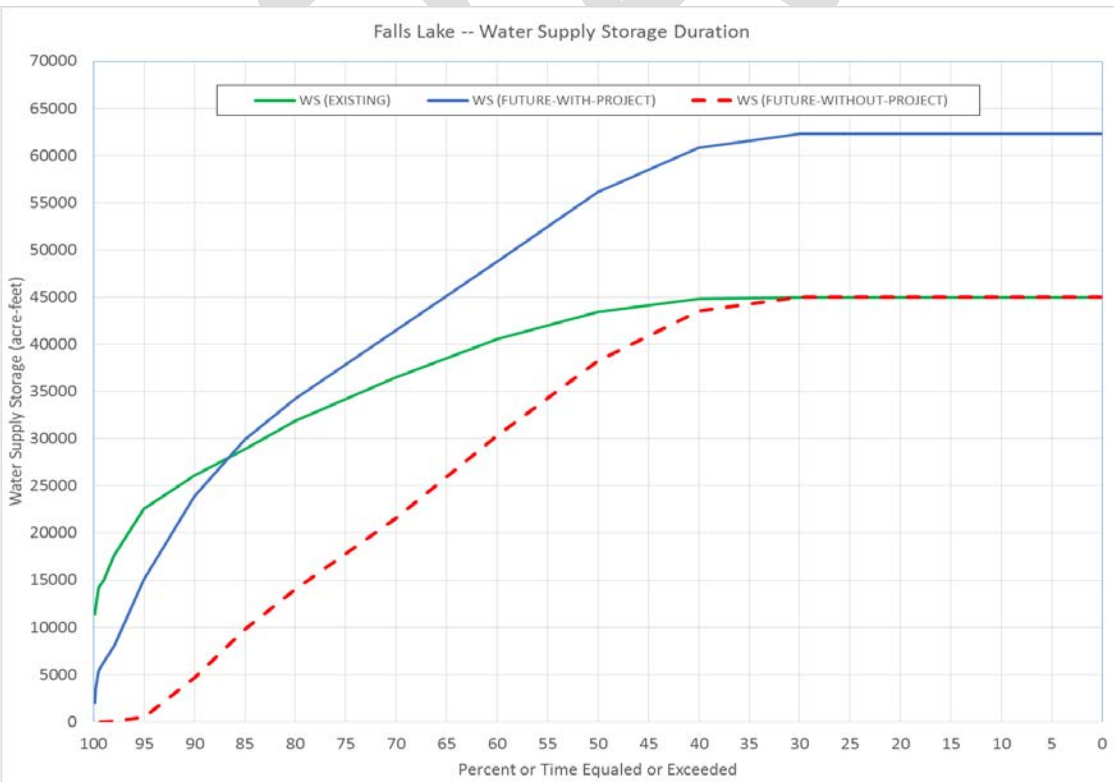


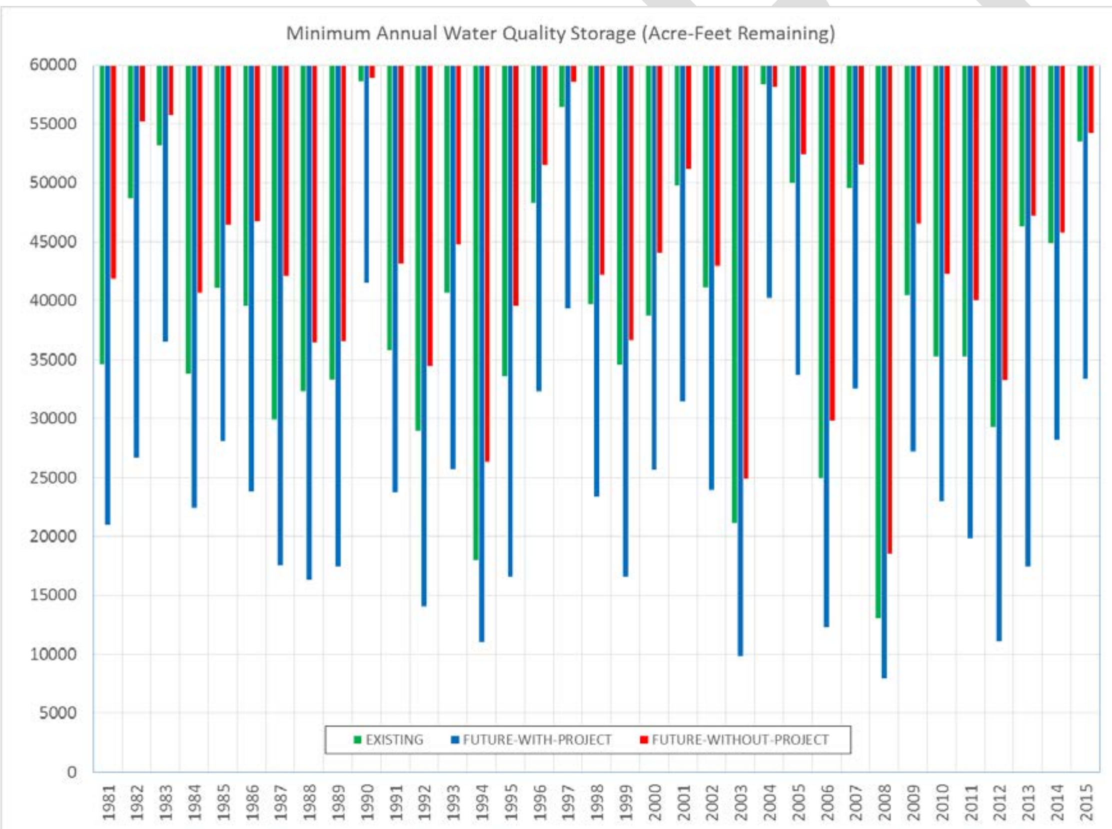
Figure 10. Falls Lake Water Supply Storage Duration for All Model Conditions



4.3 Water Quality Storage

Minimum annual water quality storage for the 1980-2015 modeling period was compared for existing, future with reallocation, and future without reallocation conditions (see Figure 11). As previously discussed, the performance of the water quality storage is directly influenced and supported by Raleigh's water supply withdrawals from Falls Lake and the subsequent return of most of that water as treated effluent back into the Neuse River downstream of Falls Dam. For existing conditions of 2015-2016 water demands and the current 61,322 AF of water quality storage, the lowest minimum water quality storage occurred in the 2007-2008 climatic year, with approximately 21% of water quality storage still remaining. For future without reallocation conditions, 2045 basin demands were modeled without reallocation of any additional water supply storage, resulting in consistently higher minimum annual water quality storage amounts than under existing conditions due to Raleigh's higher water withdrawals/returns—with water quality storage not dropping below 30% remaining. For future with reallocation conditions, 2045 basin demands were modeled with reallocation of 17,300 AF of storage from water quality to water supply. Even with the resulting smaller 44,022 AF water quality pool, the lowest minimum annual water quality storage during the modeling period is approximately 7900 AF, or about 18% still remaining.

Figure 11. Falls Lake Minimum Annual Water Quality Storage for All Model Conditions



The water quality storage duration plots (Figure 12) show that under both existing and future without reallocation conditions, the larger existing water quality storage always exceeds the smaller water quality storage under the future with reallocation conditions; however, the smaller water quality storage is clearly never depleted under 2045 conditions. In fact, at least half (22,011 AF) of the smaller water quality storage is still remaining almost 90% of the time.

As discussed, Raleigh's downstream wastewater discharge helps to meet the downstream water quality flow target at Clayton. Assuming that the proposed 17,300 AF reallocation is approved, it is important to evaluate how the smaller 44,022 AF water quality pool would perform in the early years following the reallocation, before Raleigh's water use and subsequent wastewater returns had increased very much above existing levels. To evaluate this concern, 2020 and 2025 water demands were modeled to see how the reduced water quality pool would perform. The OASIS modeling assumes a 10% overshoot of the Clayton target to account for the variability and uncertainty with real-time operations to meet an instantaneous minimum Clayton flow target. For example, for the 254 cfs summer minimum flow target, the model releases enough water from the dam to maintain 279 cfs. Assuming this full 10% overshoot of the Clayton minimum flow target, the water quality storage would be depleted in only 1 year out of the 35-year modeling period assuming 2020 Raleigh water usage, and no years for 2025 Raleigh water usage. In all other years, at least 10% water quality storage remains assuming 2020 Raleigh water usage and 10% overshoot. However, if only a 5% overshoot is assumed, then the water quality storage would not be depleted in any years assuming 2020 Raleigh water usage, with just under 2% of water quality storage remaining in the lowest year. If no overshoot of the Clayton target is assumed, then the lowest minimum annual water quality storage remaining increases to almost 7.5%. (See Figure 13 for comparison plots.) During a severe drought, it is not unreasonable to assume that Wilmington District Water Management staff will make every effort to minimize any overshoot of the Clayton flow target to conserve water quality storage. In fact, since the water quality storage would be well below the Falls Drought Contingency Plan threshold of 80% water quality storage remaining, it is possible that a reduced target would be in effect; however, the OASIS model is conservative in that it does not assume any reduction in the official minimum flow target at Clayton.

Figure 12. Falls Lake Water Quality Storage Duration for All Model Conditions

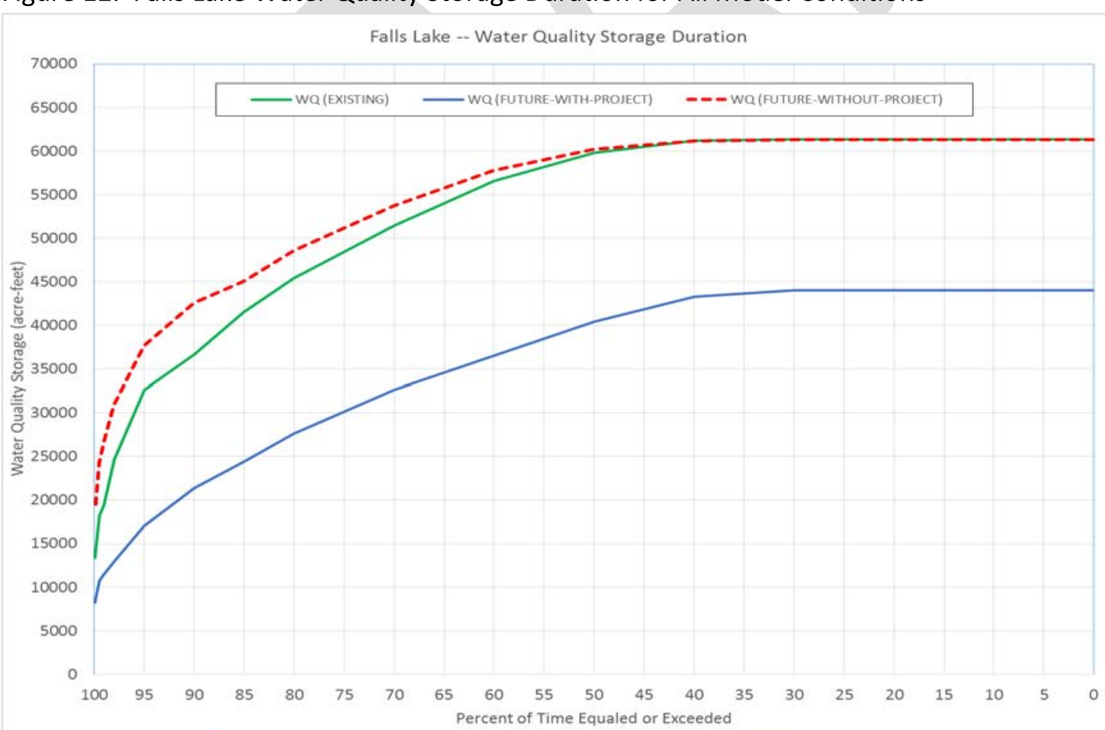
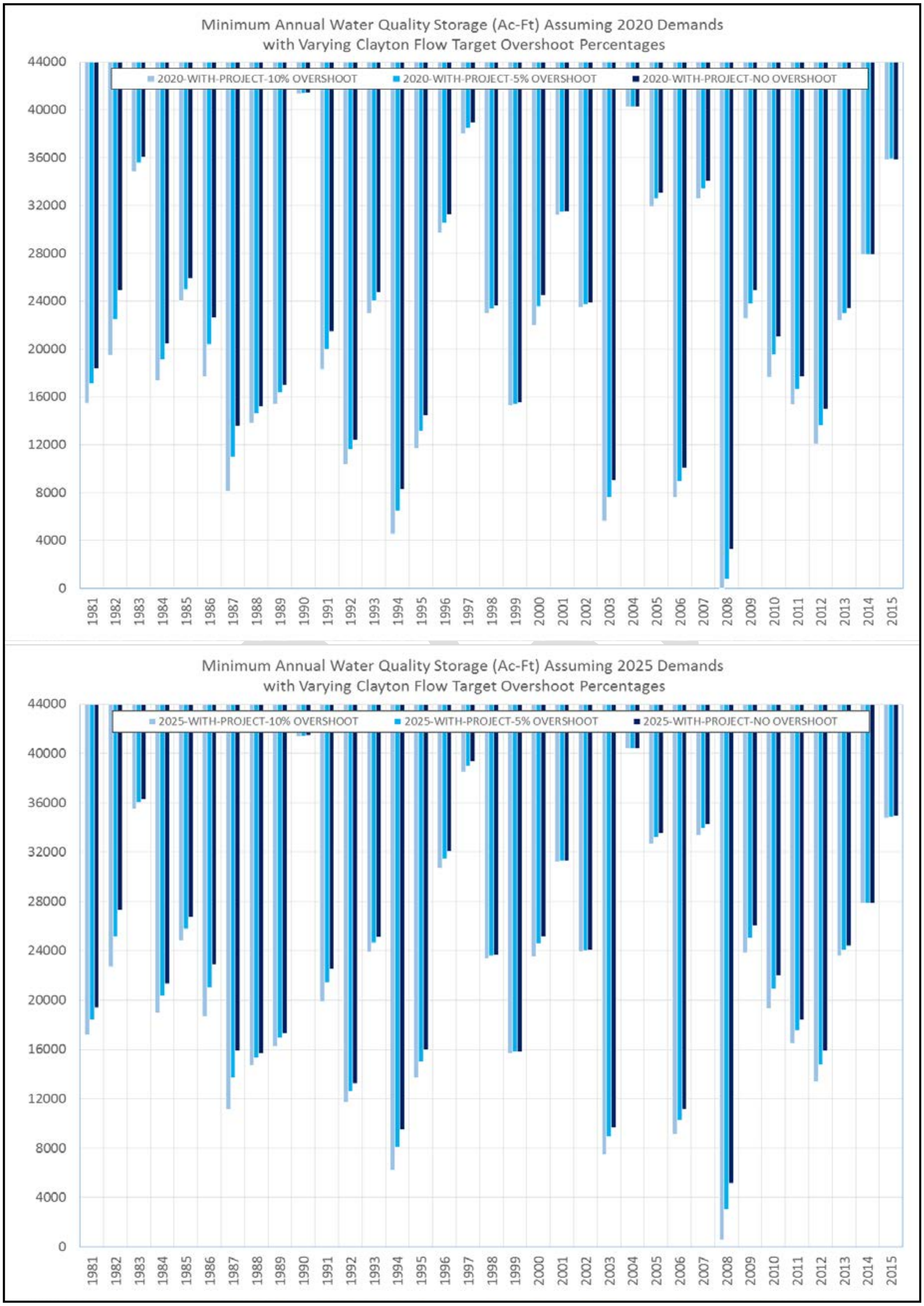


Figure 13. Effect of Clayton Flow Target Overshoot on 2020 & 2025 Water Quality Storage



4.4 Releases from Falls Dam

Releases from Falls Dam are made from water quality storage to ensure that minimum flows at the dam and downstream flow targets at Clayton are maintained (refer back to Table 2 for specifics). The proposed reallocation has no effect on flood releases from the dam. Generally speaking, the main effect the proposed reallocation will have on releases from Falls Dam (compared to existing conditions) is that as Raleigh's water usage increases over time, their wastewater discharge back to the river downstream will increase as well, allowing releases from the dam to meet the Clayton flow target to be reduced accordingly over time. The results shown below depict the future 2045 conditions when the effects of Raleigh's Falls Lake withdrawals and associated downstream discharges will be the greatest on flows between the dam and Raleigh's return flow location.

Analyses of daily releases from the dam (and downstream flows) were based on 7-day forward moving averages to smooth out some of the daily model variability resulting from strict adherence to release rules and the model's perfect knowledge of inflows and downstream flows. Release comparisons of existing, future with reallocation, and future without reallocation conditions for representative wet, average, and dry years are shown below in Figure 14; however, within any year there is still typically a range of conditions. Only releases below 1000 cfs are shown, since any concerns would be related to low flows. In all cases and at all times, minimum flows at the dam are fully met (100 cfs Apr-Oct; 50-62 cfs Nov-Mar), with additional water quality releases as needed to meet the minimum flow target at Clayton (254 cfs Apr-Oct; 184 cfs Nov-Mar). During wet years, releases from the project are typically well above minimum since higher releases are needed just to maintain normal pool levels, and any differences in releases between existing and future conditions would not be a significant concern. During average years, minimum release periods are generally more intermittent and differences in releases between existing and future conditions are still fairly limited. During dry years, minimum release periods are more common and more protracted and differences between existing and future condition releases can be more sustained. Under all three representative years (wet, average, dry) releases for the future with reallocation and future without reallocation conditions are almost always nearly identical. The only exception occurs in the dry year when Raleigh's water supply storage is depleted (and withdrawals curtailed) in late 2007 under the future without reallocation model run and water quality releases are increased to continue meeting the Clayton target.

The annual outflow duration curves (Figure 15) for the full range of releases appear quite similar, with nearly identical duration curves for the both future conditions; however, there is a distinguishable offset for the existing conditions curve between about 60% and 5% exceedance. Figure 16 is a detailed view of durations for flows below 1000 cfs; minimum releases (100 cfs or less, depending on month) are made about 30% of the time under existing conditions compared to about 50% of the time under both future with and future without reallocation conditions. Monthly outflow durations are shown for April, May, and June in Figure 17. For April, minimum releases are made about 15% of the time under existing conditions compared to about 20% of the time under both future with and future without reallocation conditions; for May, about 20% and 40%, respectively; and for June, about 20% and 60%, respectively.

For all days with minimum releases (100 cfs or less, depending on month) under the future with reallocation condition, the modeled differences in daily outflow for the existing and future without reallocation were computed. An average annual difference and monthly difference for April, May, and June were determined, along with an incremental analysis of these differences. As shown in Table 4 below, the majority of daily differences between future with reallocation and existing condition

Figure 14. Falls Dam Releases – Wet, Average, and Dry Year Comparisons

outflows are 10 cfs or less for the annual and monthly values; compared to future without reallocation, the differences are insignificant. By comparison, the increase in annual average wastewater return flow for future conditions is 49.5 cfs, and the increase in monthly average wastewater return flows are 54.3 cfs for April and 54.1 cfs for May and June; therefore, the reduction in outflow does not necessarily equal the increase in return flows since the outflow cannot be less than the minimum flow requirement at the dam.

Table 4. Average Daily Difference in Outflow (CFS) for Future With Reallocation Releases <= 100 cfs					
		Annual	April	May	June
Existing		-30.8	-55.2	-30.7	-22.7
Future Without Reallocation		-3.0	-1.5	0	0
Existing	% Days <=10 cfs Diff	69.2%	61.4%	60.4%	53.4%
	% Days <=25 cfs Diff	81.2%	71.3%	71.9%	71.7%
	% Days <=50 cfs Diff	91.1%	78.5%	84.7%	91.6%
	% Days <=100 cfs Diff	94.4%	89.8%	93.6%	95.2%
Future Without Reallocation	% Days <=10 cfs Diff	95.5%	96.4%	100.0%	100%
	% Days <=25 cfs Diff	97.0%	98.0%	100.0%	100%
	% Days <=50 cfs Diff	98.3%	99.0%	100.0%	100%
	% Days <=100 cfs Diff	99.6%	99.7%	100.0%	100%

4.5 Downstream Flows

Neuse River flows downstream of Falls Dam were analyzed at three locations: (1) just below the confluence with Crabtree Creek (a significant tributary about 17.5 river miles below Falls Dam), (2) just above the City of Raleigh's wastewater treatment plant discharge location (about 23.5 river miles below Falls Dam), and (3) the gaged downstream water quality flow target location near Clayton (about 32.5 river miles below Falls Dam). Generally speaking, flow differences at the Crabtree Creek and WWTP locations are analogous to those described previously for releases from Falls Dam (compared to existing conditions); however, flows at Clayton are actually greater under future conditions (compared to existing) because of the magnitude of Raleigh's WWTP discharges. The results shown depict the future 2045 conditions when the effects of Raleigh's Falls Lake withdrawals and associated downstream discharges will be the greatest on flows between the dam and Raleigh's WWTP.

As indicated earlier, analyses of daily releases from the dam and downstream flows are based on 7-day forward moving averages. Downstream flow comparisons of existing, future with reallocation, and future without reallocation conditions for representative wet, average, and dry years are shown in Figures 18-20; however, within any year there is still typically a range of conditions. Only flows below 1000 cfs are shown, since any concerns would be related to low flows. In all cases and at all times, minimum flows at the dam are fully met (100 cfs Apr-Oct; 50-62 cfs Nov-Mar), with additional water quality releases as needed to meet the minimum flow target at Clayton (254 cfs Apr-Oct; 184 cfs Nov-Mar). The potential for reduced downstream flows is only a concern between the dam and Raleigh's WWTP; below the WWTP, flows are actually increased due to Raleigh's return flow. During wet years, releases from Falls are typically well above minimum, and downstream flows are not a significant

Figure 15. Falls Lake Annual Outflow Duration

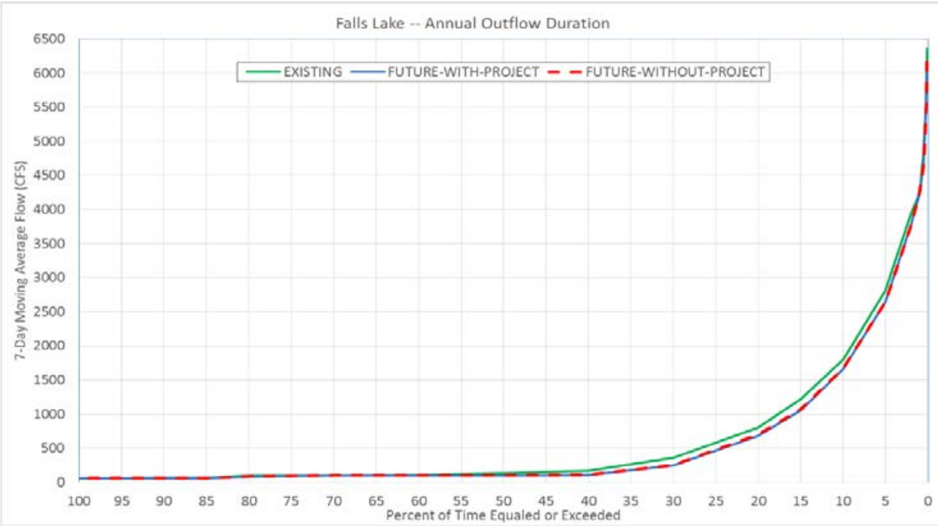


Figure 16. Falls Lake Annual Outflow Duration (Detail below 1000 cfs)

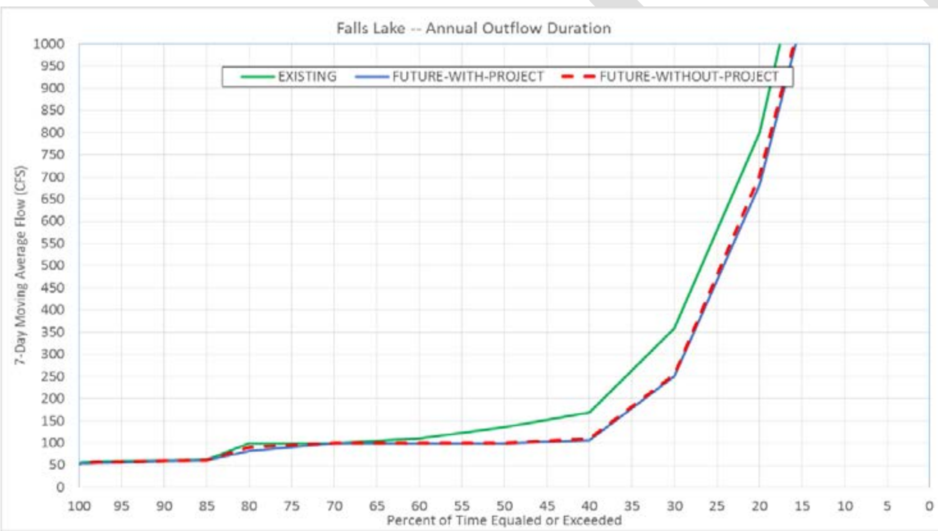
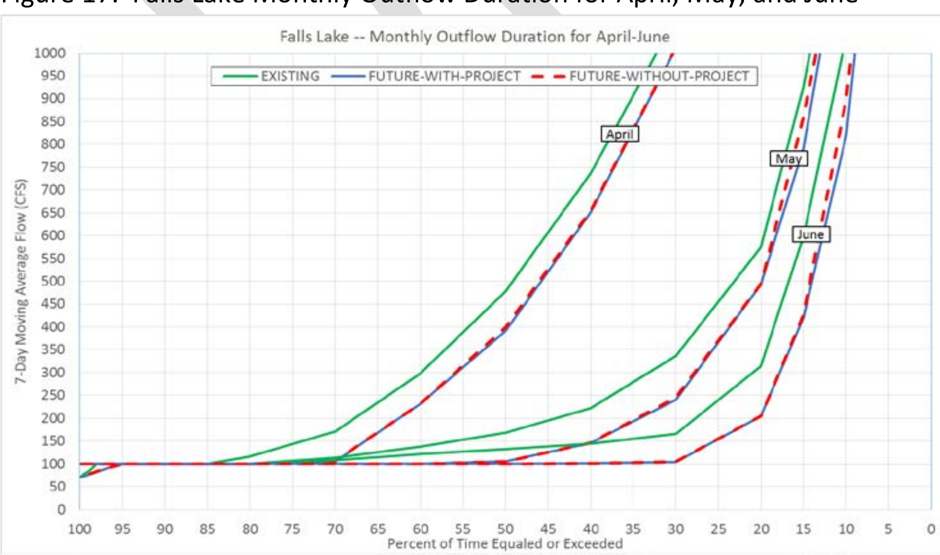


Figure 17. Falls Lake Monthly Outflow Duration for April, May, and June



concern. During average years, minimum release periods are generally more intermittent and differences in downstream flows between existing and future conditions are still fairly limited. During dry years, minimum releases from the dam are more common and more protracted and differences in downstream flows between existing and future conditions can be more sustained. Under all three representative years (wet, average, dry) releases for the future with reallocation and future without reallocation conditions are almost always nearly identical. The only exception occurs in the dry year when Raleigh's water supply storage is depleted (and withdrawals curtailed) in late 2007 under the future without reallocation model run and water quality releases are increased to continue meeting the Clayton target.

As with the outflows, the downstream annual flow duration curves for the full range of releases appear quite similar, with nearly identical duration curves for the both future conditions; however, there are distinguishable offsets for the existing conditions curves. Figure 21 contains detailed views of durations for flows below 1000 cfs for all three downstream locations; monthly flow durations for all three locations are shown in Figure 22. At these downstream flow locations, flows have increased due to contributions of tributaries and local runoff; Table 5 below compares the duration of flows below 250 cfs for the Crabtree Creek and WWTP locations and the duration of flows below 300 cfs for Clayton (since Clayton flows will be higher since it includes the wastewater return flow and also includes a 10% overshoot of the 254 cfs flow target by the model). Differences in durations of flows below 250 cfs are very minor (if any) for the Crabtree Creek and WWTP locations, both of which are upstream of the wastewater return flow location. For the Clayton location, durations of flow below 300 cfs are actually much greater under existing conditions than under future conditions, since the future return flows will be greater.

Table 5. Percent of Time Daily Flows are Less Than Designated Flow for All Model Conditions

Location	Model Condition	Designated Flow	Annual	April	May	June
Below Crabtree Creek	Existing	250 CFS	47%	21%	42%	56%
	Future With Reallocation		49%	22%	47%	60%
	Future Without Reallocation		49%	22%	47%	60%
Above WWTP	Existing	250 CFS	34%	12%	30%	43%
	Future With Reallocation		34%	12%	30%	46%
	Future Without Reallocation		34%	12%	30%	46%
Clayton	Existing	300 CFS	22%	3%	14%	27%
	Future With Reallocation		9%	0%	5%	10%
	Future Without Reallocation		10%	0%	5%	10%

Based on the above percentages, the number of days when flows are less than 250 cfs at the Crabtree Creek and WWTP locations are comparable; however, analysis was still done to compute the difference in flows for the other model conditions on days when modeled flows under the future with reallocation condition were less than 250 cfs. An average annual difference and monthly difference for April, May, and June were determined, along with an incremental analysis of these differences. As shown in Table 6, the majority of daily differences between future with reallocation and existing condition outflows is 10 cfs or less for the annual values and all the monthly values except June; compared to future without reallocation, the differences are insignificant.

Table 6. Average Daily Difference in Flow (CFS) for Future With Reallocation Flows < 250 cfs					
		Annual	April	May	June
		Below Crabtree Creek Confluence			
Existing		-13.6	-4.9	-13.8	-17.5
Future Without Reallocation		-1.7	-1.6	0	0
		Above WWTP			
Existing		-30.8	-55.2	-30.7	-22.7
Future Without Reallocation		-3.0	-1.5	0	0
		Below Crabtree Creek Confluence			
Existing	% Days <=10 cfs Diff	64.7%	75.6%	60.8%	45.8%
	% Days <=25 cfs Diff	76.1%	87.8%	73.0%	65.0%
	% Days <=50 cfs Diff	93.7%	95.4%	88.4%	92.5%
	% Days <=100 cfs Diff	98.0%	98.3%	98.4%	99.2%
Future Without Reallocation	% Days <=10 cfs Diff	96.1%	97.1%	100%	100%
	% Days <=25 cfs Diff	97.3%	98.3%	100%	100%
	% Days <=50 cfs Diff	98.6%	98.7%	100%	100%
	% Days <=100 cfs Diff	100%	99.6%	100%	100%
		Above WWTP			
Existing	% Days <=10 cfs Diff	58.6%	85.0%	56.2%	38.6%
	% Days <=25 cfs Diff	72.4%	98.3%	69.5%	60.0%
	% Days <=50 cfs Diff	94.7%	98.3%	87.9%	92.8%
	% Days <=100 cfs Diff	99.4%	100%	98.5%	99.0%
Future Without Reallocation	% Days <=10 cfs Diff	95.4%	100%	100%	100%
	% Days <=25 cfs Diff	96.7%	100%	100%	100%
	% Days <=50 cfs Diff	98.4%	100%	100%	100%
	% Days <=100 cfs Diff	100%	100%	100%	100%

4.6 Annual 7Q10 Low Flow Comparisons

A frequency analysis of modeled weekly flows was conducted to evaluate differences in 7-day, 10-year (7Q10) annual low-flow statistics for the three modeling scenarios—existing, future with reallocation, and future without reallocation. The annual 7Q10 flow is the annual 7-day minimum flow with a 10-year recurrence interval and is a common water quality-related flow parameter. Table 7 presents the annual 7Q10 flows for each of the modeling scenarios (1) immediately downstream of Falls Dam, (2) Neuse River just below Crabtree Creek confluence, (3) Neuse River just above Raleigh's WWTP, and (4) Neuse River at the USGS streamgage near Clayton.

Table 7. Annual 7Q10 Low Flow Comparisons for All Model Conditions			
Downstream Location	Annual 7Q10 Flows (CFS)		
	Existing	Future With Reallocation	Future Without Reallocation
Immediately below Dam	58	54	57
Below Crabtree Creek	106	103	109
Above WWTP	122	121	127
At Clayton Gage	207	258	216

Modeling results show only very minor differences in annual 7Q10 flows immediately downstream of the dam, below Crabtree Creek, and above the WWTP for all three scenarios—which comprise the section of river of most concern related to the proposed reallocation. The most notable impact on 7Q10 flows is at the Clayton gage, where model results indicate a 50 cfs increase in future 7Q10 flows with the reallocation compared to existing conditions. This is due to the fact that releases from Falls Dam cannot be reduced below its minimum requirement (50-65 cfs Nov-Mar; 100 cfs Apr-Oct), even if Raleigh's wastewater return flow and downstream local inflows result in flows at Clayton in excess of the flow target (184 cfs Nov-Mar; 254 cfs Apr-Oct). The water quality benefits of these higher 7Q10 flows at the Clayton gage would obviously continue into reaches of the Neuse River farther downstream as well.

5. <u>Conclusions</u>

The reallocation of 17,300 AF of conservation storage in Falls Lake from water quality to water supply will provide a firm yield (dependable yield) of 84.4 MGD for the resulting 62,300 AF of water supply storage. When combined with Raleigh's other water supply sources, this reallocation is adequate to meet the City of Raleigh's projected 2045 average daily demand of 97.9 MGD. This reallocation will not have a significant hydrological impact on the remaining water quality storage and its ability to meet downstream flow requirements, nor have a significant impact on downstream flows between Falls Dam and the downstream flow target location at Clayton. No other aspects of project operations, namely flood risk management, will be impacted.

Figure 18. Neuse River Flow Below Crabtree Creek for Wet, Average, Dry Years

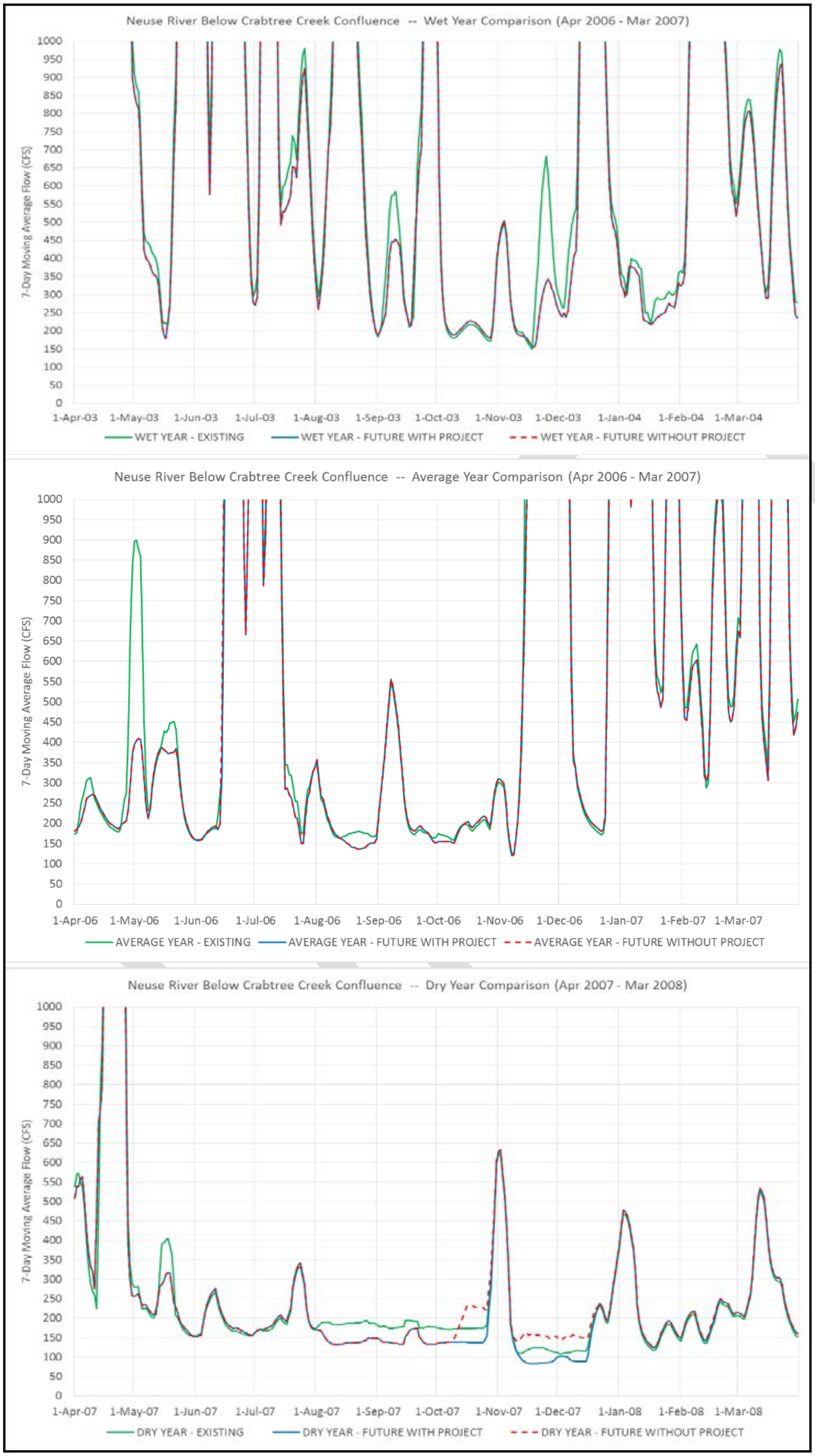


Figure 19. Neuse River Flow Above WWTP for Wet, Average, Dry Years

Figure 20. Neuse River Near Clayton for Wet, Average, Dry Years

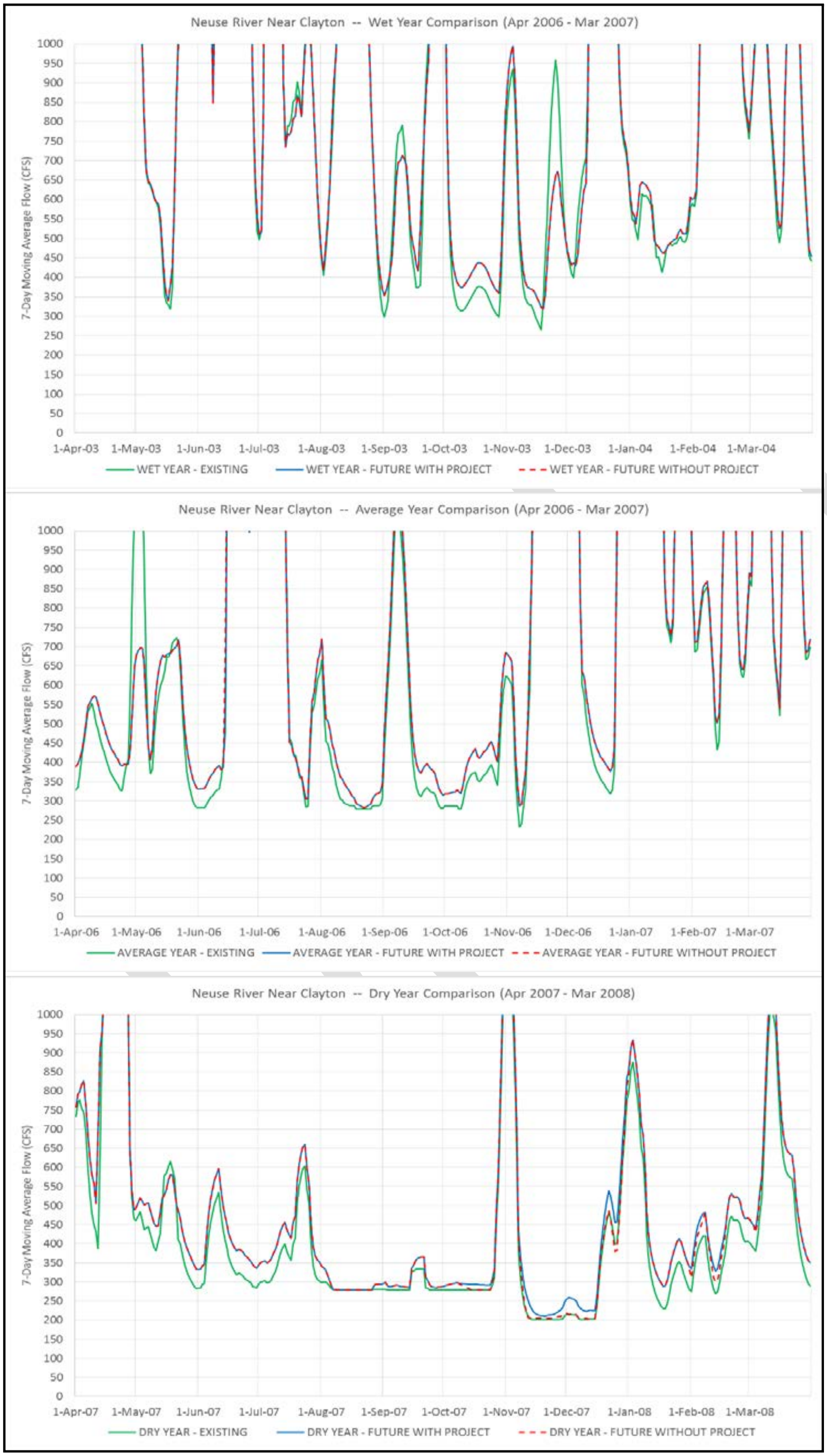


Figure 21. Downstream Neuse River Locations -- Annual Flow Durations

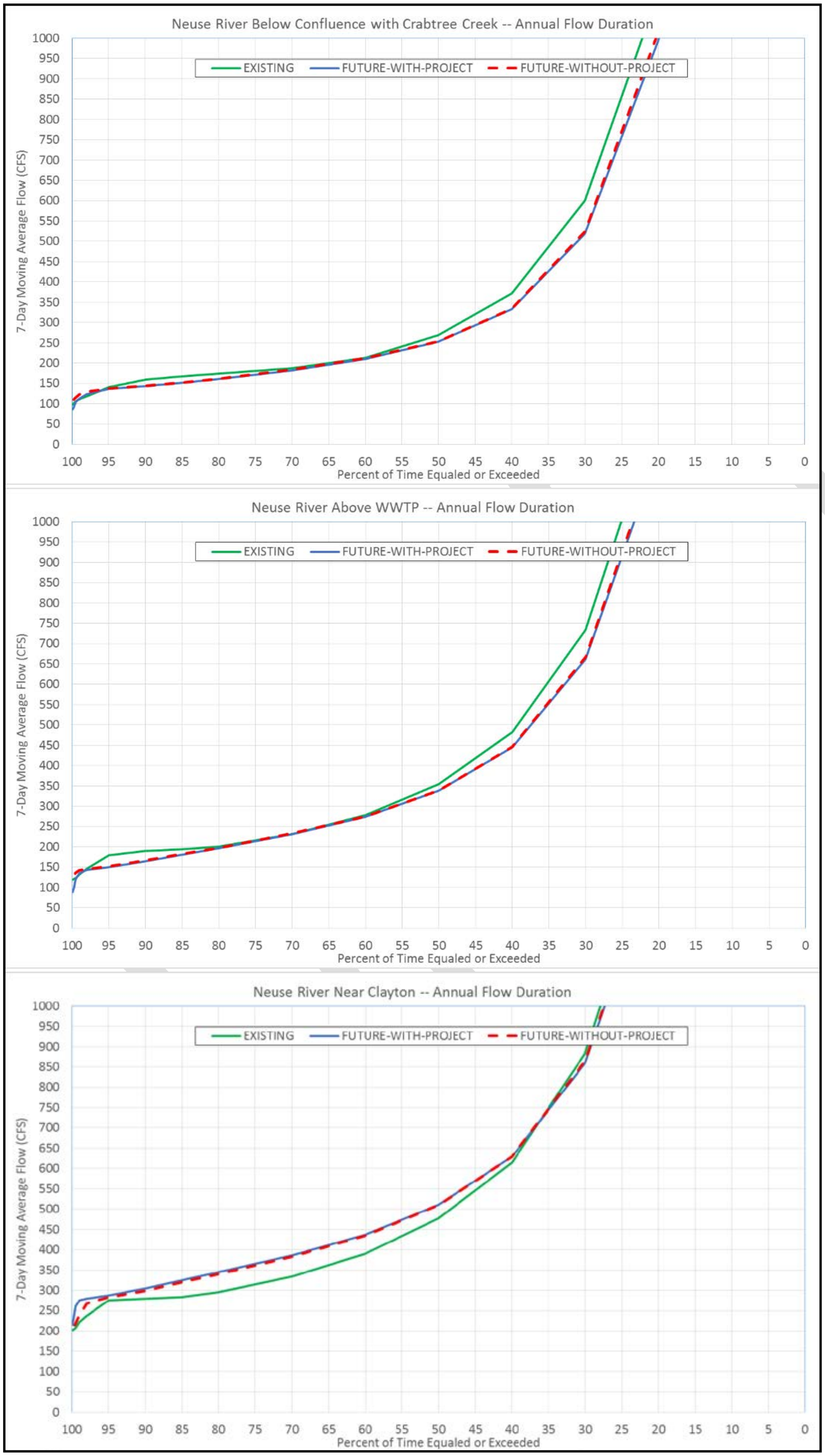
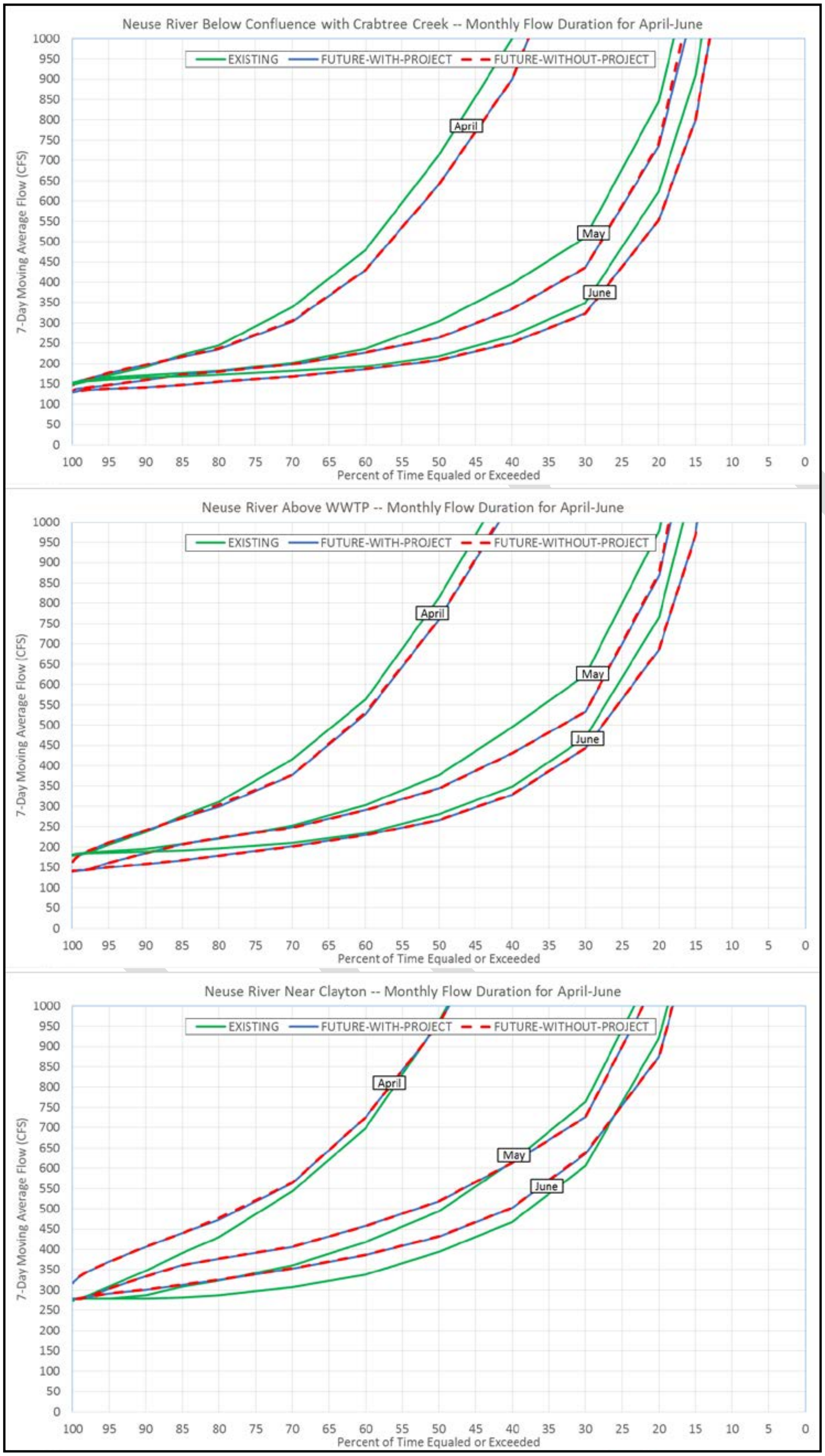


Figure 22. Downstream Neuse River Locations -- Monthly Flow Durations (Apr-Jun)



6. **References**

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ER 1165-2-119 Modifications to Completed Projects, 20 September 1982.

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Falls Lake Project, Drought Contingency Plan – Updated March 2008.

ATTACHMENT B-1

Certification of OASIS Model Review by WMRS PCX

DEPARTMENT OF THE ARMY
US ARMY ENGINEER DIVISION, SOUTHWESTERN
1100 COMMERCE STREET, SUITE 831
DALLAS TX 75242-1317

REPLY TO
ATTENTION OF

CESWD-PDP 4 August 2016

MEMORANDUM FOR Headquarters USACE (CECW-SAD/Stacey Brown), 441 G Street, NW, Washington, DC 20314-1000

SUBJECT: Certification of Review of the OASIS Model Used in the Falls Lake Storage Reallocation Study

1. The Planning Center of Expertise (PCX) for Water Management and Reallocation Studies (WMRS) in coordination with the Hydrology, Hydraulics and Coastal Engineering sub-Community of Practice (CoP) and the Hydrologic Engineering Center (HEC) has conducted a review of the OASIS model used in support of the Falls Lake Storage Reallocation Study. The model proponent is the Wilmington District. The PCX does not recommend approval for use of the model in other studies without further coordination with the HH&C sub-CoP.

2. By definition in Enterprise Standard 08101, OASIS is a piece of software that can be used to create any type of model. While the HH&C CoP believes the tool is fine for building models and is "Allowed for Use," Agency Technical Review (ATR) must be a thorough review of the inner workings of the model as well as the basic assumptions, equations, and output used. The PCX and HEC organized a model review team to perform a review of the documentation and model provided by the proponent. Staffing of the model review team was coordinated with the HEC.

3. The model review team documented comments and issues discussed with the proponent in the DrChecks review tool and prepared a statement documenting findings regarding the technical quality, system quality and usability of the models. Following discussion of the initial findings, the proponent addressed comments. The comments were resolved and closed by the model review team.

4. POC for this action is the undersigned at 501-324-5036.

CHERILYN PLAXCO
Technical Director
WMRS PCX

CF:
CECW-EC (Smith)
CESAD-PDP (Bush)
CESAW-PM-D (Castens)
CESAW-ECP-EC (Young)

ATTACHMENT B-2

Modeling the Cape Fear and Neuse River Basin Operations with OASIS

Modeling the Cape Fear and Neuse River Basin Operations with OASIS

Addendum to the User Manual for OASIS with OCL™

November 2013

Prepared for the

North Carolina Division of Water Resources

HYDROLOGICS
Advancing the management of water resources

Table of Contents

Section 1. Introduction

This report describes how OASIS is used to model the operations of the Cape Fear and Neuse River Basins in North Carolina. Combining previously separate models of each basin into a single model allows for optimizing potential transfers between users in both basins. This application of OASIS, known as the Cape Fear /Neuse Hydrologic Model, extends geographically from the headwaters of the Deep and Haw Rivers to the mouth of the Cape Fear River, and from the headwaters of the Eno, Flat and Little Rivers to the mouth of the Neuse River. This report is not intended to replace the User Manual for OASIS, which is available from the Help menu of the model. Rather, it is intended to document the data used in this application as well as the current operations of the basins. Information about the OASIS platform is included only to the extent necessary to provide context for the application-specific data.

The model is available for registered users on the Division of Water Resources (DWR) server. The model can be used in two modes: (1) a simulation mode to evaluate system performance for a given set of demands, operating policies, and facilities over the historic inflow record; and (2) a position analysis mode for real-time management. The simulation mode contains two default runs, one for conditions today and one for projected 2050 conditions. In the position analysis mode, the model uses multiple ensemble forecasts to provide a probabilistic assessment of conditions up to one year in the future. Although it can be used for other purposes as well, this feature is particularly useful for drought management.

The model uses an inflow data set that extends from January 1, 1930 through September 30, 2011. This data set was developed using a comprehensive approach that (1) relies on over 60 streamflow gages in the basins; (2) accounts explicitly for upstream alterations, or impairments, from reservoir regulation and net water consumption; and (3) uses statistical techniques to complete missing records for these gages.

Real-time drought management requires forecasts of inflow and, as noted below, the forecasts are generated based on inflows through the present day. Updating the inflows requires the collection of impairment data, which can be time intensive. It is envisioned that these data will be collected every five years. In the interim (e.g., through 2017), the inflow data starting October 2011 will be based on a provisional inflow technique so that real-time updates can be made quickly and easily without the need to collect all the impairment data.

The remainder of this document summarizes the components of the model and the major operations in the basins. Appendix A lists the static input data and run code used in the basecase simulation run that is based on today's facilities, operations, and year 2010 demands. Appendices B1 and B2 describe the approach used to establish the finalized inflow data set for the Cape Fear and Neuse basins, respectively. Appendix C describes the approach for generating provisional inflows for the basins. Appendix D describes the weighting assigned to the various nodes and arcs so that the model reflects the general priorities for water allocation in the basins.

It is important to note how the OASIS model should and should not be used. OASIS is a generalized type of mass balance model used mainly in evaluating planning and management alternatives. It is not intended for use in hydraulic routing nor flood management, although it can be linked to other models for those purposes.

In addition, since modeling results are sensitive to inflows, the user must be cautioned about accuracy of the inflows. HydroLogics spent considerable effort in developing the inflow data. The methodology ensures that the monthly naturalized flows at the gage locations match, which assumes that any measurement error is embedded in the impairments and not the streamflow data. DWR agreed to this method, which, although imperfect, is the most reasonable given the available data. Further, it is important to note that we are not trying to replicate history in computing the OASIS inflows; rather, we are trying to build a data set of daily flows whose variation is *representative* of history while preserving monthly gaged flows as “ground truth”.

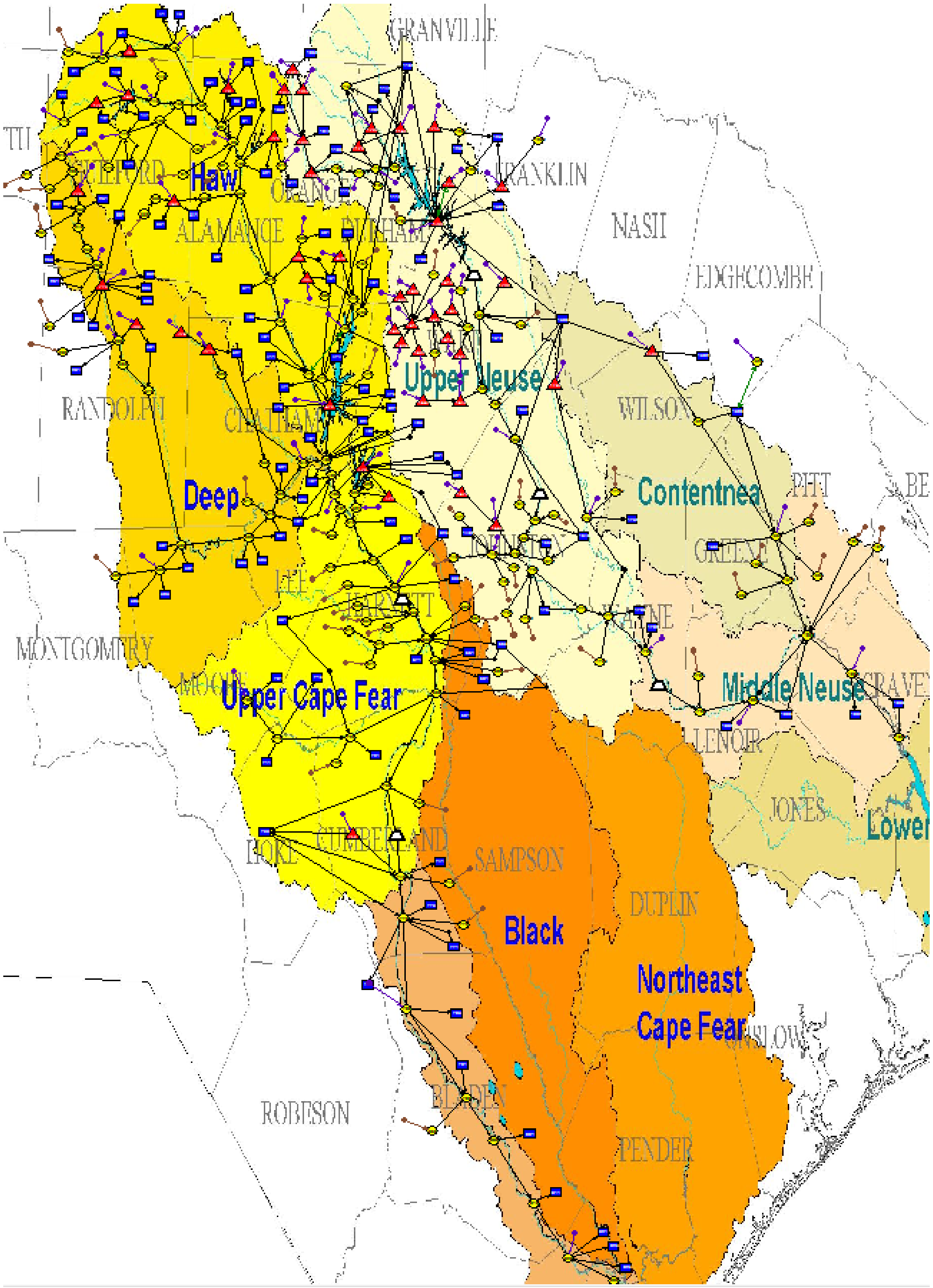
Due partly to the inaccuracy of some of the impairment data and to time of travel, negative inflows may occur. These can lead to potential model infeasibility. The model code filters out negative inflows, particularly large ones, but preserves the total inflow volume over a short period by debiting those negative inflows from subsequent positive inflows. For example, if a rainstorm hits the upstream part of the reach but not the downstream part, the gaged flow data may indicate a large negative inflow (gain) between the upstream and downstream ends. When the flow attenuates upstream and peaks downstream, the inflow becomes positive, and the negative gains from the days before are debited from the positive inflows in the days after to ensure that the average inflow over that period is preserved. The occurrence of negative inflows is reduced in the main-stem of the Neuse and Cape Fear by incorporating time-of-travel equations recommended by the Army Corps of Engineers. These equations are provided in Appendices B1 and B2.

Section 2. Model Components

2.1 Schematic

The model uses a map-based schematic that includes nodes for withdrawals (agricultural, municipal, and industrial), discharges (municipal and industrial), reservoirs, gage locations, and points along the rivers where flows are of interest. Arcs represent means of water conveyance between nodes. The model schematic is shown on the following page and is sized to show the full system. (To make the schematic more legible, the user can adjust the schematic size from the model's graphical user interface (GUI)). The schematic and associated physical data were developed with input from basin stakeholders at numerous model review meetings.

In total, the model has approximately 330 nodes and 450 connecting arcs. There are 58 reservoir 42 actual reservoirs, 11 flood impoundments on Crabtree Creek, and five artificial storage nodes used for time-of-travel flow routing), over 60 agricultural demand nodes, over 50 municipal and industrial demand nodes, 25 independent wastewater discharge nodes (i.e., not tied into a water withdrawal node), over 100 natural inflow nodes (including the reservoir nodes), and other miscellaneous nodes to account for minimum flow requirements, interconnections, and instream flow assessment for ecological needs.



GRANVILLE
FRANKLIN
NASH
EDGECOMBE
Haw
ALAMANCE
DURHAM
Upper Neuse
WILSON
RANDOLPH
CHATHAM
Deep
Contentnea
PITT
GREENE
LEE
HARNETT
MONTGOMERY
Upper Cape Fear
Middle Neuse
LENOIR
JONES
Lower
HOKE
CUMBERLAND
SAMPSON
DUPLIN
Black
Northeast
Cape Fear
ROBESON
BLADEN
PENDER

The user can click on any node or connecting arc on the schematic to access specific information, like reservoir elevation-storage-area data or minimum streamflow requirements. These data are also contained in tables contained on other tabs of the model.

To differentiate between the basins, node numbering up to 999 is assigned to nodes in the Cape Fear Basin, and 1000 up to 1999 to nodes in the Neuse Basin.

2.2 Model Input

Input data for the model is stored in three forms: static and pattern data, timeseries data, and user-defined data using operations control language (OCL). The timeseries data are stored outside the model run. The other data are embedded in the run and copy over automatically when creating a new run.

Static and pattern data are contained in the GUI and represent data that do not change during the model simulation (such as physical data like reservoir elevation-storage-area relationships) or repeating data that occurs every year in the simulation (like monthly demand patterns or seasonal minimum release patterns). Timeseries data change with each day in the simulation record and typically consist of inflows and reservoir net evaporation. OCL allows the user to define more elaborate operating rules than are permitted from the GUI.

Static and Pattern Data

Tables containing the model's static and pattern data can be found in Appendix A. Reservoir information includes elevation-storage-area relationships, minimum and maximum allowable storage, and any rule curves which dictate the preferred operating elevation throughout the year.

Minimum flows and reservoir releases are defined by minimum flow patterns on arcs.

Water treatment plant and transmission constraints are defined by maximum capacities on arcs.

Municipal and industrial demand nodes use an annual average demand subject to a monthly pattern, and an associated wastewater discharge based on a fraction of the monthly demand. Wastewater discharges not associated with demand nodes are modeled using an annual average return subject to a monthly pattern.

The model allows the user to systematically adjust all municipal and industrial demands in the basins by invoking the demand multiplier option on the Setup tab. This is useful when doing sensitivity analyses on the impact of demand growth in the basins. Note that agricultural demands and independent wastewater returns are not adjusted using this multiplier. The agricultural demand can be adjusted as described below, and the independent wastewater returns can be adjusted manually in the pattern tables.

Timeseries Data

The timeseries data are stored in a basedata timeseries file (*basedata.dss*), which contains all the inflow and net evaporation (evaporation less precipitation) data. The sources for these data are provided in Appendices B1 and B2 along with a more detailed description of how the inflows were developed. As noted, updating the timeseries data can be done in two ways: (1) using the comprehensive approach described in Appendices B1 and B2; or (2) using the provisional approach for facilitating real-time drought management described in Appendices C1 and C2. The provisional approach relies on data from select gaging and precipitation stations throughout the basins.

The provisional updates can be done directly from the interface by selecting the Update Record tab. First the user presses the Download Data Button; once the data has downloaded the user needs to check for any blanks or erroneous values. After verifying the data, the inflows can be updated by pressing the Update Record button. The update record algorithm will calculate the inflows to all the OASIS inflow nodes and net evaporation for all reservoir nodes and write them to the *basedata.dss* file automatically.

Agricultural water use is modeled as a timeseries over the historic hydrologic record. It is broken out by county and depends on livestock count, crop usage, livestock and crop water consumption, and rainfall. Evapotranspiration equations for each crop are used in conjunction with the timeseries precipitation record so that crops are only irrigated when necessary. The water use can be easily adjusted from the model interface by opening the Edit Agricultural Data dialog box on the Setup tab. The model automatically converts the input data on crop acreage and livestock count into water use values. The agricultural demand nodes are a summation of the agricultural water usage in a particular reach of interest.

Operating Rules

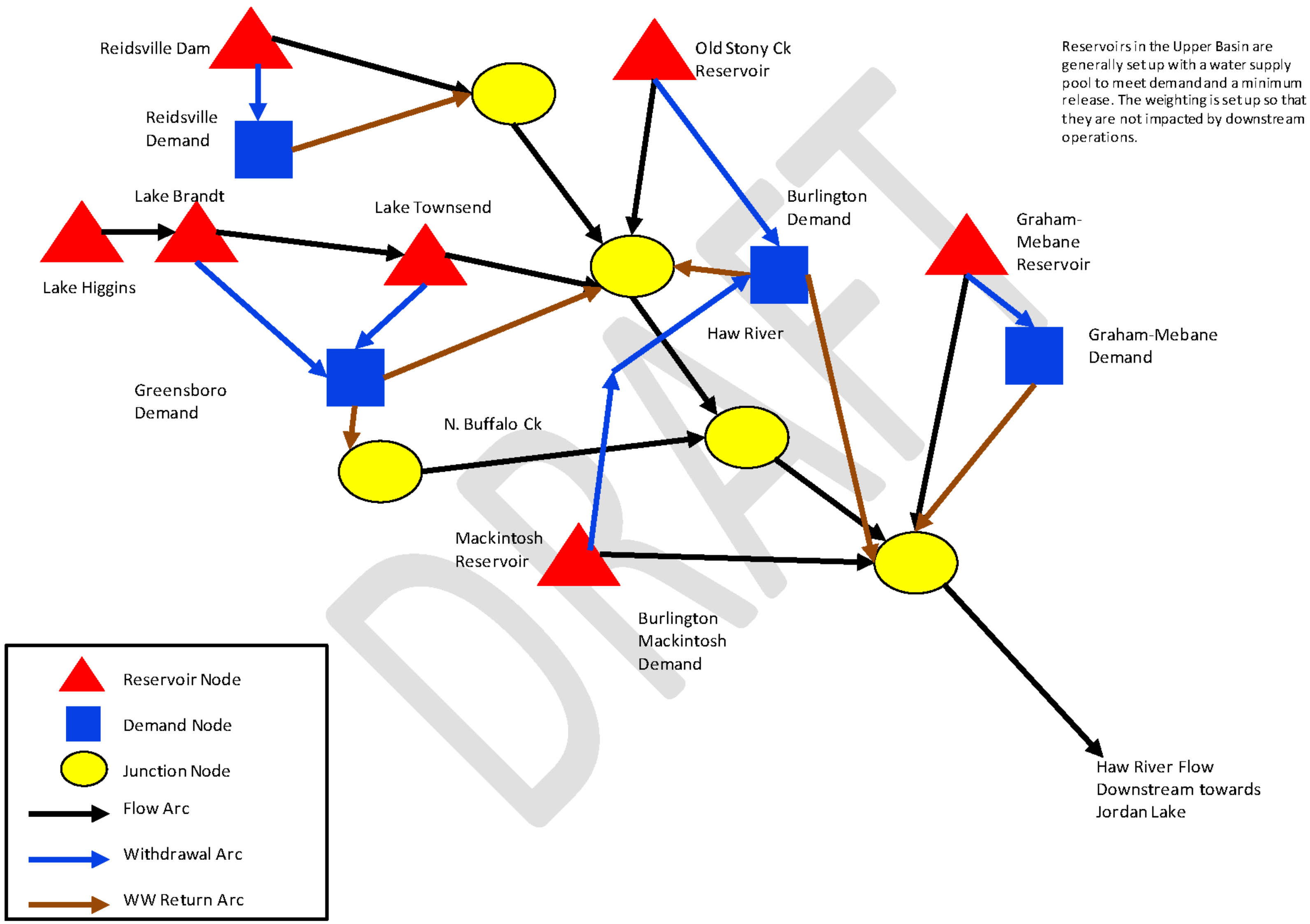
As described in more detail in Appendix D, most of the water allocation priorities are set by the user in the GUI by applying weights to nodes and arcs. The most common operating rules are for storing water in reservoirs versus releasing the water to meet local demands or minimum releases, and these are reflected by the weighting scheme. Simply stated, if a minimum flow in a river is more important than meeting the local water supply demand, a higher weight on the minimum flow means water supply deliveries will be scaled back if necessary in a drought to meet the minimum flow.

The Operations Control Language (OCL) allows the user to model more complex operating rules such as drought management protocols that tie demand reductions to reservoir levels or river flows. These files are accessible from the model interface. The

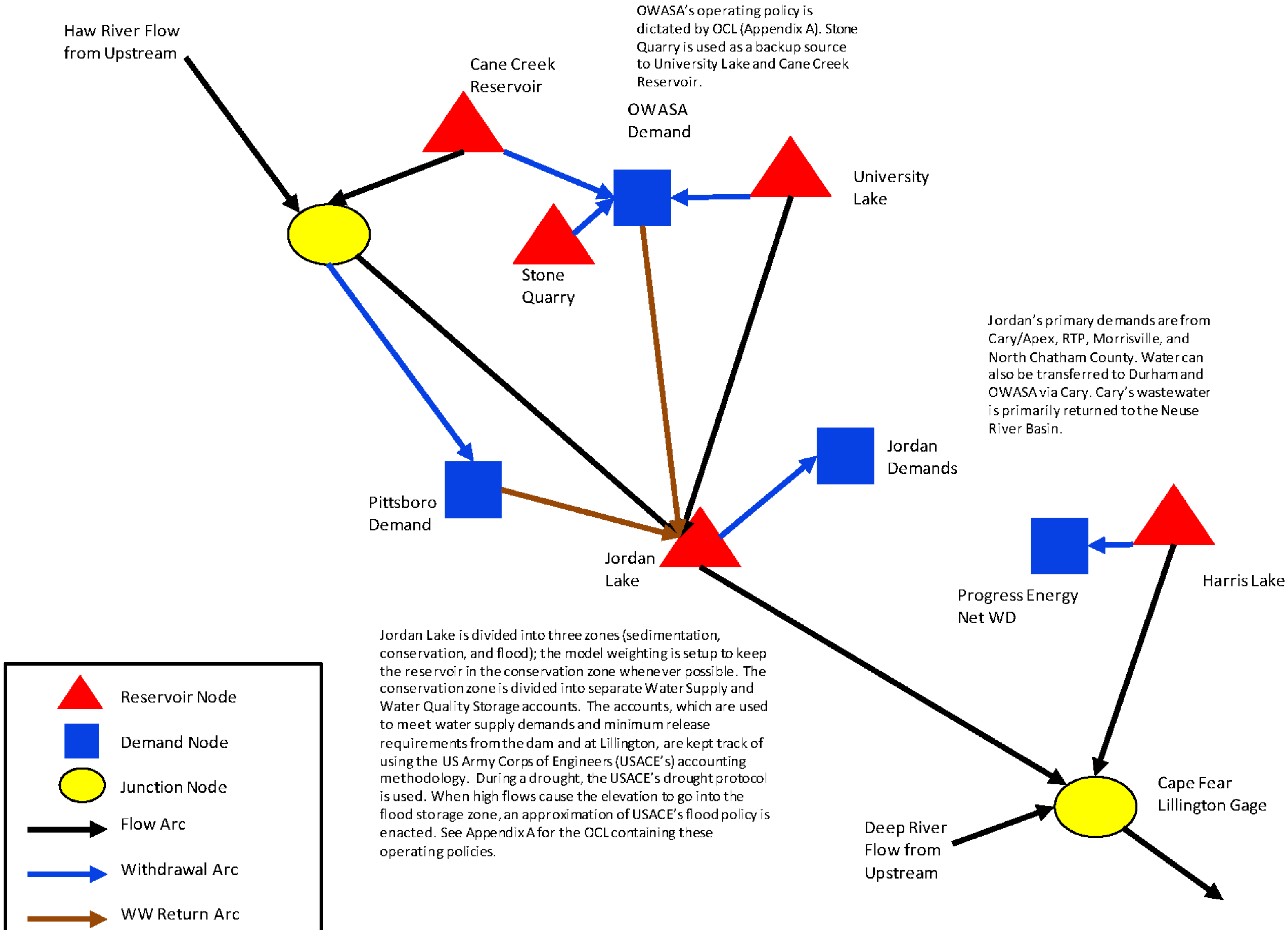
OCL files associated with the basecase simulation run that uses year 2010 demands are included in Appendix A. The key OCL files include *main.ocl*, which initializes the run and refers to all the other OCL files; *filter_inflows.ocl*, which filters the inflows for any negative gains in the provisional record; *WW_returns.ocl* which sets the wastewater returns; *routing.ocl*, which routes water to account for time of travel; *Jordan_ops.ocl, Jordan_WQ_WS_Accounts.ocl, drought_protocol_Jordan.ocl, Falls_Bdam_ops.ocl, Falls_flood_ops.ocl, and Falls_Bdam_WQ_WS_Accounts.ocl,* all of which dictate the operating policies for Jordan Lake and Falls Lake; and *drought_plans_cf.ocl* and *drought_plans_neuse.ocl* which code the Water Shortage Response Plans submitted by utilities in each basin to DWR. A number of other OCL files dictate the operating policies for other systems, and can be found in Appendix A. Appendix D details the weighting which also controls operations in the basins.

A series of stylized flowcharts are provided below summarizing the overall operations of each basin as captured in the model. Note that to simplify the flow diagrams, detailed interconnections captured in the model are not shown here.

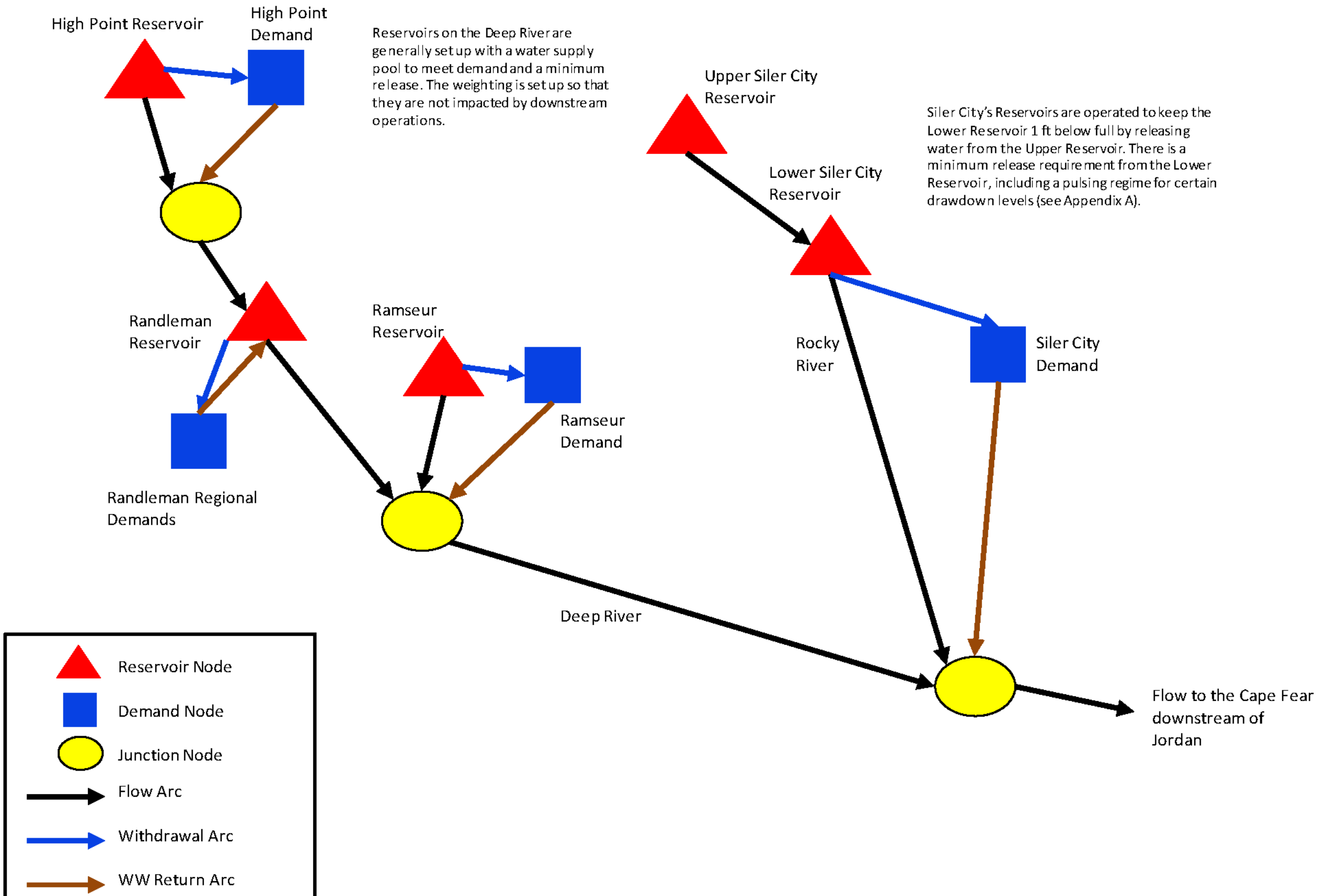
Flow Chart of Major Nodes in the Upper Cape Fear Basin



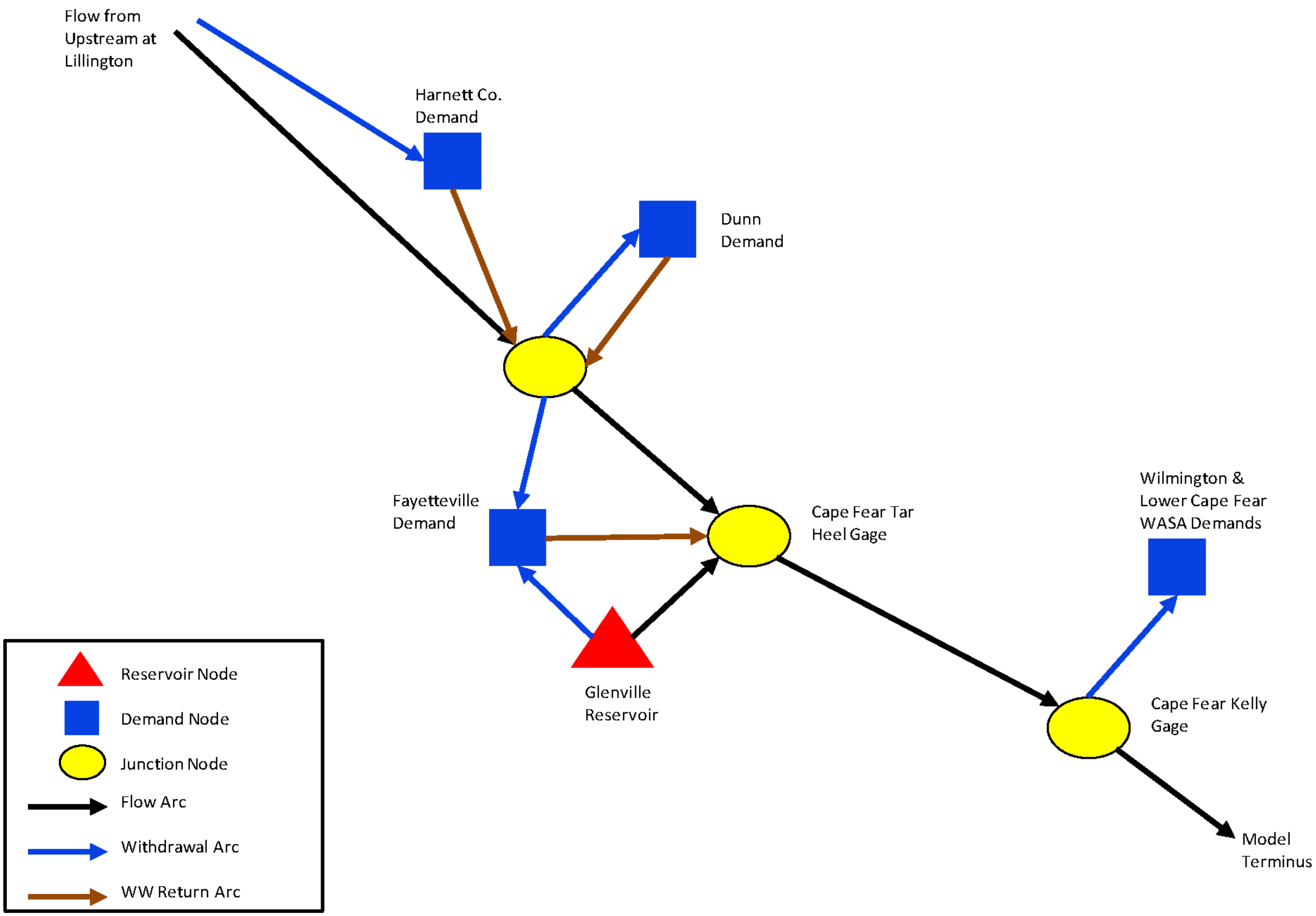
Flow Chart of Major Nodes in the Middle Cape Fear Basin



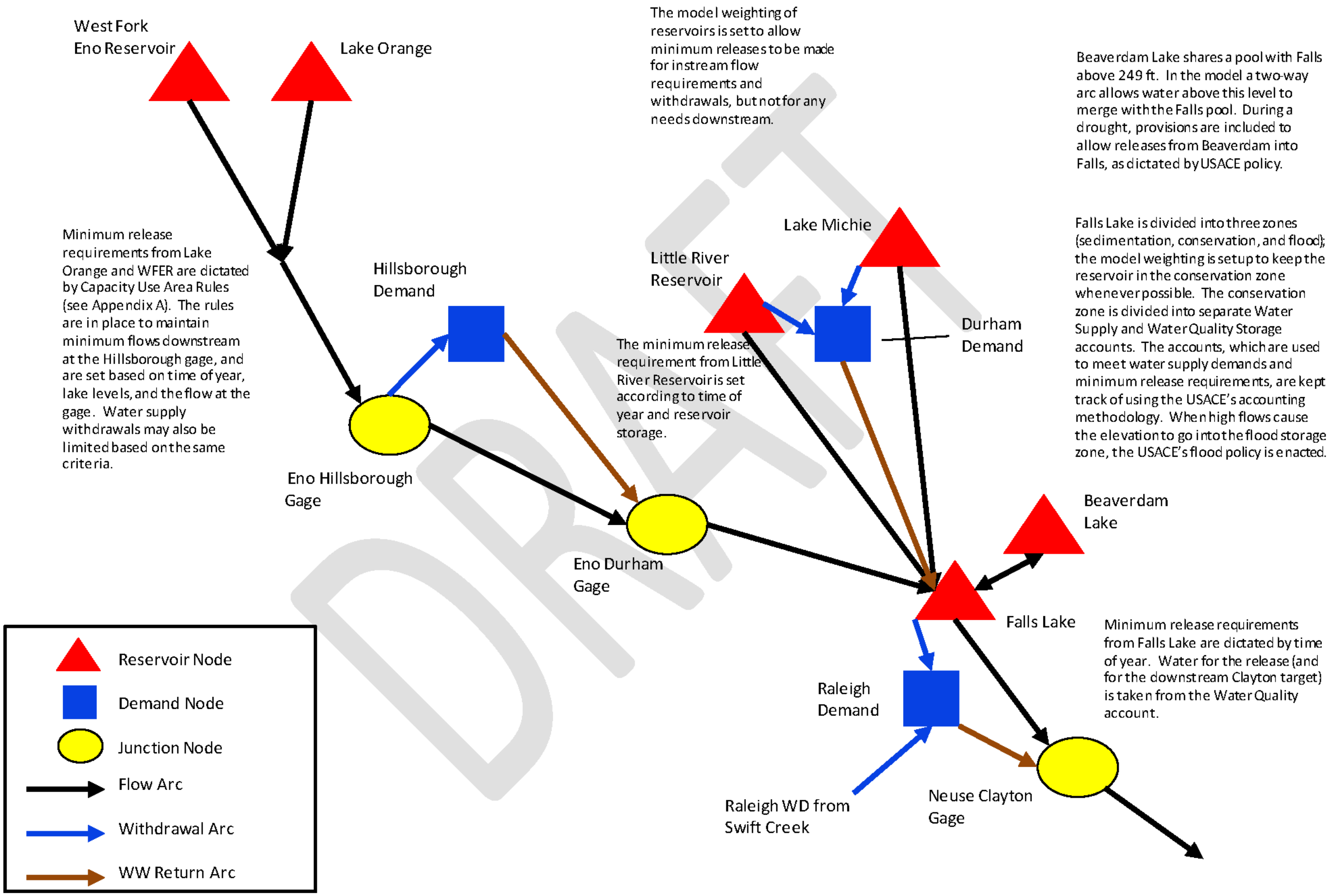
Flow Chart of Major Nodes on the Deep River



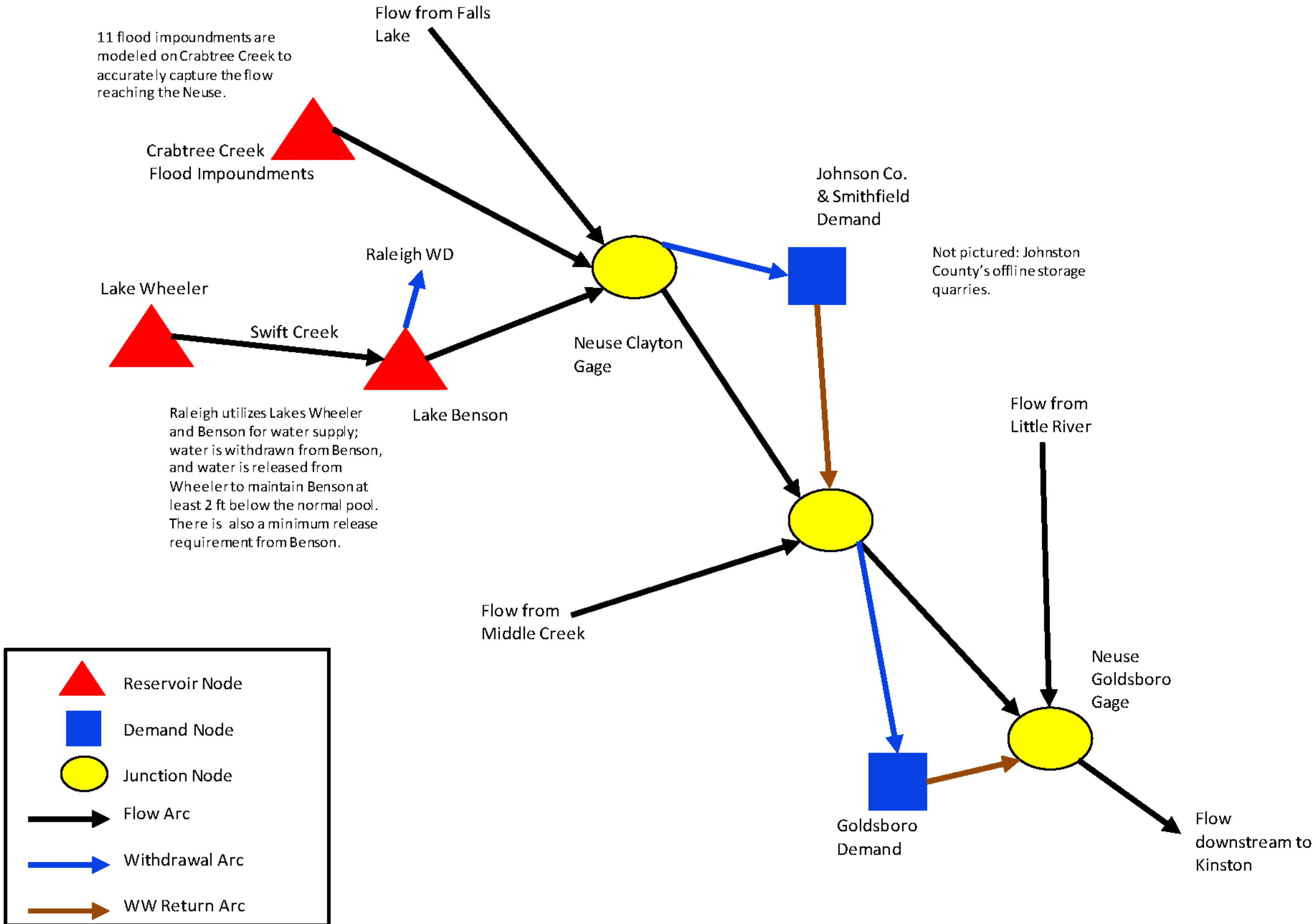
Flow Chart of Major Nodes in the Lower Cape Fear Basin



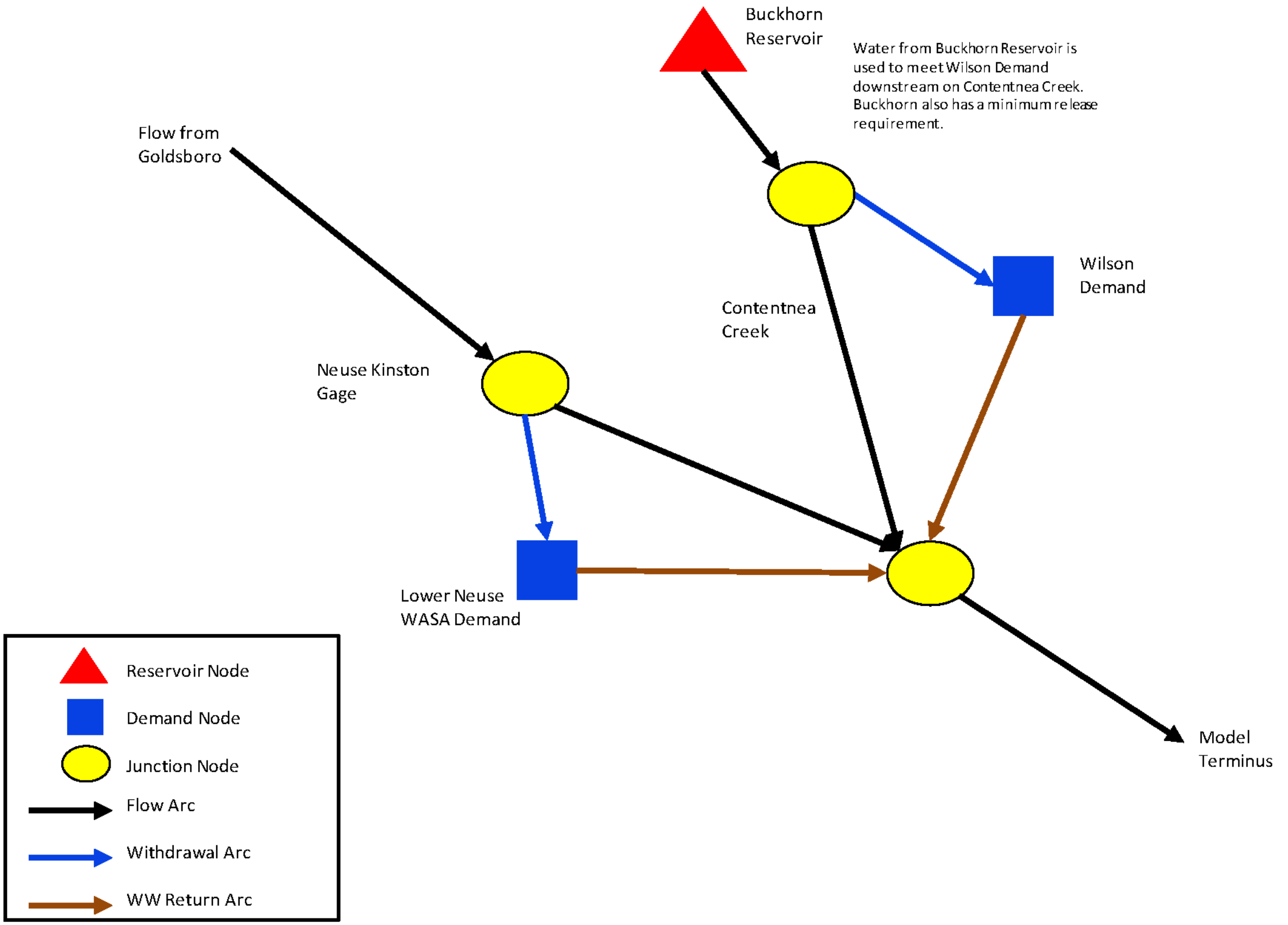
Flow Chart of Major Nodes in the Upper Neuse Basin



Flow Chart of Major Nodes in the Middle Neuse Basin



Flow Chart of Major Nodes in the Lower Neuse Basin



2.3 Run Configurations

The model can be used in two modes: (1) a simulation mode to evaluate system performance for a given set of demands, operating policies, and facilities over the historic inflow record; and (2) a position analysis mode for real-time management. General information on creating, modifying, and executing runs is provided in the User Manual for OASIS, which is available from the Help menu of the model.

Simulation:

In simulation mode, on the Setup tab, the user can select from three radio buttons: No Forecasts, Conditional Forecasts, and Non-conditional Forecasts. The latter two enable the user to evaluate forecast-based operating policies (although none are used in the basecase scenario), with inflow forecasts generated for each week in the historical inflow record. Conditional forecasts account for antecedent flow conditions while non-conditional forecasts are made independent of how wet or dry the basin is. The forecasts for the simulation mode are generated outside the GUI and stored in the basedata folder. The current forecast file is developed from the timeseries *basedata.dss* file that extends through September 2011. The forecast file should only be updated in conjunction with the comprehensive inflow updates (anticipated every five years with the next update in 2017).

To enable all utility drought plans in a run, set the *Drought Plans On* variable in the OCL Constants Table to 1. A value of 0 will turn all drought plans off.

The GUI allows for all municipal and industrial demands in the model to be uniformly increased or decreased by a user-specified fraction. To enable the demand multiplier, check the *Use Multiplier* box on the Setup tab, and enter a number in the *Multiplier Value* box. For example, setting the value to 0.9 will decrease all M&I demands by 10%, and setting it to 1.1 will increase them by 10%.

Position Analysis:

In position analysis mode, the user can select from Conditional or Non-Conditional Forecasts on the Setup tab. By executing a run, the model will produce a forecast (typically of river flows or reservoir elevations) for up to the next 365 days. A forecast can be made on any date in the historic inflow record or no more than one day after the end of the inflow record. Typically it will be used starting the day after the last update of the inflow and net evaporation record. For example, if these records end September 30, 2011, the user can run a forecast for October 1, 2011. If a month has passed, and the user wants to run a forecast for November 1, 2011, the user would update the inflows and net evaporation for October using the Update Record tab and then start the position analysis run on November 1. For a reservoir, or locations affected by the operation of a reservoir upstream, the forecast is dependent on the starting elevation of the reservoir. On the Setup tab, the user simply inputs the starting elevation (or storage), the starting date of the forecast run, and clicks Run. Note that initial storage values for the water supply and quality accounts for Jordan and Falls Lakes are handled differently, with those set in the constants table accessible from the GUI.

2.4 Model Output

The model allows the user to customize output files (tables or plots) and save them for routine use. Alternatively, the user can click on any node or arc on the schematic or go to the Setup tab and select Quick View to access and save tabular or plotted output. A number of tables and plots have been provided for points of interest in the basins. The balance sheet can also serve as a useful tool for tracking water through the system.

Included in the model output tables is a file called *xQy_ClimaticYear_Clayton.1v*. This file allows the user to compute instream flow statistics, such as 7Q10, for a specific site, in this case the Neuse River at Clayton gage. To generate statistics for a different site, the user would copy and rename the file, then change the name and associated arc listed in the file. When viewing the generated output, the default layout shows two columns, for 7- and 30-day low flows (these periods can be changed in the .1v file). Scrolling to the bottom of the output file shows Log Pearson percentiles for each column. If the user is interested in the 7Q10 (7-day low flow, 10^{th} percentile) flow, the user would look at the first column, and the row labeled LPrs.100.

In addition, the model is capable of automatically determining the safe yield for a specific demand node, in this case the demand from Falls Lake. To generate statistics for a different site, the user would copy and rename the file (currently called *SafeYield_Raleigh.1v*), then change the name and associated demand node listed in the file. The safe yield can be determined for each year in the historic inflow record (annual safe yield analysis) or for the entire period of record. The user inputs the adjustment criteria by selecting the Run Safe Yield Analysis button on the Setup tab. The safe yield routine works by tracking demand shortages for the chosen demand node, and iteratively works towards the maximum demand that produces no shortages from the supply source (in this example, Falls Lake). Note under the current output file configuration, the drought plans should be turned off when using the safe yield routine, as the demand reductions resulting from drought restrictions inherently produce a 'shortage' from the normal demand. The output file configuration can be modified if needed for the specific drought plan of each system.

US Army Corps of Engineers ®
Wilmington District

FALLS LAKE, NORTH CAROLINA

INTEGRATED WATER SUPPLY REALLOCATION FEASIBILITY STUDY

APPENDIX C

ECONOMICS

CITY OF RALEIGH, NORTH CAROLINA

MARCH 2017

Project Location

Falls Lake Dam is located on the Neuse River approximately one mile northwest of Falls, North Carolina. The reservoir created by the dam, Falls Lake, extends 28 miles up the Neuse River to just above the confluence of the Eno and Flat Rivers. The reservoir has a normal surface area of 12,410 acres with approximately 175 miles of shoreline under normal operating conditions. The drainage area of the Neuse River basin above Falls Lake Dam is approximately 770 square miles.

Related Projects

Falls Lake Dam is one of 15 reservoirs which operate as part of a system on the upper Neuse River Basin for the conservation, control and management of water resources throughout the entire basin. The system is managed for flood risk management, storm water management, fish and wildlife enhancement, recreation and water supply.

Watershed

The Neuse River Basin lies within the central and eastern part of North Carolina and drains all or parts of 22 counties. The basin is approximately 180 miles long and includes about twelve percent of the total land area of North Carolina. With a drainage area of 5,598 square miles, it is the second largest river basin lying completely within the state of North Carolina.

The Neuse River is formed at the confluence of the Eno and Flat Rivers, approximately eight miles north of the City of Durham, North Carolina. Principal tributaries of the Neuse River below Falls Lake are the Little River, Contentnea Creek and the Trent River. The Trent River joins with the Neuse River to form the Neuse River Estuary south of New Bern, North Carolina. The estuary then joins with Pamlico Sound in the lower coastal plain.

Functions, Services and Benefits

Falls Lake plays a crucial role in the Neuse River Basin as a water supply and water control reservoir, providing the city of Raleigh with municipal water, while the surrounding public lands and downstream area provide fish and wildlife habitat.

86% of the land within the Neuse River Basin is either agricultural or forest lands. The remaining 14% consists of state or federally owned lands, cities, towns and roadways. Surface water accounts for ten percent of the Neuse River Basin. Crops grown in the basin include corn, tobacco, hay, wheat and soybeans. Past agricultural practices within the Neuse River Basin have led to increases in nutrient concentrations within the basin’s rivers and streams. In 2008, Falls Lake and its source streams were listed as impaired for nutrients. Through the Upper Neuse Clean Water Initiative, the state has implemented watershed protection and land conservation projects to restore and protect forests as a means for absorbing excess nutrients, trapping sediments and controlling storm water runoff (Upper Neuse River Watershed Protection Revenueshed Analysis, August 2012).

Falls Lake Dam
NIDID - NC01713
System Map
Map Elements
Project Sites
USACE Dam/Lock
Miles From Dam
Rivers
Modeled Reach
FALLS LAKE DAM
Durham
Cary
Raleigh
Roanoke River
Tar River
Neuse River
Rocky Mount
Greenville
North Carolina
0 5 10 20 30 Miles

Zone of Influence

Falls Lake sits just outside of the City of Raleigh and draws visitors from the surrounding area. Visitor surveys were not conducted specifically for this Appendix; however, previous surveys suggest that 90 percent of visitors to the project originate from within a 50 mile radius (Banaitis 2011). As such, portions of the 16 counties that fall within this radius, referred to as the "zone of influence", were identified for demographic analysis. These counties include: Alamance, Caswell, Chatham, Durham, Franklin, Granville, Harnett, Johnston, Lee, Nash, Orange, Person, Vance, Wake, Warren, and Wilson

The US Census Bureau's designation for this region is the Raleigh-Durham-Cary Combined Statistical Area (CSA), referred to here as the Triangle CSA or Triangle. The Triangle CSA is made up of Chatham, Durham, Franklin, Harnett, Johnston, Orange, Person, and Wake counties and includes the major cities Raleigh, Durham, Chapel Hill, Cary, Wake Forest and other small neighboring towns.

Population

In 2014, North Carolina had an estimated population of just over 9,953,687. This ranks North Carolina as the 10th most populous state (including Washington, D.C.). The Triangle CSA comprises over 85 percent of the population within the zone of influence. Wake, Durham, and Johnston counties are the most populous of those in the Triangle CSA and make up nearly 62 percent of the population within Falls Lake area. Table 1 summarizes population estimates for counties within the zone of influence from 1970 to 2010 (Census 2010, NCOSBM 2015)

North Carolina's population growth rate has consistently been greater than the U.S. population growth rate over the past 20 years. Each County in the zone of influence experienced population growth from 2000 to 2010. Caswell, Granville, Nash, Vance, Wilson, and Warren counties experienced small population decreases (below 3.1 percent) from 2010 to 2014 (Census 2015, NCOSMB 2015).

The population within Triangle CSA has increased significantly over the past 20 years. The area is home to three major cities located in a close proximity to each other, Raleigh (population 432,133), Durham (population 244,108), and Cary (population 148,103) along with the nearby Town of Chapel Hill (population 59,753). Population in the Triangle CSA increased 28.1 percent (average annual increase of 3.5 percent) between 1990 and 2010, while North Carolina's population increased 14.2 percent (average annual increase of 1.8 percent) (Census 2010, NCOSBM 2015).

Population Projections

Population projections by the North Carolina Office of State Budget and Management (NCOSBM) show an annual population growth rate ranging from 1.7 percent to 3.1 percent in the Triangle CSA and 1.6 percent to 2.7 percent in the Falls Lake zone of influence over the next 20 years (NCOSMB 2015). Table 2 shows the projected populations for the counties within the zone.

Table 1: Populations of Falls Lake Zone of Influence Counties Since 1970					
County	1970	1980	1990	2000	2010
Alamance County	96,502	99,319	108,213	131,503	151,745
Caswell County	19,055	20,705	20,662	23,550	23,676
Granville County	32,762	34,043	38,341	48,837	60,122
Lee County	30,467	36,718	41,370	49,407	58,059
Nash County	59,122	67,153	76,677	87,705	96,215
Vance County	32,691	36,748	38,892	43,119	45,477
Warren County	15,340	16,232	17,265	19,992	21,022
Wilson County	57,486	63,132	66,061	73,927	81,643
Chatham County	29,554	33,415	38,979	49,725	63,870
Durham County	132,681	152,235	181,844	224,619	268,925
Franklin County	26,820	30,055	36,414	47,600	60,978
Harnett County	49,667	59,570	67,833	91,464	115,579
Johnston County	61,737	70,599	81,306	123,301	170,151
Orange County	57,567	77,055	93,662	116,017	134,325
Person County	25,914	29,164	30,180	35,744	39,585
Wake County	229,006	301,429	426,311	633,461	907,314
Triangle CSA	612,946	753,522	956,529	1,321,931	1,760,727
Area Total	956,371	1,127,572	1,364,010	1,799,971	2,298,686
North Carolina	5,082,059	5,881,766	6,628,637	8,049,313	9,535,483

Note: Counties in the Triangle CSA are in italics. Source: NCOSBM 2015

Table 2: Population Projections for Zone of Influence Through 2035			
County	2020	2030	2035
Alamance County	167,370	187,290	197,264
Caswell County	23,632	23,632	23,632
Granville County	59,236	61,145	62,100
Lee County	59,242	59,324	59,363
Nash County	93,380	91,476	90,526
Vance County	44,867	44,786	44,775
Warren County	20,515	20,514	20,513
Wilson County	84,198	90,377	93,507
Chatham County	75,494	86,776	92,418
Durham County	325,799	242,871	408,936
Franklin County	66,881	72,963	76,008
Harnett County	139,259	161,808	173,080
Johnston County	201,850	242,871	263,815
Orange County	149,922	166,565	174,888
Person County	39,588	39,950	40,071
Wake County	1,105,706	1,306,308	1,406,726
Triangle CSA	2,104,499	2,320,112	2,635,942
Area Total	2,656,939	2,898,656	3,227,622
North Carolina	**10,574,718**	**11,609,833**	**12,122,640**

Counties in the Triangle CSA are in italics

Source: NCOSBM, 2015

Race and Ethnicity

Historically, North Carolina was characterized by a large White population, substantial Black population, and very small population of other minority groups. Currently, the population of North Carolina is primarily White (73.9 percent) with Black representing the largest minority (21.6 percent). Warren and Vance counties have populations where Black is the largest racial group (Census 2010, NCOSBM 2015).

Recent economic growth centered in the Triangle, however, has changed the ethnic makeup of the region. The Hispanic population has boomed in the region, experiencing high growth rates over the past two decades. Likewise, the growth in the Asian population has outpaced the general population growth (Census 2010, NCOSBM 2015).

Age and Gender

Age and gender statistics in the Lake Falls region are generally close to the State and national averages. There is a noticeable spike in the number of 18 to 24 year olds in the Triangle CSA, which can be attributed to several universities being located within the area (Appendix J, Figure 10). The distribution of men and women in the region was fairly even, at 48.6 and 51.4 percent, respectively (Census 2010, NCOSBM 2015).

Education

The Triangle CSA is notable for a high level of education obtained by much of the population. Orange County has the highest level of educational obtainment, with 51.5 percent of the population holding a Bachelor's degree or higher. The high levels of educational attainment can be attributed to the presence of many high-tech industries, many hospitals and medical facilities, and higher learning institutions located throughout the Triangle CSA (Census 2010, NCOSMB 2015).

Economic Characteristics

The U.S. Department of Commerce divides the Triangle area into two Metropolitan Areas: the Durham-Chapel Hill Metropolitan Area and the Raleigh-Cary Metropolitan Area. In 2006, the current dollar (2008 dollars) gross domestic product for the Durham- Chapel Hill Metropolitan Area was over $28.8 billion. The Raleigh-Cary Metropolitan Area current dollar (2008 dollars) gross domestic product was over $48.0 billion. Between 2005 and 2007, these metropolitan areas experienced real gross domestic product growth above 4 percent. This growth declined, however, in 2008 due to the prevailing global recession and subsequently slow economic recovery (Table 3) (Department of Commerce 2010).

Table 3: Percent Change in the Real Gross Domestic Product for the Durham-Chapel Hill and Raleigh-Cary Metropolitan Areas

Durham-Chapel Hill Metropolitan Area						
	2005	**2006**	**2007**	**2008**	**2009**	**2010**
Percent Change, real gross domestic product (%)	4.2	11.7	9.2	1.1	4.0	7.3
Raleigh-Cary Metropolitan Area						
	2005	**2006**	**2007**	**2008**	**2009**	**2010**
Percent Change, real gross domestic product (%)	6.0	6.9	4.4	1.9	1.4	5.8

Source: Department of Commerce 2010, 2011

The City of Raleigh is the Capitol of North Carolina; therefore the State government is one of the major employers in the Falls Lake region. Other major employers with over 10,000 employees include Duke University and Medical Center, the University of North Carolina, Wake County Public School System, and IBM (Wake County 2009b). Many other high tech jobs in the region are concentrated at the Research Triangle Park, which hosts over 170 companies that employ more than 52,000 people (Research Triangle Park 2012).

The presence of many high tech jobs and an educated work force also is apparent in examination of the median incomes throughout the zone of influence. Incomes in the Triangle CSA are notably higher than the surrounding areas. Table 4 provides income data for the counties, cities, and towns immediately surrounding the project.

Since 2000, the Triangle CSA typically had unemployment rates below the North Carolina and United States average. This is likely influenced by the high number of employers in the Triangle CSA and the educated work force. These figures are illustrated in Table 5.

Table 4: Income Data

Locality	Median Household Income (2006-2010)	Per Capita Income (2010 $)	Population Below Poverty Level (%)
Town of Cary	$89,542	$41,700	5.0
Town of Chapel Hill	$52,785	$33,710	22.2
Chatham County	$56,038	$29,991	12.2
Durham County	$49,894	$27,503	16.1
City of Durham	$46,972	$26,725	17.9
Franklin County	$43,710	$21,331	15.0
Harnett County	$42,853	$19,274	16.5
Johnston County	$49,745	$22,437	15.1
Orange County	$52.981	$33,912	16.3
Person County	$44,668	$21,848	16.0
City of Raleigh	$52,219	$30,709	14.6
Wake County	$63,770	$32,592	9.7
Town of Wake Forest	$69,222	$31,185	7.5
State Average	$45,570	$24,745	15.5

Source: Census 2010

Table 5: Average Annual Unemployment Rates												
	Annual Average Unemployment Rate, Percentage of Workforce											
Metropolitan Area	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Durham-Chapel Hill Metropolitan Statistical Area	2.9	4.3	5.5	5.4	4.4	4.3	3.9	3.9	4.8	7.8	7.7	7.6
Raleigh-Cary Metropolitan Statistical Area	2.5	4.1	5.7	5.4	4.4	4.2	3.7	3.6	4.9	8.7	8.7	8.2
North Carolina	3.7	5.6	6.6	6.5	5.5	5.3	4.8	4.8	6.3	10.5	10.9	10.5
United States	4.0	4.7	5.8	6.0	5.5	5.1	4.6	4.6	5.8	9.3	9.6	9.0

Source: Department of Labor 2012

RECREATION IMPACT OF FALLS LAKE

To estimate the economic impact from the recreation related spending at locations like Falls Lake, USACE and Michigan State University jointly developed the Recreation Economic Assessment System (REAS). Essentially, REAS is an input-output model, based on recreation visits and a set of economic ratios and multipliers for a region. Without recent survey data to justify making any specific adjustments to the user inputs, the REAS estimates that recreation visitors to Falls Lake spent an estimated $35.6 million on trips within 30 miles of the project. Of this spending, 64 percent was captured by the local economy yielding $22.8 million in direct sales to tourism related firms. These sales generated $8.3 million in direct personal income and supported 317 direct jobs. With multiplier effects visitor spending resulted in $35 million total sales, $12.7 million in total personal income and supported 431 jobs (USACE 2010a).

ECONOMIC BENEFITS ANALYSIS

National Economic Development (NED) Account

The NED account compares the alternatives based on NED cost at FY 2016 price levels and interest rates. NED costs include first costs and OMRR&R costs; however, unlike financial costs, NED costs typically include interest during construction (IDC) and in this case, potential lost recreation benefits, but do not include the cost of storage. Annual NED cost, annual NED benefit, and net annual NED benefit were used to determine the NED Plan. Net annual NED benefit was the difference between the annual NED benefit and annual NED cost. Flood control benefits are not included in the NED account because the hydrologic analysis of the alternatives indicated that no significant differences occur between the alternatives' water surfaces downstream from Falls Lake. Recreation benefits are not included in the annual NED benefit according to Paragraph (1) on Page 3-35 of ER 1105-100, which states that the NED water supply benefits are measured by the cost of the alternative most likely to be implemented in the absence of the proposed plan, which in this case is Alternative 2. However, NED recreation benefits lost are considered as part of the cost of reallocated storage, as described in Appendix E of ER 1105-2-100. For most projects, the NED recreation benefits lost are typically included in the NED costs along with the environmental mitigation and recreation modification costs. In the case of the Falls Lake Reallocation Study, except for a small increment of difference in water surface elevation in times of severe drought, no net negative, effect on recreation activities are created, resulting in insignificant loss of benefits to recreation.

To determine NED benefits, comparison was made between the most economical alternative, Alternative 2 - "Reallocation of Storage in Water Quality Pool to Water Supply Pool" to those of the next least costly alternative, Alternative 7 – "New Dam and Reservoir on Little River". Both alternatives provide the same additional water supply, economic outputs, and amenities. Both alternatives generate the same annual NED benefits, because Alternative 2 provides the same water supply benefits as Alternative 7.

Table 6 summarizes the NED account for each of the proposed alternatives. Alternative 12 – "Neuse River Intake near Richland Creek with Offline Storage" is also provided as the following least costly alternative, as point of reference. Section 3 of the Main Report/EA presents the NED costs in detail. The difference in costs between Alternatives 7 and 12 would need to decrease by approximately $11 million annually and $23 million annually, respectively, before Alternatives 7 and 12 would be equal in cost to Alternative 2. Based on the costs presented in Table 6, the Recommended Plan would be most economically feasible for implementation, because of its significantly lower cost.

Table 6 – Comparison of NED Benefits – Falls Lake Reallocation Alternatives

	Alternative 2 Reallocate Storage in Conservation Pool to Water Supply Pool	**Alternative 7** Construction of a New Dam and Reservoir on Little River	**Alternative 12** Neuse River Intake Near Richland Creek with Offline Storage
Total Cost	$142,000,000	$359,000,000	$580,000,000
Annual NED Cost	$7,362,283	$18,613,096	$30,071,297
Annual NED Water Supply Benefit	$11,250,813	$11,250,813	$11, 250,813

NOTE: The NED cost includes costs required to implement the alternatives, including construction and operation and maintenance costs of $65,766 annually. Interest during construction is also included.

Regional Economic Development (RED) Account

The RED account addresses economic benefits important at a regional level: State, counties, and communities in the broad study area. Items in this account relate to economic activities such as employment and income.

Expenditures in conjunction with the reallocation of water supply at Falls Lake are of two types. The first is the payment to the Federal Treasury for the cost of the reallocated storage. The second regards the expenditures for the cost of construction and related costs for water supply infrastructure related to the project and mitigation. The cost of storage for Alternative 2 is a payment in lump sum or over a 30-year period of $142 million in FY 2016 dollars. The cost of storage for Alternative 7 is a payment in lump sum or over a 30-year period of $359 million in FY 2016 dollars. The cost of storage for Alternative 12 is a payment in lump sum or over a 30-year period of $580 million in FY 2016 dollars.

Although an outflow from the regional economy to the national economy, these figures are small compared to the size of the Raleigh-Durham area economy on an annual basis, and would not have a significant effect on the regional economy.

The second component, consisting primarily of construction, does not result in a major outflow or inflow of funds to the regional economy and would not appreciably affect RED any more than a similar expenditure would if the funds are not used for the reallocation activity. In both instances the funds are the responsibility of local sponsors and would be derived from sinking funds, bond sales, and/or income. Given that use of water contained in the reallocated pool would be largely reimbursed through income from municipal and industrial customers, there are no significant dis-benefits at an RED scale.

No federal funds would be allocated to this effort. In the event the local sponsors choose to take advantage of federal financing, they pay for reallocated storage over time along with appropriate level of interest (repayment period not to exceed 30 years). In any event, no significant RED impact is considered likely and the cost of an input-output study to better identify the impacts is not believed to be warranted for this analysis.

The National Economic Development (NED) Plan

The above analyses demonstrate that the NED Plan is the Recommended Plan – Reallocation of Falls Lake Water Quality Storage to the Water Supply Pool, in the amount of 17,300 acre-feet. This plan produces benefits in the amount of $11,250,813, at an annual cost of $7,362,283.00. . Costs include $65,766 in annual Operations and Maintenance funding for the project.

Hydropower Benefits Foregone

The Falls Lake project does not currently possess any hydropower project features at the current time, so no hydropower benefits would be foregone as a result of project implementation.

Flood Control Benefits Foregone

The Recommended Plan would not include storage reallocated from the flood control pool, would not cause changes to storage within the flood control pool, and would not cause changes to operations within periods within which the project was operated for flood control; thus, no flood control benefits would be foregone as a result of Recommended Plan implementation.

Updated Cost of Storage

The updated value of the 327,504 ac-ft of usable storage is estimated at $453,423,398 based on the standard method for calculating updated cost of storage. Total usable storage (327,504 AF) is calculated as the Flood Pool (221,182AF; EL 251.5 to 264.8) plus the Conservation Pool (106,322 AF; EL 236.5 to 251.5), excluding the Inactive Pool (sediment) (25,073 AF; EL 200.0 to 236.5). The value of the storage was determined by first computing the cost at the midpoint of construction by using the use of facilities cost allocation procedure as follows:

[Project Joint-Use Cost ($) x Storage Reallocated (AF) / Total Usable Storage (AF)] = Cost of Reallocated Storage From Water Quality Pool

The cost allocated to the additional storage on this basis is escalated to present day price levels using the estimated 2016 Civil Works Construction Cost Index System. Computations to determine the value of the 17,300 ac-ft of reallocated storage for Falls Lake are:

[$453,423,398 (FY2016) x 17,300 AF / 327,504 AF] = $23,951,539

The storage cost update for FY2016 for Falls Lake is shown in Table 7. These costs will be adjusted to the current rates at the time the water supply agreements are signed and cost indexed to the appropriate fiscal year and interest rate.

Table 7 Updated Project Cost Estimate and Costs of Storage - Falls Lake, North Carolina

UPDATED COST OF STORAGE CATEGORY	JOINT-USE COST	CWCCIS FY 2016 INDEX RATIO	UPDATED JOINT-USE COST
Land & Damages	$ 54,047,166	3.5908	$ 194,073,828
Relocations	$ 33,612,035	3.5643	$ 119,803,376
Reservoir	$ 10,090,287	3.8960	$ 39,311,758
Dams	$ 14,961,635	3.5692	$ 53,401,068
Fish & Wildlife 7	$ 10,445,255	3.4463	$ 35,997,482
Roads, Railroads & Bridges	$ 698,209	3.5643	$ 2,488,626
Cultural Resources	$ -	3.4518	$ -
Buildings, Grounds & Utilities	$ 1,974,474	3.4518	$ 6,815,489
Perm Operating Equipment	$ 443,760	3.4518	$ 1,513,771
Total	**$ 126,272,821**		**$ 453,423,398**

**Joint-Use Cost is in 1978 dollars and has been updated to 2016 dollars with 2016 CWCCIS*

User's Cost

The cost to the user of the recommended reallocation would be $23,951,539, or $1,234,493 annually over the 30-year repayment period. This is based on the updated cost of storage for the entire project ($453,423,398), multiplied by the percentage of storage reallocated from water quality to water supply (0.0528, or approximately 5.28%) as a percent of total usable storage for the project (327,504 total acre-feet of usable storage). It must be noted that the "one-time" cost of reallocated storage is annualized ($1,187,248) over the thirty year period of repayment, for a total of $37,034,795 unadjusted for inflation in future out-years.

Table 8 Falls Lake Water Supply - Repayment Cost for Additional Reallocated Storage

Item	Amount
Storage Required, ac-ft	17,300
Interest Rate, Percent	2.75%
Repayment Period, years	30
Project Storage	
Flood Control	221,182
Water Supply (portion of Water Con Pool)	61,322
Water Quality (portion of Water Con Pool)	45,000
Inactive (Sediment Pool)	25,073
Total	352,577
Percent of Additional Usable Project Storage	5.28%
Joint Use Project Cost	
Initial Construction (2016, Price Level)	$453,423,398

Table 9 Falls Lake Water Supply-Average Annual Cost

Reallocated Water Supply	
Storage Cost	$23,951,539
Annual Cost of Additional Storage	
Investment (Annual)	$1,151,176
O&M (Annual)	$65,766
TOTAL (Annual Payment Unadjusted)	$1,216,942

Total Updated Cost of Additional Storage

The total value of the additional 17,300 ac-ft of storage is estimated at $23,951,539 based on the standard method of calculating updated cost of storage. The annual investment for the reallocated portion of the project is $1,151,176; Annual Operations and Maintenance (O&M) for that portion of the project is estimated at $65,766. Total annual cost of reallocated storage is $1,216,942.

Test of Financial Feasibility

As a test of financial feasibility, the annual cost of storage should be compared to the cost of the most-likely, least-costly alternative that the applicant would undertake in the absence of utilizing the Federal project. This should be an alternative that would provide water of equivalent quality and quantity.

As wells and interbasin water transfer options are not feasible, the most likely alternative to the Federal project is the construction of another reservoir within the same major basin, at a close enough proximity to make distribution economically viable. No other industrial or municipal system within a reasonable distance is known to possess a surplus supply of water adequate to meet the City's needs.

The reallocation of storage has a significant cost advantage over the alternative construction of an additional reservoir within the basin, providing a total cost savings of approximately $257 million over a new reservoir, and would result in fewer environmental impacts than that of any other alternative.

US Army Corps
of Engineers ®
Wilmington District

FALLS LAKE, NORTH CAROLINA

INTEGRATED WATER SUPPLY REALLOCATION

FEASIBILITY STUDY

APPENDIX D

FALLS LAKE WATER QUALITY MODELING ANALYSIS

CITY OF RALEIGH, NORTH CAROLINA

MARCH 2017

Falls Lake Water Quality Modeling Analysis

Introduction

Falls Lake is designated as a nutrient-sensitive waterbody, is listed on the North Carolina Draft 2016 303(d) list for turbidity impairments, and has previously been listed for Chl-a impairments. To address water quality concerns, the North Carolina Department of Environmental Quality (NCDEQ) developed a nutrient management strategy for Falls Lake. A modeling analysis of water quality within Falls Lake was conducted to evaluate the potential impacts of a water supply pool reallocation on Chl-a levels within the lake.

In order to assist in developing the nutrient management strategy for the Falls Lake Watershed, the NCDENR (now NCDEQ) Division of Water Resources (DWR) Modeling & TMDL Unit developed a nutrient response model for Falls Lake using the Environmental Fluid Dynamics Code (EFDC) model framework. This model was completed in 2009 and developed under the guidance of the Falls Lake Technical Advisory Committee. Discussion of the model inputs, assumptions, calibration, and validation can be found within the Falls Lake Nutrient Response Model Final Report, published by the NCDENR DWR Modeling & TMDL Unit on November 30th, 2009. Although the Falls Lake EFDC model was not developed for the express purpose of evaluating impacts from reallocation, the model serves as the best available tool to evaluate potential changes in Falls Lake water quality. If consistent and substantial changes in Chl-a concentrations resulting from reallocation are evident from modeling analyses, further analyses may be needed to understand the contributing factors and potential impacts on overall water quality within Falls Lake.

EFDC Model Background

The EFDC model was setup to cover the period from March 2005 through October 2007, with inflow and outflow model inputs developed from historical data. The model was calibrated with data from 2005 and 2006, and validated using 2007 data. Analyses for development of the nutrient management plan focused predominantly upon 2006 simulations, as 2005 and 2007 were both affected by drought conditions and more data was available for 2006. Consequently, simulations of withdrawal alternatives focused on 2006 data.

The Falls Lake Nutrient Management Plan focused on maintaining Chl-a concentrations below 40 µg/l 90% of the time. The model simulated water quality at 519 locations across the lake; however, compliance with water quality targets were specifically focused at the NEU013B water quality monitoring station, approximately 1 mile southeast of Interstate 85 as shown on Figure 1.

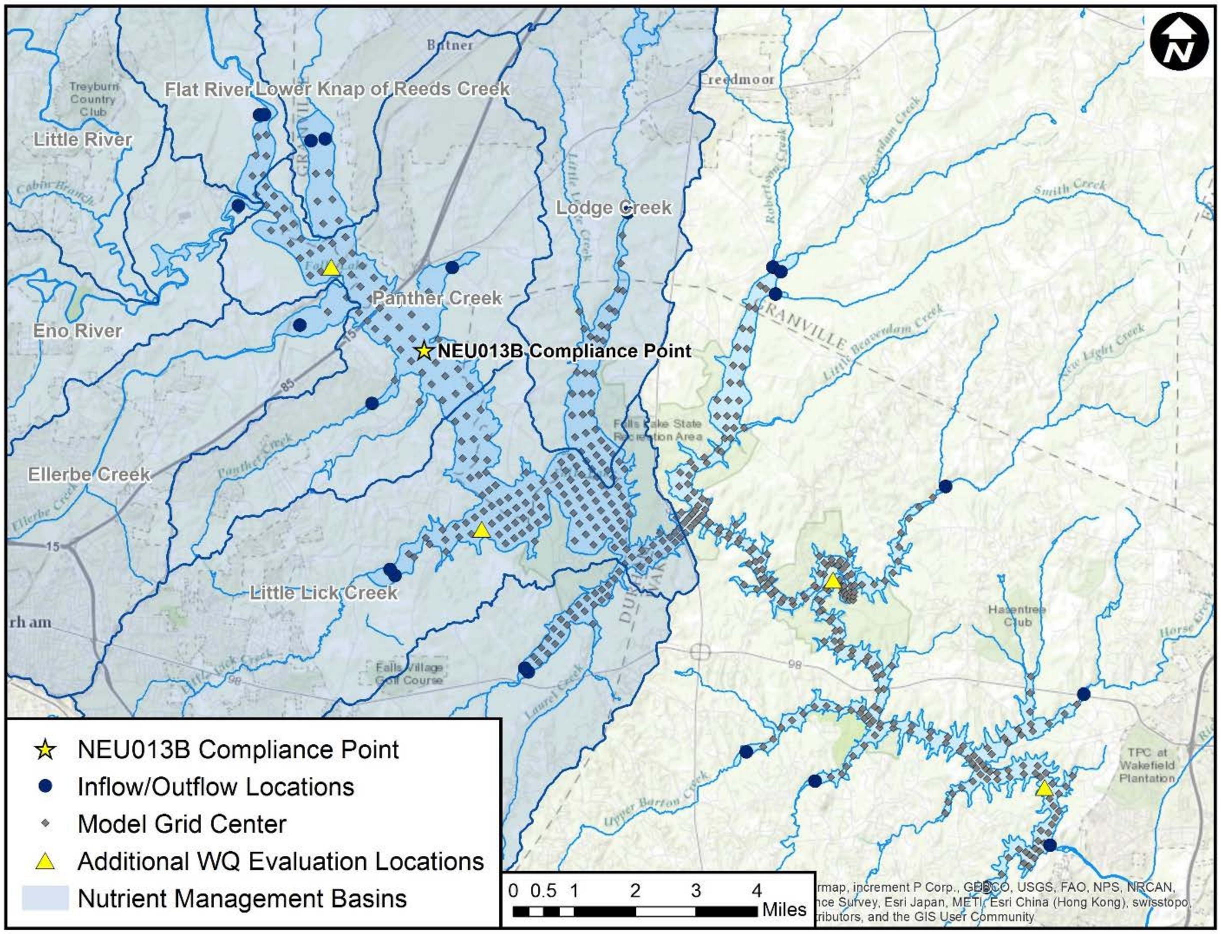


Figure 1: Geographic layout of the Falls Lake EFDC model.

Modeling Approach

Water quality evaluations considered three hydrologic scenarios: historical withdrawals, maximum possible withdrawals under the current allocation, and maximum possible withdrawals under the reallocation scenario. It should be noted that hydrologic and water quality simulations presented herein for the current allocation and reallocation scenario assume that the maximum possible water supply withdrawal is utilized consistently throughout the entire year as a worst case scenario. At no point in the history of operating the reservoir has the maximum water supply withdrawal been used to this extent.

The existing EFDC model utilizes a single outflow time series, located at the face of the dam, to simulate both releases and water supply withdrawals. After evaluation of several hydrologic modeling alternatives, the preferred approach to simulate reservoir outflow for the various modeled scenarios involved direct changes to the outflow time series, informed by historical records, withdrawal and release targets, and the Neuse River Basin Model (NRBM).

The single outflow time series within EFDC actually consists of three components: the water supply withdrawal, low flow release, and storm release, all of which are impacted when simulating an increased water supply withdrawal. Hydrologic simulations for the current allocation and reallocation scenario were both based on modifications to the historical 2006 outflow time series used in the existing EFDC model, using historical withdrawal, release, and water surface elevation records combined with reservoir operation rules to partition the singular outflow in the model into its three constituent components.

In addition to specified withdrawal scenarios, simulations were conducted for scenarios representing different nutrient inflow loads; specifically, implementation of nutrient reductions anticipated under the Falls Lake Nutrient Management Strategy. Upon full implementation, the Falls Lake Nutrient Management Strategy calls for a 40% and 77% reduction in the annual mass load of nitrogen and phosphorous, respectively, delivered to the lake. Through coordination with NCDEQ, this was implemented within the model by applying a 30% and 70% reduction to influent nitrogen and phosphorus loads for the major upstream basins (Figure 1) to reflect reductions from controllable sources. Nutrient reduction scenarios were simulated to evaluate whether changes in reservoir withdrawals would negatively affect compliance with the Chl-a standard after implementation of the Nutrient Management Strategy.

In total, there were 6 base simulation scenarios evaluated using the EFDC model (Figure 2). Analyses focused predominantly on simulated Chl-a concentrations, which were averaged over the photic zone, represented by the top two of four model layers.

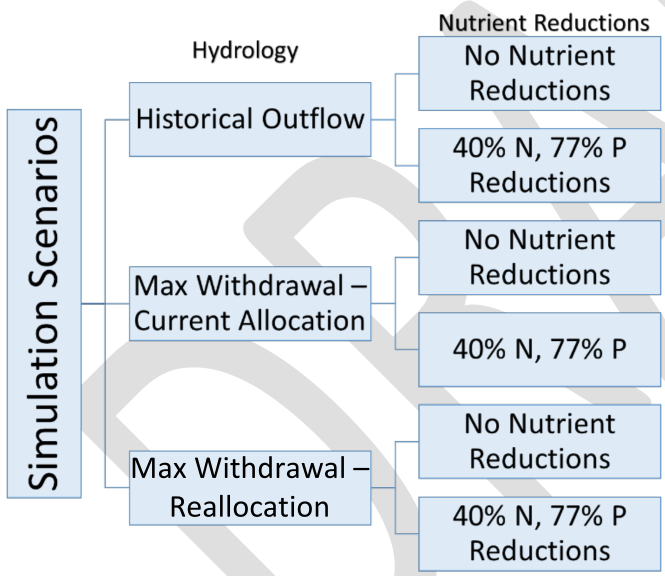


Figure 2: Outline of EFDC simulation scenarios

Results and Analysis

No Nutrient Reduction Scenarios

Chl-a concentrations within Falls Lake varied substantially throughout the year under all of the hydrologic scenarios considered (Figure 3). In general, sharp increases in Chl-a concentrations coincided with storm events, most likely due to nutrients and Chl-a delivered from the various tributaries within the model. These trends are evident when evaluating the Chl-a concentrations spatially within the reservoir over time, with concentrations frequently highest near points of substantial inflow. If increased withdrawals are associated with water quality impacts, the combination of extended periods of low inflow combined with several large storm events in 2006 presents a conservative evaluation of those potential impacts. In other words, the storm events in 2006 make compliance with the Chl-a reduction goal more difficult due to the influx of nutrients.

There were no clear or consistent increases in Chl-a concentrations observed for any of the hydrologic scenarios considered. When compared to the current allocation, Chl-a concentrations simulated for the reallocation scenario were higher from late March through June, but were generally similar or lower during other parts of the year. If there was a simple relationship between increased withdrawals or lower water surface elevations and Chl-a concentrations, consistent Chl-a differences would be expected during the periods of March through June and September through October, since reservoir inflows were relatively low during these periods.

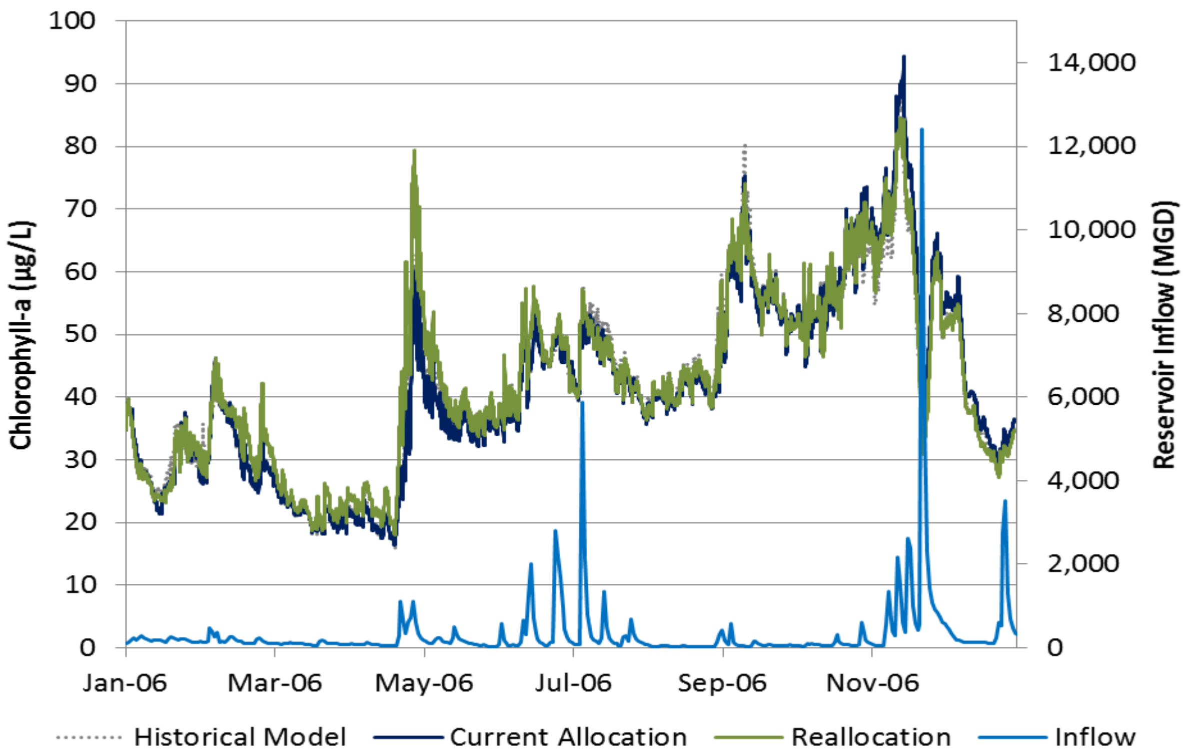


Figure 3: Simulated Chl-a concentrations at the NEU013B compliance point with no nutrient reductions

40/77% Nutrient Reduction Scenarios

Overall trends in Chl-a results with nutrient reductions in place were similar to those scenarios without nutrient reductions (Figure 4). Although Chl-a concentrations were lower, due to reduced nutrient inputs, none of the scenarios were consistently better or worse than the others. Examining the portion of simulated time when specified Chl-a thresholds are exceeded demonstrates the improvements in water quality that result from implementing the nutrient management strategy, but indicates minimal differences in overall water quality between the current and reallocation scenarios (Figure 5). Simulations suggest that under the current allocation, the 40 µg/L Chl-a target is met 91% of the time, and met 90% of the time under the reallocation scenario. Evaluations at additional locations within the reservoir revealed similar results. Concentrations were generally highest within the upper regions of the reservoir, with concentrations and relative differences between the hydrologic scenarios diminishing with proximity to the dam.

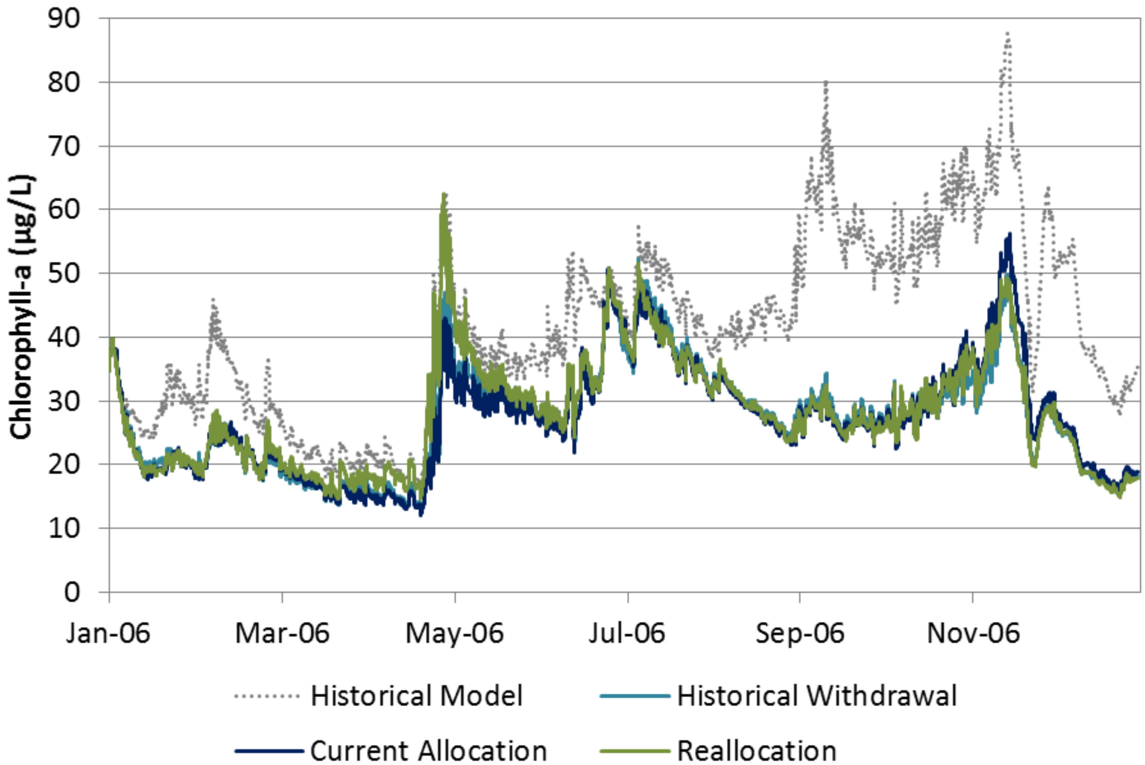


Figure 4: Simulated Chl-a concentrations at the NEU013B compliance point with 40/77% nutrient reductions

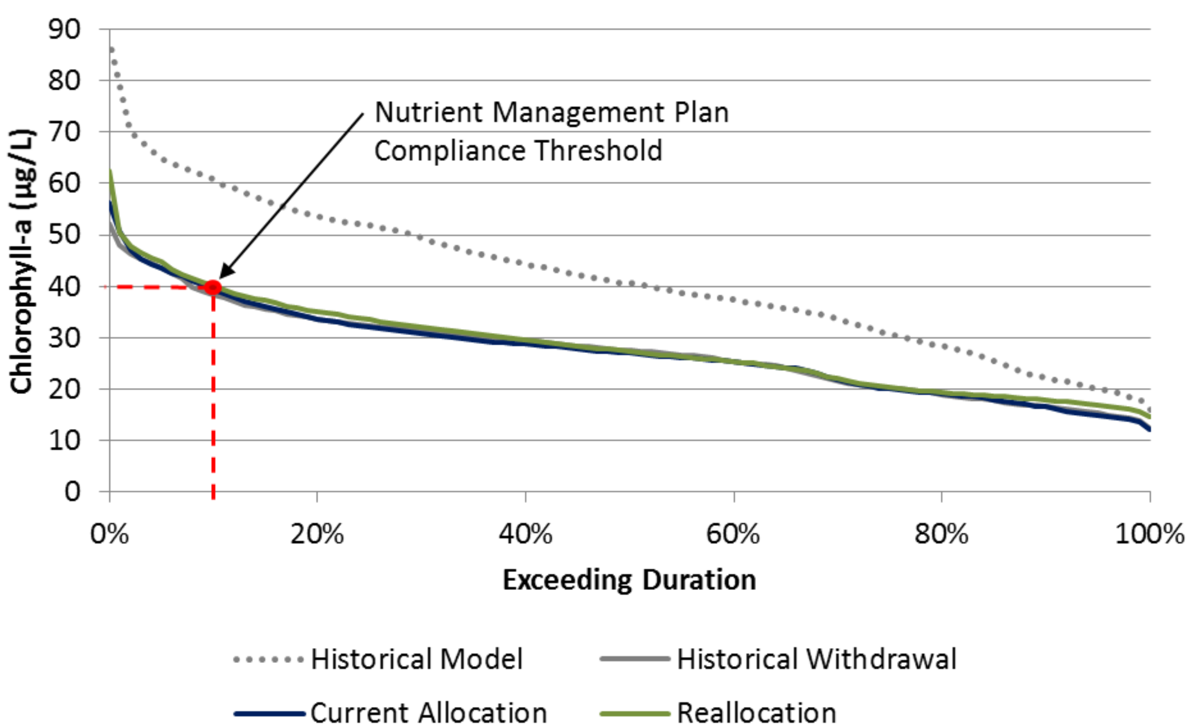


Figure 5: Percentile ranking of period specified Chl-a concentrations are exceeded at NEU013B

Conclusions

For the withdrawal scenarios evaluated herein, EFDC modeling efforts do not provide defensible nor conclusive evidence that increases in reservoir withdrawals from re-allocation increase Chl-a concentrations.

Due to the numerous complex and competing factors within the model, it is difficult to isolate any specific mechanisms through which increased water withdrawals influence reservoir water quality or to identify the driving factors behind the rather modest changes observed. While simulating implementation of the nutrient management strategy produced clear and consistent reductions in Chl-a, an increase in reservoir withdrawals produced Chl-a impacts similar or smaller in magnitude than those observed through sensitivity analyses of other model parameters like influent Chl-a concentrations, cloud cover, and wind speed. These water quality results are combined with the observation that any connections between reservoir hydrology and water quality are much more likely to be associated with large fluctuations in reservoir inflow, which are orders of magnitude larger than the relatively small changes in reservoir outflow resulting from reallocation.

The conclusions of this analysis are that simulations utilizing the best currently available model of water quality for Falls Lake do not show that increasing the size of the water supply pool to meet increased potable water demands will result in water quality degradation within the lake.

US Army Corps of Engineers
Wilmington District

FALLS LAKE, NORTH CAROLINA

INTEGRATED WATER SUPPLY REALLOCATION FEASIBILITY STUDY

APPENDIX E

PERTINENT CORRESPONDENCE

CITY OF RALEIGH, NORTH CAROLINA

MARCH 2017

www.raleighnc.gov

City Of Raleigh
NORTH CAROLINA

June 19, 2013

Colonel Steven A. Baker
District Engineer
Wilmington District, USACE
69 Darlington Ave
Wilmington, NC 28403

Dear Colonel Baker:

I am writing to you regarding the Wilmington District of the US Army Corps of Engineers Falls Lake Project. The City of Raleigh would like to have 3.8% (12,582 acre-feet) of the total storage in Falls Lake reallocated from the water quality pool to the water supply pool. To facilitate this request, the City of Raleigh would like to enter into a Memorandum of Agreement to provide funding for reallocation studies. We understand that the current cost estimate for the studies would be approximately $450,000 and that federal funds will not be available to perform the studies.

The City of Raleigh initially has $500,000, which includes the estimated cost of completing the reallocation studies and additional funds for contingency, available for this project, and will not ask to be reimbursed for these expenses at a later date. However, we will need a provision in the MOA providing that if any of these funds remain unspent after the studies are fiscally complete, the unspent funds will be returned to the City. In addition, the City's offer of these funds is dependent on both the City and the Corps of Engineers entering into the Memorandum of Agreement pursuant to which the Corps of Engineers agrees to complete the required studies necessary for a reallocation request to be decided.

The City is making this voluntary contribution of funds with the clear understanding that this contribution will not have any effect on the findings and conclusions of the study. Furthermore, the City understands that the contribution of funds for the reallocation studies will not have any impact on the evaluation and future decision related to any application filed for the City's Little River Reservoir.

One Exchange Plaza
1 Exchange Plaza, Suite 1020
Raleigh, North Carolina 27601

City of Raleigh
Post Office Box 590 • Raleigh
North Carolina 27602-0590
(Mailing Address)

Municipal Building
222 West Hargett Street
Raleigh, North Carolina 27601

We appreciate the efforts of the Corps of Engineers on this important project for City of Raleigh. For further information regarding this work please contact our subject matter experts, Mr. Kenneth Waldroup at 919-996-3489 or Mr. Dan McLawhorn at 919-996-6623. Thank you for your time and consideration of this request.

Sincerely,

J. Russell Allen

J. Russell Allen,
City Manager

cc: John Robert Carman, Public Utilities Director
Kenneth Waldroup, Assistant Public Utilities Director
Daniel F. McLawhorn, Associate City Attorney

North Carolina Department of Natural and Cultural Resources
State Historic Preservation Office
Ramona M. Bartos, Administrator

Governor Pat McCrory
Secretary Susan Kluttz

Office of Archives and History
Deputy Secretary Kevin Cherry

December 18, 2015

Elden Gatwood
Department of the Army
Wilmington Regulatory Field Office
69 Darlington Avenue
Wilmington, NC 28403

Re: Water Storage Reallocation for Falls Lake, Multi County, ER 15-2672

Dear Mr. Gatwood:

Thank you for your letter of November 25, 2015, concerning the above project.

We have conducted a review of the project and are aware of no historic resources which would be affected by the project. Therefore, we have no comment on the project as proposed.

The above comments are made pursuant to Section 106 of the National Historic Preservation Act and the Advisory Council on Historic Preservation's Regulations for Compliance with Section 106 codified at 36 CFR Part 800.

Thank you for your cooperation and consideration. If you have questions concerning the above comment, contact Renee Gledhill-Earley, environmental review coordinator, at 919-807-6579 or environmental.review@ncdcr.gov. In all future communication concerning this project, please cite the above referenced tracking number.

Sincerely,

Renee Gledhill-Earley

for Ramona M. Bartos

Location: 109 East Jones Street, Raleigh NC 27601 **Mailing Address:** 4617 Mail Service Center, Raleigh NC 27699-4617 **Telephone/Fax:** (919) 807-6570/807-6599

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Raleigh Field Office
P.O. Box 33726
Raleigh, NC 27636-3726

Date: 30-Jan-2017

Self-Certification Letter

Project Name Fall Reallocation

Dear Applicant:

Thank you for using the U.S. Fish and Wildlife Service (Service) Raleigh Ecological Services online project review process. By printing this letter in conjunction with your project review package, you are certifying that you have completed the online project review process for the project named above in accordance with all instructions provided, using the best available information to reach your conclusions. This letter, and the enclosed project review package, completes the review of your project in accordance with the Endangered Species Act of 1973 (16 U.S.C. 1531-1544, 87 Stat. 884), as amended (ESA), and the Bald and Golden Eagle Protection Act (16 U.S.C. 668-668c, 54 Stat. 250), as amended (Eagle Act). This letter also provides information for your project review under the National Environmental Policy Act of 1969 (P.L. 91-190, 42 U.S.C. 4321-4347, 83 Stat. 852), as amended. A copy of this letter and the project review package must be submitted to this office for this certification to be valid. This letter and the project review package will be maintained in our records.

The species conclusions table in the enclosed project review package summarizes your ESA and Eagle Act conclusions. Based on your analysis, mark all the determinations that apply:

- [x] "no effect" determinations for proposed/listed species and/or proposed/designated critical habitat; and/or
- [ ] "may affect, not likely to adversely affect" determinations for proposed/listed species and/or proposed/designated critical habitat; and/or
- [ ] "may affect, likely to adversely affect" determination for the Northern long-eared bat (Myotis septentrionalis) and relying on the findings of the January 5, 2016, Programmatic Biological Opinion for the Final 4(d) Rule on the Northern long-eared bat;
- [x] "no Eagle Act permit required" determinations for eagles.

We certify that use of the online project review process in strict accordance with the instructions provided as documented in the enclosed project review package results in reaching the appropriate determinations. Therefore, we concur with the "no effect" or "not likely to adversely affect" determinations for proposed and listed species and proposed and designated critical habitat; the "may affect" determination for Northern long-eared bat; and/or the "no Eagle Act permit required" determinations for eagles. Additional coordination with this office is not needed. Candidate species are not legally protected pursuant to the ESA. However, the Service encourages consideration of these species by avoiding adverse impacts to them. Please contact this office for additional coordination if your project action area contains candidate species. Should project plans change or if additional information on the distribution of proposed or listed species, proposed or designated critical habitat, or bald eagles becomes available, this determination may be reconsidered. This certification letter is valid for 1 year. Information about the online project review process including instructions, species information, and other information regarding project reviews within North Carolina is available at our website http://www.fws.gov/raleigh/pp.html. If you have any questions, you can write to us at Raleigh@fws.gov or please contact Leigh Mann of this office at 919-856-4520, ext. 10.

Sincerely,

/s/Pete Benjamin

Pete Benjamin
Field Supervisor
Raleigh Ecological Services

Enclosures - project review package

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Ecological Services Field Office
551 PYLON DRIVE, SUITE F
RALEIGH, NC 27606
PHONE: (919)856-4520 FAX: (919)856-4556

Consultation Code: 04EN2000-2017-SLI-0256 January 30, 2017
Event Code: 04EN2000-2017-E-00631
Project Name: Falls Reallocation

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The species list generated pursuant to the information you provided identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

Section 7 of the Act requires that all federal agencies (or their designated non-federal representative), in consultation with the Service, insure that any action federally authorized, funded, or carried out by such agencies is not likely to jeopardize the continued existence of any federally-listed endangered or threatened species. A biological assessment or evaluation may be prepared to fulfill that requirement and in determining whether additional consultation with the Service is necessary. In addition to the federally-protected species list, information on the species' life histories and habitats and information on completing a biological assessment or evaluation and can be found on our web page at http://www.fws.gov/raleigh. Please check the web site often for updated information or changes

If your project contains suitable habitat for any of the federally-listed species known to be present within the county where your project occurs, the proposed action has the potential to adversely affect those species. As such, we recommend that surveys be conducted to determine the species' presence or absence within the project area. The use of North Carolina Natural Heritage program data should not be substituted for actual field surveys.

If you determine that the proposed action may affect (i.e., likely to adversely affect or not likely to adversely affect) a federally-protected species, you should notify this office with your determination, the results of your surveys, survey methodologies, and an analysis of the effects of the action on listed species, including consideration of direct, indirect, and cumulative effects, before conducting any activities that might affect the species. If you determine that the proposed action will have no effect (i.e., no beneficial or adverse, direct or indirect effect) on federally listed species, then you are not required to contact our office for concurrence (unless an Environmental Impact Statement is prepared). However, you should maintain a complete record of the assessment, including steps leading to your determination of effect, the qualified personnel conducting the assessment, habitat conditions, site photographs, and any other related articles.

Please be aware that bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 *et seq.*), and projects affecting these species may require development of an eagle conservation plan (http://www.fws.gov/windenergy/eagle_guidance.html). Additionally, wind energy projects should follow the wind energy guidelines (http://www.fws.gov/windenergy/) for minimizing impacts to migratory birds and bats.

Guidance for minimizing impacts to migratory birds for projects including communications towers (e.g., cellular, digital television, radio, and emergency broadcast) can be found at: http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/towers.htm; http://www.towerkill.com; and http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/comtow.html.

Not all Threatened and Endangered Species that occur in North Carolina are subject to section 7 consultation with the U.S Fish and Wildlife Service. Atlantic and shortnose sturgeon, sea turtles,when in the water, and certain marine mammals are under purview of the National Marine Fisheries Service. If your project occurs in marine, estuarine, or coastal river systems you should also contact the National Marine Fisheries Service, http://www.nmfs.noaa.gov/

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit to our office. If you have any questions or comments, please contact John Ellis of this office at john_ellis@fws.gov.

Attachment

United States Department of Interior
Fish and Wildlife Service

Project name: Falls Reallocation

Official Species List

Provided by:

Raleigh Ecological Services Field Office
POST OFFICE BOX 33726
RALEIGH, NC 27636
(919) 856-4520

Consultation Code: 04EN2000-2017-SLI-0256
Event Code: 04EN2000-2017-E-00631

Project Type: WATER SUPPLY / DELIVERY

Project Name: Falls Reallocation
Project Description: Reallocation of Water from Water Quality Pool to the Water Supply Pool.

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.

Project Location Map:

Project Coordinates: MULTIPOLYGON (((-78.79714518785478 36.104218320209014, -78.76922607421876 36.07426598620799, -78.7536667054519 36.08314523333876, -78.75641328748316 36.06167793965001, -78.73993379529567 36.02985471372042, -78.71246797498316 36.07426598620799, -78.71246797498316 36.0409598809754, -78.70422822888942 36.01800375871416, -78.69232177734376 36.03799493963657, -78.67950899060817 36.06167793965001, -78.66760253906251 36.07352228885536, -78.67858886718751 36.04243673532787, -78.68225557263942 36.023190861789274, -78.61999056302012 36.01133890448606, -78.53759310208262 35.9550317582754, -78.47076879814267 35.721987809328716, -78.28720092773439 35.56611494756622, -78.34945223294199 35.504282143299655, -78.35586547851564 35.54376990196734, -78.3348129875958 35.570583209210845, -78.4446762688458 35.67403185377907, -78.49411474540831 35.69634053686435, -78.54171297512949 35.741686014085545, -78.55361938476564 35.89461276785915, -78.57925870455803 35.925756600060716, -78.613124107942 35.91833879171624, -78.67629549466075 35.96578065319134, -78.701014732942 35.98800747696278, -78.74221346341075 35.97762833333621, -

78.777919029817 36.01022802370618, -78.79714518785478 36.104218320209014)))

Project Counties: Durham, NC | Granville, NC | Johnston, NC | Wake, NC

United States Department of Interior
Fish and Wildlife Service

Project name: Falls Reallocation

Endangered Species Act Species List

There are a total of 8 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Critical habitats listed under the **Has Critical Habitat** column may or may not lie within your project area. See the **Critical habitats within your project area** section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

Birds	**Status**	**Has Critical Habitat**	**Condition(s)**
Red-Cockaded woodpecker *(Picoides borealis)* Population: Wherever found	Endangered		
Clams			
Dwarf wedgemussel *(Alasmidonta heterodon)* Population: Wherever found	Endangered		
Tar River spinymussel *(Elliptio steinstansana)* Population: Wherever found	Endangered		
Flowering Plants			
harperella *(Ptilimnium nodosum)* Population: Wherever found	Endangered		
Michaux's sumac *(Rhus michauxii)* Population: Wherever found	Endangered		
Smooth coneflower *(Echinacea laevigata)* Population: Wherever found	Endangered		

Insects			
rusty patched bumble bee *(Bombus affinis)* Population: Wherever found	Endangered		
Mammals			
Northern long-eared Bat *(Myotis septentrionalis)* Population: Wherever found	Threatened		

Critical habitats that lie within your project area

There are no critical habitats within your project area.

Species Conclusions Table

Project Name: Falls Reallocation

Date: 30-Jan-2017

Species / Resource Name	Conclusion	ESA Section 7 / Eagle Act Determination	Notes / Documentation
Red-Cocaded woodpecker	species not present	No effect	
Dwarf wedgemussel	species present	No effect	Adequate flows and suitable water quality will continue to be provided and therefore this project will have no effect.
Tar River spinymussel	species present	No effect	Adequate flows and suitable water quality will continue to be provided and therefore this project will have no effect.
harperella	species not present	No effect	
Michaux's sumac	species not present	No effect	
Smooth coneflower	species not present	No effect	
rusty patched bumble bee	species not present	No effect	
Northern long-eared bat	species not present	No effect	
Critical habitat	no critical habitat present	No effect	

Acknowledgement: I agree that the above information about my proposed project is true. I used all of the provided resources to make an informed decision about impacts in the immediate and surrounding areas.

GASCH.ERIC.KEVIN.1260353477 Digitally signed by GASCH.ERIC.KEVIN.1260353477
DN: c=US, o=U.S. Government, ou=DoD, ou=PKI, ou=USA, cn=GASCH.ERIC.KEVIN.1260353477
Date: 2017.01.30 12:30:35 -05'00'

30-Jan-2017

Signature /Title

Date

Species Conclusions Table

Project Name: Falls Reallocation

Date: 30-Jan-2017

Species / Resource Name	Conclusion	ESA Section 7 / Eagle Act Determination	Notes / Documentation
Bald eagle	unlikely to disturb nesting bald eagles	No Eagle Act permit required	No nest within action area

Acknowledgement: I agree that the above information about my proposed project is true. I used all of the provided resources to make an informed decision about impacts in the immediate and surrounding areas.

GASCH.ERIC.KEVIN.1260353477

Signature /Title

30-Jan-2017

Date

US Army Corps of Engineers ®
Wilmington District

FALLS LAKE, NORTH CAROLINA
INTEGRATED WATER SUPPLY REALLOCATION
FEASIBILITY STUDY

APPENDIX F

CONSIDERATION OF POTENTIAL IMPACTS OF CLIMATE CHANGE ON THE FALLS LAKE REALLOCATION

CITY OF RALEIGH, NORTH CAROLINA

MARCH 2017

Consideration of the Potential Impacts of Climate Change On the Falls Lake Reallocation

Introduction

The need to consider reliability and resilience in the face of climate change is increasingly becoming a requirement for major water resource infrastructure projects. Two separate products from the **US EPA** were used to evaluate the probable range of impacts to the proposed Falls Lake Reallocation. The first, used in a qualitative analysis, is the **US EPA's** Climate Resilience Evaluation and Awareness Tool (CREAT). The second is the **US EPA's** "Climate Change and Urban Development in 20 U.S. Watersheds" study published in 2013 that included a detailed analysis of the Neuse River basin under climate change which was used to develop a quantitative hydrologic analysis.

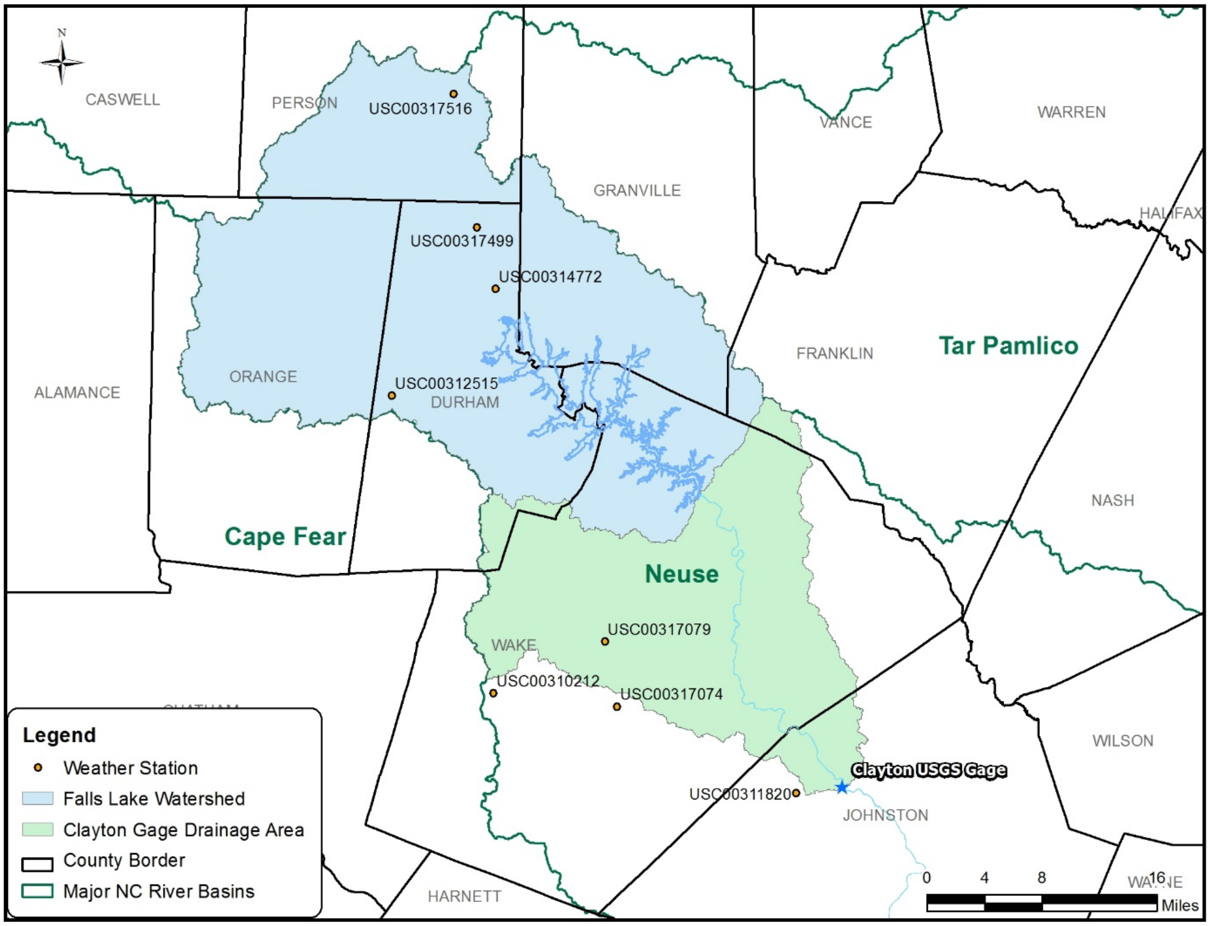
One of the challenges to considering the impacts of climate change on infrastructure projects is that there is still a gap between scientists' evolving understanding of climate change and the development of tools to apply that knowledge to evaluate engineering projects. In the case of the proposed Falls Lake Reallocation, the most significant hindrance to performing quantitative hydrologic analyses of climate change scenarios is the lack of available hydrologic data corresponding to the range of future climate scenarios. General Circulation Models (GCMs), used to study climate change, simulate weather and other environmental conditions over time based on assumptions about earth's atmosphere including atmospheric greenhouse gas (GHG) concentrations among other parameters. These models produce temperature and rainfall data for all regions on the planet, but do not simulate hydrology in sufficient detail at the regional level for direct use in hydrologic mass balance models like the Cape Fear – Neuse River Basin Hydrologic Model. However, there are methods for linking GCM output to hydrologic mass balance models and one significant effort undertaken by the **US EPA** is described in the following sections. There is also value in directly assessing the consensus expectations for temperature and precipitation trends in region. Toward this end, the **US EPA** has made available a summary of the prognostications of numerous climate models at weather stations throughout the continental United States via their Climate Resilience Evaluation and Awareness Tool (CREAT). The CREAT product offers a review of climate change scenarios grouped into three bins depending on temperature and precipitation output characteristics which are labelled as Hot/Dry, Central, or Warm/Wet. A summary of the expected change for stations in this study's area of interest (or very near to it) are shown in Table 1 below broken out by whether the station is upstream of the Falls Lake Dam, or below the dam but upstream of the USGS gaging station in Clayton, NC. Station location is shown in Figure 1.

Table 1: Summary of Temperature and Precipitation Changes Predicted by Climate Change Models
US EPA

Region	Year	Precipitation Δ (%)			Temperature Δ (°F)		
		Hot/Dry	Central	Warm/Wet	Hot/Dry	Central	Warm/Wet
Upstream of Falls Lake Dam	2035	-1.3%	+3.4%	+6.2%	+2.6	+2.3	+2.1
	2060	-2.5%	+6.6%	+12.1%	+5.1	+4.5	+4.2
Downstream of Dam, but upstream of Clayton Gage	2035	-1.5%	+2.9%	+6.7%	+2.6	+2.3	+2.1
	2060	-2.9%	+5.6%	+13.0%	+5.0	+4.5	+4.1

Data accessed from https://www.epa.gov/crwu/view-your-utilitys-scenario-based-climate-projection, on July 26, 2016.

Figure 1: Location map of Stations used in Table 1 summary



The data in the table show unanimity in predicting a warmer climate future, but there is a split regarding whether future conditions will be wetter or drier. The majority of the scenarios predict a generally wetter future, but a subset of the scenarios contain a marginally drier future. Qualitatively we expect that a wetter future will make it easier for the Falls Lake project to meet the purposes of providing water supply and meeting downstream environmental flows (the purpose of the Water Quality Pool). Warmer temperatures could make meeting these goals more challenging if it leads to increased water usage or results in an increase in evapotranspiration. Thus, the changes in temperature and precipitation are likely to exert a pull in opposing directions with respect to the ability to meet the goals of the Water Supply Pool and Water Quality Pool. Furthermore, it leaves unclear how the project's hydrology might change as temperature and precipitation patterns shift. Understanding how changes in the temperature and precipitation regimes in the region might combine to influence project function would require a quantitative modeling analysis which is described in the next section.

Quantitative Hydrologic Evaluation

The public availability of calibrated synthetic hydrology, especially for the eastern US, corresponding to the array of emissions scenarios, global circulation models, and regional circulation models or downscaling methods is limited at this time. The most probable reason for the lack of hydrologic data is the high degree of effort it requires to set up and calibrate rainfall-runoff models over areas as large as the Falls Lake Watershed or the Neuse River Basin. Nevertheless, the **US EPA** has completed a study on the potential hydrologic impacts of climate change and land use in 20 large watersheds across the US ranging in size from 6,000 to 27,000 square miles. One of the subject watersheds of the study was the Neuse River Basin. The study is titled "Watershed modeling to assess the sensitivity of streamflow, nutrient and sediment loads to potential climate change and urban development in 20 U.S. watersheds" (hereafter referred to as the **EPA 20 Study**), and was published in late 2013[1]. It contains results for a "base case" calibrated to historical watershed conditions; a single emissions scenario that is run with 6 different combinations of climate models; and 2 land use scenarios. The emissions scenario used is quite pessimistic, predicting an increase in atmospheric greenhouse gas (GHG) concentrations that is as severe as the Intergovernmental Panel on Climate Change's (IPCC) current worst case scenario[2, 3]. An overview of the Global Circulation Models (GCMs) and Regional Climate Models (RCMs) used can be found through the IPCC and its publications[4]. The two land use scenarios cover: 1. An approximate present-day case based on a 2005 land use survey; and 2. A future case land use condition anticipated in 2050. A summary of the 14 scenarios in the study is presented in Table 2 below.

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[1] U.S. EPA. Watershed Modeling to Assess the Sensitivity of Streamflow, Nutrient, and Sediment Loads to Potential Climate Change and Urban Development in 20 U.S. Watersheds (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-12/058F, 2013.

[2] *Meinshausen, M.; et al. (November 2011), "The RCP greenhouse gas concentrations and their extensions from 1765 to 2300", Climatic Change,* ***109*** *(1-2): 213–241, doi:10.1007/s10584-011-0156-z*.

[3] http://www.ipcc-data.org/observ/ddc_co2.html, accessed November 4, 2016.

[4] IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Table 2: Summary of Climate Change Models by US EPA

Scenario Abbreviation*	Emission Scenario	Climate Model(s) (GCM/RCM)	Land Use Scenario	Rainfall-Runoff Model
L0W0	None (historical)	none	2005	SWAT
L0W1	IPCC SRES A2	CGCM3/CRCM	2005	SWAT
L0W2	IPCC SRES A2	HadCM3/HRM3	2005	SWAT
L0W3	IPCC SRES A2	GFDL/RCM3	2005	SWAT
L0W4	IPCC SRES A2	GFDL/GFDL hi res	2005	SWAT
L0W5	IPCC SRES A2	CGCM3/RCM3	2005	SWAT
L0W6	IPCC SRES A2	CCSM/WRFP	2005	SWAT
L1W0	None (historical)	none	2050 estimated	SWAT
L1W1	IPCC SRES A2	CGCM3/CRCM	2050 estimated	SWAT
L1W2	IPCC SRES A2	HadCM3/HRM3	2050 estimated	SWAT
L1W3	IPCC SRES A2	GFDL/RCM3	2050 estimated	SWAT
L1W4	IPCC SRES A2	GFDL/GFDL hi res	2050 estimated	SWAT
L1W5	IPCC SRES A2	CGCM3/RCM3	2050 estimated	SWAT
L1W6	IPCC SRES A2	CCSM/WRFP	2050 estimated	SWAT

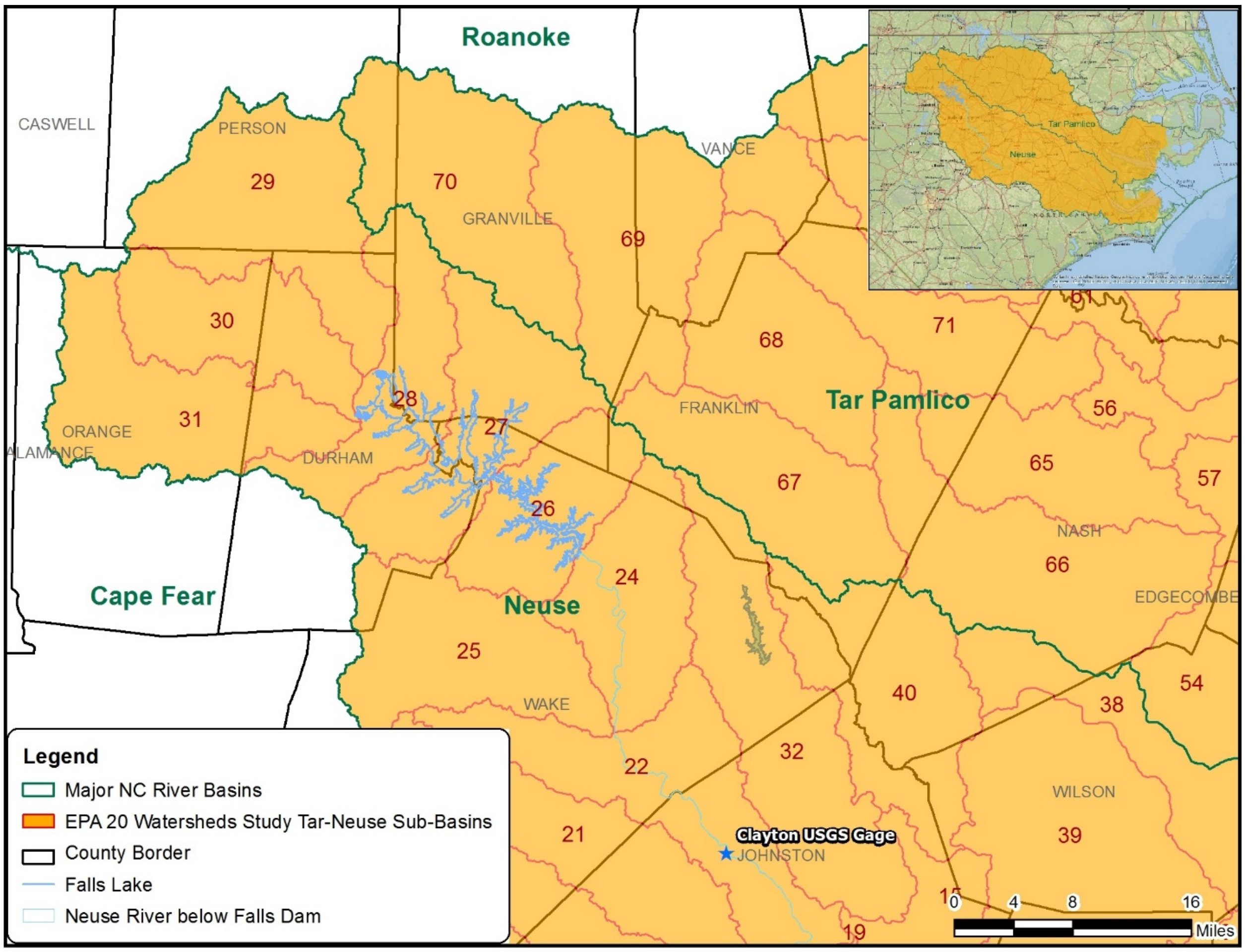
** - Scenario nomenclature: L – land use; W – weather/climate; 0 – historical conditions; 1-6 indicates future conditions are applied*

As can be discerned from Table 2, the study design allows a comparison of the relative impacts of projected climate change, urban and residential development (land use change), and the combined effects of climate change and urban development. The outputs available include streamflow rates and an array of water quality parameters among others. The hydrology set contains a "base case" that is calibrated to historical flows in the basin. The study results are intended to represent projected climate conditions for the 2041-2070 time period, which includes, but is somewhat later than the ultimate planning horizon for the Falls Lake Reallocation Study of 2045. The historical, base case, hydrology scenario covers the period from 1974 to 2004.

Hydrology

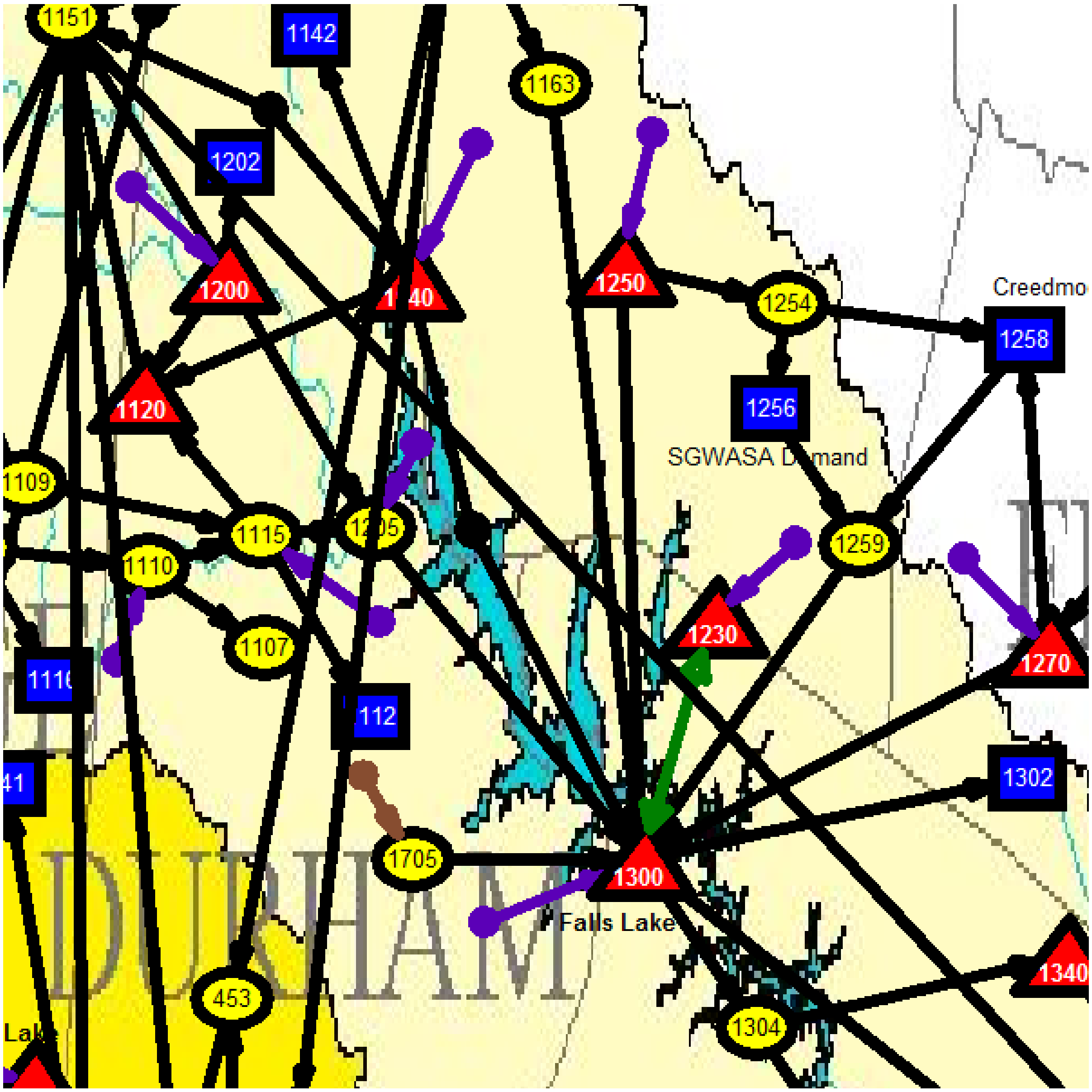
The hydrologic outputs from the EPA 20 Study were imported into the approved-for-use OASIS Cape Fear/Neuse River Basin Hydrologic Model (OASIS Model) to conduct a performance analysis of the proposed Falls Lake Reallocation (17,300 acre-feet) under a set of climate change scenarios. The EPA 20 Study creators made available a set of daily flow hydrology for 71 different subbasins within the Tar and Neuse River basins. These subbasins are illustrated in Figure 2 below with each of the subbasins assigned a number 1-71. The hydrologic datasets for each subbasin cover a 30 year period intended to represent the climate in the years 2041-2070. Daily unit runoff (i.e streamflow in cfs/mi^2 of drainage area) was calculated for each subbasin and was applied to the OASIS Model inflow arcs corresponding to each EPA 20 Study subbasin. For OASIS nodes that span more than one EPA 20 Study subbasin, the unit runoff from multiple subbasins was applied in proportion to the node's drainage within the EPA 20 Study subbasin. For example, the Falls Lake local inflow arc (inflow 1300) corresponds to subbasins 26, 27, and 28. Therefore, the unit runoff from all three subbasins was used to synthesize the daily inflow record for node 1300. Figure 3 shows a schematic of a portion of the OASIS Model that covers Falls Lake. Detailed information about the OASIS model is provided in Appendix B – Hydrologic and Hydrologic Report. The hydrology set contains a "base case" scenario (scenario L0W0 from Table 2 above) that assumed historical climate and land use which was calibrated to historical hydrology in the basin[5]. The results from the other 13 climate change and land use change scenarios are compared to the L0W0 scenario rather than to the performance of the standard OASIS Model. This helps avoid conflating changes due to climate change or land use change with those owing to hydrologic differences between the EPA's rainfall-runoff model (SWAT) and the USGS gage based hydrology contained in the standard OASIS Model. Differences in hydrology between the EPA's rainfall runoff model and the OASIS Model owe to the fact that the EPA model was not calibrated to the flows in the OASIS Model.

Figure 2: Reference Map for EPA 20 Watersheds Study



[5] Ibid. 1, Appendix J.

Figure 3: Schematic of Upper Neuse River Basin within the OASIS Model



Evaporation

The EPA 20 Study included an output parameter for daily evapotranspiration for each of the 71 subbasins in the study. However, this evapotranspiration parameter is not equal to, and does not correlate well with, evaporation from a lake surface. Evapotranspiration is a net sum of direct evaporation from both water and land surfaces as well as transpiration from vegetation. Transpiration becomes limited when soil moisture limited (i.e. transpiration drops during hot/dry weather when the soil dries out) whereas evaporation from a reservoir surface is often at a maximum under such conditions. The SWAT model output is an aggregate of the two components (evaporation and transpiration) and a separate value for each component is not available. As such, another method for estimating reservoir evaporation was required and was developed from the temperature and precipitation data available for each scenario. The Penman-Monteith[6, 7]method was used to estimate reservoir evaporation from daily temperature data and then adjusted that calculation with a monthly adjustment coefficient to convert free water surface evaporation to reservoir evaporation estimated by the USGS[8]. Evaporation estimates were created for a number of weather stations used in the EPA 20 Study and combined with the precipitation value for the given station and scenario to produce a value of net evaporation (evaporation minus precipitation) which is an estimate of the net gain or loss from a hypothetical reservoir co-located with the weather station. The reservoirs modeled in the CF-NRBHM were then assigned the net evaporation-precipitation value for the closest weather station, or in some cases a combination of the two or three nearest weather stations in the same manner it was done in the development of the original OASIS Model[9]. The daily time series values for net evaporation were then placed into the OASIS Model for each reservoir and climate change scenario (See Table 2 for description of scenarios).

Results of Modeling Climate Scenarios using the OASIS Hydrologic Model

The data in the model provided through the EPA 20 Study represents either the model estimated runoff from historical precipitation over the 1975-2004 period (scenarios ending in W0) or model estimated runoff that would occur from the impacts of climate change in the period 2041-2070 (scenarios whose names end W1 – W6). Since only 30 years of output is provided in the EPA 20 Study, the statistics for this exercise are also based on 30 years of hydrology rather than the 85 years used in other parts of the Reallocation document. As such, the yield numbers correspond better to a once in thirty year recurrence interval. The OASIS Model was iteratively executed to determine the operational yield of CORPUD's water supply system with a 17,300 AF Reallocation of Falls Lake. The results, relative to the base case scenario "L0W0" are presented in Table 3 below in terms of a percentage change in the 30 year yield (i.e. drought of record in the 30 years of hydrology for each scenario).

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[6] Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56 RG Allen, LS Pereira, D Raes, M Smith - FAO, Rome, 1998.

[7] Zotarelli, L., M.D. Dukes, C. Romero, K. Migliacio, K.T. Morgan. 2010. Step by step calculation of the Penman Monteith evapotranspiration (FAO-56 method). Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. EDIS Publication AE459. 10p. http://edis.ifas.ufl.edu/ae459

[8] USGS. "Evaporation from Lake Michie North Carolina 1961-1970", USGS Water Resource Investigation 38-73, WL Yonts, GL Giese, EF Hubbard. August 1973

[9] NC DEQ, Cape Fear – Neuse Combined River Basin Model, Appendix B2, p. 3, https://deq.nc.gov/about/divisions/water-resources/planning/basin-planning/map-page/cape-fear-river-basin-landing/cape-fear-neuse-combined-river-basin-model

Table 3: Change in CORPUD Water Supply Operating Yield Under Climate Change from EPA 20 Study

Scenario	Land Use Scenario	Climate Timeframe	Change in 30-year yield
Baseline Scenario			
L0W0	2005	1975 - 2004	-
Climate Change, No Land Use Change			
L0W1	2005	2041 - 2070	+10%
L0W2	2005	2041 - 2070	+35%
L0W3	2005	2041 - 2070	+11%
L0W4	2005	2041 - 2070	+9%
L0W5	2005	2041 - 2070	+23%
L0W6	2005	2041 - 2070	-0.7%
		Median	**+11%**
Historical Climate w/ Land Use Change			
L1W0	2050	1975 - 2004	+6%
Climate Change and Land Use Change			
L1W1	2050	2041 - 2070	+14%
L1W2	2050	2041 - 2070	+37%
L1W3	2050	2041 - 2070	+16%
L1W4	2050	2041 - 2070	+14%
L1W5	2050	2041 - 2070	+26%
L1W6	2050	2041 - 2070	+7%
		Median	**+15%**

The results show that both climate change (estimated for 2041 – 2070) and land use change through 2050 generally increase water quantity available in Falls Lake and Raleigh's other water sources. Land use change alone increases operating yield by an average of 5% in these model scenarios (6% in the historical weather scenario W0). Five of the six climate change scenarios also produce an increase in operating yield as well. The only scenario which does not produce an increase in operating yield is scenario L0W6, which holds land use constant, and operating yield drops by less than 1%. For the 6 scenarios that combine both land use change with climate change (L1W1 through L1W6), the average change in operating yield of Raleigh's water supply is an increase of 19%.

Results for the median minimum annual storage in the Falls Lake Water Quality Pool are shown in Table 4. The net change in the annual minimum is mixed, but increases in a majority of scenarios. For the six scenarios that include both climate change and land use change (L1W1 through L1W6) the median annual minimum is over 4,200 acre-feet greater than the baseline scenario. Among these, the two driest scenarios, L1W4 and L1W6, have annual minimums that are 3% and 5% lower, respectively, in a typical year than the baseline scenario.

Table 4: Median Annual Minimum Water Quality Pool Storage with Reallocation

Scenario	Median Annual Minimum WQ Pool Storage (acre-feet)	Median Annual Minimum WQ Pool Storage (% of Current 61322 AF Max WQ Storage)	Net Change from base scenario L0W0[a]
Baseline Scenario			
L0W0	26,611	43%	-
Climate Change, No Land Use Change			
L0W1	26,984	44%	+1%
L0W2	36,261	59%	+16%
L0W3	31,634	52%	+8%
L0W4	22,973	37%	-6%
L0W5	31,941	52%	+9%
L0W6	20,099	33%	-11%
Median	**29,309**	**48%**	**+4%**
Historical Climate w/ Land Use Change			
L1W0	28,836	47%	+4%
Climate Change and Land Use Change			
L1W1	28,702	47%	+3%
L1W2	37,078	60%	+17%
L1W3	32,943	54%	+10%
L1W4	24,748	40%	-3%
L1W5	33,261	54%	+11%
L1W6	23,605	38%	-5%
Median	**30,823**	**50%**	**+7%**

a – the percentage change in this column is a based on the current WQ Pool volume of 61,322 AF, with a 1% change representing about 613 AF. Due to rounding, numbers may not appear to be additive.

The absolute minimum storage during each 30 year hydrologic sequence is higher in 12 of the 13 scenarios as compared to the baseline scenario. The exception occurs in the L0W6 scenario wherein minimum storage is not only lower, but there is a 5 day period in which the WQ Pool is depleted and unable to meet the minimum release and the Clayton Gage target. A contributing factor in the depletion of the WQ Pool storage is that Durham's water supply is depleted prior to depletion of the WQ Pool. Durham's supply shortage causes a cessation in wastewater discharge. A significant portion of Durham's wastewater normally discharges into Falls Lake and therefore Durham's water supply shortage has a negative impact on storage in Falls Lake. Durham's shortage in the L0W6 scenario is extensive and lasts for approximately 5 weeks prior to the Falls Lake WQ Pool depletion. However, Durham's shortage seems unlikely given its plan to build a new intake and water treatment plant on Jordan Lake that it could make greater use of than was assumed in the model. Once projected land use change is coupled with the W6 climate scenario (scenario L1W6), the WQ Pool remains viable throughout the 30 year scenario without exception though minimum annual storage in the WQ Pool is 5% lower than in the base case.

Scenario Conservatism

There are two conservative assumptions built into the model scenarios described above. These assumptions are:

1. Atmospheric levels of GHGs used in the EPA 20 Study are equal to or higher than the current worst case projected emissions scenario (RCP 8.5). In 2014 the IPCC replaced the set of emissions scenarios used for the EPA 20 Study with an updated set known as the RCP[10].
2. The mid-point of the evaluated time horizon is 2055 which is 10 years beyond the planning horizon for this study (2045). Furthermore, the event in scenario L0W6 in which the Water Quality Pool is briefly depleted takes place in simulation year 2068 – which is 23 year past the planning horizon for this study.

Conclusions

The quantitative modeling exercise undertaken shows results that are in-line with the qualitative results described in the introductory section showing increased temperatures and a range in precipitation outcomes generally skewing toward a wetter future. Median increase in water supply operating yield and annual minimum Water Quality Pool storage are 15% and 7% respectively for scenarios incorporating climate change and anticipated urban development. While the possibility of a marginally drier future cannot be ruled out, the magnitude of drying seems modest and manageable. Furthermore, the more likely possibility appears to be one of greater hydrologic abundance reducing concern about the ability of the Falls Lake Project to meet the needs set forth in the rest of this document under a climatically shifted future. Given the large uncertainty in the state of the science regarding the enormously complex processes at play in the determination of climate for a particular region, and the relatively small number of scenarios available for modeling, these results cannot be deemed conclusive, however, they are encouraging because they imply a future where the Falls Lake Water Supply Pool and Water Quality Pool will both be able to meet anticipated demands, and the downside risks appear manageable.

[10] Ibid. 2-4.

US Army Corps of Engineers ®
Wilmington District

FALLS LAKE, NORTH CAROLINA

INTEGRATED WATER SUPPLY REALLOCATION

FEASIBILITY STUDY

APPENDIX G

REAL ESTATE

CITY OF RALEIGH, NORTH CAROLINA

MARCH 2017

Appendix G – Real Estate – Falls Lake Integrated Reallocation Feasibility Study/EA

There is no Real Estate acquisition or easement requirement for the Recommended Plan. Because the reallocation has no project construction or modifications to the existing project, no construction easements, permanent easements, or real estate acquisition are necessary to implement the Recommended Plan.

The existing project contains a raw water intake within the footprint of the reservoir. Should an additional, or enlarged water intake and transmission lines be required at some point in the future, the existing easement would be utilized.