North Carolina Department of Environment and Natural Resources

Pat McCrory
Governor

John E. Skvarla, III
Secretary

Staff Summary
Cape Fear/Neuse River Basin Hydrologic Model
August 28, 2014

- Background
- Comments Received
- Demonstration of Cape Fear/Neuse River Basin Hydrologic Model Compliance with NC G.S. 143-355(o)
- Staff Recommendation
- Appendix - NC S.L. 2010-143

Background

In April 2011, the N.C. Division of Water Resources (DWR) contracted with Hydrologics, Inc. to update the river basin hydrologic model for the combined Cape Fear and Neuse River basins to be used for water resource planning. The modeling software that was utilized to develop the model was Operational Analysis and Simulation of Integrated Systems (OASIS), which contains the following features:

a) A clickable map-base schematic with nodes representing reservoirs;
b) Withdrawals, dischargers, stream gages, and inflow locations;
c) Operation rules for reservoirs and water supply withdrawals;
d) Position analysis mode for real time operations;
e) Model runs that include both existing and future conditions scenarios;
f) A customized interface including an irrigation withdrawal update table and automatic safe yield analysis; and
g) Output options including USGS plots and 7Q10 statistics.

During the model building process, DWR held two public meetings. The main objective of these meetings was to seek and solicit input from the local water systems and the public in an effort to enhance the modeling process. The involvement of the local water systems ensured that the model was based on the most accurate data regarding withdrawals and discharges in the basin. In addition, training was offered for anyone interested in learning how to use the finished model. DWR has conducted numerous exercises to validate the performance of the model.

In February 2014, the division published a public notice recommending that the Environmental Management Commission considers approval of the Cape Fear/Neuse River Basin Hydrologic Model. This notice provided a 60-day public comment period, which ended on April 21, 2014. During the comment period, DWR received one comment from the City of Raleigh, in which the

City objected to the EMC's approval of the models, and comments from both the Town of Cary and CH2MHill in support of the model. The comments are attached. Raleigh pointed out a segment of the Neuse, between Falls dam and the Clayton flow gage, where the simulated flow oscillates under certain conditions. The oscillation occurred in an earlier Neuse model. It will be corrected if it occurs again. Raleigh also questioned the use of the model to analyze ecological flows.

Additional information and details about the Cape Fear/Neuse River Basin Hydrologic Model are available on the division's website by going to:
http://www.ncwater.org/data_and_modeling/Cape_Fear-Neuse/.

<u>Comments Received</u> on Cape Fear/Neuse Basin Hydrologic Model

Comment period: February 17 – April 21, 2014

Comments were received from:

- Town of Cary
- CH2M Hill
- City of Raleigh

Division of Water Resources, NC DENR
August 28, 2014

Email Received: Mon 4/21/2014 3:54 PM

To Whom it May Concern:

The purpose of this email is comment on the Division of Water Resources' (DWR) recommendation that the Environmental Management Commission (EMC) approve the Cape Fear/Neuse River Basin Hydrologic Model (model).

The Town of Cary has been involved in the development and use of every iteration of the Cape Fear and Neuse Hydrologic Models since the very first in both basins. Each version has been an improvement over the previous, and this latest is no exception. Town of Cary staff participated in development of the model, have attended training for the model, and have closely coordinated with DWR staff and DWR's consultant on ensuring that the portions of the model designed to simulate the Town's water supply withdrawals and wastewater effluent discharges are appropriately represented. We have reviewed the "SimBase" model scenario (based on 2010 conditions) with DWR and are satisfied that it is suitable for use as a tool to evaluate the relative hydrologic impacts of water resources management scenarios in the Cape Fear-Neuse Basins. As with all models, especially this large and complex, as it is used more and more, it's inevitable that there will be some minor improvements needed, and we recommend that the EMC approval allow for continued refinement of the model by DWR.

Cary is involved in two ongoing processes that involve use of the model – the Round 4 Jordan Lake Allocation process and our Interbasin Transfer certificate modification process (Notice of Intent submitted to the EMC September 30, 2013.) With the current absence of an EMC-approved model, the Town of Cary, along with others, has begun using the model (as noticed for approval) in order to evaluate the relative impacts of alternatives. While it is possible that the model may be approved before the EMC is asked to take any action relative to these processes, it is our understanding that these ongoing processes will proceed in a timely manner independent of the model approval process, and we support this approach.

We appreciate the time and effort it's taken to develop the models, and being included as stakeholders in the model development.

Best regards,

Leila Goodwin

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At the Town of Cary we focus every day on enriching the lives of our citizens by creating an exceptional environment and providing exemplary services that enable our community to thrive and prosper.

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Division of Water Resources, NC DENR
August 28, 2014

Email Received: Mon 4/21/2014 4:25 PM

To whom it may concern:

CH2M HILL has utilized the OASIS models developed for hydrological analyses of several North Carolina River Basins for a variety of water supply and environmental impact analyses for more than 5 years. We have also used the original Cape Fear River Hydrological Model that was developed in a different modeling platform more than 10 years ago. We have reviewed the current iteration of the Cape Fear – Neuse model and believe that it will be a useful tool for water resources planning. The previous models were useful as planning tools and the revised model is an improvement over the previous Cape Fear and Neuse models.

The revised model is significantly more complicated and will require a greater understanding of the OASIS operations control language and the interaction of the different systems in the basins. This added complexity seems to be justified as it provides more realistic representation of operating rules and the balance between withdrawals and discharges. While more refinements could be made, the resulting improvements would provide minimal benefits and the model would become more cumbersome and very difficult to modify and provide Quality Control checks.

In our review, we did not identify any errors with inputs or results which could not be explained with further investigation into the model inputs and rules. As with all models, some level of numerical error is inherent and should be considered when applying model results to specific measures. As a model running on a daily timestep, results are best analyzed for the next greater timestep, i.e. weekly or monthly averages.

The model should provide reliable, defensible results and will be useful as a planning tool as long as metrics used to address questions are carefully selected. Metrics for any given analysis should consider the limitations of the model, be flexible enough to minimize the effects of artifacts of the model that do not represent reality, and evaluate the flow on an appropriate timescale to the question at hand. Overall, we feel that the revised model provides the necessary level of accuracy and complexity to support evaluation of water resources questions for the often interdependent entities in these basins.

If you have any questions, please do not hesitate to contact me.

Regards

Bill Kreutzberger

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Division of Water Resources, NC DENR
August 28, 2014

City Of Raleigh

April 16, 2014

Mr. Benne Hutson, Chairman

North Carolina Environmental Management Commission

1617 Mail Service Center

Raleigh, NC 27699-1617

North Carolina Department of Environment and Natural Resources (NCDENR)
Division of Water Resources
Modeling and Assessment Branch
1611 Mail Service Center
Raleigh, North Carolina 27699-1611

RE: Comment on DWR Recommendation that the EMC Approve the Cape Fear- Neuse Combined River Basin Hydrologic Model

These comments are presented on behalf of the City of Raleigh. The City previously commented on the Tar River Basin Hydrologic Model and its variances from the requirements set forth in N.C. Gen. Stat. § 143-355(o). Raleigh's general objections to the Tar River Basin Hydrologic Model apply equally to the Cape Fear-Neuse Combined River Basin Hydrologic Model. To avoid duplication, Raleigh relies on its general objections to the Tar Model in this comment on the Cape Fear-Neuse Combined River Basin Hydrologic Model. Recent information exchanges with DWR have resulted in some variations from the Tar Comment, which are reflected in this Comment. Briefly, Raleigh objects to adoption of both models on these three grounds:

- ***AS NOTICED AND PRESENTED TO THE EMC, THE MODEL DOES CONTAIN INFORMATION OR PROCESSES SUFFICIENT FOR A PUBLIC WATER SUPPLIER TO ANALYZE A PROPOSED NEW WATER WITHDRAWAL TO DETERMINE WHETHER ADVERSE IMPACTS WILL OCCUR TO PROTECTED ECOLOGICAL FLOW.***

The model was developed in a manner that is inconsistent with the requirements for model development as set forth in N.C. Gen. Stat. § 143-355(o). DWR's noticed model only complies with the requirement set forth in the first part of the model requirements. It is a model that establishes the 2010 exiting status, and not a model that can be used to analyze the impacts of new water withdraws as required by N.C. Gen. Stat. § 143-355(o)(3)b. DWR has hidden from the public and the Commission the means by which it will set the ecological flow as a part of the minimum flow requirements to be applied to water withdrawal and other supply projects. ["The Department shall characterize the ecology in the different river basins and identify the flow necessary to maintain the ecological integrity." N.C. Gen. Stat. § 143-355(o)(4)].The methodology is not provided in the Models, but instead DWR has advised Raleigh that it will use some unspecified parts of the recommendations from the Ecological Flow Science Advisory Board's (EFSAB) report in a non-regulatory setting while they figure out how to minimize the problems with its application. [1] It is clear, that absent this information, the notice for comments and the request for EMC approval are premature. The impacted public cannot know if the selected methodology takes into account the "prevailing ecological conditions" or the anthropogenic water uses. Moreover, based on the current version of DWR's intended use of the EFSAB report, it appears that the ever-changing newly adopted methodology ignores the statutory requirement that the models should allow for temporary flow disruptions when needed to complete installation of a withdrawal project.

- ***DENR FAILED TO INCLUDE PRESUMPTIVE SET-ASIDES FOR ECOLOGICAL FLOW IN THE MODEL, BUT HAS ANNOUNCED IT WILL IMPLEMENT A NEW DAILY FLOWBY REQUIREMENT OF 85% OF HISTORIC FLOWS – A PLAIN AND CLEAR VIOLATION OF THE STATUTE – WHEN CONSIDERING APPLICATIONS FOR WATER WITHDRAWALS.***

The presumptive set-asides now being implemented by DWR, and proposed as a part of the cape Fear-Neuse Combined Basin Model, violate statutory limitations imposed on the models by N.C. Gen. Stat. § 143-355(o). The presumptions will vary from the existing regulatory requirements related to water quality and water resources. Under the existing regulatory standards and prior DENR policy, an environmental assessment was required when proposed withdrawals were greater than 20% of 7Q10, retaining 80% of 7Q10 to specific water-quality criteria such as aquatic life criteria, dissolved oxygen (DO), pH, temperature, turbidity, and toxics as well as the human health criteria for noncarcinogens. The new methodology requires maintenance of 80-90% [but at a conference on March 21st it was indicated by DWR that 85% flowby will the criteria] of instantaneous flows, with higher set asides when threatened or endangered species are impacted. The second alternative means in the methodology, "Percentage of Flow Strategy," is based on natural, unaltered flows with no distinction between smaller streams and larger, more resilient streams. Thus, DENR has moved from a system of

[1] The undersigned, on behalf of the City, has made repeated requests for the methodology. DWR's staff indicated that it would prepare and issue a memorandum setting forth the standards to be applied by its modelers. That document has not been forthcoming, or at least DWR has failed to provide it to the City despite requests made pursuant to the N.C. Public Records Act, N.C. Gen. Stat. § 132-6. The City was forced to rely on a presentation at seminar by DWR staff to analyze the impact of the new methodology.

water allocation that assured minimum stream flows during periods of drought, or other low flows, to a system that assures minimum stream flows at all times including average and high flow periods. This is a dramatic and unauthorized reallocation of the waters of the State to protection of ecological integrity. Based on DWR's new presumptive flowby requirement, Raleigh's consultants found the yield from its proposed Little River Reservoir will be reduced to 4 million gallons per day (MGD), instead of the 10+ MGD estimated to be available based on prior needs identified by resource agencies.

- ***DWR'S NEW STATEWIDE 85% FLOWBY POLICY IS A "RULE" AND DENR VIOLATES STATE LAW BY IMPLEMENTING THIS CHANGE IN THE REQUIREMENTS RELATED TO WATER QUALITY AND WATER RESOURCES.***

Because DWR has adopted a single statewide uniform methodology instead of developing science based criteria unique to each basin, the methodology is a "rule" within the meaning of state law and can only be applied once it has been duly adopted in accordance with Part 2 the Administrative Procedure Act, N.C. Gen. Stat. § 150B-21.1 *et seq.* The EMC has no such rule and its approval of the Cape Fear-Neuse Combined River Basin Hydrologic Model will violate limits on its authority as set forth in N.C. Gen. Stat. 143-355(o) and the APA.

SPECIFIC OBJECTIONS TO THE CAPE FEAR-NEUSE

COMBINED RIVER BASIN HYDROLOGIC MODEL

It is widely acknowledged by Raleigh and DENR that Raleigh is the most water-stressed metropolitan region in the State. Raleigh sits at the head of the Neuse River. Through its cooperation with the United States, the Falls Lake reservoir was created to address the water shortage problems confronting Raleigh as early as the 1970's. After it was constructed, the Legislature imposed severe limitations on interbasin transfers, a means used to address numerous other metropolitan areas facing water shortages. Based on the impacts of N.C General Statute § 143-215.22L, Raleigh has sought new water resources within the Neuse Basin. Since the early 1980's, the primary opportunity has been the development of a final reservoir in eastern Wake County in the upper reaches of the Little River, within the Neuse Basin. The proposal moved forward as a joint project of Wake County and Raleigh. The lands have been acquired. For more than 7 years, Raleigh has been in the planning stages for the preparation and submission of a NEPA document to the Corps of Engineers to support the Section 404 permit for construction of the necessary dam. The anticipated yield from the Little River Reservoir is 13.8 MGD, after allowing for the minimum downstream flows deemed necessary for ecological protection of existing water uses. That addition to Raleigh's other water supply resources extends substantially the ability to meet demand, but it is still not enough water to meet the anticipated 50 year future growth of the seven municipalities served by Raleigh.

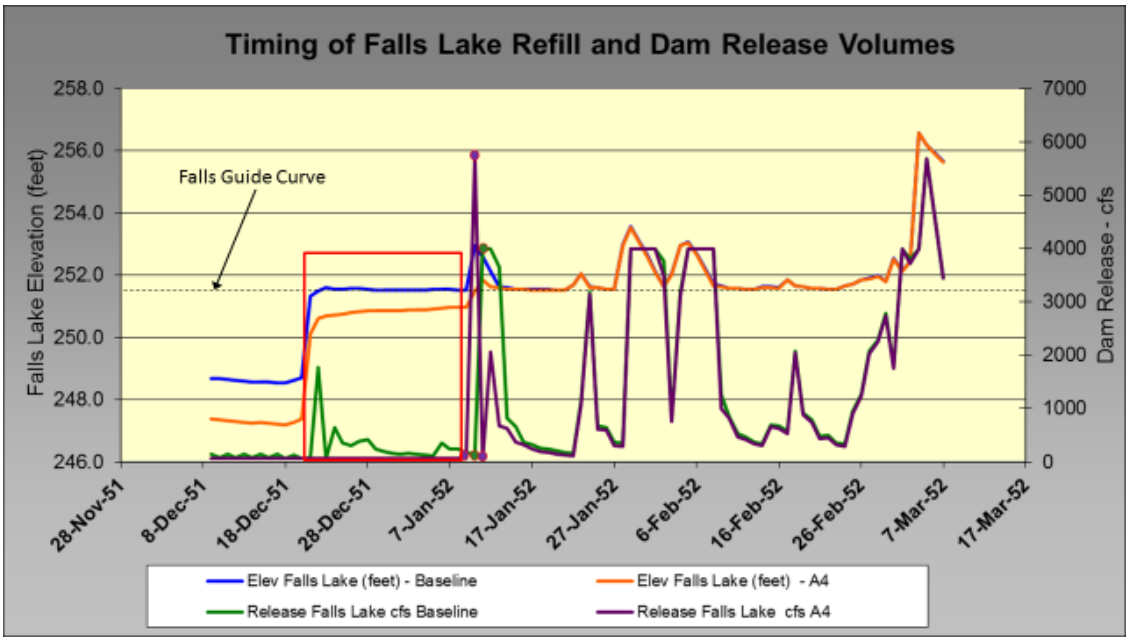
Raleigh's has been in active discussion with federal and state agencies responsible for the protection of natural resources that will be impacted by the Little River Reservoir. The process includes the creation of working group for a flow study of needs for the environmental resources dependent on flow. Approximately four years ago, after a multi-million dollar investment in water resource planning, Raleigh's consultants did additional model runs to determine the anticipated yield in light of anticipated agency requests for ecological needs. If the anticipated demands are met in full, the resulting yield of the proposed reservoir would be reduced from 13.8 MGD to approximately 10+ MGD.

In the recent past, Raleigh and the agencies agreed on three alternatives to the Little River Reservoir that could meet Raleigh's next need for 13.8 MGD. DWR was a primary agency in identifying the alternatives to be examined. Based on the recommendation of DWR, Raleigh offered to enter into a $500,000 agreement with the Corps of Engineers to evaluate one of the most promising alternatives in June, 2013. That offer has advanced through the Corps of Engineers and was submitted for Congress to consider in the fall of 2013. Modeling exercises indicate that reallocating 4.1 billion gallons (BG) of storage from the water quality pool to the water supply pool could provide the same increase in operational water supply yield as the 13.8 MGD anticipated from the proposed Little River Reservoir while retaining the ability of the water quality pool to meet existing flow targets in the Neuse River below Falls Dam as shown in the Neuse Hydrologic Model. This alternative is also referred to as Alternative A4 in several of the graphs shown later in this comment.

As with the Tar Model, the noticed Cape Fear-Neuse Combined Model does not contain the information by which ecological flow can be calculated for future projects. The OASIS model, as described by its owner Hydrologics, requires the operator to provide the minimum flow for each arc as well as the weighting description for that rule. While that information appears in the noticed document, it is based entirely on 2010 information and includes no statement of ecological flow needs. For that reason, Raleigh was forced to rely on the evolving information on DWR's intended method for setting ecological flow needs. To apply the proposed model to its immediate and long range issues for water supply, Raleigh's consultants, including Reed Palmer, P.E. an expert modeler, met with DWR on March 14, 2014 to discuss the anticipated impacts on the three alternatives as well as the Little River Reservoir. At that meeting, Raleigh's modeler also demonstrated to DWR instances where the basin model, when used to evaluate the daily flowby component of the EFSAB recommendations, behaves in a manner inappropriate with the need to compare a baseline scenario and a future use scenario across every single day in the hydrologic record.

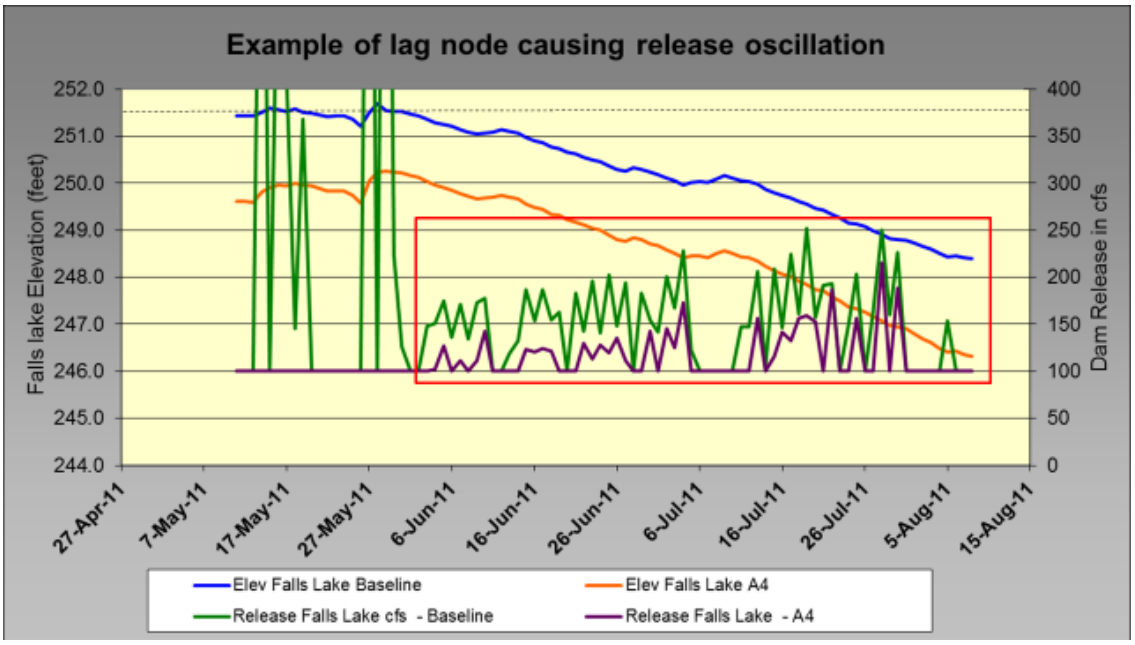
The proposed application of ecological flow limits on the three alternatives shows that, based on the current rules used in the model, each of the alternatives will violate the 85% flowby requirement that DWR proposes to apply to future water withdrawals. This is due in large part to the fact that the increased water supply withdrawals from any reservoir (as compared to any established baseline) will

cause reservoir drawdown periods of greater duration. During the days that constitute the extended drawdown period, it is unrealistic to expect that an 85% flowby criteria could ever be met. In Mr. Palmer's opinion, the DWR model also demonstrates occasional quirks that make it incapable of accurately predicting deviations from the 85% flowby criteria in the area between the Falls Dam and the gage in Clayton at which compliance with the operating requirements for the dam is measured. The model uses a flow release protocol that varies from the manner in which the Corps of Engineers actually operates the dam. That set of issues is illustrated as shown below:



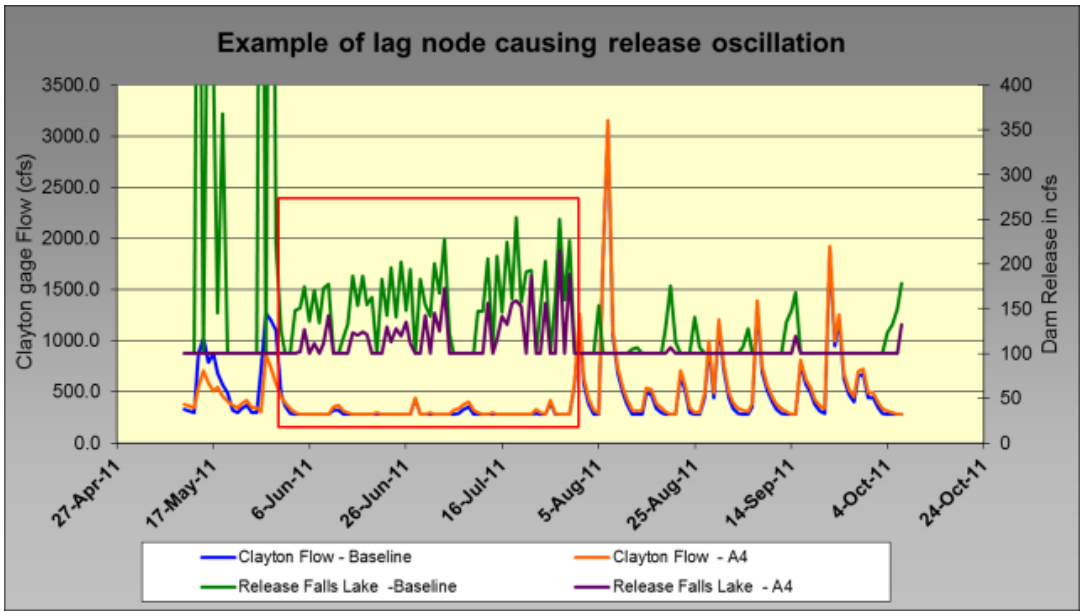
Mr. Palmer made the following observation to explain the graph:

> "The month or so highlighted in the red box represents a particularly prolonged delay in Lake refill between the baseline scenario (blue line) and full use of the reallocated (A4) Falls Lake conservation pool (orange line). During that period (days inside red box) the model estimated releases from Falls Lake in the baseline scenario (green line) greatly exceed those in the Reallocation scenario (purple line). Once Falls Lake does refill in the Reallocation scenario, release patterns still differ another 7-10 days. Some of this difference is due to model release protocol (see dots in graphic above) that is much less sophisticated than actual USACE practice. There are consecutive days when the release from Falls Lake goes from the minimum release, to several thousand cubic feet (cfs), and back to under 200 cfs. This reservoir release behavior is an artifact of the model and as such using the model output may lead to an over-estimate of the frequency that 85% flowby is not met in the future use scenario."



Mr. Palmer explains this slide as follows:

> "Lag nodes in the model have introduced an unintended behavior under certain conditions wherein the release from the dam oscillates (green and purple lines) in order to meet the Clayton Flow target. This arbitrary behavior represents a case where a nominally daily time-step model is really not usable for day-to-day comparisons as required in the EFSAB guidelines."



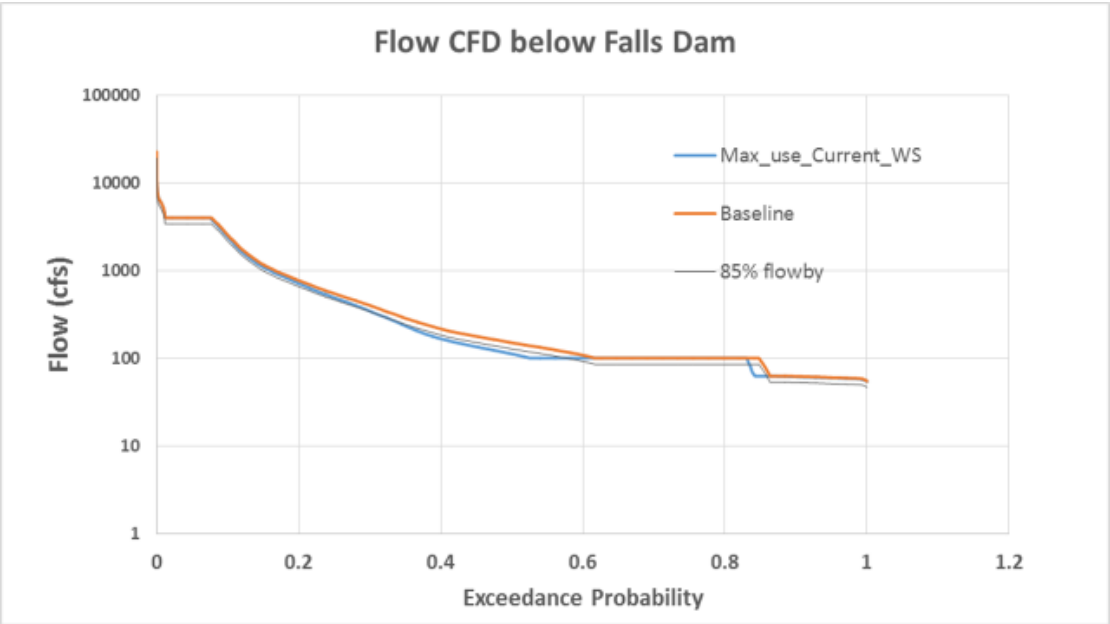
Mr. Palmer explains:

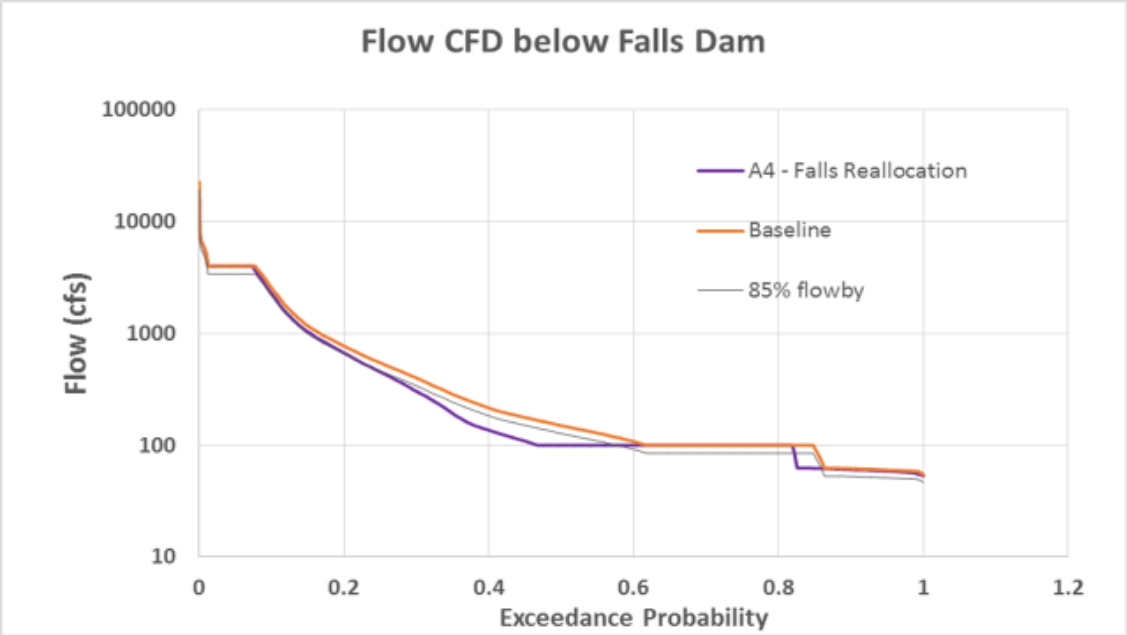
> "In this graph, the same time-series comparison as in the previous graphic is displayed but the Falls Lake elevation information has been replaced with Clayton Gage flow information (orange and blue lines – on primary y-axis). While the dam release is oscillating, the flow arriving at the Clayton Gage does not oscillate – and it never drops below the minimum target. When flows pick up in August 2011, the baseline scenario and Reallocation scenario show very similar characteristics of flow magnitude, duration, frequency, timing, and rate of change at the Clayton gage. Flow magnitude, duration, frequency, timing, and rate of change are the flow characteristics that the EFSAB intends to protect. The two scenarios show a good match in these characteristics without having those characteristics being programmed into the flow targets in the model. They are largely intact for the majority of the model period of record. So the two take home points here are: 1. <u>Model needs improvement to be used as a daily comparison tool.</u> and 2. <u>The flow characteristics the EFSAB wants to preserve are largely preserved without any additional regulation once we get a fair distance downstream of a regulating impoundment (Falls Lake) and, especially, below the point at which the non-consumptive portion of water supply withdrawals (i.e. wastewater discharge) is returned to the river."</u>

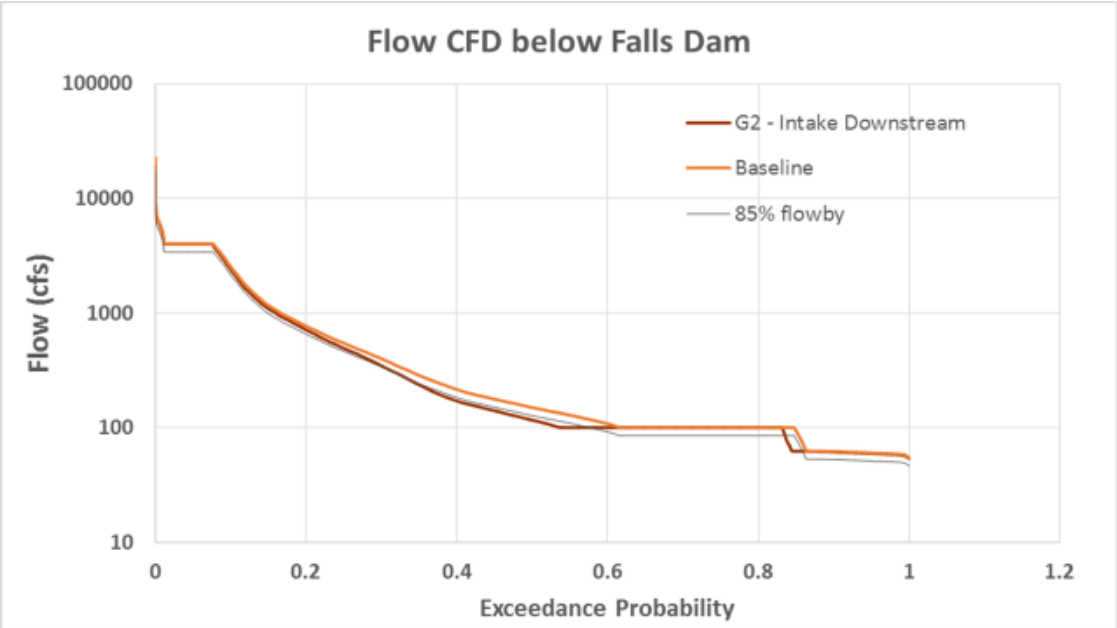
Mr. Palmer also prepared slides to show that if the requirement to compare every day of a future use scenario to the analogous day in the baseline scenario (and there are roughly 30,000 days in the hydrologic record, any one of which can be the cause of non-compliance) were replaced with a comparison of flow frequency distributions that a similar requirement to deviate no more than 15% from that baseline would be achievable below the wastewater discharge point in Raleigh's case. Mr. Palmer concludes that while the models have proven invaluable for the evaluation of future water

supply attributes, as well as drought management, their use in conjunction with DWR's intended adoption of the EFSAB recommendations is not appropriate.

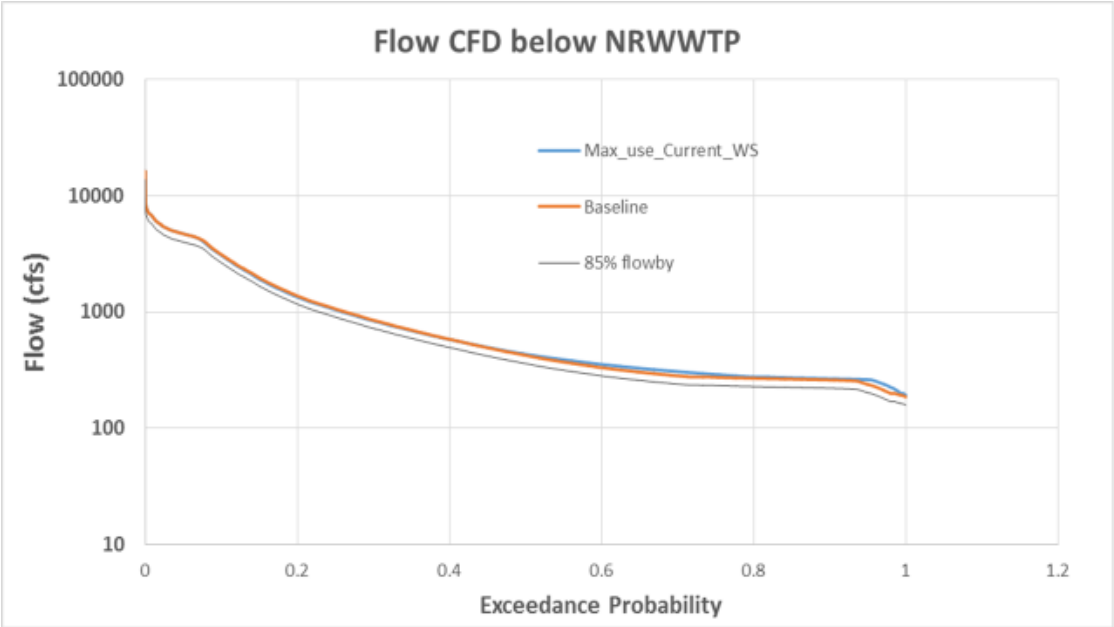
> "The next slides are all flow-duration curves, a.k.a cumulative flow distribution curves for the various modeled scenarios at the two points we looked at (below the dam and below NRWWTP) and compared to the baseline scenario. These graphs help one get away from the direct day-to-day comparison that appears to be problematic with the basin model in its current form [or problem with the guidelines as they are currently written]. They show the chance that a given flow is exceeded – hence the x-axis label "Exceedance Probability". For example, going to 0.2 on the x-axis and up to the orange and blue lines we can see that there is about a 20% chance that flow below Falls dam would exceed 800 cfs on any given day. If we go over to 0.8 we could say that there is an 80% chance that flow will be at or above 100 cfs in both scenarios. For reference, the thin black line shows the 85% flow-by threshold. That line helps us compare the future modeled scenario to the baseline scenario and see that the greatest chance for failing to meet the 85% flowby criteria would be met in the middle of the flow spectrum (it looks like from about the 35th percentile to 55th percentile of wettest days would be most problematic, though deviation below 85% in the range appears slight)."

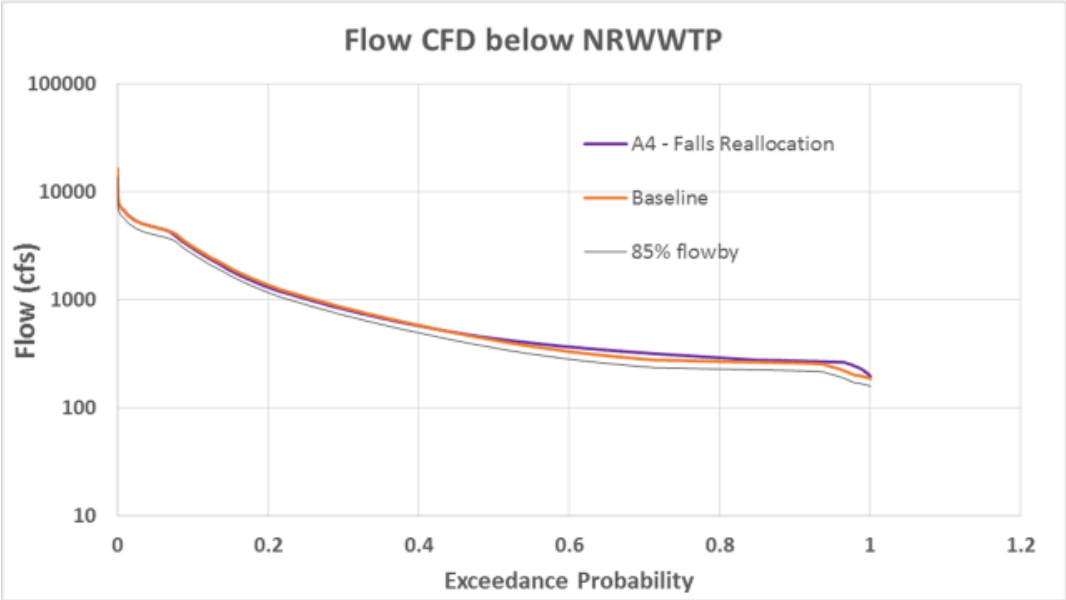



Flow CFD below Falls Dam
100000
10000
1000
100
10
Flow (cfs)
0
0.2
0.4
0.6
0.8
1
1.2
Exceedance Probability
A4 - Falls Reallocation
Baseline
85% flowby


Flow CFD below Falls Dam
100000
10000
1000
100
10
Flow (cfs)
0
0.2
0.4
0.6
0.8
1
1.2
Exceedance Probability
G2 - Intake Downstream
Baseline
85% flowby

"Below the NR WWTP the comparison of the flow spectrum changes between baseline and future use scenarios shows much smaller changes. All of the future use scenarios remain above the 85% flowby over the entire spectrum. This does not mean there are no violations of 85% flowby when compared day-to-day (3-5% of days do violate the direct daily comparison standard). It does mean that where there is one day in the record where the flow fails to meet the 85% flowby criteria there is likely another similar day in the record where the future flowby exceeds baseline flowby by a similar amount to the deficit on the day that failed to meet the criteria – in other words they are cancelling each other out. On the whole there does not appear to be a major shift in the flow spectrum at this location. There is a subtle re-distribution from higher flow times to low-flow times (i.e. future scenarios have slight decreases in the high flow range compared to the baseline scenario and increases in the low-flow range)."




Flow CFD below NRWWTP
100000
10000
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10
Flow (cfs)
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0.2
0.4
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0.8
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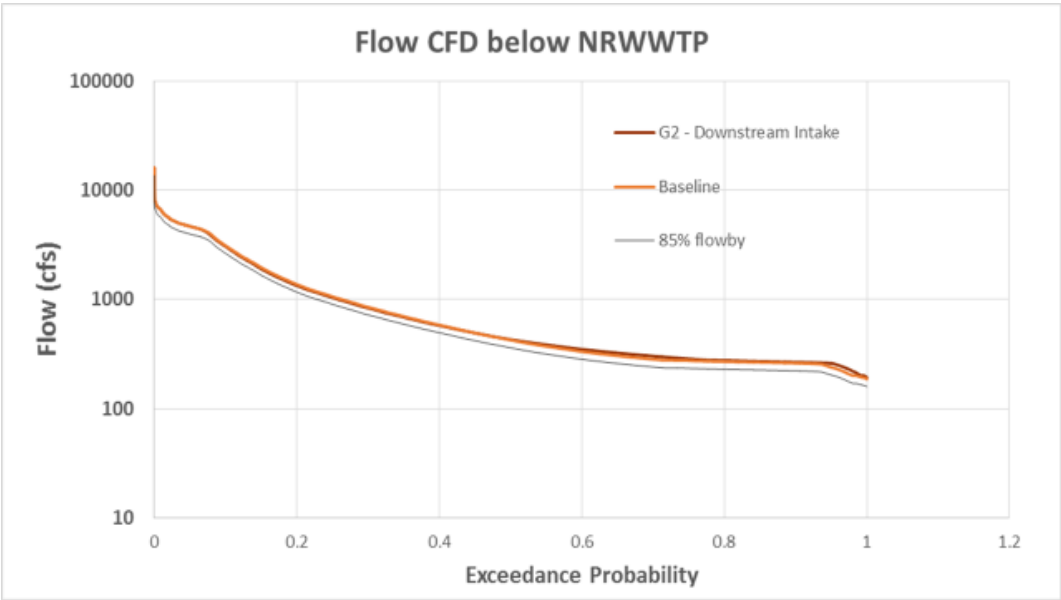
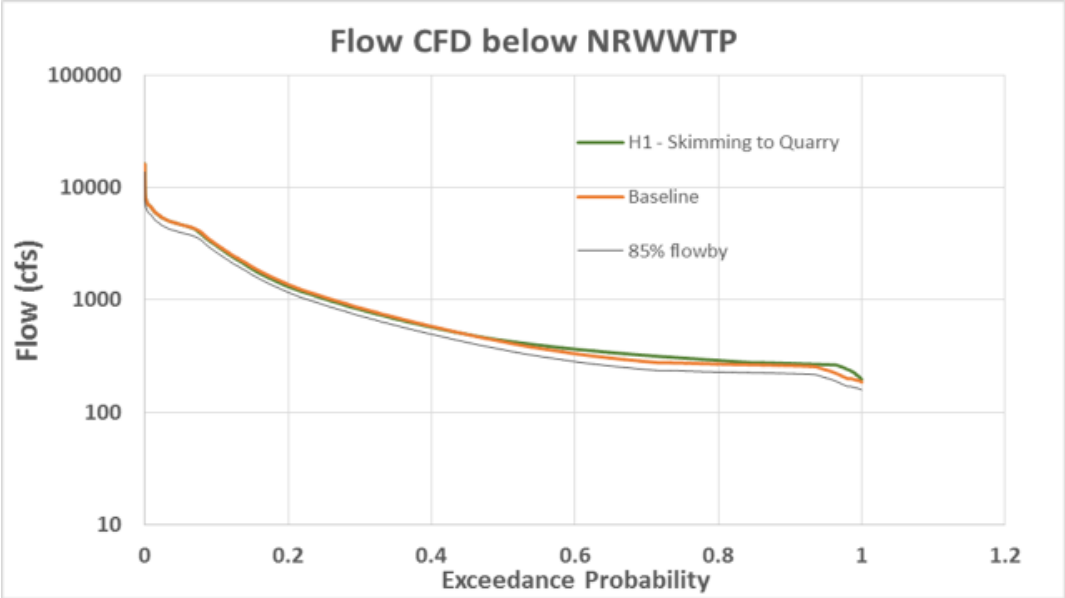
1.2
Exceedance Probability
A4 - Falls Reallocation
Baseline
85% flowby


Flow CFD below NRWWTP
100000
10000
1000
100
10
Flow (cfs)
0
0.2
0.4
0.6
0.8
1
1.2
Exceedance Probability
G2 - Downstream Intake
Baseline
85% flowby



CONCLUSION

These graphs clearly depict major flaws with the model sent to notice and pending before the EMC when it is applied to an actual project that has been in the planning stages for several years. Mr. Palmer examined the impact of the DWR 85% daily flowby policy on the yield of the Little River Reservoir. In past interactions with the resource agencies, the City's consultants estimated that, even with the most aggressive needs' showings by them, the yield would be at least 10+ MGD. Based on DWR's new presumptive flowby requirement, Raleigh's consultants found the yield will be reduced to 4 MGD. That illustrates the importance of the new flowby limits on all flows as opposed to the prior system of protecting and preserving a minimum low flow, and the additional flow required to protect appropriately designated federally threatened and endangered species.

The reasons for this failure and the problems with the noticed model require that the EMC reject its approval and send it back to DWR for more consideration and revision. DWR has ignored the critical limitations imposed on it by the enabling legislation. Based on the reasons set forth above the model should be rejected.

- As noticed and presented to the EMC, the model does contain information or processes sufficient for a public water supplier to analyze a proposed new water withdrawal to determine whether adverse impacts will occur to protected ecological flow. The model can only be used to establish the 2010 exiting status, and it cannot be used to analyze the impacts of new water withdraws as required by N.C. Gen. Stat. § 143-355(o)(3)b. DWR has advised Raleigh that it will use some unspecified parts of the recommendations from the Ecological Flow Science Advisory Board's (EFSAB) report in a non-regulatory setting while they figure out how to minimize the problems with its application. It is clear, that absent this information, the notice for comments and the request for EMC approval are premature.

- DENR failed to include presumptive set-asides for ecological flow in the model, but has announced it will implement a new daily flowby requirement of 85% of historic flows – a plain and clear violation of the statute – when considering applications for water withdrawals. DENR has moved from a system of water allocation that assured minimum stream flows during periods of drought, or other low flows, to a system that assures minimum stream flows at all times including average and high flow periods. This is a dramatic and unauthorized reallocation of the waters of the State to protection of ecological integrity. It violates the enabling statute for the hydrologic models as DWR has used the results from the EFSAB recommendations as it basis for varying from the existing water quality and water resources regulatory requirements as well as for imposing additional regulatory requirements. See N.C. Gen. Stat. § 143-355(o)(8).
- DWR's new statewide 85% flowby policy is a "rule" and DENR violates state law by implementing this change in the requirements related to water quality and water resources. Because DWR has adopted a single statewide uniform methodology instead of developing science based criteria unique to each basin, the methodology is a "rule" within the meaning of state law and can only be applied once it has been duly adopted in accordance with Part 2 the Administrative Procedure Act, N.C. Gen. Stat. § 150B-21.1 *et seq.*

Thank you for your time and consideration of these comments, our staff stands ready to answer any questions or concerns that may arise from your evaluation. Please feel free to contact me at 919-996-6623 to discuss the content and context of our observations.

Sincerely,

Dan McLawhorn

Dan McLawhorn

Associate City Attorney, City of Raleigh

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Demonstration of Cape Fear/Neuse River Basin Model Compliance with NC G.S. 143-355(o)

The complete text of NC S.L. 2010-143, which added subsection (o) to NC G.S. 143-355, can be found in the Appendix.

(o)(3) Model. - Each basinwide hydrologic model shall:

a. Include *(numbers added for reference; detailed information is provided for each)*

1) surface water resources within the river basin
2) groundwater resources within the river basin to the extent known
3) transfers into and out of the river basin that are required to be registered
4) other withdrawals
5) ecological flow
6) instream flow requirements
7) projections of future withdrawals
8) an estimate of return flows within the river basin
9) inflow data
10) local water supply plans
11) other scientific and technical information

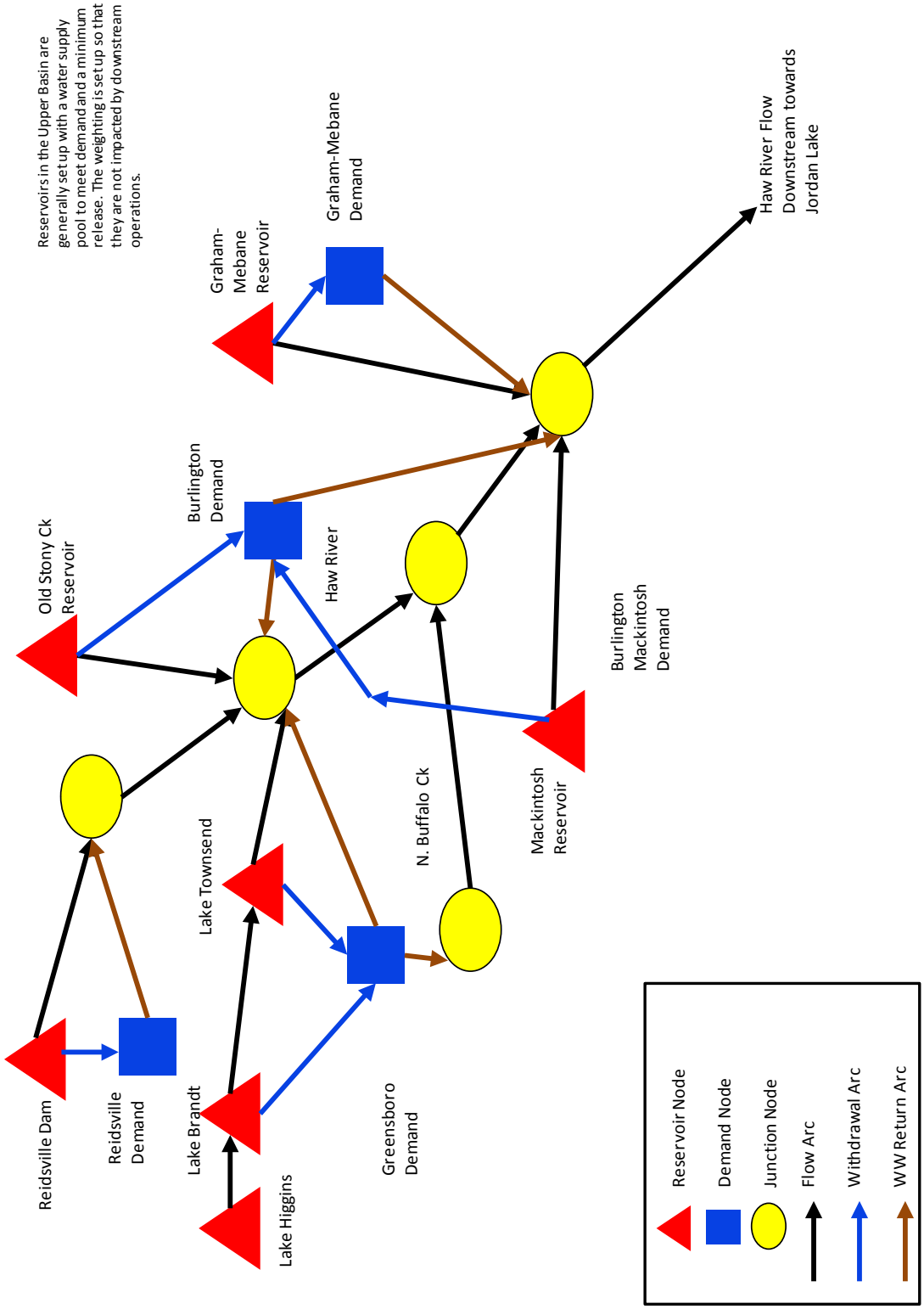
1) surface water resources within the river basin
DWR includes stream reaches and reservoirs that currently have or are projected to have a withdrawal or discharge of 100,000 gpd or will impact the flows for those reaches. 100,000 gpd is based on the current registration requirements. The following table and figures are a summary of the included streams and reservoirs.

Surface Water Resources Discretely Modeled **Cape Fear - Neuse River Basin Hydrologic Model**	
Stream	**Reservoir**
Back Creek	Graham-Mebane Reservoir
Bear Creek	C B Brooks Reservoir
Brush Creek	Lake Higgins
Buckhorn Creek	Harris Lake
Buckhorn Creek	
Cane Creek	Cane Creek Reservoir
Cape Fear River	
Contentnea Creek	Buckhorn Lake
Contentnea Creek	Wiggins Mill Reservoir
Contentnea Creek	
Crabtree Creek	

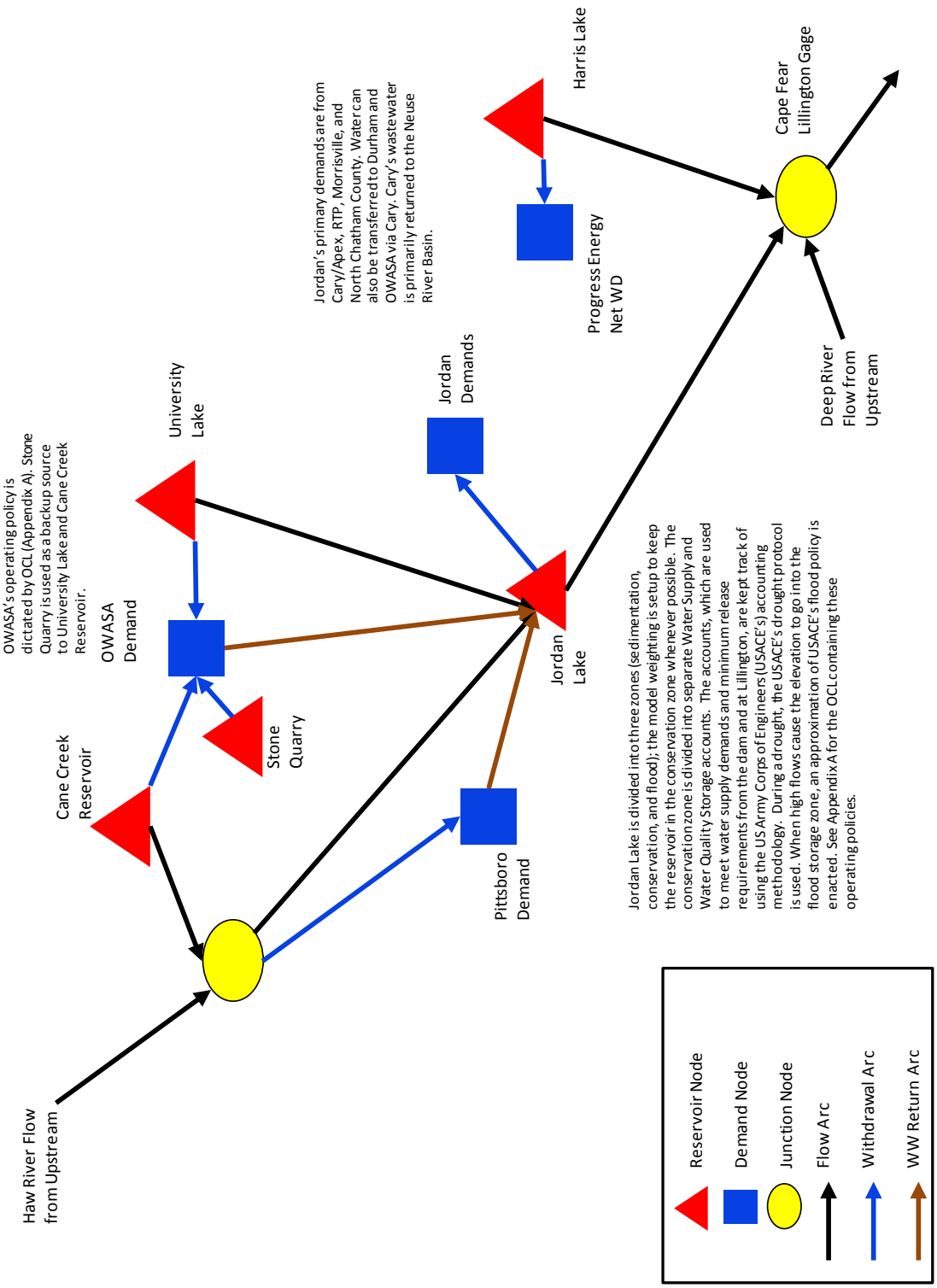
Surface Water Resources Discretely Modeled Cape Fear - Neuse River Basin Hydrologic Model	
Stream	**Reservoir**
Deep River	City Lake
Deep River	Randleman Regional Reservoir
Deep River	
Eno River	Teer/Hanson Quarry
Eno River	
Flat River	Lake Michie
Great Alamance Creek	Lake Mackintosh
Haw River	Jordan Lake
Haw River	
Knapp of Reed's Creek	R D Holt Reservoir
Knapp of Reed's Creek	
Little Cross Creek	Glenville Lake
Little River	Little River Reservoir
Little River	
Middle Creek	
Moadams Creek	
Morgan Creek	University Lake
Morgan Creek	
Neuse River	Falls Lake
Neuse River	
New Hope Creek	
Nicks Creek	
North Buffalo Creek	
Northeast Creek	
Reedy Fork Creek	Lake Brandt
Reedy Fork Creek	Lake Townsend
Rich Fork Creek	
Richland Creek	
Rockfish Creek	
Rocky River	Upper and Lower Reservoir
Sandy Creek	Sandy Creek Reservoir
South Buffalo Creek	
Stoney Creek	Stoney Creek Reservoir
Swift Creek	Lake Benson
Toisnot Swamp	Lake Wilson
Toisnot Swamp	Toisnot Reservoir

Surface Water Resources Discretely Modeled Cape Fear - Neuse River Basin Hydrologic Model	
Stream	**Reservoir**
Troublesome Creek	Lake Reidsville
Utley Creek	

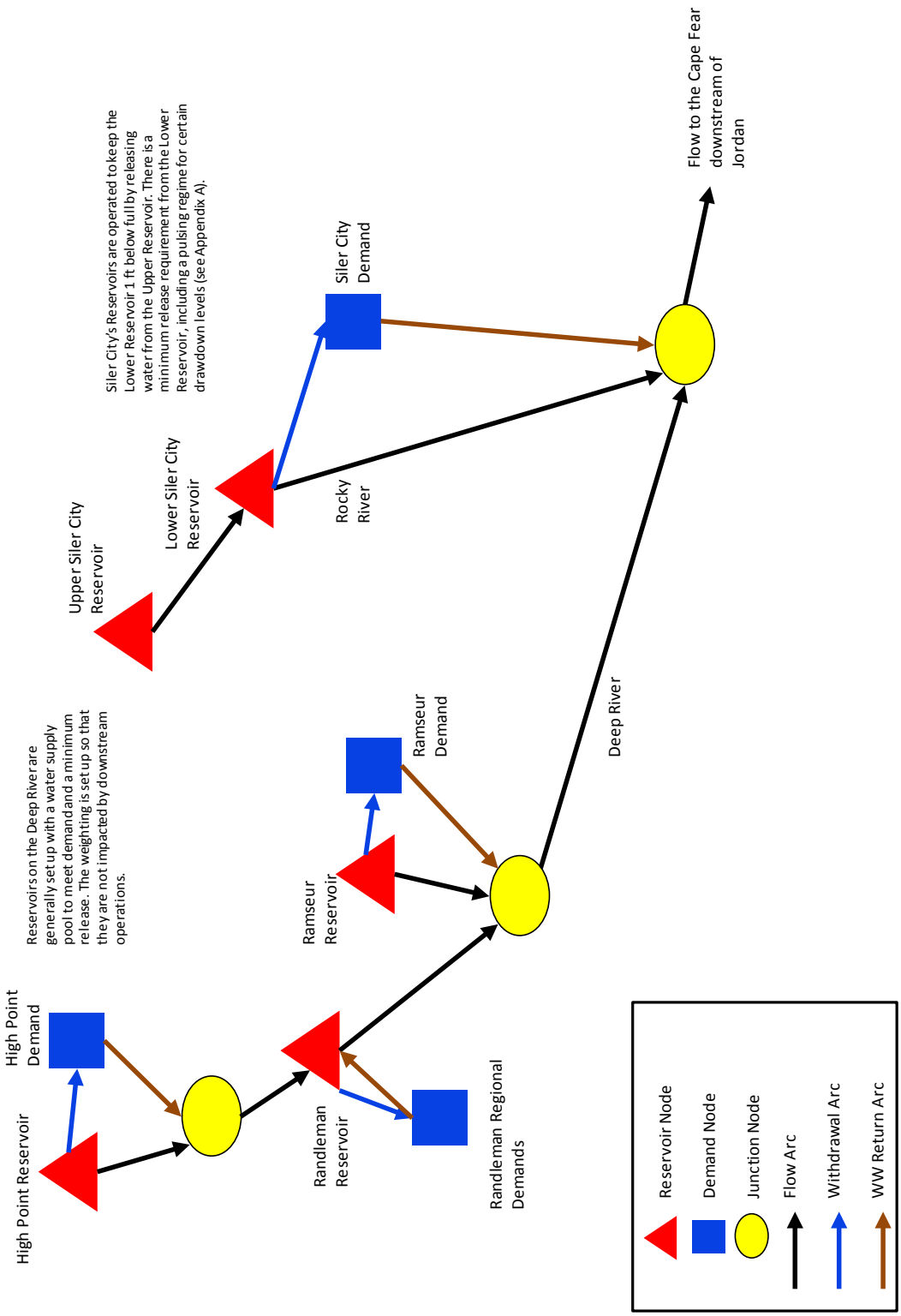
Flow Chart of Major Nodes in the Upper Cape Fear Basin



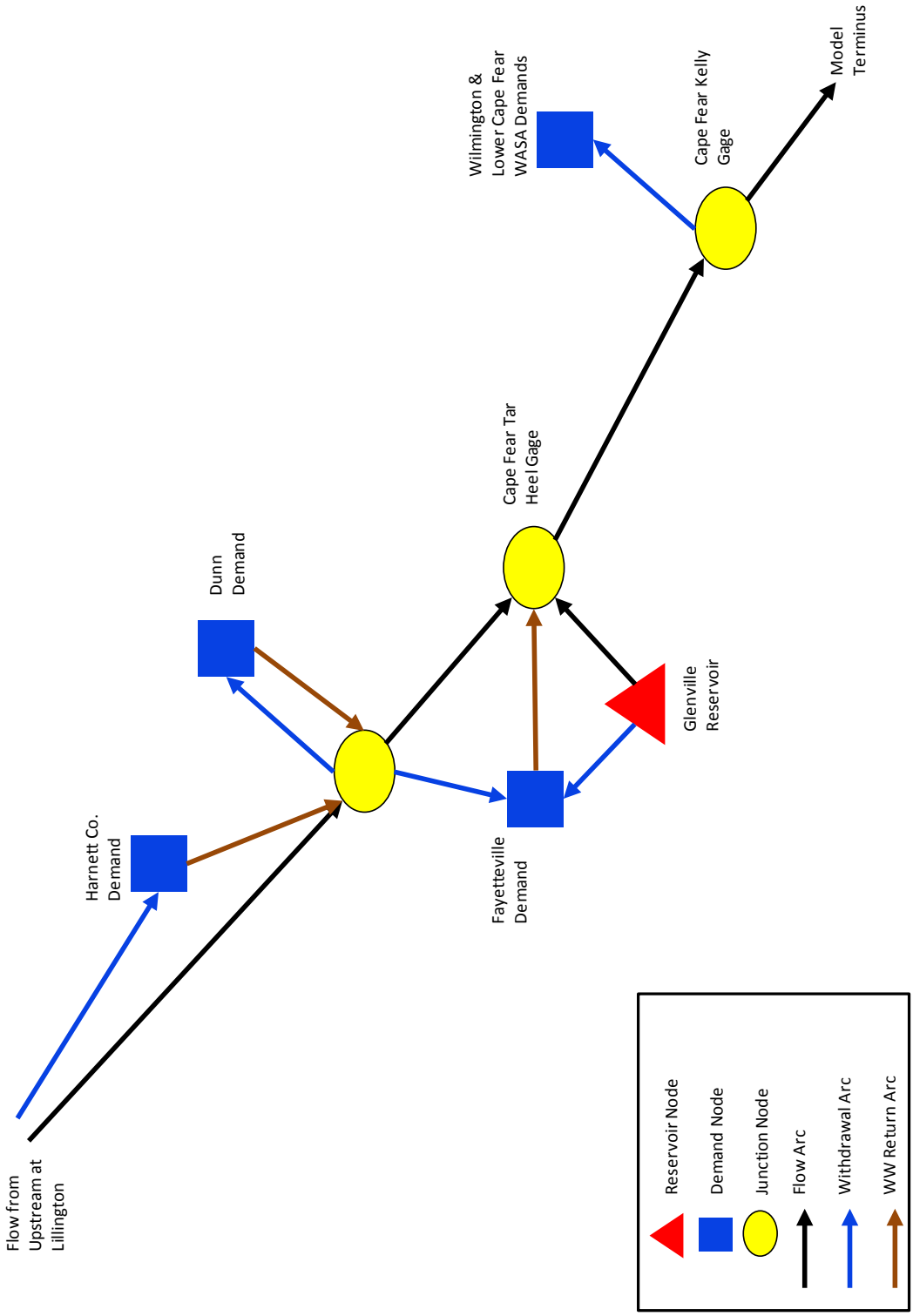
Flow Chart of Major Nodes in the Middle Cape Fear Basin



Flow Chart of Major Nodes on the Deep River

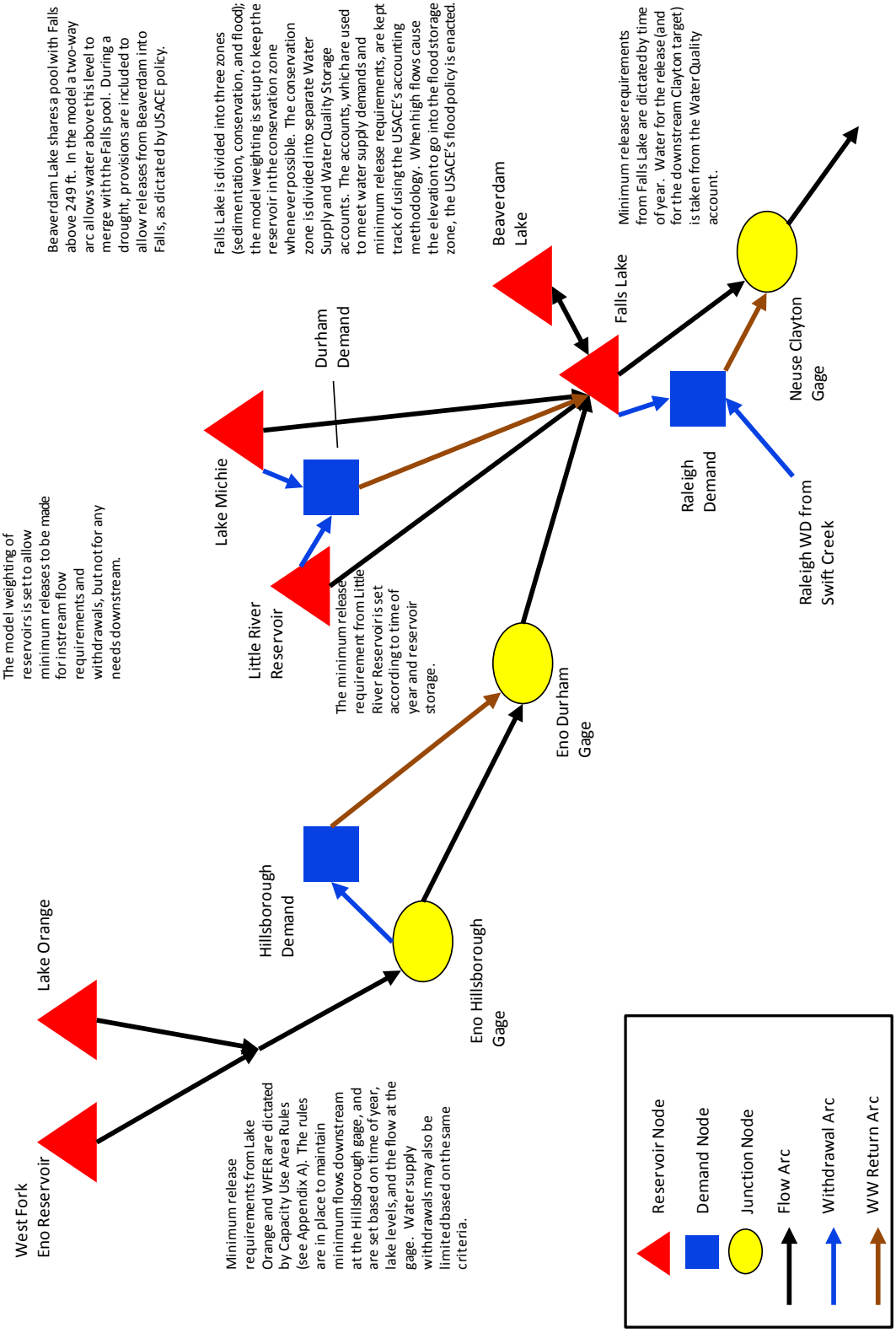


Flow Chart of Major Nodes in the Lower Cape Fear Basin

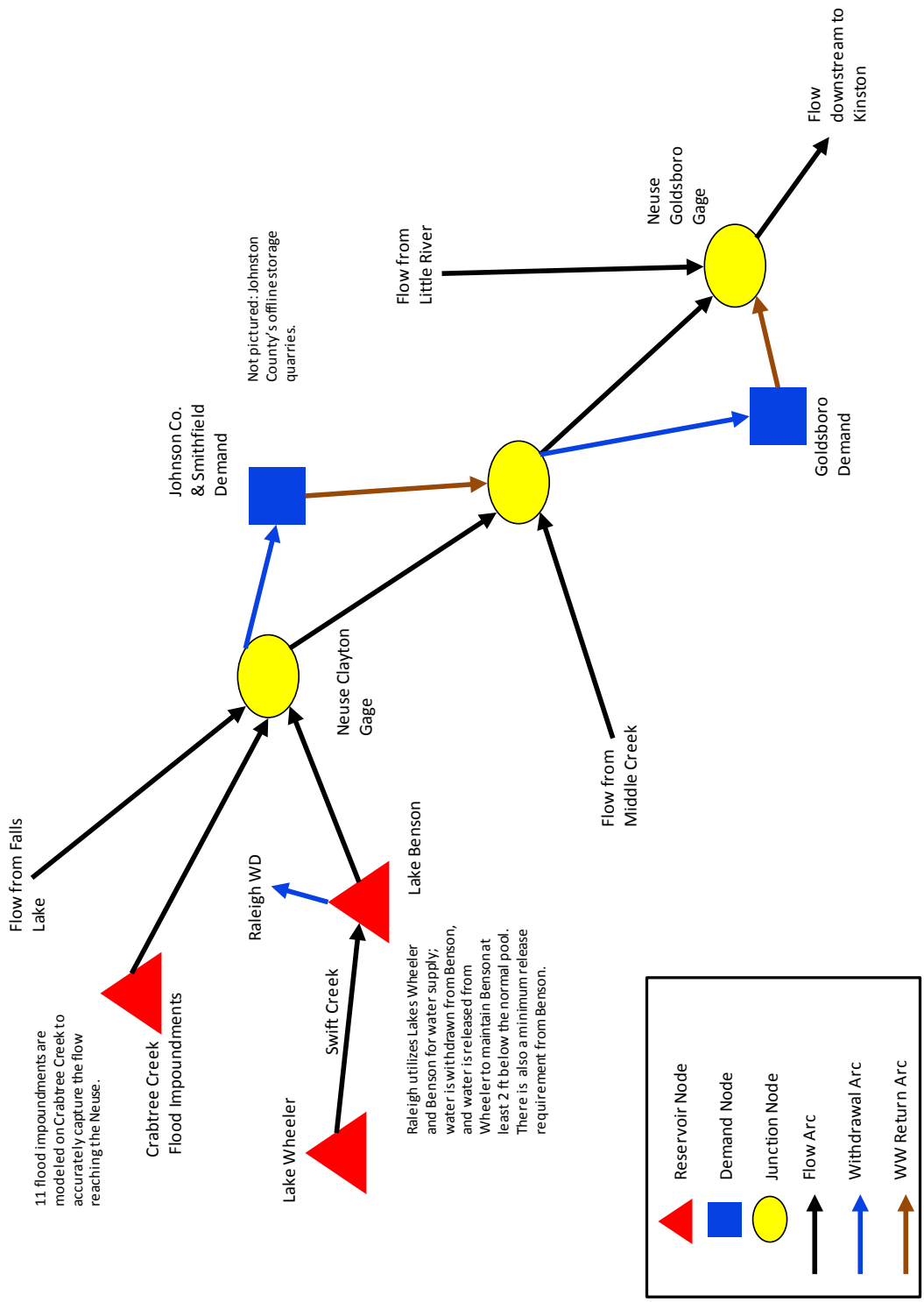


Division of Water Resources, NC DENR
August 28, 2014

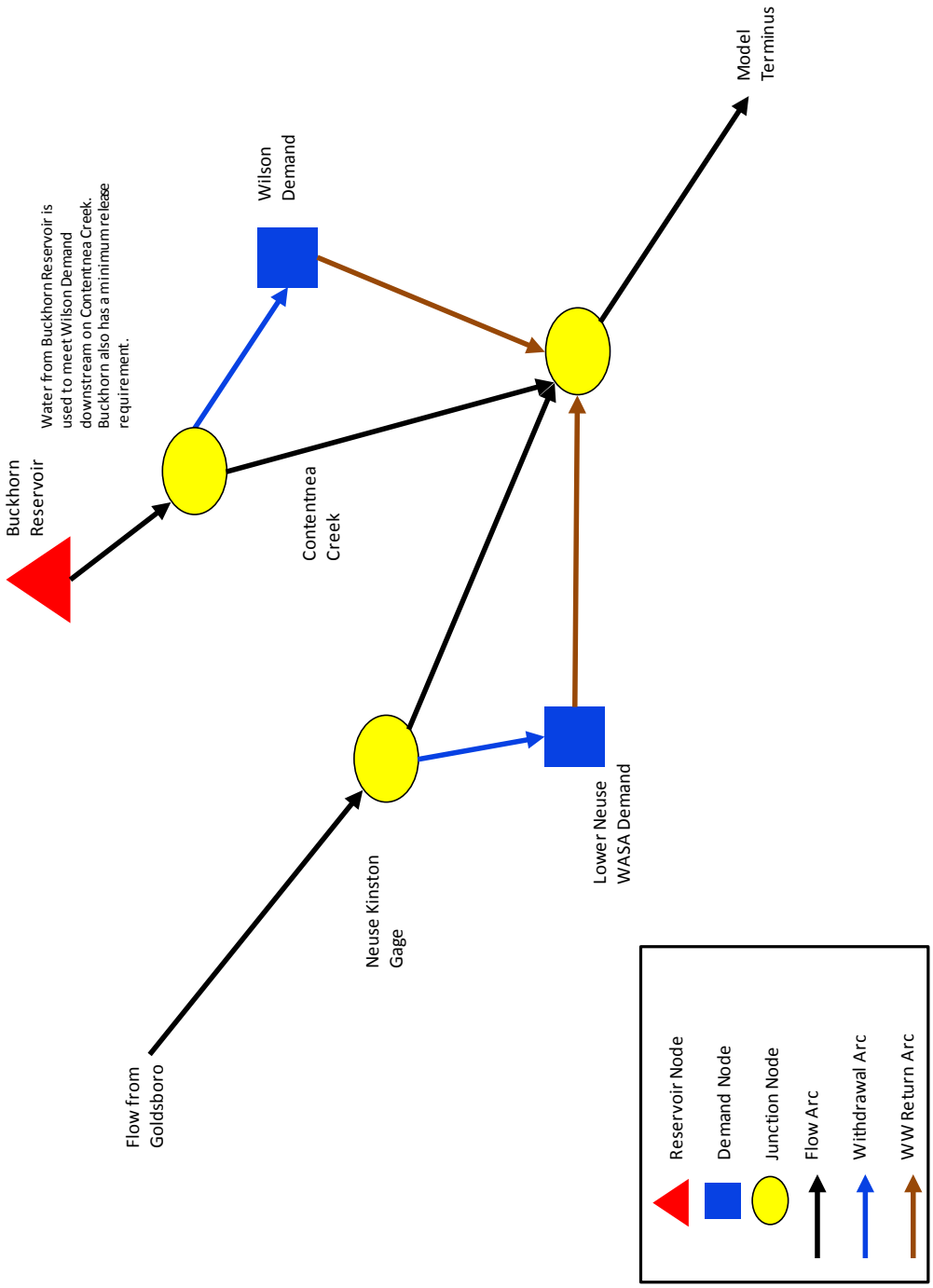
Flow Chart of Major Nodes in the Upper Neuse Basin



Flow Chart of Major Nodes in the Middle Neuse Basin



Flow Chart of Major Nodes in the Lower Neuse Basin



2) groundwater resources within the river basin to the extent known by the Department
Groundwater is currently not directly modeled. A common approach to understanding surface and groundwater interaction is to estimate base flows. DWR looks at changes in base flows to evaluate surface and groundwater interactions. If groundwater systems have surface water discharges, those discharges are included in the model. See the table in item 10).

3) transfers into and out of the river basin that are required to be registered under G.S. 143-215.22H
DWR includes registered interbasin transfers. The following table is a summary of interbasin transfers included in the model.

Interbasin Transfers
Reidsville WTP water supply
Greensboro Mitchell Water Supply
Greensboro Townsend Lake water supply
High Point F.Ward water supply
Randleman water supply
Cary Apex water supply
RTP Demand
Morrisville demand
Harnett County water supply
Robbins CB Brooks water supply
Dunn water supply A
Wilmington water supply
Greensboro Demand Randleman Lake
High Point Demand Randleman
Jamestown Demand Randleman
Archdale Demand Randleman
Randleman Demand Randleman
Randolph Co Demand Randleman
Holly Springs Cape Fear Demand
Holly Springs Demand Jordan Lake
Orange_Alamance Demand
Durham Demand 1
Raleigh Demand
Wilson Demand
J. County Demand
Fuquay-Varina
Neuse River WASA

4) other withdrawals

DWR includes known losses greater than 100,000 gpd. This includes reservoir evaporation, agricultural and golf course irrigation, public and self-supplied industrial withdrawals, and interbasin transfers. The following tables summarize reservoir evaporation, irrigation, and self-supplied industrial withdrawals that are included in the model.

Reservoir Evaporation	
Reidsville Dam	Lake Michie
Old Stony Creek Res	Little River Res.
Brandt Res	Beaverdam Lake
G/T Lake	Lake Holt_Butner
High Point Res	Lake Rogers
Randleman Res	Wake Forest Lake
Ramseur Res	Falls Lake
Graham Mebane Res	Crabtree Flood Control #1
Siler City Upper Reservoir	Crabtree Flood Control #2
Siler City Lower Reservoir	Crabtree Flood Control #3
Mackintosh Res	Crabtree Flood Control #5A
Cane Creek Res	Crabtree Flood Control #18
Stone Quarry	Crabtree Flood Control #20A
Univ Lake	#23 (Lake Crabtree)
Jordan Lake	Crabtree Flood Control #11A
Harris Lake	Crabtree Flood Control #25
Aux Reservoir	Crabtree Flood Control #22B
Glenville Res	Lake Wheeler
Orange Upstream Pond	Crabtree Flood Control #13
West Fork Eno Reservoir	Lake Benson
Lake Orange	Lake Johnson
Corp. Lake	Lake Raleigh
Lake Ben Johnston	Buckhorn Reservoir

Agricultural and Golf Course Irrigation

Counties	**Irr Tobacco**	**Turf**	**Golf**	**Cont Nurs**	**Field Nurs**	**Irr Cotton**	**Irr Early Soy**	**Irr Late Soy**	**Irr Corn**	**Irr Veg**	**Irr Pas&Hay**	**Irr Peanut**	**Irr Blueberry**	**Irr Strawberry**	**Irr Fruit**
Alamance	x	x	x	x	x			x	x	x	x			x	
Bladen	x	x	x	x				x	x	x	x	x	x	x	x
Wake, Franklin, Johnston, Nash, Wilson	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Agricultural and Golf Course Irrigation

Counties	Irr Tobacco	Turf	Golf	Cont Nurs	Field Nurs	Irr Cotton	Irr Early Soy	Irr Late Soy	Irr Corn	Irr Veg	Irr Pas&Hay	Irr Peanut	Irr Blueberry	Irr Strawberry	Irr Fruit
Caswell	x									x	x			x	
Chatham	x		x	x	x					x	x		x	x	x
Wake, Franklin, Johnston	x	x	x	x	x		x	x	x	x	x		x	x	x
Cumberland	x	x	x	x	x	x		x	x	x	x	x		x	
Durham	x		x	x	x				x	x					
Durham, Orange	x	x	x	x	x				x	x			x	x	
Durham, Franklin, Granville, Person, Wake	x	x	x	x	x		x	x	x	x			x	x	x
Forsyth	x									x	x		x	x	
Wake, Johnston, Wayne	x	x	x	x	x				x	x	x		x	x	
Guilford	x	x	x	x	x				x	x	x		x	x	x
Harnett	x	x	x	x	x			x	x	x			x	x	
Hoke	x	x	x	x	x			x		x	x		x	x	x
Greene, Johnston, Nash, Wayne, Wilson	x	x	x	x	x	x	x	x	x	x	x	x		x	x
Greene, Lenoir	x	x	x	x	x				x	x	x				
Lee	x		x	x					x	x	x			x	x
Wake, Franklin, Johnston, Wilson	x	x	x	x	x		x	x	x	x	x		x	x	x
Durham, Orange	x	x	x	x	x				x	x			x	x	
Durham, Person	x		x	x	x				x	x				x	
Wake, Johnston	x	x	x	x	x				x	x	x		x	x	
Montgomery		x		x	x					x	x				
Moore	x	x	x	x	x	x			x	x	x		x	x	x
Orange	x	x	x	x	x					x			x	x	
Randolph	x		x	x	x					x	x		x	x	x
Rockingham	x		x	x	x			x	x	x	x		x	x	x
Wake	x	x	x	x	x				x	x			x	x	
Craven, Greene, Lenoir, Pitt, Wilson	x	x	x	x	x				x	x	x	x		x	

Industrial Withdrawals
Burlington Ed Thomas water supply
Cone Mills-Haw River Lake Jeannette water supply
Cone Mills Richland Lake water supply
Cone Mills Buffalo Lake water supply
Allied Signal water supply
Sierra Pine Weyerhaeuser water supply
Progress Cape Fear water supply
Progress Harris water supply
Lee Cummock water supply (Pilgrims Pride)
Burlington Ind (Swift Tex./Erwin Mills] WS
Monsanto water supply
Piedmont Minerals Demand
Old Burlington Industries
Progress Demand
Weyerhaeuser Demand

5) ecological flow
DWR's models do include ecological flows that are part of an existing permit requirement or part of the operational plan of federal projects, such as COE or TVA reservoirs. Ecological flows included in the model are a subset of instream flow requirements. See item 6).

6) instream flow requirements
DWR's models include instream flow requirements that are part of an existing permit requirement or part of the operational plan of federal projects, such as COE or TVA reservoirs. The following table is a summary of the instream flow requirements included in the model.

Instream Flow Requirements	
Node	**Type**
Reidsville Dam	Dam Safety
Brandt Reservoir	Dam Safety
Lake Townsend	Dam Safety
High Point Reservoir	Dam Safety
Randleman Reservoir	Dam Safety
Graham Mebane Reservoir	Dam Safety
Siler City	Dam Safety
Cane Creek Reservoir	Dam Safety
Jordan Lake	Operational Plan
Lillington	Jordan Lake Operational Plan
Glenville Reservoir	Dam Safety
West Fork Eno River Reservoir	Dam Safety

Instream Flow Requirements	
Node	**Type**
Lake Orange	Voluntary Capacity Use Agreement
Hillsb. Gage Flow	Voluntary Capacity Use Agreement
Little River Reservoir	Dam Safety
Falls Lake	Operational Plan
Clayton Gage	Falls Lake Operational Plan
Lake Benson	Dam Safety

7) projections of future withdrawals
DWR develops model scenarios for current and 50-year projected withdrawals in 10-year increments. See item 8).

8) an estimate of return flows within the river basin
DWR develops return flow estimates based on historical withdrawal discharge patterns. The following table includes the water use projections and return flow ratios based on the 2010 local water supply plans (LWSP). These values are updated periodically based on LWSP updates. The projections are for long-range planning only and their inclusion in the model should not be interpreted as approval for expansion or for the installation of new facilities. (WWR=Water Withdrawal Registration, NPDES=National Pollutant Discharge Elimination System, CCPCUA=Central Coastal Plain Capacity Use Area)

Projected Withdrawals and Return Flows
Cape Fear - Neuse River Basin Hydrologic Model

Data Source	Withdrawer or Discharger	2020 Million Gallons / Day	2030 Million Gallons / Day	2035 Million Gallons / Day	2040 Million Gallons / Day	2045 Million Gallons / Day	2050 Million Gallons / Day	2060 Million Gallons / Day
LWSP	Reidsville Withdrawals	4.576	4.842	4.978	5.113	5.255	5.397	5.757
LWSP	Reidsville Return Flows	2.718	2.876	2.957	3.037	3.122	3.206	3.420
LWSP	Burlington Withdrawals	20.039	22.081	23.232	24.384	25.660	26.936	26.825
LWSP	Burlington Return Flows	17.416	19.191	20.192	21.193	22.302	23.411	23.314
LWSP	Greensboro Withdrawal	39.434	44.144	47.210	50.276	53.873	57.469	65.658
LWSP	Greensboro Total Wastewater	32.586	36.479	39.012	41.546	44.518	47.490	54.257
LWSP	High Point Withdrawals	13.614	15.501	16.202	16.903	17.656	18.409	20.050
LWSP	High Point Return Flow	14.453	16.497	17.242	17.986	18.795	19.604	21.368
LWSP	Archdale Return Flow (water from PTRWA)	1.137	1.158	1.166	1.174	1.183	1.193	1.205
LWSP	Randleman Return Flow (purchased water)	0.888	0.991	1.059	1.127	1.202	1.277	1.322
LWSP	Piedmont Triad RWA Withdrawal	15.734	17.338	18.462	19.585	20.856	22.128	24.342
LWSP	Piedmont Triad RWA Return Flow	1.683	1.855	1.975	2.096	2.232	2.368	2.605
LWSP	Asheboro Return Flow	5.921	0.505	0.525	0.544	0.564	0.584	0.614

Projected Withdrawals and Return Flows
Cape Fear - Neuse River Basin Hydrologic Model

Data Source	Withdrawer or Discharger	2020 Million Gallons / Day	2030 Million Gallons / Day	2035 Million Gallons / Day	2040 Million Gallons / Day	2045 Million Gallons / Day	2050 Million Gallons / Day	2060 Million Gallons / Day
LWSP	Ramseur Withdrawal	0.514	0.616	0.640	0.664	0.688	0.712	0.749
LWSP	Ramseur Return Flow	0.176	0.211	0.220	0.228	0.236	0.244	0.257
LWSP	Graham-Mebane Withdrawal	4.390	5.758	6.410	7.061	7.699	8.336	9.511
LWSP	Graham-Mebane Return Flow	3.393	4.451	4.955	5.458	5.951	6.444	7.352
LWSP	Siler City Withdrawal	1.613	1.724	1.783	1.841	1.909	1.977	2.121
LWSP	Siler City Return Flow	1.466	1.567	1.621	1.674	1.736	1.797	1.928
LWSP	Pittsboro Withdrawal	3.300	7.800	8.900	10.100	10.400	10.800	11.800
LWSP	Pittsboro Return Flow	1.053	2.488	2.839	3.222	3.318	3.445	3.764
LWSP	Orange Water and Sewer Authority Withdrawal	8.320	9.680	10.235	10.790	11.325	11.860	12.910
LWSP	OWASA Return Flow	7.946	9.244	9.774	10.304	10.815	11.326	12.329
LWSP	Cary Apex Combined Withdrawal	28.940	36.980	40.820	43.920	45.820	47.520	48.330
LWSP	Cary Apex Combined Return Flow	18.701	23.896	26.378	28.381	29.609	30.707	31.231
LWSP	Chatham County North Water System Withdrawal	5.290	8.330	10.130	11.920	13.300	14.140	18.120
WWR	Performance Fibers/Allied Signal	0.201	0.201	0.201	0.201	0.201	0.201	0.201
WWR	Cape Fear Steam Plant (return > withdrawal)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LWSP	Sanford Withdrawal	8.022	11.191	13.029	14.866	17.428	19.989	24.175
LWSP	Sanford Return Flow	5.774	8.074	9.408	10.742	12.600	14.458	17.496
LWSP	Broadway Return Flow	0.078	0.093	0.100	0.106	0.114	0.121	0.138
WWR	Harris Nuclear Station Withdrawal	20.000	20.000	20.000	20.000	20.000	20.000	20.000
WWR	Harris Nuclear Station Return Flow	12.317	12.317	12.317	12.317	12.317	12.317	12.317
LWSP	Harnett County RWS Withdrawal	21.405	27.005	29.573	32.142	34.963	37.784	43.171
LWSP	Harnett County RWS Return Flow	7.611	9.940	11.071	12.201	13.473	14.746	17.128
LWSP	Holly Springs Return Flow	3.625	4.620	5.033	5.445	5.850	6.254	7.089
LWSP	Robbins Withdrawal	0.263	0.285	0.289	0.292	0.300	0.308	0.366
LWSP	Star Return Flow	0.050	0.050	0.050	0.050	0.050	0.050	0.050
WWR	Pilgrims Pride Withdrawal	0.884	0.884	0.884	0.884	0.884	0.884	0.884
WWR	Pilgrim's Pride Return Flow	0.039	0.039	0.039	0.039	0.039	0.039	0.039
LWSP	Dunn Withdrawal	2.930	2.989	3.013	3.037	3.072	3.108	3.328
LWSP	Dunn Return Flow	1.059	1.072	1.078	1.084	1.090	1.096	1.109
LWSP	Carolina Trace Return Flow	0.186	0.186	0.186	0.186	0.186	0.186	0.186
LWSP	Carthage Withdrawal	0.499	0.533	0.543	0.553	0.554	0.554	1.272
LWSP	Spring Lake Return Flow	0.923	0.980	1.044	1.108	1.177	1.245	1.374

Projected Withdrawals and Return Flows
Cape Fear - Neuse River Basin Hydrologic Model

Data Source	Withdrawer or Discharger	2020 Million Gallons / Day	2030 Million Gallons / Day	2035 Million Gallons / Day	2040 Million Gallons / Day	2045 Million Gallons / Day	2050 Million Gallons / Day	2060 Million Gallons / Day
LWSP	Fayetteville PWC Withdrawal	37.883	49.033	54.777	60.520	65.045	69.570	78.300
LWSP	Fayetteville PWC Return Flow	33.824	44.663	50.183	55.704	60.019	64.335	72.766
LWSP	Raeford Return Flow	2.488	2.535	2.565	2.594	2.630	2.665	2.735
WWR	DuPont Withdrawal	11.170	11.170	11.170	11.170	11.170	11.170	11.170
WWR	DuPont Return Flow	11.170	11.170	11.170	11.170	11.170	11.170	11.170
LWSP	LCFWSA-Bladen Bluffs Withdrawal	2.252	2.252	2.252	2.252	2.252	2.252	2.252
WWR	Smithfield Packing - Tar Heel Division Return Flow	2.252	2.252	2.252	2.252	2.252	2.252	2.252
LWSP	Cape Fear Public Utility Authority Withdrawal	14.156	16.278	17.498	18.719	20.122	21.526	26.023
LWSP	Lower Cape Fear WSA - Kings Bluff Withdrawal	16.814	18.653	19.207	19.761	20.790	21.820	24.133
LWSP	Franklinville Return Flow	0.042	0.044	0.045	0.045	0.046	0.046	0.047
LWSP	Elizabethtown Return Flow	0.407	0.515	0.557	0.599	0.659	0.720	0.720
LWSP	Orange-Alamance Eno River Withdrawal	0.211	0.218	0.220	0.223	0.226	0.230	0.235
LWSP	Orange-Alamance Return Flow	0.019	0.020	0.020	0.020	0.021	0.021	0.022
LWSP	Hillsborough Withdrawal	2.320	2.700	2.870	3.040	3.220	3.390	3.700
LWSP	Hillsborough Return Flow	1.494	1.739	1.849	1.958	2.074	2.184	2.383
LWSP	Piedmont Minerals	0.000	0.000		0.000		0.000	0.000
LWSP	Durham Withdrawal	30.700	34.100	36.100	38.100	40.000	41.900	44.400
LWSP	Durham Return Flow	25.609	28.445	30.113	31.782	33.367	34.952	37.037
LWSP	South Granville WSA Withdrawal	3.230	3.652	3.879	4.105	4.346	4.586	4.956
LWSP	South Granville WSA Return Flow	2.016	2.279	2.420	2.562	2.712	2.862	3.093
LWSP	Raleigh Withdrawal	64.400	78.200	84.800	91.300	97.000	102.650	115.000
LWSP	Raleigh Return Flow	57.429	69.735	75.620	81.417	86.500	91.538	102.551
WWR	Riverplace II LLC Return Flow	0.100	0.100	0.100	0.100	0.100	0.100	0.100
LWSP	Motiva Enterprises Return Flow	0.170	0.170	0.170	0.170	0.170	0.170	0.170
LWSP	Wilson Withdrawal	9.882	11.342	11.902	12.461	13.078	13.694	14.858
LWSP	Wilson Return Flow	8.556	9.820	10.305	10.789	11.323	11.857	12.865
LWSP	Stantonsburg Return Flow	0.141	0.152	0.156	0.159	0.163	0.166	0.173
LWSP	Maury Sanitary Land District Return Flow	0.054	0.056	0.058	0.059	0.062	0.065	0.067
LWSP	Farmville Return Flow	1.600	1.600	1.600	1.600	1.600	1.600	1.600
LWSP	Snow Hill Return Flow (groundwater source)	0.224	0.254	0.271	0.287	0.305	0.324	0.362
LWSP	Johnston County Withdrawal	9.534	11.758	13.105	14.452	16.128	17.804	21.729

Projected Withdrawals and Return Flows Cape Fear - Neuse River Basin Hydrologic Model								
Data Source	**Withdrawer or Discharger**	**2020 Million Gallons / Day**	**2030 Million Gallons / Day**	**2035 Million Gallons / Day**	**2040 Million Gallons / Day**	**2045 Million Gallons / Day**	**2050 Million Gallons / Day**	**2060 Million Gallons / Day**
LWSP	Johnston County Return Flow	2.447	3.018	3.364	3.709	4.140	4.570	5.577
LWSP	Smithfield Withdrawal	3.547	4.332	4.812	5.291	5.877	6.464	9.455
LWSP	Aqua NC - Hawthorne Return Flow	0.140	0.140	0.140	0.140	0.140	0.140	0.140
LWSP	Fuquay-Varina Return Flow	2.463	3.870	4.639	5.408	6.178	6.947	7.762
LWSP	Kenly Return Flow	0.453	0.559	0.622	0.686	0.766	0.846	1.032
LWSP	Princeton Return Flow	0.190	0.190	0.190	0.190	0.190	0.190	0.190
LWSP	Benson Return Flow	0.339	0.348	0.350	0.353	0.359	0.366	0.435
NPDES	Jerry G Williams Return Flow	0.140	0.140	0.140	0.140	0.140	0.140	0.140
CCPCUA	Lee Steam Station Withdrawal	8.077	8.077	8.077	8.077	8.077	8.077	8.077
LWSP	Goldsboro	6.914	11.452	12.340	13.228	14.253	15.277	17.644
LWSP	Goldsboro Return Flow	9.731	16.119	17.369	18.618	20.060	21.502	24.834
LWSP	Neuse Regional Water and Sewer Authority Withdrawal	9.230	11.274	11.762	12.250	12.796	13.341	13.954
LWSP	Neuse Regional Water and Sewer Authority Return Flow	0.631	0.770	0.804	0.837	0.874	0.912	0.954
LWSP	Kinston Return Flow	5.807	7.093	7.400	7.707	8.051	8.394	8.779
LWSP	Ayden-Grifton Return Flow	1.597	1.950	2.035	2.119	2.214	2.308	2.414
WWR	Weyerhaeuser Withdrawal	14.471	14.471	14.471	14.471	14.471	14.471	14.471
WWR	Weyerhaeuser Return Flow	14.080	14.080	14.080	14.080	14.080	14.080	14.080

9) inflow data

Inflow records are developed using USGS stream gage data adjusted for historical withdrawals, discharges, and changes in reservoir storage. The following tables list the stream flow gages used to create the model inflows.

List of Gages for Cape Fear Basin	
USGS Number	**Description**
2094500	**Reedy Fork nr. Gibsonville**
2096500	**Haw R. at Haw R.**
2097000	**Haw R. nr. Pittsboro**
2098000	**New Hope R. nr. Pittsboro**
2099000	**Deep R. nr. High Point**

List of Gages for Cape Fear Basin	
USGS Number	**Description**
2099500	**Deep R. nr. Randleman**
2100500	**Deep R. at Ramseur**
2102000	**Deep R. at Moncure**
2102192	**Buckhorn Ck nr. Corinth**
2102500	**Cape Fear R. at Lillington**
2105500	**Cape Fear at Huske Lk nr. Tarheel**
2105769	**Cape Fear R. at Lock 1 nr. Kelly**

List of Gages for Neuse Basin	
USGS Number	**Description**
2085000	**Eno R. at Hillsborough**
2085070	**Eno R. nr. Durham**
2087000	**Neuse R. nr. Northside**
2087183	**Neuse R. nr. Falls**
2087500	**Neuse R. nr. Clayton**
2088000	**Middle Ck. nr. Clayton**
2088500	**Little R. nr. Princeton**
2089000	**Neuse R. nr. Goldsboro**
2089500	**Neuse R. at Kinston**
2091500	**Contentnea Ck. nr. Hookerton**

10) local water supply plans

Local water supply plans from the systems in the following table were used as the data source for identifying historical, current, and projected water supply sources, demands, and discharges. (The table in item 8) summarizes the local water supply plan information. Smaller system's demands may be aggregated as part of a larger water system's demand in the modeled systems in item 8).)

Local water supply systems used to develop the Cape Fear/Neuse River Basin Hydrologic Model		
ID #	**Name**	**Groundwater systems with surface water discharge**
02-01-035	Alamance	
03-43-015	Angier	
03-92-045	Apex	
03-63-114	Aqua NC - Woodlake	
02-76-030	Archdale	
02-76-010	Asheboro	
04-74-025	Ayden	
04-64-035	Bailey	*
04-10-130	Bald Head Island Utilities Dept.	
03-92-373	Aqua NC - Bayleaf Master	*
04-74-045	Bell Arthur WC	
03-51-025	Benson	
04-98-035	Black Creek	*
50-43-001	Bragg Communities/NTA Water System	
03-53-015	Broadway	
04-10-045	Brunswick County	
04-10-070	Brunswick Regional WSD	
02-01-010	Burlington	
03-63-040	Cameron	
03-43-030	Campbell University	
04-65-010	Cape Fear Public Utility Authority - Wilmington	
03-53-101	Carolina Trace WS	
03-63-025	Carthage Withdrawal	
03-92-020	Cary	
04-10-055	Caswell Beach	
40-19-010	Chatham County Asbury	
03-19-126	Chatham County North Water System	
03-19-050	Chatham County SW	
03-51-020	Clayton	

Local water supply systems used to develop the Cape Fear/Neuse River Basin Hydrologic Model		
ID #	**Name**	**Groundwater systems with surface water discharge**
03-43-020	Coats	
02-39-015	Creedmoor	
02-29-025	Davidson Water Inc	
04-54-030	Deep Run WC	
03-43-010	Dunn	
03-32-010	Durham	
50-63-011	East Moore Water District	
04-74-015	Eastern Pines Water Corporation	
50-26-027	Eastover SD	
03-09-010	Elizabethtown	
04-98-020	Elm City	
02-01-025	Elon	
03-26-035	Falcon	
04-74-020	Farmville	*
03-26-010	Fayetteville PWC	
03-51-195	Flowers Plantation	
04-96-060	Fork Township SD	*
03-51-035	Four Oaks	
02-76-035	Franklinville	
04-96-025	Fremont	*
03-92-055	Fuquay-Varina	
02-41-025	Gibsonville	
03-26-050	Godwin	
04-96-010	Goldsboro	
03-19-025	Goldston Gulf SD	
02-01-015	Graham	
02-01-030	Green Level	
02-41-010	Greensboro	
04-74-035	Grifton	
03-43-045	Harnett County Regional Water System	
02-01-020	Haw River	
02-41-020	High Point	
03-68-015	Hillsborough	
03-47-025	Hoke RWS	
03-92-050	Holly Springs	

Local water supply systems used to develop the Cape Fear/Neuse River Basin Hydrologic Model		
ID #	**Name**	**Groundwater systems with surface water discharge**
02-41-030	Jamestown	
03-51-070	Johnston County	
03-51-030	Kenly	
04-54-010	Kinston	
50-09-013	LCFWSA - Kings Bluff	
50-09-012	LCFWSA_Bladen Bluffs	
70-10-058	Leland	
02-76-025	Liberty	*
03-43-025	Lillington	
03-26-045	Linden	
04-98-030	Lucama	*
04-40-015	Maury Sanitary Land District	
02-01-018	Mebane	
40-51-008	Micro (County Line)	
04-64-050	Middlesex	*
50-63-021	Moore County Public Utilities-High Falls	
03-63-103	Moore County Public Utilities-Hyland Hills	
03-63-108	Moore County Public Utilities-Pinehurst	
03-63-155	Moore County Public Utilities-Robbins	
03-63-117	Moore County Public Utilities-Seven Lakes	
03-63-045	Moore County Public Utilities-Vass	
04-10-065	Navassa	
60-54-001	Neuse Regional Water and Sewer Authority	
04-54-025	North Lenoir Water Corp.	
70-10-045	Northwest	
04-10-020	Oak Island	
04-10-035	Ocean Isle Beach	
50-26-019	Old North Utility Services, Inc.	
03-68-010	Orange Water and Sewer Authority	
03-68-020	Orange-Alamance	
30-76-010	Piedmont Triad Regional Water Authority	
04-96-030	Pikeville	*
04-54-020	Pink Hill	
03-19-015	Pittsboro	
03-51-050	Princeton	

Local water supply systems used to develop the Cape Fear/Neuse River Basin Hydrologic Model		
ID #	**Name**	**Groundwater systems with surface water discharge**
03-47-010	Raeford	*
03-92-010	Raleigh	
02-76-020	Ramseur	
02-76-015	Randleman	
02-79-020	Reidsville	
03-63-015	Robbins	
02-79-050	Rockingham Co	
70-10-057	Sandy Creek	
03-53-010	Sanford	
04-98-040	Saratoga	*
04-10-025	Shallotte	
03-19-010	Siler City	
04-98-045	Sims	
03-51-010	Smithfield	
0429-0002	Smithfield Packing - Tar Heel Division	
04-40-010	Snow Hill	*
02-39-107	South Granville Water and Sewer Authority	
04-96-045	Southern Wayne SD	*
04-10-010	Southport	
03-26-020	Spring Lake	
04-98-025	Stantonsburg	
03-62-025	Star	
03-26-030	Stedman	
30-01-005	Swepsonville	
04-96-155	Walnut Creek	*
04-96-065	Wayne WD	*
03-63-112	Whispering Pines	
04-98-010	Wilson	
04-98-010	Wilson	
40-98-014	Wilson County SEWD	*
40-98-012	Wilson County SWWD	*
40-39-004	Wilton Water and Sewer	
02-34-010	Winston-Salem	
04-74-040	Winterville	*

11) other scientific and technical information the Department deems relevant

The two key additional technical add-ons are inclusion of the drought plans (water shortage response plans for water systems and low inflow protocols for hydropower projects) and conditional streamflow forecasts. Conditional forecasts are generated based on a function built into the OASIS model. The following table is a summary of the drought plans included in the model.

Water Shortage Response Plan Summary for Major Water Systems	
Water System	**Source**
Clayton	Johnston County
Durham	Little River Reservoir + Lake Michie
Goldsboro	Neuse River
Hillsborough (ENO MP)	Lake Orange + West Fork Eno Reservoir
Orange Alamance (ENO MP)	Lake Orange
Johnston County	Neuse River
Kenly	Johnston County
Kinston	Neuse River
Princeton	Johnston County
Raleigh	Falls Lake
Smithfield	Neuse River
SGWASA	Lake Butner/Holt
Wilson	Buckhorn Reservoir
Burlington	Mackintosh & Old Stoney Cr Reservoirs
Greensboro	Lakes Townsend/Higgins/Brandt
High Point	High Point Reservoir
Reidsville	Reidsville Reservoir
Ramseur	Ramseur Reservoir
Graham Mebane	Graham Mebane Reservoir
Siler City	Siler City Reservoirs
Pittsboro	Haw River
Cary - Apex - RTP- Morrisville	Jordan Lake
Chatham North	Jordan Lake
Sanford	Deep River
Harnett Co	Cape Fear
Dunn	Cape Fear
Holly Springs	Jordan Lake/Harnett Co

Water Shortage Response Plan Summary for Major Water Systems	
Water System	**Source**
Carthage	Little River
Fayetteville	Cape Fear River & Glenville Lake

(o)(3) Model. - Each basinwide hydrologic model shall:

b. Be designed to simulate the flows of each surface water resource within the basin that is identified as a source of water for a withdrawal registered under G.S. 143-215.22H in response to different variables, conditions, and scenarios. The model shall specifically be designed to predict the places, times, frequencies, and intervals at which any of the following may occur:

1. Yield may be inadequate to meet all needs.
2. Yield may be inadequate to meet all essential water uses.
3. Ecological flow may be adversely affected.

Demonstration that the model is capable of simulating flows and predicting adequacy and adverse effects is accomplished through validation. Validation is an evaluation of model performance, i.e., whether the model possesses a satisfactory range of accuracy consistent with its intended application. Validation refers to the processes and techniques that are used to assure that the model represents the real system to a sufficient level of accuracy. Validation compares simulated system output with real system observations. Validation is evaluated through qualitative and quantitative measures, involving both graphical comparisons and statistical tests.

The model is designed to show variations in flow that occur because of changes in water use. The model output can be used to determine the times, frequencies, and intervals of flow changes that exceed a threshold. The model output also provides information that can be used to estimate the magnitude of any water supply shortages.

Statistical test results and graphical comparisons for the Cape Fear/Neuse River Basin Hydrologic Model are provided in the following table and figures.

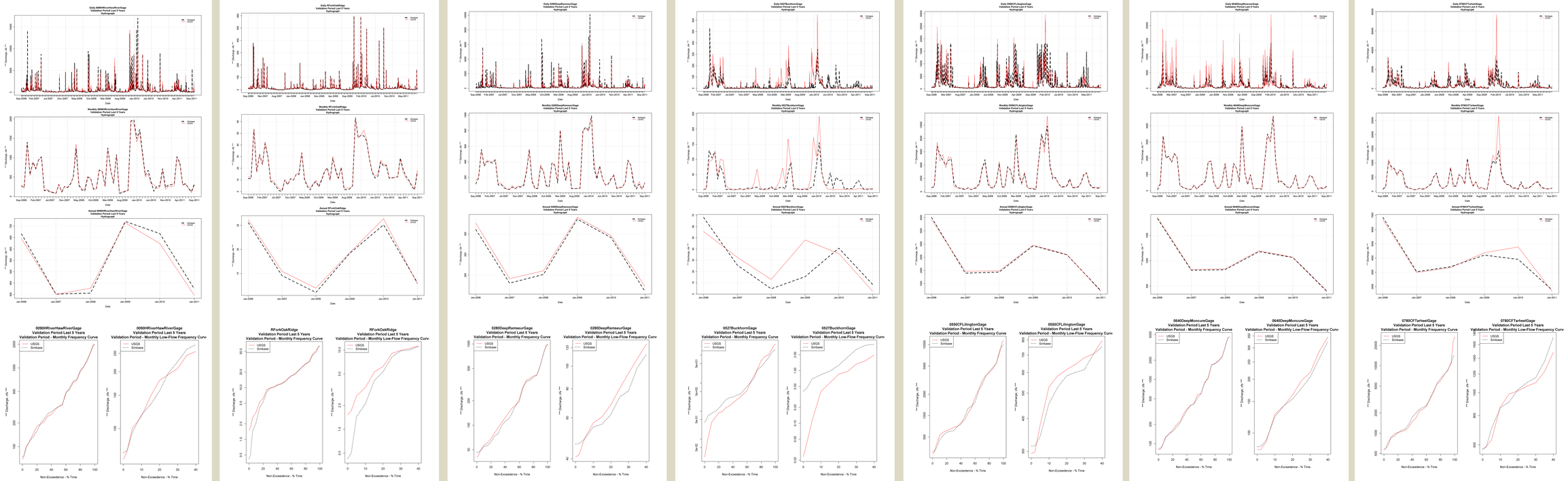
Goodness-Of-Fit Statistics Summary Table - CF-Neuse River Basin Gage Flow						
Gages/Location	GOF Results			Drought Period, Days		
	Monthly					
	NSE > 0.5	RSR ≤ 0.70	PBIAS ≤ ± 25%	Data	Total	% Difference ≤ ± 25%
0090 Haw River at Haw River Gage	0.9905	0.0968	1.8	USGS	557	
	Satisfactory	Satisfactory	Satisfactory	Simbase	633	13.64%
0110 RFork Oak Ridge Gage	0.9917	0.0903	-3.6	USGS	724	

Goodness-Of-Fit Statistics
Summary Table - CF-Neuse River Basin Gage Flow

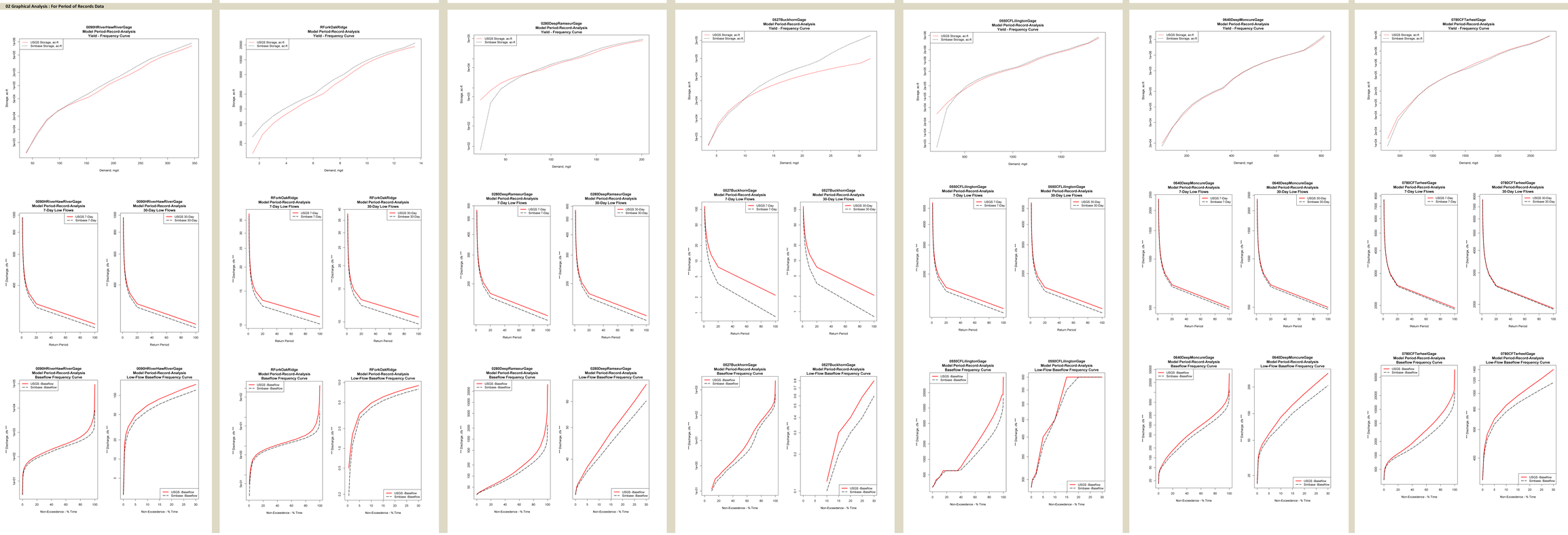
Gages/Location	GOF Results			Drought Period, Days		
	Monthly					
	NSE > 0.5	RSR ≤ 0.70	PBIAS ≤ ± 25%	Data	Total	% Difference ≤ ± 25%
	Satisfactory	Satisfactory	Satisfactory	Simbase	761	5.11%
0145 R Fork at Gibsonville Gage	0.925	0.2715	-6.3	USGS	995	
	Satisfactory	Satisfactory	Satisfactory	Simbase	777	-21.91%
0170 North Buffalo Creek Gage	0.9416	0.2396	8.7	USGS	870	
	Satisfactory	Satisfactory	Satisfactory	Simbase	0	-100.00%
0280 Deep River at Ramseur Gage	0.9942	0.0755	-3.2	USGS	422	
	Satisfactory	Satisfactory	Satisfactory	Simbase	606	43.60%
0400 Haw Eiver at Bynum Gage	0.9946	0.073	4.4	USGS	595	
	Satisfactory	Satisfactory	Satisfactory	Simbase	521	-12.44%
0527 Buckhorn Creek Gage	0.5603	0.6576	-23.7	USGS	777	
	Satisfactory	Satisfactory	Satisfactory	Simbase	754	-2.96%
0550 Cape Fear at Lilington Gage	0.9693	0.1738	-1.2	USGS	631	
	Satisfactory	Satisfactory	Satisfactory	Simbase	944	49.60%
0640 Deep River at Moncure Gage	0.9995	0.0216	-1.5	USGS	606	
	Satisfactory	Satisfactory	Satisfactory	Simbase	578	-4.62%
0780 Cape Fear at Tarheel Gage	0.8542	0.3787	-4.7	USGS	728	
	Satisfactory	Satisfactory	Satisfactory	Simbase	728	0.00%
1110 Eno Hillsborough Gage	0.9898	0.1	-0.7	USGS	756	
	Satisfactory	Satisfactory	Satisfactory	Simbase	512	-32.28%
1115 Eno Durham Gage	0.9978	0.0466	-0.7	USGS	600	
	Satisfactory	Satisfactory	Satisfactory	Simbase	536	-10.67%
1480 Middle Creek Gage	0.9984	0.0399	-0.3	USGS	392	
	Satisfactory	Satisfactory	Satisfactory	Simbase	425	8.42%
1560 Hookerton Gage	0.9749	0.157	11.1	USGS	603	
	Satisfactory	Satisfactory	Satisfactory	Simbase	582	-3.48%
1630 Neuse R Clayton Gage	0.8635	0.3664	1.4	USGS	459	
	Satisfactory	Satisfactory	Satisfactory	Simbase	158	-65.58%
1660 Neuse R Smithfield Gage	0.9254	0.2709	-13	USGS	200	

Goodness-Of-Fit Statistics Summary Table - CF-Neuse River Basin Gage Flow						
Gages/Location	GOF Results			Drought Period, Days		
	Monthly					
	NSE > 0.5	RSR ≤ 0.70	PBIAS ≤ ± 25%	Data	Total	% Difference ≤ ± 25%
	Satisfactory	Satisfactory	Satisfactory	Simbase	159	-20.50%
1750 Neuse R Princeton Gage	0.9972	0.0525	0.3	USGS	670	
	Satisfactory	Satisfactory	Satisfactory	Simbase	661	-1.34%
1780 Neuse R Goldsboro Gage	0.9824	0.1317	-0.7	USGS	532	
	Satisfactory	Satisfactory	Satisfactory	Simbase	559	5.08%
1800 Neuse R Kinston Gage	0.9805	0.1386	-1.2	USGS	492	
	Satisfactory	Satisfactory	Satisfactory	Simbase	574	16.67%

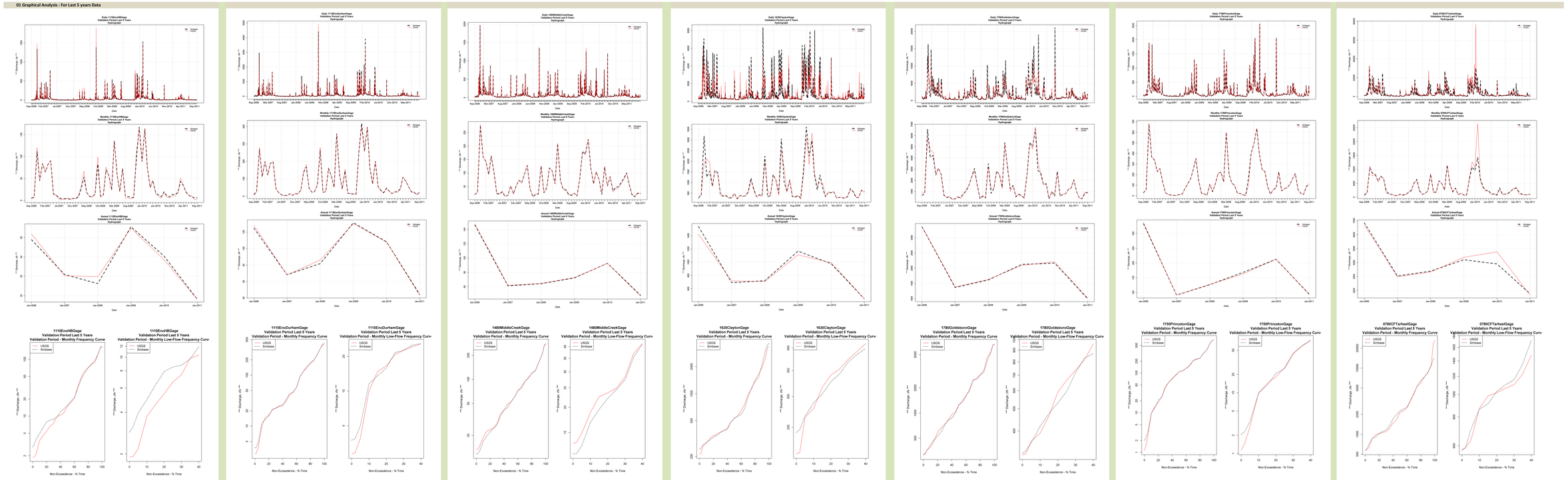
01 Graphical Analysis : For Last 5 years Data



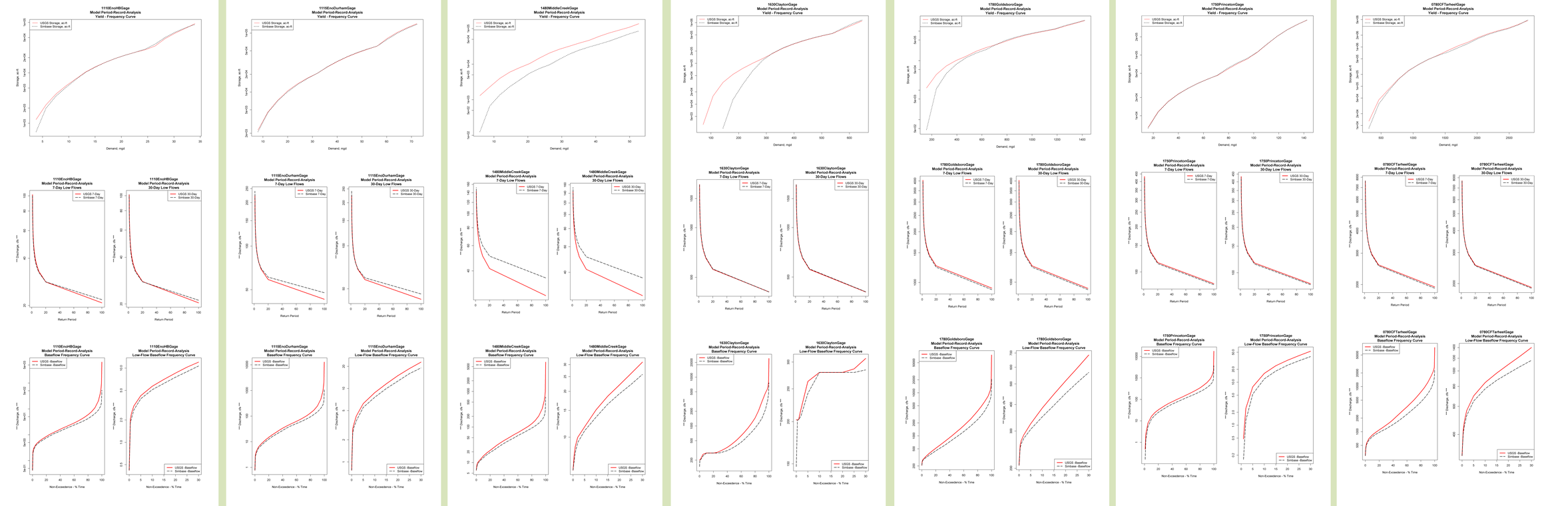
02 Graphical Analysis : For Period of Records Data



01 Graphical Analysis : For Last 5 years Data



02 Graphical Analysis : For Period of Records Data



(o)(3) Model. - Each basinwide hydrologic model shall:
c. Be based solely on data that is of public record and open to public review and comment.

Flow records used in modeling are from streamflow data collected by the U.S. Geological Survey at gaging stations throughout the basin. The withdrawal and discharge information is from various DWR databases such as the local water supply plan, withdrawal registration and NPDES. All of these databases are publicly available. For example, future demand scenarios were derived from data submitted by local government water systems and other large community water systems as part of their local water supply plans.

During the model building process, DWR held two public meetings. The main objective of these meetings was to seek and solicit additional input from the local water systems and the public in an effort to enhance the modeling process. The involvement of the local water systems ensured that the model was based on the most accurate data regarding withdrawals and discharges in the basin.

In February 2014, the division published a public notice recommending that the Environmental Management Commission consider approval of the Cape Fear/Neuse River Basin Hydrologic Model. This notice provided a 60-day public comment period, which ended on April 21, 2014.

The model, modeling report, and supplemental information are available on DWR's website. Anyone may obtain an account to run the model through an email or phone request.

(o)(5) Interstate cooperation. - To the extent practicable, the Department shall work with neighboring states to develop basinwide hydrologic models for each river basin shared by North Carolina and another state.

Not applicable.

(o)(6) Approval and modification of hydrologic models. -
a. Upon completion of a hydrologic model, the Department shall:
1. Submit the model to the Commission for approval.
2. Publish in the North Carolina Register notice of its recommendation that the Commission approve the model and of a 60-day period for providing comment on the model.
3. Provide electronic notice to persons who have requested electronic notice of the notice published in the North Carolina Register.
b. Upon receipt of a hydrologic model, the Commission shall:
1. Receive comment on the model for the 60-day period noticed in the North Carolina Register.
2. Act on the model following the 60-day comment period.

All of these requirements will be met when the Commission acts on the model.

(o)(6) d. A hydrologic model is not a rule, and Article 2A of Chapter 150B of the General Statutes does not apply to the development of a hydrologic model.

The model is not a rule.

(o)(8) Construction of subsection. - Nothing in this subsection shall be construed to vary any existing, or impose any additional regulatory requirements, related to water quality or water resources.

The model is for planning purposes only, and will not be used to regulate water quantity or quality.

Staff Recommendation

Based on compliance with N.C. G.S. 143-355(o), public comment, and staff certification of the model, the division recommends that the EMC approve the Cape Fear/Neuse River basin hydrologic model.

APPENDIX - NC S.L. 2010-143

GENERAL ASSEMBLY OF NORTH CAROLINA
SESSION 2009

SESSION LAW 2010-143
HOUSE BILL 1743

AN ACT TO DIRECT THE DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES TO DEVELOP BASINWIDE HYDROLOGIC MODELS, AS RECOMMENDED BY THE ENVIRONMENTAL REVIEW COMMISSION.

The General Assembly of North Carolina enacts:

SECTION 1. G.S. 143-350 reads as rewritten:

"**§ 143-350. Definitions.**

As used in this Article:

…

(3) "Essential water use" means the use of water necessary for firefighting, health, and safety; water needed to sustain human and animal life; and water necessary to satisfy federal, State, and local laws for the protection of public health, safety, welfare, the environment, and natural resources; and a minimum amount of water necessary to ~~maintain~~ support and sustain the economy of the State, region, or area.

…."

SECTION 2. G.S. 143-355 is amended by adding a new subsection to read:

"(o) Basinwide Hydrologic Models. - The Department shall develop a basinwide hydrologic model for each of the 17 major river basins in the State as provided in this subsection.

(1) Definitions. - As used in this subsection:

a. "Ecological flow" means the stream flow necessary to protect ecological integrity.

b. "Ecological integrity" means the ability of an aquatic system to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to prevailing ecological conditions and, when subject to disruption, to recover and continue to provide the natural goods and services that normally accrue from the system.

c. "Groundwater resource" means any water flowing or lying under the surface of the earth or contained within an aquifer.

d. "Prevailing ecological conditions" means the ecological conditions determined by reference to the applicable period of record of the United States Geological Survey stream gauge data, including data reflecting the ecological conditions that exist after the construction and operation of existing flow modification devices, such as dams, but excluding data collected when stream flow is temporarily affected by in-stream construction activity.

e. "Surface water resource" means any lake, pond, river, stream, creek, run, spring, or other water flowing or lying on the surface of the earth.

(2) Schedule. - The Department shall develop a schedule for basinwide hydrologic model development. In developing the schedule, the Department shall give priority to developing hydrologic models for river basins or portions of river basins that are experiencing or are likely to experience water supply shortages, where the ecological integrity is threatened or likely to become threatened, or for which an existing hydrologic model has not been developed by the Department or other persons or entities.

(3) Model. - Each basinwide hydrologic model shall:

a. Include surface water resources within the river basin, groundwater resources within the river basin to the extent known by the Department, transfers into and out of the river basin that are required to be registered under G.S. 143-215.22H, other withdrawals, ecological flow, instream flow requirements, projections of future withdrawals, an estimate of return flows within the river basin, inflow data, local water supply plans, and other scientific and technical information the Department deems relevant.

b. Be designed to simulate the flows of each surface water resource within the basin that is identified as a source of water for a withdrawal registered under G.S. 143-215.22H in response to different variables, conditions, and scenarios. The model shall specifically be designed to predict the places, times, frequencies, and intervals at which any of the following may occur:

1. Yield may be inadequate to meet all needs.
2. Yield may be inadequate to meet all essential water uses.
3. Ecological flow may be adversely affected.

c. Be based solely on data that is of public record and open to public review and comment.

(4) Ecological flow. - The Department shall characterize the ecology in the different river basins and identify the flow necessary to maintain ecological integrity. The Department shall create a Science Advisory Board to assist the Department in characterizing the natural ecology and identifying the flow requirements. The Science Advisory Board shall include representatives from the Divisions of Water Resources and Water Quality of the Department, the North Carolina Wildlife Resources Commission, the North Carolina Marine Fisheries Commission, and the Natural Heritage Program. The Department shall also invite participation by the United States Fish and Wildlife Service; the National Marine Fisheries Service; representatives of organizations representing agriculture, forestry, manufacturing, electric public utilities, and local governments, with expertise in aquatic ecology and habitat; and other individuals or organizations with expertise in aquatic ecology and habitat. The Department shall ask the Science Advisory Board to review any report or study submitted to the Department for consideration that is relevant to characterizing the ecology of the different river basins and identifying flow requirements for maintenance of ecological integrity. The Department shall consider such other information, including site specific analyses, that either the Board or the Department considers relevant to determining ecological flow requirements.

(5) Interstate cooperation. - To the extent practicable, the Department shall work with neighboring states to develop basinwide hydrologic models for each river basin shared by North Carolina and another state.

(6) Approval and modification of hydrologic models. -

a. Upon completion of a hydrologic model, the Department shall:

1. Submit the model to the Commission for approval.
2. Publish in the North Carolina Register notice of its recommendation that the Commission approve the model and of a 60-day period for providing comment on the model.
3. Provide electronic notice to persons who have requested electronic notice of the notice published in the North Carolina Register.

b. Upon receipt of a hydrologic model, the Commission shall:

1. Receive comment on the model for the 60-day period noticed in the North Carolina Register.
2. Act on the model following the 60-day comment period.

c. The Department shall submit any significant modification to an approved hydrologic model to the Commission for review and approval under the process used for initial approval of the model.

d. A hydrologic model is not a rule, and Article 2A of Chapter 150B of the General Statutes does not apply to the development of a hydrologic model.

(7) Existing hydrologic models. - The Department shall not develop a hydrologic model for a river basin for which a hydrologic model has already been developed by a person or entity other than the Department, if the Department determines that the hydrologic model meets the requirements of this subsection. The Department may adopt a hydrologic model that has been developed by another person or entity that meets the requirements of this subsection in lieu of developing a hydrologic model as required by this subsection. The Department may make any modifications or additions to a hydrologic model developed by another person or entity that are necessary to meet the requirements of this subsection.

(8) Construction of subsection. - Nothing in this subsection shall be construed to vary any existing, or impose any additional regulatory requirements, related to water quality or water resources.

(9) Report. - The Department shall report to the Environmental Review Commission on the development of basinwide hydrologic models no later than November 1, of each year."

SECTION 3. The first report required by G.S. 143-355(o), as enacted by Section 2 of this act, is due no later than November 1, 2011.

SECTION 4. This act is effective when it becomes law.

In the General Assembly read three times and ratified this the 8th day of July, 2010.

s/ Walter H. Dalton
President of the Senate
s/ Joe Hackney
Speaker of the House of Representatives
s/ Beverly E. Perdue
Governor
Approved 1:52 p.m. this 22nd day of July, 2010