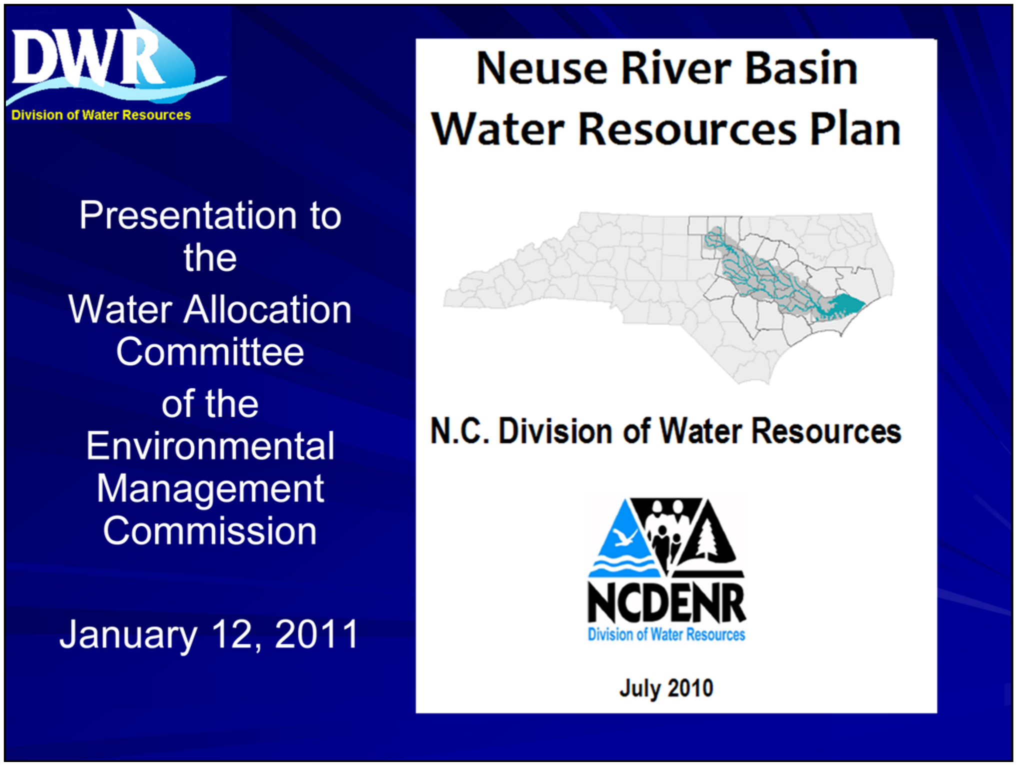
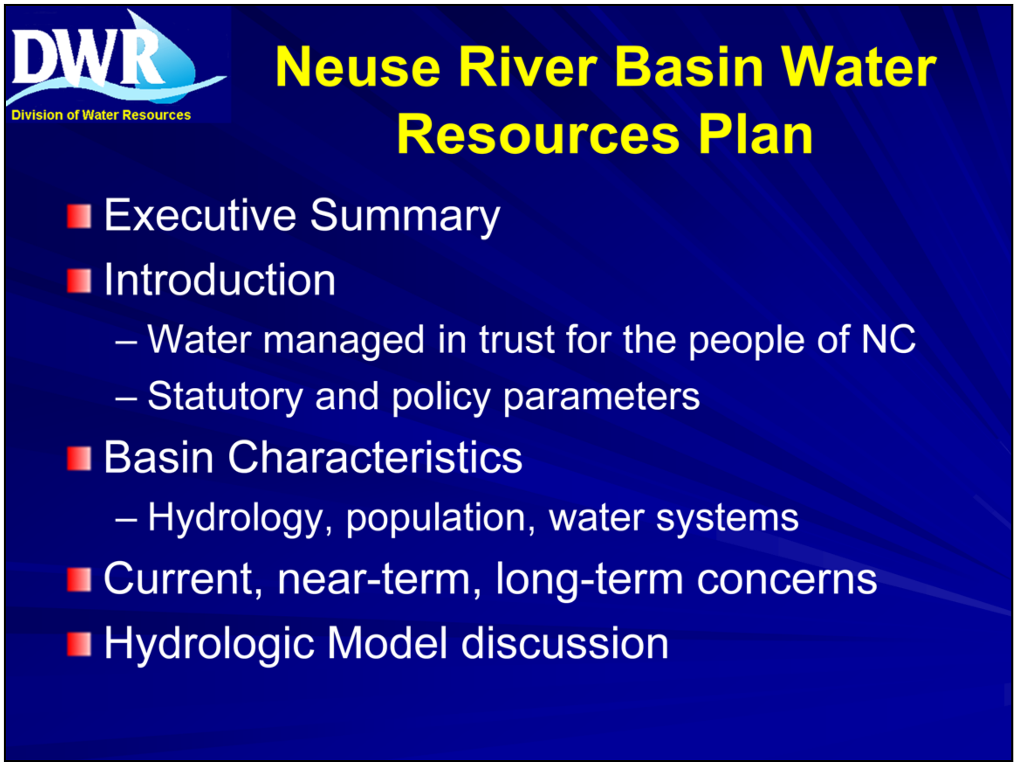


In response to the impacts of drought conditions in the late 1980s the General Assembly mandated development of local water supply plans to be submitted by units of local government that supply drinking water to the public. The local plans were to provide an information basis for the development of a North Carolina Water Supply Plan (State Plan). The local water supply plans present a summary of current and future water supplies and demands. Collectively the local plans provide information for evaluating potential water supply conflicts. While developing the state plan the DWR staff realized that more specific information on water availability would be needed to conduct the analysis envisioned in the legislation. To fill this void, the Division began work on computer-based hydrologic models that could simulate water resource conditions and characterize natural variations in water availability. The most recent incarnation of this ongoing process is the Neuse River Basin Water Resources Plan.

This presentation will review the basic structure of the plan followed by a brief discussion of the modeling on which the plan is based and then results of this analysis as presented in the plan.



The Neuse River Basin Water Resources Plan is available on the Division of Water Resources website (www.ncwater.org).

The Division of Water Resources uses the same planning basin boundaries used by the Division of Water Quality for the Basinwide Water Quality Plans.

The structure of the plan is designed to present information in several levels of detail to meet the needs of a broad spectrum of the public and professional communities.

The Executive Summary provides a concise overview of the plan and the results of the analysis on which it is based.

Other chapters provide context to the water management paradigms and regulations that influence water resource management in NC, describe relevant characteristics of the basin and discuss in more detail the current and potential issues to be addressed by drinking water systems in the basin.

Chapter 5 provides a detailed discussion of the Neuse River Basin Hydrologic Model.

Chapter 6 presents detailed discussions of the water use, water sources used by drinking water systems, and potential water shortages for each of the hydrologic sub-units in the larger Neuse River Basin.

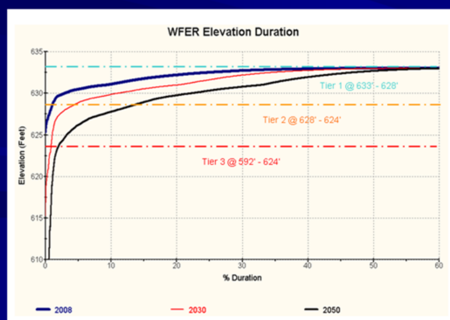
DWR

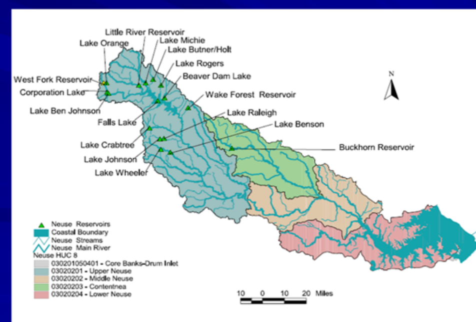
Division of Water Resources

Hydrologic unit discussions

- Water use
- Water supplies
- Management protocols affecting supply
- Impacts of withdrawals
- Potential drinking water shortages
- Surface water transfers

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





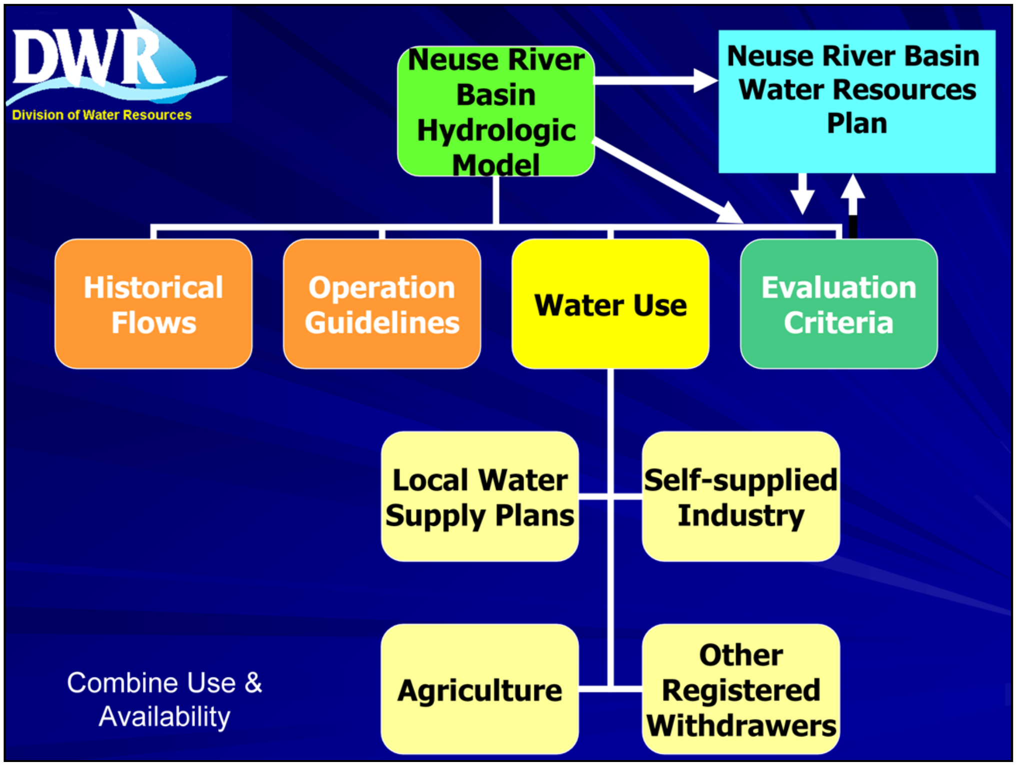
Each hydrologic sub-unit discussion covers similar information. The depth and complexity of the discussion depends on the specific features of each geographic area. The map in the lower right shows the delineation of the hydrologic sub-units used. These are based on the federally defined 8-digit hydrologic unit codes.

The Upper Neuse hydrologic unit is used primarily for examples in this presentation. The Upper Neuse area encompasses the drainage area of the Neuse River from the headwaters above Durham downstream to Goldsboro.

The table summarizes water users in this portion of the basin. The plan contains a similar table for each sub-unit in the basin. The graph shows one presentation of how the data derived from the model is presented to explain the implications of future water withdrawals. This particular graph shows how water levels may change in the West Fork Eno Reservoir compared to the basecase model scenario and the potential implications for drought response actions.

The final chapter of the plan discusses other water resource management activities underway in the basin.

For those interested in more in-depth knowledge of the data and analysis on which the plan is based detailed discussions of model development, model results and access to the model are available through the Division's website.

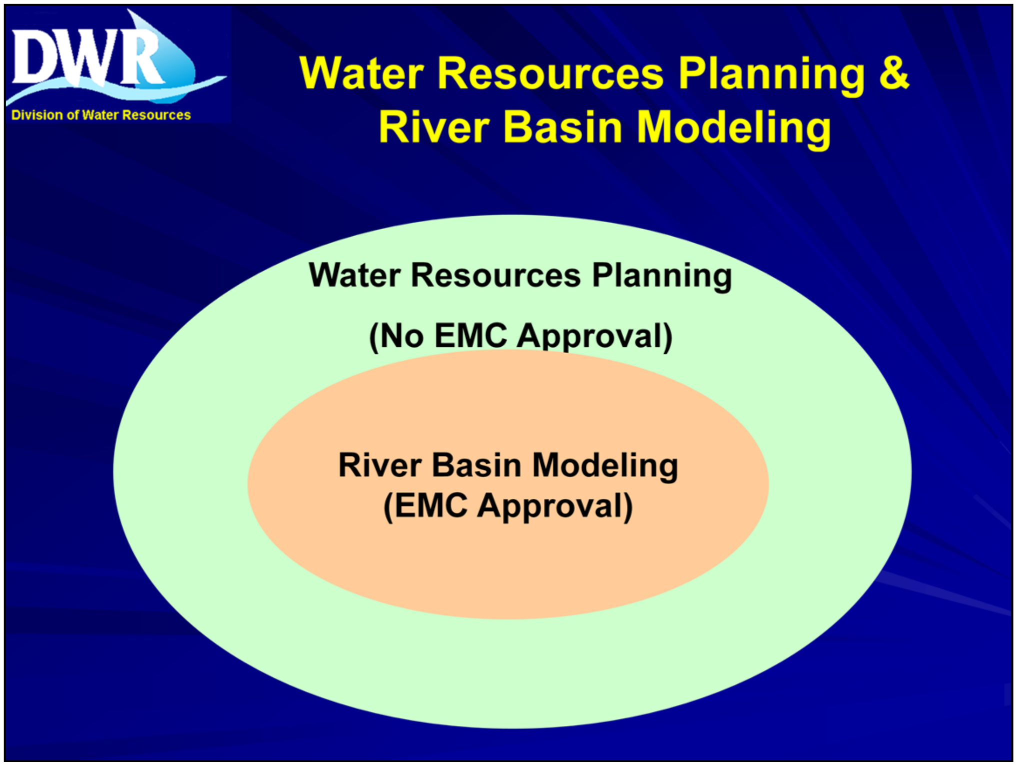


The development of river basin water resources plans depends on the ability to combine water use data from a variety of sources with data on historical hydrologic conditions and operation protocols that affect water movement. This is accomplished by using a computer-based mathematical model designed to simulate surface water movement in the Neuse Basin. During data collection and model development DWR staff meets with water users and other interested parties in the basin. This process allows us to identify issues that are important to basin residents and where possible to develop ways to evaluate these issues in the modeling and planning process.

Legislation passed last year requires that in the future the EMC must approve these basin models. So you can look forward to more detailed discussions of river basin hydrologic modeling in the near future. Today we'll touch on some model basics to show how hydrologic models contribute to the development of the river basin water resources plans.

The Neuse River Basin Hydrologic Model was developed using a computer program called OASIS with OCL™ developed by HydroLogics, Inc. It is specifically designed to model water resources.

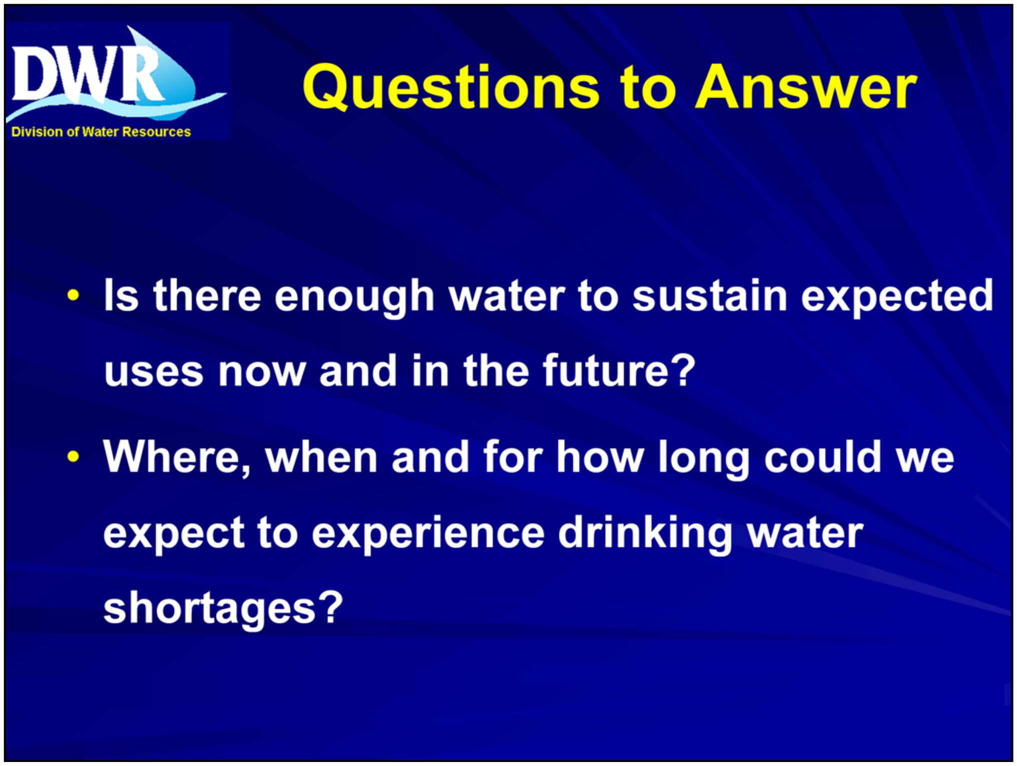
Historic flow data, operation guidelines, and water use data are combined using the program to develop a basin-specific model. The final model is constructed to produce the data necessary to address the evaluation criteria important for this basin.



A river basin hydrologic model is an essential tool to evaluate the cumulative impacts of a set of primarily independent decisions and expectations about water system growth given the water resources available in the basin.

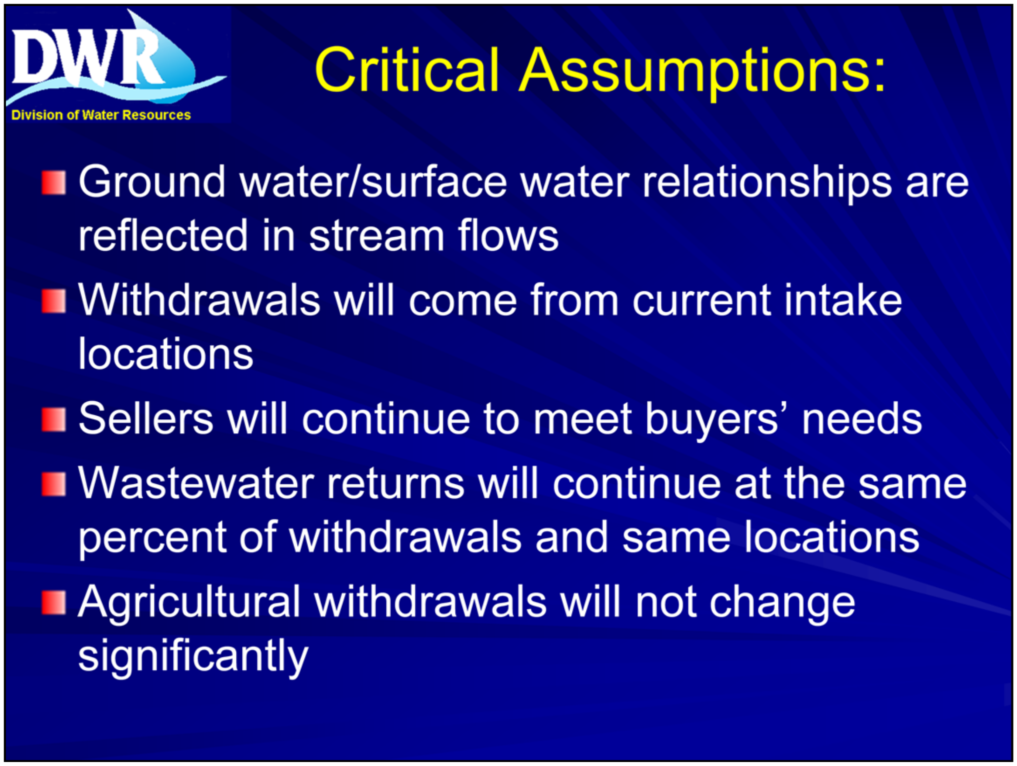
The plan presents an interpretation of the modeling results and the implications of these independent decisions on the water resources of the basin and for water withdrawers.

In the future the EMC will have the opportunity to review and approve river basin models.
However, unlike the Basinwide Water Quality Plans, EMC approval of the River Basin Water Resources Plans is not required.



The river basin planning approach has evolved from the Division's mandate to work with local government water systems for the sustainable use of water resources. To support this effort the basin planning process is targeted to provide the information necessary to answer some critical questions. The overarching concerns for this analysis are to determine if there is enough water available to meet demands. Additional evaluation criteria were established during model development to flesh out the impacts that may emerge in the future.

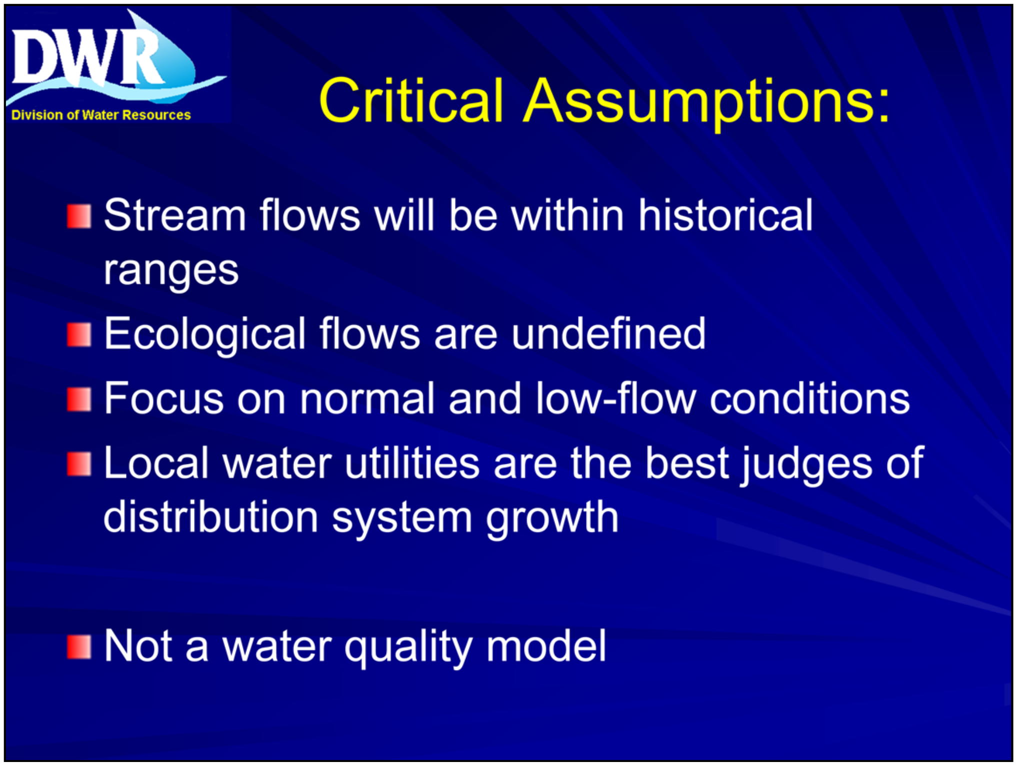
To answer these questions we must define where, when and how much water is currently being withdrawn in the basin and evaluate the possibility of being able to meet those levels of demand over the range of hydrologic conditions that have been experienced in the basin. This is followed by similar evaluations of the increased withdrawals expected to be needed to meet demands at points in the future.



It is important to understand the limitations of the current analysis and resulting plan. Conducting this type quantitative analysis with limited data necessitates making certain assumptions about how and where water is used.

Unless there is better information these assumptions were used in this analysis.

Ground water is not explicitly included in the model.



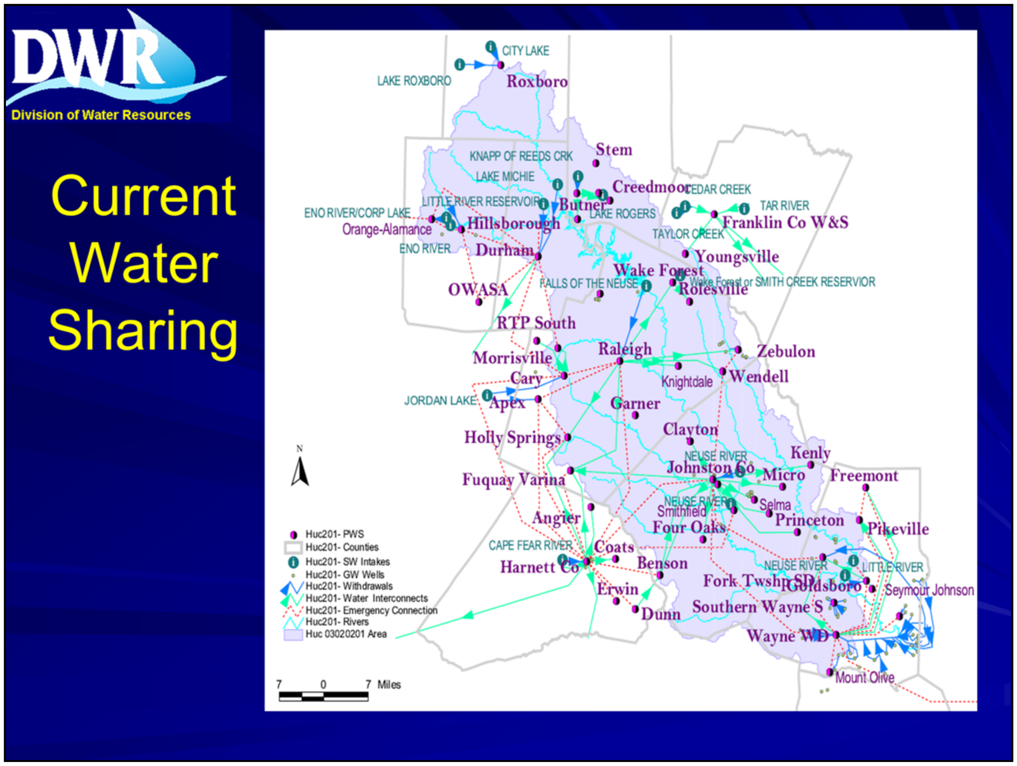
Water availability in the basin is characterized using a 78-year record of stream flows that includes dry, normal and very wet conditions including the recent record droughts. When the model is run the level of demands specified in the scenario is evaluated for each of the more than 28,000 days in that historical record.

This model and analysis does NOT currently include consideration of ecological flows. However, the model is designed to accommodate the addition of ecological flow evaluations in the future. A scientific advisory board has been established to develop recommendations for establishing ecological flow guidelines. This process is expected to take two to three years.

The model is not intended for flood studies. It is designed and calibrated to emphasize characterization of normal and low-flow conditions. Therefore, it is not intended for flood impact evaluations.

The level of water demand faced by each local water system is directly dependent on local decisions on treatment plant and distribution system development. Therefore local officials have the best understanding of how their local water system may expand. Their expectations are reflected in the information contained in the local water supply plans.

The basin model evaluates changes in water quantity in terms of flow or volume. It is NOT a water quality model. DWR and DWQ staff are exploring ways the two sets of plans can be coordinated.



Given that set of assumptions we collect the available data and begin to characterize the basin.

A key component of this process in identifying the current location and volume of surface water withdrawals.

To accurately represent the total demands at each withdrawal location water sharing arrangements are scrutinized to develop the best possible understanding of how communities are interconnected.

This image shows the networks of water sharing arrangements in the Upper Neuse basin.

Similar networks exist for wastewater collection and treatment. These are also studied to characterize where used water is returned to the surface waters of the basin.

DWR
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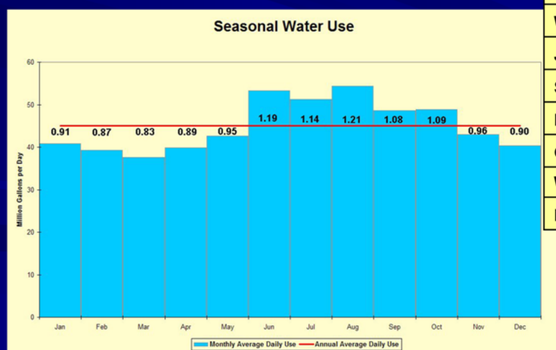
Current Water Use

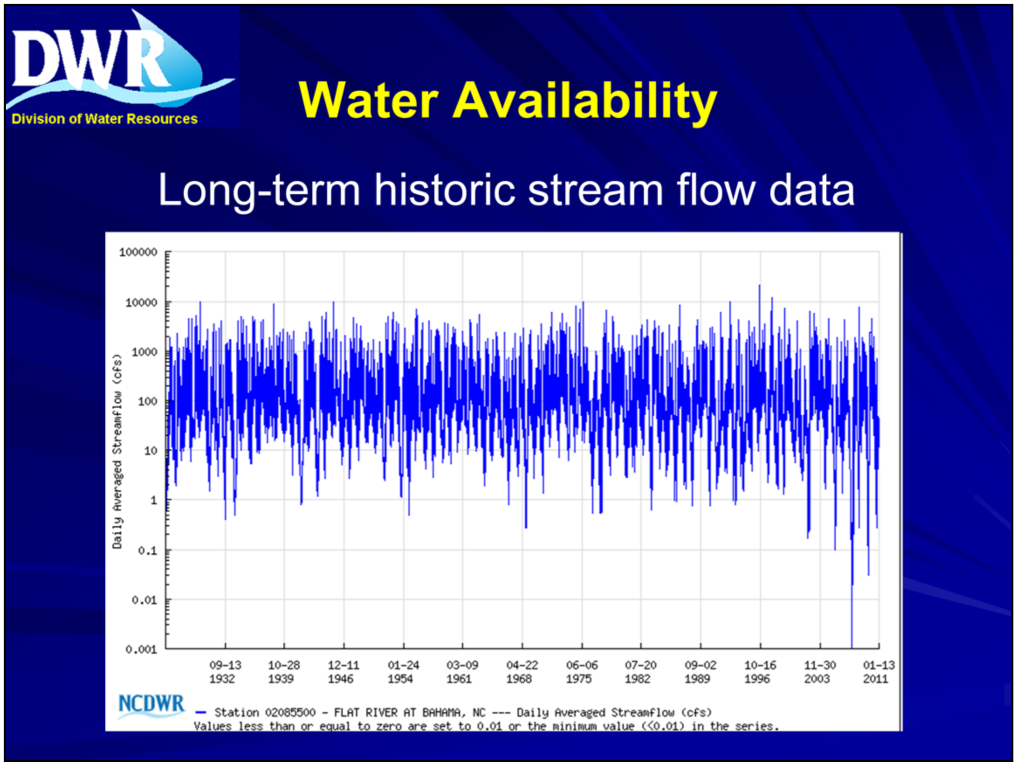
Water System	Average Daily Demand (MGD)
Orange-Alamance	0.16
Hillsborough	1.14
Durham	24.37
South Granville WASA	2.58
Creedmoor	0.30
Raleigh	45.22
Wilson	8.91
Johnston County	7.19
Smithfield	2.99
Progress Energy - Lee	7.67
Goldsboro	4.64
Weyerhaeuser	15.38
Neuse Regional WASA	6.08



The methodology used for plan development depends on constructing a hydrologic model that reasonably approximates historical conditions. We refer to this scenario as the basecase. For the Neuse model the basecase scenario represents conditions in 2008. Local water supply plans and water withdrawal registrations provide the majority of water use data.

This table shows the average daily water use figures used in the basecase of the Neuse River Basin Hydrologic Model. Obviously that volume of water is not used every day of the year. So, information supplied in the local water supply plans and data reported under the Central Coastal Plain Capacity Use Area reporting requirements were used to establish seasonal use patterns based on average daily use for each month in the year. This method provides a more realistic representation of how water is actually used.

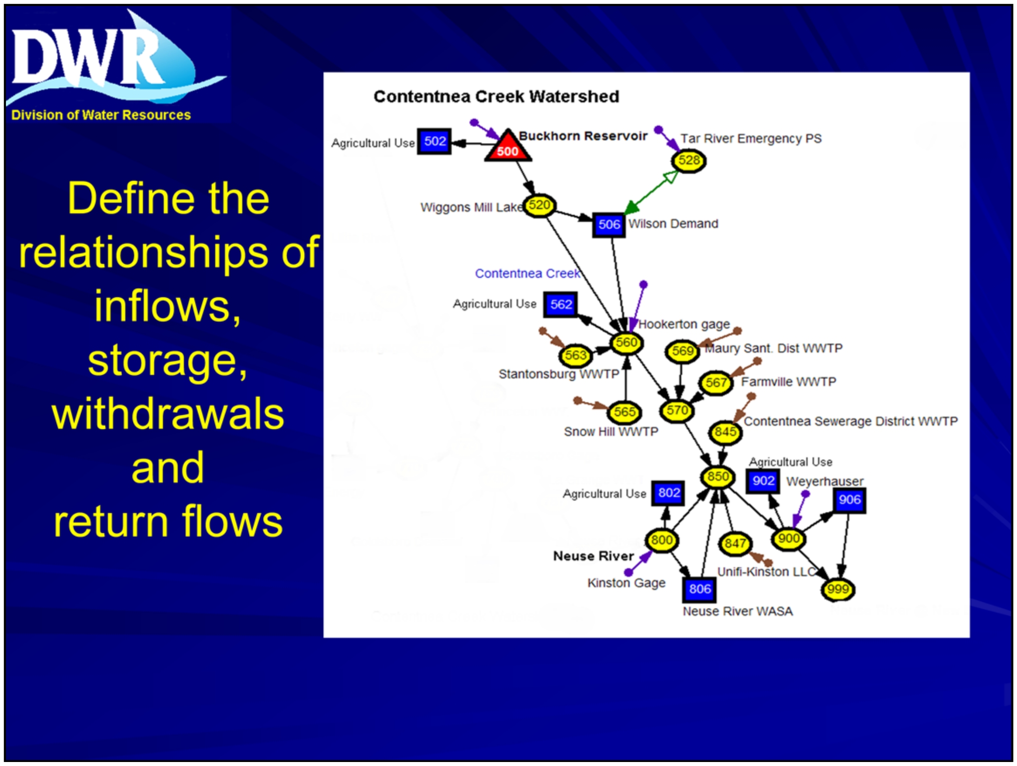
A sample of these calculations is shown in the graph. The line shows annual average daily water usage and the shaded area shows the monthly variations in use. The numbers show the relationship of monthly average daily use to annual average daily use. Each water system's monthly pattern is unique.



As noted earlier, water availability is characterized by 78 years of flow data that reflect hydrologic conditions in the basin from 1930 – 2008.

The plot shows the historic record of flows at one location in the basin. In this case the stream gage on the Flat River in northern Durham County. As you can see the record represents a wide range of flows including very wet and very dry periods and the recent record droughts.

The flow data is adjusted to compensate for water withdrawals and wastewater return flows to create an inflow data set that approximates flow conditions with no withdrawals.



After the inflow data is compiled it is subdivided by watersheds within the basin and combined with the locations of intakes, discharges and impoundments to create a mathematical model of water movement in the basin.

This slide displays the Contentnea Creek portion of the Neuse model schematic showing the relationships of inflows, storage, withdrawals and wastewater return flows in the model. Each of the polygons represents a model node where data enters the model or where a solution is calculated to determine how much water will be passed to the next downstream node.

Arrows represent the direction of water movement.

The green arrow represents an emergency source of water that is not used on a regular basis.

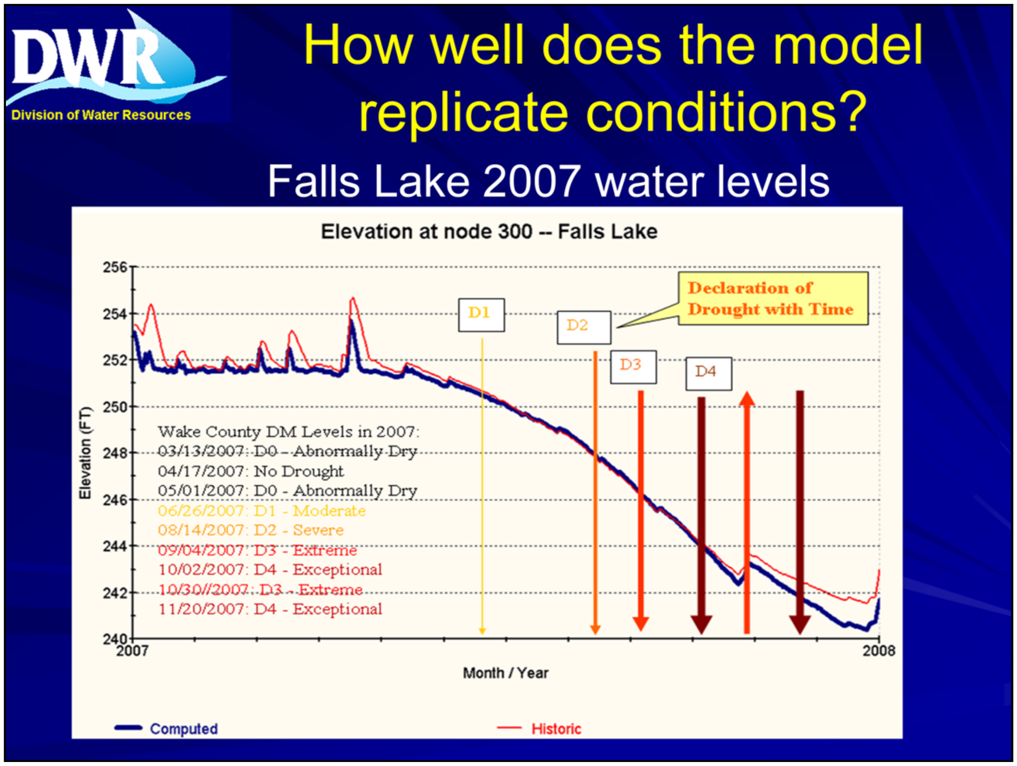
Purple arrows indicate water flowing into the system from the watershed.

Brown arrows indicate wastewater return flows not directly associated with a withdrawal in the model.

Blue squares represent demands for water.

Red triangles indicate storage impoundments like Falls Lake.

Yellow ovals represent points where the model performs an evaluation of inflows and outflows to calculate how much water will pass to the next downstream node.

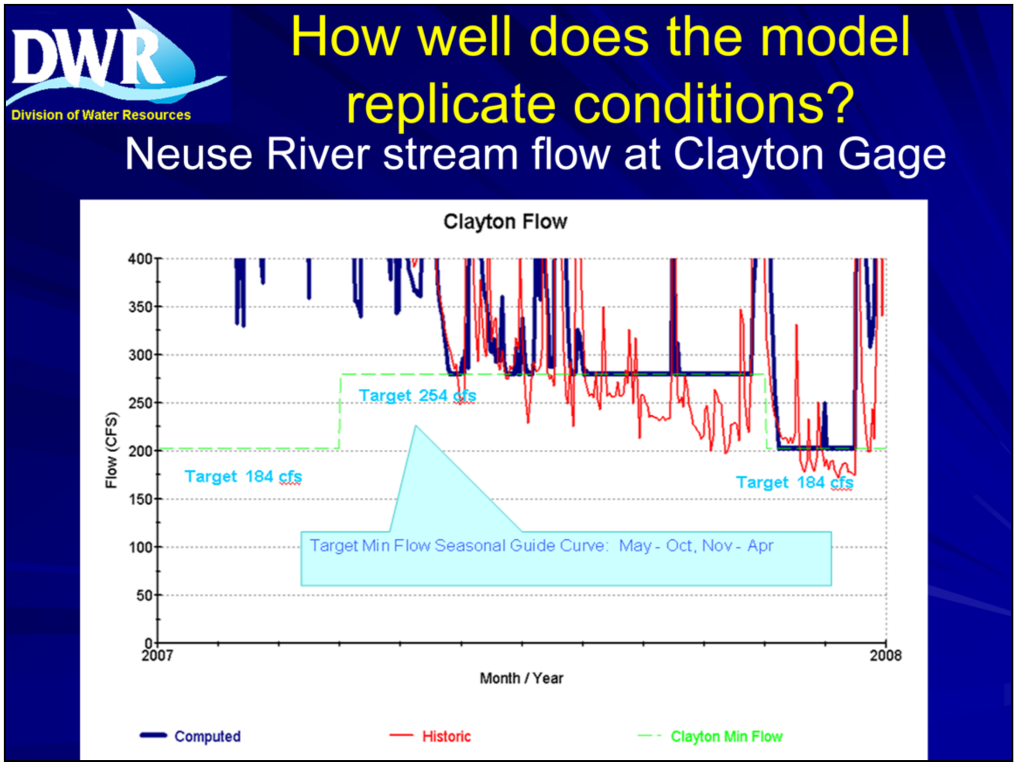


When the basecase scenario is completed it is evaluated to determine how well it reproduces conditions during a known period where model outputs can be compared to historical data.

This plot shows water levels of Falls Lake during 2007 as estimated by the hydrologic model using normal operating rules (blue line) and the water levels reported by the Army Corps of Engineers, who manage the reservoir (red line).

Variations between these tracings are attributed to the fact that the model contains a very specific set of decision criteria, in the form of inflexible mathematical equations, that determine how water is dispatched to the specified demands. On the other hand the actual operations of the reservoir may differ from this set of criteria in order to make timely changes to adapt to current hydrologic conditions such as droughts.

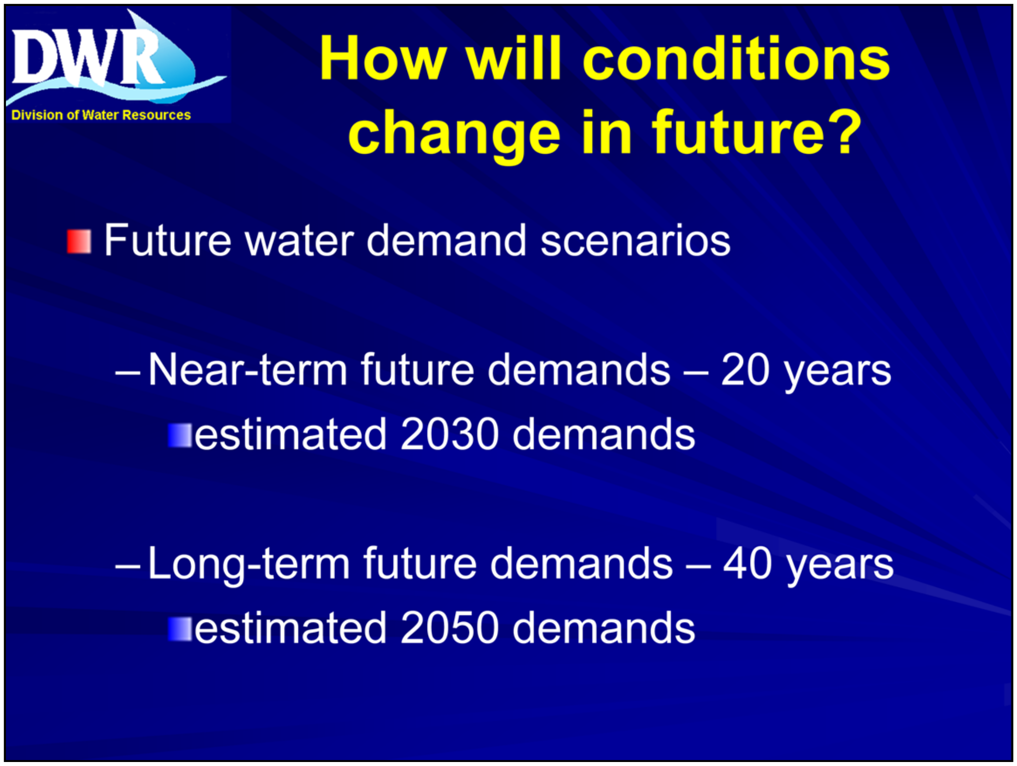
Note the divergence in the tracings in late 2007 when normal operations were altered in response to significantly reduced inflows to the reservoir because of drought conditions.



This plot shows stream flows during 2007 at the stream gage on the Neuse River at Clayton. Releases from Falls Lake are made to meet a designated flow target at this gage. The blue line shows flows estimated by the model based on the decision criteria incorporated in the model. The red line shows the historic data recorded by the US Geological Survey. The dashed green line indicates the target flows that govern water releases from Falls Lake. This plot shows that the model releases water from Falls Lake as it was programmed, to not violate the target flow requirement downstream.

The divergence of these tracings shows the difference that results from the model's ability to release exactly the amount needed to hit the target flow and real world limitations physical infrastructure and management decisions made to adjust to hydrologic conditions, especially droughts.

The plot shows releases during the drought when normal operating rules were altered to preserve water in the flow augmentation pool of the reservoir.



Once the model is capable of replicating basin conditions with sufficient accuracy as a water resources planning tool then DWR staff can create model scenarios to identify how future withdrawals and wastewater returns could change hydrologic conditions. Impacts are determined by comparing the results of future demand scenarios with conditions shown in the model's basecase. It is important to remember that the model is primarily used as a planning tool.

Modeling results are dependent on the data and assumptions used in each scenario. Changing the data or the assumptions will change the model results.

The analysis looked at future conditions at two points in the future. To identify issues that may need to be addressed in the near-future estimates of water demands thought to be needed 20 years in the future where evaluated. For this scenario we used water demand projections contained in local water supply plans for the year 2030. To gain insight into potential long-term issues we developed a scenario based on projected demands for 2050, 40 years in the future. A primary goal of this exercise is to identify potential problems early enough to allow local governments to adjust expectations and plans to avoid wasteful expenditures and serious environmental impacts.

It is important to remember that, while the document and this discussion refers to the various scenarios by date, what is actually being modeled and evaluated are specific magnitudes of water withdrawals. These levels of withdrawals may be reached well before or well after the reference dates depending on actual demand growth and water system expansions.

DWR
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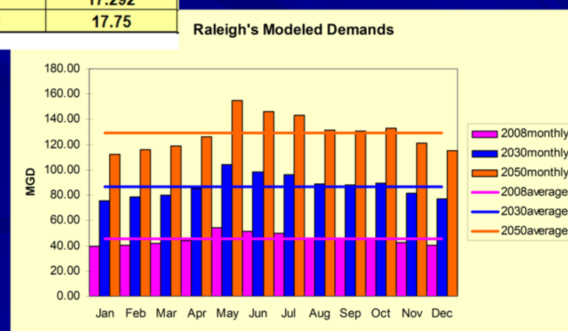
Water Demands

Annual Average Use

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

Source: NCDENR, Division of Water Resources

Seasonal Use Patterns



Here is a summary table of daily water demands used in the three scenarios modeled and a graph showing the monthly use values used to characterize Raleigh's water demands.

Average daily water demand estimates for 2030 and 2050 are used to characterize surface water withdrawals and wastewater return flows in the future. These are analyzed in the model based on monthly use patterns reflected in available data.

This approach increases withdrawals in the months when water use has historically been higher than average and reduces withdrawals in months when withdrawals have typically been less than average.

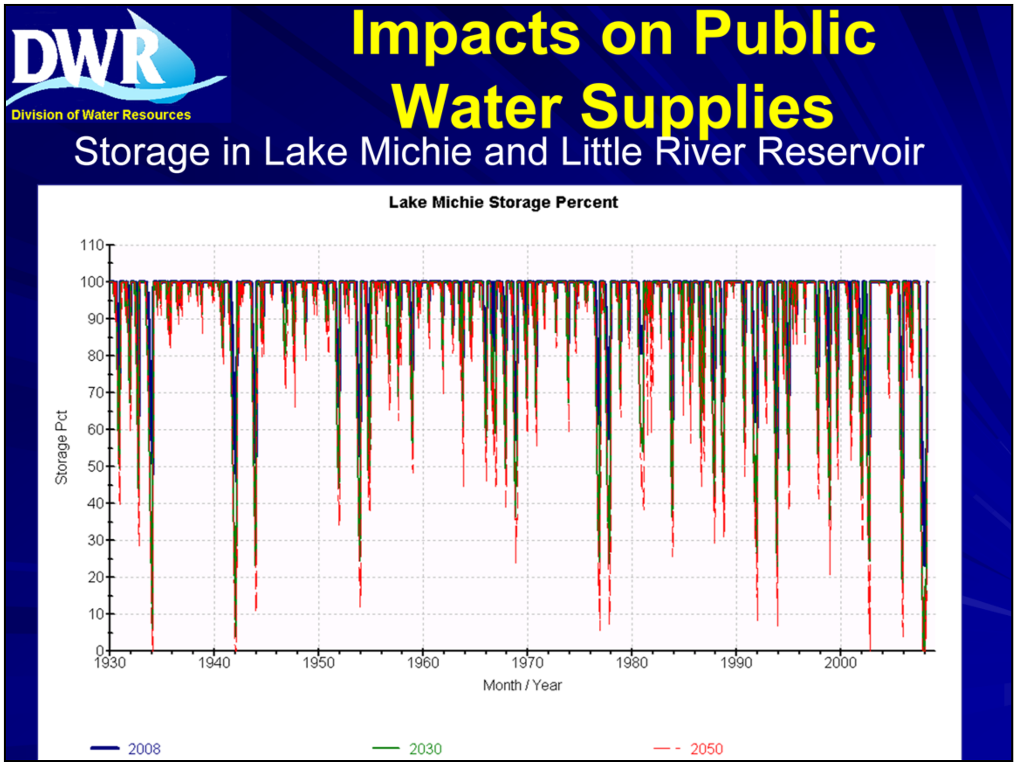
Estimated demands for 2030 are used to determine potential issues that need to be addressed in the near future and 2050 demands are used to identify more long-term issues.

Division of Water Resources

Estimated waste water return flows (MGD)

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

Estimated wastewater return flows were also calculated for each model scenario.



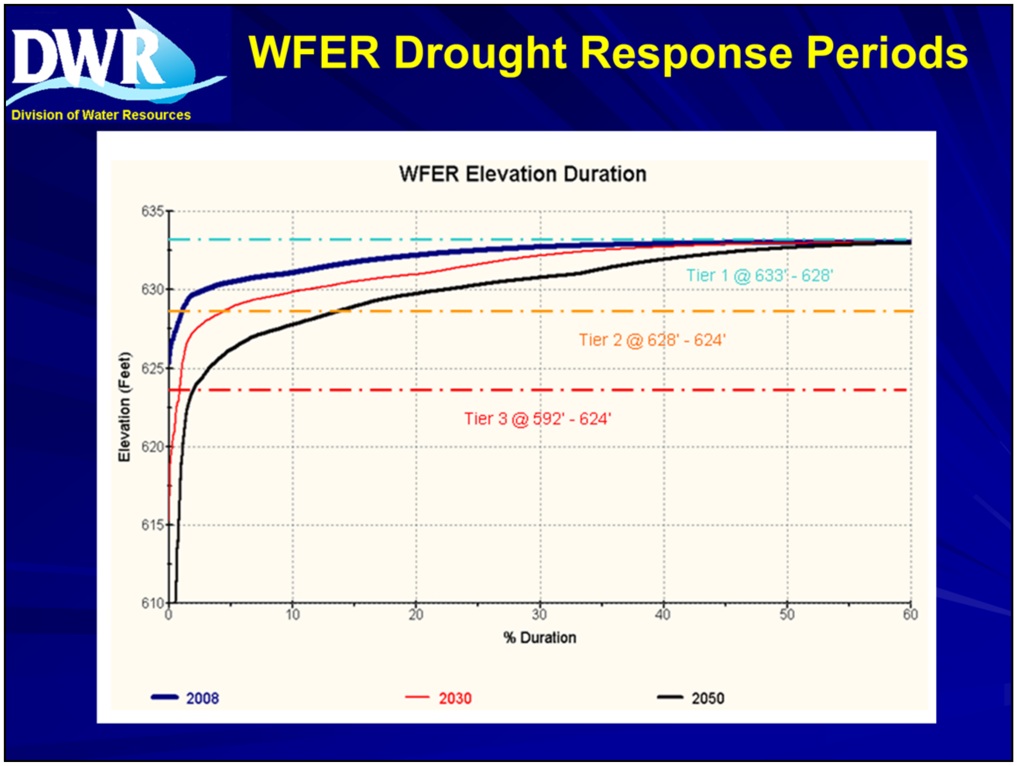
When all the data are entered into the model and the various scenarios are run DWR staff analyzes the model outputs in the context of the critical questions identified during development of the model.

So, given Durham's existing sources of water, how could future withdrawals affect the Durham's available supply of water?

This graph overlays the results of the basecase, the near-term future, and long-term future demand scenarios showing how the percent of storage remaining in Durham's Lake Michie reservoir changes. Without the implementation of drought response actions or development of additional sources of water, if Durham's demand for water grows as expected, the supply in this reservoir could be completely depleted during the recurrence of several low-flow patterns in the historical record.

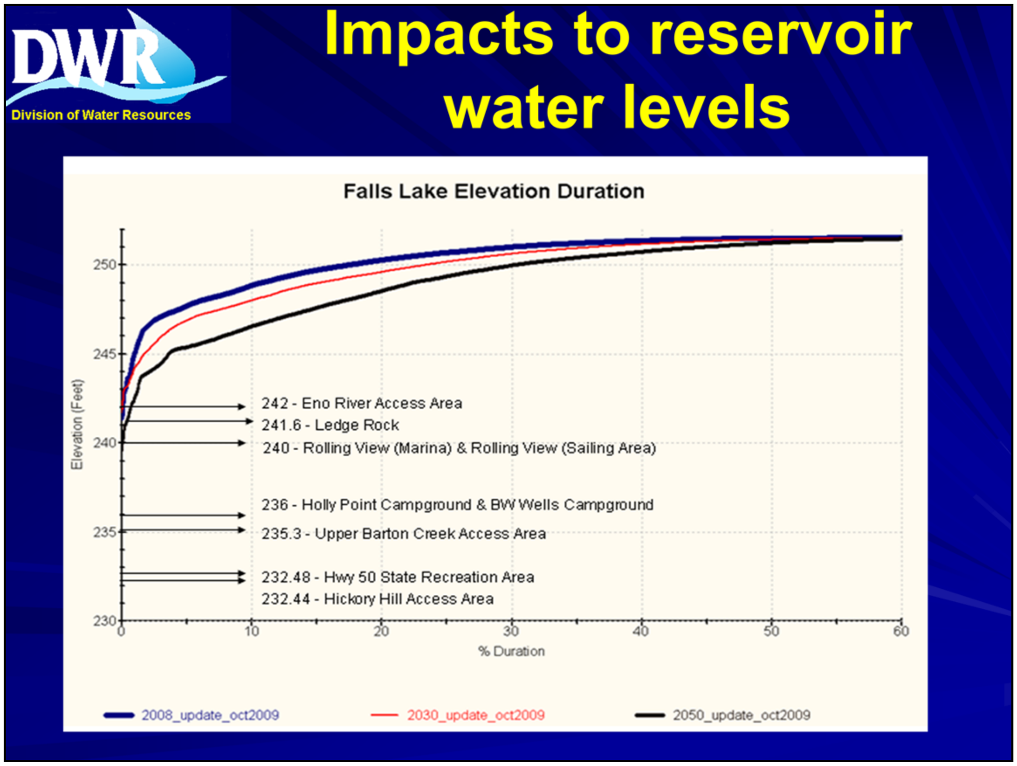
Lake Michie and Little River Reservoir are modeled to drawdown equally based on storage. Therefore the plot for Little River Reservoir would be similar to this one.

Durham's currently available supplies are the only water sources considered in this analysis. It does not include the potential offstream storage in Teer Quarry or their existing allocation from Jordan Lake that will increase available supplies in the near future.



This plot shows the changes in the occurrence of specific water levels in West Fork Eno Reservoir under the three different demand scenarios. The blue line represents the percent of days in the basecase scenario that water levels are predicted to be at or below the elevations noted on the vertical scale (over the range of flows in the model). The red line shows how these values could change under the near-term future demand scenario and the black line indicates the changes that could result under the long-term demand scenario.

The horizontal colored lines indicate the water levels that trigger drought response actions. The graph shows that with the current configuration of this reservoir and the demands modeled for Hillsborough, residents could face longer periods of time in each of their drought response stages as demands increase.



Similar to the last graph this plot shows the changes in the occurrence of specific water levels in Falls Lake under the three different demand scenarios. Under normal conditions the water level in Falls Lake is kept at 251.5 feet the elevation shown in the upper right of this graph. The horizontal lines on this graph indicate the elevations at which certain boat ramps are unusable. According to this graph, the Eno River and the Ledge Rock Access Areas could be unusable for more days in the future if there are no additional sources of water to help meet Raleigh's water demands.

These three graphs show some of the ways hydrologic conditions are evaluated in the Neuse River Basin Water Resources Plan.

Supply Deficits

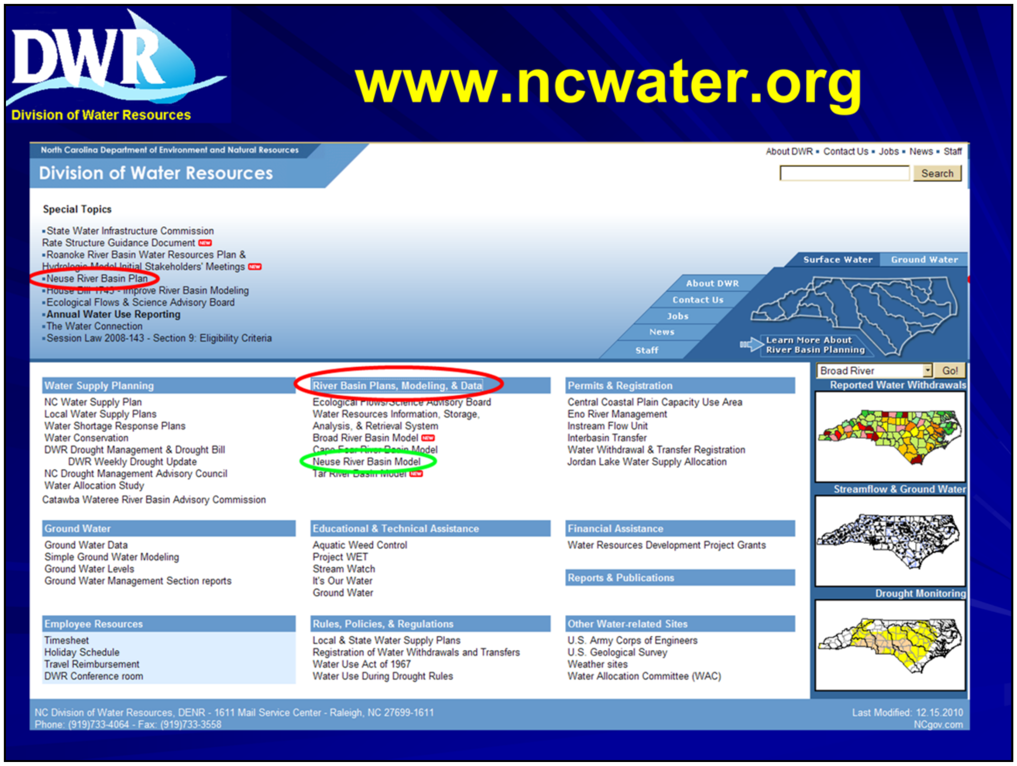
Deficits	Average Daily Demand (MGD)	Longest Deficit Period (Days)	# of annual flow patterns in 78 years when demand is not fully met
Near-term Future (2030)			
Durham	35.83	37	1
Raleigh	86.99	10	1
Long-term Future (2050)			
Orange-Alamance	0.21	30	2
Hillsborough	2.76	30	2
Piedmont Minerals	0.25	30	2
Raleigh	129.23	124	36
Durham	40.92	60	5
South Granville WASA	10.01	79	14

With the emphasis of this analysis on evaluating the probability of water systems to be able to meet future water demands this table shows the most important results of this evaluation exercise. It summarizes the answers to the critical questions identified earlier.

Given current sources of water and the assumptions used in the analysis; when the levels of future withdrawals modeled are reached several communities COULD experience significant water shortages.

While the model incorporates the drought management protocols of the Voluntary Eno River Capacity Use Area it does not include water systems' water shortage response plans (WSRPs) or drought response protocols for Falls Lake. Given the new requirement for local water supply plan systems to adopt water shortage response plans communities should be able to design protocols that will minimize negative impacts at least for the short-term and infrequent events. Drought protocols for Falls Lake are still under review by the US Army Corps of Engineers.

Before the Neuse Plan was finalized DWR staff met with representatives of Durham, Raleigh and the South Granville Water and Sewer Authority to discuss these results and to double check demand and water availability data for each of these systems. They were aware of the potential issues shown in the table and were already taking actions to reduce the potential for supply deficits and the resulting impacts to customers.



The current version of the Neuse River Basin Water Resources Plan is available on the Division of Water Resources website.

Either of the red-highlighted links will get you to the plan.

The link highlighted in green provides in-depth information on the hydrologic model.

The Neuse River Basin Hydrologic Model is scheduled to be updated in conjunction with the evaluation of allocations of water supply storage in Jordan Lake.

Questions?

www.ncwater.org

919-733-4064

Division of Water Resources