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Document Review and Approval

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Determination of Future Harris Reservoir Storage Requirements

Shearon Harris Nuclear Power Plant Units 2 and 3 (HAR)

Prepared for

Progress Energy Carolinas, Inc.

Prepared by

CH2MHILL

August 2010

Contents

Figure

Appendix

Purpose of Technical Memorandum

The purpose of this memorandum is to describe the modification to the storage volume in Harris Reservoir that is necessary to support the operation of the two additional nuclear reactor units proposed for the Shearon Harris Nuclear Power Plant in Wake County, North Carolina. The memorandum describes the purpose and need for the modification and presents the results of analyses completed to determine the required modification for reservoir storage volume.

Relevant History of the Shearon Harris Nuclear Power Plant

A facility with four nuclear reactor units was planned and designed for the Shearon Harris site in the early 1980's. The design included the construction of a dam on Buckhorn Creek to create Harris Reservoir, which would provide cooling and process water for the Shearon Harris Nuclear Power Plant. The reservoir receives flow from the Buckhorn Creek watershed, which provides sufficient water to maintain an operating level of 220 feet National Vertical Geodetic Datum of 1929 (NGVD29).

The original plans allowed for an elevation of 260 feet NGVD29 for the Main Dam with an expected operating level for Harris Reservoir of 250 feet NGVD29. The original design also specified the use of makeup water pumps on the Cape Fear River to supplement the inflows from the Buckhorn Creek watershed in order to maintain the reservoir at the 250-foot NGVD29 operating level. After the dam was constructed to 260-feet NGVD29, only one of the four units was completed, so the reservoir was filled only to 220-feet NGVD29. The Shearon Harris Nuclear Power Plant Unit 1 (HNP) was completed in the first phase of construction and began commercial operation in 1987.

Need for Electrical Power

As described in Chapter 8 of the Shearon Harris Nuclear Power Plant Units 2 and 3 (HAR) Combined License Application (COLA) Part 3, *Environmental Report* (Progress Energy Carolinas, Inc. [PEC], 2010a), power demands in the region are expected to grow in the future. Regional planners predict the following:

- An increase in population of more than 20,000 annually within the PEC service area.
- A corresponding increase in electrical demand for residential and commercial users.

PEC's objective is to provide reliable power, which is defined as the ability to continuously generate power (that is, no unplanned outages).

Summary of Proposed Project

To meet increased electrical demand in the region, PEC is proposing to add generating capacity to its service area through the construction of two General Electric AP1000 reactor units (HAR 2 and HAR 3) at the Shearon Harris site. The nuclear reactors will provide baseload electrical generation to the region. As determined in the original planning, licensing, and environmental analysis, the selected source of the cooling water for the two units is Harris Reservoir.

PEC proposes to raise the water level in Harris Reservoir to the design level in order to provide sufficient cooling water to operate the HNP and HAR reliably. Inflow from the Buckhorn Creek watershed and pumping from the Cape Fear River will be required to maintain the operating level of the reservoir.

Cooling Water Requirements

Current Cooling Water Requirements

Harris Reservoir supplies the cooling water for the HNP. Inflow from the Buckhorn Creek watershed is the primary source of water for Harris Reservoir. Based on estimates used for the calculations presented in Appendix A, the average inflow from the watershed has historically been 65 cubic feet per second (cfs). Approximately 22.3 cfs of water are lost due to evaporation from the existing cooling tower. Inflow from the Buckhorn Creek watershed is the primary source of water to the reservoir. Based on a water balance of inflow to Harris Reservoir and the current cooling tower requirement, the average inflow is sufficient to maintain the reservoir at the operating level of 220 feet NGVD29 for one nuclear reactor unit.

Additional Cooling Water Requirements Necessitated by Adding Two Additional Units

The two additional reactors (HAR 2 and HAR 3) proposed for the facility will also use Harris Reservoir for cooling water supply. It is estimated that the normal net consumptive usage for the additional reactor units will be approximately 63 cfs (PEC, 2010a), primarily due to evaporation from the cooling towers. As described in the previous section, the current inflow to the Harris Reservoir is sufficient to maintain the operating level of 220 feet NGVD29 with only one nuclear reactor in operation. Additional water supply to the Harris Reservoir from the Cape Fear River will be required to maintain an increased reservoir operating level necessary to meet the increased consumptive demand from the additional reactors. Without increasing the current operating level of the reservoir, the reservoir level does not meet the minimum operating level for HNP, HAR2 and HAR3 and unscheduled shutdowns will occur frequently as described in the "no action alternative" discussed later in this document.

The HAR designs specify the use of three pumps to withdraw water from the Cape Fear River between B. Everett Jordan Reservoir and Buckhorn Dam, with each pump capable of pumping 20,000 gallons per minute (gpm) (44.6 cfs) for a maximum rate of 60,000 gpm (134 cfs). The average flow in the river at the U.S. Geological Survey (USGS) gage near Lillington, NC (USGS02102500) from January 1, 1924 through December 31, 2009, was 3,308 cfs (USGS, 2010).

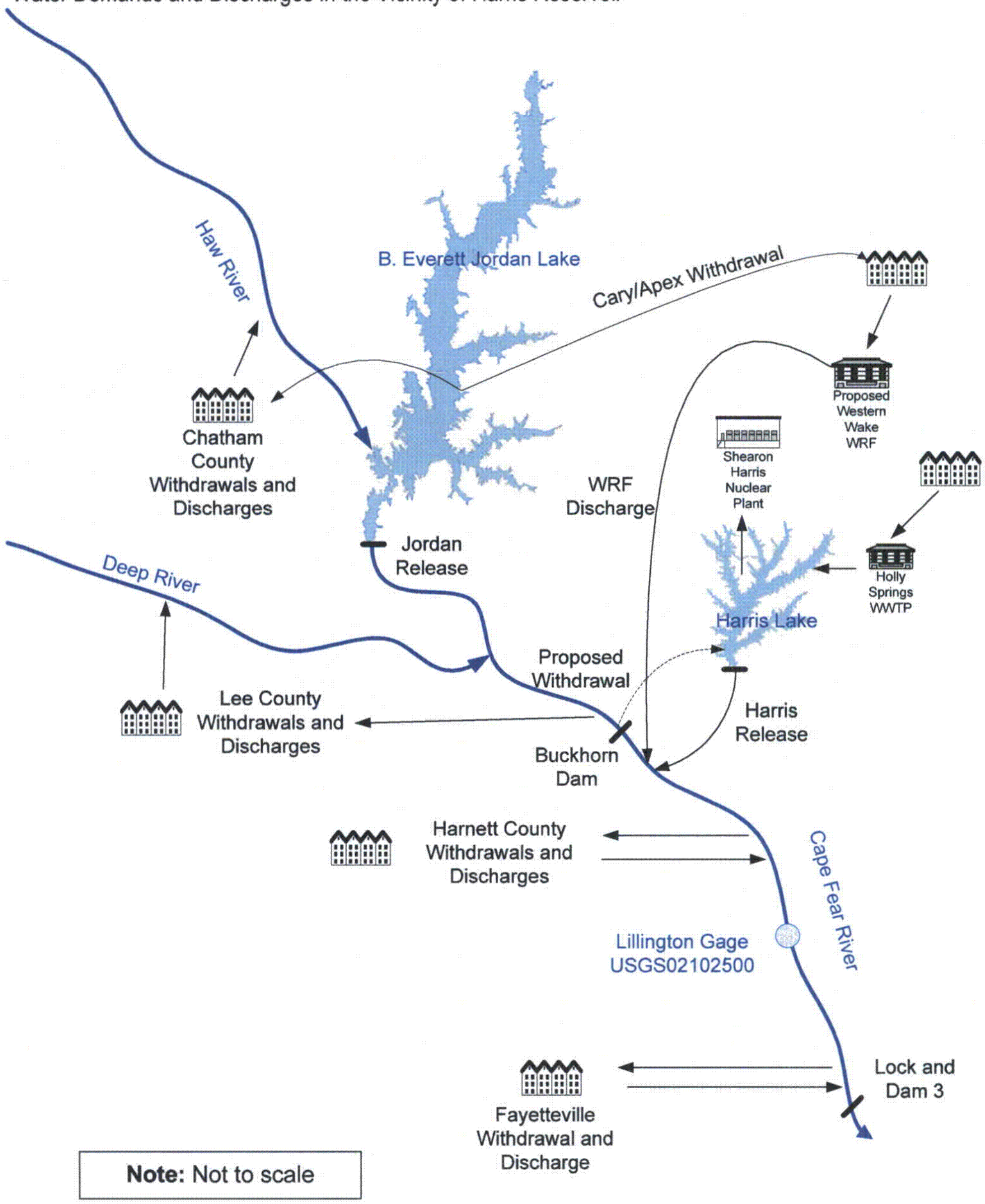
Water Supply in the Cape Fear River Basin

During drought conditions, water resources in the Cape Fear River Basin are severely limited. A number of municipalities in the basin rely on surface water for their water supply. Point source discharge permits are also calculated to minimize potential water quality impacts based on the flow volume in the Cape Fear River. Jordan Reservoir, an impoundment on the Cape Fear River, is managed to provide water supply to municipalities above Harris Reservoir and to maintain a minimum discharge to support downstream users and aquatic life. Figure 1 presents the relationship of some of the water resources in the basin.

To minimize impacts to water resources in the Cape Fear River, withdrawals from the Cape Fear River may be restricted during extreme drought periods. The use of an expanded Harris Reservoir would provide a consistent source of water and a mechanism for capturing and storing water when Cape Fear River flows are adequate and reducing or suspending withdrawals from the Cape Fear River when river flows are low.

The Western Wake Regional Water Reclamation Facility (WRF) is a wastewater treatment facility that will treat sewage for municipalities in the Western Wake County area, including the towns of Cary, Apex, and Holly Springs. This facility is designed to discharge up to 38 mgd by the Year 2050, including a contribution of 8 mgd from Holly Springs. The Western Wake Partners have evaluated the potential for discharging the effluent from the WRF to Harris Reservoir. This discharge would provide a steady inflow to the reservoir and would meet part of the increased water demand. However, the regulations for interbasin transfers have made this option infeasible.

FIGURE 1
Water Demands and Discharges in the Vicinity of Harris Reservoir



Evaluation of Increased Harris Reservoir Storage

PEC proposes to raise the water level of Harris Reservoir to provide the necessary cooling water for the simultaneous operation of the HNP and HAR. Inflows solely from the Buckhorn Creek watershed will be insufficient to maintain an operating reservoir level above 220-feet NGVD29 with more than one reactor in operation, as discussed previously. Therefore, water must be pumped from the Cape Fear River to maintain the reservoir at the necessary operating elevation. The North Carolina Division of Water Resources (NCDWR) has indicated that during low flow periods, withdrawal from the Cape Fear River may need to be reduced or suspended. Reducing or suspending withdrawals from the Cape Fear River will have a cumulative effect on the availability of water to meet cooling water requirements, given that periods with restricted withdrawals from the river historically coincide with periods in which the inflow from the Buckhorn Creek watershed is minimal.

Hydrologic analyses were used to determine the operating level that would allow PEC to meet the following criteria:

1. Reliable generation of power
    a. No required shutdowns
    b. Minimal time operating within the reserve pool
2. No exceedance of safe operating levels (flood related)
3. Long-term reliability, including the potential for reduced water availability impacts due to global climate change

Approach for Determining the Required Reservoir Level

The NCDWR's Cape Fear River Hydrologic Model (CFRBHM) is used by the State of North Carolina to evaluate current and future water supply in the Cape Fear River. The model dynamically simulates inflow, flow routing, and storage for all significant withdrawals and discharges from the headwaters of the Cape Fear River to United States (U.S.) Lock and Dam Number 1.

The CFRBHM was used to predict the available water supply in the Cape Fear River Basin and the volume of Harris Reservoir storage for several potential operational scenarios. The model was run for an 80-year simulation period using meteorological data from 1930 through 2009 to evaluate reservoir levels for a wide range of hydrologic conditions. Demand and discharge projections for the Year 2050 were input to represent potential future conditions. Available water supply in the reservoir was based on an allocation of the reservoir pool being split into a regular operating pool and a reserve pool. The reserve pool was specified as 20 percent of the available storage based on guidelines provided by the NCDWR and the need to allow for revisions to plant design as the project moves from the conceptual phase to the construction phase. The reserve pool extends from a minimum level of 224-feet NGVD29 as specified by engineering constraints and an upper level of 229-feet NGVD29. A detailed description of the model's inputs and assumptions is provided in Appendix A.

Upper Reservoir Level Constraints

The Main Dam was constructed to accommodate reservoir elevations up to 250 feet NGVD29, which is 30 feet above the current normal operating level of 220 feet NGVD29. The dam configuration can accommodate a reservoir elevation of 240 feet NGVD29 without major modification. Analyses developed in support of the HAR COLA Part 2, *Final Safety Analysis Report* (PEC, 2010b) evaluated the condition of the dam and demonstrated its ability to store water safely at a 240-foot NGVD29 level (Sargent & Lundy, 2007). This evaluation included analyses for Operating Basis Earthquake, Safe Shutdown Earthquake, and various flood levels up to a level of 245 feet NGVD29. These analyses indicate that dam safety is not an issue for reservoirs at least as high as 245-feet NGVD29.

A probable maximum hurricane (PMH) analysis was performed in support of the HAR COLA Part 2 *Final Safety Analysis Report* (PEC, 2010b). The PMH is a hypothetical steady-state hurricane having a combination of values of meteorological parameters that will give the highest sustained wind speed. A PMH could cause a water level change in the Main Reservoir and the Auxiliary Reservoir. The resulting high water levels, if not considered in the project design, could affect the safety of the Main Dam, Auxiliary Dam, or safety-related structures located at the plant site. This analysis determined that a reservoir level of more than 240 feet NGVD29 would not provide an adequate margin against flooding of the safety related structures associated with HNP, HAR 2, and HAR 3.

Minimum Required Reservoir Elevation

The CFRBHM was run to determine the reservoir level that would allow the three reactor units to operate continuously over the simulation period using the normal pool. A description of the model assumptions and inputs is provided in Appendix A. The analysis shows that a reservoir level of 241.5 feet NGVD29 is required to maintain the reservoir level above the reserve level at all times (see Figure A2 in Appendix A).

The CFRBHM was used to evaluate alternative reservoir levels. The different operating levels were defined based on the identification of the upper boundary conditions for the reservoir level, defined in the preceding sections. Model runs were performed for a no action alternative (220-foot NGVD29 operating level) and 236-, 238-, and 240-foot NGVD29 operating levels. More detail regarding the inputs, assumptions, and results of the reservoir analyses and the documentation of the safety related analyses can be found in Appendix A.

Results of the Required Reservoir Level Evaluation

No Action Alternative

A "no action alternative" was evaluated to determine the reliability of the cooling water supply if the reservoir level was maintained at its current 220-foot NGVD29 operating level, supplemented by withdrawals from the Cape Fear River, and used to supply cooling water to all three nuclear reactor units. As described in Appendix A, the reservoir provided an insufficient water supply for the facility for more than 40 percent of the simulation period.

Reservoir Operational Levels

Subsequent model runs were performed to evaluate the impacts on the reserve pool and plant operations using reservoir levels of 236-, 238-, and 240-feet NGVD29. For each of the proposed operating levels, the model was run over the entire simulation period. Details of each scenario are provided in Appendix A. The daily reservoir levels and amount of time the levels fell below the reserve pool were calculated.

- A 240-foot NGVD29 operating level met the objective of providing a reliable source of power at all times. The maximum drop in reservoir level was an elevation of 226.6 feet NGVD29, which is 2.4 feet below the reserve level. Water was withdrawn from the reserve pool for 343 days or approximately 1.17 percent of the 80-year evaluation period. Occasional brief withdrawals from the reserve pool are acceptable since one purpose of the reserve pool is to provide a cooling water supply in the case of extreme conditions or unforeseen conditions. The period from May 1988 through April 1989 was one such period where rainfall was limited and flow in the Cape Fear River was frequently less than 600 cfs. During this period, water was withdrawn for 207 of 365 days or 56.7 percent of the time of withdrawal from the reserve pool.

- A 238-foot NGVD29 operating level does not meet the reliability criteria. In the model run, shutdown was required twice during late 1988 and early 1989. The first occurrence began on September 24, 1988 and lasted for 39 days. The reservoir level fell to 223.6 feet NGVD29, which is below the 224-foot NGVD29 minimum level required by engineering design. The second shutdown began on December 27, 1989 and continued for 11 days. The second shutdown would have occurred when power demands were potentially very high due to use for heating.

  The operating level of 238 feet NGVD29 would require withdrawals from the reserve pool for approximately 939 days over the 80-year evaluation period or 3.2 percent of the time. For the same extreme drought period from May 1988 through April 1989, water was withdrawn from the reserve pool for 249 of 365 days or 68.2 percent of the time.

- A 236-foot NGVD29 operating level would not meet the reliable generation of power criteria. In this scenario, the reservoir level fell to 220.3 feet NGVD29, requiring the plant to shut down. For this scenario, the plant would be shut down for 231 days during the period from July 1988 through February 1989. Four other shutdowns of shorter duration were predicted to occur in the period from 1930 through 2009. These shutdowns would occur during the summer when power demands could potentially be very high due to use cooling requirements and during the winter when power demands could potentially be very high due to use for heating.

  A 236 foot NGVD29 operating level increased the number of days the reserve pool was used to 1,986 or 6.8 percent of the time over the 80-year evaluation period. For the same extreme drought period from May 1988 -through April 1989, water was withdrawn from the reserve pool for 324 of 365 days or 88.8 percent of the time.

Sensitivity Analyses

Analyses were performed to evaluate the sensitivity of the model predictions to global climate change (GCC) and the discharge from the Holly Springs Wastewater Treatment Plant (WWTP). A sensitivity analysis on impacts to wetlands under different reservoir levels was also performed. These analyses are described in more detail in Appendix A.

One sensitivity analysis evaluated the impact of GCC on the reservoir level required to be maintained above the reserve pool. As discussed in Appendix A, a 10-percent factor was used in the determination of the required reservoir level. This level had been suggested in discussions with NCDWR and is approximately the same magnitude as the predicted decreases in annual rainfall for the Southeast. A scenario with no GCC impacts and scenarios with changes -10, -20, +10, and +20 percent on inflows were tested in the model. A "no change" scenario was also tested to demonstrate the required level if rainfall patterns do not change in the future. Each 10-percent increment of rainfall reduction appears to cause an approximate change in reservoir level of 2 to 3 feet.

The Holly Springs WWTP currently discharges approximately 1.5 mgd to Harris Reservoir. The town is part of the Western Wake Partnership that is proposing a new discharge to the Cape Fear River. Under the partnership, the current discharge would be removed from Harris Reservoir and all current and future discharges would be routed to the Western Wake Regional WRF for discharge to the Cape Fear River. The interbasin transfer regulations that discouraged the Western Wake WRF from discharging to Harris Reservoir do not apply to the discharge from Holly Springs. For this reason, it would be possible for the Holly Springs WWTP to continue to discharge to Harris Reservoir.

A sensitivity run was carried out by performing an additional run with the Holly Springs discharge being separated from the remaining WRF discharge in order to determine the impacts to reservoir levels. Increasing the discharge to Harris Reservoir would provide a steady inflow to the reservoir and could reduce the required reservoir elevation. However, the Holly Springs WWTP is currently one of the entities involved in the Western Wake WRF project and has been authorized to discharge to the Cape Fear River. The Record of Decision for the discharge to the Cape Fear River was published for public review on July 28, 2010 (USACE, 2010). No alternative to this discharge has been approved by the North Carolina Division of Water Quality (NCDWQ).

A sensitivity analysis was performed to determine the impacts to jurisdictional wetlands associated with reservoir levels of 240, 238, and 236 feet NGVD29. The results showed that approximately 565.2 acres or 91.3 percent of the total wetland impacts occur if the reservoir is raised above 224-feet NGVD29. Additional impacts occur gradually at higher elevations. Approximately 614.2 acres of wetlands may be impacted if the reservoir operating level is 236-feet NGVD29. An additional increase of 0.5 percent (2.8 acres) of wetland impacts is associated with a reservoir level of 238 feet NGVD29. Approximately 4.9 acres of additional wetland impacts, an increase of 0.8 percent is associated with a reservoir level of 240 feet NGVD29.

Conclusion and Recommendation

Technical hydrologic analyses determined that a reservoir level of 240-feet NGVD29 is necessary to provide sufficient cooling water storage and ensure reliable operation of three Shearon Harris units during extreme drought. To minimize impacts to ecology and water supply in the Cape Fear River, withdrawals from the Cape Fear River may be restricted during periods of extreme drought. Under these conditions, a large storage reservoir of cooling water will greatly extend the period during which the units can operate with no net water consumption from the Cape Fear River. A 240-foot elevation in Harris Reservoir will support the purpose and need of the project, providing continued reliable power generation from the three units while minimizing impacts to water resources in the Cape Fear River Basin.

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APPENDIX A

Evaluation of Water Supply from Harris Reservoir to Support Reactor Expansion

Progress Energy Carolinas, Inc. (PEC) proposes to construct two additional nuclear reactors at the Shearon Harris Nuclear Power Plant. The existing Shearon Harris Nuclear Power Plant Unit 1 (HNP) uses Harris Reservoir as its source for cooling water. The reservoir receives flow from the Buckhorn Creek watershed, which provides sufficient water to maintain the operating level of 220 feet National Geodetic Vertical Datum of 1929 (NGVD29). Expansion of the Shearon Harris nuclear facility would require cooling water in excess of that which would be available from the Harris Reservoir at the current operating level. PEC proposes to raise the level of Harris Reservoir and use water from the Cape Fear River to supplement the watershed flows in order to meet the total cooling water requirements of the HNP and Shearon Harris Nuclear Power Plant Units 2 and 3 (HAR).

Purpose of Appendix

A number of technical analyses were required to determine the required reservoir level that would allow the HNP and HAR to operate reliably. The results were summarized in the main body of the technical memorandum (TM) and documentation of the approach, assumptions, and results used to determine the required operational level for Harris Reservoir to support the HNP and HAR are provided in this appendix.

Summary of Approach

A combination of calculation review and additional modeling assessments were used to determine the required reservoir level. These assessments included establish the cooling water requirements of the HNP and HAR, determining the minimum reservoir level required to operate the units reliably, the safe reservoir operating level, and the optimal reservoir operating level.

Cooling Water Needs

Water usage estimates for the HNP were determined using estimates in the *HNP Final Safety Analysis Report* (PEC, 1983). Water usage for the HAR was determined using estimates developed to support the HAR Combined License Application (COLA), Part 3, *Environmental Report* (PEC, 2010a), based on the conceptual design for the AP1000 reactors.

Reservoir Modifications

Technical analyses of dam safety and flooding conditions were performed based on calculations developed to support the HAR COLA, Part 2, *Final Safety Analysis Report* (FSAR) (PEC, 2010b).

Modeling analyses were performed using the Cape Fear River Basin Hydrological Model (CFRBHM) from the North Carolina Division of Water Resources (NCDWR). The modeling analyses evaluated the potential impacts of different operational scenarios on water levels of Harris Reservoir. The following scenarios were evaluated:

- **No Action Alternative** – Under this scenario, the reservoir is maintained at the current operating level with the HNP and HAR in operation. Water is pumped from the Cape Fear River to provide supplemental flow.
- **Minimum Required Elevation** – The CFRBHM was run to determine the level that would allow the HAR to operate reliably.
- **Maximum Allowable Elevation** – Dam safety documents and probable maximum flood and probable maximum hurricane (PMH) analyses were reviewed to establish the maximum allowable operating elevation.
- **Potential Operating Elevations** – A number of operating levels were tested to evaluate impacts on reservoir levels and reliability.

Sensitivity Analyses

Sensitivity analyses were also performed to assess the sensitivity of the conclusions of the reservoir level analyses to three factors: (1) global climate change (GCC), (2) discharge of wastewater from Holly Springs to Harris Reservoir, and (3) impacts to wetlands for different operating levels. The GCC and Holly Springs analyses were performed using the CFRBHM. The wetlands evaluation was based on wetlands mapping data and geographical information system (GIS) analyses.

Cooling Water Requirements

Current Requirements

Harris Reservoir is the cooling water supply for the HNP. Approximately 22.3 cubic feet per second [cfs] of water are lost due to evaporation from the existing cooling tower.

Inflow from the Buckhorn Creek watershed is the primary source of water to the reservoir. The inflow to Harris Reservoir from the Buckhorn watershed is not gaged. Buckhorn Creek below the Main Dam is monitored but these measurements reflect the losses associated with the HNP and evaporation from the reservoir surface.

Inflows to Harris Reservoir were based on back-calculated data when available. Inflows are back-calculated by adding back to the historical release (as measured by the downstream flows at the Buckhorn Creek gage, adjusted for drainage area), the change in storage, the net cooling water consumption, and estimated net evaporation from the reservoir. Historical operating data are available from 1987 to present. For the periods prior to the dam's construction and after the Buckhorn Creek gage was operational (1972 to 1980), the back-calculated inflows are based on a drainage area adjustment of the Buckhorn Creek gage.

To extend the inflow record to the start of the Cape Fear model inflow record (1930), the Harris Reservoir inflows were extended by using the Middle Creek gage in the adjacent Neuse River Basin. Middle Creek near Clayton, North Carolina (NC) has a gaging station with flow record from 1930 to present. The Middle Creek gage has a drainage area of 83.5

square miles while the Buckhorn Creek drainage area is approximately 71 square miles, resulting in a drainage area ratio of 0.85.

As discussed in Section 2.4 of the HNP FSAR (PEC, 1983), the Buckhorn Creek flow correlates reasonably well with that of Middle Creek due to their proximity and similar size. Regression equations were derived to estimate what the inflows to Harris Reservoir would have been in the absence of back-calculated inflows based on the relationship with the Middle Creek gage.

The average inflow to Harris Reservoir for the period from 1930 through 2009 was calculated to be 65 cfs. Based on a water balance of inflow to Harris Reservoir and the current cooling tower requirement, the average inflow is sufficient to maintain the reservoir at the operating level of 220 feet NGVD29 with one reactor in operation.

Requirements with the Addition of Two Nuclear Reactor Units

The two additional reactors (HAR 2 and HAR 3) will also use Harris Reservoir as their source of cooling water. It is estimated that the normal net consumptive usage for the additional reactor units will be approximately 63 cfs (PEC, 2010a), primarily due to evaporation from the cooling towers. As described in the previous section, the current inflow to the Harris Reservoir is sufficient to maintain the operating level of 220 feet NGVD29 with only one reactor in operation. Additional water supply to the Harris Reservoir from the Cape Fear River will be required to maintain an increased consumptive demand from the additional reactors and an increased reservoir operating level.

The HAR designs specify the use of three pumps to withdraw water from the Cape Fear River between B. Everett Jordan Reservoir and Buckhorn Dam, with each pump capable of pumping 20,000 gallons per minute (gpm) (28.8 mgd, 44.6 cfs) for a maximum rate of 60,000 gpm (86.6 mgd, 134 cfs).

Cooling Water Availability

Cape Fear River and Jordan Reservoir Water Management

PEC proposes to use water from the Cape Fear River to supplement the watershed flows in order to meet the total cooling water requirements of the HNP and HAR. The average flow in the river at the U.S. Geological Survey (USGS) gage near Lillington, NC (USGS02102500) from January 1, 1924, through December 31, 2009, was 3,308 cfs (USGS, 2010). The lowest mean daily flow recorded recently in the Cape Fear River at Lillington was 155 cfs during drought conditions in August 2002 (USGS, 2010).

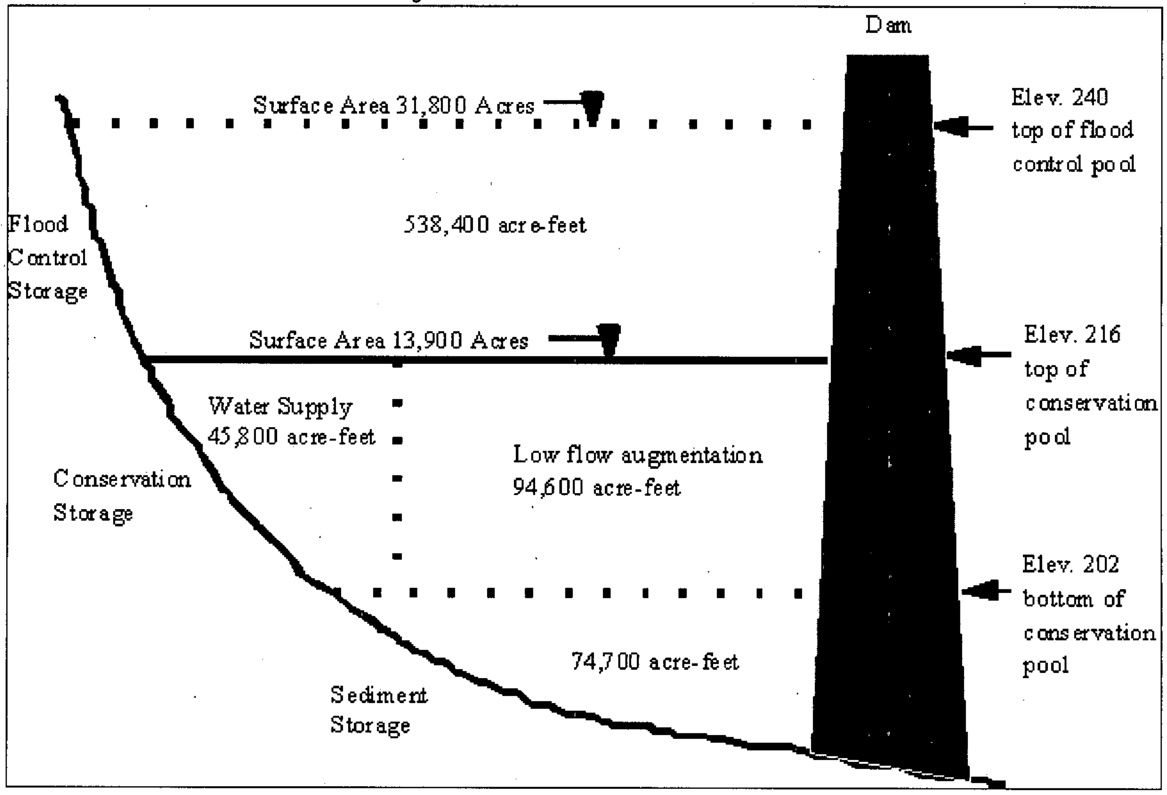
Based on the U.S. Army Corps of Engineers (USACE) Jordan Reservoir Rules, the Jordan Dam is operated to maintain a minimum target flow of 600 cfs at the USGS gage at Lillington under normal conditions (USACE, 2007). However, releases from Jordan Reservoir can drop to as low as 40 cfs depending on the amount of water remaining in the conservation pool.

A study by the NCDWR indicated that municipal water demand is expected to increase significantly in the future (NCDWR, 2008). The current withdrawals from Jordan Reservoir for water supply purposes are approximately 16.94 mgd (26.2 cfs). These are expected to increase to 73.54 mgd (113.8 cfs) by 2050. Jordan Reservoir and the Cape Fear River are actively managed to meet upstream and downstream needs. Increased demands in the future make these resources all the more critical. One objective of the NCDWR is to ensure that water supply is managed so that demands from all users in the basin are met.

Water in Jordan Reservoir is considered to be in one of three storage pools: flood storage, conservation storage, and sediment storage (see **Figure A1,** *Schematic of Jordan Reservoir Water Storage Areas*). The conservation storage pool is further split into a water supply pool and a water quality pool. Support for aquatic life and other downstream uses comes from the water quality pool. Water supply releases for permitted users come from the water supply pool. When full, the water quality and water supply pools contain approximately 140,400 acre-feet of water. Under drought conditions, the level of the conservation storage pool drops, since inflows to the reservoir are limited but releases to the Cape Fear River continue. Adding a withdrawal to provide additional cooling water would add to required releases during drought periods if no alternative storage is available.

The current and expected future needs for water from the Cape Fear River and the multi-purpose functions of the Jordan Reservoir as managed by USACE call for water users in the Cape Fear River Basin to optimize their resources and manage water needs for the benefit of the entire system. Because of the minimum releases specified in the Jordan Reservoir rules, users both upstream and downstream of the proposed withdrawal could be impacted by withdrawals from the Cape Fear River during drought conditions. Expansion of Harris Reservoir provides a mechanism for capturing and storing water for the purpose of providing cooling water for power generation when Cape Fear River flows are adequate and reducing or suspending withdrawals from the Cape Fear River when flows are low. This flexibility in withdrawals helps to minimize impacts to the ecology of the Cape Fear River, water quality in the river, and water supply for upstream and downstream water users.

FIGURE A1
Schematic of Jordan Reservoir Water Storage Areas



Source: NCDWR, 2008.

Determination of Availability and Required Reservoir Elevation

Modeling analyses were performed using the CFRBHM to evaluate the potential impacts of different operational scenarios, for example, the no action alternative and minimum required level, on water levels of Harris Reservoir. The CFRBHM was developed by Hydrologics, Inc. for the NCDWR to evaluate water supply allocations in the Cape Fear River Basin (NCDWR, 2008). Modifications were made to the model by NCDWR in 2008 to incorporate revised water demand estimates for users in the basin and to provide future estimates of water availability. Additional modifications were performed in 2010 by Hydrologics to evaluate potential operating scenarios for Harris Reservoir that would meet both PEC's and NCDWR's objectives.

Model Description

The CFRBHM describes the Cape Fear River Basin through a set of nodes, representing storage and demands, and a set of links, which define the inflows, outflows, and the routing within the system. Withdrawals and discharges are defined through the use of time series records, user-specified patterns, or operational control language (OCL) rules. Inflows to the system are primarily due to rainfall runoff and point source discharges. Contributions of flow from the watershed and meteorological inputs were estimated by NCDWR for use as model inputs for the period from January 1930 through December 2009.

The model dynamically simulates inflows, routing, and storage for all nodes and links in the system. The scope of the model includes all significant withdrawals and discharges from the headwaters of the Cape Fear River to United States (U.S.) Lock and Dam Number 1 (see **Figure A2,** *Cape Fear River Basin Hydrologic Model Schematic*). **Figure A3,** *Close-up of the Cape Fear River Basin Hydrologic Model Schematic for the Jordan Reservoir and Harris Reservoir Area,* shows a close view of the area of interest for this study.

The CFRBHM is designed to be used by an interested party to evaluate changes in withdrawals or discharges. Any changes to withdrawals or discharges in the basin are likely to require evaluation using the CFRBHM to affirm that no detrimental effects would occur and that sufficient water availability remains for other uses.

FIGURE A2
Cape Fear River Basin Hydrologic Model Schematic

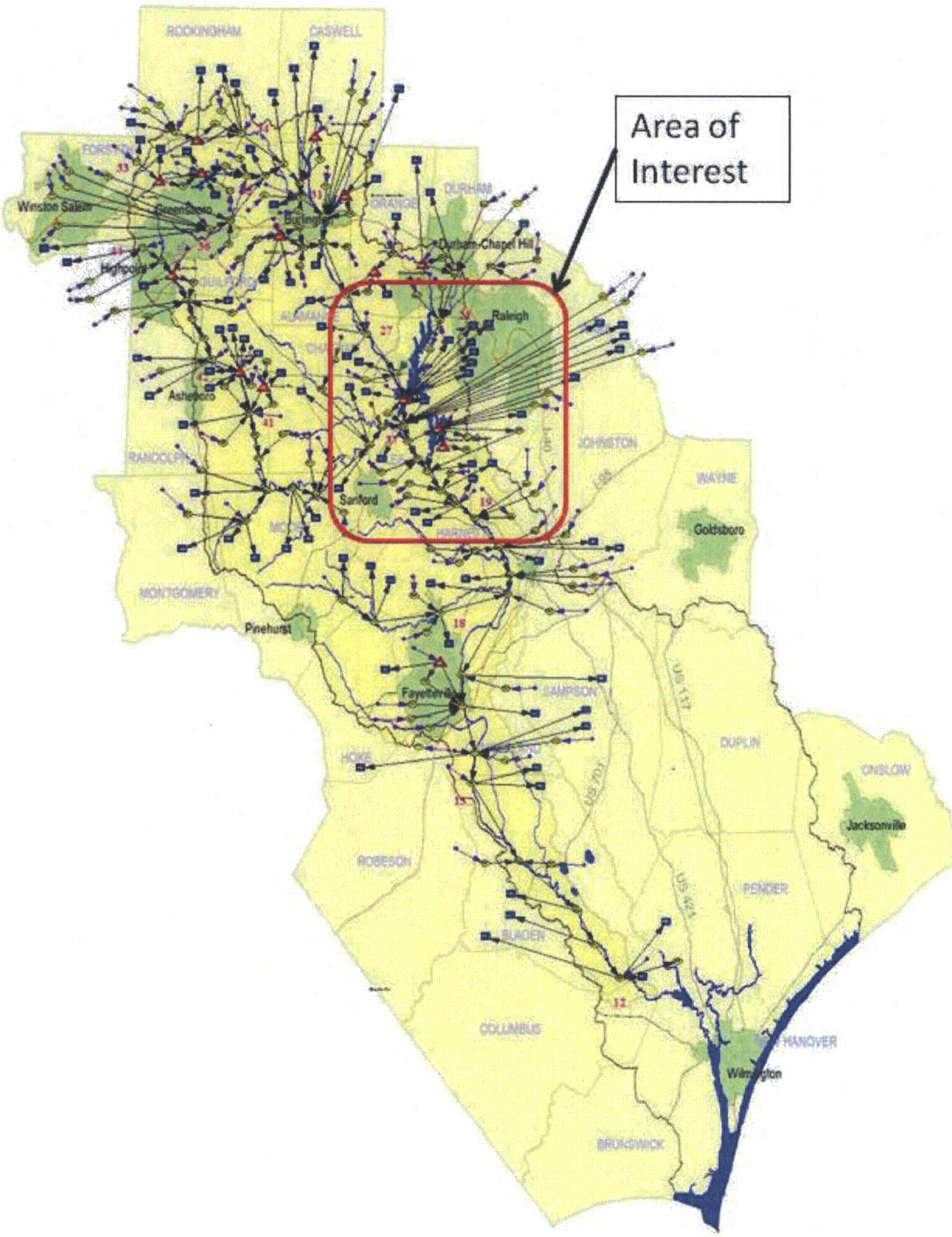
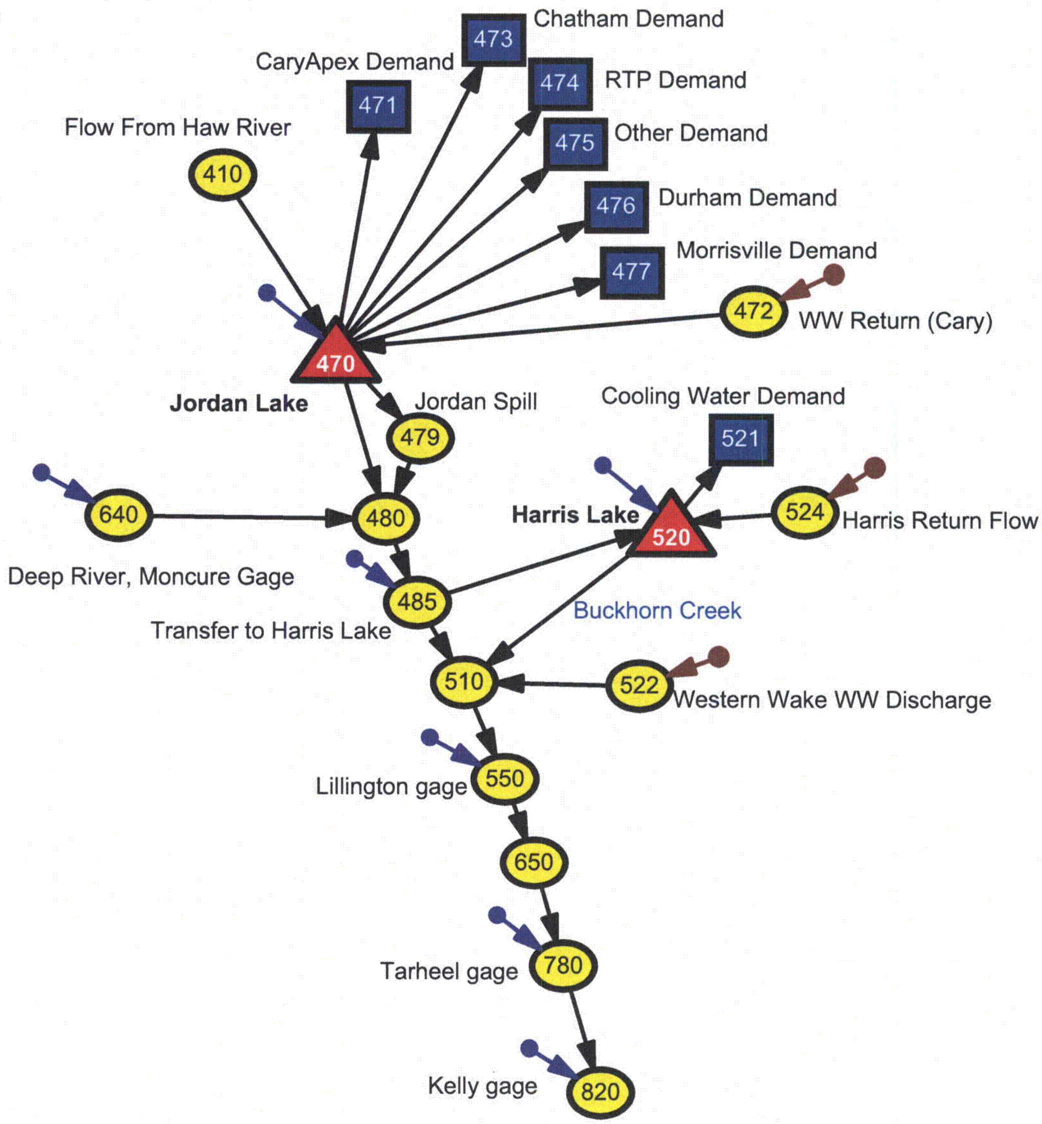


FIGURE A3
Close-up of the Cape Fear River Basin Hydrologic Model Schematic for the Jordan Reservoir and Harris Reservoir Area



Model Inputs and Assumptions

The CFRBHM was modified by Hydrologics to incorporate details associated with the operation of the HNP and HAR. The model predicts long-term water supply and reservoir elevations based on a mathematical representation of entities within the system, for example, a reservoir is represented by a stage-storage relationship.

A number of constraints and assumptions are made in revising the model to evaluate the required reservoir level. The constraints and assumptions relevant to the reservoir level analysis include future demands, the minimum withdrawal level, the maximum safe operating level, future inflow rates to the Cape Fear River, and potential withdrawal rates from the Cape Fear River.

Future Demands

To capture the potential changes in demand in the basin over the life of the project, the 2050 scenario developed by NCDWR was used. While this does not cover the entire potential life of the project, which is at least 60 years, this scenario indicates future trends in water use.

Determination of Normal Pool Volume

The evaluation of the required operating level includes the determination of the range over which water can be withdrawn from the reservoir. This includes the minimum elevation based on engineering constraints, and a reserve pool and a maximum elevation based on dam safety and flooding concerns.

Minimum Withdrawal Elevation

The bottom elevation for the normal cooling water volume of Harris Reservoir is based on the minimum level that the raw water pumps can operate and the elevation of the top of the reserve pool.

The design of the cooling water system includes the use of three pumps, each capable of drawing approximately 13,000 gpm from Harris Reservoir. The bottom of the intake structure is designed to be constructed on hard rock at 210 feet NGVD29.

Technical specifications for this size pump were obtained to determine the minimum water level that is required for the operation of these pumps. A minimum operating level of 224 feet NGVD29 was calculated based on the intake elevation, pumping rate, and submergence requirements (Worley Parsons, 2010). This elevation is the engineering threshold below which the HAR would need to shut down.

Available water supply in the reservoir was based on an allocation of the reservoir pool being split into a normal operating pool and a reserve pool. The reserve pool provides a margin of safety to address a number of factors including seepage from the dam, losses to groundwater, unforeseen events, and the need to allow for revisions to plant design as project moves from the conceptual to the construction phase.

Determination of Reserve Pool Volume

The 224-foot elevation quantifies the absolute minimum level at which the pumps should be operated. A reserve pool of water was calculated beginning from this level. The NCDWR has set 20 percent of a water supply as a guideline for when demand has reached a critical point (NCDWR, 2009). For long-term planning, entities must identify alternative sources of water when the existing supply approaches this point, implement a demand management program, and apply restrictive measures for withdrawal.

Beginning with a level of 224 feet NGVD29, 20 percent of the volume for elevations between 234- and 240-feet NGVD29 was calculated. This represents 20 percent of the available pool depending on the required operating level. Volume information is available based on detailed bathymetry data collected by PEC in January 2009. The 20 percent volume was added to the volume below 224 feet NGVD29, 82,104 ac-ft, and then converted back to elevation to determine the top of the reserve pool.

The results of the calculations are provided in **Table A1**, *Estimates of Harris Reservoir Reserve Pool*, and show that the volume between 224 and 229 feet NGVD29 would provide a 20 percent buffer for an operating level of 240-feet NGVD29. The volume between 224 and 228 feet NGVD29 would provide a 20-percent buffer for an operating level of 238-feet NGVD29.

TABLE A1
Estimates of Harris Reservoir Reserve Pool

Upper Level (ft)	Lower Level (ft)	20% of Volume (ac-ft)	Minimum Volume (ac-ft)	Equivalent Elevation (ft)
240	224	19,417	101,521	229
238	224	16,431	98,535	228
236	224	13,581	95,684	227
234	224	10,858	92,961	227

Dam Safety

The Main Dam was constructed to accommodate reservoir elevations up to 250 feet NGVD29, which is 30 feet above the current normal operating level of 220 feet NGVD29. The dam configuration can accommodate a reservoir elevation of 240 feet NGVD29 without major modification. Analyses developed in support of the FSAR evaluated the condition of the dam and demonstrated its ability to store water safely at a 240-foot-NGVD29 level. The reports include *Review of Lake Main Dam Slope Protection* (Sargent and Lundy, 2007a), *Harris Main Dam Slope Stability Analysis* (Sargent and Lundy, 2007b), and *Review of Main Dam Slope Stability Analysis* (Sargent and Lundy, 2007c). These analyses indicate that dam safety is not an issue for reservoirs at least as high as 245 feet NGVD29.

A PMH analysis was performed in support of the FSAR (PEC, 2010b). The PMH is a hypothetical steady-state hurricane having a combination of meteorological parameters that will give the highest sustained wind speed. A PMH could cause a water level change in the Main Reservoir and the Auxiliary Reservoir. The resulting high water levels, if not considered in the project design, could affect the safety of the Main Dam, Auxiliary Dam, or safety-related structures located at the plant site. This analysis determined that a reservoir level of more than 240 feet NGVD29 would not provide an adequate margin against flooding of the safety-related structures associated with the HNP, HAR 2, and HAR 3.

Estimation of Pumping Rates

Section 316(b) of the Clean Water Act addresses cooling water intake structures. For new cooling water supplies, Title 40 *Code of Federal Regulations* (CFR) Part 125.84(b)(3) interprets the final rule as requiring withdrawals for cooling water supplies to be limited to 5 percent of the average flow of a river. For the 10-year period from January 1, 2000, through December 31, 2009, the estimated allowable flow was approximately 123 cfs. The long-term average allowable flow, based on the entire period of record, is approximately 155 cfs (USGS, 2010).

The current design plan calls for three pumps to withdraw water from the Cape Fear River between B. Everett Jordan Reservoir and Buckhorn Dam, with each pump capable of pumping 20,000 gpm (28.8 mgd, 44.6 cfs) for a maximum rate of 60,000 gpm (86.6 mgd, 134 cfs). This capacity is within the range of recent and long-term allowable pumping rates.

As described above, the Jordan Reservoir operating rules require a flow of 600 cfs at the Lillington, NC USGS gage. Withdrawals from the Cape Fear River were restricted in the model so that they occurred only when flow in the Cape Fear River at Lillington was above 600 cfs. Pumps were individually turned on for flow between 645 cfs and 750 cfs to allow for maximum withdrawals without causing a drop below the 600 cfs threshold.

Global Climate Change

The Council on Environmental Quality (CEQ) has recommended that GCC be considered by federal agencies in their evaluation of proposals for federal actions under the National Environmental Policy Act (NEPA) (CEQ, 2010). This guidance recognizes that much uncertainty exists regarding GCC but directs federal agencies to consider the potential effects that GCC could have on the proposed action.

As discussed in the next section, a 10-percent factor was used to determine the required reservoir level. This level had been suggested in discussions with NCDWR and is approximately the same magnitude as the predicted decreases in annual rainfall for the Southeast United States. These changes will be incorporated into the CFRBHM as direct changes to inflows to the river system.

Results of Reservoir Scenarios

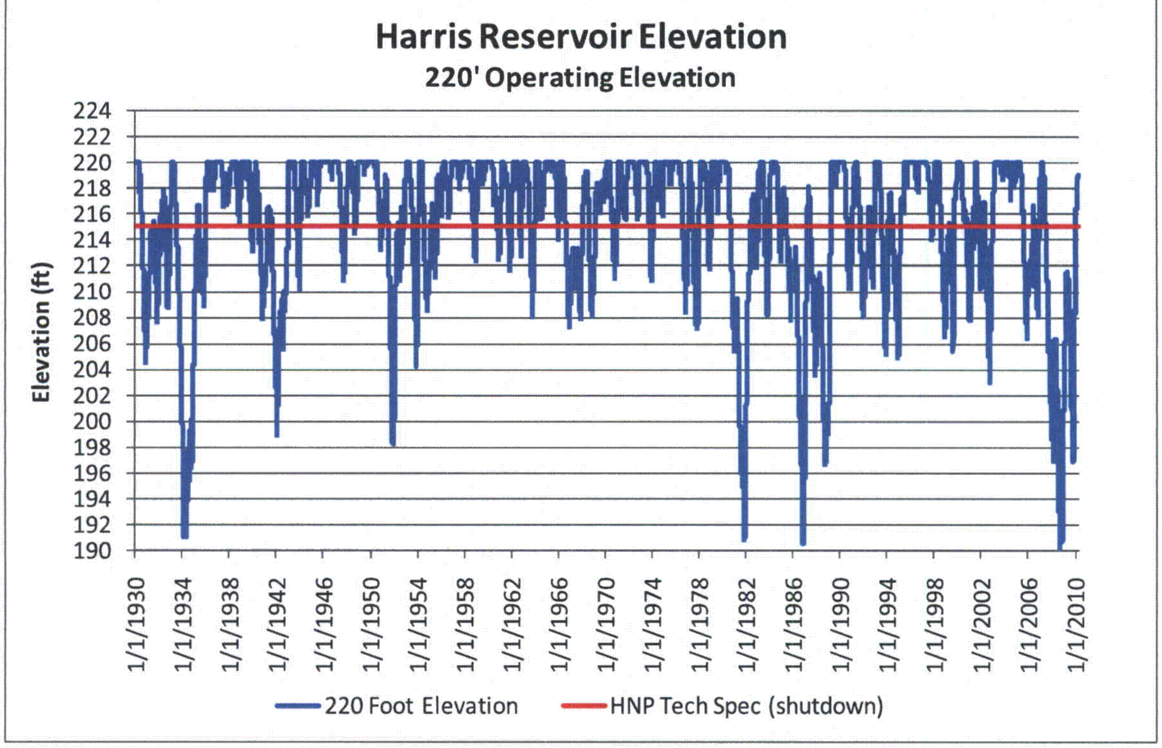
The CFRBHM was used to determine the required operating level based on the constraints stated above. The model was used to determine the operating level that would allow PEC to meet the following criteria:

1. Reliable generation of power
    a. No required shut downs
    b. Minimal time operating within the reserve pool
2. No exceedance of safe operating levels (flood related)
3. Long-term reliability, including the potential for reduced water availability impacts due to GCC

No Change Scenario

The CFRBHM was first run to evaluate a scenario in which the operating level of the reservoir was maintained at 220 feet NGVD29. Based on the engineering design of the raw water intake pumps, this operating level is not feasible. For this exercise however, it was assumed that the HAR could withdraw water down to the tech spec of 215 feet NGVD29 set for the HNP. The tech spec, which applies only to the HNP, is a constraint based on requirements for cooling of safety related heat exchangers. The model was run for the period from 1930 through 2009. Results are shown in **Figure A4,** *Predicted Water Levels with a Reservoir Operating Level of 220 feet NGVD29 and Three Units in Operation*. Water level falls below the HNP tech spec of 215 feet NGVD29 for approximately 38 percent of the time. This indicates that a no action alternative does not meet the statement of needs for the project.

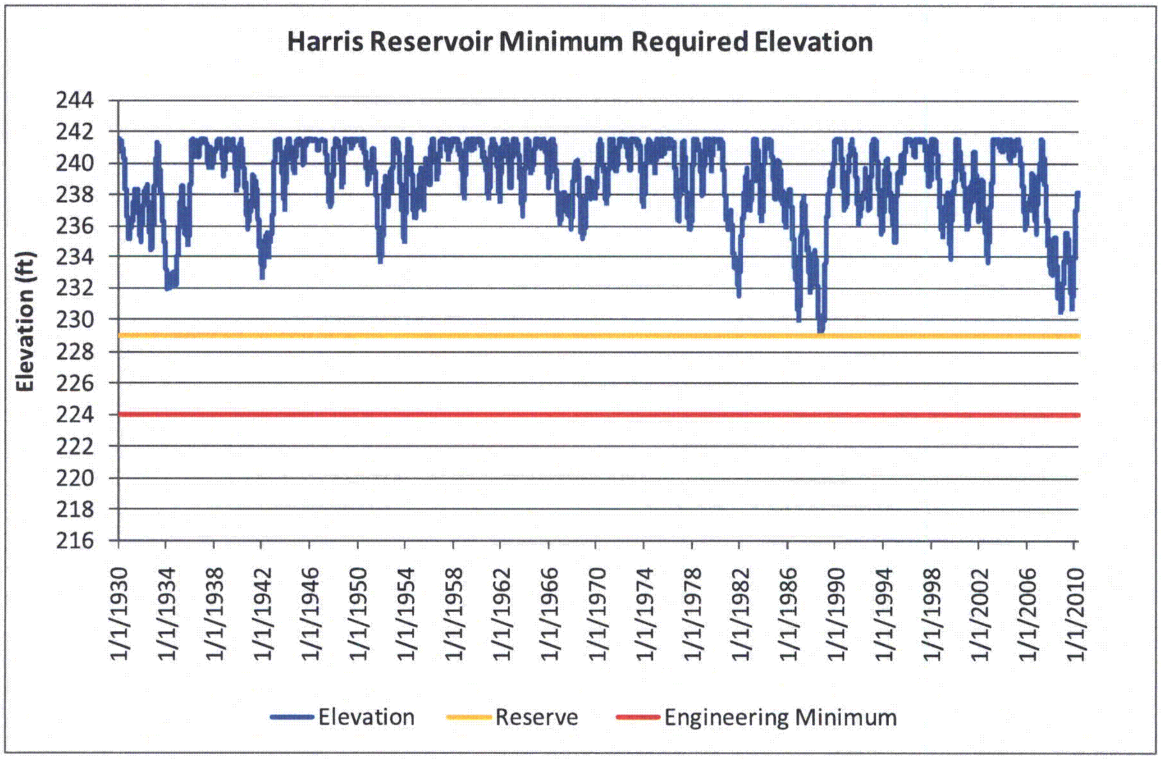
FIGURE A4
Predicted Water Levels with a Reservoir Operating Level of 220 feet NGVD29 and Three Units in Operation



Desired Reservoir Operating Level

The CFRBHM was then run to determine the reservoir level that would allow the three reactor units to operate continuously over the simulation period using the normal pool. The run included the 10-percent reduction in inflows to include consideration of GCC. The model was run iteratively, starting at 234 feet NGVD29, to determine what operating level would maintain the reservoir level above the reserve pool of 229 feet NGVD29. It was determined that a reservoir level of 241.5 feet NGVD29 would be required to maintain reservoir levels above the reserve pool as shown in **Figure A5,** *Evaluation of Minimum Required Reservoir Level for Volume above Reserve Pool*.

FIGURE A5
Predicted Required Reservoir Operating Level with 3 Units in Operation



Reliable Operation Scenarios

A reservoir of 241.5 feet NGVD29 would be required to ensure that the reserve pool was not used under foreseeable conditions. This level, however, is above the allowable elevation based on the PMH calculations. Subsequent model runs were performed to evaluate the impacts of reservoir operating levels of 236, 238, and 240 feet NGVD29, all of which are allowable elevations based on the PMH calculations, on the reserve pool and plant operation. The model was run over the entire simulation period for each of the proposed operating levels. The daily reservoir levels and amount of time the levels fell below the reserve pool were calculated.

A 240-foot NGVD29 operating level met the objective of providing a reliable source of power at all times. The maximum drop in reservoir level was an elevation of 226.6 feet NGVD29, which is 2.4 feet below the reserve level. Water was withdrawn from the reserve pool for 343 days or approximately 1.17 percent of the 80-year evaluation period. Occasional brief withdrawals from the reserve pool are acceptable since one purpose of the reserve pool is to provide a cooling water supply in the case of extreme conditions or unforeseen conditions. The period from May 1988 through April 1989 was one such period where rainfall was limited and flow in the Cape Fear River was frequently less than 600 cfs. During this period, water was withdrawn for 207 of 365 days or 56.7 percent of the time of withdrawal from the reserve pool. The results are shown in **Figure A6**, *Evaluation of Minimum Required Reservoir Level for Volume above Reserve Pool.*

A 238-foot NGVD29 operating level does not meet the reliability criteria. In the model run, shutdown was required twice during late 1988 and early 1989. The first occurrence began on September 24, 1988 and lasted for 39 days. The reservoir level fell to 223.6 feet NGVD29, which is below the 224-foot NGVD29 minimum level required by engineering design. The second shutdown began on December 27, 1989 and continued for 11 days. The second shutdown would have occurred when power demands were potentially very high due to use for heating.

The operating level of 238 feet NGVD29 would require withdrawals from the reserve pool for approximately 939 days over the 80-year evaluation period or 3.2 percent of the time. For the same extreme drought period from May 1988 through April 1989, water was withdrawn from the reserve pool for 249 of 365 days or 68.2 percent of the time. The results are shown in **Figure A7**, *Evaluation of 238-foot NVGD29 Normal Operating Levels.*

A 236-foot NGVD29 operating level would not meet the reliable generation of power criteria. In this scenario, the reservoir level fell to 220.3 feet NGVD29, requiring the plant to shut down. For this scenario, the plant would be shut down for 231 days during the period from July 1988 through February 1989. Four other shutdowns of shorter duration were predicted to occur in the period from 1930 through 2009. These shutdowns would occur during the summer when power demands could potentially be very high due to use cooling requirements and during the winter when power demands could potentially be very high due to use for heating.

A 236 foot NGVD29 operating level increased the number of days the reserve pool was used to 1,986 or 6.8 percent of the time over the 80-year evaluation period. For the same extreme drought period from May 1988 -through April 1989, water was withdrawn from the reserve pool for 324 of 365 days or 88.8 percent of the time. The results are shown in **Figure A8**, *Evaluation of 236-foot NVGD29 Normal Operating Levels.*

FIGURE A6
Evaluation of 240-foot NVGD29 Normal Operating Levels

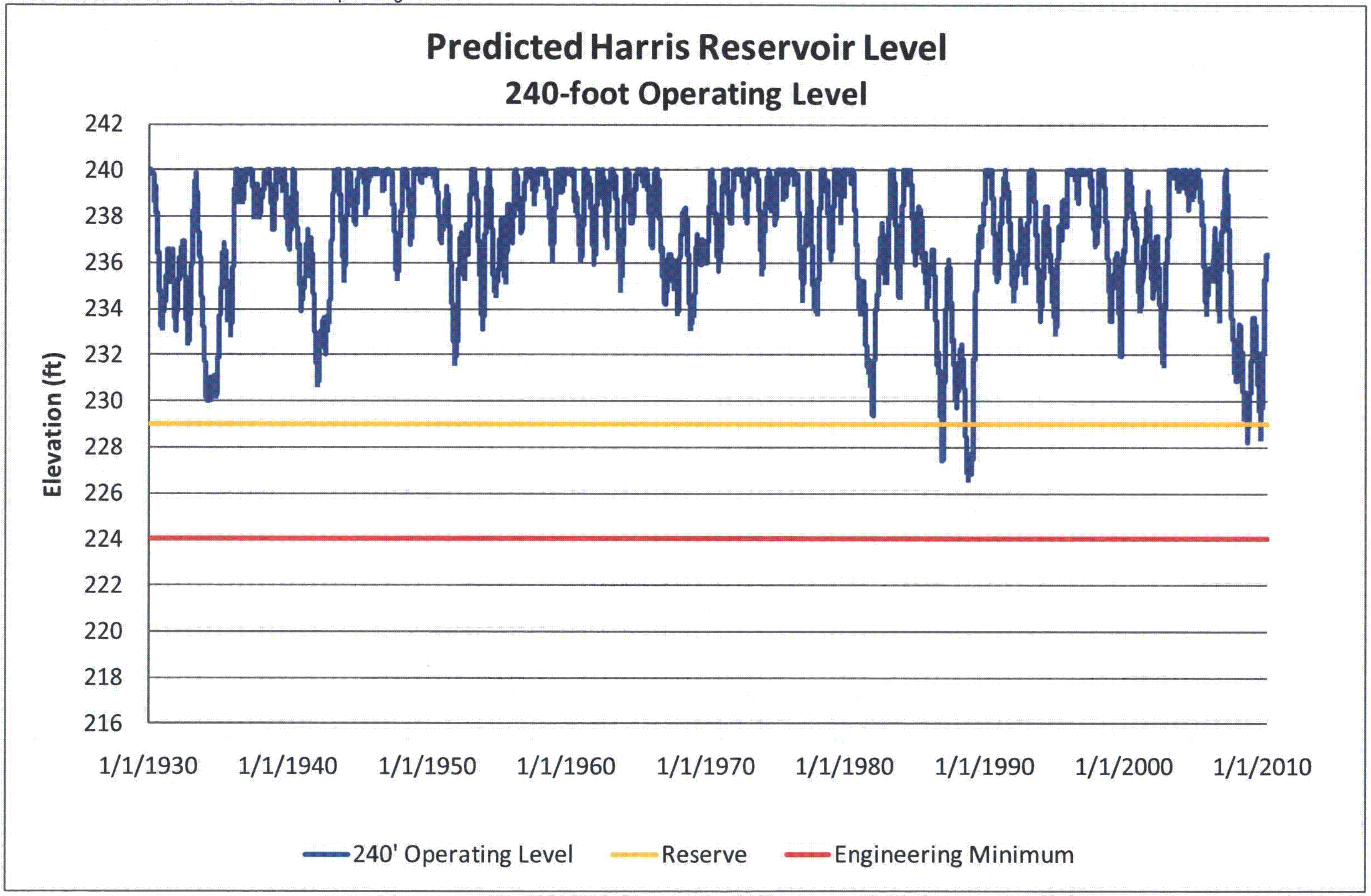


FIGURE A7
Evaluation of 238-foot NVGD29 Normal Operating Levels

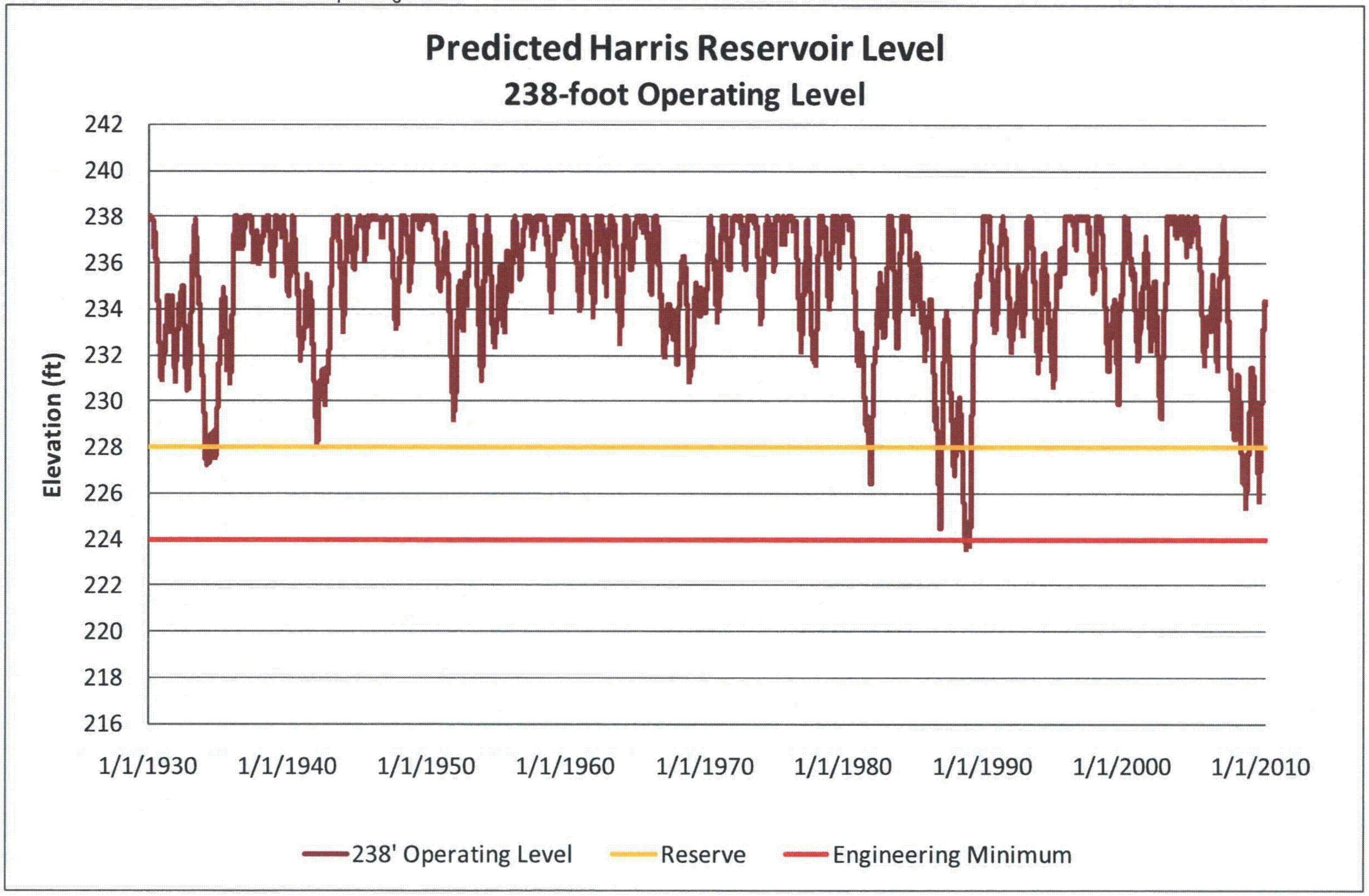
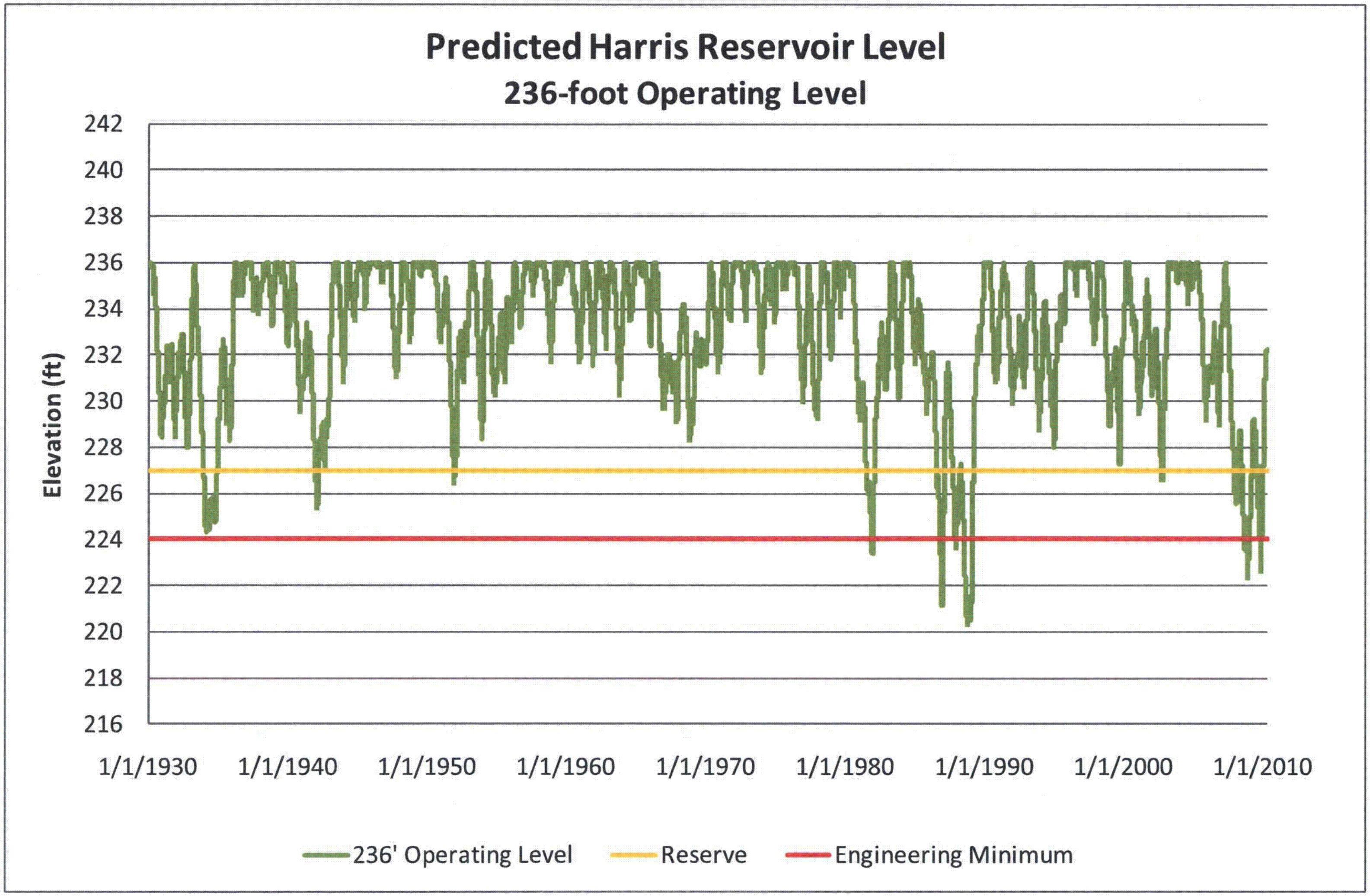


FIGURE A8
Evaluation of 236-foot NVGD29 Normal Operating Levels



Sensitivity Runs

Sensitivity analyses were performed to evaluate the sensitivity of the model predictions to GCC and the discharge from the Holly Springs Wastewater Treatment Plant (WWTP). A sensitivity analysis on impacts to wetlands under different reservoir levels was also performed.

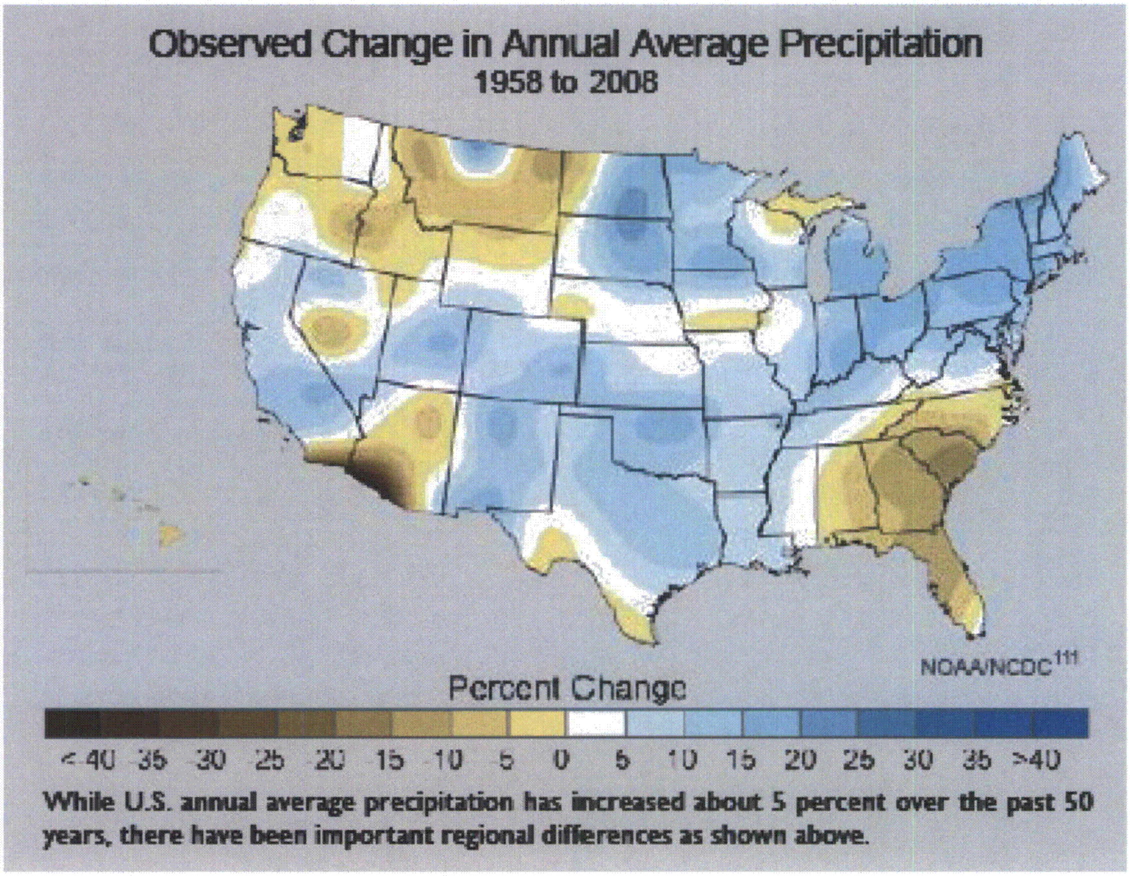
Global Climate Change

The CEQ has recommended that GCC be considered by federal agencies in their evaluation of proposals for federal actions. For the HAR project, the primary, direct impact would be on the availability of cooling water. Predictions compiled by the U.S. Climate Change Program suggests that the Southeast United States will see limited increases in temperature and changes in precipitation amount compared with other regions of the United States (Karl, et. al. 2009). The overall predictions are that extreme events will become more extreme. Droughts have the potential to be more extended and flood events could be larger. The report predicts that the frequency, duration, and intensity of droughts in the region are likely to increase. The report states that average annual precipitation in the Southeast for the period from 1970 to 2008 has decreased by 7.7 percent, with the largest decreases occurring in the mid-Atlantic. **Figures A9** and **A10** show the historical changes in precipitation and drought frequency. Springtime rainfall has decreased by nearly 30 percent in the same period. The tendency for droughts has been increasing in the Southeast, as shown in **Figure A10**, *Observed Change Drought Trends (1958-2007).*

Predictions for changes in rainfall at the HAR site indicated a moderate change (see **Figure A9**, *Observed Change in Annual Average Precipitation*). However, the report suggests that the greatest uncertainty in predictions is likely to occur in the transition zones between wetter and drier areas. **Figure A11,** *Predicted Change in North American Precipitation by 2080-2099,* shows the predicted change in seasonal rainfall for the 2080 to 2099 time period.

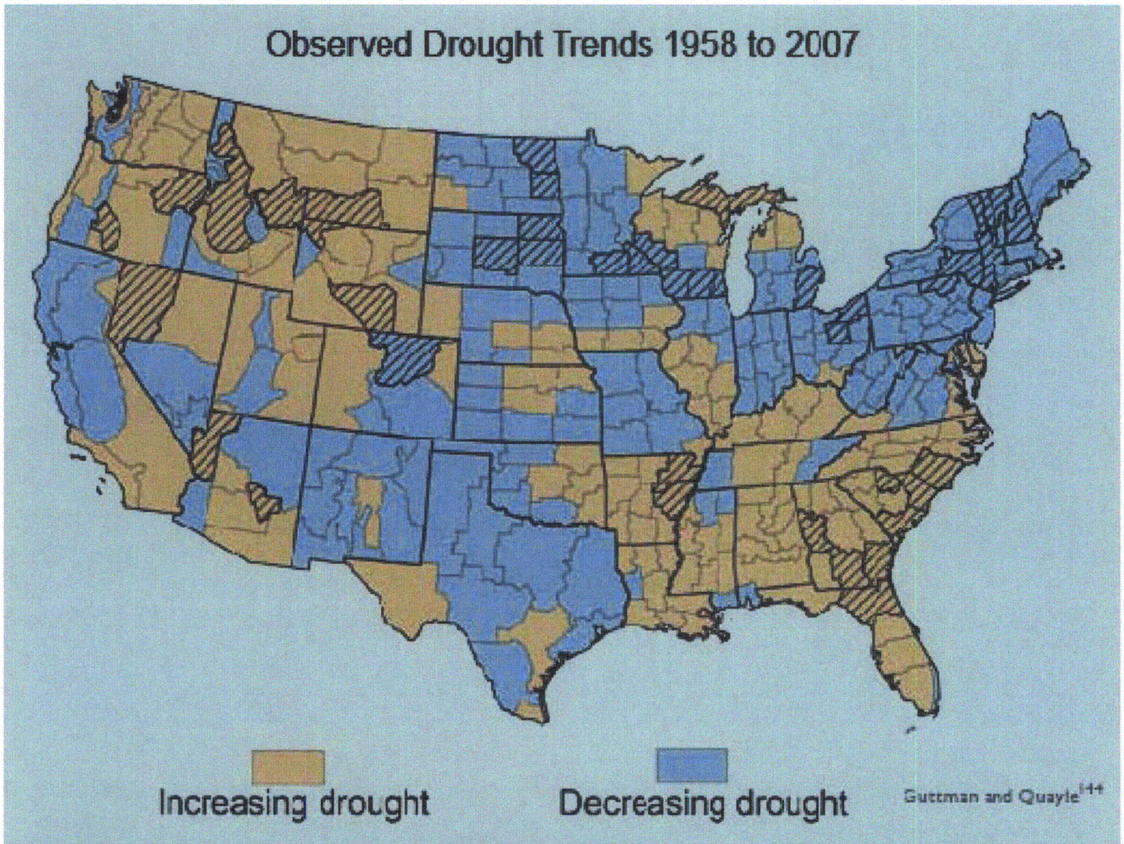
As discussed previously, a 10-percent factor was used in the analyses since it was approximately the same magnitude as the predicted decreases in annual rainfall for the Southeast and was the level discussed with NCDWR. A sensitivity analysis was performed on this factor due to the uncertainty of predicting changes in climate. A scenario with no GCC impacts and scenarios with changes of -10, -20, +10, and +20 percent on river inflows were tested to provide an understanding of the potential impacts of GCC on the water supply for the HAR. The results of these analyses, as shown in **Figure 12**, *Sensitivity of Required Reservoir Levels to Global Climate Change Assumptions*, suggest that each 10 percent change in river inflow could potentially change the reservoir levels by 2 to 3 feet.

FIGURE A9
Observed Change in Annual Average Precipitation



Source: Karl et.al, 2009.

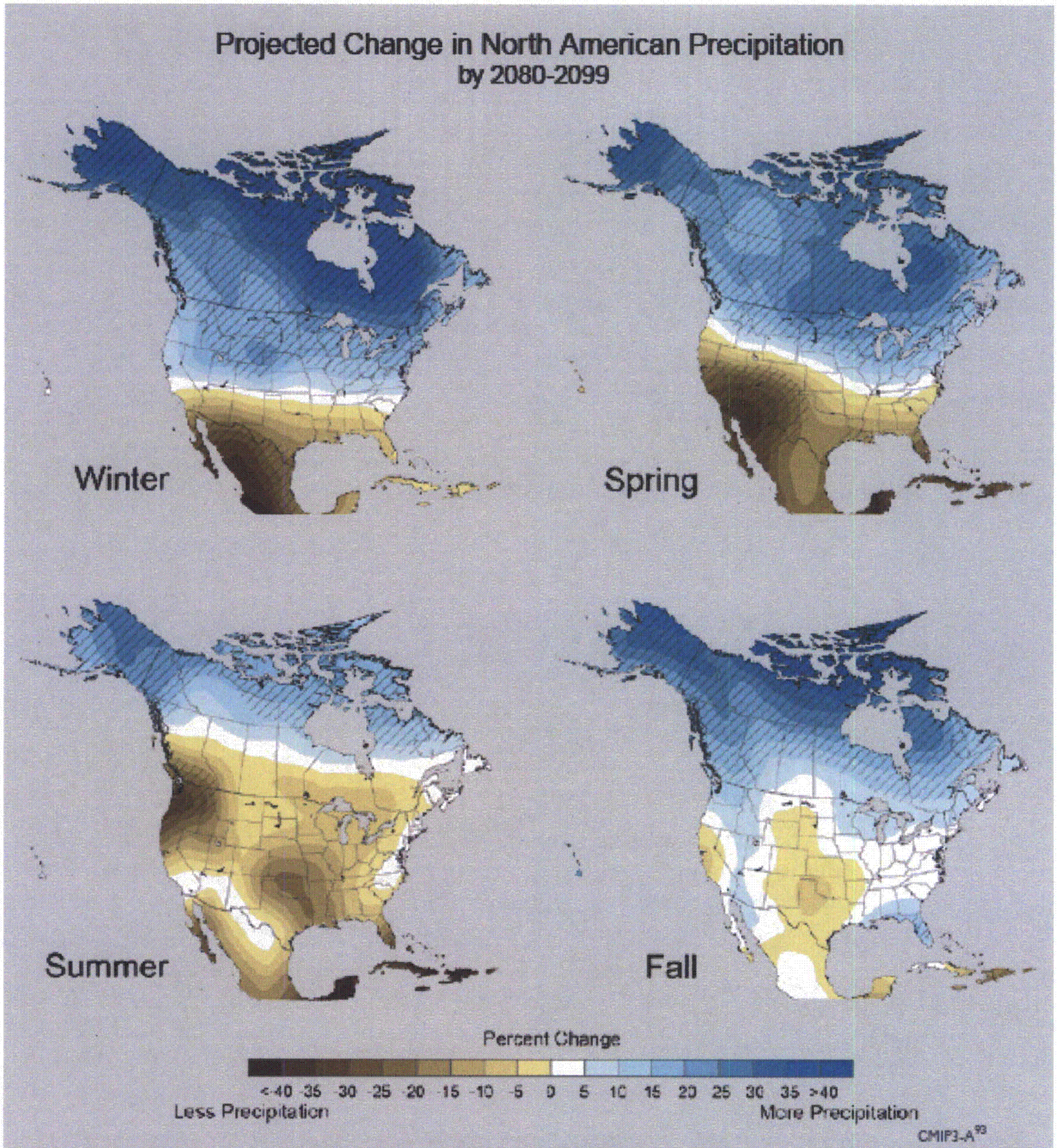
FIGURE A10
Observed Change Drought Trends (1958-2007)



Trends in end-of-summer drought as measured by the Palmer Drought Severity Index from 1958 to 2007 in each of 344 U.S. climate divisions.[144] Hatching indicates significant trends.

Source: Karl et.al, 2009.

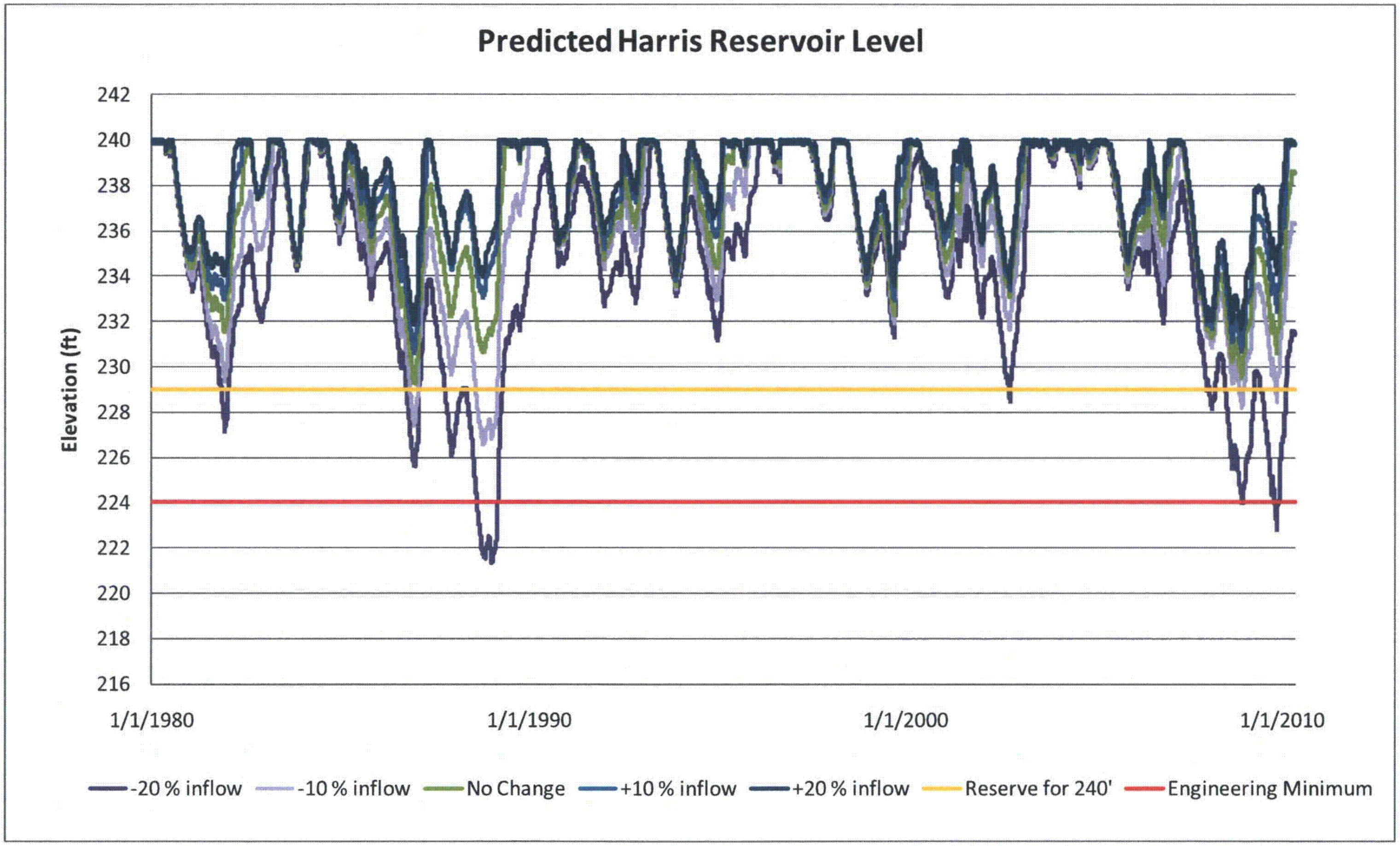
FIGURE A11
Predicted Change in North American Precipitation by 2080-2099



The maps show projected future changes in precipitation relative to the recent past as simulated by 15 climate models. The simulations are for late this century, under a higher emissions scenario.[91] For example, in the spring, climate models agree that northern areas are likely to get wetter, and southern areas drier. There is less confidence in exactly where the transition between wetter and drier areas will occur. Confidence in the projected changes is highest in the hatched areas.

Source: Karl et.al, 2009.

FIGURE A12
Sensitivity of Required Reservoir Levels to Global Climate Change Assumptions

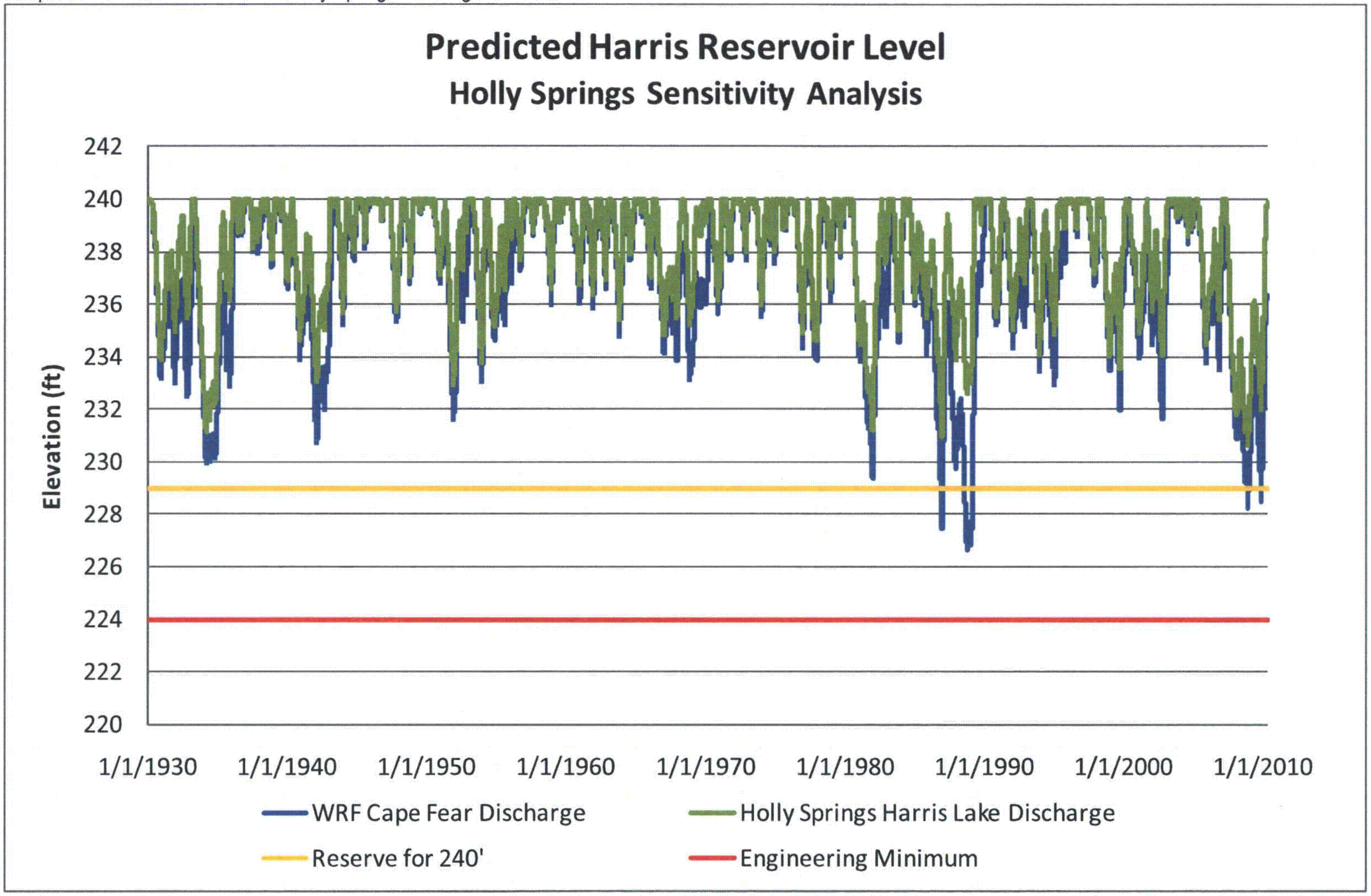


Holly Springs Wastewater Discharge

The Western Wake Regional Water Reclamation Facility (WRF) is a proposed wastewater treatment facility that will treat sewage for municipalities in the Western Wake County area, including the towns of Cary, Apex, and Holly Springs. This facility is designed to discharge up to 38 mgd, including a contribution of 8 mgd from Holly Springs, by 2050. The Western Wake Partners have evaluated the potential for discharging the effluent from the WRF to Harris Reservoir. However, the regulations for interbasin transfers have made this option infeasible.

Holly Springs currently discharges approximately 1.5 mgd to Harris Reservoir. The interbasin transfer regulations that disallowed the overall Western Wake Regional WRF do not apply to the discharge from Holly Springs. For this reason, it is possible for the Holly Springs discharge to continue flowing to Harris Reservoir. A sensitivity run was performed by performing an additional run with the Holly Springs discharge being separated from the remaining WRF discharge. Increasing the discharge to Harris Reservoir would provide a steady inflow to the reservoir and could reduce the required reservoir elevation as shown in **Figure 13,** *Comparison of Reservoir Levels for Holly Springs Discharge Scenarios*. However, Holly Springs is currently one of the entities involved in the Western Wake Regional WRF project and has been authorized to discharge to the Cape Fear River. The Record of Decision for the discharge to the Cape Fear River was published for public review on July 28, 2010 (USACE, 2010). No alternative to this discharge has been approved by the North Carolina Division of Water Quality.

FIGURE A13
Comparison of Reservoir Levels for Holly Springs Discharge Scenarios



Wetlands

A sensitivity analysis was performed to determine the impacts to wetlands associated with reservoir levels of 240, 238, and 236 feet NGVD29. A detailed evaluation of jurisdictional wetlands was performed to support the *Environmental Report* (PEC, 2010a). The information collected during the wetlands assessment was used to quantify the amount of wetlands that would be impacted at different reservoir elevations. The delineated pond, fringe, and emergent wetlands were overlaid with elevation contours to calculate the amount that would be lost for each 2-foot change in reservoir elevation. As shown on **Table A2**, the majority of the wetlands occur in the first 4 feet of elevation above 220 feet NGVD29. This is due to the fact that the wetlands that would be impacted are primarily emergent, fringe, and pond wetlands that occur at the current operating level of the reservoir. Approximately 82 percent occur at or below 222 feet NGVD29, with an additional 9 percent occurring in the next 2 feet.

Approximately 614.2 acres of wetlands may be impacted if the reservoir operating level is 236-feet NGVD29. An increase of 0.5 percent (2.8 acres) of wetland impacts is associated with a reservoir level of 238 feet NGVD29. Approximately 4.9 acres of additional wetland impacts, an increase of 0.8 percent is associated with a reservoir level of 240 feet NGVD29.

An analysis of stream length impacts showed a consistent amount of impact per each increase in elevation. This result is consistent with the fact that the streams travel a fairly linear path from their headwaters through the area within the 220-foot to 240-foot NGVD29 contour.

TABLE A2

Comparison of Jurisdictional Wetland Impacts versus Reservoir Elevation

Min Elevation	Wetland Pond Acreage	Wetland Fringe Acreage	Wetland Emergent Acreage	Total Wetland Acreage	Cumulative Area	Percentage
Various (associated with intake structure)	7.2			7.2	7.2	1.2%
<220			340.5	340.5	347.7	55.0%
220 - 222	97.2	63.9		161.1	508.8	82.1%
222 - 224	56.6			56.6	565.4	91.3%
224 - 226	25.5			25.5	590.9	95.4%
226 - 228	9.3			9.3	600.2	96.9%
228 - 230	3.3			3.3	603.6	97.5%
230 - 232	3.1			3.1	606.6	98.0%
232 - 234	4.6			4.6	611.2	98.7%
234 - 236	3.2			3.2	614.4	99.2%
236 - 238	2.8			2.8	617.2	99.7%
238 - 240	1.8			1.8	619.0	99.9%
>240	0.3			0.33	619.3	100.0%

Note: Wetland areas presented in this table may differ slightly from those used in the jurisdictional determination due to rounding errors which were introduced when the computer aided design files containing the wetlands delineations were converted to GIS shapefiles and overlayed with elevation contours.

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