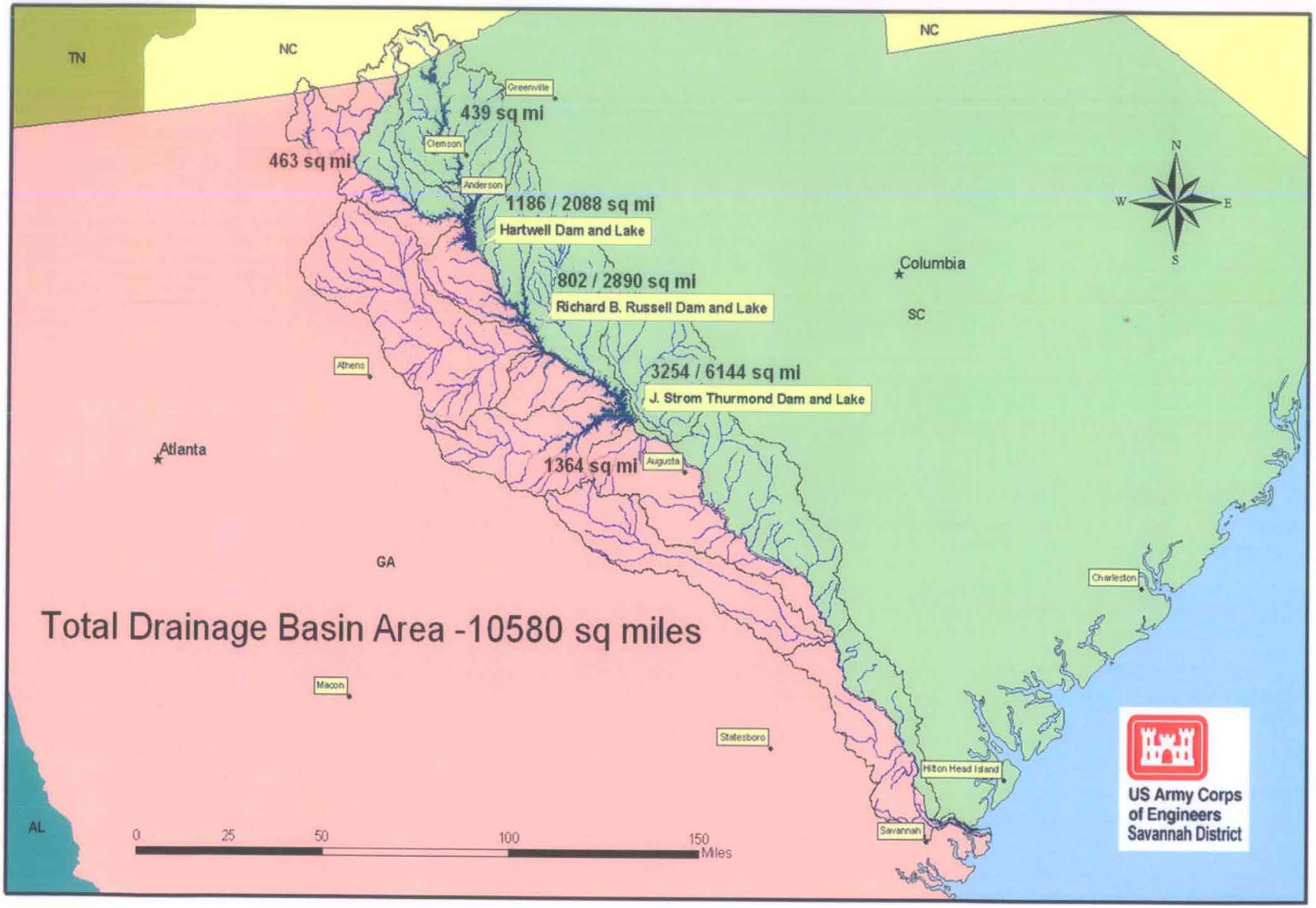
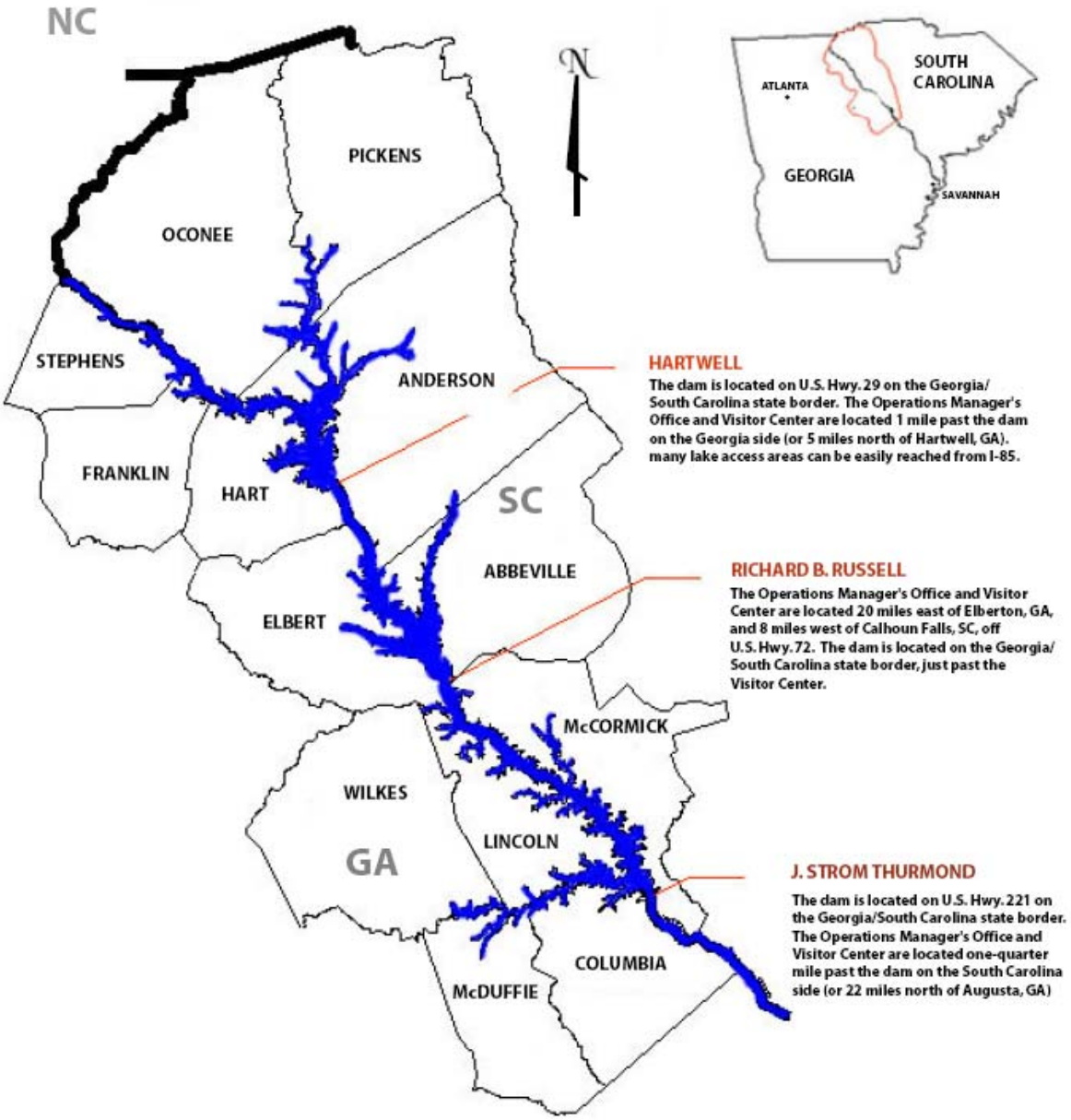
APPENDIX A

SAVANNAH RIVER BASIN MAPS

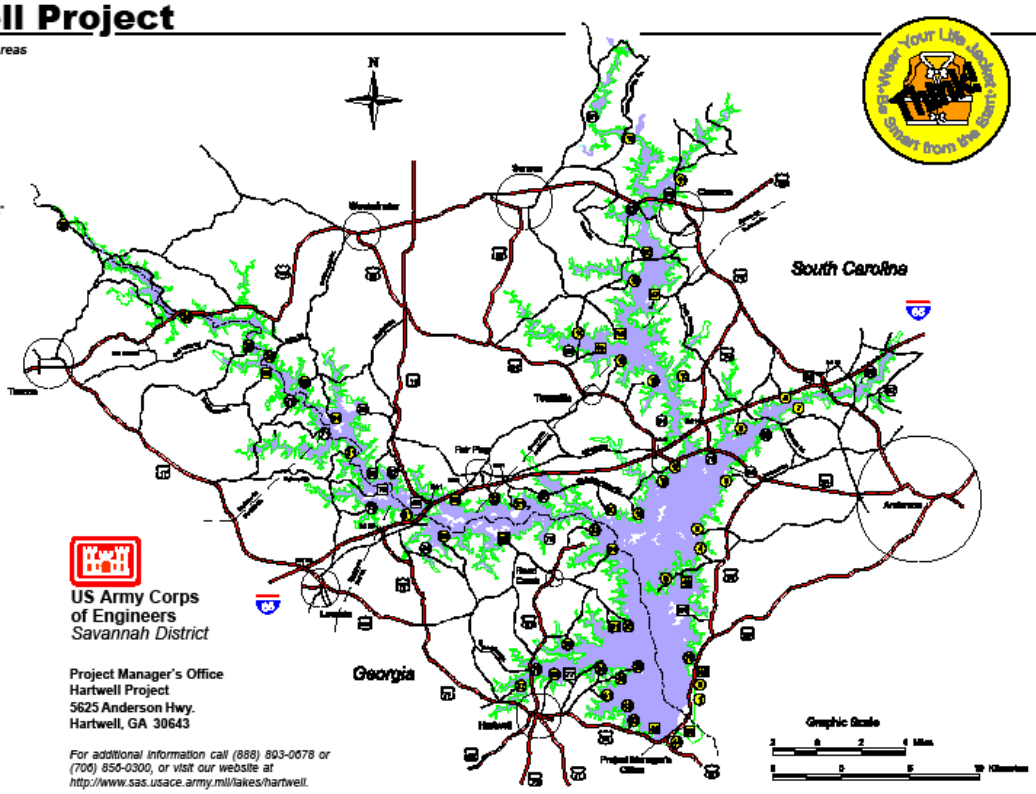

TN
NC
NC
Greenville
439 sq mi
Clemson
463 sq mi
Anderson
1186 / 2088 sq mi
Hartwell Dam and Lake
802 / 2890 sq mi
Richard B. Russell Dam and Lake
Columbia
SC
N
W
E
S
Athens
3254 / 6144 sq mi
J. Strom Thurmond Dam and Lake
Atlanta
1364 sq mi
Augusta
GA
Charleston
Total Drainage Basin Area -10580 sq miles
Macon
Statesboro
Hilton Head Island
Savannah
AL
0
25
50
100
150
Miles
US Army Corps
of Engineers
Savannah District


NC
N
PICKENS
OCONEE
STEPHENS
ANDERSON
FRANKLIN
HART
SC
ABBEVILLE
ELBERT
McCORMICK
WILKES
LINCOLN
GA
COLUMBIA
McDUFFIE
ATLANTA
SOUTH CAROLINA
GEORGIA
SAVANNAH
HARTWELL
The dam is located on U.S. Hwy. 29 on the Georgia/ South Carolina state border. The Operations Manager's Office and Visitor Center are located 1 mile past the dam on the Georgia side (or 5 miles north of Hartwell, GA). many lake access areas can be easily reached from I-85.
RICHARD B. RUSSELL
The Operations Manager's Office and Visitor Center are located 20 miles east of Elberton, GA, and 8 miles west of Calhoun Falls, SC, off U.S. Hwy. 72. The dam is located on the Georgia/ South Carolina state border, just past the Visitor Center.
J. STROM THURMOND
The dam is located on U.S. Hwy. 221 on the Georgia/South Carolina state border. The Operations Manager's Office and Visitor Center are located one-quarter mile past the dam on the South Carolina side (or 22 miles north of Augusta, GA)

Hartwell Project

Corps Recreation Areas

1 Hartwell Dam
2 Singing Pines
3 Jarrett*
4 Richland Creek
5 River Forks
6 Green Pond
7 Honea Path*
8 Denver
9 Asbury
10 Eighteen Mile Creek*
11 Twelve Mile
12 Lawrence Bridge
13 Martin Creek
14 Friendship
15 Townville
16 Camp Creek
17 Broyles
18 Apple Island*
19 Double Springs
20 Weldon Island
21 Glenn Ferry
22 Durham*
23 Fair Play
24 Choestoea
25 Mullins Ford
26 Tabor*
27 Walker Creek*
28 Stephens County
29 Spring Branch
30 Jenkins Ferry
31 Poplar Springs
32 Rock Springs
33 Mary Ann Branch
34 Crawfords Ferry
35 Carters Ferry*
36 New Prospect
37 Cleveland*
38 Gum Branch
39 Long Point
40 Duncan Branch*
41 Powderbag Creek*
42 Elrod Ferry
43 Hartwell Group
44 Big Oaks
47 Twin Lakes
53 Georgia River



US Army Corps of Engineers
Savannah District

Project Manager's Office
Hartwell Project
5625 Anderson Hwy.
Hartwell, GA 30643

For additional information call (888) 893-0678 or (706) 856-0300, or visit our website at http://www.sas.usace.army.mil/lakes/hartwell.

Corps Campgrounds

45 Crescent Group Camp
46 Springfield
47 Twin Lakes
48 Oconee Point
49 Coneross
50 Paynes Creek
51 Milltown
52 Watsadler
53 Georgia River

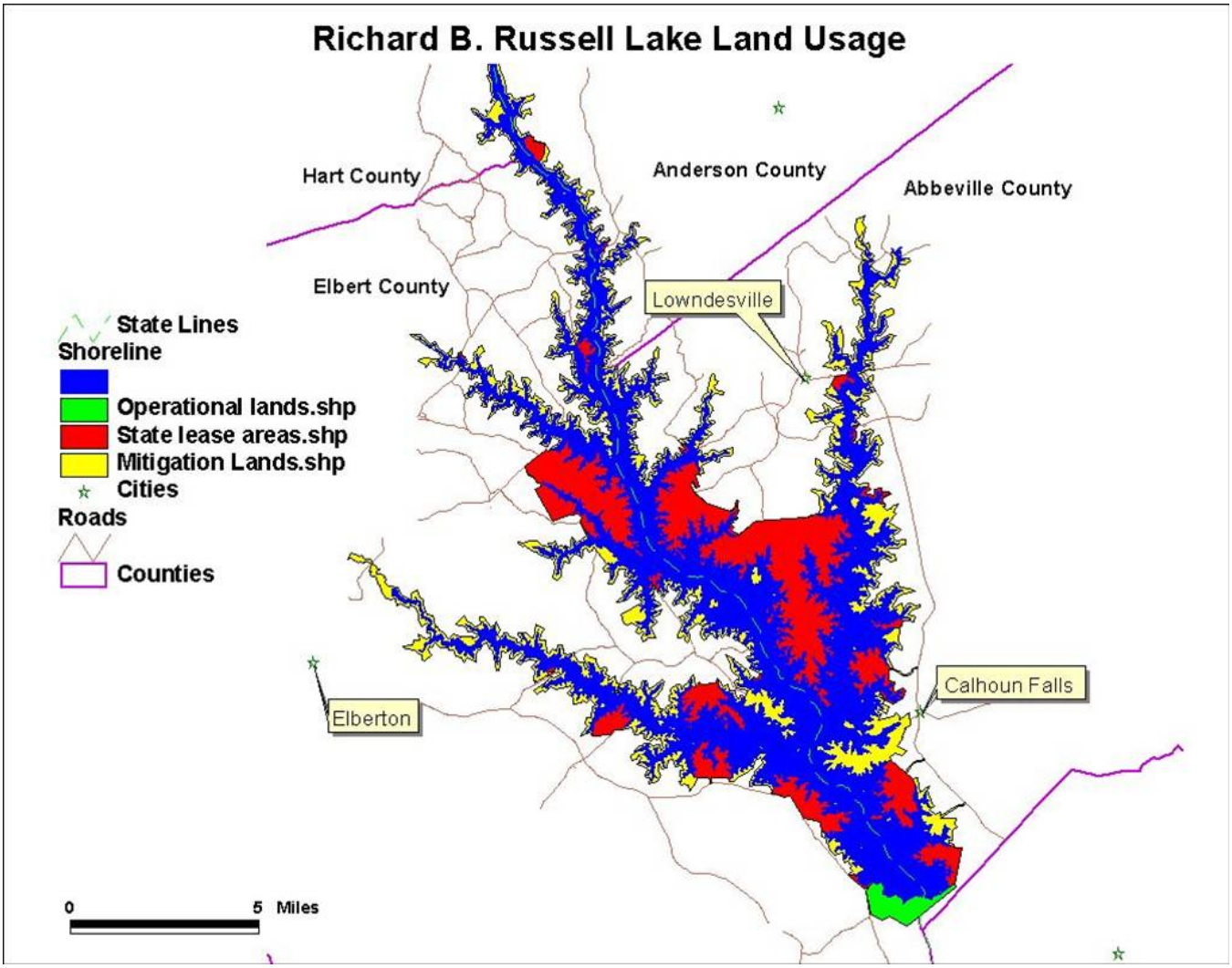
State & Municipal Recreation Areas

54 Sadlers Creek State Park
55 Jack's Landing*
56 White City*
57 Brown Road*
58 Darwin H. Wright
59 Hurricane Creek*
60 Clemson*
61 Holder's*
62 Seneca Creek*
63 Timberlake*
64 Hoyt-Tilley*
65 Cove Inlet*
66 Lake Hartwell State Park
67 Barton's Mill*
68 Port Bass*
69 South Union*
70 Bruce Creek*
71 Holcomb*
72 Tugaloo State Park
73 Franklin County*
74 Rocky Ford*
75 Reed Creek*
76 Bradberry*
77 Hart State Park

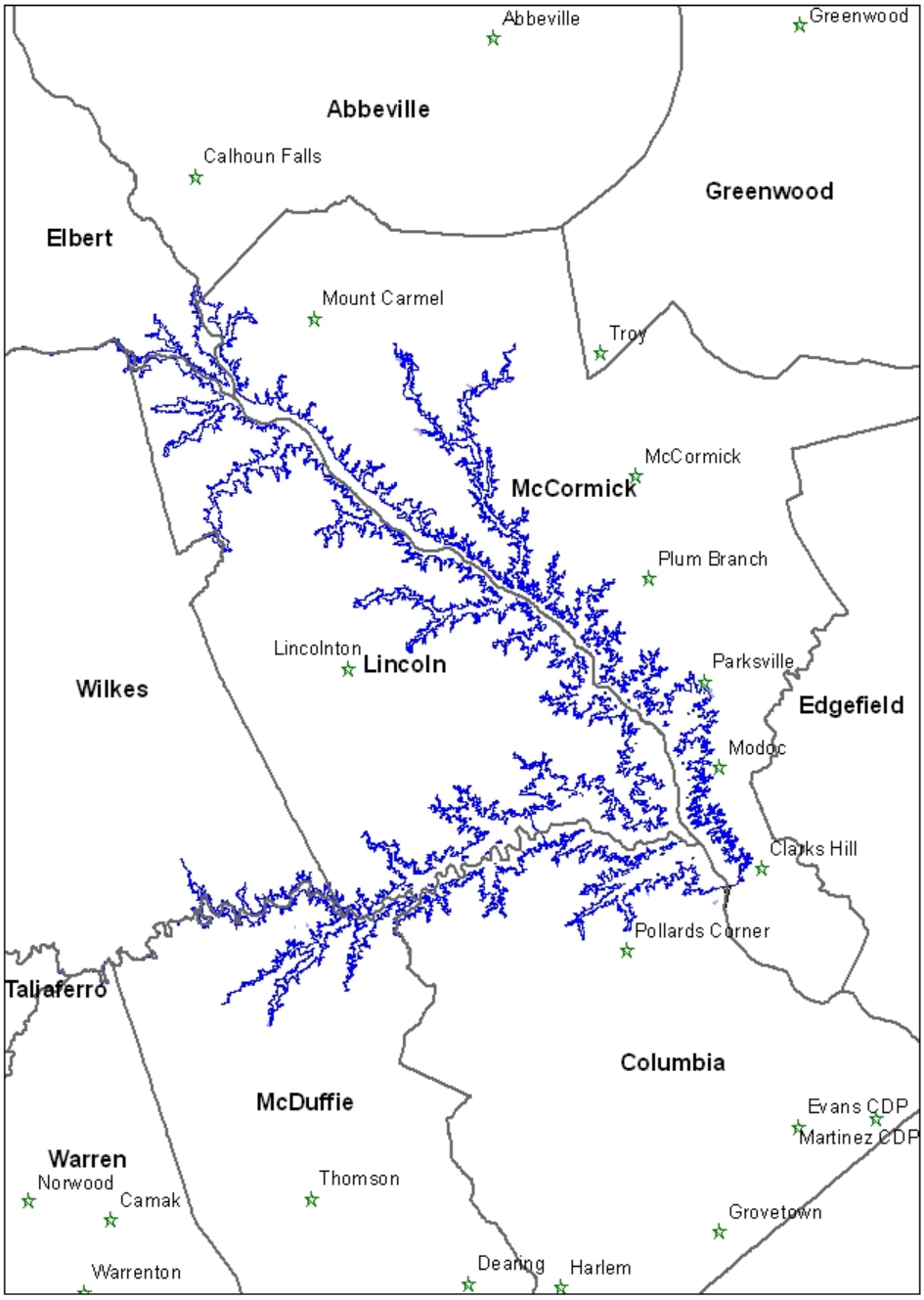
Commercial Marinas

78 Big Water
79 Portman
80 Seneca
81 Harbor Light
82 Hartwell

** Ramp access only*


Richard B. Russell Lake Land Usage
Hart County
Anderson County
Abbeville County
Elbert County
Lowndesville
Calhoun Falls
Elberton
State Lines
Shoreline
Operational lands.shp
State lease areas.shp
Mitigation Lands.shp
Cities
Roads
Counties
0
5 Miles

J. STROM THURMOND RESERVOIR



APPENDIX B

SAVANNAH RIVER SYSTEM

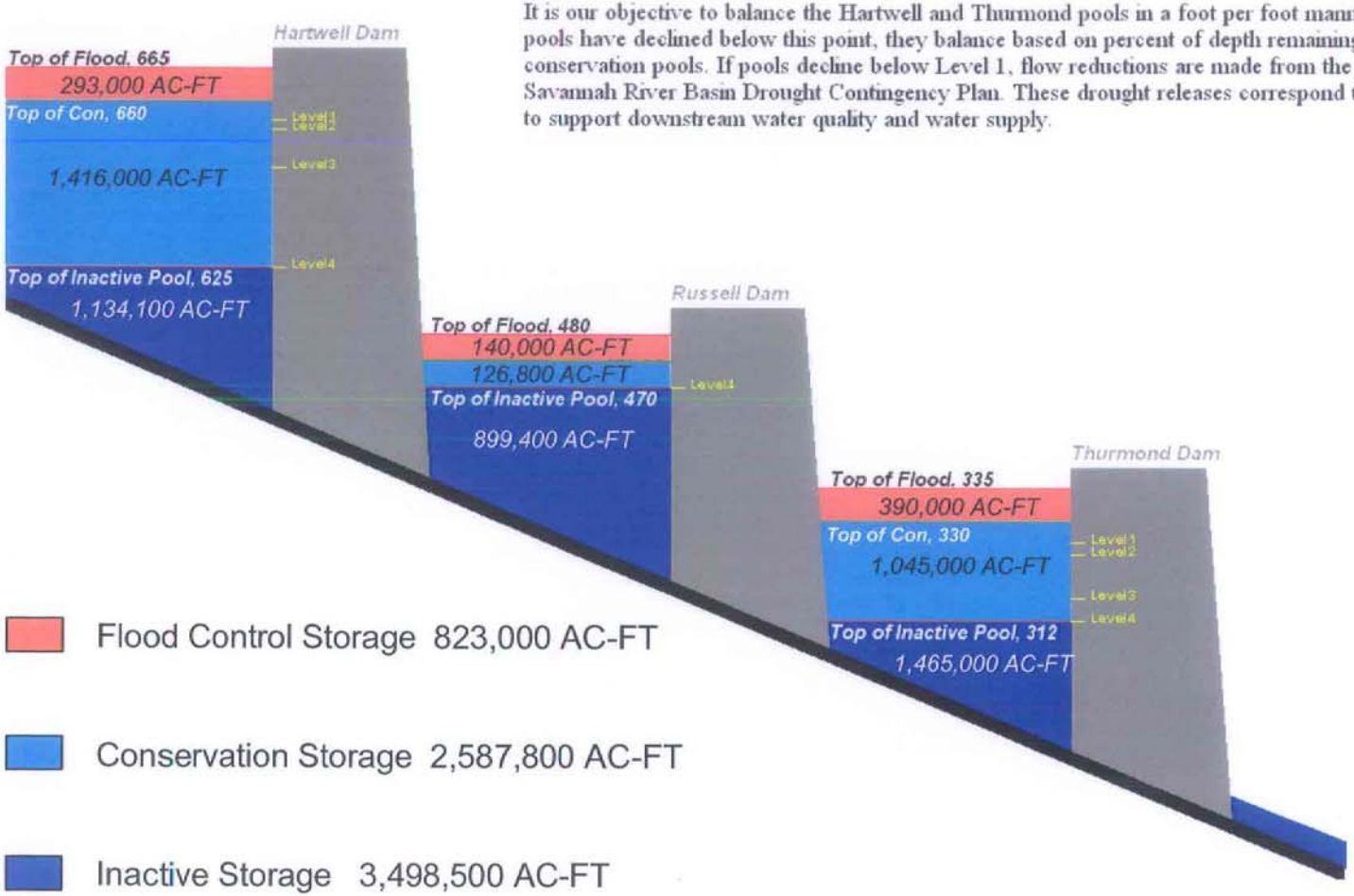
POOL SCHEMATIC

AND

LAKE LEVEL GRAPHS

Savannah River System
Pool Schematic

It is our objective to balance the Hartwell and Thurmond pools in a foot per foot manner for the top 15 feet. Once the pools have declined below this point, they balance based on percent of depth remaining in their respective conservation pools. If pools decline below Level 1, flow reductions are made from the system in accordance to the Savannah River Basin Drought Contingency Plan. These drought releases correspond to the minimum flows needed to support downstream water quality and water supply.



Flood Control Storage 823,000 AC-FT

Conservation Storage 2,587,800 AC-FT

Inactive Storage 3,498,500 AC-FT

APPENDIX C

2008 AGENCY PROPOSAL

Proposed Changes to Lake Thurmond Releases to Mitigate Drought Impacts

Georgia Department of Natural Resources, Environmental Protection Division

(Georgia EPD)

South Carolina Department of Health and Environmental Control

(SCDHEC)

South Carolina Department of Natural Resources

(SCDNR)

July 2008

Executive Summary

As the ongoing drought in the southeastern U.S. approaches its third summer, the Savannah River reservoir system operated by the Army Corps of Engineers (hereafter referred to as the Savannah System) is experiencing extreme pressure and difficulties. As of July 23, 2008, the system has only 46% of its conservation storage remaining. Hartwell and Thurmond, the two large storage reservoirs, are approximately 12 feet below normal pool levels. Hartwell has less than 57% of its conservation storage left, and Thurmond has only 28% of its conservation storage remaining.

The recharge season of the year has long gone, and the status of the system is of particular concern to many parties in both Georgia and South Carolina depending on the resources provided by the storage in these reservoirs. Low inflows to the system last year and early this year raised the prospect that the system storage may be exhausted in the near future and a consequent transition to Level 4 operations (only releasing inflow) may be on the horizon.

Based on the Information Paper provided by the Army Corps of Engineers (Corps) and information compiled by other cooperating institutions, Georgia EPD, in coordination with SCDHEC and SCDNR, conducted a thorough analysis of potential operations of the system under a variety of hydrologic conditions. Georgia EPD, SCDHEC, and SCDNR propose that the current operation (i.e. a Thurmond release of 3,600 cfs) be revised to maintaining a 3,600 cfs release from Thurmond Dam in the warmer months of March through September and reducing the release to 3,100 cfs in the cooler months of October to February of next year.

The analysis conducted by Georgia EPD, in coordination with SCDHEC and SCDNR, indicated that such operations would be able to stabilize the system and substantially reduce the speed of decline in system storage. Even under a very pessimistic assumption of inflow (10% worse than the lowest historic inflow) for the next three consecutive years, the proposed operations would be able to prevent the system conservation storage from being depleted. System storage would only approach depletion toward the later part of 2011, with the assumption that worse-than-the-worst hydrology will persist through the years (a highly improbable event).

Our analyses indicate that water users along the river will not be impacted as a result of this revised operation. Also, modeling and field observations indicated that it is unlikely that water quality will be of a concern. Further modeling can be conducted if stakeholders raise additional concerns. In addition, water quality monitoring stations will need to be enhanced at strategic river locations to ensure that there is sufficient real time data available to evaluate and appropriately respond to during modified dam operations.

With respect to intake limiting factors, some of the intakes at the lower reaches may experience little margin in their access to water and thus their functionality. If the lowest incremental flow (recorded in 2007) were to take place again this year, some intakes may not function well in the short period of a few days. However, there are actions that can be taken to mitigate the impact, such as drought-proof engineering measures that will either deepen the bottom elevation at the intake or elevate the surface elevation, or adaptive management measures whereby the facility monitors the river elevation to make sure that sufficient flow takes place when incremental flow is not sufficient. Vulnerable facilities all across the basin will be part of a process that will ensure that proper emergency management measures are incorporated into local planning during this drought emergency.

Background Information

The Savannah River Basin has been experiencing a drought since early 2006. Rainfall and resulting stream flow have been particularly low, causing the reservoirs to drop faster than during previous droughts. If low inflows persist or deteriorate, the current drought could become the new drought-of-record for the basin.

The Corps manages its three impoundments on the Savannah River as a system and uses a Water Control Manual to describe how it will operate those projects. The Drought Contingency Plan is a component of that Manual and was developed (1) to address the effects of the Corps' operation on those impoundments and the downstream portion of the river, and (2) to assist the States of Georgia and South Carolina in drought contingency planning in their water management responsibilities for the Savannah River Basin.

The Corps' 1989 Drought Contingency Plan (DCP) and a 2006 Environmental Assessment (EA) describe activities that would be conducted during four stages of a continuing drought. Those four stages correspond to different lake levels. When the reservoirs reach the Level 1 trigger elevation, the Corps issues a public safety advisory concerning recreational use of the reservoirs. The Corps also reduces discharges from the reservoirs when Levels 1-3 are reached. When Level 4 is reached, the conservation pools are empty. If drought conditions persist after Level 4 is reached, discharges are further reduced to the point where the outflow from the lakes equals the net inflow.

The actions the Corps would take surrounding the Level 4 trigger were never evaluated in detail when the plan was originally developed or during the 2006 Update. The Reservoir System Simulation modeling conducted to analyze the effects of the various operational scenarios during development of the 1989 DCP and its 2006 EA for the DCP Update always indicated that the lakes would not reach the bottom of conservation pool. This modeling was conducted using inflows that were the drought of record at that time. Sensitivity analyses revealed that the drought would need to extend three additional years to reach Level 4. Therefore, detailed consideration was never given for the best way to operate once that trigger was reached.

It should be noted that when a new drought of record takes place, the Corps' operational objective should always be to avoid ever reaching the bottom of the conservation pool. This requires a constant evaluation of the current operations and the update of the drought of record. If the current drought becomes the drought of record, then additional measures not included in the previous Manual or Drought Contingency Plan should be considered and evaluated to achieve this objective.

Status of System and Issue of Concern

As of 8:00 am July 23, 2008, the federal reservoirs on the Savannah River have 1.19 million acre-feet of conservation storage remaining. This is equivalent to 46% of the system conservation storage. Hartwell has 57% of its conservation storage remaining, while Thurmond has only 28% of its conservation storage available.

The recharge period in 2008 is over at this time, and both Hartwell and Thurmond are roughly 12 feet below their respective normal pool levels. Through the summer months, the evaportranspiration rate will increase, making it all but impossible for the reservoirs to meaningfully gain any storage during this time. This holds true regardless of the prospect of precipitation in the summer, even with the overly optimistic assumption that normal rainfall takes place.

Recent updates from climatologists and meteorologists suggest that it is likely that the current drought will extend into this summer and beyond. If this holds true, it is expected that inflow to the reservoir system will remain low or at least below normal, making it a likely scenario that the Corps will need to use storage to augment releases prescribed by the operation Manual and the Drought Contingency Plan.

If the drought persists or deteriorates, it is not inconceivable that the limited conservation storage will be exhausted, or at least be depleted to an intolerable extent. It is extremely important that all measures be evaluated to prevent the depletion of the Savannah System conservation storage. The following sections of this report document contemplated ways to achieve this.

Principles of Operations

We believe the principles of operating the Savannah System are the following: (1) To the extent possible, the Corps should try all it can to avoid depleting the conservation storage. (2) In order to achieve that, the Corps should take early measures to avoid ever reaching the bottom of the conservation pool. (3) The Corps should more explicitly identify the elevation and flow thresholds below which serious impacts take place at facilities across the basin. (4) If hydrologic conditions are such that an early intervention is unavoidable, then the Corps should identify the flow level below 3,600 cfs that bears the least impact and reduce its release from Thurmond Dam to that level. (5) The water users should identify ways (e.g. local engineering measures) of avoiding or mitigating impacts of such flow reduction and communicate such measures as well as the costs of such measures to the Corps and the States.

Proposed Hydrologic Conditions for Evaluation

On an annual basis, the total amount of inflow to the Savannah System (defined as the Savannah River reservoir system operated by the Army Corps of Engineers) was lowest in 1988, averaging only 3,286 cfs. The second lowest year was 2007, with an average inflow of 3,302 cfs. Based on a long-term average annual inflow of 7,852 cfs, the amounts of inflow in these two years are 42% of normal.

It is thus suggested that the hydrologic conditions of these two years be used to evaluate adverse conditions the system may experience in the rest of 2008 and the next two years. We believe it is a conservative assumption that the on-going drought (which is very close to the drought of record), after impacting for more than two years now, would repeat itself in the next three years. This basically means that after a year of 3,302 cfs inflow, inflow at this level would repeat again and again in each of the next three years.

We also suggest that variations of the 1988 and 2007 hydrology (e.g. 10% reduction in inflow) be used to evaluate potential operations of the Savannah System. We believe it is a very conservative assumption that another round of drought of record with a magnitude of 10% reduction in inflow

will repeat itself in 2008, 2009, 2010, and 2011. This gives us the possible but very unlikely hydrologic scenario that after a year of 3,302 cfs inflow, we would have another two to three years in a row with inflow lower than 3,000 cfs (38% of normal).

Baseline Operations under Proposed Hydrologic Conditions

The Corps' current operation calls for a release of 3,600 cfs from Thurmond Dam. This operation's impact on the reservoirs can be assessed with the Corps' spreadsheet tool. Using this tool and the assumed hydrologic conditions, we were able to show how system conservation storage would change as a result of the baseline operation.

Fig. 1 shows the impact of the baseline operation on system conservation storage under recorded 2007 inflow and a variation of this inflow series. Under 2007 hydrology, system storage will continue to decline to dangerously low levels toward the end of 2008, with only 18% of conservation storage remaining in Hartwell, Russell, and Thurmond. System conservation storage will recover somewhat in early 2009, but start declining again in April 2009 and reach 15% late 2009.

Under the hydrologic scenario with a 10% reduction in inflow, the system will fare even worse. There will be about 16% of system conservation storage left by the end of 2008, and only 3% remaining by the end of 2009. The conservation pool would be virtually empty at this point. The conservation pool will be completely exhausted by November 2010.

Fig. 2 shows the impact of the baseline operation on system conservation storage under another record dry year with a different precipitation pattern, year 1988. Under this hydrology, system conservation storage will see a less dramatic decline in the summer and fall seasons, but also with a less pronounced recovery in the following winter and spring. Overall, there will be a declining trend.

Under the reduced 1988 inflow scenario, system storage will reach 10% by the end of 2009, and be completely exhausted by October 2010.

In order to gauge the potential of devastating consequences, a probability of status analysis was performed for the Savannah River basin. It is assumed that 2007 hydrology is to repeat itself in 2008, and the resulting system storage by December 31, 2008 would be around 16% (see Fig. 1). With this as the starting condition for 2009, and hydrologic conditions from 1954 through 2007 applied to the Savannah system, there is a substantial probability (see Fig. 17) that the system will either be completely empty by the summer of 2009 (2% probability), or that the system will be further depleted toward the end of 2009 (6% probability). The probability of such catastrophe may be small, but it is substantial and its consequences severe.

It is apparent that if the current drought persists at its current intensity or if it intensifies, the baseline operation is not enough to stabilize conservation storage, let alone refilling the system. For the benefit of all stakeholders in the basin, more needs to be done to stop the loss of conservation storage in the middle of this drought.

Critical Flow Requirements

Prior work done by Georgia and South Carolina resource agencies and the federal government provided critical elevations for most withdrawing facilities along the main stem of the Savannah River downstream of Thurmond Dam. This information is provided in Table 1.

Based on rating curves provided by Georgia EPD's Savannah River water quality model, we were able to calculate flow rates that correspond to these minimum elevations. The flow rates are also provided in Table 1.

From this exercise, it is clear to us that the likely controlling flow rates are those at Savannah Electric-Plant McIntosh and Georgia Pacific. The minimum desired flow rate at the intake of Savannah Electric-Plant McIntosh is calculated to be 3,500 cfs. The minimum desired flow at the intake of Georgia Pacific is calculated to be 3,300 cfs. However, since surface elevation in the river at these two facilities is under tidal influence, which may nullify the effects of low stream flow in the river, this tidal influence may help ease the concern that potential reduction in Thurmond release would impact the facilities' intake.

Since flows desired at the locations of the other facilities are much lower than what is needed to sustain water access at these two facilities, we believe these flow rates should serve as the basis for the computation of any potential relief of flow requirement at Thurmond Dam.

Another factor to consider is that there exists substantial amount of incremental flow between Thurmond Dam and the intakes of either Savannah Electric-Plant McIntosh or Georgia Pacific. A flow at the locations of these facilities is the result of Thurmond release supplemented by incremental flow between Thurmond and the concerned location.

Recorded Incremental Flow

If the Corps considers potential relief from the 3,600 cfs minimum release requirement from Thurmond, then it is critically important to determine the amount of incremental flow between Thurmond and the locations of the controlling facilities. Since the closest USGS gauge to the two controlling facilities, Savannah Electric-Plant McIntosh and Georgia Pacific, is Savannah River near Clyo, Georgia (02198500), we need to use the incremental flow between Thurmond and the Clyo gauge to estimate the amount of incremental flow. Also, since the Clyo gauge is upstream of these two facilities, the entire amount of incremental between Thurmond Dam and the Clyo gauge can be applied to both facilities.

Using release data from Thurmond (Corps) and gauged stream flow data at the Clyo gauge (USGS), we were able to derive incremental flow between these two locations. For the purpose of smoothing out the impact of routing and travel time, we applied a 7-day moving average for both variables.

As shown in Fig. 3, the magnitude of incremental flow between Thurmond and the Clyo gauge stayed above 500 cfs for most of 2007, with the exception of a few days in November 2007, when it dropped to around 300 cfs. For the previous drought of record, year 1988, the incremental flow between these two locations remained higher than 800 cfs (See Fig. 4).

As the U.S. Drought Monitor (Figs. 5 and 6) indicate that the lower Savannah River Basin is in better shape compared to the worst time in last year, when the incremental flow was the lowest in November 2007, and the fact that the coastal area may benefit from ocean-originated precipitation in the summer and fall, it is reasonable to assume that the incremental flow between Thurmond and Clyo this year will not be at a level worse than in 2007. In other words, it is not unreasonable for us to expect at least 300 cfs to 500 cfs of incremental flow between Thurmond and the Clyo gauge.

Proposed Relief from Thurmond Minimum Flow Requirement

We use the most severe hydrologic conditions suggested earlier in this document to evaluate the contemplated alternative operations of the Savannah System. These conditions are recorded 2007 inflow with a 10% reduction and recorded 1988 inflow with a 10% reduction. A repetition of such conditions, after two years of record-breaking drought, for the next three or four years, in our opinion, provides enough of a challenge to the entire system. Table 2 provides a summary of all the simulations.

Based on the estimated minimum incremental flow of 300 cfs to 500 cfs, we can use a Thurmond release of 3,300 cfs and 3,100 cfs to test the impact to the reservoir system and the downstream river. It is reasonable to assume that at these levels of Thurmond release, the needs of the other stakeholders are met (Table 1).

We first tested a flat release from Thurmond Dam of 3,300 cfs and 3,100 cfs with both hydrologic conditions. Table 2 provides a summary of the hydrologic conditions and alternative operations in the tested scenarios. The resulting reservoir conservation storage change is shown in Figs. 7 and 8.

Under the recorded 2007 hydrology (with a 10% reduction in inflow), a release of 3,300 cfs from Thurmond Dam will not be enough to stabilize the reservoir system. There will be a sharp decline of system conservation storage, resulting in a low system storage at 20% toward the end of 2008. Storage will recover somewhat during the winter and spring period of 2009, but will start to decline again and reach a new low (16%) toward the end of 2009. If hydrologic conditions do not improve

dramatically, this downward trend will continue, and the low system storage will keep declining year after year (Fig. 7).

If release at Thurmond Dam is reduced to 3,100 cfs, however, the trend of decline will be stopped. The system storage will still go up and down seasonally, but the declining trend under the 3,300 cfs release will cease to exist.

Under the recorded 1988 hydrology (with a 10% reduction in inflow), the seasonal decline in the summer and fall will be less dramatic than under the 2007 inflow, however, there will be less of a recovery in the following rainy season (Fig. 8). Under a 3,300 cfs Thurmond release, system storage will reach 34% by the end of 2008 and around 24% toward the end of 2009. This moderate reduction in Thurmond release is far from enough to stop the sharp declining trend in system storage.

If release at Thurmond Dam is at 3,100 cfs level, the overall declining trend will still exist. However, the rate of decline of system conservation storage will be much more moderate compared to the rate of decline under a release of 3,600 cfs (baseline) or 3,300 cfs (Fig. 8).

We understand that a full-scale deviation from the minimum release of 3,600 cfs may require the Corps to go through the NEPA process and to conduct an Environmental Impact Study, which may take years to complete and cause the loss of opportunity to slow the decline of system storage. We also understand that a seasonal deviation (e.g. a reduced release from Thurmond Dam in the cooler seasons) may be easier to achieve, since an Environmental Assessment may suffice in this case.

Thus, we tested an operation scenario where release from Thurmond will be kept at 3,600 cfs for the months of March through September and reduced to 3,100 cfs for the cooler seasons (October through February). The resulting conservation storage percentage (under both 2007 and 1988 inflow with a 10% reduction) is shown in Fig. 9. It can be seen that system conservation storage will remain available at least throughout the next three years. With such adverse hydrologic conditions, system storage will continue to decline, but at a comparatively slow rate.

Under this operation scheme, even if record-breaking drought conditions continue during the next three years, there will be enough conservation storage to support the revised Thurmond release, and the Corps will have enough time to make further revision of its operations in response to persistent or deteriorating conditions.

We make the recommendation that the Corps adopt this operation scheme.

Impacts to Lake and River Water Users

The suggested operation will not be any different from the current baseline operation in the months between March and September, and should not have any impact on water supply intakes throughout the basin during this time period.

In the cooler seasons when Thurmond release is reduced to 3,100 cfs, the most likely impact, based on information in Table 1 and earlier analysis, will be felt by facilities downstream of Thurmond Dam. These facilities include Savannah Electric-Plant McIntosh and Georgia Pacific. Because the proposed operation will not deplete system conservation storage, water users whose intakes are located in the pools of Hartwell, Russell, and Thurmond will not be affected.

Flow at the locations of Georgia Pacific can be determined by Thurmond release with the addition of incremental flow between Thurmond and the Georgia Pacific intake, which is estimated to be around 500 cfs at the driest times, except for a few days, when it may be as low as 300 cfs. This will result in the lower flow at the Georgia Pacific intake to be at 3,600 cfs generally, and at 3,400 cfs at the lowest level. Given that the facility intake will function at flows higher than 3,300 cfs, it is expected that the proposed revision in operation will not have any impact to this facility.

Flow at the intake of Savannah Electric-Plant McIntosh can also be determined similarly. The proposed operation may result in an at-site flow of 3,400 cfs to 3,600 cfs at the intake of Plant McIntosh. Table 1 shows that the intake at Plant McIntosh functions at the minimum flow of 3,500 cfs. So, if the lowest incremental flow (recorded in 2007) were to take place again this year, the intake at this facility may not function well in the short period of a few days when the at-site flow is as low as 3,400 cfs. However, since water surface elevation at this facility's intake is under tidal influence, any impact resulting from reduced Thurmond release may be nullified.

Also, there are measures that can be taken to mitigate the impact. First, drought-proof engineering measures can be taken to either deepen the bottom elevation at the intake or to elevate the water surface elevation. The Corps may be able to help such measures through federal emergency programs. In fact, we encourage all water users in the basin to consider local measures that can make water supply more secure.

Second, adaptive management can be put in place to monitor the elevation at this facility to make sure that sufficient flow takes place when incremental flow is not enough.

There may also be concern from water users along the Augusta Canal. Diversions into the Augusta Canal is managed by the City of Augusta to maintain a minimum of 1500 cfs (1500 cfs May through January and 1800 cfs otherwise) through the shoals. Three electronically controllable gates, operated by the City of Augusta, allow for instantaneous changes of flow to the canal should a management target be approached.

Based on current permit information on the City of Augusta intake, the City is allowed to withdraw no more than 45 MGD (about 70 cfs). The City has four turbines to operate for water supply operations. These turbines are driven by water in the Canal. Then in turn they drive pumps to pump water for water supply purpose. It usually uses two of its four turbines units (Units 1 and 4) with the need of a flow of 1364 cfs. This amount is passed through the turbines and returned entirely to the main stem Savannah River (about two thirds of the length of the shoals).

There are three mills downstream of the City's intake. They are Sibley, King, and Enterprise. All these mills have turbines that are driven by water in the Canal. All return the water used back to the main stem Savannah River downstream of the shoals. Sibley Mill needs a flow of 1024 cfs; King needs approximately 880 cfs; and Enterprise needs a flow of approximately 560 cfs.

At the current level of Thurmond release (3600 cfs), if there is no incremental flow between the dam and the Canal inlet, then 1500 cfs would have to be left to pass the shoals. That leaves only 2100 cfs to go through the Canal. After the City turbines and intake, there would be less than 800 cfs left in the Canal.

Under the proposed release strategy, Thurmond release would be reduced to 3100 cfs from October through February. If the City operates the gates to pass 1500 cfs to the shoals, the amount of water going through the Canal would be 1600 cfs, assuming little incremental flow. This will be enough to sustain the City's water supply operations. However, after that, there would be less than 300 cfs left to go through the rest of the Canal, and the operations of the mills will be impacted.

We understand that the mills are connected to the power grid and alternative power is available in case their generating capacity is limited.

Impact to Water Quality

To assess the potential impact on water quality of the proposed operation, Georgia EPD, in coordination with SCDHEC and SCDNR, has performed water quality (dissolved oxygen - DO) modeling of both the Savannah River downstream of Thurmond Dam and the Savannah Harbor. The modeling results indicate that the seasonal reduction of Thurmond release would not cause water quality problems in the river or the harbor.

1. Savannah River downstream of Thurmond Dam

The first model simulation has been conducted with 2007 meteorological data, 2007 tributary inflows, 2007 Thurmond release data, and waste load discharges and water withdrawals as recorded in 2006. This run was performed to see how well the model is calibrated to observed DO data. Figs. 10 and 11 show the observed DO data (red squares) measured in 2007, which never went below 6.5 mg/L and 6.29 mg/L at River Mile (RM) 119 and RM 61, respectively, versus the approximate calibration run. It is an approximate calibration run since the model did not include

2007 discharge and withdrawal data, but rather that of 2006. Despite the approximation of this model run, the results indicate that the model has been calibrated relatively well.

Second and third model simulations were conducted with 2007 meteorological data, 2007 tributary inflows, and waste load discharges and water withdrawals as recorded in 2006. However, these model scenarios incorporated Thurmond releases of 3,600 and 3,100 cfs.

Figs. 12 and 13 show the results of the 3,600 cfs simulation. Under a Thurmond release of 3,600 cfs, the simulated DO concentrations at RM 119 were predicted to be above 5 mg/L throughout the year (Fig. 12). Fig. 13 shows simulated DO concentration at River Mile 61 under a Thurmond release of 3,600 cfs. Again, the simulated DO concentrations were predicted to be higher than 5 mg/L throughout the year. The water quality model shows that the 5.0 mg/L DO standard would not be breached by a Thurmond release of 3,600 cfs.

Figs. 14 and 15 show the simulated DO concentrations at River Mile 119 and River Mile 61 respectively, under a Thurmond release of 3,100 cfs. Even though we do not propose a reduction of Thurmond release in the summer time, our model indicated that there would not be a DO problem throughout the year. For the cooler months from October to February, DO concentration would always be higher than 6.0 mg/L and almost always higher than 7.0 mg/L at both River Mile 119 and River Mile 61.

We need to point out that the water quality model used in this analysis does not contain any modules simulating algal activity in the river. This lack of simulated algal activity means that our model tends to give overly pessimistic DO concentrations. It is highly likely that field data will provide higher DO concentrations than the model predicted.

The proposed action includes a continuation of 3,600 cfs release from Thurmond Dam in the months of March through September and a 3,100 cfs reduced release from Thurmond Dam in the cooler seasons (October through February). This action will not result in any adverse change in DO concentration in the warmer months. We suggest that monitoring stations be set up at locations along the river to monitor the change of DO concentration along the lower reaches, if the proposed operation is adopted. We also suggest that adaptive management be used as part of the Corps' operation. If field observation indicate any problem with DO concentration, then prompt actions can be taken to mitigate the adverse conditions.

2. Savannah Harbor

Two water quality related effects of lower Savannah River streamflows resulting from reduced Thurmond Reservoir releases were assessed. These were elevated chloride concentrations at the City of Savannah municipal water intake on Abercorn Creek, and dissolved oxygen concentrations in the Harbor.

The City of Savannah's municipal water intake is located on Abercorn Creek approximately two miles from the Savannah River. The City of Savannah is concerned about distributing water to its customers, particularly industries, when chloride concentrations in Abercorn Creek are greater than 12 milligrams per liter (mg/L). Such concentrations have been shown to cause scaling in boilers.

Sources of chloride in Abercorn Creek are upstream inflows from the Savannah River, and salinity intrusion from the downstream Savannah Harbor estuary. Studies have shown a good relationship between River flows at the U.S. Geological Survey's Clyo, Georgia stream gage location and chloride concentrations. Results have shown that the Savannah River contains approximately 10 mg/L of chloride during low flows, and 4 mg/L during high flows as a result of greater dilution. Therefore, it is during low flow periods where River chloride concentrations are as high as10 mg/L when salinity intrusion from downstream can cause an additional 2-4 mg/L in the vicinity of the intake and exceed the 12 mg/L threshold. Analysis of the historical chloride data collected at the City's intake shows that during drought years the number of samples with chlorides exceeding 12 mg/L ranges from 21 to 58 percent, and concentrations have approached 19 mg/L.

Lowering releases from Thurmond Reservoir, by itself, does not create higher chloride concentrations at the City of Savannah's water withdrawal. Rather, it is the combination of low releases from Thurmond Reservoir and low streamflows from the downstream watershed that create a condition for elevated chloride concentrations at the City's withdrawal. Therefore, the proposed reservoir operation schedule will not improve conditions for chloride concentrations at the City's intake, and with sufficient downstream inflows these conditions should remain unchanged. However, given the existing sensitivity of the City's intake to chloride concentrations greater than 12 mg/L as shown by the historical exceedances of this threshold, proposed reservoir operation combined with low downstream inflows might increase the number and magnitude of chloride concentrations greater than 12 mg/L at the City of Savannah municipal water withdrawal. Therefore, it is recommended that Savannah River flows at Clyo and chloride concentrations at the City's water intake be monitored closely to assess the effects of reservoir operation.

The effect of the proposed Thurmond reservoir operation on dissolved oxygen concentrations in Savannah Harbor was evaluated using the Savannah Harbor Model. Savannah River Model streamflow and water quality results provided input for the upstream boundary of the Savannah Harbor Model. Model results and the effects on dissolved oxygen concentrations were evaluated at the U.S. Army Corps of Engineers' dock located in the Harbor. The results were compared to the existing coastal fishing classification whose dissolved oxygen criteria is no less than 3.0 mg/L during June through October, no less than 3.5 mg/L in May and November, and no less than 4.0 mg/L during December through April. The results are shown in Figure 16. With respect to Dissolved Oxygen Standards applicable to the Harbor, at the present time, the Savannah Harbor is under a Total Minimum Daily Load for Georgia which indicates 0 assimilative capacity available for the NPDES permitted wastewater treatment system dischargers. The TMDL is based on a 1989 Georgia

seasonal Dissolved Oxygen standard which was never approved by the EPA. The GAEPD is in the process of revising the Harbor DO standard which will provide some assimilative capacity for the dischargers, and be similar and consistent with the South Carolina DO standard. Harbor dissolved oxygen monitoring will continue and impact to harbor dissolved oxygen attributable to seasonal dam releases will be evaluated and those operations modified as appropriate.

Other Potential Impacts

Since a seasonal deviation from the 3,600 cfs Thurmond release does not constitute a significant change in operations of the system, we do not foresee any impacts on other aspects and other water users of the Savannah River Basin.

We are willing to work with other resource agencies to address such concerns, if additional stakeholder groups raise concerns. We believe technical tools, such as WASP model and other models exist and are available for use to address salinity, temperature, and other issues.

Table 1. Major facilities along the main stem Savannah River and their tolerance of low elevations and flow rates

FACILITY NAME	INVERT ELEVATION (FT-MSL)	MINIMUM ELEVATION (FT-MSL)	NOTES	CORRESPONDING FLOW TO MIN ELEV. (CFS)
Columbia County			Their withdrawal is upstream from the Stevens Creek Dam.	
Augusta Canal			The necessary flow to support the municipal water withdrawal is 600-800 cfs. There is a deisel back-up pump but it is not capable of providing the full supply requirement. At some flow rate the downstream electric generation will be halted.	~1600 cfs in the Canal + 1000 cfs in shoal
Edgefield County	149.50	149.50	1989 Drought Plan. This value was confirmed by SCDHEC.	
City of Augusta		119.5		
City of North Augusta	106.00	109.00	Minimum elevation value came from the New Savannah Bluff Lock and Dam Project Disposition Report.	1000 cfs at elevation 109 ft
South Carolina Electric and Gas	106.00	105.50	Minimum elevation value came from the New Savannah Bluff Lock and Dam Project Disposition Report.	900 cfs at elevation 106 ft
PCS Nitrogen	97.75	103.90	PCS Nitrogen and DSM Chemical share the same intake structure. A minimum elevation value of 110	1300 cfs at elevation 110 ft

			came from the New Savannah Bluff Lock and Dam Project Disposition Report. Actual numbers came from a contact with PCS Nitrogen.	
DSM Chemicals	97.75	103.90	PCS Nitrogen and DSM Chemical share the same intake structure. A minimum elevation value of 110 came from the New Savannah Bluff Lock and Dam Project Disposition Report. Actual numbers came from a contact with PCS Nitrogen.	1300 cfs at elevation 110 ft
General Chemical	110.20	111.00	Minimum elevation value came from the New Savannah Bluff Lock and Dam Project Disposition Report.	1800 cfs at elevation 111 ft at DSM Chemical
Kimberly Clark		109.00	Minimum elevation value came from the New Savannah Bluff Lock and Dam Project Disposition Report.	1060 cfs at elevation 109 ft
International Paper	94.00	94.00		2800 cfs at elevation 94 ft
Savannah River Site	79.00	79.00	Latest information indicates that 79 ft is sufficient	3400 cfs at elevation 81 ft, 2300 cfs at elevation 79 ft
Plant Vogtle	70.00	70.00		always met
Savannah Electric-Plant McIntosh	7.50	7.50		3500 cfs at elevation 7.5 ft
Georgia Pacific	-1.00	5.16	Georgia Pacific stated that their minimum operational level is equivalent to a gage height of 2.0 feet at Clyo. Since the gage datum at Clyo is 13.39 feet-msl this results in a minimum elevation at Clyo of 15.39 feet-msl which is equivalent to a Savannah River flow of 3300 cfs. This corresponds to a water surface elevation of 5.16 ft-msl at the Georgia Pacific withdrawal.	3300 cfs per note
City of Savannah		-10.22		
Beaufort-Jasper		-3.0		

Table 2 Simulated hydrologic and operational scenarios

Scenario	A: Recorded 2007 Inflow	B: 2007 Inflow * 90%	C: Recorded 1988 Inflow	D: 1988 Inflow * 90%	B3300: Thurmond release of 3300 cfs	B3100: Thurmond release of 3100 cfs	D3300: Thurmond release of 3300 cfs	D3100: Thurmond release of 3100 cfs	B: 2007 Inflow 3100 Seasonal	D: 1988 Inflow 3100 Seasonal
Hydrology (Inflow to reservoir system)	Recorded 2007 inflow	Recorded 2007 inflow with a 10% reduction	Recorded 1988 inflow	Recorded 1988 inflow with a 10% reduction	Recorded 2007 inflow with a 10% reduction	Recorded 2007 inflow with a 10% reduction	Recorded 1988 inflow with a 10% reduction	Recorded 1988 inflow with a 10% reduction	Recorded 2007 inflow with a 10% reduction	Recorded 1988 inflow with a 10% reduction
Operation	Thurmond release of 3600 cfs	Thurmond release of 3600 cfs	Thurmond release of 3600 cfs	Thurmond release of 3600 cfs	Thurmond release of 3300 cfs	Thurmond release of 3100 cfs	Thurmond release of 3300 cfs	Thurmond release of 3100 cfs	Thurmond release of 3600 cfs in warmer months, and 3100 cfs in cooler months	Thurmond release of 3600 cfs in warmer months, and 3100 cfs in cooler months

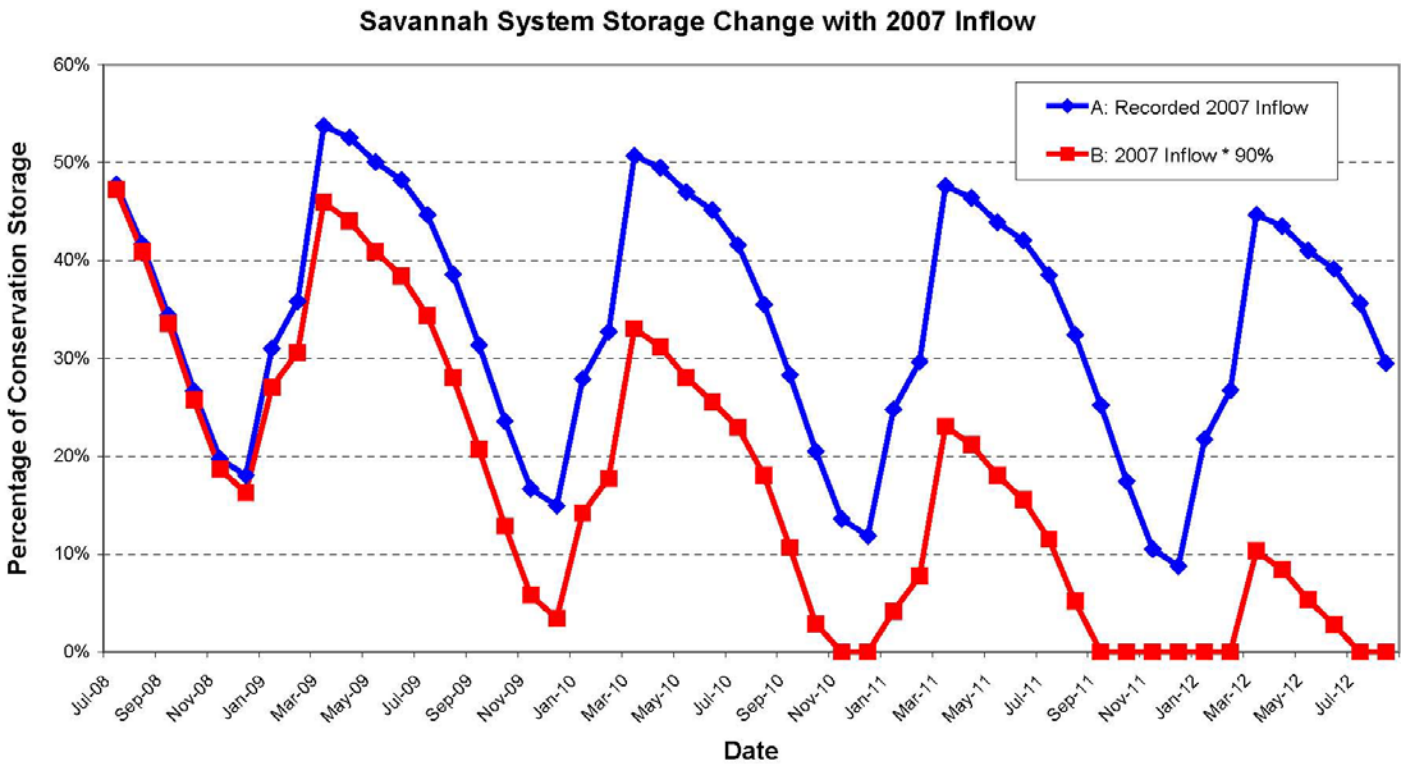


Fig. 1 Change of system conservation storage under 2007 hydrology and variation

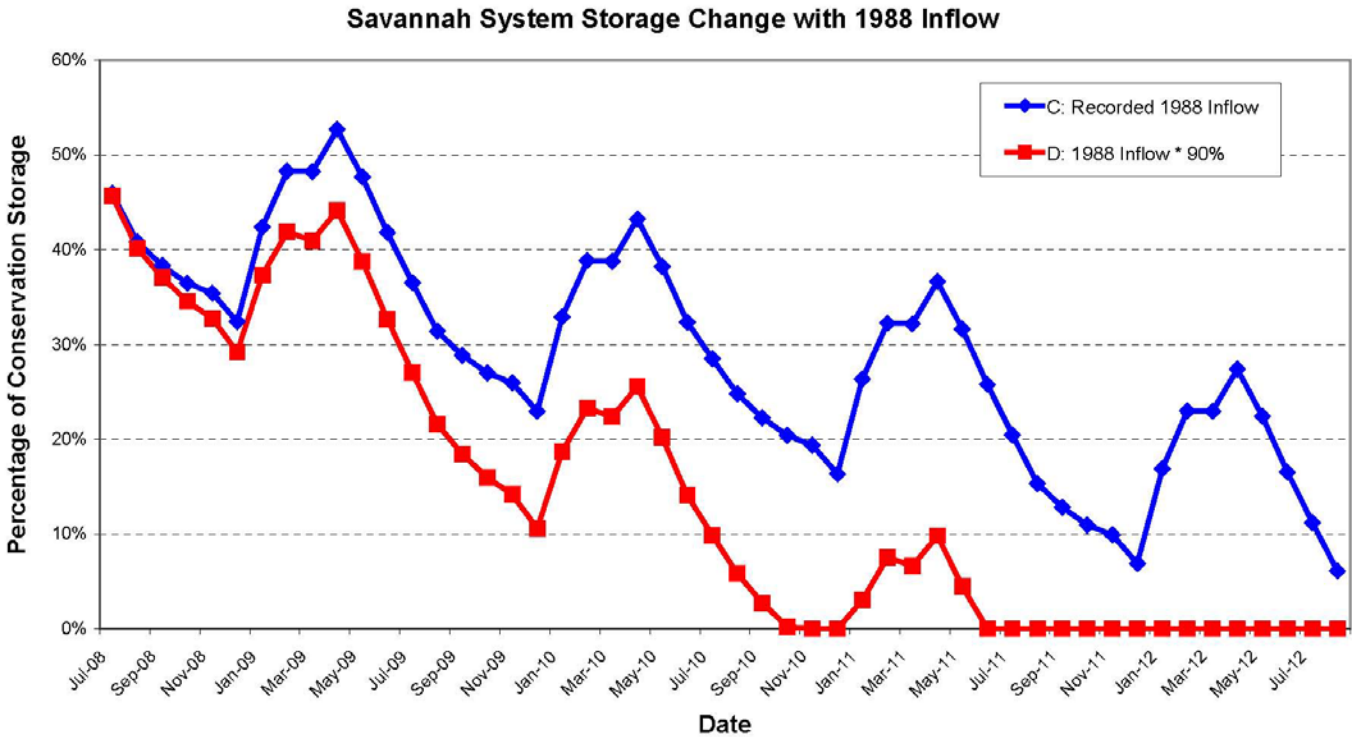
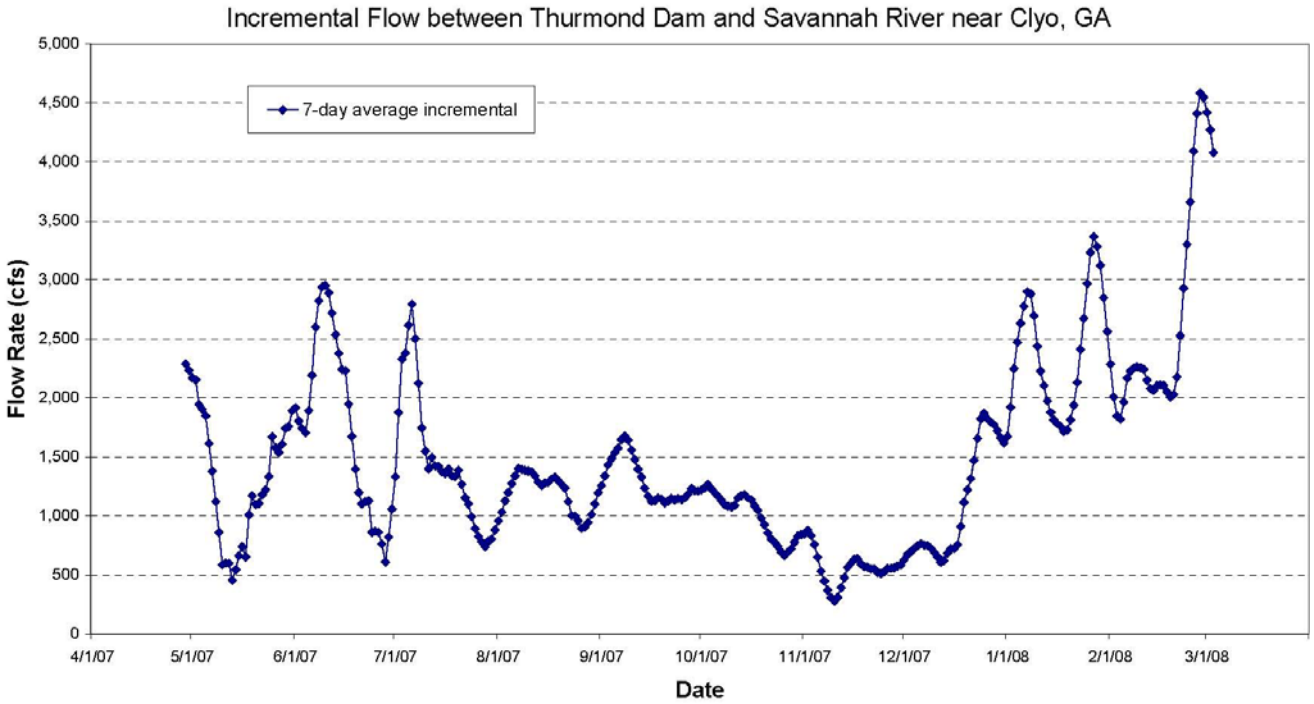


Fig. 2 Change of system conservation storage under 1988 hydrology and variation

Fig. 3 Incremental flow between Thurmond Dam and USGS Clyo gage in 2007-2008 period



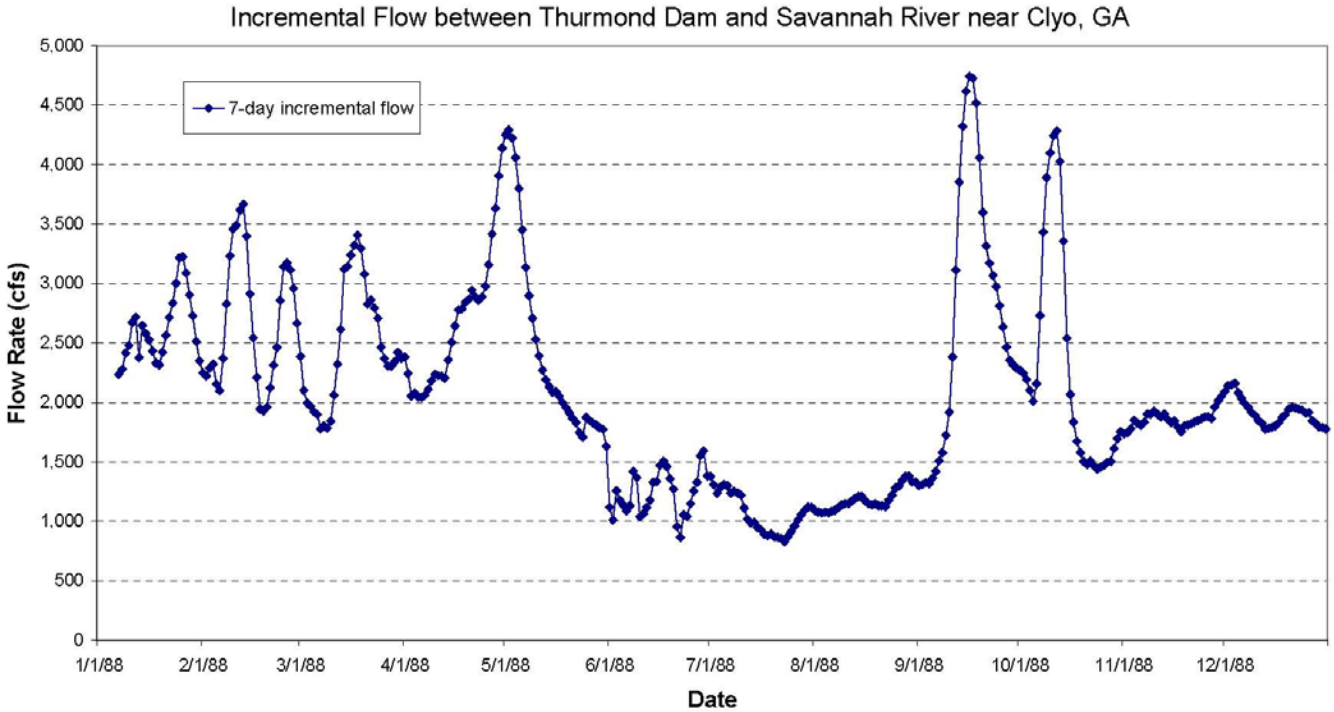


Fig. 4 Incremental flow between Thurmond Dam and the USGS Clyo gage in 1988

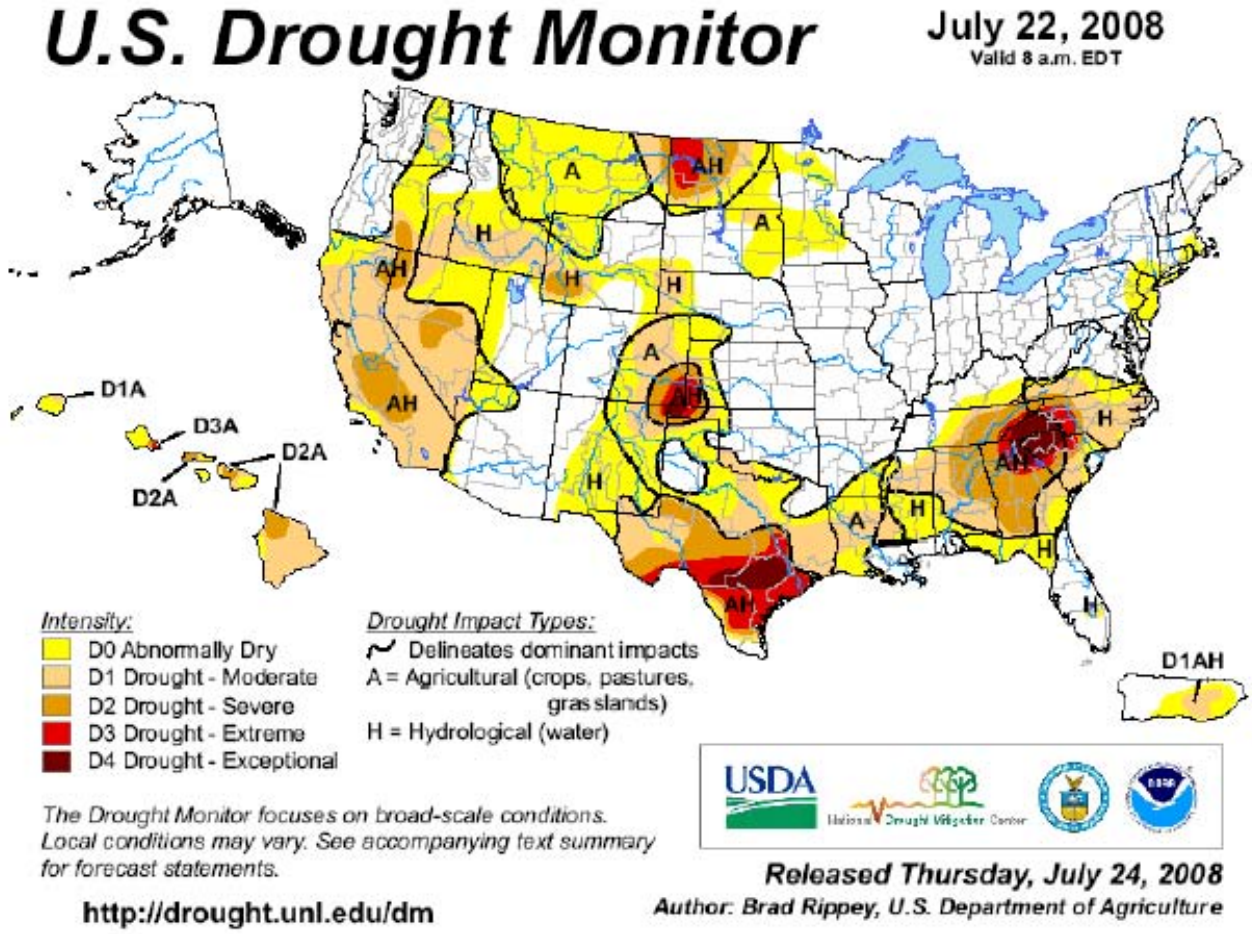


Fig. 5 U.S. Drought Monitor July 2008

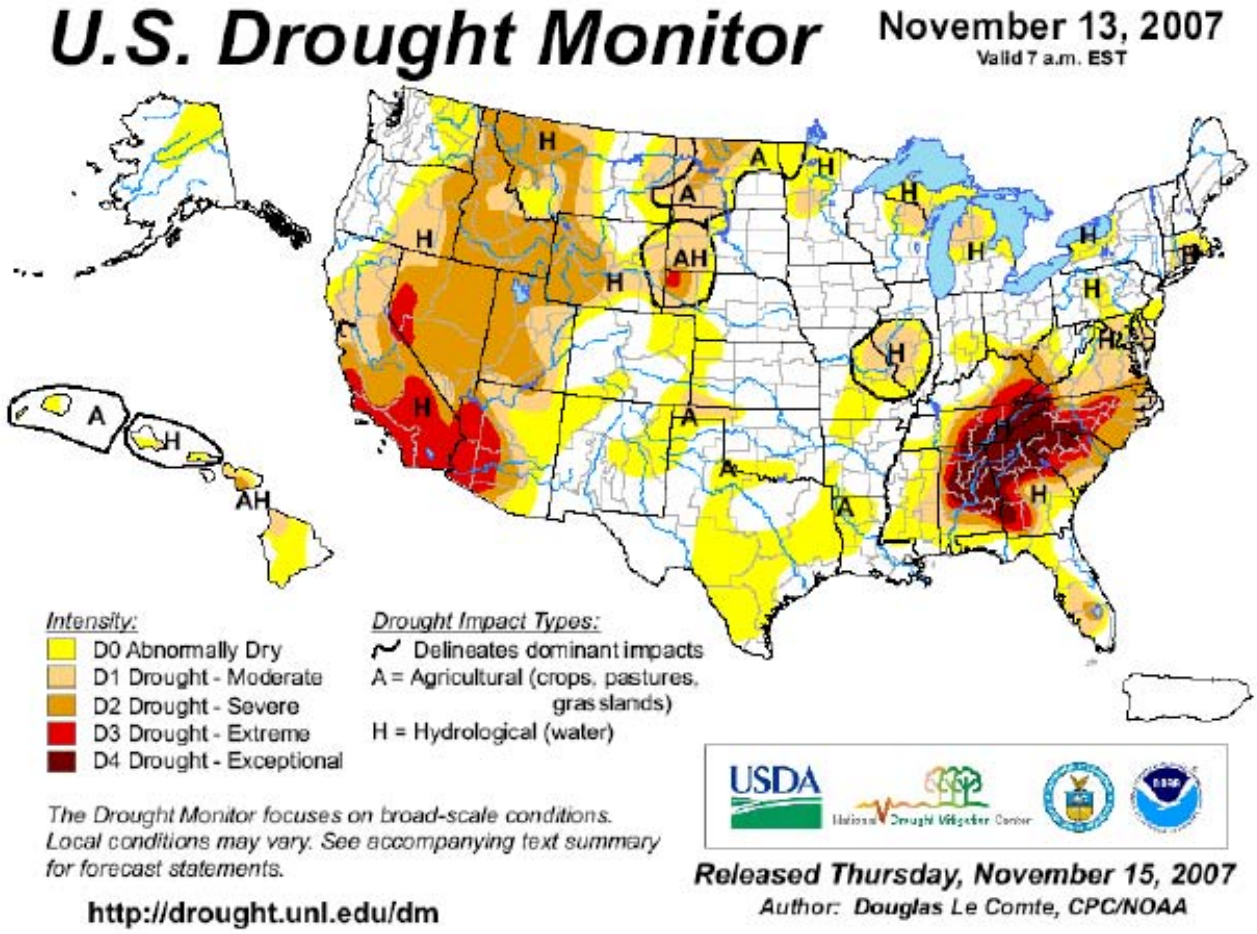
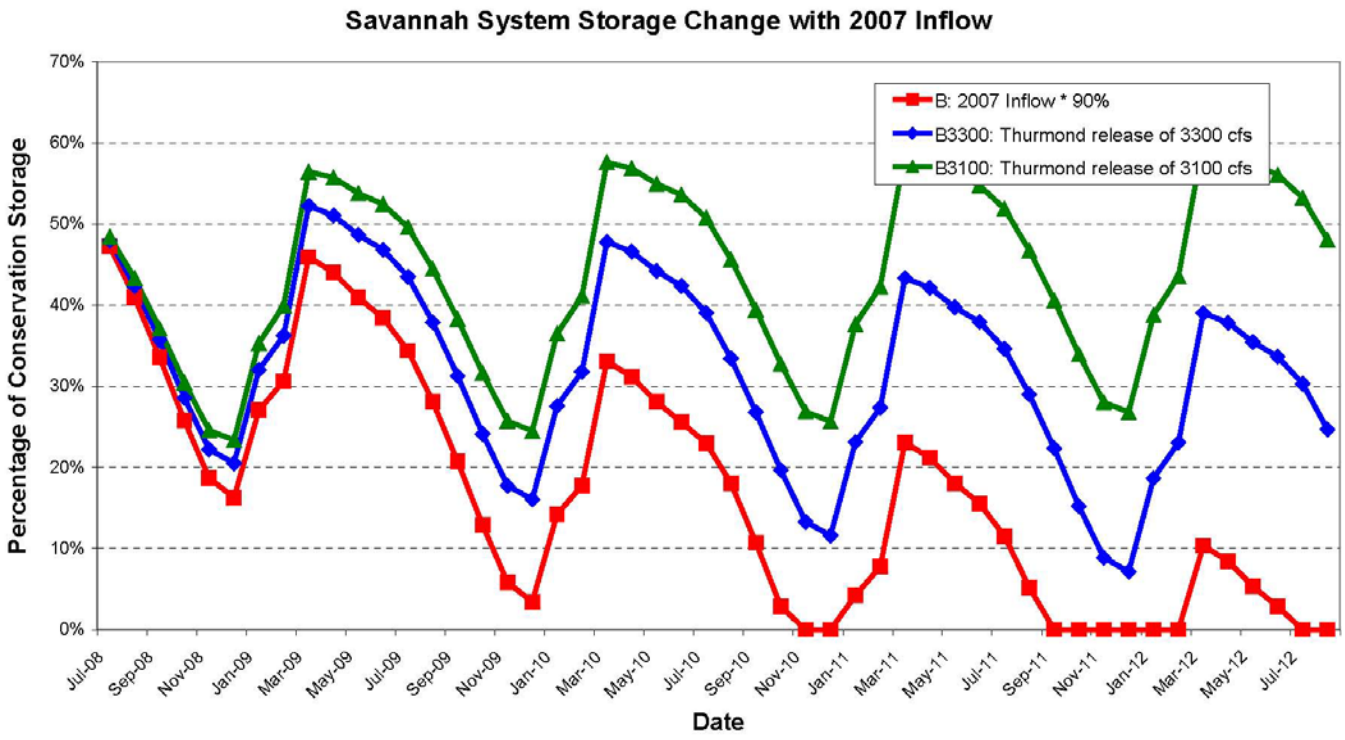


Fig. 6 U.S. Drought Monitor November 2007

Figure 7 Change of system conservation storage with 2007 hydrology and relief release at Thurmond



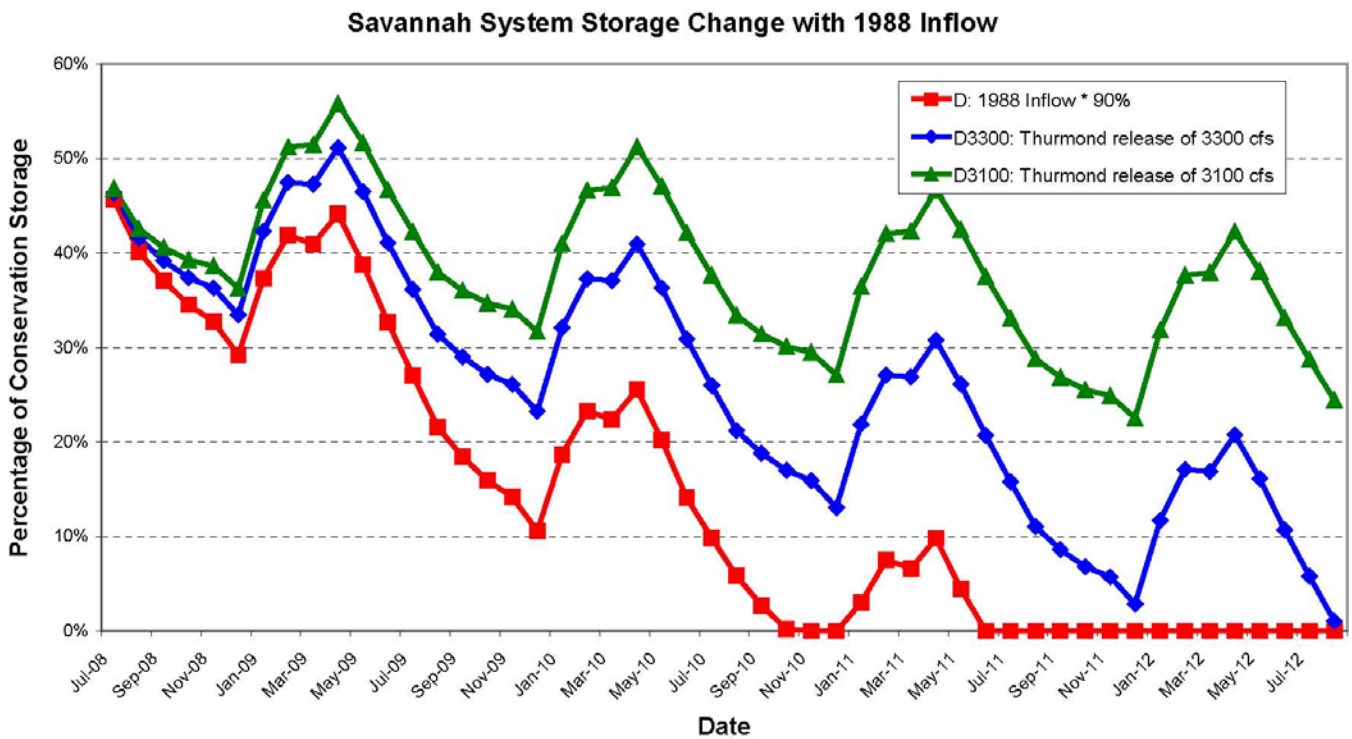


Fig. 8 Change of system conservation storage with 1988 hydrology and relief release at Thurmond

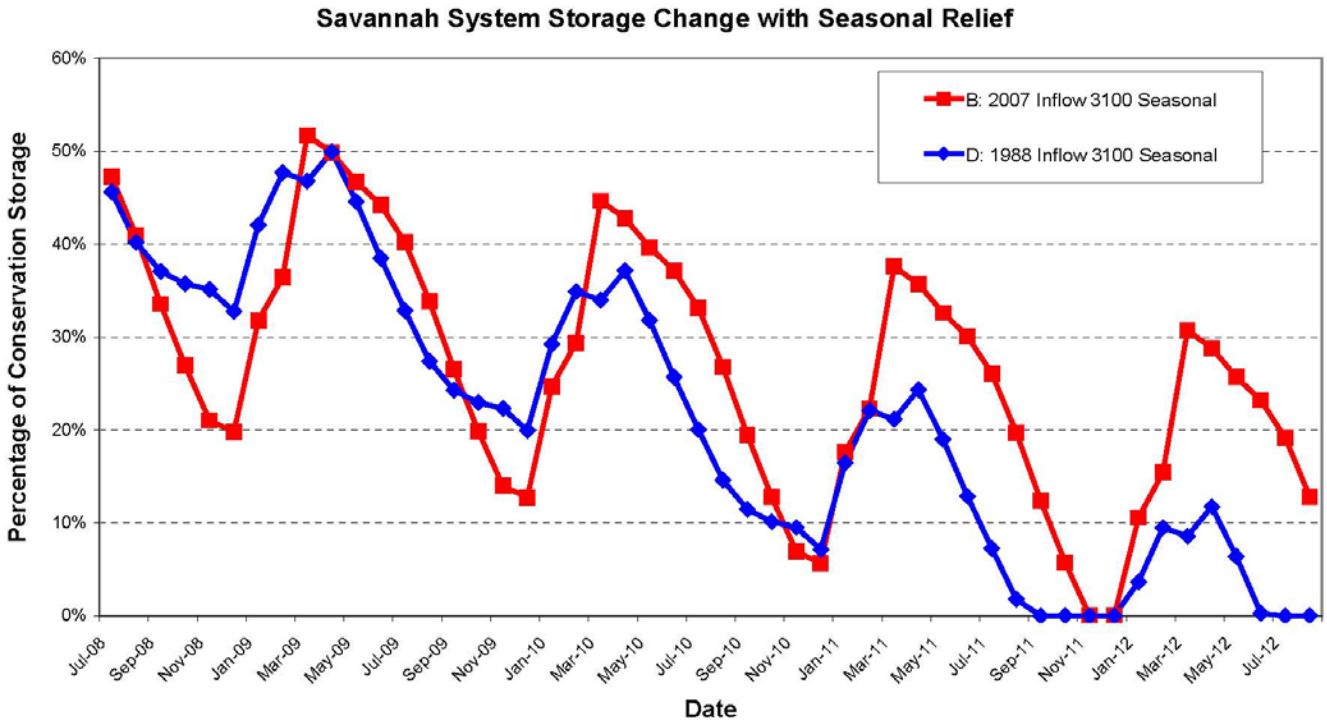


Fig. 9 Reducing Thurmond release to 3,100 cfs only in the cool season results in more stabilized system storage, even with worse-than-record inflow (90% of 2007 and 1998 recorded inflow)

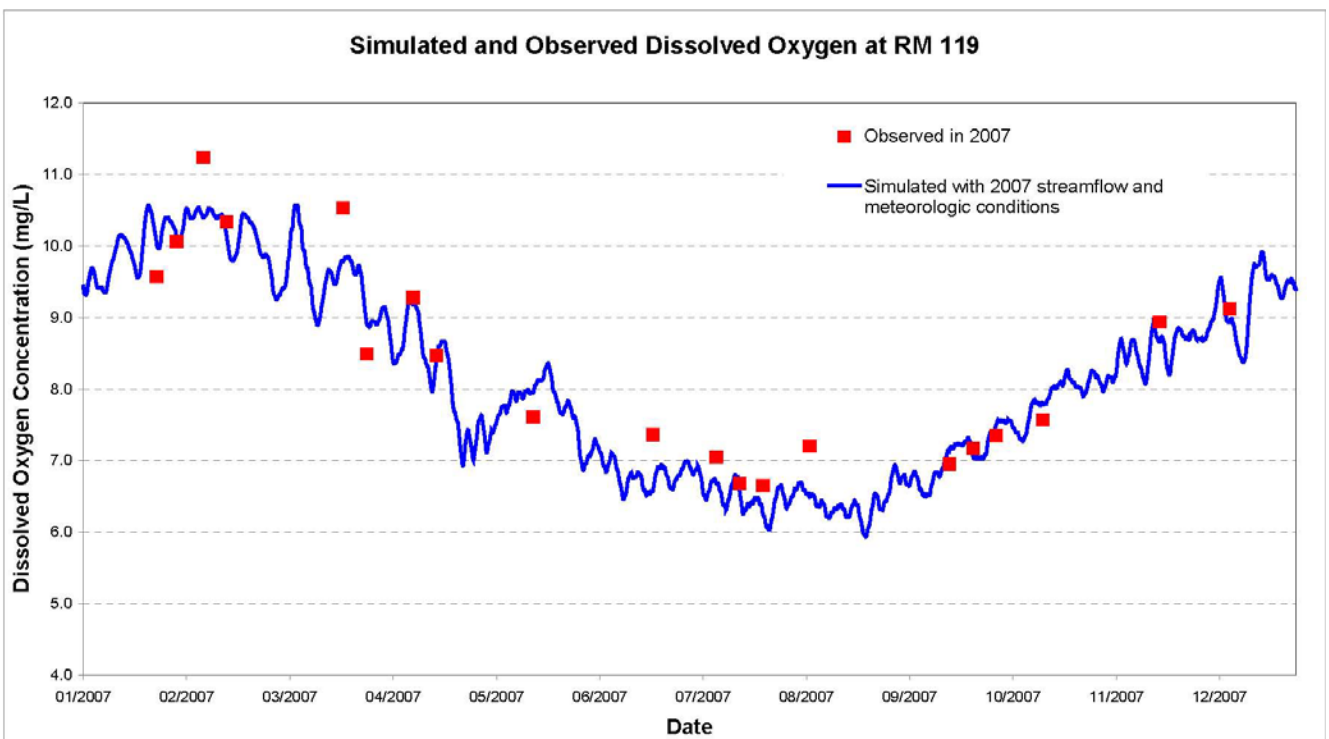
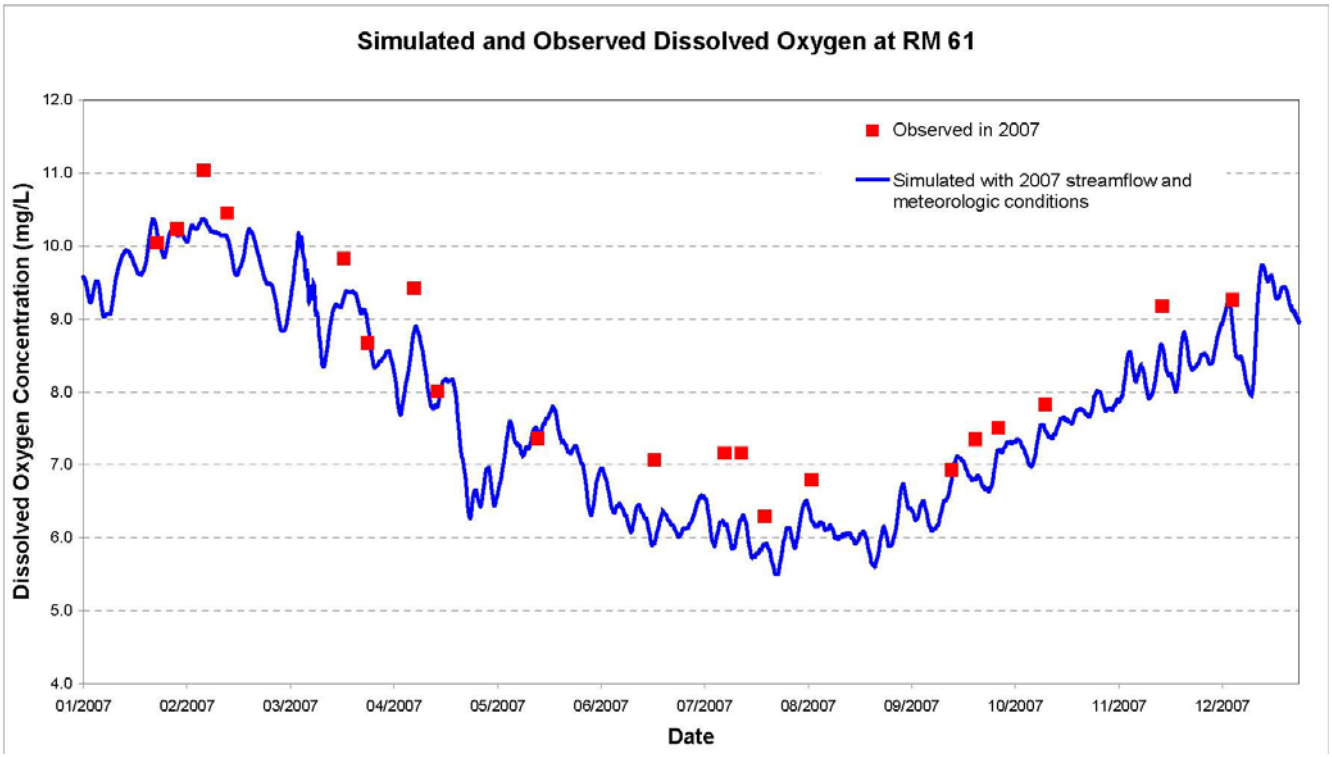


Fig. 10 Calibration of Savannah River water quality model at River Mile 119 (2007 Thurmond release)

Fig. 11 Calibration of Savannah River water quality model at River Mile 61 (2007 Thurmond release)



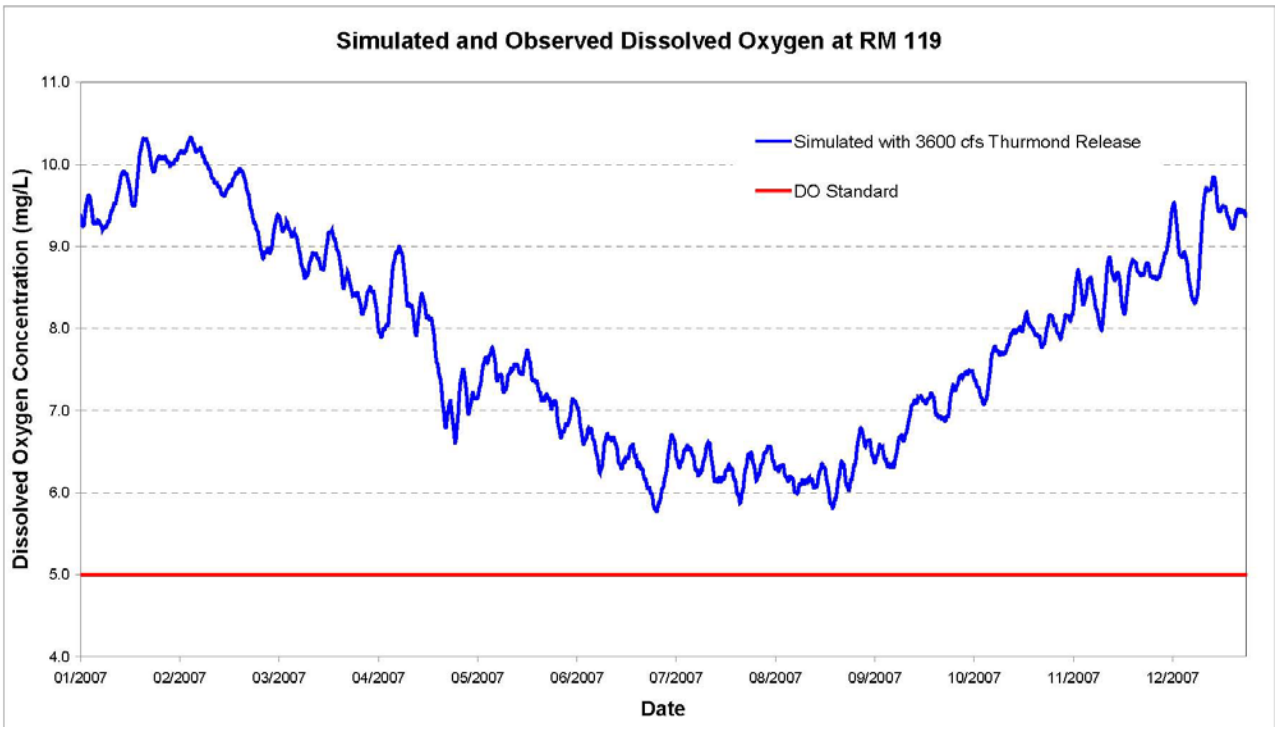


Fig. 12 Dissolved oxygen at RM 119 (with 2007 tributary inflow and meteorological data)

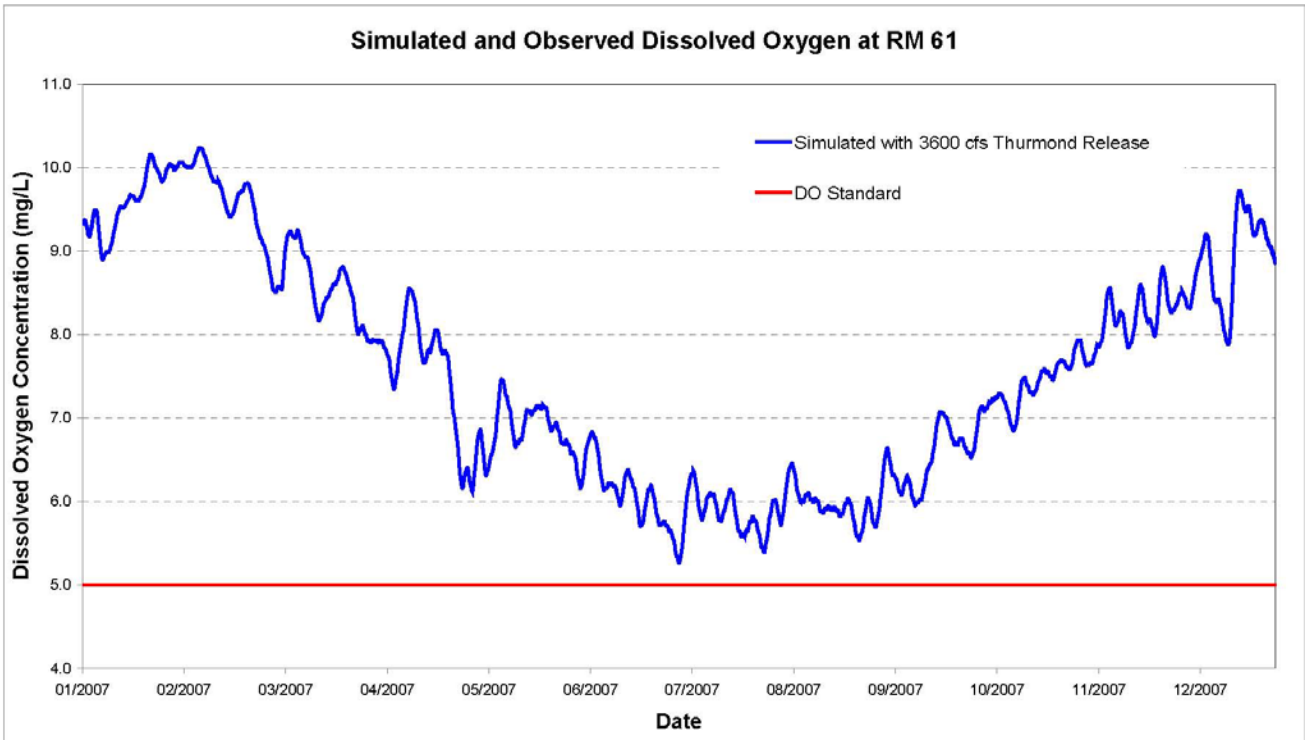


Fig. 13 Dissolved oxygen at RM 61 (with 2007 tributary inflow and meteorological data)

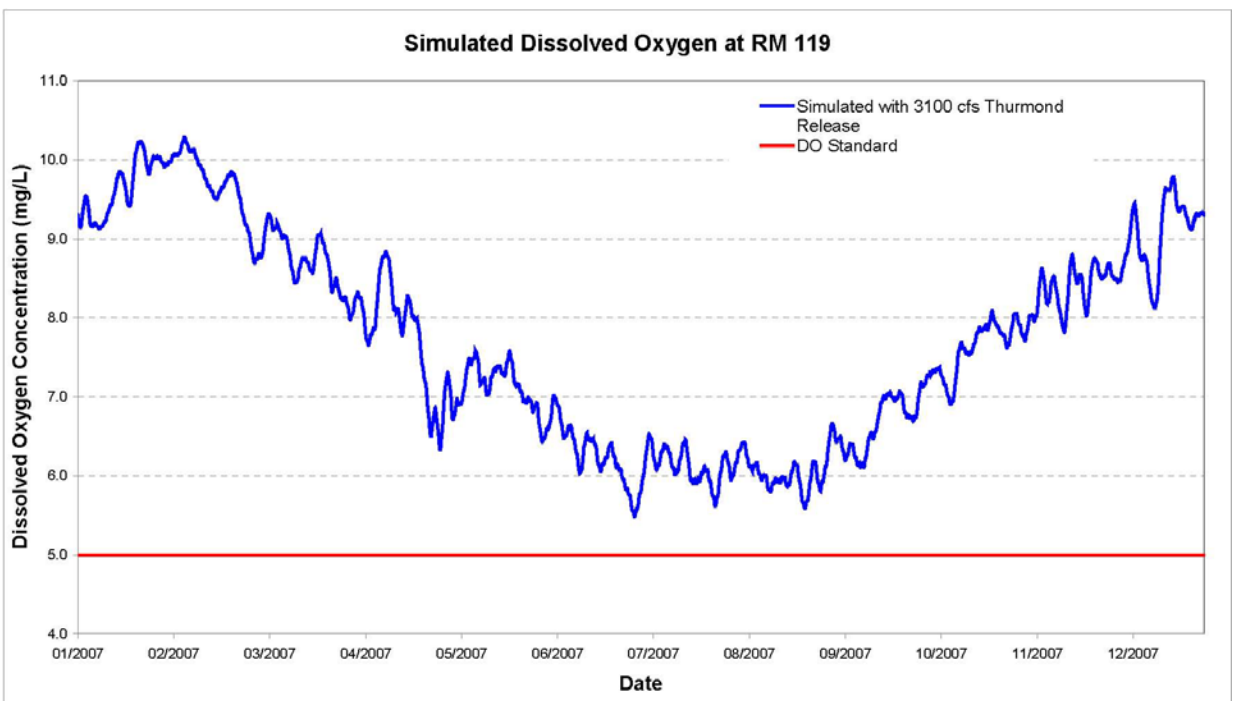


Fig. 14 Simulated dissolved oxygen at RM 119

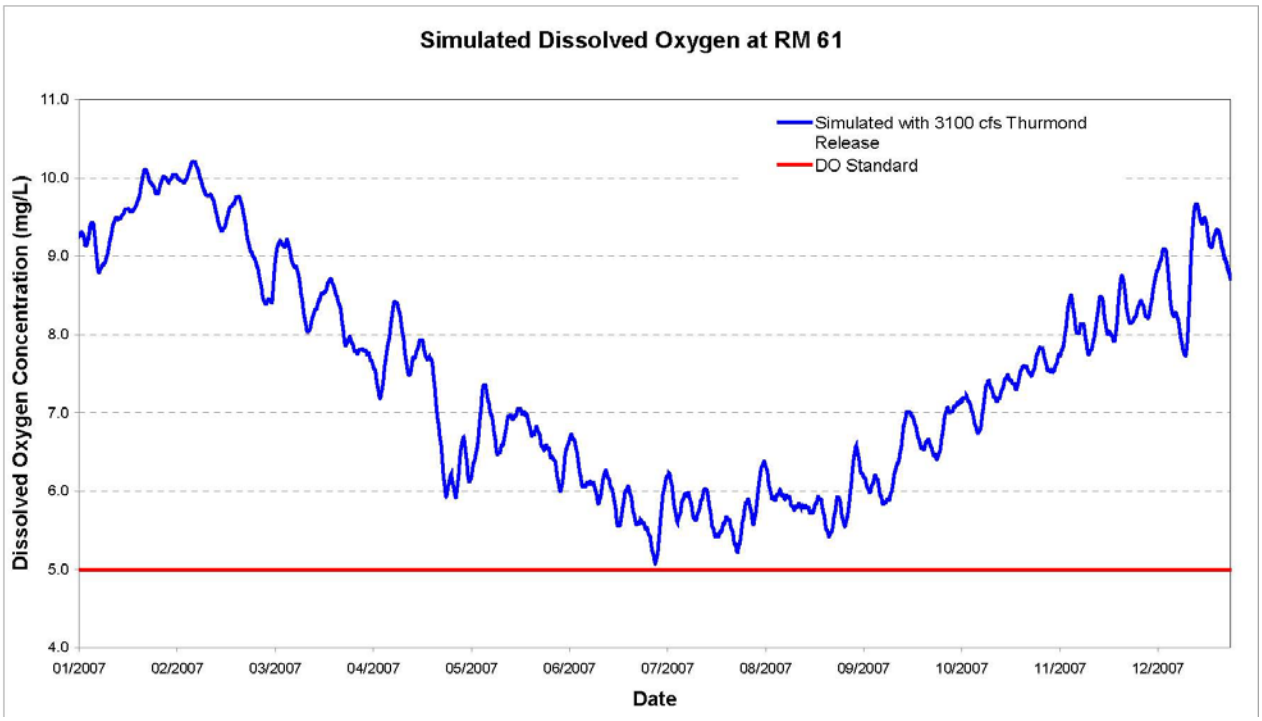


Fig. 15 Simulated dissolved oxygen at RM 61

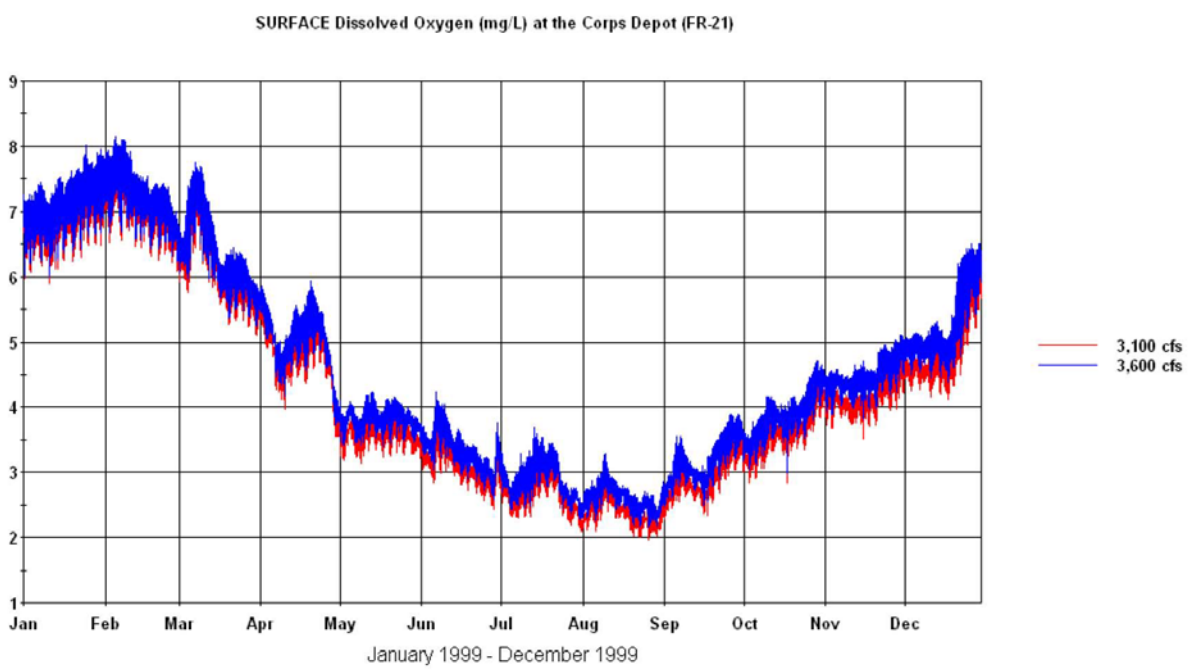
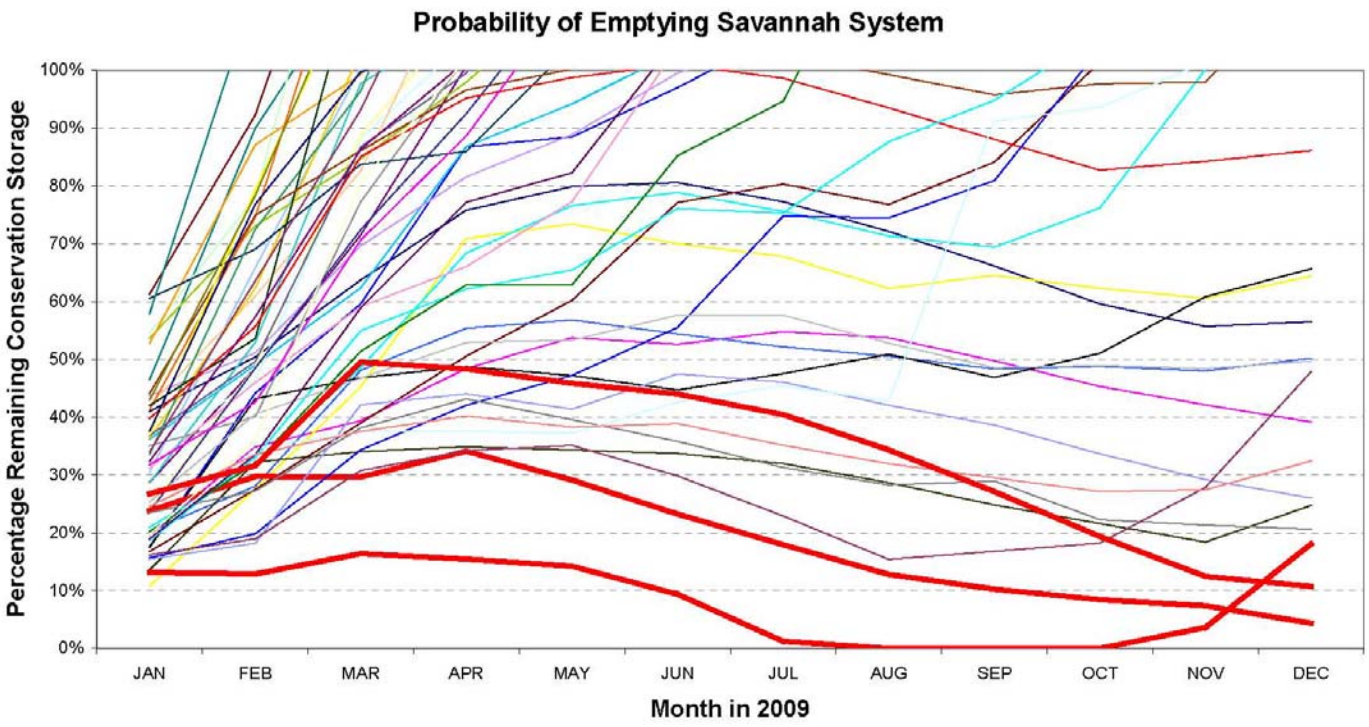


Fig. 16 Simulated surface dissolved oxygen in Savannah harbor

Fig. 17 Probability of refill (emptying) analysis reveals real danger of exhausting system conservation storage



Low Flow (Real Time) Management Plan
for Emergency Drought Response in the Savannah River Basin

A. Purpose/Background

As a result of extreme drought conditions in northeast Georgia, the Georgia Environmental Protection Division (GAEPD), South Carolina Department of Health and Environmental Control (SCDHEC), and South Carolina Department of Natural Resources (SCDNR) are proposing a temporary release reduction at Thurmond Dam from 3600 cfs to 3100 cfs beginning October 1st through the end of February. The Proposed Changes to Lake Thurmond Releases to Mitigate Drought Impact seeks to minimize the depletion of reservoir storage during extreme drought when less than 35% of system conservation remains. Minimizing the depletion of storage will affect both Lake Hartwell and Thurmond Lake. Implementation of the proposed changes should result, at current drought conditions, with the delay of lake level reductions to Level 4 (outflow=inflow) until sometime during the time period of September through November 2011.

This Low Flow (Real Time) Management Plan provides a method for implementing the Proposed Changes to Lake Thurmond Releases to Mitigate Drought Impacts, and for considering potential upward adjustments to the 3100 cfs (not to exceed 3600 cfs) should a decision be made that significant environmental impacts are occurring. The strategy and plan are not meant to replace the Army Corps of Engineers (ACE) current drought management plan, but instead are to be considered temporary modifications to the plan based on extreme drought conditions in the Savannah River Basin. Both documents were developed with input from multiple stakeholders.

B. Affected Environmental Elements/Low Flow Conditions

- Water quality standards (DO, pH, Temperature)
    - Important for maintaining aquatic biology
- Salt wedge location
    - Important for City of Savannah/BJWSA water supply intakes
    - Important for freshwater habitat maintenance
- Water levels at water intake structures
    - Important for all water users
- Habitat water levels/in-stream flow volumes
    - In shoal habitat within the Central Savannah River Area (CSRA)

Important for fish spawning and the Rocky Shoals Spider Lily

- In river bends that could be isolated
  Important for mussel habitat
- At critical in-stream fish habitat
  Important for determining impact to known fish spawning habitat, especially those species that are endangered

C. Baseline Monitoring Parameters/Low Flow Conditions

- Water quality
  - Continuous sonde data
    dissolved oxygen
    pH
    temperature
    specific conductance
- Water quantity (Savannah River flow)
  - Continuous discharge measurements
  - Continuous water levels
    At critical habitat locations
    At water intake structures

All current monitoring locations within the basin are shown in the Appendix.

D. Management Plan Elements

1. Dams and Diversions (operational strategies for river impoundments and the Augusta Canal System)

a). Storage and Discharge from J. Strom Thurmond Dam

GAEPD, SCDHEC, and SCDNR are proposing a seasonal release from Thurmond Dam constituting 3600 cfs from March through September and 3100 cfs from October through February. Beginning October 1st, discharges from Thurmond Dam would be transitioned down to 3100 cfs over a one-week period. Once the 3100 cfs objective is reached, it would be maintained until 28 February or until such time that 1) a listed monitoring site fails to meet its environmental target and 2) a decision is made by GAEPD, SCDHEC and SCDNR to modify the 3100 cfs. If such an event were to occur, discharges from Thurmond would be incrementally increased by 100 cfs/week until the impact is alleviated or 3600 cfs is reached. It's important to note however that any increase in flow up to and including 3600 cfs during the winter months could result in Level 4 arriving sooner than the currently predicted time period of September through November 2011.

b). Storage and Discharge from Stevens Creek Dam

Stevens Creek Dam attenuates the large, hourly discharge peaks from Thurmond Dam. The Stevens Creek Reservoir will continue to be managed to release as flat a schedule as possible equaling the daily average release at Thurmond Dam plus any local inflows.

c) Discharge between Shoals and Augusta Canal at the Augusta Diversion Dam

Diversions into the Augusta Canal are managed by the City of Augusta to maintain a minimum of 1500 cfs through the Shoals (FERC) from May though January and 1800 cfs in the remaining months. Three electronically controllable gates, operated by the City of Augusta, allow for instantaneous changes of flow to the canal. Based on current permit information on the City of Augusta intake, the City is allowed to withdraw no more than 45 MGD (about 70 cfs). The City has four turbines in its water supply operation. These turbines are driven by canal water, which in turn operates raw water pumps. Usually the City operates Units 1 and 4 to supply water needs at 1364 cfs. This amount is passed through the turbines and returned entirely to the main stem of the Savannah River (discharged into the last third of the shoals).

There are three mills using canal water downstream of the Augusta intake: Sibley, King, and Enterprise. All three mills have turbines used for hydropower generation that are driven by canal water. All water is passed through to the main stem of the Savannah River; in this case downstream of the shoals. Sibley Mill reportedly needs a flow of 1024 cfs, King 880 cfs and Enterprise 560 cfs.

At 3600 cfs (current release from Thurmond), and without consideration of incremental flows (very low), 1500 cfs would have to be provided at the diversion for the shoals (FERC), leaving 2100 cfs for the canal. After the City's turbines and intake, there would be less than 800 cfs remaining for the canal and downstream use. Reportedly, at this time, the mills are still able to operate.

Under the proposed seasonal flow strategy, a 3100 cfs flow would be released from Thurmond Dam from October through February. If the City operates the gates to ensure 1500 cfs through the shoals, the remaining water through the canal would be 1600 cfs (again assuming low incremental flows). While this should be sufficient water for Augusta's water supply needs, the downstream mills would be receiving less than 300 cfs for their hydropower operations.

Reportedly, the mills are connected to the power grid. Discussions will need to occur with the mills to determine their abilities to operate at the 3100 cfs and to use, if necessary, power from the grid during the low flow periods.

d) CSRA pool elevation/discharge over NSBL&D

Discharge from the Lock and Dam would be adjusted to maintain the pool within its current operating limits.

2. Water Management Targets

a). Water quality standards (DO, pH, temperature) within the lower Savannah River Basin (Table 1)

At this time, most of the continuous monitors within the mainstem of the freshwater portion of the river are not Internet accessible. Flow correlations to continuous data can only be established after data has been downloaded and analyzed. However, USGS operates a continuous monitor in the Savannah River at the USACE Dock (021989773). This monitor is located near where the dissolved oxygen concentration is typically the lowest in the Savannah River Basin. If a violation of water quality standards occurs, specifically for DO, pH, and/or temperature, a decision will be made by GAEPD, SCDHEC and SCDNR as to the need to incrementally increase the release from Thurmond Dam by 100 cfs/week until the standard is met or until 3600 cfs is reached..

Table 1. Water quality standards

Waterbody	Dissolved Oxygen	Temperature	pH
Savannah River	5.0 mg/L daily average 4.0 mg/L instantaneous	≤ 90 ºF	6-8.5
[1] South Carolina Regulations 61-68 & 61-69, Water Classifications and Standards			
[2] Georgia DNR EPD Regulations 391-3-6-.03, Water Use Classifications and Water Quality Standards			

b). Saltwater Wedge

The USGS operates a water quality monitor at I-95 near Port Wentworth (02198840). A maximum specific conductivity level of 10,000 microseimens measured at I-95 will be considered a management target for unacceptable migration of the salt-water wedge. Conductivity of 8000 microseimens was measured at I-95 during the 1998-2002 drought, so 10,000 is considered a valid and conservative number. The City of Savannah's intake water quality could be adversely affected by expansion of this wedge. Currently the City collects chloride data in Abercorn Creek. If the City's intake chloride concentrations increase to 16 ppm , then the City of Savannah will be consulted prior to any decision by GAEPA, SCDHEC and SCDNR to release additional water from Thurmond Dam. Typically the spring tide causes the largest intrusion of salt water upriver. If needed, benefit may come from releasing more water in time to meet the spring tide after which flows could be reduced back to the 3100 cfs.

c). Flows at Clyo/Savannah Harbor

There is a USGS gauge at Clyo (02198500), which also can be used as a management location. If the flows at Clyo are greater than 5000 cfs, there would be no need to increase flow above 3100 cfs from Thurmond Dam regardless of the water quality violations in the Harbor since the reduced flows from Thurmond Dam should not be the cause of the

violations. However, if the flow at Clyo is less than 4500 cfs then closer evaluation of the water quality standards is warranted. Should water quality violations be occurring, then a decision will need to be made by GAEPD, SCDHEC and SCDNR regarding incrementally increasing flows from Thurmond Dam by 100 cfs/week until either the water quality standard is met or 3600 cfs is reached. Finally, if the flow at Clyo is between 4500 and 5000 cfs, then an evaluation of the situation to determine if there are unusual circumstances such as higher than normal tides, off shore storms, will be performed to assist in deciding if increase flows from Thurmond are warranted to help solve the problem.

d). Water levels at Permitted Surface Water Intakes

Initial minimum stage requirements have been established for each permitted intake (see Table 2 below). Each permit holder will monitor intake performance. If intakes become impacted and/or unusable due to insufficient river stage, releases from Thurmond Dam will be as required to ensure that the river stage is sufficient to return the intake to service. This is a high priority consideration for protection of public health. Should a problem with an intake arise, consultations with the affected intake operator will also occur to discuss the possibility of employing emergency measures that may be successful in adapting to the lower flows.

Table 2. Intake requirements for entities along the Savannah River.

Facility Name	Invert Elevation	Minimum Elevation Required	Corresponding Flow to Min. Elev (cfs)
Columbia Cty			
Augusta Canal			1600 cfs in canal + 1000 cfs in shoals
Edgefield Cty	149.5	149.5	
City of Augusta		119.5	
City of North Augusta	106	109	1000 cfs at elevation 109 ft
SCE&G	106	105.5	900 cfs at elevation 106 ft
PCS Nitrogen	97.75	103.9	1300 cfs at elevation 110 ft
DSM Chemical	97.75	103.9	1300 cfs at elevation 110 ft
General Chemical	110.2	111	1800 cfs at elevation 111 ft at DSM Chemical
Kimberly Clark		109	1060 cfs at elevation 109 ft
International Paper	94	94	2800 cfs at elevation 94 ft
Savannah River Site	81	81	3400 cfs at elevation 81 ft; 2300 cfs at elevation 79 ft
Plant Vogtle	70	70	always met
Savannah Electric- Plant McIntosh	7.5	7.5	3500 cfs at elevation 7.5 ft
Georgia Pacific	-1	5.16	3300 cfs at elevation 15.39 ft (at Clyo)
City of Savannah		-10.22	
Beaufort-Jasper		+3	

modified from GAEPD, SCDHEC, and SCDNR Draft, *Proposed Changes to Lake Thurmond Releases to Mitigate Drought Impacts*, July 2008

e). Sturgeon Protection

Sturgeon passage and spawning activity is monitored by SCDNR (fish are tagged and their movement closely observed). SCDNR can determine whether or not fish are successfully navigating toward their spawning habitat. Should problems result in sturgeon migration at lower flows, then a decision will need to be made by GAEPD, SCDHEC and SCDNR on releasing additional water up to the 3600 cfs for the required navigational period.

E. Habitat Water Levels/Instream Flow Volume Considerations

At this point, there is no correlation between discharge at the New Savannah Bluff Lock and Dam (NSBL&D) gauge and water elevation within the shoals. Water depths for fish spawning and habitat have not been established. There is no correlation between discharge and water elevation/depth within the cutoff bends which may affect mussel habitat. There is also no correlation between discharge and water elevation at critical in-stream fish habitat. Discharge measurements should be measured at the habitat site and correlated to a nearby USGS gauge.

The correlation between discharge and critical habitat will require measuring water depth and percent inundation at various discharges at the specific mussel and fish habitat sites. A mesohabitat study showing shoal habitat classifications/areas in response to a range of flows will need to be done. Fish passage monitoring for diadromous fish at the NSBL&D and sampling for juvenile diadromous fish, at least shad and striped bass in the Savannah River from the Augusta Dam downstream to appropriate sampling areas below the NSBL&D will need to be conducted. Juvenile/adult index could then be correlated with river basin flows from year to year. The Southeast National Sciences Academy (SNSA) is working with Augusta State, USFWS, TNC and others to determine these water level targets.

However, developing water level targets for the shoal habitat, the cutoff river bends, and at the critical instream fish habitat cannot be developed within the current time frame for this winter season. Information gathered this fall/winter could be used to develop water level targets that may be used if extreme drought conditions continue in the basin.

F. Monitoring Locations/Communication routes

The following table lists those parties that will be responsible for reporting to GAEPD on specific environmental targets. Upon review of that information, and discussion with SCDHEC and SCDNR, decisions will be made on notifying the ACE of appropriate adjustments to Thurmond release levels.

Table 3

Location	Target	Responsible Party
Shoals	Flow 1500 cfs	City Of Augusta
USGS 021989773	DO 5.0 mg/L daily average DO 4.0 mg/L instantaneous Temperature ≤ 90 ºF pH 6-8.5	GAEPD
USGS 02198840	Conductivity 10,000 µS/cm	GA EPD
Abercorn Creek	Chloride 16 ppm	City of Savannah
USGS 02198500	Flow < 4,500 cfs	SC DHEC
Various	Water level at the intakes	Intake operators
Various	Sturgeon migration	SC DNR

APPENDIX D

2008 AGENCY LOW FLOW

REQUEST LETTERS

Georgia Department of Natural Resources
2 Martin Luther King Jr., Drive, Suite 1152 East Tower, Atlanta, Georgia 30334
Noel Holcomb, Commissioner
Carol A. Couch, Ph.D., Director
Environmental Protection Division
(404) 656-4713

October 1, 2008

Colonel Edward J. Kertis, Jr.
District Commander
U.S. Army Corps of Engineers
Savannah District
100 W. Oglethorpe Ave.
P.O. Box 889
Savannah, Georgia 31402-0889

RE: Savannah River Basin Drought
Request for Modification to the Drought
Contingency Plan Through
The Environmental Assessment Process (EA)

Dear Colonel Kertis:

As you are aware, since the US Army Corps of Engineers (USACE), Savannah District, first declared, in June of 2007, an Action Level 1 release from Thurmond Dam (4200 cfs), the State of Georgia Environmental Protection Division (GA EPD), along with the State of South Carolina, and other Federal, State and local stakeholders, have been routinely discussing and evaluating the drought crisis in the Upper Savannah River Basin via USACE bi-weekly conference calls. These calls have been very helpful and have allowed the participants to fully understand the status of drought in this region, predictions on persistence of the drought, how it might affect those users downstream of Thurmond dam, and how it is affecting the levels of Lakes Hartwell, Russell and Thurmond.

In response to continuing concerns regarding lake levels and predictions on when Action Level 4 (outflow =inflow) might be reached, in December of 2007, the GA EPD organized a Technical Coordination Group (TCG), comprised of Federal and State agencies (see attached list), whose charge was to analyze and evaluate possible alternatives to the existing releases as authorized under the USACE's Drought Contingency Plan. At that time, Thurmond Dam was being operated in accordance with a Modified Action Level 2 (3600 cfs minimum).

Through subsequent TCG meetings, and then just as critically, through breakout meetings involving the States of Georgia and South Carolina, a finalized proposal has been developed on how to extend storage in the lake system through a seasonal release strategy for Thurmond Dam. The attached document entitled Proposed Changes to Lake Thurmond Releases to Mitigate Drought Impacts (authored by the GA EPD, the South Carolina Department of Health and Environmental Control and the South Carolina Department of Natural Resources) provides the rationale for extending the life of each conservation pool via a seasonal release from Thurmond Dam (3100 cfs from October through February, with a return to a release of 3600 cfs (daily) from March

through September). The other attached document entitled Low Flow (Real Time) Management Plan for Emergency Drought Response in the Savannah River Basin (accomplished with an even broader stakeholder group) provides a program for monitoring appropriate environmental targets with the potential to adjust the 3100 cfs should unacceptable impacts occur to those targets during the October through February time period.

Throughout this process, the USACE has not only been vital in providing predictive information on lake storage levels, but with providing information on how best to expedite implementation of a seasonal strategy using the USACE's Environmental Assessment (EA) process. To that end, I am requesting that the USACE submit to public notice, via its EA process, a strategy for operating the Lake Thurmond project as detailed in the attached documents. Since I consider this an emergency situation and one worthy of reduced EA timelines, I request that the EA process be accomplished, if possible, through a 15 day public notice. The release from Thurmond Dam is now at Action Level 3 (3600 cfs daily), so time is of the essence in initiating the EA process so that the USACE can quickly implement these modifications.

Your continued cooperation in addressing this critical situation is appreciated.

Sincerely,

Carol A. Couch
Director

CC: Mr. Robert W. King, Jr.
Deputy Director
South Carolina Department of Health & Environmental Control-EQC

Mr. D. Breck Carmichael, Jr.
Deputy Director
Wildlife and Freshwater Fisheries Division
South Carolina Department of Natural Resources

ATTACHMENT

D H E C

PROMOTE PROTECT PROSPER

C. Earl Hunter, Commissioner

Promoting and protecting the health of the public and the environment.

~~DE~~
OP
cf: DE
DC
DP
CS
DX
S: 24 Oct 08

October 6, 2008

Colonel Edward J. Kertis, Jr.
District Commander
U.S. Army Corps of Engineers
Savannah District
100 W. Oglethorpe Ave.
PO Box 889
Savannah, Georgia 31402-0889

Re: Savannah River Basin Drought
Request for Modification to the Drought Contingency Plan
Georgia Department of Natural Resources letter dated October 1, 2008

Dear Colonel Kertis:

The referenced letter from the Georgia Department of Resources discussed the background and actions taken to date on this matter, so I will not restate them here. The South Carolina Department of Health and Environmental Control (SCDHEC) supports the proposed temporary changes to Lake Thurmond releases to mitigate drought impacts as outlined in Dr. Couch's letter, and also requests an expedited Environmental Assessment process.

If you have any questions, please let me know.

Sincerely,

Robert W. King, Jr., P.E.
Deputy Commissioner
Environmental Quality Control

CC: Dr. Carol Couch, Director
Georgia Environmental Protection Division

John Frampton, Director
SC Department of Natural Resources

South Carolina Department of
Natural Resources

John E. Frampton
Director

October 10, 2008

Col. Edward J. Kertis, Jr.
District Commander
U.S. Army Corps of Engineers
Savannah District
100 W. Oglethorpe Ave., PO Box 889
Savannah, GA 31402-0889

Dear Colonel Kertis:

As we all are aware, the upper Savannah River basin has experienced a severe drought for the past two and a half years that, despite conservation efforts by the Corps of Engineers, has lowered water levels in Hartwell, Russell, and Thurmond Reservoirs to near record-low levels.

These reservoirs are extremely important to both South Carolina's and Georgia's economies, natural resources, and the health of our citizens. Not only are the reservoirs themselves vital to South Carolina and Georgia, but during this severe drought, releases from the reservoirs are enhancing the flow of the Savannah River, thereby protecting downstream ecosystems, public water supplies, industries, and power plants.

The South Carolina Department of Natural Resources (SCDNR) has worked cooperatively with representatives from the Georgia Environmental Protection Division (GAEPD), the South Carolina Department of Health and Environmental Control (SCDHEC), the U.S. Army Corps of Engineers, and other agencies and stakeholders to develop a proposal to delay the complete depletion of the lakes' conservation pools. Together, the States of South Carolina and Georgia have finalized a proposal to reduce releases from Thurmond Reservoir during the winter months if this severe drought persists. The document entitled *Proposed Changes to Lake Thurmond Releases to Mitigate Drought Impacts*, coauthored by GAEPD, SCDHEC, and SCDNR, and which has already been presented to you by GAEPD, describes the seasonal flow reduction agreed upon by both States.

Due to the importance of this matter, I am recommending that you implement this flow reduction plan as soon as possible.

Rembert C. Dennis Building • 1000 Assembly St • P.O. Box 167 • Columbia, S.C. 29202 • Telephone: 803/734-4007
EQUAL OPPORTUNITY AGENCY • framptonj@dnr.sc.gov • www.dnr.sc.gov • PRINTED ON RECYCLED PAPER

Because the proposed release reduction from Thurmond Reservoir cannot be initiated until the Corps of Engineers complete an Environment Assessment, I am urging you to begin the Environment Assessment process immediately, and to make every effort to complete it as quickly as possible, including, if possible, the use of a 15-day public comment period. The opportunity for release reductions for October of this year has already been lost, but quick action by the Corps can allow these reductions to go into effect by November of this year.

Also, I would like to request that your staff work with representatives from both States in planning for the transition into Level 4 drought releases (outflow equals inflow) should this severe drought continue and our efforts to preserve the conservation pools prove unsuccessful.

I appreciate your serious consideration of this proposal.

Sincerely,

John E. Frampton
Director

cc: Michael G. McShane, Chairman, SCDNR Board
Robert W. King, Deputy Commissioner, SCDHEC
Noel Holcombe, Director, GADNR
Carol Couch, Director, GAEPD
Steve de Kozlowski, Interim Deputy Director, SCDNR-LWC
Bob Perry, Director, Office of Environmental Programs, SCDNR

APPENDIX E

U.S. FISH AND WILDLIFE

FLOW RECOMMENDATION LETTER

JUNE 4, 2009

United States Department of the Interior

Fish and Wildlife Service
105 West Park Drive, Suite D
Athens, Georgia 30606
Phone: (706) 613-9493
Fax: (706) 613-6059

West Georgia Sub-Office
Post Office Box 52560
Fort Benning, Georgia 31995-2560
Phone: (706) 544-6428
Fax: (706) 544-6419

Coastal Sub-Office
4980 Wildlife Drive
Townsend, Georgia 31331
Phone: (912) 832-8739
Fax: (912) 832-8744

JUN 04 2009

Mr. William Bailey (ATTN: PD-E)
Environmental Resources Branch
United States Army Corps of Engineers
100 West Oglethorpe Avenue
Savannah, Georgia 31401-3640

Subject: Savannah River flow recommendations below Thurmond Dam
FWS Log No. 41460-2009-FA-0650

Dear Mr. Bailey:

The U.S. Fish and Wildlife Service (Service) has reviewed your March 16, 2009, email correspondence requesting information on biological and physical flow thresholds in the Savannah River below the United States Army Corps of Engineers (COE) reservoirs. According to your email, this information will be used to evaluate a reduction of the releases below the COE reservoirs during future fall, winter, and spring periods, especially related to fish spawning. The COE recently reduced flows from the J. Strom Thurmond Reservoir (Thurmond) from a daily average flow of 3,600 to 3,100 cubic feet per second (cfs), as measured at Thurmond, from November 2008 to the end of January 2009 in accordance with the Temporary Deviation Drought Contingency Plan for the Savannah River Basin (COE 2008, Ed Betross, GDNR, 2009, personal communication). Per your April 6, 2009, phone conversation with the Service, the COE is now gathering information for the development of an Environmental Assessment (EA) in relation to extending this flow reduction period. We submit the following comments under the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*) and as technical assistance under the Fish and Wildlife Coordination Act (FWCA)(48 Stat. 401, as amended; 16 U.S.C. § 661 *et seq.*).

Endangered Species Act

On October 27, 2008, the Service concurred with your determination that the COE's reduction of flows from 3600 cfs to 3100 cfs from November 1, 2008 to February 28, 2009 was not likely to adversely affect federally-listed or proposed endangered and threatened species under our jurisdiction, including the wood stork (*Mycteria americana*) and manatee (*Trichechus manatus*). Based on the information provided thus far, the Service does not expect adverse affects to these

species for this new proposed action. The shortnose sturgeon (*Acipenser brevirostrum*) is federally endangered under the purview of the National Oceanic and Atmospheric Administration (NOAA) Fisheries for the ESA.

Fish and Wildlife Coordination Act

We are concerned about the effects of a proposed flow reduction in the Augusta Shoals and the lower Savannah River. The Service is particularly concerned about effects to the:

- federally endangered shortnose sturgeon;
- Federal species of concern robust redhorse (*Moxostoma robustum*). The robust redhorse, although not federally-listed, is the subject of a pre-listing recovery approach by the Robust Redhorse Conservation Committee (RRCC). The COE, along with the Service, is a member of the RRCC. The RRCC is a voluntary stakeholder partnership charged with the overall responsibility for directing the recovery of the robust redhorse. As a member, the Service has included comments about potential impacts to robust redhorse.
- striped bass (*Morone saxatilis*);
- Georgia State threatened Savannah lilliput (*Toxolasma pullus*). Additionally, Savannah lilliput is undergoing a status review to determine the need to be elevated to a Federal candidate species;
- Georgia and South Carolina State endangered brother spike (*Elliptio fraterna*);
- Georgia State threatened Altamaha arcmussel (*Alasmidonta arcula*);
- Georgia State threatened shoals spiderlily (*Hymenocallis coronaria*); and
- tidal freshwater habitat provided for wetland-dependant migratory birds on the Savannah National Wildlife Refuge.

The Service provided flow recommendations for the Savannah River below the COE reservoirs in our 2003 Draft FWCA Report to the COE. Those recommendations were divided by dry, average, and wet years and were developed to benefit the entire ecosystem downstream of the COE reservoirs. We recommend the COE review this document when developing their EA. The flows for the Augusta Shoals do not include the diverted flows into the Augusta Canal; therefore those diverted flows would need to be added to the Augusta Shoals flows listed below to generate the upstream flow releases. The recommendations for **dry** years are as follows:

Month	Augusta Shoals (cfs)	Savannah River-Floodplain (cfs)	Savannah River-Estuary (cfs)
January	4000	7500	8000
February	4000	7500	8000
March	4000 (pulse of 12500-14500)	7500 (pulse of 16000-18000)	8000 (pulse of 16000-18000)
April	4000 (pulse of 12500-14500)	7500 (pulse of 16000-18000)	8000 (pulse of 16000-18000)
May	2700	6200	6200

June	2700	6200	6200
July	2700	6200	6200
August	2000	5500	6000
September	2000	5500	6000
October	2000	5500	6000
November	2700	6200	6200
December	2700	6200	6200

Additionally, the Service's Draft FWCA Report recommended the COE address critical research needs for informed management of the lower Savannah River that were developed at the Savannah River Ecosystem Flow Workshop in April 2003 (Attachment A). Since the 2003 Ecosystem Flows Workshop and the Service's Draft FWCA Report, there has been little monitoring and research to refine these flow recommendations.

A summary of the monitoring and research that has been accomplished is compiled in Wrona et al. (2007). Additionally, the Southeastern Natural Sciences Academy sent you a summary of monitoring information that may be helpful to the development of your EA (Oscar Flite, Southeastern Natural Sciences Academy, 2009, pers. comm.). Other pertinent post-2003 FWCA Report research is as follows:

• Ongoing negotiations for the Federal Energy Regulatory Commission (FERC) relicensing of the Augusta Canal project involve flows that are based on levels equal to or greater than 3600 cfs at Thurmond Dam. Due to ongoing canal maintenance, the Augusta Canal is currently not operational and nearly all discharge released from Thurmond Dam currently flows into the Augusta Shoals. Using the pre-dam discharge dataset, 3100 cfs in the Augusta Shoals is expected to occur approximately every 1.5-2 years, on average. From an ecological perspective, the discharge in the Augusta Shoals without the water diversion is likely to occur within the natural range of variation. Shoal-inhabiting organisms are unlikely to be adversely affected, assuming water quality is unimpaired. However, once the Augusta Canal is operational, and depending upon how much water is provided to the Augusta Shoals by the City of Augusta, the discharge in the Augusta Shoals may not be within the natural range of variation and adverse impacts to aquatic populations may occur.

• Shortnose sturgeon are now known to spawn on gravel bars in the Savannah River downstream of the New Savannah Bluff Lock and Dam (NSBLD) as early as mid-February (Ed Eudaly, USFWS, October 27, 2008, written correspondence to Bill Bailey, COE).

• Robust redhorse in the Savannah River are known to initiate upstream spawning migrations in March when water temperatures are 10-12 degrees Celsius and spawn from May to mid-June at several gravel bars below NSBLD. The upper gravel bar is located at river kilometer (rkm) 299.4 and the lower gravel bar at rkm 283.7. Individuals were observed on the gravel bars in 2004 and

2005 when water temperatures were 16.6-21.8 degrees Celsius. They were observed in spawning areas with a mean depth of 0.74 meters [± 0.017 standard error (SE)], mean velocity of 0.24 meters/second (± 0.014 SE), mean slope of 0.07 (± 0.003 SE), mean substrate particle size of 14.3 millimeters (± 0.272 SE), and modal substrate size of 32.0 millimeters. Depth and velocity at the gravel bars varied with discharge at the NSBLD. Robust redhorse on the upper gravel bar were found consistently in the same areas regardless of water level. The spawning areas at the upper gravel bar remained underwater and flow was maintained under all observed levels of discharge, ranging from approximately 3000 to over 30,000 cfs, as measured at the United States Geological Survey (USGS) gage 02197000 (Savannah River at Augusta, Georgia). However, on the lower gravel bar, robust redhorse initiated spawning on the Georgia side of the bar and expanded spawning activity to the center and South Carolina edge as spawning intensity increased. Redd sites on the center and South Carolina edge of the bar were exposed and degraded by fluctuating water levels during the period of observation (T. Grabowski, 2006, Ph.D dissertation). Flow levels at 3600 cfs already limit the amount of available gravel bar spawning habitat, and flow reductions to 3100 cfs would be expected to exacerbate this loss (T. Grabowski, 2009, pers. comm.).

• The Nature Conservancy (TNC) has also collected some information regarding levels of discharge and correlations to exposure of the gravel bars mentioned above. Flow data should be correlated to gravel bar exposure by examining the data collected by Tim Grabowski and TNC.

• A portion of the robust redhorse population is also present above the NSBLD in the Augusta Shoals. Unlike their counterparts below the NSBLD, it appears these individuals do not make extensive migrations and remain in the Augusta Shoals year-round (T. Grabowski, 2006, Ph.D dissertation).

• As noted in your October 2008 Draft EA (COE 2008), a freshwater mussel survey of the Savannah River from the Augusta Shoals downstream to the tidewater region near Savannah (river mile 22.8) totaling thirty-nine individual survey sites was conducted in 2006 (The Catena Group 2007). Rare species detected include the State listed Altamaha arcmussel, the brother spike, and the Savannah lilliput. The brother spike was found in the Augusta Shoals and the mainstem Savannah River, and the Altamaha arcmussel and the Savannah lilliput were found within cut-off bends of the Savannah River.

• As we stated in our October 27, 2008, letter, the Savannah National Wildlife Refuge (NWR) provides habitat for an average 23% of South Carolina's waterfowl, based on mid-winter waterfowl surveys from 1990-2002. Freshwater (salinity less than 0.5 parts per thousand) is necessary to maintain maximum waterfowl use and provide essential habitat for wetland-dependent migratory birds on the Savannah NWR. Additionally, Savannah NWR has the legal mandate of providing freshwater to several adjacent landowners for agricultural and wildlife management purposes (Chuck Hayes, Savannah NWR, wildlife biologist, 2009, pers. comm.). Studies have concluded that freshwater coastal impoundments in South Carolina produce a

greater variety of marsh plants, many of which are desirable waterfowl food, than brackish impoundments.

• The recommended flow for "dry" years from the 2003 Draft FWCA report is set at a range of 6,000 - 6,200 cfs for the critical period for the Savannah NWR of August – December as measured at USGS gage 02198500 (Savannah River near Clyo, Georgia). The Service has reviewed the most readily available USGS salinity data (October 2006 - present) at USGS gage 021989784 (Little Back River above Lucknow Canal, near Limehouse, South Carolina), the entrance to the Freshwater Diversion Canal. Savannah NWR is already experiencing salinity spikes during these critical months ranging from > 0.5 - 3.2 parts per thousand (ppt), when flow at Clyo during these periods is much less than the lower recommended range of 6,000 cfs. It appears the salinity spikes are occurring with higher tides on a lunar cycle. Savannah NWR relies on high tides to fill the Freshwater Diversion Canal; thus, the impoundments are being inundated with saline water. These small increases in salinity on a repetitive cycle can have deleterious cumulative effects on the vegetation that Savannah NWR is managing to provide high-quality habitat for migrant birds. Further reducing flow in an already stressed environment could potentially have more severe and prolonged negative effects on the Savannah NWR.

• During our May 11, 2009, meeting, the effects of a flow reduction to salinity levels as they relate to blue crab (*Callinectes sapidus*) parasite issues was briefly discussed. The EA should examine this potential impact.

Conclusion

The Augusta Shoals area is important year-round habitat for many native riverine species, including the robust redhorse, the shoals spiderlily, and the brother spike. The Augusta Shoals require not only inundation, but also suitable current velocities to allow for survival and reproduction of aquatic organisms. We are unclear as to 1) the amount of flow that would be provided to the Augusta Shoals by the City of Augusta, and 2) if the agreed-upon flows to the Augusta Shoals would be implemented in full without a binding agreement involving the City of Augusta.

The gravel bars downstream of NSBLD serve as critically important spring spawning habitat for a multitude of riverine species, including the shortnose sturgeon and the robust redhorse. Gravel deposits are extremely rare in the main channel of the lower Savannah River (T. Grabowski, 2006, Ph.D dissertation). Suitable depths and velocities at these gravel bars need to be present to inundate, but also protect the suitability of, spawning habitat. Additionally, natural springtime flows need to be present to cue migratory fishes to initiate their upstream migrations.

Reduced flows have caused backwater and oxbow habitat to transition into sediment-laden areas colonized with vegetation. Backwaters and oxbows are habitat for many native freshwater mussels and the only known habitat for the Altamaha arcmussel and Savannah lilliput in the

Savannah River. Preliminary observations indicate a loss of connectivity occurs between these habitats and the main river at flows below 4,000 cfs (COE 2008).

Savannah NWR is already experiencing unsuitable salinity levels during the COE's current releases. The harbor is currently approximately twice its historic depth and Savannah NWR is unfortunately already experiencing salinity levels higher than ever anticipated at the northern intake of the Diversion Canal during these critical periods. The Service is concerned that a future reduction in flow will exacerbate the salinity conditions at Savannah NWR during their critical period of August-December. Cumulative impacts to salinity levels, including climate change and the proposed Savannah Harbor deepening, should also be considered.

We are aware of very little additional research and monitoring for informed management of the Savannah River since the Ecosystem Flows Workshop and the Service's Draft FWCA Report. If future seasonal flow reductions are deemed necessary for maintenance of water in the reservoirs during drought, the COE should initiate some of the recommended studies to better anticipate flow needs for all downstream resources.

In light of these concerns, and without our critical research needs addressed, we do not recommend a flow reduction to 3,100 cfs. Both the long duration and timing of the protracted period would be of concern. Additionally, if implemented in 2009, the proposed reduction would be in addition to the recent long-term, low-flow conditions, which could exacerbate environmentally stressful conditions and amplify otherwise negligible biological impacts. We appreciate the opportunity to comment during the planning stages of this project. If you have any questions, please contact staff biologists Lora Zimmerman (Charleston Field Office) at (843) 727-4707 ext. 226 or Alice Lawrence (Athens Field Office) at (706) 613-9493 ext. 222.

Sincerely,

Sandra S. Tucker
Field Supervisor
Georgia Ecological Services

Jane Griess
Project Leader
Savannah Coastal Complex

cc: Lora Zimmerman, USFWS, Charleston, SC
Amanda Hill, USFWS, Charleston, SC
Russell Webb, USFWS, Savannah, GA
Chuck Hayes, USFWS, Savannah, GA
Stephania Bolden, NOAA Fisheries, St. Petersburg, FL
Prescott Brownell, NOAA Fisheries, Charleston, SC
Ed Betross, GDNR, Thomson, GA

Oscar Flite, Southeastern Natural Sciences Academy, Augusta, GA
Amanda Meadows, TNC, Savannah, GA

References

Entrix. 2002. Savannah River Instream Flow Study, Augusta Canal Hydropower Project (FERC No. 11810), prepared for the City of Augusta and ZEL Engineers, Inc. September 2002.

Grabowski, Tim. 2006. Reproductive ecology and seasonal migrations of robust redhorse (*Moxostoma robustum*) in the Savannah River, Georgia and South Carolina. A dissertation presented to the graduate school of Clemson University. May 2006. 73 pp.

The Catena Group. 2007. Freshwater mussel surveys, the Savannah River from Augusta to Savannah: South Carolina and Georgia. Prepared for: International Paper and the U.S. Fish and Wildlife Service, Hillsboro, North Carolina, December 17, 2007. 42 pp.

United States Army Corps of Engineers. 2008. Draft Environmental Assessment and Finding of No Significant Impact, Temporary deviation drought contingency plan, Savannah River Basin, Savannah District, October 2008. 65 pp.

Wrona, A. D. Wear, J. Ward, R. Sharitz, J. Rosenzweig, J.P. Richardson, D. Peterson, S. Leach, L. Lee, C. R. Jackson, J. Gordon, M. Freeman, O. Flite, G. Edison, M. Davis, and D. Batzer. 2007. Restoring ecological flows to the lower Savannah River: A collaborative scientific approach to adaptive management. Proceedings of the 2007 Georgia Water Resources Conference, March 27-29, 2007, University of Georgia. 12 pp.

Attachment A

Critical Research Needs Developed at the Savannah River Ecosystem Flow Workshop
April 2003

Shoals

- Real time streamflow gauging in shoals along with temperature: allows for the development of a streamflow-temperature model
- Fish, plant, invertebrate distribution and composition (and movement tied to flows over time)
- Physical dynamics during low and high flow extremes: informs sediment transport and deposition study
- Spiderlily flow needs
- Robust redhorse spawning habitat
- Atlantic sturgeon spawning and passage information along with shortnose sturgeon passage data in relation to flow
- Striped bass passage and thermal requirements as well as egg drift requirements for movement past New Savannah Bluff Lock and Dam

Floodplain

- Cross-sectional and/or spatial topography at fine resolution
- Vegetation community distributions
- In-channel survey of physical structure (woody debris, sand and gravel bars, etc)
- Location of gravel patches below New Savannah Bluff Lock and Dam and flow-habitat relationships
- Oxbows & sloughs – at what flows will water be exchanged with river, and how do these exchanges affect water quality
- Duration of inundation in floodplain after flood events
- Modify existing USGS streamgauges to include temperature, turbidity, dissolved oxygen
- Revisit COE cut-off bend study

Estuary

- Relate flow at Clyo to salinity distribution in estuary
- Fish community distributions, inter-tidal marsh conditions during high flow periods (similar to what has been done for drought period)
- Relate salinity conditions to inter-tidal/floodable habitat
- How does flow affect spawning and recruitment success for estuary-dependent (including diadromous) fish species
- Relationship between flow and dissolved oxygen
- Analyze fish community data with a focus on flow impacts

APPENDIX F

NOAA FISHERIES

FLOW RECOMMENDATION LETTER

JUNE 24, 2009

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Southeast Regional Office
263 13th Avenue South
St. Petersburg, Florida 33701-5505
(727) 824-5317; FAX (727) 824-5300
http://sero.nmfs.noaa.gov/

June 24, 2009 F/SER4:PB/pw

(sent via electronic mail)

Colonel Edward J. Kertis
Commander, Savannah District
U.S. Army Corps of Engineers
100 W. Oglethorpe Avenue
Savannah, Georgia 31401-3640

Attention: Jeffrey Morris

Dear Col. Kertis:

NOAA's National Marine Fisheries Service (NMFS) reviewed your letter, dated June 4, 2009, requesting information on the impacts to fishery resources and habitats from the reduced outflows from the J. Strom Thurmond (JST) Dam during the 2006-2009 drought of record in the Savannah River Basin.

During the drought, NMFS participated in frequent meetings with your staff, state and federal resource agencies, local governments, and non-governmental organizations concerning the water resource issues presented by the drought. Our concerns regarding potential effects of reduced water flows on marine and migratory diadromous fish were presented and discussed during the meetings.

Public trust resources potentially affected by altered Savannah River instream flow conditions include migratory diadromous species such as striped bass, American shad, blueback herring, Atlantic and shortnose sturgeon, and American eel. Shortnose sturgeon is listed as endangered under the Endangered Species Act and present in the Savannah River downstream of Augusta Diversion Dam and Savannah Bluff Lock & Dam as well as the Savannah River estuary. Riverine and estuarine habitats downstream from the JST Dam provide spawning and maturation habitat for those migratory species. Aquatic habitats and fishery resources of the Savannah River estuary are also potentially affected by altered JST outflow conditions, in combination with potential effects of the Savannah Harbor Expansion Project.

Attached is a summary of concerns and recommended studies we provided by email to Mr. Bill Bailey of your staff following the interagency meeting on May 11, 2009, at the Phinizy Swamp Nature Park Conference Center. That meeting provided for helpful interagency discussions of potential impacts from flow reductions and the information that would be within future assessments.

We hope this information is helpful. Related correspondence should be directed to the attention of Mr. Prescott Brownell at our Atlantic Branch office, 219 Fort Johnson Road, Charleston, South Carolina, 29412. He may be reached by telephone at (843) 953-7204, or by e-mail at Prescott.Brownell@noaa.gov. For information specific to the endangered shortnose sturgeon, correspondence should be directed to Dr.

Stephania Bolden, Protected Resources Division, at the letterhead address, by telephone at (727) 824-5312, or by e-mail at Stephania.Bolden@noaa.gov.

Sincerely,

Pete Willey

/ for

Miles M. Croom
Assistant Regional Administrator
Habitat Conservation Division

cc:

CESAS, Jeffrey.S.Morris@usace.army.mil
CESAS, William.G.Bailey@usace.army.mil
FWS, Lora_Zimmerman@fws.gov
SCDHEC, TURNERLE@dhec.sc.gov
SCDNR, PerryB@dnr.sc.gov
flite@naturalsciencesacademy.org
F/SER3, Stephania.Bolden@noaa.gov

Response to COE: Savannah River: Low Flow/Drought
NOAA National Marine Fisheries Service
May 22, 2009

Unanticipated record drought conditions and critical water flow issues experienced in 1998-2009, particularly since 2005, have reduced reservoir storage capacity, and limited flexibility in regulating water flow in the Savannah River Basin. Strong concerns have been expressed by residents in the upper Savannah Basin regarding reduced water levels in the reservoirs, and potential effects on municipal water supply intakes, marina operations, and recreational water access.

A temporary reduction in the specified drought management plan occurred in early 2009; flow was reduced from 3,600 cfs to 3,100 cfs. It is anticipated that a flow reduction may again be requested by the U.S. Army Corps of Engineers (COE) in the future.

Reduction of minimum drought flows may affect both anadromous fish spawning and recruitment potential in the Savannah River. Species under NMFS stewardship that would likely be affected by reduced flow include American shad, blueback herring striped bass, Atlantic sturgeon, and shortnose sturgeon. The shortnose sturgeon is an endangered species listed under the Endangered Species Act (ESA); the Atlantic sturgeon is a candidate for listing. All of these fish are known to spawn in the early spring (February through March); therefore, any flow regime must be thoroughly analyzed to assess its effects on both spawning migration and habitat, particularly for the shortnose sturgeon pursuant to section 7 of the ESA.

Recently The Nature Conservancy (TNC) organized a meeting to discuss the biological and ecological flow requirements for the Savannah River during extreme low flow/drought conditions. Participants included TNC, NMFS, COE, USFWS, SCDNR, GADNR, GADDR, UGA, SCDHEC, and SCDNR. At the meeting conclusion, the COE requested that each agency submit a list of constraints, concerns and recommendations. The following is a summary from NMFS:

1. Constraint: shortnose sturgeon spawning period between February 1 and May. Shortnose sturgeon utilize the gravel bar just below New Savannah Bluff Lock and dam during the spawning season; all habitat upstream of this location is not accessible due to lack of fish passage. Assurances that any reduction in flow from the current flow regime of 3,600 cfs would not affect shortnose sturgeon or its limited spawning habitat.
2. Concerns:
    a. Little information exists on how flow rates impact the availability of spawning habitat in terms of water depth, substrate availability, migratory cues, larval dispersal, etc.
    b. Limited flow gauges on the river provide insufficient data to determine downstream effects of regulated flow.
    c. The guide curve regulating flow and reservoir depth in the upper Savannah River has greatly reduced the seasonal variability in water flow.
    d. The conservation level and full pool depths may not be appropriate and have not been recently analyzed and were designated about 50 years ago.

e. A deviation in flow from the 3,600 cfs to 3,100 cfs translates into 0.6 ft per month in reservoir elevation.

3. Recommendations:
    a. COE revisit the guide curve including the conservation depth and full pool levels.
    b. COE revisit the potential to provide fish passage appropriate for sturgeon around NSBLD.
    c. Assessment of the habitat at Augusta Shoals as potential spawning habitat for shortnose sturgeon.
    d. Analysis of hydrologic records (pre-dam) to identify periods of high flow and natural seasonal variability. Correlation of flow regimes to spawning periodicity of anadromous fish inhabiting the Savannah River and required cues; ensure appropriate flow/species (see Kynard 1997 for shortnose sturgeon).
    e. Assessment of habitat suitability/availability under different flow regimes.
    f. Assessment of flow regimes on sediment distribution and re-suspension, especially relative to shortnose sturgeon spawning habitat.
    g. A technical (site specific) instream flow assessment to provide an adequate basis for evaluation of potential effects on sturgeon and other anadromous species spawning habitats. Details are provided in Appendix A. (Attached).

Appendix A. Instream Flow Study

Prior ecological instream flow studies on the upper Savannah were not designed to assess extreme drought flow conditions in the Thurmond and Stevens Creek tailwater reaches, the Augusta Shoals, the riverine habitat reach below Savannah Bluff Lock & Dam, and the lower Savannah River.

An instream flow would provide a sound technical basis for evaluation of alterative drought flows, and potential effects on aquatic species, important habitats and water quality. Site-specific studies may be focused on specific reaches where prior studies did not fully address the potential effects of extreme drought flows on important species life cycle needs.

The study approach should include the following key study elements:

- Establish an interagency instream flow study team
- Review prior instream flow studies conducted in the upper Savannah River
- Determine the appropriate study area(s) where additional assessment is needed
- Identify key aquatic species or guilds potentially affected
- Identify key habitat suitability criteria for each species
- Select instream flow study methodologies (IHA + species/habitat field study)
- Develop draft and final study plans

Key evaluation species to be considered

- Shortnose sturgeon
- Atlantic sturgeon
- American shad, hickory shad, river herring
- Striped bass (Inland spawning stock model)

Key habitat considerations to be evaluated:

- Anadromous species spawning habitats, maturation habitats (areal extent, suitability, accessibility)
- Effects of flows on fish movements to and from spawning habitats
- Effects of flows on fish passage and facility operations (existing and planned)

Instream flow methodologies to consider

- IFIM/PHABSIM
- HEC-EFM
- MESOHABSIM (may be best suited for sturgeon habitat characterization and assessment of instream flows)
- IHA (In combination with a technical instream flow assessment)

APPENDIX G

GEORGIA

DEPARTMENT OF NATURAL RESOURCES

ENVIRONMENTAL PROTECTION DIVISION

SUMMARY OF FINDINGS ON

2008

3,100 CFS DISCHARGE

JUNE 22, 2009

Proposed Changes to Lake Thurmond Releases to Mitigate Drought Impacts

During the ongoing drought in the southeastern U.S., the Savannah River reservoir system operated by the Army Corps of Engineers (ACE) experienced extreme pressure and difficulties. In the summer of 2008, based on the Information Paper provided by the Army Corps of Engineers (Corps) and information compiled by other cooperating institutions, Georgia EPD, in coordination with South Carolina Department of Health and Environmental Control (SCDHEC) and South Carolina Department of Natural Resources (SCDNR), conducted a thorough analysis of potential operations of the system under a variety of hydrologic conditions. At that time, Georgia EPD, SCDHEC, and SCDNR propose that the operation (i.e. a Thurmond release of 3,600 cfs) be revised to maintain a 3,600 cfs release from Thurmond Dam in the warmer months of March through September and reducing the release to 3,100 cfs in the cooler months of October to February. The analysis indicated that this reduction would stabilize the system and substantially reduce the speed of decline in system storage. In addition, the analysis showed that the water users along the river would not be impacted as a result of this revised operation and modeling and field observations indicated that it was unlikely that water quality would be of a concern. The Army Corps of Engineers implemented the reduced flow from Thurmond Dam to 3,100 cfs from November 2008 through January 2009. The period of reduced releases was shortened due to shortnosed sturgeon spawning.

It was suggested several real time monitoring stations be examined to reviewed changes in flow, dissolved oxygen concentrations, and conductivity measurements in the lower reaches of the Savannah River as a result of the reduced releases from Thurmond Dam. It was suggested that adaptive management be used as part of the Corps' operation. If field observation indicate any problem with DO concentration and conductivity levels, then prompt actions can be taken to mitigate the adverse conditions.

The following table lists those parties that were responsible for reporting on specific environmental targets. Upon review of that information, and discussion with SCDHEC and SCDNR, decisions were to be made on notifying the ACE of appropriate adjustments to Thurmond release levels. No problems will targets were ever reported.

Location	**Target**	**Responsible Party**
Shoals	Flow 1500 cfs	City Of Augusta

USGS 021989773	DO 5.0 mg/L daily average DO 4.0 mg/L instantaneous Temperature ≤ 90 ºF pH 6-8.5	GAEPD
USGS 02198840	Conductivity 10,000 µS/cm	GA EPD
Abercorn Creek	Chloride 16 ppm	City of Savannah
USGS 02198500	Flow < 4,500 cfs	SC DHEC
Various	Water level at the intakes	Intake operators
Various	Sturgeon migration	SC DNR

A plot of the flow measured in the Savannah River near Clyo, Georgia that includes the period of reduced releases from Thurmond is shown in Figure 1.

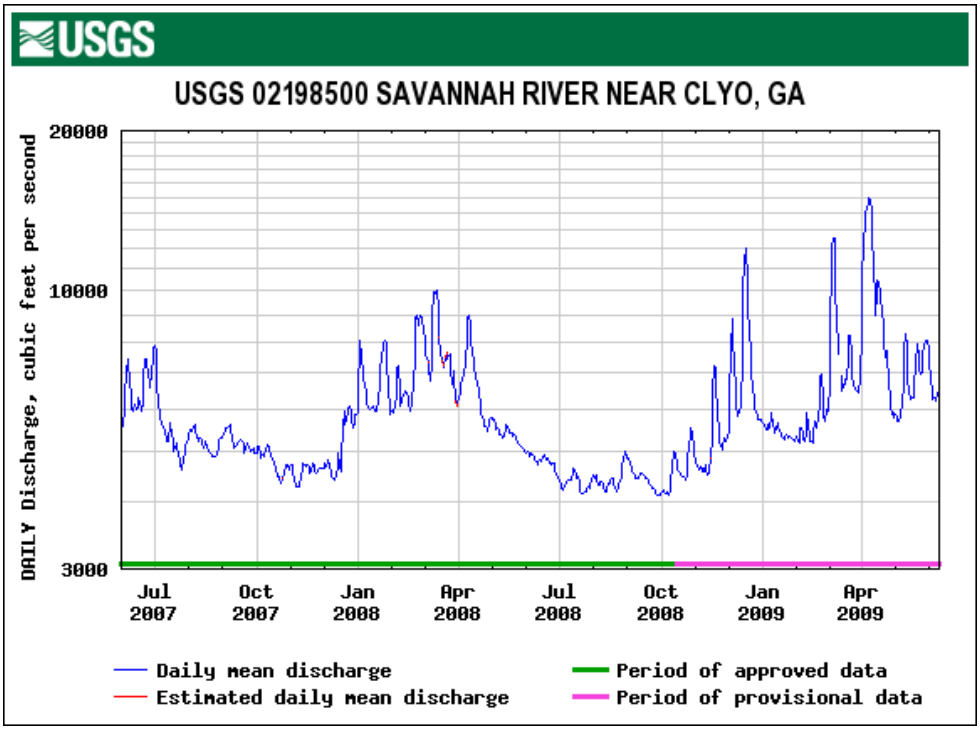


Figure 1. Flow at Savannah River Flow near Clyo, Georgia

A plot of the conductivity measured in the Savannah River near Port Wentworth, Georgia that includes the period of reduced releases from Thurmond is shown in Figure 2.

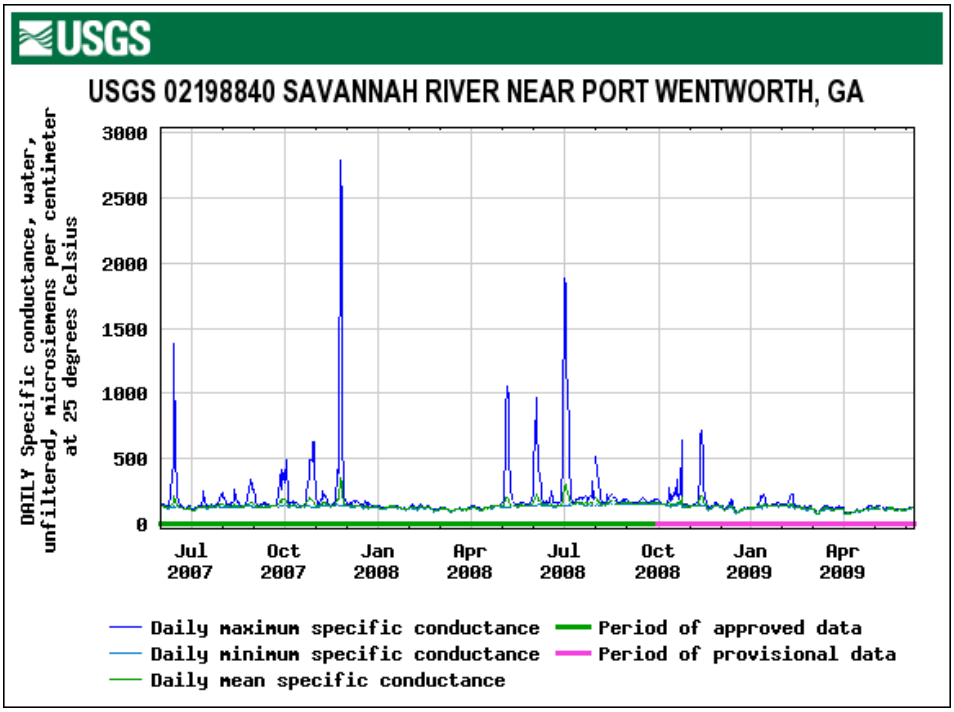


Figure 2. Conductivity in Savannah River near Port Wentworth, Georgia

A plot of the dissolved oxygen measured in the Savannah Harbor at the Corps Dock that includes the period of reduced releases from Thurmond is shown in Figure 3.

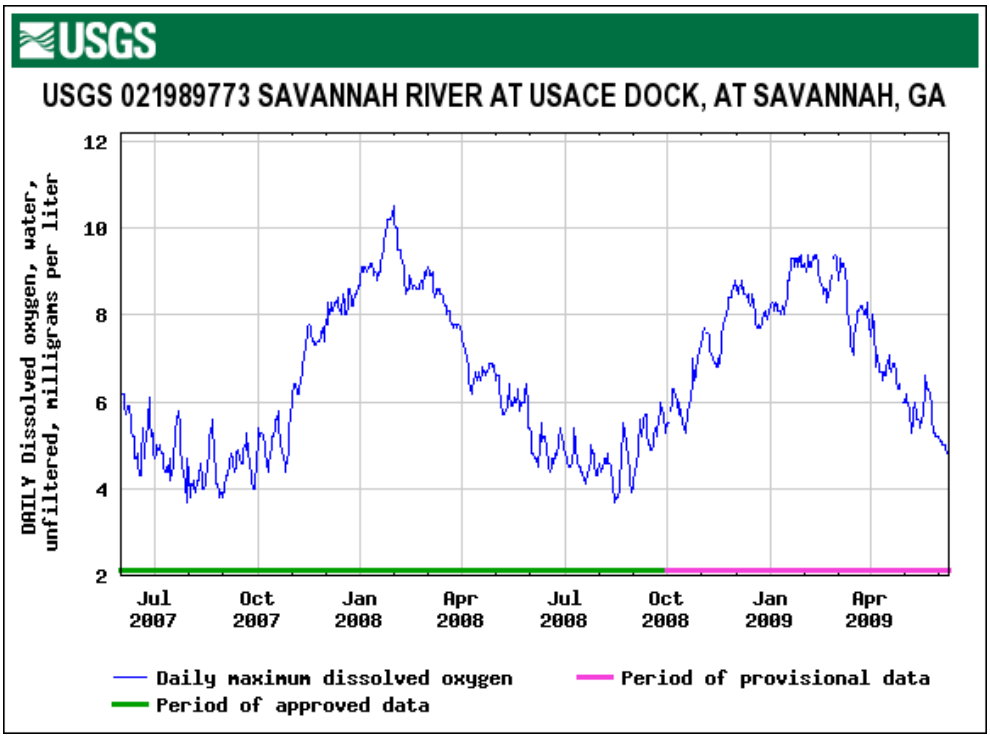


Figure 3. Dissolved Oxygen Savannah River at the Corps Dock

All three of these plots indicate that there was no problem with water quality in the Savannah River system due to the reduced releases from Thurmond. In fact, the period that the releases are reduced could be extended using an adaptive management approach. There could be reduced releases from Thurmond Dam during period when the dissolved oxygen concentration in the Savannah Harbor is greater than 5.0 mg/L and the gage at the Corps Dock could be used to determine this period. Thurmond Dam releases could be increased during fish spawning (i.e., February – March for shortnosed sturgeon, May robust redhorse), but reduced once fishing spawning is over if the dissolved oxygen levels in the Harbor are sufficient (i.e., >5.0 mg/L).

APPENDIX H

RECOMMENDATIONS

FROM

2003 ECOSYSTEM FLOW WORKSHOP

FOR

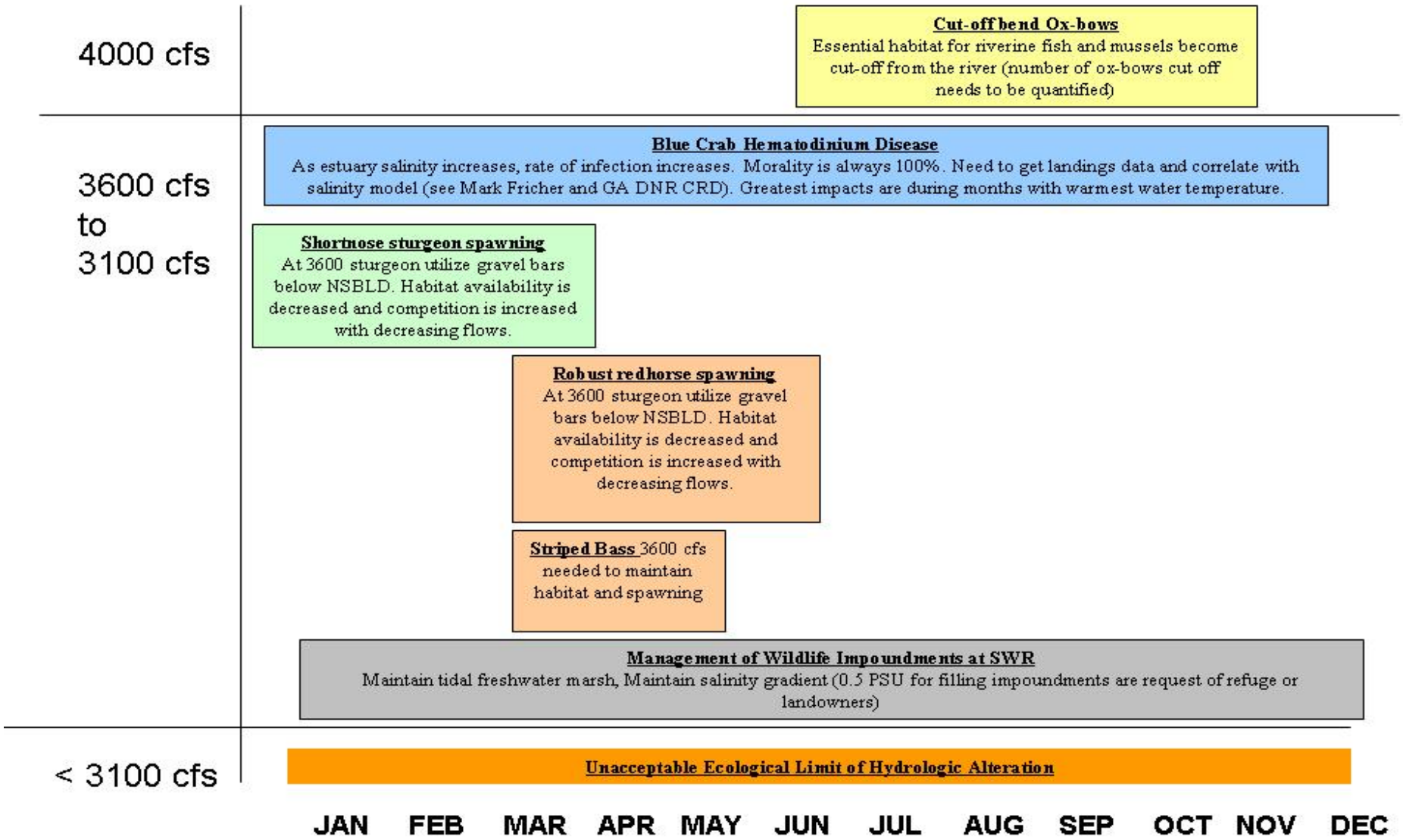
SAVANNAH RIVER

DOWNSTREAM OF

THURMOND DAM

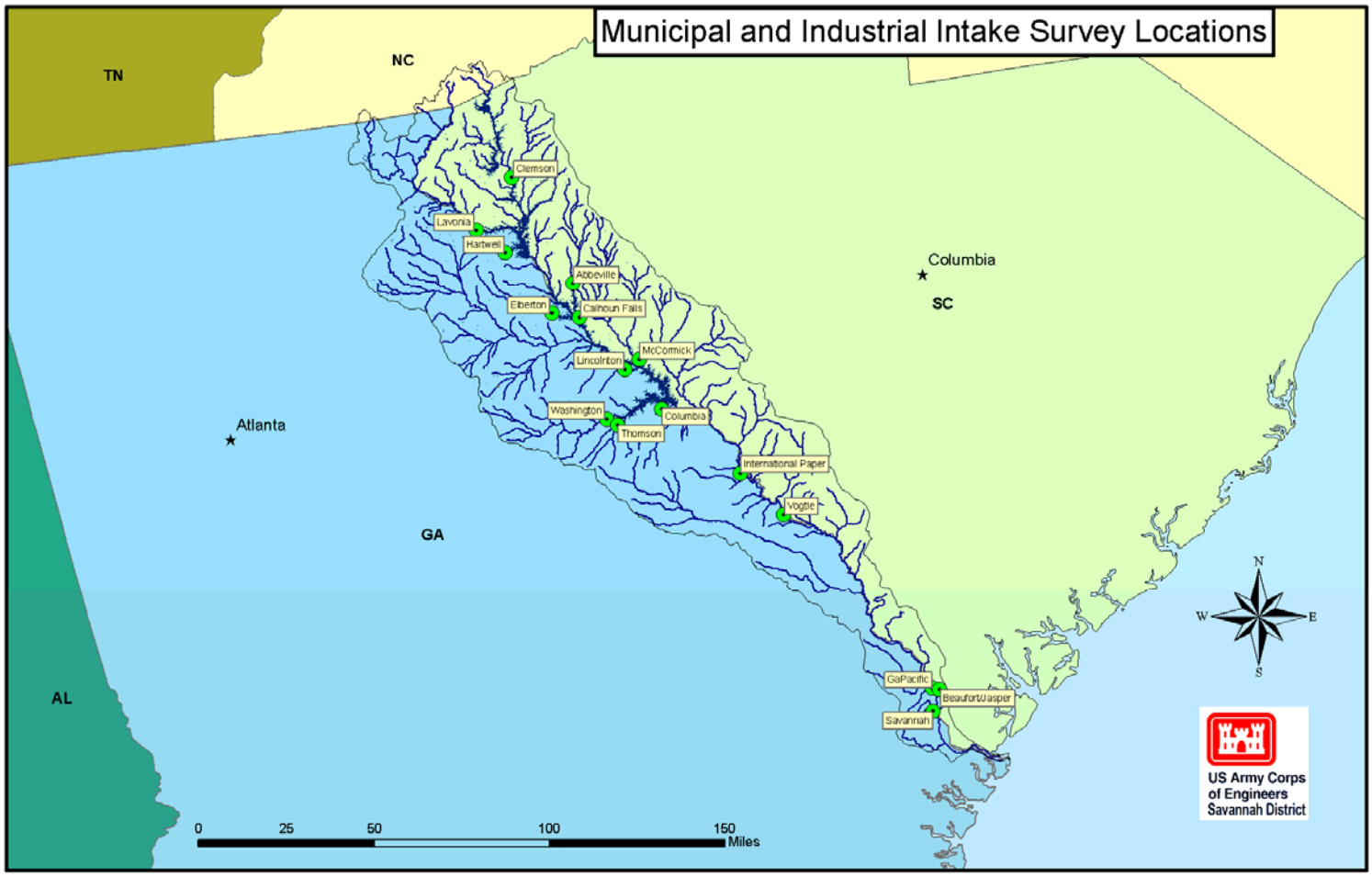
Ecosystem Flow Recommendations

Savannah River, below Thurmond Dam (Extreme Low Flows)



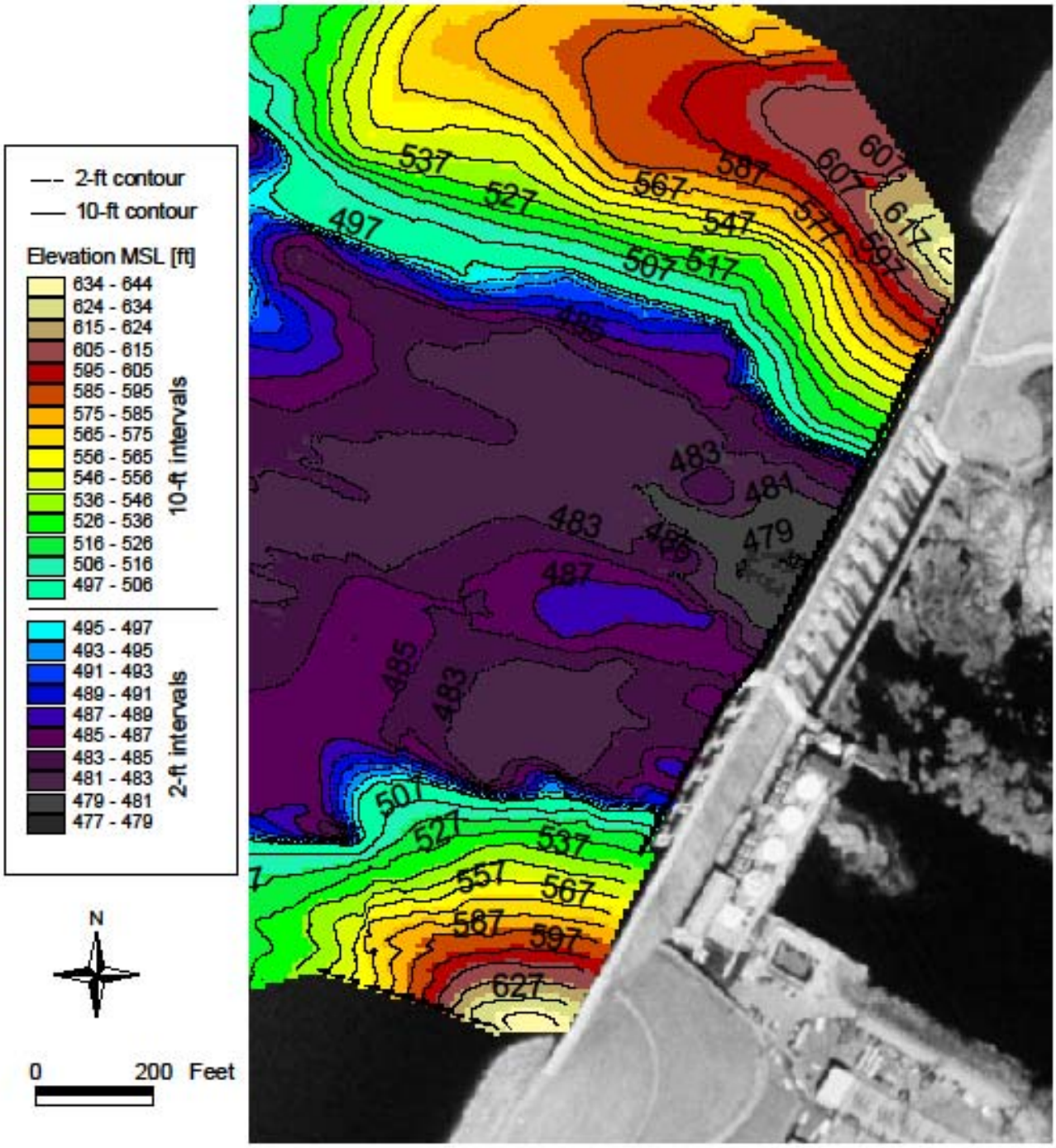
APPENDIX I

BATHYMETRIC SURVEY OF INTAKE LOCATIONS

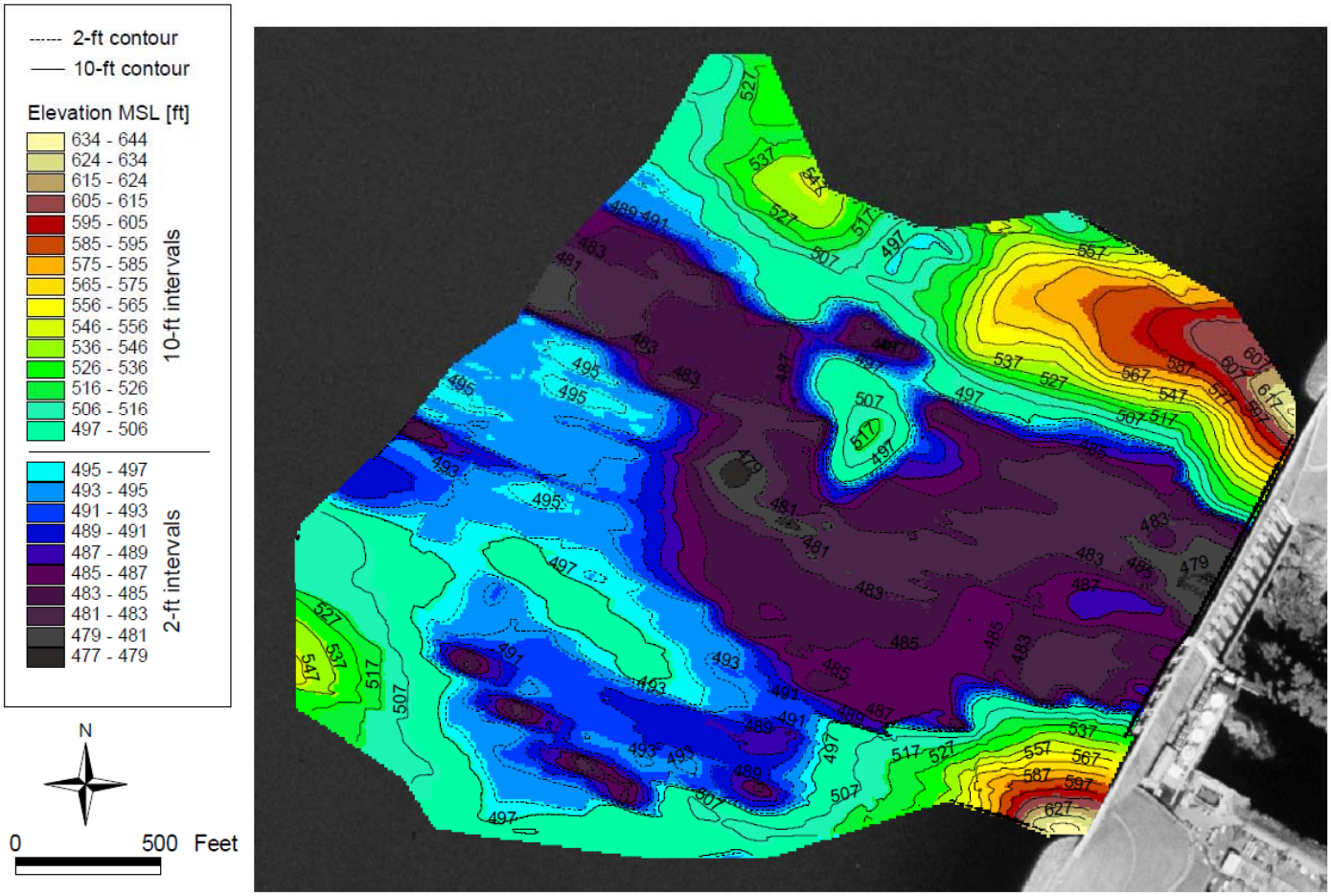

Municipal and Industrial Intake Survey Locations
TN
NC
SC
GA
AL
Columbia
Atlanta
Clemson
Lavonia
Hartwell
Abbeville
Elberton
Calhoun Falls
McCormick
Lincolnton
Washington
Thomson
Columbia
International Paper
Vogtle
GaPacific
Beaufort/Jasper
Savannah
N
W
E
S
0
25
50
100
150
Miles
US Army Corps
of Engineers
Savannah District

Hartwell Forebay Bathymetry (4/8/2009)

(dam area enlarged)



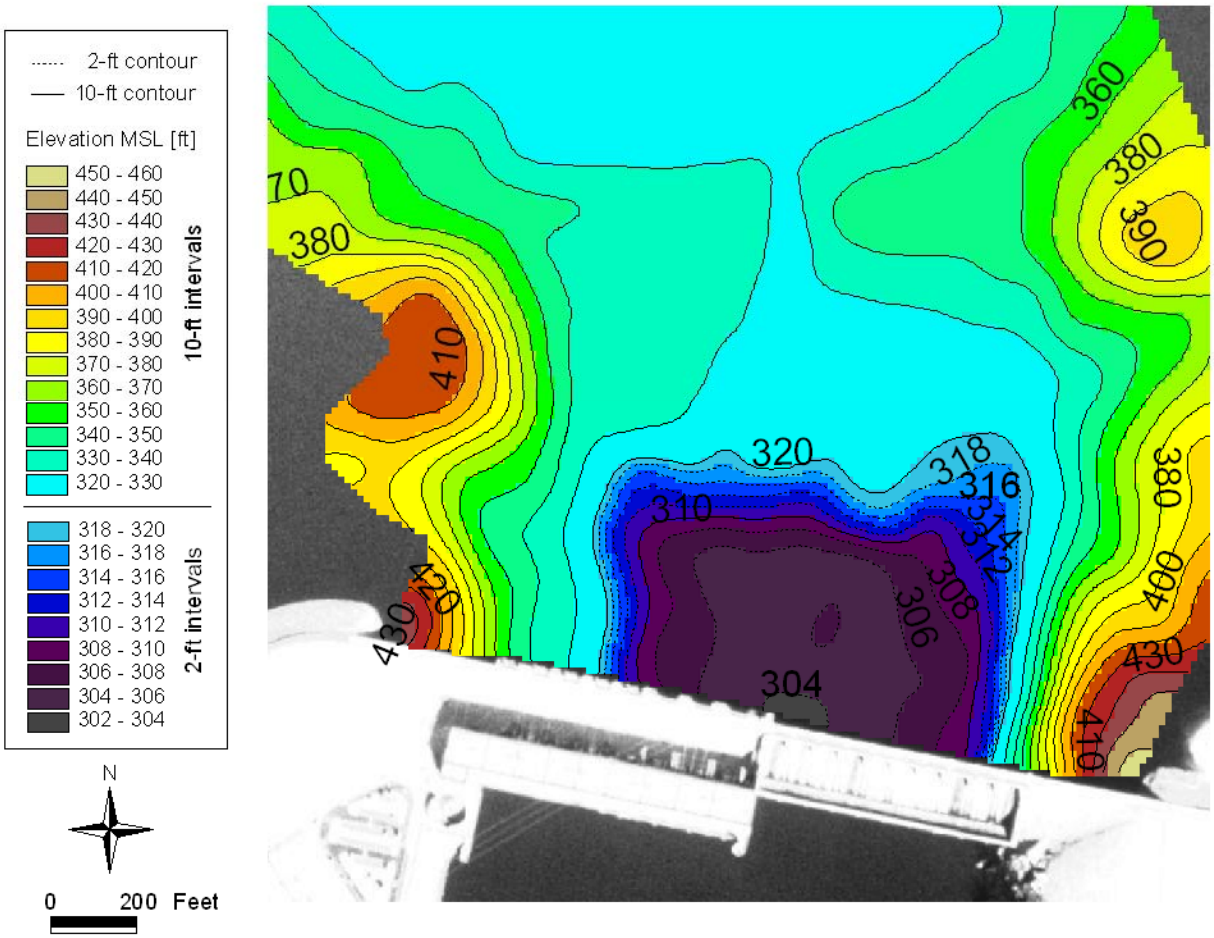
Hartwell Forebay Bathymetry (4/8/2009)



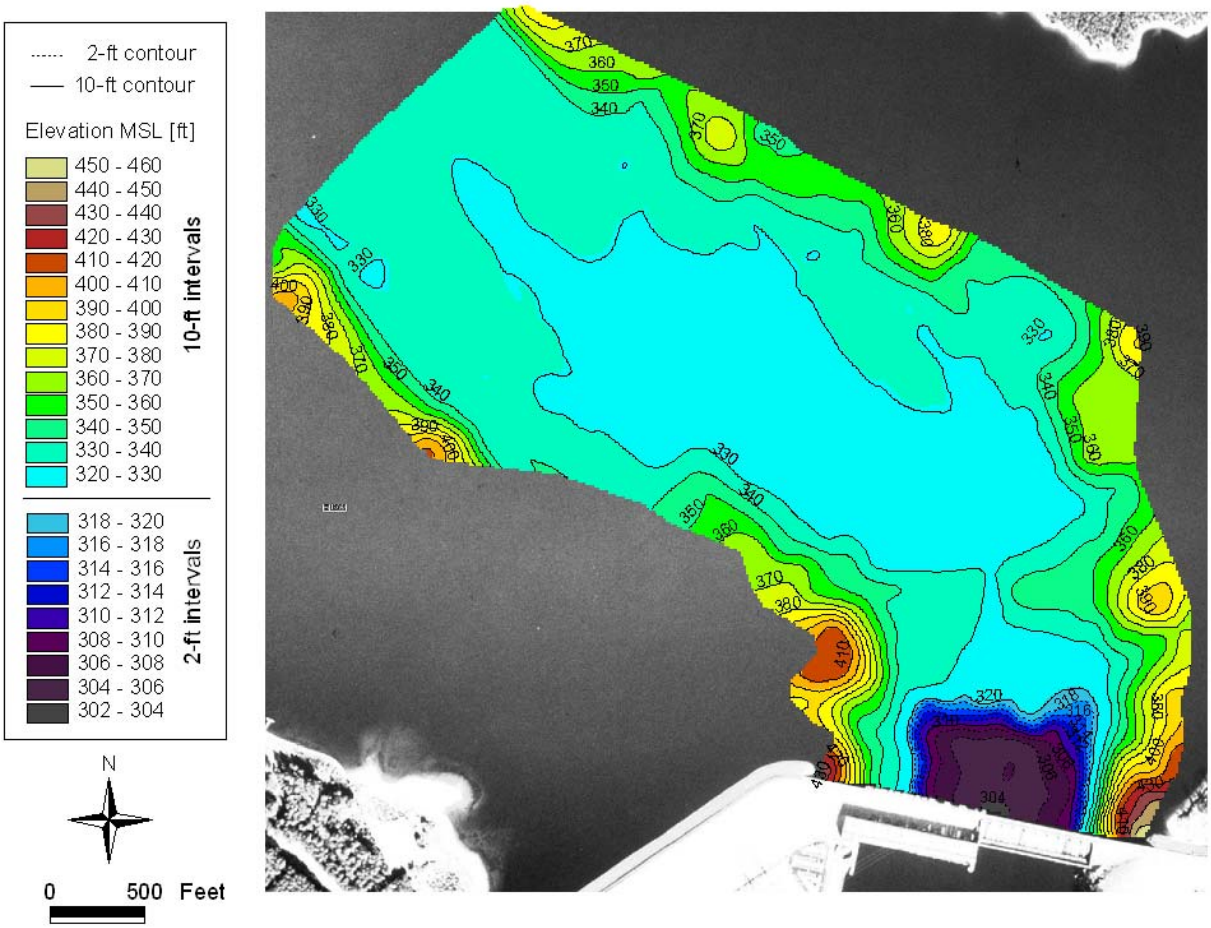
|

RBR Forebay Bathymetry (12/16/2008)

(dam area enlarged)

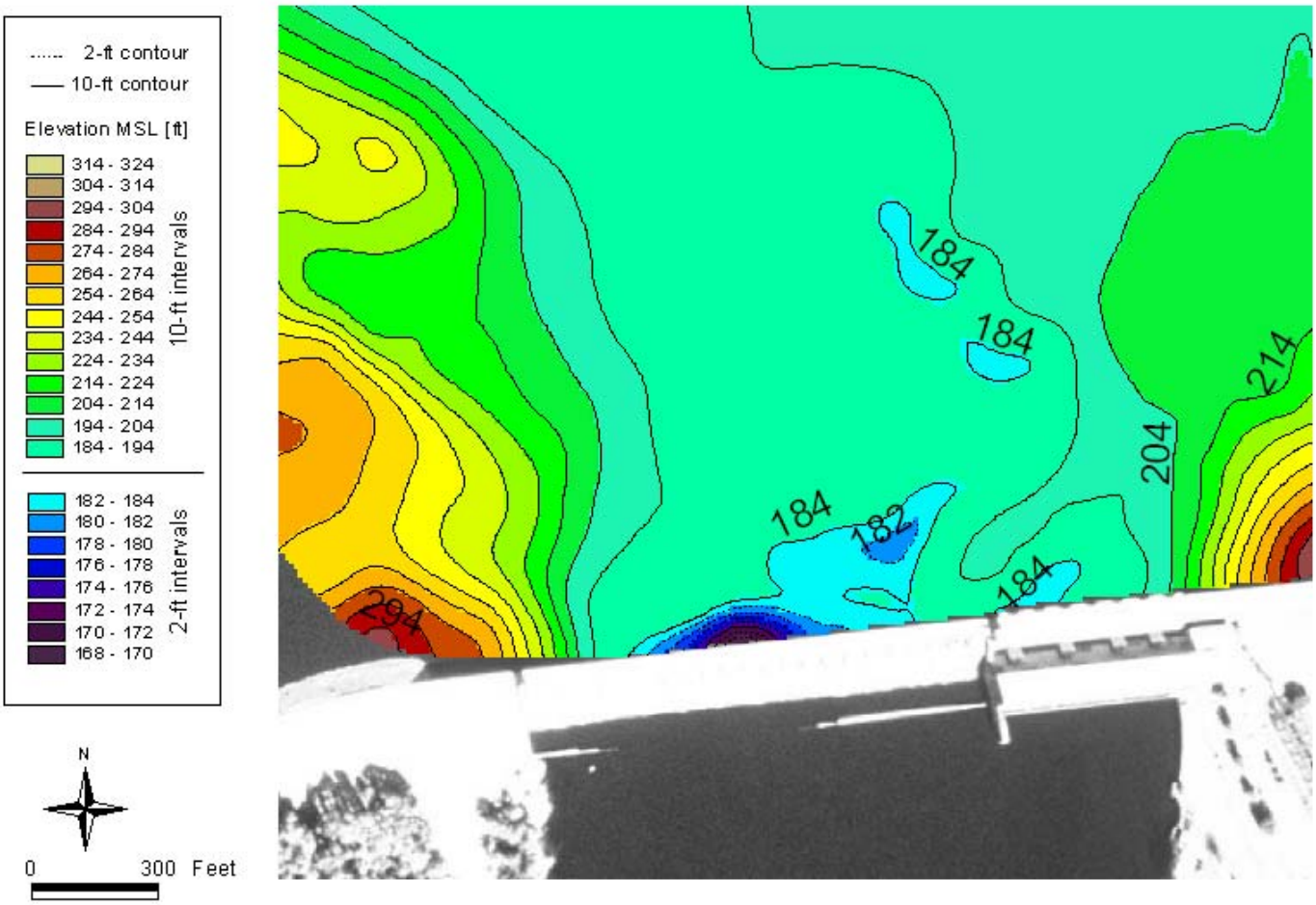


RBR Forebay Bathymetry (12/16/2008)

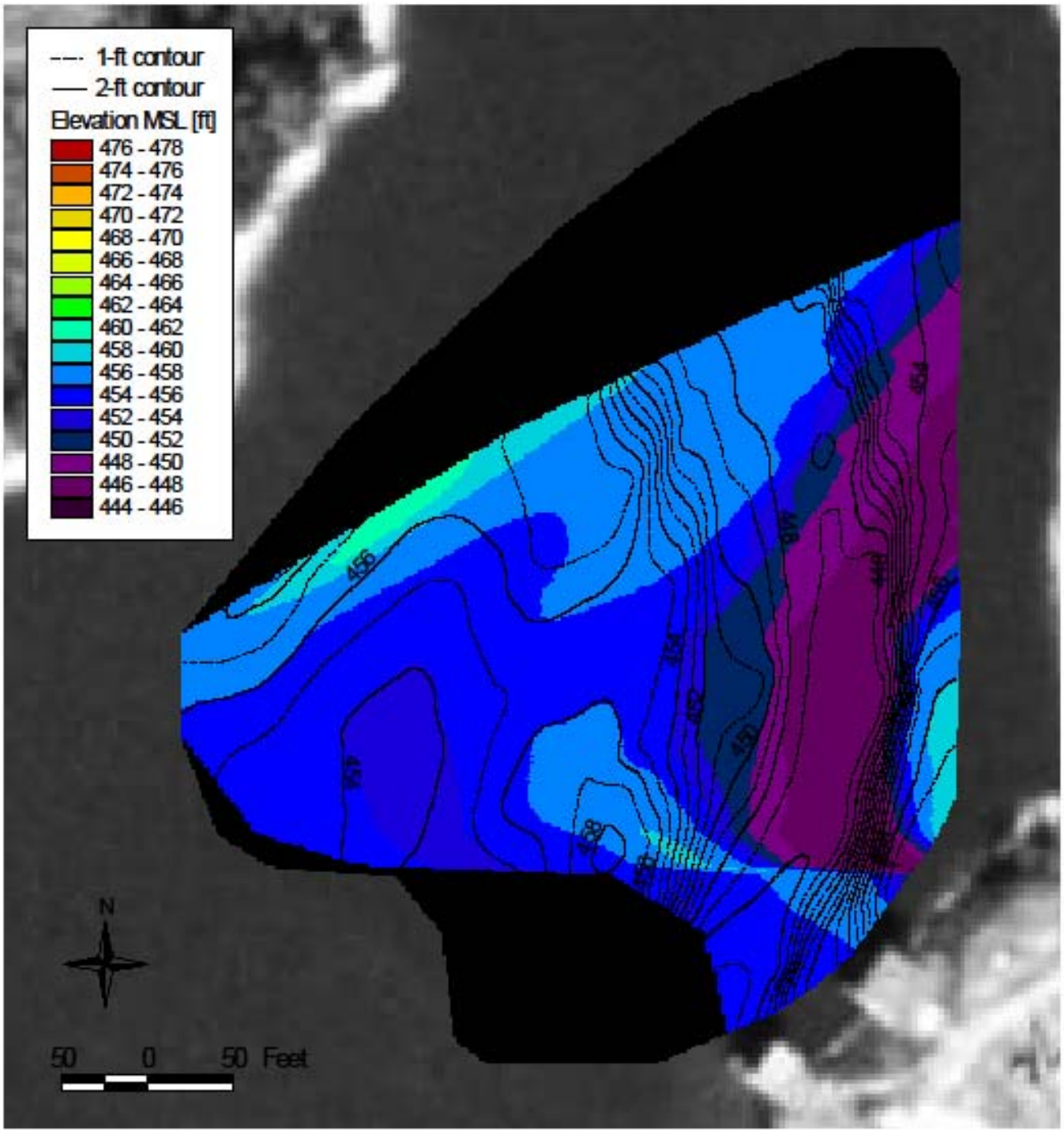


JST Forebay Bathymetry (4/27/2009)

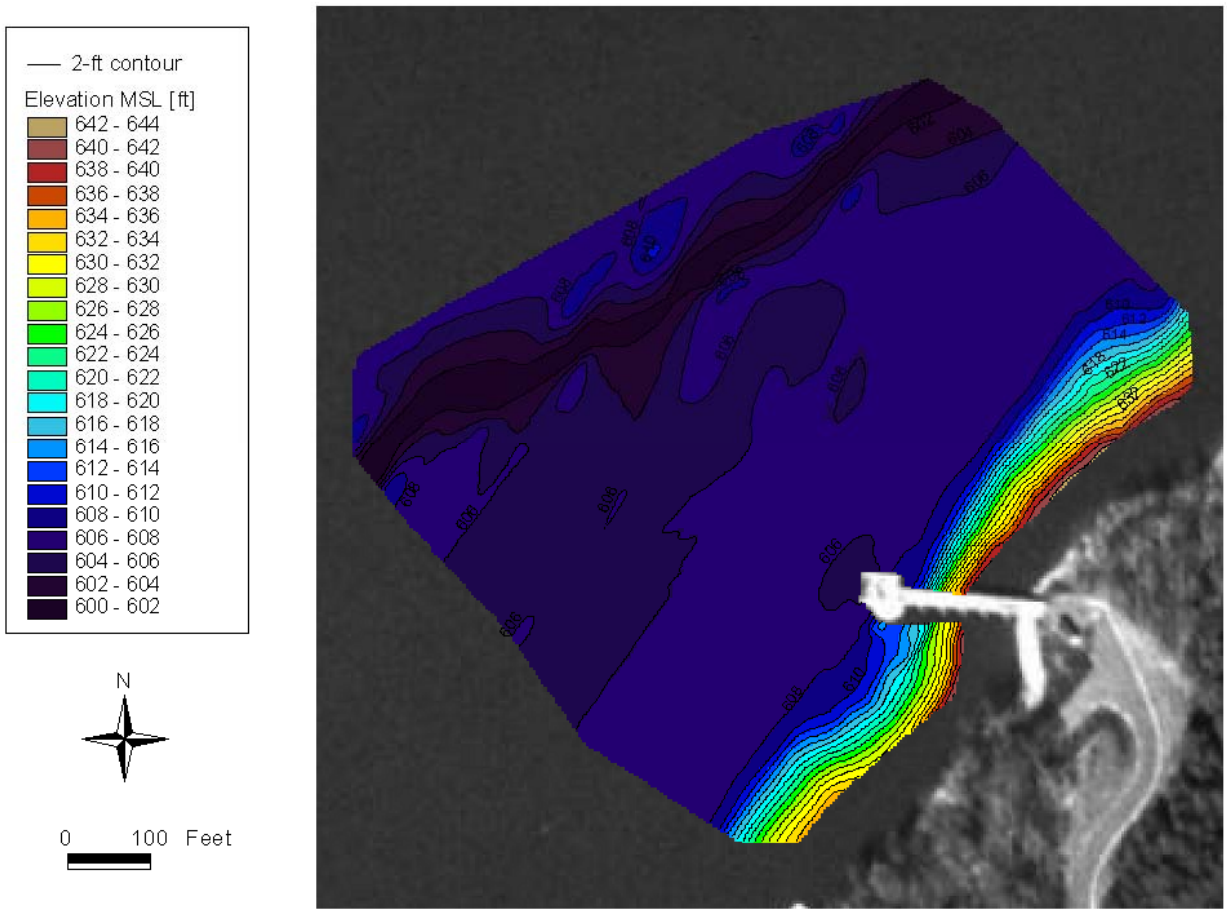
(dam area enlarged)



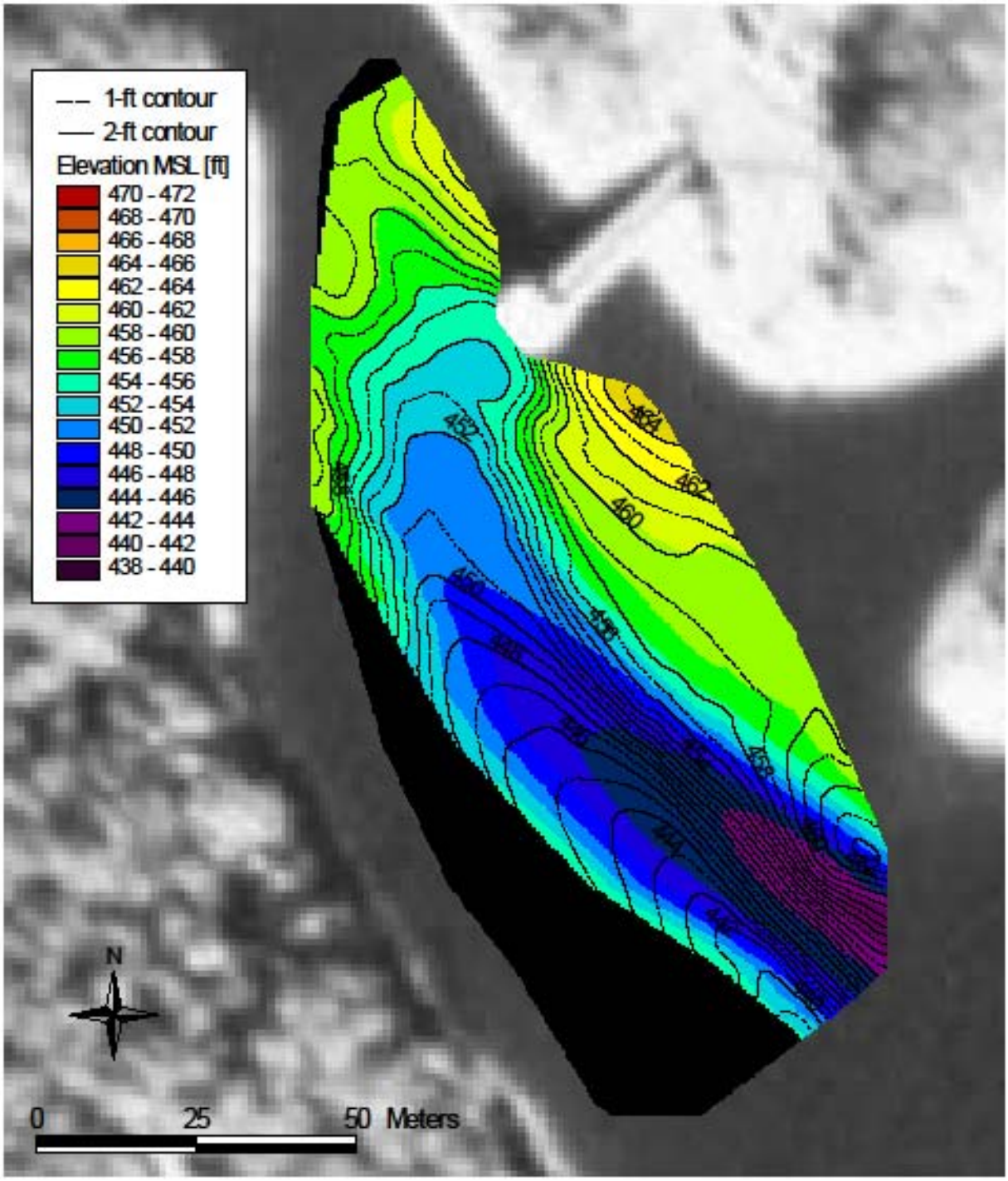
Abbeville Bathymetry (12/16/2008)



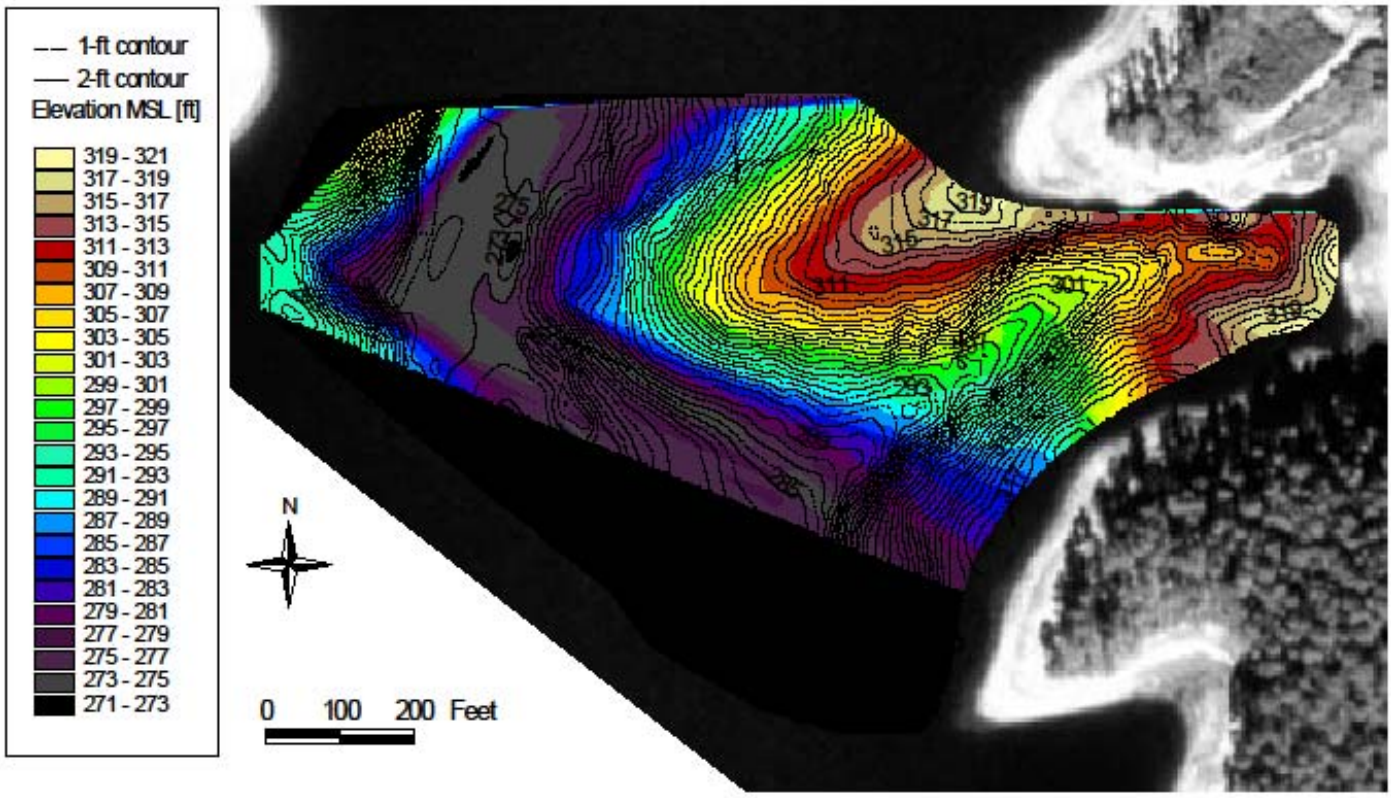
Anderson Bathymetry (4/21/2009)



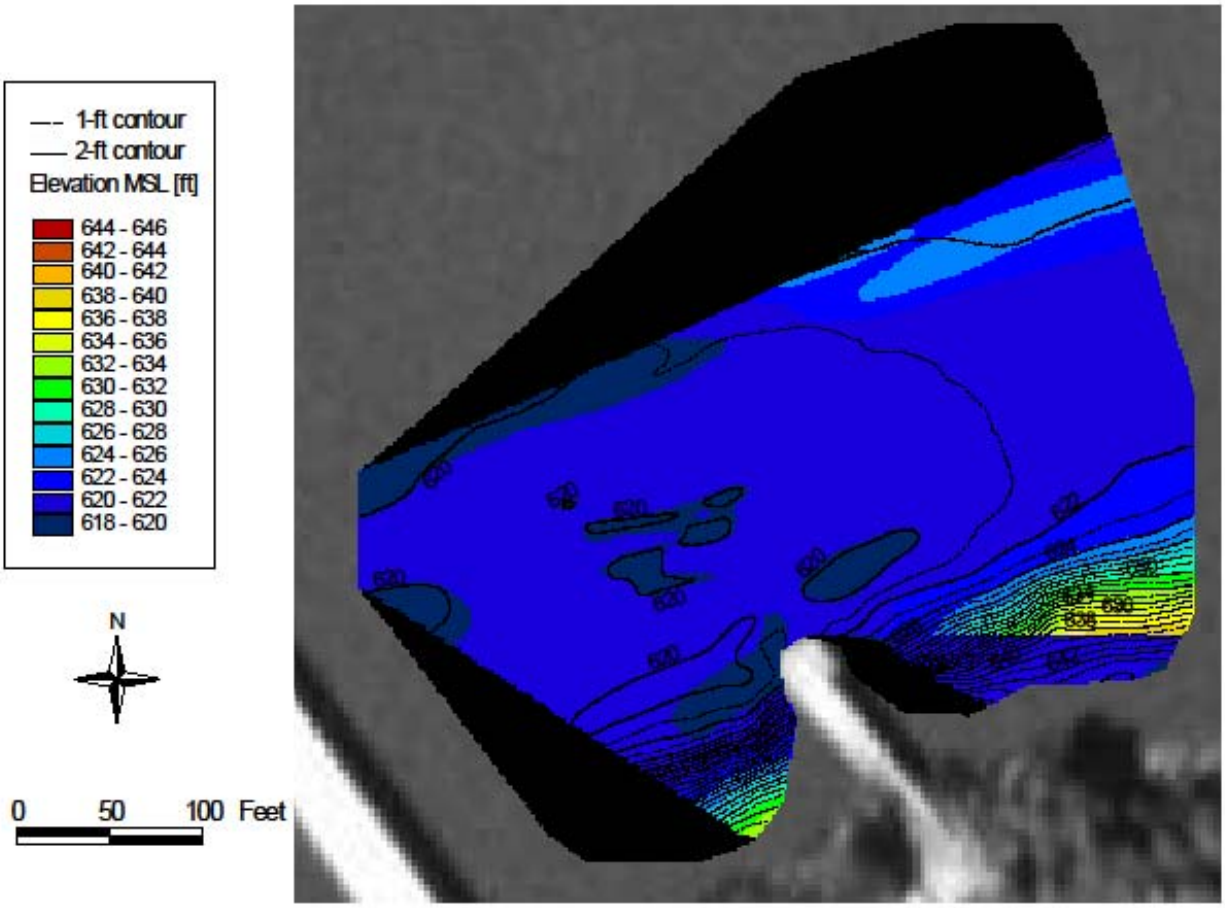
Calhoun Bathymetry (12/16/2008)



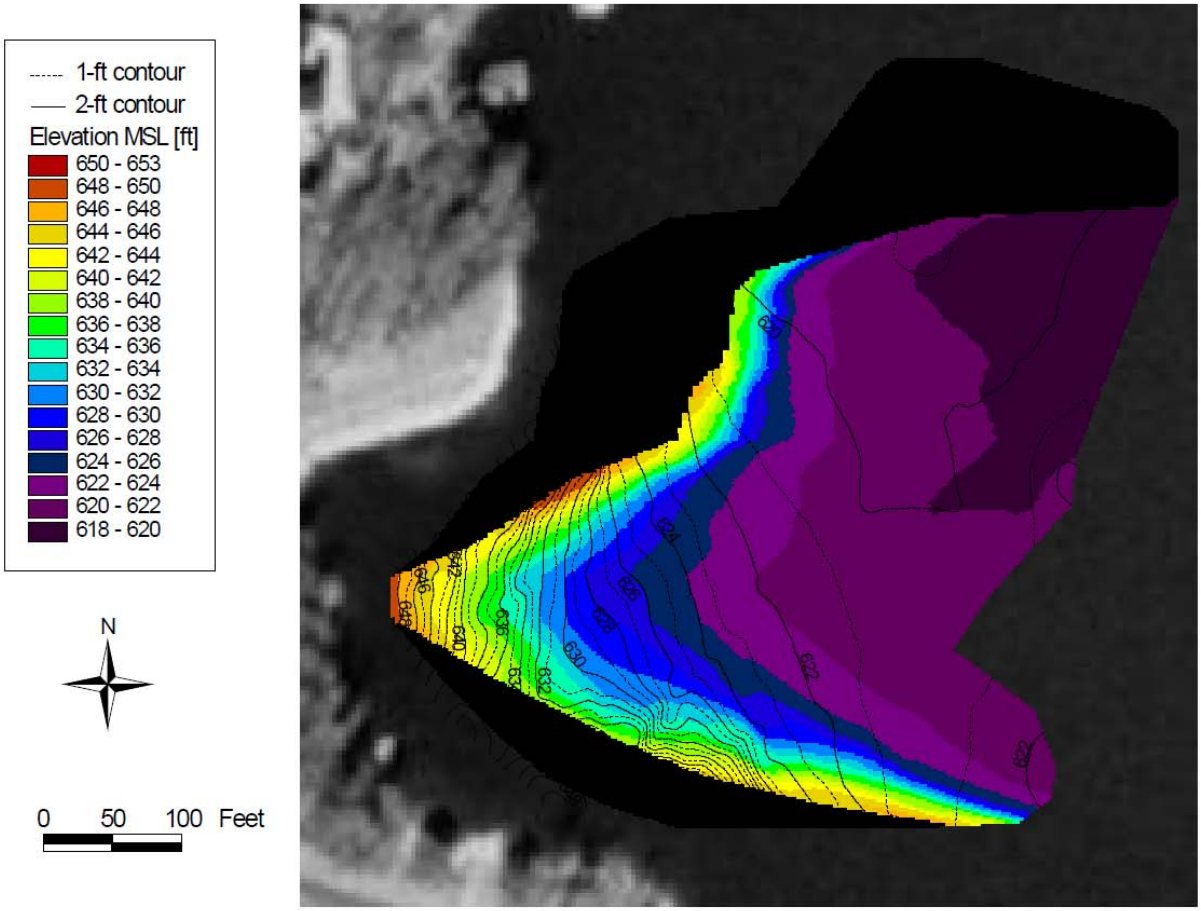
Columbia Bathymetry (4/27/2009)



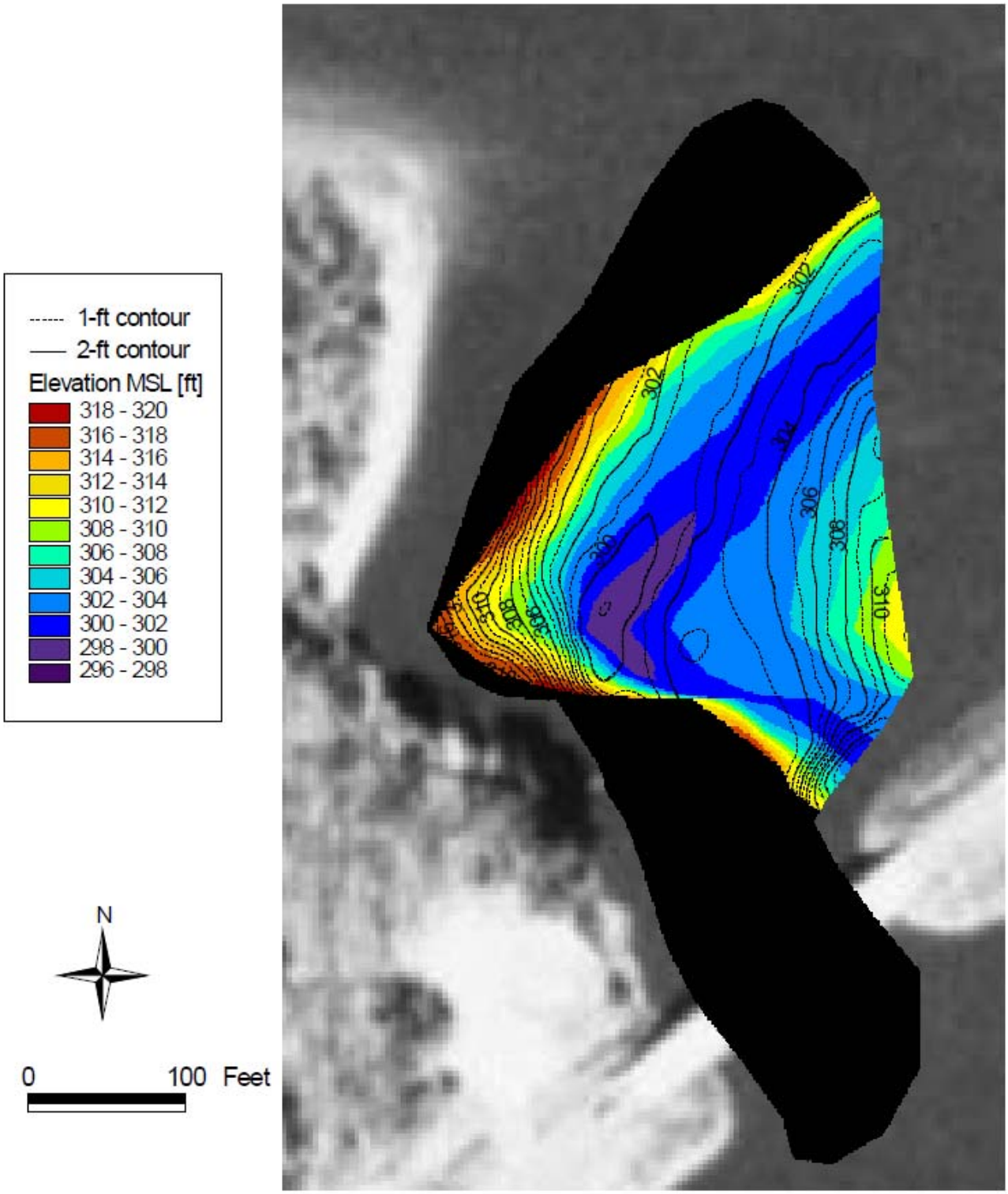
Clemson Bathymetry (4/8/2009)



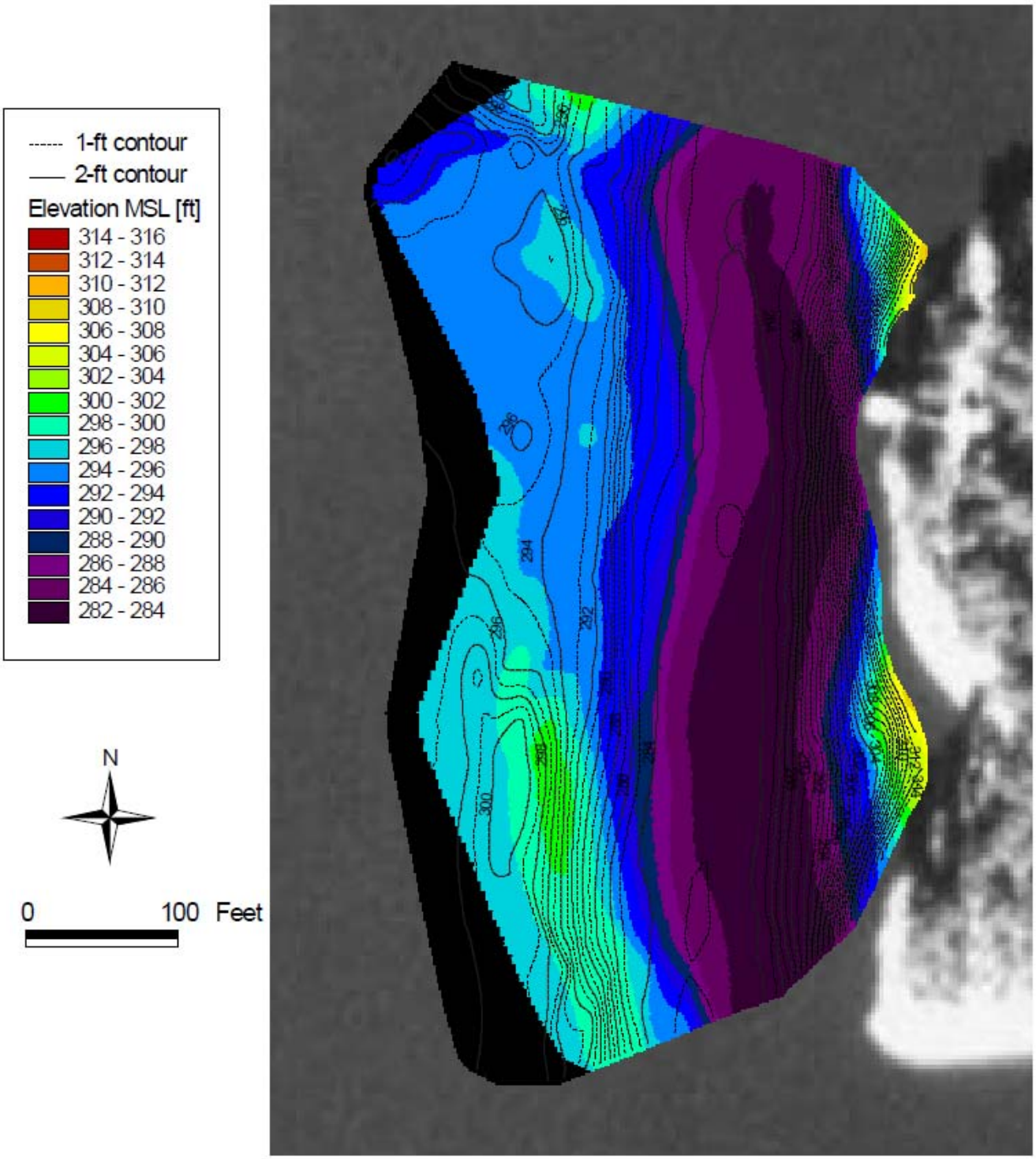
Lavonia Bathymetry (4/21/2009)



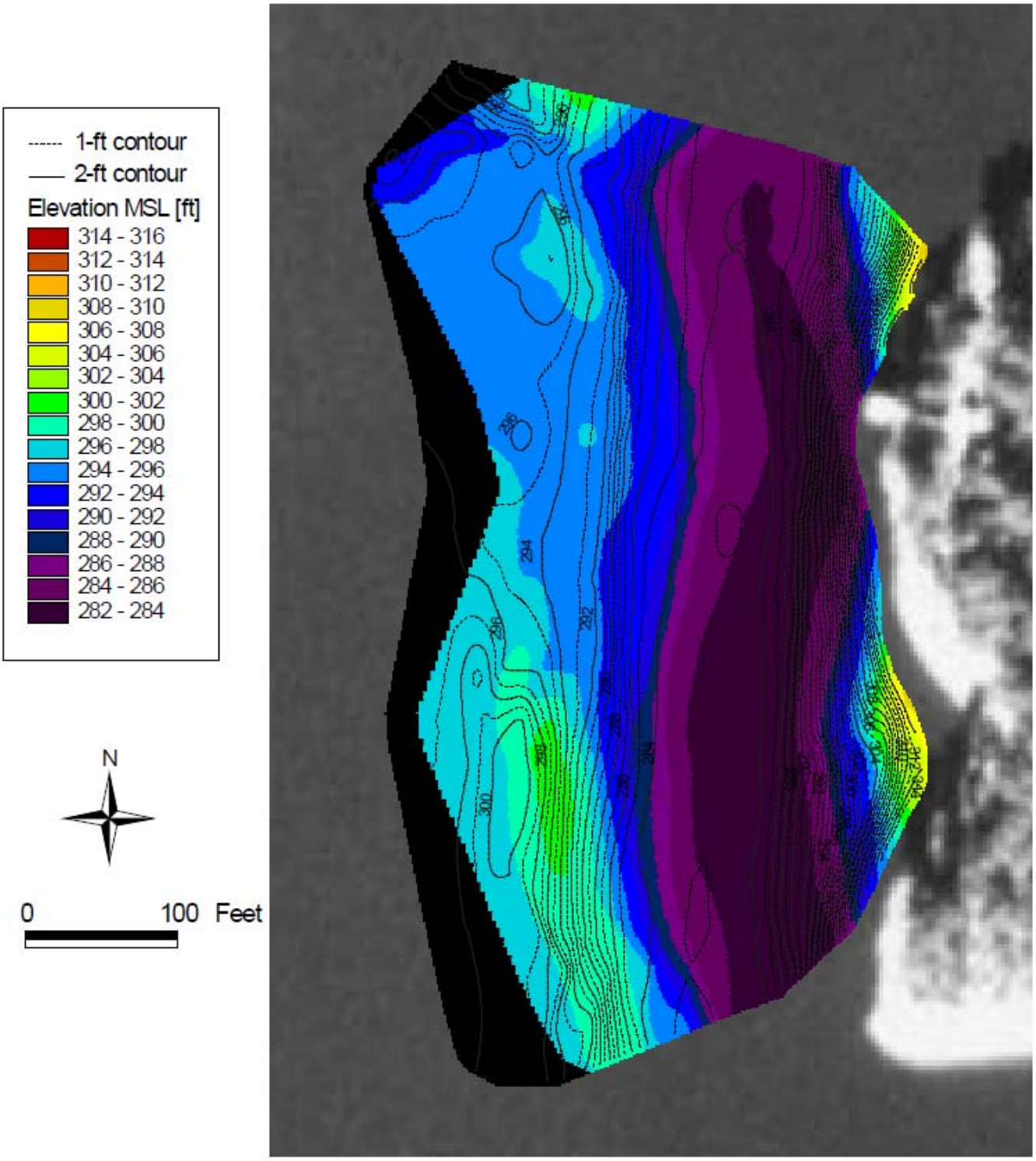
Lincolnton Bathymetry (4/16/2009)



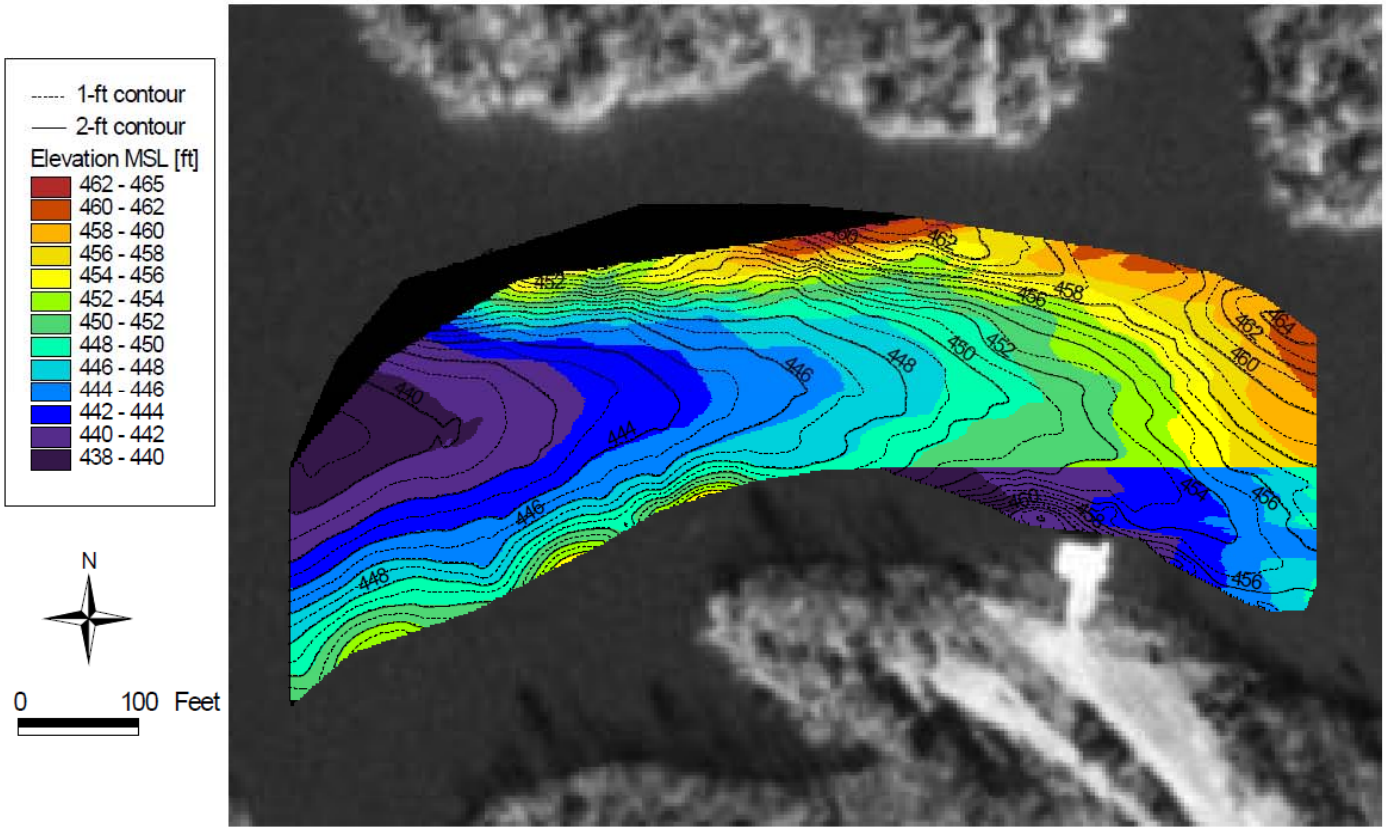
McCormick Bathymetry (4/16/2009)



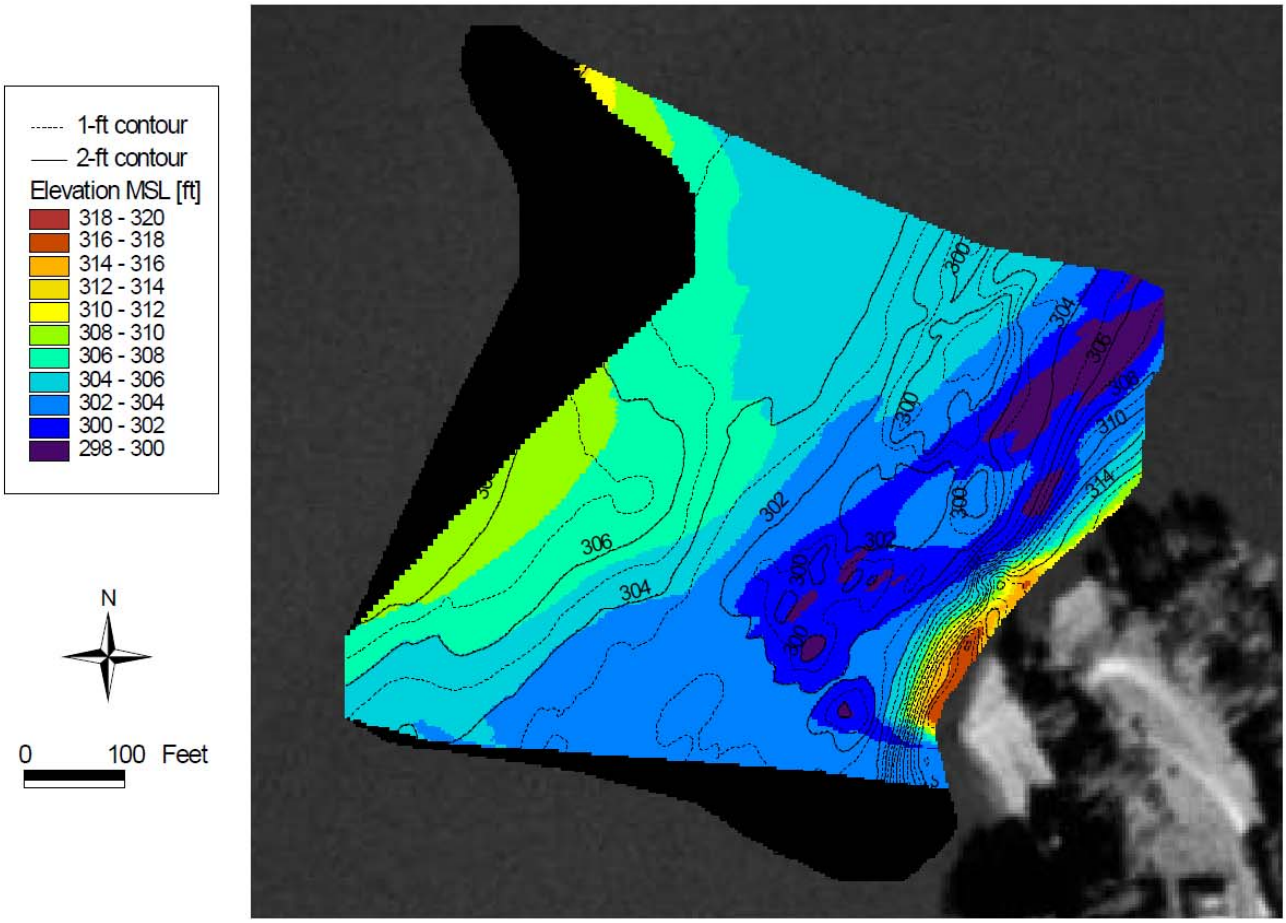
McCormick Bathymetry (4/16/2009)



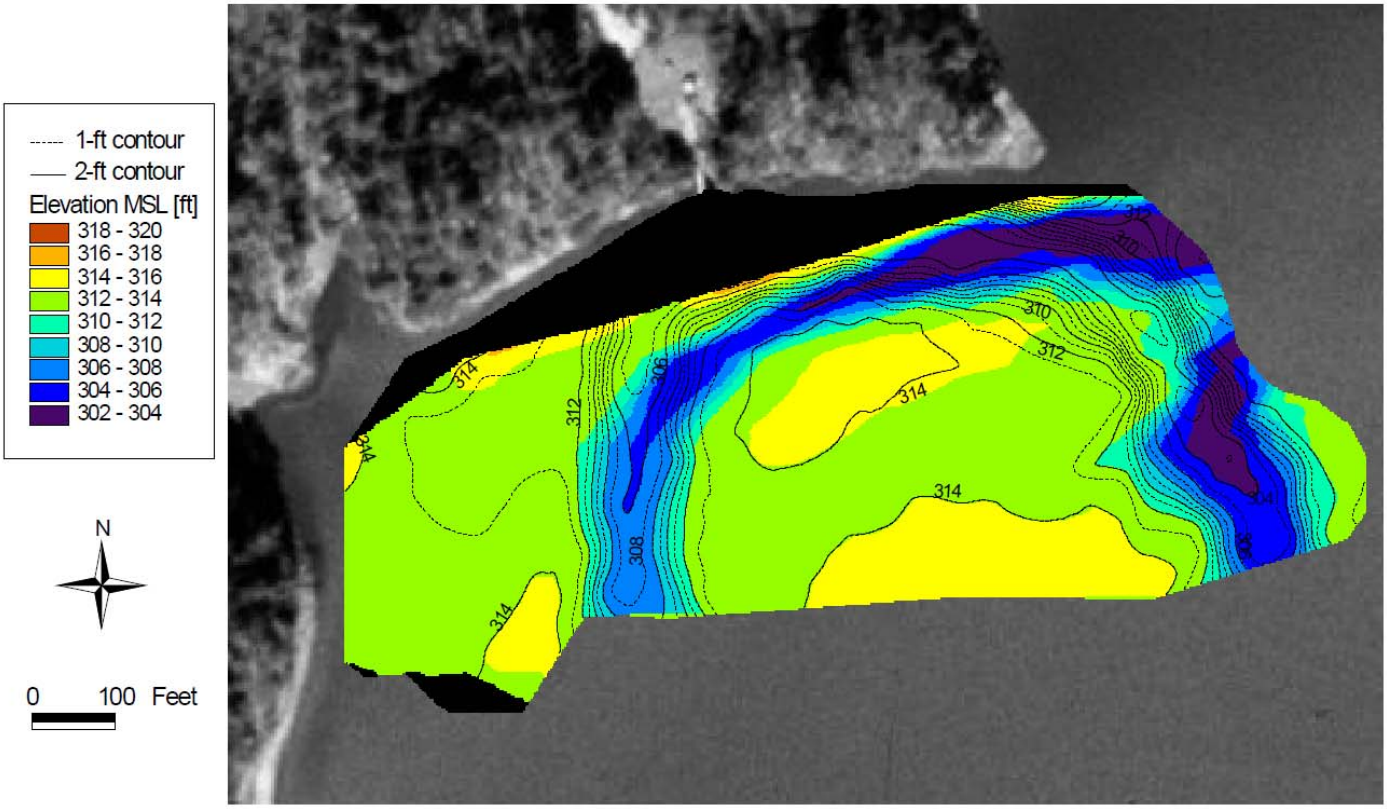
Mohawk Bathymetry (12/16/2008)



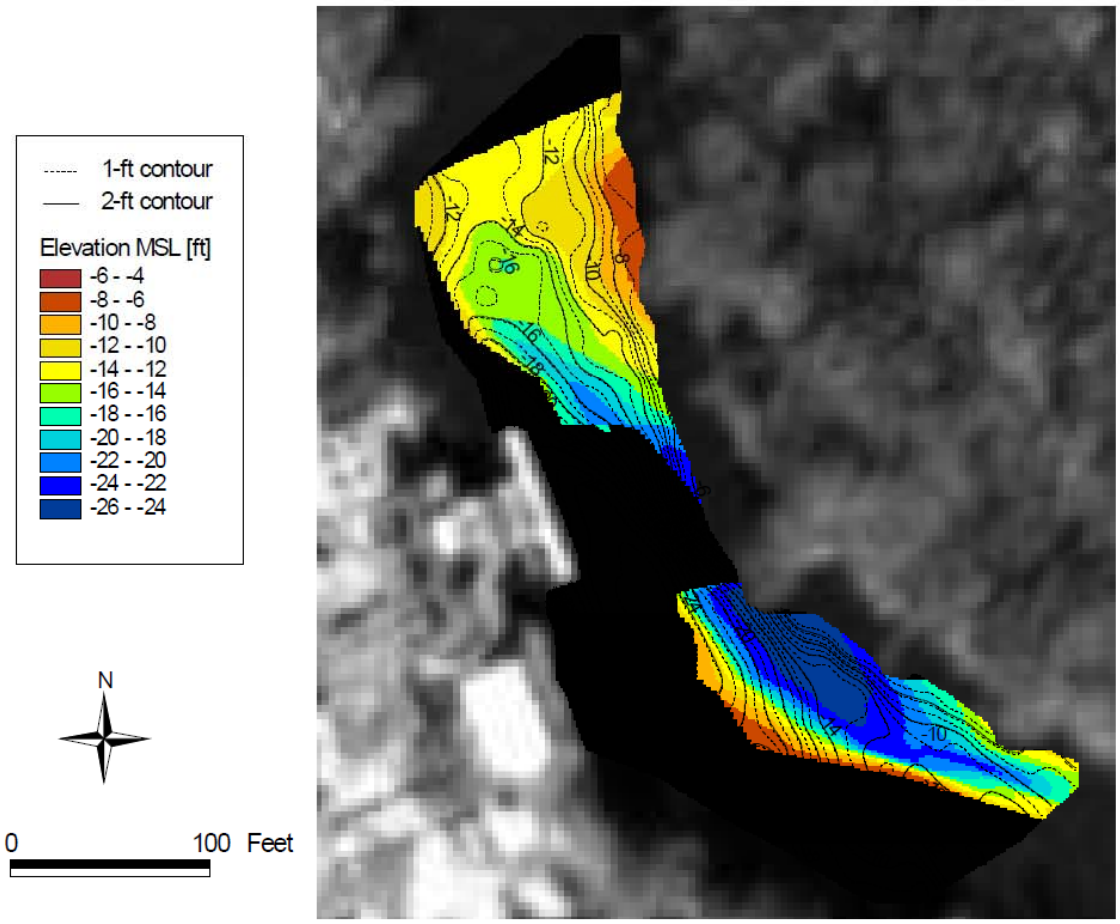
Thomson Bathymetry (4/22/2009)



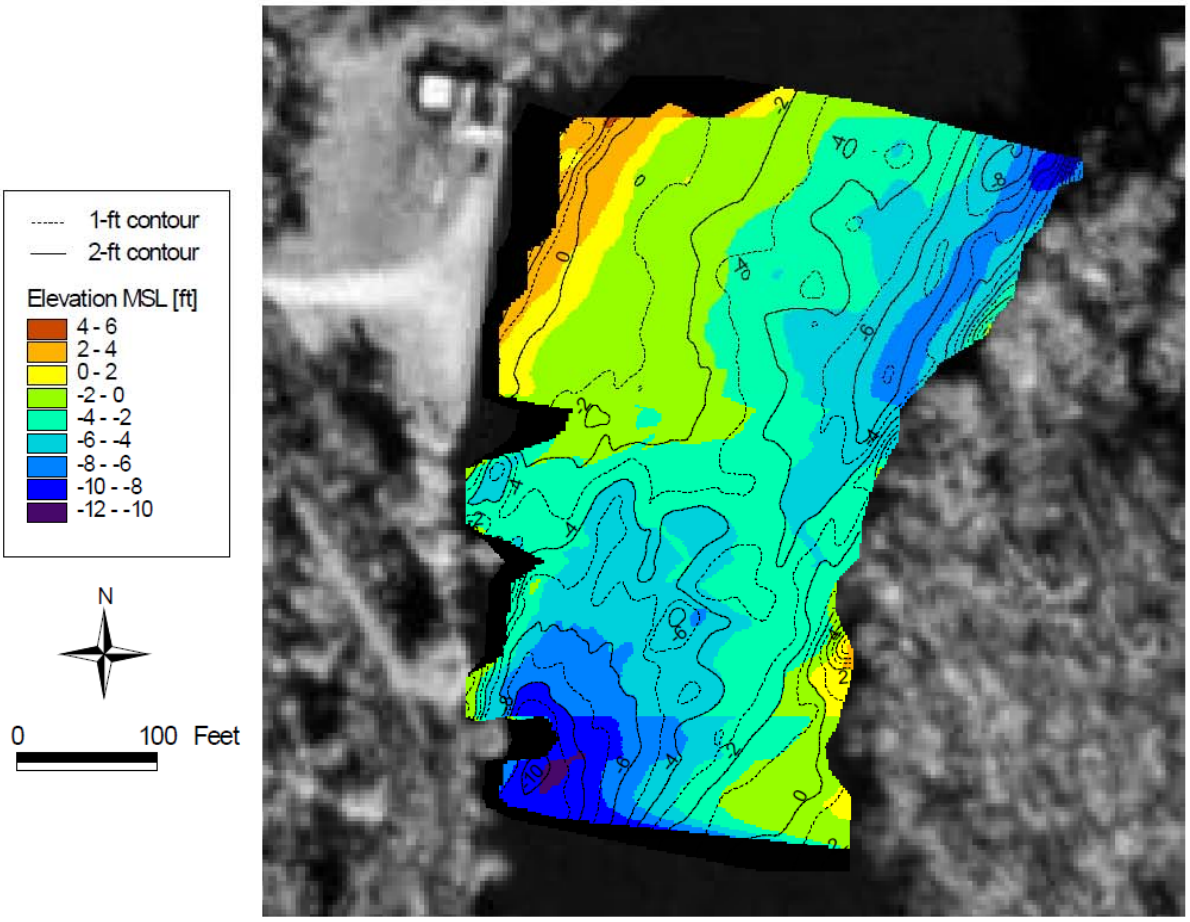
Washington Bathymetry (4/22/2009)



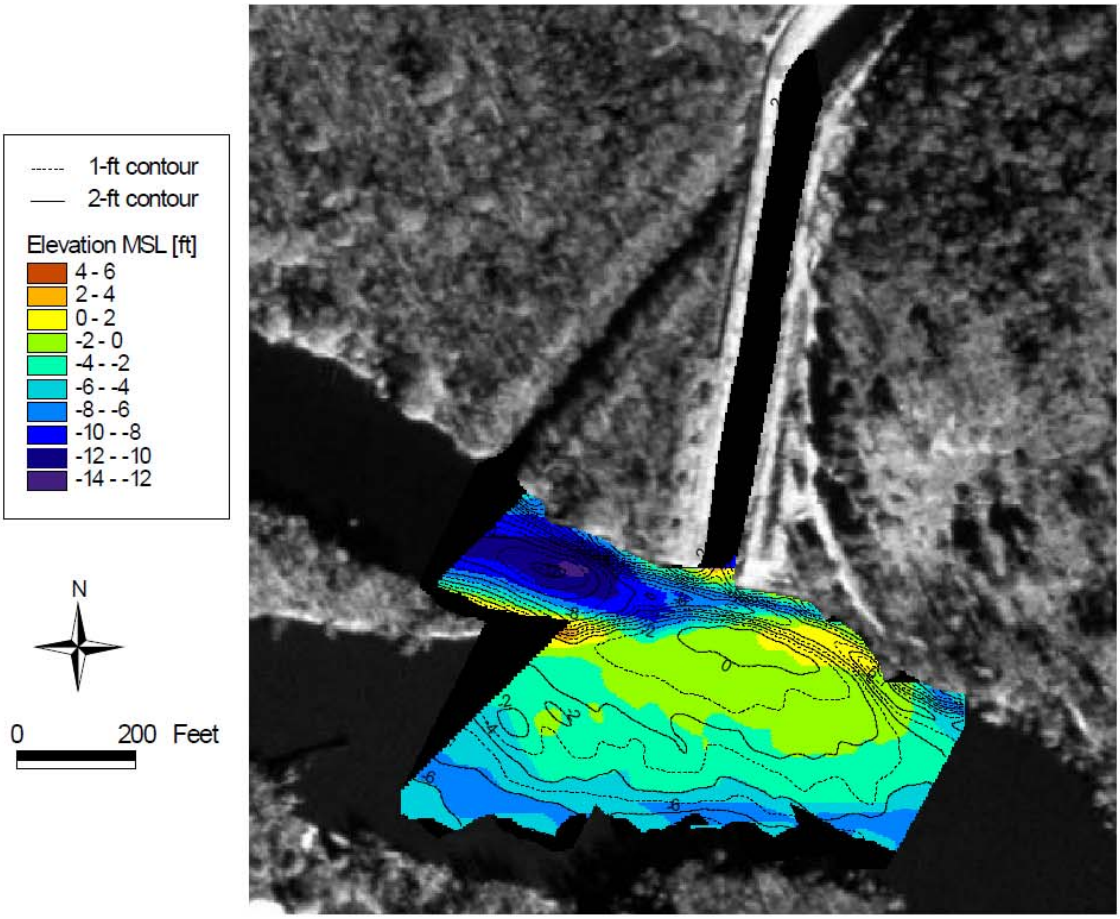
Abercorn Creek Bathymetry



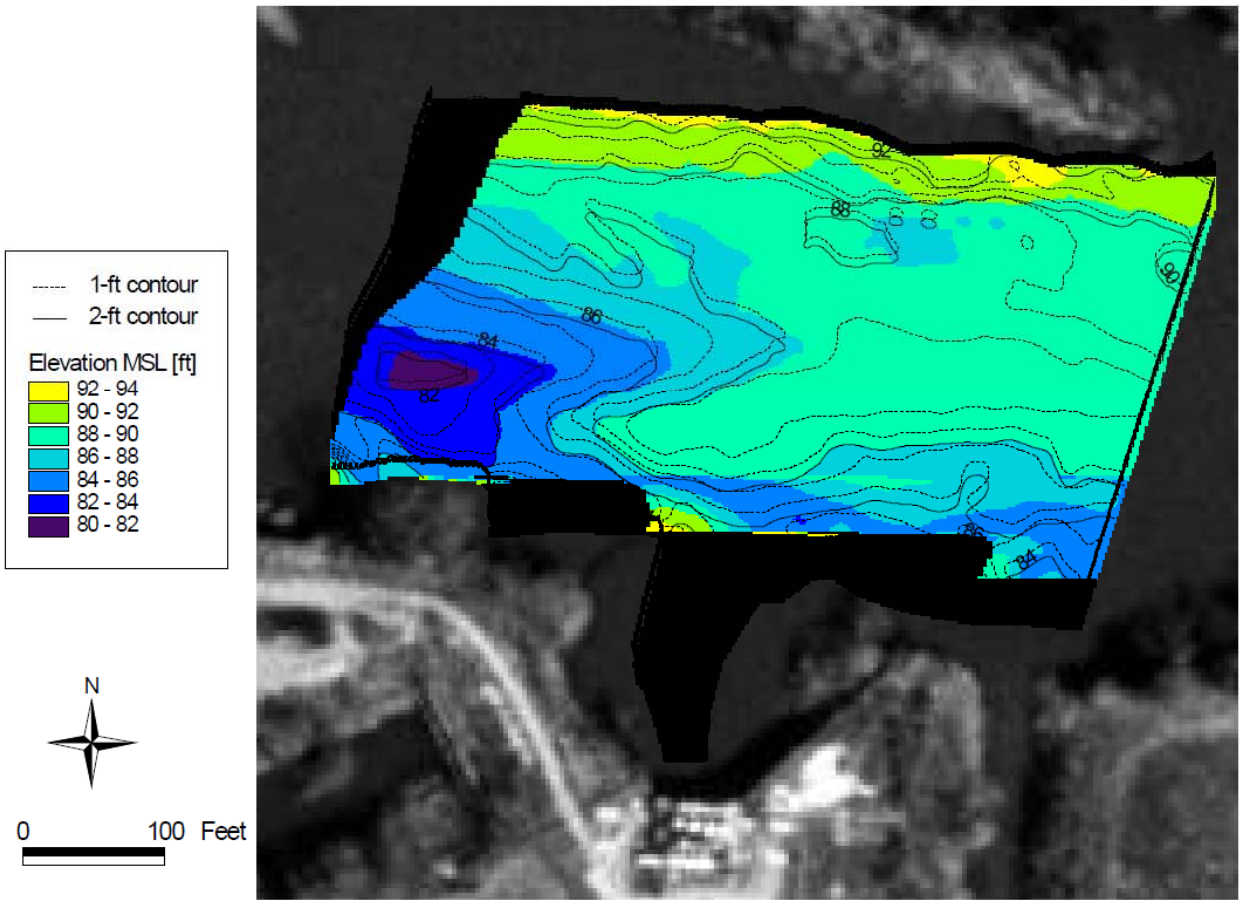
Georgia Pacific Bathymetry



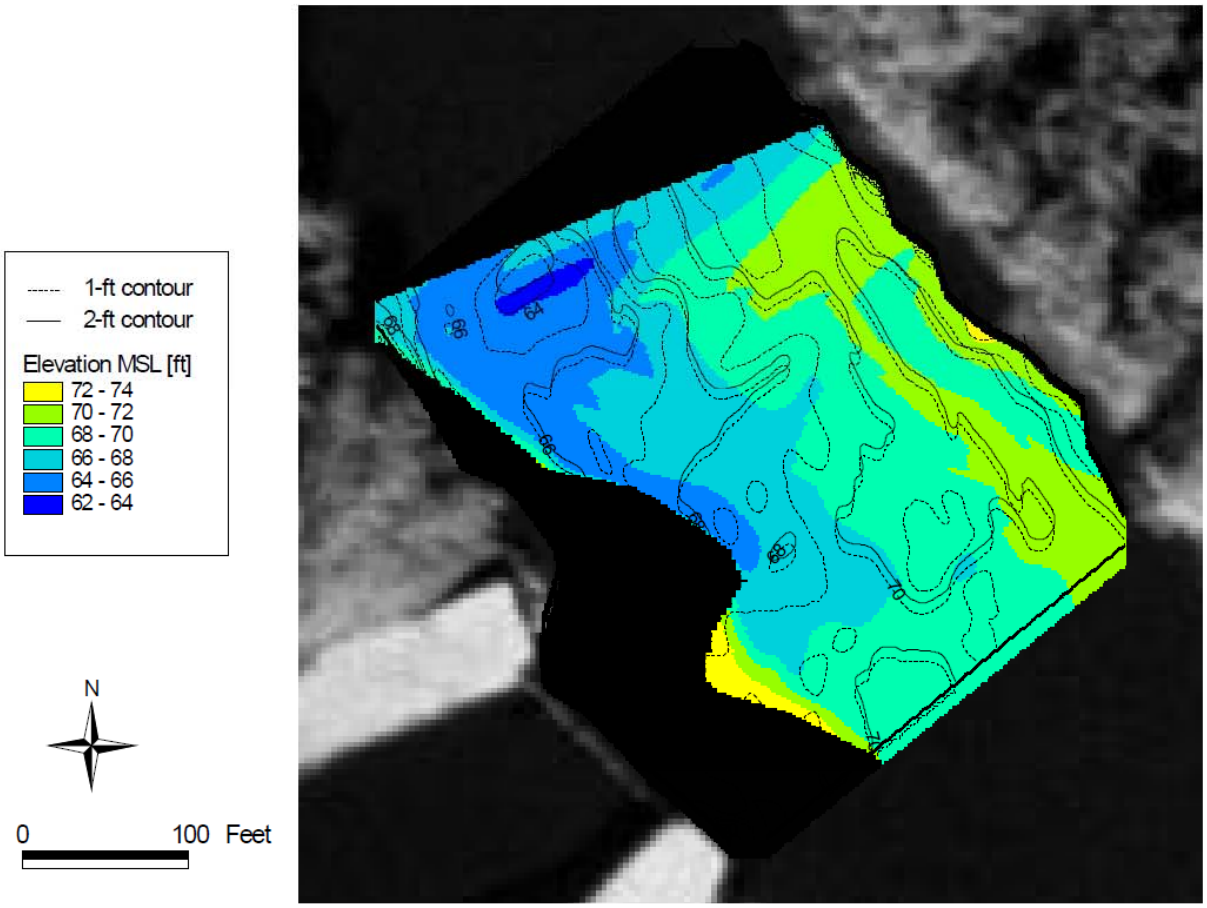
Hardeeville Bathymetry



International Paper Bathymetry



Vogtle Bathymetry



APPENDIX J

TURBINE PERFORMANCE AT LOW FOREBAY LEVELS

US Army Corps

of Engineers

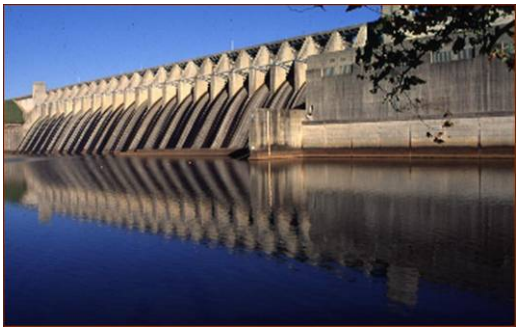
Savannah District Drought Study

Turbine Performance at Low Forebay Levels

HYDROELECTRIC DESIGN CENTER

Hartwell Project

R. B. Russell Project



G. Strom Thurmond Project

Prepared By:

Brian Moentenich, US Army Corps of Engineers, Portland District

Hydroelectric Design Center, January, 2010

PREPARED BY

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Turbine Performance at Low Forebay Levels

1.0 Executive Summary

If the reservoir levels fall by as much as 40 to 50 feet below the bottom of the conservation pool levels at the Thurmond, R. B. Russell and Hartwell projects, the turbines are expected to be able to discharge water – either by generating or by spinning at their synchronous speed and not generating.

2.0 Purpose

The purpose of this study is to determine if the turbines at the G. Strom Thurmond, R. B. Russell and Hartwell powerhouses will be able to continue to operate at lower than design reservoir and tailwater levels.

3.0 List of Assumptions

The following assumptions were made during the production of this report:

The powerhouse station service (house electrical power) will continue to operate normally.

The water cooling systems for the generators and turbines were designed with ample margins.

The turbines will be able to operate in generating mode satisfactorily down to 70% efficiency.

The performance of Hartwell turbine units 1-4 can be predicted by using Unit 5 model data.

4.0 References

The following documents were used in the production of this report:

G. Strom Thurmond turbine model test report

G. Strom Thurmond Unit 5 turbine field performance test report

R. B. Russell Units 1-4 turbine model test report

R. B. Russell Unit 3 turbine field performance test report

R. B. Russell Units 5-8 turbine model test report

Hartwell Unit 3 turbine field performance test report

Hartwell Unit 5 turbine model test report

Hartwell Unit 5 turbine field performance test report

Technical Paper entitled: "*Spring-supported thrust bearings used in hydroelectric generators: Should I be concerned about bearing temperature?*" by Jim Ferguson et al, GE Hydro, 2003.

Technical Paper entitled: "*Vortices at Intakes*" by J. L. Gordon, Hydro Division, Montreal Engineering Co. Ltd., Waterpower, April, 1970.

5.0 General

Operating a hydroelectric powerhouse at lower than design forebay levels can impact the ability of a turbine to operate satisfactorily. Lower forebay levels result in lower operating head. Lower forebay levels also can induce the formation of surface vortices which may entrain air. Where powerhouses are located in a river basin where the forebay level of one influences the tailwater level of an upstream project, then lower forebay levels also result in lower tailwater levels. This is the case for the Hartwell and R. B. Russell plants.

Lower tailwater levels also can impact turbine operation by causing the turbines to cavitate. Cavitation is the process of bubble formation[1] in low pressure regions and the subsequent bubble collapse when it flows into a region of higher pressure. Bubbles collapsing/imploding send out a shock wave which can cause metal fatigue over time if the location of the imploding bubbles are near a metal surface.

Historically, using turbine model performance to predict prototype (i.e. full – size) turbine performance has been found to be quite accurate. Some model test reports (especially the more recent ones) often have model performance information outside the guaranteed head range. Specifically, model runaway performance information often exists because guaranteed prototype runaway speeds were usually required to be verified during a model test. Note that runaway performance means no power is being generated. This is, in fact, the same as "speed-no-load" performance. In some cases, predicted model performance when generating power is provided over a wider head range than guaranteed. No model cavitation performance data is available outside the guaranteed operating range.

At the Thurmond, R. B. Russell and Hartwell powerhouses, there are a total of five "families" of turbines. These are: Thurmond Units 1-7, R. B. Russell Units 1-4, R. B. Russell Units 5-8, Hartwell Units 1-4, and Hartwell Unit 5. Every turbine within a family is identical.

6.0 Turbine Operation when Generating at Heads below Design Values

Usually a turbine will be able to operate satisfactorily when generating down to some value below it's minimum guaranteed operating head. Operating "satisfactorily" means the turbine is able to operate without excessive vibration and cavitation. It is generally believed by hydro turbine engineers that Francis[2] turbines should be able to operate satisfactorily down to about 70% efficiency.

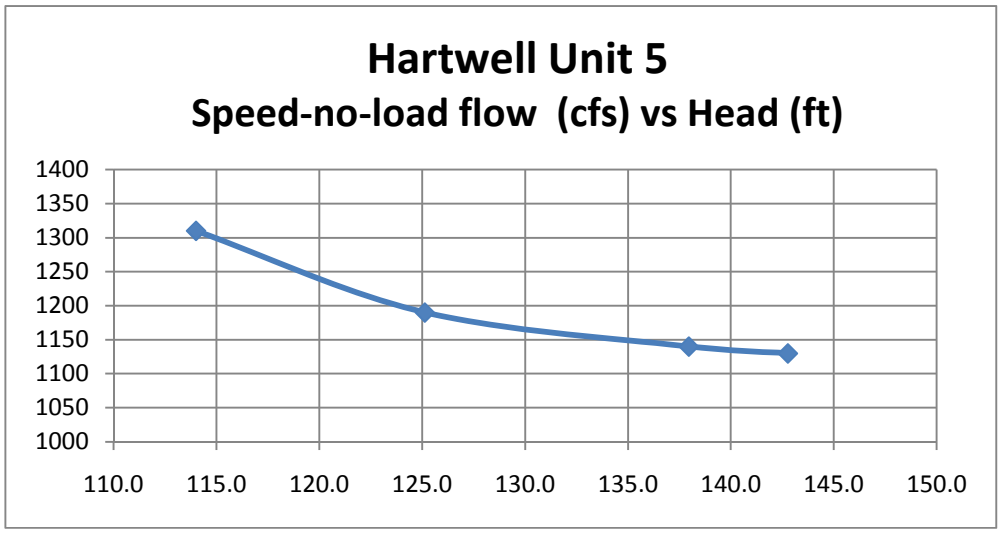
---

[1] The gas within these bubbles is water vapor and not air

[2] All of the turbines at the three plants are "Francis" type.

7.0 Turbine Operation at Speed-no-Load at Heads below Design Values

When operating a turbine in generating mode gets to be unacceptable due to low head or low forebay or tailwater elevations, then operation at speed-no-load (SNL) is the next option available to pass water through the turbine. This means the turbine is spinning at approximately ***synchronous speed*** and the circuit breaker is open (i.e. the generator is de-energized and no electrical power is being generated). While it is possible to operate the unit at higher than synchronous speed while not generating, it is not recommended. Even when not generating, the turbine will still be producing some power to overcome bearing friction and windage of the rotating parts. For example, the friction & windage power required for a Thurmond generating unit is approximately 500 hp. Speed-no-load operation is what occurs when a turbine is started and the generator is not yet connected to the line. The governor is designed to keep the unit at or near synchronous speed. Sustained speed-no-load operation should not be injurious to the turbine. When operated at SNL, the water flow rate through the turbine increases with decreasing head as can be seen in the graph for Hartwell Unit 5 shown below:



Operation at speed-no-load should be possible down to relatively low heads. It is probable that unacceptable operating behavior such as excessive vibration or shaft runout will occur before this head is reached. If that occurs, then the unit should be shut down. The decision to shut down the unit should be made by plant O&M personnel based upon observed unit behavior.

8.0 Unacceptable Operation Guidelines

There are no hard and fast guidelines on what constitutes excessive vibration or shaft runout. Most large turbines have shaft bearing clearances of 0.015” to 0.018”. During normal operation, the shaft runout seldom exceeds 0.003” to 0.005”. Therefore sustained shaft runouts exceeding 0.010” to 0.012” should be considered excessive.

Head cover vibration in the vertical direction in the vicinity of the packing box and draft tube door vibration in the horizontal direction may vary considerably from unit to unit. The vibrations should be measured on several units of the same family at various power levels and the results compared. Vertical vibration amplitudes of the head cover and/or horizontal amplitudes in the middle of the draft tube mandoor exceeding twice the normal maximum amplitudes should be considered to be excessive.

9.0 Turbine Discharge Measurement

One of the turbines in each family was tested shortly after commissioning using a process which measured actual turbine discharge. During these tests, the Winter-Kennedy piezometer taps were calibrated. This makes discharge measurement a relatively easy task. If the difference in pressure (as measured by a differential pressure gage) between the piezometer tap on the outside of the spiral case and one of the inner ones is known, then the discharge can be calculated using the appropriate formula[3] provided in the turbine field performance test report.

10.0 Cavitation Performance

Model cavitation performance data is not available outside the normal guaranteed operating range. However, the propensity for a turbine to cavitate generally decreases with decreasing power output and head. Lower than normal tailwater levels can, however, cause unacceptable cavitation damage. The final determination of the severity of cavitation on a prototype turbine when operated at heads and tailwater levels below design values remains with the plant operating staff. The onset of significant cavitation can usually be determined simply by listening to the noise generated – usually at the draft tube mandoor. Cavitation noise is distinctly different from other flow and turbulence-generated noise. Cavitation sounds more like popcorn popping or firecrackers going off as opposed to the more typical rumbling noise which is flow generated. It isn't possible to know just by listening if the collapse of cavitation bubbles[4] is attacking nearby metal surfaces or not. Bubbles collapsing away from metal surfaces cause no harm. If a unit is experiencing what sounds to be significant cavitation, it should be visually inspected periodically to determine if the metal surfaces are suffering unduly from cavitation attack.

11.0 Vibration and Rough Operation

Generally speaking, high noise levels do not always mean unacceptably rough operation. Measurements of vibration and shaft runout are usually more meaningful than noise level. Fortunately, such measurements are relatively easy to perform and special instrumentation is not required. Portable vibration monitors are widely available with probes to check the amplitude of vibration (in mils peak-to-

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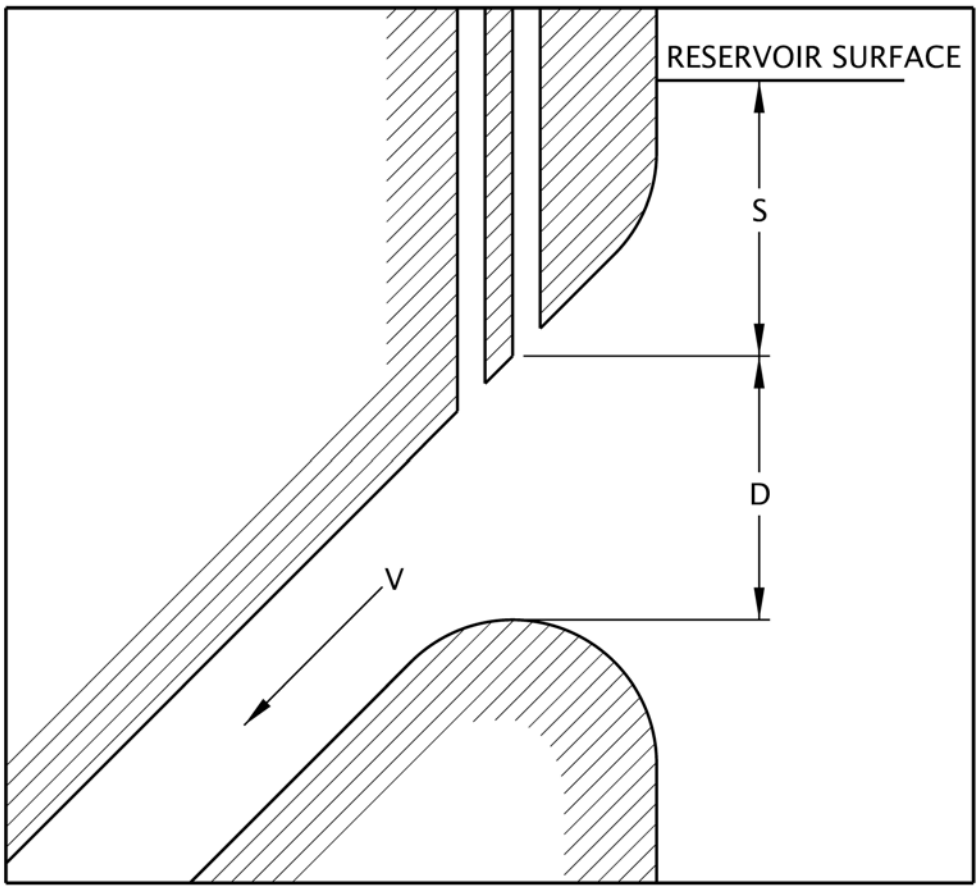
[3] Typically, more than one formula is provided because there are normally several pairs of *Winter-Kennedy* piezometer taps which were calibrated during the field performance test.

[4] The gas inside a cavitation bubble is water vapor and not air as is commonly believed. Vapor bubbles form when the local pressure drops to the vapor point which is approximately 0.5 psia at normal water temperatures.

peak) of any surface they touch. Also, dial indicators can be used to measure shaft runout. Measuring head cover vibration (in the vertical direction), draft tube mandoor vibration (in the horizontal direction) and the shaft runout at the turbine bearing will provide valuable information on rough operation. These tools are not expensive and can be used for other maintenance needs.

12.0 Surface Vortex Formation

As the forebay levels decrease, there is less submergence of the top of the penstock intake. Surface vortex formation is generally not a problem until the vortices begin to entrain air. Air passing through the turbine may cause rough operation. There is very little research available on vortex formation in intakes for hydroelectric powerhouses. The April, 1970 edition of *Waterpower* contained an article written by J. L. Gordon entitled "Vortices at Intakes".



The data was based upon observation of a total of 29 intakes of hydro plants when at low reservoir levels. It was used as a basis of estimating minimum acceptable forebay levels due to formation of air-entraining vortices when generating and when operating at speed-no-load. It needs to be noted that the resulting reservoir limits from using J. L. Gordon's formula are not hard. Small and moderate volumes of air passing through a turbine may not induce unacceptably rough operation. Actual unit

roughness should be used (to decide to shut down a unit) if very low reservoir levels actually occur. J. L. Gordon's formula was used to predict, for planning purposes, when air-entraining vortices would begin to form. For symmetrical intakes, the following formula was empirically developed by J. L. Gordon:

$$S = 0.3 * V * (D)^{0.5}$$

Where: S is the minimum submergence depth (ft) from the reservoir surface to the upper stationary intake gate sealing surface (see sketch)

V is the velocity of flow in the penstock in ft/sec.

D is the intake gate height in feet

For Hartwell Unit 5, the elevation of the top of the gate seal is approximately at 568 FMSL[5], the gate height is approximately 28 feet and the penstock diameter is 24 feet.

For a discharge of 6,000 ft^3/sec., S is calculated to be 21 feet. This would yield a minimum reservoir elevation (to prevent vortices) of approximately 590 FMSL when the unit is generating power. For a speed-no-load discharge of 1,400 ft^3/sec., the minimum forebay would be approximately 575 FMSL.

13.0 Cooling & Lubricating Water

There are some additional things to consider when determining what is the minimum forebay level a turbine-generating unit can operate at. Water for cooling the generator stator windings, the main shaft bearings and lubricating the turbine shaft packing and the upper and lower turbine seal rings is required. The source of this water for each of the three powerhouses[6] is the forebay via a connection to the penstock. Therefore, some water will always be provided to the respective systems. There is no way to predict if adequate flow rates will exist to permit the units to operate either in generating mode or speed-no-load mode. However, it is quite likely that adequate flow rates will exist as Corps powerhouse designers were typically quite conservative.

Generator cooling water flow rates are usually quite restricted during normal operation to maintain desired stator temperatures. Usually much more flow is possible simply by opening the control valves. The generators should not be operated above their stator RTD (resistance temperature detector) limits. If the RTD limit is reached, then generation should be stopped and the speed-no-load mode of operation should be commenced if the head continues to be reduced.

Most bearing cooling water systems were generously sized. In fact, the bearings at many Corps plants usually operate at very low temperatures because operators commonly want an extra margin of

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[5] Feet Mean Sea Level

[6] For the R.B. Russell Units 5-8, water is gravity fed from the penstock when generating and pumped from the tailrace when pumping.

protection & open the valves (sometimes full open) all the time. As the head is decreased, bearing temperatures will be elevated from normal levels. This should not be a problem until the shoe RTD Temperature exceeds 90°C . This is a very high temperature for a bearing. However, thrust & guide bearings can and do run as hot as that at many plants and have done so for decades without problems[7].

14.0 Prior Operation of Turbines at Low Reservoir Levels

During the winter of 2008, the Savannah River flow rate was reduced to extremely low levels due to a drought in the region. As a result of this drought, reservoir levels were lower than normal but still above the bottom of their conservation pools.

14.1 Thurmond Powerhouse

The normal minimum forebay level is 312.0 FMSL which is also the top of the inactive storage pool[8]. The minimum observed forebay level in the past four years was 313.68 FMSL. The minimum observed tailwater elevation in the past four years was 178.34 FMSL. All of the turbines operated normally during these conditions. When the Thurmond pool was being filled for the first time, the units were operated in the generating mode satisfactorily with a forebay level as low as 292 FMSL.

14.2 R. B. Russell Powerhouse

The normal minimum forebay level is 470.0 FMSL which is also the top of the inactive storage pool. The minimum observed forebay level in the past four years was 473.64 FMSL. The minimum observed tailwater elevation in the past four years was 312.33 FMSL. All of the turbines operated normally during these conditions.

14.3 Hartwell Powerhouse

The normal minimum forebay level is 625.0 FMSL which is also the top of the inactive storage pool. The minimum observed forebay level in the past four years was 649.5 FMSL. The minimum observed tailwater elevation in the past four years was 476.64 FMSL. All of the turbines operated normally during these conditions.

15.0 Turbine Operation based upon Predicted Performance for Planning Purposes

The following operating guidelines are based upon extrapolation of the data in the turbine model test report for each family of units[9] and upon research performed on vortex formation in turbine intakes. The data should be used for *planning* purposes . *If and when extreme low forebay levels actually occur,*

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[7] *Spring-supported thrust bearings used in hydroelectric generators: Should I be concerned about bearing temperature?* by Jim Ferguson et al, GE Hydro, presented at Waterpower XIII Conference, 2003.

[8] The bottom of the conservation pool is the top of the inactive storage pool.

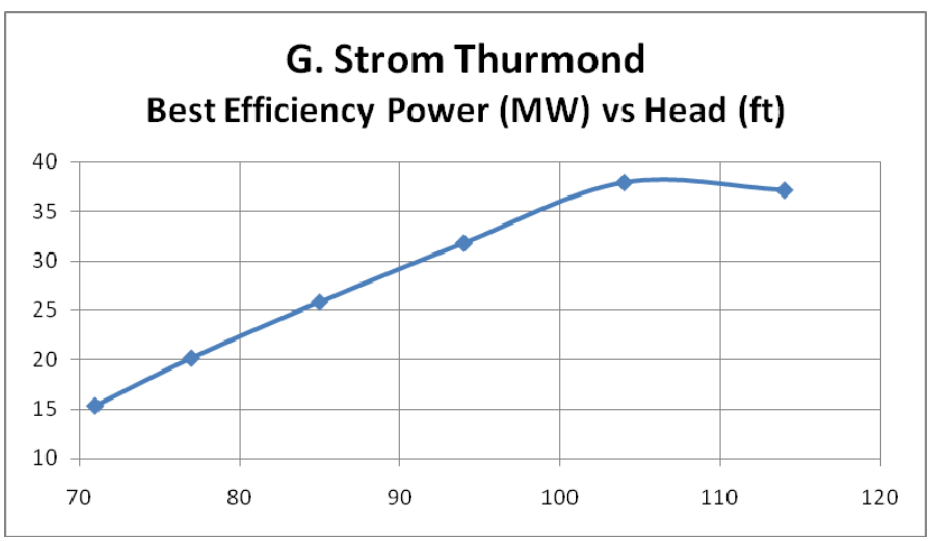
[9] Model data for Hartwell units 1-4 was unavailable so the model data for Unit 5 was used for Units 1-4.

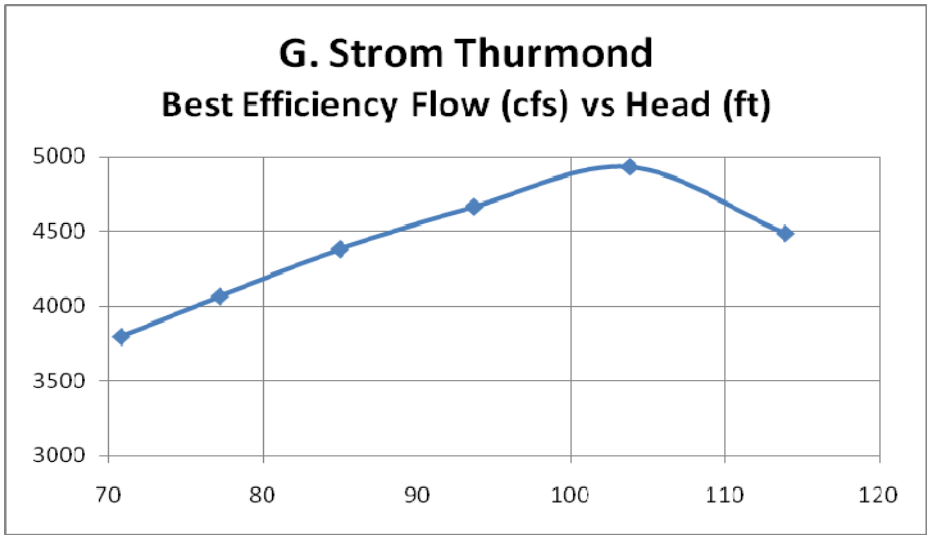
decisions to continue unit operation should be made by plant O&M personnel based upon observed unit behavior. Note that head is sometimes referred to as "head" and also as "net head". The term "head" means the gross difference between the forebay and tailrace water surface elevations. Turbines are always rated & guaranteed to operate at "net head" which is gross head minus intake losses. Intake head loss includes sudden contraction loss, trash rack loss and friction loss in the penstock. For example, at Hartwell, the intake loss for Unit 5 is approximately 1 foot at a turbine discharge of 6,000 ft^3/sec. and less than 0.1 foot at a discharge of 1,400 ft^3/sec.

15.1 G. Strom Thurmond Units 1-7

These turbines were designed to operate satisfactorily over a net head range from 148.5 feet down to 114 feet. There is no reason to believe the turbines will not continue to operate in an acceptable manner at some heads lower than 114 feet. Continuing to operate the turbine while generating power at or near best efficiency should be possible down to a forebay level of 294 FMSL. This would result in a net head on the turbine of approximately 109 ft. (assuming a tailwater elevation of 184 FMSL and an intake head loss of one foot). When generating below a forebay level of 294 FMSL, air-entraining vortices in the intake are predicted to begin to form which may cause the turbine to run unacceptably rough.

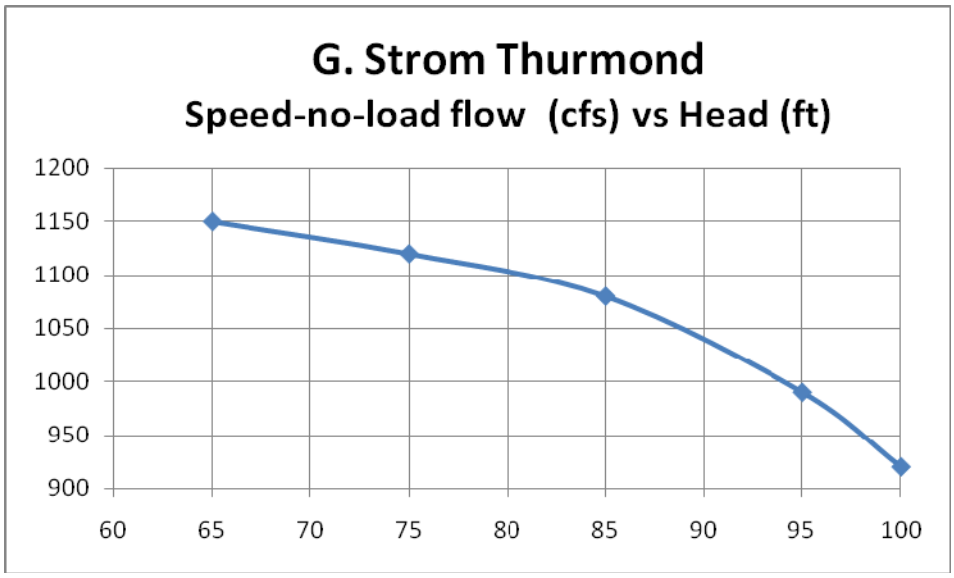
G. Strom Thurmond Best Efficiency Generation Peformance			
Head (ft)	*Power (MW)*	*Q (cfs)*	*Forebay (FMSL)*
71	15	3800	256
77	20	4070	262
85	26	4380	270
94	32	4660	279
104	38	4930	289
114	37	4490	299





Operating the turbine in a speed-no-load condition should be possible at all forebay elevations down to 275 FMSL where again air-entraining vortices are predicted to commence.

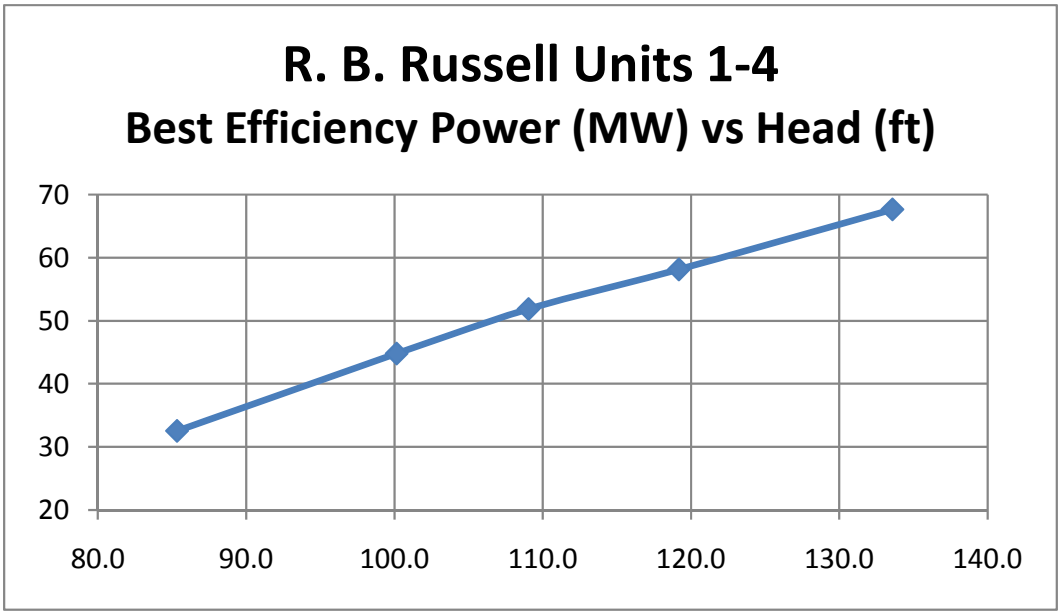
Thurmond Speed-no-Load Performance		
Head (ft)	*Flow (cfs)*	*Forebay (FMSL)*
65	1150	249
75	1120	259
85	1080	269
95	990	279
100	920	284

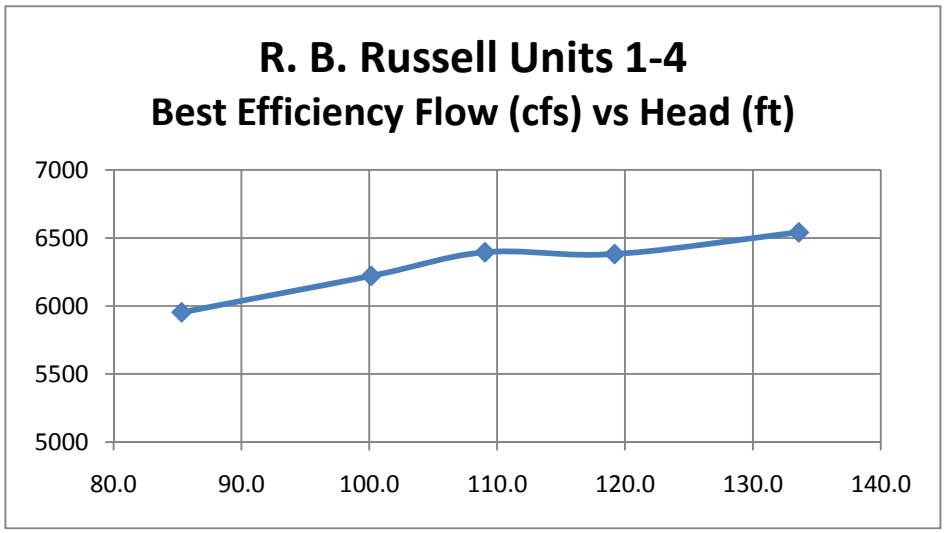


15.2 Richard B. Russell Units 1-4

These turbines were designed to operate satisfactorily over a net head range from 162 feet down to 134 feet. There is no reason to believe they will not continue to operate in an acceptable manner at some heads lower than 134 feet. Continuing to operate the turbine while generating power at or near best efficiency should be possible down to a forebay level of 434 FMSL. This would result in a net head on the turbine of approximately 113 ft. (assuming a tailwater elevation of 318 FMSL and an intake head loss of one foot). When generating below a forebay level of 434 FMSL, air-entraining vortices in the intake are predicted to begin to form which may cause the turbine to run unacceptably rough.

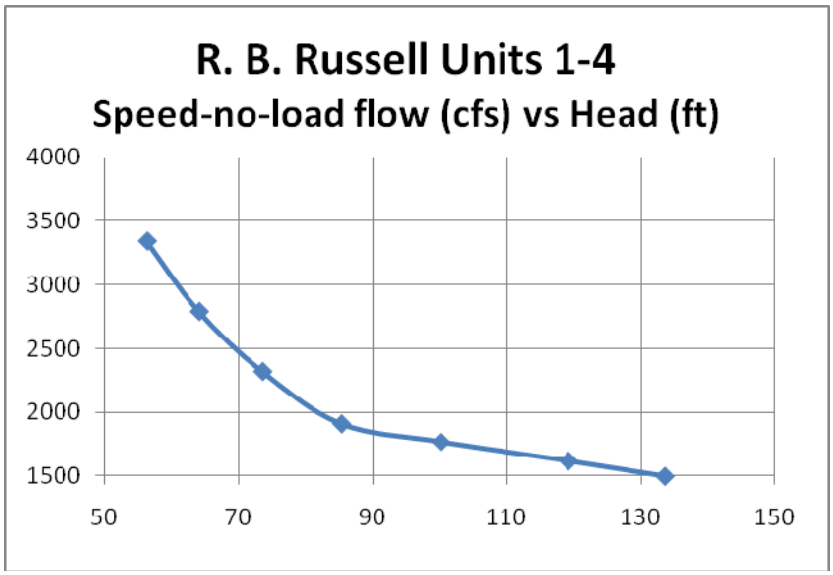
R. B. Russell Units 1-4 Best Efficiency Generation Performance			
Head (ft)	*Power (MW)*	*Q (cfs)*	*Forebay (FMSL)*
85	33	5950	396
100	45	6220	411
109	52	6400	420
119	58	6380	430
134	68	6540	445





Operating the turbine in a speed-no-load condition should be possible at all forebay elevations down to 418 where again air-entraining vortices are predicted to commence.

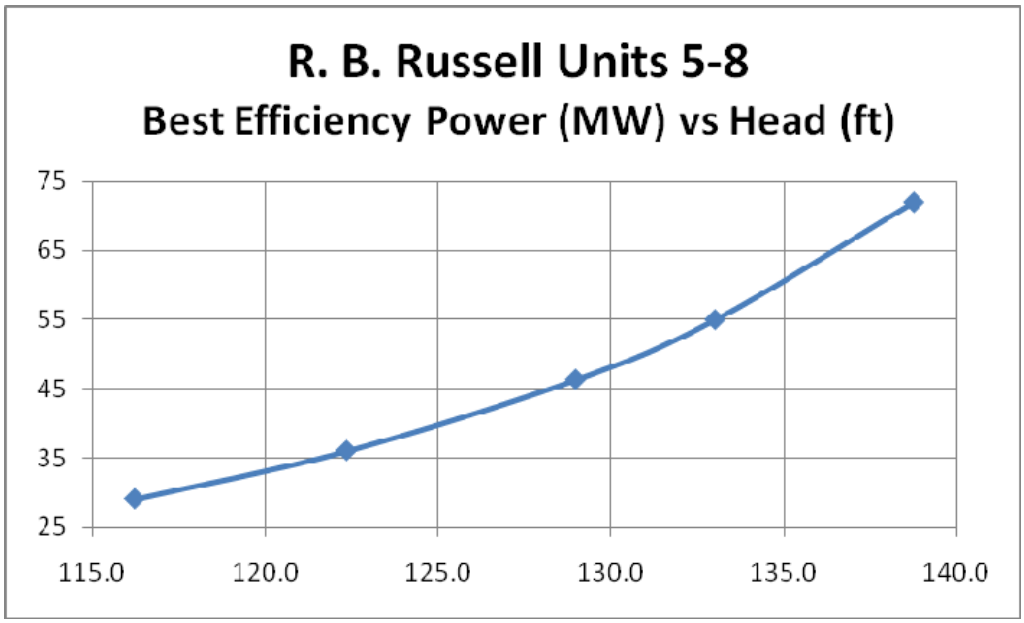
RB Russell Units 1-4 Speed-no-Load Performance		
Head (ft)	*Flow (cfs)*	*Forebay (FMSL)*
56	3340	366
64	2790	374
74	2320	384
85	1910	395
100	1770	410
119	1620	429
134	1500	444

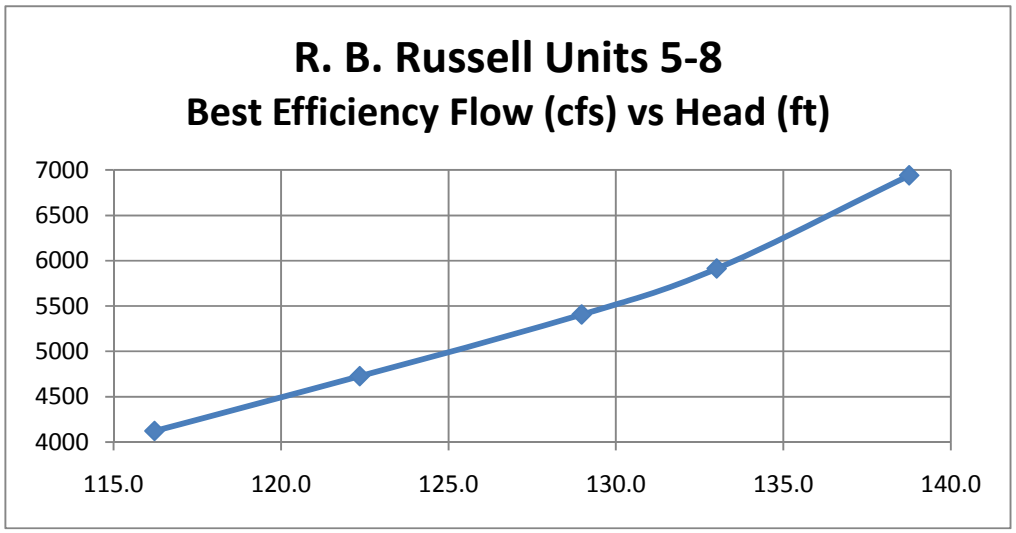


15.3 Richard B. Russell Units 5-8

These turbines were designed to operate satisfactorily over a net head range from 162 feet down to 139 feet. There is no reason to believe the turbines will not continue to generate in an acceptable manner at some heads lower than 139 feet. Continuing to operate the turbine while generating power at or near best efficiency should be possible down to a forebay level of 430 FMSL. This would result in a net head on the turbine of approximately 117 ft. (assuming a tailwater elevation of 312 FMSL and an intake head loss of one foot). When generating below a forebay level of 430 FMSL, air-entraining vortices in the intake are predicted to begin to form which may cause the turbine to run unacceptably rough.

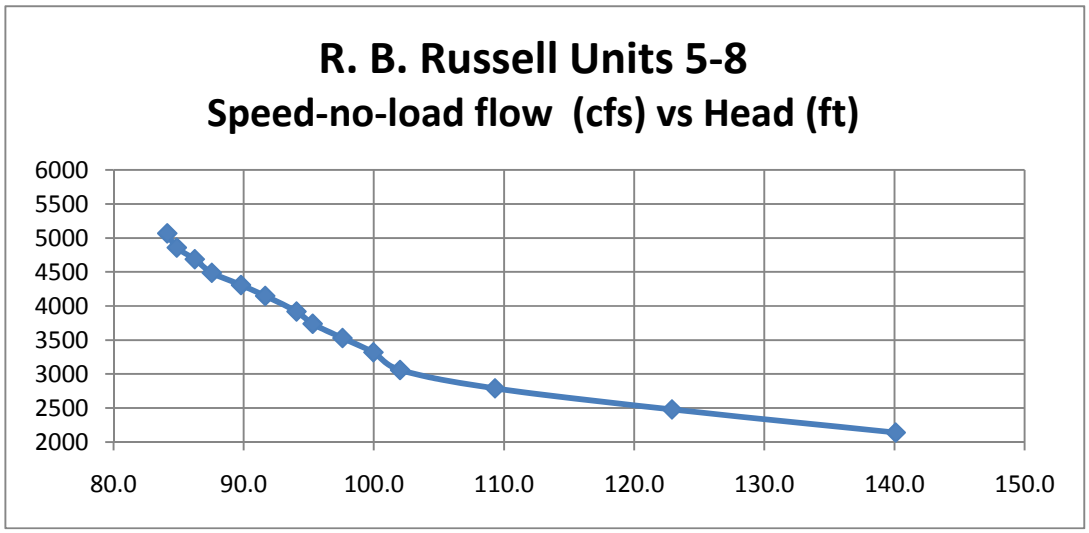
R. B. Russell Units 5-8 Best Efficiency Generation Performance			
Head (ft)	*Power (MW)*	*Q (cfs)*	*Forebay (FMSL)*
116	29	4120	427
122	36	4730	433
129	46	5410	440
133	55	5910	444
139	72	6940	450





Operating the turbine in a speed-no-load condition should be possible at all forebay elevations down to 415 FMSL where again air-entraining vortices are predicted to commence. A forebay level of 415 FMSL would result in a net head across the turbine of 103 feet.

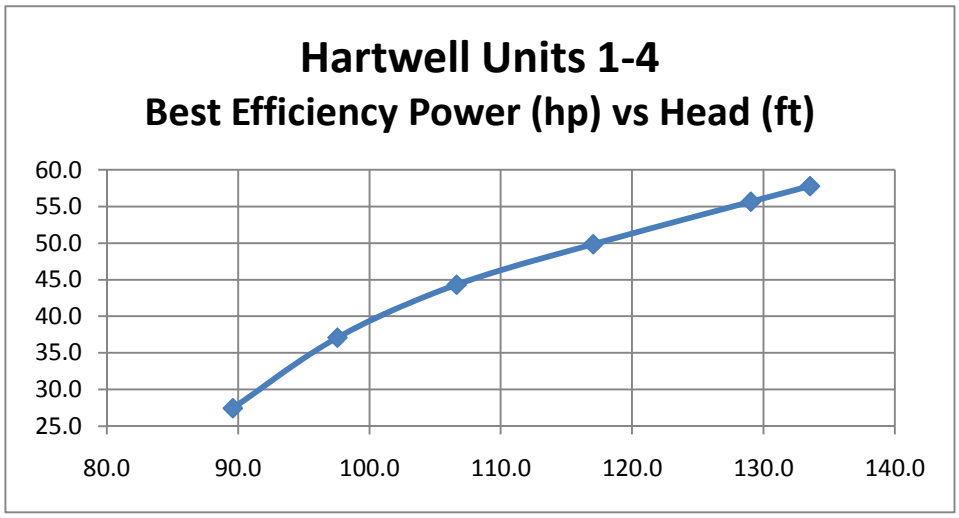
R. B. Russell Units 5-8 Speed-no-Load Performance		
Head (ft)	*Flow (cfs)*	*Forebay (FMSL)*
84	5070	394
85	4860	395
86	4690	396
88	4490	398
90	4310	400
92	4150	402
94	3920	404
95	3740	405
98	3530	408
100	3320	410
102	3060	412
109	2790	419
123	2480	433
140	2140	450

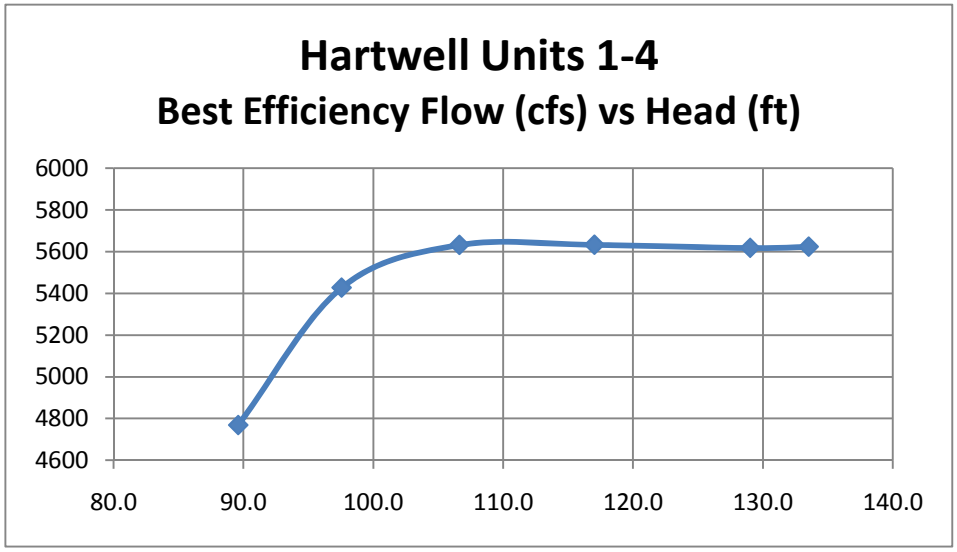


15.4 Hartwell Units 1-4

No turbine model data was available to predict unit performance. The model data for Unit 5 was used to predict performance of Units 1-4. These turbines were designed to operate satisfactorily over a net head range from 187 feet down to 144 feet. There is no reason to believe they will not continue to operate in an acceptable manner at some heads lower than 144 feet. Continuing to operate the turbine while generating power at or near best efficiency should be possible down to a forebay level of 596 FMSL. This would result in a net head on the turbine of approximately 122 ft. (assuming a tailwater elevation of 473 FMSL and an intake head loss of one foot). When generating below a forebay level of 596 FMSL, air-entraining vortices in the intake are predicted to begin to form which may cause the turbine to run unacceptably rough.

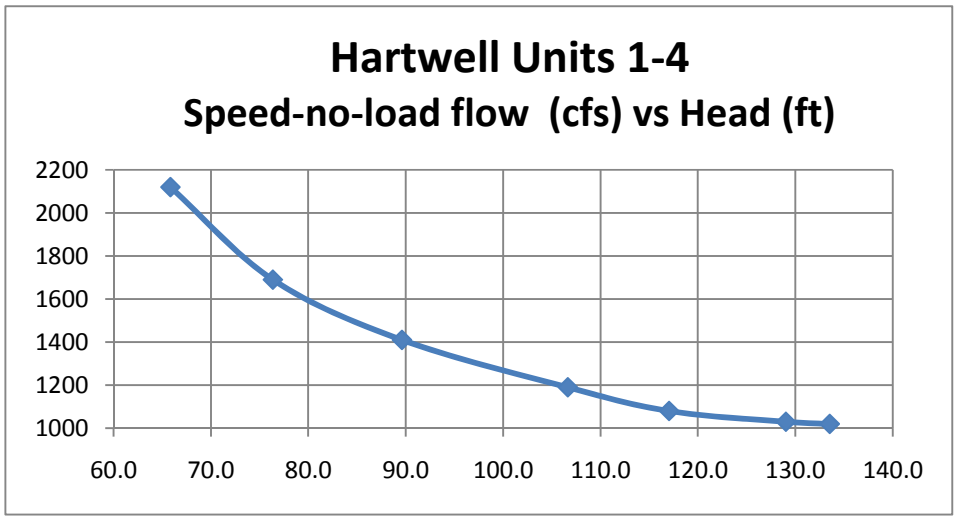
Hartwell Units 1-4 Best Efficiency Generation Performance			
Head (ft)	*Power (MW)*	*Q (cfs)*	*Forebay (FMSL)*
90	27	4770	564
98	37	5430	572
107	44	5630	581
117	50	5630	591
129	56	5620	603
134	58	5620	608





Operating the turbine in a speed-no-load condition should be possible at all forebay elevations down to 574 FMSL where again air-entraining vortices are predicted to commence.

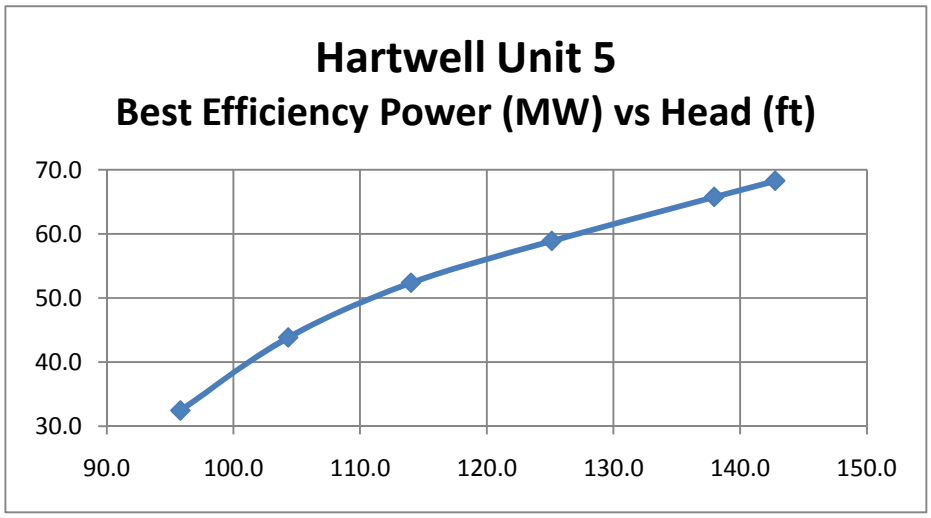
Hartwell Units 1-4 Speed-no-Load Data		
Head (ft)	*Flow (cfs)*	*Forebay (FMSL)*
66	2120	539
76	1690	549
90	1410	563
107	1190	580
117	1080	590
129	1030	602
134	1020	607

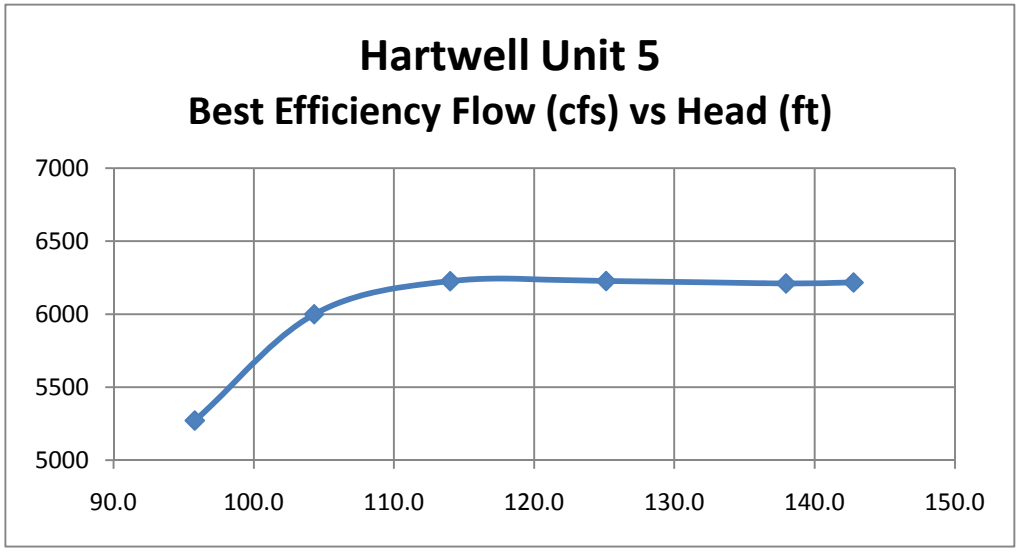


15.5 Hartwell Unit 5

This turbine was designed to operate satisfactorily over a net head range from 187 feet down to 143 feet. There is no reason to believe it will not continue to operate in an acceptable manner at some heads lower than 143 feet. Continuing to operate the turbine while generating power at or near best efficiency should be possible down to a forebay level of 591 FMSL. This would result in a net head on the turbine of approximately 117 ft. (assuming a tailwater elevation of 473 FMSL and an intake head loss of one foot). When generating below a forebay level of 591 FMSL, air-entraining vortices in the intake are predicted to begin to form which may cause the turbine to run unacceptably rough.

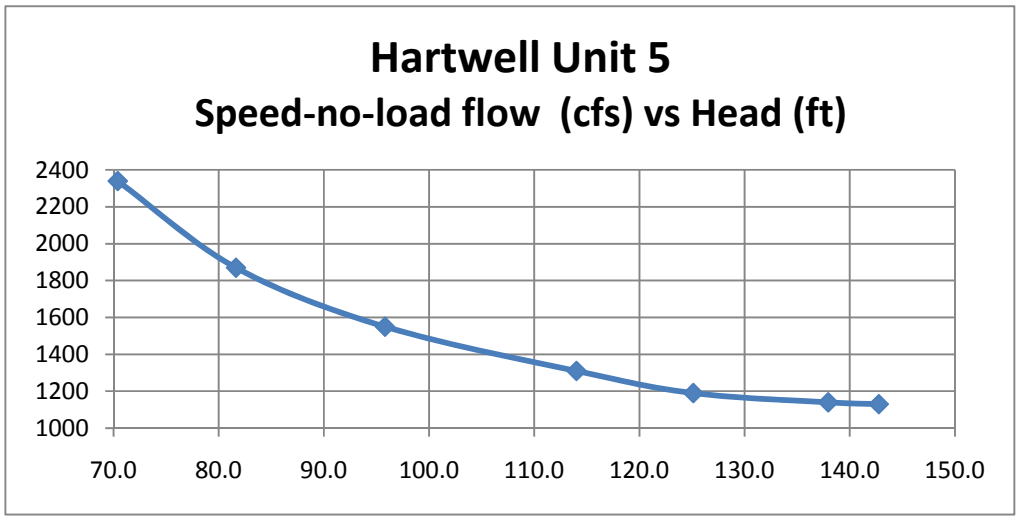
Hartwell Unit 5 Best Efficiency Generation Performance			
Head (ft)	*Power (MW)*	*Q (cfs)*	*Forebay (FMSL)*
96	32	5270	570
104	44	6000	578
114	52	6230	588
125	59	6230	599
138	66	6210	612
143	68	6220	617





Operating the turbine in a speed-no-load condition should be possible at all forebay elevations down to 573 FMSL where again air-entraining vortices are predicted to commence.

Hartwell Unit 5 Speed-no-Load Performance		
Head (ft)	*Flow (cfs)*	*Forebay (FMSL)*
70	2340	543
82	1870	555
96	1550	569
114	1310	587
125	1190	598
138	1140	611
143	1130	616



16.0 Summary of Planned Operation at Extreme Low Forebay Levels

Shown below is a table of various minimum forebay levels which should be used for planning purposes for powerhouse operating guidelines to use the turbines to pass minimum flows during drought conditions. The data shown is a summary of the data provided in paragraphs 11.1 through 11.5 above. At forebay levels above "Design", the turbines will be operating normally within their design net head range. At forebay levels between "Design" and "Generation", the turbines should be operated in the generating mode at the turbine's best efficiency point. At forebay levels between "Generation" and "Speed-no-Load", the turbines should be operated in speed-no-load mode. At forebay elevations lower than those listed under "Speed-no-Load", water passage should be done using other means such as the sluice gates.

Summary of Operations at Various Forebay Levels					
		Minimum Forebay Level (FMSL)			Assumed Tailwater level
Powerhouse	*Units*	*Design*	*Generation*	*Speed-no-Load*	(FMSL)
G. Strom Thurmond	1-7	312	294	275	184
R. B. Russell	1-4	470	434	418	310
R. B. Russell	5-8	470	430	415	310
Hartwell	1-4	625	596	574	473
Hartwell	5	625	591	573	473

The table above is based upon *predicted unit performance* and should be used for planning purposes only. If the forebay levels actually do drop below their design values, the determination of when to change modes should be made by powerhouse O&M personnel based upon observed unit behavior. Also, if the unit runs smoother (when generating) at a different power output, it should be operated there.

APPENDIX K

LIST OF PREPARERS

LIST OF PREPARERS

Larry Olliff Biologist	USACE Planning - Environmental 29 years USACE
William Bailey Physical Scientist	USACE Planning 29 years USACE
Stan Simpson Water Manager	USACE Engineering - Water Management 27 years USACE
Jason Ward Water Manager	USACE Engineering - Water Management 8 years USACE

APPENDIX L

PUBLIC NOTICE

DEPARTMENT OF THE ARMY
SAVANNAH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 889
SAVANNAH, GEORGIA 31402-0889

REPLY TO
ATTENTION OF:

June 14, 2011

Planning Division

JOINT PUBLIC NOTICE
US Army Corps of Engineers, Savannah District,
and the
Georgia Department of Natural Resources, Coastal Resources Division
and the
South Carolina Department of Health and Environmental Control Office of Ocean and Coastal Resource Management

TO WHOM IT MAY CONCERN:

SUBJECT: Notice of Availability of a Draft Environmental Assessment (EA) and Draft Finding of No Significant Impact (FONSI) for a modification to the US Army Corps of Engineers' Savannah River Basin Drought Contingency Plan (SRBDCP) on the Savannah River in Georgia and South Carolina.

Notice of the following is hereby given:

a. Pursuant to the National Environmental Policy Act of 1969, notice is hereby given that the US Army Corps of Engineers, Savannah District proposes a modification to the March 1989 SRBDCP, as revised.

b. The Savannah District announces the availability to the public of a Draft EA and Draft FONSI concerning the action. Copies of the Draft EA and unsigned FONSI can be obtained from the following website: http://www.sas.usace.army.mil/planning/ or by calling Larry Olliff at (912)652-5690.

c. Written statements regarding the Draft EA and FONSI for the proposed action will be received at the Savannah District Office until

12 O'CLOCK NOON, July 14, 2011

from those interested in the activity and whose interests may be affected by the proposed action.

PROJECT DESCRIPTION: The proposed action consists of a modification to the 1989 SRBDCP. Average daily releases from J. Strom Thurmond (JST) Dam would be reduced from 3,600 to 3,100 cubic feet per second (cfs) during the period 1 November through 28 February, when the Corps' reservoirs on the Savannah River are in Level 4 drought conditions. The action would retain the major components of the 1989 SRBDCP and adjust one feature (discharge during winter) to proactively manage outflow from those Corps projects.

Alternatives to the Proposed Action were developed as part of the planning process. The alternatives that were considered were as follows:

a) No Action Alternative (Continue with the 1989 SRBDCP as updated in 2006 which includes an average discharge from J. Strom Thurmond (JST) Dam of 3,600 cfs for drought level 4.)

b) Alternative 1 (Selected Alternative): Retain the major components of the 1989 SRBDCP and adjust one feature. If Level 4 drought conditions exist, the daily average release at Thumond Dam would be adjusted from 3,600 cfs to 3,100 cfs during the period 1 November through 28 February.

AUTHORIZATIONS REQUIRED FROM THE STATE OF GEORGIA:

Coastal Zone Consistency: Savannah District has evaluated the proposed project and believes it is consistent with the Georgia Coastal Zone Management Program to the maximum extent practicable. The District will submit its evaluation to the Georgia Department of Natural Resources, Coastal Resourses Division in Brunswick, Georgia, who administers that program.
The State will review the proposed action and determine whether it concurs that the proposed project is consistent with the State's Coastal Zone Management Program to the maximum extent practicable. Any person who desires to comment or object to Georgia Coastal Zone Management Consistency Certification must do so in writing within 30 days of the date of this notice to the Federal Consistency Coordinator, Georgia Department of Natural Resources, Coastal Resources Division, Suite 300, One Conservation Way, Brunswick, Georgia 31520-8687 and state the reasons or basis for the objections.

AUTHORIZATION REQUIRED FROM THE STATE OF SOUTH CAROLINA:

Coastal Zone Consistency: Savannah District has evaluated the proposed project and believes it is consistent with the South Carolina Coastal Zone Management Program to the maximum extent practicable. The District will submit its evaluation to the South Carolina Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management in Charleston, South Carolina, who administers that program. The State will review the proposed action and determine whether it concurs that the proposed project is consistent with the State's Coastal Zone Management Program to the maximum extent practicable. Any person who desires to comment or object to South Carolina Coastal Zone Management Consistency Certification must do so in writing within 30 days of the date of this notice to the South Carolina Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management; 1362 McMillan Avenue; Suite 400, Charleston, South Carolina 29405 and state the reasons or basis for the objections.

DEPARTMENT OF THE ARMY EVALUATION:

Environmental Assessment: Savannah District has prepared a Draft Environmental Assessment (EA) and found that an Environmental Impact Statement will not be required for this action. The Draft EA is being coordinated concurrently with this Notice to Federal and State natural resource agencies for review and comment. No wetlands would be filled, but riparian wetlands could be temporarily impacted by reduced river flows. No discharge of dredged or fill material into waters of the US is included in the proposed action, so no evaluation is required under Section 404 of the Clean Water Act.

Threatened and Endangered Species: The District reviewed the most recent information on Federally-listed endangered or threatened species and determined that the proposed action may effect, but is not likely to affect shortnose sturgeon, manatee, and wood stork. This proposed action is being coordinated with the US Fish and Wildlife Service and the National Marine Fisheries Service under Section 7 of the Endangered Species Act.

Cultural Resources: In accordance with the National Historic Preservation Act (P.L. 89-655, as amended) and 36 CFR, Part 800, Savannah District has evaluated the proposed action's potential effect upon historic properties. The District has determined the proposed action will have no adverse effect upon historic properties and has initiated consultation with the Georgia and South Carolina State Historic Preservation Officers and eighteen Native American Tribes.

Essential Fish Habitat: Savannah District evaluated the proposal's potential effects on Essential Fish Habitat. The project's effects would be of relatively short duration. As a result, the District believes the proposed action would not produce long term effects on these valuable coastal habitats that warrant

mitigation. The District is coordinating the proposed action with the National Marine Fisheries Service under the Magnuson-Stevens Fishery Conservation and Management Act.

Coastal Zone Consistency: Savannah District evaluated compliance of the proposed action with both the Georgia and South Carolina Coastal Management Programs (CMP). The District believes that the proposed action is consistent with the CMPs to the maximum extent practicable. The District will submit the EA to the Georgia Department of Natural Resources, Coastal Resources Division in Brunswick, Georgia and to the South Carolina Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management in Charleston, South Carolina.

Public Interest Review: The Decision whether to proceed with the project as proposed will be based on an evaluation of the probable impact, including cumulative impacts, of the proposed activity on the public interest. That decision will reflect the national concern for both the protection and use of important resources. The benefits which reasonably may be expected to accrue from the proposal will be balanced against its reasonably foreseeable detriments. All factors that may be relevant to the proposal will be considered, including the cumulative effects thereof. Among these are conservation, economics, aesthetics, general environmental concerns, wetlands, historic properties, fish and wildlife, flood hazards, flood plains, land use, navigation, shoreline erosion/accretion, recreation, water supply and conservation, water quality, energy needs, safety, food and fiber production, mineral needs, consideration of property ownership, environmental justice, and, in general, the needs and welfare of the people.

Consideration of Public Comments: The US Army Corps of Engineers is soliciting comments from the public; Federal, State, and local agencies and officials; Native American Tribes; and other interested parties in order to consider and evaluate the impacts of the proposed activity. Any comments received will be considered by the US Army Corps of Engineers in its deliberations on this action. To make this decision, comments are used to assess impacts to endangered species, wetlands, historic properties, water quality, general environmental effects, socioeconomic effects, and the other public interest factors listed above. Comments are used in the preparation of the Environmental Assessment pursuant to the National Environmental Policy Act. Comments are also used to determine the need for a public hearing and to determine the overall public interest of the proposed activity.

Comment Period: Anyone wishing to comment to the Corps on this proposed action should submit comments no later than the end of the comment period shown in this notice, in writing, to the US Army Corps of Engineers, Attn: PD, Savannah District, Savannah, Georgia 31402-0889, by FAX to 912-652-5787, or by emailing the comments to the following address: CESAS-PD@usace.army.mil.

Any person who desires to comment or object to Georgia Coastal Zone Management Consistency Certification must do so in writing to the Georgia Department of Natural Resources, Coastal Resources Division, Federal Consistency Coordinator, Suite 300, One Conservation Way, Brunswick, Georgia 31520-8687.

Any person who desires to comment or object to South Carolina Coastal Zone Management Constency Certification must do so in writing to the South Carolina Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management; 1362 McMillan Avenue; Suite 400, Charleston, South Carolina 29405.

William G. Bailey
Chief, Planning Division
Savannah District
US Army Corps of Engineers

APPENDIX M

AGENCY RESPONSE LETTERS