Duke Energy Carolinas, LLC
Response to Comments on
NPDES Permit Application
William States Lee III Nuclear Station
SC0049140
December 22, 2011

Comments on Volume I

1) Part III PER Page 19 - What volume of wastewater is expected to be generated from the Steam Generator Blowdown System when the steam generators and feedwater piping is drained?

Duke Energy Response:

The volume of wastewater generated from the Steam Generator Blowdown System (BDS) when both steam generators are drained is approximately 90,000 gallons. The feedwater piping does not need to be drained to effect drainage of the steam generators. However, if the main and startup feedwater lines are both drained from the steam generator to the nearest point of isolation, roughly an additional 4,000 gallons of wastewater would be generated.

2) Part VI Mixing Zone Request Page 3 – What is the likelihood that hydroelectric power turbine units 5 and 6 may become operable?

Duke Energy Response:

Upgrade of Units 5 and 6 for future operations is not economically justifiable at this time. Therefore, Duke Energy has no plans to return these two units to service.

3) Part VI Mixing Zone Request Pages 7, 10, and 14 – Was the temperature rise modeling referred to on page 7 conducted at worst case winter conditions? The results of research by Dr. Roberts reported on page 10 included temperature rise modeling for winter conditions, but this research was reportedly for the purpose of optimizing the diffuser design, not to address NPDES mixing zone requirements. In addition, Dr. Roberts's research was based on a discharge temperature of 91°F, not 95°F (p.16). Please provide information showing that the temperature rise criterion of 5°F has been considered at worst-case winter conditions.

Duke Energy Response:

The maximum delta T occurs during the colder ambient months. During colder months the discharge will be less than 90°F. An additional model run was conducted for winter conditions to confirm that the 90°F plume presented in the mixing zone request is bounding. The model used a 26°F delta temperature, which was the largest delta temperature value provided in the Roberts report. The results of this model run are attached (Attachment 1). In summary, the greater than 5°F delta plume is very small and smaller than the projected greater than 90°F plume. Attachment 1 replaces the mixing zone report included in Volume I

of the August 2011 NPDES permit application for Part VI. Specifically, changes were made on pages i, ii, 14, 17, 18, 20, 21 and 22. Changes were also made to Figure 18 in the attached report.

Comments on Volume II

4) Page vii and 3-22 – Under what conditions is the maximum consumptive water use expected to occur, and at what frequency is the normal consumptive water use expected to be exceeded? Why not consider 483+63=546 cfs (rather than 483+55=538 cfs) as the Broad River flow at which water from Ponds B and C begin to be used? If the cooling towers are operating in a mode of maximum consumptive water use, and the river flow is 538 cfs, only 475 cfs, not 483 cfs, would be available to downstream users.

Duke Energy Response:

Consumptive water use varies monthly due to cooling tower evaporation with the summer months being the highest. The following table from Duke Energy's response to NRC RAI 216 shows the monthly consumptive water use. Under the Lee Nuclear Station water management plan, the station would not withdraw any consumptive water from the Broad River if the flow is 483 cfs or less. The station would only withdraw consumptive water from flows above 483 cfs. If the flow in the Broad River is less than required to maintain the 483 cfs flow and fully supply the consumptive needs of the station, the station would withdraw the flow above 483 cfs for consumptive needs and withdraw additional consumptive water needs from the drought contingency Ponds (Ponds B and C).

Broad River Monthly Threshold Flows to Support Withdrawal of All Consumptive Needs from the Broad River (Not Considering Pond Evaporation)

Month	Broad River Minimum Low Flow cfs	Total Station Consumptive 2 Units cfs	Broad River Threshold Flows cfs
Jan	483	50.9	533.9
Feb	483	52.1	535.1
Mar	483	55.2	538.2
Apr	483	58.2	541.2
May	483	60.1	543.1
Jun	483	61.9	544.9
Jul	483	63.0	546.0
Aug	483	62.3	545.3
Sep	483	60.4	543.4
Oct	483	57.4	540.4
Nov	483	54.6	537.6
Dec	483	51.9	534.9

5) Page 3-2 – Provide information that demonstrates that four cycles of concentration (or possibly two cycles of concentration during periods of high turbidity) is the maximum acceptable level of cycles of concentration. This information should demonstrate that higher cycles of concentration are not acceptable.

Duke Energy Response:

Four cycles represents the maximum acceptable concentration level. The Broad River is subject to total suspended solids (TSS) excursions, especially when the watershed receives large amounts of precipitation. These TSS excursions are accommodated in the Lee Nuclear Station design by routing withdrawals from the Broad River into Make-Up Pond A, where settling processes decrease suspended solids. Also, Duke Energy plans to use a cooling tower fill that can tolerate operation at higher TSS levels. The Lee Nuclear Station is designed for continuous operation for an 18 month fuel cycle, and the recirculating water cooling towers cannot be shut down to remove solids accumulation in the tower fill or basin. The maximum limit of four cycles of concentration ensures TSS values remain in a range that supports reliable recirculating water cooling tower operation.

The recirculating water cooling tower blowdown is also used to dilute wastewater treated by the Liquid Radwaste System before release to the environment. This dilution ensures that radiological doses to individuals offsite are minimized as discussed in Subsection 5.2.3.3 of the Lee Nuclear Station Environmental Report. A minimum blowdown flow of 6000 gpm is

required from the circulating water cooling towers in each unit to provide this dilution. Limiting cooling tower operation to four cycles of concentration ensures that minimum dilution flow is maintained, including a prudent design margin.

6) Page 3-2 – The minimization of evaporation and drift is directly related to the requirement that make-up flows be minimized. Provide information that demonstrates that the recirculating cooling water system and service water system will be operated in a manner such that evaporation and drift will be minimized.

Duke Energy Response:

Evaporation from the recirculating water and service water cooling towers depends on the heat load from the power plant and ambient temperature conditions. The plant heat load is prescribed by the selected power plant design; ambient temperature conditions are beyond permittee control. Other than reducing the plant's generation output, there are no operational controls available to reduce these heat loads and minimize evaporation.

Regarding losses associated with cooling tower drift, the cooling towers in the recirculating water and service water systems will be equipped with drift eliminators representing the best available technology to minimize water loss. The drift eliminators in recirculating water cooling towers reduce water loss associated with drift to 0.0005% of recirculating water flow.

7) Page 3-14 – The justification for the request for alternative requirements based on significant adverse impact to local water resources (other than impingement or entrainment) appears to be based primarily on the assertion that compliance with the 5% proportional flow rule would "prevent some waterbodies from maintaining minimum flows during extended drought years." During drought conditions, minimum flows may not be maintained for natural reasons. There may be significant adverse impact to local water resources as a result of natural reasons. The justification for the alternative requirement must quantify the additional incremental significant adverse impact to local water resources resulting from compliance with the 5% proportional flow rule. (It would seem that "compliance" for the Duke Lee Nuclear Station would be an average withdrawal rate of 78 cfs.)

Duke Energy Response:

Kozlowski (1988, South Carolina Instream Flow Study-Phase II) noted that low flow events in flowing waters occur naturally, in response to interannual variability in precipitation totals, and such events may impact streams. Water use strategies that withdraw, divert, or withhold water from streams during low flow periods can increase the frequency, duration, and severity of such impacts. Principal instream uses to consider when evaluating low flow impacts include, among others, survival and propagation of aquatic biota, assimilation of

discharged wastewater, protection of water quality, recreational activities, aesthetic appeal of water bodies, and preservation of flood plain wetland and riparian vegetation (SCDNR 2009, South Carolina Water Assessment). In place of the Track I proportional flow requirement, which does not include provisions for withdrawal restrictions under low flows, Duke Energy has proposed to restrict withdrawal during low flow periods, by implementing its requested alternative requirement, to ensure significant adverse impacts to the water resource do not occur as a result of station operations during these events.

Duke Energy performed hydrologic modeling of the Broad River to compare the impact of the two withdrawal strategies (Track I proportional flow requirement option and the alternative requirement option) on the frequency and duration of low flow events against baseline conditions (no withdrawals by Lee Nuclear Station). See Attachment 2. The modeling demonstrates that compliance with the Track I proportional flow requirement without regard to instream flow levels during low flow periods results in a nearly 39% increase in the number of days that river flow is below 483 cfs over the 85 year period of record and an approximately 25% increase in the number of days that river flow is below 483 cfs over the previous ten years (Attachment 2, Table 1). Under Duke Energy's proposed alternative requirement, there are no additional days over baseline conditions when the river flow is below 483 cfs from operation of the station.

Moreover, droughts have a disproportionate impact on the aquatic resource as flow decreases. The modeling illustrated that the additional consumptive withdrawal following a Track I compliance option with no restrictions resulted in a significant increase in the duration and magnitude of the more extreme low flow conditions, including a four-fold increase in the number of days below 100 cfs over the last ten years (Attachment 2, Figure 1). Conversely, no changes above baseline conditions were projected from station operations using Duke Energy's proposed alternative requirement option and utilization of the drought contingency storage ponds and refill outside spawning periods and during periods of higher flow in the river. If the station was operating with an additional consumptive withdrawal following a Track I compliance option with no restrictions in low flow periods the modeled downstream river flows during the August 2002 drought would have dropped to 47 cfs (estimated dam leakage for that date) for a five day period and a large part of the Ninety-Nine Islands Reservoir surface area would have gone dry (Attachment 2, Figure 2, Table 3). In contrast, under natural conditions, the river dropped to 47 cfs only one day and quickly recovered above 100 cfs, was back above 200 cfs within four days, and reservoir surface area remained at normal levels (Attachment 2, Table 2). These modeling results are based solely on bathymetry from late 2007 and the historical flows and do not account for future unknowns associated with climate variability or future uses.

The expected environmental impacts of additional consumptive water withdrawals following a Track I compliance option on the aquatic resources during these extreme low flow periods would be significant. Some areas below the dam would begin to form semi-isolated pools with limited interconnecting flow. See Attachment 2, Figure 2. These low flow periods correlate to the warmest time of the year further compounding the impacts. Significant adverse impacts associated with the increased magnitude and duration of these low flow

periods due to the project withdrawing additional water for consumptive needs under the Track I option would include, among others, higher temperatures, reduced dissolved oxygen, restricted fish travel, reduced wastewater assimilation capacity, restricted recreational use opportunities such as fishing and canoeing, and negative aesthetic impacts to the scenic river and the reservoir. Such impacts are contrary to the objectives of existing state law and the FERC license. No such project related impacts occur under Duke Energy's proposed alternative requirement.

8) Page 3-15 – Under Option 1, why would 98 cfs be continuously withdrawn when an average of only 78 cfs is needed?

Duke Energy Response:

98 cfs was the maximum that could be withdrawn (5% proportional flow rate). 98 cfs was not continuously withdrawn; the water model only withdrew from the Broad River what was needed by the station and to make up for pond evaporation. This demand varied by month primarily due to cooling tower evaporation. The pond evaporation also varied monthly but this demand is small.

9) Provide information that justifies the 206 cfs capacity of the drought contingency portion of the river intake as being no greater than is justified by the wholly out of proportion costs, or the significant adverse impacts to local energy markets, local air quality, or local water resources. One possible way to justify the capacity of the drought contingency section of the river intake would be to use the water model spreadsheet at lower drought contingency section capacities to demonstrate lower capacities are not sufficient.

Duke Energy Response:

The capacity of the drought contingency refill was based on the historical droughts to date and consideration for the uncertainty of future droughts. After analysis of the back to back drought years of 2007 and 2008, the refill pumps were sized to refill the ponds by the end of the year. This ensures the station is prepared in the event that the following year is also a drought year. Refill of the ponds by December 31 allows sufficient margin to accommodate unknown magnitudes of future droughts. This is critical in back to back drought years, such as that seen in 2007-08, since if the refill extends into the next year the ponds may not get refilled before the spawning season (March – June). The refill pumps will not be operated during the spawning season and the spawning season does not end until June 30. Droughts typically start in May. With the ponds not being full going into a drought, the station runs the risk of having to shut down the nuclear units.

Listed below are the dates when the ponds would have been refilled based on modeling of 206 cfs (200 cfs for refill and 6 cfs for screen wash) and a potential drawdown of 30 ft in both Ponds B and C.

Drought Year	Date Ponds Refilled
2002	11/6/2002
2007	1/3/2008
2008	12/24/2008

In addition, Appendix L is included to further demonstrate that the requested alternative requirement is no less stringent than justified by the wholly out of proportion cost or significant adverse impacts as outlined in §125.85(a)(3). The sole intent of the Track I proportional flow requirement is to ensure entrainment is maintained at acceptable levels. (66 Fed Reg 65301). Appendix L demonstrates that the requested alternative requirement results in less entrainment than the Track I proportional flow requirement.

10) Page A-2 and A-6 - What is the available volume of Pond C based on a 30-foot drawdown? (i.e. the volume contained in the uppermost 30 feet of the pond) (Page 7 of Appendix G IV Enclosure 2 of Volume II of the application shows the 30-foot drawdown volume of Pond B as 3156 acre-feet, and the 45-foot drawdown capacity of Pond C as 17,493 acre-feet.)

Duke Energy Response:

A 30 ft drawdown on Pond C would provide 13,684 ac-ft of supplemental water.

11) Page A-9 - Under what conditions is the maximum blowdown of 62 cfs expected to occur, and at what frequency is the average blowdown of 18 cfs expected to be exceeded? Page 13 of the PER in Part III of Volume 1 states that when the cooling towers operate at two cycles of concentration, the estimated blowdown flow is 28,023 gpm (62 cfs), but how often and for what length of time is this expected to occur? What will be the source of cooling water under maximum blowdown conditions?

Duke Energy Response:

The recirculating cooling water system remains the primary heat sink during maximum blowdown conditions. Blowdown would only be increased to control suspended solids in the cooling towers when the Broad River experiences TSS excursions. These excursions occur when the watershed receives large amounts of precipitation and are relatively short in duration.

Water withdrawn from the Broad River is stored in Make-Up Pond A before it is utilized by the recirculating cooling water towers, so settling processes in the pond are expected to limit and moderate TSS excursions. The historical record of TSS data on the Broad River in the vicinity of the Lee Nuclear Station does not identify any occurrences where TSS conditions would have required the cooling towers to operate at two cycles of concentration. As a result, operation at two cycles of concentration is anticipated to be a rare occurrence, with a duration of less than two days. The two cycles of concentration case was developed as a limiting design value, and utilized to size system piping and control valves. Considering that withdrawals from the primary section of the river intake structure are limited to 5% proportional flow rate, a portion of the make-up water required to support maximum blowdown conditions under two cycles of concentration will be provided by drought contingency Ponds B and C.

12) Page A-9 – A-11 – For the river and pond intakes, what is the expected capacity of the pumps at actual design conditions?

Duke Energy Response:

Design capacities for river and pond intake pumps are summarized below.

	Pump Type	Pump Capacity		Number of Pumps		Intake Flow	
				Operating	Back-up		
		cfs	gpm			cfs	gpm
Plant River Water Pumps	Variable Speed	46.8	20,980	2	2	93.5	41,960
Screen Wash Pumps	Constant Speed	4.5	2,000			4.5	2,000
Total Plant intake flow						98.0	43,960
Refill Pumps	Variable Speed	50.2	22,500	4	0	200.6	90,000
Screen Wash Pumps	Constant Speed	5.6	2,500			5.6	2,500
Total Refill intake flow						206.2	92,500
Pond A Pumps	Constant Speed	33.4	15,000	4	2	133.7	60,000
Screen Wash Pumps	Constant Speed	4.5	2,000			4.5	2,000
Total Refill intake flow						138.2	62,000
Pond B Main Pumps	Variable Speed	22.3	10,000	3	1	66.9	30,000
Pond B Ancillary Pump(1)	Constant Speed	13.4	6,000	1	0	13.4	6,000
Pond C Pumps	Constant Speed	22.3	10,000	3	0(2)	66.9	30,000
Table Notes							
1) Ancillary Pump will not be run at the same time as main pumps							
2) Additional Backup Pump is being considered							

13) Page A-11 – By what means is water transported from Pond A to Pond B?

Duke Energy Response:

Figure A-12 shows a pipeline that runs between Ponds A and B. This pipeline will be used to transport water from Pond B to Pond A to provide supplemental water and will also be used to send water from Pond A to Pond B to make up for evaporation losses of Pond B and to slowly refill this pond if the flows in the Broad River are not high enough to run the refill pumps.

14) Page A-11 – How will Ponds B and C be refilled to make up for evaporation from the ponds?

Duke Energy Response:

Figure A-12 shows a pipeline that runs between Ponds A and B. This pipeline will be used to send water from Pond A to Pond B to make up for evaporation losses of Pond B.

In order to refill Pond C for evaporation, the water will be pumped into Pond A, then into Pond B and finally to Pond C. The ancillary pump on Pond B will be used to pump water from Pond B to Pond C to make up for evaporation loss on Pond C. Figure A-12 shows the pipeline from Pond B to Pond C.

15) Page A-11 and Appendix C Passive Screen Calculations Pages 12 and 13 – The application must specify a final design for the Pond B and Pond C cylindrical screens (e.g. length, diameter, mesh size, and screen type – coarse or fine).

Duke Energy Response:

For both the traveling screens (River Intake and Pond A Intake) and passive screens (Ponds B and C Intakes), Duke Energy has calculated both the minimum size fine mesh screens and the minimum size coarse mesh screens required to maintain through-screen velocity less than 0.5 ft/sec (Attachment 3). Duke Energy is still reviewing operating experience throughout the industry and additional supplier information prior to finalizing a design decision on mesh type to use in the traveling and passive screens. Attachment 3 replaces Appendix C in Volume II of the August 2011 NPDES permit application.

16) Page A-12 – What design elements of the Pond A intake are not finalized?

Duke Energy Response:

A design study is underway that is targeted for completion in January 2012. This study is re-evaluating the sizing of the pumps for Pond A in order to efficiently meet the water needs of the station.

17) The drought contingency section of the river intake includes four 50 cfs fixed drive pumps. By what means will the flow rate to Ponds B and C be controlled? In incremental steps of 50 cfs - 50, 100, 150, 200? (Page A-10 states that the drought contingency pumps will be fixed speed, but page 4 of Appendix B states that the drought contingency pumps will be variable speed.)

Duke Energy Response:

The refill pumps are variable speed pumps. Page A-10 incorrectly stated they were fixed speed. Refill pumps will be started and variable flow rate controlled as the overall Broad River flow will allow, but these pumps would only be used to refill drought contingency Ponds B and C after a drawdown due to a low flow event.

18) Page vii and A-13 – The normal operation of the Pond A intake will withdraw 137 cfs, correct? 33x4 + 5 = 137.

Duke Energy Response:

Page A-13 states that normal operation of the Pond A intake pumps will withdraw 139 cfs (actual pump capacity is 33.4 cfs but this value was rounded down to 33 cfs when reported on page A-10 [33.4 x 4 + 5 = 139 cfs]). Average flow required to support station operation is 73.6 cfs with 60 cfs being recirculated back to Pond A.

As mentioned in item 16, a design study is underway that is targeted for completion in January 2012. This study is re-evaluating the sizing of the pumps for Pond A in order to efficiently meet the water needs of the station.

19) Page A-14 – If Broad River flow is 538 cfs, and the primary river intake withdraws 98 cfs, only 463 cfs, not 483 cfs, will be available to downstream users. Please clarify the second sentence of the last paragraph.

Duke Energy Response:

The 538 cfs is based on average consumptive use of 55 cfs + 483 cfs = 538 cfs. The 23 cfs for screen wash and blowdown will always be withdrawn regardless of flow in the Broad River since these components are not consumed and are returned to the river and do not impact downstream users. In order to withdraw 75 cfs (98 - 23 = 75 cfs) for consumptive use, the flow in the Broad River would need to be 483 cfs + 75 cfs = 558 cfs. If the flow in the Broad River is less than required to maintain the 483 cfs flow and fully supply the consumptive needs of the station, the station would withdraw the flow above 483 cfs for consumptive needs and supply the shortfall from drought contingency Ponds B and C.

20) Appendix A Figures – "Cooling water intake structure" is defined in 40 CFR 125.83 as extending to the point at which water is withdrawn from the surface water. The engineering drawings of the cooling water intake structures must show the intake screens.

Duke Energy Response:

Attachment 4 includes updated Figures A-15, A-16, A-18, A-20, A-21, A-22 and A-23 that include the location of the intake screens for all the intakes for the Lee Nuclear Station project. These figures replace the figures with the same page numbers located in Appendix A in Volume II of the August 2011 NPDES permit application.

21) Appendix B Page 7 – Is the chosen river flow of 2260 cfs for scenario 3 reflective of worst-case conditions? Why not choose a river flow of 746 cfs (483+63+200) as a worst-case flow?

Duke Energy Response:

The river flow of 2260 cfs used for scenario 3 is not reflective of worst-case conditions. This river flow is representative of high flow during the typical refill period of September through December when all four (4) refill pumps would be run as required to refill drought contingency Ponds B and C.

22) Appendix B Page 10 – Please clarify if Figure 4 represents ambient conditions ("Figure 4 provides river flow direction and velocities for ambient river conditions near the intake absent any pumping activity.") or conditions involving pumping at 98 cfs ("It can be seen from Figure 4 that although approximately 43,960 gpm (98 cfs) is removed from the river...)? If Figure 4 represents ambient conditions, please provide a similar figure representing pumping conditions. If Figure 4 represents pumping conditions, please provide a similar figure representing ambient conditions.

Duke Energy Response:

In the August 2011 NPDES permit application submittal, Figure 4 in Volume II Appendix B represents pumping conditions at 98 cfs. Appendix B has been updated to include ambient conditions in the Hydraulic Zone of Influence (HZI) calculations (Attachment 5). New figures are now included to represent ambient conditions. These new figures are: Figure 4, 9 and 12. Other changes to Appendix B are on pages 4, 5, 6 and 7. Attachment 5 should replace Appendix B in the August 2011 NPDES permit application.

With reference to Attachment 3, the cylindrical wedge-wire screens for Ponds B and C have increased in diameter and length, thus increasing the surface area. In general the modeled dimensions will give conservative results relative to the expected results using the new intake dimensions for Ponds B and C. The dimensions of the bays for the intake structure on the river and Pond A have not changed, and although the wetted area of the traveling screens has decreased, this has no effect on the HZI external to the structures.

23) Appendix B – Please provide velocity vector figures for the ambient conditions of Scenarios 2 and 3.

Duke Energy Response:

Updated figures are included in Attachment 5.

24) Appendix C Passive Screen Calculations Page 10 – Please provide justification for the 4% clogging factor for the passive screens as compared to 25% for the traveling screens.

Duke Energy Response:

The 4% clogging factor was based on the ponds being a cleaner environment with less debris and solids. However, as a safety factor the passive screen calculation has been revised to use a 25% clogging factor (Attachment 3).

25) Appendix C Passive Screen Calculations Page 12 - The velocity expected at the Pond C screens appears to be higher than 0.5 feet per second based on the selected screen diameter, selected length, assumed fine mesh size, and assumed clogging percentage.

v=Q/A

$$v = \frac{(30{,}000\ \text{gal/min})(1\ \text{ft}^3/7.48\ \text{gal})(1\ \text{min}/60\ \text{sec})}{(\text{Pi})(8.13\ \text{ft})(5.83\ \text{ft})(1-0.047)(0.4585)(2)} = 0.51\ \text{ft/sec}$$

This also appears to be the case for the Pond C coarse mesh calculation.

$$v = \frac{30{,}000/7.48/60}{(Pi)(6.44)(5.0)(1-0.111)(0.7136)(2)} = 0.52 \text{ ft/sec}$$

(Suggestion: The problem appears to be with Equations 3 and 4 on page 9. Perhaps equation 3 should read $A_{slot} = (1 - m)(A_{tot})$ and Equation 4 read $A_{clog} = (\%\ clogged)(A_{tot})$. Since $A_{tot} - A_{slot} - A_{clog} = A_{vel}$, A_{tot} can be solved as $A_{tot} = A_{vel}/(m - \%\ clogged)$. The same problem appears in Equations 2 and 3 on page 8 of the traveling screen calculations, but the calculated velocity is acceptable because greater margin is built into those calculations. Also, the calculated velocity for the Pond B screens is acceptable because of the margin from using four screens.)

Duke Energy Response:

Attachment 3 provides updated calculations for the traveling and passive screens. These calculations determine the minimum screen sizes for both fine mesh and for coarse mesh required to ensure that through-screen velocity is less than 0.5 ft/sec.

26) Appendix D Page 6 – The thermal stratification model should be run also for the scenario of Pond A receiving water from the Broad River to operate the plant. According to Page 2 of Appendix D, this is the case approximately 97% of the time.

Duke Energy Response:

In Attachment 6, Appendix D has been revised to provide updated figures that represent inflow from the river (Figure 3a) and inflow from Pond B (Figure 3b) to Pond A and then to the station. Figure 3a represents the dominant (approximately 97% of the time) flow condition. In the model supporting Figure 3a, the temperature of the Broad River is applied to flows pumped into Pond A from the river. Figure 3b shows the thermal stratification under the scenario of refilling Pond A from Pond B. Attachment 6 provides an updated report that replaces Appendix D in the August 2011 NPDES permit application for Volume II. Changes to Appendix D include changes to Figures 3a, 3b and also the discussion of these changes are included on page 7 of this report.

27) Page 1-2 – The mean annual flow of the Broad River from 2001 to 2010 is reported as 1956 cfs on page 1-2. According to page A-6, this value is apparently based on the Gaffney Gage (i.e. USGS station 02153500). According to the USGS website, this station does not appear to have daily streamflow data for the period of 2001 to 2010. Please clarify how the mean annual flow was determined. Please explain why the USGS station downstream of the Ninety-Nine Islands Dam (02153551) was not used.

Duke Energy Response:

There is only a 1.5% difference between the mean average flows at the Gaffney gauge (02153500) and the Ninety-Nine Islands Dam gauge (02153551). The Gaffney gauge was used for the following reasons:

- This gauge will be used to determine withdrawal limits for both primary and drought contingency pumps at the river intake structure; therefore, the mean annual flow was determined at this gauge.
- This gauge was also used to determine how often low flow conditions in the Broad River would result in Lee Nuclear Station having to rely on drought contingency Ponds B or C for supplemental cooling water. The gauge closest to the station with the longest flow record should be used.
- There were issues with the gauge below Ninety-Nine Islands not recording the correct flows and the USGS had to relocate the gauge.

Page 3-5 of Volume II, Part VII of the application explains how the flow record from 1926-2010 was developed. Excerpts from this paragraph are included below:

> The U.S. Geological Survey (USGS) gauge used was the Broad River at Gaffney, South Carolina (Gauge No. 2153500), chosen due to its proximity to Lee Nuclear Station. Daily average flows for this gauge were compiled using a combination of actual data from the gauge at Gaffney (1938–1971, 1986–1990) and pro-rated flow data from two upstream USGS gauges on the main stem of the Broad River. The two upstream gauges used were the Broad River near Blacksburg, South Carolina (No. 2153200, 3.1 river miles upstream from the Gaffney gauge), and the Broad River near Boiling Springs, North Carolina (No. 2151500, 16.2 river miles upstream from the Gaffney gauge). For periods where data were not available from the Gaffney USGS gauge, the preference was to use pro-rated data from the Blacksburg gauge. If Blacksburg gauge data were not available, the Boiling Springs gauge was used. Pro-rated flows were calculated using drainage area ratios for the two upstream gauges resulting in an 85-year period of record for the Broad River at the Gaffney gauge location (1926–2010).

The Gaffney gauge has been re-established by USGS and now is reporting discharge data beginning with February 2010.

28) During operation of the river intake, how and at what frequency will the Broad River streamflow be determined? How will the river intake flow rate (for both the primary and the drought contingency sections) be controlled to meet the plan proposed in the alternative requirement request?

Duke Energy Response:

The Gaffney gauge (USGS station 02153500) will be used to determine flow in the Broad River. This gauge will be used to determine the withdrawal of both the primary and drought contingency pumps. The flow will be checked every 24 hours and the pumps will be adjusted based on the average flowrate for the previous 24 hours. The Blacksburg gauge will be used as a backup should the Gaffney gauge not be working. The flows from the Blacksburg gauge would be adjusted for the difference in drainage areas.

29) Appendix L – Because 125.85(a)(2) does not allow the consideration of impingement or entrainment impacts when considering the significant adverse impacts to local water resources in determining whether or not to grant an alternative requirement, this appendix is not relevant to the consideration of an alternative requirement. To the degree Appendix L is relevant as supplementary information, should not the average withdrawal rate of 78 cfs have been used for the Track 1 compliance option rather than the 5% of annual mean flow figure of 98 cfs – the maximum allowable withdrawal under the proportional flow rule?

Duke Energy Response:

Similar to response to technical comment #8, 98 cfs was the maximum that could be withdrawn (5% proportional flow limit). The water model only withdrew from the Broad River what was needed by the station and to make up for pond evaporation. This demand varied by month primarily due to cooling tower evaporation. The pond evaporation also varied monthly but this demand is small. For the case of low flow events, the model withdrew more to refill Pond B when it was used for supplemental flow for the times that the flow in the Broad River was not sufficient. For the case of Lee Nuclear Station continuing to withdraw from the Broad River with no minimum flow limit of 483 cfs, the flows in the Broad River were not sufficient for 1 day in 2001 and 2 days in 2002 and Pond B was used for supplemental water. Appendix L is included to demonstrate that the requested alternative requirement is no less stringent than justified by the wholly out of proportion cost or significant adverse impacts as outlined in §125.85(a)(3). The requested alternative requirement results in less entrainment during low flow periods than the Track I proportional flow requirement.

ATTACHMENT 1

RESPONSE TO COMMENT # 3

Part VI

Mixing Zone Request

This Page Intentionally Left Blank

South Carolina Department of Health and Environmental Control

NPDES APPLICATION SUPPLEMENT

Mixing Zone Request for Surface Water Discharges

NPDES #: A new discharge to Broad River (Ninety-Nine Islands Reservoir)

Facility Name: Lee Nuclear Station

County: Cherokee

Are you requesting a mixing zone for whole effluent toxicity (WET) in accordance with the back of this form?

☐ **No.** No further information is needed. Submit this form. If WET testing is required, a chronic test at 100% will be required, unless the IWC is at least 80%. Proposed IWC ______%

☑ **Yes.** Check one of the boxes below and submit this form with the appropriate information.

☐ Check this block if you are proposing to perform or have performed a mixing zone demonstration to determine the appropriate zone of initial dilution (ZID) and/or mixing zone size. Complete the remainder of this form and submit a mixing zone demonstration plan as described on the back of this form. The Department recommends the demonstration plan be approved prior to implementation of any demonstration work.

☑ Check this block if you are requesting a mixing zone by providing limited information such as a mixing model like CORMIX to determine mixing in accordance with suggested zone of initial dilution (ZID) and/or mixing zone sizes. Complete the remainder of this form, as applicable, and submit the CORMIX Supplement and modeling results (or other model assumptions, inputs and results).

Please see Section 4.2 of Part VI Narrative

What is the proposed ZID size (in meters)? Length: N/A m Width: N/A

What is the proposed acute WET test concentration? 20 %

What is the proposed mixing zone size (in meters)? Length: 66 m Width: 22

What is the proposed chronic WET test concentration? 20 %

Printed Name: Ronald A. Jones **Firm:** Duke Energy Carolinas, LLC

Signature: [signature] **Date:** 8-11-11

Mixing Zone Analysis and Boundary Conditions

Mixing zones must have the qualities of no acutely toxic impact, must allow for safe passage of aquatic organisms, must provide for protection of existing and designated uses of the waterbody, and must not endanger public health and welfare. The Department recognizes different methods for establishing a mixing zone and its boundary conditions and suggests using the following protocol.

The Department has approved the establishment of mixing zones using the following methods of analysis.

- CORMIX modeling or other modeling tools (use the attached information from Chapter 4 of the CORMIX 5.0GT Manual)
- Instream assessments using dyes or conductivity measurements.
- Other appropriate methods.

Boundary conditions of mixing zones may be established as follows.

- *Effluent dominated discharges.* For situations where the instream waste concentration (IWC) using design flow conditions for domestic facilities or long term average flow for industrial facilities and where critical flow conditions (e.g., 7Q10) represent at least 80%, the Department considers that the discharge will be completely mixed within a reasonably minimized area and therefore, test concentrations may utilize 100% of the critical flow condition (e.g., 7Q10). Therefore, use of the complete dilution of the receiving body is appropriate.

- *Other discharges.* For other situations, a demonstration is required to minimize the mixing zone by using the above-mentioned methods to determine chronic mixing permit conditions based on a boundary of one-half the width of the stream (width) and a length downstream of twice the width of the river. Acute mixing conditions are based on a boundary of one-tenth the width of the stream (width) and a length downstream of one-third the width of the river. At the discretion of the permittee (or applicant), an alternative analysis may be prepared for possibly larger mixing zone boundaries, but methods should be used that address a mixing zone analysis consistent with the EPA Technical Support Document for Water Quality-based Toxics Control (TSD) and the water quality standards regulatory mixing zone requirements (e.g., biological, chemical, engineering, hydrological and physical factors).

- *Discharges with Diffusers.* Where a properly installed diffuser provides for a mixing zone that meets the criteria above and addresses biological, chemical, engineering, hydrological and physical factors, a test concentration can be set in a permit at the justified percentage of the critical flow condition (e.g., 7Q10) up to 100% of that critical flow condition. For boundary conditions, please see above.

Prepared for

Duke Energy Carolinas, LLC
526 South Church Street
Charlotte, NC 28201

MIXING ZONE REQUEST
WILLIAM STATES LEE III NUCLEAR STATION
NPDES PERMIT
CHEROKEE COUNTY, SOUTH CAROLINA

Prepared by

Geosyntec consultants

engineers | scientists | innovators

&

MMI

engineers • scientists • innovators

Project Number GK4270

December 20, 2011

This Page Intentionally Left Blank

MMI
engineers • scientists • innovators

Geosyntec consultants

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

TABLE OF CONTENTS (Continued)

This Page Intentionally Left Blank

1. INTRODUCTION

Duke Energy Carolinas, LLC (Duke Energy) is making application to the South Carolina Department of Health and Environmental Control (SCDHEC) for a National Pollutant Discharge Elimination System (NPDES) permit for its proposed new William States Lee III Nuclear Generating Station (Lee Nuclear Station) to be constructed in Cherokee County near Gaffney, South Carolina.

This document presents background and technical information supporting formal requests to SCDHEC for Thermal and Whole Effluent Toxicity (WET) mixing zones for the Lee Nuclear Station effluent discharge to the Broad River pursuant to Rule 61-68 (Water Classifications and Standards) Section C.10.

1.1 Facility Description

Lee Nuclear Station will be a twin reactor facility with a total electric generating capacity of approximately 2,200 MWe. A Combined Construction and Operating License (COL) application was prepared for the facility in accordance with U.S. Nuclear Regulatory Commission (NRC) regulations, and submitted to NRC at the end of 2007. Plans are for Lee Nuclear Station to be operational by 2021.

Lee Nuclear Station will use as its primary cooling water source waterbody, an existing impoundment on the Broad River created by the Ninety-Nine Islands Hydroelectric Project. The Ninety-Nine Islands impoundment/reservoir (Ninety-Nine Islands) covers about 430 acres and has a total storage capacity of about 2,300 acre-feet (ac-ft) [Reference 1; Chapter 2]. The reservoir is characterized by three hydrographic areas, the main river channel and two backwater areas that have developed because of sedimentation patterns since impoundment of the river. The two backwater regions exhibit very little circulation during non-flood periods. Therefore, the average transit time through the reservoir is conservatively estimated from the volume of the reservoir along the main channel excluding the backwater areas. Consequently, a storage volume of 570 ac-ft along the main channel results in an average hydraulic retention time of about 3 hours under annual average flow conditions [Reference 1; Chapter 2].

As further described below, the Ninety-Nine Islands Hydroelectric project is regulated by the Federal Energy Regulatory Commission (FERC) who has specified certain

minimum water levels to be met in the reservoir and minimum seasonal flows to be released downstream of Ninety-Nine Islands Dam.

1.2 Operational Discharges to the Broad River

As a twin reactor/unit facility, Lee Nuclear Station will require approximately 35,030 gallons per minute (gpm) (78 cubic feet per second (cfs)) of cooling water withdrawal from the Broad River for its closed-cycle cooling system [Reference 1; Chapter 3 – Figure 3.3-1]. An average of approximately 71 percent (24,800 gpm or 55 cfs) of the withdrawal will be consumptive due to evaporative and drift losses from the cooling towers, with 2,000 gpm (5 cfs) returned to the river as screen wash water. In addition to approximately 18 cfs (8,200 gpm) of cooling tower blowdown discharged to the Broad River, other waste streams of much lesser volume include facility process (< 0.28 cfs [< 125 gpm]) and treated radionuclide wastewaters (< 0.009 cfs [<4 gpm]) [Reference 1; Chapter 3 – Figure 3.3-1]. For the purposes of evaluating Lee Nuclear Station discharges to the Broad River, a total average discharge flow from the final outfall 001 of 18.3 cfs (8,216 gpm; as associated with two-unit, normal operation) was used in the current analyses of mixing as reported herein.

The plant will discharge approximately 18.3 cfs of cooling water blowdown and treated process waters to the Broad River more than 95 percent of the time. Less than 5 percent of the time, blowdown discharge could be as low as 9 cfs or as high as 64 cfs. The variation in atypical discharge flows are associated respectively with scheduled unit refueling outages and adjusted (lower) cooling tower cycling rates when necessary to manage high total solids originating from the cooling water source waterbody .

Discharge to the Broad River will be via a submerged multi-port diffuser, designated as NPDES outfall 001, attached to the upstream face of the Ninety-Nine Islands dam spillway in the western portion of Ninety-Nine Islands reservoir forebay (Figure 1). The diffuser design (see Section 2) will consist of an 88-foot (ft)-long pipe, 36 inches inside diameter and having 64 4-inch holes (ports) spaced 1.4 ft apart discharging horizontally [Reference 2]. Extending horizontally from west to east along the dam (and parallel to flow), the diffuser will be positioned approximately 750 ft from the west shore near the Ninety-Nine Islands dam trash sluice structure, and submerged midway in the water column (approximate centerline elevation 505 ft above mean sea level (msl)) [Reference 1; Chapter 5 – Figure 5.3-4]. At normal water elevation of 511 ft msl, the centerline of the pipe will be submerged approximately 6 ft; total depth at this

location is approximately 12 ft. Based on FERC-specified management of the Ninety-Nine Islands impoundment (see next section), depth of the submerged diffuser could range seasonally from 4 to 6 ft (greater during flood flows), with the shallower depth associated with low river flows and pulsed operation of the Ninety-Nine Islands Hydroelectric facility; conditions that occur rarely.

The Lee Nuclear Station cooling water system is designed to achieve a maximum discharge temperature of 91°F during critical summertime conditions of high ambient river and air temperatures, and seasonally low flows. However, as presented later, a discharge temperature of 95°F was also considered in the mixing zone modeling as a rare worst case scenario. Duke Energy is requesting the thermal mixing zone associated with the postulated 95°F discharge temperature as this approach provides added conservatism to the compliance format. Maximum discharge temperatures would be expected to occur during extreme summertime conditions when water temperature and ambient air temperatures are at their seasonal highs.

Additional details about the Lee Nuclear Station cooling water and process wastewater system, including a water balance diagram, have been provided on SCDHEC/U. S. Environmental Protection Agency (EPA) Forms 1 and 2D of the primary NPDES application package.

1.3 Ninety-Nine Islands Dam Operations

Duke Energy's Ninety-Nine Islands Dam is located on the Broad River approximately 4.5 river miles downstream from the Cherokee Falls Dam and is operated under a FERC license (FERC Project No. 2331) [Reference 3]. The Ninety-Nine Islands Dam and associated hydroelectric plant were constructed in 1910, and the dam structure is a concrete gravity dam. The facility operates as a modified peaking plant where the reservoir, augmented by inflow, supports daily operation (i.e., there is no appreciable storage volume).

Although initially designed with six hydroelectric power turbine units, currently only Units 1-4 are operable. Units 5 and 6 are not currently operable. Units are numbered sequentially from the east side of the powerhouse beginning with Unit 1. Thus, the two idled units are those located closest to the proposed Lee Nuclear Station discharge diffuser. Range in approximate distance from the centerline of the proposed discharge diffuser to the turbine units is 130 ft (Unit 6) to 260 ft (Unit 1). Currently, the closest

operable unit (Unit 4) is approximately 175 ft from the proposed diffuser location. At normal water elevation (511 ft. msl), centerline elevation of the turbine inlets is approximately 494.1 ft msl [Reference 3], or about 11 ft deeper than the centerline elevation of the proposed Lee Nuclear Station discharge diffuser (505 ft msl).

During normal river flows, the Ninety-Nine Islands hydroelectric generating units are operated within the FERC license-specified drawdown limits[1] for the reservoir (1 ft below full reservoir (511 ft msl) from March through May and 2 ft below full reservoir from June through February) [Reference 4]. Total hydraulic capacity of the 20 megawatt (MW) Ninety-Nine Islands Dam powerhouse (six units authorized) is 5,220 cfs [Reference 3]. Hydraulic capacity of the four currently operable units (Nos. 1-4; rated at ~14.450 MW total) is 3,510 cfs; thus, as currently configured/operated, the Broad River flows in excess of this amount pass over the dam spillway.

In addition to drawdown limitations, the FERC license for Ninety-Nine Islands Dam also specifies certain seasonally adjusted minimum flows to be maintained below the dam [Reference 4]:

- 966 cfs January through April;
- 725 cfs May, June, and December; and,
- 483 cfs July through November.

If the above-referenced flows cannot be maintained during December through June without dropping below the reservoir level restrictions described above, then at least 483 cfs is required to be released. If there is insufficient water to maintain at least 483 cfs of continuous flow release, the operating license provides that one hydroelectric unit can be operated at its minimum hydraulic output for that portion of every hour that is necessary to release the approximate accumulated inflow, i.e. a pulse flow operational format [Reference 5].

[1] Drawdown limits may be temporarily modified in the event of operating emergencies beyond Duke Energy's control.

As indicated above, the FERC-specified July through November minimum flow is 483 cfs. Based on analysis of the Broad River period of record flows (85 years) performed by Duke Energy contractor HDR|DTA, flows were greater than 483 cfs 98.2 percent of the time [Reference 6]. Of the 31,046 days that flows were measured by the U.S. Geological Survey (USGS) for the Broad River since 1926, flows less than 483 cfs were recorded for just 545 days (1.8 percent). Consequently, pulsed flow operations of Ninety-Nine Islands hydroelectric power generation are rare events.

1.4 Chronological Summary of Related Modeling Work

There have been a number of numeric modeling efforts conducted as part of the design and NRC licensing of Lee Nuclear Station. These efforts are summarized in the following sections.

1.4.1 Clemson University Study

The thermal discharge to the Broad River was initially evaluated through limited work performed by Clemson University [Reference 7]. The researchers employed simplifying assumptions and analytical calculation methods, in lieu of a three-dimensional model, to identify any "fatal flaws" in the discharge diffuser concept being developed at that time with regard to thermal gain in the Ninety-Nine Islands forebay and downstream of the dam. The results, not meant to be highly definitive, provided gross insight into the potential thermal effects of the Lee Nuclear Station cooling water discharge in the Broad River above and below Ninety-Nine Islands Dam. The Clemson researchers concluded that, based on conservative assumptions, thermal gain above the dam may range from 1.2 to 3.7°F; with a thermal gain of up to 1.7°F predicted for waters below the dam.

1.4.2 Enercon Study

In support of the COL application, additional modeling was conducted by Duke Energy contractor Enercon, which used a more sophisticated modeling approach employing Cornell Mixing Zone Expert (CORMIX) modeling software (Version 4.3) to simulate the thermal plumes above and below Ninety-Nine Islands Dam [Reference 1]. This effort was coupled with a mass balance analysis to determine expected temperature of water discharged by Lee Nuclear Station after mixing with the Broad River water in the Ninety-Nine Islands hydroelectric station turbines.

Results of the CORMIX simulations predicted a small thermal plume that dissipates quickly. Results of the heat balance calculation indicated that the maximum temperature change downstream of Ninety-Nine Islands Dam is expected to be less than 1.4°F.

1.4.3 Computational Fluid Dynamics Modeling

The results of the CORMIX modeling, though more accurate than the Clemson work, still did not consider the important effects on Lee Nuclear Station thermal discharge mixing characteristics brought about due to variation in reservoir bathymetry, flow velocity, and flow vector (direction) in the Ninety-Nine Islands Dam forebay at the diffuser location. Likewise, the hydraulic influences of the Ninety-Nine Islands Dam hydroelectric generating units on thermal plume characteristics were not considered.

In subsequent discussions with regulatory agencies pertaining to the appropriate permitting approach for Lee Nuclear Station, concerns were raised about the mixing behavior of the thermal discharge from the station in the forebay and the potential effect of this discharge on the aquatic community, particularly on the smallmouth bass (*Micropterus dolomieui*) fishery present downstream of Ninety-Nine Islands Dam.

In order to more definitively characterize the Lee Nuclear Station thermal discharge into the hydrodynamically and spatially complex mixing environment present in the Ninety-Nine Islands Reservoir forebay, a more robust modeling approach was needed. As such, three-dimensional Computational Fluid Dynamics (CFD) modeling technology was conducted [Reference 8].

CFD modeling is based on the Navier-Stokes equations for fluid motion, which are simply an expression of Newton's laws of motion with additional viscous stress terms required to calculate fluid flow [Reference 9]. The equations express the laws of conservation of mass, momentum and energy and are hence a "fundamental" set of equations (i.e., no assumptions are made in forming the basic equation set).

CFD modeling has been used successfully for over 40 years in a variety of industrial and environmental applications. Similar to its use in the current study, the Tennessee Valley Authority (TVA) used CFD modeling to evaluate the multi-port diffused thermal discharge from its Browns Ferry Nuclear Power Plant to Wheeler Reservoir in north Alabama [Reference 10]. The CFD model allowed TVA to determine thermal plume mixing and temperature rise patterns as well as other hydrodynamic features of the

discharge. Notably, TVA found close agreement between CFD model predicted water temperatures and direct temperature measurements at the operating diffusers.

Other examples of CFD environmental applications include the U.S. Department of Energy's Pacific Northwest National Laboratory use of CFD in the hydrodynamic evaluation of the North Fork Dam forebay on the Clackamas River in Oregon and to model the three-dimensional velocity field below Bonneville Dam to enhance fish passage [Reference 11]. CFD has also been used to investigate the increased discharge associated with the re-powering of an existing power plant [Reference 12].

In this initial CFD evaluation of the Lee Nuclear Station thermal discharge, mean annual flow (2,538 cfs[2]), low flow (483 cfs) and extreme low flow (157 cfs) discharge scenarios were conservatively calculated to determine the potential effects of the Lee Nuclear Station cooling water discharge on the Broad River and Ninety-Nine Islands Reservoir environments. Discharge temperatures of 91°F and 95°F were evaluated. In all the cases studied, the maximum temperature rise at the Ninety-Nine Islands hydro turbine intakes was 0.72°F. Therefore, the maximum temperature rise passed through to the Ninety-Nine Islands Dam tailrace would also be 0.72°F. For all other scenarios examined, predicted water temperature rises at the turbines were less than 0.4°F. Based on the minimal temperature rise predicted by the CFD model, the study concluded there would be no substantive changes to the summertime thermal regime that currently exists in the tailrace. Thus, there would be no detrimental impacts to the smallmouth bass fishery.

Modeling of the extreme low flow scenario (157 cfs) also predicted that under certain conditions heat may accumulate in the Ninety-Nine Islands Dam forebay if the pattern of Ninety-Nine Islands hydroelectric station pulsed flow operation is insufficient to fully remove the Lee Nuclear Station heat addition. A pulsed flow operational pattern matched to 322 cfs was predicted through extrapolation to preclude accumulation of heat in the forebay.

---

[2] At the time that the initial CFD evaluation was performed, 2,538 cfs was the accepted value for mean annual flow. It has since been recalculated based on data from 1926 through 2010 as 2,495 cfs.

1.4.3.1 Presentation of CFD Model Results to SCDHEC

A comprehensive report of the initial CFD thermal modeling, prepared in support of the COL application, was submitted to NRC on 24 September 2009 [Reference 8]. Results were presented directly to SCDHEC on 27 August 2009. Based on SCDHEC feedback regarding apparent accumulation of heat in the Ninety-Nine Islands forebay, additional modeling was performed to further evaluate thermal discharges under critical low flow at times when the Ninety-Nine Islands hydroelectric generating station is operating in pulsed generation mode. The 7Q10 critical low flow of 464 cfs was determined by SCDHEC [Reference 13] to be the appropriate flow value to use for modeling NPDES-permitted discharges to the Broad River from Lee Nuclear Station. The additional CFD modeling was conducted as requested by SCDHEC to: 1) address the issue of heat accumulation in the Ninety-Nine Islands Dam forebay; and 2) to support requests for thermal and whole effluent toxicity (WET) mixing zones in accordance Rule 61-68 (Water Classifications and Standards) Section C.10 [Reference 14].

SCDHEC also requested additional information about the design of the proposed submerged multi-port discharge diffuser; particularly with regard to its efficiency in mixing Lee Nuclear Station discharges with the Broad River receiving waters.

The sections that follow present technical information on optimization of the Lee Nuclear Station discharge diffuser, and supporting information for the Thermal and WET Mixing Zone requests.

2. DISCHARGE DIFFUSER OPTIMIZATION

Duke Energy contracted with Philip J. Roberts, Ph.D. of Georgia Tech's School of Civil and Environmental Engineering to support design optimization for the Lee Nuclear Station submerged multi-port discharge diffuser [Reference 2]. Dr. Roberts has published extensively on such technical topics as environmental fluid mechanics, mixing and dynamics of rivers, lakes, coastal waters, and estuaries; optimization of outfalls for wastewater discharge; and mathematical models of wastewater fate and transport. Dr. Roberts' work is cited multiple times in EPA's *Technical Support Document for Water Quality-Based Toxics Control* (EPA/505/2-90-001), which is the seminal work upon which permitting of potentially toxic discharges to waters of the United States is based.

The following represents a summary of Dr. Roberts' work in optimizing the design of the Lee Nuclear Station discharge diffuser.

2.1 Design Study Objectives

Dr. Roberts' work focused on the optimization of the Lee Nuclear Station diffuser engineering design to satisfy plant operational parameters, promote efficient mixing of the effluent, and limit temperature rise in the receiving waterbody (Broad River). Performance criteria for the discharge design included achievement of a temperature rise in the river at the water surface near the diffuser of no more than 5°F with a maximum temperature not to exceed 90°F (analysis of mixing needed to address chemical constituents in the discharge was not conducted). While water quality criteria for temperature were used to inform the design of the diffuser, it was not the intent of Dr. Roberts' work to directly address an NPDES compliance-based mixing zone. That objective was addressed by the additional CFD modeling reported herein (see Sections 3 and 4).

2.2 Assessment Methodology

The initial multi-port diffuser design proposed by Duke Energy was a submerged 65-ft-long pipe of 36-inch diameter attached to the upstream face of the Ninety-Nine Islands Dam spillway in the western portion of Ninety-Nine Islands Reservoir forebay. The diffuser was to consist of 16 3-inch holes (ports) per square foot. For the optimization study, multiple discharge flow rates (9 cfs [4,039 gpm] to 64 cfs [28,725 gpm]), diffuser

port depth (6 to 8 ft), diffuser nozzle spacings (1 to 10 ft) and nozzle diameters (3 to 4 inches) were modeled by Dr. Roberts using EPA's Visual Plumes model. Modeling targeted two seasons: (i) winter when differential between monthly average ambient river temperature (44.1°F) and cooling tower blowdown (discharge) temperature (70.4°F) is estimated to be greatest (ΔT=26.3°F); and (ii) in summer when maximum monthly average river temperature and blowdown discharge temperature are at their seasonal highs: 82.3°F and 91°F, respectively. The modeling assumed there was no ambient river flow whatsoever in the forebay into which the discharge was made, an attribute reported as conservative by Dr. Roberts [Reference 2].

The Visual Plumes model predicts the buoyant thermal plume to follow a curved trajectory from the submerged diffuser as it rises to the water surface (ports/nozzles are located on the upstream side of the diffuser, away from the face of the dam). As the plume rises, it entrains ambient water that mixes and dilutes the discharge and reduces the temperature rise. The maximum surface temperature occurs where the jet centerline impacts the water surface [Reference 2]. This impact zone represents the maximum spatial extent of model predictability for surface water temperature (i.e., the model domain extends from the point of port/nozzle discharge to impact of the plume with the water surface).

Visual Plumes consists of a suite of models intended for various purposes. In this case, the UM3 model was considered the most appropriate model [Reference 2]. UM3 is a three-dimensional Lagrangian entrainment model for jets and plumes. External fluid is assumed to be entrained into the rising buoyant thermal plume at a rate proportional to the local plume centerline velocity. The local profiles of velocity, density deficiency, and tracer concentrations are assumed to be self-similar and the equations for conservation of mass and momentum, are integrated over the plume cross-section. The equations are solved numerically to predict plume conditions, including dilution and plume width, along the jet trajectory. If the ports are close together, the plumes may merge. The merging of the thermal plumes is considered in the routines of the UM3 model. Entrainment models are widely used in engineering to predict a wide variety of flows related to wastewater and atmospheric discharges.

2.3 Study Findings

It was determined that a minimum mixing dilution ratio of 5.3 to 1 was needed to meet the applicable thermal water quality criteria (ΔT ≤ 5°F and 90°F maximum). All

combinations of discharge flow rates, diffuser port spacings and port diameters modeled indicated the needed dilution could be achieved. Based on Dr. Roberts' analysis, the optimally designed submerged, multi-port discharge diffuser (pipe) is approximately 88-ft long with an inside diameter of 36 inches and has 64 4-inch ports spaced 1.4 ft apart. The Visual Plumes model indicates that if the Lee Nuclear Station heated effluent were discharged to the Broad River via a diffuser of this design, the result will be a temperature rise at the water surface (where the buoyant plume emerges) that will always be less than 5°F and have a maximum temperature at the water surface of less than 90°F based on the assumed conditions. The lateral distance from the diffuser port to the point of plume impact with the water surface was estimated to range from 14 ft (9 cfs discharge flow rate) to about 76 ft (64 cfs discharge flow rate).

3. THERMAL MIXING ZONE REQUEST

The Lee Nuclear Station thermal discharge is predicted at times to potentially exceed water quality criteria for temperature (e.g. 90°F). Because the spatial extent of such exceedance in the receiving waterbody is expected to be small, a regulatory mixing zone presents an allowable compliance approach provided requirements specified in Rule 61-68 (Water Classifications and Standards) Section C.10 can be met [Reference 14].

3.1 Background

As indicated previously, Dr. Roberts' work focused on optimizing the design of the submerged multi-port discharge diffuser and not the determination of a regulatory mixing zone. It is important to note, however, that rapid mixing of the Lee Nuclear Station discharge was demonstrated by Dr. Roberts' analysis, with achievement of temperature criteria predicted upon impact of the buoyant plume with the receiving water surface (under the conditions considered).

The limitations of the Visual Plumes model used by Dr. Roberts (as well as the CORMIX model used by Enercon [Reference 1]) to evaluate thermal discharge mixing zones are primarily associated with the orientation of the discharge diffuser parallel to ambient flow along the Ninety-Nine Islands Dam (Figure 1). Typically, a discharge diffuser is oriented perpendicular to flow whereby the discharge from each port/nozzle may be entrained into ambient receiving water unaffected by the discharge. Such orientation provides for efficient mixing of the discharge with the receiving waterbody. The Visual Plumes and CORMIX models are best suited for these conditions.

Constraints imposed by conditions in the Broad River (i.e., heavy debris and sediment accumulation) necessitated placement of the Lee Nuclear Station discharge diffuser along the face of Ninety-Nine Islands Dam, parallel to flow. In the case of diffuser orientation parallel to flow, the discharge from ports located on the "downstream" end of the diffuser entrains the effluent discharged from the "upstream" ports thereby affecting mixing characteristics. This physical phenomena is accounted for in the CFD model, since the parallel flow of the thermal discharges are included automatically (or, more accurately, the parallel flow in the CFD model is due to the influence of the river flow being obstructed by the dam) and allowed to mix according to the fundamental laws of fluid motion. The discharge diffuser is not modeled explicitly as jets emanating

from each port, as this would be too computationally expensive. Rather, the discharge is treated as a mass source at the location of the discharge diffuser, and is allowed to diffuse equally in all directions and mix as the ambient flow dictates.

In the CFD model, a temperature transport model derived from the law of conservation of energy is included. Temperature is transported in the model domain by convection with the water flow, and molecular and turbulent diffusion. It has an influence on the flow profile as the heated water plumes rise – this is included in the calculations via the Boussinesq buoyancy model. As the temperature and flow fields are interdependent it is essential that the flow, turbulence and temperature equations are calculated simultaneously. Heat can also be lost or gained through the model boundaries. For example, heat lost or gained through the free surface will modify the temperature in the reservoir and this can be included in the calculation by selection of appropriate boundary conditions. It is likely that heating and cooling in the forebay is influenced by river temperature, air temperature, cloud cover, sun elevation, shading by vegetation and other effects. In the absence of full knowledge of these variables, heat loss/gain through the free surface cannot be calculated accurately. Instead, adiabatic conditions were specified at the free surface, a conservative modeling approach.

3.2 Current Thermal Modeling Effort

Geosyntec Consultants/MMI Engineering (Geosyntec) was contracted by Duke Energy to conduct the necessary calculations/modeling to determine the Lee Nuclear Station thermal discharge mixing characteristics in the Broad River for the purposes of NPDES permitting of the new facility. Based on SCDHEC feedback received at the 27 August 2009 meeting regarding apparent accumulation of heat in the Ninety-Nine Islands forebay, additional modeling was performed to further evaluate thermal discharges under critical low flow at times when the Ninety-Nine Islands hydroelectric generating station is operating in pulsed generation mode. The 7Q10 critical low flow of 464 cfs was determined by SCDHEC [Reference 13] to be the appropriate flow value to use for modeling NPDES-permitted discharges to the Broad River from Lee Nuclear Station. This modeling scenario (critical conditions and pulsed flow) was used to estimate spatial boundaries for a thermal mixing zone.

The SCDHEC further indicated their focus will be on the size of the Lee Nuclear Station thermal plume relative to the specified <u>acute</u> mixing zone boundary. Duke Energy has assumed SCDHEC is referring to that portion of the plume/mixing zone

where temperatures may potentially exceed 90°F (maximum ambient water quality criterion) as discharge temperatures in excess of 90°F would only be expected to occur during summer - the time when critical low flows in the river (e.g., 7Q10 flows) can also occur. The other component of the state's temperature criteria (adapted from EPA), "*free flowing* [waters] *shall not be increased more than 5°F (2.8°C) above natural temperature conditions*", [Reference 14] is largely based on the objective to "*maintain a well-rounded population of warmwater fishes*" [Reference 15]. In the case of power plant additions, it is further based on the objective to avoid fish lethality resulting from a sudden *drop* in water temperature (should the plant shut down) during winter months when the potential for $\Delta T > 5°F$ to occur is greatest [Reference 2]. As such, the 90°F maximum temperature criterion was selected as the acute condition and the additional CFD modeling was conducted to address this component of the mixing zone request.

Duke Energy is also aware of SCDHEC's interest in temperature differential between the discharge and ambient Broad River as exemplified by the $\Delta T \leq 5°F$ criterion [Reference 14]. A simulation of the $\Delta T \geq 5°F$ under worst-case winter conditions ($\Delta T = 26°F$ at the discharge) at mean annual flow has been run, and the results are presented later in this report. In addition, the previous comprehensive CFD thermal modeling report (see Section 1.4.3) speaks directly to this issue and includes several CFD modeling runs that address plume characteristics of $\Delta T \geq 5°F$. In all cases conservatively modeled, plume spatial dimensions associated with temperatures of $\Delta T \geq 5°F$ are very small. This finding is further supported by Dr. Roberts' additional analysis of the discharge diffuser that indicates the ΔT will always be < 5°F at the point of buoyant plume impact with the water surface [Reference 2].

As is presented in the following text, an approved mixing zone request based upon plume dimensions for the ≥ 90°F isotherm associated with a discharge temperature of 95°F will fully encompass the area occupied by that portion of the plume exhibiting $\Delta T \geq 5°F$. This has been shown to be the case in the results presented in this report. Therefore, as the additional modeling requested by SCDHEC (acute, critical summer condition) is most relevant to the Thermal Mixing Zone request, the results thereof are summarized in the following text.

3.3 Critical Conditions Modeling

The Lee Nuclear Station thermal discharge characteristics under critical condition 7Q10 flow of 464 cfs were conservatively calculated using CFD models to determine the

potential effects of the Lee Nuclear Station cooling water discharge on the Broad River and Ninety-Nine Islands Reservoir forebay environments, particularly with regard to that portion of the thermal plume where temperatures are ≥ 90°F plume. Under 7Q10 flow conditions, the Ninety-Nine Islands Hydroelectric Generating Station is expected to operate in a pulsed mode format whereby a single turbine is pulsed "on" and "off" over an hourly cycle to comply with FERC-specified minimum water levels to be maintained in the impoundment and minimum seasonal flows to be released downstream. The CFD model was configured to address this pulsed mode of operation.

In this specific case, bathymetry data, as well as water column acoustic Doppler velocity and vector data directly for the Ninety-Nine Islands Reservoir forebay measured by Duke Energy, were incorporated into the CFD model. This and other CFD model spatial and temporal features supported a more definitive evaluation of the influences of the Lee Nuclear Station thermal discharge on ambient forebay temperatures and prediction of water temperatures at the Ninety-Nine Islands Dam turbine inlets, and thus, the temperatures that would be discharged to the Broad River below the dam.

The CFD model used in this study is similar to the earlier work [Reference 8] where a more detailed overview of the model is given. The geometry and mesh were slightly changed after this work to reflect the correct position and length of the discharge diffuser (an initial design was used in the previous work), and are shown in Figures 2 through 5 for reference[3].

The model was run in transient mode to capture the pulsed operation of the turbines. As with the previous studies, the diffuser discharge was applied as a mass source at the location of the diffuser and allowed to diffuse equally in all directions. This tends to result in a conservative result for the thermal plume as the momentum induced by the multi-port discharge diffuser will be greater in reality than in the model. This increase in momentum will encourage entrainment of ambient water and enhance cooling of the plume. Therefore, the under-representation of momentum in the CFD model is conservative.

---

[3] Please note that for Figures 4 and 5 the viewer's perspective is from the east bank of Broad River (looking southwesterly), upstream of the dam, and somewhat elevated. This is also true for subsequently-referenced Figures 6-10, 12, 15, 16, 20 and 21.

3.3.1 Methodology

Geosyntec/MMI Engineering uses a variety of classical and computational analysis techniques to assess the performance of fluid systems and processes. For detailed CFD analysis, calculations are made with the general purpose, commercial CFD code ANSYS-CFX Version 12 [Reference 16]. This is the CFD model code selected for the current analysis.

The extent (geometry) of the Ninety-Nine Islands Reservoir/Broad River environment in the CFD models included:

- The Ninety-Nine Islands Dam, forebay, turbine intakes, and Lee Nuclear Station diffuser discharge;
- the backwater areas in the locality of the forebay; and,
- a reach of the Broad River extending approximately 0.5 mile upstream of the forebay.

Total surface area of the modeled domain was approximately 61 acres.

Bathymetry data for the reservoir forebay area and river was provided by Duke Energy contractor, DTA [Reference 17] in the form of point-depth measurements in a series of transects. These point data were interpolated to form the river/reservoir bed in the CFD models. The data received did not include the dam or turbine intakes, which were incorporated into the model by reference to the civil engineering drawings of the Ninety-Nine Islands hydropower station [References 18 and 19].

The Lee Nuclear Station cooling water discharge was defined in the CFD models based on reference to the Duke Energy drawings of the discharge [References 19 and 20]. The location of the discharge relative to the turbine intakes is shown in Figure 1. Only the discharge diffuser detail was included in the model; the remainder of the discharge pipe work has no significant effect on plume behavior.

3.3.1.1 CFD Model Relationship to Dr. Roberts' Diffuser Design Study

It is important to acknowledge that at the time the additional CFD modeling (reported herein) was conducted, Dr. Roberts' work in optimizing the discharge diffuser design

had not been completed. It should be noted that that Dr. Roberts used a maximum *monthly* average temperature of 82.3°F and normal discharge temperature of 91°F in his discharge diffuser design optimization study; whereas, the CFD model uses a *daily* average maximum temperature of 88.2°F and both 91°F and 95°F discharge temperatures to evaluate worse case conditions of summer in the determination of mixing zones. These differences are simply the result of independent investigations, conducted at different times, and with differing objectives in mind, and would have no material impact on the CFD model results.

3.3.2 Scenarios Modeled

Three CFD calculations (scenarios or cases) were performed. The first two were relevant to the 90°F plume with the following variables common to both cases:

- River flow rate was set to 464 cfs in accordance with the 7Q10 level specified by SCDHEC for the NPDES permitting [Reference 13] ;
- River temperature (background) was set to 88.2°F as determined from Duke Energy continuous water temperature data collected in the Ninety-Nine Islands forebay during June-August 2008 (when 7Q10 flows might be expected to occur) [Reference 21];
- Turbine flow rate was set to 500 cfs when "on" and 53 cfs when "off" (due to leakage through the turbine penstock);
- Ninety-Nine Islands Hydroelectric Station turbine operation:
    - Only 1 turbine unit is in operation.
    - The unit is "off" for the first 4.3 minutes per hour, flow accumulates in the forebay and only leakage flow passes to the tailrace. The unit is "on" for the remaining 55.7 minutes per hour. These timings were calculated by considering the balance of the river and turbine flow rates only.
- Diffuser discharge rate was set to 18.3 cfs.

The scenarios differed in the temperature of the diffuser discharge. In Scenario 1 the discharge temperature was set to 95°F, while in Scenario 2 it was 91°F.

The third scenario is relevant to the ΔT = 5°F plume. In this case, the following variables were set:

- River flow rate was set to 1,956 cfs representing mean annual flow.
- River temperature (background) was set to 44.1°F in alignment with the diffuser optimization report [Reference 2].
- Turbine flow rate was set to approximately 500 cfs when "on" (in the model, a value of (1,956 + 18.3)/4 = 494 cfs was used to satisfy the mass balance).
- Ninety-Nine Islands Hydroelectric Station turbine operation:
  - Four turbine units in operation.
  - The four turbine units are continually on.
- Diffuser discharge rate was set to 18.3 cfs.
- The discharge temperature was set to 70.4°F in alignment with the diffuser optimization report [Reference 2].

3.3.3 Model Results – 90°F Plume

For the 7Q10 river flow rate of 464 cfs, the peaks of the average temperatures at the Ninety-Nine Islands Hydroelectric Station turbine inlet calculated from the CFD model are as follows:

- Scenario 1 (95°F discharge temperature): 88.57°F or 0.37°F above ambient river temperature (88.2°F).
- Scenario 2 (91°F discharge temperature): 88.36°F or 0.16°F above ambient river temperature (88.2°F).

It is apparent from the above that the Lee Nuclear Station thermal discharge will have minimal impact on the thermal regime of the Broad River downstream of the Ninety-Nine Islands Hydroelectric Project.

With regard to the Ninety-Nine Islands Dam forebay, the CFD modeling of two consecutive one-hour cycles demonstrated that heat did not accumulate in the forebay beyond initial start-up, and that steady-state conditions were reached by the end of the second hour of pulsed operation. This was determined to be true for both Scenario 1, and is a feature of Scenario 2 as well, although the thermal plumes are much smaller.

For Scenario 1 (95°F discharge temperature), Figure 6 illustrates the 90°F area by the blue iso-surface 20 minutes into the first cycle modeled. At the end of the first cycle, the plume is of a different shape and slightly smaller (see Figure 7). The variation in plume size and shape throughout the cycle is an important consideration in the modeling, and is a feature of Scenario 2 as well, although the thermal plumes are much smaller because the discharge temperature is lower for Scenario 2 (91°F). See Figure 8 and Figure 9 for the thermal plumes for Scenario 2.

The variation in plume volume over two cycles is an important dynamic in the model. As the CFD model uses a uniform temperature throughout the domain of 88.2°F as a starting point (an initial assumption to start the model), the 90°F thermal plume is zero volume, but after the first 15 minutes the volume is approximately constant for the first cycle. Because the turbine is turned off at the start of the second cycle, the thermal plume increases in size, and even increases when the turbine is turned back on for a short period (this lag is to be expected as the turbine does not immediately influence the entire domain as soon as it is turned on), before returning to approximately the steady-state volume in the first cycle. As the plume volume at the end of the second cycle is approximately the same as at the end of the first cycle, the second cycle can be assumed to be the "repeating" cycle. A similar pattern was also observed for Scenario 2.

Dimensions of the thermal plume were taken at the end of the second cycle in each case, as this is the "steady-state" plume that is the best representation of the plume over the hourly cycle. Figures 10 through Figure 13 show the steady-state plumes for Scenarios 1 and 2, respectively. The plan views (Figure 11 and Figure 13) of the plumes provide a perspective of the size of the plume in comparison to the forebay of the dam. A detailed summary of the plume dimensions for each scenario are shown on the table in the following section. The volume of the thermal plume for Scenario 1 is 0.994 ac-ft (43,339 ft^3), while the surface area is 0.358 acres (15,603 ft^2). The cross-section area (see Figure 15) is 630 ft^2 which constitutes 3.7 percent of the forebay cross-sectional area. The maximum plume length, taken from the end of the discharge diffuser, is 198 ft (approximately 19 percent of the width of the Broad River at the forebay of the dam)

while the width of the plume is 63 ft. The maximum and average depths are 7.7 ft and 1.6 ft, respectively. The bar chart showing percent of plume volume against depth for this scenario (Figure 14) indicates that the majority of the plume is less than 7 ft depth – in fact, 97% of the plume volume is less than 5 ft depth for Scenario 1.

For Scenario 2 the thermal plume is significantly smaller, as would be expected, with a volume of 0.087 acre-ft (3,798 ft^3) and a surface area of 0.032 acres (1,389 ft^2). The cross-section area (see Figure 16) is 125 ft^2 which constitutes 0.7 percent of the forebay cross-sectional area. The maximum plume length, calculated from the end of the discharge diffuser, is 30 ft (approximately 3 percent of the forebay length) while the width of the plume is 32 ft. The maximum and average depths are 5.8 ft and 1.6 ft, respectively. The bar chart showing percent of plume volume against depth for this scenario (Figure 17) indicates that the majority of the plume is less than 5 ft depth.

3.3.4 Model Results – ΔT = 5°F Plume

The ΔT = 5°F plume for Scenario 3 is shown on Figure 18. Note that in this scenario, four turbines are "on", indicated in orange in the figure. As the flow rate for the simulation is much higher (1,956 mean annual flow cf. 464 cfs for 7Q10 critical flow) the turbines are not in pulsed mode operation, so the plume is more slender than the plumes for scenarios 1 and 2. As anticipated, the plume is much smaller than Scenario 1, with a volume of 0.211 acre-ft (9,171 ft^3) and a surface area of 0.036 acres (1,555 ft^2). Due to the difference in the shape of the plume, the average and maximum depths are greater than the 90°F plumes, but are still relatively shallow at 2.8 ft average depth and 9.2 ft maximum depth. The shape of the plume also results in a relatively long (156 ft maximum length) but narrow (10 ft maximum width) mixing zone.

3.3.5 Results Summary

The CFD model inputs and resulting spatial dimensions of the ≥ 90°F plume under each scenario were determined for the steady-state condition and are summarized on the following table:

	Scenario 1	Scenario 2
River Flow	464 cfs 7Q10 Critical Flow	464 cfs 7Q10 Critical Flow
River Temperature	88.2°F	88.2°F
Discharge Flow	18.3 cfs	18.3 cfs
Discharge Temperature	**95°F**	**91°F**
Dimensions of Steady-state ≥ 90°F Thermal Mixing Zone for Repeating Cycle		
	Scenario 1	**Scenario 2**
- **Volume**	0.994 acre-ft 43,339 ft^3	0.087 acre-ft 3,798 ft^3
- **Surface area**	0.358 acre 15,603 ft^2	0.032 acre 1,389 ft^2
- **Cross-Sectional area** o **Percent of forebay**	630 ft^2 3.7 %	125 ft^2 0.7 %
- **Average Depth/Thickness**	1.6 ft	1.6 ft
- **Maximum Depth/Thickness**	7.7 ft	5.8 ft
- **Maximum Width**	63 ft	32 ft
- **Maximum Length**[4]	198 ft	30 ft

It is important to note (as detailed in the next section) that proper interpretation of the model results (i.e. spatial attribute) relative to a regulator mixing zone should consider orientation of the diffuser and buoyant properties of the thermal plume.

The CFD model inputs and spatial dimensions of the ΔT ≥ 5°F plume for the steady-state condition are summarized on the table below.

[4] Calculated from the end of the discharge diffuser.

	Scenario 3
River Flow	1,956 cfs Mean Annual Flow
River Temperature	44.1°F
Discharge Flow	18.3 cfs
Discharge Temperature	**70.4°F**
Dimensions of Steady-state ΔT ≥ 5°F Thermal Mixing Zone for Repeating Cycle	
- **Volume**	0.211 acre-ft 9,171 ft^3
- **Surface area**	0.036 acre 1,556 ft^2
- **Average Depth/Thickness**	2.8 ft
- **Maximum Depth/Thickness**	9.2 ft
- **Maximum Width**	10 ft
- **Maximum Length**[5]	156 ft

Hereafter, discussion of the thermal plume and associated mixing zone for Lee Nuclear Station conservatively assumes the 95°F discharge temperature under critical low flow (7Q10) conditions, since this is the worst-case scenario out of all the scenarios modeled.

3.4 Relevance to the Thermal Mixing Zone Request

As indicated previously, SCDHEC indicated a significant consideration in its analysis will be on the size of the Lee Nuclear Station thermal plume relative to the specified acute mixing zone boundary. Duke Energy has assumed this to be that portion of the plume/mixing zone where temperatures are in excess of the 90°F criterion. This has also been shown to be more onerous than the ΔT ≥ 5°F criterion. As the discussion hereafter focuses on the plume area characterized by temperatures ≥ 90°F and analogous to the acute mixing zone, the terms "plume" and "mixing zone" are used interchangeably.

[5] Calculated from the end of the discharge diffuser.

Mixing zone boundary conditions set by SCDHEC seek to keep the size of mixing zones to a minimum. According to SCDHEC requirements, acute mixing zones are limited to no more than one-tenth (10 percent) of the width of the stream (width) and a length downstream of one-third (33.3 percent) the width of the stream, although alternatives may be considered for larger mixing zones [Reference 22].

Unlike the conventional configuration where the discharge diffuser extends laterally from shore and is positioned perpendicular to the flow, the Lee Nuclear Station discharge diffuser is attached to a dam and oriented parallel to river flow (i.e., flow is along the dam face toward the hydroelectric turbines). These attributes make the direct application of the SCDHEC acute mixing zone length/width proportional dimensions to the Lee Nuclear Station thermal plume somewhat atypical.

For example, given the placement of the discharge diffuser parallel to flow along the face of the Ninety-Nine Islands Dam, it is necessary to define length of the plume/mixing zone as running parallel to the longitudinal centerline of the diffuser pipe (i.e., easterly), and width as perpendicular to the diffuser (i.e., northerly). As such, the maximum downstream length of the buoyant 90°F plume (acute mixing zone) is conservatively estimated to be 198 ft, which is approximately 19 percent of the width of the Broad River at the forebay of the dam (1,031 ft), while the plume width is conservatively estimated to be 63 ft, or 6 percent the width of the stream. Accordingly, the size of the acute thermal mixing zone for the Lee Nuclear Station discharge as conservatively determined by the CFD model falls well within the maximum spatial boundary conditions, for the mixing zones established by SCDHEC. In addition, including the enhanced mixing properties afforded by the high-velocity multi-port diffuser, which was not fully considered by the CFD model (see Section 3.3), will further diminish the size of the thermal mixing zone reported herein.

Also, while seasonal temperature data for the Ninety-Nine Islands forebay demonstrate the water column is well mixed and oxygenated all year, the buoyancy of the thermal plume results in an uneven dispersal of heated water vertically in the water column. That is, at the maximum horizontal extent (length) of the $\geq$ 90°F plume (198 ft), the plume/mixing zone does not extend vertically downward into the water column. Although the maximum depth of the mixing zone (extending from the surface downward) is 7.7 ft, only a very small proportion of the plume is at that depth; 97 percent of the mixing zone volume is found at 5 ft depth or less (Figure 14). The average depth/thickness of the mixing zone is just 1.6 ft. As the average depth is so

shallow, there is a significant distance between the mixing zone and the bottom of the forebay where fish may escape or swim around the area.

Given the above discussion, an alternative/analogous approach for evaluating minimization of the size of the Lee Nuclear Station thermal mixing zone relative to the receiving waterbody may be to use percent cross-sectional area of the forebay occupied by the ≥ 90 °F or greater plume/mixing zone. This approach is fully consistent with SCDHEC mixing zone requirements and EPA guidance [Reference 23], which seeks to limit exposure to fish and other organisms to acute conditions. Using this approach, the cross-sectional area of the plume was determined by positioning an east-west oriented line (aligned with the dam and diffuser) through the thickest part of the vertical plane of the plume. This cross-sectional area of the ≥ 90°F plume (associated with a 95°F discharge temperature) measures 630 ft^2 in size; proportionally, this represents just 3.7 percent of the cross-sectional area of the forebay (Figure 15). Thus, under conservative conditions there is very limited potential exposure to the thermal plume for free-swimming fish or benthic organisms and their passive life stages.

EPA guidance provides that the areal extent and concentration isopleths (for toxics) of a mixing zone must be such that the 1-hour average exposure of organisms passing through the mixing zone is less than the acute criteria [Reference 23]. Though maximum temperature criteria are based on experimental studies using longer averaging periods [Reference 15], the 1-hour average exposure period was used as a conservative means of evaluating, through additional analysis, the potential lethality to passive organisms from exposure to elevated water temperature (> 90°F) in the mixing zone.

The average velocity in the steady-state plume was obtained from the CFD model and divided into the greatest length of the plume (198 ft) to estimate potential travel time through the plume for a passive organism. For Scenario 1, the average velocity was estimated at 0.158 feet per second (ft/s). As such, travel time through the plume was determined to be approximately 21 minutes. For Scenario 2 the average velocity is 0.119 ft/s and the length of the plume is 30 ft, so travel time is 4 minutes. Thus, no passive organisms/life stages will be exposed to water temperatures > 90°F for extended periods of time and any exposures will be well below an hour.

Determination of velocities throughout the plume is a complex exercise given the dynamic conditions in the forebay. However, the analysis is conservative in that the conditions considered (i.e., flow velocities) have been determined for the steady state

condition of the plume under rare pulsed-flow conditions. Under typical continuous operation of the Ninety-Nine Islands hydroelectric facility turbines, ambient and turbine-induced flows would be expected to substantially reduce travel time for passive organisms through the mixing zone.

With regard to the downstream extent of the thermal plume, it is important to note that based on the CFD-modeling results (see Section 3.3.3 above), water temperatures greater than 90°F are not predicted to reach the Ninety-Nine Islands hydroelectric turbine inlets and pass downstream to the tailrace under critical conditions. Thus, the acute mixing zone boundary does not extend downstream from the forebay area.

3.5 Thermal Mixing Zone Request

The text provided in this document constitutes Duke Energy's formal request to SCDHEC to authorize a thermal mixing zone for the Lee Nuclear Station thermal discharge to the Broad River. The technical information presented herein fully addresses South Carolina Regulation 61-68 Water Classifications and Standards as they relate to mixing zones for surface waters (Section C.10.); specifically:

- The size of the requested thermal mixing zone has been reasonably minimized based on the proportion of the discharge flow to receiving waterbody critical 7Q10 flow (i.e., < 4 percent). This will be accomplished through the active design and construction of a closed-cycle re-circulating cooling water system at Lee Nuclear Station as opposed to an open-cycle, once-through cooling water system.

- The size of the requested mixing zone has been further minimized through the use of a submerged multi-port discharge diffuser that provides rapid mixing of the thermal discharge in the receiving waterbody.

- Considering potential acute thermal affects to aquatic life, under a rare worst case discharge temperature of 95°F concurrent with critical 7Q10 low flow conditions, the areal extent of the ≥ 90°F acute mixing zone is predicted by the conservatively applied CFD modeling to be well within SCDHEC's specified spatial boundaries for such mixing zones of no more than one-tenth (10 percent) of the width of the stream (width) and a length downstream of one-third (33.3 percent) the width of the stream [Reference 22]. The Lee Nuclear Station

thermal mixing zone width and length are predicted by the model to be 6 and 19 percent, respectively, of the width of the Broad River at the discharge location.

Under the same discharge scenario, the cross-sectional area of the ≥ 90°F plume is proportionally 3.7 percent of the total cross-sectional area of the Broad River at the discharge location. In addition, the plume is relatively shallow (97% of the plume is at 5 ft depth or less, and the maximum plume depth is 7.7 ft) so that there is a significant distance between the thermal plume and the bottom of the forebay where fish may escape, or swim under the plume.

Further, the CFD modeling indicates that under the worse case conditions considered, water temperatures ≥ 90°F will not extend to the Ninety-Nine Islands Hydroelectric Station turbine inlets and pass downstream to the tailrace. Notably, maximum temperature rise at the turbine inlets under modeled conditions is predicted to be < 0.4°F.

Additionally, travel time for passive organisms through the thermal plume/mixing zone was determined to be approximately 21 minutes for Scenario 1 (95°F discharge temperature), and 4 minutes for Scenario 2 (91°F discharge temperature). Thus, exposure of passive organisms/life stages to water temperatures > 90°F for extended periods of time will not occur under critical conditions.

- Given the small size of the thermal discharge area and acute mixing zone (≥ 90°F) relative to the receiving waterbody, there is no reasonable expectation that the thermal discharge and requested mixing zone would "*result in undesirable aquatic organisms or a dominance of nuisance species outside of the mixing zone*".

- Given there are no federally-listed endangered or threatened aquatic species or habitats in the Broad River in the vicinity of the discharge [Reference 1], there is no reasonable expectation that the requested thermal mixing zone "*would adversely affect a federally-listed endangered or threatened aquatic species, its habitat, or a proposed or designated critical habitat*".

- Based on the small proportion of the discharge flow to receiving waterbody critical 7Q10 flow (i.e., < 4 percent), minimization of the thermal mixing zone

to meet SCDHEC spatial requirements for mixing zones, and limited travel time through the plume for passive organisms, the requested thermal mixing zone will allow for safe passage of aquatic organisms and the protection and propagation of a balanced indigenous aquatic community in and on the Broad River.

- The requested mixing zone will not endanger public health and welfare.

The CFD modeling was conservatively applied in this study and demonstrates the minimal impact the Lee Nuclear Station thermal discharge is predicted to have on the thermal regime of the Broad River and Ninety-Nine Islands Reservoir forebay, and associated aquatic communities they support.

Based on the above evidence, Duke Energy requests that SCDHEC authorize a thermal mixing zone as defined for a potential daily average discharge temperature of 95°F, as part of the NPDES permit for the Lee Nuclear Station thermal discharge to the Broad River.

4. WHOLE EFFLUENT TOXICITY MIXING ZONE REQUEST

South Carolina water quality regulations allow mixing zones for discharges to state waters [Reference 14]. A mixing zone is defined in the regulations as:

"*...an area where a discharge undergoes initial dilution and is extended to cover the secondary mixing in the ambient waterbody. A mixing zone is an allocated impact zone where water quality criteria can be exceeded as long as acutely toxic conditions are prevented (except as defined within a Zone of Initial Dilution) and public health and welfare are not endangered.*"

Zone of Initial Dilution is defined as:

"*that minimal area of a mixing zone immediately surrounding the outfall where water quality criteria are not met, provided there is no acute toxicity to drifting organisms and public health and welfare are not endangered.*"

As an applicant for an NPDES point source discharge permit in South Carolina, SCDHEC provided Duke Energy with procedures for requesting a WET Mixing Zone [Reference 22], including a form to be completed and submitted as part of the NPDES permit application package for Lee Nuclear Station. Completion of the form provides SCDHEC with information needed to determine mixing zone size for chemical constituents potentially present in the Lee Nuclear Station discharge and associated WET requirements.

CORMIX is a common water quality model used by SCDHEC and other regulatory permitting agencies to determine mixing zone size and other attributes to establish WET requirements. In the case of the Lee Nuclear Station submerged multi-port discharge diffuser, the orientation of the discharge diffuser parallel to ambient flow along the Ninety-Nine Islands Dam precluded the use of the more traditional CORMIX model to determine mixing zone size (see discussion in Section 3.1). Consequently, Geosyntec employed CFD modeling to accomplish this task. The results thereof are summarized in the following text.

4.1 Computational Fluid Dynamics Modeling – Approach

4.1.1 Overview

Modeling was conducted to evaluate mixing characteristics of the discharge with the Broad River, and determine spatial dimensions of the mixing zone. The CFD model used was similar to that reported above for the thermal discharge analyses (see Section 3). The geometry and computational mesh were unchanged and are shown in Figure 2 through Figure 5 for reference. To evaluate the mixing of the cooling water with the ambient water of the Broad River, a "passive scalar" approach (physically similar to a dye tracer) was used, as the concentration of constituents was low enough that they would have no significant effect on the overall flow field. A source for this passive scalar was imposed on the volume representing the discharge diffuser. From the concentration of the passive scalar at each point in the flow field, relative to the initial concentration, the dilution of the diffuser discharge could be determined.

The model was run in transient mode to capture the pulsed operation of the turbines. As with the previous effort, the diffuser discharge was applied as a mass source at the location of the diffuser and allowed to diffuse equally in all directions. This will tend to result in conservative results for the mixing zones as the momentum induced by the multi-port discharge diffuser will be greater in reality than in the model. This increase in momentum will encourage entrainment of ambient water and enhance mixing. As a result, the under-representation of momentum in the CFD model is conservative.

4.1.2 Definition of Dilution Ratio

To evaluate mixing, a "dilution ratio" was defined that represented the total number of parts of fluid (background plus discharge) to the number of parts of discharge fluid only. Thus, a dilution ratio of one represents fluid that is purely from the discharge, while a dilution ratio of four indicates three parts background to one part discharge fluid. A useful alternative view is that a dilution ratio of one represents a 100 percent concentration of discharge fluid, while a dilution ratio of four indicates a 25 percent concentration. This is particularly useful as the discharge fluid concentration is a direct output of the CFD model, so that the dilution ratio, *r*, can be calculated using:

$$r = \frac{1}{C_s} \tag{1}$$

where C_s is the concentration of the passive scalar (in the CFD model, the initial passive scalar concentration is 1 so that the above equation holds).

4.1.3 Scenarios Modeled

Similar to modeling of the thermal discharge, the two CFD calculations (scenarios or cases) were performed with the following variables common to both cases:

- River flow rate was set to 464 cfs in accordance with the 7Q10 level specified by SCDHEC for the NPDES permitting [Reference 13];
- River temperature (background) was set to 88.2°F as determined from Duke Energy continuous water temperature data collected in the Ninety-Nine Islands forebay during June-August 2008 (when 7Q10 flows might be expected to occur) [Reference 21];
- Turbine flow rate was set to 500 cfs when "on" and 53 cfs when "off" (due to leakage through the turbine penstock);
- Ninety-Nine Islands Hydroelectric Station turbine operation:
  - Only 1 turbine unit is in operation.
  - The unit is "off" for the first 4.3 minutes per hour, flow accumulates in the forebay and only leakage flow passes to the tailrace. The unit is "on" for the remaining 55.7 minutes per hour. These timings were calculated by considering the balance of the river and turbine flow rates only.
- Lee Nuclear Station discharge rate was set to 18.3 cfs.

The scenarios differed in the temperature of the cooling water discharge which affects water density and associated mixing characteristics. In Scenario 1 the discharge temperature was set to 95°F, while in Scenario 2 it was 91°F.

4.2 Definition of Mixing Zones

Under typical circumstances, SCDHEC requirements [Reference 22] specify that the length of the acute mixing zone (or Zone of Initial Dilution, ZID) extending

downstream should not exceed one-third (33.3 percent) the width of the river and the width of the mixing zone should not exceed one-tenth (10 percent) the width of the river. In addition, the chronic mixing zone should not exceed twice (200 percent) the width of the river in length and should not exceed one-third (33.3 percent) the width of the river in width. However, the nature of the flows in this instance is atypical due to the operation of the nearby hydroelectric power station. For example, under 7Q10 flow conditions, the single operating turbine intake is approximately 175 feet from the end of the discharge diffuser. The flow through the turbine intake must contain discharge fluid at an average concentration of less than 4% (from a simple mass balance calculation of 18 cfs discharge flow and 464 cfs 7Q10 river flow). As the width of the river at this point is approximately 1,031 ft, the turning of the discharge flow into the turbine intake occurs well within the limit of the acute mixing zone length of 344 ft (one-third of 1,031 ft). Downstream of the turbine, the river will maintain a concentration of less than 4% discharge flow.

An alternative definition for the mixing zone is presented that is better suited to the flows in the proximity of the discharge in this case. That is, the volume of fluid with a dilution ratio less than or equal to the lowest value of dilution ratio at the turbine intake. Note that although the average concentration at the turbine intake is around 4%, there is significant spatial variation over intake area. The turbine intake is therefore taken to be the boundary where the highest concentration (or the lowest dilution ratio) is set for the mixing zone.

This approach yields only one value for dilution ratio. It is proposed that this value defines the chronic mixing zone, and the acute mixing zone is not defined.

In both modeling scenarios, an appropriate value of dilution ratio that represented the minimum value at the turbine intake was 5, or 20% concentration. The chronic mixing zone was thus defined as the volume less than, or equal to, a dilution ratio of 5.

4.3 Model Results

Contours of dilution ratio (defined as shown in Equation (1)) for Scenario 1 (95°F discharge temperature) are shown on Figure 19. As expected, the low values of dilution ratio are located close to the discharge diffuser, with the higher values (indicating that the fluid is mostly background) much further away. It should be noted that as the turbine switches on and off during the hourly cycle, the shape of the dilution contours

changes throughout the cycle. However, for the majority of the cycle the plume does not change significantly, and this is referred to as the "steady-state" plume. The results here, and in all other figures, are for this steady-state plume, which is shown after the second hourly cycle in the CFD model. Tests have shown that these results are accurate (in other words the steady-state plume does not increase in size) for subsequent cycles.

Figure 20 shows contours of dilution ratio for Scenario 2 (91°F discharge temperature). The plume in this case is less spread than in Scenario 1. This is due to the difference in discharge temperature in the two scenarios. For Scenario 1 where the discharge temperature is higher, the plume rises to the surface quickly due to its positive buoyancy and then spreads in a relatively thin, shallow layer. The "cooler" discharge in Scenario 2 rises much slower and does not spread as rapidly just below the water surface. Therefore, in general, the cooler plume of Scenario 2 is less spread, but deeper. The differences between the two plumes become greater as the dilution ratio increases.

The volume representing the chronic mixing zone is defined as having a dilution ratio less than or equal to 5 (concentration of 20% or more). A perspective view of the mixing zone looking from above and towards the dam is shown on Figure 21 for Scenario 1 and Figure 22 for Scenario 2. The boundaries of the mixing zone are shown by the solid purple isosurfaces in each figure. Note in particular that the depth of the mixing zones in each case is shallow relative to the depth of the forebay.

4.3.1 Spatial Dimensions of the WET Mixing Zone

Results of the CFD modeling for the chronic mixing zone are summarized in the table below:

	Scenario 1	Scenario 2
River Flow	464 cfs 7Q10 Critical Flow	464 cfs 7Q10 Critical Flow
River Temperature	88.2°F	88.2°F
Discharge Flow	18.3 cfs	18.3 cfs
Discharge Temperature	**95°F**	**91°F**
CHRONIC MIXING ZONE (5:1 dilution, equivalent to 20% concentration)		
- **Volume**	1.25 acre-ft 54,523 ft^3	0.939 acre-ft 40,916 ft^3
- **Surface area**	0.397 acre 17,275 ft^2	0.251 acre 10,936 ft^2
- **Cross-Sectional area**	758 ft^2 4.5% of forebay x-area	932 ft^2 5.5% of forebay x-area
- **Average Depth/Thickness**	1.8 ft	2.0 ft
- **Maximum Depth/Thickness**	12.4 ft	8.5 ft
- **Maximum Width**	72 ft	40 ft
- **Maximum Length**[6]	215 ft	200 ft

[6] Calculated from the end of the discharge diffuser.

There were noted differences in the lateral extent of mixing zones output by the CFD model for the two scenarios considered (Figures 18 and 19). This was the result of changes in density/buoyancy attributable to the two different discharge temperatures modeled. In establishing the mixing zone size for the WET Mixing Zone request, worst case maximum dimensions for length and width were used from each of the scenarios modeled.

Recall from the thermal mixing zone request narrative that the Lee Nuclear Station discharge diffuser is different than the conventional configuration where the discharge diffuser extends laterally from shore and is positioned perpendicular to river flow (see Section 3.1). In this case, plume length runs parallel to the longitudinal centerline of the diffuser pipe (i.e., easterly); and width as perpendicular to the diffuser (i.e., northerly). As determined from the CFD model, the worst case maximum lateral dimensions of the chronic mixing zone are 72 ft in width and 215 ft in length (7% and 21% of the river width respectively).

As for the thermal mixing zone described previously, it is also important to consider the vertical profile of the mixing zone as the lateral dimensions of maximum length and width perhaps overstate the potential impact on aquatic organisms that might be exposed to acute and chronic conditions. Although the maximum depth of the chronic mixing zone (extending from the surface downward) is 12.4 ft, only a small proportion of the mixing zone is at that depth. Specifically, 90 percent of the mixing zone volume is found at 4 ft depth or less for Scenario 1. The same was found for Scenario 2. The average depth/thickness of the chronic mixing zone is just 1.8 ft for Scenario 1 and 2.0 ft to Scenario 2.

The relative profile of the mixing zones is further demonstrated by considering cross-section area, which for the chronic mixing zone is just 4.5 and 5.5 percent of the total forebay cross-sectional area for Scenarios 1 and 2, respectively.

Thus, given the relatively small lateral dimensions and cross-sectional profile of the mixing zone modeled under very conservative conditions, there is limited potential exposure to acute and chronic conditions for free-swimming fish or benthic organisms and their passive life stages.

As presented earlier (Section 3.4), EPA guidance provides that the area extent and concentration isopleths of a mixing zone must be such that the 1-hour average exposure

of organisms passing through the mixing zone is less than the acute criteria [Reference 23]. Based on this guidance, the potential lethality to passive organisms from acute exposure within the chronic mixing zone was determined.

The average velocity in the steady-state plume was obtained from the CFD model and divided into the greatest length of the mixing zone (215 ft) to estimate potential travel time through the zone for a passive organism. For Scenario 1 (95°F discharge), the average velocity was estimated at 0.16 ft/s. As such, travel time through the plume was determined to be approximately 22 minutes. For Scenario 2 (90°F), the average velocity was also 0.16 ft/s. The length of the plume is 200 ft so travel time is 21 minutes. Thus, no passive organisms/life stages will remain in the mixing zone for extended periods of time and certainly not an hour.

Again, determination of velocities throughout the plume is a complex exercise given the dynamic conditions in the forebay. However, the analysis is believed conservative in that the conditions considered (i.e., flow velocities) have been determined for the steady state condition of the plume under rare pulsed-flow conditions. Under typical continuous operation of the Ninety-Nine Islands hydroelectric facility turbines, ambient and turbine-induced flows would be expected to substantially reduce travel time for passive organisms through the mixing zone.

Further, as previously stated, including the enhanced mixing properties afforded by the high-velocity multi-port diffuser not fully considered by the CFD model (see Section 3.3) will further diminish the size of the mixing zones reported herein and lessen exposure for passive organisms.

4.3 Whole Effluent Toxicity Parameters

Duke Energy is requesting a WET mixing zone be authorized for the Lee Nuclear Station discharge to the Broad River and has completed the SCDHEC-provided WET Mixing Zone Request Form. Information requested on the SCDHEC form is repeated here with supporting narrative.

What is the proposed ZID size (in meters)? N/A

Please refer to the site-specific definition of mixing zone given in Section 4.2 of this report.

What is the proposed acute WET test concentration? N/A

Please refer to the site-specific definition of mixing zone given in Section 4.2 of this report.

What is the proposed mixing zone size (in meters)? Length 66 m x Width 22 m

This proposed mixing zone size is deemed necessary to allow for adequate mixing of the discharge to the edge of the mixing zone defined by the turbine intake, and was conservatively determined based on the CFD model output.

What is the proposed chronic WET test concentration? 20.0 percent

A representative value for minimum dilution at the turbine intake was calculated as 5, corresponding to a WET test concentration of 20%.

4.4 WET Mixing Zone Request

In addition to the completed SCDHEC WET Mixing Zone Request Form, this document constitutes Duke Energy's formal request to SCDHEC to authorize a WET mixing zone for the Lee Nuclear Station discharge to the Broad River. The technical information presented herein fully addresses South Carolina Regulation 61-68 Water Classifications and Standards as they relate to mixing zones for surface waters (Section C.10.); specifically:

- The size of the requested mixing zone has been reasonably minimized based on the proportion of the discharge flow to receiving waterbody critical 7Q10 flow (i.e., < 4 percent).
- The size of the requested mixing zone has been further minimized through the use of a submerged, multi-port discharge diffuser that provides rapid mixing of the discharge in the receiving waterbody.
- Initial analysis showed that the spatial dimensions of the acute mixing zone (based on a maximum width of 10% of the width of the river and a maximum length of 33% of the width of the river) almost entirely contained the discharge plume due to the turning of the flow towards the turbine. Thus the turbine intake

was defined as the maximum extent in this case for the chronic mixing zone, while no definition or dimensions were given for the acute mixing zone.

- The spatial dimensions of the chronic mixing zone fall well within SCDHEC's specified spatial boundaries for such mixing zones of no more than one-third (33.3 percent) the width of the river (width) and a length downstream of twice (200 percent) the width of the river [Reference 22]. For the Lee Nuclear Station discharge, the length and width of the chronic mixing zone represent approximately 21 percent and 7 percent respectively of the width of the Broad River at the forebay of the dam.

- The cross-sectional areas of the mixing zones modeled relative to the total forebay cross-sectional area were small, ranging from 4.5 to 5.5 percent. As such, there is limited potential exposure to chronic conditions for free-swimming fish and their passive life stages.

- Travel time through the acute mixing zone under each discharge scenario was determined to be approximately 20 minutes. Thus, no passive organisms/life stages will be exposed remain in the chronic mixing zone for extended periods of time (well less than an hour).

- Given the small size of the discharge area and requested mixing zone relative to the receiving waterbody, there is no reasonable expectation that the Lee Nuclear Station discharge would "*result in undesirable aquatic organisms or a dominance of nuisance species outside of the mixing zone.*"

- Given there are no federally-listed endangered or threatened aquatic species or habitats in the Broad River in the vicinity of the discharge [Reference 1], there is no reasonable expectation that the requested mixing zone "*would adversely affect a federally-listed endangered or threatened aquatic species, its habitat, or a proposed or designated critical habitat.*"

- Based on the small proportion of the discharge flow to receiving waterbody critical 7Q10 flow (i.e., < 4 percent), minimization of the mixing zone to meet SCDHEC spatial requirements for mixing zones, and limited travel time through the plume for passive organisms, the requested mixing zone will allow for safe

passage of aquatic organisms, and allow for the protection and propagation of a balanced indigenous aquatic community in and on the Broad River.

- The requested mixing zone will not endanger public health and welfare.

Based on the above weight of evidence, Duke Energy requests that SCDHEC authorize a WET mixing zone as defined in this request for outfall 001. In summary a WET limit for outfall 001 is requested to be for chronic testing only at a Chronic Test Concentration of 20%.

5. REFERENCES

[1] *Duke Energy Combined Construction and Operating License Application for William States III Nuclear Station*; Environmental Report (Rev.1). http://adamswebsearch2.nrc.gov/idmws/ViewDocByAccession.asp?AccessionNumber=ML090990348.

[2] Technical Memorandum dated May 21, 2010: *Diffuser Design for the Lee Nuclear Power Station*. Prepared for Duke Energy by Philip J.W. Roberts, PhD, PE; Atlanta, Georgia.

[3] Amendment to Exhibit A & B and Authorized Installed Capacity for Ninety-Nine Islands Project 2331 dated January 26, 2007. FERC "eLibrary": http://elibrary.ferc.gov/idmws/nvcommon/NVViewer.asp?Doc=11345136:0.

[4] Duke Power Company, DPC Ninety-Nine Islands Dam Project License Renewal – Environmental Report, revised 1996.

[5] U.S. Federal Energy Regulatory Commission (FERC). Order Issuing New License. Project no. 2331-002, June 17, 1996.

[6] Devine, Tarbell & Associates (DTA) e-mail communication to Duke Energy (Justin Schumacher to Robert Wylie) dated 27 July 2011 conveying Broad River flow frequency information.

[7] *Hydrodynamic Assessment of Discharge from Cooling Tower Blowdown to Broad River, Lee Nuclear Station, Cherokee County, South Carolina*. Clemson University, The Strom Thurmond Institute of Government & Public Affairs. Clemson, SC. September 20, 2007.

[8] *Computational Fluid Dynamics Thermal Modeling* – Lee Nuclear Station Site, Cherokee County, South Carolina. Geosyntec Consultants, July 2009; Prepared for Duke Energy Carolinas, LLC; submitted to NRC on 24 September 2009 (accession # ML092730480). http://adamswebsearch.nrc.gov/scripts/rwisapi.dll/@pip1.env

[9] Henk Kaarle Versteeg and Weeratunge Malalasekera. 2007. "*An Introduction to Computational Fluid Dynamics: The Finite Volume Method*". Second Edition. Pearson Education, Ltd., 503pp.

[10] Fangbiao Lin and George E. Heckler, Alden Research Laboratory, Inc., Holden, MA; and Brennan T. Smith and Paul N. Hopping, Tennessee Valley Authority, Knoxville, TN. "*Nuclear Power Plant Thermal Discharge*", Fluent News, Spring 2004 and associated reference: D.F.R. Hardeman, L.C. Hall, and T.G. Curtis. "*Thermal Diffusion of Condenser Water in a River during Steady and Unsteady Flows with Application to the TVA Browns Ferry Nuclear Power Plant*". Hydrodynamics Laboratory Report No. 111, Massachusetts Institute of Technology, Cambridge, MA, September 1968.

[11] "*Computational Fluid Dynamics Modeling of the North Fork Dam Forebay, Clackamas River, Oregon*" and "*Bonneville Tailrace Project: Three-Dimensional CFD Models and Flow Measurements*". Pacific Northwest National Laboratory, Richland, WA.

[12] Liaqat A. Khan, Edward A. Wicklein, and Mizan Rashid. "*A 3D CFD Model Investigation of an Outfall Reservoir Hydraulics for Repowering a Power Plant*". Examining the Confluence of Environmental and Water Concerns; Proceedings of the World Environmental and Water Resources Congress. 2006

[13] *Review of 7Q10 and Average Annual Flow (AAQ) Proposed by Duke Energy for Broad River at Lee Nuclear Site.* Internal memorandum from Larry Turner, Manager, Water Quality Section to Melinda Vickers, Project Manager, Industrial Wastewater Permitting Section, dated October 19, 2009. South Carolina Department of Health and Environmental Control; Columbia, SC.

[14] *South Carolina Regulation 61-68 Water Classification and Standards*, Effective April 25, 2008. Bureau of Water, South Carolina Department of Health and Environmental Control; Columbia, SC.

[15] "*Temperature Criteria for Freshwater Fish: Protocol and Procedures*" (EPA-600/3-77-061). May 1977. Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protectiona Agency, Duluth, MN.

[16] ANSYS,Inc., Southpointe, 275 Technology Drive, Canonsburg, PA 15317. http://www.ansys.com/default.asp.

[17] Devine Tarbell & Associates, Inc., Ninety-Nine Islands Bathymetry and Velocity Study Report, May 2008.

[18] Duke Energy Drawing: Ninety-Nine Islands Hydro Station, Plan, Profile and Spillway Rating Curve. (Exhibit F Sheet 2) undated. Forwarded to Geosyntec Consultants as "SFX43A.pdf".

[19] Duke Energy Drawing: WWS Discharge General Area Plan. WLG-3900-P6H-001.pdf dated 07/24/08.

[20] Duke Energy Drawing: Discharge Pipe Support Details. WLG-3900-P6H-002.pdf dated 07/24/08.

[21] Duke Energy Temperature Measurements in Broad River and Ninety-Nine Islands Islands Forebay. Forwarded to Geosyntec Consultants as MS Excel files "LNSupres2007all.xls" and "LNSupres2008all.xls".

[22] *NPDES Application Supplement – Mixing Zone Request.* Memorandum to NPDES Permittees from Water Facilities Permitting Division dated May 21, 2009. South Carolina Department of Health and Environmental Control; Columbia, SC.

[23] *Technical Support Document for Water Quality-based Toxics Control.* EPA/505/2-90-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

This Page Intentionally Left Blank

FIGURES

This Page Intentionally Left Blank

Figure 1 – Plan view of the geometry used in the CFD model

This Page Intentionally Left Blank

Figure 2 – Plan view of the geometry used in the CFD model

This Page Intentionally Left Blank

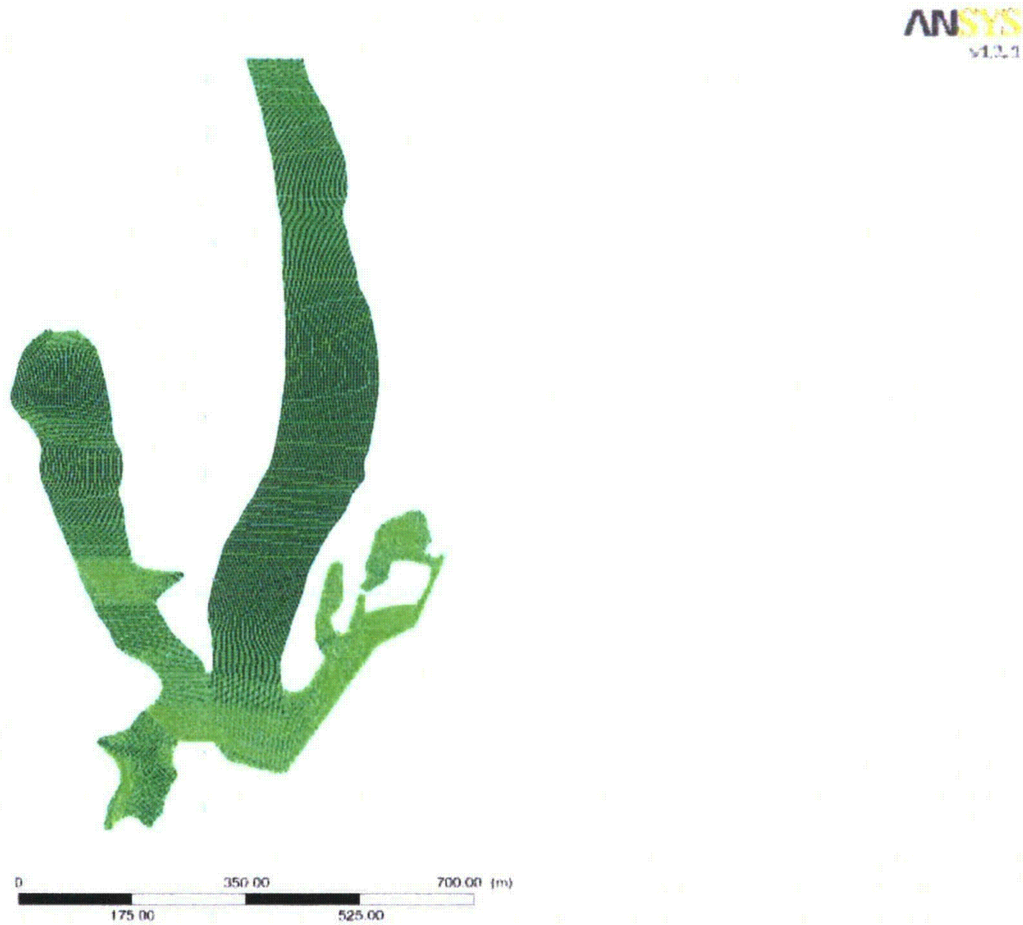


Figure 3 – Computational Mesh

This Page Intentionally Left Blank

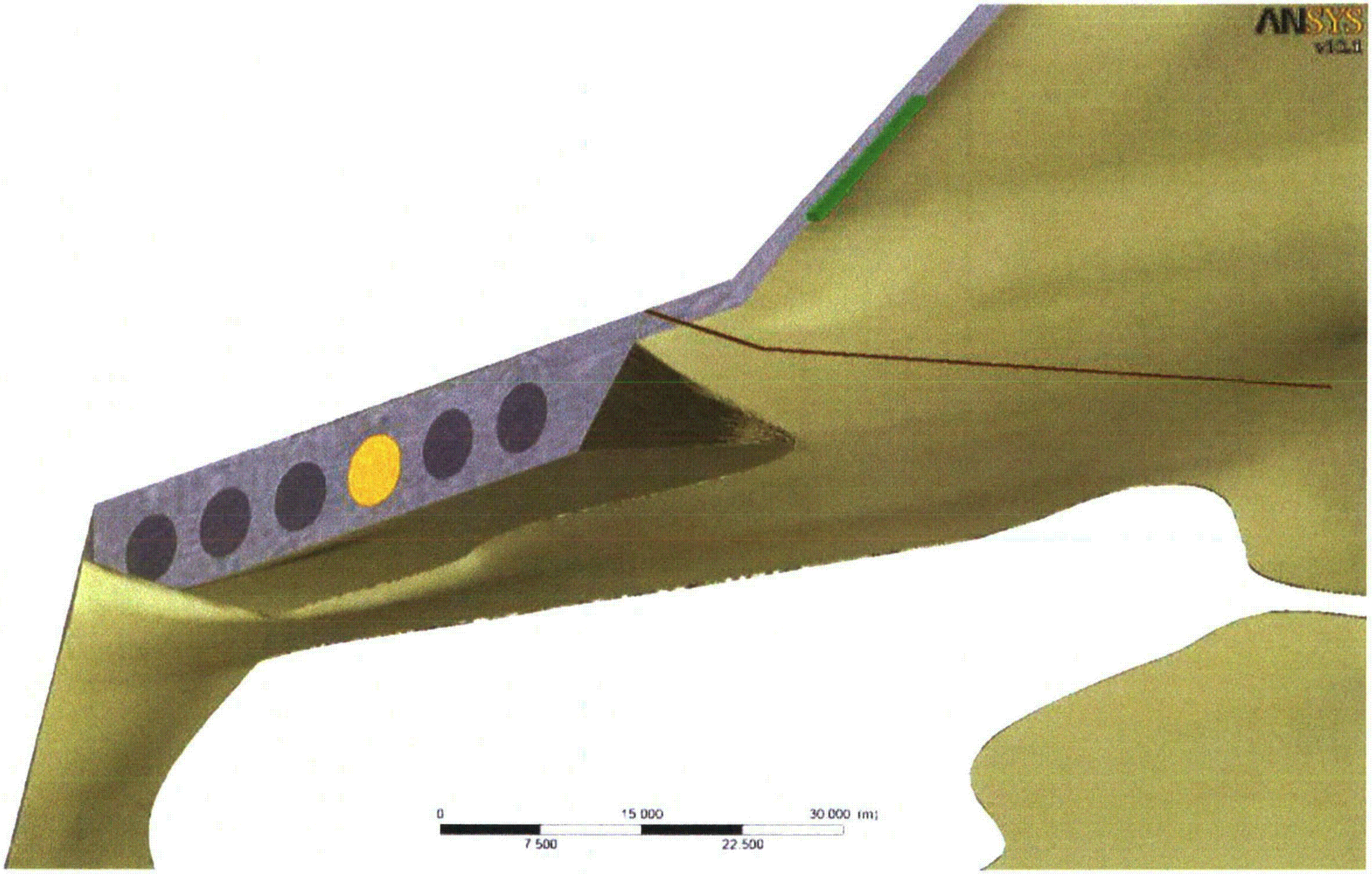


Figure 4 – Close view of geometry, showing forebay, dam, turbine openings (turbine 4 is colored orange) and volume representing the discharge diffuser (green).

This Page Intentionally Left Blank

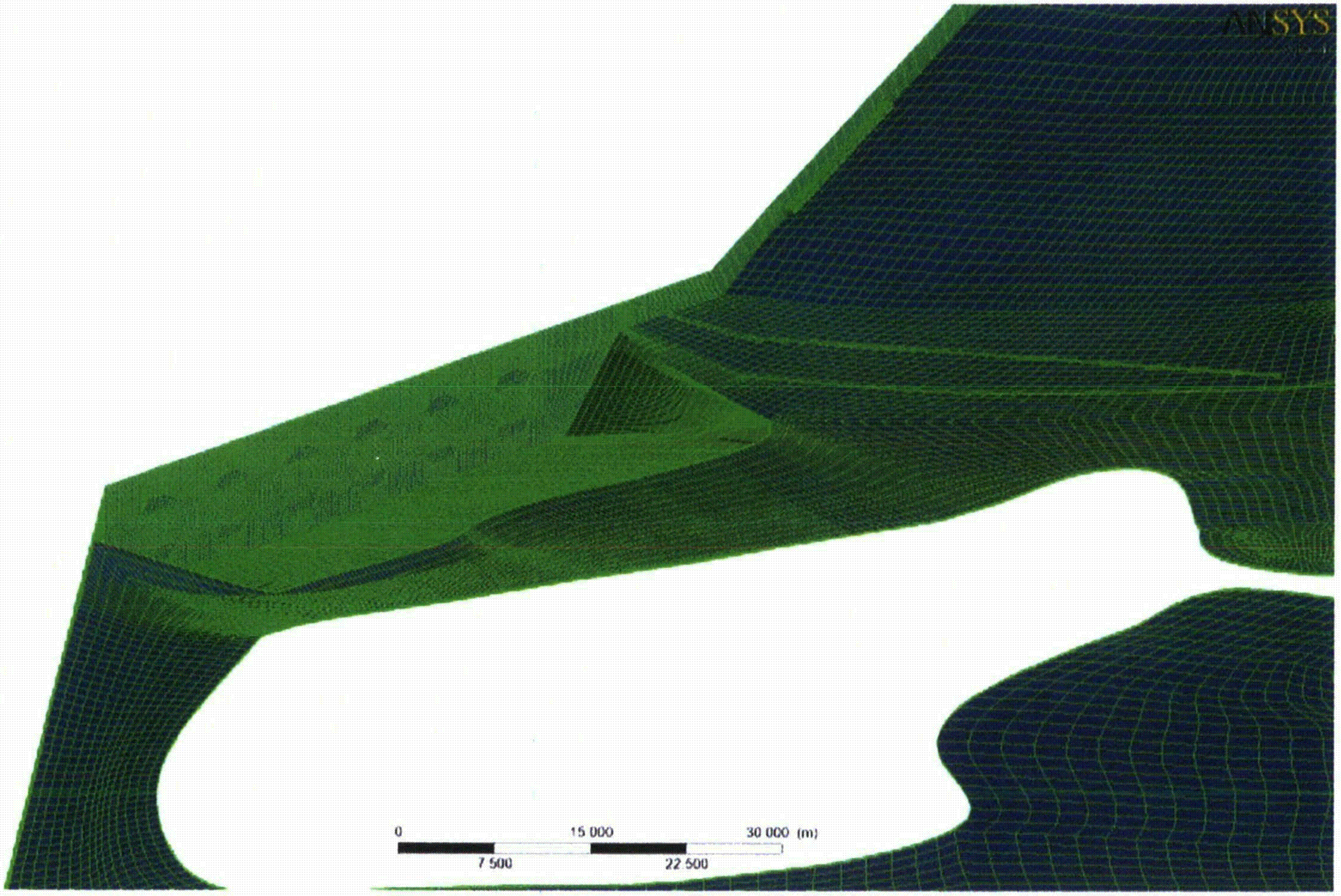


Figure 5 – Close view of the computational surface mesh in the forebay.

This Page Intentionally Left Blank

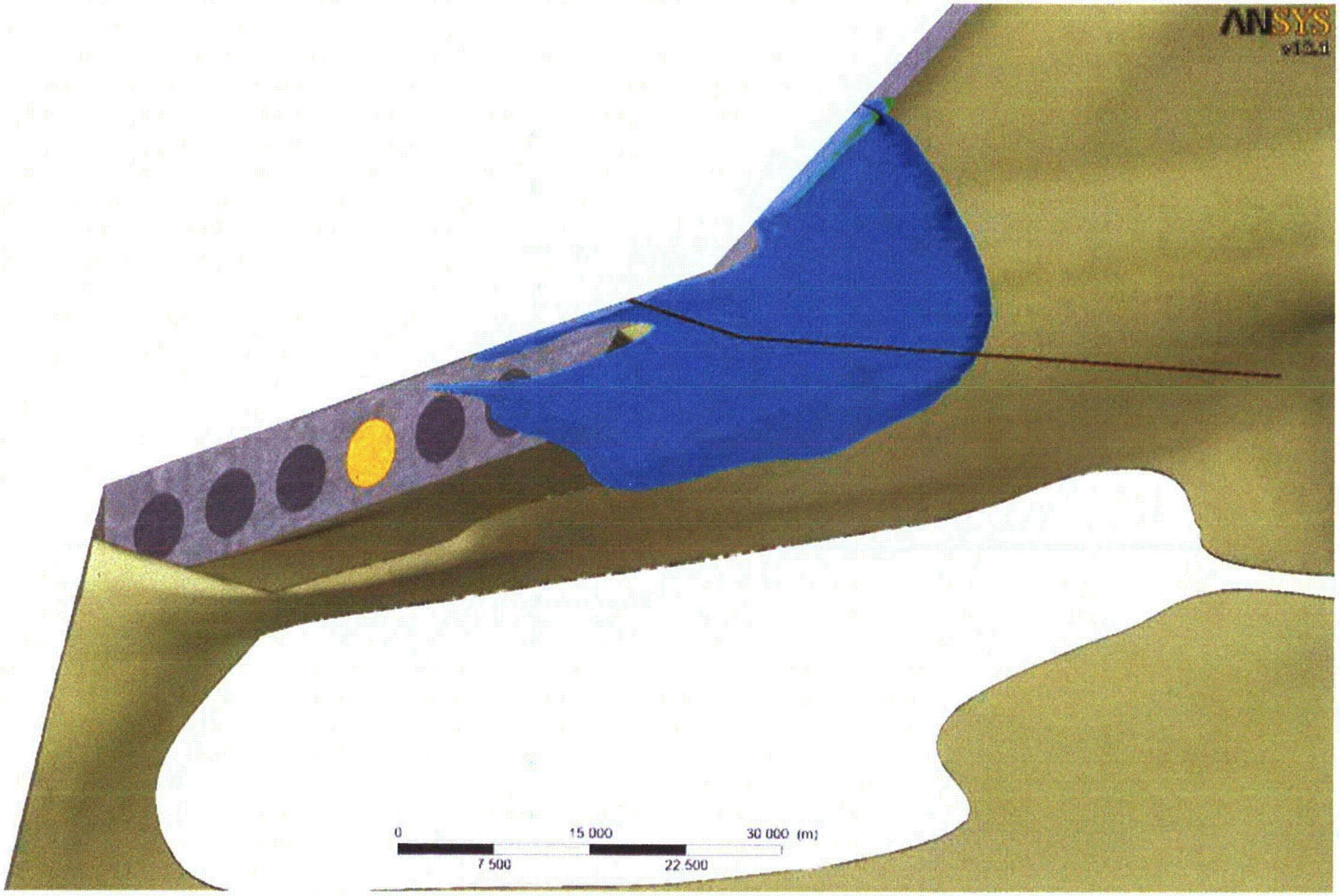


Figure 6 – Blue iso-surface showing 90°F plume for Scenario 1, 20 minutes into cycle 1.

This Page Intentionally Left Blank

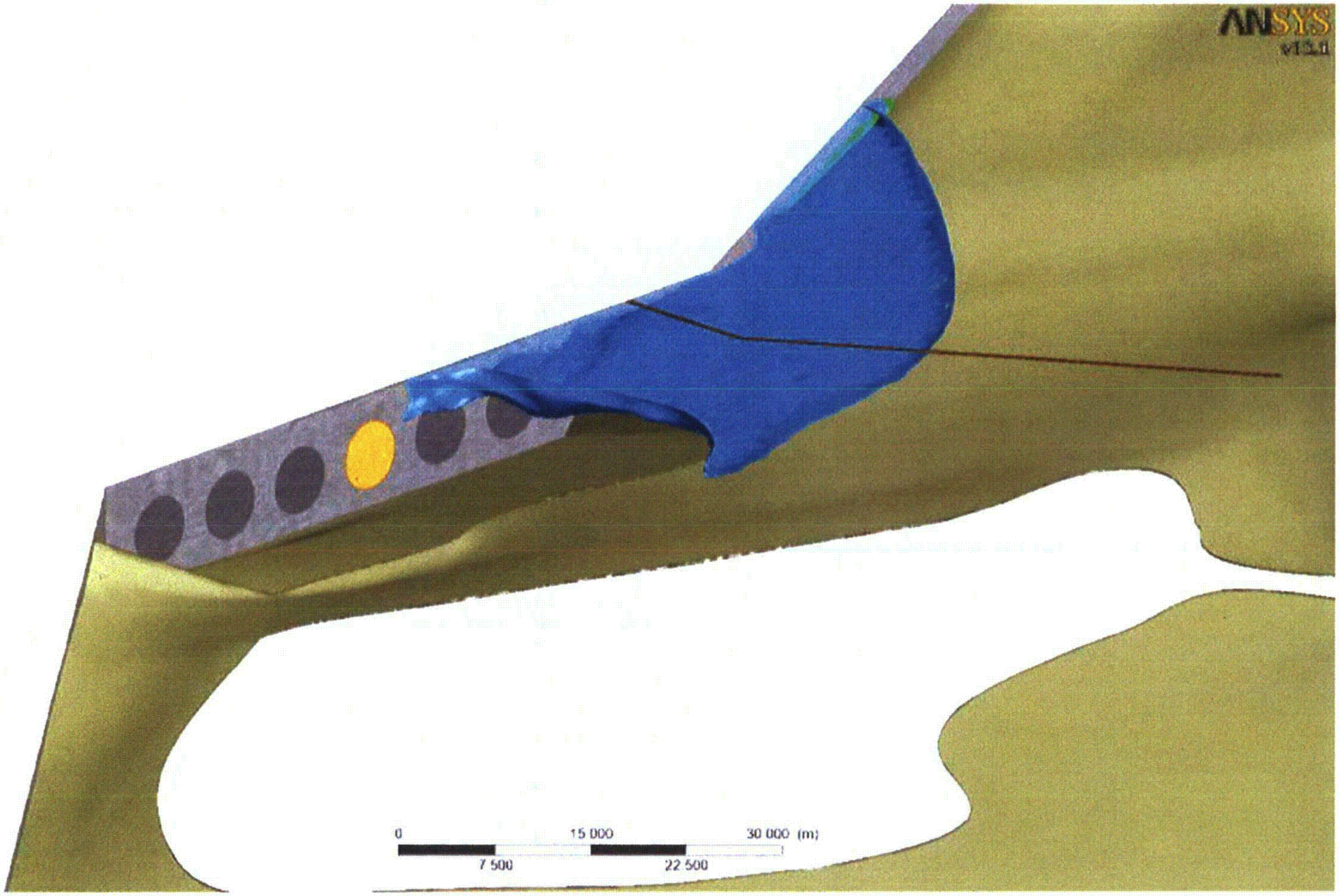


Figure 7 – Blue iso-surface showing 90°F plume for Scenario 1, end of cycle 1.

This Page Intentionally Left Blank

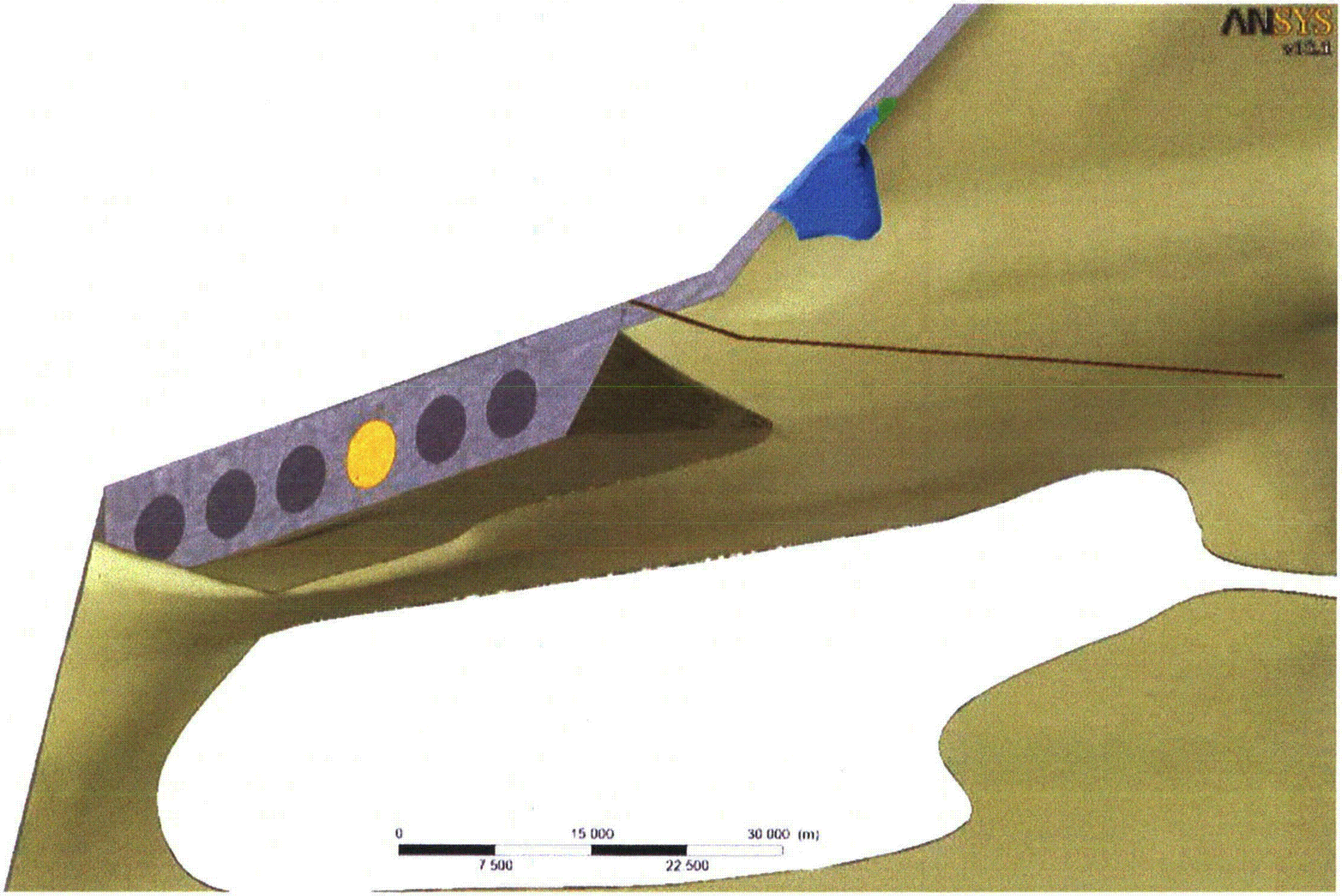


Figure 8 – Blue iso-surface showing 90°F plume for Scenario 2, 20 minutes into cycle 1.

This Page Intentionally Left Blank

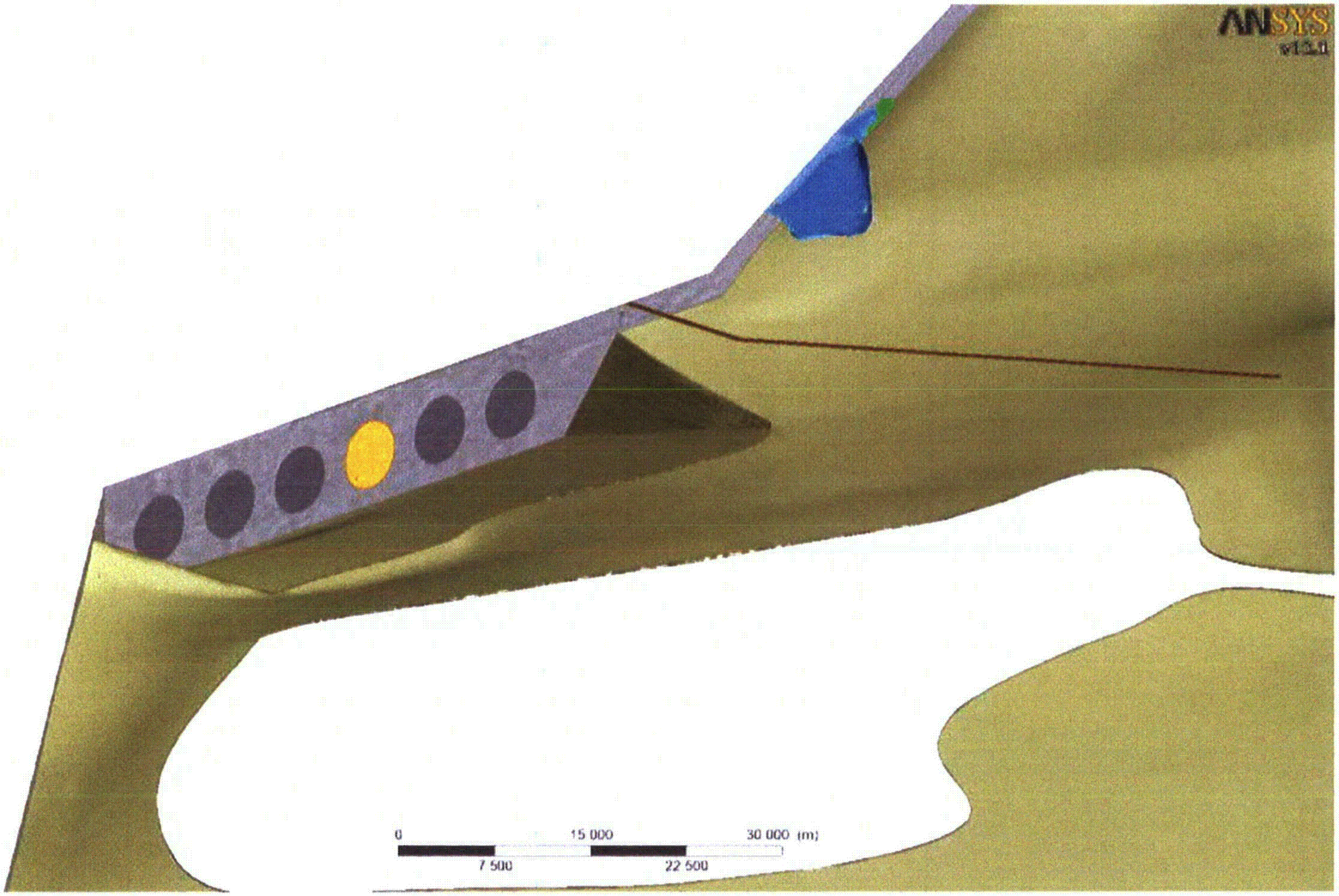


Figure 9 – Blue iso-surface showing 90°F plume for Scenario 2, end of cycle 1.

This Page Intentionally Left Blank

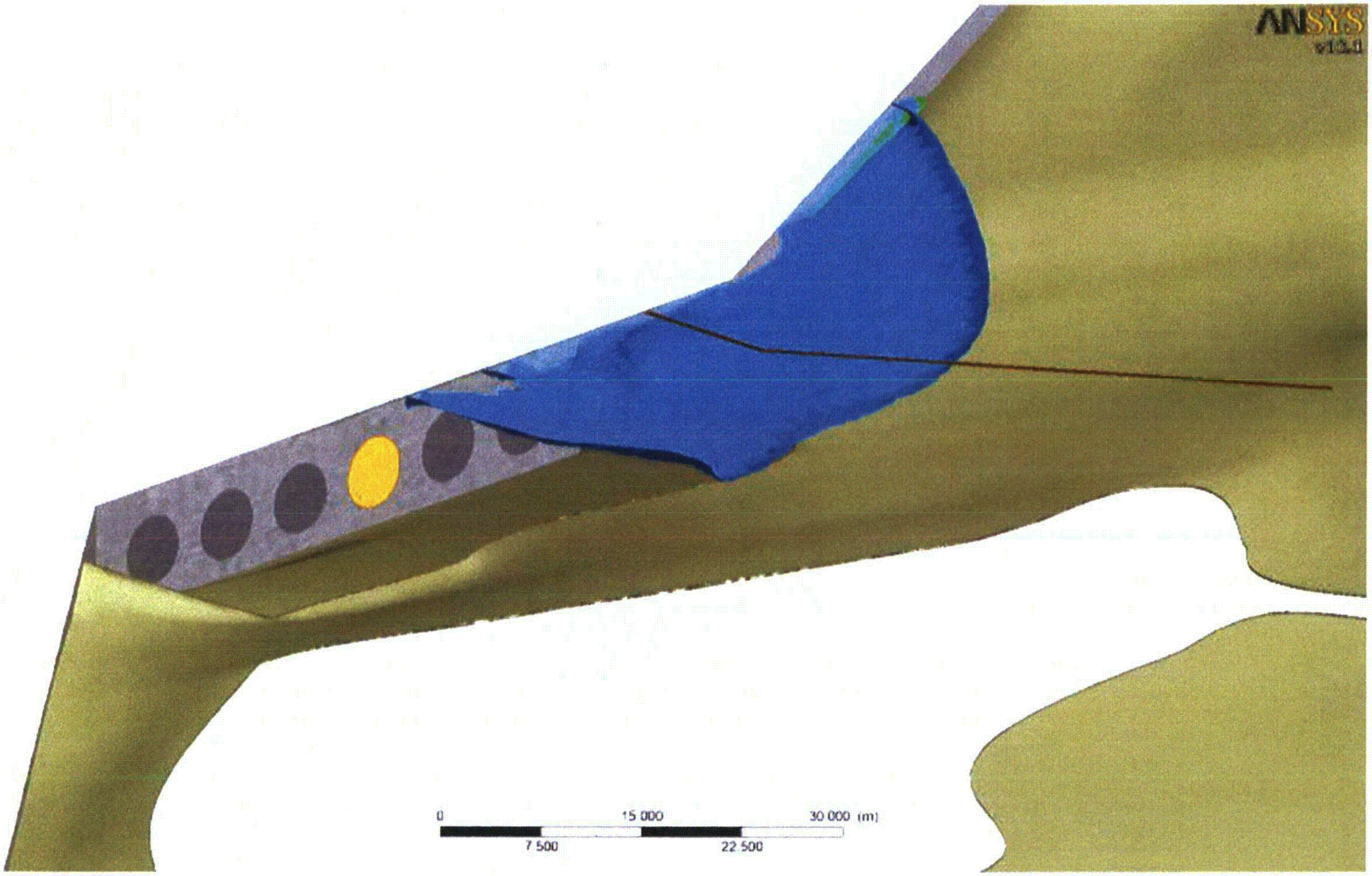


Figure 10 – Blue iso-surface showing steady-state 90°F plume for Scenario 1.

This Page Intentionally Left Blank

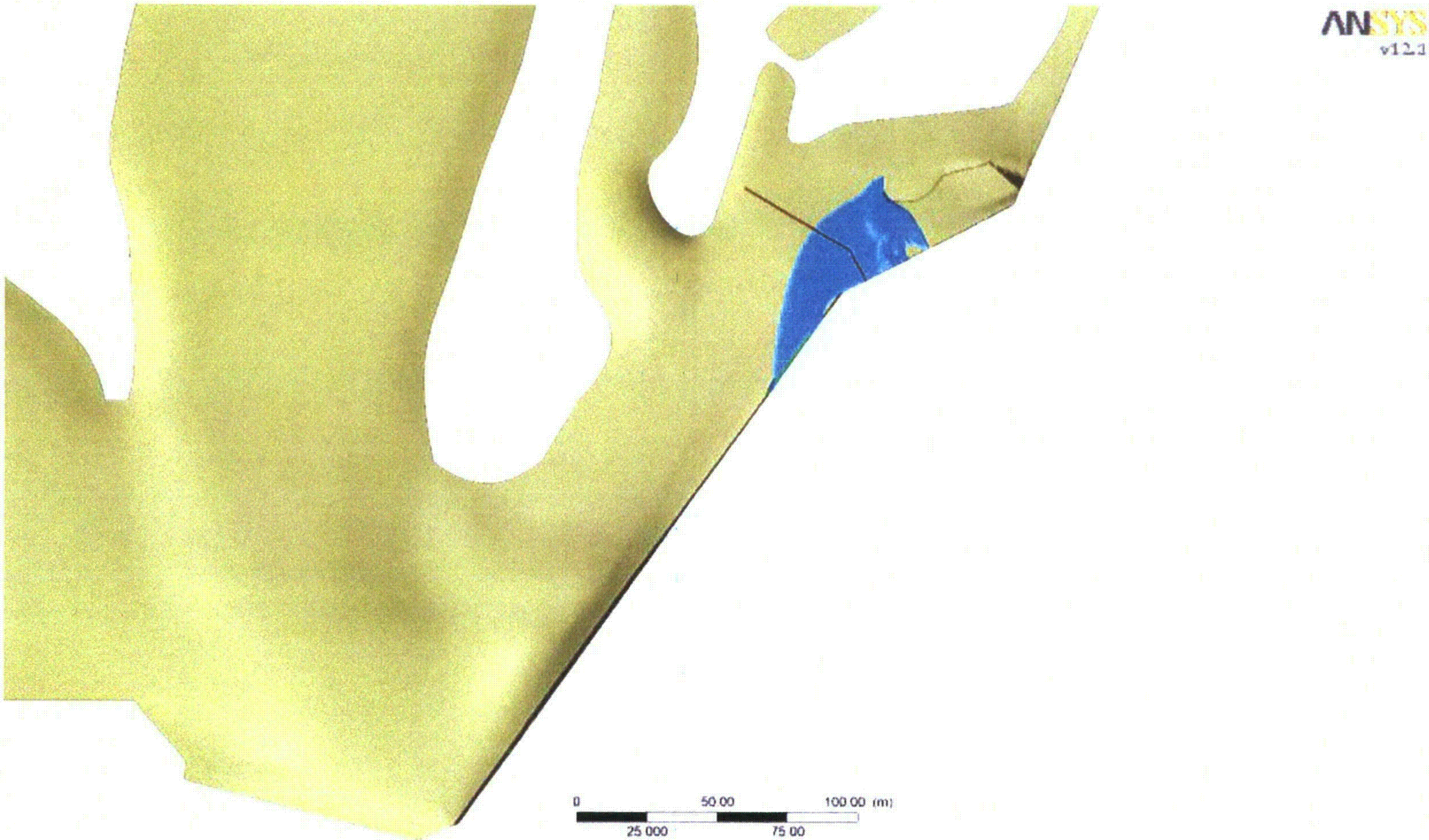


Figure 11 – Blue iso-surface showing steady-state 90°F plume for Scenario 1, plan view

This Page Intentionally Left Blank

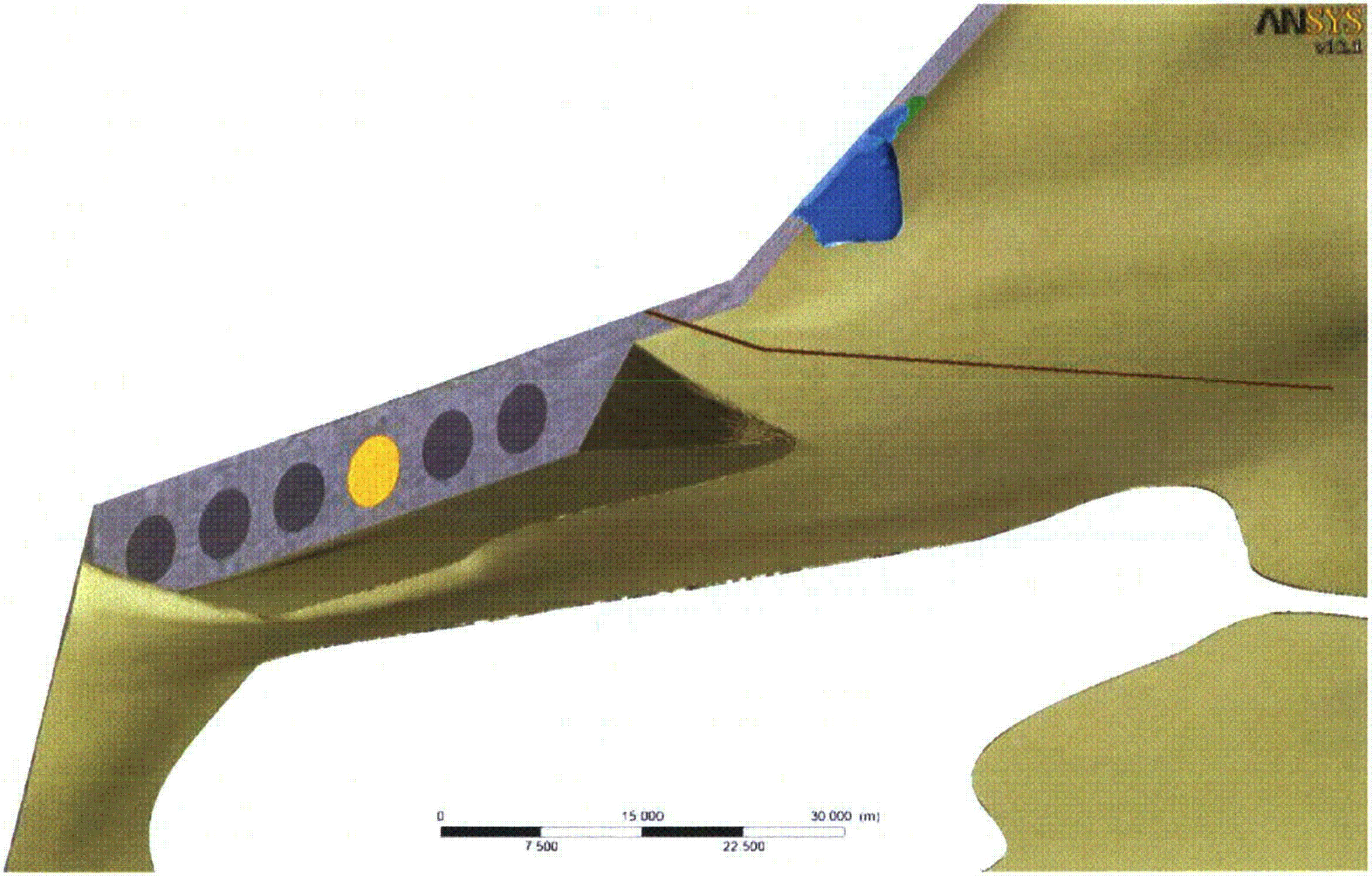


Figure 12 – Blue iso-surface showing steady-state 90°F plume for Scenario 2.

This Page Intentionally Left Blank

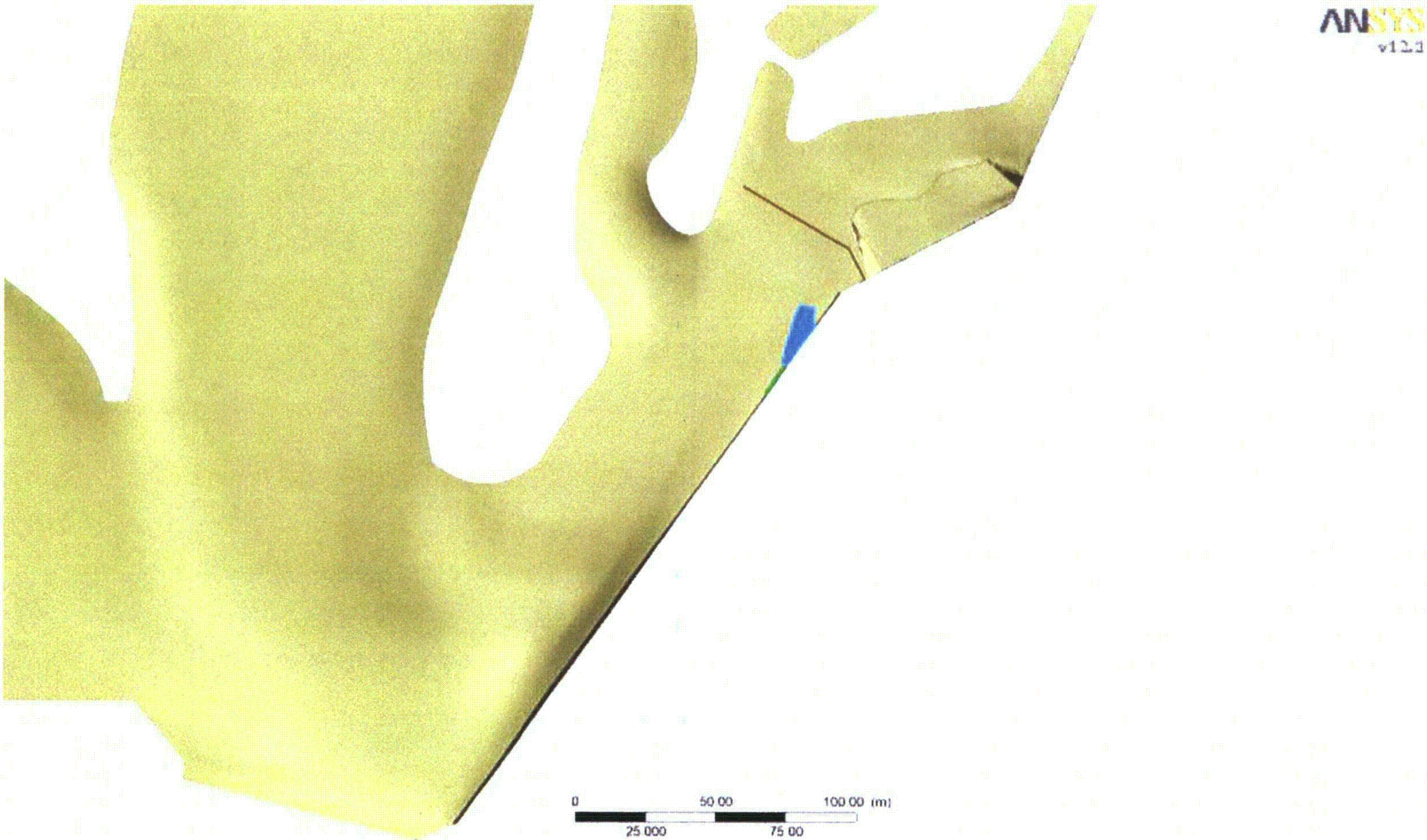


Figure 13 – Blue iso-surface showing steady-state 90°F plume for Scenario 2, plan view

This Page Intentionally Left Blank

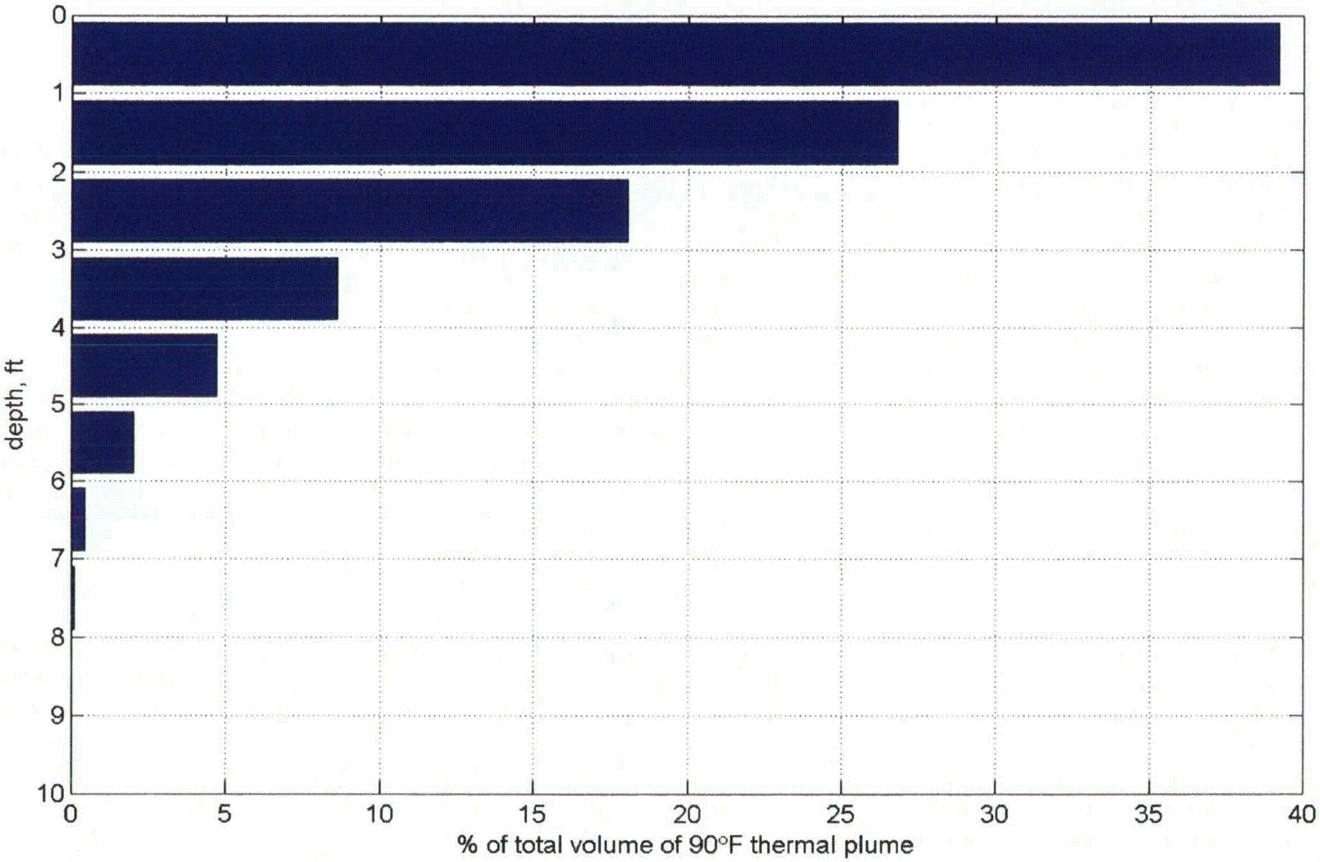


Figure 14 – Bar chart showing percent plume volume against depth for Scenario 1.

This Page Intentionally Left Blank

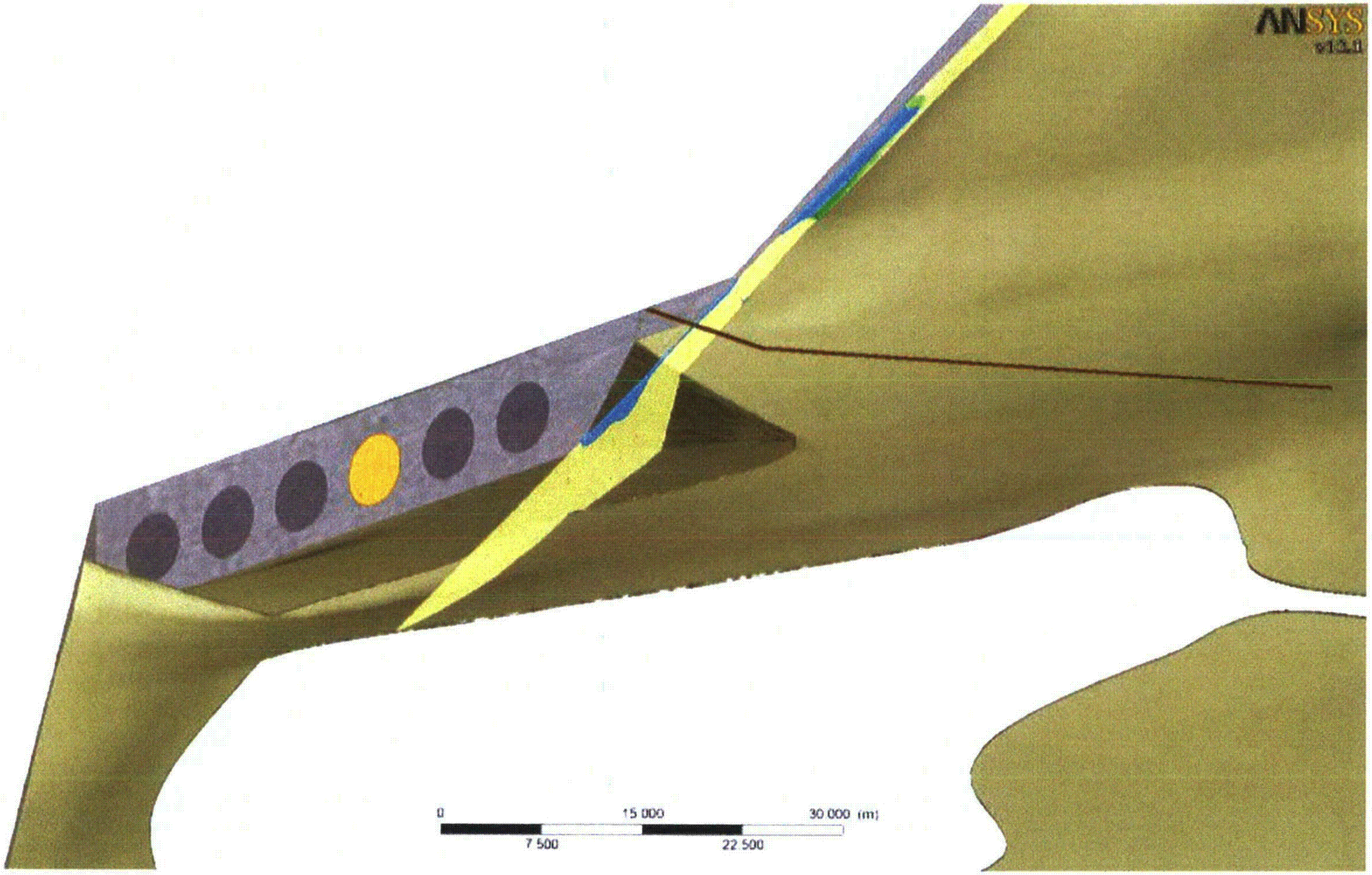


Figure 15 – Blue area showing cross-section of steady-state 90°F plume for Scenario 1.

This Page Intentionally Left Blank

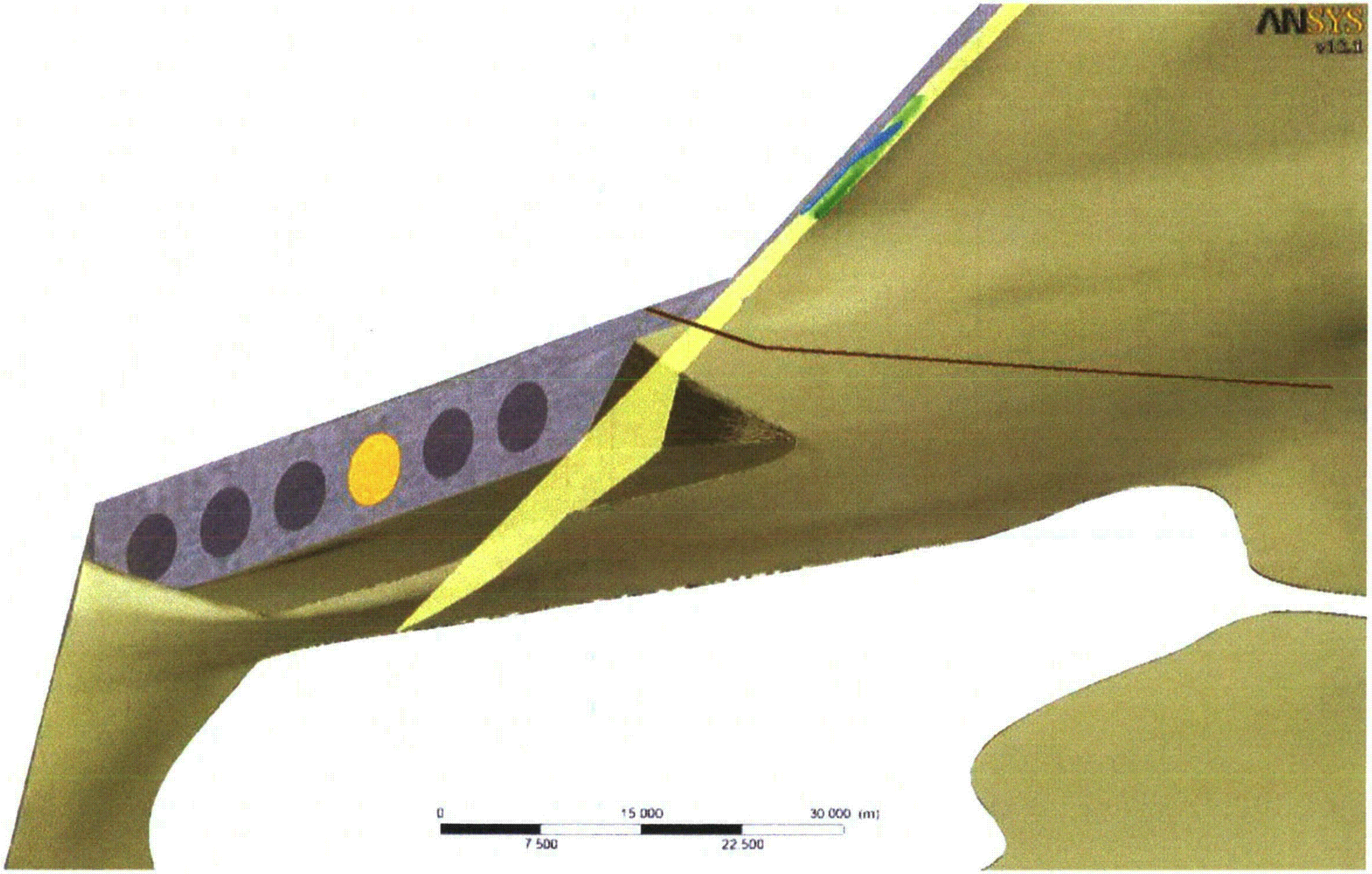


Figure 16 – Blue area showing cross-section of steady-state 90°F plume for Scenario 2.

This Page Intentionally Left Blank

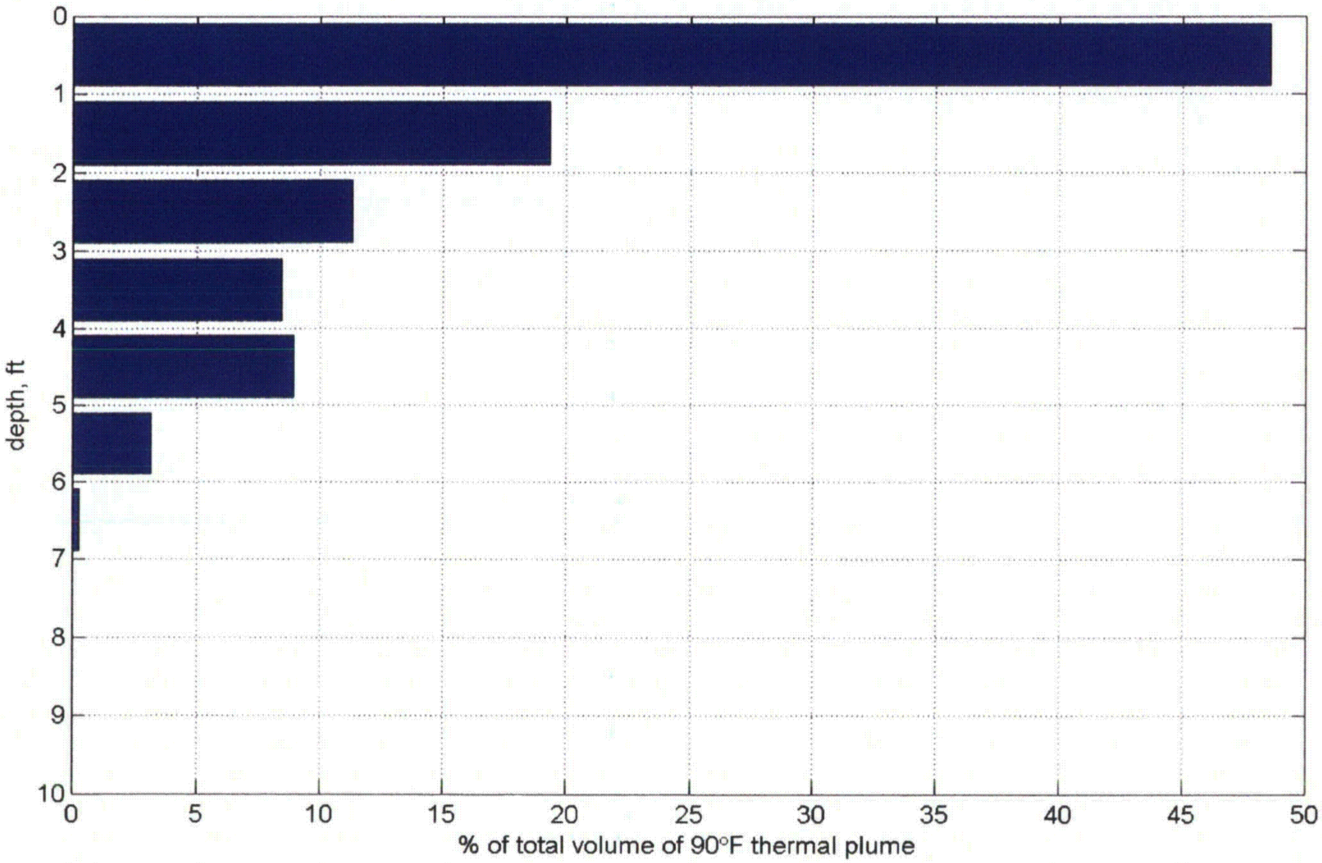


Figure 17 – Bar chart showing percent plume volume against depth for Scenario 2.

This Page Intentionally Left Blank

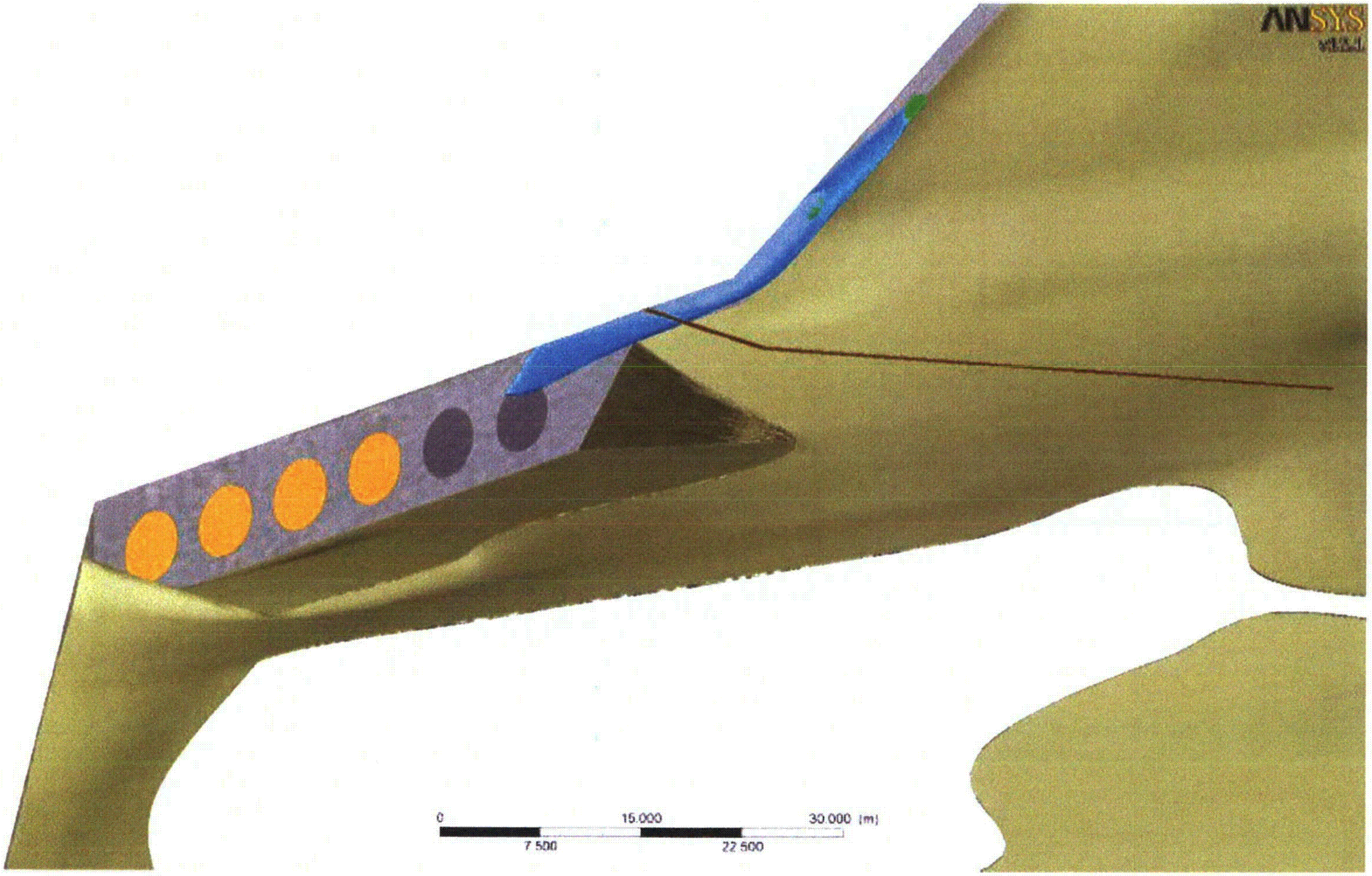


Figure 18 – Blue iso-surface showing steady-state ΔT = 5°F plume for Scenario 3.

This Page Intentionally Left Blank

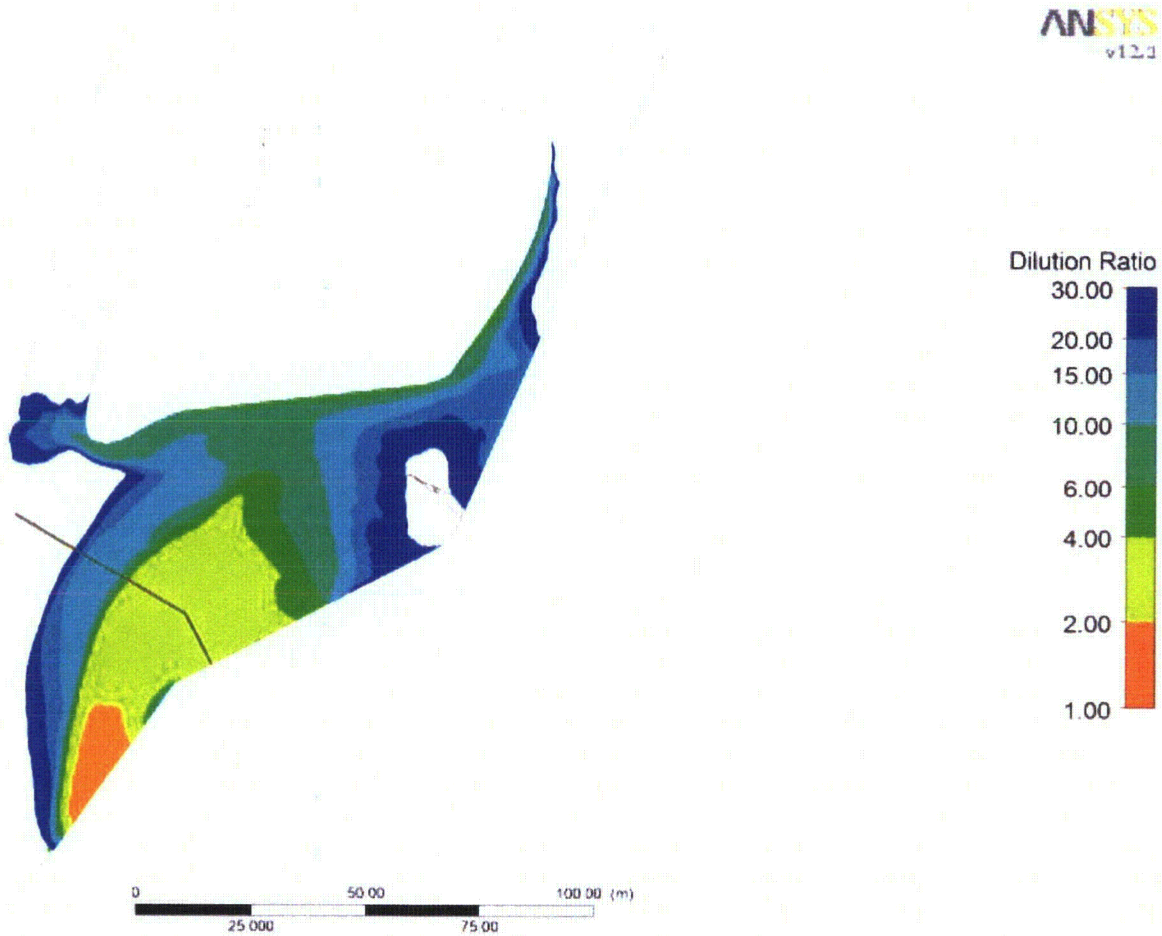


Figure 19 – Contours of dilution ratio for Scenario 1 (95° F discharge).

This Page Intentionally Left Blank

Figure 20 – Contours of dilution ratio for Scenario 2 (91° F discharge).

This Page Intentionally Left Blank

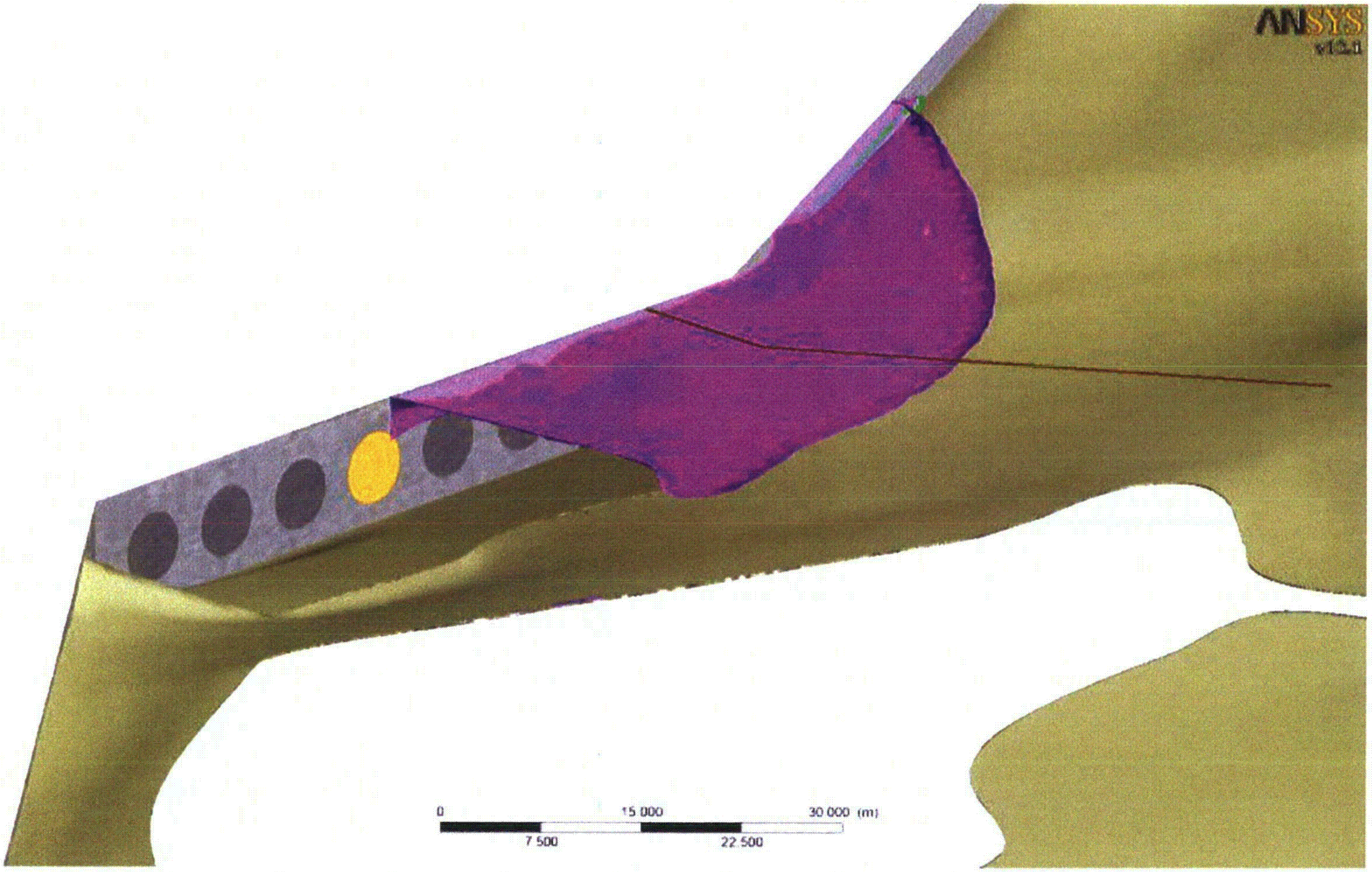


Figure 21 – Chronic mixing zone, 5:1 dilution ratio, for Scenario 1 (95° F discharge).

This Page Intentionally Left Blank

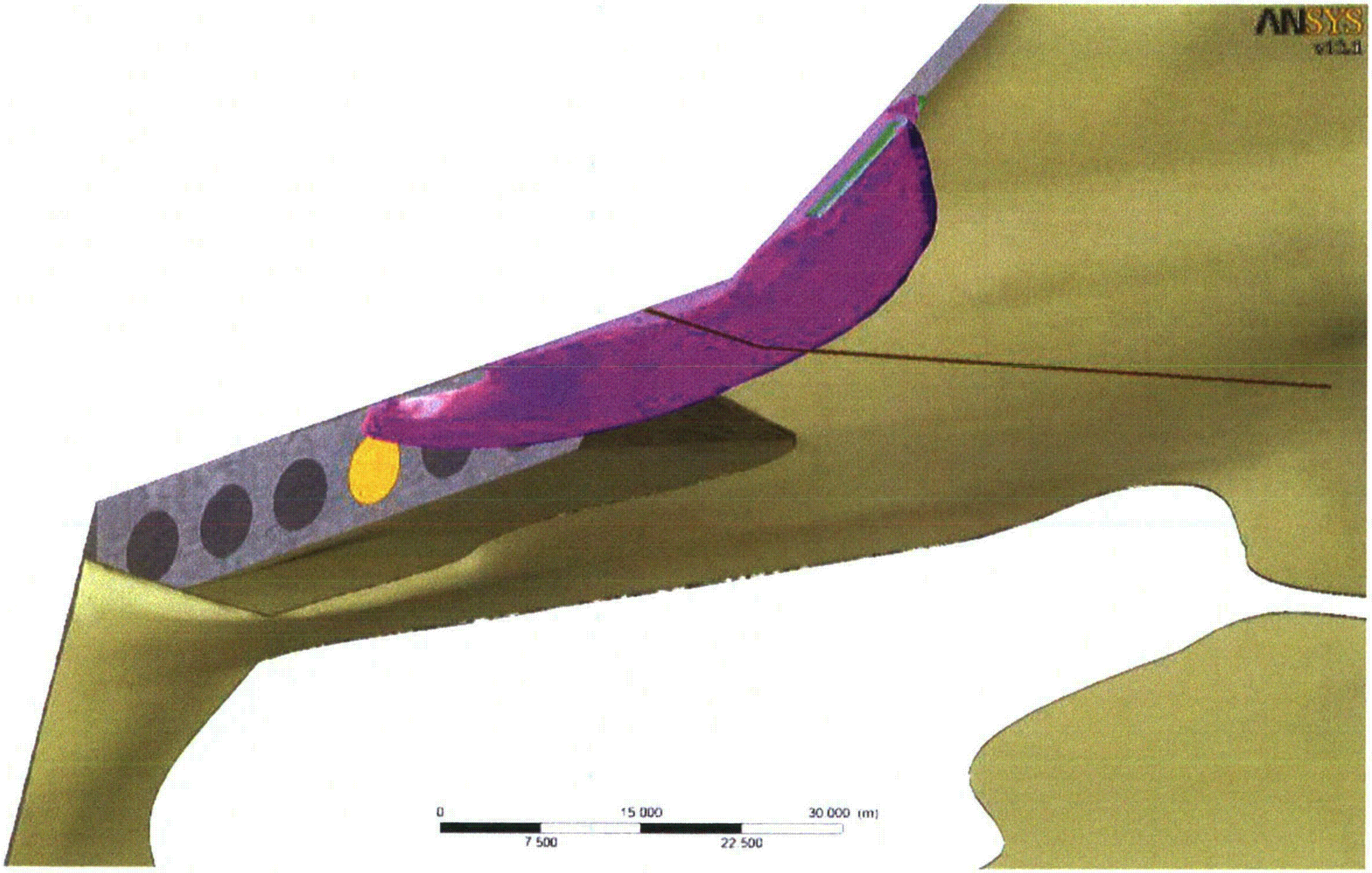


Figure 22 – Chronic mixing zone, 5:1 dilution ratio, for Scenario 2 (91° F discharge).

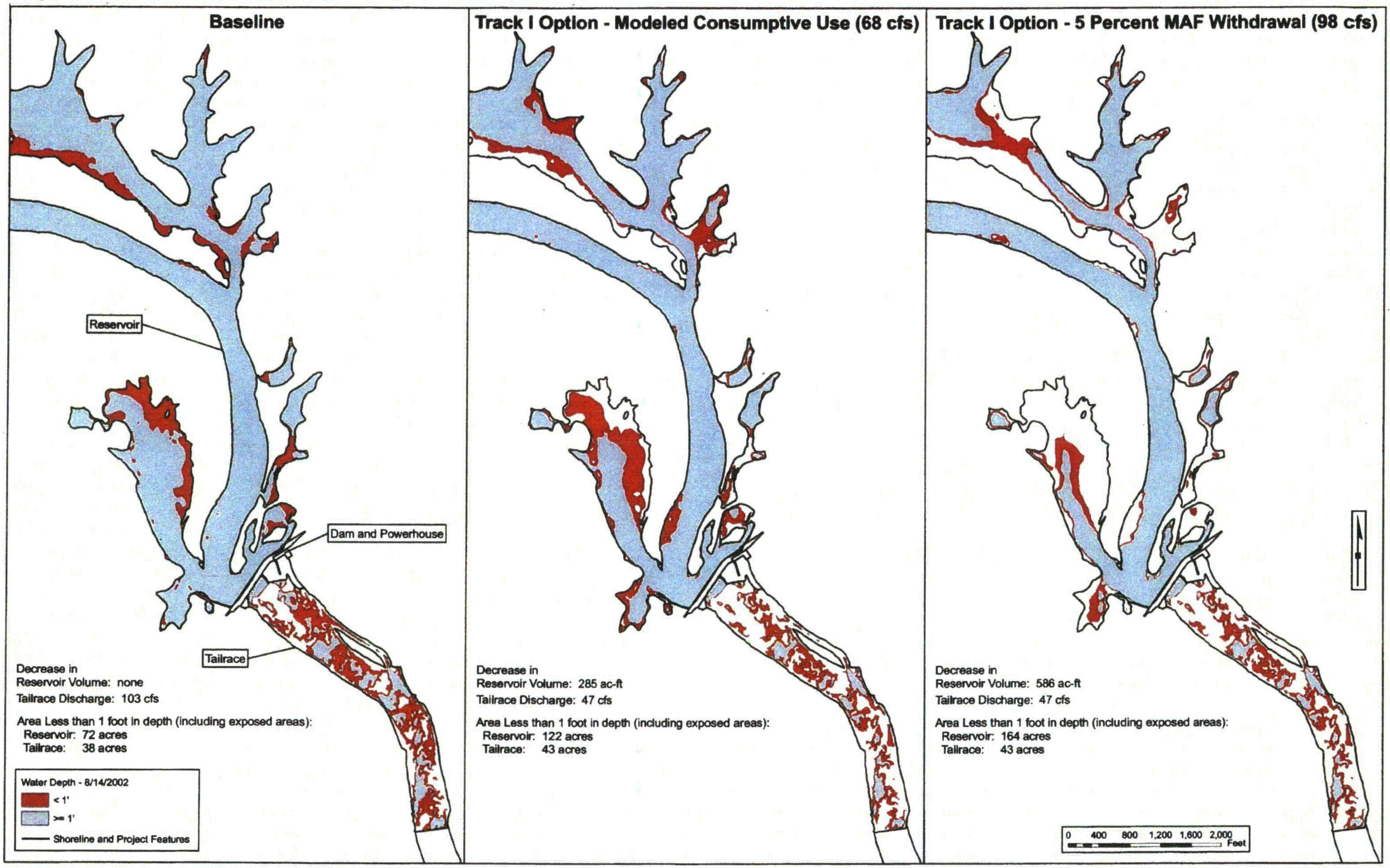
This Page Intentionally Left Blank

Table 3. Broad River Flows Below Ninety-Nine Islands Dam During the 2002 Drought Period

Date	Baseline and Alternative Requirement Option Broad River Flow (cfs)	Track I Option Modeled Consumptive Use (cfs)	Resulting Downstream Flow (cfs)	Ninety-Nine Islands Storage Used		Track I Option 5 Percent MAF Withdrawal (cfs)	Resulting Downstream Flow (cfs)	Ninety-Nine Islands Storage Used	
				(cfs)	(ac-ft)			(cfs)	(ac-ft)
7/28/2002	355	69	286	0	0	98	257	0	0
7/29/2002	340	69	271	0	0	98	242	0	0
7/30/2002	326	69	257	0	0	98	228	0	0
7/31/2002	314	69	245	0	0	98	216	0	0
8/1/2002	308	68	240	0	0	98	210	0	0
8/2/2002	284	68	217	0	0	98	186	0	0
8/3/2002	271	68	204	0	0	98	173	0	0
8/4/2002	241	68	174	0	0	98	143	0	0
8/5/2002	214	68	146	0	0	98	116	0	0
8/6/2002	193	68	125	0	0	98	95	0	0
8/7/2002	192	68	124	0	0	98	94	0	0
8/8/2002	193	68	125	0	0	98	95	0	0
8/9/2002	152	68	85	0	0	98	54	0	0
8/10/2002	111	68	47	4	7	98	47	34	68
8/11/2002	74	68	47	41	81	98	47	71	141
8/12/2002	47	68	47	68	134	98	47	98	194
8/13/2002	95	68	47	20	40	98	47	50	100
8/14/2002	103	68	47	12	23	98	47	42	84
8/15/2002	148	68	80	0	0	98	50	0	0
8/16/2002	213	68	145	0	0	98	115	0	0
8/17/2002	211	68	144	0	0	98	113	0	0
8/18/2002	245	68	177	0	0	98	147	0	0
8/19/2002	274	68	206	0	0	98	176	0	0
8/20/2002	418	68	351	0	0	98	320	0	0
8/21/2002	275	68	207	0	0	98	177	0	0
8/22/2002	262	68	195	0	0	98	164	0	0
8/23/2002	244	68	176	0	0	98	146	0	0
8/24/2002	214	68	146	0	0	98	116	0	0
8/25/2002	191	68	123	0	0	98	93	0	0
8/26/2002	178	68	110	0	0	98	80	0	0
8/27/2002	210	68	143	0	0	98	112	0	0
8/28/2002	216	68	148	0	0	98	118	0	0
8/29/2002	288	68	220	0	0	98	190	0	0

Date	Baseline and Alternative Requirement Option Broad River Flow (cfs)	Track I Option Modeled Consumptive Use (cfs)	Resulting Downstream Flow (cfs)	Ninety-Nine Islands Storage Used		Track I Option 5 Percent MAF Withdrawal (cfs)	Resulting Downstream Flow (cfs)	Ninety-Nine Islands Storage Used	
				(cfs)	(ac-ft)			(cfs)	(ac-ft)
8/30/2002	198	68	130	0	0	98	100	0	0
8/31/2002	202	68	135	0	0	98	104	0	0
9/1/2002	210	66	145	0	0	98	112	0	0
9/2/2002	210	64	146	0	0	98	112	0	0
9/3/2002	215	64	150	0	0	98	117	0	0
9/4/2002	340	64	275	0	0	98	242	0	0
9/5/2002	119	64	54	0	0	98	47	26	52
9/6/2002	143	64	79	0	0	98	47	2	4
9/7/2002	146	64	81	0	0	98	48	0	0
9/8/2002	141	64	76	0	0	98	47	4	8
9/9/2002	166	64	102	0	0	98	68	0	0
9/10/2002	169	64	104	0	0	98	71	0	0
9/11/2002	144	64	80	0	0	98	47	1	1
9/12/2002	127	64	63	0	0	98	47	18	36
9/13/2002	114	64	50	0	0	98	47	31	61
9/14/2002	113	64	49	0	0	98	47	32	63
9/15/2002	162	64	97	0	0	98	64	0	0

Figure 2. Comparison of Baseline/Alternative Requirement Option and Track I Options -- Depths Above and Below Ninety-Nine Islands Dam



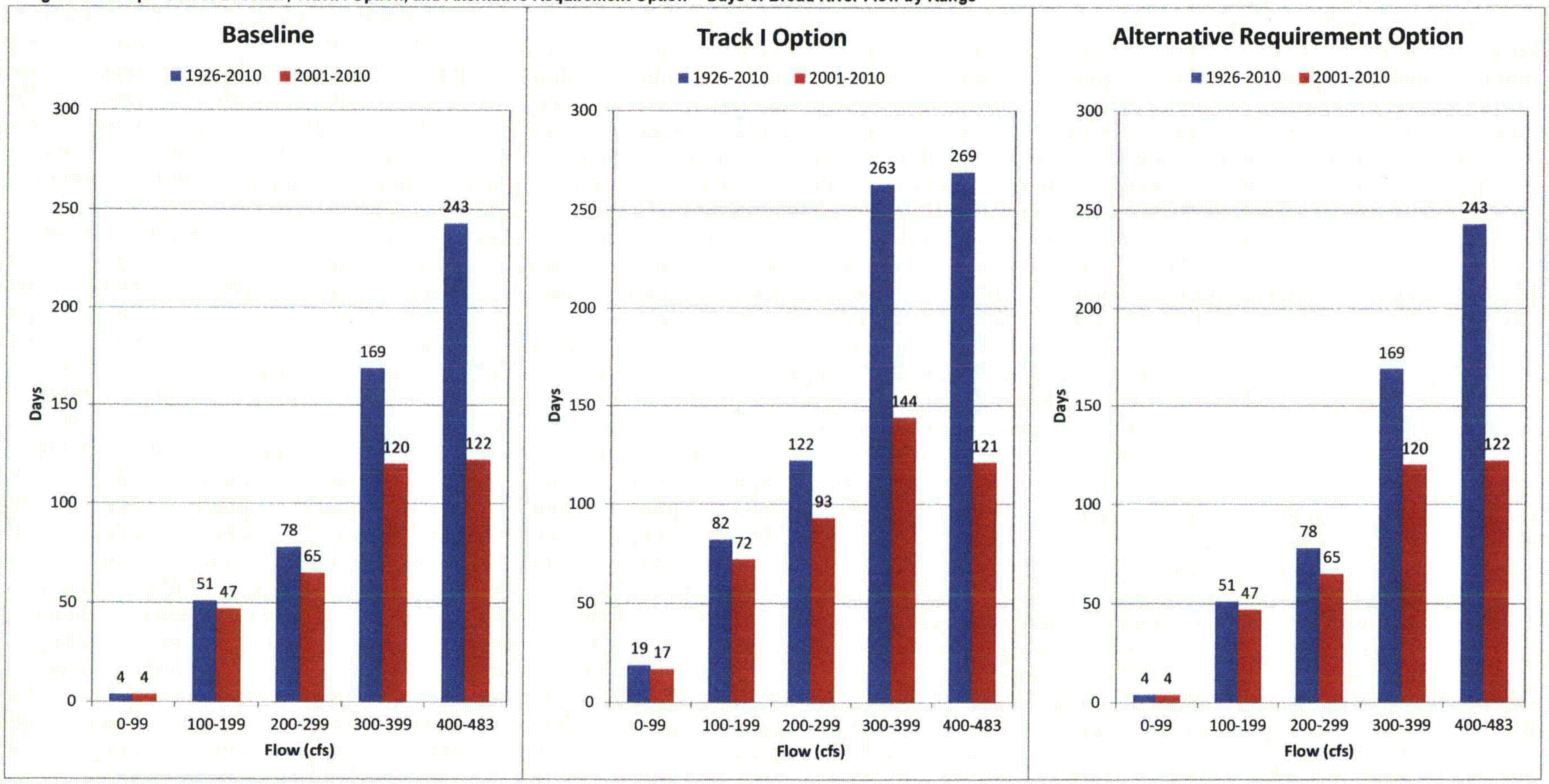
ATTACHMENT 2

RESPONSE TO COMMENT No. 7

Table 1. Number of Days that Broad River Flow is Projected to be less than 483 cfs

Time Period	Total Days in Period	Number of Days < 483 cfs				
		Baseline	Track I Option		Alternative Requirement Option	
		Days	Days	Percent Increase from Baseline	Days	Percent Increase from Baseline
1926-2010	31,046	545	755	38.5%	545	0.0%
2001-2010	3,652	358	447	24.9%	358	0.0%

Figure 1. Comparison of Baseline, Track I Option, and Alternative Requirement Option -- Days of Broad River Flow by Range



Note: For the Track I and Alternative Requirement Options, withdrawals assumed only consumptive use and pond refill.

Table 2. Number of Consecutive Days When Broad River Flows Are Less Than 483 cfs

Time Period Mo/Yr	Number of Consecutive Days* < 483 cfs	
	Baseline and Alternative Requirement Option	Track I Option
Sep 1954	6	11
Sep-Oct 1954	7	24
Aug 1956	10	14
Aug-Sep 1956	10	11
Sep 1956	16	17
Jul 1986	6	12
Aug 1999	5	12
Sep 1999	8	9
Jul 2000	6	7
Aug 2000	7	10
Aug-Sep 2001	12	14
Sep 2001	3	9
Jun 2002	11	18
Jul-Sep 2002	72	77
Jul 2007	2	10
Aug 2007	7	9
Aug 2007	9	9
Sep 2007	13	13
Sep-Oct 2007	32	32
Jun-Jul 2008	30	33
Jul-Aug 2008	33	35
Oct 2008	8	9
Total Days	313	395

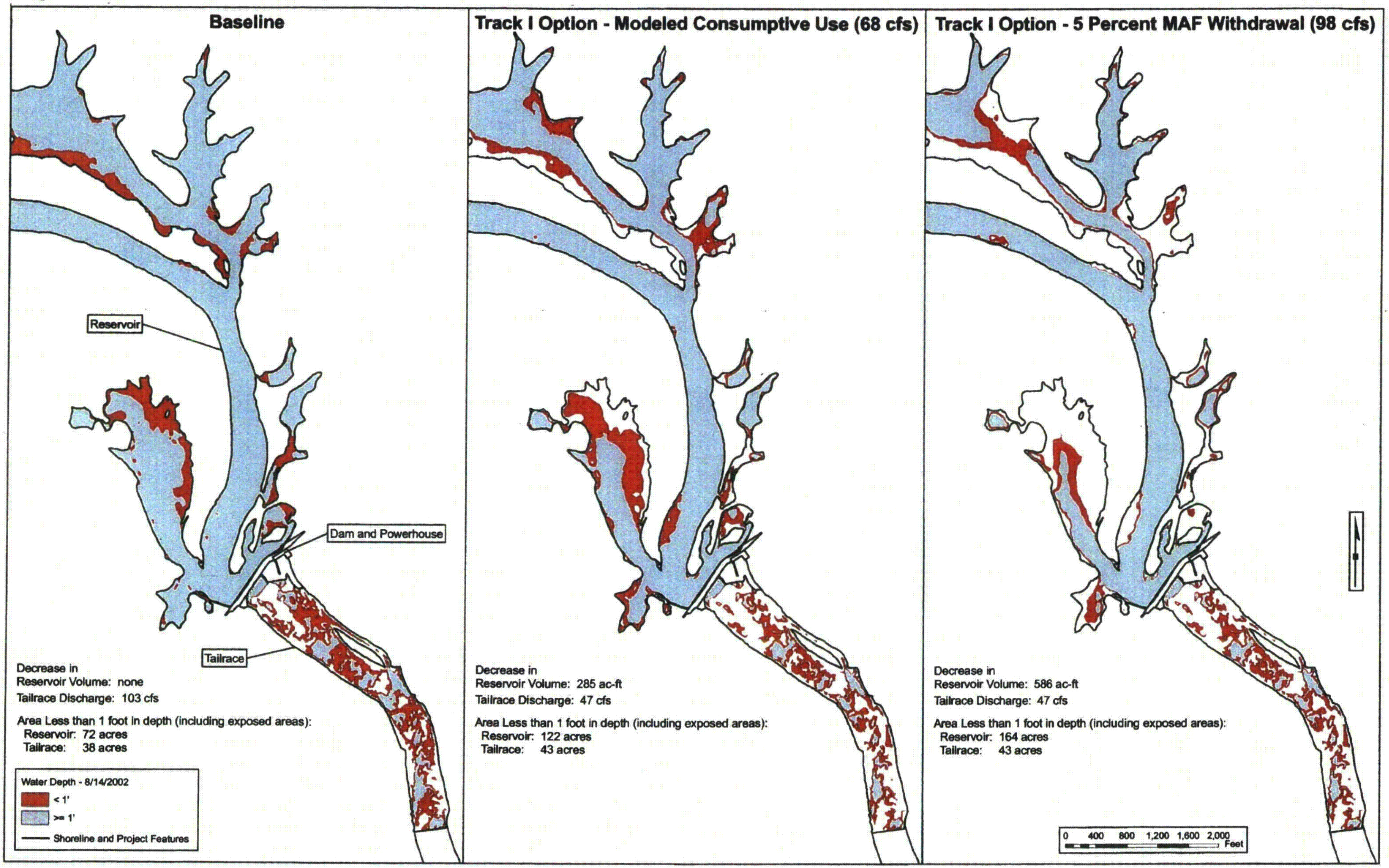
* All events greater than 7 days for Track I Option are listed.

Table 3. Broad River Flows Below Ninety-Nine Islands Dam During the 2002 Drought Period

Date	Baseline and Alternative Requirement Option Broad River Flow (cfs)	Track I Option Modeled Consumptive Use (cfs)	Resulting Downstream Flow (cfs)	Ninety-Nine Islands Storage Used		Track I Option 5 Percent MAF Withdrawal (cfs)	Resulting Downstream Flow (cfs)	Ninety-Nine Islands Storage Used	
				(cfs)	(ac-ft)			(cfs)	(ac-ft)
7/28/2002	355	69	286	0	0	98	257	0	0
7/29/2002	340	69	271	0	0	98	242	0	0
7/30/2002	326	69	257	0	0	98	228	0	0
7/31/2002	314	69	245	0	0	98	216	0	0
8/1/2002	308	68	240	0	0	98	210	0	0
8/2/2002	284	68	217	0	0	98	186	0	0
8/3/2002	271	68	204	0	0	98	173	0	0
8/4/2002	241	68	174	0	0	98	143	0	0
8/5/2002	214	68	146	0	0	98	116	0	0
8/6/2002	193	68	125	0	0	98	95	0	0
8/7/2002	192	68	124	0	0	98	94	0	0
8/8/2002	193	68	125	0	0	98	95	0	0
8/9/2002	152	68	85	0	0	98	54	0	0
8/10/2002	111	68	47	4	7	98	47	34	68
8/11/2002	74	68	47	41	81	98	47	71	141
8/12/2002	47	68	47	68	134	98	47	98	194
8/13/2002	95	68	47	20	40	98	47	50	100
8/14/2002	103	68	47	12	23	98	47	42	84
8/15/2002	148	68	80	0	0	98	50	0	0
8/16/2002	213	68	145	0	0	98	115	0	0
8/17/2002	211	68	144	0	0	98	113	0	0
8/18/2002	245	68	177	0	0	98	147	0	0
8/19/2002	274	68	206	0	0	98	176	0	0
8/20/2002	418	68	351	0	0	98	320	0	0
8/21/2002	275	68	207	0	0	98	177	0	0
8/22/2002	262	68	195	0	0	98	164	0	0
8/23/2002	244	68	176	0	0	98	146	0	0
8/24/2002	214	68	146	0	0	98	116	0	0
8/25/2002	191	68	123	0	0	98	93	0	0
8/26/2002	178	68	110	0	0	98	80	0	0
8/27/2002	210	68	143	0	0	98	112	0	0
8/28/2002	216	68	148	0	0	98	118	0	0
8/29/2002	288	68	220	0	0	98	190	0	0

Date	Baseline and Alternative Requirement Option Broad River Flow (cfs)	Track I Option Modeled Consumptive Use (cfs)	Resulting Downstream Flow (cfs)	Ninety-Nine Islands Storage Used		Track I Option 5 Percent MAF Withdrawal (cfs)	Resulting Downstream Flow (cfs)	Ninety-Nine Islands Storage Used	
				(cfs)	(ac-ft)			(cfs)	(ac-ft)
8/30/2002	198	68	130	0	0	98	100	0	0
8/31/2002	202	68	135	0	0	98	104	0	0
9/1/2002	210	66	145	0	0	98	112	0	0
9/2/2002	210	64	146	0	0	98	112	0	0
9/3/2002	215	64	150	0	0	98	117	0	0
9/4/2002	340	64	275	0	0	98	242	0	0
9/5/2002	119	64	54	0	0	98	47	26	52
9/6/2002	143	64	79	0	0	98	47	2	4
9/7/2002	146	64	81	0	0	98	48	0	0
9/8/2002	141	64	76	0	0	98	47	4	8
9/9/2002	166	64	102	0	0	98	68	0	0
9/10/2002	169	64	104	0	0	98	71	0	0
9/11/2002	144	64	80	0	0	98	47	1	1
9/12/2002	127	64	63	0	0	98	47	18	36
9/13/2002	114	64	50	0	0	98	47	31	61
9/14/2002	113	64	49	0	0	98	47	32	63
9/15/2002	162	64	97	0	0	98	64	0	0

Figure 2. Comparison of Baseline/Alternative Requirement Option and Track I Options -- Depths Above and Below Ninety-Nine Islands Dam



ATTACHMENT 3

RESPONSE TO COMMENTS # 15, 24 and 25

Shaw NUCLEAR — CALCULATION

CLIENT: Duke Energy Carolinas, LLC PROJECT: Lee Nuclear Station Units 1 and 2	PAGE 1 OF 21 **TOTAL PAGES: 21** **(Including attachments)**
CALCULATION TITLE: **RWS Traveling Screen Calculation**	QA CATEGORY ☐ - I Nuclear Safety Related ☐ - II ☐ - III Safety Class - **E**

CALCULATION IDENTIFICATION NUMBER

J.O. or W.O. NO.	DISCIPLINE CODE	CALCULATION NUMBER	REVISION NUMBER
124029	M	WLG-WWS-M3C-012	1

REVIEW AND APPROVAL	SUPERSEDES CALC. NO.: N/A	CONFIRMATION REQUIRED YES ☒ NO ☐

FUNCTION:	PRINT/SIGN	DATE	FOR PAGES:
Preparer(s)	M. R. Austin/ [signature]	12/5/11	All
	N/A	N/A	N/A
Reviewer(s)	S. S. Fong/ [signature]	12/5/11	All
	N/A	N/A	N/A
	N/A	N/A	N/A
	N/A	N/A	N/A
	N/A	N/A	N/A
	N/A	N/A	N/A
	N/A	N/A	N/A
	N/A	N/A	N/A

Design Verification Method: ☒ N/A ☐ Independent Review ☐ Alternate Calculation ☐ Qualification Testing

Design Verifier	N/A	N/A	N/A

SOUTH CAROLINA REGISTERED No. 5871 ROBERT M. DULIN, JR. ENGINEER

SOUTH CAROLINA CERTIFICATE OF AUTHORIZATION STONE & WEBSTER, INC. No. C02366

Approver:	S S. Fong / [signature]	Date:	12/6/11

Record of Revisions

Rev. No.	Description of Changes/ Reason for Change	Pages Revised	Pages Added	Pages Replaced
0	Issue for permit	N/A	N/A	N/A
1	Revised equations 3, 4, and 5, updated screen width, added "Refill portion" screen width size, and incorporated new template and mechanical peer review comments on screen width. Due to significant changes, revision bars were omitted.	All	N/A	N/A

Table of Contents

1.0 Introduction

1.1 Background

The Raw Water System (RWS) River Water Intake consists of two subsystems, the Refill subsystem and the River Water subsystem.

- The Refill subsystem consists of four pumps separated in four pump bays. Each pump has a maximum capacity of 22,500 gpm (REF 3.1.5). These pumps are connected to a common header and will be used to transfer water from the Broad River to either Pond B or Pond C.
- The River Water subsystem consists of four pumps separated in four pump bays. Each pump has a maximum capacity of 20,980 gpm (REF 3.1.1). Two of these pumps are considered in standby. These pumps are connected to a common header and will be used to transfer water from the Broad River to Pond A.

The RWS Raw Water Supply (Pond A) Intake consists of the Raw Water Supply subsystem.

- The Raw Water Supply subsystem consists of six pumps separated in six pump bays. Each pump has a maximum capacity of 15,000 gpm (REF 3.1.6). Two of these pumps are considered in standby. These pumps are connected to a common header and will be used to transfer water from Pond A to meet the nuclear station's water demands.

1.2 Purpose

This calculation will determine the minimum dimensional requirements for traveling screens in both the river water and raw water supply intake structures which will meet the maximum 0.5 feet/second through-screen velocity requirement:

- Minimum screen width
- Minimum wetted screen height

This calculation will determine the above dimensions for both a coarse mesh size and fine mesh size. This information is required as input to the design, specifically the traveling screen region, of the river water and the raw water supply intake structures in support of both Units 1 and 2.

1.3 Limits of Applicability

This calculation is only applicable to the William State Lee III Nuclear Station Units 1 and 2 river water and raw water supply intake structures, in all modes of operation.

2.0 Summary of Results and Conclusions

2.1 Results

The minimum traveling screen dimension results are given in **Table 2-1**.

Table 2-1 Minimum Traveling Screen Dimensions

Dimension	At Primary Side "River Portion" of River Intake Structure	At Secondary Side "Refill Portion" of River Intake Structure	At Make-up Pond A Intake Structure
Minimum Traveling Screen Width (W) with Fine Mesh, ft	13.67	11.76	10.0
Minimum Wetted Screen Height (Y) with fine mesh, ft	8.1	10.1	7.92
Minimum Traveling Screen Width (W) with Coarse Mesh, ft	11.68	10.04	10.0
Minimum Wetted Screen Height (Y) with coarse mesh, ft	8.1	10.1	6.76

2.2 Conclusions / Recommendations

- The results listed in the previous section are based on the best available information. Although there will be changes to the Raw Water System (RWS) as the design progresses, the sizing of the traveling screens must maintain compliance with the acceptance criteria in Section 5.2.1. The traveling screens shall be re-sized if required during the design process to maintain thru-screen velocity less than 0.5 ft/s per Ref. 3.2.3.
- This calculation should be used as input to the design of both the river water and raw water supply intake structures. All minimum dimensions, developed from this calculation, shall be no less than the corresponding value, from **Table 2-1** , for example the width of the traveling screen (W) should be no less than 13.67 ft for a fine mesh screen at the river intake structure.
- The intake screen procurement specification shall include the scope of calculating actual head loss by supplier.
- An enveloping traveling screen width of 13.67 feet could be used for both the "River Portion" and the "Refill Portion" of the river intake structure if desired.

3.0 References

3.1 AP1000 Documents

3.1.1 WLG-RWS-M3C-006, "RWS, River Water Subsystem Hydraulic Analysis", Revision B

3.1.2 WLG-7500-CCH-002, "Lee Nuclear Station Units 1& 2 River Water and Refill Intake Structure Plans and Section" Revision D

3.1.3 WLG-RWS-MY18-001, "Intake Screen Selection for the Raw Water System," Revision A

3.1.4 WLG-RWS-M3C-004, "Raw Water (Makeup Pond A) Intake Hydraulic Calculation," Revision B

3.1.5 WLG-RWS-M3C-007, "RWS, Refill Subsystem Hydraulic Analysis" Revision B

3.1.6 WLG-RWS-M3C-008, "RWS, Raw Water Subsystem Hydraulic Analysis" Revision B

3.1.7 WLG-7510-CCH-003, "Lee Nuclear Station Units 1& 2 Make-up Pond A Intake Structure Plans and Section" Revision C

3.2 Other

3.2.1 "Cameron Hydraulic Data," C.C. Heald, 19th Edition, 2002

3.2.2 "Particle Size/ Screen Mesh Comparison Table," Screen Technology Group, Inc, February 08 2009 (http://wovenwire.com/reference/particle-size)

3.2.3 40 CFR Part 125: National Pollutant Discharge Elimination System—Amendment of Final Regulations Addressing Cooling Water Intake Structures for New Facilities (Implements Requirements of Section 316B of the Clean Water Act).

4.0 Calculation Inputs

4.1 Inputs

4.1.1 Maximum Flow Rate

Each river water pump has a maximum capacity of 20,980 gpm (REF 3.1.1); each refill pump has maximum capacity of 22,500 gpm (REF 3.1.5), each raw water supply pump has maximum capacity of 15,000 gpm (REF 3.1.6 and REF 3.1.4). The river water pump flow will be used as the design input for determining the traveling screen size on the "River portion" of the river intake structure. The refill pump flow will be used as the design input for determining the traveling screen size on the "Refill portion" of the river intake structure. The flow of the raw water supply will be used as the design input for determining the traveling screen size on the Make-up Pond A intake structure. The screen wash pump flow, which is an intermittent flow, is not included in the traveling screen design flow rate.

4.1.2 Intake Structure Floor Top of Concrete (TOC)

Broad River intake structure floor TOC is El 497' (REF. 3.1.2)

Make-up Pond A intake structure floor TOC is El 510' (REF. 3.1.7)

4.1.3 Low Water Elevation

The Broad River low water El is 509.1' (REF. 3.1.2). This elevation was used in determining the traveling screen width for the River Water Subsystem pumps.

However, the Refill Subsystem pumps will use the Broad River normal water El 511.1' (REF.3.1.2). The normal water elevation is appropriate since this subsystem is not used during low flow conditions (low water level). The Refill Subsystem is utilized to refill the drought contingency Ponds B and C which occur during high flow river conditions following a drought.

The Make-up Pond A low water elevation will not vary significantly from the full pond elevation of 547' (REF. 3.1.7) during plant operation. In addition, the traveling screen is submerged well below the expected low water elevation. Therefore, the Make-up Pond A traveling screen width is not dependent on the water depth. Since a maximum standard screen width is 10 feet based on discussions with vendors, a minimum wetted screen height and associated minimum water elevation were determined such that a 0.5 ft/s through-screen velocity is maintained given a screen width of 10 feet.

4.1.4 Standoff Height of Screen

Based on discussions with vendors, typical height the traveling screen stands off the intake structure floor is approximately 4 feet (Open Item 4).

4.1.5 Percentage Open Area

4.1.5.1 Fine Mesh

The traveling screen shall filter debris and aquatic life 2 mm in size and larger (REF 3.1.3). Based on an approximate 2 mm mesh size, the equivalent percent open area can be determined. The value used is 56.3% referenced from Appendix B (Opening = 0.0787 inches).

4.1.5.2 Coarse Mesh

The traveling screen shall filter debris and aquatic life 6 mm in size and larger (REF 3.1.3). Based on an approximate 6 mm mesh size, the equivalent percent open area can be determined. The value used is 65.9% referenced from Appendix B (Opening = 0.2205 inches).

5.0 Assumptions and Acceptance Criteria

5.1 Discussion of Significant Assumptions

5.1.1 Pump Bay Design

- Each pump will be separated in individual pump bays
- Dual flow traveling screens will be used in each pump bay. Screen width will be calculated based on 2 screens considering the dual flow design.

5.1.2 Clogged Screen

This calculation assumes added margin for meeting the 0.5 ft/s requirement up to a 25% clogged screen. This margin is recommended by Duke Energy, based on discussion with a subject matter expert from the Electric Power Research Institute (EPRI). The maximum head loss across the screens will be verified by the supplier when this equipment is purchased.

5.2 Acceptance Criteria

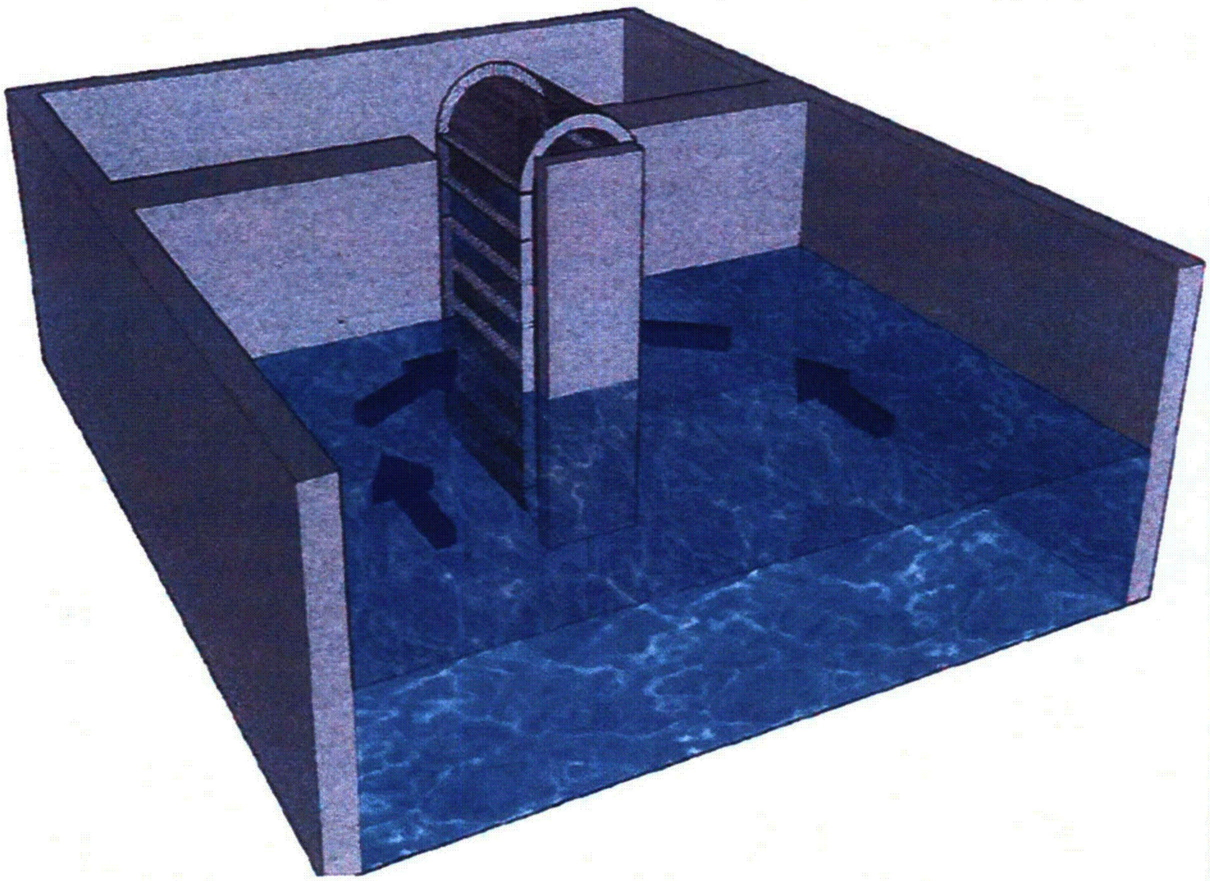
5.2.1 The required through-screen velocity for each traveling screen shall be less than or equal to 0.5 ft/s per REF 3.2.3.

6.0Methods

6.1 Method Discussion

A general pump bay layout is shown below.

Figure 6-1 General Pump Bay Layout



Note: Bar screen is not depicted on this figure

The preliminary traveling screen sizing was calculated using equations constructed per REF 3.2.1 and simple geometry of a rectangle. The significant assumptions, inputs, and acceptance criteria are noted in the following sections.

The following steps were used to calculate a traveling screen width:

1. Determine the screen design flow (Q, ft^3/s).

2. Select maximum velocity (V, ft/s).

3. Calculate the minimum required area (A, ft^2) based on the maximum velocity (V) using below equation (REF 3.2.1, page 2-13).

$$A_{vel} = \frac{Q}{V} \quad \text{(Equation 1)}$$

4. Select a mesh size opening (m, %) using Appendix B.

5. Calculate the screen metal area ($A_{screen\ metal}$, ft^2) based on the selected mesh size opening using the below equation.

$$A_{screen\ metal} = \left(\frac{1}{m} - 1\right) A_{vel} \quad \text{(Equation 2)}$$

6. Calculate the additional area (A_{clog}, ft^2) based on a 25% clogged screen using the below equation.

$$A_{clog} := (\%\ clogged\_screen) \cdot \left[\frac{(A_{screen\_metal} + A_{vel})}{(1 - \%clogged\_Screen)}\right] \quad \text{(Equation 3)}$$

7. Determine the total adjusted area (A_{total}, ft^2) based on the summation of Equation 1, Equation 2, and Equation 3.

8. Determine the minimum wetted screen height (Y, ft) using references 3.1.2 and 3.1.7 (see section 4.1.2 and 4.1.3).

   Y = (Low Water Level – Intake Structure Floor TOC) - Screen Standoff Height (Equation 4)

9. Calculate the minimum traveling screen width (W, ft) using the below equation. (see Section 5.1.1)

$$W = \frac{A_{total}}{2(Y)} \quad \text{(Equation 5)}$$

7.0 Confirmation Required

ITEM NO.	DESCRIPTION	COMMENT
1.	**PUMP BAY DESIGN** **The pump bay design is a significant assumption within this calculation (See Section 5.1.1). Once the intake structural design is finalized, section 5.1.1 should be reviewed and made consistent with the final intake design.**	**Review final intake structure design to ensure consistency**
2.	**UNAPPROVED DESIGN INPUTS** **This calculation is created using the design inputs based on references 3.1.1, 3.1.2, 3.1.3, and 3.1.4, 3.1.5, 3.1.6, and 3.1.7. Each reference should be reviewed and made consistent with section 4.1.**	**Once references are finalized this calculation should be reviewed against references and made consistent.**
3.	**TRAVELING SCREEN DESIGN** **This calculation has added margin to account for some screen clogging, however the change in pressure (head loss) with respect to a dirty or clogged screen will be analyzed based on the actual size of the traveling screen, by the supplier. Section 5.1.2 should be reviewed and made consistent with the final traveling screen design.**	**Review manufacturer's data for any impact.**
4.	**SCREEN STANDOFF HEIGHT** **The final screen standoff height from the intake structure floor needs to be reviewed to verify screen width.**	**Review manufacturer's screen design.**

8.0 Computer Code Identification

Table 8-1 Summary of Computer Codes Used in Calculation

Code No.	Code Name	Code Ver.	Configuration Control Reference	Basis (or reference) that supports use of code in current calculation
1	N/A			
2	N/A			

Table 8-2 Electronically Attached File Listing

Run No.	Table 6-1 Code No.	Computer Run Description	Machine Name Run Date/Time	File Type	EDMS File Name or File Location
1		N/A			
2					
3					
4					
5					
6					
7					
8					

9.0 Detailed Analysis/Calculations and Results

9.1 Calculations

Table 9-1: Fine Mesh (2.0 mm) "River Portion" of River Intake Screen Calculation Results

No.	Parameter	Value	Units	Comments
1.	Design Flow (Q_{design})	20,980	gpm	Input 4.1.1
2.	Converted Flow (Q)	46.75	ft^3/s	Q_{design}/ 448.83
3.	Screen Velocity (V)	0.5	ft/s	Acceptance Criterion 5.2.1
4.	Area based on Velocity (A_{vel})	93.49	ft^2	Equation 1
5.	Percentage Open Area (m)	56.30	%	Appendix B
6.	Area based on Screen Metal ($A_{screen\ metal}$)	72.57	ft^2	Equation 2
7.	Percentage of Clogged Screen	25	%	Assumption 5.1.2
8.	Area based on Clogged Screen (A_{clog})	55.35	ft^2	Equation 3
9.	Total Adjusted Area (A_{total})	221.42	ft^2	Eq 1+ Eq 2 + Eq 3
10.	Screen Standoff Height	4	ft	Input 4.1.4
11.	Intake Structure Bottom Floor TOC Elevation	497	ft	Input 4.1.2
12.	Low Water Elevation	509.1	ft	Input 4.1.3
13.	Screen Wetted Height (Y)	8.1	ft	Equation 4
14.	Screen Width (W)	13.67*	ft	Equation 5

*Based on conversations with vendor values in this range can be fabricated.

Table 9-2: Coarse Mesh (6.0 mm) "River Portion" of River Intake Screen Calculation Results

No.	Parameter	Value	Units	Comments
1.	Design Flow (Q_{design})	20,980	gpm	Input 4.1.1
2.	Converted Flow (Q)	46.75	ft^3/s	Q_{design}/ 448.83
3.	Screen Velocity (V)	0.5	ft/s	Acceptance Criterion 5.2.1
4.	Area based on Velocity (A_{vel})	93.49	ft^2	Equation 1
5.	Percentage Open Area (m)	65.90	%	Appendix B
6.	Area based on Screen Metal ($A_{screen\ metal}$)	48.38	ft^2	Equation 2
7.	Percentage of Clogged Screen	25	%	Assumption 5.1.2
8.	Area based on Clogged Screen (A_{clog})	47.29	ft^2	Equation 3
9.	Total Adjusted Area (A_{total})	189.16	ft^2	Eq 1+ Eq 2 + Eq 3
10.	Screen Standoff Height	4	ft	Input 4.1.4
11.	Intake Structure Bottom Floor TOC Elevation	497	ft	Input 4.1.2
12.	Low Water Elevation	509.1	ft	Input 4.1.3
13.	Screen Wetted Height (Y)	8.1	ft	Equation 4
14.	Screen Width (W)	11.68*	ft	Equation 5

*Based on conversations with vendor values in this range can be fabricated.

Table 9-3: Fine Mesh (2.0 mm) "Refill Portion" of River Intake Screen Calculation Results

No.	Parameter	Value	Units	Comments
15.	Design Flow (Q_{design})	22,500	gpm	Input 4.1.1
16.	Converted Flow (Q)	50.13	ft^3/s	Q_{design}/ 448.83
17.	Screen Velocity (V)	0.5	ft/s	Acceptance Criterion 5.2.1
18.	Area based on Velocity (A_{vel})	100.27	ft^2	Equation 1
19.	Percentage Open Area (m)	56.30	%	Appendix B
20.	Area based on Screen Metal ($A_{screen\ metal}$)	77.83	ft^2	Equation 2
21.	Percentage of Clogged Screen	25	%	Assumption 5.1.2
22.	Area based on Clogged Screen (A_{clog})	59.36	ft^2	Equation 3
23.	Total Adjusted Area (A_{total})	237.46	ft^2	Eq 1+ Eq 2 + Eq 3
24.	Screen Standoff Height	4	ft	Input 4.1.4
25.	Intake Structure Bottom Floor TOC Elevation	497	ft	Input 4.1.2
26.	Low Water Elevation	511.1	ft	Input 4.1.3
27.	Screen Wetted Height (Y)	10.1	ft	Equation 4
28.	Screen Width (W)	11.76*	ft	Equation 5

*Based on conversations with vendor values in this range can be fabricated.

Table 9-4: Coarse Mesh (6.0 mm) "Refill Portion" of River Intake Screen Calculation Results

No.	Parameter	Value	Units	Comments
15.	Design Flow (Q_{design})	22,500	gpm	Input 4.1.1
16.	Converted Flow (Q)	50.13	ft^3/s	Q_{design}/ 448.83
17.	Screen Velocity (V)	0.5	ft/s	Acceptance Criterion 5.2.1
18.	Area based on Velocity (A_{vel})	100.27	ft^2	Equation 1
19.	Percentage Open Area (m)	65.90	%	Appendix B
20.	Area based on Screen Metal ($A_{screen\ metal}$)	51.88	ft^2	Equation 2
21.	Percentage of Clogged Screen	25	%	Assumption 5.1.2
22.	Area based on Clogged Screen (A_{clog})	50.72	ft^2	Equation 3
23.	Total Adjusted Area (A_{total})	202.87	ft^2	Eq 1+ Eq 2 + Eq 3
24.	Screen Standoff Height	4	Ft	Input 4.1.4
25.	Intake Structure Bottom Floor TOC Elevation	497	Ft	Input 4.1.2
26.	Low Water Elevation	511.1	Ft	Input 4.1.3
27.	Screen Wetted Height (Y)	10.1	Ft	Equation 4
28.	Screen Width (W)	10.04*	ft	Equation 5

*Based on conversations with vendor values in this range can be fabricated.

Table 9-5: Fine Mesh (2.0 mm) Make-up Pond A Intake Screen Calculation Results

No.	Parameter	Value	Units	Comments
1.	Design Flow (Q_{design})	15,000	gpm	Input 4.1.1
2.	Converted Flow (Q)	33.42	ft^3/s	Q_{design}/ 448.83
3.	Screen Velocity (V)	0.50	ft/s	Acceptance Criterion 5.2.1
4.	Area based on Velocity (A_{vel})	66.85	ft^2	Equation 1
5.	Percentage Open Area (m)	56.30	%	Appendix B
6.	Area based on Screen Metal ($A_{screen\ metal}$)	51.88	ft^2	Equation 2
7.	Percentage of Clogged Screen	25.00	%	Assumption 5.1.2
8.	Area based on Clogged Screen (A_{clog})	39.58	ft^2	Equation 3
9.	Total Adjusted Area (A_{total})	158.31	ft^2	Eq 1+ Eq 2 + Eq 3
10.	Screen Standoff Height	4	ft	Input 4.1.4
11.	Intake Structure Bottom Floor TOC Elevation	510	ft	Input 4.1.2
12.	Screen Width (W)	10.0	ft	Input 4.1.3
13.	Screen Wetted Height (Y)	7.92	ft	Item 9/(Item 12*2)
14.	Low Water Elevation	521.92**	ft	Item 10+ Item 11+ Item 13

** Min elevation at which through-screen velocity is ≤ 0.5 ft/s given a screen width of 10 feet.

Table 9-6: Coarse Mesh (6.0 mm) Make-up Pond A Intake Screen Calculation Results

No.	Parameter	Value	Units	Comments
1.	Design Flow (Q_{design})	15,000	gpm	Input 4.1.1
2.	Converted Flow (Q)	33.42	ft^3/s	Q_{design}/ 448.83
3.	Screen Velocity (V)	0.50	ft/s	Acceptance Criterion 5.2.1
4.	Area based on Velocity (A_{vel})	66.85	ft^2	Equation 1
5.	Percentage Open Area (m)	65.90	%	Appendix B
6.	Area based on Screen Metal ($A_{screen\ metal}$)	34.59	ft^2	Equation 2
7.	Percentage of Clogged Screen	25.00	%	Assumption 5.1.2
8.	Area based on Clogged Screen (A_{clog})	33.81	ft^2	Equation 3
9.	Total Adjusted Area (A_{total})	135.25	ft^2	Eq 1+ Eq 2 + Eq 3
10.	Screen Standoff Height	4	ft	Input 4.1.4
11.	Intake Structure Bottom Floor TOC Elevation	510	ft	Input 4.1.2
12.	Screen Width (W)	10	ft	Input 4.1.3
13.	Screen Wetted Height (Y)	6.76	ft	Item 9/(Item 12*2)
14.	Low Water Elevation	520.76**	ft	Item 10+ Item 11+ Item 13

** Min elevation at which through-screen velocity is ≤ 0.5 ft/s given a screen width of 10 feet.

9.2 Results of Calculation

In conclusion, the minimum traveling screen width (W) dimensions shown in Tables 9-1 through 9-6 ensure a through screen velocity less than or equal to 0.5 ft/s (REF 3.2.3). Moreover all dimensions developed within this calculation are minimums and the actual dimensions of the traveling screen should be larger than that of the calculated values.

Appendix A: Calculation Preparation Checklist

(Completed By Author(s))Item	Yes	No	N/A	Comments
1. Has the latest Calculation Cover Sheet been used?	☒	☐	☐	
2. Has the calculation been numbered in accordance with DAPP 5-8?	☒	☐	☐	
3. Has the Safety Classifications been marked on the Calculation Cover Sheet in accordance with DAPP 5-2?	☒	☐	☐	
4. Is this a non-safety related calculation? If YES, has the design verification method block been marked "N/A"?	☒	☐	☐	
5. Have English units been used throughout the calculation?	☒	☐	☐	
6. Are all the pages sequentially numbered, and are the calculation number, revision number, and appropriate proprietary classification listed on each page? Are the page numbers in the Table of Contents correct?	☒	☐	☐	
7. Has the objective/purpose been included in Section 1.2 of the calculation?	☒	☐	☐	
8. Is the Summary of Results and Conclusions provided in Section 2.0 consistent with the purpose stated in Section 1.2 and Results of Calculation contained in Section 9.2?	☒	☐	☐	
9. Is sufficient information provided for all references in Section 3.0 to facilitate their retrieval; or has a copy been provided as appendices?	☒	☐	☐	
10. Are the references accurate? Do the references to other documents point to the latest revision? If not, are the reasons documented?	☒	☐	☐	
11. Is the Method of Calculation/Analysis clearly described in Section 6.0 and reasonable?	☒	☐	☐	
12. Have all the inputs and assumptions listed in Section 4.0 of the calculation? Do all design input values have source identified?	☒	☐	☐	
13. Does the calculation contain Unapproved Inputs? If YES, has the Check Box on the Calculation Cover Sheet been marked? Have the Unapproved Inputs been listed in Section 2.3 (Open Items)?	☒	☐	☐	
14. Are the acceptance criteria define appropriately in Section 5.2?	☒	☐	☐	
15. Do the results and conclusions meet the acceptance criteria? Do the results and conclusions make sense and support the purpose stated in Section 1.2?	☒	☐	☐	
16. Does Table 8-1 identify all software used in the calculation? Are all software used in the calculation listed on the Approved Computer Program List?	☐	☐	☒	
17. Does Table 8-2 identify all electronic files for the calculation?	☐	☐	☒	
18. Are all attachments/appendices included in the calculation and noted in the Table of Contents page?	☒	☐	☐	
19. Is the calculation acceptable with respect to spelling, punctuation, and grammar?	☒	☐	☐	
20. Have all comments been resolved?	☒	☐	☐	

Appendix B: Mesh Size Equivalent Comparison

STG Particle Size / Screen Mesh Comparison

(800) 440-MESH Phone: (360) 835-8936 Fax: (360) 835-8966

Particle Size		Stainless Steel Bolting Cloth					Market Grade					U.S. Std. Sieve	
Inches	Microns	Mesh	Opening Inches	Opening Microns	Wire Dia.	Open Area	Mesh	Opening Inches	Opening Microns	Wire Dia.	Open Area	Closest Sieve	Opening In Inches
.2500	7097						3	.2790	7087	.0540	70.1%		
.2230	5660						4	.2023	5138	.0475	65.9%	3.5	.2205
.1870	4750						4	.1870	4750	.0630	56.0%	4	.1870
.1570	4000						5	.1590	4039	.0410	63.2%	5	.1575
.1320	3350						6	.1318	3348	.0348	62.7%	6	.1319
.1110	2820						7	.1080	2743	.0350	57.2%	7	.1102
.0937	2380						8	.0964	2449	.0286	60.2%	8	.0929
.0787	2000						10	.0742	1885	.0258	56.3%	10	.0787
.0730	1854						11	.0730	1854	.0180	64.5%		
.0661	1680	14	.0620	1575	.0090	76.4%	12	.0603	1532	.0230	51.8%	12	.0669
.0555	1410	16	.0535	1359	.0090	73.3%	14	.0510	1295	.0204	51.0%	14	.0551
.0469	1190	18	.0466	1184	.0090	70.2%	16	.0445	1130	.0181	50.7%	16	.0465
.0410	1041	20	.0410	1041	.0090	67.2%							
.0394	1000	22	.0380	965	.0075	69.7%	18	.0386	980	.0173	48.3%	18	.0394
.0331	841	24	.0342	869	.0075	67.2%	20	.0340	864	.0162	46.2%	20	.0335
.0310	784	26	.0310	787	.0075	64.8%							
.0278	707	28	.0282	716	.0075	62.4%	24	.0277	704	.0140	44.2%	25	.0280
.0268	681	30	.0268	681	.0065	64.8%							
.0248	630	32	.0248	630	.0065	62.7%							
.0234	595	34	.0229	582	.0065	60.7%						30	.0236
.0213	541	36	.0213	541	.0065	58.7%	30	.0203	516	.0128	37.1%		
.0197	500	38	.0198	503	.0065	56.7%						35	.0197
.0185	470	40	.0185	470	.0065	54.8%							
.0183	465	42	.0183	465	.0055	59.1%							
.0172	437	44	.0172	437	.0055	57.4%	35	.0176	447	.0118	37.9%		
.0165	420	46	.0162	411	.0055	55.8%						40	.0167
.0153	388	48	.0153	389	.0055	54.2%	40	.0150	381	.0104	36.0%		
.0145	368	50	.0145	368	.0055	52.6%							
.0139	354	52	.0137	348	.0055	51.0%						45	.0140
.0130	330	54	.0130	330	.0055	49.4%							
.0127	323	58	.0127	323	.0045	54.6%							
.0122	310	60	.0122	310	.0045	53.3%							
.0117	297	62	.0116	295	.0045	51.7%						50	.0118
.0111	282	64	.0111	282	.0045	50.7%	50	.0110	279	.0090	30.3%		
.0106	270	70	.0106	269	.0037	54.9%							
.0102	260	72	.0102	259	.0037	53.8%							
.0098	250	74	.0098	249	.0037	52.7%						60	.0098
.0095	241	76	.0095	241	.0037	51.7%							
.0091	231	78	.0091	231	.0037	50.6%	60	.0092	234	.0075	30.5%		
.0088	224	80	.0088	224	.0037	49.6%							
.0083	210	84	.0084	213	.0035	49.8%						70	.0083
.0079	200	88	.0079	201	.0035	47.9%							
.0076	193	90	.0076	193	.0035	47.8%							
.0070	177	94	.0071	180	.0035	45.0%	80	.0070	178	.0055	31.4%	80	.0071
.0065	165	105	.0065	165	.0030	46.9%							
.0059	149	120	.0058	147	.0025	47.3%	100	.0055	140	.0045	30.3%	100	.0059
.0049	125	145	.0047	119	.0022	46.4%	120	.0046	117	.0037	30.5%	120	.0049
.0041	105	165	.0042	107	.0019	47.1%	150	.0041	104	.0026	37.9%	140	.0042
.0035	88	200	.0034	86	.0016	46.2%	170	.0035	89	.0024	35.4%	170	.0035
.0029	74	230	.0029	74	.0014	46.0%	200	.0029	74	.0021	33.6%	200	.0030
.0025	63						250	.0024	61	.0016	36.0%	230	.0025
.0021	53	300	.0022	56	.0012	42.0%	270	.0021	53	.0016	32.0%	270	.0021
.0017	44						325	.0017	43	.0014	30.5%	325	.0018
.0015	38						400	.0015	38	.0010	36.0%	400	.0015
.0010	25						500	.0010	25	.0010	25.0%	500	.0010
.0008	20						635	.0008	20	.0008	25.0%	635	.0008

Shaw® NUCLEAR

CALCULATION

CLIENT: Duke Energy Carolinas, LLC PROJECT: Lee Nuclear Station Units 1 and 2	PAGE 1 OF 23 TOTAL PAGES: 23 (Including attachments)
CALCULATION TITLE: **Standard RWS Passive Screen Calculation**	QA CATEGORY ☐ - I Nuclear Safety Related ☐ - II ☐ - III Safety Class - E

CALCULATION IDENTIFICATION NUMBER

J.O. or W.O. NO.	DISCIPLINE CODE	CALCULATION NUMBER	REVISION NUMBER
124029	M	WLG-WWS-M3C-013	2

REVIEW AND APPROVAL	SUPERSEDES CALC. NO.: N/A	CONFIRMATION REQUIRED YES ☒ NO ☐

FUNCTION:	PRINT/SIGN	DATE	FOR PAGES:
Preparer(s)	M. R. Austin/ [signature]	12/5/11	All
	N/A	N/A	N/A
Reviewer(s)	S. S. Fong/ [signature]	12/5/11	All
	N/A	N/A	N/A
	N/A	N/A	N/A
	N/A	N/A	N/A
	N/A	N/A	N/A
	N/A	N/A	N/A
	N/A	N/A	N/A
	N/A	N/A	N/A

Design Verification Method: ☒ N/A ☐ Independent Review ☐ Alternate Calculation ☐ Qualification Testing

Design Verifier:	N/A		N/A

SOUTH CAROLINA REGISTERED No. 5871 PROFESSIONAL ENGINEER ROBERT M. DULIN, JR. [signature]

SOUTH CAROLINA STONE & WEBSTER, INC. No. C02300 CERTIFICATE OF AUTHORIZATION

Approver:	S. S. Fong/ [signature]	Date:	12/6/2011

CLASS 2	*Duke Energy's use of information on this document is limited to the design, licensing, operation, maintenance and modification of the Lee Nuclear Station, pursuant to the terms and conditions of the written agreement under which it is provided. To the extent this document is marked as containing Background, Confidential, and/or Proprietary information, such information is proprietary to the Shaw Power Group ("Shaw") and may include proprietary information of Stone & Webster, Inc. No rights to this document or to information contained herein are granted to any Party except as set forth in a written agreement signed by Shaw.*
©2011 Shaw Nuclear	
Governing PP 4-1	
Form Rev. Date: 0911	

Record of Revisions

Rev. No.	Description of Changes/ Reason for Change	Pages Revised	Pages Added	Pages Replaced
0	Issue for permit	N/A	N/A	N/A
1	Incorporates two screen alternative for Pond C.	N/A	N/A	N/A
2	Revised equation 4, updated screen lengths and screen diameters, incorporated new template, updated Table 2.1 and Section 9.1.1. Due to significant changes, revision bars were omitted.	All	N/A	N/A

Table of Contents

1.0 Introduction

1.1 Background

The Raw Water System (RWS) Pond B Intake consists of the Pond B subsystem and contains two types of pumps. The Pond B subsystem consists of five (5) pumps separated in two (2) forebays.

- There are four (4) Pond B Main pumps and each pump has a maximum capacity of 10,000 gpm (REF 3.1.1). One of the pumps is in standby. These pumps are connected to a common header and will be used to transfer water from Pond B to Pond A.
- There is one (1) Pond B Ancillary pump, and has a maximum capacity of 6000 gpm (REF 3.1.7). This pump will be used to transfer water from Pond B to Pond C.

The RWS Pond C Intake consists of the Pond C subsystem.

- The Pond C subsystem consists of three (3) pumps in one (1) forebay, separated by interior walls which do not span the length of the forebay. Each pump has a maximum capacity of 10,000 gpm (REF 3.1.6). These pumps are connected to a common header and will be used to transfer water from Pond C to Pond B.

1.2 Purpose

This calculation will determine the minimum dimensional requirements for a standard size passive screen in both the Pond B and Pond C intake structures which will meet 0.5 feet/second velocity requirement:

- Minimum screen length
- Minimum screen diameter

This calculation will determine the screen length and screen diameter for both a coarse mesh and a fine mesh. This information is required as input to the design of the Pond B and Pond C intake structures in support of both Units 1 and 2.

1.3 Limits of Applicability

This calculation is only applicable to the William State Lee III Nuclear Station Units 1 and 2, Pond B and Pond C structures.

2.0 Summary of Results and Conclusions

2.1 Results

The general passive screen dimension results are given in **Table 2-1**.

TABLE 2-1 GENERAL PASSIVE SCREEN DIMENSIONS

Screen Mesh	DIMENSION	VALUE	UNITS
FINE	Minimum Passive Screen Length (L)	9.52	ft
	Minimum Passive Screen Diameter (D)	6.5	ft
	Maximum Slot Opening	2.0	mm
	Wedge Wire Size	0.093	in
COARSE	Minimum Passive Screen Length (L)	7.23	ft
	Minimum Passive Screen Diameter (D)	5.5	ft
	Maximum Slot Opening	10.0	mm
	Wedge Wire Size	0.158	in

Pond B will utilize two (2) pump forebays with two (2) passive intake screens per pump forebay while Pond C will utilize one (1) pump forebay with two (2) passive intake screens. The ancillary pump in Pond B is located within one of the main pump forebays and therefore utilizes the main pump screen. The ancillary pump does not operate concurrently with the main pumps.

2.2 Conclusions / Recommendations

- The results listed in the previous section are based on the best available information. Although there will be changes to the Raw Water System (RWS) as the design progresses, the sizing of the passive screens must maintain compliance with the acceptance criteria in Section 5.2.4. The passive screens shall be re-sized if required during the design process to maintain thru-screen velocity less than 0.5 ft/s per Ref. 3.2.4.
- This calculation should be used as input to the design of both the Pond B and Pond C intake structures. All general dimensions, developed from this calculation, shall be no less than the corresponding value from Table 2-1, for example the length of the passive screen (L) should be no less than 9.52 ft, fine mesh, or 7.23 ft, coarse mesh.
- The centerline of the passive screens should be installed as stated in the Section 5.2.2 and consistent with the Ref. 3.1.4.
- The intake screen procurement specification shall include the scope of calculating actual head loss by supplier.

- The percent clogging of the screen will need to be monitored with instrumentation to ensure the available flow area maintains a velocity no greater than 0.5 ft/s. Instrumentation measuring a differential pressure associated with the maximum allowed clogging will require the screen to be cleaned. The type of device utilized will depend on discussions with the manufacturer and will be incorporated in a subsequent design phase.

3.0 References

3.1 AP1000 Documents

3.1.1 WLG-RWS-M3C-010, "RWS, Make-up Pond B Subsystem Hydraulic Analysis", Revision B

3.1.2 WLG-RWS-MY18-001, "Intake Screen Selection for the Raw Water System," Revision A

3.1.3 WLG-RWS-M3C-005, "Make-up Pond C & B Intake Hydraulic Calculation," Revision B

3.1.4 WLG-XXER-GF-018, "RFI SHAW Input for Duke Energy's Response to NRC No RAI 210", 09/30/2010

3.1.5 Project Number GK4270, "Cooling Water Intake Structures Hydraulic Zone of Influence William States Lee III Nuclear Station Cherokee County, South Carolina", prepared by Geosyntec Consultants and MMI, 07/27/2011

3.1.6 WLG-RWS-M3C-011, "RWS, Make-up Pond C Subsystem Hydraulic Analysis", Revision B

3.1.7 WLG-RWS-M3C-009, "RWS, Make-up Pond B to Make-up Pond C", Revision B

3.2 Other

3.2.1 "Cameron Hydraulic Data," C.C. Heald, 19th Edition, 2002

3.2.2 "Johnsons Screens: An Overview," Johnson Screens, Inc, 2010 (http://www.johnsonscreens.com/sites/default/files/2/680/Johnson%20Industrial%20Screens.pdf)

3.2.3 "Revolutionary Cleaning Technology Cylinder Screen with External and Internal Brush System," Intake Screens, Inc (http://www.intakescreensinc.com/files/ISIBrushedCylinder.pdf)

3.2.4 40 CFR Part 125: National Pollutant Discharge Elimination System—Amendment of Final Regulations Addressing Cooling Water Intake Structures for New Facilities (Implements Requirements of Section 316B of the Clean Water Act).

3.2.5 W. S. Lee III Nuclear Station NPDES Permit Application, August, 2011, Duke Energy Carolinas, LLC, Figure A-21 and Figure A-23

4.0 Calculation Inputs

4.1 Inputs

4.1.1 Maximum Flow Rate

Each Pond B main pump has a design capacity of 10,000 gpm (REF 3.1.1); the Pond B ancillary pump has a design capacity of 6,000 gpm (REF 3.1.7), each Pond C pump has a design capacity of 10,000 gpm (REF 3.1.6). Both drought-contingency Ponds have three (3) pumps normally operating. Drought-contingency Pond B also has one (1) standby pump.

To standardize the stationary screen design, the maximum thru-screen design flow for Pond B and Pond C utilized a flow rate of 15,000 gpm (based on total system flow for Pond C divided by the number of screens (2 screens). See Reference 3.2.5.

4.1.2 Percentage Open Area

4.1.2.1 Fine Mesh

The passive screen shall filter debris and aquatic life 2 mm in size and larger (REF 3.1.2). Based on an approximate 2 mm mesh size, the equivalent percent open area can be determined. The value calculated was 45.85%, using an equation referenced from Appendix B.

4.1.2.2 Coarse Mesh

The passive screen shall filter debris and aquatic life 10 mm in size and larger. Based on an approximate 10 mm mesh size the equivalent percent open area can be determined. The value calculated was 71.36%, using an equation referenced from Appendix B.

4.1.3 Pond B Drawdown Level

The occasional pond drawdown is 30 feet (REF. 3.1.5).

4.1.4 Pond C Drawdown Levels

The occasional pond drawdown is 30 feet; and, the maximum pond drawdown is 45 feet REF. 3.1.5).

5.0 Assumptions and Acceptance Criteria

5.1 Discussion of Significant Assumptions

5.1.1 Pump Forebay and Pump Bay Design

- Pond B will utilize two (2) pump forebays with two (2) passive intake screens per pump forebay while Pond C will utilize one (1) pump forebay with two (2) passive intake screens. The ancillary pump in Pond B is located within one of the main pump forebays and therefore utilizes the main pump screen. The ancillary pump does not operate concurrently with the main pumps.
- Each pump will be separated in individual pump bays, except for one bay in the Make-up Pond B intake structure in which an ancillary pump coexists with one of the main pumps. The pump bay interior walls do not span the length of the forebay.

5.1.2 Clogged Screen

This calculation assumes added margin for meeting the 0.5 ft/s requirement up to a 25% clogged screen. This margin is recommended by Duke Energy, based on discussion with a subject matter expert from the Electric Power Research Institute (EPRI). The maximum head loss across the screens will be verified by the supplier when this equipment is purchased (Open Item 3).

5.2 Acceptance Criteria

5.2.1 The length of the passive screen shall be less than 150% or 1.5 times the diameter of the passive screen (See Appendix C, Item 2).

5.2.2 The centerline of the passive screens should be installed at a minimum of one screen diameter from the intake structure bottom (supplier recommendation) plus one to five feet to account for sediment loading.

5.2.3 To prevent possible pump cavitation problems, the top of the passive screens shall be lower than the minimum water level of ponds (to keep the screens submerged). This will also ensure that the 0.5 ft/s velocity limit is not exceeded.

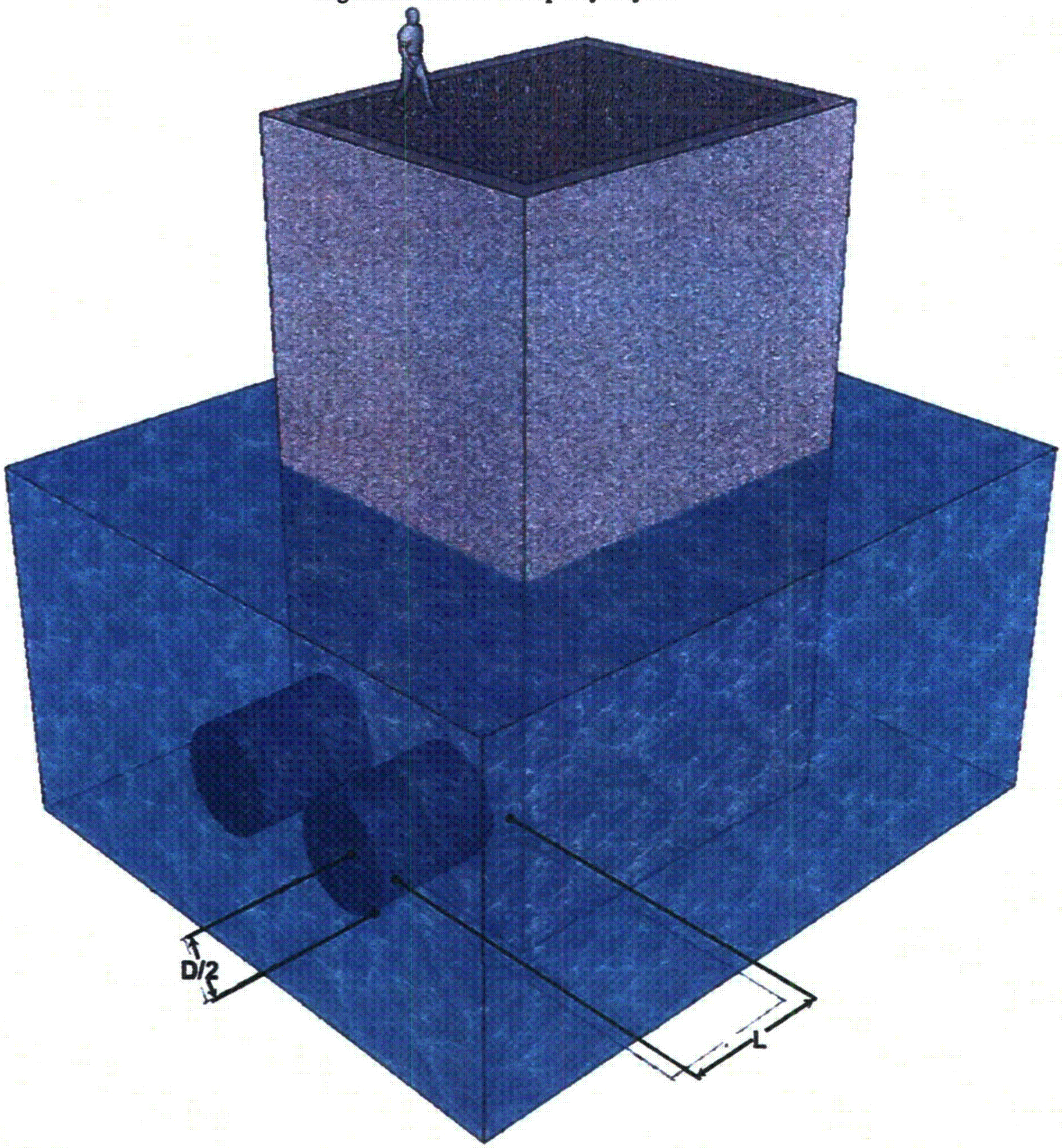
5.2.4 The thru-screen velocity for each passive screen shall be less than or equal to 0.5 ft/s per Ref. 3.2.4.

6.0Methods

6.1 Method Discussion

A general pump bay layout is shown below.

Figure 6-1 General Pump Bay Layout



Note: For comparison of passive screen diameter and minimum water level at intake see Section 9.1.1.

The preliminary standard passive screen sizing was calculated using equations constructed per REF 3.2.1 and simple geometry of a cylinder.

The following steps were used to calculate a standard passive screen length for both fine mesh and coarse mesh:

1. Determine the thru-screen design flow (Q, ft^3/s).

2. Select maximum velocity (V, ft/s). A maximum velocity of 0.5ft/s will be used to meet section 316B of the Clean Water Act.

3. Calculate the minimum required area (A, ft^2) based on the maximum velocity (V) using below equation (REF 3.2.1, page 2-13).

$$A_{vel} = \frac{Q}{V} \quad \text{(Equation 1)}$$

4. Select a passive screen opening (O, ft). Values of 2 mm and 10 mm are examined (REF 3.2.1).

5. Select a passive screen wire size (W, ft) using Appendix B.

6. Calculate the percentage of open area (m, %) using the following equation.

$$m = \frac{O}{W+O} \quad \text{(Equation 2)}$$

7. Calculate the screen metal area ($A_{screen\ metal}$, ft^2) based on the selected mesh size opening using the below equation.

$$A_{screen\ metal} = \left(\frac{1}{m} - 1\right) A_{vel} \quad \text{(Equation 3)}$$

8. Calculate the additional area (A_{clog}, ft^2) to account for a clogged screen using the below equation.

$$A_{clog} := (\%\ clogged\_screen) \cdot \left[\frac{(A_{screen\_metal} + A_{vel})}{(1 - \%clogged\_Screen)}\right] \quad \text{(Equation 4)}$$

9. Determine the total adjusted area (A_{total}, ft^2) based on the summation of Equation 1, Equation 3, and Equation 4.

10. Determine the minimum passive screen diameter (D, ft) using Appendix C, item 1.

11. Calculate the minimum passive screen length (L, ft) using the below equation.

$$L = \frac{A_{total}}{\pi D} \quad \text{(Equation 5)}$$

12. Calculate the length (L) vs. diameter (D) ratio (R). Ensure the ratio is less than 1.5.

13. Calculate the minimum number of screens (N) per intake for Pond B and Pond C. The actual number of screens is determined based on the design flow through the screen and the layout of the pump intake.

7.0 Confirmation Required

ITEM NO.	DESCRIPTION	COMMENTS
1	**PUMP BAY DESIGN** The pump bay design is a significant assumption within this calculation (See Section 5.1.1). Once the intake structural design is finalized, section 5.1.1 should be reviewed and made consistent with the final intake design.	Review final design to verify dimensions
2	**UNAPPROVED DESIGN INPUTS** This calculation is created using the design inputs based on references 3.1.1, 3.1.3, 3.1.6, and 3.1.7. Each reference should be reviewed and made consistent with section 4.1.	Review final input design numbers in References
3	**PASSIVE SCREEN DESIGN** This calculation has added margin to account for some screen clogging, however the change in pressure (head loss) with respect to a dirty or clogged screen will be analyzed based on the actual size of the passive screen, by the supplier. Section 5.1.2 should be reviewed and made consistent with the final passive screen design.	OPEN
4	**POND DRAWDOWN LEVELS** Assumptions 4.2.3 and 4.2.4 require confirmation later. Information from the HZI analysis, to be provided by Duke Energy, is required to confirm pond drawdowm levels and to possibly replace RFI-SSWN-LEE-000047 as a reference.	Closed in Rev. 2; See Reference 3.1.5

8.0 Computer Code Identification

Table 8-1 Summary of Computer Codes Used in Calculation

Code No.	Code Name	Code Ver.	Configuration Control Reference	Basis (or reference) that supports use of code in current calculation
1	N/A			
2	N/A			

Table 8-2 Electronically Attached File Listing

Run No.	Table 6-1 Code No.	Computer Run Description	Machine Name Run Date/Time	File Type	EDMS File Name or File Location
1		N/A			
2					
3					
4					
5					
6					
7					
8					

9.0 Detailed Analysis/Calculations and Results

9.1 Calculations

Table 9-1: Fine Mesh Calculation

No.	Parameter	Value	Units	Comments
1.	Thru-Screen Design Flow (Q_{design})	15,000	gpm	Input 4.1.1
2.	Converted Flow (Q)	33.42	ft^3/s	Q_{design}/ 448.8
3.	Screen Velocity (V)	0.50	ft/s	Acceptance Criterion 5.2.4
4.	Area based on Velocity (A_{vel})	66.84	ft^2	Equation 1
5.	Slot Opening Size (O_{mesh})	2.00	mm	Input 4.1.2.1
6.	Converted Slot Opening Size (O)	0.0787	in	O_{mesh}/25.4
7.	Wire Size (W)	0.0930*	in	Input (Appendix B)
8.	Percentage Open Area (m)	45.85	%	Equation 2
9.	Area based on Screen Metal ($A_{screen\ metal}$)	78.95	ft^2	Equation 3
10.	Percentage of Clogged Screen	25**	%	Assumption 5.1.2
11.	Area based on Clogged Screen (A_{clog})	48.60	ft^2	Equation 4
12.	Total Adjusted Area (A_{total})	194.39	ft^2	$A_{vel}+A_{screen\ metal}+A_{clog}$
13.	Typical Screen Diameter (D_{screen})	78	in	Input (Appendix C, Item 1)
14.	Converted Screen Diameter (D)	6.5	ft	D_{screen}/12
15.	Screen Length (L)	9.52	ft	Equation 5
16.	Length vs. Diameter Ratio (R < 1.5)	1.47	na	L/D
17.	Pond B Pump Flow (Q_{mkupb})	10,000	gpm	Input 4.1.1
18.	Number of Pond B Normally Operating Pumps (N_{mkupb})	3	qty	Input 4.1.1
19.	Required Pond B Screens ($N_{screenb}$)	2***	qty	Minimum 4 screens required** *
20.	Pond C Ind. Pump Flow (Q_{mkupc})	10,000	gpm	Input 4.1.1
21.	Number of Pond C Normally Operating Pumps (N_{mkupb})	3	qty	Input 4.1.1
22.	Required Pond C Screens ($N_{screenc}$)	2	qty	Minimum of 2 screens

* A value of 0.0930 inches is selected for the fine mesh based on engineering judgment and conversation with a screen vendor for the determination of screen size limits. Actual wire sizes will be determined based on the design loads required for the screens.

** Meets assumption 5.1.2.

*** The conceptual layout of the Pond B intake structure has two (2) forebays separated by an interior concrete wall with two (2) main pumps associated with each forebay. The combined pump flow associated with each forebay is 20,000 gpm. Given the design flow of the passive

screen is 15,000 gpm, two (2) passive screens are needed per forebay for a total of four (4) passive screens. Providing two (2) passive screens per forebay allows any three (3) of four (4) main pumps to be normally operating.

Table 9-2: Coarse Mesh Calculation

No.	Parameter	Value	Units	Comments
1.	Thru-Screen Design Flow (Q_{design})	15,000	gpm	Input 4.1.1
2.	Converted Flow (Q)	33.42	ft^3/s	Q_{design}/ 448.83
3.	Screen Velocity (V)	0.50	ft/s	Acceptance Criterion 5.2.4
4.	Area based on Velocity (A_{vel})	66.84	ft^2	Equation 1
5.	Slot Opening Size (O_{mesh})	10.00	mm	Input 4.1.2.2
6.	Converted Slot Opening Size (O)	0.3937	in	O_{mesh}/25.4
7.	Wire Size (W)	0.1580*	in	Input (Appendix B)
8.	Percentage Open Area (m)	71.36	%	Equation 2
9.	Area based on Screen Metal ($A_{screen\ metal}$)	26.83	ft^2	Equation 3
10.	Percentage of Clogged Screen	25**	%	Assumption 5.1.2
11.	Area based on Clogged Screen (A_{clog})	31.22	ft^2	Equation 4
12.	Total Adjusted Area (A_{total})	124.89	ft^2	A_{vel}+$A_{screen\ metal}$+A_{clog}
13.	Typical Screen Diameter (D_{screen})	66	in	Input (Appendix C, Item 1)
14.	Converted Screen Diameter (D)	5.5	ft	D_{screen}/12
15.	Screen Length (L)	7.23	ft	Equation 5
16.	Length vs. Diameter Ratio (R < 1.5)	1.31	na	L/D
17.	Pond B Pump Flow (Q_{mkupb})	10,000	gpm	Input 4.1.1
18.	Number of Pond B Normally Operating Pumps (N_{mkupb})	3	qty	Input 4.1.1
19.	Required Pond B Screens ($N_{screenb}$)	2***	qty	Minimum 4 screens required***
20.	Pond C Pump Flow (Q_{mkupc})	10,000	gpm	Input 4.1.1
21.	Number of Pond C Normally Operating Pumps (N_{mkupb})	3	qty	Input 4.1.1
22.	Required Pond C Screens ($N_{screenc}$)	2	qty	Minimum of 2 screens

* A value of 0.1580 in is selected for the coarse mesh based on engineering judgment and conversation with a screen vendor for the determination of screen size limits. Actual wire sizes will be determined based on the design loads required for the screens.

** Meets assumption 5.1.2.

*** The conceptual layout of the Pond B intake structure has two (2) forebays separated by an interior concrete wall with two (2) main pumps associated with each forebay. The combined

pump flow associated with each forebay is 20,000 gpm. Given the design flow of the passive screen is 15,000 gpm, two (2) passive screens are needed per forebay for a total of four (4) passive screens. Providing two (2) passive screens per forebay allows any three (3) of four (4) main pumps to be normally operating.

9.1.1 Screen Diameter Compared to Minimum Pond Level

This section is to verify that the screens remain covered under the various pond levels, based on the occasional and maximum drawdown levels.

- Pond B normal level is assumed to be 570 msl and occasional drawdown is 30 feet (Input 4.1.3) resulting in a level of 540 msl. The screen centerline is located at 528 msl or 8 feet above the bottom of the intake structure (Ref 3.1.4). At minimum pond level there is a water cover depth of approximately 12 feet to the screen centerline or 8.75 feet to the top of the screen assuming a 6.5 foot diameter for the screen.
- Pond C normal level is assumed to be 650 msl and occasional drawdown is 30 feet (Input 4.1.4) resulting in a level of 620 msl. The screen centerline is located at 553 msl or 8 feet above the bottom of the intake structure (Ref 3.1.4). At minimum pond level there is a water cover depth of approximately 67 feet to the screen centerline or 63.75 feet to the top of the screen assuming a 6.5 foot diameter for the screen.
- Pond C normal level is assumed to be 650 msl and maximum drawdown is 45 feet (Input 4.1.4) resulting in a level of 605 msl. The screen centerline is located at 553 msl or 8 feet above the bottom of the intake structure (Ref 3.1.4). At minimum pond level there is a water cover depth of approximately 52 feet to the screen centerline or 48.75 feet to the top of the screen assuming a 6.5 foot diameter for the screen.

9.2 Results of Calculation

In conclusion, the minimum passive screen length (L) dimension is validated based on a size ratio less than 1.5 times passive screen diameter (D) (see section 5.2.1).

The screens location satisfies the requirement for the screens to remain submerged based on the pond drawdown. Dimensions developed within this calculation are minimums and the actual dimensions of the passive screen should be larger than that of the calculated values.

Appendix A: Calculation Preparation Checklist

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O NUMBER 124029	DISCIPLINE CODE M	CALCULATION NUMBER WLG-WWS-M3C-013	REVISION NUMBER 2	Page 19 of 23

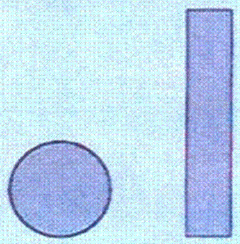
	(Completed By Author(s))Item	Yes	No	N/A	Comments
1.	Has the latest Calculation Cover Sheet been used?	☒	☐	☐	
2.	Has the calculation been numbered in accordance with DAPP 5-8?	☒	☐	☐	
3.	Has the Safety Classifications been marked on the Calculation Cover Sheet in accordance with DAPP 5-2?	☒	☐	☐	
4.	Is this a non-safety related calculation? If YES, has the design verification method block been marked "N/A"?	☒	☐	☐	
5.	Have English units been used throughout the calculation?	☒	☐	☐	
6.	Are all the pages sequentially numbered, and are the calculation number, revision number, and appropriate proprietary classification listed on each page? Are the page numbers in the Table of Contents correct?	☒	☐	☐	
7.	Has the objective/purpose been included in Section 1.2 of the calculation?	☒	☐	☐	
8.	Is the Summary of Results and Conclusions provided in Section 2.0 consistent with the purpose stated in Section 1.2 and Results of Calculation contained in Section 9.2?	☒	☐	☐	
9.	Is sufficient information provided for all references in Section 3.0 to facilitate their retrieval; or has a copy been provided as appendices?	☒	☐	☐	
10.	Are the references accurate? Do the references to other documents point to the latest revision? If not, are the reasons documented?	☒	☐	☐	
11.	Is the Method of Calculation/Analysis clearly described in Section 6.0 and reasonable?	☒	☐	☐	
12.	Have all the inputs and assumptions listed in Section 4.0 of the calculation? Do all design input values have source identified?	☒	☐	☐	
13.	Does the calculation contain Unapproved Inputs? If YES, has the Check Box on the Calculation Cover Sheet been marked? Have the Unapproved Inputs been listed in Section 2.3 (Open Items)?	☒	☐	☐	
14.	Are the acceptance criteria define appropriately in Section 5.2?	☒	☐	☐	
15.	Do the results and conclusions meet the acceptance criteria? Do the results and conclusions make sense and support the purpose stated in Section 1.2?	☒	☐	☐	
16.	Does Table 8-1 identify all software used in the calculation? Are all software used in the calculation listed on the Approved Computer Program List?	☐	☐	☒	
17.	Does Table 8-2 identify all electronic files for the calculation?	☐	☐	☒	
18.	Are all attachments/appendices included in the calculation and noted in the Table of Contents page?	☒	☐	☐	
19.	Is the calculation acceptable with respect to spelling, punctuation, and grammar?	☒	☐	☐	
20.	Have all comments been resolved?	☒	☐	☐	

Appendix B: Wire Information

WIRES AND RODS INFORMATION

A wide range of wire and rod shapes make it possible to achieve the optimum balance of strength, open area, abrasion resistance and dewatering/separation efficiency

JOHNSON SCREENS® ROUND AND STRIP SUPPORT RODS



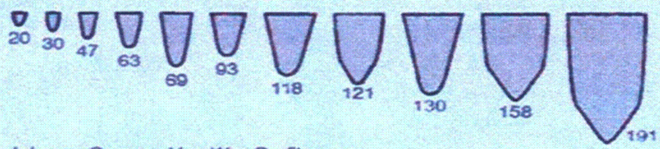
Johnson Screens round rods are available in diameters ranging from 0 125 in (3 175 mm) to 0 500 in (12 7 mm) Strip rods are available in widths from 0 070 in (1 778 mm) to 0 188 in (4 775 mm) and heights ranging from 0 375 in (9 525 mm) to 2 0 in (50 8 mm)

OPEN AREA CALCULATIONS

To calculate the open area of a certain screen, use the simple formula provided

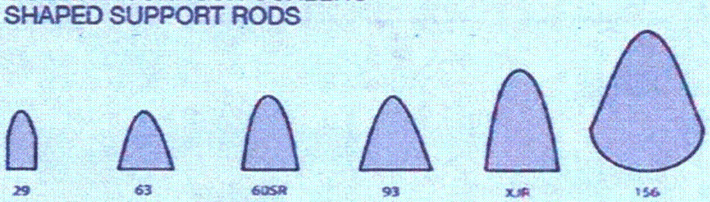
$$\text{Open Area (\%)} = \frac{\text{Slot size} \times 100}{\text{Slot size} + \text{Wire width}}$$

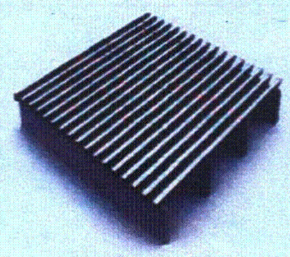
JOHNSON SCREENS VEE-WIRE® PROFILES



Johnson Screens Vee-Wire Profile wires range in widths from 0 020 in (0 508 mm) to 0 195 in (4 953 mm) and heights ranging from 0 040 in (1 016 mm) to 0 363 in (9 220 mm) Other wire shapes (Tri-Wire, Iso-Wire, Iso-Grizzly Wire, Grizzly-Wire, and more) also available

COMMON *JOHNSON SCREENS* SHAPED SUPPORT RODS

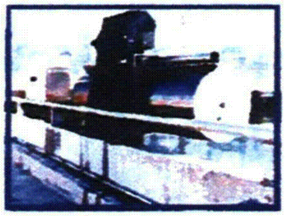




Johnson Screens shaped support rods range in widths from 0 029 in (0 737 mm) to 0 151 in (3 835 mm) and heights ranging from 0 102 in (2 591 mm) to 0 120 in (3 048 mm)

Appendix C: Screen Information

Off-Shore Intakes - River Diversions - Facility Retrofits

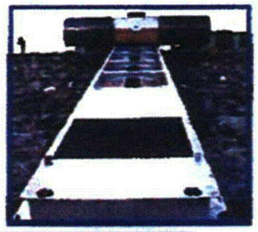


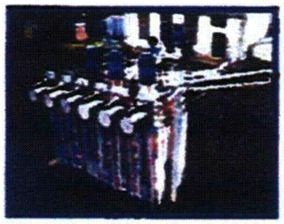
Left: Screens can be retrieved for inspection or during periods of non-use. Tracks can be installed on vertical walls or sloping banks.

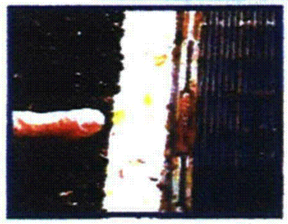
Left Below: Cylinder screens can be mounted to existing facilities and can significantly increase intake screen surface area

Right: Trashrack protects intake while screen is retracted. Rolling manifold and sealing system holds unit securely sealed over intake when deployed

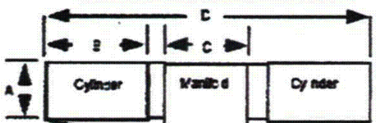
Center: Screens can be manifolded to meet additional flow requirements for large installations. 72-inch diameter screens shown.







Above: Exterior and interior brushing action keeps screen surface very clean, minimizing headloss issues.



Cylinder Screen Specifications

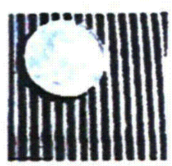
Model *	Unit Dimensions A - B - C - D	Unit Weight	Screen Surface Area	Slot Velocity @ 0.5 ft/sec (0.08 m/s)	Allowable Flow Rates ** Approach Velocity @ 0.2 ft/sec (0.06 m/s)	Approach Velocity @ 0.33 ft/sec (0.10 m/s)	Approach Velocity @ 0.4 ft/sec (0.12 m/s)
ISI T30-42	30" - 42" - 36" - 128"	1,400 lbs.	55.0 ft^2 (5.11 m^2)	13.7 cfs (388 l/s)	9.4 cfs (266 l/s)	18.1 cfs (513 l/s)	22.0 cfs (623 l/s)
ISI T36-54	36" - 54" - 48" - 164"	1,900 lbs.	84.8 ft^2 (7.88 m^2)	21.2 cfs (600 l/s)	17.0 cfs (481 l/s)	28.0 cfs (793 l/s)	33.9 cfs (960 l/s)
ISI T42-66	42" - 66" - 60" - 200"	2,200 lbs.	119.5 ft^2 (11.10 m^2)	29.9 cfs (847 l/s)	23.9 cfs (676 l/s)	39.4 cfs (1116 l/s)	47.8 cfs (1354 l/s)
ISI T48-72	48" - 72" - 60" - 212"	2,900 lbs.	150.8 ft^2 (14.01 m^2)	37.5 cfs (1062 l/s)	30.2 cfs (885 l/s)	48.8 cfs (1382 l/s)	60.3 cfs (1708 l/s)
ISI T60-90	60" - 90" - 60" - 248"	3,800 lbs.	235.6 ft^2 (21.89 m^2)	58.9 cfs (1668 l/s)	47.1 cfs (1334 l/s)	77.8 cfs (2203 l/s)	94.2 cfs (2667 l/s)

ITEM 1 → * Available in Diameters from 24 to 96 inches (with custom lengths) — Call for more information

ITEM 2

** 1) Allowable flows based on using wedgewire screens with 50% open area. Typical screen with 1.75mm wire is shown below;
2) Maximum recommended slot velocity is 0.5 fps for most applications subjected to heavy debris or poor hydraulic conditions;
3) Cylinder lengths are typically limited to 1.5 times the diameter as shown in the table above. Shorter cylinder lengths are available;
4) Many fisheries agencies use a maximum approach velocity criteria instead of slot velocity. Approach Velocity is the component of velocity perpendicular to the screen surface and measured 3 inches away. A minimum open area is generally specified;
5) Single cylinder units (i.e. "drums" or half of a "T") are also available;
6) Regulatory design criteria varies and typically depends on fish protection needs. Call for information on slot sizes below 1mm.

ISI Intake Screens, Inc.



For more information contact:

E-mail: screens@intakescreensinc.com
Website: www.IntakeScreensInc.com
Office: 8417 River Road, Sacramento, CA 95832
Phone: (916) 665-2727 Fax: (916) 665-2729