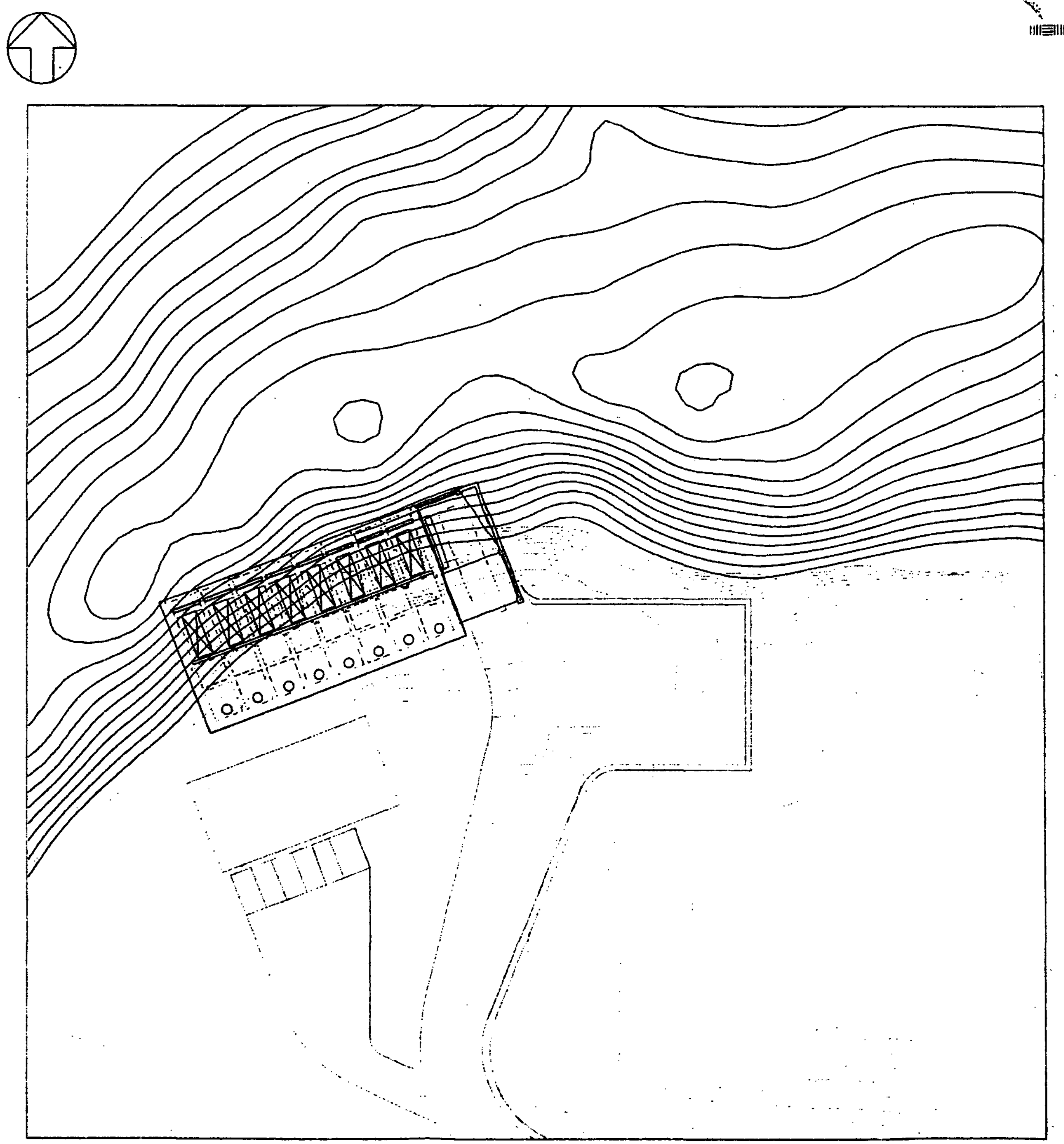
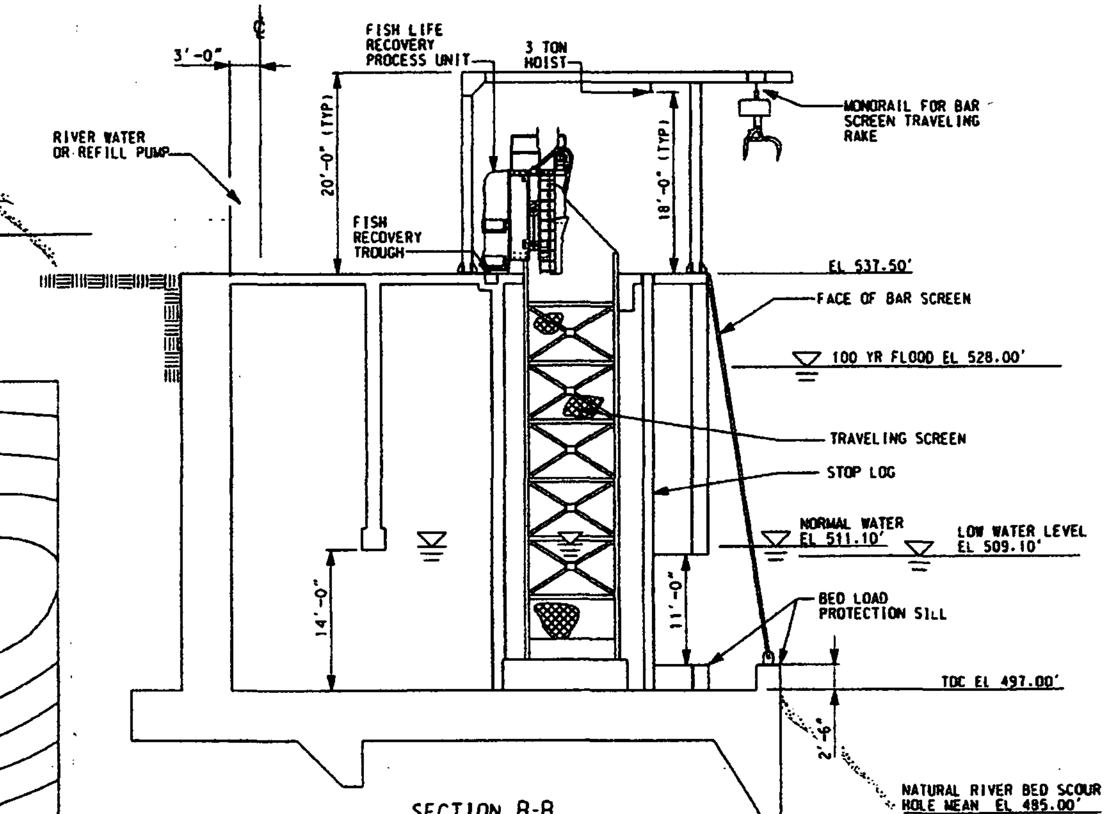
ATTACHMENT 4

RESPONSE TO COMMENT #20





SECTION B-B

PUMP AND PIPE OUTLINE NOT TO SCALE

WILLIAM STATES LEE III NUCLEAR STATION UNITS 1 AND 2
River Intake Structure Sheet 2 of 3 Figure A-15 Rev 1

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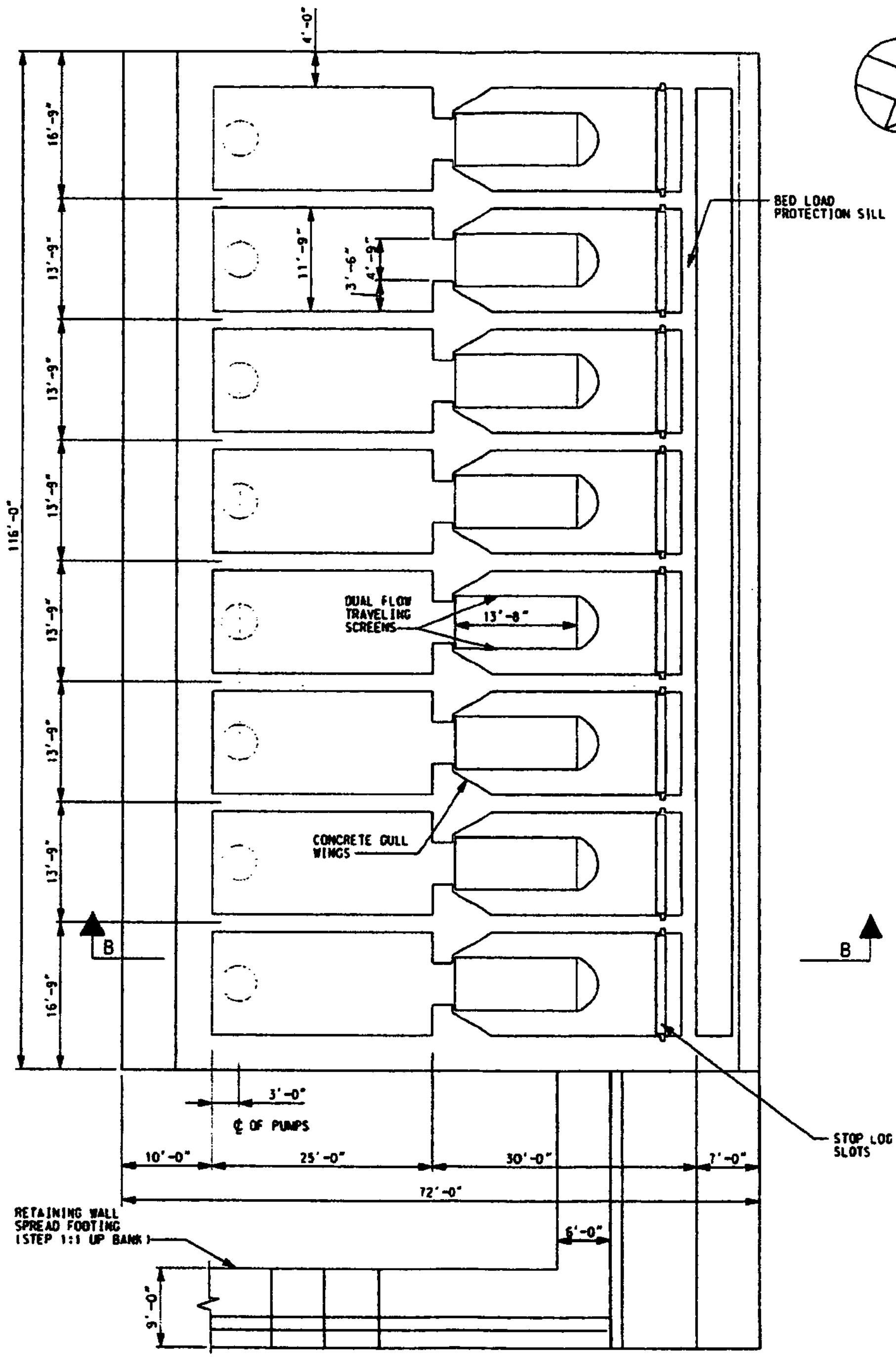
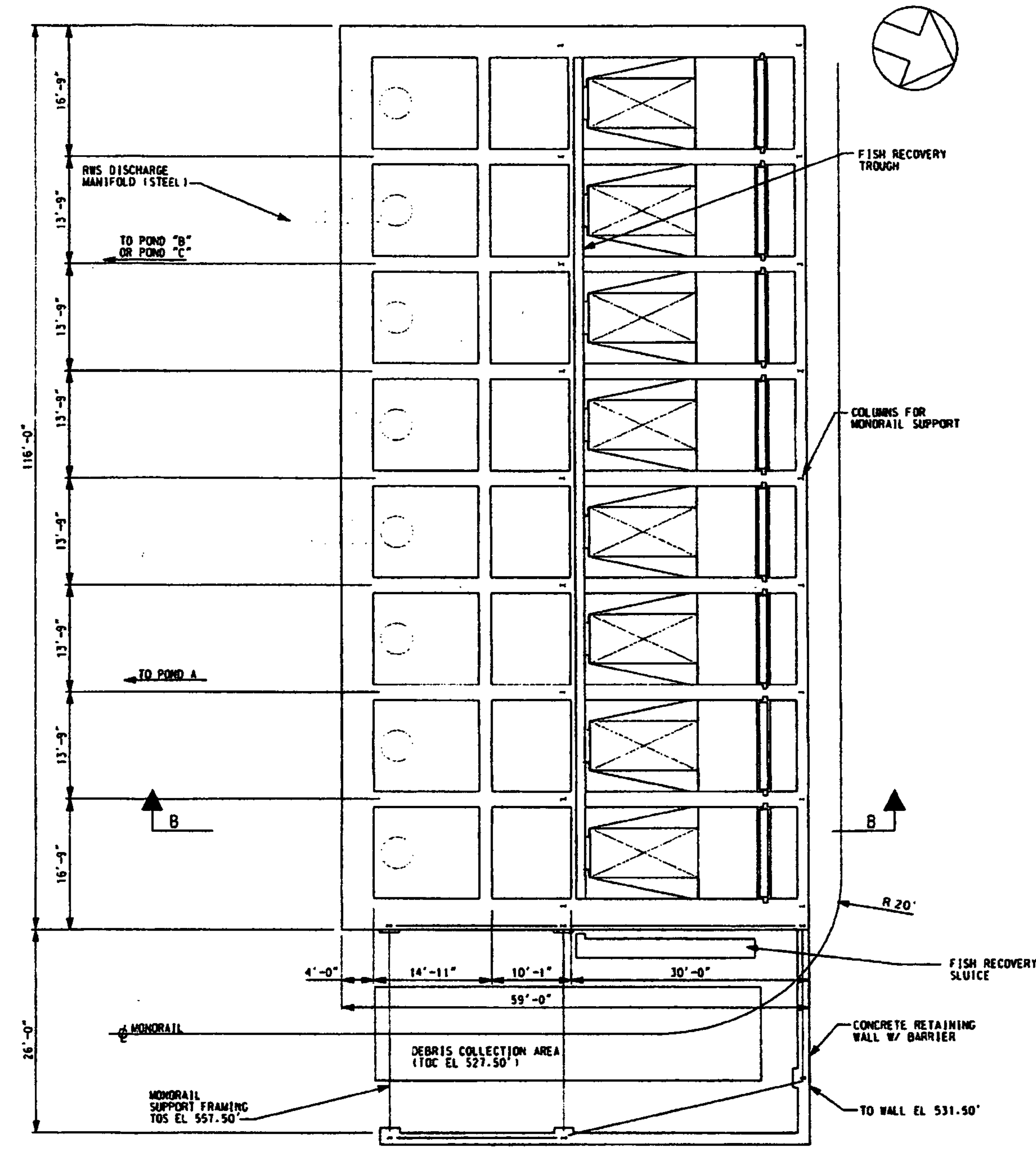


MAT PLAN @ EL 497.00'

PUMP AND PIPE OUTLINE NOT TO SCALE



DECK PLAN

PUMP AND PIPE OUTLINE NOT TO SCALE

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 AND 2

River Intake Structure
Sheet 3 of 3

Figure A-16 Rev 1

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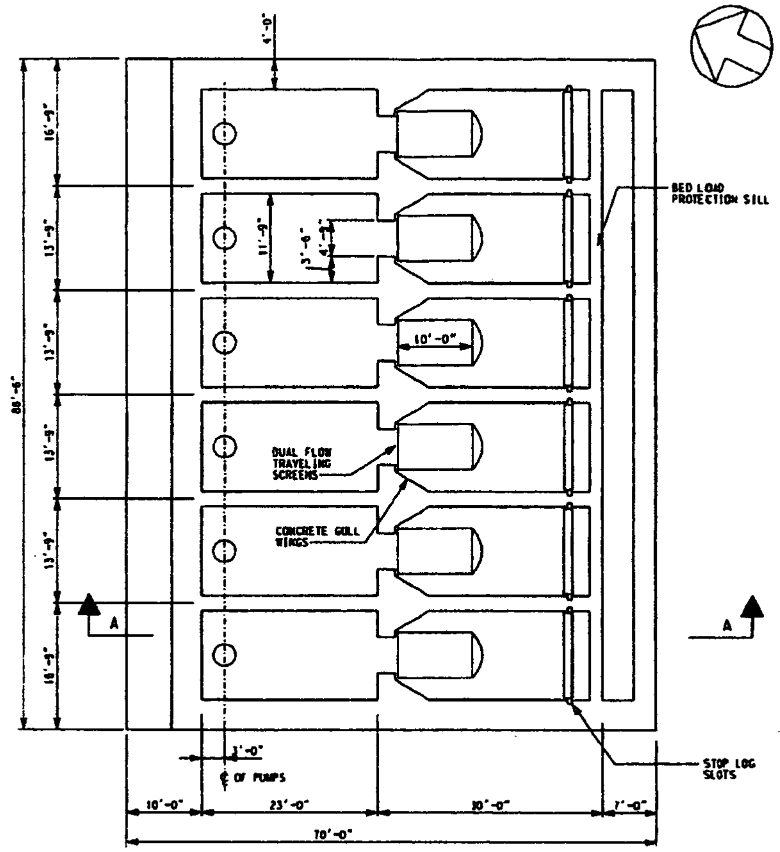

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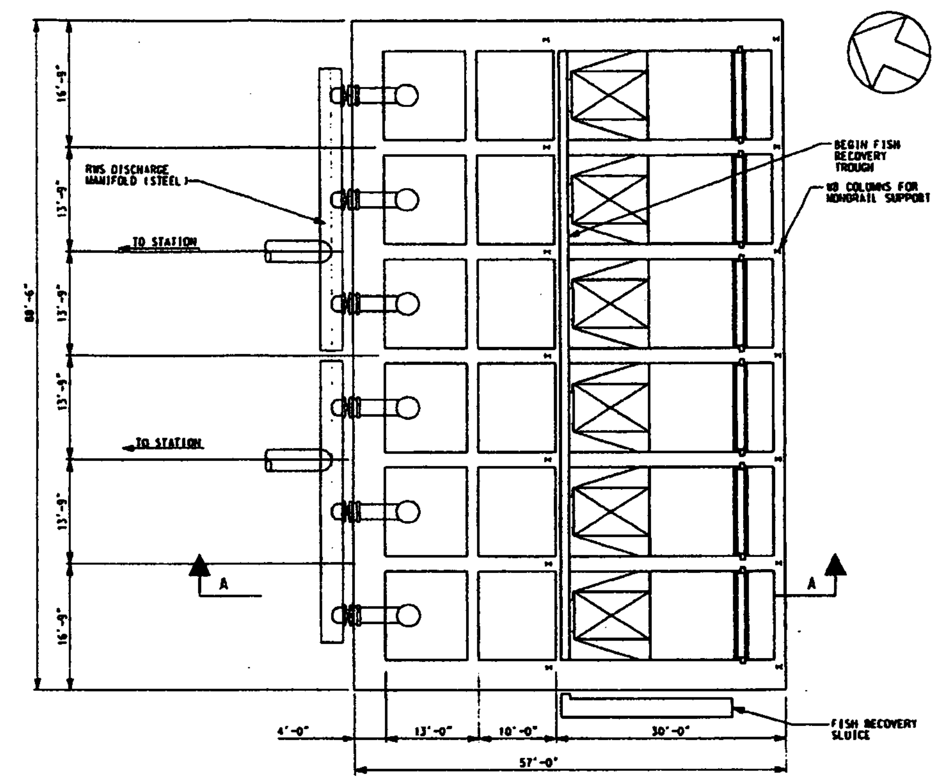

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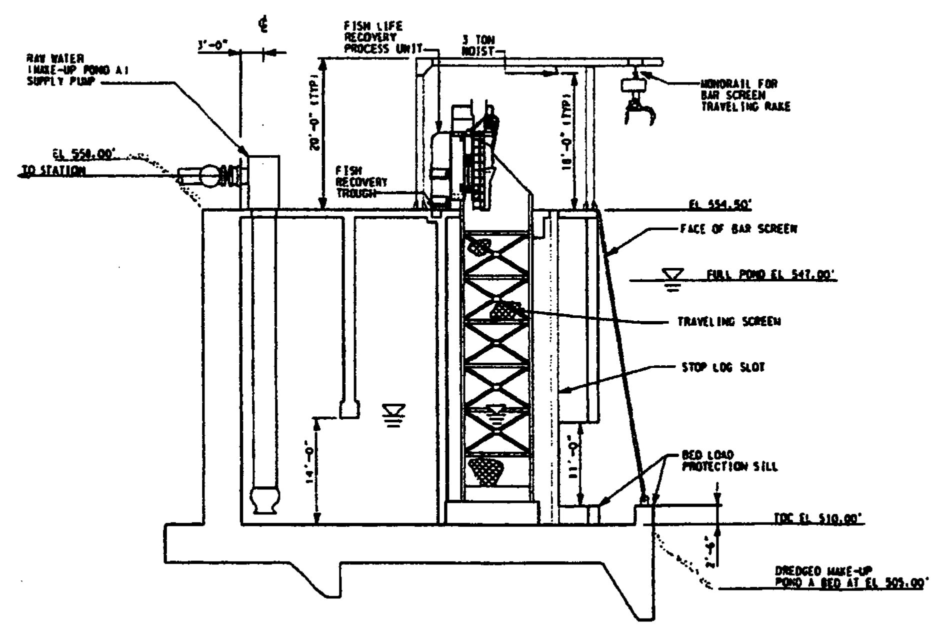

SECTION A-A
PUMP AND PIPE OUTLINE ARE NOT TO SCALE

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 AND 2

Pond A Intake Structure
Sheet 2 of 2
Figure A-18 Rev 1

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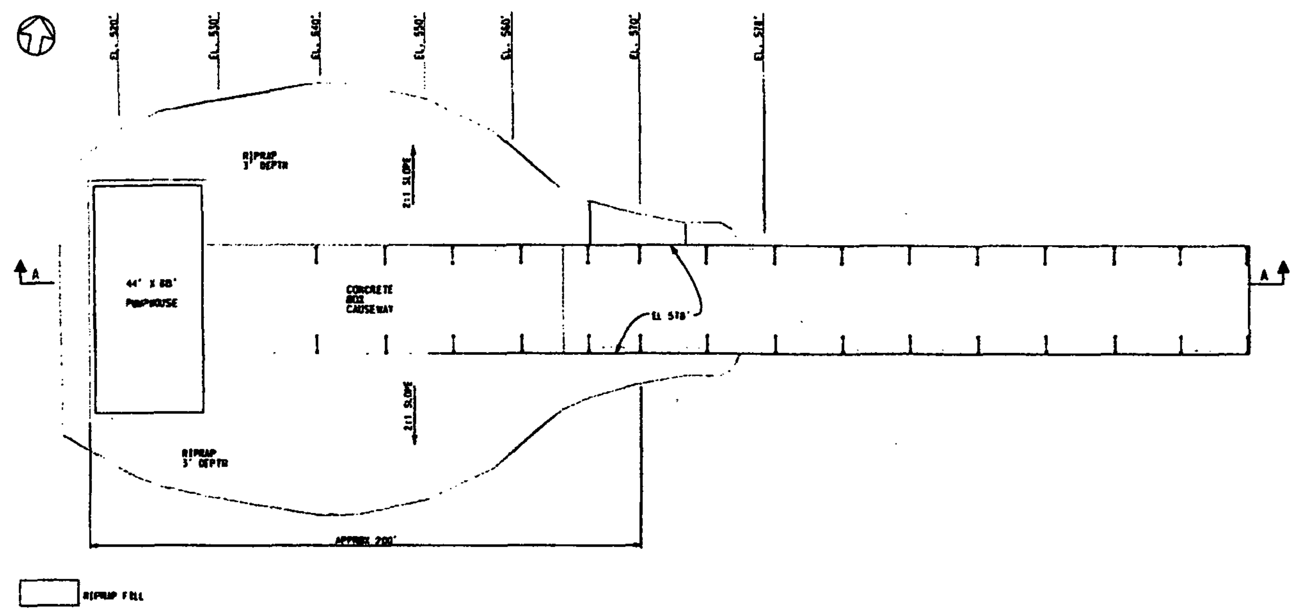
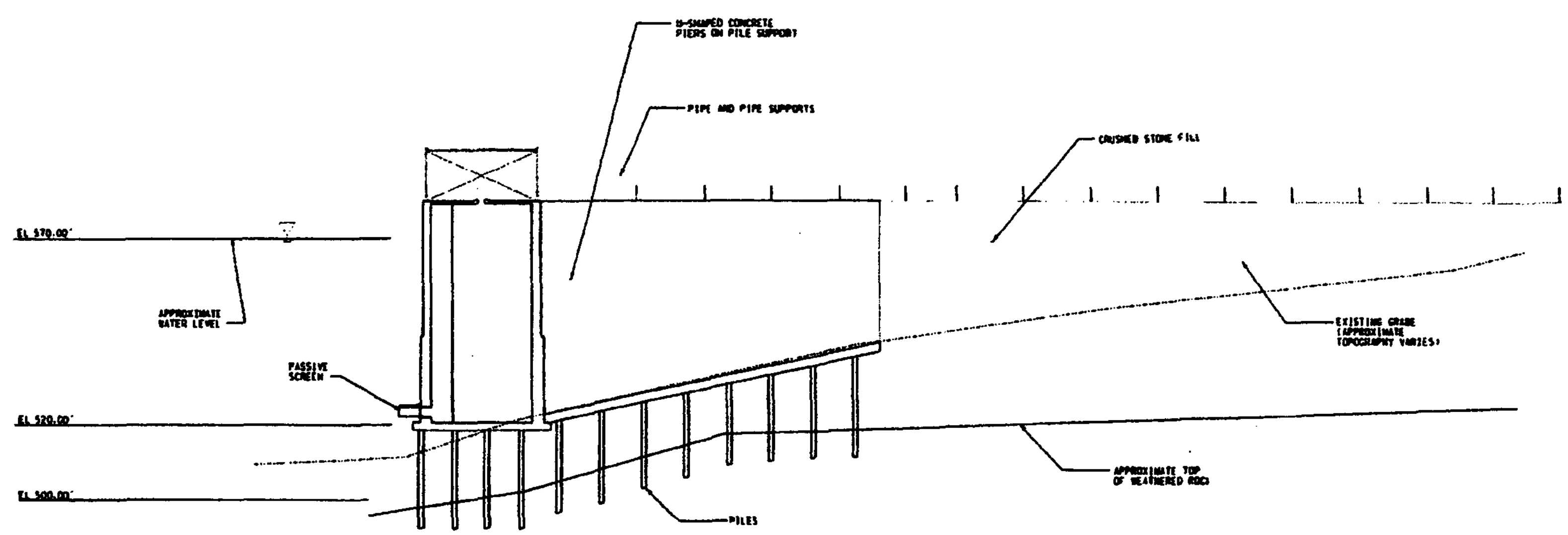


MAKE-UP POND B INTAKE STRUCTURE PLAN
PUMP AND PIPE OUTLINE ARE NOT TO SCALE



MAKE-UP POND B INTAKE STRUCTURE SECTION A-A
PUMP AND PIPE OUTLINE ARE NOT TO SCALE

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 AND 2

Pond B Intake Structure
Sheet 2 of 3
Figure A-20 Rev 1

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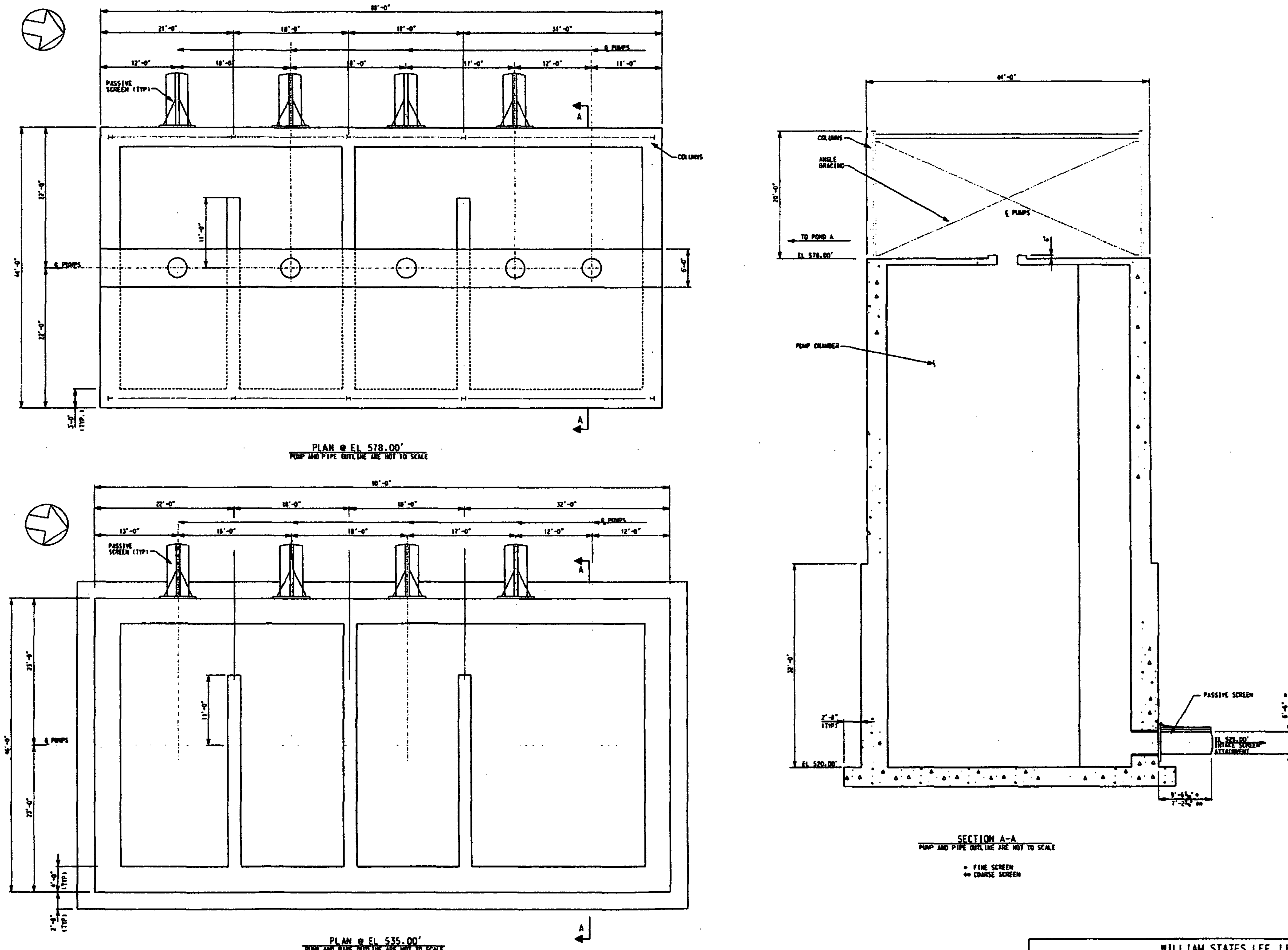

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 AND 2

Pond B Intake Structure
Sheet 3 of 3

Figure A-21

Rev 1

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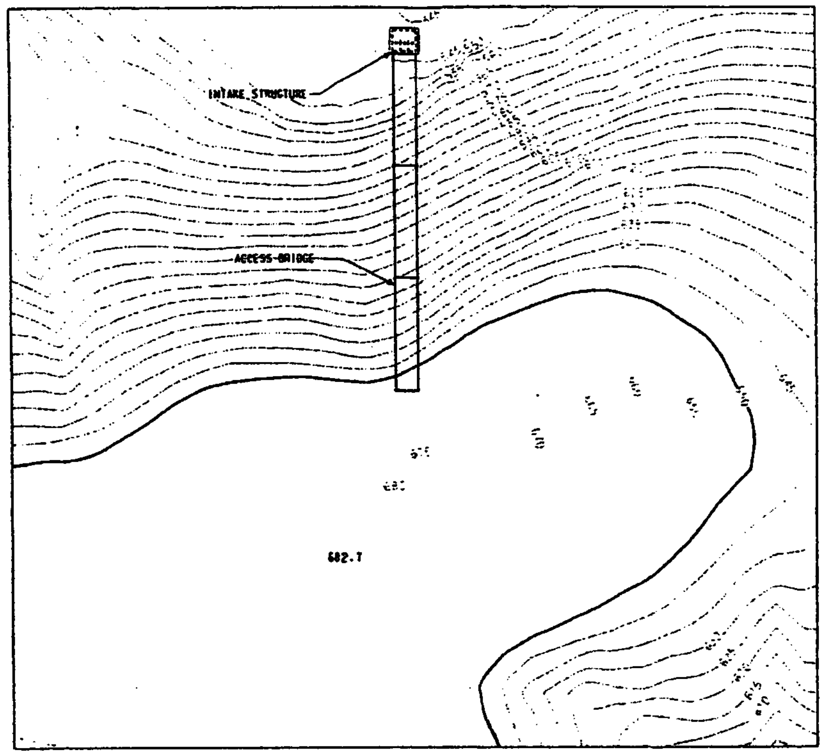
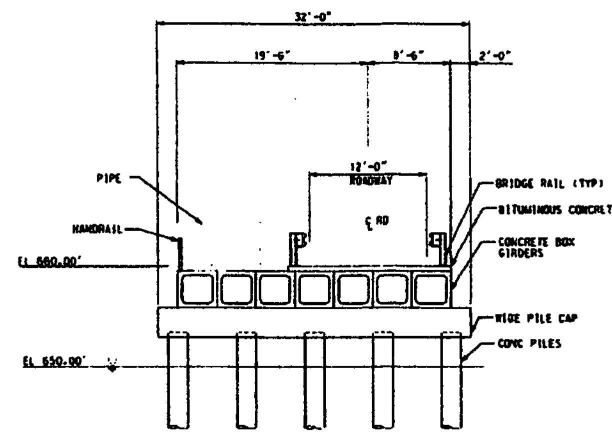
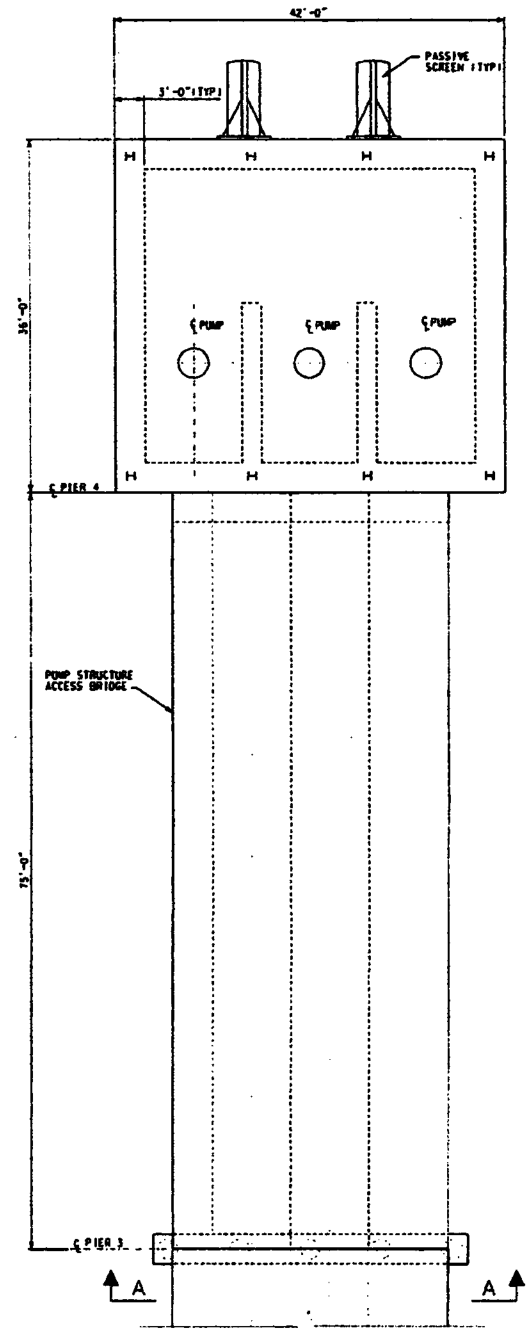


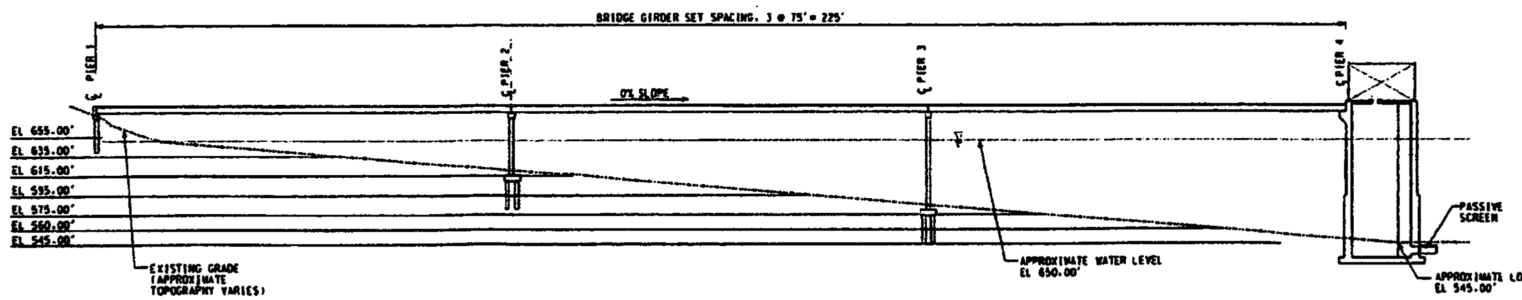
MAKE-UP POND C ACCESS BRIDGE AND INTAKE STRUCTURE LOCATION PLAN
SCALE: 1" = 200'-0"



SECTION A-A @ BRIDGE PIER
SCALE: 1/4" = 1'-0"



INTAKE STRUCTURE PLATFORM PLAN
SCALE: 1/4" = 1'-0"
PUMP AND PIPE OUTLINE ARE NOT TO SCALE



MAKE-UP POND C BRIDGE SECTION
SCALE: 1" = 40'-0"
PUMP AND PIPE OUTLINE ARE NOT TO SCALE

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 AND 2

Pond C Intake Structure
Sheet 1 of 2
Figure A-22

Rev 1

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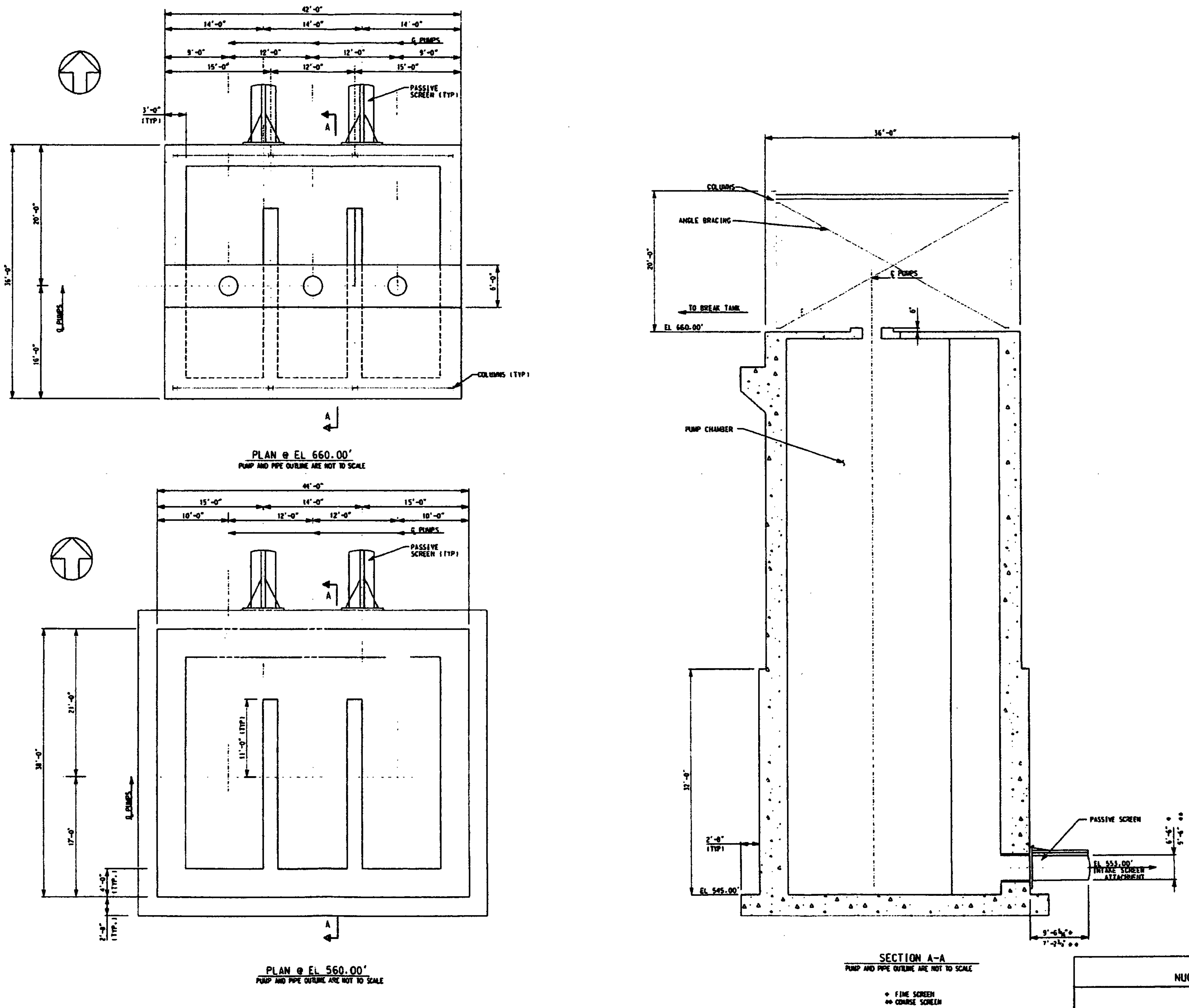

WILLIAM STATES LEE III
NUCLEAR STATION UNITS 1 AND 2

Pond C Intake Structure
Sheet 2 of 2
Figure A-23 Rev 1

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ATTACHMENT 5

RESPONSE TO COMMENTS # 22 AND 23

Appendix B

Hydraulic Zone of Influence

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Duke Energy®

Prepared for

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

COOLING WATER INTAKE STRUCTURES HYDRAULIC ZONE OF INFLUENCE WILLIAM STATES LEE III NUCLEAR STATION CHEROKEE COUNTY, SOUTH CAROLINA

Prepared by

Geosyntec consultants

engineers | scientists | innovators

&

MMI

engineers • scientists • innovators

Project Number GK4270

December 16, 2011

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ATTACHMENTS

1. INTRODUCTION

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 Reservoir covers about 430 acres and has a total storage capacity of about 2,300 acre-feet (ac-ft) [Reference 1; Chapter 2]. Ninety-Nine Islands 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 reservoir. The two backwater regions exhibit very little circulation during non-flood periods. Therefore, the average transit time is conservatively estimated from the volume of 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].

The cooling water intake structure on the Broad River (river intake) will be located within the Federal Energy Regulatory Commission (FERC) project boundary for the Ninety-Nine Islands Reservoir. The river intake will have two sections: the primary intake, and the drought contingency intake. At this point, the width of the river is 240 ft. [Reference 1; Chapter 2].

As a 2,200 megawatt facility, Lee Nuclear Station will require approximately 78 cubic feet per second (cfs) or 35,030 gallons per minute (gpm) of cooling water withdrawal from the Broad River for station operations. Approximately 71 percent (55 cfs or 24,800 gpm) of the withdrawal will be consumptive due to evaporative and drift losses from the cooling towers, with 5 cfs (2,000 gpm) returned to the river as screen wash water and about 18 cfs (8,200 gpm) returned to the river as cooling tower blowdown and smaller process-related waste streams.

The design and capacity of cooling water intake structures are regulated under the National Pollutant Discharge Elimination System (NPDES) permitting program. The South Carolina Department of Health and Environmental Control (SCDHEC) administers this program under delegated authority from the U.S. Environmental Protection Agency (EPA). EPA has promulgated rules pursuant to Clean Water Act Section (§) 316(b) that requires new facilities with cooling water intake structures to apply "Best Technology Available" (BTA) to reduce "adverse environmental impact"

associated with entrainment and impingement of fish and shellfish. SCDHEC has adopted EPA's regulations.

The §316(b) regulations at §122.21(r)(2) specify the submittal of "Source Water Physical Data" upon application for an NPDES permit for new facilities with regulated cooling water intake structures. Among other data, the applicant is required to identify and characterize the source waterbody's hydrological and geomorphologic features, "*as well as the methods you used to conduct any physical studies to determine your intake's area of influence within the waterbody and the results of such studies*".

In addition to the river intake, Lee Nuclear Station will require additional intake structures on other ponds, one sedimentation pond (Pond A) and two drought contingency ponds (Pond B and the proposed Pond C).

Geosyntec was contracted by Duke Energy to conduct the necessary calculations/modeling to determine the hydraulic zone of influence (HZI) for the Lee Nuclear Station intake structures to support the NPDES permit application for this new facility. To accomplish this task, Geosyntec employed Computational Fluid Dynamics (CFD) modeling to simulate the flows induced by the intakes, with the results from these simulations providing the basis for the HZI determination.

2. COOLING WATER OPERATION AND MODELING SCENARIOS

The modeled scenarios approximate normal and worst-case operating conditions of the intakes in order to provide a conservative assessment of the HZI. Under normal operating conditions, 35,030 gpm (78 cfs) will be withdrawn from the Broad River via the primary section of the river intake: 33,030 gpm (73 cfs) as plant make-up water and 2,000 gpm (5 cfs) as screen wash water returned to the Broad River at the intake (maximum withdrawal approximately 43,960 gpm (98 cfs)) [Reference 1; Chapter 3 – Figure 3.3-1]. This raw water from the primary section will be pumped directly to Pond A, which will be used on a daily basis as a settlement/equalization basin. Under normal operating conditions, Drought Contingency Ponds B and C will not be used. However, during low flow conditions on the Broad River, consumptive water will be supplied by Ponds B and/or C rather than the Broad River. When supported by higher flows in the Broad River, water may be pumped for Lee Nuclear Station operations via the primary section of the intake (two pumps (20,980 gpm (46.8 cfs) each) and screen wash (2,000 gpm (4.5 cfs)), at a total rate of approximately 43,960 gpm (98 cfs). The drought

contingency section will have four additional refill and screen wash pumps, with a total rate of approximately 92,500 gpm (206 cfs) [Reference 2 and 3]. After periods of extreme drought, when the flows in the Broad River return to normal, Duke Energy will operate both the primary and drought contingency sections of the river in order to meet the operating requirements of Lee Nuclear Station while at the same time refilling the drought contingency ponds.

2.1 Intake Structure Specifications

In addition to the Environmental Report (Rev. 1) associated with the Duke Energy Combined Construction and Operating License Application for the facility [Reference 1], specifications, and maximum and normal operational parameters for each Lee Nuclear Station intake structure, were obtained from the following documents:

- Duke Energy Response to NRC Request for Additional Information (RAI) No.: 190 – "Site Layout and Plant Description" dated 22 July 2010 [Reference 3]
- Duke Energy Response to NRC RAI No.: 210 Supplement – "Ecology – Aquatic" dated 12 November 2010 [Reference 4]
- Shaw Group Response to Duke Energy Request for Information (RFI) No.: WLG-XXER-GF-018 related to NRC RAI No.: 210 dated 30 September 2010 [Reference 5]
- Duke Energy Response to NRC RAI No.: 210 – "Ecology – Aquatic" dated 14 October 2010 [Reference 6]
- Shaw Nuclear Calculation WLG-RWS-M3C-012 Rev. E, *Standard RWS Traveling Screen Calculation*, dated July, 2011 [Reference 11]
- Shaw Nuclear Calculation WLG-RWS-M3C-013 Rev. E, *Standard RWS Passive Screen Calculation*, dated July, 2011 [Reference 12]

River Intake

The river intake will consist of two subsystems: 1) the primary section, and 2) the drought contingency section; both will be fitted with traveling screens.

Primary Section

This section will have four intake bays open to the Broad River aligned parallel to shore and flow. Each bay will be 11 feet (ft) 9 inches (in) wide, by 11 ft high fully submerged at river elevation, 511 ft above mean sea level (msl) (elevation at annual mean flow). There will be one variable-speed pump in each bay, rated at 20,980 gpm (46.8 cfs) each, for a total of four pumps. Two pumps will support Unit 1 and two pumps will support Unit 2; one pump for each Unit will be a back-up pump. Pump arrangement based on designated Unit will be: 1-1-2-2. This section will also have screen wash pumps rated at approximately 2,000 gpm (4.5 cfs).

Drought Contingency Refill Section

This section will also have four intake bays open to the Broad River, aligned parallel to shore and flow. Each bay will be 11 ft 9 in wide, by 11 ft high fully submerged at elevation 511 ft msl. There will be one variable-speed pump in each bay, rated at 22,500 gpm (50 cfs) each, for a total of four pumps. Though total pumping capacity will be 90,000 gpm (200 cfs), normal refill operation will be 45,000 gpm (100 cfs). Pump arrangement based on Unit will be: R1-R1-R2-R2. This section will also have screen wash pumps rated at approximately 2,500 gpm (5.5 cfs).

It is noted that the traveling screens, which are located inside the pump bays, are submerged by 10.1 ft rather than 11 ft. However, this has no impact on the HZI as area of the pump bays through which the river water is initially drawn is the critical area parameter, rather than the area of the traveling screens.

Pond A – Raw Water Supply Intake

Cooling water from the primary intake will be fed into Pond A where the Lee Nuclear Station Raw Water Intake will be located (the river water feed into Pond A is subsequently referred to as the "refill" flow in the pond). This intake structure will be aligned parallel to shore, and will have six intake bays open to the pond that will be

fitted with traveling screens; each bay will be 11 ft 9 in wide by 11 ft high and fully submerged at normal full pond elevation of 547 ft msl. The presence of a sediment seal extending 2 ft 6 in up from the intake bay floor is accounted for in the intake bay dimensions modeled [Reference 4].

There will be one pump in each bay rated at approximately 15,000 gpm (33 cfs) each; for a total of six pumps (two pumps will be back-up), at a maximum capacity of 60,000 gpm (134 cfs). Three pumps will support Unit 1 and three pumps will support Unit 2. Current planned operation calls for each pump to be fixed-speed and operated at full pump capacity with system flow controlled via a flow control return loop. However, the use of variable-speed pumps is under consideration for this intake. Dual-flow vertical traveling screens will be fitted to each intake bay opening. A range of screen mesh sizes; from 0.236 in (6.0 millimeter (mm)) to 0.079 in (2.0 mm) yielding a percent open area of 65.9 percent to 56.3 percent, is being considered by Duke Energy for Pond A [References 5 and 11]. As the smaller mesh size would be expected to produce a larger HZI, the CFD modeling was performed using the conservative 2.0 mm mesh size with an assumed 25 percent blockage due to debris buildup on the screen. Raw Water Intake pump arrangement based on Unit served is: 1-1-1-2-2-2. This subsystem will also have screen wash pumps rated at approximately 2,000 gpm (4.5 cfs).

Similar to the river intake, the traveling screens for the Pond A intake are submerged by 10.1 ft rather than 11ft, but this will not affect the HZI for the same reasons given in the previous section for the river intake.

Drought Contingency Pond B Intake

This intake structure will support five pumps positioned within two pump bays/wet wells [Reference 4]. One wet well will contain three pumps: two main pumps each rated at 10,000 gpm (22 cfs) and one ancillary pump rated at 6,000 gpm (13 cfs). The second wet well will contain two main pumps rated at 10,000 gpm (22 cfs) each. One 10,000 gpm pump will be a back-up pump. The ancillary pump will deliver water from Pond B to Pond C and will not be operated concurrent with the primary 10,000 gpm pumps. Normal summer operation will consist of three pumps delivering an effective flow rate of 30,000 gpm (67 cfs).

Pond B intake structure will be configured with four passive wedge-wire drum-type screens with each screen designed to handle the capacity of one 10,000 gpm (22 cfs)

pump. A range of wedge-wire screen diameters and lengths, and screen slot sizes are being considered for Pond B. Screens will be 5 ft to 5.83 ft in diameter and 6.44 ft to 8.13 ft in length, extending out into the pond parallel with the intake pump structure causeway. The screens will be separated by a distance of 17 ft to 18 ft. The wedge-wire screens will have 0.394 in (10 mm) to 0.079 in (2 mm) slot openings yielding a percent open area of 71.36 percent to 45.85 percent, respectively [References 5, 6 and 12]. Expected to produce a larger HZI, the CFD modeling was performed using the conservative 2.0 mm slot size with an assumed 25 percent blockage due to debris buildup on the screen. As dictated by the smaller slot size, the greater screen diameter (5.83 ft) and length (8.13 ft) were also input to the model accordingly.

Elevation of the centerline of the cylindrical wedge wire drum-screen will be: 528 ft msl.

Drought Contingency Pond C Intake

This intake structure will support three pumps rated at 10,000 gpm (22 cfs) each; all configured in one common pump bay/wet well. These pumps will deliver water from Pond C to Pond B. Normal summer operation will consist of all three pumps delivering an effective flow rate of 30,000 gpm (67 cfs). The Pond C intake will also use wedge-wire drum-screens. In this case, two wedge wire drum-type screens will be fitted to the single wet well. Screens will be 5 ft to 5.83 ft in diameter and 6.44 ft to 8.13 ft in length, extending out into the pond parallel with the intake pump structure causeway. The screens will be separated by a distance of 14 ft. The wedge wire screens have 0.394 in (10 mm) to 0.079 in (2 mm) slot openings, yielding a percent open area of 71.36 percent to 45.85 percent, respectively [References 5, 6 and 12]. As the wedge-wire screen and slot size specifications for Pond C are the same as for Pond B, the CFD model inputs used were the same.

Elevation of the centerline of the cylindrical wedge wire drum-screen will be: 553 ft msl.

Subsequent to the models being run, the wedge-wire screens for Ponds B and C were increased in size from 5-5.83 ft to 5.5-6.5 ft diameter, and the length was increased from 6.44-8.13 ft to 7.23-9.52 ft. These slight changes to the dimensions of the screens will have a negligible effect on the size of the HZI.

2.2 Intake Pumping Scenarios Modeled

Considering the above intake specifications and possible operating regimes, the following scenarios were selected for the conservative determination of respective hydraulic zones of influence using CFD modeling techniques:

- For the **River Intake**, three pumping scenarios were evaluated:

  1. Withdrawal of approximately 43,960 gpm (98 cfs)[1] via the primary section to support normal operations under the Broad River mean annual flow conditions[2] (1,956 cfs at 511 ft msl reservoir/river surface elevation) [Reference 7]. Two adjacent pumps were selected for the HZI determination under this scenario: 1-**1**-**2**-2.

  2. Withdrawal of 35,030 gpm (78 cfs) via the primary section to support normal operations prior to invoking the low flow protocol using the drought contingency ponds (river flow set to 538 cfs, accounting for both the FERC minimum release[3] of 483 cfs and the 55 cfs consumptive withdrawal). Additionally, the Ninety-Nine Islands impoundment elevation is set to 2 ft below normal pool elevation of 511 ft msl in accordance with the conditions of the FERC license. Two adjacent pumps were selected for the HZI determination under this scenario: 1-**1**-**2**-2.

  3. Maximum withdrawal of approximately 92,500 gpm (206 cfs)[4] through the drought contingency section, plus approximately 43,960 gpm (98 cfs)[5] through the primary section under conditions representative of high flows in the Broad River. This high flow condition has been determined by Duke Energy as an average flow of 2,260 cfs, which is a high flow during the refill period for the ponds (July to February) [Reference 2]. The surface elevation is set at 511 ft msl. Primary and drought contingency pumps selected for the

---

[1] Two pumps at 20,980 gpm (47 cfs) each plus screen wash pumpage of 2,000 gpm (5 cfs).

[2] Mean annual flow is based on 2001-2010 in accordance with §316(b) guidance for determining mean annual flow.

[3] The FERC requires a 483 cfs minimum release from the Ninety-Nine Islands Hydroelectric Station as part of the FERC license for the project.

[4] Four pumps at 22,500 gpm (50 cfs) each plus screen wash pumpage of 2,500 gpm (6 cfs).

[5] Two pumps at 20,980 gpm (47 cfs) each plus screen wash pumpage of 2,000 gpm (5 cfs)

HZI determination under this scenario were: **R1-R1-R2-R2** | **1** 1 **2** 2 , operating a River Water Subsystem pump adjacent to the Refill Water Subsystem pumps to maximize the zone of hydraulic influence.

- For the **intake on Pond A**, two pumping scenarios were evaluated:

  1. Operation of four variable-speed pumps plus screen wash (2,000 gpm (5 cfs)) for a total flow rate of 35,030 gpm (78 cfs) at a normal/full pond water level elevation of 547 ft msl (Pond A water level is maintained at a constant elevation). Pumps selected for the HZI determination under this scenario were: 1-**1-1-2-2**-2, operating adjacent pumps for each Unit to maximize the zone of hydraulic influence.

  2. Operation of four fixed-speed pumps at full capacity of 60,000 gpm (134 cfs) plus screen wash of 2,000 cfs for total flow rate of 62,000 gpm (139 cfs) with 26,970 gpm (61 cfs) plus screen wash returned to the pond. The four pumps selected for the HZI determination under this scenario were: **1-1-1-2-**2-2.

- For the intake structure on **Pond B**, one pumping scenario was evaluated:

  1. Normal operation of three pumps at a combined flow rate of 30,000 gpm (67 cfs) at the maximum estimated drawdown elevation of 540 ft msl (30 ft below full pond elevation). The maximum drawdown elevation during severe drought conditions was used, as the reduced volume will result in a conservative value for the HZI. Based on configuration of the wedge wire drum screens, it was conservatively assumed that a single pump will pump water through the open area of one screen. [Reference 4].

- For the intake structure on **Pond C**, two pumping scenarios were evaluated:

  1. Normal operation of all three pumps at a combined flow rate of 30,000 gpm (67 cfs) at the maximum estimated drawdown elevation of 620 ft msl (30 ft below full pond elevation). Pumps selected for the HZI determination under this scenario were: **1-2-3**. Based on configuration of the wedge wire drum screens, it was assumed that all three pumps will pump water through the open area of two screens [Reference 4].

2. Normal operation of all three pumps at a combined flow rate of 30,000 gpm (67 cfs) at the maximum estimated drawdown elevation of 605 ft msl (45 ft below full pond elevation). The maximum drawdown elevation during severe drought conditions was used for the same reason given for Pond B. Pumps selected for the HZI determination under this scenario were: **1-2-3**. Based on configuration of the wedge wire drum screens, it was assumed that all three pumps will pump water through the open area of two screens [Reference 4].

3. MODELING METHODOLOGY

Computational Fluid Dynamics modeling was applied to the above scenarios. The use of CFD is appropriate as the flows in the river and ponds are complex and cannot be modeled as accurately using simpler techniques which, by necessity, make broad assumptions regarding the nature of the flow (e.g., velocity profiles). By contrast, CFD solves the fundamental fluid flow equations (Navier-Stokes equations) with no assumptions regarding flow profiles or other broad generalizations.

3.1 Generation of the Computational Model

To model the intake flows in the river and ponds, a three-dimensional geometry was defined based on elevation data from various sources [References: 3, 4, 5, 6, 8, 9, 10, 11, and 12]. For the river simulations, a large section of the Broad River was modeled, including the section containing the river intake. On the upstream face of the modeled river section, the appropriate flow rate was input for each Scenario of interest. The upstream section of the model allowed the flows in the river to develop realistic, complex profiles in the vicinity of the river intake. The river intake design and location were based on information and drawings in References 3 and 8, with the primary and drought contingency section pump bays represented as rectangular faces on the intake structure. Figures 1 and 2 show the modeled section of Broad River and the intake structure in the CFD model. For the pond models, a similar approach was taken to the generation of the geometry and mesh.

Further technical details regarding the CFD model are given in Attachment B.1.

3.2 Definition of the Hydraulic Zone of Influence

The §316(b) regulations at §125.82 define the HZI broadly as: "*that portion of the source waterbody hydraulically affected by the cooling water intake structure withdrawal of water.*" A more quantitative definition is not provided. Due to the physical differences between the flows in the river and the ponds, separate definitions of the HZI were used in each case evaluated. For the river scenarios, a location was included in the HZI if the flow vector at that location pointed directly towards the intake structure – in other words, if a particle were to follow the direction of the flow at that point, and did not change direction, then it would be drawn toward the intakes. For the pond scenarios, this definition was not practical, as the flow vector may well point towards the intake structure, but the flow velocity at that point may be so low that it is impractical to consider it within the HZI. As such, a location was included in the HZI for the pond intakes if the velocity at that point was greater than 0.1 foot per second (ft/s), irrespective of the flow vector.

4. RESULTS & DISCUSSION

The results from the CFD modeling are discussed below. An overview of the results for the dimensions of the HZI for each scenario is provided in Section 5.

4.1 River Scenarios

Figure 3 shows velocity contours on the river surface for **River Scenario 1** (mean annual flow and approximately 43,960 gpm [98 cfs] through the primary section) for the modeled section of the Broad River. The variation in velocity is due to the three-dimensional nature of the model, which reflects the effect of bends and undulating river bed (see Figure 1) on velocity. Figure 4 provides river flow direction (vector ►) and velocities (vector color) for ambient river conditions near the river intake without any pumping activity. Ambient flows show considerable variation in both velocity and direction, and large recirculation regions are shown by the velocity vectors (Figure 4). Notably, ambient river flows unaffected by the primary section withdrawal naturally exceed 0.5 ft/s.

It can be seen from Figure 5 that although approximately 43,960 gpm (98 cfs) is removed from the river at the primary section intake pump bays, the flow vectors in general remain aligned with the river flow direction. The streamlines on Figure 6 show

that, the flow directed into the primary section intake bays is in fact from the southern edge of the river, and the angle of the flow does not turn perpendicular to the pump bays but is more aligned with the river flow direction. As such, the HZI as defined in Section 3.2 is relatively small, and does not protrude far into the river. A visualization of the HZI for Scenario 1 is shown on Figure 7. The volume of the HZI under these flow conditions is 0.129 ac-ft and it extends into the Broad River a maximum of 9.2 ft perpendicular to the intake structure.

The velocity vectors for **River Scenario 2** (538 cfs flow and 35,030 gpm [78 cfs] through the primary section) are shown on Figure 8, with the blue coloration indicative of the lower velocities (< 0.5 ft/s) associated with the low flow condition. For comparison, the velocity vectors without pumping (ambient conditions only) are shown on Figure 9. Figure 10 shows the HZI, and as expected it is slightly larger than the previous case due to the lower river flow rate – the HZI volume is 0.200 ac-ft and it extends 14.4 ft into the Broad River from the cooling water intake structure.

The final scenario (**River Scenario 3**) considered for the river intake is the high river flow condition of 2,260 cfs and total withdrawal capacity of 136,460 gpm through the primary and drought contingency sections (approximately 43,960 gpm (98 cfs) through the primary section and 92,500 gpm (206 cfs) through the drought contingency section). Similar to the mean annual flow model (River Scenario 1), ambient river flows unaffected by the river intake withdrawal naturally exceed 0.5 ft/s under conditions of high river flow.

The velocity vectors on the river surface near to the river intake for this case are shown on Figure 11 (compare to Figure 12 which shows the vectors with the pumps off), while the HZI can be seen on Figure 13. Notice that the HZI is much larger than the previous two scenarios, as the drought contingency section of the river intake contributes to the HZI, whereas for the previous two scenarios it did not. The HZI volume in this case is 0.316 ac-ft while extending into the Broad River is 15.4 ft.

4.2 Pond Scenarios

The computational model for the two **Pond A** scenarios [(1) withdrawal of 35,030 gpm (78 cfs) and (2) withdrawal of 62,000 gpm (139 cfs) with 26,970 gpm (61 cfs) returned to the pond] is shown on Figures 14-19. The model assumes the future removal of the temporary cofferdam that is indicated by the current bathymetry data. The intake

structure is shown, as is the location of the refill inlet from the river intake subsystem on the Broad River into Pond A. A closer view of the intake structure is shown on Figure 15. A contour plot of velocity magnitude for the flows for **Scenario 1** in Pond A is shown on Figure 16 with the contours "clipped" to 0.1 ft/s (i.e., the red areas show velocities at, or greater than, 0.1 ft/s). This scale (velocity greater or equal to 0.1 ft/s) was used as the definition of the HZI for the pond simulations. Although it appears that the flow through Pond A is very large, in fact the flows are almost entirely induced by the refill flow from the primary section intake to Pond A and, *not* caused by the withdrawal of water via intake for Pond A. Although there are large areas within Pond A (see Figure 16) where the model predicts velocities greater than 0.1 ft/sec, as shown in Figure 17, the HZI is localized and small; the volume is 0.054 ac-ft and it extends 3.7 ft outward of the intake bays.

For **Pond A-Scenario 2**, four pumps/bays are operational, and the flow rate withdrawn from the pond is increased to 62,000 gpm[6] (139 cfs). The maximum refill flow rate into the pond from the the primary section intake structure remains at 38,400 gpm (86 cfs); and 26,970 gpm (61 cfs) is returned to the Pond A via a flow control return loop from the pond intake structure. This return flow has not been included in the model so that the hydraulic zone of influence of the intake structure can be isolated. Mesh size for the dual-flow vertical traveling screens was set at 2.0 mm with an assumed 25 percent blockage due to debris buildup on the screen. The velocity contours for this scenario are shown on Figure 18, and are similar to those for Scenario 1 as the refill flow (the primary influence on flows in the pond) has not changed. However, as is shown on Figure 19, the HZI of the Pond A intake structure is greater due to the increase in the withdrawal flow rate, with a volume of 0.150 ac-ft, extending outward 9.2 ft into the pond.

Figure 20 shows the computational model for **Pond B**, while the intake structure is shown on Figure 21. The model considers the breaching of the temporary cofferdam indicated by the bathymetry data [Reference 10]. In this case, the Pond B intake structure is 90 ft wide and has two pump bays [Reference 4]. The intake design for Pond B includes four cylindrical wedge-wire screens, two for each bay [Reference 4] – depicted as yellow areas on Figure 21. Modeling was performed based on a screen diameter of 5.83 ft and length of 8.13 ft. Screen slot size was set at 2.0 mm with an

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[6] Includes 2,000 gpm (5 cfs) screen wash pumpage.

assumed 25 percent blockage due to debris buildup on the screen. The velocity contours on the bottom of the pond (Figure 22) show that velocities greater than 0.1 ft/s (red areas) exist only very close to the intake screens (Figure 23). The total HZI for Pond B (all four screens collectively) is 0.039 ac-ft in volume, and the HZI only extends a distance of 7.2 ft from the intake structure.

The model for **Pond C** is shown on Figure 24. Notice the dam in the upper right section of the figure. The intake structure, shown on Figure 25, is similar to that of Pond B, but in this case, it extends about 180 ft into the pond (at a water surface elevation of 620 ft msl) and is 44 ft wide [Reference 4]. The two intakes to the single pump bay are cylindrical wedge-wire screens of the same dimensions as those for Pond B [Reference 4], and are highlighted yellow in Figure 25. As the wedge-wire screen and slot size specifications for Pond C are the same as for Pond B, the CFD model inputs used were the same. Figure 26 shows that the HZI (red areas on the contour plot) is again very local to the intakes, and is barely discernable on the scale shown on the figure. A close-up view of the intake structure reveals the HZI for the 30 ft drawdown model (red areas in Figure 27); the total volume of the HZI (both wedge-wire screens collectively) is 0.062 ac-ft and it extends 9.2 ft from the intake structure. At the lower water surface elevation of the 45 ft drawdown model, the total volume of the HZI is 0.061 ac-ft and it also extends 9.2 ft from the intake structure. Figure 28 shows that the HZI (red areas on the contour plot) is again very local to the intakes, and is barely discernable on the scale shown on the figure. A close-up view of the intake structure reveals the HZI from the 45 ft drawdown model (red areas in Figure 29). The similarity between the two results, even though the water surface elevation is different, is due to the fact that the HZI in both cases is well below the water surface and the flow is relatively unaffected by changes in surface elevation in the range considered

5. RESULTS SUMMARY

5.1 River Intake Scenarios - Primary and Drought Contingency Sections

	Scenario 1	Scenario 2	Scenario 3
Intake flow	43,960 gpm *Primary Section at normal pumping capacity*	35,030 gpm *Primary Section at normal pumping capacity*	136,460 gpm *43,960 gpm Primary Section plus* *92,500 gpm Drought Contingency Section*
River flow	1,956 cfs *Mean annual flow*	538 cfs *483 cfs FERC flow plus 55 cfs consumptive*	2,260 cfs *High flow during refill period (Sept-Dec)*
Surface Elevation	511 ft msl	509 ft msl	511 ft msl
	Hydraulic Zone of Influence		
- **Volume**	0.129 ac-ft	0.200 ac-ft	0.316 ac-ft
- **Surface area**	0.004 acre	0.013 acre	0.025 acre
- **Extending Distance**	9.2 ft	14.4 ft	15.4 ft

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5.2 Pond Scenarios

	Pond A-Scenario 1	Pond A-Scenario 2	Pond B	Pond C	Pond C
Intake Flow	35,030 gpm *Normal 4-pump capacity* *(variable speed)*	62,000 gpm *Normal 4-pump capacity* *(fixed speed)*	30,000 gpm *Normal 3-pump capacity*	30,000 gpm *Normal 3-pump capacity*	30,000 gpm *Normal 3-pump capacity*
Pond Elevation	547 ft msl *Full Pond*	547 ft msl *Full Pond*	540 ft msl *30 ft drawdown*	620 ft msl *30 ft drawdown*	605 ft msl *45 ft drawdown*
	Hydraulic Zone of Influence				
- **Volume**	0.054 ac-ft	0.150 ac-ft	0.039 ac-ft	0.062 ac-ft	0.061 ac-ft
- **Surface area**	0.004 acre	0.011 acre	0.004 acre	0.005 acre	0.005 acre
- **Extending Distance**	3.7 ft	9.2 ft	7.2 ft	9.2 ft	9.2 ft

6. CONCLUSIONS

A series of CFD simulations were run to support the NPDES application for the Lee Nuclear Station located in Cherokee County, South Carolina. The purpose of the simulations was to determine the hydraulic zone of influence for the cooling water intake structures located on the Broad River and in the ponds under several operational and flow conditions. In all cases the HZI remained localized to the intake structures and did not extend significantly into the Broad River or affect the flows greatly within the ponds. Full details of the HZI dimensions for each scenario considered have been given in the preceding pages.

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7. REFERENCES

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[2] *E-mail correspondence dated February 4, 2010* from T. Bowling (Duke Energy) to T. Cheek (Geosyntec Consultants).

[3] Duke Energy Response to NRC Request for Additional Information (RAI) No.: 190 – "Site Layout and Plant Description" dated 22 July 2010.

[4] Duke Energy Response to NRC RAI No.: 210 Supplement – "Ecology – Aquatic" dated 12 November 2010.

[5] Shaw Group Response to Duke Energy Request for Information (RFI) No.: WLG-XXER-GF-018 related to NRC RAI No.: 210 dated 30 September 2010.

[6] Duke Energy Response to NRC RAI No.: 210 – "Ecology – Aquatic" dated 14 October 2010.

[7] *William S. Lee III Nuclear Station Hydrology Report* prepared by HDR Engineering, Inc. Of The Carolinas, dated July, 2011.

[8] *Conceptual Design Package for RWS*, Report prepared by Shaw Nuclear, Document Ref. 11887902-F-RWS-CDP-0, 2009.

[9] *Site Plan – East Lee Nuclear Station Units 1 & 2*, Drawing Ref. WLG-0000-X2-005 Rev. C, 2009.

[10] *Lee Nuclear Station Reservoirs Bathymetry Report*, Report prepared by Devine Tarbell and Associates for Duke Energy Carolinas LLC, 2007.

[11] Shaw Nuclear, Calculation WLG-RWS-M3C-012 Rev. E, *Standard RWS Traveling Screen Calculation*, dated July, 2011.

[12] Shaw Nuclear, Calculation WLG-RWS-M3C-013 Rev. E, *Standard RWS Passive Screen Calculation*, dated July, 2011.

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FIGURES

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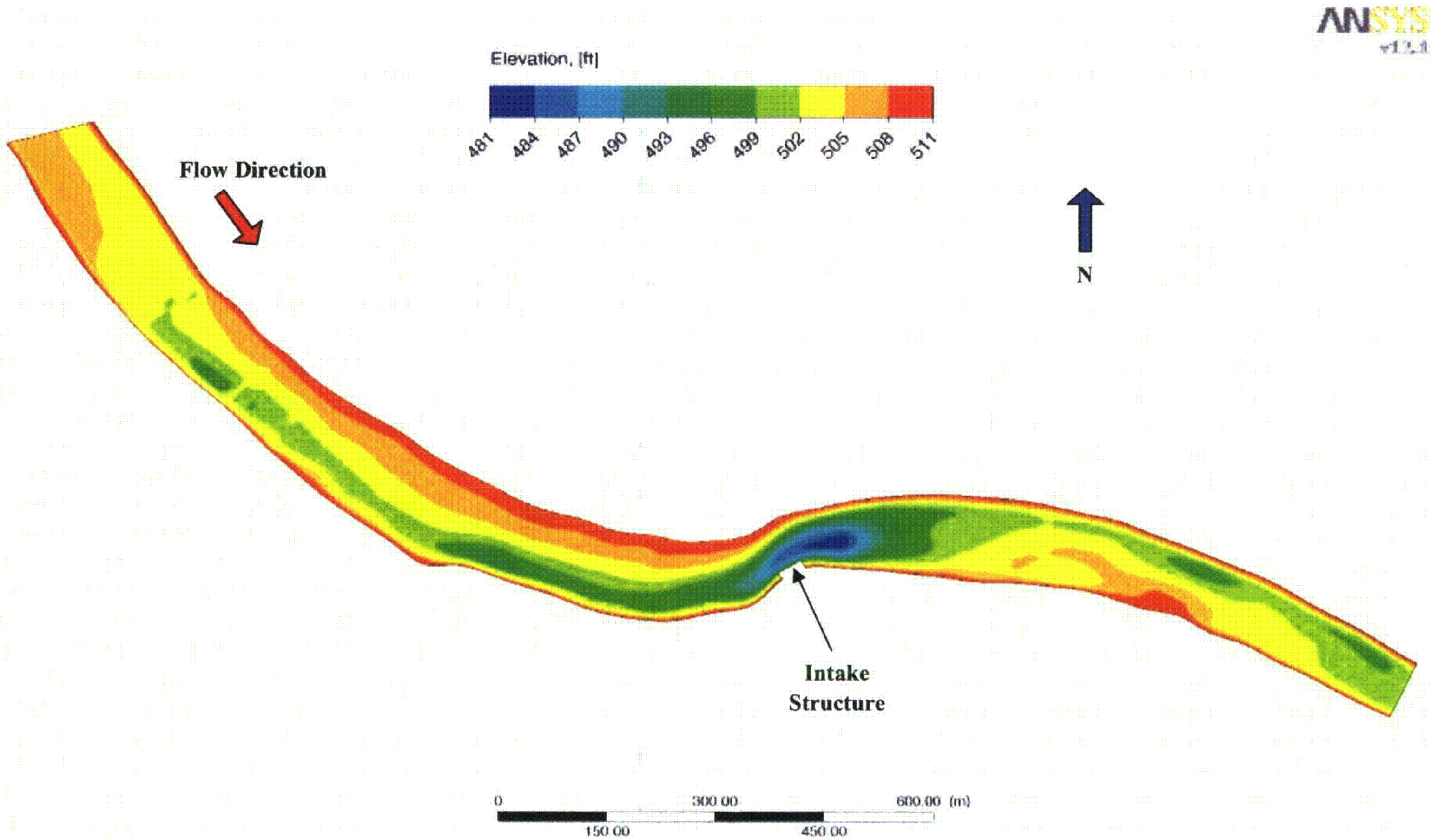

Figure 1 – Plan view of modeled section of the Broad River showing the river intake location

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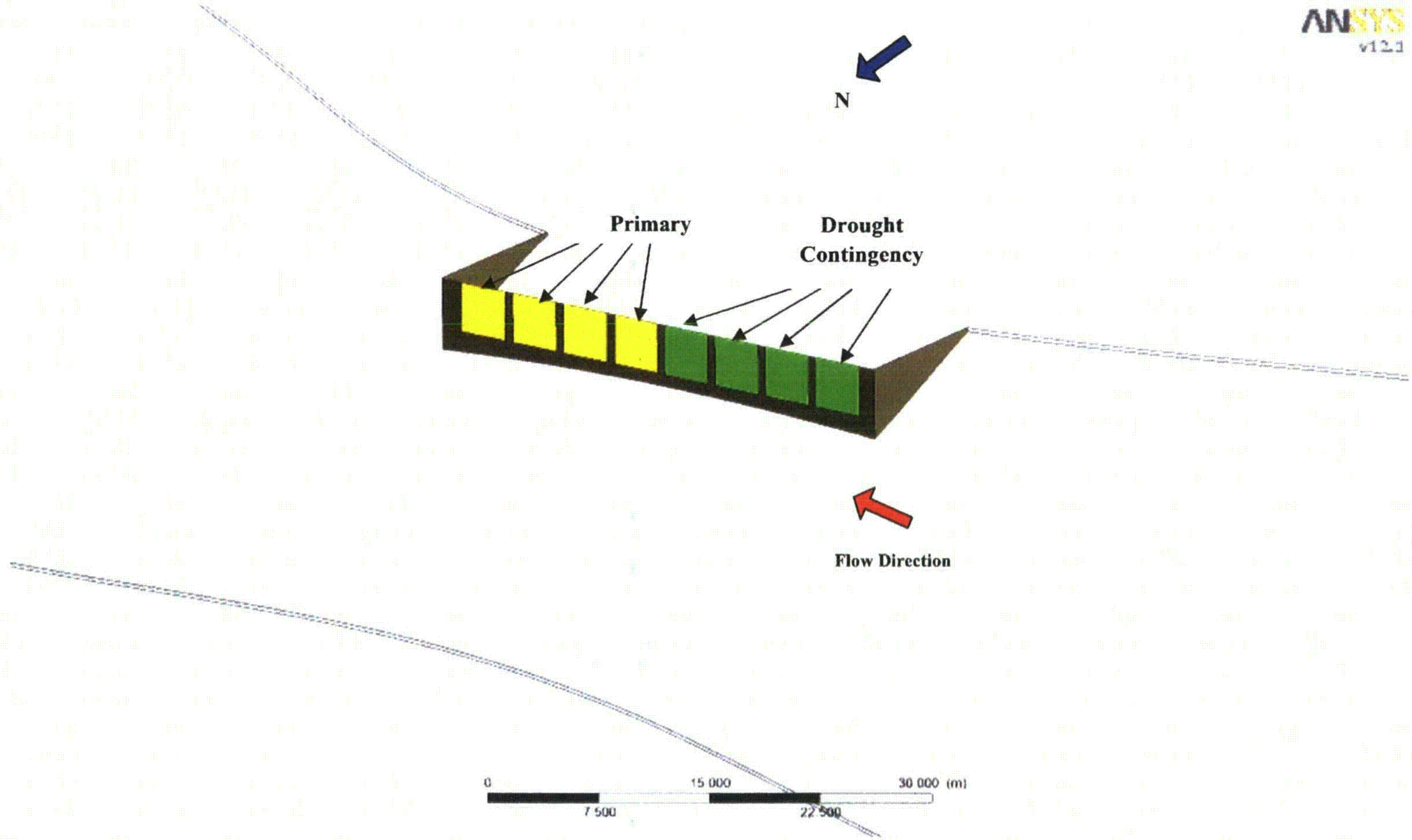

Figure 2 –View of the river intake structure showing four primary (yellow) and four drought contingency (green) intakes.

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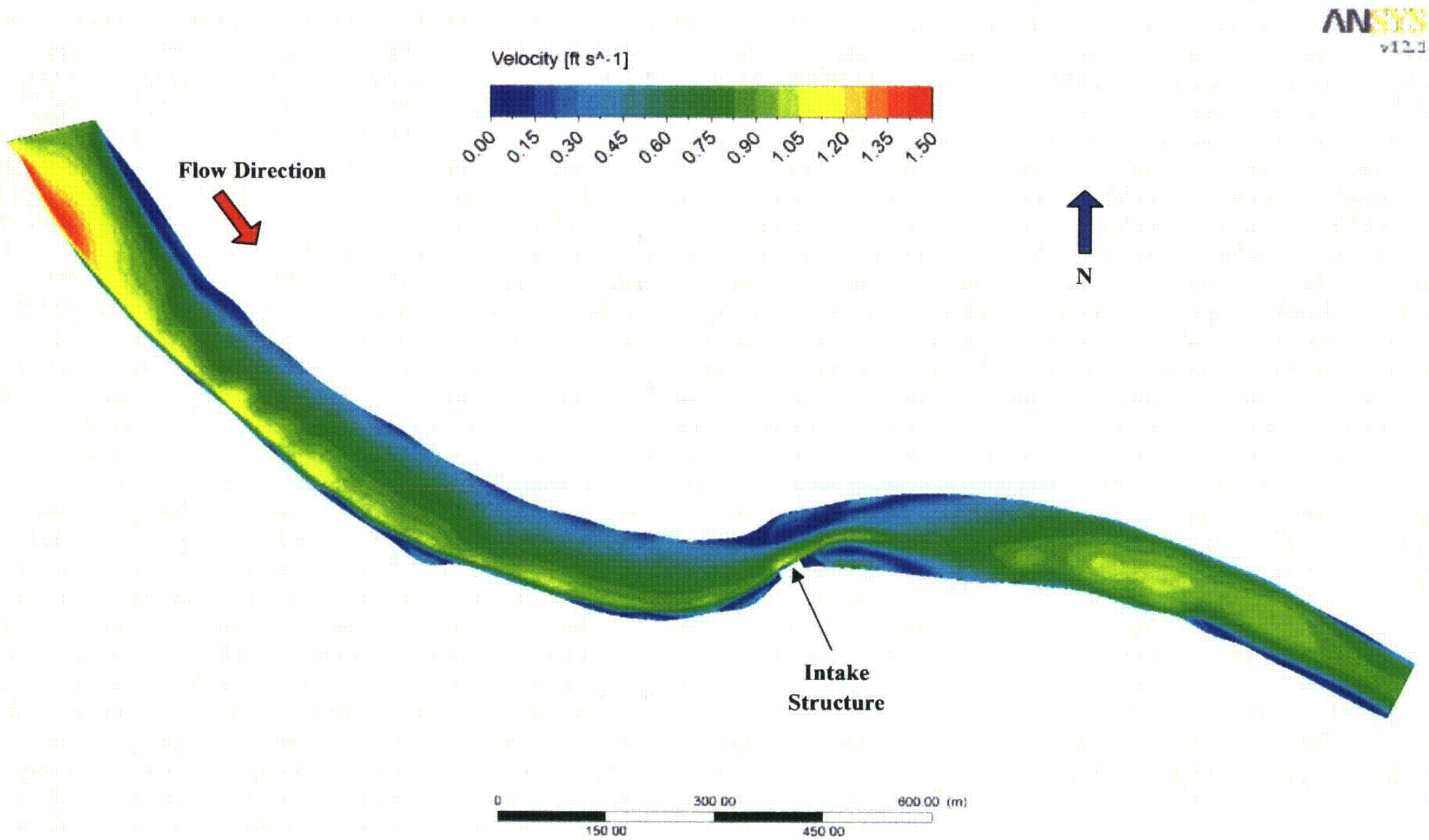

Figure 3 – Contour plot of velocity magnitude, Scenario 1.

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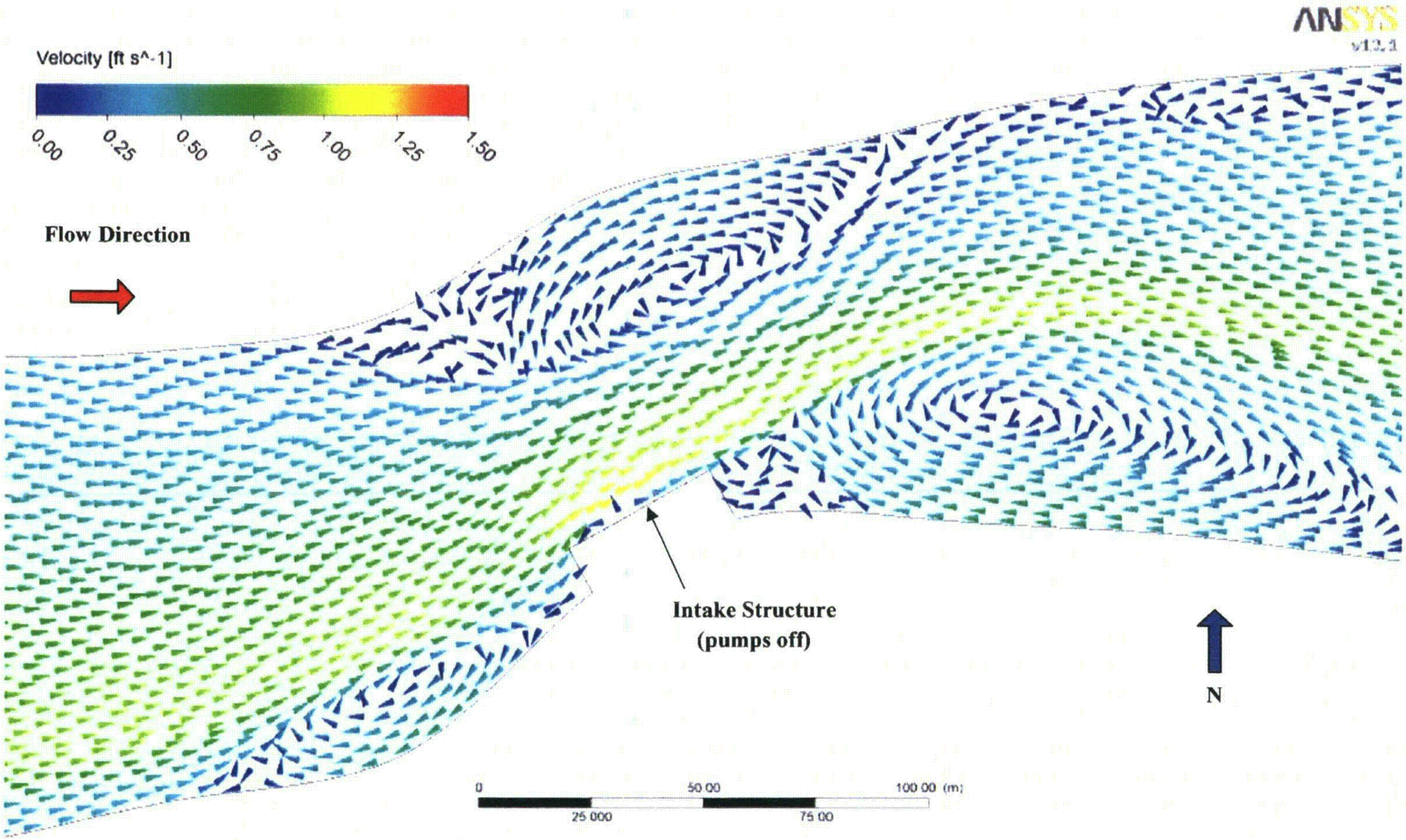

Figure 4 – Velocity vectors near the river intake structure, Scenario 1, pumps off.

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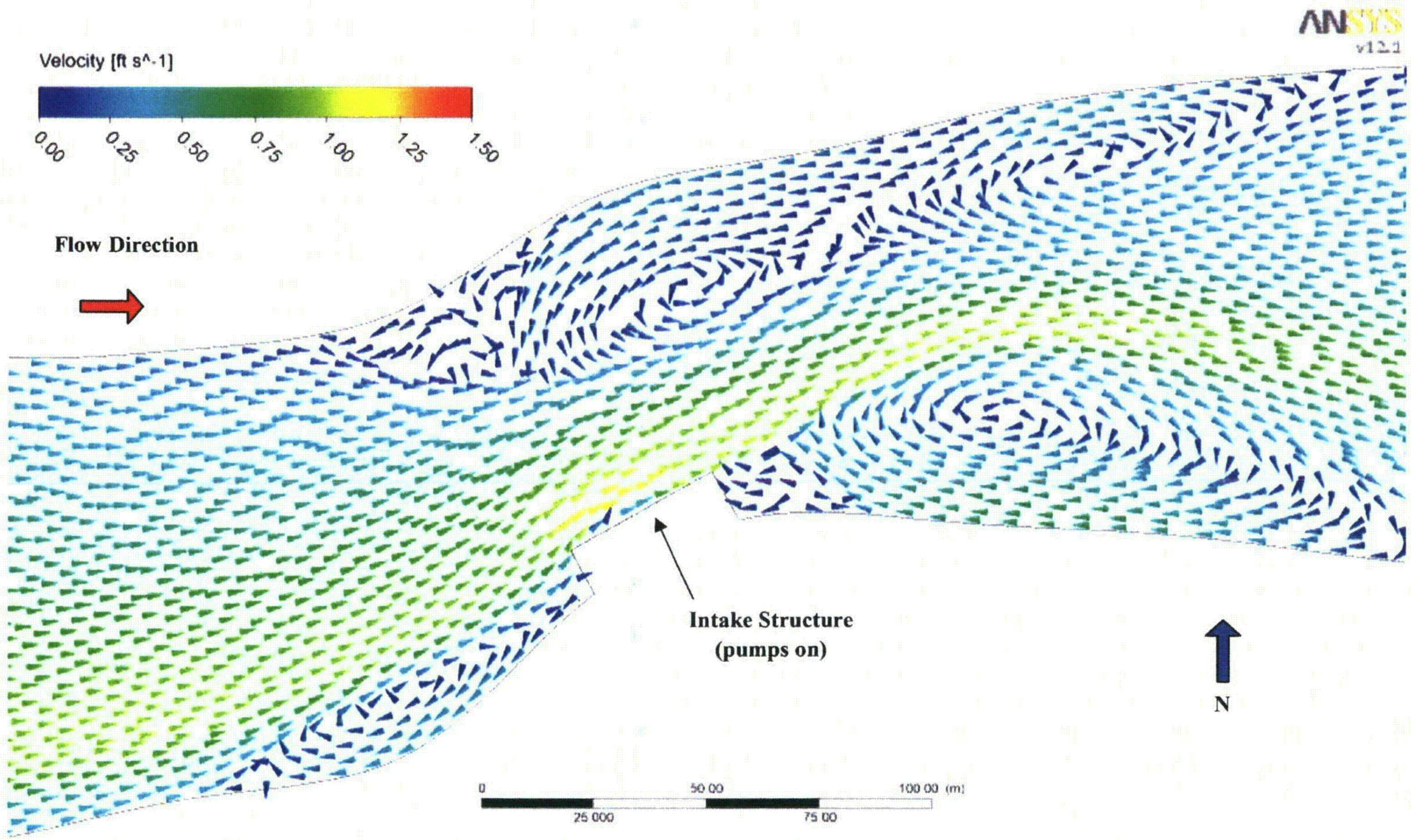

Figure 5 – Velocity vectors near the river intake structure, Scenario 1, pumps on.

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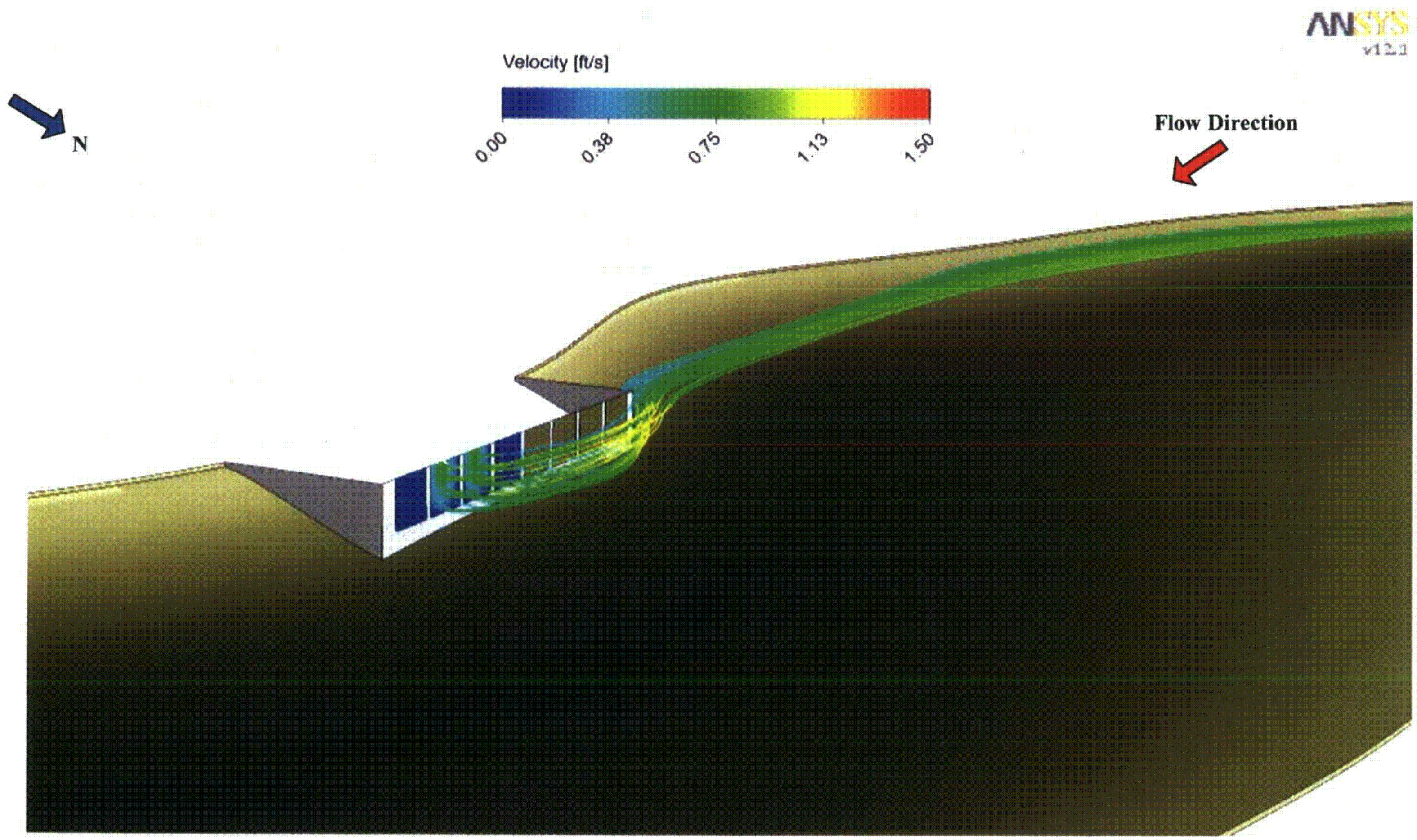

Figure 6 – Streamlines into the primary section intakes, Scenario 1.

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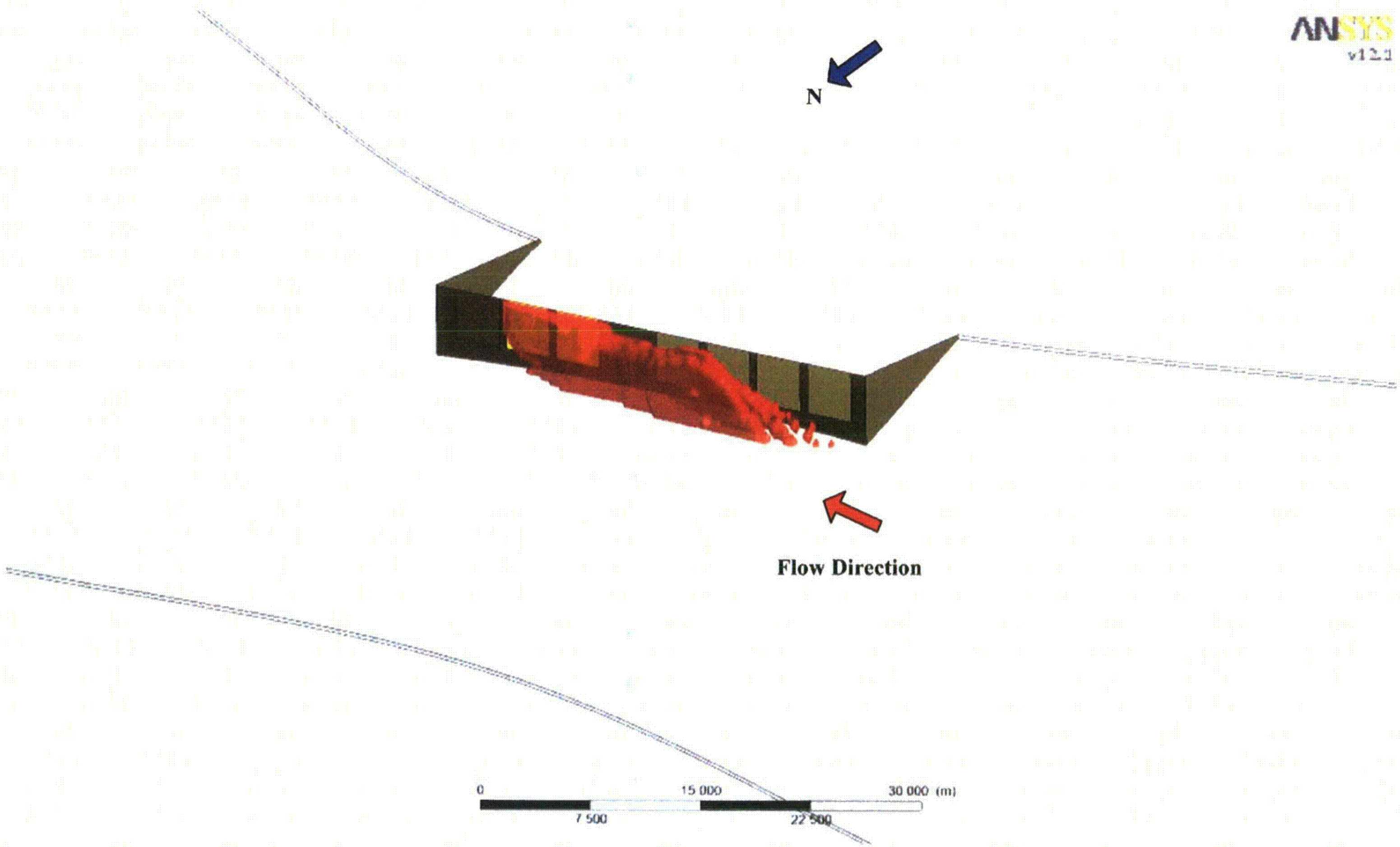

Figure 7 – Hydraulic zone of influence (indicated in red) for Scenario 1.

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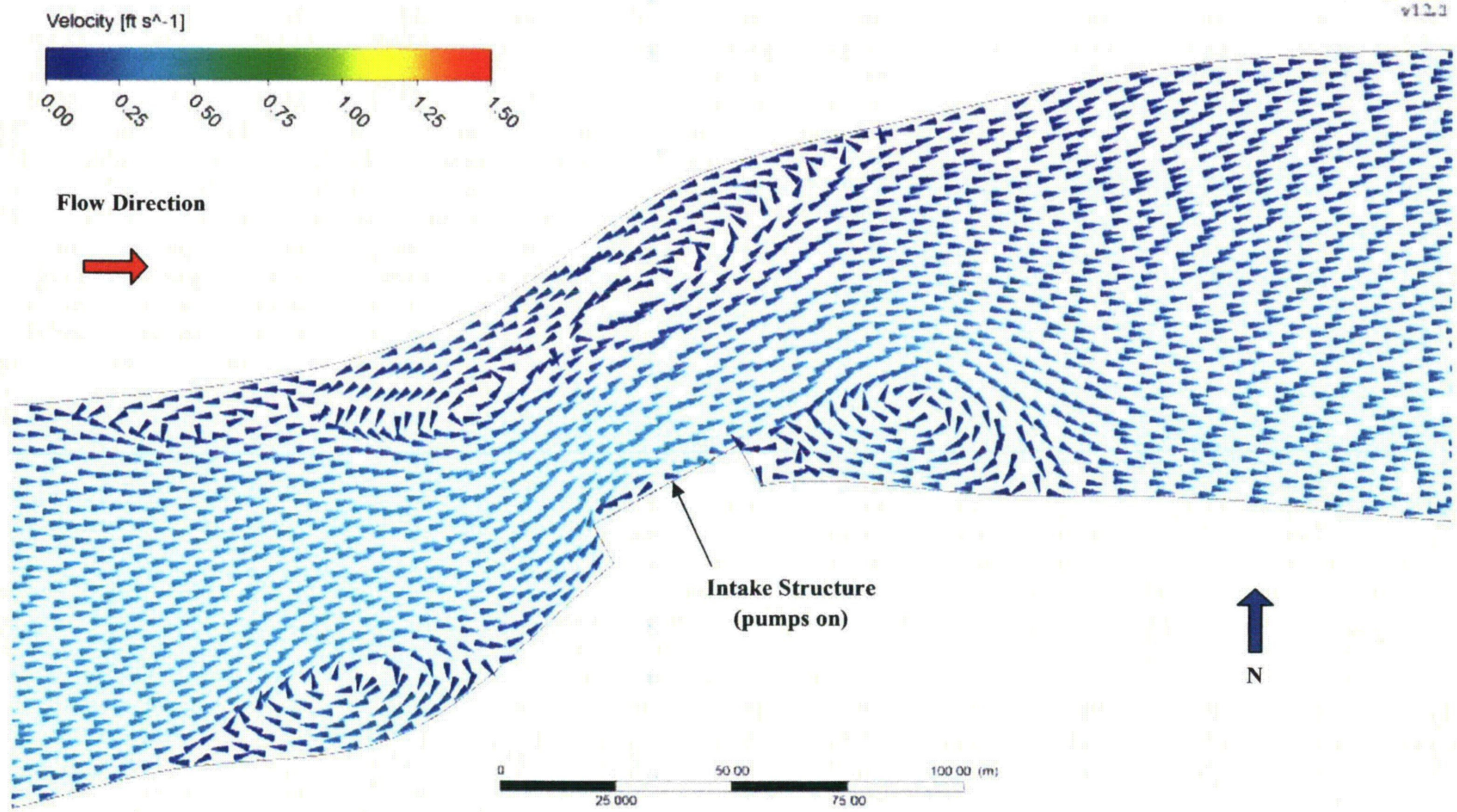

Figure 8 – Velocity vectors near the river intake, Scenario 2, pumps on.

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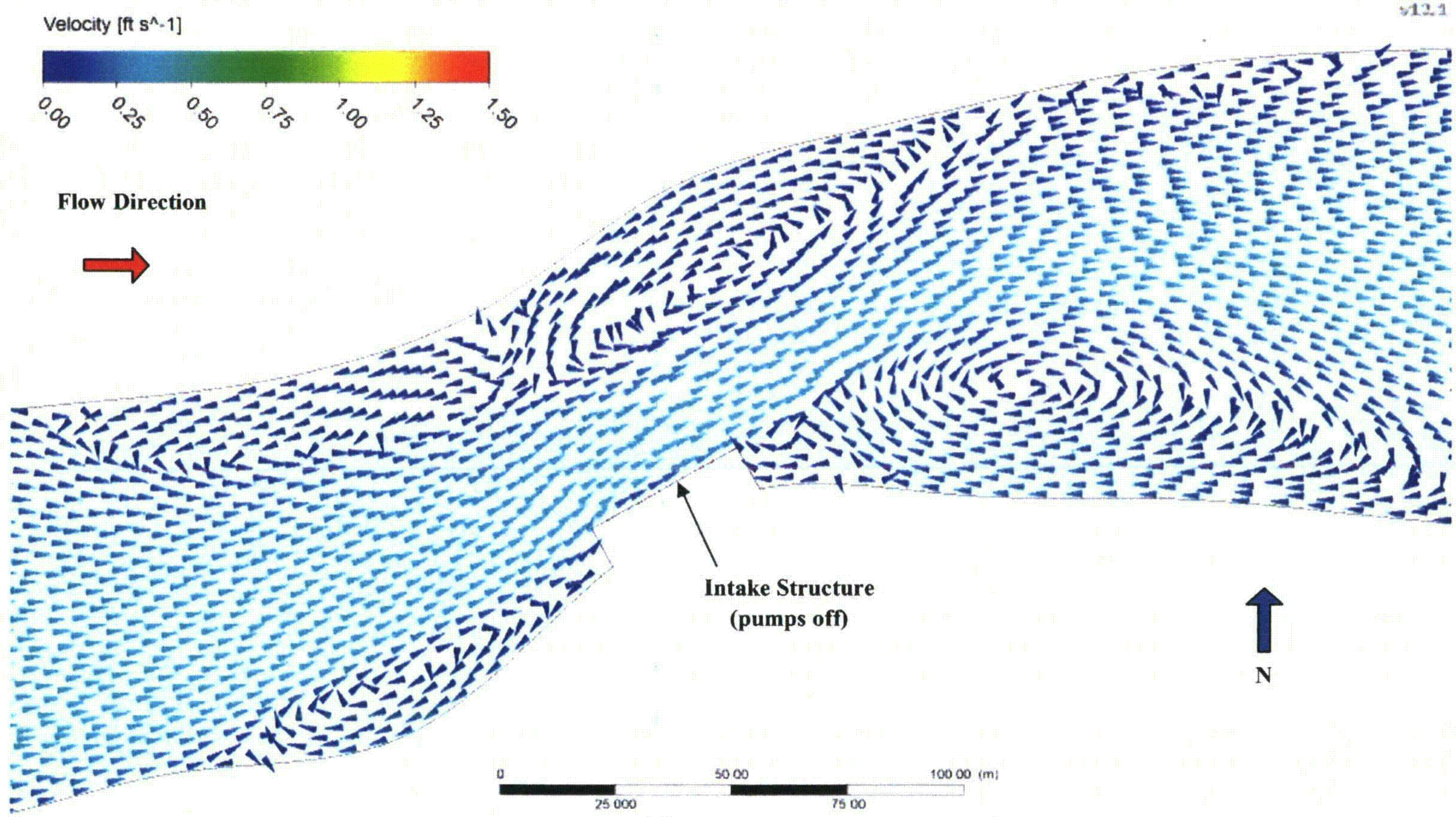

Figure 9 – Velocity vectors near the river intake, Scenario 2, pumps off.

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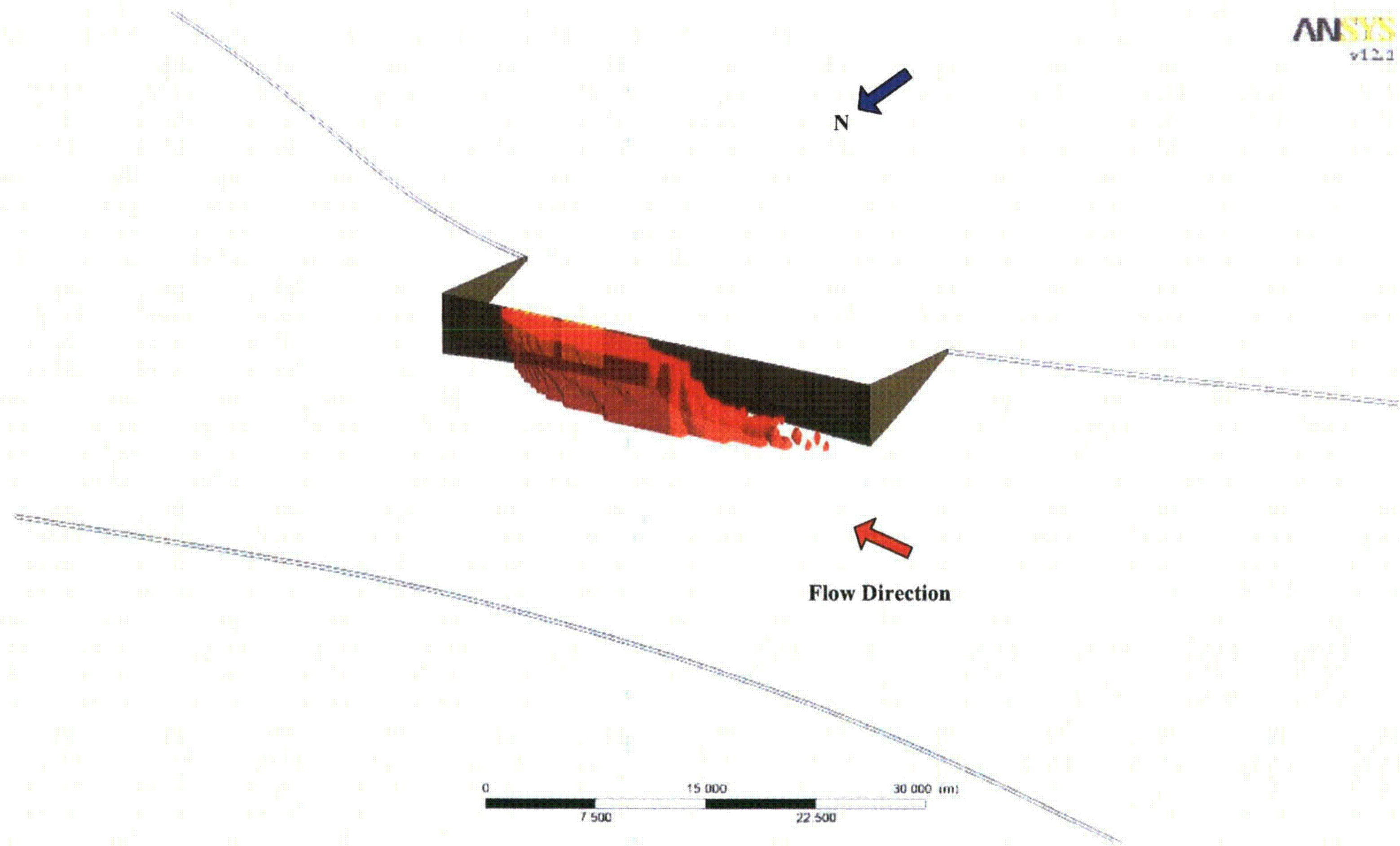

Figure 10 – Hydraulic zone of influence (indicated in red) for Scenario 2.

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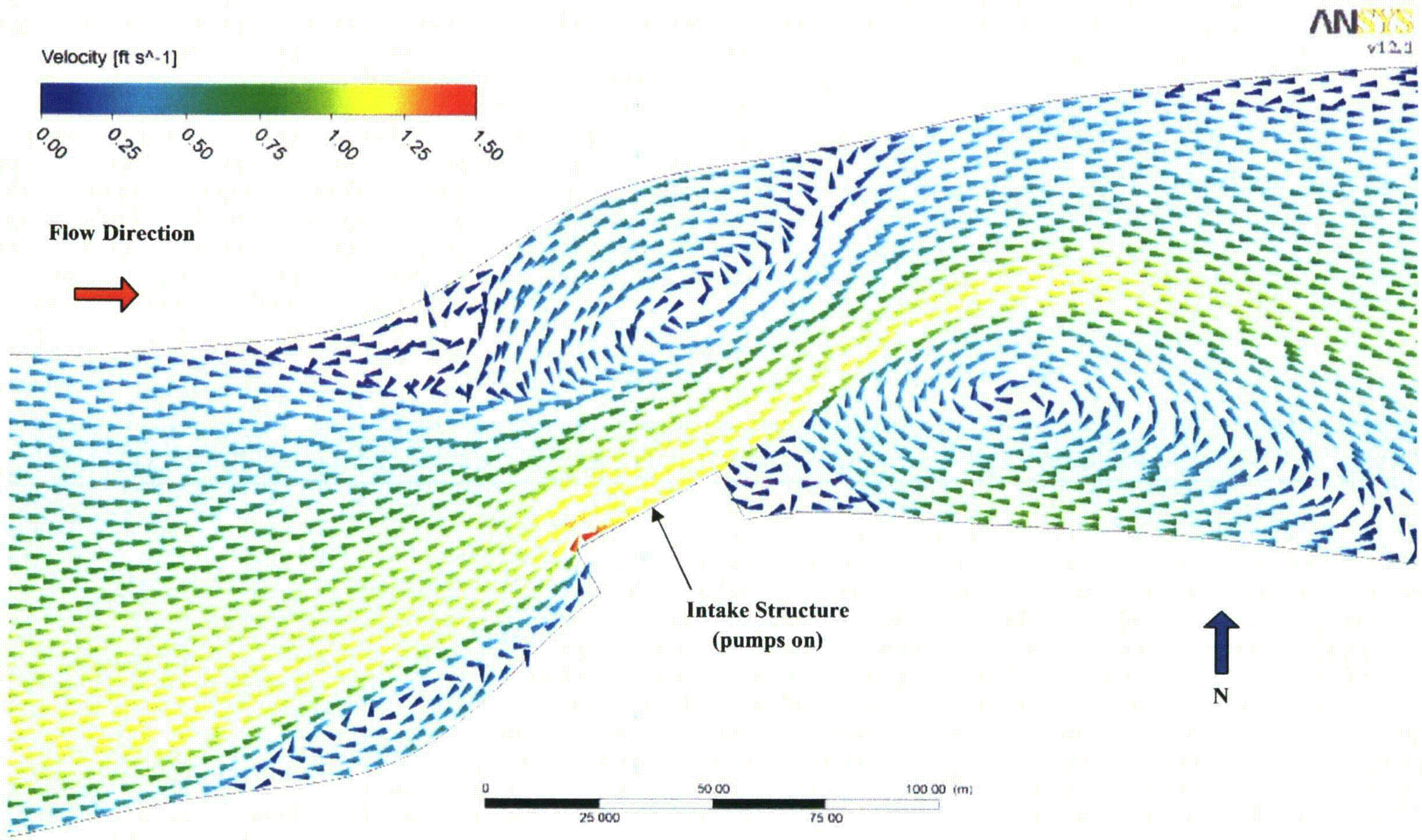

Figure 11 – Velocity vectors near the river intake, Scenario 3, pumps on.

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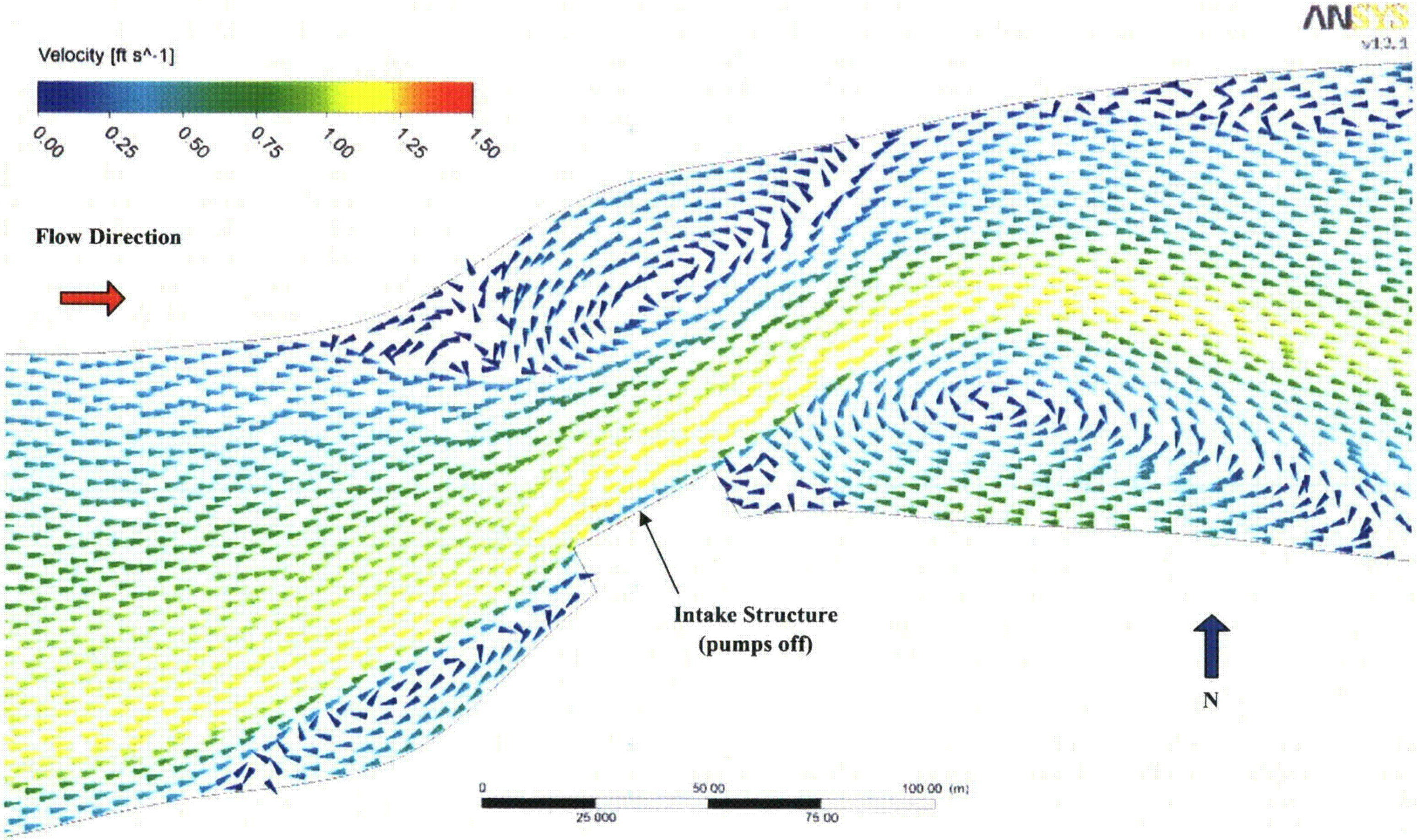

Figure 12 – Velocity vectors near the river intake, Scenario 3, pumps off.

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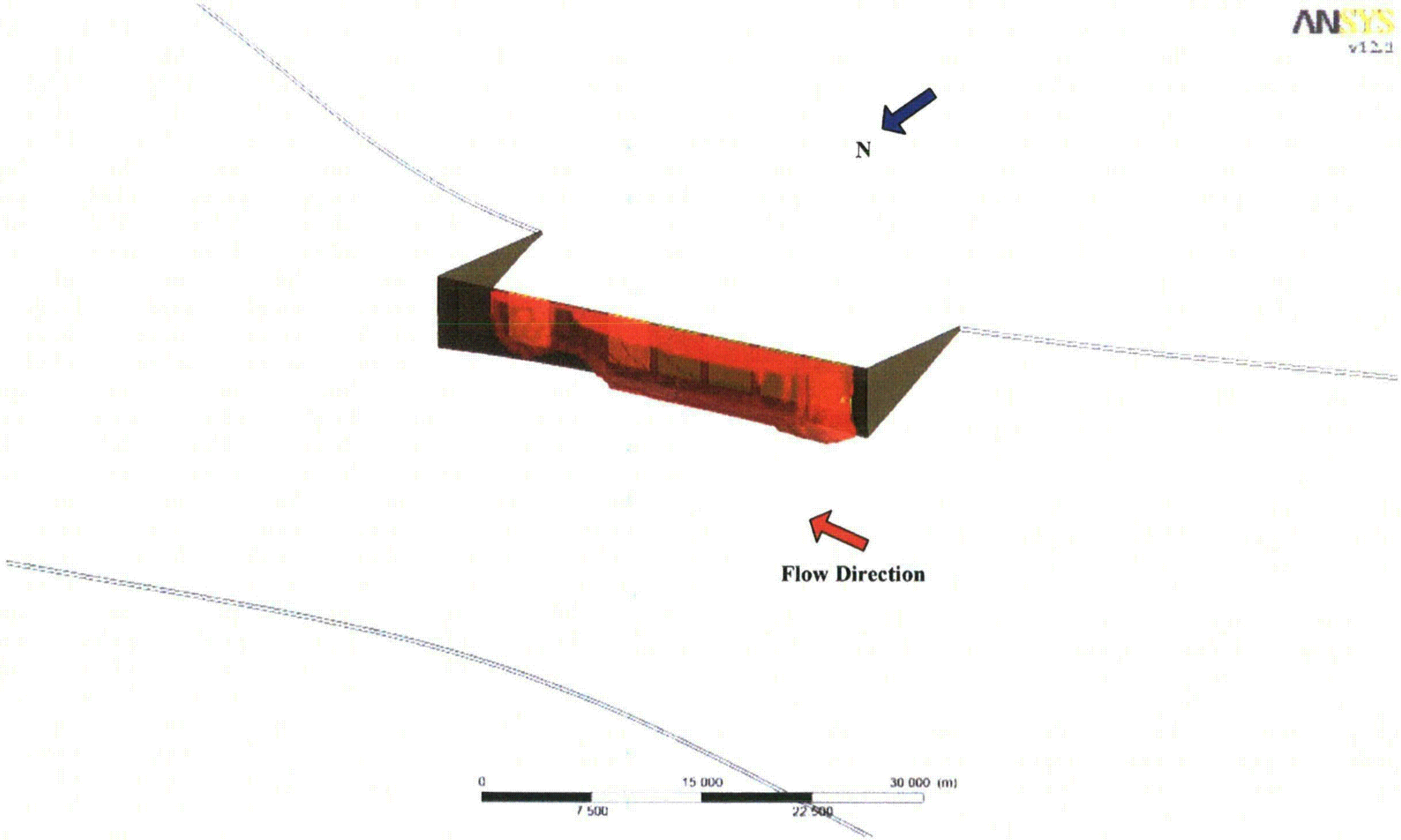

Figure 13 – Hydraulic zone of influence (indicated in red) for Scenario 3.

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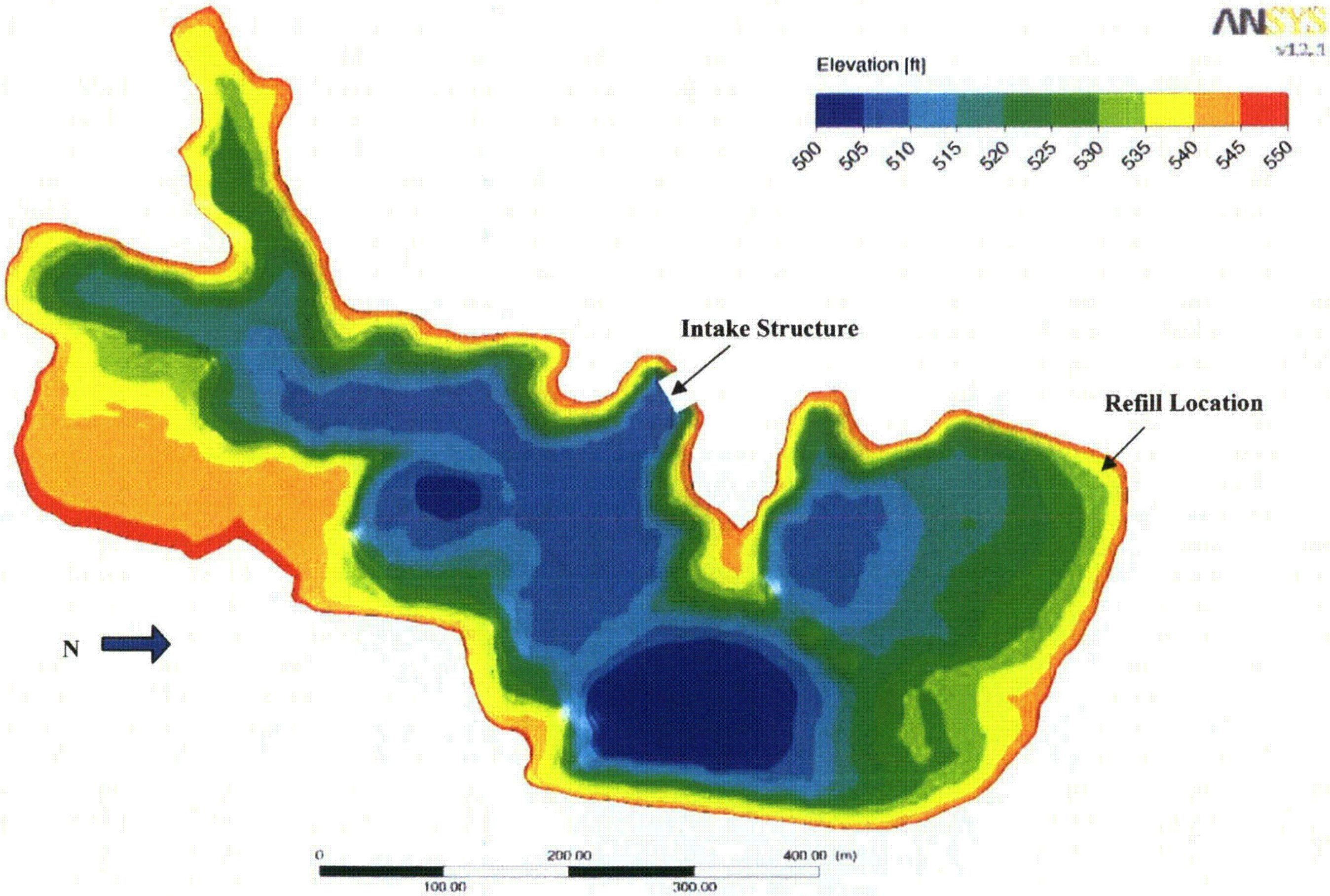

Figure 14 – Model of Pond A showing surface elevations and intake and refill locations.

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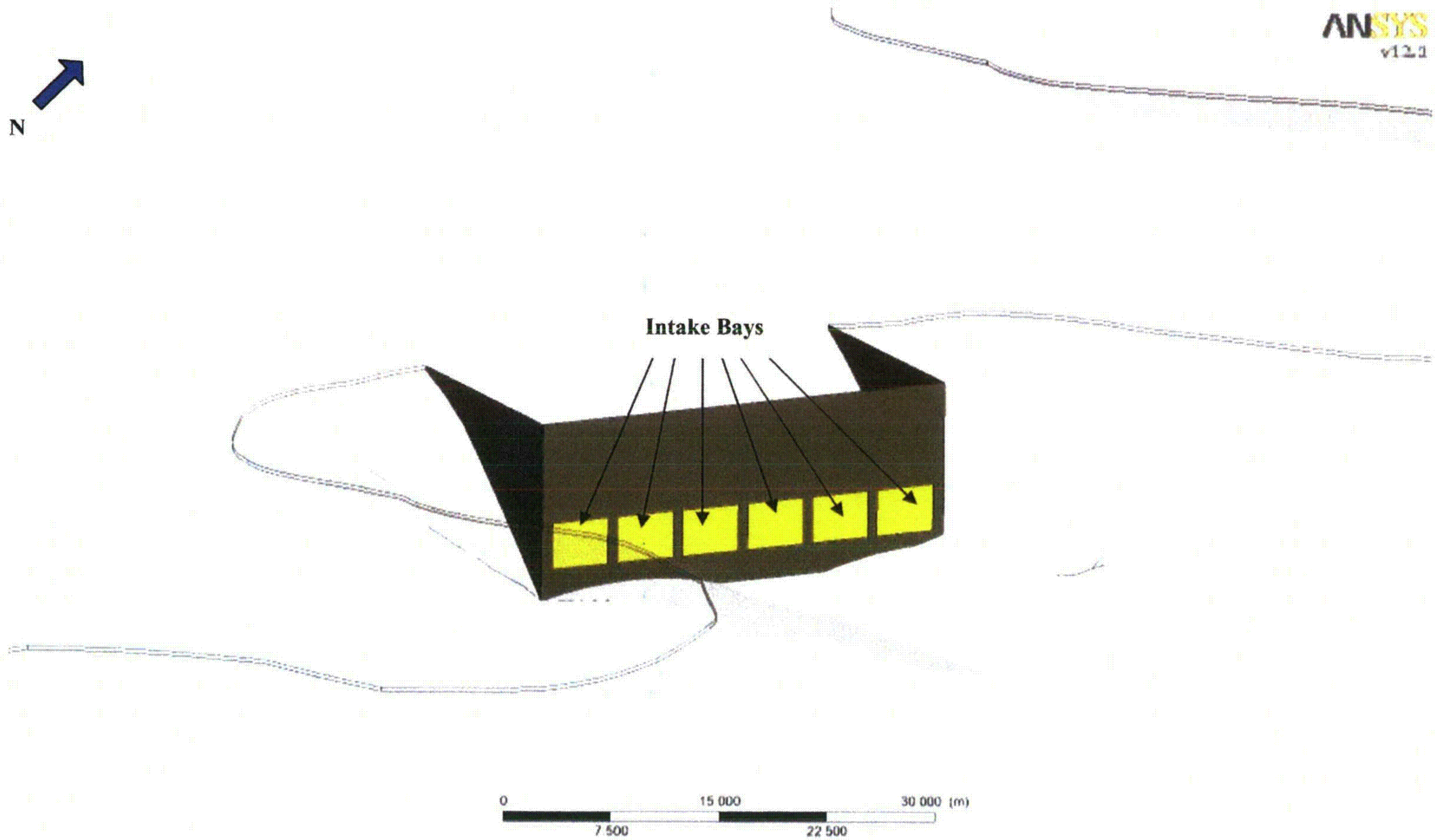

Figure 15 – Pond A intake structure showing six pump bays (yellow).

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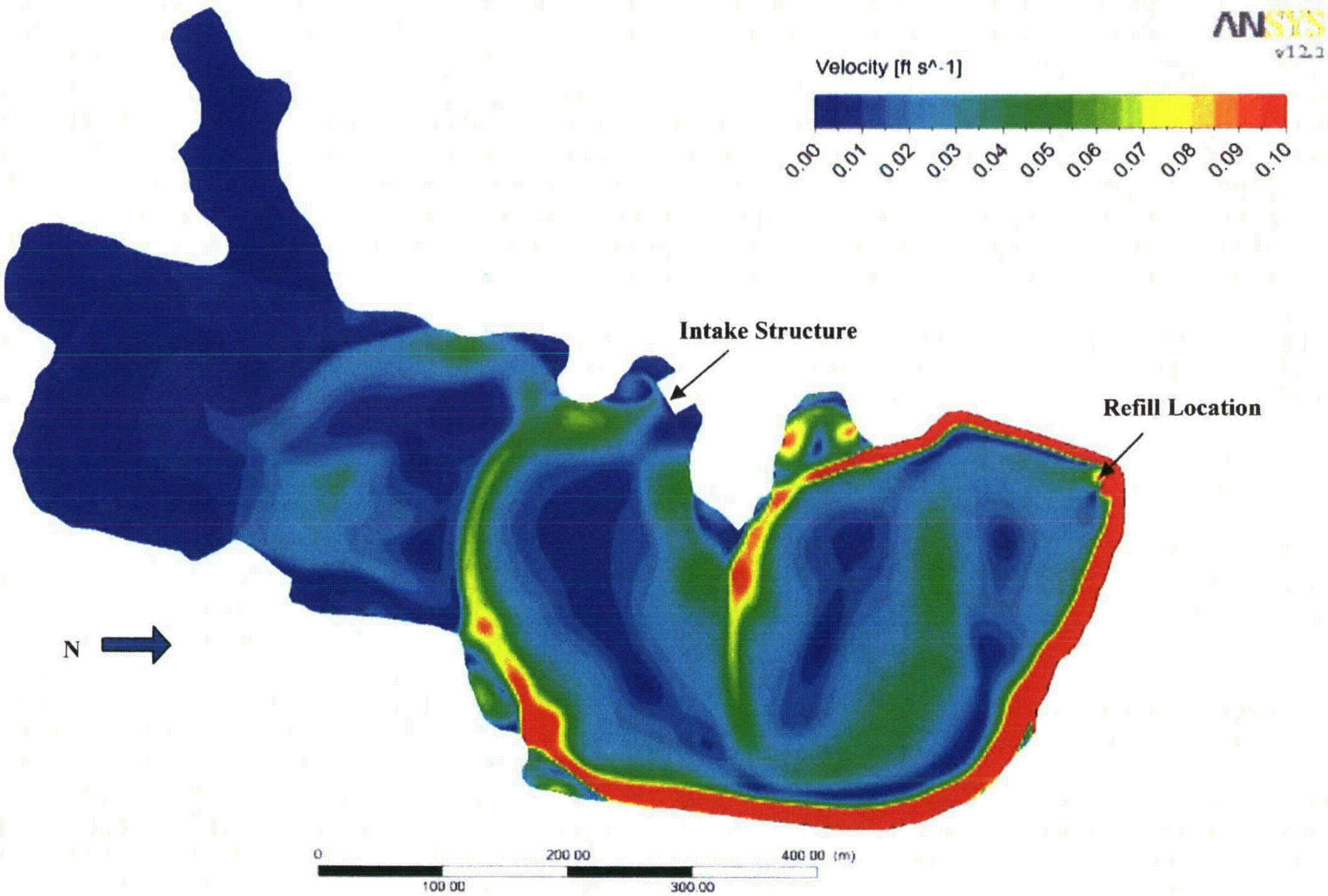

Figure 16 – Velocity contours for Pond A, Scenario 1.

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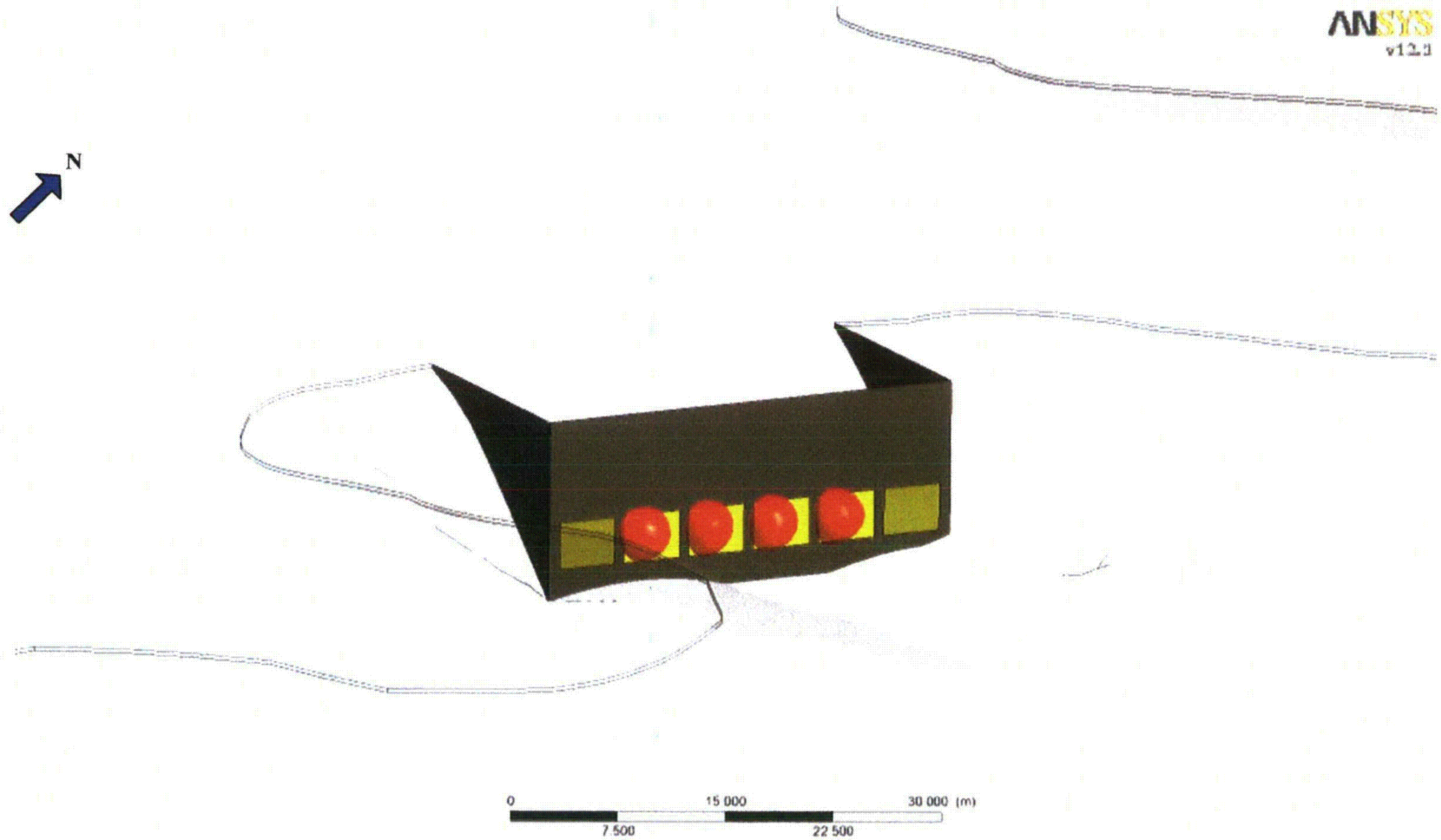

Figure 17 – Pond A hydraulic zone of influence (indicated in red) for Scenario 1; four middle bays active.

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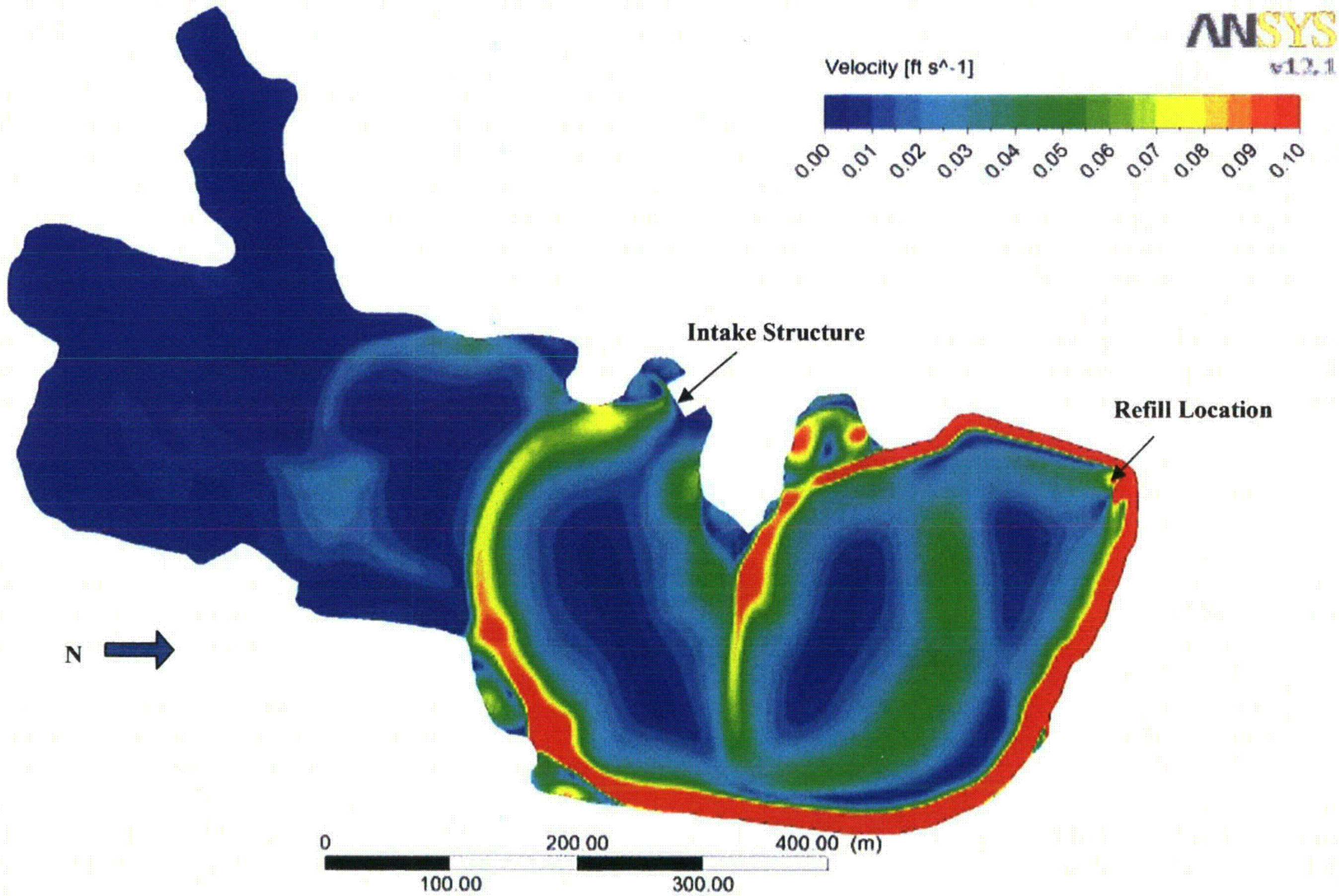

Figure 18 – Velocity contours for Pond A, Scenario 2.

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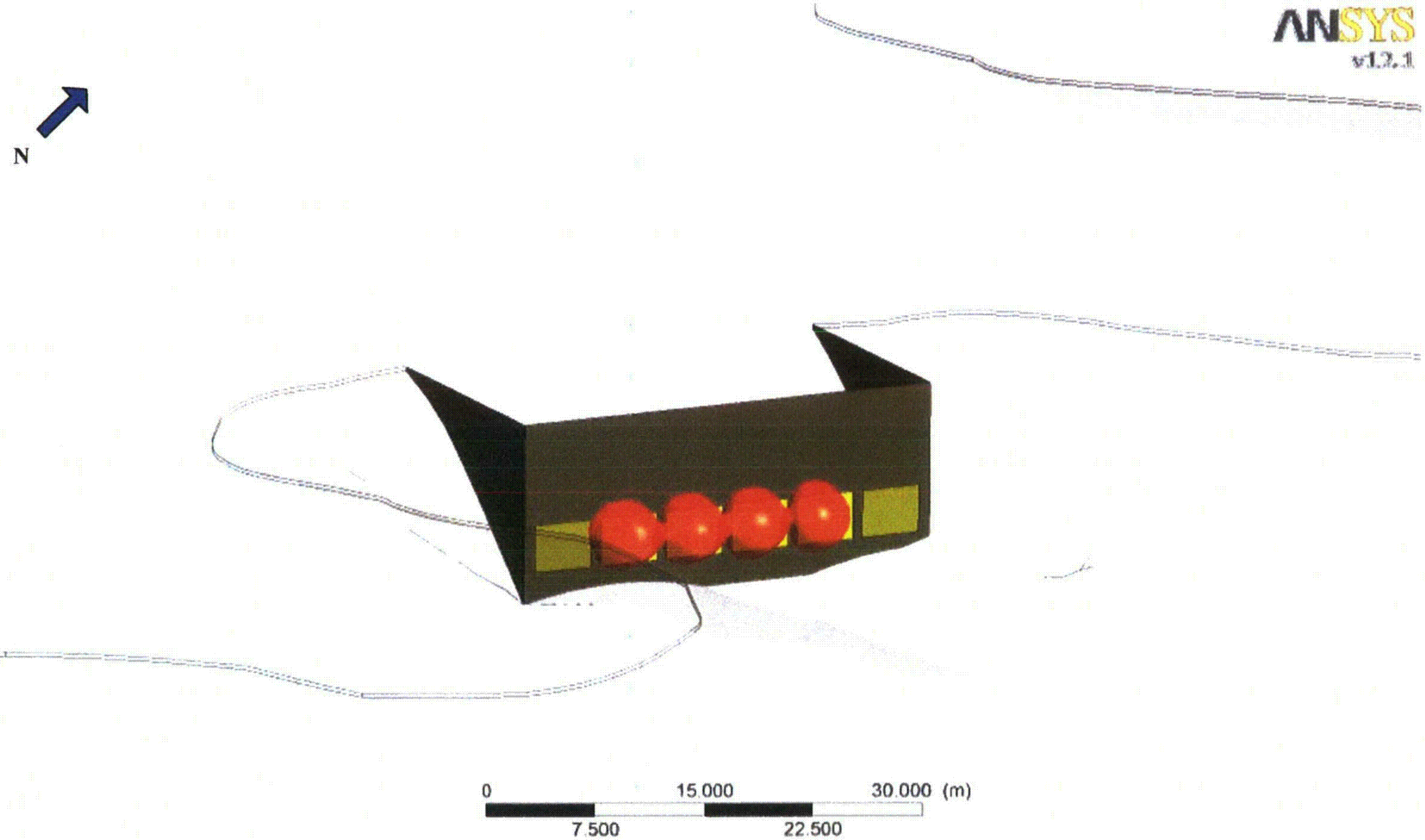

Figure 19 – Pond A hydraulic zone of influence (indicated in red) for Scenario 2; four middle bays active.

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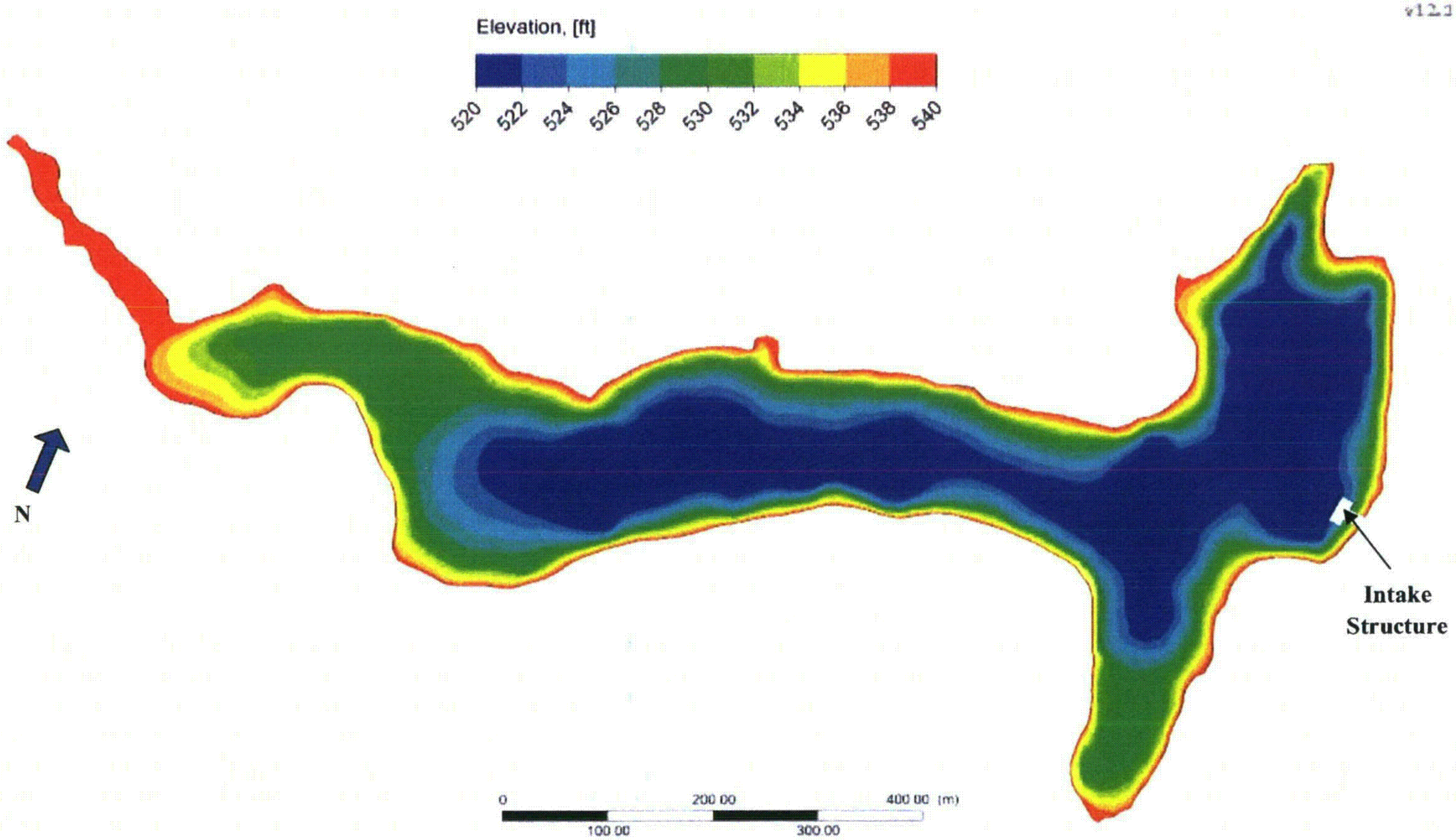

Figure 20 – Model of Pond B showing surface elevations and intake location.

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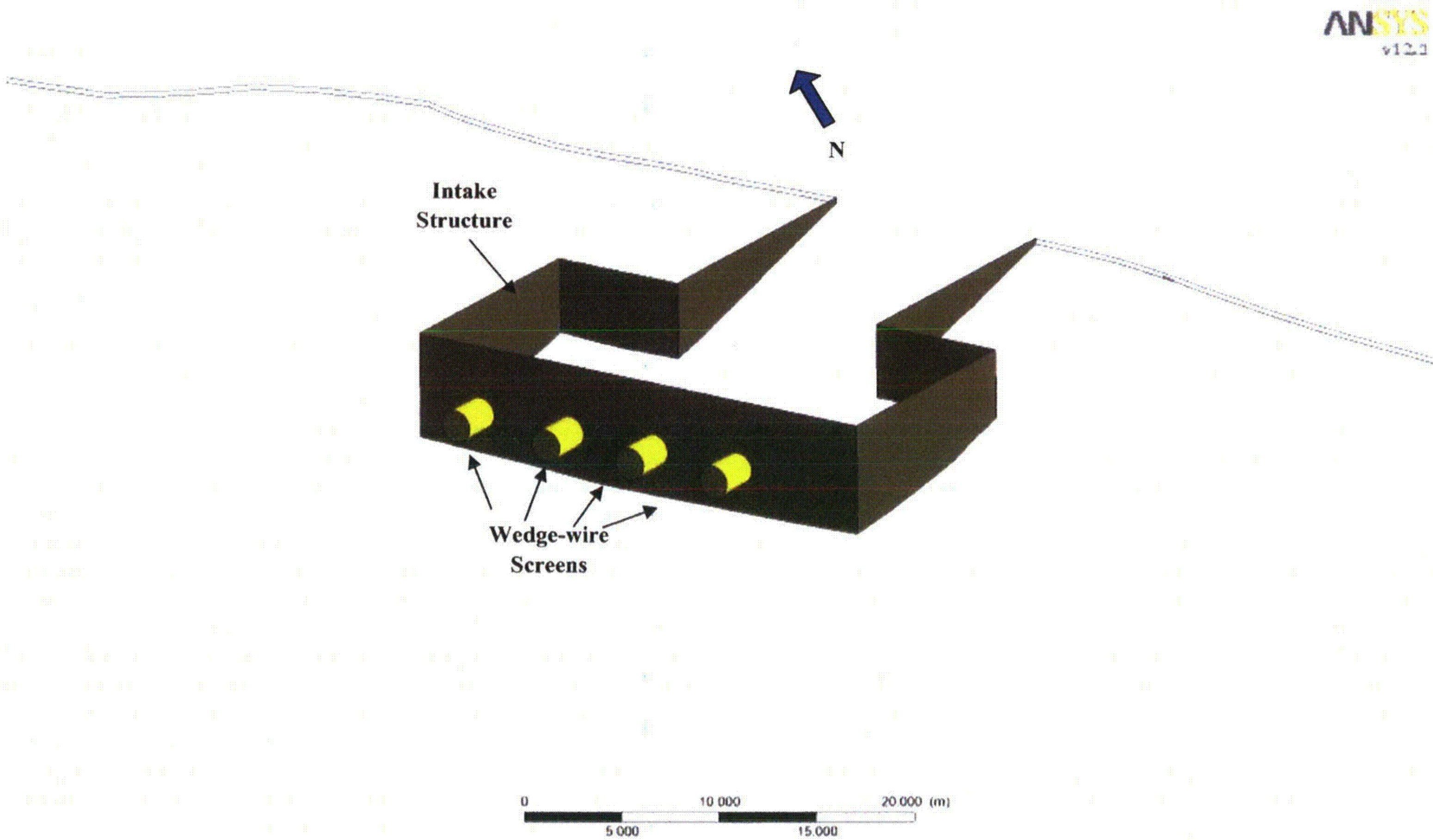

Figure 21 – Pond B intake structure showing intakes in yellow.

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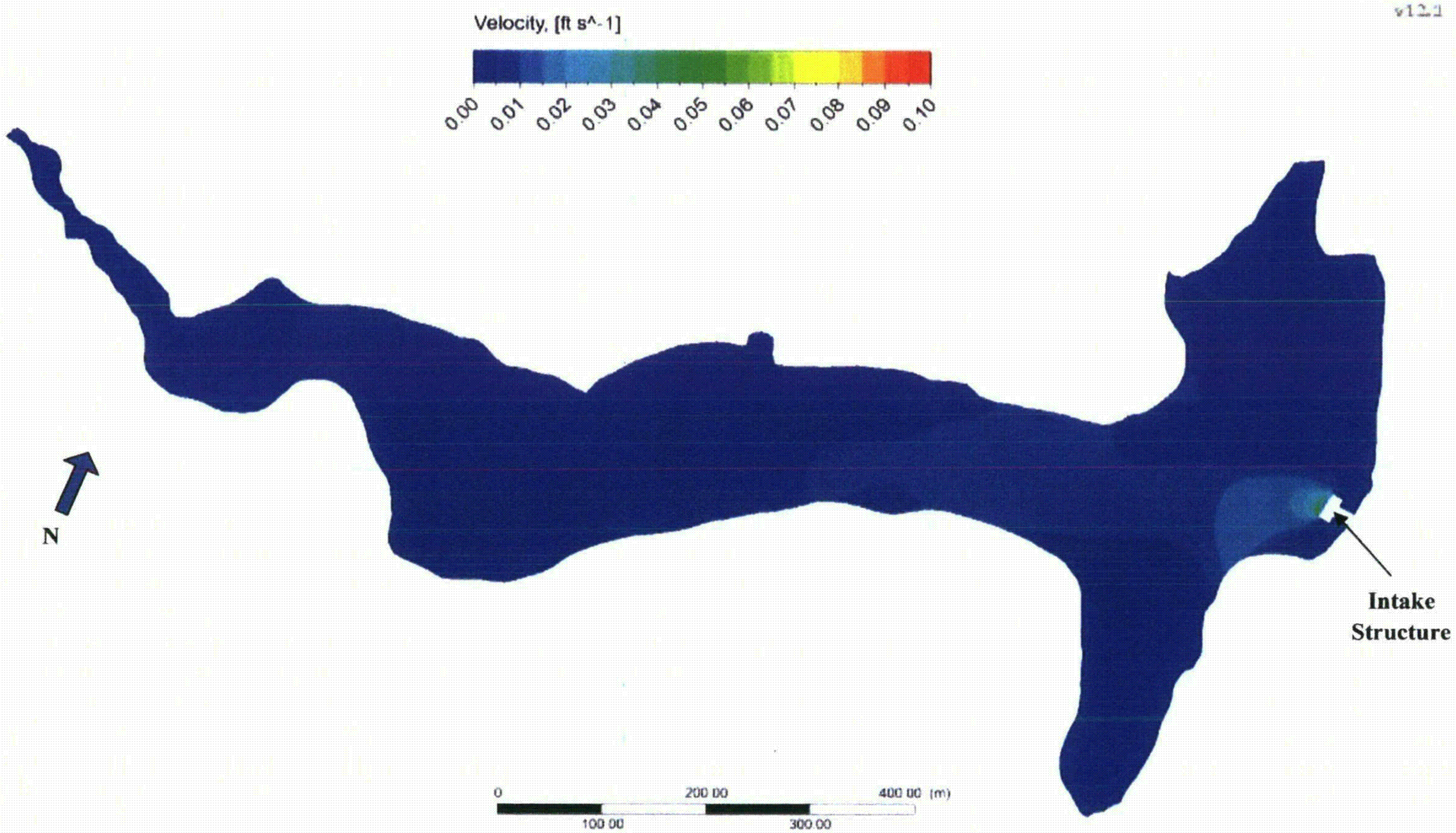

Figure 22 – Pond B velocity contours.

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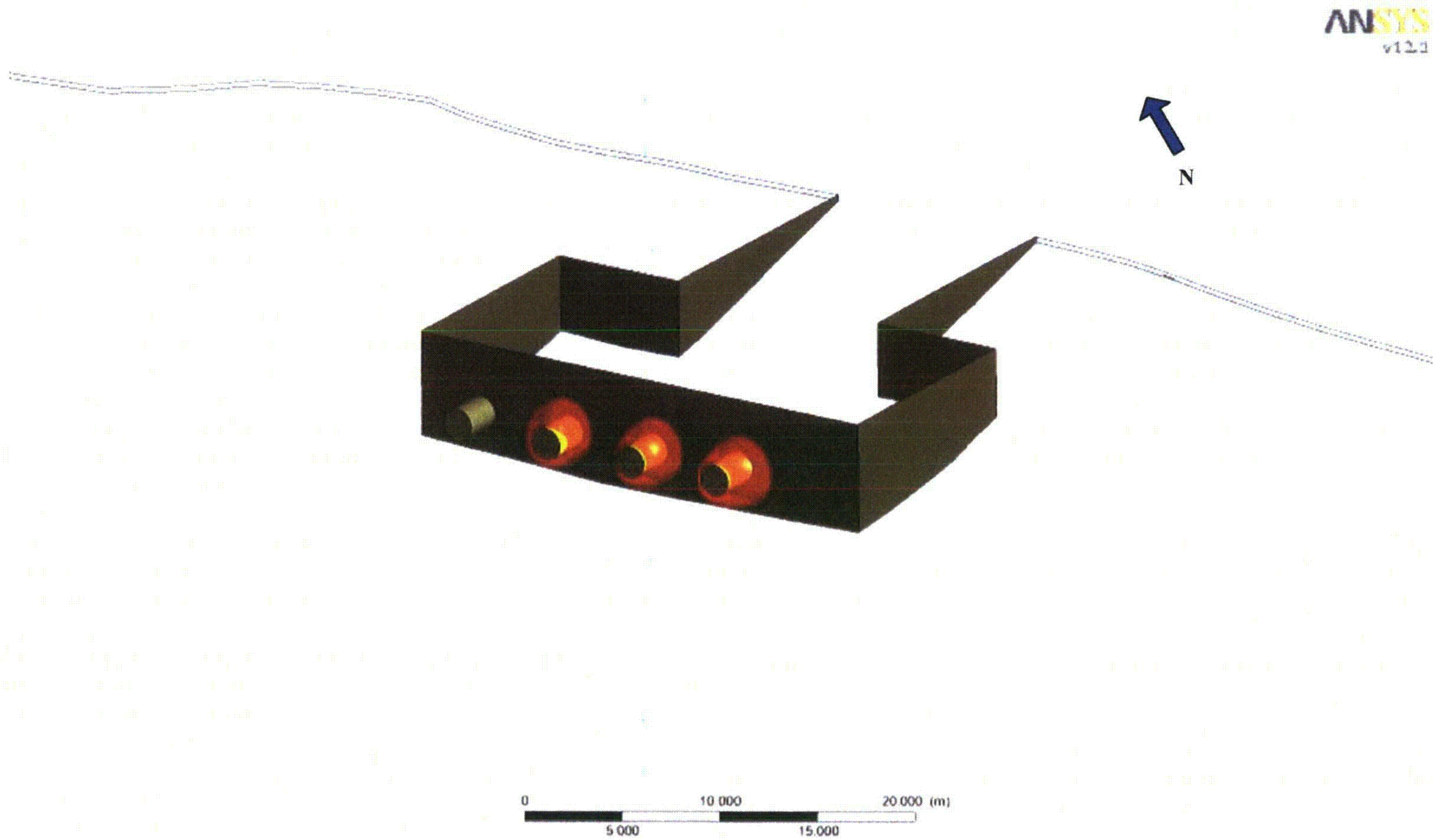

Figure 23 – Pond B hydraulic zone of influence (indicated in red) for the two intake structure pump bays.

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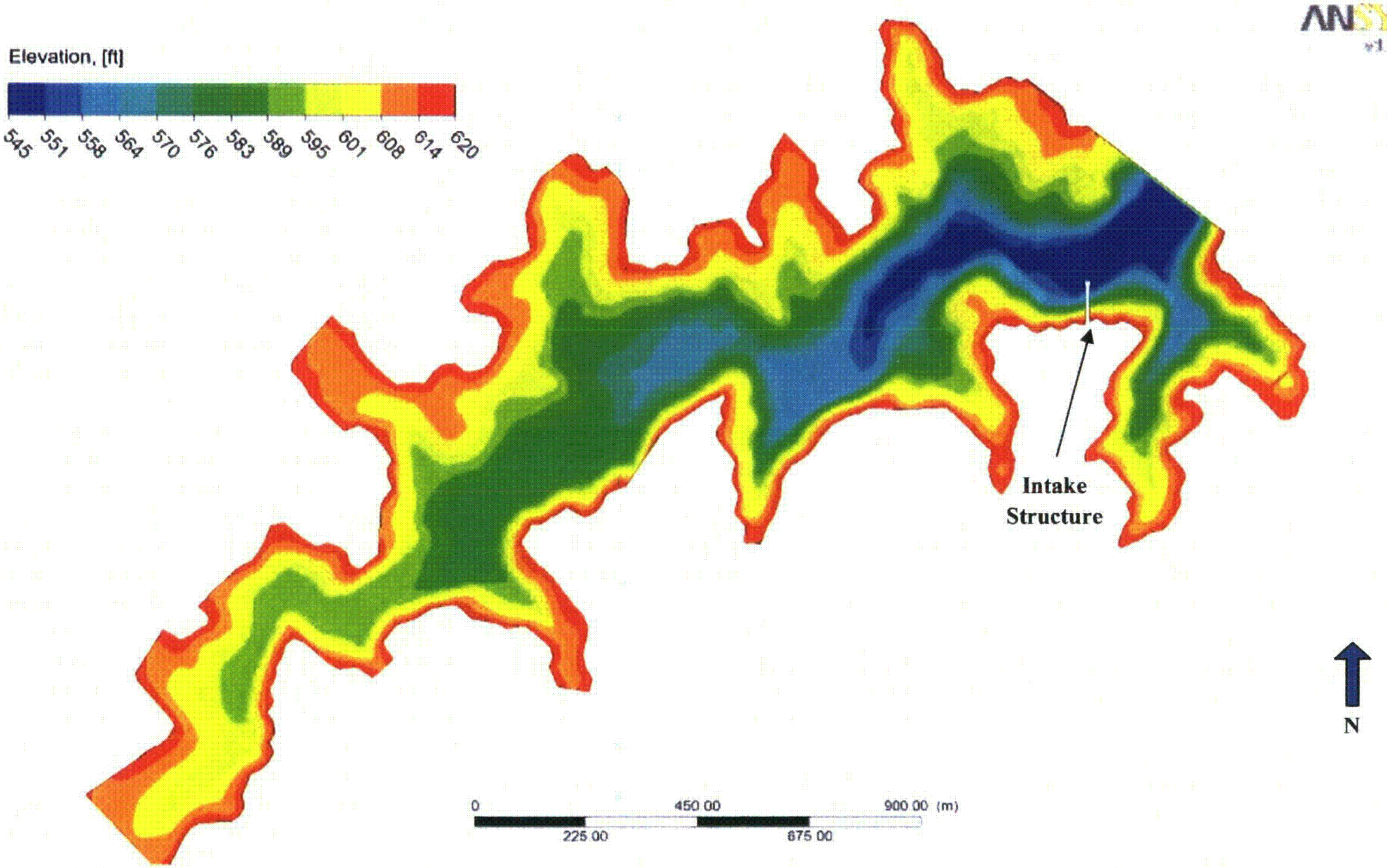

Figure 24 – Model of Pond C (30 ft drawdown) showing surface elevations and intake location.

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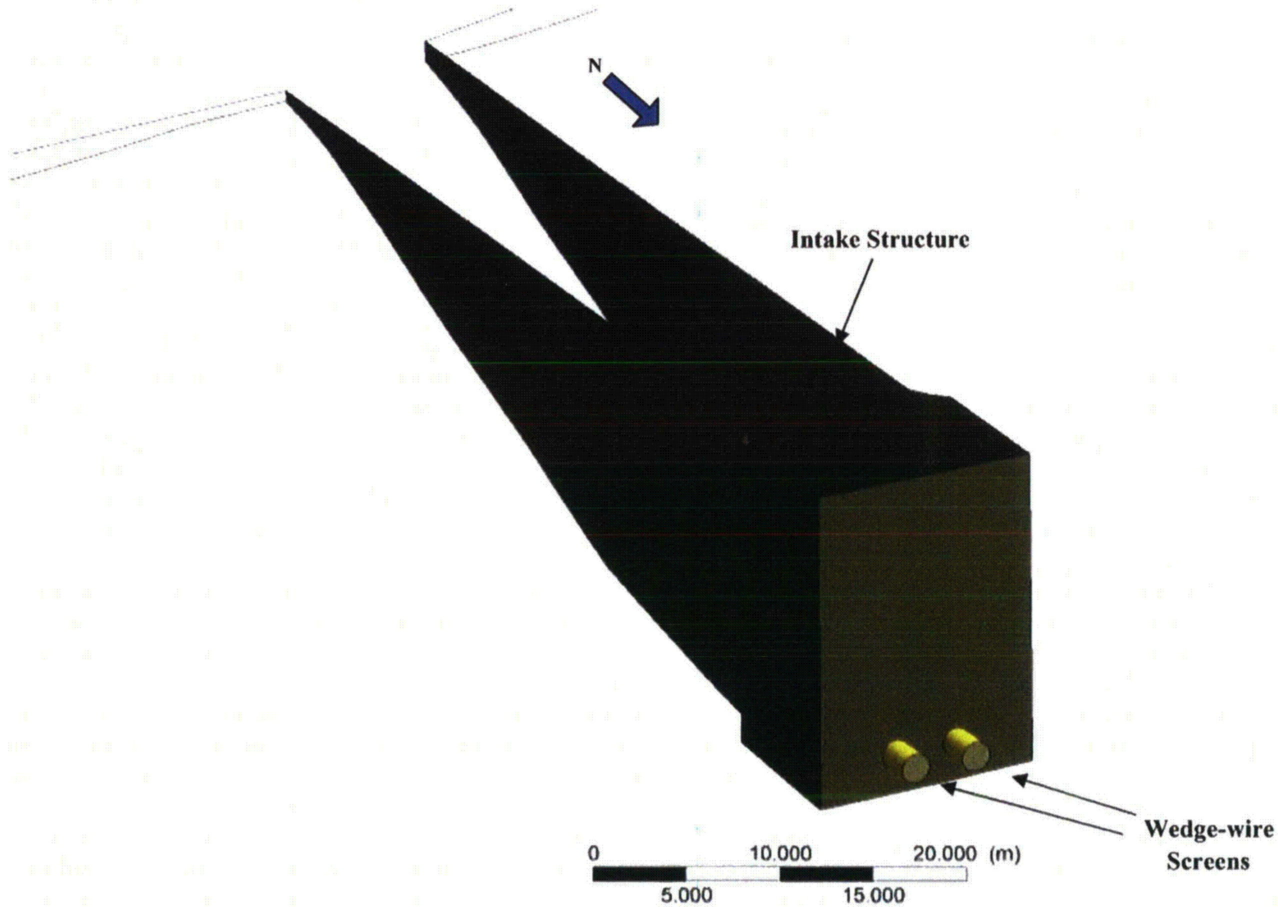

Figure 25 – Pond C intake structure showing pump bay intakes (wedge-wire screens).

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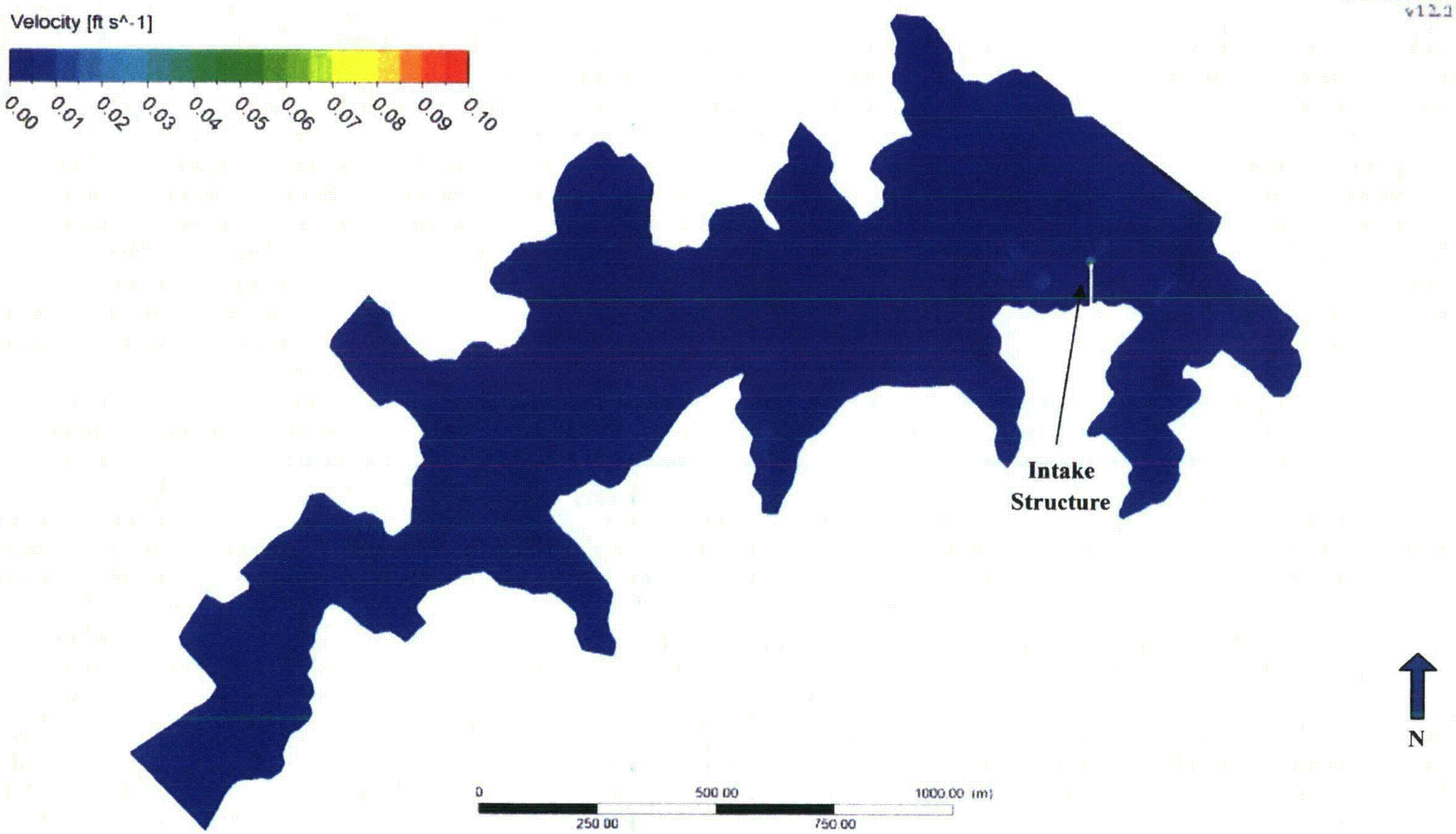

Figure 26 – Pond C velocity contours, 30 ft drawdown.

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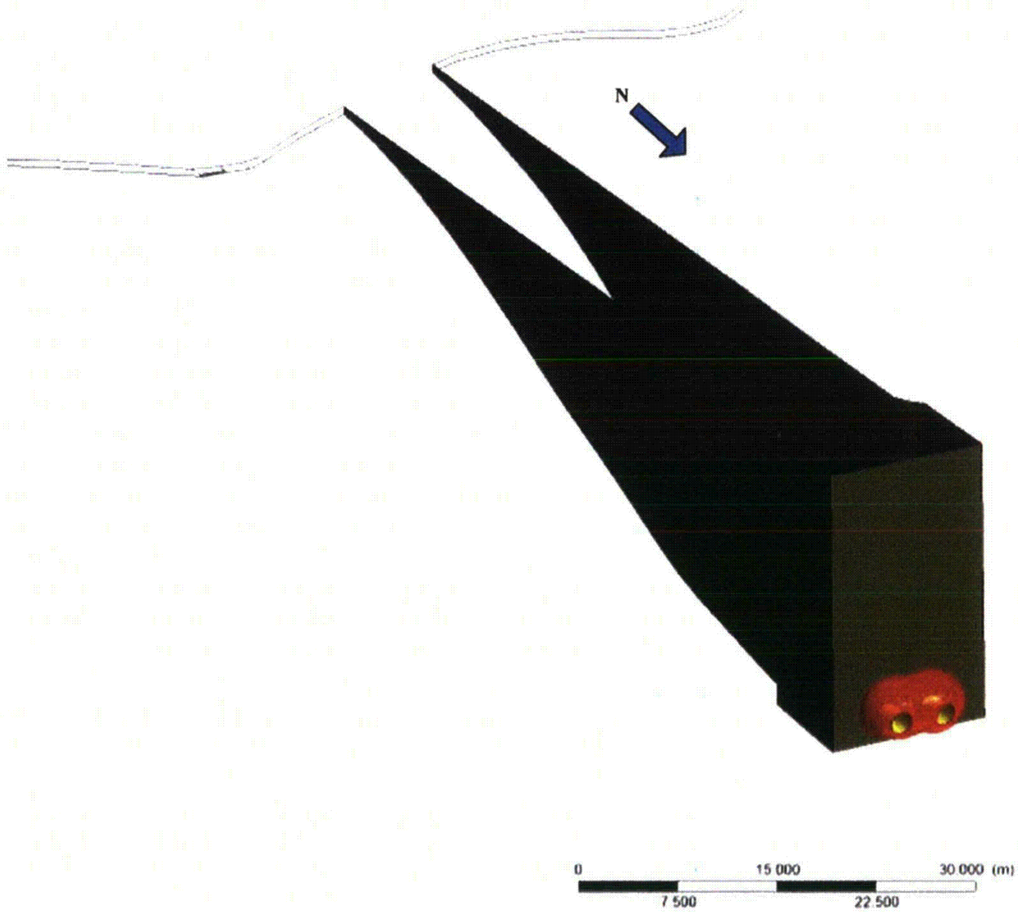

Figure 27 – Pond C hydraulic zone of influence (indicated in red) for the single intake structure pump bay, 30 ft drawdown.

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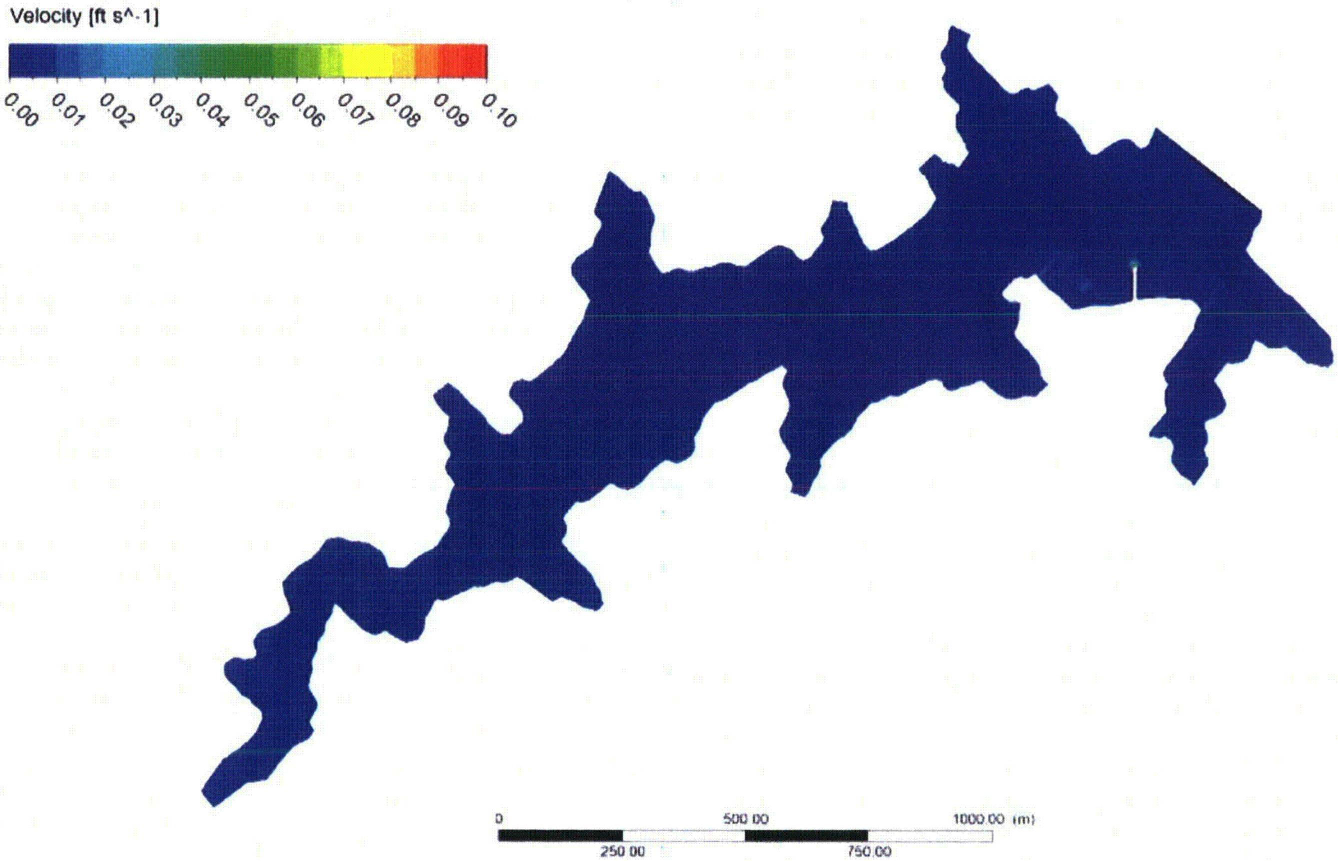

Figure 28 – Pond C velocity contours, 45 ft drawdown.

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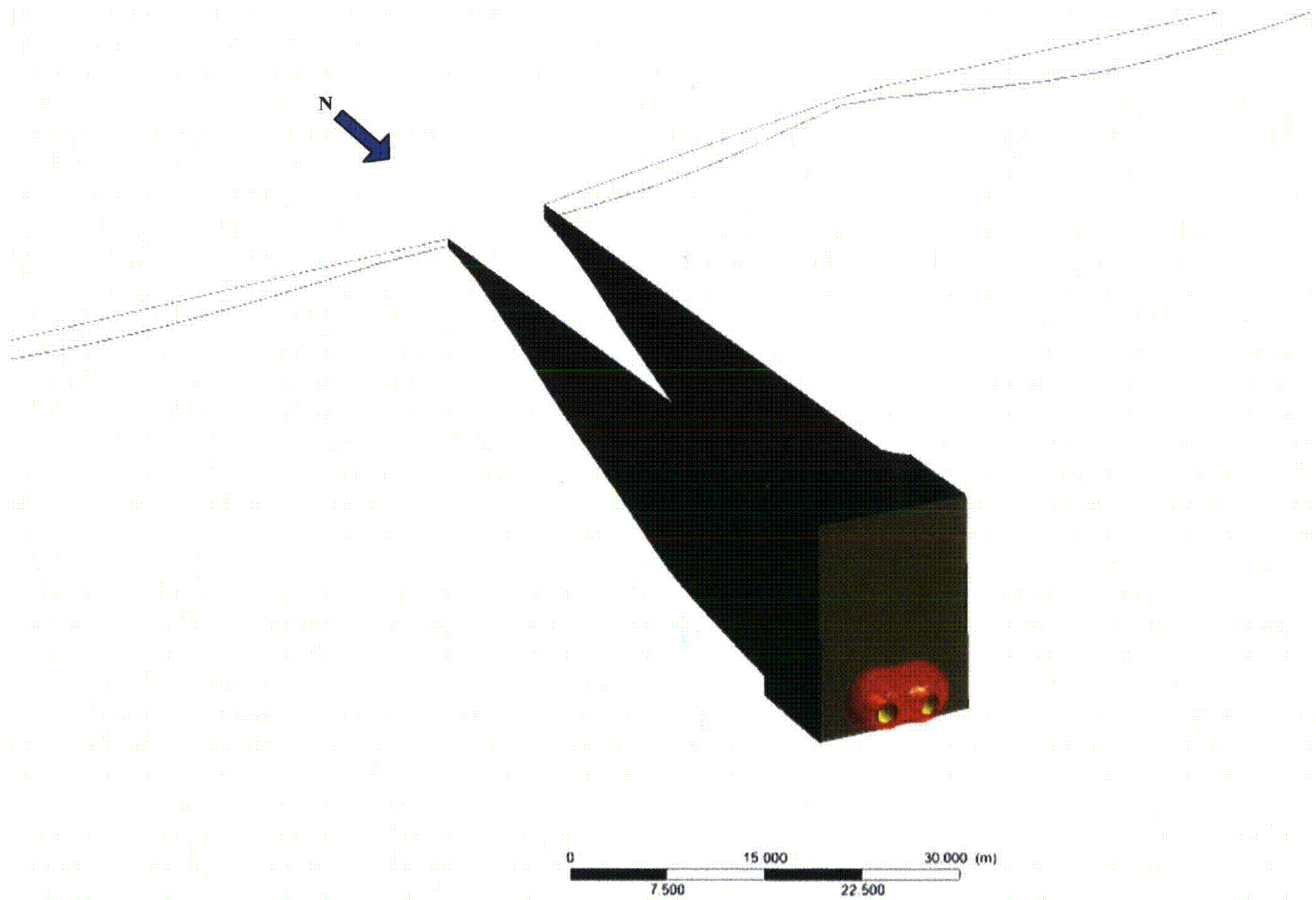

Figure 29 – Pond C hydraulic zone of influence (indicated in red) for the single intake structure pump bay, 45 ft drawdown.

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ATTACHMENT B.1

Details of the CFD Model

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DETAILS OF THE CFD MODEL

1. GEOMETRY AND MESH

The elevation data required to describe the bottom surfaces for the river and pond simulations were digitized from bathymetry data in References [B.1, B.2, and B.3]. The exception was the model for Pond C, where the bottom surface was interpreted from digital elevation data for existing land contours. In all models the surface of the river or pond was set to the correct height; thus, two separate meshes were created for the river scenarios, as two surface elevations were used.

The number of cells in the models ranged from around 500,000 cells in the river scenarios to nearly 1,000,000 cells for Pond C. In all cases a mesh resolution of approximately one-tenth of the size of the intakes was used around the intake structure, with considerably larger cells in regions in the far-field. In all cases, the mesh was 10-15 cells deep (i.e., 10-15 control volumes from the surface to the bottom at any one point). The velocity gradients in the vertical direction were small enough so that this resolution is appropriate, and typical for CFD models. In the vicinity of the intake structures, the cells have been refined by a factor of 3 (30-45 control volumes in the vertical direction) to provide additional resolution.

Please refer to Figures B.1-1 through B.1-6 in this Attachment for graphical depictions of the CFD geometry and computational mesh for the river and pond models.

2. BOUNDARY CONDITIONS

2.1 <u>River Simulations</u>

On the upstream face of the river section, perpendicular to the river flow, an inlet boundary condition was employed. A mass flow condition was set at this inlet. On the downstream face, a zero-pressure opening boundary condition was set, with zero-gradient for all variables. The bottom and sides of the river were set as no-slip walls, while the surface was set to a free-slip wall.

The intake structure was set to a no-slip wall boundary condition, while the intakes were set to outlets. A mass flow was set at each intake, which was equivalent to the flow rate withdrawn through the intake by the pump in the pump bay. The velocity at the intakes is therefore part of the solution (the CFD code does not constrain the velocity to be perpendicular to the intake face), which is a more realistic boundary

condition than the alternative of specifying a uniform perpendicular velocity; as the flow is unlikely to enter the intakes at a uniform angle perpendicular to the intake structure, due to the ambient flow direction of the river.

2.2 Pond Simulations

A no-slip wall boundary condition was used on the bottom and sides of the ponds, as well as the intake structure, while a free-slip boundary condition was used on the water surface. The bay intakes (for Pond A) and wedge-wire screen intakes (for Ponds B and C) were set to outlets with the mass flow divided equally between all intakes/ screens. For Pond A, inlet boundary at the refill pipe outlet was used to represent the refill flow from the primary section of the river intake. However, for Ponds B and C the only boundary conditions were walls and outlets, a situation that would inevitably end with the model crashing due to the intractability of the pressure (if flow can only go out of the domain without being replaced, the negative fluid imbalance causes the pressure to drop unrealistically and eventually causing out-of-bounds errors). To account for this, a mass source equal to the intake was set equally over all cells of the computational domain, purely to keep the pressure to a sensible value while causing no other impact to the flow (i.e., this would not result in a net momentum source). While this is an unusual approach, it was considered the best alternative. For example, if an inlet is placed at some point in the domain, this will induce spurious flows in the pond that do not reflect the physical reality. A free-surface or a deforming mesh (surface compression) approach was possible, although highly computationally expensive especially considering that the very low reduction in surface velocity (typically on the order of 1 inch per hour) would not cause significant flow velocities that would change the flow patterns in the lake or would affect the size of the HZI.

3. COMPUTATIONAL MODELS

3.1 Thermodynamic

A constant density was set for the water fluid in the domain of 998 kg/m^3.

3.2 Turbulence

The shear-stress transport model (SST) was used for all simulations, which is a blend of the well-recognized k-ε and k-ω turbulence models [Reference B.4].

4. NUMERICS

4.1 Model

All simulations were performed using Ansys-CFX 12.0, a widely recognized industrial CFD software package. For the river simulations, the model was run in transient mode as transient instabilities in the flow field were observed in the CFD calculation – the results described in this report, and used to obtain the hydraulic zones of influence (HZI), are time-averages. For the pond models the model was run in steady-state mode as similar transient instabilities were not observed.

4.2 Discretization

For the river simulations, "High Resolution" spatial discretization was used, which is second-order except where the numerical restriction of boundeness is violated, in which case a blend of first- and second-order is used (including pure first-order if required) for numerical stability. Second-order time discretization was employed for the transient river simulations. First-order spatial discretization was required for the pond simulations for numerical stability. Although this results in greater numerical diffusion (i.e. gradients are leveled because of the reduced order representation) the spatial gradients are generally so low in this case that the source of numerical error is not significant.

4.3 Convergence

The transient CFD simulations (rivers) were set to a convergence criterion of 1e-04 on the RMS normalized residuals, which was obtained in all cases. A convergence criterion of 1e-05 was used for the steady-state pond simulations. These criteria comply with the guidelines for the ANSYS-CFX solver.

5. REFERENCES

[B.1] *Conceptual Design Package for RWS*, Report prepared by Shaw Nuclear, Document Ref. 11887902-F-RWS-CDP-0, 2009.

[B.2] *Site Plan – East Lee Nuclear Station Units 1 & 2*, Drawing Ref. WLG-0000-X2-005 Rev. C, 2009.

[B.3] *Lee Nuclear Station Reservoirs Bathymetry Report*, Report prepared by Devine Tarbell and Associates for Duke Energy Carolinas LLC, 2007.

[B.4] *Two-equation eddy-viscosity turbulence models for engineering applications*, Menter, F. R., AIAA Journal 32(8), pp. 1598-1605, 1994.

6. FIGURES

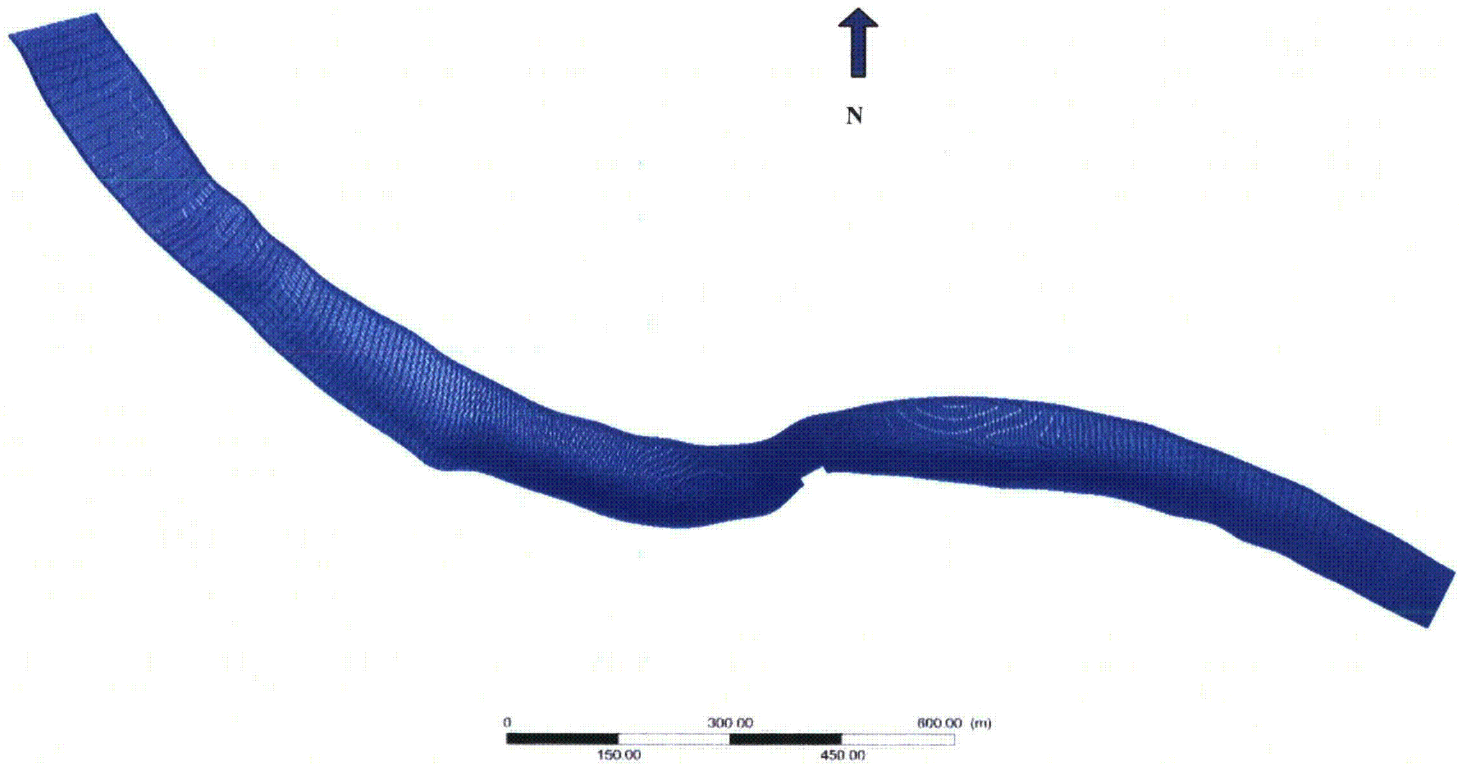

Figure B.1-1 – Computational mesh for the river scenarios

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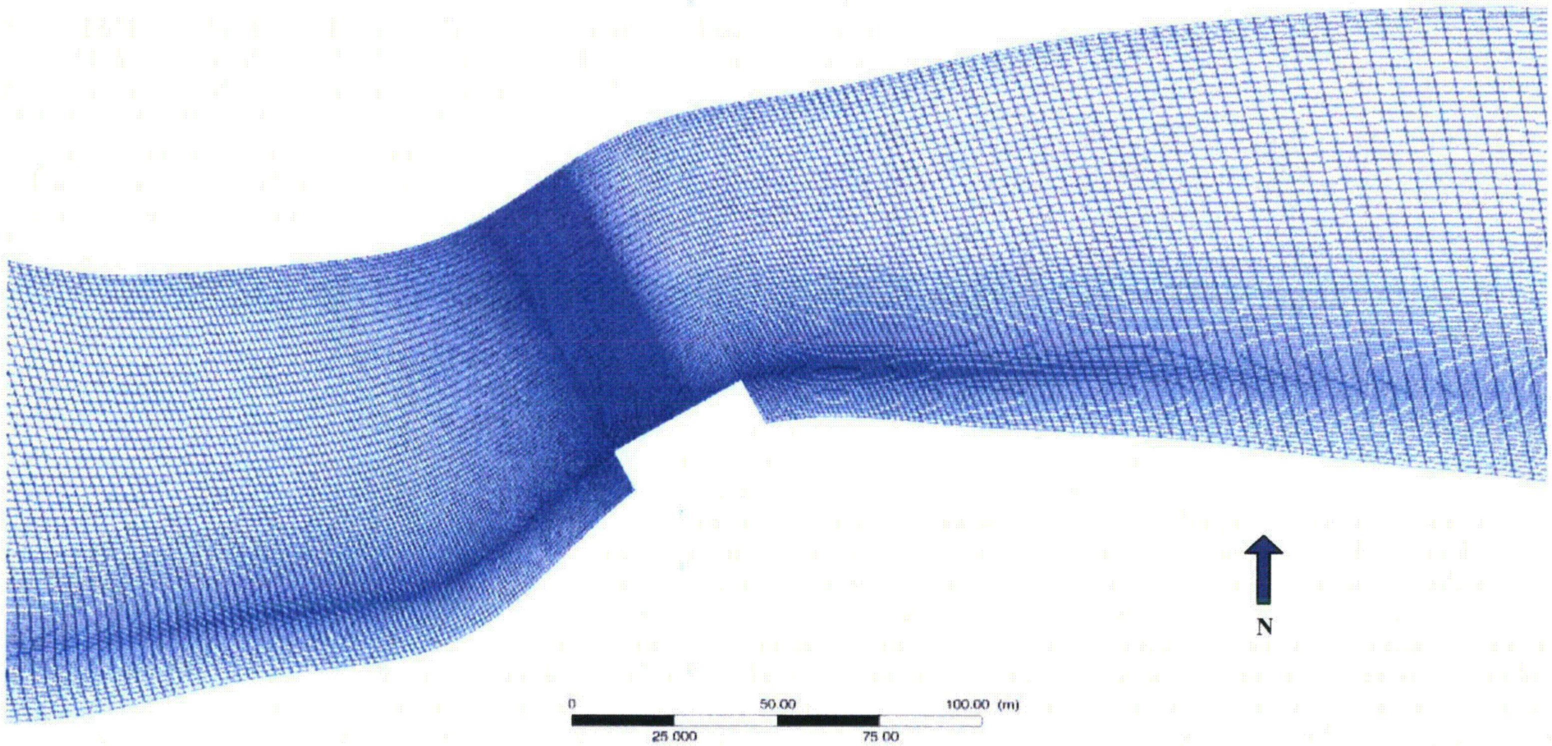

Figure B.1-2 – Close view of Computational mesh showing refinement around the primary cooling water intake structure.

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ANSYS v12.1

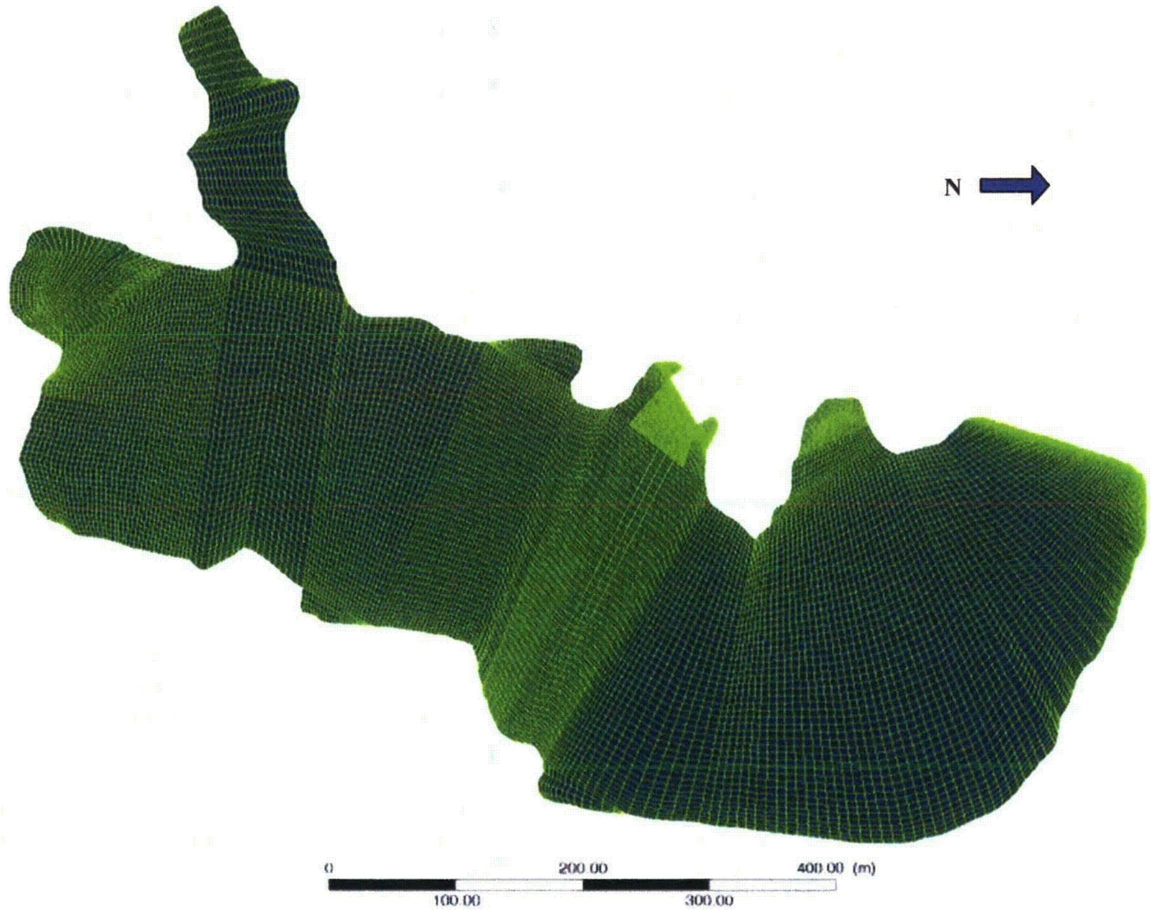

Figure B.1-3 – Computational mesh Pond A.

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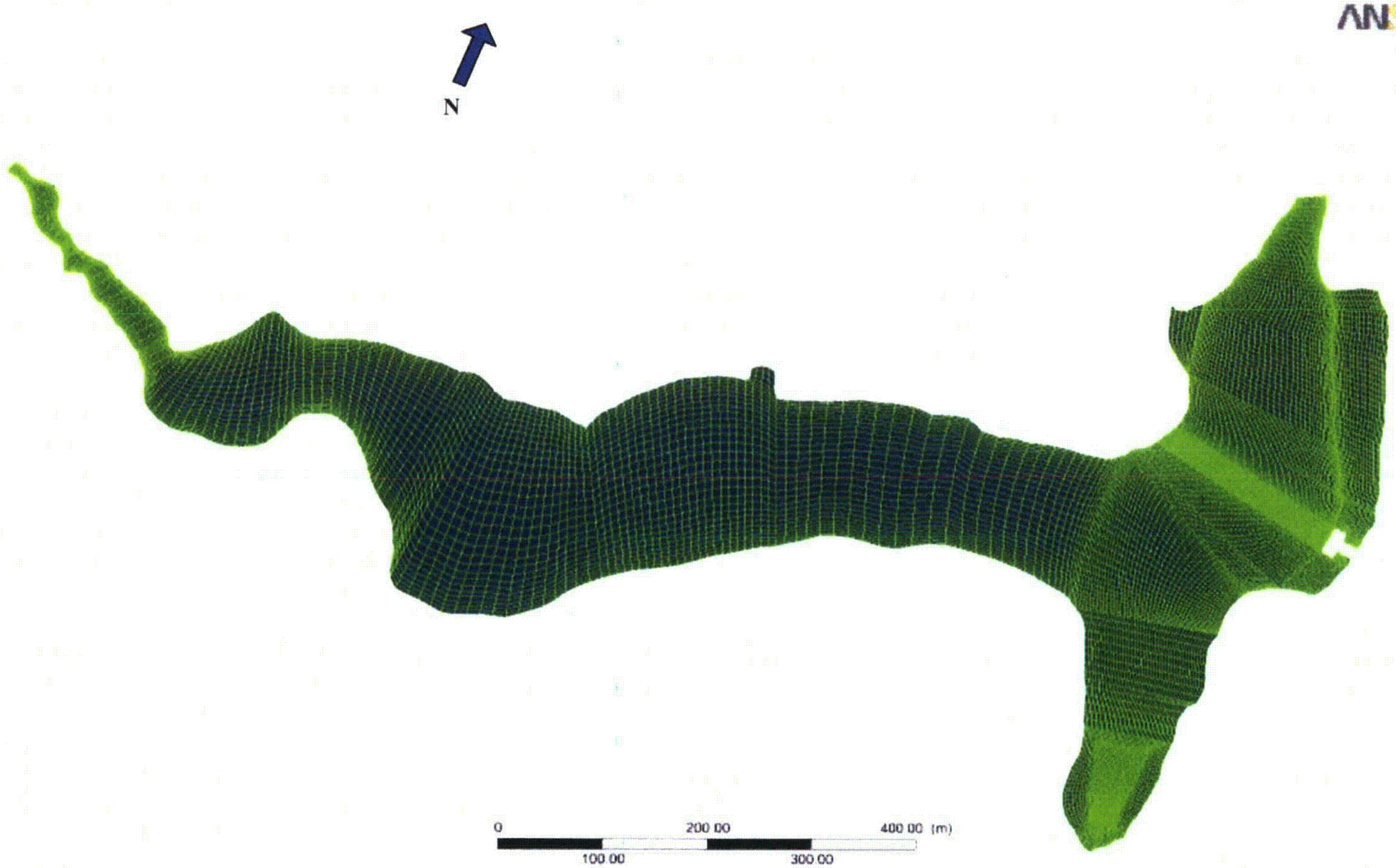

Figure B.1-4 – Computational mesh for Pond B.

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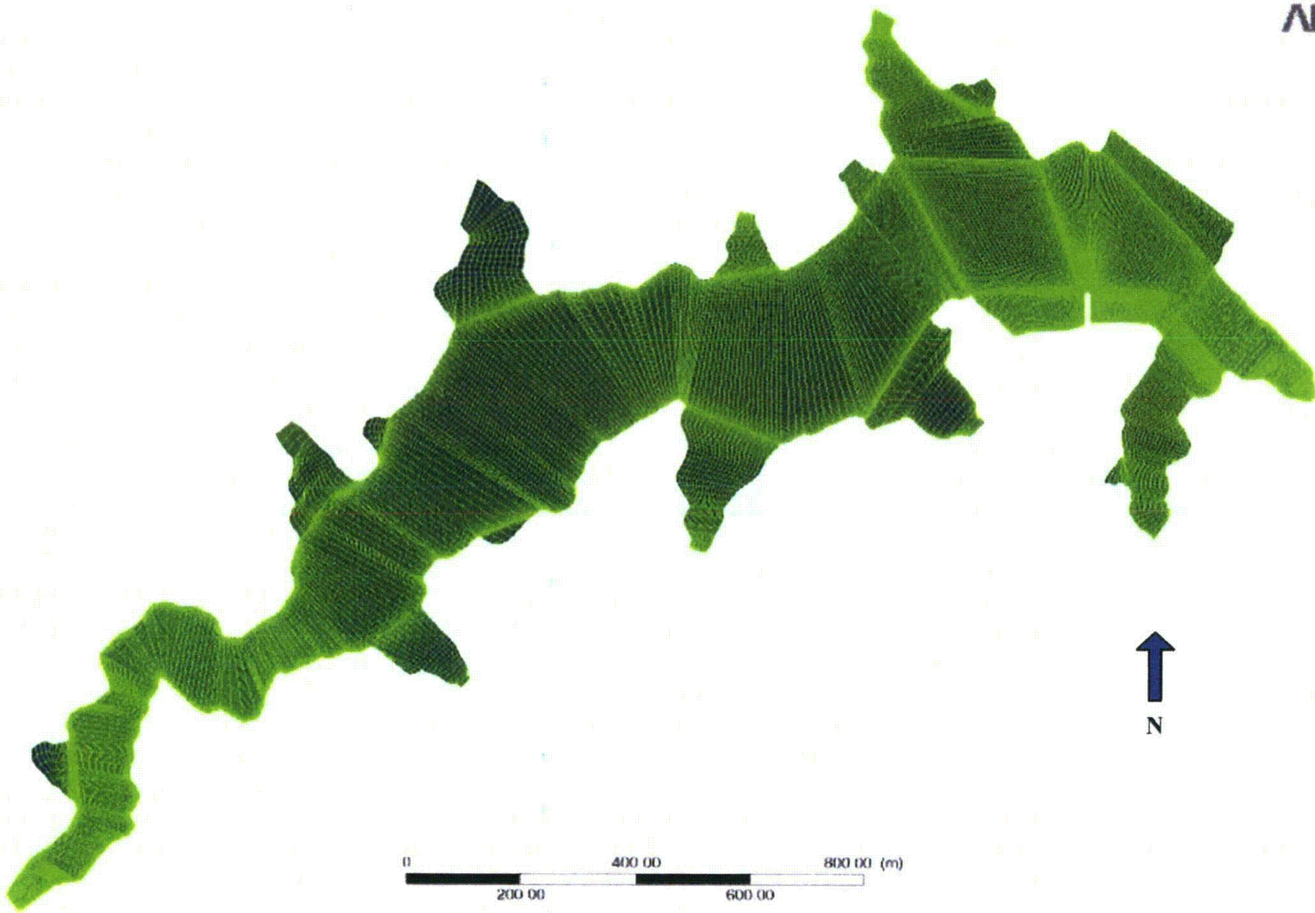

Figure B.1-5 – Computational mesh for Pond C – 45 ft drawdown.

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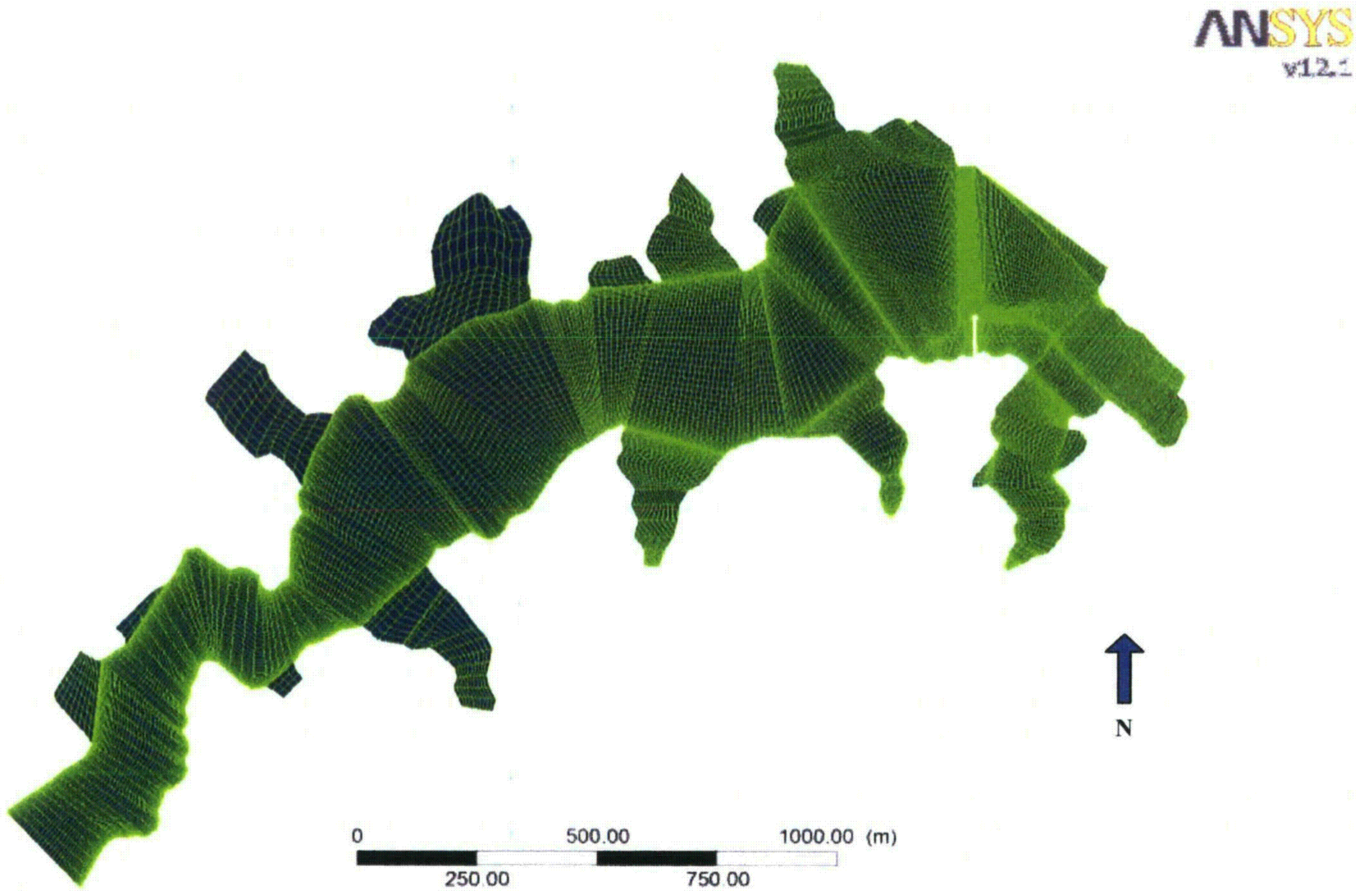

Figure B.1-6 – Computational mesh for Pond C – 30 ft drawdown.

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ATTACHMENT 6

RESPONSE TO COMMENT # 26

§ 316(b) DEMONSTRATION FOR WILLIAM STATES LEE III NUCLEAR STATION

APPENDIX D

THERMAL STRATIFICATION

Prepared for:
DUKE ENERGY CAROLINAS, LLC
Charlotte, North Carolina

Prepared by:
HDR ENGINEERING, INC. OF THE CAROLINAS
Charlotte, North Carolina

December 16, 2011

HDR

WILLIAM STATES LEE III NUCLEAR STATION
THERMAL STRATIFICATION

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Executive Summary

Duke Energy Carolinas, LLC's (Duke Energy) proposed William States Lee III Nuclear Station (Lee Nuclear Station) will be located on the Broad River in Cherokee County, South Carolina. Under normal river flow conditions, Lee Nuclear Station will pump water from the Broad River through existing Pond A to support station operations. During significant drought periods, water stored in two drought contingency ponds (the existing Pond B and the proposed Pond C) will be used to support station operations and comply with the proposed Water Management Plan. These drought contingency ponds will be refilled by natural inflow and water withdrawn from the Broad River when river flows return to normal conditions.

The two-dimensional CE-QUAL-W2 model was used to model Pond A as a stand-alone water body. A research version of the CE-QUAL-W2 model, which is capable of simulating water flows pumped between two interconnected ponds, was used to develop a thermal model of the interconnected Ponds B and C. A stand-alone Pond B model was first calibrated to available data, and the resulting calibration coefficients were applied to the Pond A model and to the combined Ponds B and C model.

The CE-QUAL-W2 models were run to determine the projected thermal stratification in the ponds and to determine whether the total design intake flow of the cooling water intake structures for each pond would disrupt ("rupture" or "break apart") the projected thermal stratification. A hypothetical "no withdrawal" case for Ponds A, B, and C was run to determine the thermal stratification for these ponds. Proposed Pond C is designed to be a drought contingency storage pond, and its intended use is to store water that will be used as needed during periods of low flow in the Broad River. Since the use of the drought contingency storage ponds is anticipated to be infrequent, Pond C is expected to develop thermal stratification and a turnover pattern similar to Pond B.

To simulate extended drought conditions and to determine whether thermal stratification in Ponds B and C would be disrupted during implementation of Duke Energy's proposed Water Management Plan, Ponds B and C were each modeled to be in continuous use. This hypothetical "continuous withdrawal" was modeled through each drought contingency pond's cooling water

intake at its design intake capacity until each pond had been drawn down 30 feet. This hypothetical drawdown is more severe than any that would have occurred in the entire period of record (1926-2010) for Broad River flows.

Modeling results for Pond A indicate that the thermocline would be depressed to 509 ft mean sea level (msl) as a result of continuous pumping through the pond to operate the plant and show that the thermal stratification would not be disrupted. Modeling results show that Pond B would remain thermally stratified although the thermocline would be lowered to 523 ft msl as a result of a hypothetical 30 ft drawdown of Pond B; with the water being removed from the bottom of the pond. Pond C would also remain thermally stratified, although the thermocline would be lowered to 546 ft msl as a result of a hypothetical 30 ft drawdown of Pond C; with the water being removed from the bottom of the pond.

Section 1
Introduction

Duke Energy Carolinas, LLC's (Duke Energy) William States Lee III Nuclear Station (Lee Nuclear Station) is a proposed two-unit, 2,234 MW power plant to be located on the Broad River in Cherokee County, South Carolina. Lee Nuclear Station will have a cooling water intake on the Broad River composed of two pumping sections: the primary section and the drought contingency section. Under normal river flow conditions, Lee Nuclear Station will pump water from the Broad River through the primary section to Pond A in support station operations. During significant drought periods, water stored in two drought contingency ponds (the existing Pond B and the proposed Pond C) will be used to support station operations and comply with the proposed Water Management Plan. These ponds will be refilled via natural inflow and water withdrawn from the Broad River through the drought contingency section when river flows return to normal conditions. Pond B is an existing on-site drought contingency pond, and the proposed Pond C will be formed by damming London Creek just upstream from its confluence with the Broad River.

Broad River flows from the existing period of record (1926 – 2010) were used to determine how often the drought contingency ponds would be used. To demonstrate the rarity of drought contingency storage use for station operations, the number of days either pond would have been used to provide cooling water for Lee Nuclear Station operations was determined from the station operations water balance model. The number of days Ponds B and C would have been used was converted to the percentage values shown in Table 1 by dividing the number of days Ponds B and C would have been used by the total number of days from 1926 through 2010. These numbers are based on Pond B's usable storage being used first (drawdown of 30 feet) followed by Pond C.

TABLE 1
PERCENTAGE OF DAYS WHEN DROUGHT CONTINGENCY PONDS WOULD HAVE BEEN USED

Pond	Cooling Water Withdrawal
B	2.8%
C	0.4%

During the 1926 through 2010 period of record, three significant drought periods have been identified: 1954-1956, 1998-2002, and 2007-2008. Most of the drought contingency pond-use-days in Table 1 occurred during one of these significant drought periods.

Table 1 shows how infrequently the drought contingency ponds would have been used to support station operations. Under Duke Energy's proposed Water Management Plan, the Broad River would have been able to support station operations 96.8 percent of the time during the 85-year period of record (1926 through 2010).

Pond A and drought contingency Ponds B and C, under 316(b) of the Clean Water Act and corollary State law, are considered to be reservoirs since they have an average hydraulic retention time of greater than 7 days.

The regulations state at 125.84(b)(3)(ii) that:

> "...in a lake or reservoir, the total design intake flow must not disrupt natural thermal stratification or turnover pattern (where present) of the source water except in cases where the disruption is determined to be beneficial to the management of fisheries for fish and shellfish by any fishery management agency(ies);"

Therefore, Duke Energy must establish that the thermal stratification and/or turnover patterns, if any, in each of the three ponds, are not disrupted. Section 125.83 defines natural thermal stratification as:

"...the naturally-occurring division of a waterbody into horizontal layers of differing densities as a result of variations in temperature at different depths."

Since the Environmental Protection Agency (EPA) did not define disrupt, the definition of disrupt (to break apart; rupture) as found in the Merriam-Webster dictionary is used.

HDR|DTA was commissioned by Duke Energy to develop two thermal models. The first model simulates Pond A as a stand-alone pond while the second model simulates the interconnected operation of existing drought contingency Pond B and proposed drought contingency Pond C. The thermal modeling and evaluations summarized in this report indicate that the total design intake flow for Lee Nuclear Station during normal and significant drought conditions will not disrupt the thermal stratification in Pond A, nor in drought contingency Ponds B and C.

The seasonal turnover pattern exhibited in existing Ponds A and B is anticipated to continue following start-up of Lee Nuclear Station, with thermal stratification during the summer months and near isothermal conditions during the winter. Proposed Pond C is expected to exhibit similar turnover patterns. The drought contingency ponds are anticipated to be used during low flow periods in the Broad River which typically occur during the hotter months when the ponds are thermally stratified. When these ponds are being used to supply water to the station, the total design intake flow will not disrupt the thermal stratification or turnover pattern.

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Section 2

Model Development

All thermal modeling was performed using a research version of the widely accepted two-dimensional CE-QUAL-W2 reservoir modeling software (Environmental Laboratory 2008). Unlike the standard version of the CE-QUAL-W2 modeling software, the research version is capable of modeling flows pumped between Ponds B and C as well as flows withdrawn from the Broad River into the ponds.

The CE-QUAL-W2 model requires numerous input data files to describe the geometry of the ponds mathematically, the influence of meteorology on the ponds, runoff inflows into the ponds, and operational design intake flows pumped out of the ponds, and refill flows pumped into the ponds. The model computes in metric units, with inputs and outputs in meters and degrees Celsius. The outputs have been converted to English units for presentation in this report in feet and degrees Fahrenheit.

Meteorological data used to model pond thermal stratification processes include air temperature, dew point, wind speed, wind direction, solar radiation, and cloud cover. Data for the study periods were obtained from the National Oceanic and Atmospheric Administration (NOAA 2009).

Related parameters used by the CE-QUAL-W2 model to influence meteorological effects on the ponds are wind sheltering coefficients and shading coefficients for each segment. These coefficients were determined by a combination of site familiarity and model calibration to the measured temperature profiles in Pond B from 2006. The wind sheltering and shading coefficients work in conjunction with the azimuth of each segment to influence mixing and evaporation due to wind action as well as heating due to solar radiation.

Meteorological data were also used to determine the temperature of the inflows. The temperature of stream flow and direct runoff into the ponds was assumed to be at equilibrium temperature, which was approximated by the three-day trailing average of air temperatures. This

same equilibrium temperature approximation was used for the water temperature of flows withdrawn from the Broad River into the ponds.

Once a model was built, it was calibrated by running the model for a period of time for which field data was available and adjusting the model's internal parameters so that the model output matches the field data as closely as possible.

The Pond B CE-QUAL-W2 model was calibrated to 2006 data because four temperature profiles were available for that year. Water temperatures were collected by Duke Energy staff on four days in 2006: February 27, May 1, August 22, and October 31. For calibration, Pond B was modeled exactly as it existed in 2006 when the temperature data was collected.

The Pond B model was used to compute temperature profiles for four days in 2006 when the temperature data was collected. The computed temperature profiles were compared to the temperature profiles based on the actual temperature data collected as shown in Figure 1. With the modeled temperature profiles close to the field-measured temperature values, the CE-QUAL-W2 model for Pond B was considered adequately calibrated with respect to temperature.

Since the existing Pond A and the proposed Pond C are located near Pond B and have similar natural inflow characteristics to those of the existing Pond B, the model parameters determined during Pond B calibration were applied to Pond A and Pond C.

Pond A was modeled as a stand-alone water body with flows pumped through it consistent with the operation of Ponds B and C. For example, the combined Ponds B and C model's temperature time series at the Pond B intake structure location is used for the temperature of flows pumped from Pond B to Pond A in the Pond A model.

The combined Ponds B and C model simulates the connections between Ponds B and C and the Broad River to demonstrate the influence of station operations on the thermal profiles in each pond.

Section 3
Model Results

To demonstrate whether or not the total design intake flow of the cooling water intake structures on each pond would disrupt the thermal stratification or turnover pattern, two cases were run for the three ponds. The first case was to model the ponds with no pumping into or out of the ponds to determine the natural or expected thermal stratification in the ponds. The second case was to model drought pumping operations through Pond A and hypothetical thirty foot maximum drawdown limitation in Ponds B and C to determine whether the natural or expected thermal stratification in the three ponds would be disrupted. The second case represents the worst case conditions under Duke Energy's proposed Water Management Plan.

Figure 2 shows the thermal profiles for the case of no withdrawal from Pond A. Figure 3(a) shows the results for Pond A with pumping operations through the pond when the pond is refilled from the Broad River. Figure 3(b) shows the results for Pond A with pumping operations through the pond when the pond is refilled from Pond B. In both figures, Pond A would remain thermally stratified with the thermocline depressed to an elevation of 509 ft msl during summer as a result of continuous pumping through the pond to operate the plant. The thermal stratification of Pond A would not be disrupted. Figure 4 shows the thermal profiles for the case of no withdrawal from Pond B. Figure 5 shows the results for a 30 ft drawdown on Pond B. Pond B would remain thermally stratified-although the thermocline would drop to an approximate elevation of 523 ft msl as a result of the 30 ft drawdown limitation (note that the water would be removed from the bottom of Pond B). Figure 6 shows the thermal profiles for the case of no withdrawal from Pond C. Figure 7 shows the results for a 30 ft drawdown on Pond C. Pond C would remain thermally stratified although the thermocline would drop to an approximate elevation of 546 ft msl as a result of the 30 ft drawdown limitation. Similar to Pond B, cooling water from Pond C would also be withdrawn from the bottom of the pond.

The drought contingency ponds are anticipated to be used in during low flow periods on the Broad River that typically occur during the hotter months when the ponds are thermally stratified. When these ponds are being used to supply water to the station, the total design intake flow will not disrupt the thermal stratification or turnover pattern.

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Section 4

Conclusions

Section 316(b) of the Clean Water Act and corollary State law governing cooling water intake structures at new facilities states at 125.84(b)(3)(ii) that:

> "...in a lake or reservoir, total design intake flow must not disrupt natural thermal stratification or turnover pattern (where present) of the source water except in cases where the disruption is determined to be beneficial to the management of fisheries for fish and shellfish by any fishery management agency(ies)."

Pond A and drought contingency Ponds B and C, for the purposes of SCDHEC's regulations, are considered to be reservoirs.

Section 125.83 defines natural thermal stratification as:

> "...the naturally-occurring division of a waterbody into horizontal layers of differing densities as a result of variations in temperature at different depths."

Since EPA did not define disrupt, the definition of disrupt (to break apart; rupture) as found in the Merriam-Webster dictionary is used.

The thermal modeling studies, commissioned by Duke Energy and summarized in this report, indicate that the withdrawal of cooling water for Lee Nuclear Station during normal and significant drought conditions will not disrupt the thermal stratification in Ponds A, B and C. The thermocline in Pond A would drop to an approximate elevation of 509 ft msl as a result of continuous pumping through the pond to operate the plant, but the thermal stratification would not be disrupted. The turnover pattern currently exhibited by existing Ponds A and B is anticipated to continue, with thermal stratification during the summer months and near isothermal conditions during the winter. Proposed Pond C is expected to exhibit similar turnover patterns. Drought contingency Ponds B and C are anticipated to be used during low flow periods on the Broad River which typically occur during the hotter months when the ponds would be thermally stratified. When Ponds B and C are being used to supply water to the station, the total design intake flow will not disrupt the thermal stratification or turnover pattern in the ponds.

This report is focused on the significant drought scenarios when the cooling water intakes on Ponds B and C are used to move water to Pond A. Keep in mind that significant drought periods represent a small percentage of overall station operations. During the 85-year period of record, pumping from drought contingency pond storage would have been used to support station operations approximately 3.2 percent of the time.

Section 5
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FIGURES

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FIGURE 1
POND B CALIBRATION TEMPERATURE PROFILES

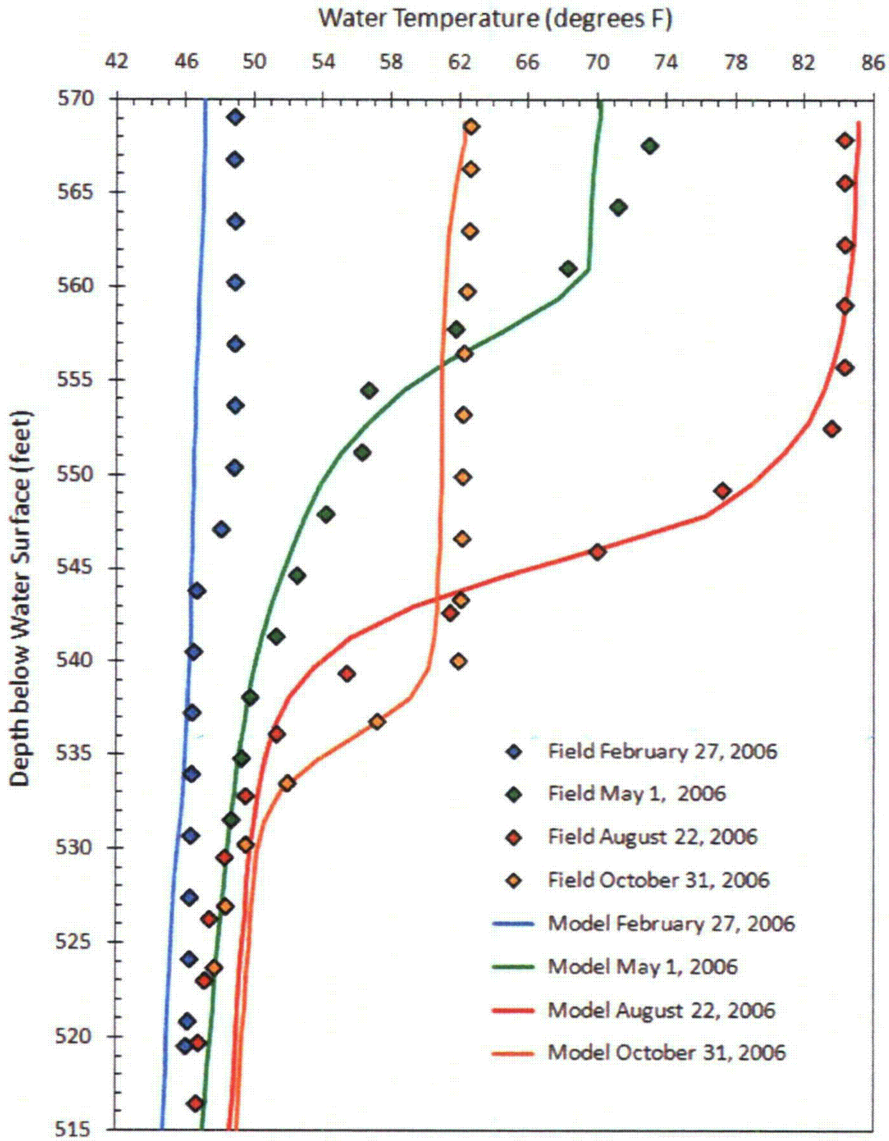


FIGURE 2

POND A THERMAL PROFILES FOR NO WITHDRAWAL FROM POND

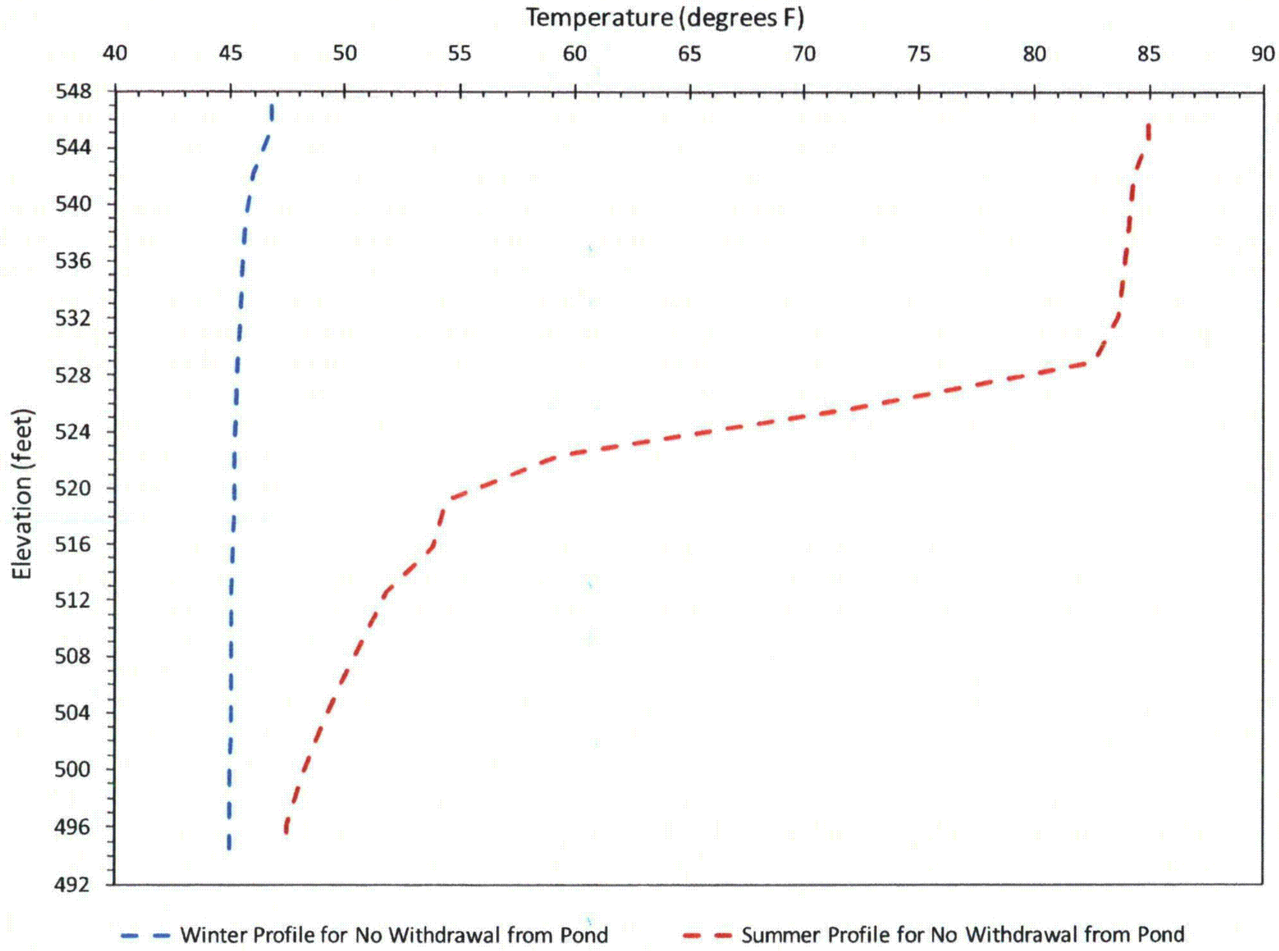


FIGURE 3(a)
POND A THERMAL PROFILES FOR WITHDRAWAL AND NORMAL REFILL
(Pond A refilled from Broad River during 2006)

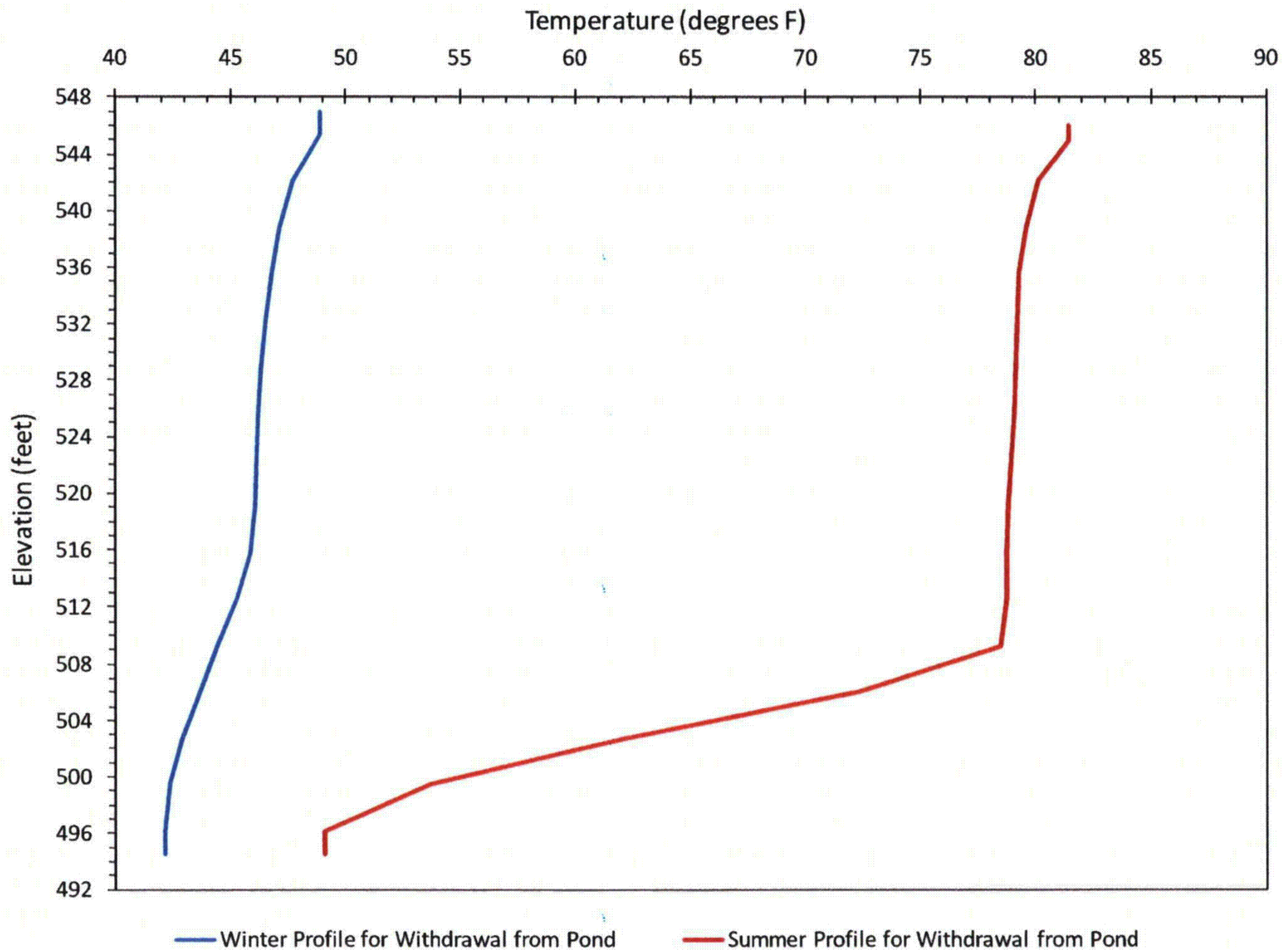
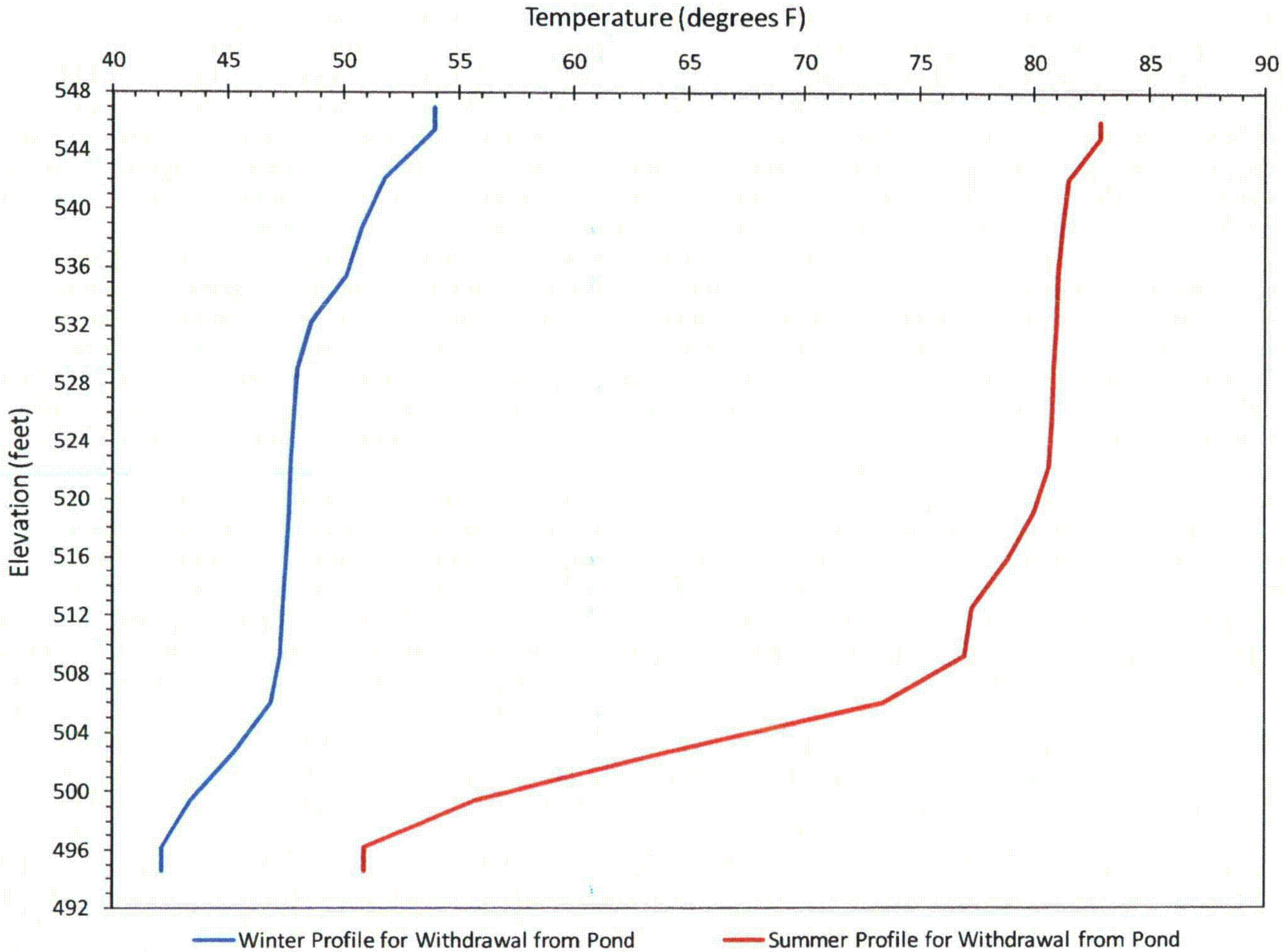


FIGURE 3(b)
POND A THERMAL PROFILES FOR WITHDRAWAL AND ALTERNATE REFILL
(Pond A refilled from Pond B during 2001) [1]



Note 1: Winter profile is based on refill from Broad River because winter river flow supports station needs.

FIGURE 4
POND B THERMAL PROFILES FOR NO WITHDRAWAL FROM POND

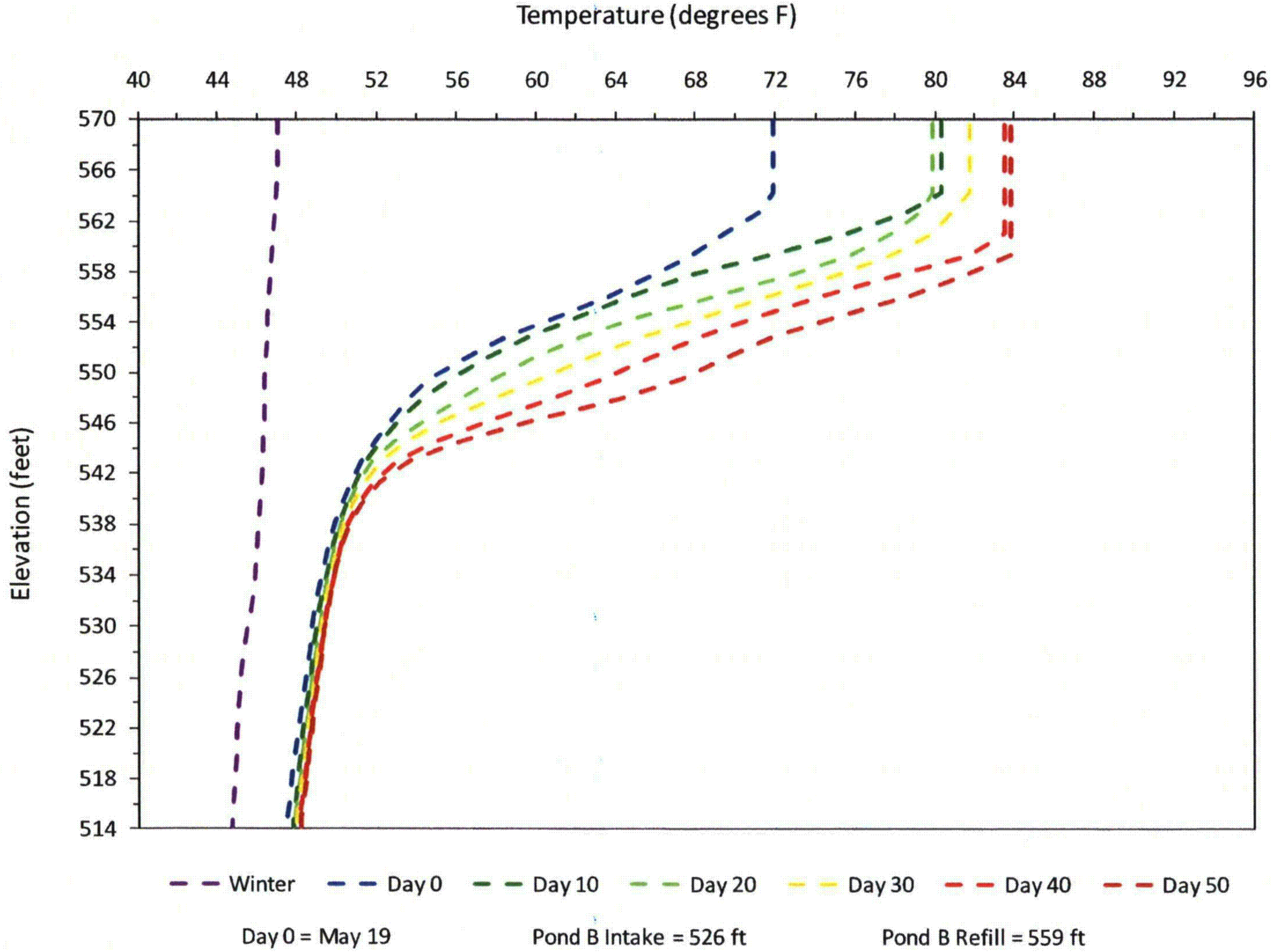


FIGURE 5
POND B THERMAL PROFILES DURING MAXIMUM 30 FT DRAWDOWN

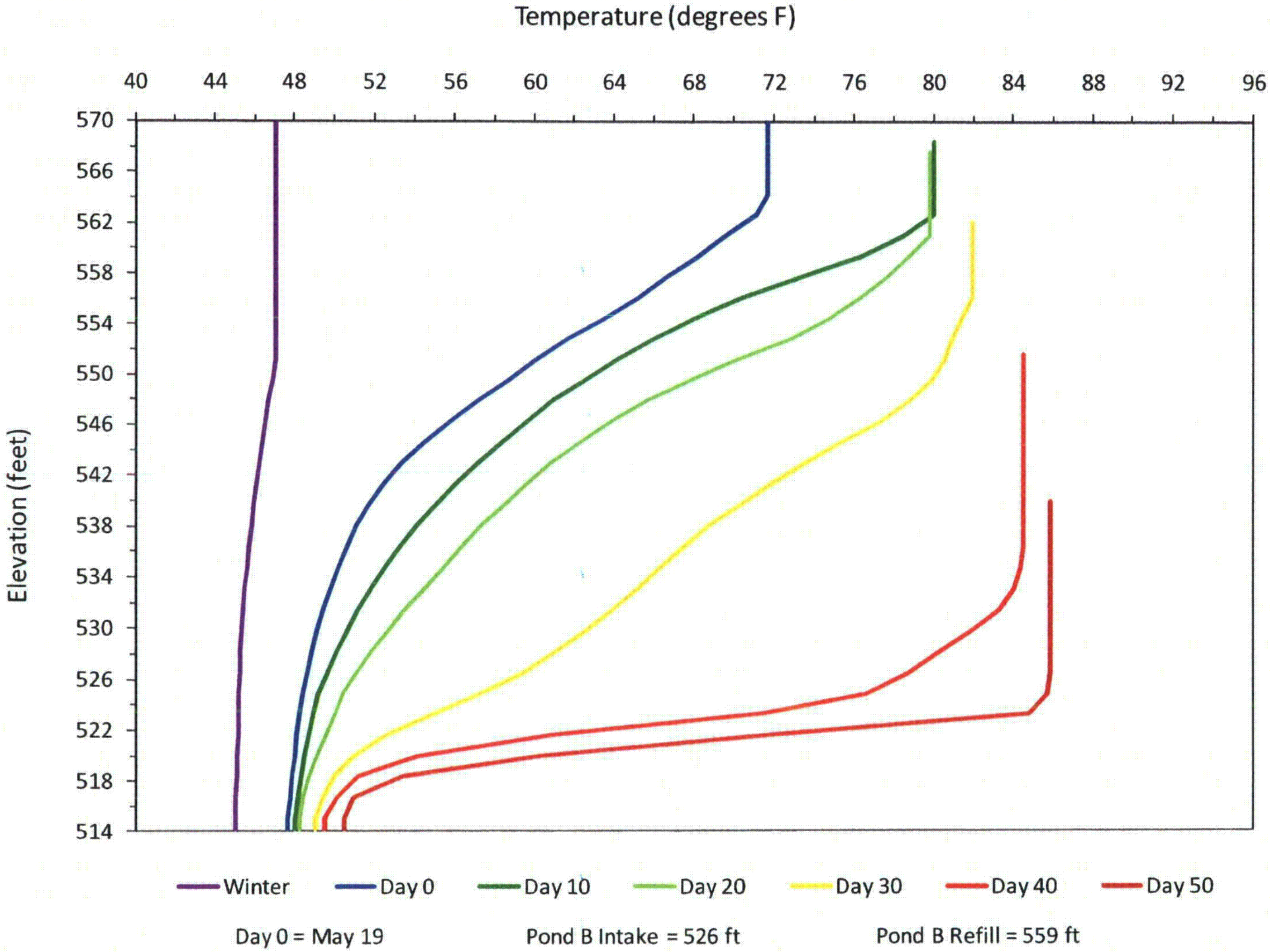


FIGURE 6

POND C THERMAL PROFILES FOR NO WITHDRAWAL FROM POND

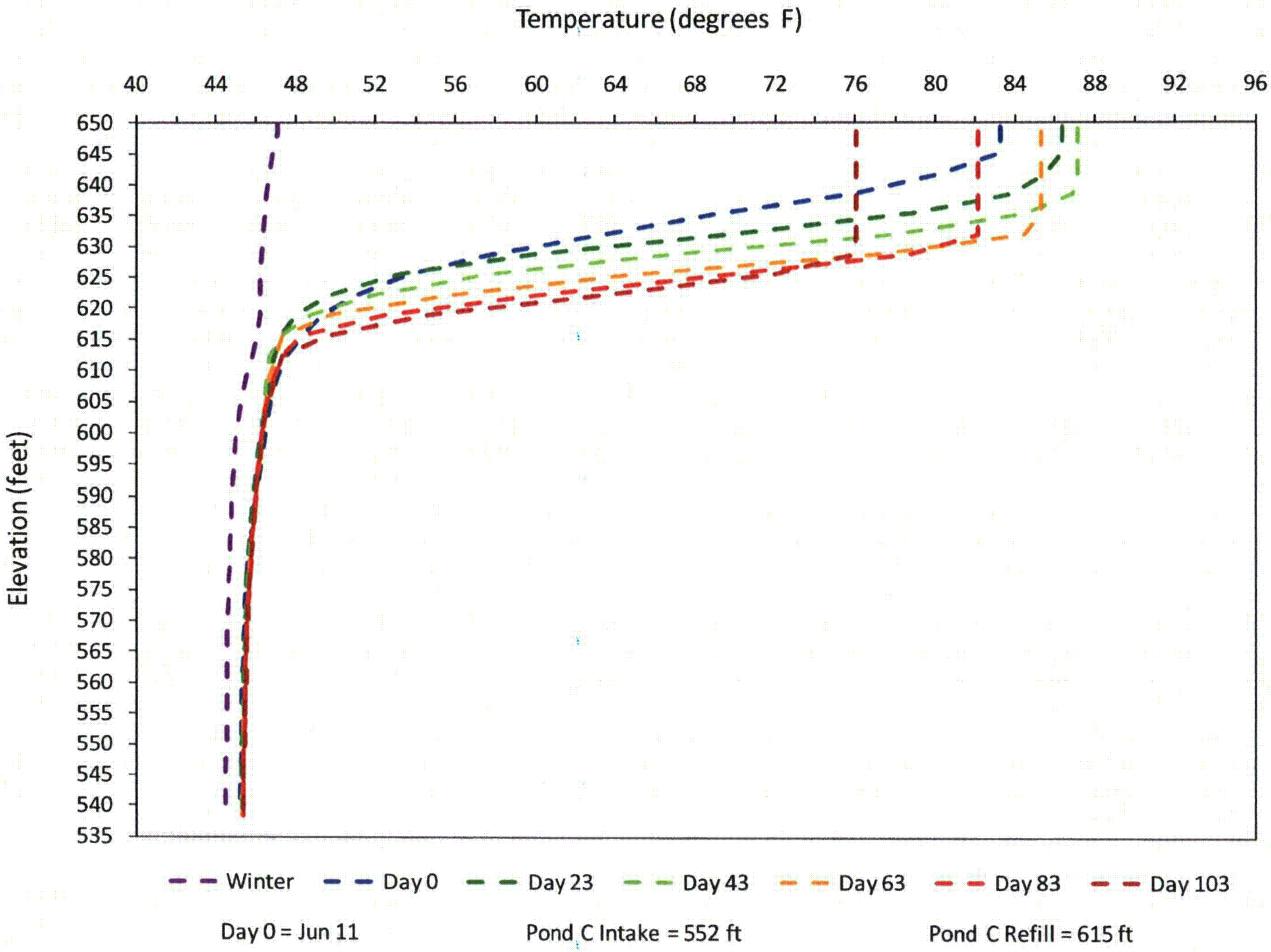


FIGURE 7
POND C THERMAL PROFILES DURING MAXIMUM 30 FT DRAWDOWN