REPORT

SUBSTANTIAL NPDES PERMIT REVISION ST. LUCIE PLANT RESPONSE TO FDEP RFI #1

Florida Power & Light Company

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Substantial Permit Revision Request – St. Lucie Plant

Comment 1: **As the responses to the request below require engineering review and calculations, please submit the responses under the seal of Florida Power and Light's Engineer of Record for this project in accordance with Chapter 471 (P.E.), Florida Statutes.**

Response 1: These responses are submitted under the seal of FPL's Engineer of Record, Harold A. Frediani, Jr., P.E, including the attached Calculations 25, 26, 27, 28, 29, 30, 31, 32, and 33.

Comment 2: **It was unclear from the application whether the requested revisions to the discharge temperature limitations in the existing permit were for an entire calendar year or for certain months in the year. Please clarify the request.**

Response 2: FPL requests the following maximum instantaneous discharge temperature limits, with the cooler months defined as December through May, and the warmer months defined as June through November:

REQUESTED TEMPERATURE LIMITS NORMAL OPERATIONS

	Cooler Months	Warmer Months
Discharge Temperature	117°F	119°F

Based on the Department's Comment 7, FPL understands FDEP's position on this matter that water quality standards for temperature must be applied based on instantaneous maximum levels; therefore, with this document, FPL revises its request that the discharge temperature and temperature rise limits be based on averages. Accordingly, in order to develop proposed instantaneous temperature limits, FPL has performed statistical analysis on recorded intake temperatures for two annual periods, the cooler months of December through May, and the warmer months of June through November, for the period of record August 2005 through May, 2010 (the POR). The maximum intake water temperature during the cooler months was 82.2°F, during the warmer months the maximum intake water temperature was 88.4°F. The response to Comment 4 below describes four operating cases that FPL has analyzed to determine the maximum instantaneous discharge temperatures and temperature rise values for both periods. Case 1, which involves both units operating normally at full load with all eight Circulating Water (CW) pumps operating, can occur during any time of year, and results in a post-uprate discharge temperature rise of 28°F (see Response to Comment 4 below). Based

on that temperature rise, the maximum discharge temperature based on the POR for the cooler months would be 110.2°F (assuming an intake temperature of 82.2°F), and for the warmer months would be 116.4°F (assuming an intake temperature of 88.4°F).

Case 2, which involves both units operating normally at full load with only six CW pumps (three per unit) operating, is expected to occur primarily during the cooler months, and results in a post-uprate discharge temperature rise of 32.1°F (see Response to Comment 4 below). However, based on the cooler values of intake temperatures recorded, 6-pump operation could occur during any time of year. Based on the 32.1°F temperature rise, the maximum discharge temperature based on the POR for the cooler months would be 114.3°F (assuming an intake temperature of 82.2°F).

Case 3, involving the normal operation of only one unit with its four CW pumps energized, results in a post-uprate discharge temperature rise of 28.4°F (see Response to Comment 4 below); therefore Case 3 results in maximum discharge temperatures of 110.6°F during the cooler months (assuming an intake temperature of 82.2°F), and 116.8°F during the warmer months (assuming an intake temperature of 88.4°F).

Case 4 is the maintenance case, involving the operation of both units at full load, with 4 CW pumps energized for one unit and 3 CW pumps energized for the other unit. This operating scenario produces a discharge temperature rise of 29.2°F (see Response to Comment 4 below). That results in a maximum discharge temperature of 111.4°F for the cooler months (assuming an intake temperature of 82.2°F) and 117.6°F for the warmer months (assuming an intake temperature of 88.4°F).

In summary, the maximum discharge temperatures for each case are predicted, based on the POR, to be as follows:

PREDICTED DISCHARGE TEMPERATURES BASED ON POR

Case No.	Cooler Months	Warmer Months
Case 1	110.2°F	116.4°F
Case 2	114.3°F	N/A
Case 3	110.6°F	116.8°F
Case 4	111.4°F	117.6°F

In developing instantaneous temperature limits, FPL proposes that it is reasonable to take into account that the POR is less than 5 years, the plant is licensed by the NRC to operate another 40 years, and the historical record indicates ambient water temperatures in the past have exceeded those in the POR (see Response 6 below) by as much as

1.6^{0}F. Accordingly, in proposing temperature limits, FPL has added a safety factor of 1.6^{0}F to the expected intake water temperatures, and rounded the result up to whole numbers. Additionally, as described in Comment 4 below, FPL believes it is appropriate to add a safety factor to the expected temperature rise of an additional 1^{0}F during cooler months, based on historical data. The results after adding these safety factors are the following requested temperature limits:

REQUESTED TEMPERATURE LIMITS NORMAL OPERATIONS

	Cooler Months	Warmer Months
Discharge Temperature	117°F	119°F

The normal operation maximum discharge temperatures are greater than or equal to the maintenance discharge temperatures; therefore, FPL no longer requests separate limits for discharge temperature during maintenance operations.

Comment 3: **FPL claims in its application that the cooling water discharge temperature is approaching the permit limitation of 113°F at the point of discharge due to rising temperatures at the intake to the nuclear units during normal operations, maintenance activities, or both. The existing permit contains two temperature limitations: 113°F for normal operations and 117°F for maintenance activities, which includes chlorination of the cooling water system. The monthly temperature data submitted to the Department does not separate the discharge temperature data for normal operations from that associated with maintenance activities. Please provide discharge temperature data for the past five years that shows the maximum instantaneous and monthly average temperatures for both normal operation and maintenance activities for each month. If maintenance activities were not conducted in a given month, please indicate that in the submittal.**

Response 3: As a point of clarification, FPL's request for an increased discharge temperature limit was precipitated by a combination of higher Atlantic Ocean temperatures observed in the latter part of the summer of 2007 and 2009, combined with the approximately 3°F increase in discharge temperature from the EPU. These higher temperatures are within the expected range of ambient water temperatures, but were significantly more frequent than in 2005 and 2006 (the years used as the basis for the previous minor permit revision request). Under these 2007 and 2009 conditions, and conservatively projecting them as probable scenarios in the future, the units likely would have to be down-rated to meet the 113°F discharge limit more often than previously expected.

FPL does not track and separate discharge temperature observations during maintenance activities from observations during normal periods of operation unless the discharge temperature exceeds 113°F. This condition, exceeding 113°F discharge temperature, has not occurred during the past permit cycle so FPL has no "separated" temperature information to provide. That being said, the available discharge temperatures have been provided in the response to Comment 5.c. below.

The specific condition setting a 117°F discharge temperature limit applicable during maintenance activities has been present in all St. Lucie NPDES permits issued since the early 1980s. Since that time, certain chlorination and maintenance procedures at the plant have changed, which may now warrant a different permitting approach. Below is a summary and "current situation" for the chlorination and maintenance activities as requested in an email from Marc Harris requesting clarification on this issue:

- What is the frequency of chlorine addition?

  The main turbine condensers are chlorinated daily using sodium hypochlorite for less than 100 minutes per unit.

- What is the frequency of throttling of circulating water pumps?

  Circulating water pump discharge valves are throttled very infrequently. This could occur on a very short term basis during a unit shut down or to mitigate the potential effects of unusual operating events such as a clogged circulating water filter screen, or to minimize chlorine usage.

- How often does the once-through cooling water system become biofouled?

  Subsequent to installing the Taprogge Debris Filter and Condenser Tube Cleaning Systems (CTCS), biofouling of the tubes is uncommon. Use of the CTCS minimizes tube fouling, which increases turbine performance, thus reducing the amount of heat rejected to the circulating water system. The CTCS normally operates continuously to maintain optimum turbine efficiency.

- Is there a different chlorination practice used when the condenser becomes fouled?

  No.

Comment 4: **In the application FPL requested that the statistical basis for the temperature rise limitation across the main condensers during normal plant operations be changed from instantaneous maximum to monthly average. Based on this request it would appear that FPL anticipates the temperature rise to exceed the permit limitation 30°F for normal plant operations after the uprate of Units 1 and 2. However, FPL**

indicated that the worst-case instantaneous maximum temperature rise would be 28.85°F. Please provide engineering calculations for heat transfer between the steam system and once-through cooling water system, including the calculated worst-case temperature rise across the once-through cooling water system, for both pre- and post-uprate of Units 1 and 2 during both normal plant operations and maintenance activities. Please indicate the instantaneous maximum and monthly average being requested for normal plant operations and maintenance activities. In addition, please provide the rationale for the request if greater than the calculated temperature rises for post uprate of Units 1 and 2.

Response 4: As discussed in Response 2 above, FPL has revised it's request for thermal limits based on average temperatures. FPL requests the following instantaneous maximum discharge temperature rise above ambient limits:

Discharge Temperature Rise	33°F

The attached Calculation 25 derives the expected temperature rises for four different post-uprate cases, defined as follows:

- Case 1. Maximum discharge temperature during normal summertime full load operation of both units (eight Circulating Water (CW) pumps running);
- Case 2. Maximum discharge temperature rise over ambient during normal wintertime full load operation of both units (six CW pumps running);
- Case 3. Maximum discharge temperature during normal summertime full load operation of one unit (four CW pumps running); and
- Case 4. Maximum discharge temperature and discharge temperature rise above ambient during transient full load conditions with both units operating (seven CW pumps running).

The post-uprate results are summarized on page 5 of Calculation 25, and are as follows:

POST-UPRATE RESULTS

Post-Uprate Case	Temperature Rise (°F)
1	27.99
2	32.08
3	28.36
4	29.2

Similarly, Calculation 26 derives the expected temperature rises for the same four different cases for the pre-uprate condition. The results are summarized on page 5 of Calculation 26, and are as follows:

PRE-UPRATE RESULTS

Pre-Uprate Case	Temperature Rise (°F)
1	25.45
2	29.16
3	25.74
4	26.46

Cases 1, 2, and 3 are all normal operating scenarios while Case 4 is the maintenance scenario. Examination of the historical data provided in the Response to Comment 5.d. (see Figure 5-d-1 below) indicates that actual recorded temperature differences have been as high as 29.6^{0}F on August 19, 2005, when the plant was presumably operating in Case 1. Because this temperature rise exceeds that predicted above by about 1.6^{0}F, FPL believes it is appropriate to add a safety factor of 1^{0}F to the requested limits. The resulting requested limits are summarized below:

	Cooler Months	Warmer Months
Normal Operations Discharge Temperature Rise	33°F	33°F
Maintenance Discharge Temperature Rise	33°F	33°F

Because the normal operation maximum discharge temperatures rises are as great as the maintenance discharge temperature rises, FPL no longer requests separate limits for discharge temperature rise during maintenance operations.

Comment 5: **Insufficient information has been received to initiate the review process for thermal mixing zone request. Below is a list of items, at minimum, that are required before the review process can begin. Additional information and materials may be requested after the initial review.**

a) **Complete Part III Receiving Water Information on page 2CS-17 of the permit application. Provide any supplemental documents as needed for a mixing zone request.**

b) **Provide all temperature monitoring data for sample point, INT-1, since the current permit issuance.**

c) **Provide all temperature monitoring data from sample point, EFF-2, since the current permit issuance.**

d) **Provide the calculated temperature difference between EFF-2 and INT-1 for the same period of record.**

e) **Expand the thermal discharge study to include far-field analysis of the predicted maximum surface temperature rise above ambient and the location of the isotherms (1°F to 5°F) under slack and bi-directional velocities (10th and 90th percentiles).**

Response 5:

a. The completed Part III is attached as Attachment 5a.

b. The temperature monitoring data is provided electronically as worksheet INT-1 in Excel spreadsheet RFI-1-5. These temperatures have been plotted as Figure 5-b-1.

c. The temperature monitoring data is provided electronically as worksheet EFF-2 in Excel spreadsheet RFI-1-5. These temperatures have been plotted as Figure 5-c-1.

d. The calculated temperature difference between EFF-2 and INT-1 is provided electronically as worksheet Delta T in Excel spreadsheet RFI-1-5. These temperatures have been plotted as Figure 5-d-1.

e. The Operating License Environmental Report for Unit 2 (SL2-ER-OL) includes numerous "tests" that were run to document the expected thermal discharge impacts of operating St. Lucie Units 1 and 2. FPL commissioned field surveys, hydraulic model simulations, and mathematical modeling efforts to produce these tests. For a full description, see Section 5.1 of the SL2-ER-OL (Section 5.1, attached). The hydraulic model studies not only simulated the two different diffusers, but also the site-specific morphometry of the ocean bottom and the shoreline. This response demonstrates which test results are applicable to the proposed uprated units, and what the results from those tests were.

Section 5.1 describes 21 different modeling analyses (tests) for both near and far field which were performed during the permitting of Unit 2. In the interest of conservatism, some of these runs were performed for a heat rejection rate significantly larger than what was expected from the units at full load at that time. Although the heat rejection rate was nominally set at 7 billion Btu per hour per unit for full load conditions, the actual heat rejection rates modeled varied above that due to conservative rounding of input numbers. Table 5-e-1 tabulates the salient characteristics of the model runs (identified as tests) reported in Section 5.1, including actual modeled heat rejection rates.

Tests 1 through 7 were performed to simulate Unit 2 operating alone. Tests 8 through 14 were performed to simulate Unit 1 operating alone. These tests were performed to

simulate the near-field conditions. The hydraulic model studies demonstrated that in the near field, the thermal plumes from the Y-port and the multiport diffusers never interfere with each other (Section 5.1.2.2.2.2 a); therefore, they could be modeled separately and the resultant estimated individual unit volumes enclosed by each isotherm could then be added together to obtain the two-unit volumes. The mathematical model used was the Koh and Fan model, with coefficients calibrated from the hydraulic model studies (Reference 16, Section 5.1).

The hydraulic model studies also demonstrated that the far-field thermal plumes from Units 1 and 2 do not interfere with each other during the nearshore current patterns of flow along the shore, which have a prevailing northward direction and a secondary mode to the south (Section 5.1.2.2.1.2 c). Those current conditions, representing 84% of the measurements taken (Table 5.1-3), were modeled assuming the most frequent current velocities of 0.85 feet per second northward alongshore and 0.85 feet per second southward alongshore (Table 5.1.3). The results from the PDS runs for each unit were then superimposed for those non-slack cases. Slack tide conditions, estimated to occur about 8% of the time (Section 2.4.2.3 of SL2-ERE-OL, attached) were also modeled and shown to be the worst case both for near and far field with respect to the volumetric size of the isotherms. Slack tide was found to be the only condition under which the Unit 1 and Unit 2 far fields interfered with each other. The Prych-Davis-Shirazi model (PDS, reference 18 in Section 5.1) was calibrated with the hydraulic model study data and used to simulate the far-field conditions. Under the two longshore current conditions modeled, the PDS runs were done separately and predicted no interference between each other. For the slack tide case, the PDS model was run to the point where the two plumes intersected; at that point a new source was formulated with its characteristics determined by conserving or combining the total heat, volume, and momentum flux of both discharges, and the modeling was continued for that combined source.

FPL has identified two full-load normal operating scenarios that will determine the maximum expected discharge temperature and the maximum expected discharge temperature rise from the facility. These two cases will bound the expected size of the mixing zone. The maximum discharge temperature, which has been identified as Case 1, is expected to occur when the units are both operating at full load with all eight Circulating Water (CW) pumps energized and the maximum intake water temperature (CW intake temperature or CWIT). Based on the intake water temperature analysis described in Response to Comment 6, FPL estimates that the maximum expected CWIT is 90 degrees F. The maximum discharge temperature rise, which has been identified as Case 2, is expected to take place during wintertime, when the units are both operating at full load, with only six CW pumps energized, three per unit. FPL has identified the 90%

intake water temperature (that temperature equaled or exceeded 90% of the time) as 70°F to be used with Case 2.

FPL has identified two other cases to be examined. Case 3 is when only Unit 1 is operating, and its discharge is leaving via both diffusers. Because the resultant CW flow rate is approximately half that of Case 1, the jet discharge velocity from all diffuser ports is lower in Case 3. Therefore, FPL has determined that Case 3 is the worst case with respect to the 97°F limit on the water surface. Case 4 is a maintenance case, which assumes Unit 1 is operating at full load with four CW pumps energized and Unit 2 is operating at full load with three CW pumps energized; with the fourth CW pump out of service for maintenance.

Table 5-e-2 tabulates the salient features of the four cases FPL has identified. FPL submits that a comparison of Table 5-e-2 with Table 5-e-1 demonstrates that the following tests from Section 5.1 adequately address the conditions for modeling the designated cases:

1. Test 19 is a valid simulation for Case 1. They have the following characteristics:

	Heat Rejection Rate (Btu per hour)	Temperature Rise (°F)	CW Flow Rate (cfs)
CASE 1	14.2 billion	27.99	2,301
TEST 19	14.2 billion	28	2,290

Although the ambient water temperature and discharge water temperature in Test 19 are 3°F lower than those in Case 1, if the model results are expressed in terms of temperature rise above ambient, the plume configuration will be nearly identical, as demonstrated in Section 3.1 of the Thermal Discharge Study submitted with the original application for permit modification.

2. Test 15 is a valid simulation for Case 2. They have the following characteristics:

	Heat Rejection Rate (Btu per hour)	Temperature Rise (°F)	CW Flow Rate (cfs)
CASE 2	14.3 billion	32.08	2,014
TEST 15	14.2 billion	32	2,003

3. Test 12 is a valid simulation for Case 3. They have the following characteristics:

	Heat Rejection Rate (Btu per hour)	Temperature Rise (°F)	CW Flow Rate (cfs)
CASE 3	7.2 billion	28.4	1,143
TEST 12	7.1 billion	28	1,145

There are no good matches among the tests for Case 4. However, the Case 4 far field results are expected to lie between those of Cases 1 and 2, since all three cases have the same approximate heat rejection rate. Therefore, Case 4 will not be a worst case.

In order to determine which of the tests, or Cases, is the worst case with respect to far-field surface isotherms, the areal extent of the 2°F and 5°F surface isotherms have been tabulated in Tables 5-e-3 and 5-e-4, respectively. In the north and south longshore tests (or Cases), the areas for each unit are tabulated separately and added together to find the total combined areas for both units. In the stagnant (or slack) condition, the combined units' operation has been estimated with the PDS model as described above. The information from Tables 5-e-3 and 5-e-4 has been plotted in Figures 5-e-1 and 5-e-2, respectively.

Based on the results shown in Tables 5-e-3 and 5-e-4, and Figures 5-e-1 and 5-e-2, it is concluded that the largest far-field thermal plumes, with respect to the size of the surface isotherms, occur during Case 2. This was expected because Case 2 has a higher ΔT and lower CW flow rate than the other cases. Because of the lower flow rate, the discharge velocity at the diffuser ports is lower; therefore, the offshore component of the plume's velocity is smaller. Because Case 2 produces the largest thermal plume, and the thermal plume with the least offshore penetration, the SL2-ER-OL provided surface isotherm plots only for that Case. Further, because the results of Unit 1 hydraulic model studies indicate the Unit 1 thermal plume configuration is independent of the current conditions (see Section 5.1.2.3.2.1), the SL2-ER-OL only presented surface isotherms for the Unit 1 thermal plume under slack tide conditions. For that reason, Section 5.1 of the SL2-ER-OL included Unit 1 effects only in the plots of estimated surface isotherms for the slack tide conditions.

FPL has used the SL2-ER-OL thermal plume isotherm maps to prepare composite thermal plume maps of the combined plume for both units under worst-case conditions based on the thermal plume maps provided in the SL2-ER-OL. Figures 5.1-3 (Unit 2 isotherms for southward current) and Figure 5.1-5 (Unit 1 surface isotherms) have been combined to produce Figure 5-e-3 Combined Surface Isotherms for Units 1 and 2 under Southward Current Conditions. Figures 5.1-4 (Unit 2 isotherms for northward current) and Figure 5.1-5 (Unit 1 surface isotherms) have been combined to produce Figure 5-e-4 Combined Surface Isotherms for Units 1 and 2 under Northward Current Conditions. Figure 5.1-6 has been reproduced as Figure 5-e-5 Combined Surface Isotherms for Units 1 and 2 under Slack Current Conditions.

Examination of Figures 5-e-3, 5-e-4, and 5-e-5 leads to the following observations:

1. The surface thermal plume is influenced by the ambient current direction, bending to the north during northward currents, to the south during southward currents, and moving directly offshore during slack current.
2. The surface thermal plumes in all 3 current conditions that were modeled are entirely seaward of the 18-foot contour, which crosses the seaward end of the Y-nozzle diffuser.
3. The only 5°F surface thermal contour is produced by the Unit 1 discharge, and encompasses less than 5 acres for Cases 1 and 3, and less than 15 acres for Case 2 (see Table 5-e-4).

Based on these observations, the following conclusions can be drawn:

1. Because the 18-foot depth contour defines the landward extent of Open Waters (see FAC 62-302.520(3)(f), and the thermal plumes are all seaward of that 18-foot contour, the thermal plume does not enter the coastal waters; therefore, coastal waters thermal limits do not apply to the St. Lucie Plant thermal discharge.
2. Because the thermal criteria for open waters limits water temperatures to 17°F above ambient, outside of any mixing zone, the mixing zone needed for the St. Lucie Plant is smaller than the 5°F isotherm shown on Figure 5-e-3.
3. Outside of the designated mixing zone, water quality standards for open waters will be met; therefore, it can be presumed that far field effects on biota will not be adverse.

However, Comment 5.e. specifically asked for the location of the 1°F to 5°F isotherms under slack and bidirectional currents. Although such isotherms were not produced for the SL2-ER-OL, they were produced for the earlier Unit 2 Construction Permit Environmental Report (SL-2), and the construction permit for Unit 2 was granted based on the environmental impacts described in that document. The analysis performed was identified as conservative, in that isotherm sizes resulting from the modeling were understood to be much larger than those which would occur in the real world. They are more conservative than known at that time because the multiport diffuser modeled in SL2 assumed discharge ports perpendicular to the main diffuser axis (i.e., with no offshore velocity component). These isotherm maps are presented in response to this comment with the understanding that they are conservative, including Figure 5.1-14 for southward currents, Figure 5.1-15 for northward currents, and Figure 5.1-16 for slack conditions.

It is valuable to repeat the conclusions reached by the agency in charge of the permitting of St Lucie at the time of the Environmental Reports that have been referenced above. In the Unit 2 FES, April, 1982, the U.S. Nuclear Regulatory Commission stated, "Heated

water will slightly increase the water temperature of the Atlantic Ocean in the vicinity of the discharge, but the effects on marine biota will be minimal."

Comment 6: **FPL noted an increased rise in ambient temperature at sampling point INT-1 and attributes the rise to increased Atlantic Ocean temperatures. According to Rule 62-302.520(3)(a), F.A.C., ambient temperature of a receiving body of water is determined at a location unaffected by manmade thermal discharges and at the same depth and exposure to winds and currents as the most stable portions of the receiving body of water. No persuasive data have been submitted to demonstrate that INT-1 monitoring data are representative of ambient conditions. For instance, analyses of global surface temperature change are routinely carried out by several groups including the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the National Research Council (NRC), and the Intergovernmental Panel on Climate Change (IPCC). The analyses encompass global climate data, decades of long-term measurements and modeling simulations to determine changes in surface temperature. Similar efforts by FPL will be necessary to supplant its case that INT-1 is representative of ambient Atlantic Ocean temperatures at the ocean intake structure and that the change in ocean temperatures is significantly higher than that claimed by the organizations mentioned above.**

Response 6: FPL is not asserting that there has been an increased rise in ocean ambient temperatures as a general matter, but that it is appropriate to account for temperature extremes that will be faced by a facility expected to operate for the next 40 years. The U.S. Nuclear Regulatory Commission reported that "Sea water temperatures on the Atlantic Ocean offshore of the site were found to range from about 15°C (59°F) to 32°C (90°F) between 1971 and 1978." (Section 4.3.3 of the Unit 2 Final Environmental Statement related to the operation of St. Lucie Plant Unit No. 2, Docket No. 50-389, USNRC, April, 1982). Based on that evidence, FPL has assumed a design maximum intake water temperature of 90°F is appropriate.

With respect to FPL's assumption that the intake water temperature is a reasonable surrogate for the ambient water temperature, FPL has analyzed the frequency distribution of water temperatures at the St. Lucie intake and at two National Data Buoy Center Stations, Station 41114 off Fort Pierce, Florida, and Station 41009, off Cape Canaveral. Both measure sea surface water temperatures at a depth of about 1 meter. The frequency distributions for the three sampling locations are shown on Figure 6-1. The frequency distributions indicate the following:

- The St Lucie intake water temperatures are less than or equal to the Buoy 41114 water temperatures about 94% of the time, for all temperature less than or equal to 84°F.
- Both the St Lucie intake water temperatures and the 41114 buoy water temperatures are generally about 2°F lower than the Canaveral Buoy water temperatures at any given frequency of occurrence.

Based on these data, it is concluded that the St. Lucie intake water temperature is an excellent surrogate for the ambient water temperature.

Comment 7: **In the application FPL requested that the temperature limitation for normal plant operations be raised from 113°F to 115°F at the point of discharge and that the statistical basis be changed from instantaneous maximum to monthly average. Temperature limits as set forth in Rule 62-302.520(5)(b), F.A.C., are based on maximums not on monthly averages.**

The application included a thermal discharge study report in which modeling was conducted to assess the thermal plume impacts associated with an instantaneous maximum discharge of 115°F. Based on the request to change the statistical basis, it would appear that FPL anticipates exceeding a discharge temperature of 115°F. Using the results of the calculations from item 4 and ambient Atlantic Ocean temperature from item 6 above, please provide the following:

a. calculations for the instantaneous maximum at the point of discharge pre and post uprate of Units 1 and 2 during both normal plant operations and maintenance activities;

b. the instantaneous maximum and monthly average being requested for normal plant operations and maintenance activities, as well as the rationale of greater than the calculated temperatures for post uprate of Unit 1 and 2;

c. a revised thermal discharge study report using the absolute instantaneous maximum temperatures and maximum temperature differences between the effluent and ambient conditions; and

d. the revised thermal discharge study report must also demonstrate whether the thermal discharge plume is entrained back into the plant; taking into account the approach velocities at the Atlantic Ocean intake structures.

Response 7: a. The attached Calculation 25 derives the expected temperature rises for four different post-uprate cases, as described in Response 4 above. Similarly, Calculation 26

derives the expected temperature rises for the same four different cases, for the pre-uprate condition. Cases 1, 2, and 3 are normal operation cases and Case 4 is the maintenance case.

b. As indicated above, FPL has revised its request for any average temperature limits, and now requests only instantaneous limits.

FPL requests the maximum instantaneous temperature limitations described in Response to Comments 2 and 4 above, as follows:

REQUESTED TEMPERATURE LIMITS NORMAL OPERATIONS

	Cooler Months	Warmer Months
Discharge Temperature	117°F	119°F
Discharge Temperature Rise	33°F	33°F

Because the normal operation maximum discharge temperatures and temperature rises are as great as the maintenance discharge temperatures and discharge temperature rises (see responses to Comments 2 and 4 above), FPL no longer requests separate limits for discharge temperature and temperature rise during maintenance operations.

c. FPL has revised and attached the Revised Thermal Discharge Study to address the absolute instantaneous maximum temperatures and maximum temperature differences between the effluent and ambient conditions.

d. FPL provided a detailed explanation of the process in which a small portion of the thermal discharge can be recirculated into the intake during the final permitting of Unit 2. This discussion is in Section 5.1.2.3.3 of the SL2-ER-OL (attached) and concludes that recirculation can only occur during southward currents, and that it would amount to a maximum increase of 1.2°F in magnitude. Based on the response to Comment 6 above, recirculation actually measured appears to be minimal.

Comment 8: **The Department considers the proposed discharge to be an expanded discharge and thereby subject to anti-degradation requirements in Rules 62-4.242 and 62-302.300, F.A.C. As part of the anti-degradation demonstration, please provide an evaluation of the feasibility of other options in addition to those proposed in the submitted analysis. The options evaluation should include extending the multiport and "Y" port discharge pipes to eliminate any entrainment of heated discharge at the Atlantic Ocean intake structure, converting the "Y" port into a multi-port diffuser, as well as options for additional heat removal at the primary, secondary**

and tertiary cooling systems. Please note that FPL may need to conduct modeling for some of these options to demonstrate whether changes to the thermal plume are significant.

Response 8: FPL provided antidegradation analysis in its application for permit revision. As requested, FPL additionally has evaluated the costs and benefits of the following options (see Attachment 8-1):

1. Extending the y-port diffuser.

   This option would result in removing the existing y-port diffuser and rebuilding it 2,600 feet further seaward to eliminate all possibilities for recirculation. Further modeling (including physical modeling) would be required to determine an exact location. This is the same for each of the options. Costs could be less if less piping is required and more if more piping is required.. The total cost was conservatively estimated at $40 MM. The environmental impacts of this option, mainly associated with dredging to install new pipe, would be significant, but temporary.

2. Extending the multi-port diffuser.

   This option would include capping the existing multi-port diffuser, extending the pipe 700 feet seaward and construction of a new, identical multiport diffuser. The total cost is conservatively estimated at $26 MM. The environmental impacts of this option, mainly associated with dredging to install new pipe, would be significant, but temporary.

3. Replacing the current y-port diffuser with a new multi-port diffuser 4,100 feet seaward of the dune line.

   This option would require construction of 4,100 feet of a new 16-foot pipe and a new multi-port diffuser at the end. The total cost is conservatively estimated at $43 MM. The environmental impacts of this option, mainly associated with dredging to install new pipe, would be significant, but temporary.

Completely eliminating recirculation would require a combination of either Option 1 and 2, or Option 2 and 3. The first combination would have a total cost of $66 MM, while the second would have a total cost of $69 MM. These values represent approximately 8% of the total cost of the EPU.

Please note that, based on modeling conducted as part of the facility's Unit 2 Environmental Report Operating License Application (Section 5.1.2.3.3, which is attached), the current configuration of y-port, multi-port and intakes result in recirculation

during some southerly currents with a very conservatively estimated maximum increase in intake temperature of 1.2°F. As demonstrated in FPL's response to Comment 6, which compared St. Lucie Plant intake temperatures to the National Data Buoy Center Station 41114, off of Ft. Pierce, Florida, the recirculation actually measured is minimal, as the plant intake temperatures are less than or equal to the 41114 buoy water temperatures about 94% of the time, and for all temperatures less than 84°F.

Furthermore, if FPL makes any of the physical modifications presented above, it will not remove the need for utilizing one of the options presented in the original application (listed below) so the facility will be able to meet the current 113°F discharge limit.

In the original substantial revision application, FPL explored several options as part of the anti-degradation determination. As requested by FDEP, FPL is amending that application to present the percentage of the estimated total cost of the EPU project associated with each of the options previously presented:

Option	Percent of Total Project Cost	Estimated Total Cost
Increase Intake Flow	10 – 14%	$80 – 120 Million
Helper Cooling Towers	11%	$95 Million
Reducing Power When Discharge Limit is Exceeded		$6 Million/year – O&M Only

Note: FPL has not evaluated "additional heat removal at the primary, secondary and tertiary cooling systems" for the following reasons: The Intake Cooling Water (ICW) System provides cooling for various plant primary, secondary and tertiary cooling systems. This system shares the ocean intake and discharge tunnels with the Circulating Water (CW) System. The total ICW System flow from both Unit 1 and Unit 2 is 58,000 gpm, which is quite small compared to the total flow of 974,600 gpm form the CW System. The heat rejected by the ICW System is approximately 390 million Btu/hr, which is only 2.8% of the approximately 13,800 million BTU/hr from the CW System. As such, the contribution of additional heated water flow to the Discharge Tunnels is insignificant. Miscellaneous effluent discharge flows into the discharge flumes are significantly less than Intake Cooling Water and are of no significance in the total flow discharged to the Atlantic Ocean. As any changes to the primary, secondary and tertiary cooling systems are regulated by the NRC, they would be extremely costly to make such changes at this point of the project, and would result in little or no reduction to the ocean discharge temperature.

Comment 9: **Please note that the application was insufficient to begin a review of whether the proposed increase in discharge temperature affects the extent of the thermal plume under certain oceanic conditions and ultimately the indigenous population of flora and fauna in and on the receiving water body. Hence, there may be additional questions from Department's Biology Section and the Florida Fish and Wildlife Conservation Commission after FPL submits the requested information and modeling for the thermal plume.**

Response 9: The response to Comment 5e describes in detail the multiple thermal modeling analyses for both near and far field which were performed by FPL during permitting for Unit 2. Please refer to that response for a detailed description of the extent of the thermal plume under the most likely oceanic conditions. The current conditions used for this modeling effort were based on actual current measurements taken during a 12-month period in 1974 – 1975. These current measurements demonstrate that nearshore currents generally flow parallel to the shoreline, with a prevailing northward direction and a secondary mode to the south. The oceanic conditions modeled were current patterns of flow along the shore (representing 84 percent of the time), and slack tide conditions (representing about 8 percent of the time).

As presented in the Revised Thermal Discharge Study (June 2010) the difference in the *extent and volume of the thermal plume attributable to the increase in discharge* temperature from 113 to 119 degrees F is relatively small. For the Y-nozzle diffuser, the increase in size for the 17 degree F isotherm is about 6,858 cubic feet (from about 2,439 cubic feet to 9,297 cubic feet). The 17-degree F isotherm increase for the multiport diffuser is negligible (from 614 to 652 cubic feet).

The increase in size of the 17-degree F thermal plume in the Atlantic Ocean is about the size of a cube, 19-feet on each side. Heated water exiting the diffusers at 119 degrees F would be cooled down to 97 degrees F within about 25 seconds. The proposed change in the thermal discharge will increase the temperature of a small volume of the Atlantic Ocean water column in the vicinity of the St. Lucie Plant discharge. The proposed thermal discharge is expected to quickly mix with the Ocean waters and is not expected to interact with benthic organisms (see Section 5 of the original Thermal Discharge Study).

The plume is expected to float as it mixes, thus water column organisms may interact with the surfacing heated plume. It is important to note that the water is discharged from the diffusers at high velocity and thus in effect will displace ambient water as it mixes. This is important in regards to the interaction of planktonic organisms such phytoplankton (algae), zooplankton (floating early life stages of invertebrates), and ichthyoplankton (early life stages of fish). These free-floating organisms can't avoid a thermal plume, but due to the initial exit velocity they would be expected to be pushed away from the diffuser by the turbulent diffusing thermal plume and are less likely to be entrained in the higher temperature plume. Fish and other swimming organisms, such as sea turtles, have been shown to avoid high temperature areas by simply swimming away from the source.

The Operating License Environmental Report for Unit 2 (SL2-ER-OL) includes a thorough discussion of the effects of the Plant operation on the Atlantic Ocean in the vicinity of the

St. Lucie Plant. This thermal literature review and conclusions remain relevant to the operation of the Plant. For a full description, see Section 5.1.3.2 of the SL2-ER-OL, attached. The ABI 1980 report entitled "Effects of Increased Water Temperature on the Marine Biota of the St. Lucie Plant Area" cited in this section was previously submitted to the FDEP and it includes the detailed thermal review.

The following are some of the report conclusions:

- Fish: fishes are highly mobile and will avoid unfavorable thermal regimes near the discharge;
- Sea Turtles: Adult marine turtles are mobile and will avoid unfavorable thermal regimes. Based on studies of swimming speed of sea turtle hatchlings in response to thermal increases, it is anticipated that the few turtles that might encounter these higher water temperatures would resume normal swimming speed after leaving the exposure area. No effects on distribution, nesting, egg development, or survival are expected;
- Benthic Macroinvertebrates: no impact on the benthic macroinvertebrate community is anticipated;
- Phytoplankton: impact on phytoplankton should be insignificant and rapid turnover rates in the community would compensate for this reduction; and
- Ichthyoplankton, zooplankton: some temperature effects can be expected on ichthyoplankton and zooplankton being entrained in the heated plume.

Comment 10: The industrial wastewater NPDES permit for the St. Lucie power plant expires on January 19, 2011. In accordance with federal regulations at 40 CFR 122.5(a), the Department is unable to finalize a revision to an industrial wastewater NPDES permit once the permit has expired; even when the permit is administratively continued. If the revision is not finalized prior to permit expiration, the requested revision can either be finalized once the permit is renewed or, at the request of the permittee, included as part of the permit renewal. Note, the thermal plume modeling requested in this letter is a completeness requirement for this revision application and the upcoming permit renewal application. Please account for this regulation when scheduling information gathering and modeling activities to provide a complete application and to meet FPL's own timeframes for completing the uprate project.

Response 10: No response required.

TABLES

TABLE 5-e-1
MODEL RUNS IN OLER SECTION 5.1.

Tests from U2-OLER (Table 5.1-7)

Test	Units Operating (at full load)	CW pumps operating	CW Flow gpm	CW Flow cfs	Heat Rejection Rate - Btu/hour	Heat Rejection Rate - Billion Btu per Hour	CWIT	CWOT	ΔT
1	2	4	449,473	1001.5	7,088,504,832	7.09	87	119	32
2	2	4	426,809	951	6,731,071,488	6.73	87	119	32
3	2	3	489,192	1090	7,714,897,920	7.71	87	119	32
4	2	3	375,197	836	5,917,114,368	5.92	87	119	32
5	2	4	513,876	1145	7,091,159,040	7.09	87	115	28
6	2	4	630,115	1404	8,695,185,408	8.70	87	115	28
7	2	4	482,460	1075	6,657,638,400	6.66	87	115	28
8	1		449,473	1001.5	7,088,504,832	7.09	87	119	32
9	1		472,138	1052	7,445,938,176	7.45	87	119	32
10	1		305,184	680	4,812,963,840	4.81	87	119	32
11	1		419,179	934	6,610,747,392	6.61	87	119	32
12	1	4	513,876	1145	7,091,159,040	7.09	87	115	28
13	1		397,637	886	5,487,132,672	5.49	87	115	28
14	1		545,292	1215	7,524,679,680	7.52	87	115	28
15	1 & 2		898,946	2003	14,177,009,664	14.18	87	119	32
16	1 & 2		898,946	2003	14,177,009,664	14.18	87	119	32
17	1 & 2		794,376	1770	12,527,861,760	12.53	87	119	32
18	1 & 2		794,376	1770	12,527,861,760	12.53	87	119	32
19	1 & 2	8	1,027,752	2290	14,182,318,080	14.18	87	115	28
20	1 & 2	8	1,027,752	2290	14,182,318,080	14.18	87	115	28
21	1 & 2	8	1,027,752	2290	14,182,318,080	14.18	87	115	28

Conversion Factor
221,184

TABLE 5-e-2.
CASES IDENTIFIED BY FPL TO ANALYZE

Cases from Calc 25

Case	Units Operating (at full load)	CW pumps operating	CW Flow gpm	CW Flow cfs	Heat Rejection Rate - Btu/hour	Heat Rejection Rate - Billion Btu per Hour	CWIT	CWOT	ΔT
1	1 & 2	8	1,032,600	2,301	14,199,110,000	14.20	90	118.0	27.99
2	1 & 2	6	904,000	2,014	14,298,000,000	14.30	70	102.1	32.08
3	1	4	513,000	1,143	7,148,350,000	7.15	90	118.4	28.36
4	1 & 2	7	993,000	2,213	14,246,990,000	14.25	90	119.2	29.20

TABLE 5-e-3.
MODEL RESULTS FROM SECTION 5.1 FOR
2 DEGREE F. SURFACE ISOTHERM

Test Number	Associated Case	Area enclosed by 2 degree Isotherm		
		Stagnant	Southward	Northward
19 [1]	1			
	Unit 1 [b]	173	173	173
	Unit 2 [a]	172	175	28
	Units 1 & 2 [c]	345	348	405
15 [2]	2			
	Unit 1 [b]	270	270	270
	Unit 2 [a]	285	872	589
	Units 1 & 2 [c]	555	1142	644
12	3			
	Unit 1 [b]	173	173	173
	Unit 2	-	-	-
	Units 1 & 2	173	173	173

[1] Test 19 = Test 5 plus Test 12
[2] Test 15 = Test 1 plus Test 8
[a] from Table 5.1-7
[b] from Table 5.1-12
[c] from table 5.1-13, stagnant conditions only, by superposition for northward and southward

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TABLE 5-e-4.
MODEL RESULTS FROM SECTION 5.1 FOR 5 DEGREE F. SURFACE ISOTHERM

Test Number	Associated Case	Area enclosed by 5 degree Isotherm		
		Stagnant	Southward	Northward
19 [1]	1			
	Unit 1 [b]	4.9	4.9	4.9
	Unit 2 [a]	0	0	0
	Units 1 & 2 [c]	4.9	4.9	4.9
15 [2]	2			
	Unit 1 [b]	14.6	14.6	14.6
	Unit 2 [a]	0	0	0
	Units 1 & 2 [c]	14.6	14.6	14.6
12	3			
	Unit 1 [b]	4.9	4.9	4.9
	Unit 2	-	-	-
	Units 1 & 2	4.9	4.9	4.9

[1] Test 19 = Test 5 plus Test 12
[2] Test 15 = Test 1 plus Test 8
[a] from Table 5.1-7
[b] from Table 5.1-12
[c] from table 5.1-13, stagnant conditions only, by superposition for northward and southward

TABLE 5.1-3

FREQUENCY DISTRIBUTION OF LONGSHORE CURRENT SPEED AND DIRECTION AT THE ST LUCIE SITE

Current Speed Group (ft/sec)	Southward Frequency (%)	Quadrant Cumulative	Northward Frequency (%)	Quadrant Cumulative
0.0 - 0.1	0.06	0.06	0.44	0.44
0.1 - 0.2	0.33	0.39	0.52	0.96
0.2 - 0.3	0.76	1.15	0.82	1.78
0.3 - 0.4	0.97	2.12	0.97	2.75
0.4 - 0.5	3.27	5.39	3.92	6.67
0.5 - 0.6	3.25	8.64	3.68	10.35
0.6 - 0.7	4.11	12.75	5.57	15.92
0.7 - 0.8	4.28	17.03	6.49	22.41
0.8 - 0.9	5.65	22.68	8.65	31.06
0.9 - 1.0	3.27	25.95	5.61	36.67
1.0 - 1.1	3.66	29.61	4.99	41.66
1.1 - 1.2	2.22	31.83	3.48	45.14
1.2 - 1.3	1.19	33.02	1.69	46.83
1.3 - 1.4	0.58	33.60	1.05	47.88
1.4 - 1.5	0.36	33.96	0.48	48.36
1.5 - 1.6	0.20	34.16	0.27	48.63
1.6 - 1.7	0.12	34.28	0.24	48.87
1.7 - 1.8	0.17	34.45	0.20	49.07
1.8 - 1.9	0.03	34.48	0.14	49.21
1.9 - 2.0	0.08	34.56	0.19	49.40

FIGURES

Figure 5-b-1. Intake Temperature
1/4/2005 through 5/31/2008

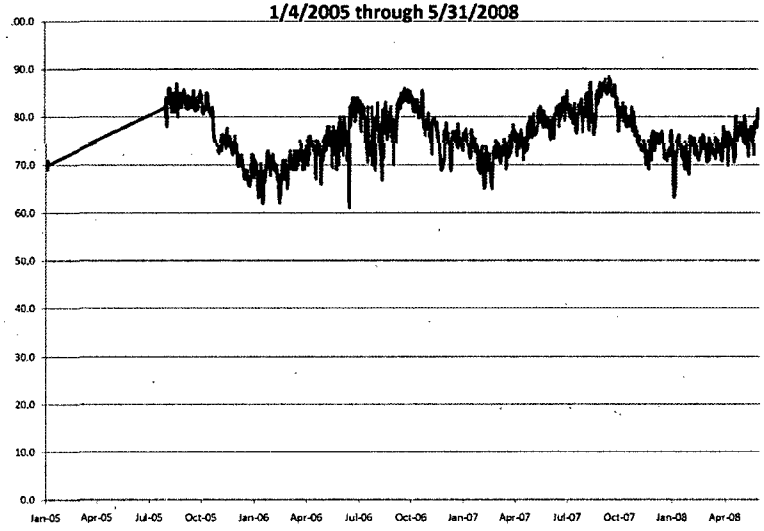
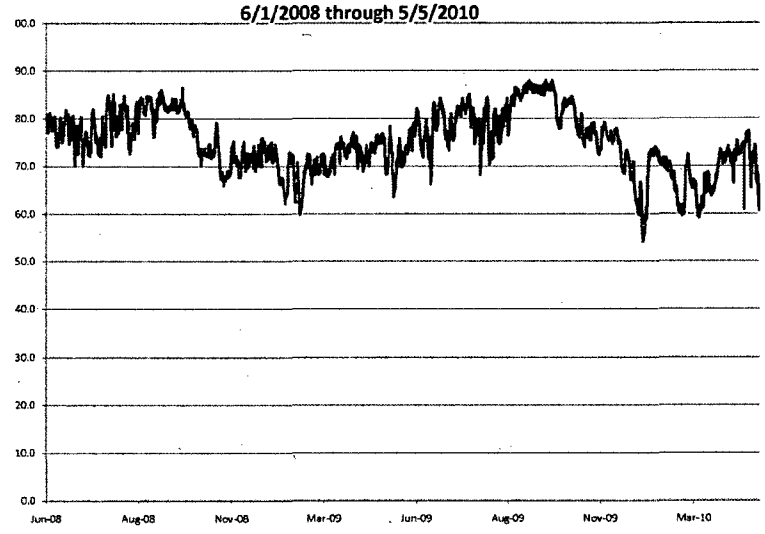


Figure 5-b-1. Intake Temperature
6/1/2008 through 5/5/2010



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TITLE

Intake Temperature

CLIENT/PROJECT

FPL/St. Lucie Plant/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687	
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
REVIEWED GP	FILE NO. 09387687 Figure 5-b-1	SUBTITLE	FIGURE NO. 5-b-1

Figure 5-c-1. Discharge Temperature
1/4/2005 through 5/31/2008

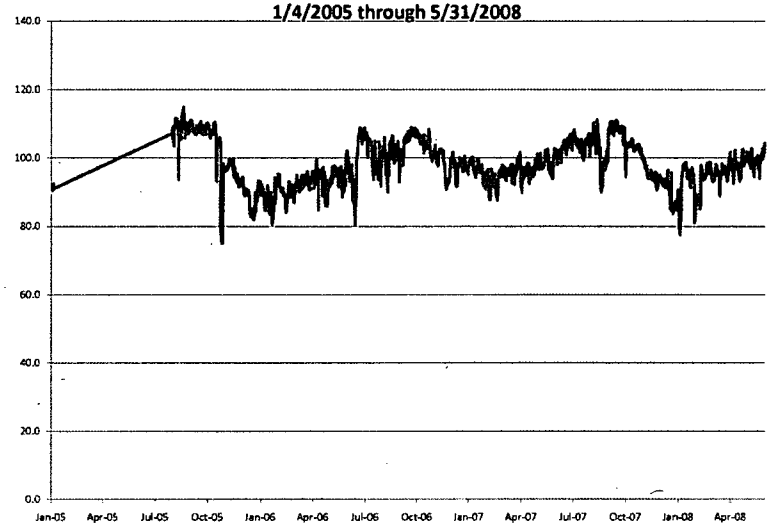
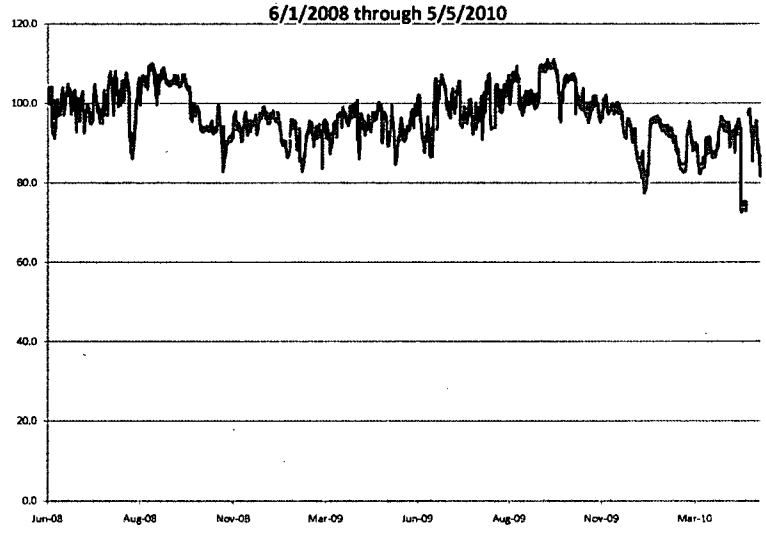


Figure 5-c-1. Discharge Temperature
6/1/2008 through 5/5/2010



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Discharge Temperature

CLIENT/PROJECT

FPL/St. Lucie Plant/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687	
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
REVIEWED GP	FILE NO. 09387687 Figure 5-c-1	SUBTITLE	FIGURE NO. 5-c-1

Figure 5-d-1. Temperature Difference Between Intake and Discharge
1/4/2005 through 5/31/2008

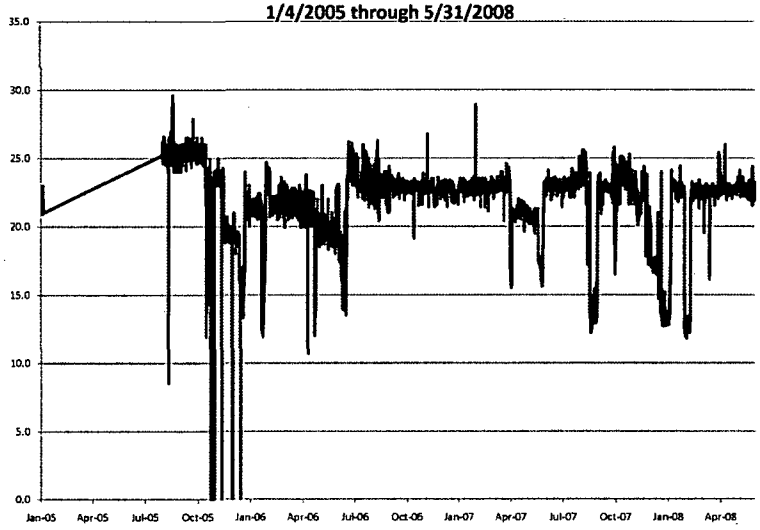
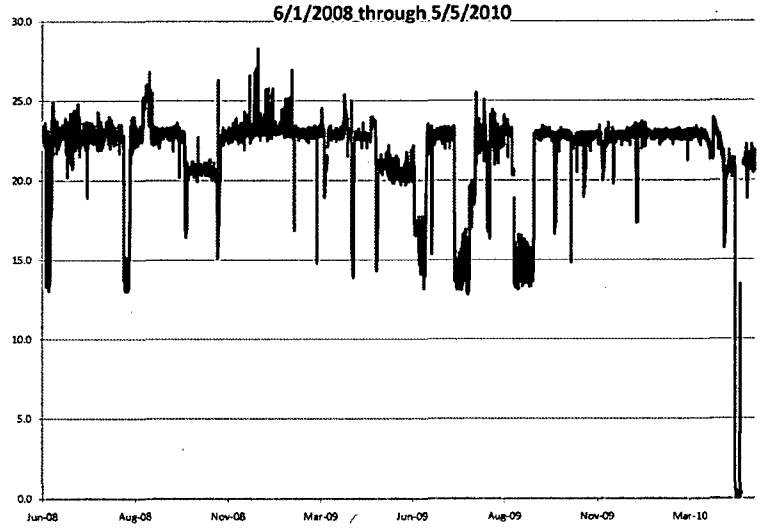


Figure 5-d-1. Temperature Difference Between Intake and Discharge
6/1/2008 through 5/5/2010



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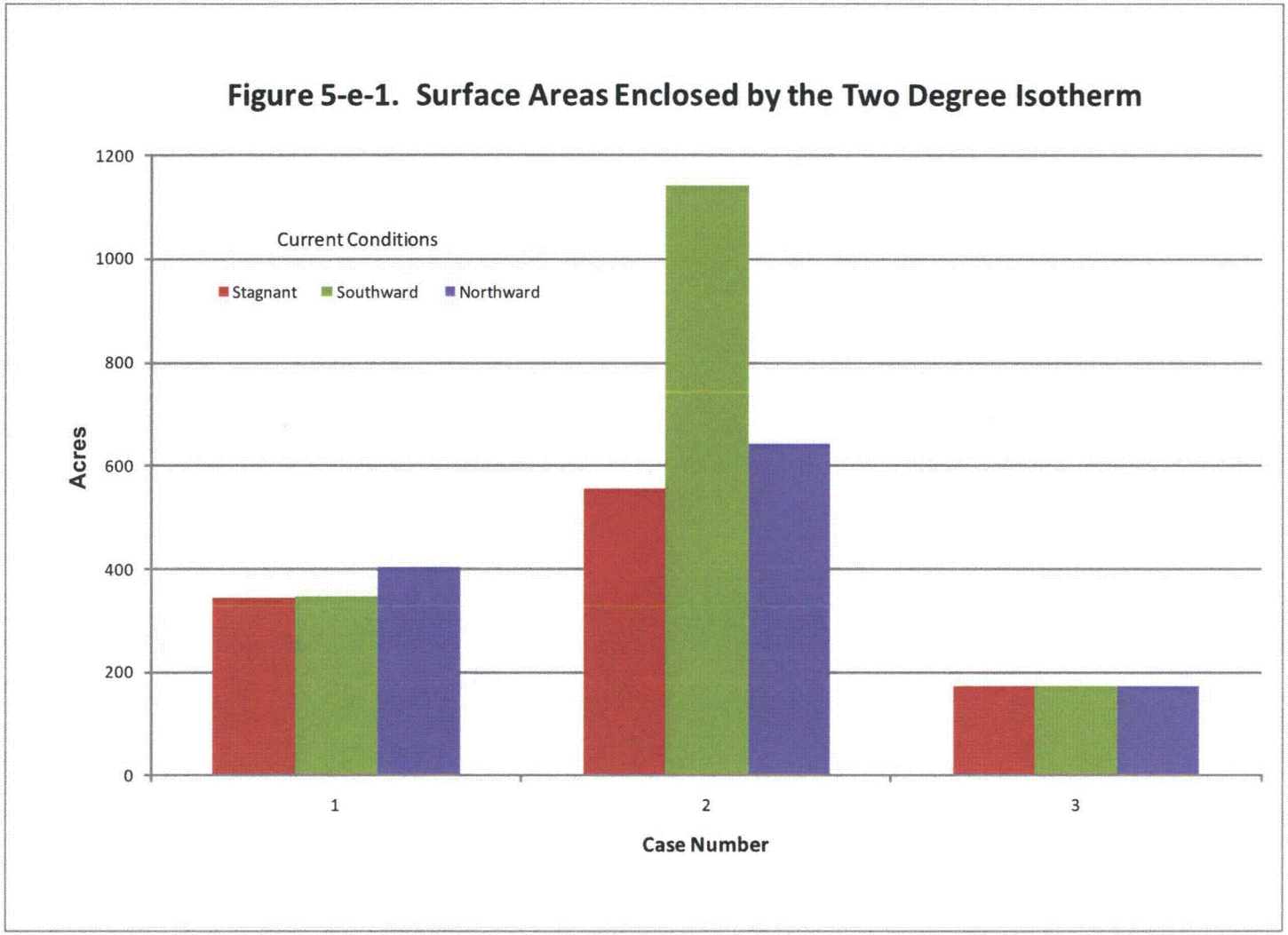
TITLE

Temperature Difference
Between Intake and Discharge

CLIENT/PROJECT

FPL/St. Lucie Plant/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687	
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
REVIEWED GP	FILE NO. 09387687 Figure 5-d-1	SUBTITLE	FIGURE NO. 5-d-1



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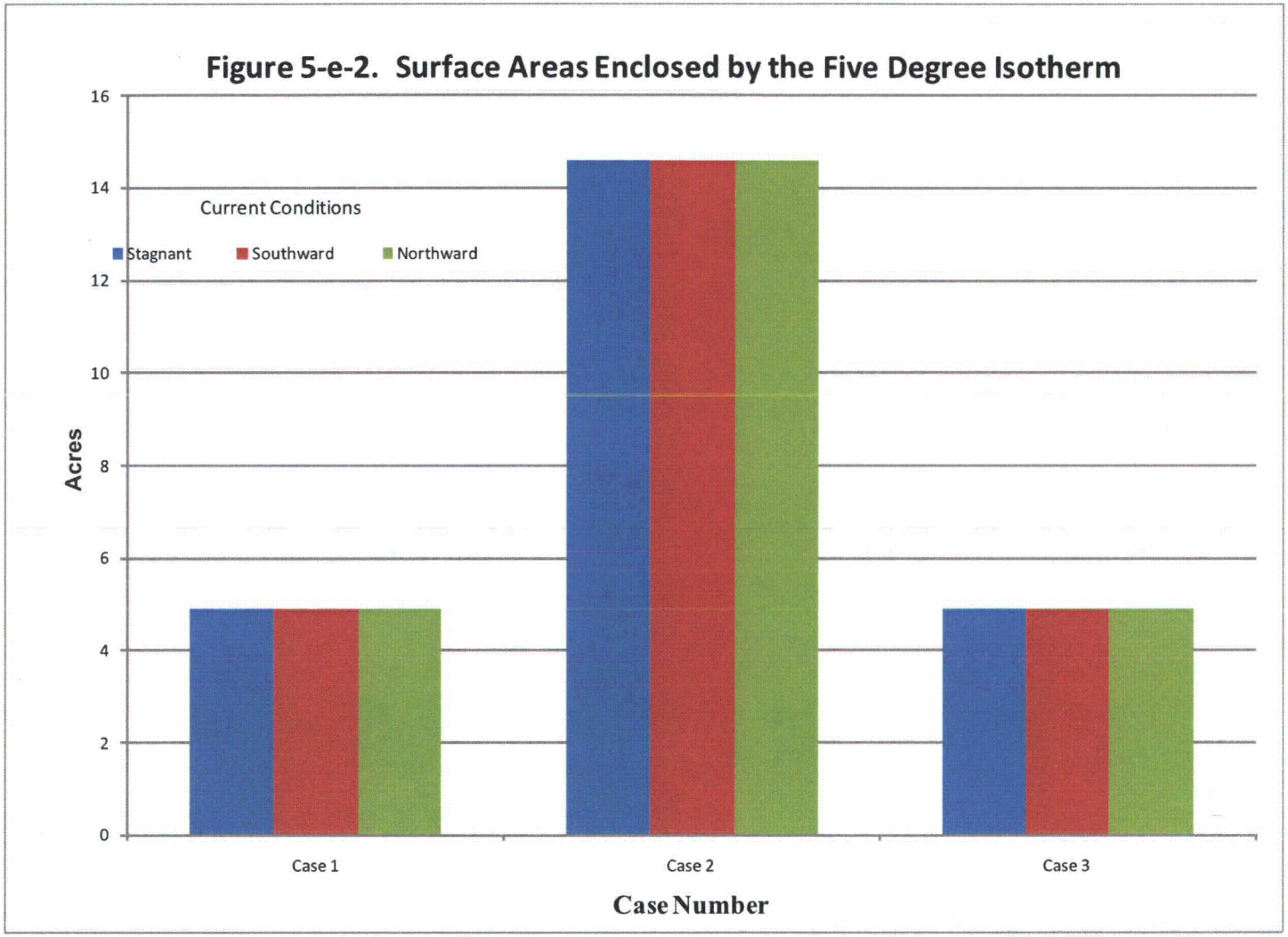
TITLE

Surface Areas Enclosed by the Two Degree Isotherm

CLIENT/PROJECT

FPL/St. Lucie Plant/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687		
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.	
REVIEWED GP	FILE NO. 09387687 Figure 5-e-1	SUBTITLE	FIGURE NO. 5-e-1	



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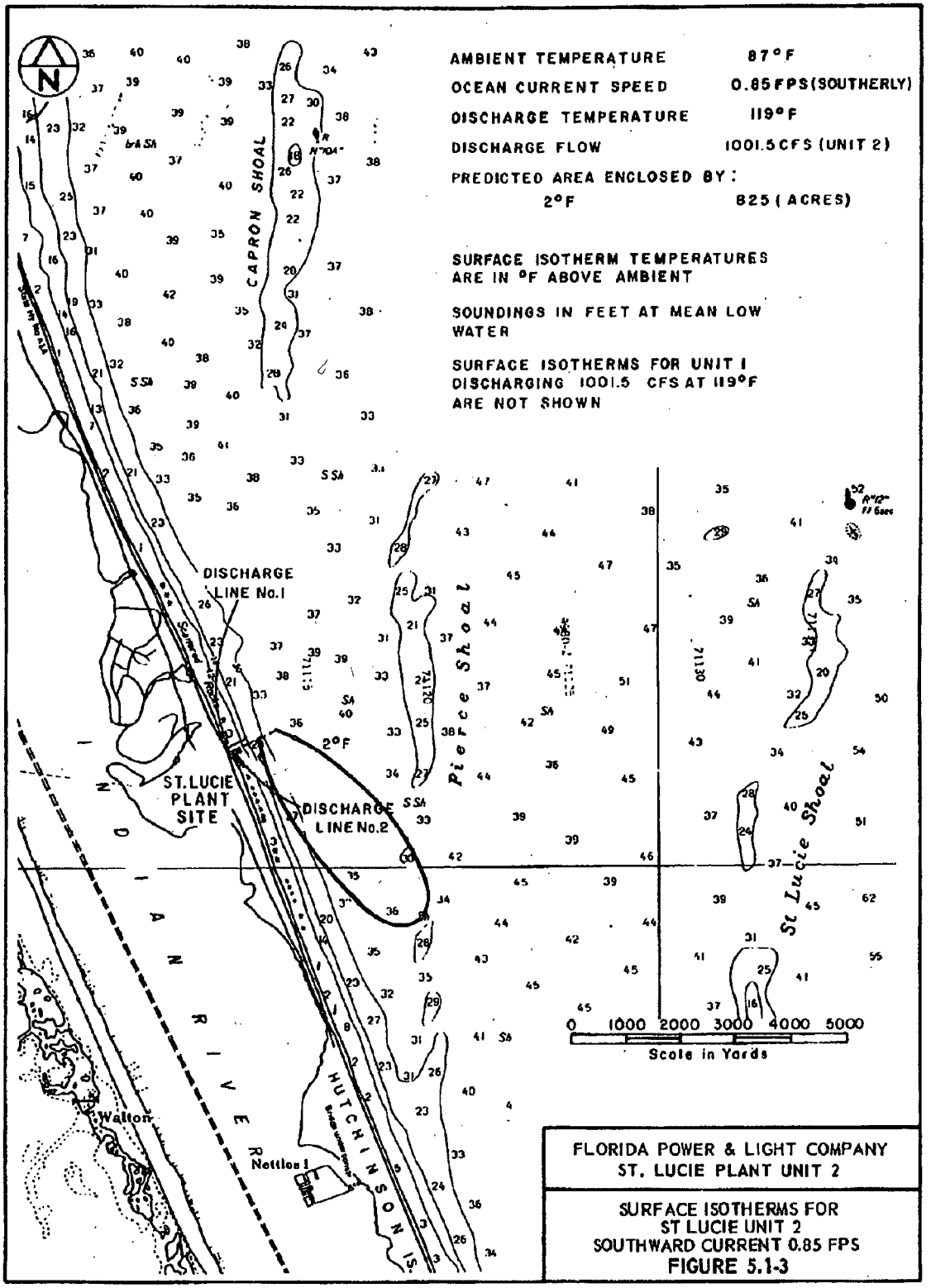
TITLE

Surface Areas Enclosed by the Five Degree Isotherm

CLIENT/PROJECT

FPL/St. Lucie Plant/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687	
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
REVIEWED GP	FILE NO. 09387687 Figure 5-e-2	SUBTITLE	FIGURE NO. 5-e-2



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

SURFACE ISOTHERMS FOR
ST LUCIE UNIT 2
SOUTHWARD CURRENT 0.85 FPS
FIGURE 5.1-3

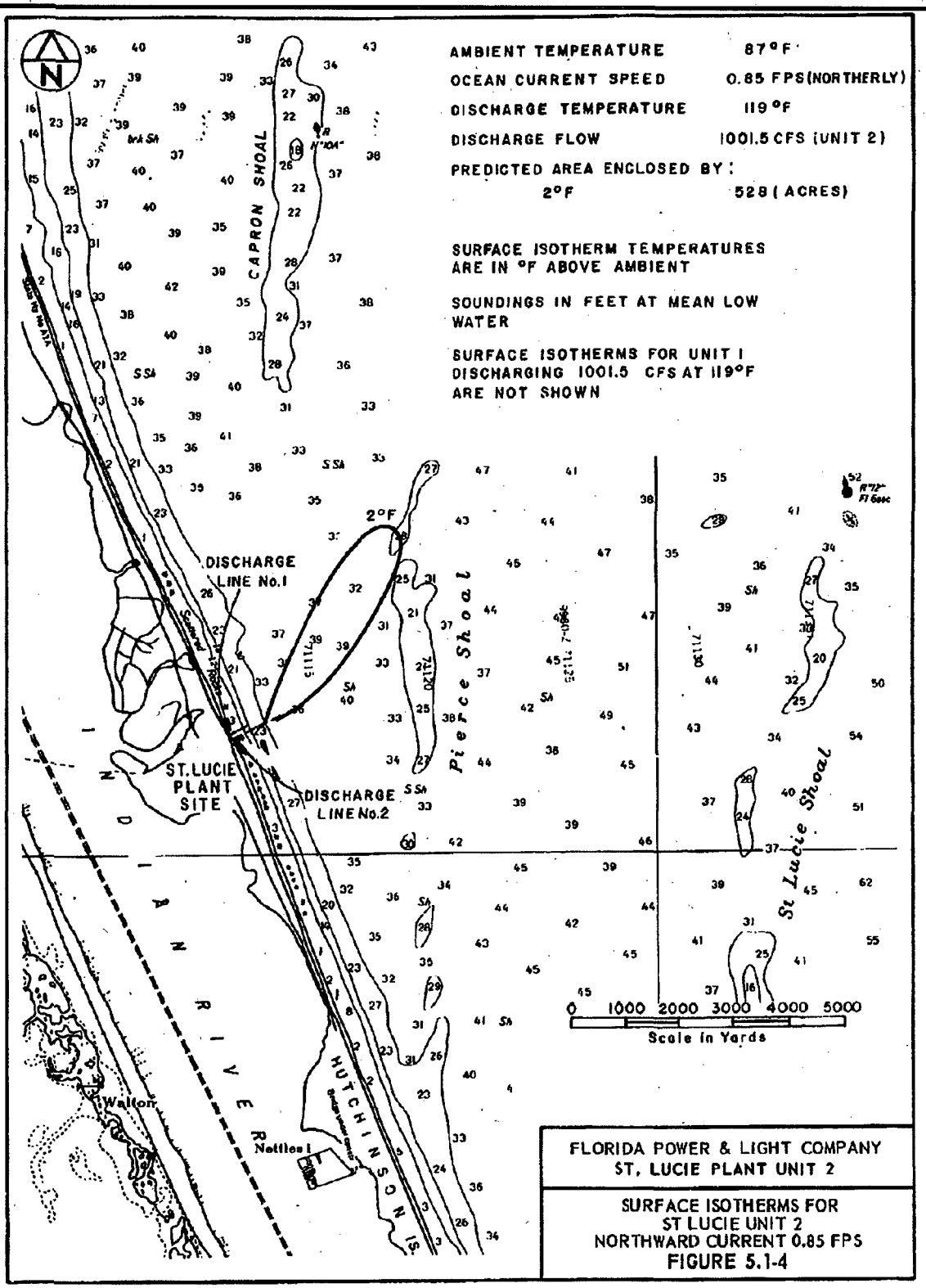
Source: St. Lucie Unit 2 Operating License Environmental Report

Golder Associates
Atlanta, Georgia

TITLE
Surface Isotherms for St. Lucie Unit 2
Southward Current

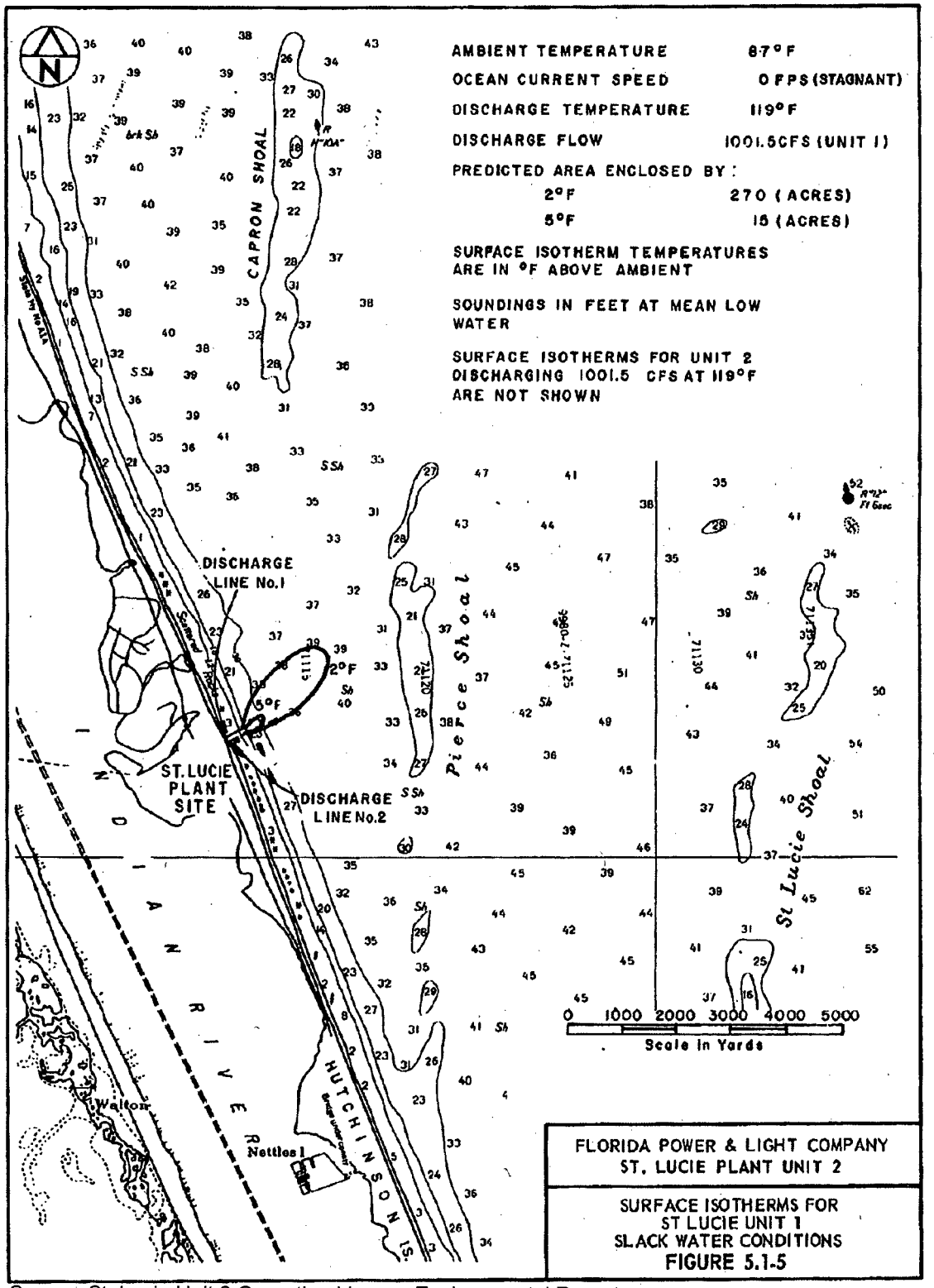
CLIENT/PROJECT
FPL/St. Lucie Plant/FL

DRAWN	DATE	JOB NO.	
MAT	6/1/2010	09387687	
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
REVIEWED GP	FILE NO. 09387687 Figure 5.1-3	SUBTITLE	FIGURE NO. 5.1-3



Source: St. Lucie Unit 2 Operating License Environmental Report

Golder Associates, Atlanta, Georgia	TITLE: Surface Isotherms for St. Lucie Unit 2 Northward Current			
CLIENT/PROJECT: FPL/St. Lucie Plant/FL	DRAWN: MAT	DATE: 6/1/2010	JOB NO.: 09387687	
	CHECKED: SH	SCALE: NTS	DWG. NO.	REV. NO.
	REVIEWED: GP	FILE NO.: 09387687 Figure 5.1-4	SUBTITLE	FIGURE NO.: 5.1-4



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

SURFACE ISOTHERMS FOR
ST LUCIE UNIT 1
SLACK WATER CONDITIONS
FIGURE 5.1-5

Source: St. Lucie Unit 2 Operating License Environmental Report

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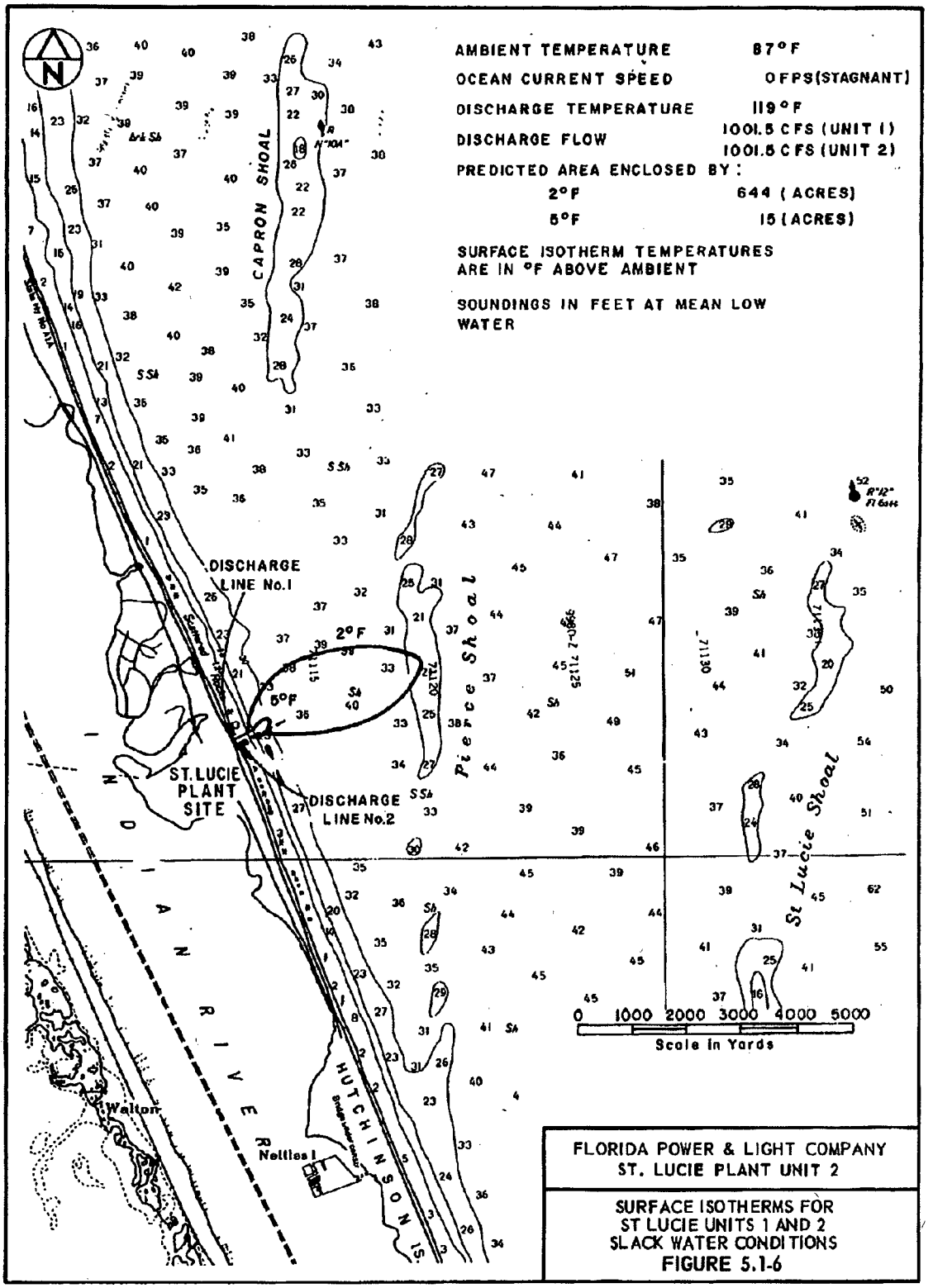
Atlanta, Georgia

TITLE
Surface Isotherms for St. Lucie Unit 1
Slack Water Conditions

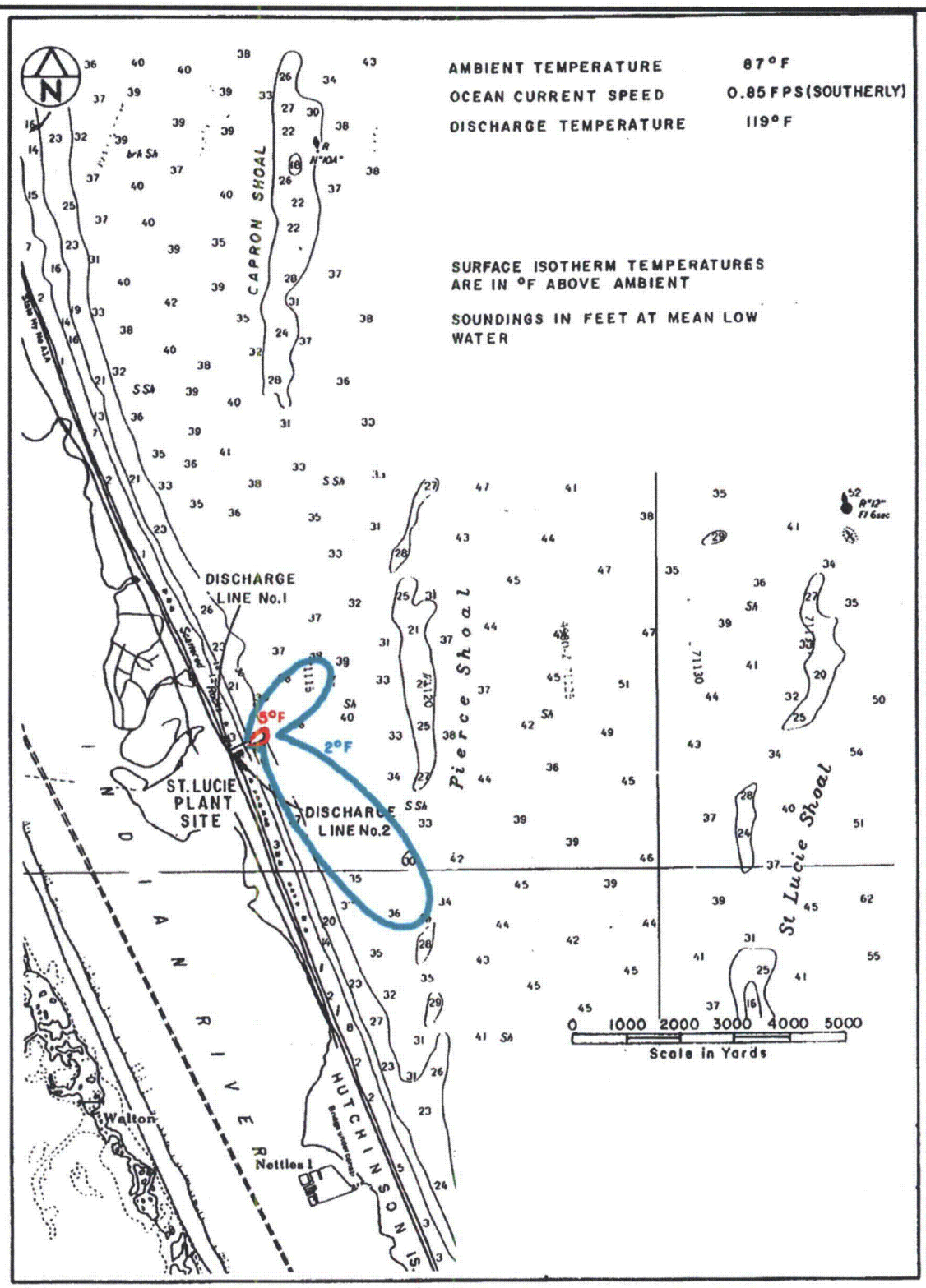
CLIENT/PROJECT
FPL/St. Lucie Plant/FL

DRAWN MAT	DATE 6/1/2010	JOB NO. 09387687	
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
REVIEWED GP	FILE NO. 09387687 Figure 5.1-5	SUBTITLE	FIGURE NO. 5.1-5



Source: St. Lucie Unit 2 Operating License Environmental Report

Golder Associates, Atlanta, Georgia	TITLE: Surface Isotherms for St. Lucie Unit 1 and 2 Slack Water Conditions			
CLIENT/PROJECT: FPL/St. Lucie Plant/FL	DRAWN: MAT	DATE: 6/1/2010	JOB NO.: 09387687	
	CHECKED: SH	SCALE: NTS	DWG. NO.	REV. NO.
	REVIEWED: GP	FILE NO.: 09387687 Figure 5.1-6	SUBTITLE	FIGURE NO.: 5.1-6



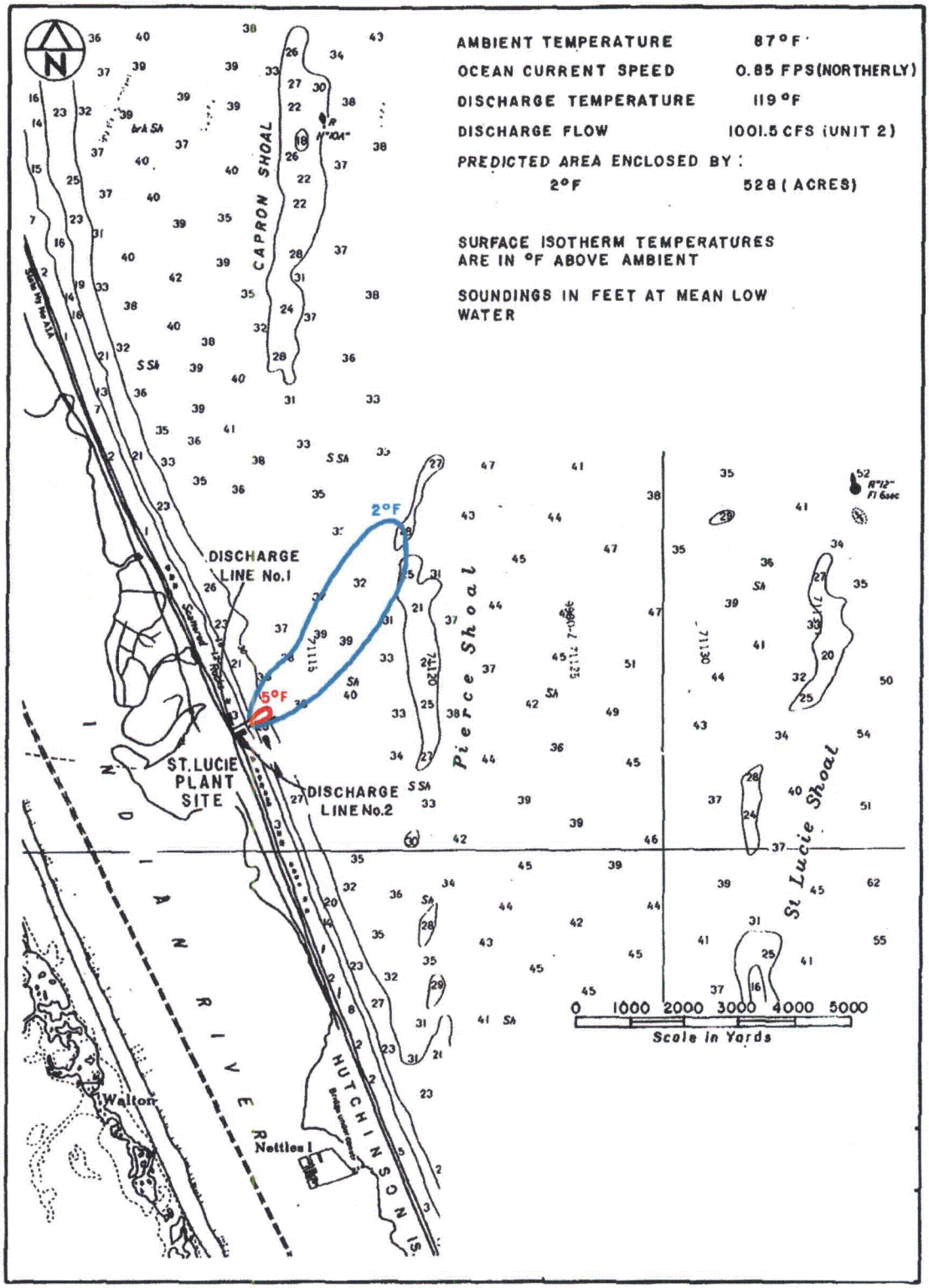
Source: St. Lucie Unit 2 Operating License Environmental Report- Modified by Golder

Golder Associates
Atlanta, Georgia

TITLE
Combined Surface Isotherms Under Southward Currents

CLIENT/PROJECT
FPL/St. Lucie Plant/FL

DRAWN MAT	DATE 6/1/2010	JOB NO. 09387687	
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
REVIEWED GP	FILE NO. 09387687 Figure 5-e-3	SUBTITLE	FIGURE NO. 5-e-3



Source: St. Lucie Unit 2 Operating License Environmental Report- Modified by Golder

Golder Associates
Atlanta, Georgia

TITLE
Combined Surface Isotherms Under Northward Currents

CLIENT/PROJECT
FPL/St. Lucie Plant/FL

DRAWN MAT	DATE 6/1/2010	JOB NO. 09387687	
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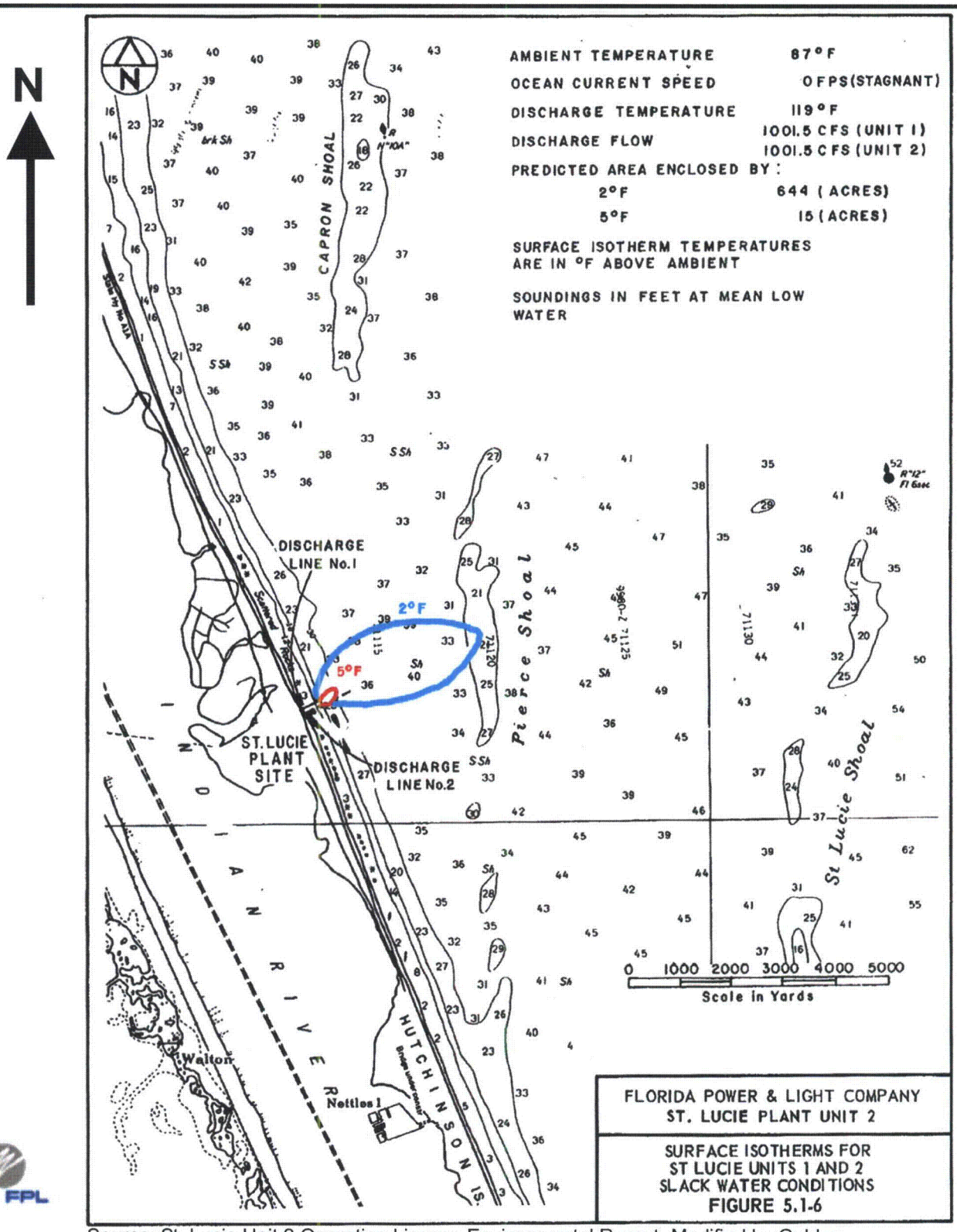

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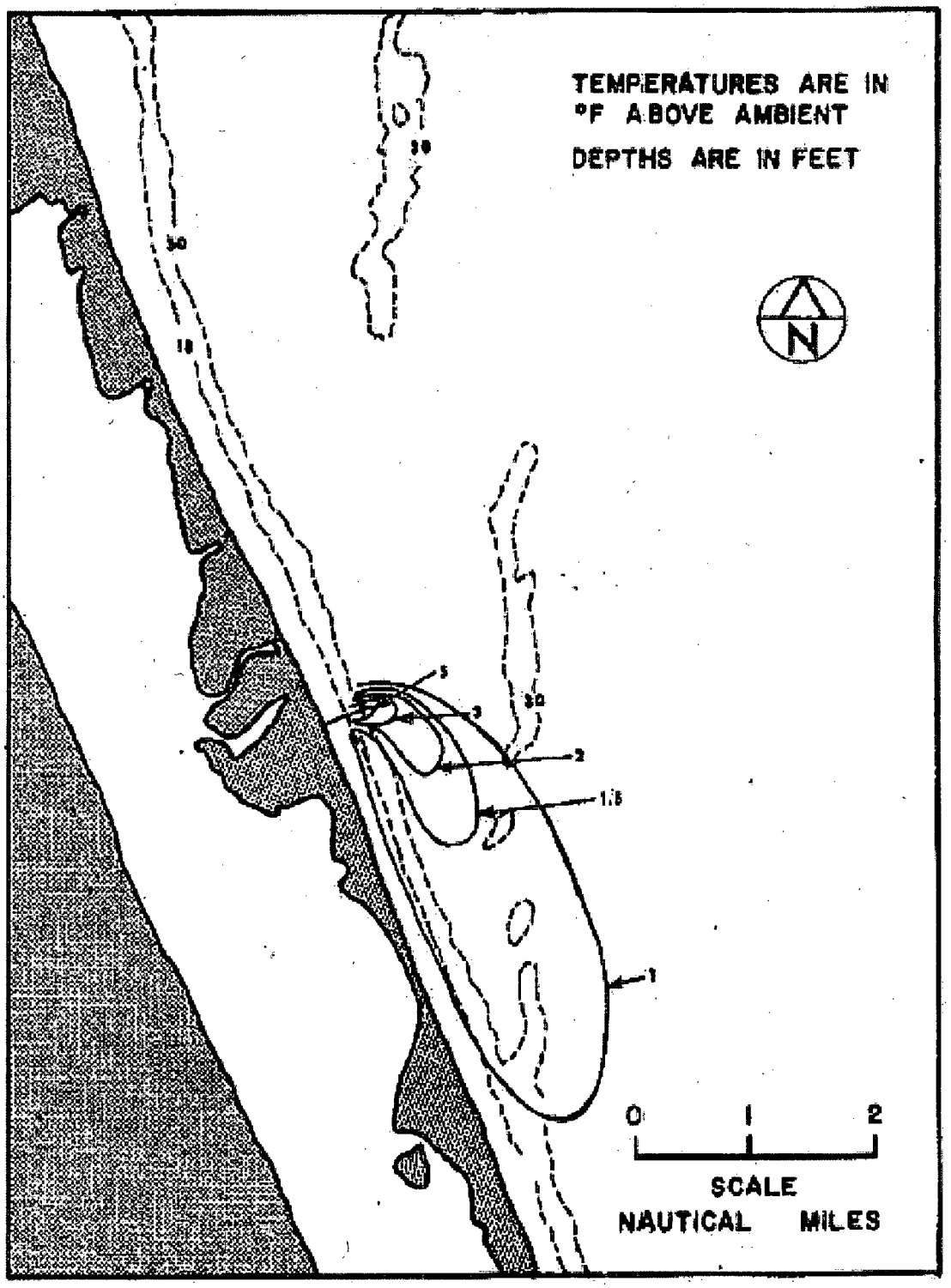
Golder Associates

Atlanta, Georgia

TITLE

Combined Surface Isotherms Under Slack Water Conditions

CLIENT/PROJECT	DRAWN	DATE	JOB NO.	
FPL/St. Lucie Plant/FL	MAT	6/1/2010	09387687	
	CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
	REVIEWED GP	FILE NO. 09387687 Figure 5-e-5	SUBTITLE	FIGURE NO. 5-e-5



Source: St. Lucie Unit 2 Operating License Environmental Report

Golder Associates

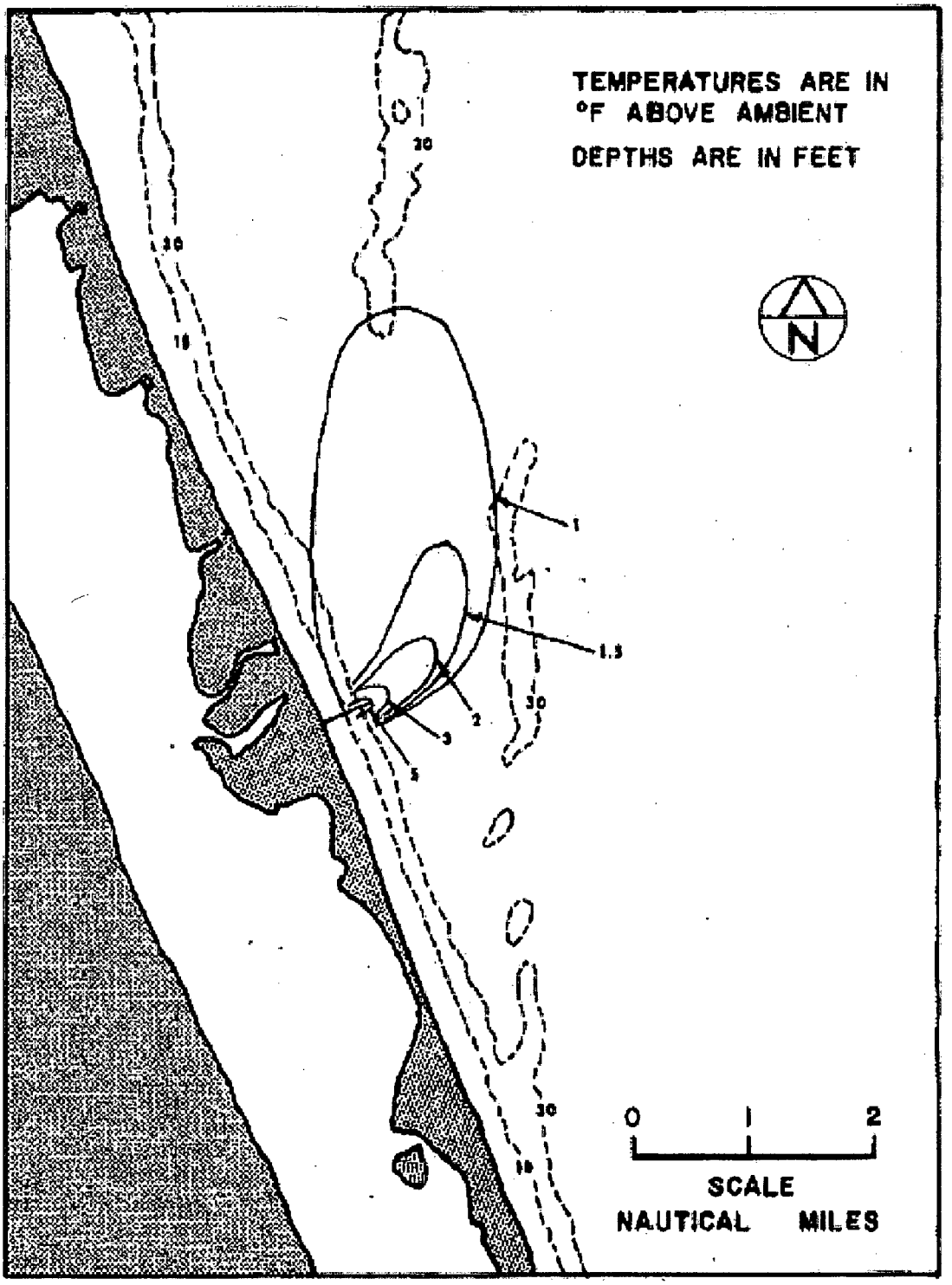
Atlanta, Georgia

TITLE Predicted Surface Water Temperature Rises for Units 1 and 2 During Maximum Observed Southerly Currents of 1.3 fps

CLIENT/PROJECT

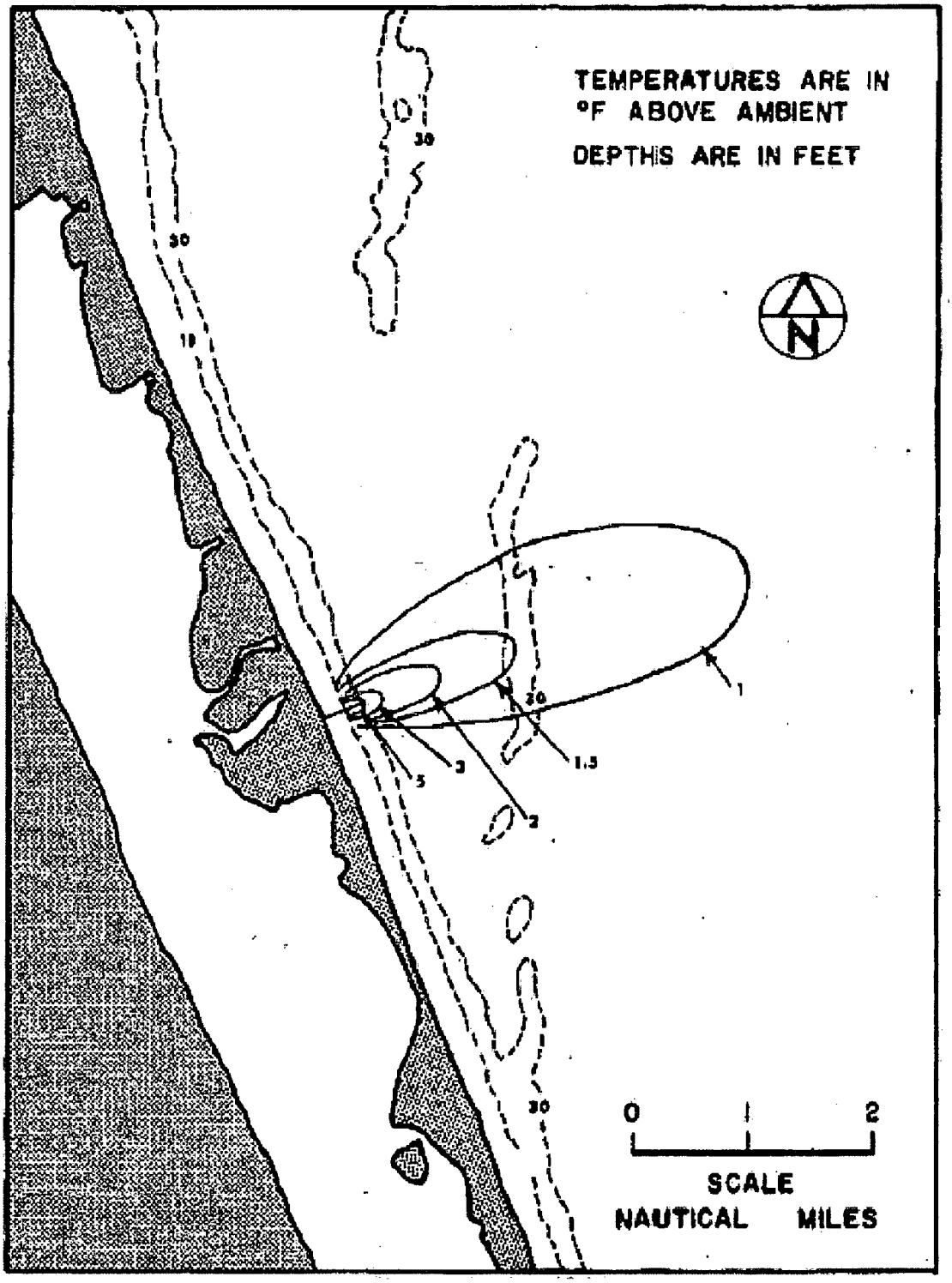
FPL/St. Lucie Plant Units/FL

DRAWN MAT	DATE 6/1/2010	JOB NO. 09387687		
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.	
REVIEWED GP	FILE NO. 09387687 Figure 5.1-14	SUBTITLE	FIGURE NO. 5.1-14	



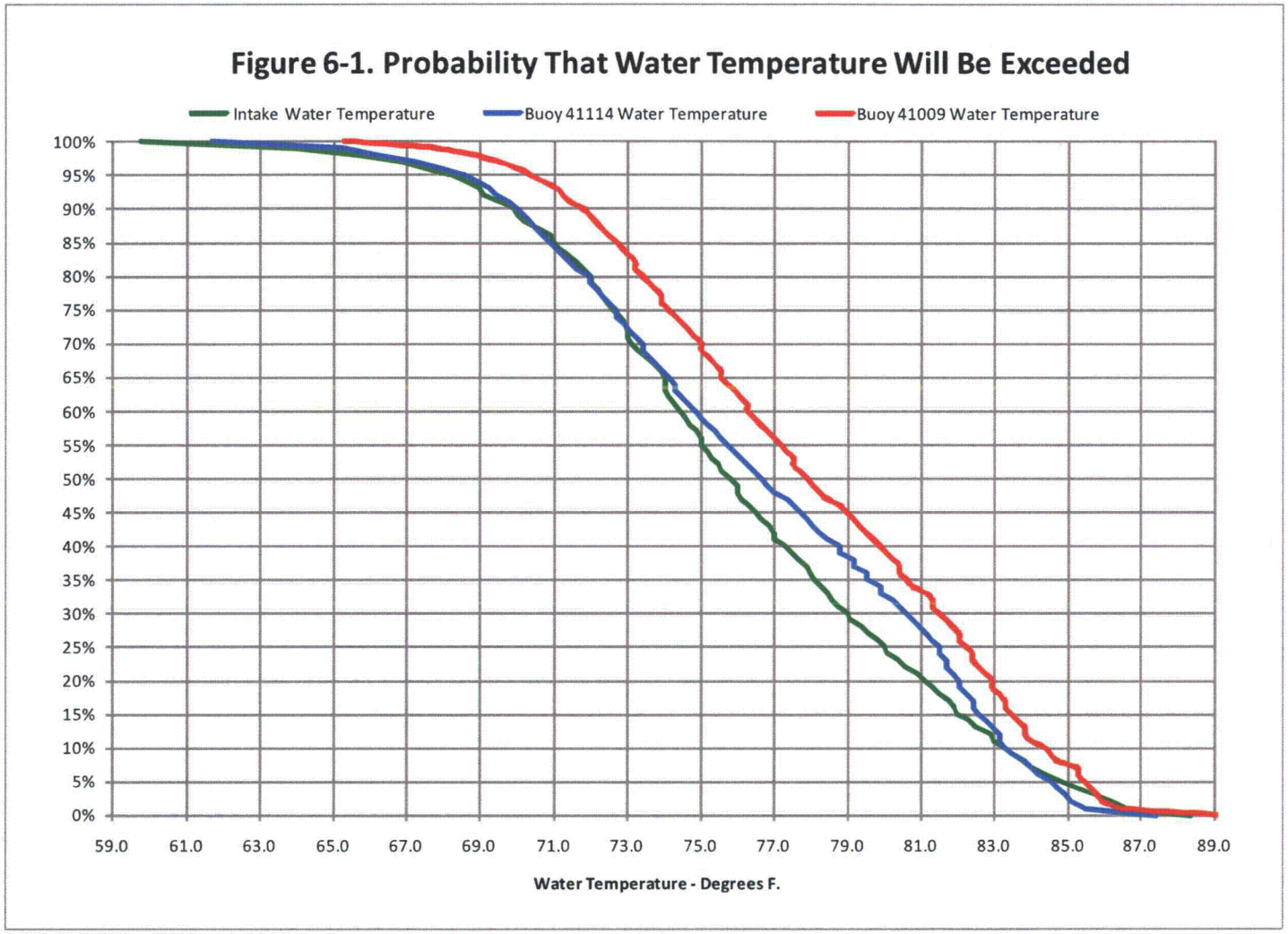
Source: St. Lucie Unit 2 Operating License Environmental Report

Golder Associates, Atlanta, Georgia	TITLE: Predicted Surface Water Temperature Rises for Units 1 and 2 During Maximum Observed Northerly Currents of 0.7 fps			
CLIENT/PROJECT: FPL/St. Lucie Plant/FL	DRAWN: MAT	DATE: 6/1/2010	JOB NO.: 09387687	
	CHECKED: SH	SCALE: NTS	DWG. NO.	REV. NO.
	REVIEWED: GP	FILE NO.: 09387687 Figure 5.1-15	SUBTITLE	FIGURE NO.: 5.1-15



Source: St. Lucie Unit 2 Operating License Environmental Report

Golder Associates, Atlanta, Georgia	TITLE: Predicted Surface Water Temperature Rises During Slack Water for Units 1 and 2			
CLIENT/PROJECT: FPL/St. Lucie Plant/FL	DRAWN: MAT	DATE: 6/1/2010	JOB NO.: 09387687	
	CHECKED: SH	SCALE: NTS	DWG. NO.	REV. NO.
	REVIEWED: GP	FILE NO.: 09387687 Figure 5.1-16	SUBTITLE	FIGURE NO.: 5.1-16



FPL

Golder Associates

Atlanta, Georgia

TITLE

Probability That Water Temperature Will Be Exceeded

CLIENT/PROJECT

FPL/St. Lucie Plant/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687	
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
REVIEWED GP	FILE NO. 09387687 Figure 6-1	SUBTITLE	FIGURE NO. 6-1

ATTACHMENT A

Facility I.D. Number: FL 0002208

III RECEIVING WATER INFORMATION

For each surface water that will receive effluent, supply the following information:

A. Name of Receiving Water	B. Check One		C. Classification (See Ch. 62-302, F.A.C.)	D. Type of Receiving Water (canal, river, lake, etc.)
	Fresh	Salt or Brackish		
Atlantic Ocean	☐	☒	III-Marine	Open Waters
	☐	☐		
	☐	☐		
	☐	☐		
	☐	☐		
	☐	☐		

E. Minimum 7-day 10-year low flow of the receiving water at each outfall (if appropriate).

Not Applicable

F. Identify and describe the flow of effluent from each outfall to a major body of water. A suitably marked map or aerial photograph may be used.

See Attachment III-F

G. Do you request a mixing zone under Rule 62-4.244, F.A.C.? If yes, for what parameters or pollutants?

Yes, for Water Temperature

IV FLOWS, SOURCES OF POLLUTION, AND TREATMENT TECHNOLOGIES

A. Attach a line drawing showing the water flow through the facility. Indicate sources of intake water, operations contributing wastewater to the effluent, and treatment units labeled to correspond to the more detailed descriptions in Item B. Construct a water balance on the line drawing by showing average flows between intakes, operations, treatment units, and outfalls. If a water balance cannot be determined (e.g., for certain mining activities), provide a pictorial description of the nature and amount of any sources of water and any collection or treatment measures.

B. For each outfall, provide a description of:

1. All operations contributing wastewater to the effluent; including process wastewater, sanitary wastewater, cooling water, and stormwater runoff;

2. The average flow contributed by each operation; and

3. The treatment received by the wastewater.

Use the space on the next page. Continue on additional sheets, if necessary.

2.3.4.2 Atlantic Ocean

The continental shelf water mass includes an inner shelf between the beach and the 120-ft isobath approximately 12 miles east of the St. Lucie Plant, and an outer shelf from the 120-ft contour to the 600-ft isobath approximately 8 miles further offshore. Continental shelf waters adjacent to Hutchinson Island originate north of Cape Canaveral, especially during the winter. Additional contributions are derived locally from the Indian River and the Florida Current systems. The northern water mass flows southward as a wind-driven coastal counter-current.

Worth and Hollinger reported salinities of 33 to 38 ppt for inner shelf Hutchinson Island waters less than 33 ft deep. Highest salinities occur in the summer, when southeasterly winds tend to minimize the inflow from the north. The reverse occurs during winter. The water temperature range is greatest near shore and diminishes with increasing depth to the shelf break (about 20 miles off-shore). Anderson, *et al.* (1960), reported that the shelf waters off Hutchinson Island ranged from a winter low of 68.0°F to a summer high of 84.2°F.

The Florida Current is a major component of the Gulf Stream. It flows northward at a velocity of 4 to 6 fps in a narrow channel between the continental U.S. on the west and the Bahamian-Caribbean Archipelago on the east. The western wall of the Florida Current is usually near the 600-ft isobath some 20 miles seaward of the St. Lucie Plant. Water temperatures in the western portion of the Florida Current ranged from a winter low of 78.8°F to a summer high of 86.0°F, while salinities ranged between 36.0 and 36.1 ppt (Wennekens, 1959).

Intake water temperatures measured hourly at the plant for the period from August 2005 through September 2007 are presented in Figure 2.3.4-1. These temperatures ranged between a low of 59.8°F and a high of 88.4°F.

2.3.4.3 Existing St Lucie Plant Effects

The effects of the existing St. Lucie Plant on surface waters occur exclusively within the inner continental shelf water mass. These effects are a result of the St. Lucie Plant's Heat Dissipation System including the CWS, which provides once-through non-contact condenser cooling water, and the AECWS, which provides once-through non-contact cooling water for auxiliary equipment (Figure 2.3.4-2).

Each plant intake structure consists of four bays, each containing one coarse screen, one traveling screen, and one CWS pump. Each of these structures also contains three AECWS (ICWS) pumps, two of which are normally operated and one is a spare. Water is pumped from these intake structures through the unit's condensers and auxiliary equipment heat exchangers to the discharge canal.

The design flow rates for each unit are calculated as follows:

	Unit 1 (gpm)	Unit 2 (gpm)
Flow rate for each CWS pump	121,000	122,650
Flow rate for each AECWS (ICWS) pump	14,500	14,500
Flow rate for 4 CWS pumps	484,000	490,600
Flow rate for 2 AECWS (ICWS) Pumps	29,000	29,000
Total flow rate	513,000	519,600
Total 2-unit flow rate = 1,032,600 gpm = 1,487 MGD = 2,301 cubic feet per second (cfs).		

The discharge canal ends in two headwall structures, each of which connects to a discharge pipeline. Each discharge pipeline connects to a submerged diffuser.

The northernmost discharge pipeline is a 12-ft-diameter pipeline that extends offshore to an ocean discharge structure consisting of a short transition section and a Y-type 45-degree two-port diffuser discharging horizontally (see Figures 2.3.4-3 and 2.3.4-4). Each port has a diameter of 7.5 ft. Although the ocean depth at the discharge structure location was originally about 18 ft below mean low water, the area has been excavated to a depth of 40 ft below mean low water so that the centerline of the discharge port is at an elevation of 34 ft below mean low water. At the design discharge flow rate, the exit velocity from each port is about 13 fps, resulting in a predicted mixing zone (defined by 17°F above ambient isotherm) extending approximately 63 ft horizontally from each port, and approximately 0.8 ft vertically (see Figures 2.3.4-5 and 2.3.4-6). Details of the mathematical thermal discharge modeling performed to estimate the size of the existing thermal plume are presented in Appendix 10.6.

The second (southernmost) discharge line extends offshore approximately 1,959 ft to the first of 58 ports (see Figure 2.3.4-7). The multiport section is approximately 1,368 ft long, so that the furthest port is approximately 3,327 ft offshore. Each port is mounted in a 14-ft-high vertical riser

with a 4-ft-inside diameter (see Figure 2.3.4-8). The ports have a 17 ¾-inch (1.48 ft) inside diameter and are oriented in an offshore direction at a horizontal angle alternating 25 degrees left and right from the long axis of the diffuser. Therefore, ports discharging water to the same side of the diffuser are 48 ft apart and direct the flow of the jet away from the shore. Jet velocity exiting each port is about 11.5 fps, resulting in a mixing zone (defined by the 17°F above ambient isotherm) extending about 12.4 ft horizontally from each port and essentially horizontal (see Figures 2.3.4-9 and 2.3.4-10). Details of the mathematical thermal discharge modeling performed to estimate the size of the existing thermal plume are presented in Appendix 10.6.

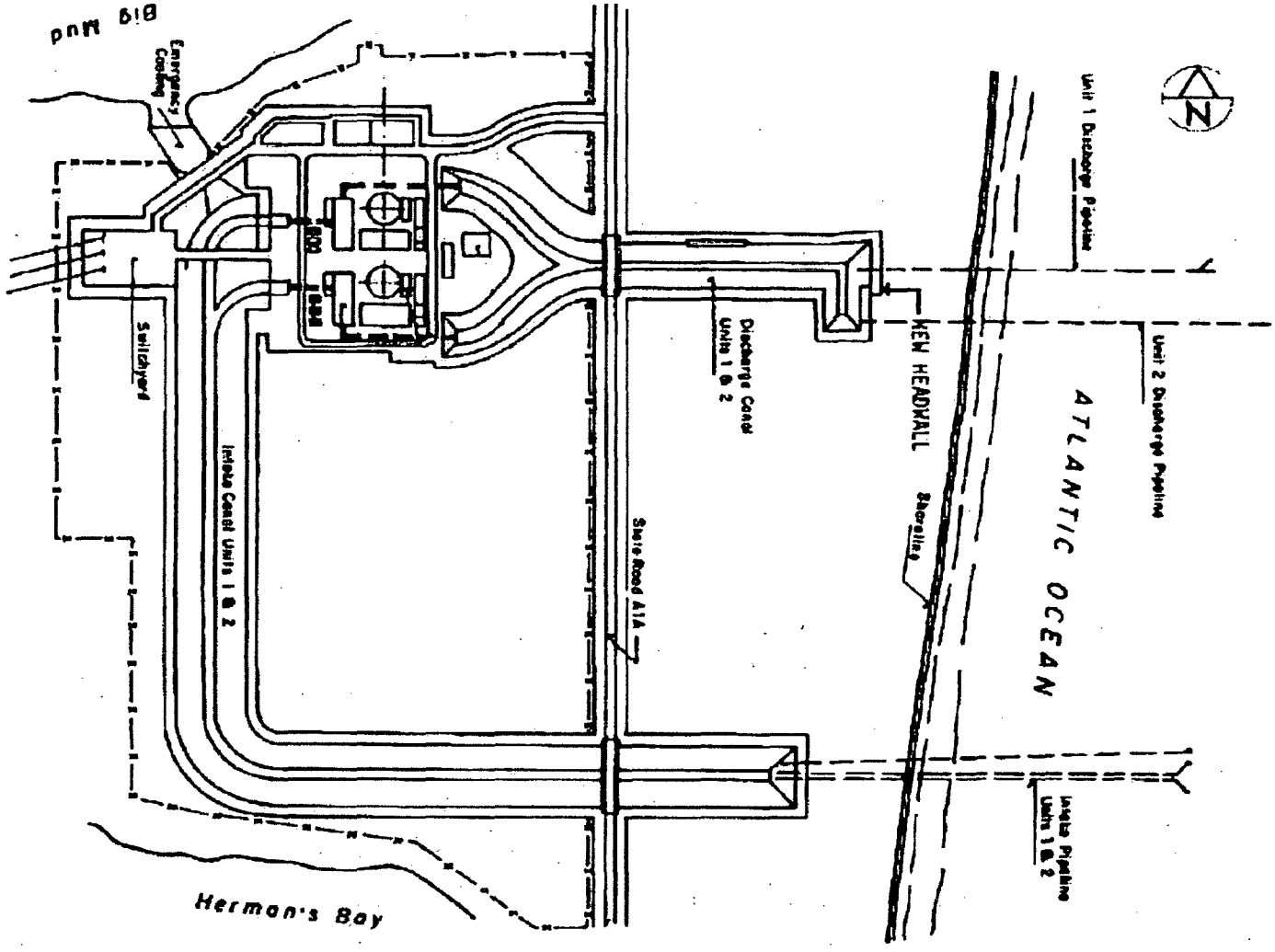


Figure 2.3.4-2
Circulating Water System Plan (View 1) at the St. Lucie Plant

Source: Golder, 2007.

FPL

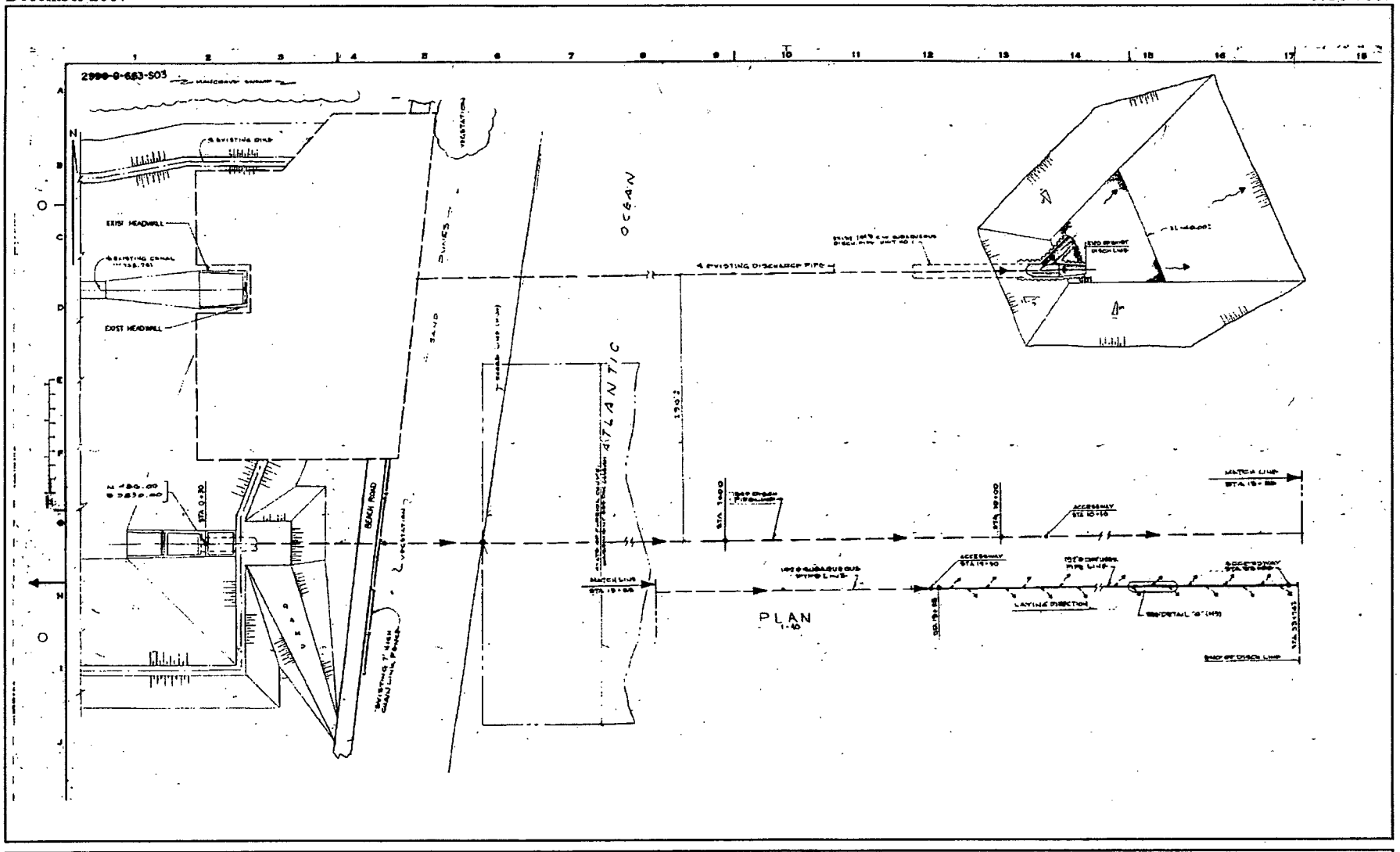


Figure 2.3.4-3
Circulating Water System Discharge Plan (View 2) at the St. Lucie Plant

Source: Golder, 2007.

FPL

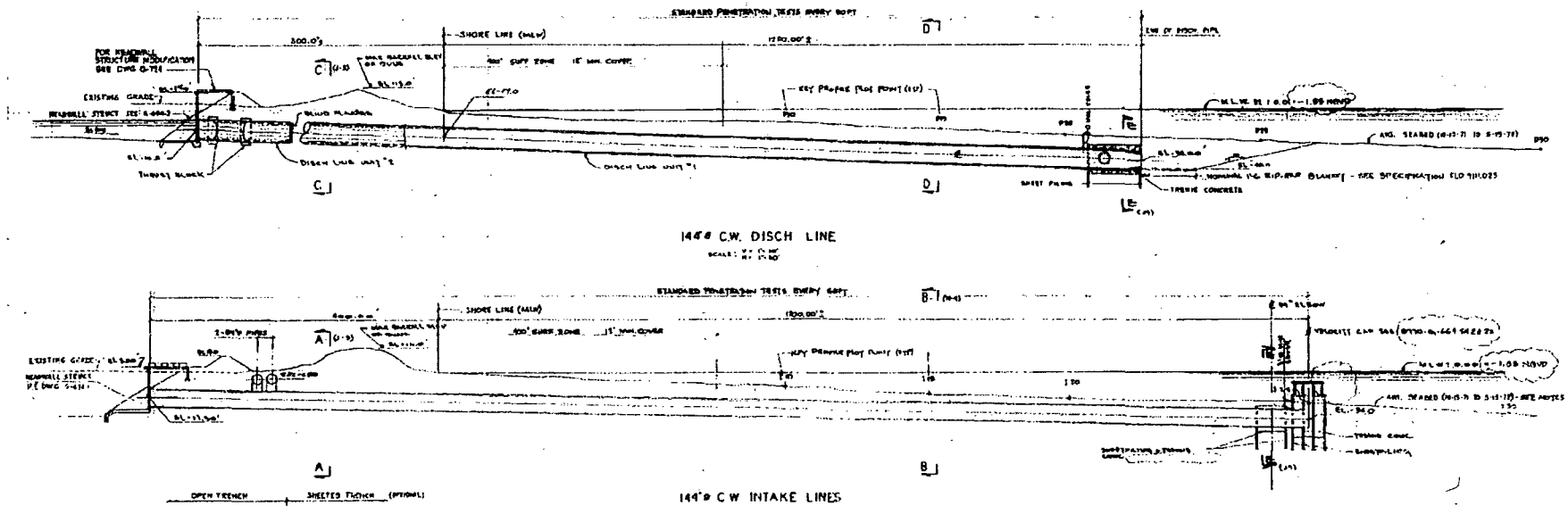


Figure 2.3.4-4
Circulating Water System Y-Port Profile at St. Lucie Plant (Intake also shown.)

Source: Golder, 2007.

ATTACHMENT B

5.1 EFFECTS OF OPERATION OF HEAT DISSIPATION SYSTEM

5.1.1 EFFLUENT LIMITATIONS AND WATER QUALITY STANDARDS

St Lucie Unit 2 is an existing unit pursuant to the Clean Water Act, because FP&L incurred substantial obligation and costs on or before March 4, 1974 for the purchase of facilities and/or equipment for St Lucie Unit 2. Federal thermal effluent limitations for existing electric generating facilities, as specified in 40CFR423, are currently being reviewed by EPA.

State of Florida rules and regulations pertaining to Water Quality Standards, Ch. 17-3 Florida Administrative Code (FAC), establish specific standards for thermal discharges into state waters (s. 17-3.05, Thermal Surface Water Criteria). Upon application on a case-by-case basis, the Florida Department of Pollution Control (now the Department of Environmental Regulation (DER) can establish a zone of mixing beyond the point of discharge to afford a reasonable opportunity for dilution and mixture of heated water discharges with the receiving water body.

The discharge from St Lucie Unit 2 will not affect the quality of the water of any other State.

5.1.2 PHYSICAL EFFECTS

5.1.2.1 Introduction

This section describes the characteristics of the St Lucie Unit 2 thermal plume, including the effects of the St Lucie Unit 1 thermal plume, when the two plumes interact. Thermal plume analyses for St Lucie Unit 2 were included in the St Lucie Unit 2 Environmental Report - Construction Permit. Since that document, the results of several studies have permitted optimization of diffuser design[1-7]. In addition, analyses of St Lucie Unit 1 discharge characteristics have been performed since 1973[8,9].

FP&L has also undertaken two bathymetric surveys: one by Continental Shelf Associates in 1972 and the other by Envirosphere in 1977 to define the bathymetry in the vicinity of St Lucie Units 1 and 2 discharges.

The original "alternating" St Lucie Unit 2 diffuser, details of which were presented in the St Lucie Unit 2 Environmental Report - Construction Permit, was optimized based on the thermal-hydraulic model studies[2-6]. The St Lucie Unit 2 diffuser is designed with 58 jet ports, each 16 inches in diameter. The length of the diffuser is 1368 ft, and the port spacing is 24 ft. The 16 ft diameter diffuser manifold was optimized with ports alternating on each side with each port oriented in an offshore direction at an angle of 25 degrees from the manifold centerline.

Results of recent studies at MIT[10], Alden Research laboratories[11], Acres Laboratory,[12] Argonne National Laboratory,[13] Caltech[14], and Iowa Institute of Hydraulic Research (II HR)[2] show that such "offshore angled" or "staged diffusers" are state-of-the-art and provide the

most efficient means of dispersing heated water in semi-infinite coastal bodies of water. These studies show that such diffusers perform better under all current situations, unlike 90 degree "alternating" diffusers which show "good" performance only under high currents. Recent studies [10,13] also conclude that "offshore angled" or "staged" diffusers with net offshore momentum perform better than either alternating, coflowing, tee or oblique diffusers under different current situations. Table 5.1-1 summarizes the qualitative performance of various submerged diffusers in semi-infinite bodies of shallow water. St Lucie Units 1 and 2 discharge structures are described in Section 3.4.

5.1.2.2 Methodology

This section discusses the methodology used to select the appropriate modeling approach, describes the models utilized and presents predicted thermal plumes for St Lucie Unit 2 and the combined St Lucie Units 1 and 2 discharges.

5.1.2.2.1 Data Requirements

To predict thermal plume configurations resulting from the operation of St Lucie plant, both plant operating data and ambient oceanographic data are required.

5.1.2.2.1.1 Plant Operating Data

a) Plant Discharge Flow and Temperature Rise

The discharge flow consists primarily of condenser cooling water and intake cooling water flow. At 100 percent power output, the heat rejection rate of each unit is 6.4×10^9 Btu/hr; the rated discharge flow and condenser rise are 1160 cfs and 25°F respectively.

However to ensure operating flexibility, discharge flows were computed assuming a heat rejection rate of 7×10^9 Btu/hr/unit for eight pump operation and discharge temperature rises of 32°F and 28°F. Plume computations were performed for seven different cases shown in Table 5.1-2 that envelope different flows, temperatures and heat discharge rates.

b) Discharge Canal Temperature

Discharge canal temperature, for the purpose of thermal plume evaluation, is obtained by adding the ambient ocean temperature to the temperature rise within the plant. In order to maximize the thermal plume characteristics (such that the impact can be assessed conservatively), the September maximum ocean temperature of 87°F [15] was used in all cases. Resulting discharge canal temperature would either be 119°F or 115°F, reflecting a plant temperature rise of either 32°F or 28°F.

5.1.2.2.1.2 Oceanographic Data

a) Temperature and Salinity

Ocean temperature data were obtained from National Ocean Survey "Surface Water Temperature and Density" Publication 31-1, March 1973[15]. Monthly mean and maximum temperature data for the 1946-1962 period of record at Canova Beach, Florida, are used to represent ambient conditions at the St Lucie site. The monthly maximum temperature of 87°F for September is used for thermal plume analysis. Ocean salinity is specified as 35 ppt.

b) Ocean Bathymetry

For each case, an ocean depth corresponding to mean low water (MLW) was used for purposes of determining initial dilution. Based on the data available, an ocean depth of 23 ft at the St Lucie Unit 1 discharge and an average ocean depth of 35 ft at St Lucie Unit 2 discharge is used.

c) Currents

Current data used to determine surface plume temperatures and frequencies of occurrence of plume configurations are based on site specific measurements made during a 12 month period in 1974-1975[7]. These data were subsequently analyzed for joint-frequency distribution of current speed and direction as shown in Table 5.1-3.

Current measurements taken at the St Lucie site during 1974-1975[7] and 1977[8] demonstrate that nearshore currents generally flow parallel to the shoreline, with a prevailing northward direction and a secondary mode to the south (see Section 2.4). Based on an analysis of current measurements, plume computations are performed for stagnant ocean conditions and for most frequent current in northward (0.85 fps) and southward (0.85 fps) directions.

5.1.2.2.2 Predictive Techniques

Total cooling water flow from both units is discharged into the common discharge canal and carried into the ocean through two buried pipelines. The combined flow is distributed between the existing 12 ft diameter St Lucie Unit 1 ocean discharge pipeline and the 16 ft diameter St Lucie Unit 2 ocean discharge pipeline as noted in Table 5.1-2.

5.1.2.2.2.1 St Lucie Unit 2 Thermal Plume

Warm water discharged as a high velocity jet has both inertial and buoyant forces acting on it. Jet temperature, as the plume rises toward the surface, decreases steadily due to turbulent mixing and entrainment. This region of the jet, where conditions at the discharge point influence jet temperature distribution, is designated the near-field. Once the submerged jet reaches the surface, the jet "boils" up at the surface and spreads into a stable layer over the surface. The jet still has momentum when it

reaches the surface and moves horizontally in a manner similar to a surface jet discharge. The plume spreads over the ocean surface and decreases in temperature due to turbulent mixing and other factors. The surface jet, as it travels away from the boil area, reaches a zone where temperature distribution is no longer influenced by the effects of discharge conditions. That zone, where ambient ocean conditions dominate temperature decay is called the far-field.

With the present "offshore angle" diffuser, diluting ocean water comes primarily from the plume sides and the bottom. For the ports located near the inshore end of the diffuser manifold, the diluent comes from around the individual jets, while for ports located near the offshore end, diluent water comes primarily from both sides of the diffuser. The offshore jets entrain part of the thermal plumes from jets located immediately inshore of them. As a result of this partial re-entrainment of warm water (for jets located towards the offshore end), the temperature near that end will be slightly higher than that at the inshore end. Thus, the net volume of ocean water entrained decreases towards the offshore end, resulting in a lesser temperature decrease. This difference, however, is compensated for by the increase of mixing depth with distance offshore.

a) Near-field (Subsurface) Thermal Plume Characteristics of St Lucie Unit 2 Discharge.

For modeling discharges from the "offshore angle" diffuser, a calibrated Koh-Fan mathematical model[16] was utilized to describe the near-field or submerged jet region. Koh-Fan model computer runs were made with known plant conditions as used in the physical model studies. The entrainment coefficient was varied until the predicted (from Koh-Fan model) and the maximum observed surface temperature rises (from physical model studies) matched. The resulting entrainment coefficients are respectively 0.028, 0.050 and 0.057 for stagnant, southward and northward currents conditions. The calibrated Koh-Fan model was utilized to establish near-field jet characteristics for all other discharge and ambient conditions.

Recently USNRC[17] utilized the Koh-Fan model to analyze the near-field performance of the "offshore angle" diffuser for a once-through cooling system (located near Block Island Sound in Charlestown, RI). NRC concluded that the results from Koh-Fan model were similar to those determined in the physical model studies.

b) Far-Field (Surface) Thermal Plume Characteristics of Unit 2 Discharges

The thermal plume from the St Lucie Unit 2 "offshore angle" diffuser, when it reaches the surface, interacts with ambient ocean and moves away from the diffuser due to residual momentum. The resulting thermal plume does not lend itself to exact analysis by available state-of-the-art models. For modeling surface plumes, the calibrated PDS model[18] was adopted. From the results of the calibrated near-field Koh-Fan model (Section 5.1.2.2.2.1a), maximum temperature rise at the surface and corresponding surface

velocity was obtained for each case of interest. From the results of the physical model studies, the depth of the thermal layer was determined to be 15.4 feet. With these parameters known, the width of the surface layer was determined. The surface jet source was assumed to be located at the offshore end of the diffuser for stagnation conditions and along the diffuser for southward and northward currents.

For these known initial conditions, the PDS model was calibrated for the results of the physical model studies for stagnation, southward and northward currents. The values of Eo, (jet entrainment coefficient), XK_1 (spreading coefficient), E_H (horizontal turbulent diffusion/exchange coefficient) and R_F (function of local Richardson number) for stagnation case are respectively 0.05, 5.0, 0, and 0.05. Similar values for southward and northward current cases are respectively 0.05, 160, 0 and 0.001 and 0.05, 70, 0 and 0.001. The PDS model was utilized to obtain surface plume details for all cases of interest.

5.1.2.2.2.2 St Lucie Units 1 and 2 Thermal Plume Under Combined Operation

a) Near-Field (Subsurface) Thermal Plume Characteristics Under Combined St Lucie Units 1 and 2 Operation

Results obtained from the physical model studies[2] indicate that the design and separation distance between the two discharge lines results in negligible interference between the thermal discharges from St Lucie Units 1 and 2. The results of near-field analysis for St Lucie Unit 1 and for St Lucie Unit 2 (Section 5.1.2.2.2.1a) individually are also appropriate for combined operation. The Koh-Fan model[18] is used to describe submerged near-field jet temperatures resulting from St Lucie Unit 1 discharges.

b) Far-Field (Surface) Thermal Plume Characteristics of St Lucie Unit 1 Discharges

For modeling surface plumes, the calibrated Prych - Davis - Shirazi (PDS)[20] model was adopted. From the results of the near-field Koh-Fan model (Section 5.1.2.2.2.1a) the jet velocity and temperature rise at the surface was obtained for each case. The results of the Koh-Fan model are used as one of the initial input conditions for the PDS model. From field measurements and St Lucie Unit 1 physical model studies, the location of the beginning of the surface layer and an initial surface layer depth of 12.5 feet is established[8]. With known values of the amount of heat discharged, surface temperature and velocity, depth of surface layer, the width of the surface layer is then established.

The PDS model is calibrated with results from the physical model studies[4]. The values of the calibration coefficients for stagnation conditions are; E_o (jet entrainment coefficients) =

0.05; E_H (horizontal turbulent diffusion/exchange coefficient)= 0.00004; XK_1 (spreading coefficient)= 45; R_F (a function of local Richardson Number) = 0.0031. Corresponding values for southward current conditions are 0.05, 0.0, 45 and 0.021. For northward current conditions, calibration values are 0.05, 0.00006, 45 amd 0.0031, respectively.

The calibrated PDS model also verifies St Lucie Unit 1 discharge results obtained during the March 1977 survey when St Lucie Unit 1 was operating at 99 percent power output. The PDS model predicted areas are 27 acres and 401 acres for 3 and 1.5°F, respectively. The corresponding prototype measurements are 18 acres and 278 acres, establishing the applicability of PDS model. The calibrated PDS model was utilized to obtain surface plume details for all test cases.

c) Far-Field (Surface) Thermal Plume Characteristics Under Combined St Lucie Units 1 and 2 Operation

When St Lucie Units 1 and 2 are in operation, the following procedure is used to estimate plume area. Details of the surface plume resulting from the St Lucie Unit 1 discharge, under stagnation conditions, were computed utilizing the calibrated PDS model. Plume computations were carried out to a distance where interaction with the St Lucie Unit 2 discharge occurs. At that point, a new source is formulated and its characteristics (such as width, velocity, temperature, depth) are determined by conserving or combining the total heat, volume and momentum flux of both discharges. With details of the new source known, the PDS model is again applied to determine the details of the combined plumes under stagnant conditions.

Based on tests conducted on St Lucie Unit 1 and on combined St Lucie Units 1 and 2 discharges, IIHR concluded that "there is almost no interference between Units 1 & 2."[2] Essentially this means that under both southward (0.85 fps) and northward currents (0.85 fps), even though the individual plumes from St Lucie Units 1 and 2 are oriented in the direction of the current, the areas of an isotherm (such as 2°F), under combined operation will equal the sum of the areas of isotherms from the individual units.

5.1.2.3 Results

In this section, results of the thermal plume analyses are discussed. Discharge plumes from St Lucie Unit 2 are discussed for stagnation, southward and northward currents. Discussion of plumes resulting from the combined operation of St Lucie Units 1 and 2 is restricted to only those (stagnant) cases where the individual plumes from both units (of 2°F) interfere.

The results described below are conservative, and reflect the assumed heat rejection rate of 7×10^9 Btu/hr/unit. Results presented herein for St Lucie Units 1 and 2 do not reflect normal operating conditions, due to the above assumption.

5.1.2.3.1 St Lucie Unit 2 Thermal Plume

5.1.2.3.1.1 Near-Field (Subsurface) Plume Characteristics

For St Lucie Unit 2 discharges, the resulting maximum surface temperatures are strongly dependent on ocean current conditions. Results of the St Lucie Unit 2 physical model studies [2] showed that surface temperatures are highest for stagnant situations and decrease as ambient current speed increases. This largely reflects the availability of additional ambient water for mixing and dilution, whenever there is a cross current.

The subsurface plume temperature distribution, volumes of isotherms and times of travel for St Lucie Unit 2 discharges are developed utilizing the Koh-Fan model. Table 5.1-4 presents the results of the analyses, and Figure 5.1-1 shows a typical example of the plume in the subsurface region. In this analysis, the jet centerline temperature rise at 5/6 the ocean depth over the nozzle is assumed to be the maximum surface temperature. Other investigators [19,20] of jets have shown that at this depth (i.e., the top 1/6 depth of the ocean), temperature decay is significantly less than that in the remainder of the water column. Further, this assumption adds conservatism to the analysis.

For seven pump operation with a ΔT_o of 32°F, the predicted ΔT_{max} is 4.9°F for a discharge flow of 836 cfs and 4.3°F for a discharge of 1090 cfs. However, for eight pump operation with a ΔT_o of 32°F, the predicted ΔT_{max} is 4.4°F for a flow of 1001.5 cfs and 4.6°F for a flow of 951 cfs. For the same eight pump operation, when ΔT_o is 28°F, the predicted ΔT_{max} is 3.6°F for a flow of 1075 cfs and 3.1°F when the flow is 1404 cfs.

The ΔT_{max} discussed above occur during stagnant or slack water ocean conditions. When other factors which influence temperature decay are held constant, the ambient current will increase mixing and dilution, resulting in a lower surface temperature rise. This is shown by a review of the results presented in Table 5.1-5. The ΔT_{max} varies from 1.9°F to 3.2°F, and surface temperature rises are about 50 to 30 percent lower than corresponding temperatures during stagnation conditions. Further, all the temperatures presented in Table 5.1-4 are the resulting temperature rises at the offshore end of the St Lucie Unit 2 "offshore angled" diffuser. As discussed in Section 5.1.2.2.2.1 and seen from the results of the physical model studies, ΔT_{max} values vary along the diffuser. At the inshore end, estimated ΔT_{max} values are one-half to one-third of those presented in Table 5.1-4. In this analysis, only characteristics of the offshore jet are considered, to provide conservative estimates of areas and volumes affected by elevated temperatures.

Predicted length of the jet trajectory (Table 5.1-4) varies between 81 and 130 ft, depending upon initial jet conditions. The predictions presented here are average lengths. However, under actual ocean conditions (ocean currents, stratification, etc) and from St Lucie Unit 1 operating experience and observations made during March 1977 field survey [8], it is expected that the trajectory length would be longer, by as much as 50 percent of the predicted values.

The jet surface velocity is predicted with the Koh-Fan model. Predicted velocities vary from 2.7 fps under stagnant conditions to 2.0 to 1.7 fps under southward or northward ocean currents.

Time of travel (Table 5.1-5) of a plume-entrained organism through the 20°F, 10°F and 5°F isotherms were predicted. From the discharge point, the maximum time required to traverse the 20°F, 10°F and 5°F isotherms are about 2 secs, 7 secs and 21 secs, respectively.

Volumes enclosed by 20°F, 10°F, 5°F and 2°F isotherms for all test cases are shown in Table 5.1-6. The largest volumes of 20°F, 10°F and 5°F are found to be respectively 0.02 ac-ft, 0.19 ac-ft and 1.51 ac-ft; this occurs when the discharge flow is 1090 cfs and ΔT_o is 32°F. Volume enveloped by each successive isotherm increases as the plume is diluted.

5.1.2.3.1.2 Far-Field (Surface) Plume Characteristics

The maximum surface temperature rise (ΔT_{max}), velocity, width and depth of the jet impingement zone form the primary input data for computation of the far-field or surface plume temperature distribution. Initial thermal layer depth at the offshore end of the diffuser is estimated to be 15.4 feet[2]. The width is calculated from the heat rejection rate, depth of the thermal layer and the near-field analysis. Predicted plume widths for September vary between approximately 140 and 760 feet, depending upon discharge temperature, discharge flow and ambient current conditions.

Utilizing the calibrated PDS Model (Section 5.1.2.2.2.1b), volumes, areas and travel times up to 2°F through the surface plume are computed for stagnation, southward and northward currents. The predicted results are presented in Tables 5.1-5 through 5.1-7. Figures 5.1-2 through 5.1-4 show examples of surface isotherms for a flow of 1001.5 cfs and ΔT_o of 32°F for stagnation, southward and northward currents, respectively. For stagnation conditions, the plume is oriented in the offshore direction while for other current conditions, surface plume orientation and shape is determined by ambient current direction and speed.

Table 5.1-7 and Figures 5.1-3 and 5.1-4 show that the isotherm shape for southward currents is similar and areas are of the same order of magnitude as that for northward currents. These similarities in the gross characteristics of the shape and size of the isotherms are explained by the approximate symmetry of the diffuser with respect to the currents. Differences in plume area are attributed to the nature of the shore. The plume in the southward direction is more likely to encounter shallow depths within a zone where comparatively smaller amounts of ocean water are available for dilution, while the reverse is true for a northward plume. This, in general, results in a diminished ability for the southward plume to entrain water, which results in slightly higher temperatures and larger areas of isotherms for southward currents.

Maximum surface areas generally occur with southward current conditions and minimum areas under either northward current or stagnation conditions. Maximum area of the 2°F isotherm is 963 acres, and results from a southward current when the discharge flow is 836 cfs and ΔT_o is

32°F. Volume of the 2°F isotherm (Table 5.1-6) under this condition is 629 ac-ft.

In one case (discharge flow of 1404 cfs, ΔT_o of 28°F), the ΔT_{max} will reach 1.9°F, therefore no 2°F surface isotherms will occur. Average depth of the 2°F isotherm varies between a maximum of about 2.5 ft under stagnation situations to almost zero under other current (discharge flow of 1404 cfs and ΔT_o of 28°F with a northward current) situations.

Travel times of a surface plume entrained organism through 2°F are presented in Table 5.1-5. Travel times vary from a maximum of 169.4 minutes (flow is 336 cfs and ΔT_o is 32°F) to a minimum of less than a minute (flow is 1404 cfs and ΔT_o is 28°F).

5.1.2.3.2 St Lucie Units 1 and 2 Thermal Plume Under Stagnant Ocean Conditions

5.1.2.3.2.1 Near-Field (Subsurface) Plume Characteristics

Table 5.1-8 presents subsurface jet characteristics for the St Lucie Unit 1 Y-nozzle discharge. Unlike the resulting maximum surface temperatures from St Lucie Unit 2, the physical model studies showed that the temperatures from St Lucie Unit 1 remain essentially unaltered under different ocean current conditions.[2] This is because of the high residual momentum of the St Lucie Unit 1 jets through the water column and at the surface in comparison to the momentum of the ocean currents. The plume would traverse an estimated horizontal distance of less than 150 feet, when it surfaces. Given that the separation distance between the St Lucie Unit 1 Y-nozzle and the St Lucie Unit 2 diffuser is about 450 feet; and the St Lucie Unit 2 diffuser ports are oriented offshore, for all practical purposes the St Lucie Unit 1 and St Lucie Unit 2 subsurface plumes do not influence each other in any way. Physical model studies[4] also show that the design and separation distance of the two discharge lines is such that the subsurface or near-field plumes from St Lucie Units 1 and 2 do not interact. Predicted travel times and volumes for stagnant ocean conditions are shown in Tables 5.1-9 and 5.1-10 respectively.

Results shown in Table 5.1-4 for St Lucie Unit 2 (Test Cases 1 through 7) and Table 5.1-8 for St Lucie Unit 1 (Test Cases 8 through 14), individually, would thus hold good for combined operation of St Lucie Units 1 and 2 (Test Cases 15 through 21) also. Thus, when the St Lucie plant is under seven pump operation, discharging a combined flow of 1770 cfs at a ΔT_o of 32°F, the resultant ΔT_{max} from the Y-nozzle is predicted to be 9.7°F and ΔT_{max} from the diffuser will range between 2.6 and 4.9°F, depending upon plant and ambient current conditions. For eight pump operation, with a combined flow of 2003 cfs at a ΔT_o of 32°F, resulting ΔT_{max} from the Y-nozzle is predicted to be 8.1°F and the ΔT_{max} from the diffuser between 2.7°F and 4.6°F. However, under the same eight pump operation, with a combined flow of 2290 cfs at a ΔT_o of 28°F, predicted ΔT_{max} from the Y-nozzle is 7.3°F and ΔT_{max} from the diffuser ranges between 1.9°F and 3.6°F, depending upon plant and ambient current conditions.

Volumes enclosed by the 20°F and 10°F isotherms for combined plant operation under stagnant ocean conditions were obtained by adding the individual volumes for St Lucie Unit 1 (Table 5.1-10) and St Lucie Unit 2 (Table 5.1-6). Results are presented in Table 5.1-11. Maximum volumes of 20°F and 10°F isotherms are 0.14 ac-ft and 0.70 ac-ft respectively.

The volumes of 5°F and 2°F isotherms, under combined operation, require surface plume analysis and are discussed in Section 5.1.2.3.2.2. Other characteristics (such as jet trajectory length, times of travel, and velocity at the surface) of the Y-nozzle (Tables 5.1-8 and 5.1-9) and diffuser (Tables 5.1-4 and 5.1-5) that are presented individually, would hold good for combined operation also.

5.1.2.3.2.2 Far-Field (Surface) Plume Characteristics

Methodology for the computation of surface areas, volumes and times of travel, when both units are in operation and under stagnant ocean conditions is explained in Section 5.1.2.2.2.2c. The surface areas of 5°F and 2°F isotherms resulting from St Lucie Unit 1 discharges are presented in Table 5.1-12. Figure 5.1-5 shows the 2°F and 5°F surface isotherms when St Lucie Unit 1 is operating alone discharging 1001.5 cfs at a ΔT_o of 32°F.

Input data for the combined plume analyses was obtained from computations performed for St Lucie Unit 1 plume and St Lucie Unit 2 plume individually. Figure 5.1-6 shows the 2°F and 5°F surface isotherms when both units are operating, discharging 2003 cfs at a ΔT_o of 32°F.

Volumes of the 5°F isotherms presented in Table 5.1-11 are primarily the result of St Lucie Unit 1 discharges. Maximum volume of the 5°F isotherm is about 25 ac-ft and occurs when the plant is discharging 2003 cfs at a ΔT_o of 32°F.

Volumes of 2°F, however, reflect contributions from both St Lucie Units 1 and 2 discharges. The volume of 2°F, under combined unit operation is greater than the sum of the individual volumes of St Lucie Unit 1 and Unit 2. In some cases, the 2°F volume under combined operation is almost 70 percent larger than the sum of the 2°F volumes found when the units are operating individually. The maximum volume of 2°F is 1889 ac-ft and occurs when plant discharge flow is 2003 cfs and ΔT_o is 32°F. The minimum volume of 2°F is 873 ac-ft and occurs when flow is 2290 cfs and ΔT_o is 28°F. Average depths of 5°F and 2°F isotherms under combined operation are about 2 ft and 3 ft, respectively.

Surface areas of 5°F isotherms presented in Table 5.1-13 are a result of St Lucie Unit 1 discharges. The maximum area of 5°F is 19.3 acres and this results when plant flow is 1770 cfs and ΔT_o is 32°F. Under stagnant conditions the 2°F isotherms from both units interfere and the areas in Table 5.1-13 are a result of the contribution of discharges from both units.

Combined or total areas of 2°F, similar to volumes, are greater than the sum of the individual areas generated by St Lucie Unit 1 and St Lucie Unit 2. In some cases (Table 5.1-13), the 2°F isotherm areas from combined

operation are almost 25 percent larger than sum of the areas found when the units are operating individually. The maximum surface area is 677 acres; this occurs when discharge flow is 1770 cfs and ΔT_o is 32°F. The minimum area of 2°F isotherm, 153 acres, results when flow is 2290 cfs and ΔT_o is 28°F.

Time of travel for an entrained organism to reach 2°F, presented in Table 5.1-14 result from St Lucie Unit 1 discharge. Maximum travel time is 9.5 minutes and occurs when the plant flows 1770 cfs and ΔT_o is 32°F. A minimum travel time of 3.8 minutes occurs when the flow is 2290 cfs and ΔT_o is 28°F. Travel times to reach the 2°F isotherm, however, are the result of both St Lucie Unit 1 and 2 discharges. The travel time to reach 2°F isotherm under combined operations is greater than the sum of individual St Lucie Unit 1 and Unit 2 travel times. In some cases, the travel times under combined operation is almost 30 percent longer than the sum of the 2°F travel times found when the units are operating individually. The maximum travel time to reach 2°F isotherm is 193 minutes, this occurs when flow is 1770 cfs and the ΔT_o is 32°F. The minimum travel time is 95 minutes and this occurs when flow is 2290 cfs and ΔT_o is 28°F.

From the discussion presented above, for a stagnation case, the 2°F surface areas, volumes and travel times when both units are in operation are greater than for either individual unit. This reflects the following phenomenon; when individual plumes interfere, they form a single plume with reduced periphery and therefore a diminished ability to entrain surrounding water. The combined plume will traverse a greater distance, covering a greater area to entrain sufficient water to reduce plume temperature to 2°F above ambient.

The discussion presented above refers to stagnant ocean conditions, when St Lucie Unit 1 and 2 plumes interfere. During both southward and northward ocean current conditions, when the ocean current speed is 0.85 fps, the individual discharge plumes of 2°F do not interfere[21]. Therefore, it is concluded that the thermal effects (of 2°F) contributed by St Lucie Unit 2 when both units are in operation, will be the same as the thermal effects obtained when St Lucie Unit 2 alone is operating, when ambient northward or southward currents (0.85 fps) occur.

5.1.2.3.3 Recirculation

Estimates of surface temperature at the intake, under St Lucie Unit 2 or combined unit operation are complicated, since the systems dealt with do not lend themselves to exact mathematical analyses. Consequently, recirculation estimates are based on the results of HHR physical model study[2] and the calibrated PDS model.

Physical model studies have shown that there is no recirculation of St Lucie thermal plumes for either individual or concurrent unit operation under stagnation and northward current conditions. The recirculation temperatures discussed below refer to southward currents.

Physical model studies showed that the St Lucie Unit 2 plume would be diluted at least 260 times with a flow of 1150 cfs and ΔT_o of 26°F. For Test Cases 1 through 7, the calibrated PDS model shows that maximum temperature rise near the intake would be about 0.5°F at the surface and almost ambient at the bottom. This should produce a recirculation temperature of no higher than 0.2°F.

Under combined operation, with ΔT_o of 26°F and discharge flow of 1150 cfs from each unit, the physical model studies showed that near the intake the surface temperature rise would be about 2°F and near the bottom it would be about 0.2°F. This results in a recirculation temperature of about 0.8°F or a minimum dilution of about 32. The calibrated PDS model shows surface and bottom temperatures of 0.8°F and 0.1°F respectively. This should result in a recirculation temperature of no higher than 1.2°F.

The recirculation temperatures presented here, 0.2°F due to St Lucie Unit 2, and 1.2°F from combined unit operation, are based on conservative assumptions. These temperature rises are small compared to natural ambient temperature variations and should not pose significant problems for plant operation.

5.1.2.3.4 Plume Frequency Analysis

Beyond the region of high jet velocity plume orientation and shape is determined by ambient current direction and speed. Since the plume is controlled by nearshore flow, the frequency of occurrence of plume orientation will be the same as that of the local current. Figure 2.4-5 presents a current rose.

For the nearshore region at St Lucie, frequency distribution of current direction is bimodal, with the primary mode in the northward direction. Within this 300-030 degree quadrant, the frequency of current direction and plume orientation is 49 percent. For the opposite quadrant (120-210 degrees) it decreases to 34 percent. Longshore flow within both quadrants accounts for plume orientation 83 percent of the time.

An onshore current within 210-300 degrees occurs at a frequency of almost nine percent, which is slightly greater than the six percent occurrence in the offshore direction. The lower frequency of onshore plume orientation in comparison to longshore directions is due to the deformation of onshore flows by the shoreline boundary.

Median longshore current speed is between 0.8 and 0.9 feet per second (fps) in either direction; ten percent of the flow is less than 0.5 fps. At high current speed, ten percent of northward flow occurs at 1.4 fps and 1.1 fps for southward flow. At low current speeds, plume shape will tend to spread more uniformly in the slack flow, whereas at high current speeds, the plume will tend to stream with the current.

5.1.3 BIOLOGICAL EFFECTS OF ST LUCIE UNIT 2 OPERATION

5.1.3.1 Intake Effects

The flow through the St Lucie intake lines from the Atlantic Ocean will be approximately 2,320 cfs when St Lucie Unit 2 goes on-line. This represents a doubling of the present capacity (St Lucie Unit 1) and will result in a doubling of velocities through the system. This increased flow will increase the rate that biota are removed from the offshore environment. Whether this increase will result in a doubling in the number of plankton and fish entrained through the system is unknown. However, such an assumption is an appropriate boundary condition for the following discussion.

The planktonic community, comprised of phytoplankton, zooplankton and ichthyoplankton, is passively conducted through the circulating water system with the flow of water and returned to the ocean. In contrast, fish entrained from the ocean into the intake canal are removed from the offshore environment and not returned to the ocean. However, not all fish in a given volume of water are entrained into the intake pipeline, because they exhibit species and/or size-specific susceptibility to such entrainment. Estimates of possible entrainment and impingement impacts by St Lucie Unit 2 are discussed below.

5.1.3.1.1 Planktonic Organisms

Plantonic organisms should be entrained into the St Lucie Unit 2 circulating water system in a nonselective manner. The impact of entrainment on the waterbody is then computed on the basis of intake water flow relative to the source water volume (and planktonic community) available to entrainment over a reasonable amount of time.

Applied Biology Inc. (ABI) has previously computed entrainment rates for St Lucie Unit 1 based on a mathematical model and a source water volume defined as that circumscribed by the array of sampling stations. Their results indicated that entrainment would be 1.8 percent of this near-field community based on the assumption of 100 percent mortality of organisms through the system, and stagnant (worst case) ocean conditions (Table 5.1-15).

St Lucie Unit 2 will double the flow, or entrainment rate at the station. Using the source water volume computed by ABI[21,22,23], this results in a doubling of the estimated portion of the near-field plankton community affected. A worst case entrainment rate of 3.6 percent of the near-field plankton community present offshore of St Lucie Unit 2 should not constitute a significant impact.

5.1.3.1.2 Active Swimmers

Impingment data collected during the three years of operational monitoring at St Lucie Unit 1 are summarized in Table 5.1-16. Figures 5.1-7 through 5.1-14 represent time series of total numbers and weight of finfish and shellfish impinged on the traveling sceens over that period.

The dominant species impinged at St Lucie are: anchovy, grunt, jack, croaker and mojarra (numerically) and jack, mojarra and grunt (gravimetrically). The length distribution of impinged organisms collected in 1978 indicates that samples are dominated by small organisms. Over 80 percent of the impinged fish were less than or equal to 8 cm in length, and almost 100 percent of the impinged shrimp were 4 cm in length or less. The number of impinged species which are commercially important is low (Table 5.1-16). Although the fish impinged are primarily forage species or species of minor commercial importance, comparison of St Lucie plant annual impingement with the commercial catch illustrates the insignificance of impingement at this station. The total weight of fish impinged in any year (conservatively assuming 365 days operation of St Lucie Unit 1) is less tan 0.04 percent of the commercial landings docked in either St. Lucie or Martin counties. The shrimps and blue crabs impinged represent organisms of commercial value; however, the biomass of impinged shellfish is less than 0.005 percent of commercial shellfish landed in either St Lucie or Martin Counties.

Current impingement rates, assuming plant operation during 365 days per year ranged from approximately 34,000 (1978) to 131,000 (1976) finfish and from 26,000 (1976) to 37,000 (1978) shellfish.

Addition of St Lucie Unit 2 capacity to the total station circulating cooling water capacity is expected to increase the impingement rate at the station. When a fish or group of fish encounters the intake, as velocity increases, the probability of impingement should also increase. However, most species will have a finite probability of encountering the intake and of those, some of the more important species appear capable of avoiding entrainment (e.g., Spanish mackerel, bluefish). As an upper (conservative) boundary, impingement at St Lucie Units 1 and 2 is estimated at approximately 160,000 fish per year and 60,000 shellfish per year. These numbers represent twice the mean annual impingement estimates calculated from three years of St Lucie Unit 1 impingement data. These are relatively low impingement rates for a power plant, and should not produce significant ecological impacts.

5.1.3.1.3 Marine Turtles

Marine turtles presently enter the intake canal through the intake pipeline. Current research is examining whether turtles are being drawn into the intake pipe as they move through the area or if they actively swim into the structure in search of food or shelter. The increase in volume of water from 1160 cfs to 2320 cfs when St Lucie Unit 2 becomes operational will increase water velocity at the perimeter of the velocity cap from 0.5 to 1.0 fps. This increase will not appreciably enlarge the area from which turtles are unable to escape the intake velocity. Hence, no increase in the number of turtles entering the intake canal is expected due to velocity.

Even if current research demonstrates that turtles are deliberately entering the intake pipeline, no increase in the number of turtles in the intake canal is expected since the offshore configuration of the intake structure will not be changed.

Water in the intake pipelines will travel at a speed of 10 ft per second. This velocity will carry turtles from the intake structure to the intake canal in less than two minutes. There is no evidence that this activity is harmful to the animals. Turtles entering the canal are generally restricted from access to the entire canal by a block net at the AIA bridge. Turtles are captured and removed from the canal by netting and are released into the ocean. Additional studies on the behavior of turtles, physical characteristics of captured turtles and tagging and recapture studies are being conducted in cooperation with federal and state agencies.

5.1.3.2 Discharge Effects

An ABI report entitled "Effects of Increased Water Temperature on the Marine Biota of the St Lucie Plant Area"[24] addressed the impact of the St Lucie Unit 1 wye-port diffuser and a 32°F plant temperature rise on Atlantic Ocean biota. This report incorporated results of thermal plume modeling conducted by Envirosphere Company, ecological monitoring performed by ABI and results of thermal bioassays reported in the literature. Because the St Lucie Unit 2 multiport diffuser will provide greater dilution of the thermal plume than does the St Lucie Unit 1 wye-port diffuser, ABI's conclusions are considered conservative as applied to St Lucie Unit 2 impacts.

A summary of thermal bioassay, preference, and avoidance work applicable to St Lucie Unit 2 impact assessment is given in Table 5.1-17. Thermal tests conducted in laboratory facilities establish specific organism temperature tolerances. However, these tests generally record tolerance to increased temperatures for extended periods (e.g. 24, 48, or 96 hour exposure) and, generally, preclude avoidance behavior. As such, these reported temperature tolerances do not reflect exposure regimes that entrained organisms would encounter in the St Lucie Unit 2 plume.

In the case of St Lucie Unit 2, physical modeling indicates that an organism entrained into the thermal plume during September (worst case conditions) at the point of discharge would be exposed to a cumulative exposure of two seconds at 107°F; 7 seconds at 97°F; 21 seconds at 92°F and 85 minutes at 89°F (travel time along the plume center line, Table 5.1-5) before reaching water ambient ocean temperatures (87°F). Therefore exposure to potentially stressful temperatures lasts for less than one minute. Similarly, exposure duration along the plume centerlines from St Lucie Unit 1 through Unit 2, to the 2°F isotherm, would be 188 minutes (from Table 5.1-14, 6 seconds at 107°F; 15 seconds at 97°F; 7.7 minutes at 92°F). Thus, thermal bioassay data may overestimate impact. Also, exposure to water 2°F above average ambient temperature is within the realm of natural temperature variation offshore of Hutchinson Island.[25] 2

5.1.3.2.1 Effects on Benthos, Plankton and Fish

The thermal plume from St Lucie Unit 2 rises rapidly from the discharge diffuser, resulting in little plume contact or scouring of the benthic substrate (Figure 5.1-1). Therefore, it is assumed that the plume will not affect the benthic biota. 2

Thermal tolerances of plankton species resident in the St Lucie area which are available in the literature (Table 5.1-17) suggest that the brief exposures (less than 8 minutes) to increased temperatures will result in negligible effects. The temperatures inducing optimum growth and abundance for phytoplankton species indigenous to the St Lucie area range from 77°F to 95°F [26,28,30,31,33,34] coinciding with temperatures which occur during periods of observed maximum cell density and productivity (Table 2.2-7). Work by Ukeles [35] indicates that temperatures exceeding 102°F completely inhibit growth of marine diatoms. Saks and Lee [32] found that chronic exposure to temperatures of 102°F resulted in zero percent survival of 12 species of salt marsh epiphytes. Recorded upper lethal temperatures for several diatoms were: 84.2°F (Chaetoceros laciniosus) [27]; 93.2 [27] and 98.6°F [29] (Skeletonema costatum); and 95°F (Nitzscia acicularis) [33]. No instantaneous thermal maxima are available for phytoplankton species found in the St Lucie area. However results for other tropical species, exposure duration models for St Lucie plumes, and empircal results suggest that impact on phytoplankton should be insignificant.

Studies conducted at utility sites in Florida suggest that zooplankton are comparatively tolerant to thermal stress resulting from plume entrainment. Reeve and Casper [37] showed that at ambient temperatures of 85°F Acartia tonsa exhibited less than 25 percent mortality following a six hour exposure to 96.8°F. Adlen [38] noted that mortality of virtually all species tested from the Crystal River Estuary increased significantly at temperatures in excess of 95°F. Thermal tolerance data for some shrimp species which have meroplanktonic (larval) life stages (Penaeus - aztecus and P. setiferus) also indicate that brief exposure to temperatures above 95°F should not cause significant mortality. For example, 24 hour LT50's for P. aztecus post larvae ranged from 97.3 to 100.9°F, depending on acclimation temperature in studies conducted by Wiesepape [39].

Observed thermal tolerance ranges from ichthyoplankton found off Hutchinson Island are quite variable (Table 5.1-17). Also, due to seasonal spawning and developmental patterns, some ichthyoplankton species will not encounter worst case conditions in which ambient ocean temperatures of 87°F and maximum plume temperature of 105°F occur.

Temperature ranges of ichthyoplankton observed empirically at St Lucie range from 32°F (menhaden larvae) to 95°F (silverside prejunveniles). The lowest 96 hour LT50 reported for a St Lucie area species was 79.5°F (mullet embryo). The highest thermal tolerance reported for a 96 hour LT50 was 97.2°F (pompano juveniles). Very short-term thermal maxima data which would be applicable to plume entrainment exposure durations at St Lucie are apparently not available for the species concerned. Some ichthyoplankton mortality will occur as a result of this additional stress in the fishes early life history, but it is unlikely that this stress will be significant in relation to other sources of mortality.

Operation of St Lucie Unit 2 should not have a significant impact on fish. A number of studies have suggested that adult fish actively avoid areas where water temperatures reach lethal temperatures [63,75,78-79,82]. Gallaway and Strawn, [78,79] observed avoidance behavior of gulf menhaden

and bay anchovy within a temperature range of 86 to 91°F. It is expected that most of the fish offshore St Lucie would avoid the plume during the warmest months of the year. For the situation studied in this report, some 25.5 acre-feet could be so affected by the interaction of St Lucie Units 1 and 2 plumes if fish avoid temperatures exceeding 92°F (sum of volumes at 20°F, 10°F, and 5°F on line 4 of Table 5.1-11). Attraction of fish during other seasons should not present a potential for cold shock if both generating units shut down (unlikely), nor should the area affected by the plumes be considered to represent a significant influence with respect to fish behavior or life functions dependent on such behavior.

5.1.3.2.2 Effects on Marine Turtles

Variations in ambient water temperatures have been associated with changes in the timing of sea turtle nesting activity and nesting rates. During all four study years, the nesting season began when maximum ocean temperatures ranged between 71.6 and 76.1°F (Figure 5.1-17). A positive relationship between rising water temperatures and increased nesting activity was observed at the onset of each nesting season at Hutchinson Island (Figure 5.1-17). Nesting and nesting crawl activity levels increased until June or July and then declined, despite generally rising water temperatures, through the remainder of the nesting season. In 1973, cooler ocean temperatures may have partially inhibited nesting until July, when the waters warmed and a great influx of nesting females was observed. In contrast, increased nesting activity was observed during the early nesting season periods of 1975 and 1977, when ambient ocean temperatures were warmer than those in the other years of observation.

While the peak period of nesting appears to be related to temperature, there is no evidence that higher temperatures caused by the operation of St Lucie Unit 1 has caused premature nesting. Many reptiles require interaction between photoperiod and temperature which may preclude nesting until minimal requirements of both factors are present.

The volume of St Lucie Unit 1 and Unit 2 discharge plumes that will exceed 2°F in March and April immediately prior to normal nesting will not exceed 1900 acre-ft. This water mass will be located primarily in the water column immediately above the point of discharge and will have a velocity of about 14 ft/sec coming from the multiport diffusers. These conditions are not expected to influence the onset of turtle nesting or nesting behavior. Turtles encountering the thermal plume would move to waters of ambient temperatures for feeding. Hatchling turtles leaving the beach in the vicinity of the thermal plume may be exposed to elevated temperatures but the combination of currents and swimming activity should enable them to leave the plume area without excessive stress.

The discharge pipe will be buried below the sea floor, and will not impede turtle movement since they will be able to swim between the vertical risers and discharge jets.

5.1.4 OTHER EFFECTS OF HEAT DISSIPATION SYSTEM

Re-evaluation of potential fogging over the St Lucie Plant discharge canal, based on a condenser rise of 32°F, site specific meteorological data (Dec 1976 to Nov 1977) and actual intake water temperatures (Dec 1976 to Nov 1977), has shown a low occurrence of fogging for all months [33]. However, the probability of St Lucie Unit 2 operation at 32°F during these months is extremely low.

Ten hours of fog, which produced visibility of less than 50 m, were predicted for the entire year. Seven hours were predicted for January 1977 and three hours were predicted for December 1976. No cases of natural fog were predicted during these occasions.

Because of the low incidence of fog predicted over the discharge canal, the occurrence of fog in the Atlantic Ocean, resulting from the operation of St Lucie Unit 2, is considered to be very low. This reflects the much lower surface water temperatures produced by discharge from the St Lucie Unit 2 multiport diffuser.

SECTION 5.1: REFERENCES

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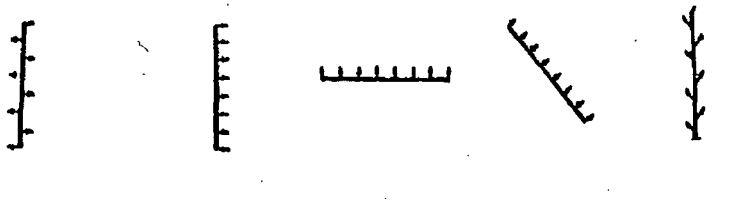
TABLE 5.1-1

QUALITATIVE PERFORMANCE OF SUBMERGED DIFFUSERS IN SEMI-INFINITE SHALLOW WATER*

TYPE OF DIFFUSER			(a) ALTERNATING	(b) COFLOWING	(c) TEE	(d) OBLIQUE	(e) STAGED**
Receiving Water Current +V							
Net Offshore Momentum			No	No	Yes	Yes	Yes
Performance in Receiving Water Currents	Unidirectional	Low Speed	Poor	Good	Good	Good	Fair
		Moderate Speed	Poor	Good	Fair	Good	Good
		High Speed	Fair	Good	Poor	Fair	Good
	Bidirectional	Low Speed	Poor	Fair	Good	Fair	Fair
		Moderate Speed	Poor	Poor	Fair	Poor	Good
		High Speed	Fair	Poor	Poor	Poor	Good

* From Reference 10.
** Staged or off-shore angled diffuser.

TABLE 5.1-2

OCEAN DISCHARGE PIPELINE FLOW DISTRIBUTION

Discharge Flow (cfs)	Discharge Temp Rise (°F)	Heat Discharge Rate (Btu/hr X10⁷)	Unit 1* Discharge Flow (cfs)	Unit 1* Velocity (fps)	Unit 1* Friction factor	Unit 2** Discharge Flow (cfs)	Unit 2** Velocity (fps)	Unit 2** Friction factor	Head++ (ft)	Flow## Variation (percent)
2003	32	14	941	10.65	0.015	1062	13.11	0.015	4.4	18.9 to 8.4
2003	32	14	836	9.46	0.030	1167	14.40	0.015	5.1	27.9 to 0.6
2003	32	14	766	8.67	0.045	1237	15.27	0.015	5.7	34 to 6.6
2003+	32	14	1001.5	11.33	0.015	1001.5	12.36	0.030	5.0	13.7
2003+	32	14	1052	11.90	0.015	951	11.74	0.045	5.5	9.3 to 18
1770#	32	12.25	830	9.39	0.015	940	11.60	0.015	5.5	9.3 to 18
1770#	32	12.25	745	8.43	0.030	1025	12.65	0.015	4.0	35.8 to 11.6
1770#+	32	12.25	680	7.7	0.045	1090	13.45	0.015	4.5	41.4 to 6.0
1770#	32	12.25	880	9.96	0.015	890	10.99	0.030	3.8	24.1 to 23.2
1770#+	32	12.25	934	10.57	0.015	836	10.32	0.045	4.3	19.5 to 27.9
2290	28	14	1065	12.05	0.015	1225	15.12	0.015	5.7	8.2 to 5.6
2290	28	14	956	10.82	0.030	1334	16.47	0.015	6.7	17.6 to 15
2290+	28	14	886	10.02	0.045	1404	17.33	0.015	7.5	23.6 to 21.0
2290+	28	14	1145	12.95	0.015	1145	14.13	0.030	6.6	1.3
2290+	28	14	1215	13.75	0.015	1075	13.27	0.045	7.3	4.7 to 7.3

* 12' Diameter
** 16' Diameter
\# Refers to 7-pump operation (one waterbox out of service).
\#\# With respect to a base flow of 1160 cfs per unit.
\+ Test cases for plume evaluation.
++ Elevation difference between ocean and discharge canal.

2

TABLE 5.1-3

FREQUENCY DISTRIBUTION OF LONGSHORE CURRENT SPEED AND DIRECTION AT THE ST LUCIE SITE

Current Speed Group (ft/sec)	Southward Frequency (%)	Quadrant Cumulative	Northward Frequency (%)	Quadrant Cumulative
0.0 - 0.1	0.06	0.06	0.44	0.44
0.1 - 0.2	0.33	0.39	0.52	0.96
0.2 - 0.3	0.76	1.15	0.82	1.78
0.3 - 0.4	0.97	2.12	0.97	2.75
0.4 - 0.5	3.27	5.39	3.92	6.67
0.5 - 0.6	3.25	8.64	3.68	10.35
0.6 - 0.7	4.11	12.75	5.57	15.92
0.7 - 0.8	4.28	17.03	6.49	22.41
0.8 - 0.9	5.65	22.68	8.65	31.06
0.9 - 1.0	3.27	25.95	5.61	36.67
1.0 - 1.1	3.66	29.61	4.99	41.66
1.1 - 1.2	2.22	31.83	3.48	45.14
1.2 - 1.3	1.19	33.02	1.69	46.83
1.3 - 1.4	0.58	33.60	1.05	47.88
1.4 - 1.5	0.36	33.96	0.48	48.36
1.5 - 1.6	0.20	34.16	0.27	48.63
1.6 - 1.7	0.12	34.28	0.24	48.87
1.7 - 1.8	0.17	34.45	0.20	49.07
1.8 - 1.9	0.03	34.48	0.14	49.21
1.9 - 2.0	0.08	34.56	0.19	49.40

TABLE 5.1-4

ST LUCIE UNIT 2: SUBSURFACE JET CHARACTERISTICS

Test No.	Discharge Flow (cfs)	Discharge Temp Rise (°F)	Max Surface Temp Rise (°F)			Ave Distance to Reach 17°F Above Ambient (ft) +			Jet Trajectory Length (ft)			Jet Velocity at the Surface (fps)		
			Stagnant	Southward Current	Northward Current	Stagnant	Southward Current	Northward Current	Stagnant	Southward Current	Northward Current	Stagnant	Southward Current	Northward Current
1	1001.5	32	4.4	2.9	2.7	15.6	13.4	13.2	101	91	87	2.7	1.9	1.8
2	951	32	4.6	3.0	2.7	15.6	13.4	13.2	98	88	86	2.6	1.9	1.8
3	1090	32	4.3	2.8	2.6	15.6	13.4	13.2	106	95	93	2.7	2.0	1.8
4	836	32	4.9	3.2	2.9	15.6	13.4	13.2	91	83	81	2.6	1.9	1.8
5	1145	28	3.5	2.3	2.1	13.5	12.0	12.0	114	100	96	2.6	1.9	1.7
6	1404	28	3.1	2.1	1.9	13.5	12.0	12.0	130	109	105	2.7	1.9	1.8
7	1075	28	3.6	2.4	2.2	13.5	12.0	12.0	110	98	93	2.5	1.8	1.7

Note:

(1) Ambient ocean temperature = 87°F.

(2) Jet characteristics shown are for the offshore port only.

\+ Distance computed along centerline of discharge, which is oriented 25° from the diffuser centerline. To determine the distance to the 17°F isotherm normal to the diffuser centerline, multiply the distance given by sin 25°.

TABLE 5.1-5

ST LUCIE UNIT 2: TRAVEL TIME ALONG PLUME CENTER LINE

			Plume Travel Time											
			Stagnant				Southward Current				Northward Current			
Test No.	Discharge Flow (cfs)	Discharge Temp Rise (°F)	Up to 20°F (sec)	Up to 10°F (sec)	Up to 5°F (sec)	Up to 2°F (min)	Up to 20°F (sec)	Up to 10°F (sec)	Up to 5°F (sec)	Up to 2°F (min)	Up to 20°F (sec)	Up to 10°F (sec)	Up to 5°F (sec)	Up to 2°F (min)
1	1001.5	32	2	6	19	70.5	2	4	12	126.3	2	4	11	137.8
2	951	32	2	6	20	74.1	2	4	13	132.8	2	4	11	149.3
3	1090	32	2	5	18	66.2	2	4	11	115.3	1	3	10	118.0
4	836	32	2	7	21	85.1	2	4	14	147.5	2	4	13	169.4
5	1145	28	1	4	14	42.0	1	3	9	55.5	1	3	8	28.1
6	1404	28	1	3	12	32.5	1	2	7	18.4	1	2	6	0.5
7	1075	28	1	4	15	43.0	1	3	9	66.9	1	3	8	40.8

TABLE 5.1-6

ST LUCIE UNIT 2: VOLUME ENCLOSED BY ISOTHERMS

Test No.	Discharge Flow (cfs)	Discharge Temp Rise (°F)	Volume (acre-ft) Enclosed by Isotherms, and Max Temp Rises														
			Stagnant					Southward Current					Northward Current				
			ΔT* Max	20°F	10°F	5°F	2°F	ΔT* Max	20°F	10°F	5°F	2°F	ΔT* Max	20°F	10°F	5°F	2°F
1	1001.5	32	4.4	0.02	0.19	1.48	584	2.9	0.02	0.12	0.88	599	2.7	0.02	0.10	0.78	500
2	951	32	4.6	0.02	0.19	1.47	536	3.0	0.02	0.12	0.88	621	2.7	0.02	0.10	0.78	534
3	1090	32	4.3	0.02	0.19	1.51	590	2.8	0.02	0.12	0.89	567	2.6	0.02	0.10	0.79	435
4	836	32	4.9	0.02	0.19	1.41	588	3.2	0.02	0.12	0.86	629	2.9	0.02	0.10	0.77	582
5	1145	28	3.5	0.02	0.12	1.04	314	2.3	0.02	0.08	0.60	170	2.1	0.02	0.07	0.53	85
6	1404	28	3.1	0.02	0.12	1.05	290	2.1	0.02	0.08	0.61	86	1.9	0.02	0.07	0.53	8
7	1075	28	3.6	0.02	0.12	1.03	250	2.4	0.02	0.08	0.60	201	2.2	0.02	0.07	0.53	100

*Maximum surface temperature rise.

TABLE 5.1-7

ST LUCIE UNIT 2: AREA OF ISOTHERMS

Test No.	Discharge Flow (cfs)	Discharge Temp Rise (°F)	Area (acres) Enclosed by 2°F Isotherms and Max Surface Temp Rises					
			Stagnant		Southward Current		Northward Current	
			ΔT* Max	Area	ΔT* Max	Area	ΔT* Max	Area
1	1001.5	32	4.4	273	2.9	825	2.7	528
2	951	32	4.6	285	3.0	872	2.7	589
3	1090	32	4.3	258	2.8	739	2.6	427
4	836	32	4.9	294	3.2	963	2.9	720
5	1145	28	3.5	172	2.3	175	2.1	28
6	1404	28	3.1	133	2.1	21	1.9	0
7	1075	28	3.6	192	2.4	226	2.2	53

*Maximum surface temperature rise.

TABLE 5.1-8

ST LUCIE UNIT 1: SUBSURFACE JET CHARACTERISTICS

Test No.	Discharge Flow (cfs)	Discharge Temp Rise (°F)	Max Surface Temp Rise (°F)	Jet Trajectory Length (ft)	Jet Velocity at the Surface (fps)
8	1001.5	32	8.1	130	3.9
9	1052	32	7.9	134	4.0
10	680	32	9.7	110	3.5
11	934	32	8.4	126	3.8
12	1145	28	6.4	144	3.9
13	886	28	7.3	127	3.6
14	1215	28	6.2	149	3.9

Notes: (1) Ambient ocean temperature = 87°F.

(2) Subsurface jet characteristics remain essentially unaltered under stagnant, southward and northward ocean current conditions.

TABLE 5.1-9

ST LUCIE UNIT 1: TRAVEL TIME ALONG PLUME CENTERLINE UNDER STAGNANT OCEAN CONDITIONS

Test No.	Discharge Flow (cfs)	Discharge Temp Rise (°F)	Max Surface Temp Rise (°F)	Plume Travel Time: Up to 20°F (sec)	Up to 10°F (sec)	Up to 5°F (min)	Up to 2°F (min)
8	1001.5	32	8.1	6	14	7.3	58.2
9	1052	32	7.9	6	13	7.0	56.2
10	680	32	9.7	8	19	9.5	75.9
11	934	32	8.4	6	15	7.7	61.5
12	1145	28	6.4	5	10	4.2	39.1
13	886	28	7.3	6	11	5.8	48.1
14	1215	28	6.2	4	10	3.8	37.3

TABLE 5.1-10

ST LUCIE UNIT 1: VOLUME ENCLOSED BY ISOTHERMS UNDER STAGNANT OCEAN CONDITIONS

Test No.	Discharge Flow (cfs)	Discharge Temp Rise (°F)	Max Surface Temp Rise (°F)	Volume (acre-ft) Enclosed by Isotherms 20°F	10°F	5°F	2°F
8	1001.5	32	8.1	0.12	0.51	23.1	542
9	1052	32	7.9	0.12	0.51	22.8	550
10	680	32	9.7	0.12	0.49	22.6	469
11	934	32	8.4	0.12	0.51	23.3	531
12	1145	28	6.4	0.09	0.37	10.9	369
13	886	28	7.3	0.09	0.37	13.0	348
14	1215	28	6.2	0.09	0.37	10.2	372

TABLE 5.1-11

ST LUCIE UNITS 1 and 2: VOLUME ENCLOSED BY ISOTHERMS UNDER STAGNANT OCEAN CONDITIONS

Test No.	Discharge Flow (cfs)	Discharge Temp Rise (°F)	Volume (acre-ft) Enclosed by Isotherms			
			20°F	10°F	5°F	2°F
15	2003	32	0.14	0.70	24.6	1701
16	2003	32	0.14	0.70	24.3	1889
17	1770	32	0.14	0.68	24.1	1673
18	1770	32	0.14	0.70	24.7	1721
19	2290	28	0.11	0.50	11.9	963
20	2290	28	0.11	0.50	14.1	873
21	2290	28	0.11	0.50	11.2	932

TABLE 5.1-12

ST LUCIE UNIT 1: AREA OF ISOTHERMS UNDER STAGNANT OCEAN CONDITIONS

Test No.	Discharge Flow (cfs)	Discharge Temp Rise (°F)	Max Surface Temp Rise (°F)	Area (acres) Enclosed by Isotherms 5°F	2°F
8	1001.5	32	8.1	14.6	270
9	1052	32	7.9	14.0	268
10	680	32	9.7	18.3	284
11	934	32	8.4	15.8	274
12	1145	28	6.4	4.9	173
13	886	28	7.3	8.2	188
14	1215	28	6.2	4.1	171

TABLE 5.1-13

ST LUCIE UNITS 1 and 2: AREA OF ISOTHERMS UNDER STAGNANT OCEAN CONDITIONS

Test No.	Discharge Flow (cfs)	Discharge Temp Rise (°F)	Areas (acres) Enclosed by Isotherms 5°F	2°F
15	2003	32	14.6	644
16	2003	32	14.0	605
17	1770	32	18.3	677
18	1770	32	15.6	660
19	2290	28	4.9	405
20	2290	28	8.2	353
21	2290	28	4.1	422

TABLE 5.1-14

ST LUCIE UNITS 1 AND 2: TRAVEL TIME ALONG THE PLUME CENTER LINES UNDER STAGNANT OCEAN CONDITIONS

Test No.	Discharge Flow (cfs)	Discharge Temp Rise (°F)	Travel Time: Up to 20°F (sec)	Travel Time: Up to 10°F (sec)	Travel Time: Up to 5°F (min)	Travel Time: Up to 2°F (min)
15	2003	32	6	14	7.3	165
16	2003	32	6	13	7.0	172
17	1770	32	8	19	9.5	193
18	1770	32	6	15	7.7	188
19	2290	28	5	10	4.2	104
20	2290	28	6	13	5.8	98
21	2290	28	4	10	3.8	95

TABLE 5.1-15

PERCENTAGE LOSS ESTIMATES OF FISH LARVAL ENTRAINMENT BASED ON PLANT OPERATING AND ICHTHYOPLANKTON SAMPLING STATISTICS
ST LUCIE PLANT
1976, 1977 AND 1978

Year	Category	Variables[a] C_r	C_p	Q_r	Q_p	m	Percentage loss (mean depth-9.2m) $\frac{mC_p}{C_r} \neq 1$	$\frac{mC_p}{C_r} = 1$	Percentage loss (mean depth-3.0m) $\frac{mC_p}{C_r} \neq 1$	$\frac{mC_p}{C_r} = 1$
1976	eggs	3.848	1.259	5474[1785]	32.36	1.0	0.19	0.59	0.59	1.81
	larvae	0.205	0.041	5474[1785]	32.36	1.0	1.07	0.59	3.29	1.81
1977	eggs	0.429	0.366	5474[1785]	32.36	1.0	0.50	0.59	1.55	1.81
	larvae	1.345	0.028	5474[1785]	32.36	1.0	0.01	0.59	0.04	1.81
1978[b]	eggs	2.709	1.503	5474[1785]	32.36	1.0	0.40	0.59	1.23	1.81
	larvae	0.421	0.087	5474[1785]	32.36	1.0	0.15	0.59	0.47	1.81

[a] C_r = Geometric mean concentration of organisms per m^3 (based on surface tows only) in offshore areas (Stations 0 through 5).

C_p = Geometric mean concentration of organisms per m^3 in the intake water (Station 11).

Q_r = Flow in m^3 per second past the plant, based on a cross-sectional area of 32,200m^2; numbers in brackets are based on a cross-sectional area of 10,500m^2.

Q_p = Water flow in m^3 per second through the plant intake, based on maximum recorded daily value.

m = Mortality rate of entrained organisms (assumed to be 100%, making m = 1.0).

b = Mean numbers of eggs or larvae per m^3 are calculated from data collected from 14 December 1977 through 28 November 1978.

TABLE 5.1-16

SUMMARY OF ST LUCIE UNIT 1 IMPINGEMENT SAMPLING (MARCH 1976 - DECEMBER 1978)[1]

	1976		1977		1978	
Days Sampled/Days on-line (%)	45/192 (23.4%)		97/339 (28.6%)		84/297 (28.3%)	
FINFISH						
Mean Number Impinged/24 hours[2]	351		223		92	
Mean Weight (kg) Impinged/ 24 hours[2]	1.2		2.7		1.2	
Species' Relative Abundance (%)	Anchovy:	54.4	Grunt:	50.3	Anchovy:	18.2
	Jack:	30.8	Anchovy:	28.0	Jack:	15.0
	Remaining:	<2.8*	Mojarra:	6.7	Croaker:	14.5
			Jack:	4.7	Mojarra:	12.5
			Remaining:	<2.9	Herring:	9.9
					Grunt:	7.2
					Remaining:	<3.8
Species' Representative Weight (%)	Anchovy:	22.9	Jack:	40.9	Jack:	20.7
	Jack:	12.2	Grunt:	31.1	Mojarra:	9.0
	Grunt:	10.7	Mojarra:	3.7	Herring:	6.1
	Remaining:	<5.8	Croaker:	3.6	Croaker:	5.0
			Filefish:	3.4	Anchovy:	1.7
			Anchovy:	3.1	Remaining:	<4.8
			Remaining:	<1.5		
Peak Sampling Period	October		August		December	
Number Commercially-Important Organisms Impinged (Annual Total)	10		76		37	
SHELLFISH						
Mean Number Impinged/24 hours[2]	72		72		101	
Mean Weight (kg) Impinged/ 24 hours[2]	0.8		0.3		0.5	
Species' Relative Abundance (%)	Shrimp:	78.2	Shrimp:	88.7	Shrimp:	84.1
	Blue Crab:	21.4	Blue Crab:	10.1	Blue Crab:	15.6
	Remaining:	<0.4	Remaining:	0.8	Remaining:	0.2
Species' Representative Weight (%)	Blue Crab	75.3	Blue Crab	54.9	Shrimp:	53.3
	Shrimp:	23.9	Shrimp:	42.1	Blue Crab:	44.8
	Remaining:	<0.7	Remaining:	<2.3	Remaining:	<1.7

TABLE 5.1-16

	1976	1977	1978
Peak Sampling Period	November	August	December

(1) Summarized from Annual Monitoring Reports, Applied Biology, Inc, 1977-1979.
(2) Means for 1976/1977 data are arithmetic means; 1978 means are geometric.

*Each remaining taxon comprised no more of the sample than the percentage shown.

TABLE 5.1-17

THERMAL TOLERANCE DATA: ORGANISMS INDIGENOUS TO HUTCHINSON ISLAND OFFSHORE ENVIRONMENT

Organism	Physiological Response	Temperature (°F)	Reference
PHYTOPLANKTON			
Nitzschia sigma	Optimal growth	77	26
Chaetoceros laciniosus	Upper lethal	84.2	27
Skeletonema costatum	Upper lethal (68°F acclimation)	93.2	27
Rhizosolenia delicatula	Optimal growth	55.4	28
Skeletonema costatum	Upper lethal	98.6	29
Nitzschia filiformis	Optimal growth	78	30
various marine diatoms	Optimal abundance	87.8 - 95.0	31
12 spp salt marsh epi-phytes	Chronic exposure: 0% survival	102.2	32
Nitzschia acicularis	Optimal growth Depressed growth Upper lethal	77 91.4 95	33
Gymnodinium simplex	Optimal growth	73.4 - 82.4	34
Prorocentrum	Optimal growth	77	34
various marine diatoms	No growth	>102	35
ZOOPLANKTON			
Acartia tonsa	Normal nauplii development	41 - 77	36
Acartia tonsa	<25% mortality	96.8 (6 hours)	37

TABLE 5.1-17

Organism	Physiological Response	Temperature (°F)	Reference
Crystal River estuary spp	Increased mortality	95	38
Penaeus aztecus	LT50 (10,000 minutes)	95 - 96.8	39
	LT50 (24 hour acclimation T = 75.2, 84.2, 93.2°F)	97.3, 99.5, 100.9	
P. setiferus	LT50 (10,000 minutes; acclimation T=84.2, 93.2°F)	96.8, 98.6	39
	LT50 (24 hour; acclimation T=84.2, 93.2°F)	100.9, 102.2	
P. setiferus	Good growth	89.6	40
P. aztecus	No growth	95	40
MACROINVERTEBRATES			
Puerto Rico benthic fauna	Decreased species diversity Decreased biomass	95	41
Tampa Bay fauna	Restrictive to benthic fauna	89.6-91.4	42
Biscayne Bay fauna	Optimal temperature	78.8-82.4	43
	50% reduction in representative species	95-102.2	43
Phragmatopoma lapidosa	Optimal larval development (to age 48 hrs)	75.2-78.8	44
	LT50 (48 hr exposure from fertilization)	85.1	
	No embryonic development	95	
Biscayne Bay ophiuroids	Upper instantaneous lethal temperatures	99.5-104.9	45
ICHTHYOPLANKTON			
Frog fish embryo, larvae	Observed temperature range	70-81	46
Silverside prejuvinels	Thermal tolerance range	46-95	47,48
Silverside embryos, larvae	Incipient lethal (upper)	82.4	49,50

TABLE 5.1-17

Organism	Physiological Response	Temperature (°F)	Reference
Jacks embryo larvae	Observed range	82.4	51
Menhaden larvae	Observed range	32-77	52
Sardine larvae	Thermal tolerance range	79-92	53
Sheepshead minnow juvenile	Observed range	109.4	54
Tarpon larvae	Observed range	68-90	55,56
Bay anchovy larvae, embryo	Incipient lethal	82	53
Striped anchovy embryo	Incipient lethal	69.8	57
Clingfish embryo	Optimal temperature	75	58
Neon goby embryo	Observed range	82.4	59
Code goby embryo	Observed range	59.9-87.8	60
Striped mullet embryo, larvae	Thermal range	45.9-87.1	61
Striped mullet larvae	Incipient lethal	89.6	57
Speckled worm eel larvae	Observed range	64.4-75.2	62
French grunt juveniles	Critical thermal max	96.8-100.4	63
Spot post larvae-juveniles	Critical thermal max	88	64
Pinfish post larvae juveniles	Critical thermal max	87.8	64

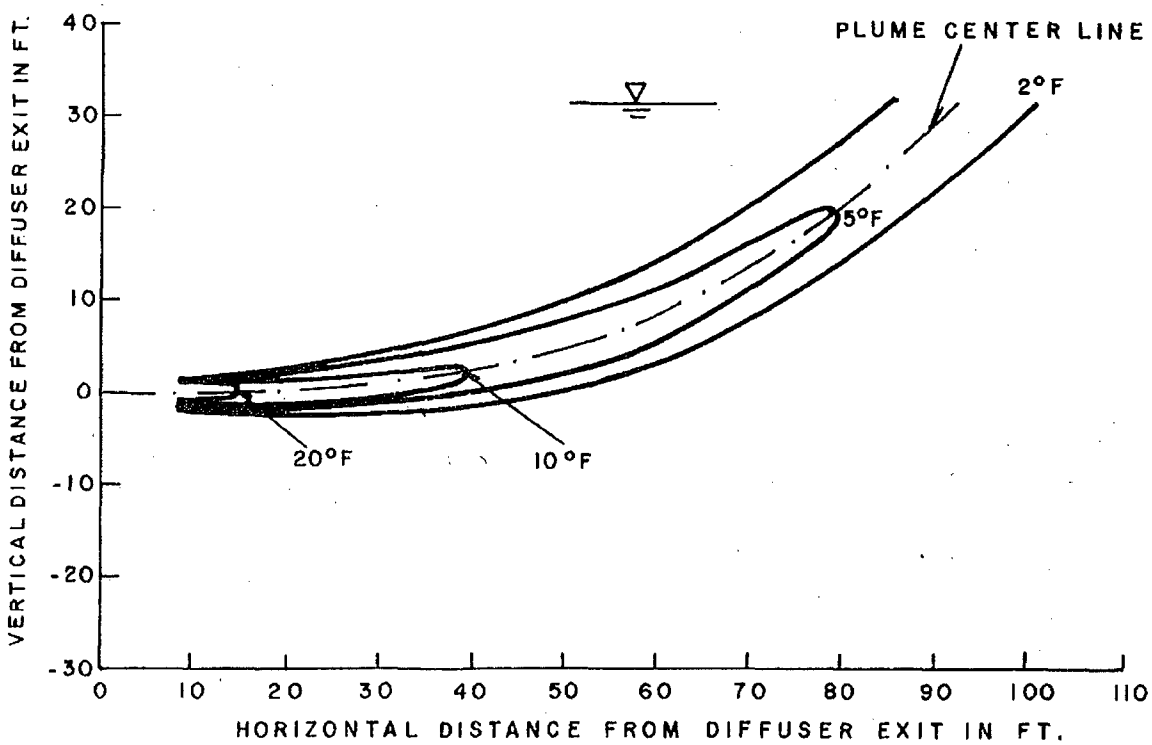
TABLE 5.1-17

Organism	Physiological Response	Temperature (°F)	Reference
Drum larvae	Optimal larval develop-	76	65
	24-hour LT50	82-90	
Menhaden	Critical thermal maximum	85	66
Spot	Critical thermal maximum	88	
Pinfish	Critical thermal maximum	88	
FISH - SHELLFISH			
Gray snapper	Lower tolerance limit	52-57	67
Spot	Observed range	34-96	68
Atlantic croaker	Observed range	32-96	
Mummichog	Upper lethal (10,000 minutes)	97.4	69
	Incipient lethal	99.5	70
Mullet	96 hour TL50	98	71
Pompano	96 hour TL50	97	71
Blue crab	96 hour TL50	98	
Menhaden	Incipient lethal	91.4	72
Bay anchovy	Observed ranged	47-91	73
Clingfish	Incipient lethal	88	58
Crested goby	Observed range	81-82	74
Atlantic mackerel Bluefish Tautog	61-190% increase in swim speed	increases over ambient	75
Tropical marine fishes	Observed range	88-90	57
	Maximum survival temperature	95	
Boney fishes	Upper lethal	100	76
Sharks/rays	Upper lethal	86	
Marine fishes	No large or diverse populations	>95	77
Galveston Bay fishes	Observed range	91-95	78,79
	Decreased spp diversity	>95	

TABLE 5.1-17

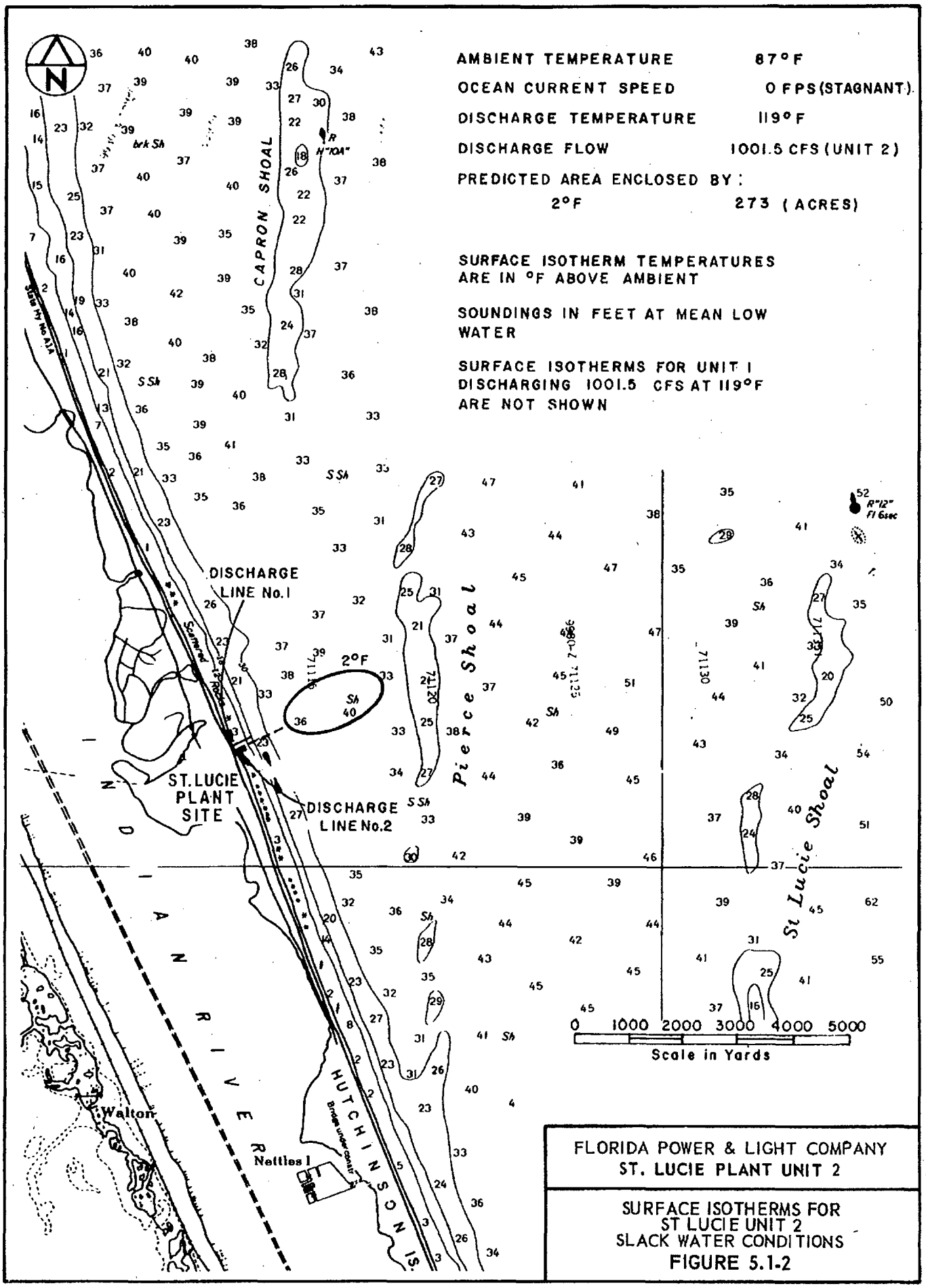
Organism	Physiological Response	Temperature (°F)	Reference
Atlantic croaker, Sea catfish	Occurrence	99	
Striped mullet	Occurrence	104	78,79
Gulf menhaden, Bay anchovy	Avoidance behavior	86-91	78,79
Sea catfish Gulf menhaden	Occasional mortality		78,79
King mackerel	Minimum of range	68	80
Spanish mackerel	Ripening of gonads Spawning	72 78	81
Bluefish	Preferred thermal range Increased swimming speed	66-72 >85	82

DISCHARGE EXIT VELOCITY	12.4 FPS
DISCHARGE FLOW RATE AT DIFFUSER OUTLET	1001.5 CFS
DISCHARGE EXIT TEMPERATURE	119.0°F
AMBIENT TEMPERATURE	87.0°F
OCEAN CURRENT SPEED	0 FPS
DETENTION TIME TO REACH SURFACE	26 SECS



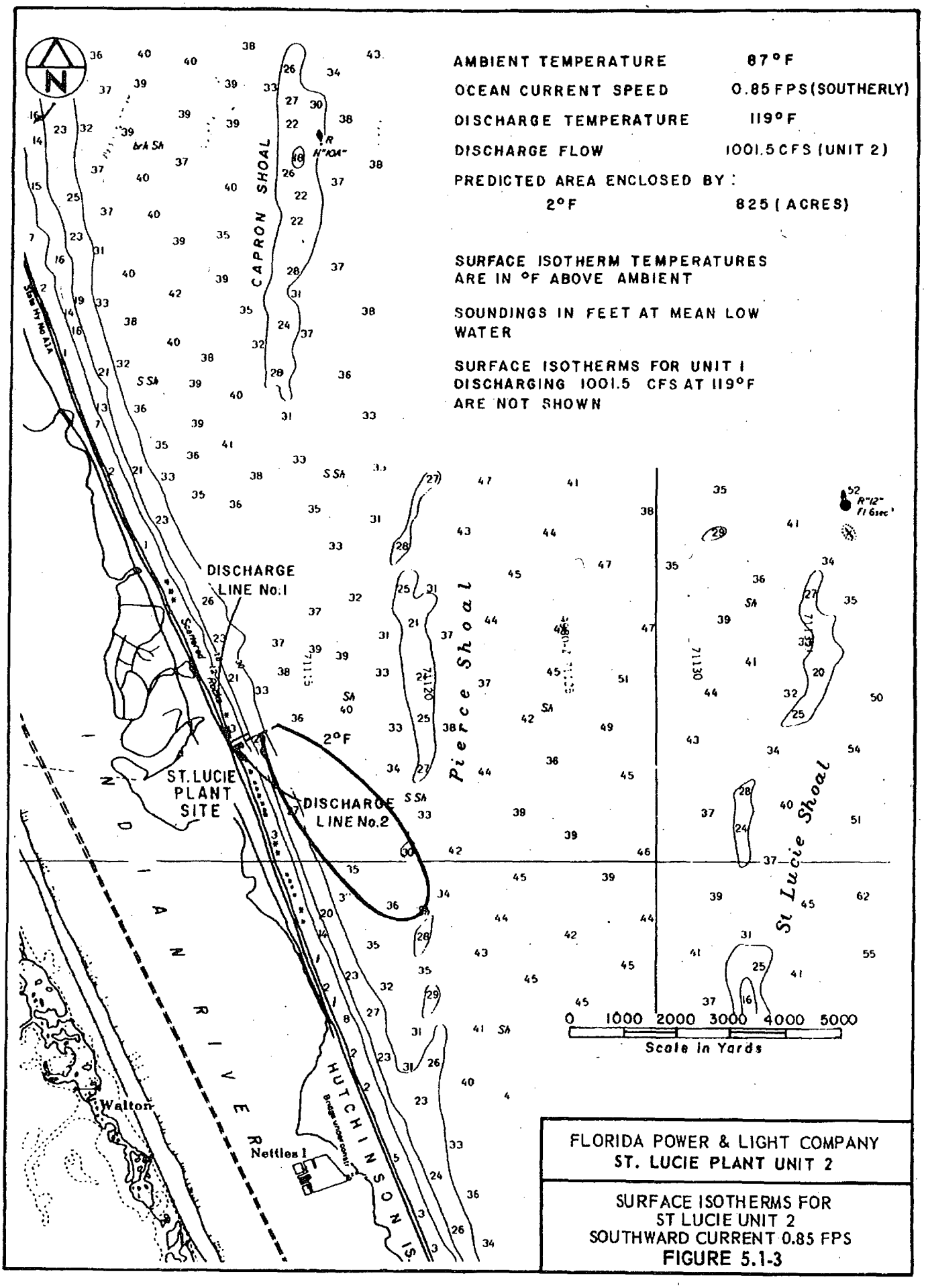
FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

SUBSURFACE ISOTHERMS FOR
ST LUCIE UNIT 2
SLACK WATER CONDITIONS
FIGURE 5.1-1



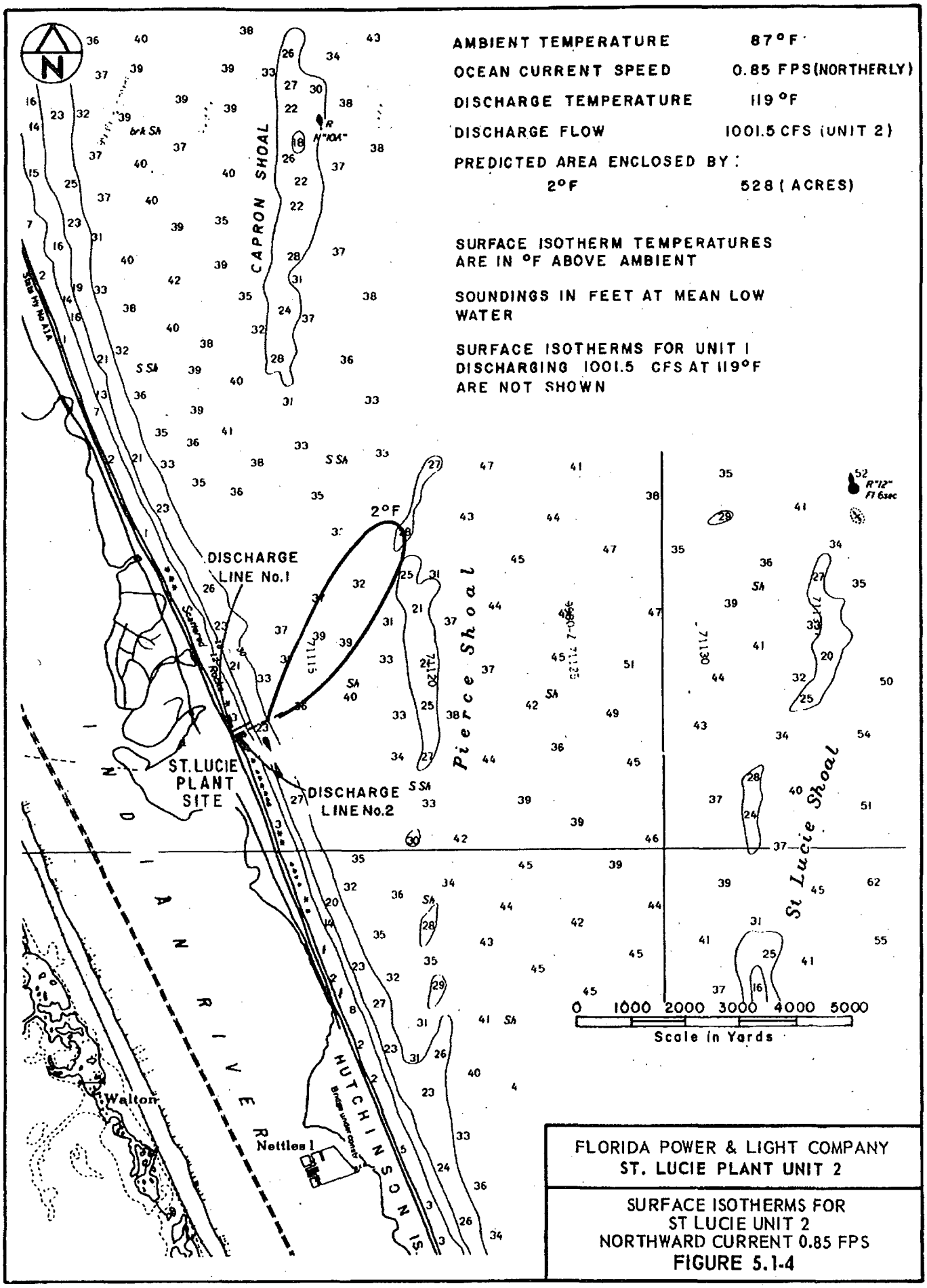
FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

SURFACE ISOTHERMS FOR
ST LUCIE UNIT 2
SLACK WATER CONDITIONS
FIGURE 5.1-2



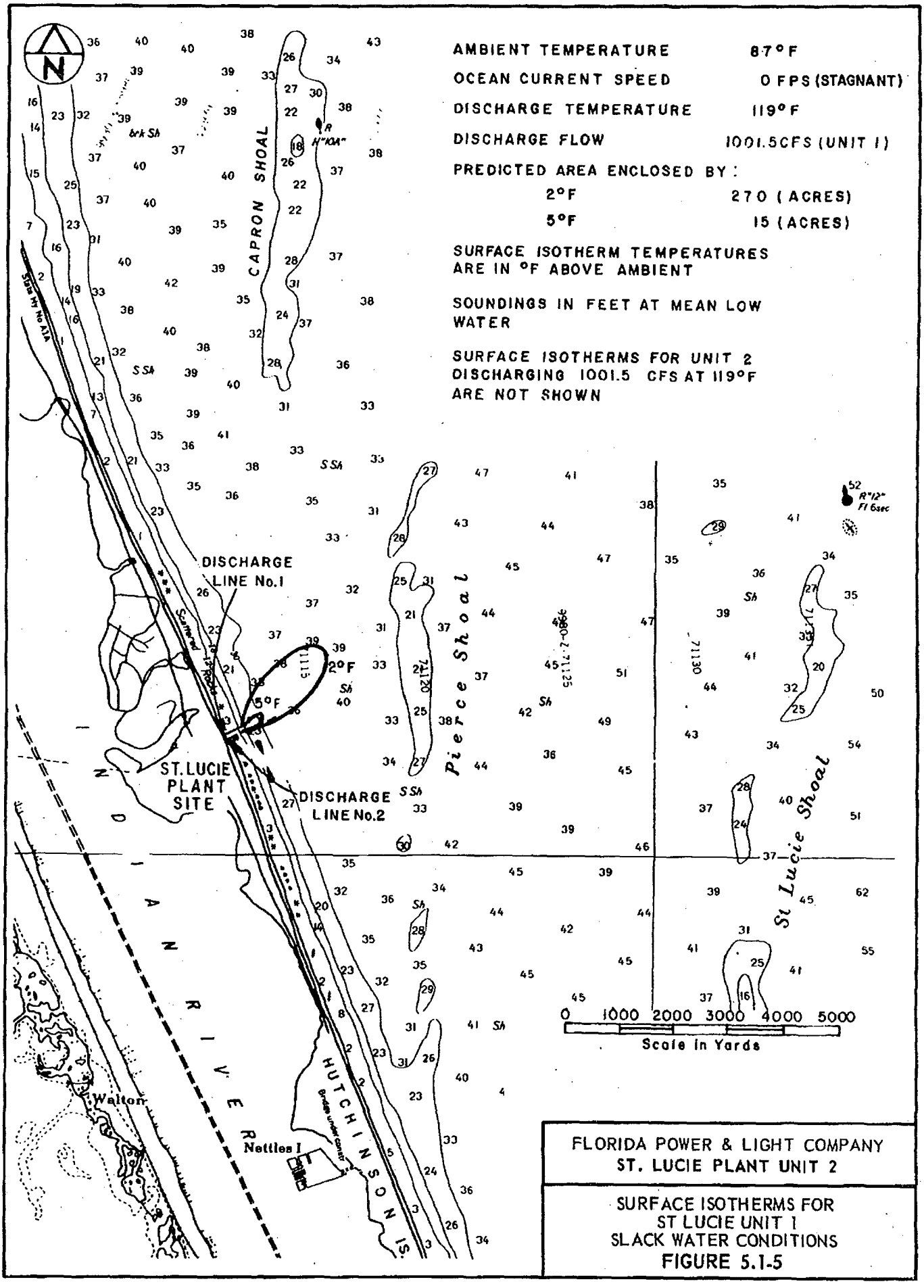
FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

SURFACE ISOTHERMS FOR
ST LUCIE UNIT 2
SOUTHWARD CURRENT 0.85 FPS
FIGURE 5.1-3



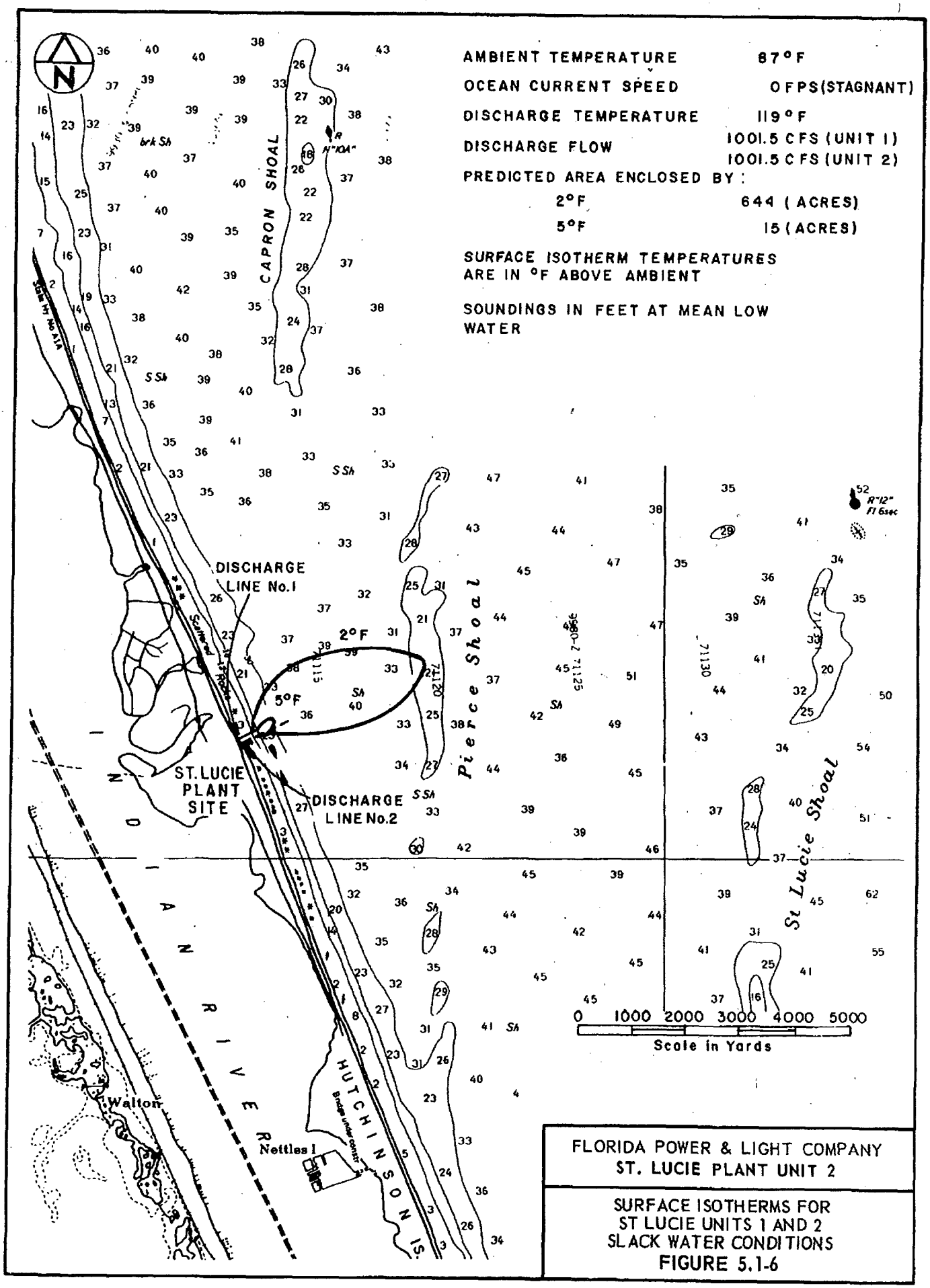
FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

SURFACE ISOTHERMS FOR
ST LUCIE UNIT 2
NORTHWARD CURRENT 0.85 FPS
FIGURE 5.1-4



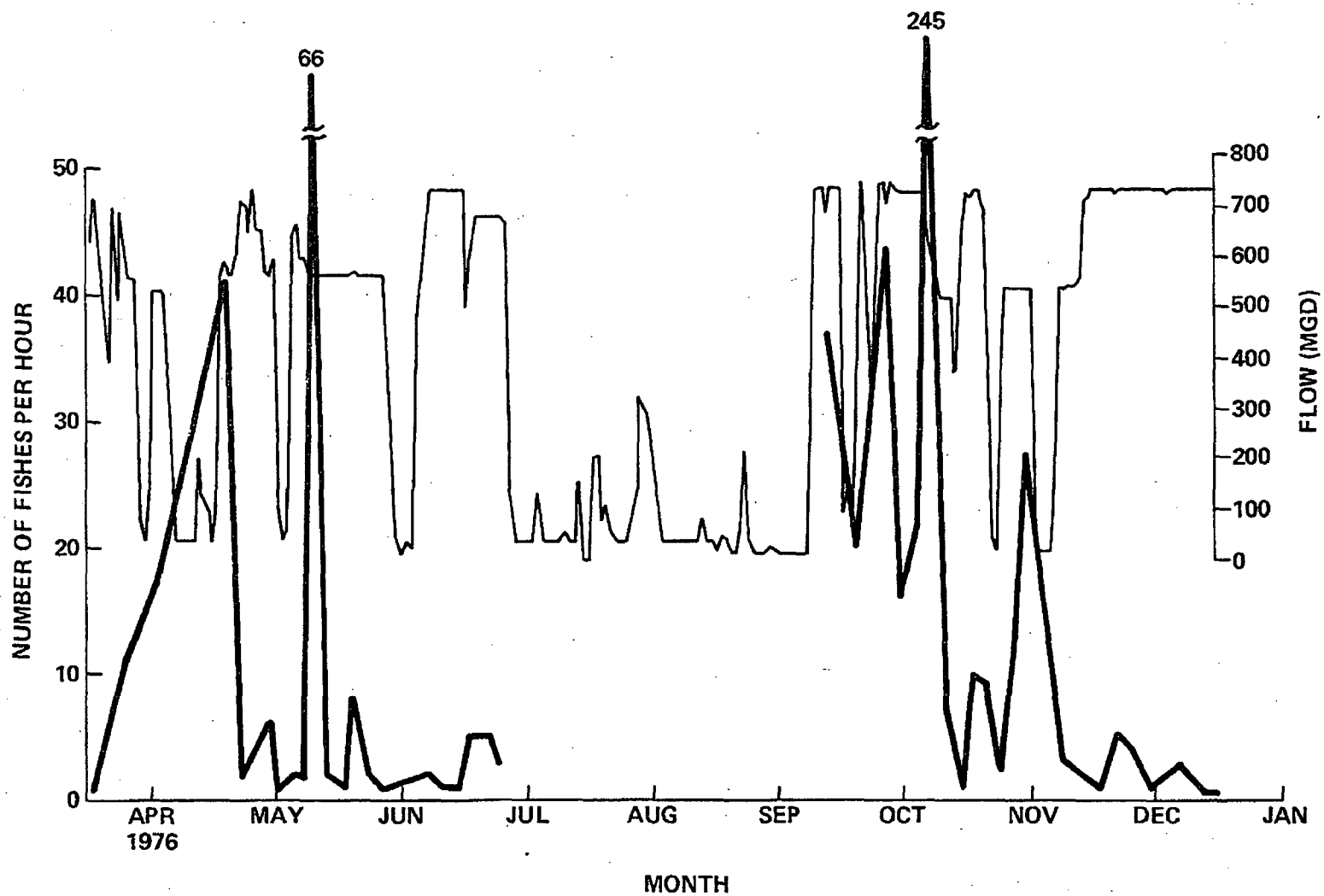
FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

SURFACE ISOTHERMS FOR
ST LUCIE UNIT 1
SLACK WATER CONDITIONS
FIGURE 5.1-5



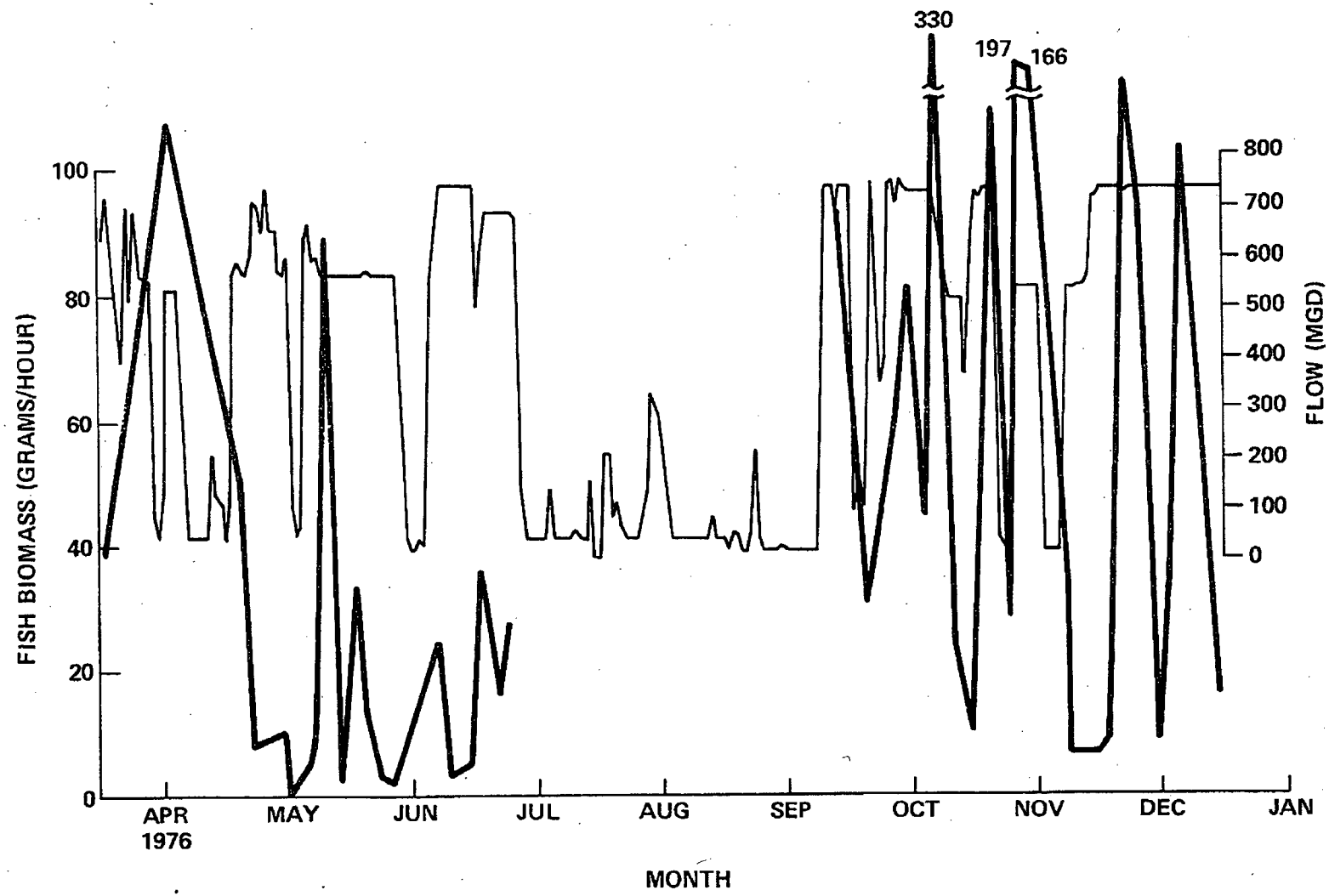
FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

SURFACE ISOTHERMS FOR
ST LUCIE UNITS 1 AND 2
SLACK WATER CONDITIONS
FIGURE 5.1-6



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

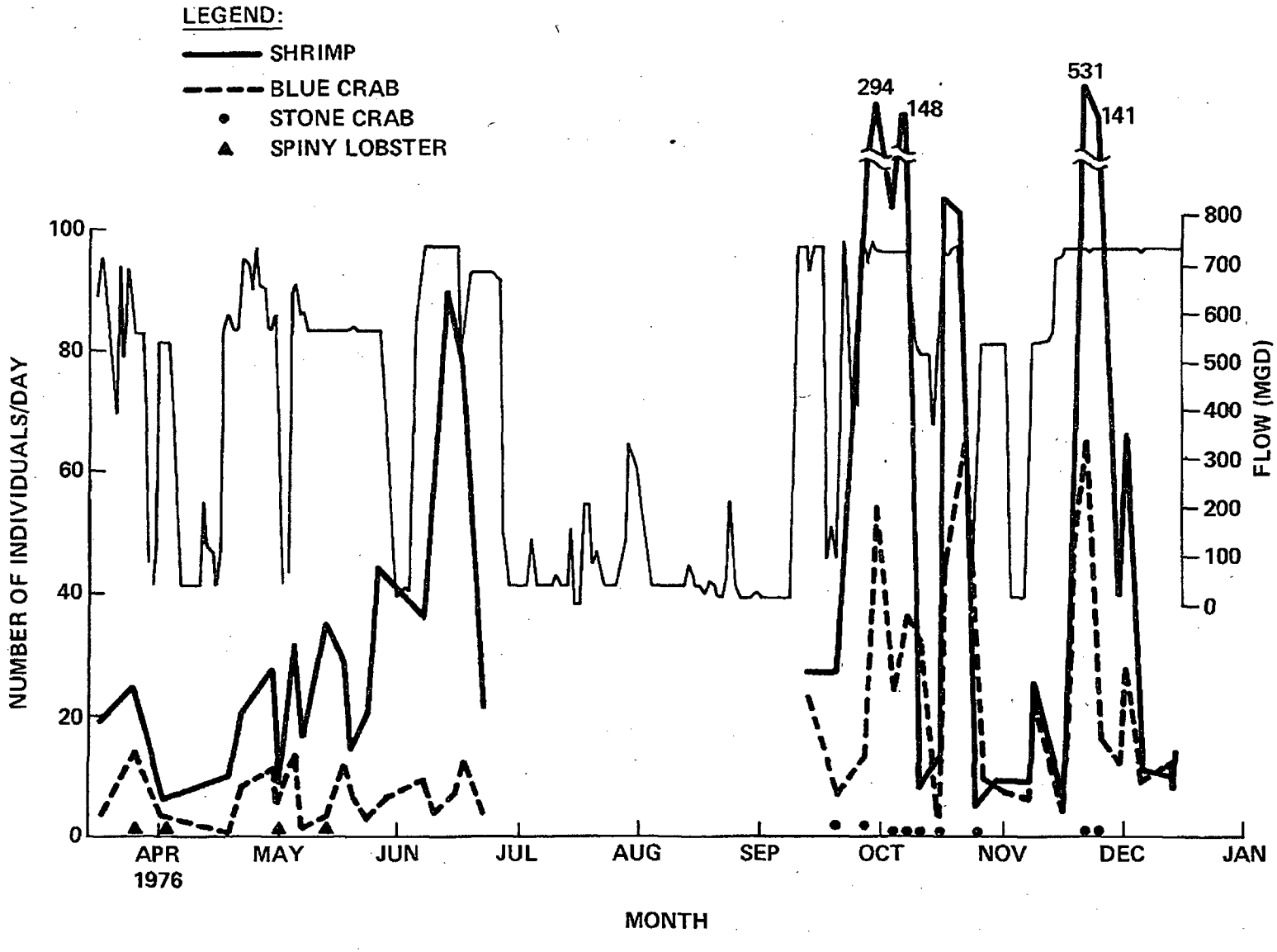
NUMBER OF FISH IMPINGED
VS. PLANT FLOW IN 1976
FIGURE 5.1-7



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

FISH BIOMASS COLLECTED VS.
PLANT FLOW IN 1976

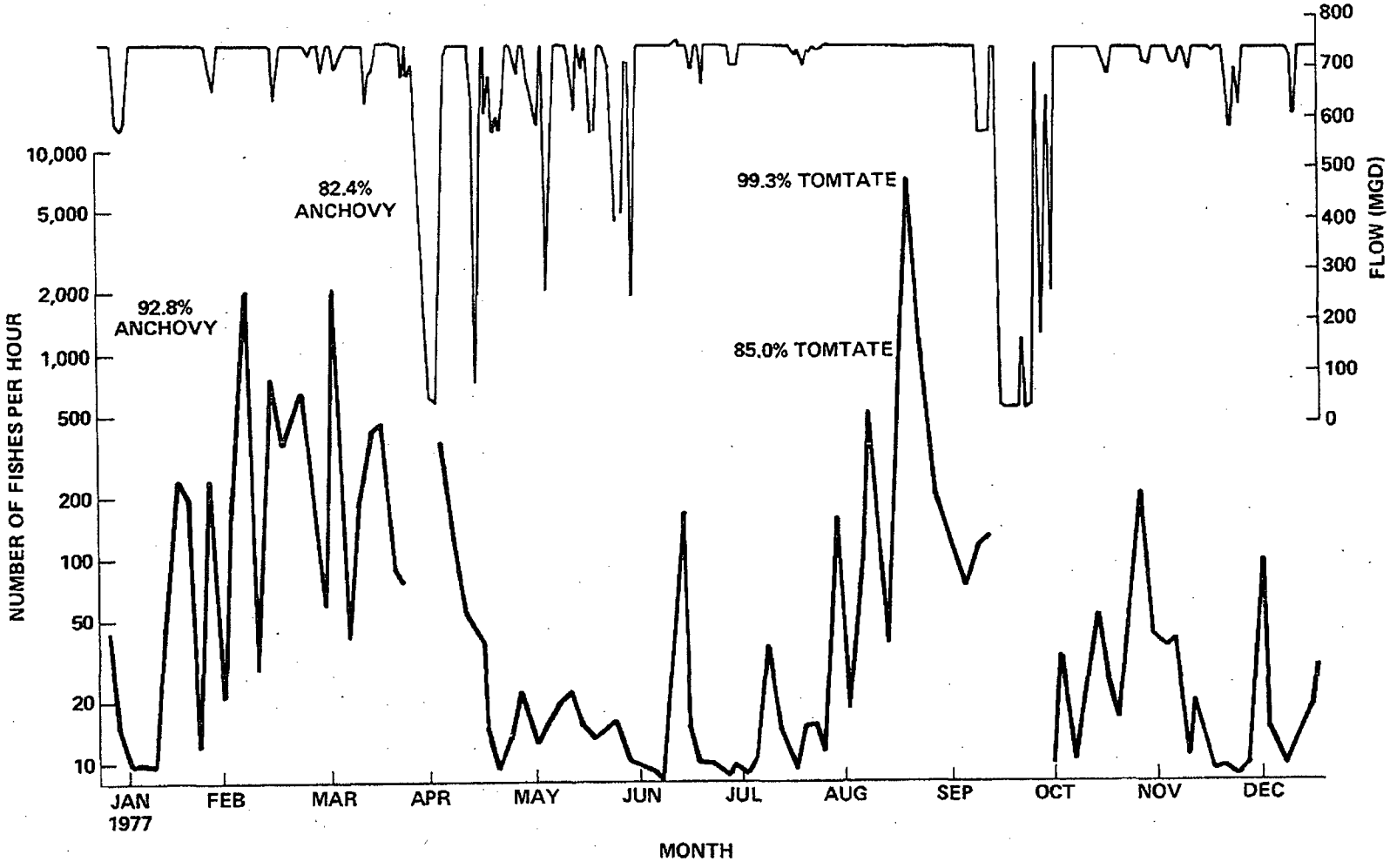
FIGURE 5.1-8



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

NUMBER OF SHELLFISHES IMPINGED
VS. PLANT FLOW IN 1976

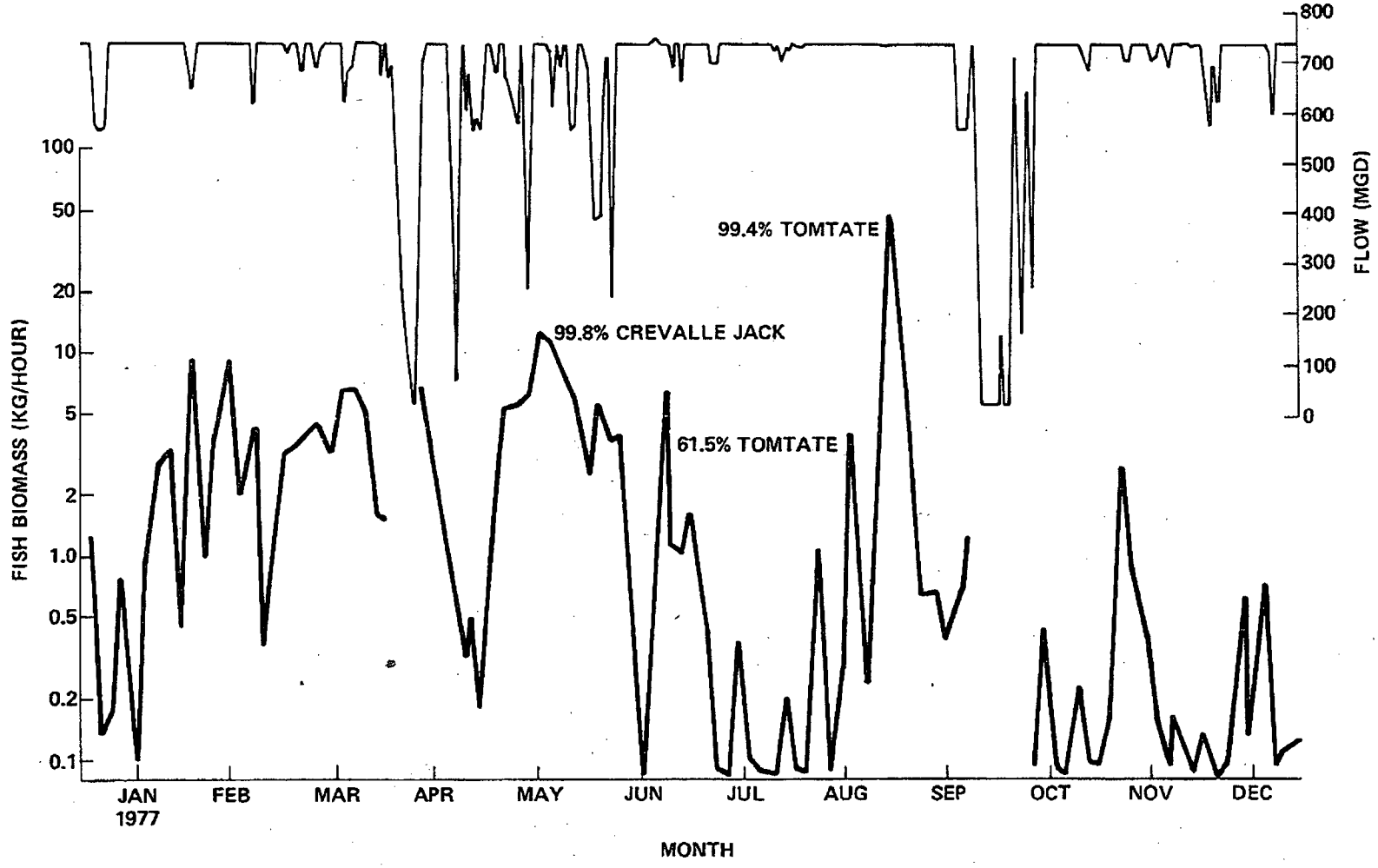
FIGURE 5.1-9



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

NUMBER OF FISHES IMPINGED
VS. PLANT FLOW IN 1977

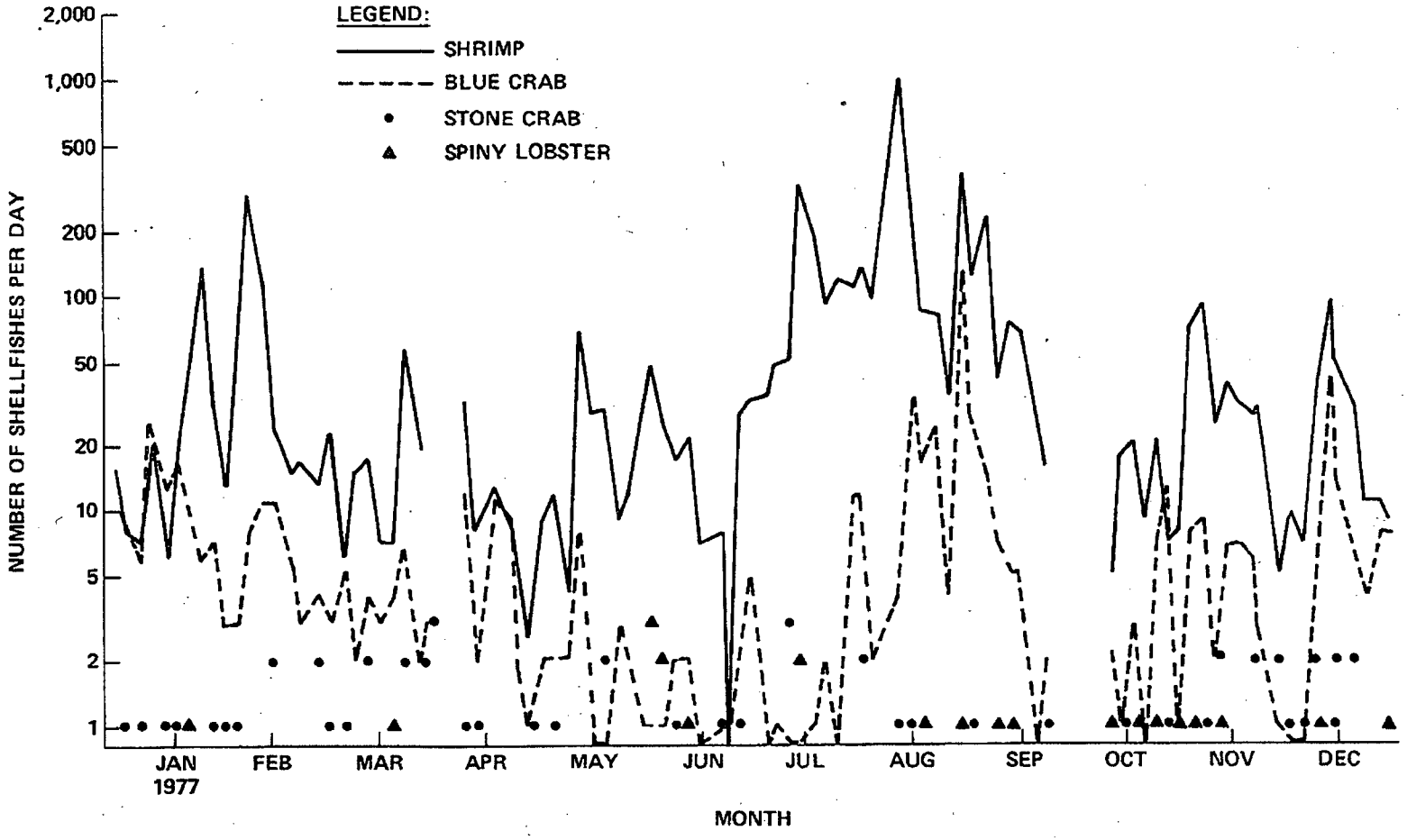
FIGURE 5.1-10



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

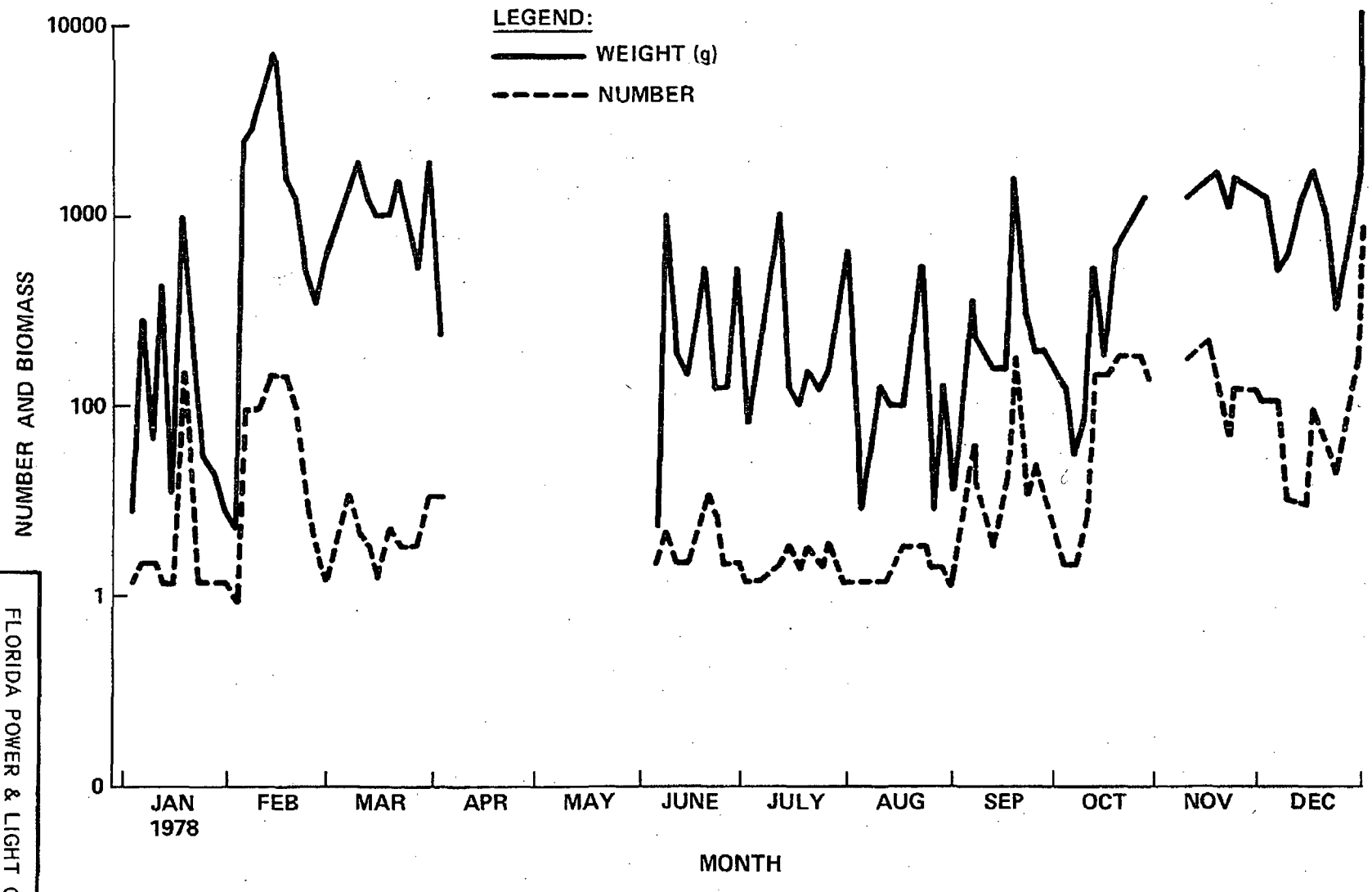
FISH BIOMASS COLLECTED VS. PLANT FLOW IN 1977

FIGURE 5.1-11



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

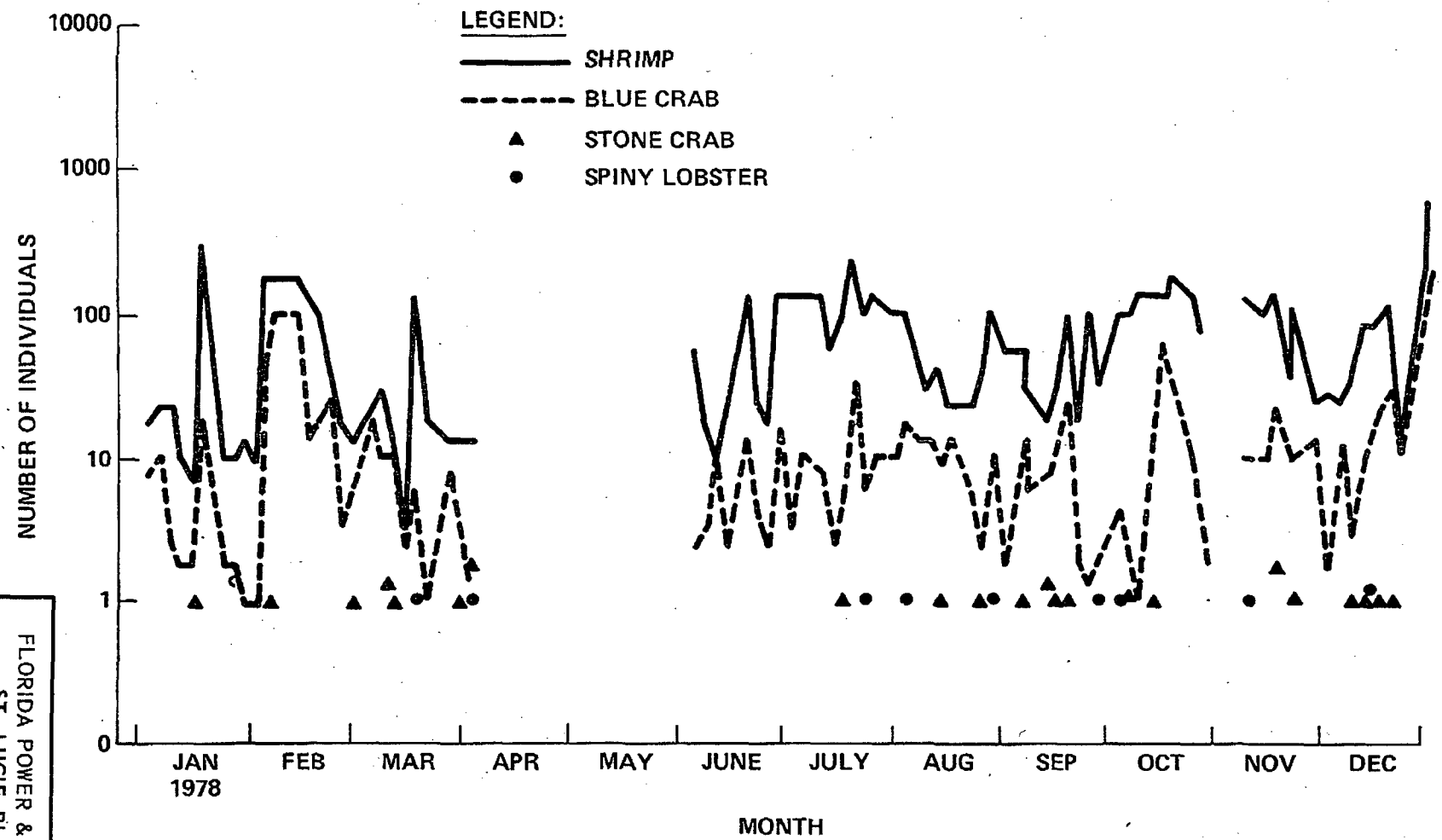
NUMBER OF SHELLFISHES IMPINGED PER DAY IN 1977
FIGURE 5.1-12



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

NUMBER OF INDIVIDUALS & BIOMASS
OF FISHES IMPINGED PER 24-HOUR
SAMPLING PERIOD IN 1978

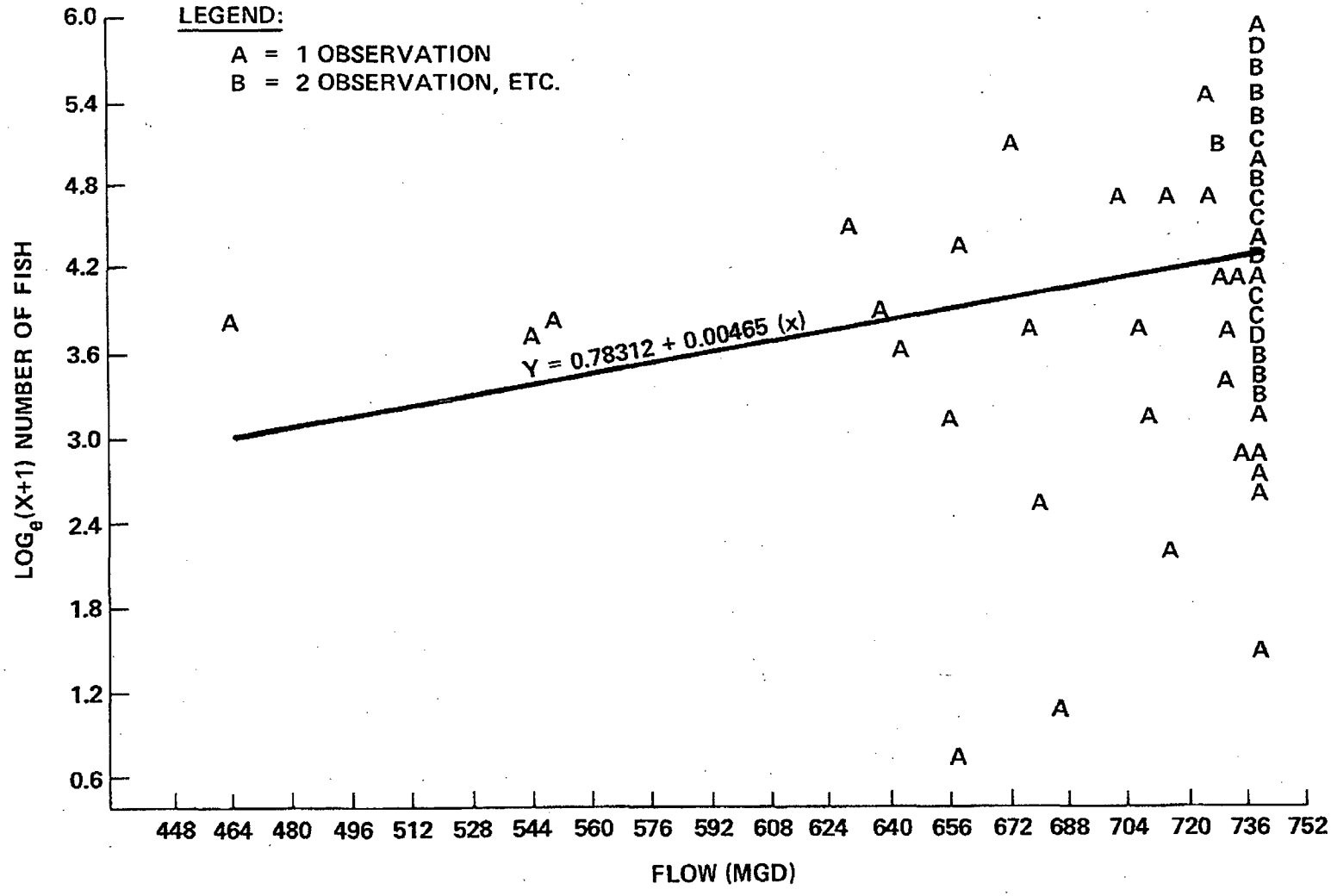
FIGURE 5.1-13



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

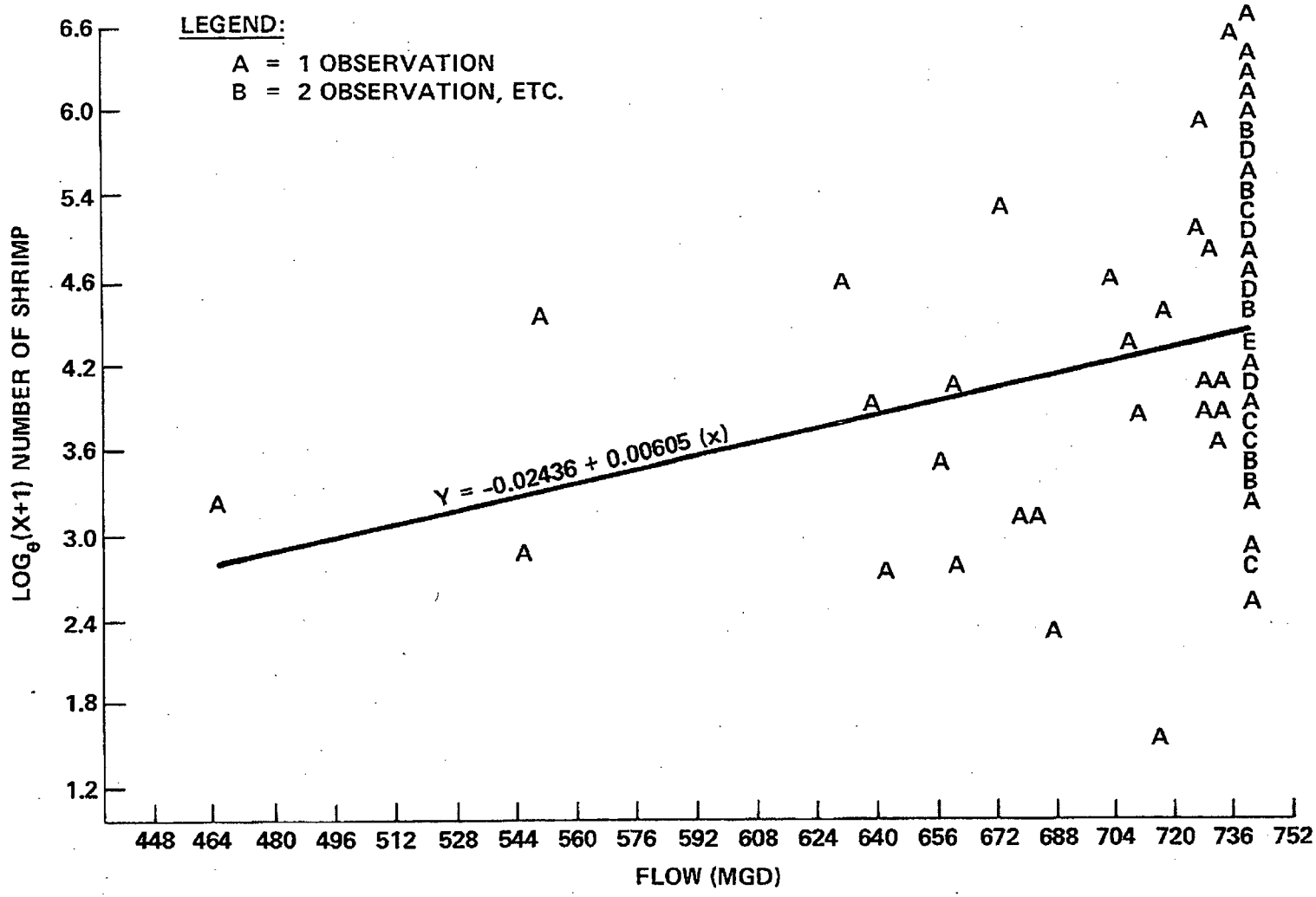
NUMBER OF SHELLFISHES IMPINGED PER 24-HOUR SAMPLING PERIOD IN 1978

FIGURE 5.1-14



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

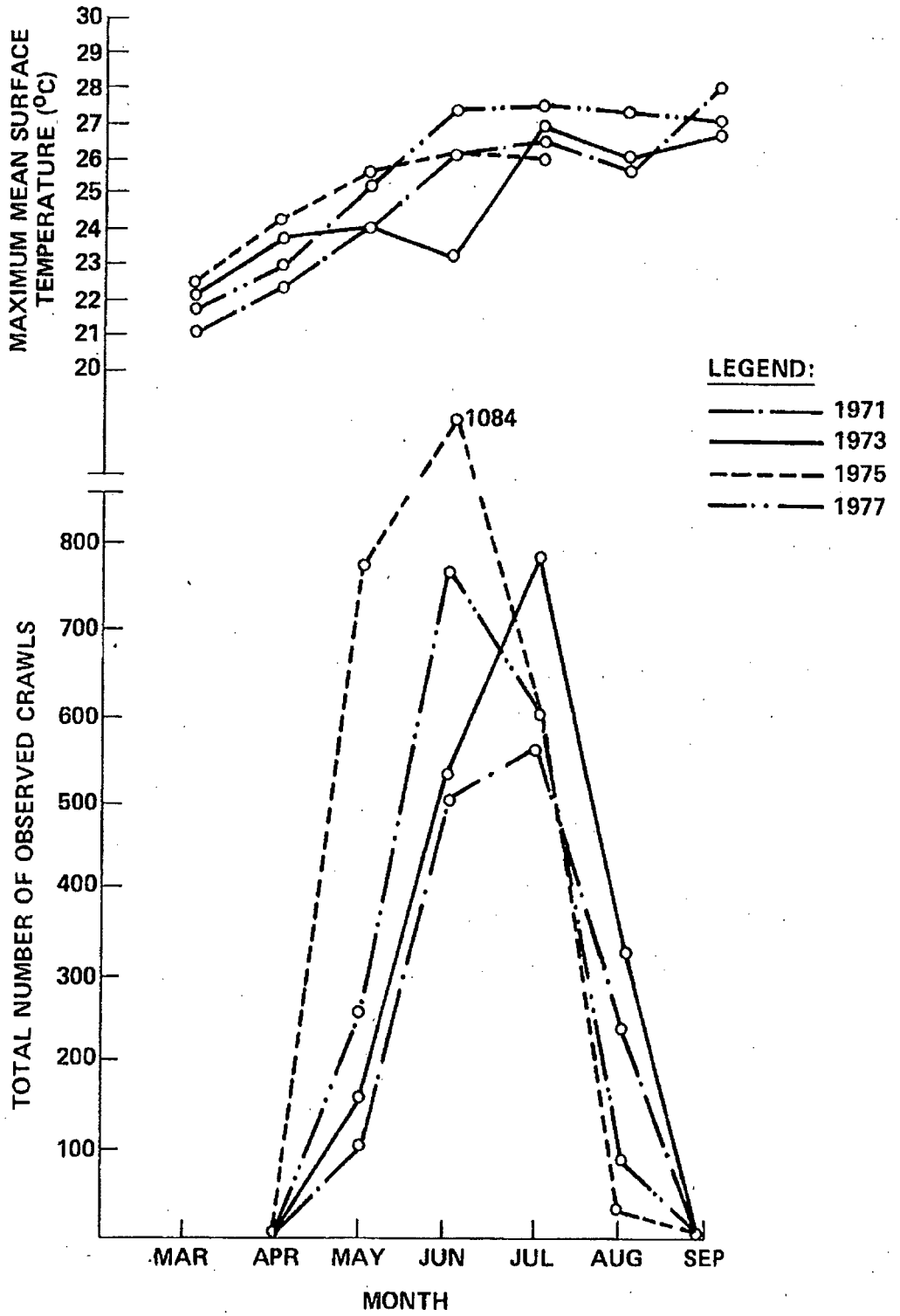
FISH IMPINGEMENT VS. PLANT FLOW,
3 JANUARY – 14 NOVEMBER 1978
FIGURE 5.1-15



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

SHRIMP IMPINGEMENT VS. PLANT FLOW,
3 JANUARY – 14 NOVEMBER 1978

FIGURE 5.1-16



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

COMPARISON OF MARINE TURTLE NESTING ACTIVITY TO OCEAN WATER TEMPS. BY MO. & YR, HUTCHINSON ISLAND

FIGURE 5.1-17

ATTACHMENT C

2.4 HYDROLOGY

2.4.1 INTRODUCTION

The Atlantic Ocean, to the east of the site (Figure 2.1-1), will provide most of the water required for plant operation. In addition, the St Lucie plant dissipates waste heat and discharges liquid wastes, after treatment, to that body of water (see Sections 3.4, 3.5, 3.6 and 3.7). This section describes surface water hydrology, ground water hydrology and surface water quality characteristics.

2.4.2 SURFACE WATER HYDROLOGY

2.4.2.1 Bathymetry

As shown in Figure 2.1-1, the Hutchinson Island shoreline and nearshore bathymetry to -30 ft Mean Low Water (MLW) are oriented along a NNW-SSE (340° - 160°) line. The nearshore ocean bottom slopes at a one on 80 gradient to about -35 ft MLW for approximately 0.5 miles before rising to Pierce Shoal (-21 ft MLW).

A slight trough with depths of nearly -50 ft MLW separates Pierce Shoal from the northward extension of St Lucie Shoal, which is five miles seaward of the coastline. Across the coastal shelf to the -120 MLW contour, the overall slope is gentle, approximately one on 600. At about 12 miles offshore, the sea floor slope increases to one to 100, reaching the -600 ft MLW contour approximately 18 miles east of Hutchinson Island. Bathymetric profiles across the coastal shelf off Hutchinson Island are shown in Figure 2.4-1.

2.4.2.2 Ocean Tides

Tidal analyses by the National Ocean Survey for several locations near the St Lucie plant are referenced to the nearest primary control station which is Miami, Florida. Published datums[1] are referred to local Mean Low Water (MLW), although all datums can be reduced to the National Geodetic Vertical Datum which is accepted as Mean Sea Level (MSL). A time series of semi-diurnal high and low tides is shown in Figure 2.4-2.

At Miami Beach, the mean range between high and low tides is 2.5 feet, and the spring range (average semi-monthly new and full moon tide) is 3.0 feet. Tide ranges increase northward to 2.8 and 3.3 feet, respectively, at Palm Beach and 3.5 and 4.1 feet at Cape Canavarel[1].

For tides monitored at Vero Beach (the temporary subordinate station nearest the St Lucie site), mean tidal range is 3.4 feet. A short interval record for October, 1972, indicates that the mean range is 3.0 feet at Seminole Shores, about 11 miles south of the plant site (unpublished records of the National Ocean Survey). The largest astronomical tide range should be approximately 5.0 feet based on maximum-mean ratio of solar and lunar tractive forces of 13 to nine[2].

A tide monitoring program was undertaken at the site by Florida Power & Light Company from May 1976 to May 1977. For the full year of measurements, a mean tidal range of 3.28 feet was determined. A comparison of these site specific measurements to corresponding predicted tides resulted in a standard deviation between 0.3 and 0.4 feet. This difference in tidal range reflects meteorological factors.

2.4.2.3 Surface Currents

Surface water circulation in the nearshore region of the St Lucie site is of the combined wind driven and rotary tidal current type. The Florida Current, a branch of the Gulf Stream System, is found offshore, beyond the 300 foot contour[3]. The rotary tidal current continuously changes direction through 360 degrees during a 12.4 hour cycle. However, near a shoreline boundary the rotary characteristic is deformed into an elliptical pattern with an ebb and flood flow alongshore.

Wind driven currents are directly related to wind direction and intensity, although near the shoreline the surface current is deflected into a longshore direction depending on the angle of the wind to the shoreline. Because of the variability of local winds at the site, current patterns will change frequently with changes in weather patterns.

To describe currents at the St Lucie site, a monitoring program was conducted from September, 1973 to May 1975 (See Section 6.1.1). Current speed and direction were measured in 32 feet of water about 2000 feet from shore in the area of the discharge location. Current data were analyzed for the frequency distribution of current speed and direction[4].

Directional frequency distribution of the nearshore current shows a bimodal annual distribution with a prevailing flow oriented 335 degrees and a secondary flow toward 165 degrees. These directions are nearly parallel to the coastline. As shown in Tables 2.4-1 and 2.4-2, respectively, the prevailing direction is within the 300-360 degree sector about 49 percent of the time at the surface and 32 percent near the bottom. In the secondary 120-180 degree sector, the respective occurrence frequencies are nearly 23 and 24 percent. Onshore flow within the 210-270 degree sector occurs less than eight percent of the time. Seasonal differences in the bimodal distribution of current direction are represented by the July and October profiles shown as Figure 2.4-3.

Average current speed is 0.74 fps near the surface and decreases to 0.54 fps close to the bottom. About 33 percent of bottom currents are less than 0.4 fps, which is the upper limit for tidal currents in open waters off Florida (Tables 2.4-3 and 2.4-4). The 50th percentile speed near the bottom is 0.4 fps, which suggests that at least half of all nearshore flows are caused by wind driven currents. Current speed ranged from near zero to more than 1.6 fps. Approximately ten percent of all current speeds measured exceeded 1.0 fps at the surface and less than three percent exceeded 1.6 fps.

Summertime flow appears to be weaker than during other seasons as indicated by the modal frequency of lower current speed during July, in comparison to October (Figure 2.4-4). When wind speed is light, the wind driven current becomes negligible, and the semidiurnal tidal current becomes more apparent.

Additional current data acquired at the St Lucie site in March - April, 1977, confirmed the prevailing longshore flow that was recognized in the earlier monitoring program. However, lower current speeds for onshore flow indicate that the earlier measurements may include a wave motion component. The current rose in Figure 2.4-5 shows current direction and speed distribution monitored for ten days in 1977.

2.4.3 GROUNDWATER

The groundwater regime of the St Lucie site and surrounding region has been described in Section 2.5 of the St Lucie Unit 2 Environmental Report - Construction Permit. The Final Environmental Statement Related to Construction of St Lucie Plant Unit 2 discusses groundwater at the site.

2.4.4 SURFACE WATER QUALITY

Worth and Hollinger[5], and Applied Biology Inc,[6,7,8] have reported surface water quality data from the St Lucie site. The majority of the data presented are from Atlantic Ocean coastal waters off Hutchinson Island, near the St Lucie site. Details of the water quality sampling programs are noted in Section 6.1.4. Figure 2.4-6 shows the locations of water quality sampling Stations 0 through 5.

A number of physical and chemical parameters are reported, including temperature, salinity, dissolved oxygen, and dissolved inorganic nutrients (nitrogen, phosphorus, and silicon). The physical and chemical data obtained in these studies from the six offshore stations sampled by Applied Biology[6,7,8], are summarized in Table 2.4-5. The ranges of concentrations of several water quality parameters investigated for the Indian River in the summer of 1974 are presented in Table 2.4-6.

2.4.4.1 Temperature

Sea water temperatures reported in these studies range from about 15 to 32°C. The mean temperature for all stations and depths reported is about 25°C. Figure 2.4-7 illustrates the seasonal variation in temperature from September, 1971 through 1978, at Station 2 which is representative of the offshore stations. Additional daily monitoring of temperature at a location near Station 1 has been performed by FP&L, and is reported by Worth and Hollinger[5], and Applied Biology[6,7,8].

2.4.4.2 Salinity

The average salinity of the Atlantic Ocean off Hutchinson Island is about 35.5 parts per thousand(ppt). A range from 33.0 to 38.5 ppt has been reported[5]; however, most values fall between 34.0 and 36.0 ppt. In general, salinity is low during fall and winter, and increases to a seasonal

maximum during the summer. Data reported by the US Coast and Geodetic Survey for the Atlantic Ocean at Canova Beach, Florida, 50 miles north of the plant site, indicated that mean salinity values are highest in May at 36.6 ppt, and lowest in November at 35.4 ppt. The wider range in values observed at the plant site are probably due to the effects of the Fort Pierce and St Lucie Inlets, intrusions of Gulf Stream water, and current effects created by the Gulf Stream[5].

2.4.4.3 Dissolved Oxygen

Typical dissolved oxygen levels in the area range between five and eight mg/l. Almost all observations fall in the range of four to eight mg/l, although extremes of 3.2 and 10.3 mg/l have been observed. Table 2.4-7 illustrates the distribution of dissolved oxygen values for the six offshore stations. About 50 percent of the values observed range between six and seven mg/l. Of all values reported, 5.9 percent were below five mg/l, and 1.7 percent were above eight mg/l. The mean seasonal distribution of dissolved oxygen for all stations is presented in Figure 2.4-8. The monthly means vary from 5.9 mg/l in August, to 6.9 mg/l in February. All months, with the exception of August, have mean dissolved oxygen levels in excess of six mg/l.

The very low dissolved oxygen concentrations (less than four mg/l) observed in July, August and September 1972 coincided with decreased water temperature, increased phosphate levels and low phytoplankton density. These phenomena are characteristic of an upwelling of deep waters, which are typically relatively cool, nutrient rich, and oxygen depleted (see Section 2.7 of the St Lucie Unit 2 Environmental Report - Construction Permit).

2.4.4.4 Nutrients

Nutrient levels are generally low. Total dissolved inorganic nitrogen (the sum of nitrate, nitrite, and ammonia) averages from about 0.03 to 0.1 mg/l as N. Dissolved silica averages 0.2 to 0.3 mg/l as Si. The values reported for dissolved phosphate show considerable disparity. Values reported by Worth and Hollinger[5] for the period 1971-1973 average about 0.15 mg/l as P. However, in the more recent data[6,7,8] for 1976, 1977 and 1978, phosphate levels rarely exceed 0.01 mg/l as P (Table 2.4-5).

Nutrient concentrations measured at the St Lucie site show no clear seasonal patterns. Nitrate and nitrite tend to peak in spring and fall. Ammonia peaks occur in summer or fall. Silica levels tend to peak in summer. No seasonal trends in phosphate levels are apparent. In general, no statistically significant variation between stations was observed for the chemical parameters measured, indicating that the coastal area investigated is well mixed.

Significant temporal variation was observed. Worth and Hollinger[5] attribute this variation to the tidal exchange between the estuarine, nutrient rich water of the Indian River and the generally low nutrient coastal water. Intrusion of Gulf Stream water was also observed during summer months.

2.4.4.5 Conclusions

The water quality of the nearshore coastal environment at the plant site reflects the interrelation of physical, chemical, and biological effects. Water circulation patterns, including tidal effects, rainfall, flows from the St Lucie and Fort Pierce inlets, upwellings, and possible Gulf Stream intrusions, appear to have a dominant effect on water quality at the St Lucie site.

Nutrient concentrations in coastal environments show considerable variation from site to site. Table 2.4-8 illustrates the range in nutrient values for coastal waters in surveys reported by Riley and Skirrow[9], Sverdrup, et al[10] and Raymont[11]. With the exception of the high phosphorus levels (~0.15 mg P/l) reported by Worth and Hollinger[5] for the period 1971-73, the nutrient values typically observed at the site are generally low and are well within the ranges reported for coastal oceans (see Table 2.4-5). Atypically high nutrient values were observed in isolated instances.

SECTION 2.4: REFERENCES

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TABLE 2.4-1

FREQUENCY DISTRIBUTION OF SURFACE CURRENT DIRECTION
MONTHLY AND ANNUAL AVERAGES WITHIN 30 DEGREE SECTORS
(PERCENT)

Month - 1974	000-030	030-060	060-090	090-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-360
Jan	12.6	6.2	3.4	4.2	0.9	3.0	4.5	2.2	4.0	5.7	18.5	32.7
Feb	1.7	1.3	1.2	2.6	6.0	11.1	4.7	1.9	1.7	6.1	27.8	33.8
Mar	3.9	1.6	1.5	4.0	10.6	16.8	9.6	2.2	0.9	3.4	12.4	33.1
Apr	3.7	1.0	1.3	2.2	9.0	15.0	5.5	1.8	2.1	7.4	24.7	26.4
May	4.7	1.5	1.4	1.1	5.1	7.4	1.9	1.9	1.9	7.5	27.8	37.9
Jun						- Data Missing -						
Jul	4.1	0.6	0.9	3.9	8.3	13.2	4.4	0.8	1.1	5.3	17.8	39.5
Aug	5.4	2.0	1.5	5.8	16.9	14.0	5.1	2.1	2.1	4.0	19.0	21.7
Sep	5.7	2.6	2.0	4.2	12.8	20.8	5.8	3.6	3.0	4.8	12.3	22.6
Oct*	4.3	3.4	3.1	6.6	16.7	22.8	10.5	6.4	6.0	5.4	8.1	6.5
Nov	4.2	3.3	1.8	2.7	11.4	18.1	7.9	3.4	2.4	3.3	14.3	27.4
Dec	4.3	2.3	1.5	2.2	8.8	19.2	15.2	3.4	0.6	4.3	11.5	26.6
Annual Average	5.0	2.2	1.9	3.3	9.0	13.9	6.5	2.3	2.0	5.2	18.6	30.2

Annual average based on ten months data. *1973 measurements not included in annual average.

TABLE 2.4-2

FREQUENCY DISTRIBUTION OF BOTTOM CURRENT DIRECTION
MONTHLY AND ANNUAL AVERAGES WITHIN 30 DEGREE SECTORS
(PERCENT)

Month - 1974	000-030	030-060	060-090	090-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-360
Jan	4.8	1.7	2.4	5.0	2.6	2.6	6.4	2.6	7.2	16.9	30.1	17.8
Feb*	1.0	3.2	1.2	1.3	2.2	18.7	33.1	1.7	1.3	2.2	4.3	29.9
Mar	3.0	6.0	1.6	7.2	8.3	9.0	6.6	4.0	4.9	10.2	18.2	21.0
Apr	5.3	2.8	1.6	4.7	7.4	14.8	11.0	3.0	1.4	7.9	16.5	23.5
May	3.8	2.0	2.9	8.2	14.0	11.1	7.1	5.5	6.1	16.8	17.0	5.5
Jun	- Data Missing -											
Jul	5.9	3.0	2.8	3.4	5.4	6.7	8.1	2.5	4.9	16.9	19.6	20.9
Aug	2.9	5.6	7.3	10.8	11.4	11.2	10.0	6.3	6.6	8.9	8.9	10.2
Sep	2.5	3.6	2.8	6.0	9.8	18.3	9.8	5.8	6.8	7.4	15.1	12.1
Oct	2.3	1.7	2.4	5.3	15.6	21.2	10.8	3.0	3.1	7.6	16.5	10.4
Nov	3.1	2.0	3.0	5.2	15.4	21.2	5.2	2.9	1.5	4.1	14.3	22.1
Dec	10.9	3.3	3.6	6.3	9.2	20.5	18.2	1.1	1.0	3.0	7.0	16.1
Annual Average	4.5	3.8	3.0	6.2	9.9	13.7	9.3	3.7	4.4	10.0	16.3	16.0

Annual average based on ten months data. *1975 measurements not included in annual average.

TABLE 2.4-3

FREQUENCY DISTRIBUTION OF SURFACE CURRENT SPEED
MONTHLY AND ANNUAL AVERAGES WITHIN 0.1 FPS INCREMENTS
(PERCENT)

Month 1974	0.0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0	1.0-1.1	1.1-1.2	1.2-1.3	1.3-1.4	1.4-1.5	1.5-1.6	1.6
Jan	0.1	0.7	2.8	4.4	13.8	9.9	15.7	16.6	14.3	6.9	7.7	4.0	0.7	1.0	0.4	0.2	0.9
Feb	0.4	1.4	1.7	3.3	12.3	6.9	13.5	16.3	12.9	11.0	10.4	5.3	1.5	1.2	0.4	0.15	1.4
Mar	0.4	1.1	0.8	3.3	11.0	8.8	14.7	12.1	13.3	7.3	10.7	6.7	3.3	2.3	0.8	0.7	2.5
Apr	0.2	2.5	2.1	1.3	8.0	7.3	11.7	12.5	13.6	11.8	9.2	7.4	3.0	3.1	1.4	0.6	4.3
May	0.6	1.4	2.3	2.3	4.8	7.5	7.2	9.5	21.0	12.3	8.3	8.0	4.9	2.5	1.8	0.5	4.7
Jun	- Data Missing -																
Jul	1.7	1.3	5.1	4.0	11.3	8.4	11.4	14.2	14.9	8.8	7.4	5.5	2.8	0.9	0.8	0.5	1.3
Aug	1.7	1.4	3.7	4.5	9.7	13.0	14.1	13.5	10.8	9.4	6.7	4.8	2.8	1.7	1.5	0.6	1.3
Sep	0.2	1.6	3.0	3.3	4.5	13.7	11.4	17.3	13.6	10.7	8.4	5.1	3.4	0.8	1.1	0.4	1.4
Oct	- Data Missing -																
Nov	1.1	3.4	4.2	3.6	11.8	9.8	11.1	6.2	18.6	7.6	8.3	6.0	3.6	1.7	0.7	1.0	1.1
Dec	0.0	1.5	1.8	3.1	13.2	7.7	14.7	10.7	23.3	5.1	9.0	3.5	1.4	1.8	0.7	0.5	2.0
Annual Average	0.64	1.63	2.87	3.31	10.04	9.3	12.55	12.89	15.63	9.09	8.63	5.63	2.74	1.7	0.97	0.52	2.3

TABLE 2.4-4

FREQUENCY DISTRIBUTION OF BOTTOM CURRENT SPEED
MONTHLY AND ANNUAL AVERAGES WITHIN 0.1 FPS INCREMENTS
(PERCENT)

Month 1974	0.1-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0	1.0-1.1	1.1-1.2	1.2-1.3	1.3-1.4	1.4-1.5	1.5-1.6	1.6
Jan	2.7	3.2	10.1	9.9	26.4	19.5	15.4	9.4	2.5	0.7	0.4						
Feb							- Data Missing -										
Mar	0.9	5.0	4.1	10.5	20.7	9.0	19.5	11.5	9.7	4.1	3.9	1.1					0.1
Apr	3.7	12.3	12.0	7.7	19.4	16.1	13.9	7.7	3.3	1.9	0.4	0.3	0.5				0.6
May	0.5	14.8	15.7	4.2	4.6	25.0	6.5	18.1	6.9	3.7							
Jun							- Data Missing -										
Jul	9.3	14.1	21.0	13.4	16.7	10.7	6.2	4.6	2.8	0.8	0.6						
Aug	3.8	3.3	24.6	13.6	22.2	18.0	7.7	3.6	1.4	1.0	0.4	0.3	0.08	0.08			
Sep	0.2	7.3	26.4	11.9	27.8	13.4	6.5	5.2	0.9	0.7							
Oct	0.7	4.0	11.4	8.4	19.0	12.0	12.8	7.6	12.2	4.6	2.6	3.1	0.6	0.3	0.1		0.4
Nov	0.1	1.3	11.4	9.2	25.7	11.6	13.9	5.0	13.6	4.6	2.1	1.2		0.1			
Dec	0.1	0.4	5.6	8.9	34.6	12.4	18.7	10.5	6.0	1.7	0.7	0.5					
Annual Average	2.2	6.6	14.2	9.8	21.7	14.8	12.1	13.3	5.9	2.5	1.1	0.7	0.1	0.05			0.5

TABLE 2.4-5

ST. LUCIE PLANT SITE - WATER QUALITY MONITORING DATA

	Worth and Hollinger[5]					Applied Biology Inc[6,7,8]#						
	1971 - 1974					1976 - 1978						
	Surface		Bottom		Range Reported	Surface		Mid-Depth		Bottom		Range Reported
Parameter	N	Mean	N	Mean		N	Mean	N	Mean	N	Mean	
Temperature, °C	199	25.5	199	24.9	19-32	204	24.3	144	23.7	204	23.8	14.6-30.8
Salinity, ppt	193	35.6	193	35.8	33.0-38.5	199	35.6	135	35.8	198	35.8	33.0-36.6
Dissolved Oxygen, mg/l	184	6.4	182	6.2	3.2-10.3	198	6.5	144	6.6	198	6.4	4.4-8.6
NO_3-N, mg/l as N	96*	0.018*	97*	0.013*	<.01-.651	126	0.013	126	0.013	126	0.014	<0.001-0.28
NH_3-N, mg/l as N	91*	0.013*	91*	0.013*	<.01-.121	204	0.064	203	0.067	204	0.067	<0.01-0.57
NO_2-N, mg/l as N	96*	0.002*	97*	0.008*	<.001-.060	204	0.001	203	0.001	204	0.001	<0.001-0.007
PO_4-P, mg/l as P	156	0.117	158	0.111	<.01-.186	174	<0.01	174	<0.01	174	0.01	<0.01-0.17
SiO_2-Si, mg/l as Si	156	0.203	159	0.204	<.05-0.91	174	0.19	174	0.19	174	0.21	<0.02-0.99
Total Particulate, mg/l	176	6.65	176	10.17	0.2-69.0	-	-	-	-	-	-	-
Total Organic Carbon, mg/l	-	-	-	-	-	204	6.5	204	5.8	204	6.7	0.6-35.5
Turbidity, FTU	-	-	-	-	-	144	-	144	-	144	-	0.0-26.8

* September, 1971 to August, 1973 only

\# During the course of the monitoring program conducted by Applied Biology, Inc, methods of analysis for NO_3, PO_4, and SiO_2 were modified. Data reported here include only data obtained using the more sensitive and accurate methods incorporated for NO_3 in April, 1977, and for PO_4 and SiO_2 in August, 1976.

TABLE 2.4-6

INDIAN RIVER WATER QUALITY DATA-SUMMER, 1974[5]

A. Nutrients, Range of Values Reported

	St. Lucie Inlet	Link Port to Jensen Beach
NH_3-N, mg/l as N	ND* - 0.221	ND - 0.046
NO_3-N, mg/l as N	ND - 0.154	0.001 - 0.270
PO_4-P, mg/l as P	0.046 - 0.329	0.050 - 0.198
SiO_2-Si, mg/l as Si	0.003 - 7.28	0.255 - 6.78

B. Salinity, Range in 0/00

	Ebb Tide		Flood Tide	
	Surface	2m Depth	Surface	2m Depth
Indian R. - North	20-32	20-35	15-33	22-35
Indian R. - South	24-35	27-35	24-35	24-35
Taylor Creek	3-12	24-33	7-14	26-31
Fort Pierce Inlet	22-36	25-36	24-36	26-36

* ND = not detectable

TABLE 2.4-7

DISTRIBUTION OF MEASURED DISSOLVED OXYGEN DATA[5,6,7,8]

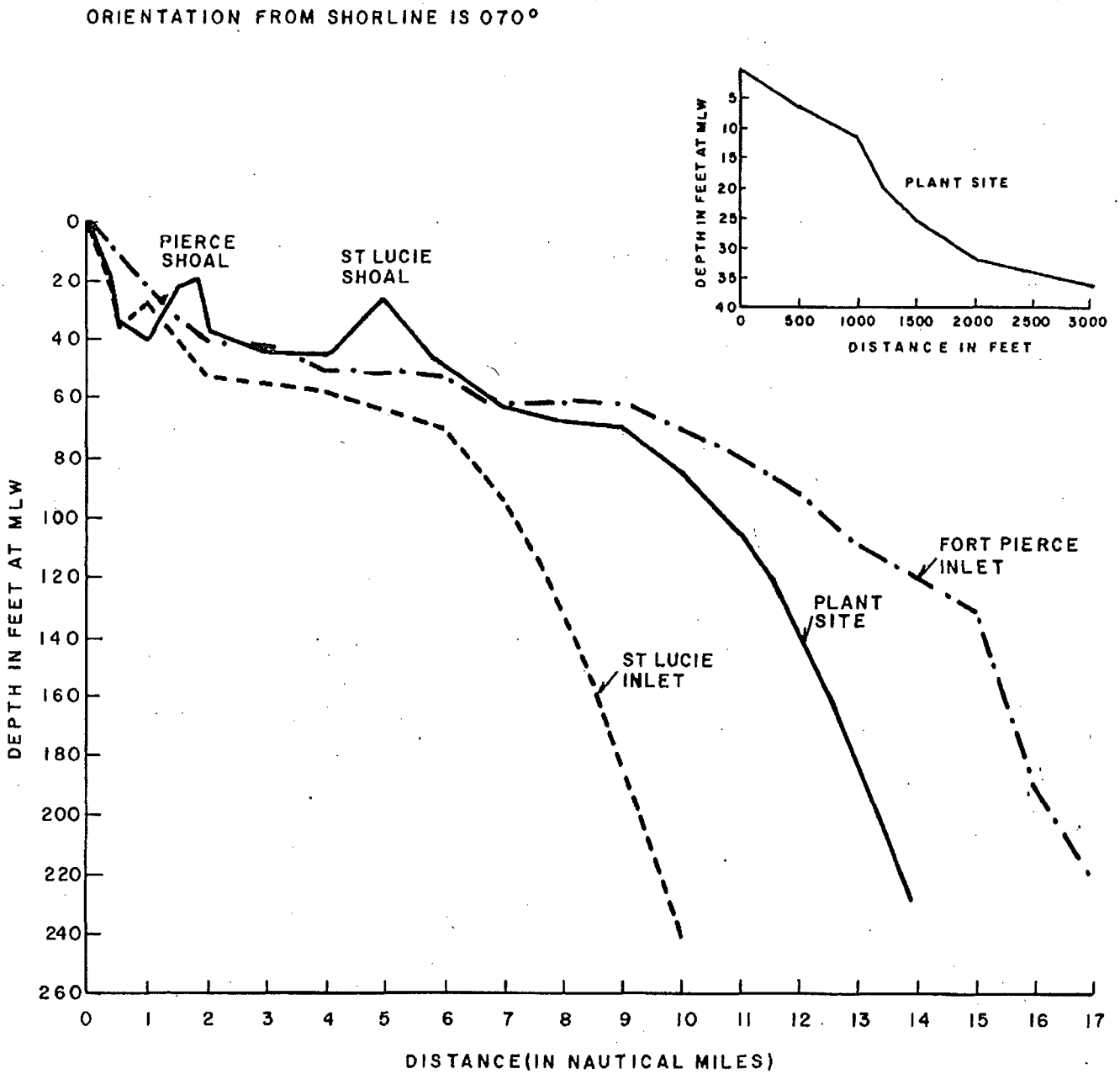
Station	No. Values Reported	Dissolved Oxygen, mg/l				
		< 5	5-6	6-7	7-8	> 8
0	87	3.4%	24.1%	46.0%	26.4%	-
1	181	4.4%	29.3%	45.3%	20.4%	0.5%
2	182	3.3%	25.8%	49.4%	20.9%	0.5%
3	177	4.0%	19.2%	53.6%	21.5%	1.7%
4*	130	6.1%	20.0%	44.6%	25.4%	3.8%
5*	127	6.3%	20.5%	43.3%	27.6%	2.4%
Total	884	4.5%	23.4%	47.5%	23.1%	1.5%

* No values reported for these stations September, 1973 to August, 1974.

TABLE 2.4-8

REPORTED RANGES OF NUTRIENT IN COASTAL OCEAN AREAS

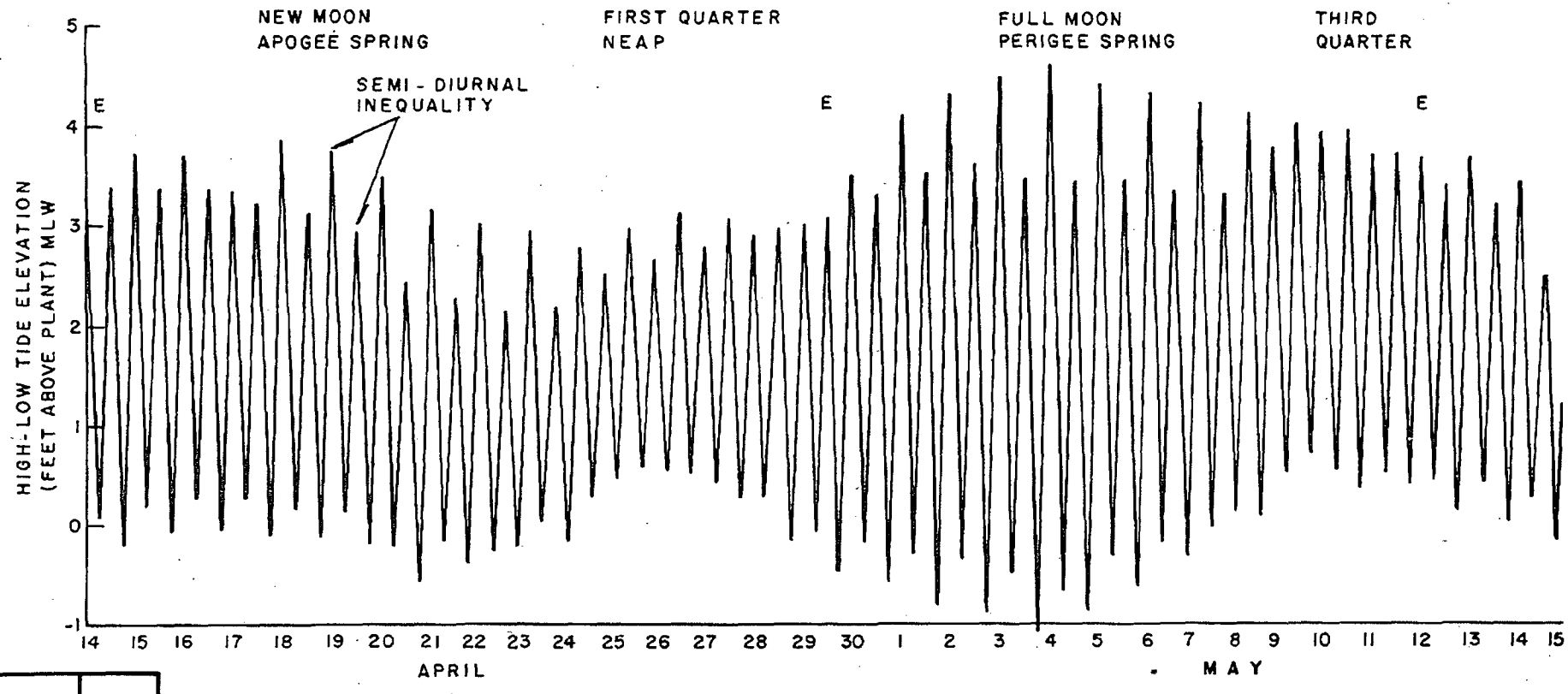
	Riley and Skirrow, 1965 (9)	Sverdrup, et al., 1942 (10)	Raymont, 1963 (11)
PO_4-P, mg/l as P	0-0.035	0.0015-0.062	0-0.060
NO_3-N, mg/l as N	0.070-0.350	0.007-0.378	<0.005-0.300
NH_3-N, mg/l as N	0-0.055	~0-0.031	0.007-0.200
NO_2-N, mg/l as N	-	~0-0.011	0-0.015
SiO_2-Si, mg/l as Si	0.010-1.68	0.014-1.68	0.010-1.50



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

BATHYMETRIC PROFILES OFFSHORE
HUTCHINSON ISLAND

FIGURE 2.4-1

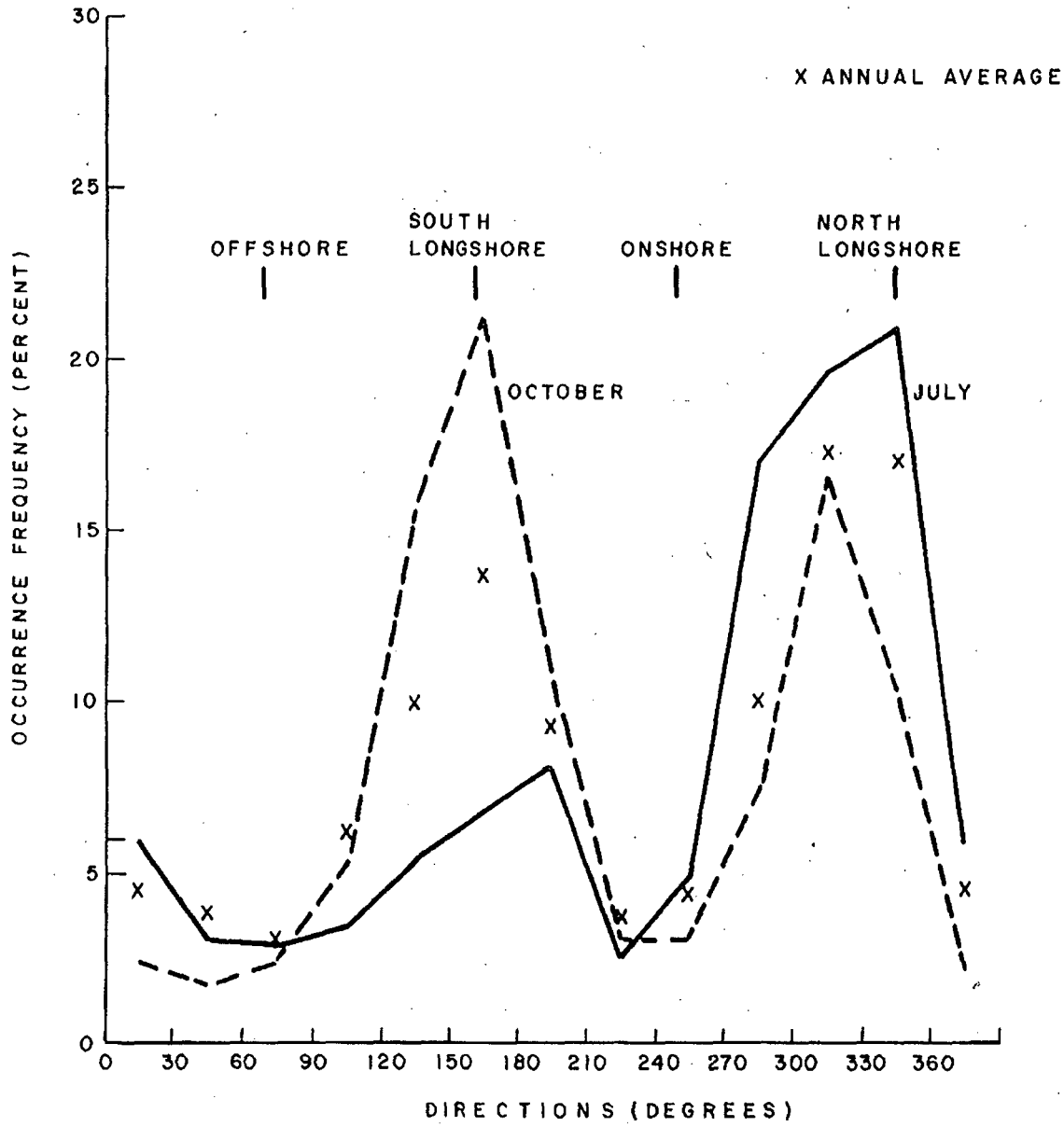


LEGEND:
HIGH-LOW TIDE ELEVATIONS
MEASURED AT ST LUCIE SITE
14 APRIL - 15 MAY, 1977.
ELEVATIONS RELATIVE TO PLANT
DATUM

FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

HIGH- AND LOW-TIDE ELEVATIONS
AT ST LUCIE SITE

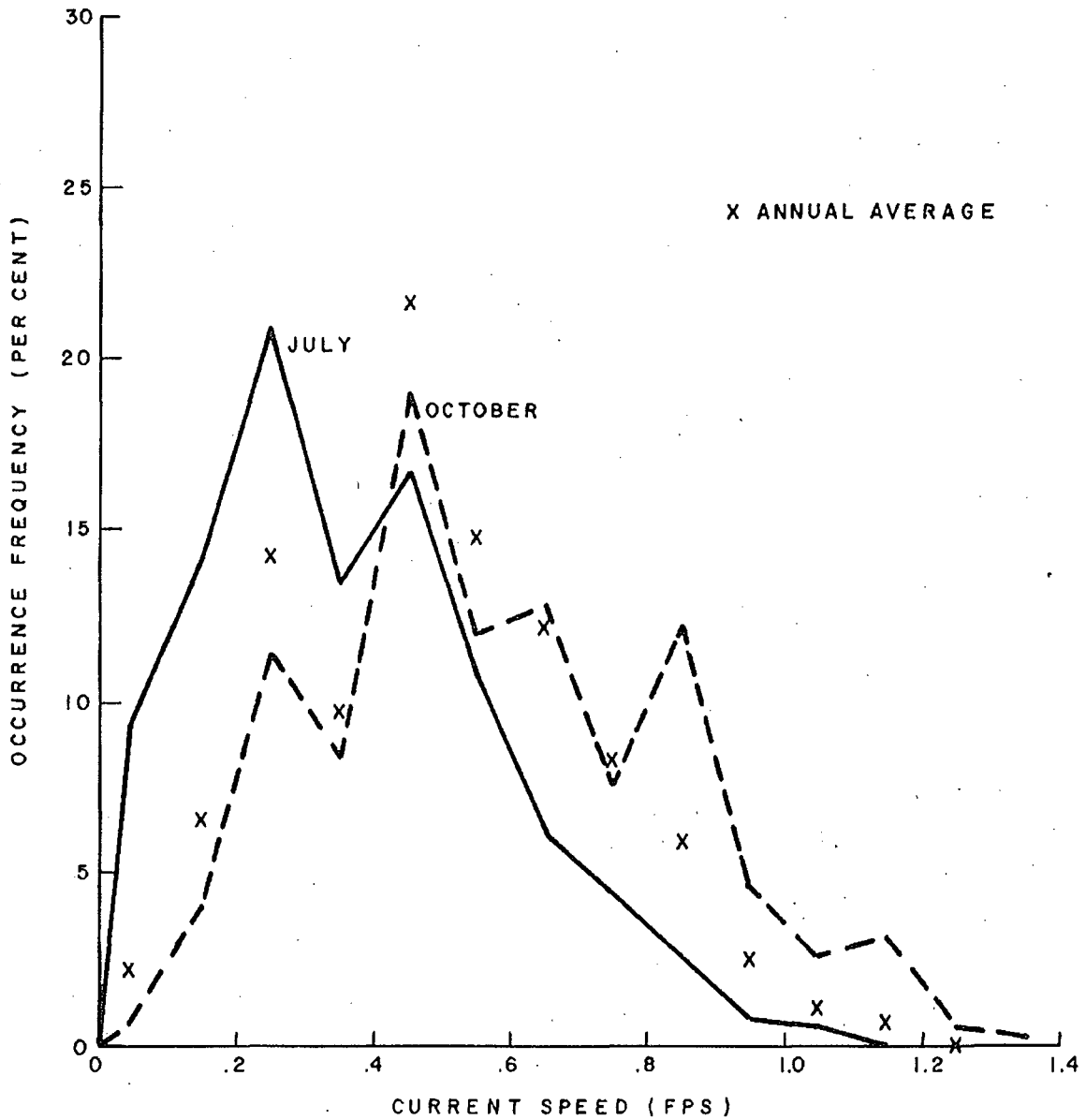
FIGURE 2.4-2



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

FREQUENCY OCCURRENCE OF NEARSHORE CURRENT DIRECTION

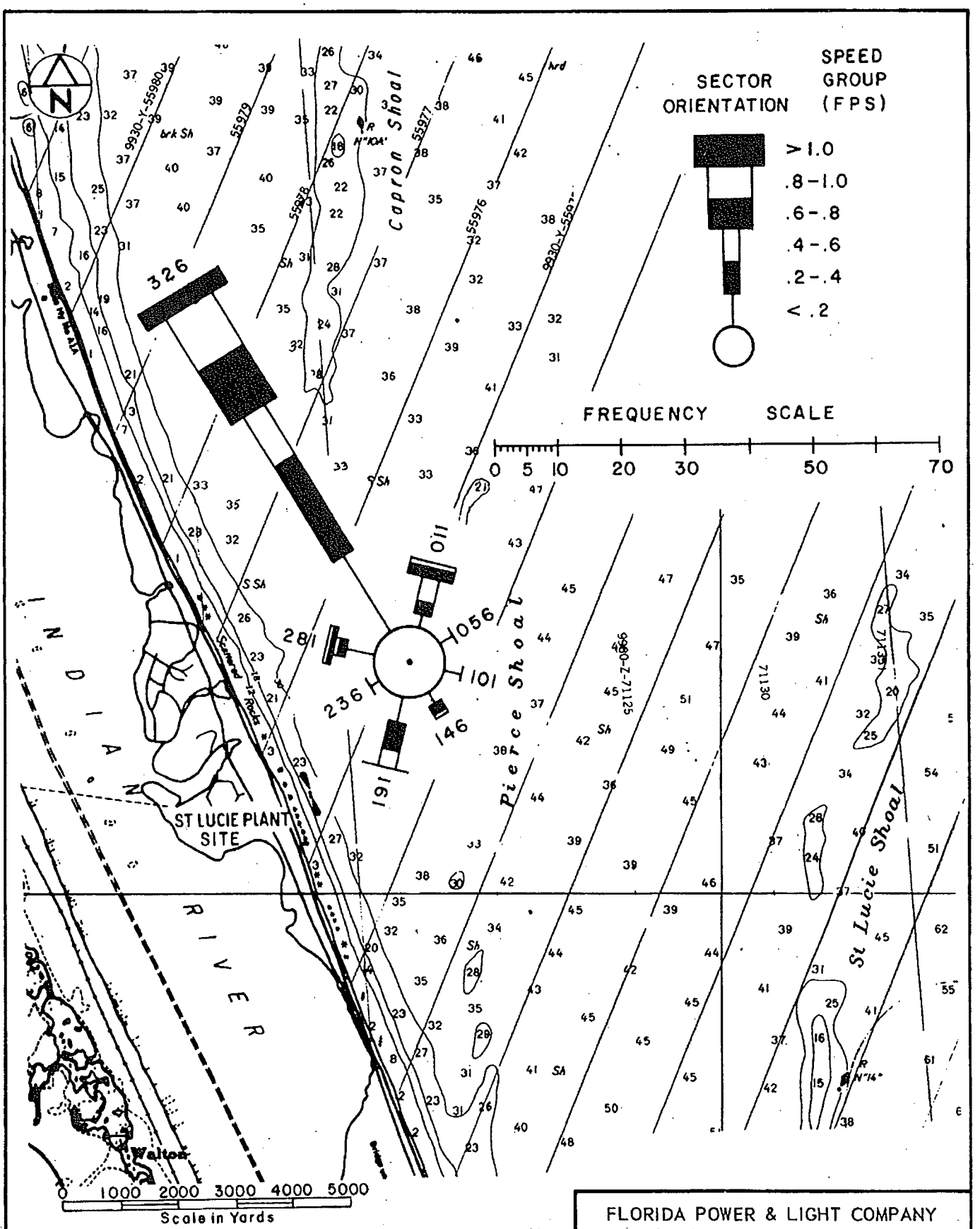
FIGURE 2.4-3



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

FREQUENCY OCCURRENCE OF NEARSHORE CURRENT SPEED

FIGURE 2.4-4

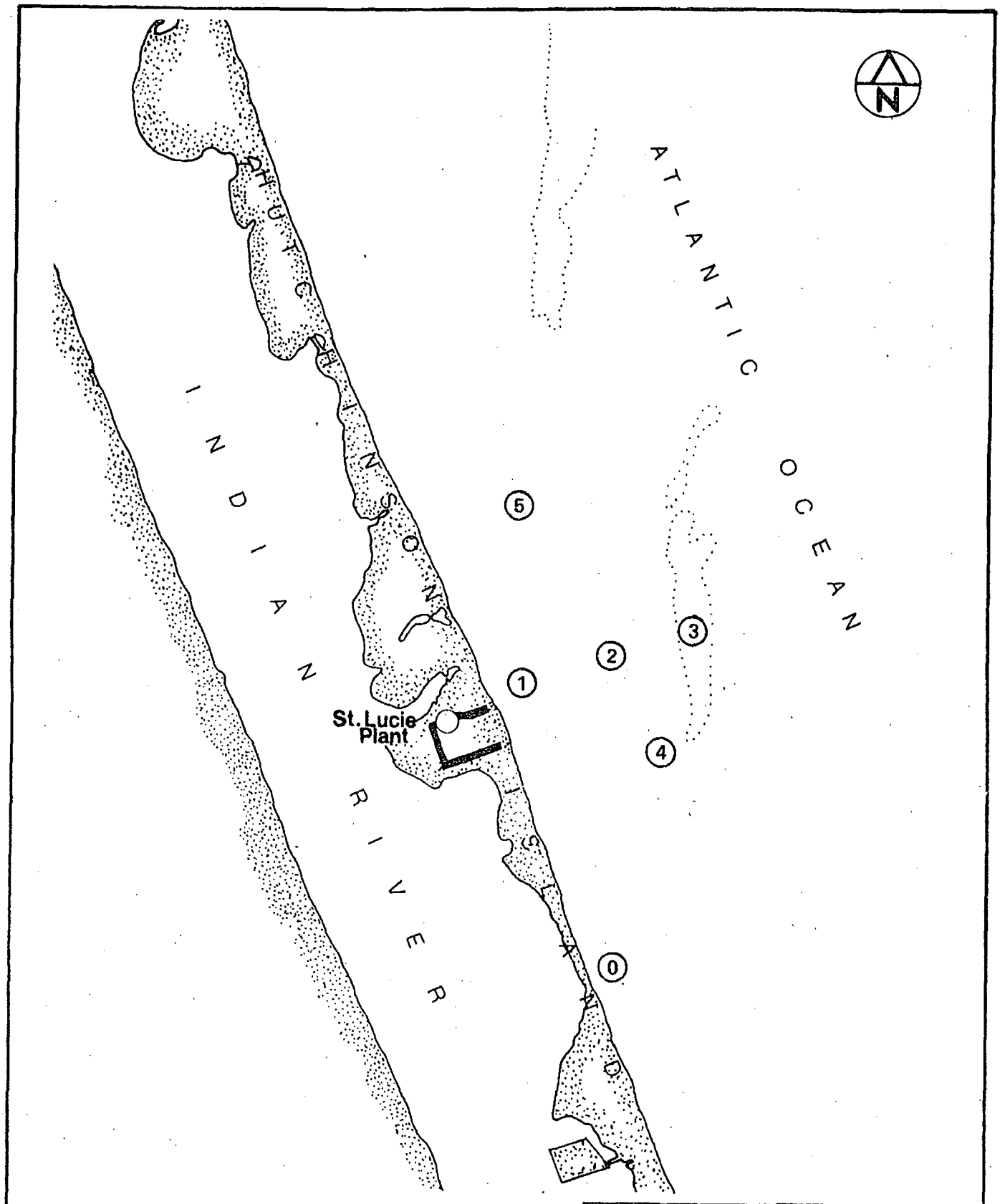


SOUNDINGS IN FEET AT MEAN LOW WATER

FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

CURRENT ROSE – ALL MEASUREMENTS
MARCH 25 – APRIL 4, 1977

FIGURE 2.4-5



FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT UNIT 2

LOCATION OF OFFSHORE SAMPLING STATIONS

FIGURE 2.4-6

ATTACHMENT D

REVISED THERMAL DISCHARGE STUDY

In Support of RFI #1
Substantial NPDES Permit Revision
Florida Power & Light St. Lucie Plant
NPDES Permit No. FL0002208

REPORT

Submitted To: Florida Power & Light Company
700 Universe Boulevard
Juno Beach, Florida 33408

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Distribution:

12 Copies – Florida Power & Light Company
6 Copies – Golder Associates Inc.

June 8, 2010

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1.0 INTRODUCTION

Florida Power & Light Company (FPL) submitted a request to modify the National Pollutant Discharge Elimination System (NPDES) permit for the St. Lucie Nuclear Power Plant (St. Lucie Plant); specifically to increase the maximum heated water temperature at the point of discharge for Outfall D-001 from 113 degrees Fahrenheit (°F) to 115°F. FDEP issued a Request for Additional Information (RFI #1) requesting that FPL revise the Thermal Discharge Study using the absolute instantaneous maximum discharge temperatures and temperature differences between the effluent and ambient conditions, and to demonstrate whether the thermal discharge plume is entrained back into the plant. Golder Associates Inc. (Golder) has performed modeling to address the former concern, and provided a copy of previous work done during the initial licensing of Unit 2 to address the latter.

2.0 DETERMINATION OF INSTANTANEOUS MAXIMUM DISCHARGE TEMPERATURE AND DISCHARGE TEMPERATURE RISE

FPL has analyzed four different cases to determine which would produce the maximum instantaneous discharge temperature and discharge temperature rise. The calculations presented in this report that perform that determination are:

- 25. Waste Heat Discharged for Modeling Cases
- 26. Waste Heat Discharged for Existing Units
- 27. Specific Heat of Sea Water at Varying Temperatures
- 32. Mixing Zone Volumes for Cases 1 through 4

Case 1 is the normal full load operation of both units with all 8 Circulating Water (CW) pumps operating. This case was expected to produce the highest discharge temperature. Based on analysis of plant intake water temperatures (see response to RFI#1 Comment 6), the design peak intake water temperature was set at 90°F. Based on the analysis in Calculation 25, the resultant discharge temperature is 117.81°F, with a temperature rise of about 28°F.

Case 2 assumes that only 3 CW pumps are operating for each unit. This mode of operation is feasible when the intake water temperature is low enough so that 3-pump operation does not result in excessive back-pressure penalties on the steam turbines. This case was expected to produce the maximum discharge temperature rise. Based on analysis of plant intake water temperatures (see response to RFI#1 Comment 6), the typical intake water temperature selected for Case 2 was 70°F , which temperature is equaled or exceeded 90% of the time. Based on the analysis in Calculation 25, the resultant discharge temperature is 102.1°F, with a temperature rise of about 32.1°F.

Case 3 was investigated because it was felt that a separate case, in which only one of the units was operating would produce a higher surface water temperature than when both units were operating. This is because the reduced CW flow rate (only 4 CW pumps operating) results in a reduced discharge velocity from the diffusers' ports, which in turn results in less turbulent mixing before the thermal plume intersects the water surface. If the surface water temperature is predicted to exceed 97°F, then a mixing zone on the water surface would be required. Maximum discharge temperature with only Unit 1 operating at full load on 4 CW pumps is estimated in Calc 25 to be about 118.4°F, with a temperature rise of about 28.4°F. Unit 1 was selected to be the operating unit in Case 3 because it produces a slightly higher temperature rise than Unit 2, due to a slight difference in CW pump flow rates.

Case 4 was investigated to determine whether a separate limit on discharge temperature and discharge temperature rise is needed for maintenance activities. It was assumed that the maximum flow reduction during the maintenance load would be when one unit was operating on 4 CW pumps and the other on 3. Unit 2 was selected to be the unit on 3 CW pumps because the Unit 2 CW pumps are each rated to produce a slightly higher flow rate than each Unit 1 CW pump, at the same pumping head. Therefore,

shutting down a Unit 2 CW pump would result in a slightly higher discharge temperature than would shutting down one of the Unit 1 CW pumps. Maximum discharge temperature with Unit 1 operating on 4 CW pumps and Unit 2 operating on 3 CW pumps is calculated in Calculation 25 to be 119.2°F, at a temperature rise of about 29.2°F.

3.0 MODELING METHODS

It is not obvious which of the four cases would result in the largest mixing zone. Therefore, FPL has performed near-field modeling for all four cases. The details of that modeling are provided in the following Calculations:

- 28. MULDIF Run – Y-Nozzle with 123°F Discharge Temperature – Case 2
- 29. MULDIF Run – Y-Nozzle with 118°F Discharge Temperature – Case 1
- 30. MULDIF Run – Y-Nozzle with 119°F Discharge Temperature – Case 3
- 31. MULDIF Run – Y-Nozzle with 120°F Discharge Temperature – Case 4
- 33. Revised Multiport Diffuser MULDIF Run

In order to maintain conservatism in the modeling, Case 2 was run with the same assumed ambient water temperature of 90°F as the other cases, although it is unlikely such a condition would actually occur.

The St. Lucie thermal discharge is into open waters, as defined by FAC 62-302.520(3)(f). The thermal standard for open waters is defined in FAC 62-302.520(4)(c) and is three-pronged:

1. Heated water up to 17°F above ambient may be discharged to open waters without a mixing zone;
2. The surface temperature of the RBW shall not be raised above 97°F ; and
3. The POD must be sufficient distance offshore to ensure that adjacent coastal waters are not heated beyond the temperatures permitted in such waters.(Limits on coastal waters are codified in 62-302.520(4)(b) and are no more than 2°F higher than ambient during June, July, August, and September, or 4°F higher during the remainder of the year).

The response to RFI # 1, Comment 5.e, demonstrates that the 2°F isotherm is seaward of the 18-foot depth contour; therefore, Item 3 above is met. As a result, only near-field modeling is needed to determine the extent of the 17°F isotherm for each case, and the maximum surface water temperature. The model used was MULDIF, which is the Envirosphere version of the near-field Koh and Fan model. Appendix 10.6 of the St. Lucie Plant Uprate Site Certification Application (SCA) includes a listing of the program and previous calculations, as well as a discussion of the historical verification of the model.

The Koh and Fan near-field model is a submerged jet model consisting of a set of seven simultaneous differential equations. They include equations of conservation of mass, horizontal momentum flux, vertical momentum flux, density deficiency flux, thermal energy flux, and two equations of horizontal and vertical distance. The solution of these equations provides jet width, dilution, temperature, density, jet trajectory, and temperature rise as a function of position. The Koh and Fan model was calibrated with physical model studies and used during the initial permitting of the St. Lucie units.

4.0 MODEL RESULTS

4.1 Temperature

Case 1 was modeled using the temperatures derived in Section 2.0 above, rounded to whole numbers. Assuming an ambient water temperature of 90°F and a temperature rise across the plant of 28°F, the discharge temperature is 118°F. Details of the modeling are described in Calculation 29, and the resultant model output is shown in Table 1. The water temperature along the plume centerline is plotted on Figure 1. The centerline temperature drops to 107°F (17°F above ambient) within about 65 feet, and the maximum surface temperature is 96.6°F.

Case 2 was modeled using the temperatures derived in Section 2.0 above, rounded up to whole numbers. Based on minimum intake water temperature analysis described in RFI # 1 Response 2, intake water temperatures are cool enough to implement case 2 (3 CW pumps operating per unit) during all months. As an upper bound to Case 2 discharge temperatures, an ambient water temperature of 90°F was assumed. Coupled with the temperature rise across the plant rounded up to 33°F (for conservatism), the discharge temperature is 123°F. Details of the modeling are described in Calculation 28, and the resultant model output is shown in Table 2. The water temperature along the plume centerline is plotted on Figure 2. The centerline temperature drops to 107°F (17°F above ambient) within about 72 feet, and the maximum surface temperature is 97.4°F. In order to meet the surface water temperature limit of 97°F, FPL will take a permit limit to not operate Case 2 whenever the intake water temperature exceeds 89.5°F. The resultant thermal plume for Case 2 with an intake temperature of 89.5°F has been assumed to be the same as shown in Table 2 for the 90°F intake temperature, except that the plume temperature and temperature rise above ambient are ½ °F lower.

Case 3 was modeled using the temperatures derived in Section 2.0 above, rounded to whole numbers. Assuming an ambient water temperature of 90°F and a temperature rise across the plant of 29°F, the discharge temperature is 119°F. Details of the modeling are described in Calculation 30, and the resultant model output is shown in Table 3. The water temperature along the plume centerline is plotted on Figure 3. The centerline temperature drops to 107°F (17°F above ambient) within about 66 feet, and the maximum surface temperature is 98.4°F. FPL will take a permit limit to not operate Case 2 whenever the intake water temperature exceeds 88.5°F in order to avoid exceeding the 97°F surface temperature limit. The resultant thermal plume for Case 3 with an intake temperature of 88.5°F has been assumed to be the same as shown in Table 3 for the 90°F intake temperature; except that the plume temperature and temperature rise above ambient are 1½ °F lower.

Case 4 was modeled using the temperatures derived in Section 2.0 above, rounded up to whole numbers. Assuming an ambient water temperature of 90°F, and a temperature rise across the plant of 30°F, the discharge temperature is 120°F. Details of the modeling are described in Calculation 31, and the resultant model output is shown in Table 4. The water temperature along the plume centerline is plotted on Figure

4. The centerline temperature drops to 107°F (17°F above ambient) within about 68 feet, and the maximum surface temperature is 96.0°F.

Based on the plume trajectories from Tables 1 through 4, the volume enclosed within the 17°F isotherm for each case has been determined in Calculation 32. The results are shown in Table 5. Based on those results, Case 2 produces the largest mixing zone.

In order to determine the maximum mixing zone size, the thermal plume for the multiport diffuser has been modeled for Case 2 conditions, and the volume associated with the 17°F above ambient isotherm from the multiport diffuser (652 cubic feet) has been added to that from the Y-nozzle diffuser (8,937 cubic feet) to obtain the maximum total volume of the 17°F isotherm of 9,589 cubic feet. The details of that model run and the associated determination of maximum volume of the mixing zone are provided in Calculation 33. The resultant model output is shown on Table 6, and the water temperature along the plume centerline has been plotted in Figure 5. The resultant maximum mixing zone size for both diffusers is thus 9,589 cubic feet.

4.2 Time/Temperature

Because the time/temperature relationship is similar for both diffusers, only the Y-nozzle diffuser has been analyzed. The time/temperature relationship is shown in Figure 6. If a particle of water were entrained into the center of the plume at the hottest temperature of 122.5°F, it would be cooled down to 97°F within about 25 seconds. The relationship for the multiport diffuser would be of the same magnitude, i.e., measured in seconds.

4.3 Dissolved Oxygen

Although the solubility of oxygen in water decreases slightly as the water temperature is increased, that effect is more than compensated for by the effects of Henry's Law, which states that the solubility of a gas in water is proportional to the partial pressure of that gas above the water. Because the St. Lucie discharges are released at depth, the pressure to keep the dissolved oxygen (DO) in solution is a function of the depth. At 24 feet depth, the extra water pressure is 10.4 psi. When added to the atmospheric pressure of 14.7 psi, this results in a pressure increase at the discharge depth of about 71%. At this pressure, DO will not come out of solution, even at the expected elevated temperature. As the thermal plume rises and the pressure lessens, mixing also causes the water temperature to drop, and the saturated DO value to rise again. Therefore, no adverse impacts to DO are expected.

4.4 Thermal Plume Vertical Profile

Figure 7 illustrates the thermal plume vertical profile for the Y-nozzle diffuser. This diffuser discharges in an area where the sea bottom was excavated to about 6 feet below natural sea bottom. As shown in Figure 7, the model predicts that the 97°F isotherm will not come in contact with the sea bottom. Figure 8

illustrates the vertical profile of the thermal plume for the multiport diffuser. As shown, the multiport diffuser is located about 8 feet above sea bottom. The thermal discharge dissipates in the water column and does not come in contact with benthic organisms in the sea bottom.

5.0 SUMMARY AND CONCLUSIONS

The difference in the extent of the thermal plume attributable to the increase in discharge temperature from 113°F to 119°F is relatively small. For the Y-nozzle diffuser, the increase in size of the 17-Degree F. isotherm is about 6,858 cubic feet, from about 2,439 cubic feet to about 9,297 cubic feet. For the multiport diffuser, the volume of the 17-degree F. isotherm increases from about 614 to about 652 cubic feet. The combined volume of the 17-degree F. isotherm from both diffusers is thus about 9,949 cubic feet for the 119°F discharge. Heated water exiting the diffusers at 119°F would be cooled down to 97°F within about 25 seconds. There is no potential decrease in dissolved oxygen concentration due to the discharge at depth; the increase in pressure more than compensated for any temperature effect.

The proposed change in the thermal discharge will increase the temperature of a small volume of the Atlantic Ocean water column in the near vicinity of the St. Lucie Plant discharge. The proposed thermal discharge is expected to quickly mix with the Ocean waters and is expected to interact with the bottom sediments in a similar manner as the currently permitted discharge; the heated water will float as it mixes.

TABLES

TABLE 1
RESULTS OF MODELING CASE 1
MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED

AA= 115.00 FEET

1------AA------1 A= 7.50 FEET

1 *--A--* * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 13.02 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 118.00 F

JET DISCHARGE DENSITY= 1.016065 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0	7.5		118				28	
46.84	0.00016	15.15771	1.01051	114.1504	1.01695	1.0225	90	24.15036	17
76.69405	1.67631	28.94036	1.93676	102.6006	1.0196	1.0225	90	12.60056	17
91.44384	4.14679	35.63834	2.40262	100.1573	1.02017	1.0225	90	10.15735	17
105.8959	7.9878	42.05587	2.87322	98.49369	1.02055	1.0225	90	8.49369	17
119.8729	13.30134	48.07619	3.35172	97.28113	1.02083	1.0225	90	7.28112	17
133.2027	20.07683	53.63039	3.84166	96.35253	1.02104	1.0225	90	6.35253	17
145.7549	28.20403	58.72078	4.34653	95.61466	1.02121	1.0225	90	5.61466	17

THIS IS FREE SURFACE

Calc 29

TABLE 2
RESULTS OF MODELING CASE 2
MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED

AA= 115.00 FEET

1------AA------1 A= 7.50 FEET

1 *--A--* * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 11.40 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 123.00 F

JET DISCHARGE DENSITY= 1.014705 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0			123			90		
46.84	0.00026	15.1577	1.01051	118.4629	1.01578	1.0225	90	28.46292	17
76.59764	2.63063	28.80174	1.93823	104.8394	1.01899	1.0225	90	14.83941	17
91.05657	6.42867	35.18377	2.4087	101.941	1.01968	1.0225	90	11.94097	17
104.8715	12.13786	41.02435	2.88996	99.95247	1.02015	1.0225	90	9.95247	17
117.7805	19.67609	46.25394	3.38778	98.48999	1.02049	1.0225	90	8.48999	17
129.6308	28.79219	50.94408	3.90735	97.36105	1.02076	1.0225	90	7.36105	17
THIS IS FREE SURFACE									
51.56	0.417418			107			90	17	
Calc 28									

TABLE 3
RESULTS OF MODELING CASE 3
MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED

AA= 115.00 FEET

1------AA------1 A= 7.50 FEET

1 *--A--* * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 6.47 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 119.00 F

JET DISCHARGE DENSITY= 1.015798 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET 9387687

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0			119			90	29	
46.84	0.00069	15.15765	1.01051	115.0129	1.01672	1.0225	90	25.01287	17
75.73824	6.59876	27.65854	1.95197	102.9489	1.01951	1.0225	90	12.94889	17
88.19025	14.83348	32.35958	2.45883	100.2796	1.02012	1.0225	90	10.27962	17
98.78712	25.36724	36.36976	3.0083	98.40205	1.02056	1.0225	90	8.40205	17

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Calc 30

TABLE 4
RESULTS OF MODELING CASE 4
MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED

AA= 115.00 FEET

1------AA------1 A= 7.50 FEET

1 *--A--* * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 12.52 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 120.00 F

JET DISCHARGE DENSITY= 1.015529 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0			120			90		
46.84	0.00019	15.15771	1.01051	115.8754	1.01649	1.0225	90	25.87539	17
76.66982	1.96048	28.90529	1.93713	103.498	1.01936	1.0225	90	13.49804	17
91.3447	4.83454	35.51991	2.40416	100.8759	1.01997	1.0225	90	10.87591	17
105.626	9.26266	41.77459	2.87754	99.08672	1.02039	1.0225	90	9.08672	17
119.3012	15.30707	47.55079	3.36126	97.77905	1.02069	1.0225	90	7.77905	17
132.1881	22.88941	52.81058	3.85953	96.77477	1.02093	1.0225	90	6.77477	17
144.1751	31.82872	57.6038	4.37615	95.97499	1.02111	1.0225	90	5.97499	17

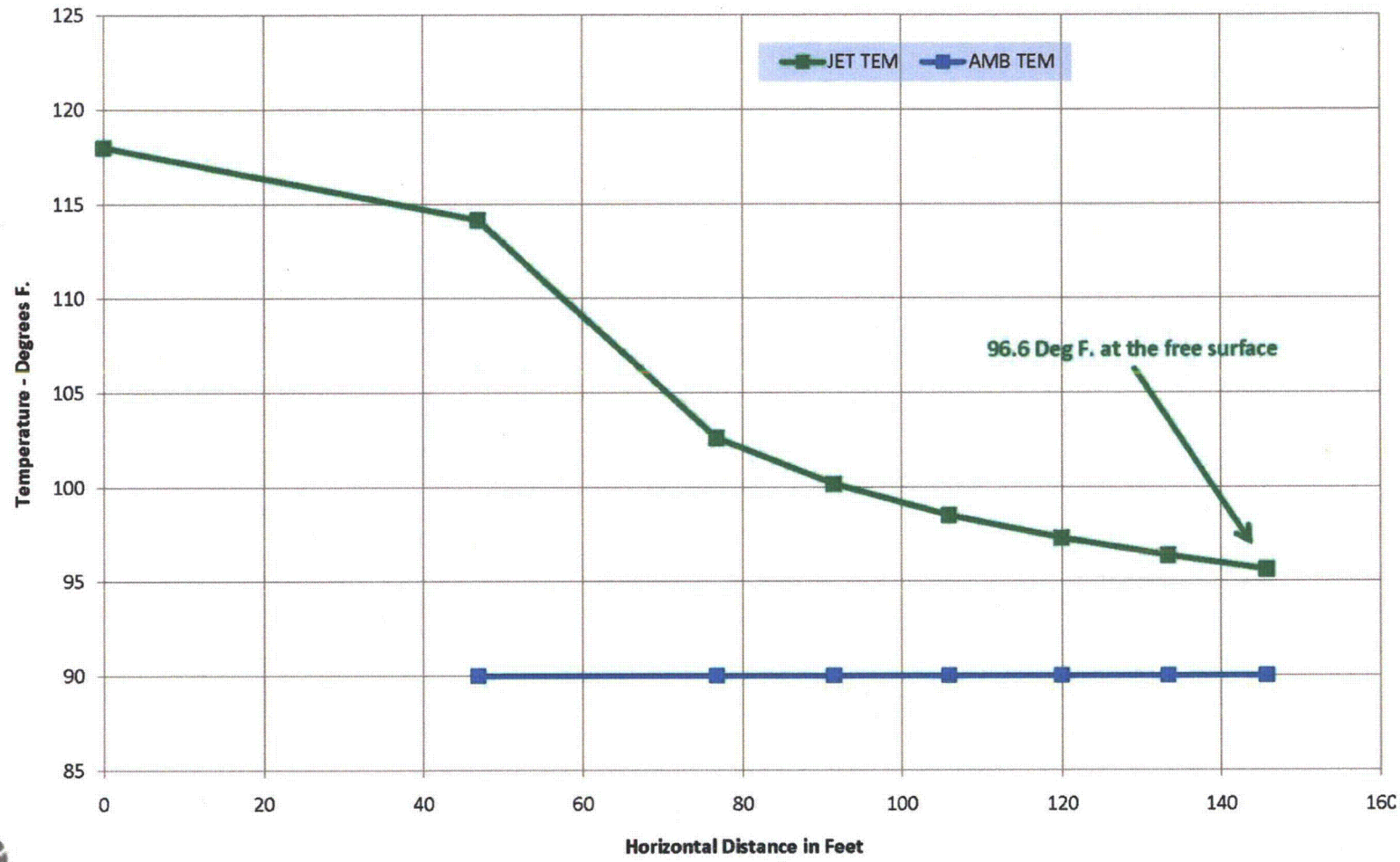
THIS IS FREE SURFACE

Calc 31

TABLE 5
Calculation of Volume of 17-Degree F Isotherm for Each Case

	Case 1	Case 2	Case 3	Case 4	Uprate as Site-Certified with 113 deg F Discharge*	Present Permit
X at start first time step	0	0	0	0		
Y at start first time step	0	0	0	0		
X at end first time step	46.84	46.84	46.84	46.84		
y at end first time step	0.00016	0.00026	0.00069	0.00019		
S for first time step	46.840	46.840	46.840	46.840		
jet diameter start of first time step	7.500	7.500	7.500	7.500		
jet diameter end of first time step	15.158	15.158	15.158	15.158		
centerline delta T at start first step	28.000	33.000	29.000	30.000		
centerline delta T at end of first step	24.150	28.463	25.013	25.875		
ratio of 17 deg to centerline delta T	0.863	0.863	0.863	0.863		
from normal distribution, # of SDs	0.540	0.540	0.540	0.540		
17 deg jet diameter end of first step	2.046	2.046	2.046	2.046		
17 deg volume of first step - cu ft	4,303	4,303	4,303	4,303		
x at end second time step	65.322	71.878	66.034	68.230		
y at end second time step	1.0378	2.2135	4.3831	1.4058		
S for second time step	18.511	25.136	19.688	21.436		
jet diameter end second time step	23.690	26.638	23.461	25.016		
centerline delta T at end second step	17	17	17	17		
17-degree volume of second step	122	165	129	141		
Total volume 17-degree isotherm per port	4,425	4,468	4,433	4,444		
for two ports (cubic feet) :	8,850	8,937	8,865	8,888	2,676	12,367,168
* From Calculation 18 (original Thermal Discharge Study)						
Calc 32						

FIGURES



FPL

Golder Associates

Atlanta, Georgia

TITLE

Water Temperature vs. Horizontal Center-Line Distance Y-Nozzle Diffuser- Case 1 118 deg F Discharge Tempeerature

CLIENT/PROJECT

FPL/St. Lucie Revised Thermal Discharge Study/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687	
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
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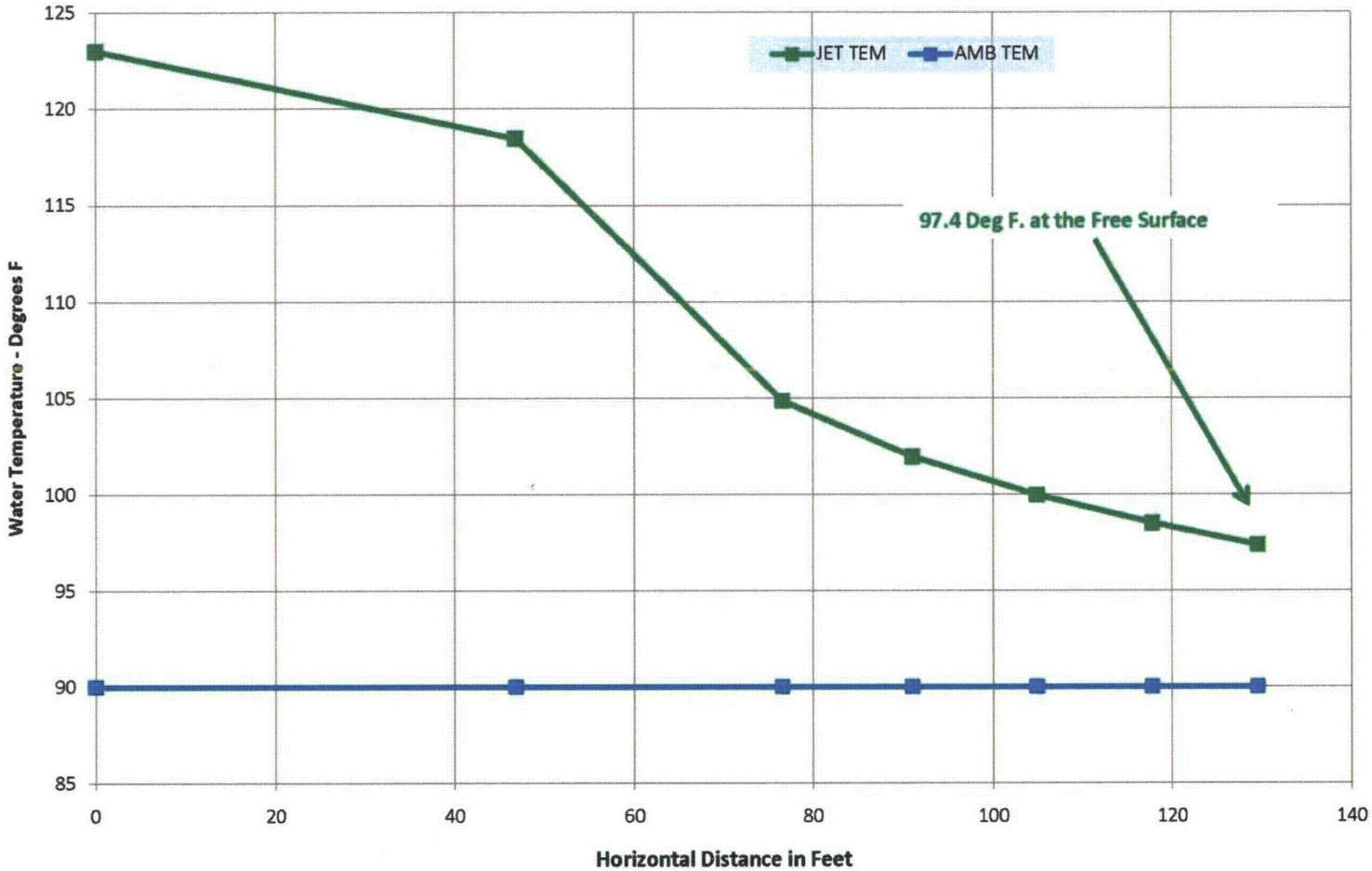

FPL

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TITLE

Water Temperature vs. Horizontal Center-Line Distance Y-Nozzle Diffuser- Case 2 123 deg F Discharge Temperature

CLIENT/PROJECT

FPL/St. Lucie Revised Thermal Discharge Study/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687	
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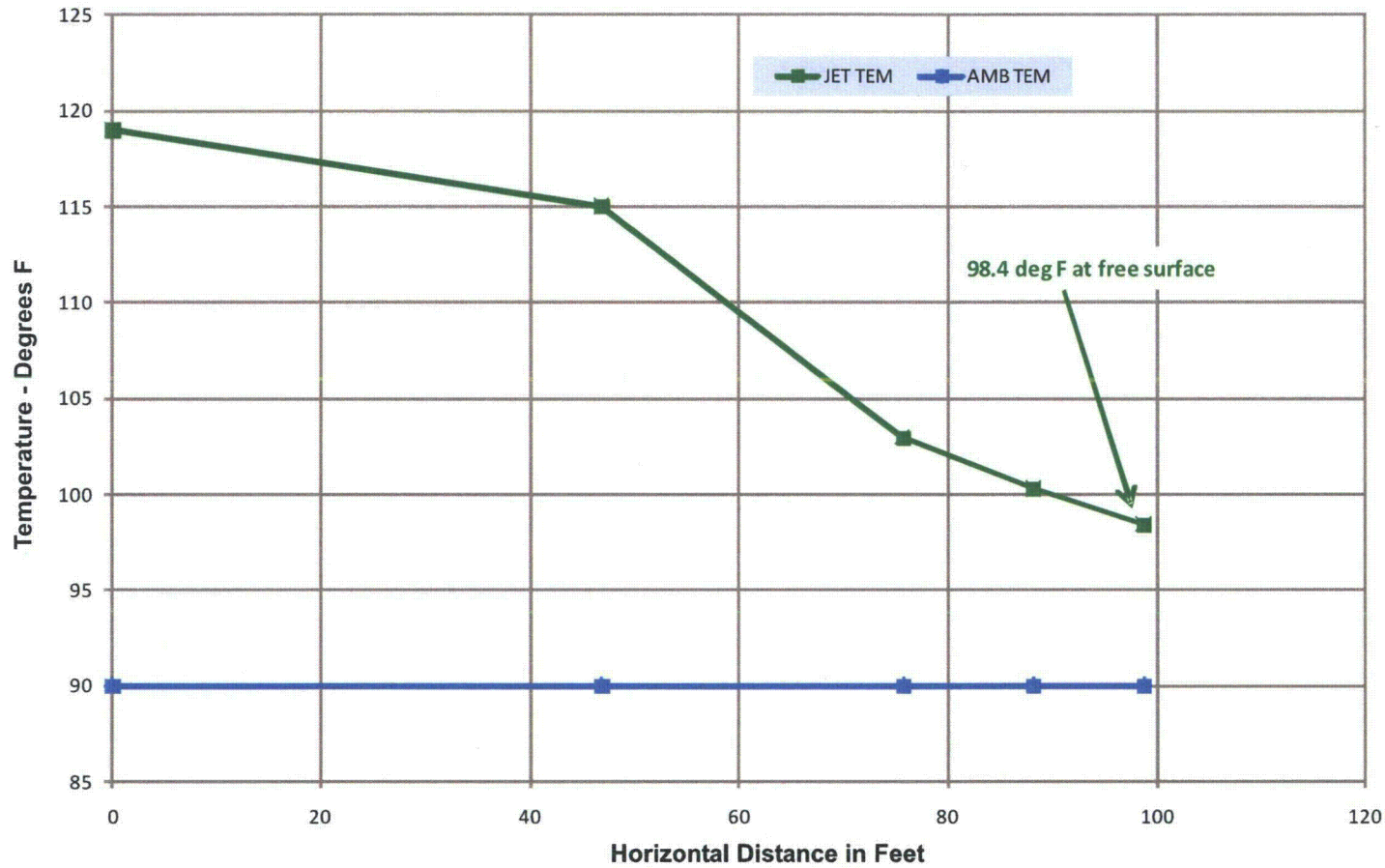

TITLE

FPL

Golder Associates

Atlanta, Georgia

Water Temperature vs. Horizontal Center-Line Distance Y-Nozzle Diffuser- Case 3 119 deg F Discharge Temperature

CLIENT/PROJECT

FPL/St. Lucie Revised Thermal Discharge Study/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687		
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.	
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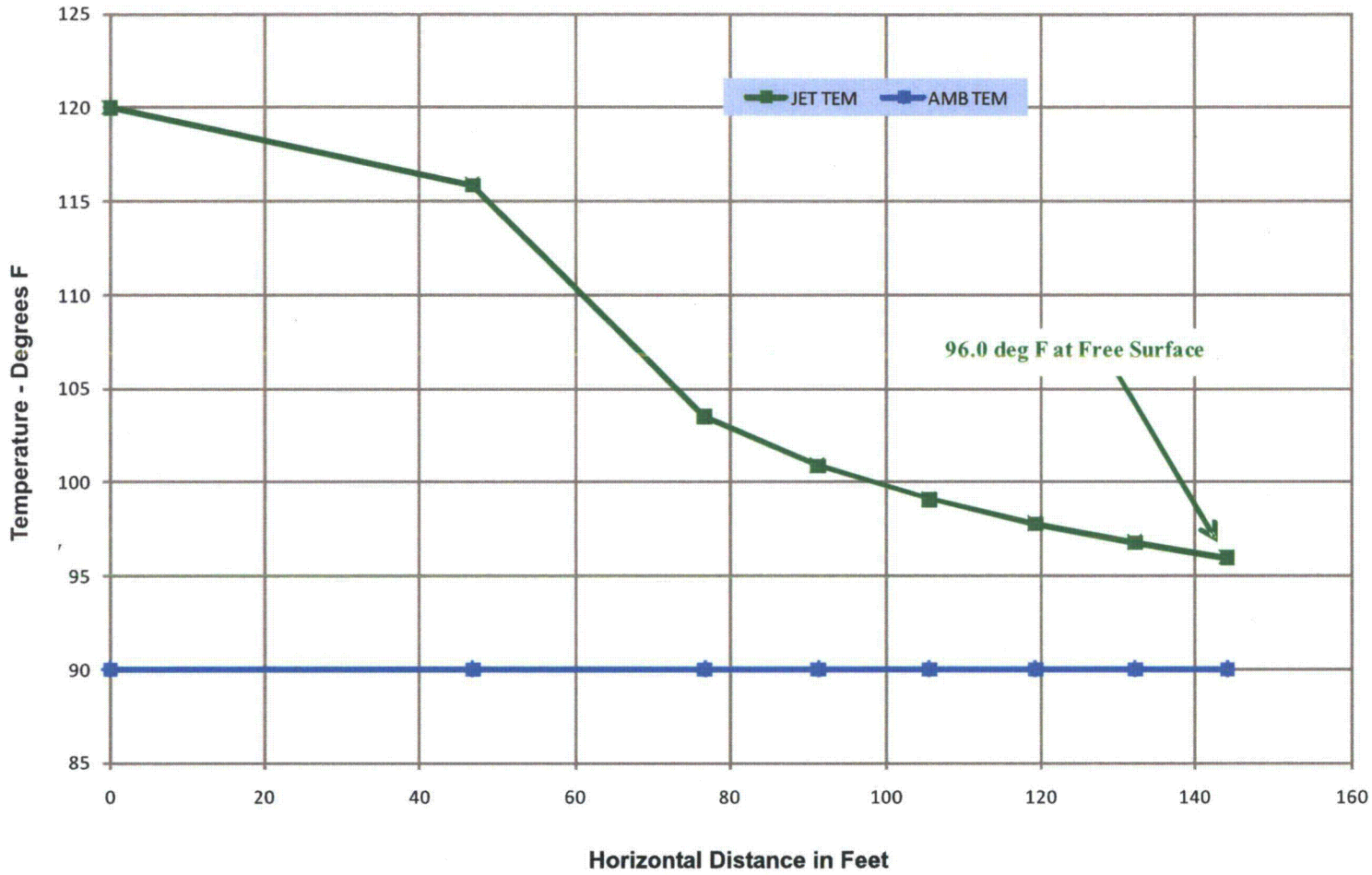

FPL

Golder Associates

Atlanta, Georgia

TITLE

Water Temperature vs. Horizontal Center-Line Distance Y-Nozzle Diffuser- Case 4 120 deg F Discharge Temperature

CLIENT/PROJECT

FPL/St. Lucie Revised Thermal Discharge Study/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687	
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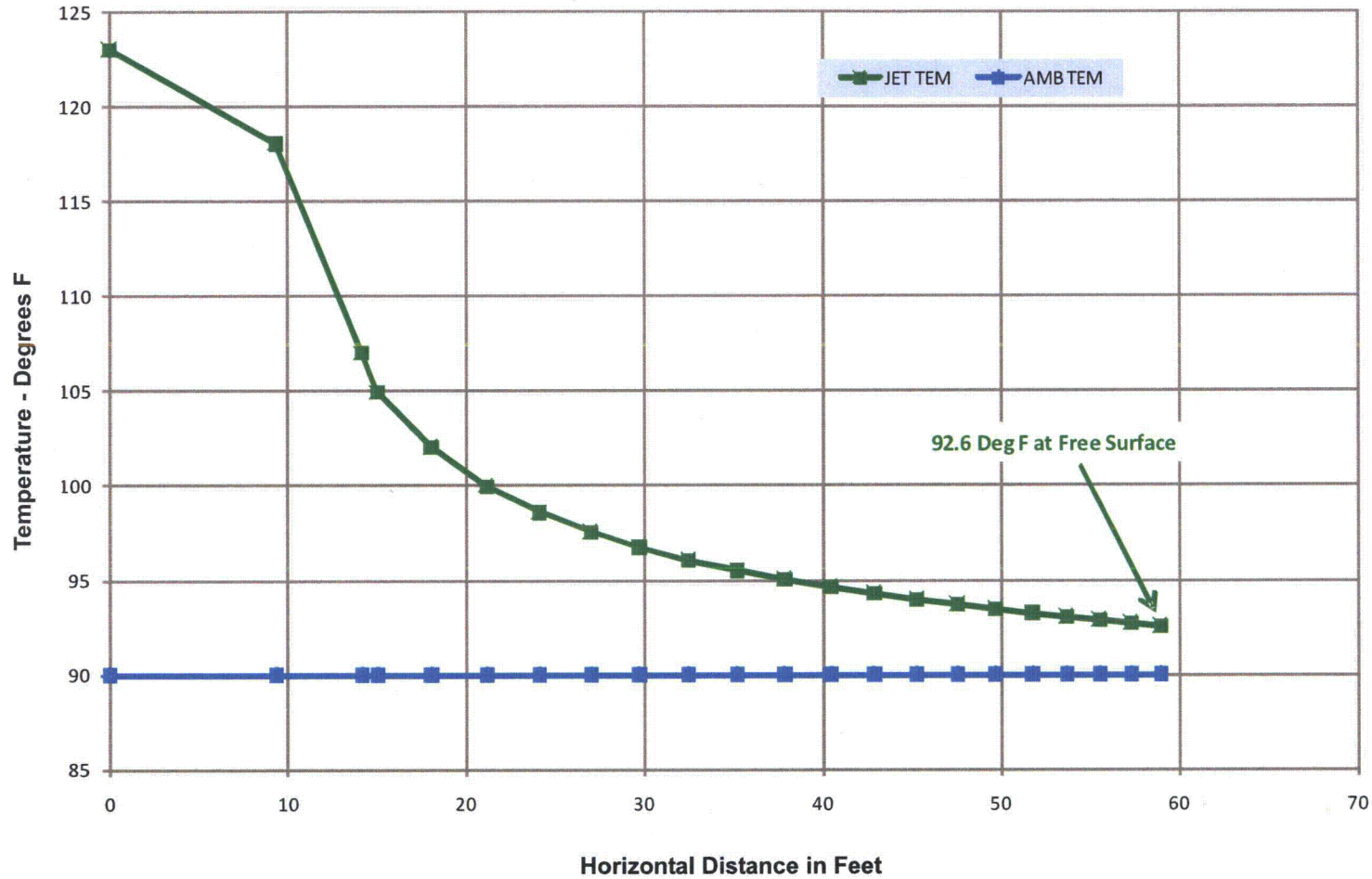
REVIEWED GP	FILE NO. TDS Figure 6	SUBTITLE	FIGURE NO. 4



Golder Associates

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TITLE

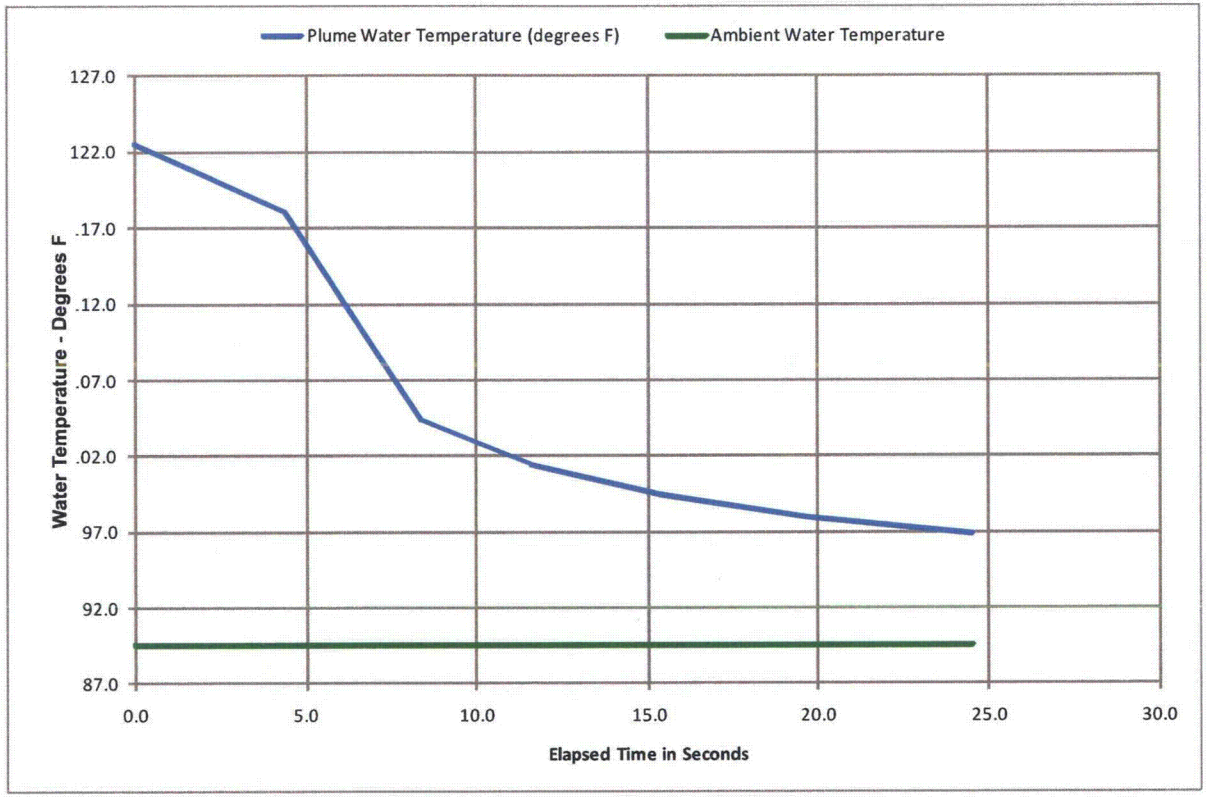
Water Temperature vs. Horizontal Center-Line Distance Multiport Diffuser- Case 2 123 deg F Discharge Temperature

CLIENT/PROJECT

FPL/St. Lucie Revised Thermal Discharge Study/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687	
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
REVIEWED GP	FILE NO. TDS Figure 5	SUBTITLE	FIGURE NO. 5

Elapsed Time (seconds)	Plume Water Temperature (degrees F)	Ambient Water Temperature
0.0	122.5	89.5
4.4	118.0	89.5
8.4	104.3	89.5
11.6	101.4	89.5
15.3	99.5	89.5
19.7	98.0	89.5
24.6	96.9	89.5



FPL

Golder Associates

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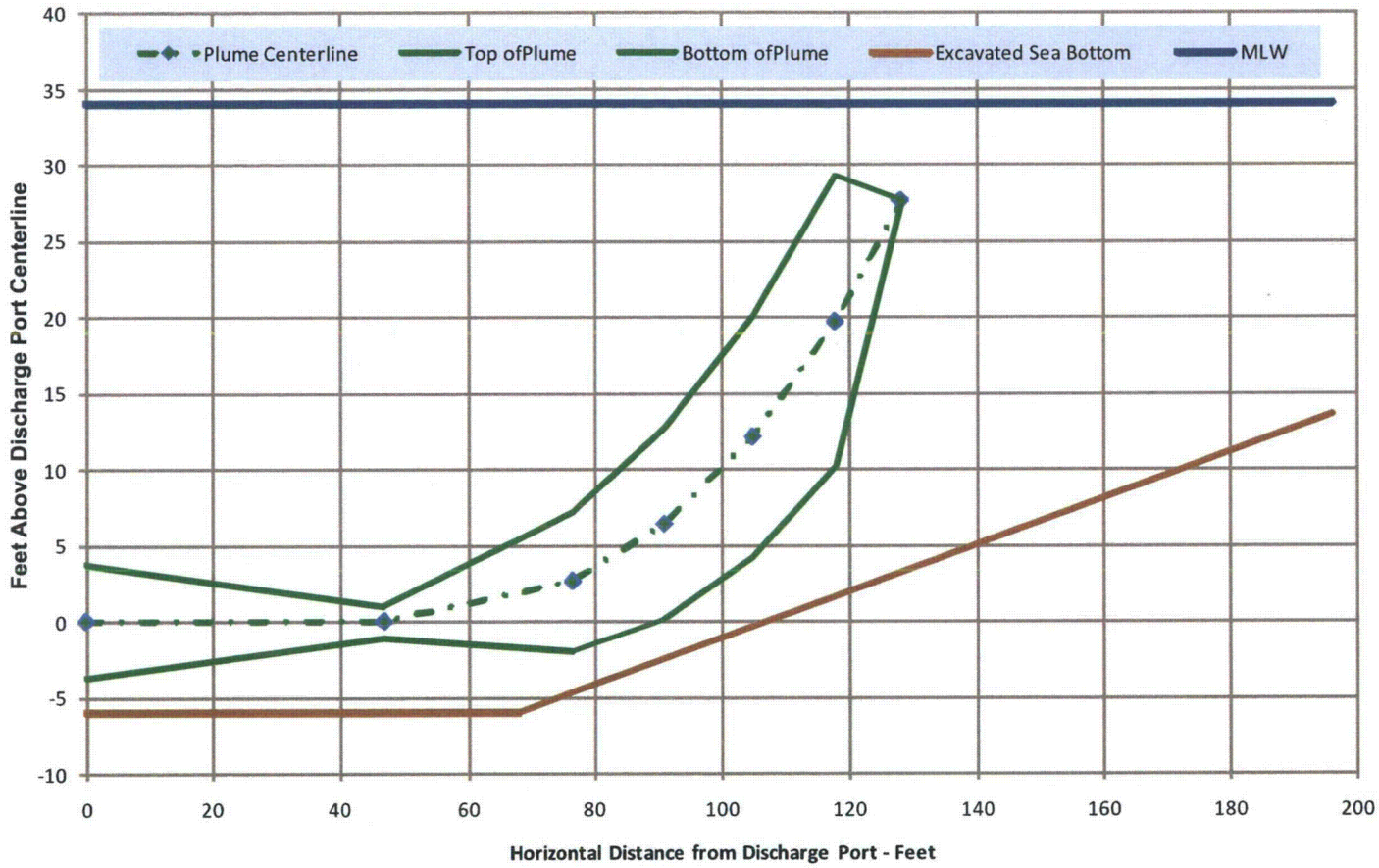
TITLE

Time/Temperature Relationship for Y-Nozzle Diffuser During Case 2

CLIENT/PROJECT

FPL/St. Lucie Revised Thermal Discharge Study/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687	
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
REVIEWED GP	FILE NO. TDS Figure 6	SUBTITLE	FIGURE NO. 6



FPL

Golder Associates

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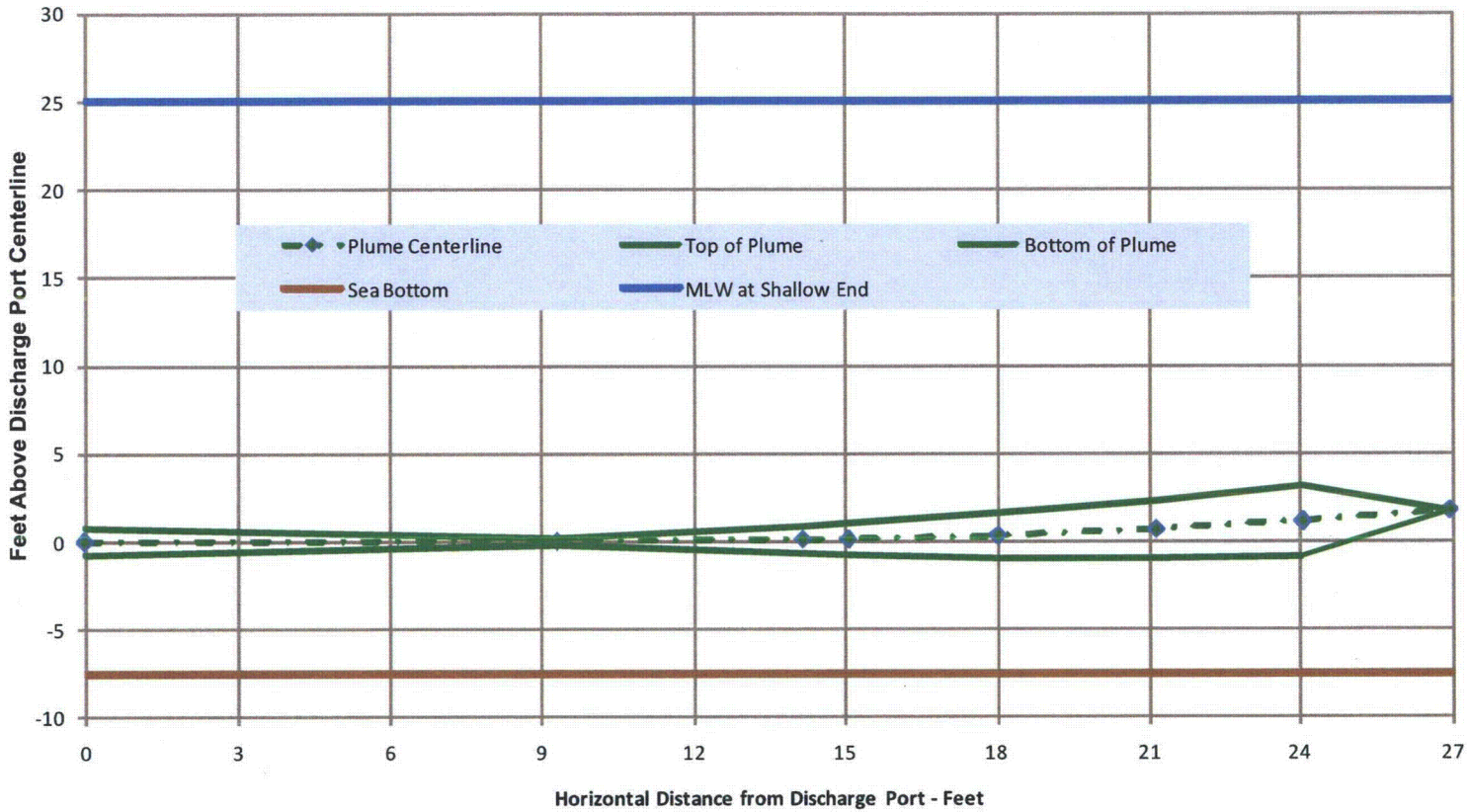
TITLE

Thermal Plume Vertical Profile for
Y-Nozzle Diffuser - 97 deg F isotherm
Case 2 with Intake Water at 89.5 deg F

CLIENT/PROJECT

FPL/St. Lucie Revised Thermal Discharge Study/FL

DRAWN MAT	DATE 6/1/10	JOB NO. 09387687	
CHECKED SH	SCALE NTS	DWG. NO.	REV. NO.
REVIEWED GP	FILE NO. TDS Figure 7	SUBTITLE	FIGURE NO. 7



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TITLE

Thermal Plume Vertical Profile for Multiport Diffuser - 97 deg F isotherm Case 2 with Intake Water at 89.5 deg F

CLIENT/PROJECT

FPL/St. Lucie Revised Thermal Discharge Study/FL

DRAWN	MAT	DATE	6/1/10	JOB NO.	09387687
CHECKED	SH	SCALE	NTS	DWG. NO.	REV. NO.
REVIEWED	GP	FILE NO.	TDS Figure 8	SUBTITLE	FIGURE NO. 8

ATTACHMENT E

Underwater Engineering Services, Inc.

June 2, 2010

Florida Power & Light
Environmental Services
Attn: Ron Hix

Subject: Budgetary Estimate for St. Lucie Nuclear Plant Offshore Work

Underwater Engineering Services, Inc. (UESI) is pleased to provide the following budgetary estimate for the St. Lucie Nuclear Plant Offshore Work.

1) Remove existing Y – port diffuser and replace 2600 feet seaward - $40,453,641.00

Includes –	Engineering up front administrative -	$ 512,966.00
	Field Mobilization (includes trestle)	$20,646,815.00
	Materials	$ 9,389.750.00
	Labor	$ 8,874,180.00
	Trestle (assumes ½ cost)	$12,500,000.00

2) Extend the multi port diffuser – Extend the multiport 700' seaward-$26,105,236.00

Includes –	Engineering up front administrative -	$ 512,966.00
	Field mobilization (includes trestle)	$20,646,815.00
	Materials	$ 2,435,125.00
	Labor	$ 1,540,700.00
	Trestle (assumes ½ cost)	$12,500,000.00

3) Replace Y Port diffuser - $43,157,480.00

Includes –	Engineering up front administrative -	$ 512,966.00
	Materials	$ 9,389.750.00
	Labor	$ 8,874,180.00
	Trestle (assumes ½ cost)	$12,500,000.00

This is a budgetary estimate only based on numerous assumptions including that work will be done to both discharge pipes. Actual costs will be based on conditions, drawings, specifications.

Should you have any questions or require additional information, please do not hesitate to contact me at (772) 337-3116.

Sincerely,

Joe Frederickson

Digitally signed by Joe Frederickson
DN: cn=Joe Frederickson, o=UESI, ou=Construction, email=jfrederickson@UESI.com, c=US
Date: 2010.06.02 17:13:19 -04'00'

Joe Frederickson
VP of Construction Operations
L065A

3306 Enterprise Road, Ste. 103 ◊ Fort Pierce, Florida 34982
Phone: 772-337-3116 ◊ Fax: 772-337-0294

ATTACHMENT F

CALCULATION 25

Golder Associates	SUBJECT : Waste Heat Discharged for Modeling Cases		
	Job No. 09387687 Ref. FPL PSL NPDES Mod, Calc 25	Made By: H. Frediani Checked Reviewed	Date 5/19/2010 Sheet 1 of 5

In response to FDEP's first request for additional information associated with the NPDES Permit FL0002208 Modification Request to increase the permit limit for discharge temperature at Outfall D-001, it was decided to model four cases:

Case 1. Maximum discharge temperature, both units operating at full load on 4 CW pumps each.

Case 2. Maximum discharge temperature rise, both units operating at full load on 3 CW pumps each.

Case 3. Maximum discharge temperature, one unit operating at full load on 4 CW pumps.

Case 4. Maximum discharge temperature, maintenance mode, Unit 1 operating at full load on 4 CW pumps and Unit 2 operating at full load on 3 CW pumps.

Based on the intake temperature frequency distribution developed in Calculation 20, the highest intake temperature seen in the Period of Record August 2005 through October 2009 was 88.4 deg F. The 90th percentile intake temperature was 70 deg F. In the Unit 2 Final Environmental Statement (FES), it was stated that the maximum ambient water temperature between 1971 and 1978 was 90 deg F. (Unit 2 FES, Page 4-19). Assume the worst-case discharge temperature will occur when the CW Inlet Temperature (CWIT) is at 90 deg F.

Case 1: Normally, four CW pumps operate per unit as follows (see the attached response to FDEP's RFI #1 dated March 5, 2008, for a previous NPDES permit modification, for flow derivation):

Unit 1 CW pumps , four pumps at 121,000 gpm each = 484,000 gpm

Unit 1 also has 2 AECW pumps at 14,500 gpm each = 29,000 gpm

(AECW = ICW) total Unit 1 = 513,000 gpm

Unit 2 has four CW pumps at 122,650 gpm each = 490,600 gpm

Unit 2 has two AECW pumps at14,500 gpm each = 29,000 gpm

total Unit 2 = 519,600 gpm

From PEPSE Heat Balances summarized in FPL's e-mail of 5/14/2010, the heat rejected for each unit with operating and 90 deg F Circulating Water Inlet Temperature (CWIT) is:

Unit 1 = 6952.35 Million Btu per hour

Unit 2 = 6854.76 Million Btu per hour

ΔT is calculated as follows: ΔT = heat rejected /(CW flow times specific heat), where CW flow is in lbs per hour

Based on Calculation 27, the specific heat of sea water in the expected range of temperatures is about 0.96 Btu per lb per degree F.

Use the density of sea water relationship developed in Calc 7 and detailed in spreadsheet "Book1.xlsx to determine the density of sea water at the desired temperatures.

In order to obtain the discharge temperature rise, we need to add in the heat load from the ICW systems. Per the FPL e-mail of 5/7/2010, Table 4.1.4-1 applies for Unit 1 :

Table 4.1.4-1 – Unit 1 EPU Normal Operation

Components	Minimum Flowrate (gpm)	Heat Load (Mbtu)	ICW Outlet Temp (°F)
CCW HX A	4,395	26.06	106.6
CCW HX B	4,395	26.06	106.6
TCW HX A	1,716	26.4	125
TCW HX B	3,119	48.0	125
OBCS HX A	2,248	34.6	125
OBCS HX B	2,248	34.6	125
TOTAL	18,121		

ICW Heat Rate = 26.06 + 26.06 + 26.4 + 48 +34.6 +34.6 = 196 million Btu/hour = 196,000,000 Btu/hour

This is the Unit 1 value, assume the Unit 2 value is the same.

For Case 1:

Assume that the maximum discharge temperature case (Case 1) occurs with 4 CW pumps operating per unit, and with an inlet CW temperature (CWIT) of 90 deg F. For Unit 1, the 4-pump flow (Case 1):

ΔT_1 = (6,952,350,000 + 196,000,000)Btu/hour/((513,000 gpm / 7.48 gal/cu ft) * ρ *C_p* 60 min/hr)

at CWIT of 90 deg F, ρ = 63.8 pcf.

ΔT_1 = (6,952,350,000+196,000,000)/(513,000 /7.48*63.8*.96*60) = 28.36 deg F.

For Unit 2, Case 1:

ΔT_2= (196,000,000 +6,854,760,000)/((519,600/7.48) * 63.8 *.96 *60) = 27.62 deg F.

For the combined flow of both units:

$\Delta T_{combined}$ = (ΔT_1* Q1 + ΔT_2 * Q2)/ (Q1 + Q2) = 27.81 deg F.

For Case 2

Assume the maximum ΔT occurs when only 3 CW pumps are operating for each unit. Based on the attached document from FPL entitled "Determination of Flow Through CW System with 6 CW Pumps Operating.doc", the CW flows through each unit are as follows:

	Unit 1	Unit 2
	422,114 gpm	423,886 gpm

Adding in the ICW flow rates, assumed unchanged from Case 1:

Unit 1 CW pumps , three pumps = 422,114 gpm

Unit 1 still has 2 AECW pumps at 29,000 gpm = 29,000 gpm

total Unit 1 = 451,114 gpm

Unit 2 has 3 CW pumps = 423,886 gpm

Unit 2 still has two AECW pumps at 29,000 gpm = 29,000 gpm

total Unit 2 = 452,886 gpm

Assume 3-pump per unit operation can only occur at lower CWIT; otherwise, the units would suffer a backpressure penalty and have to derate. Use the 90% temperature for CWIT of 70 degrees F. From PEPSE Heat Balances summarized in FPL's e-mail of 5/14/2010, the heat rejected for each unit with 6 pumps operating and 90 deg F. Circulating Water Inlet Temperature (CWIT) is:

Unit 1 = 7003.36 Million Btu per hour

Unit 2 = 6902.64 Million Btu per hour

assume these values are still good for the 70 degree F CWIT case.

For Unit 1, Case 2:

ΔT_1 = (7,003,360,000 + 196,000,000)Btu/hour/((451,114 gpm / 7.48 gal/cu ft) * ρ *C_p* 60 min/hr)

at CWIT of 70 deg F, ρ = 64.02 pcf.

ΔT_1 = (7,003,360,000+196,000,000)/(451,114 /7.48*64.02*.96*60) = 32.37 deg F.

For Unit 2, Case 2:

ΔT_2= (196,000,000 +6,902,640,000)/((452,886/7.48) * 64.02 *.96 *60) = 31.79 deg F.

For the combined flow of both units:

$\Delta T_{combined}$ = (ΔT_1* Q1 + ΔT_2 * Q2)/ (Q1 + Q2) = 32.08 deg F.

For Case 3:

For Case 3, which assumes only one unit operating, the highest discharge temperature is expected with a CWIT of 90 deg F and only Unit 1 operating. The parameters for this case have already been established as part of Case 1:

ΔT = 28.36 deg F

CW flow = 513,000 gpm

CWIT = 90 deg F.

CWOT (CW Outlet Temperature , or discharge temperature) = 118.36 deg F.

For Case 4:

For case 4, we assume a Unit 2 CW pump has tripped off , and full load is maintained on both Units. FPL has provided an analysis of the resultant 7-pump flow (see attached document "Determination of Flow Through CW System with 7 CW Pumps Operating") and concludes that the unit flow rates would be as follows:

Unit 1 - 532,663 gpm

Unit 2 - 402,337 gpm

Adding in the ICW flow rates, assumed unchanged from Case 1:

Unit 1 CW pumps ,four pumps	=	532,663 gpm
Unit 1 still has 2 AECW pumps at 29,000 gpm	=	29,000 gpm
	total Unit 1 =	561,663 gpm

Unit 2 has 3 CW pumps	=	402,337 gpm
Unit 2 still has two AECW pumps at 29,000 gpm	=	29,000 gpm
	total Unit 2 =	431,337 gpm

Using the Unit 1 heat rejection rate from Case 1, Unit 1 = 7,148,350,000 Btu/hour

Using the Unit 2 heat rejection rate from Case 2, Unit 2 = 7,098,640,000 Btu/hour

ΔT_1 = (7,003,360,000 + 196,000,000)Btu/hour/((451,114 gpm / 7.48 gal/cu ft) * ρ *C_p * 60 min/hr)

at CWIT of 90 deg F, ρ = 63.8 pcf.

ΔT_1 = (7,148,350,000)/(561,663 /7.48*63.8*.96*60) = 25.91 degrees F.

For Case 4, Uit 2:

ΔT_2= (7,098,640,000)/((431,337/7.48) * 63.8 *.96 *60) = 33.5 degrees F.

For the combined flow of both units:

$\Delta T_{combined}$ = (ΔT_1* Q1 + ΔT_2 * Q2)/ (Q1 + Q2) = 29.2 degrees F.

In Summary:

	Case 1	Case 2	Case 3	Case 4
CWIT - deg F.	90	70	90	90
ΔT - deg F	27.81	32.08	28.36	29.20
CWOT - deg F.	117.81	102.08	118.36	119.20
CW Flow - gpm	1,032,600	904,000	513,000	993,000

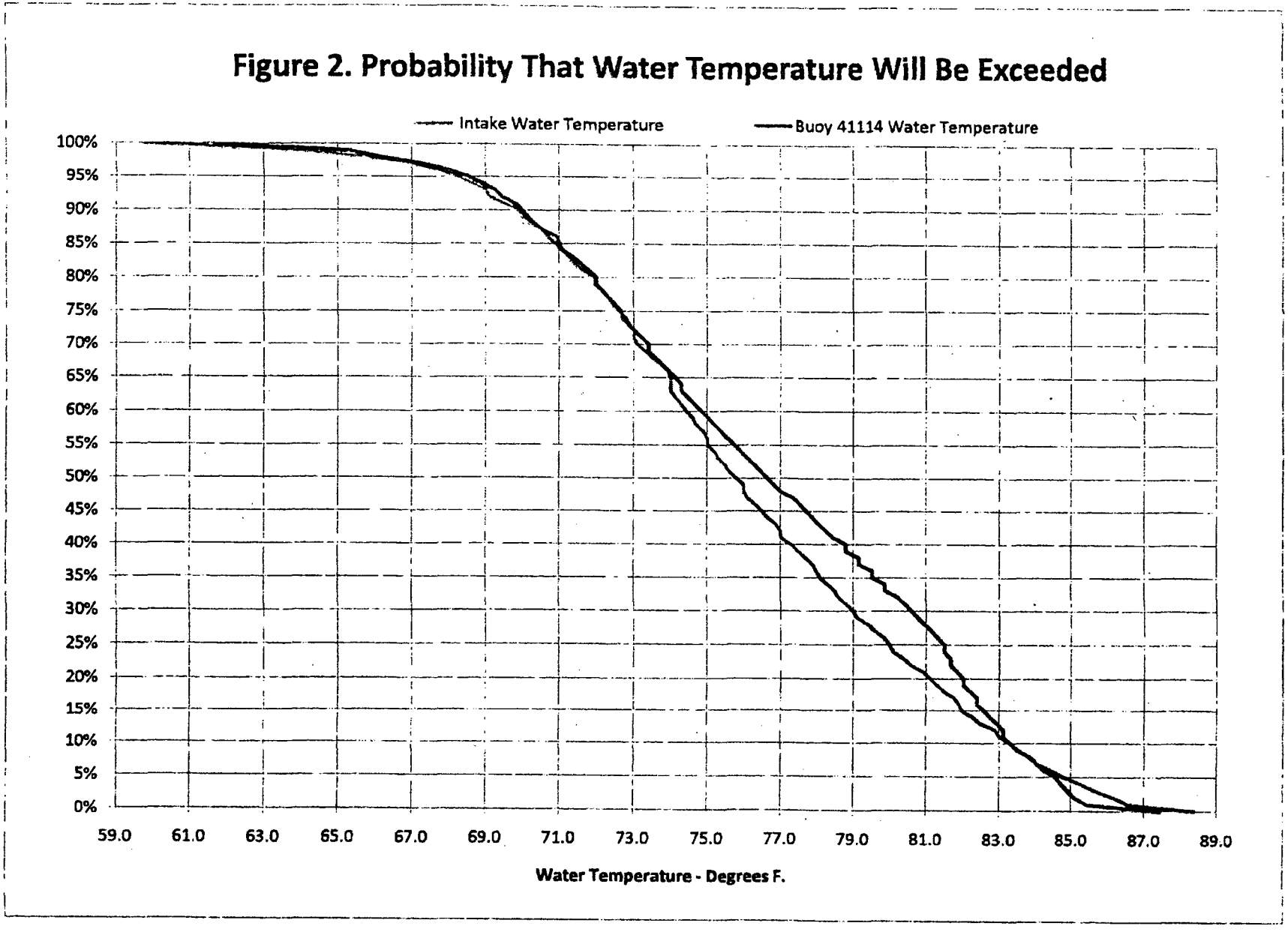
Figure 2. Probability That Water Temperature Will Be Exceeded
Intake Water Temperature
Buoy 41114 Water Temperature
100%
95%
90%
85%
80%
75%
70%
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
59.0
61.0
63.0
65.0
67.0
69.0
71.0
73.0
75.0
77.0
79.0
81.0
83.0
85.0
87.0
89.0
Water Temperature - Degrees F.

Golder Associates Inc.

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FINAL REPORT ON

FLORIDA POWER & LIGHT COMPANY
ST. LUCIE PLANT
MINOR NPDES PERMIT REVISION
RESPONSE TO FDEP RFI # 1

Submitted to:

Florida Power & Light Company
700 Universe Boulevard
Juno Beach, Florida 33408

Submitted by:

Golder Associates Inc.
3730 Chamblee Tucker Road
Atlanta, Georgia 30341
Certificate of Authorization Number: 1670

Harold A. Frediani, Jr., P.E. 36394

Distribution:

Florida Power & Light Company – 8 Copies
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March 5, 2008 07387685

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4.0 TIDAL EFFECTS 2
5.0 EFFECTS OF CLEANLINESS OF INTAKE AND DISCHARGE PIPING 3
6.0 CONCLUSIONS 3

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1.0 INTRODUCTION

This report provides information to the Florida Department of Environmental Protection (FDEP), Industrial Wastewater Section in response to their Request for Information (RFI) letter of January 18, 2008 (DEP File No. FL0002208-008-IWB/MR), relative to FPL's application for a minor permit revision to the St. Lucie Plant NPDES Permit No. FL0002208. The information provided herein has been compiled to comply with the clarifications obtained during a telephone conversation on January 30, 2008, between FPL and FDEP.

2.0 BACKGROUND

During the preparation of the Site Certification Application for the St. Lucie Uprate Project, it was discovered that an approximation had been made in calculating the design system discharge flow rate when both units are operating. In order to correct that approximation, FPL requested a minor revision to the facility's NPDES permit. The permit reviewer raised questions about the relationship between the design flow rate and the actual flow rates as influenced by tidal stages and the cleanliness of the intake and discharge piping as well as the plant facilities, primarily the condensers.

3.0 DESIGN FLOW RATE

Initially, the design flow rate was calculated for Unit 1. The discharge flow is primarily composed of two components, circulating water (CW) which is pumped through the condenser, and auxiliary equipment water (AECW, also known as Intake Cooling Water (ICW)). Figure 1 is a copy of the pump curves for Unit 1 CW, showing a design flow rate of 121,000 gpm per pump at a system head of 40 feet. Figure 2 is a copy of the pump curves for Unit 1 AECW, showing a design flow rate of 14,500 gpm at a system head of 130 feet. During normal operation of Unit 1, there are 4 CW pumps and 2 AECW pumps running, giving a total flow rate of:

4 CW Pumps @ 121,000 gpm = 484,000 gpm
2 AECW Pumps @ 14,500 gpm = 29,000 gpm

Total = 513,000 gpm = 1143 cfs = 739 MGD

When Unit 2 was added, the additional flow was estimated to be the same as Unit 1, thus the total flow rate was estimated at:

2 units @ 739 MGD = 1478 MGD

However, the actual Unit 2 CW pumps that were purchased delivered slightly more flow than the Unit 1 CW pumps. Figure 3 is a copy of the Unit 2 CW pump curves, showing a design flow rate of 122,650 gpm at a system head of 40 feet. The Unit 2 AECW pumps are the same design as those of Unit 1. During normal operation of Unit 2, there are 4 CW pumps and 2 AECW pumps running, giving a total flow rate of:

4 CW Pumps @ 122,650 gpm = 490,600 gpm
2 AECW Pumps @ 14,500 gpm = 29,000 gpm

Total = 519,600 gpm = 1158 cfs = 748 MGD

Thus Unit 2 actually has a design flow rate 9 MGD higher than Unit 1, an increase of about 1%. Therefore, the actual design flow rate for both units combined is:

$$739 \text{ MGD} + 748 \text{ MGD} = 1487 \text{ MGD} = 2{,}301 \text{ cfs}$$

The St. Lucie Uprate scope does not address a change to the design flow rate; therefore, the correct design flow rate will remain at 1487 MGD, since Unit 2 came on line in 1983.

4.0 TIDAL EFFECTS

The configuration of the St. Lucie cooling water system includes intake pipes with entrance velocity cap structures, an intake canal from which the CW and AECW pumps take suction, a discharge canal, and discharge pipes terminating in subsurface diffusers (see PSL Uprate SCA Figure 2.1.2-1).

The CW pumps and AECW pumps remove water and pump it through the condensers and auxiliary equipment heat exchangers and into the discharge canal. The intake canal level drops below the ocean level causing water to flow from the ocean into the intake canal through the velocity cap structures/intake pipes to replace the water withdrawn by the CW and AECW pumps. The discharge canal level rises above the ocean level causing water to flow through the discharge pipes/subsurface diffusers back to the ocean. As the cooling water flow remains virtually constant, the canal systems reach quasi-equilibrium with the flow entering the intake canal essentially at the same rate as the flow leaving the discharge canal, each being about the same as the flow through the CW/AECW pumps. During a rising tide, the elevation difference between the ocean and intake canal water levels increase resulting in more flow into the intake canal than is being pumped out, causing the intake canal water level to rise. During the same rising tide, the difference between the ocean and discharge canal water levels decreases resulting in less flow out of the discharge canal than is being pumped in causing the discharge canal water level to rise. When the tide ebbs, ocean level decreases and the process reverses.

FPL has simulated the above flow scenario with a mathematical model for various conditions of fouling within the intake and discharge pipes. Figure 5 depicts the results of one such simulation, assuming both the intake and discharge pipes are fouled. The simulated CW pump flow holds very constant near the design rate, while the accompanying discharge flow rate follows a sinusoidal curve, increasing on the ebbing tide and decreasing on the flood tide. The magnitude of the increase or decrease relative to the pump flow rate is dependent on the magnitude of the tidal change. The tidal range simulated in Figure 5 varied between 4.2 and 4.9 feet.

5.0 EFFECTS OF CLEANLINESS OF INTAKE AND DISCHARGE PIPING

Although normal operation of the St. Lucie Plant has been with intake and discharge piping in the fouled condition, as simulated on Figure 5, FPL has also performed a simulation assuming the intake piping was cleaned, but the discharge piping was not. The results are shown on Figure 6. The patterns are similar to those on Figure 5, except the flow magnitudes are all slightly higher. For instance, Figure 7 shows the simulated pumped flow rates for both conditions. Although the pumped flow is slightly higher with the cleaned intake pipes, the change is relatively small. Similarly, Figure 8 shows the simulated discharge flows for both conditions. Again, the flows with cleaned intake pipes are greater, the increase is not significant.

6.0 CONCLUSIONS

The discharge flow varies over time as the tidal phase changes; however, the long-term average of the discharge flow is virtually the same as the long-term average of the pumped flow.

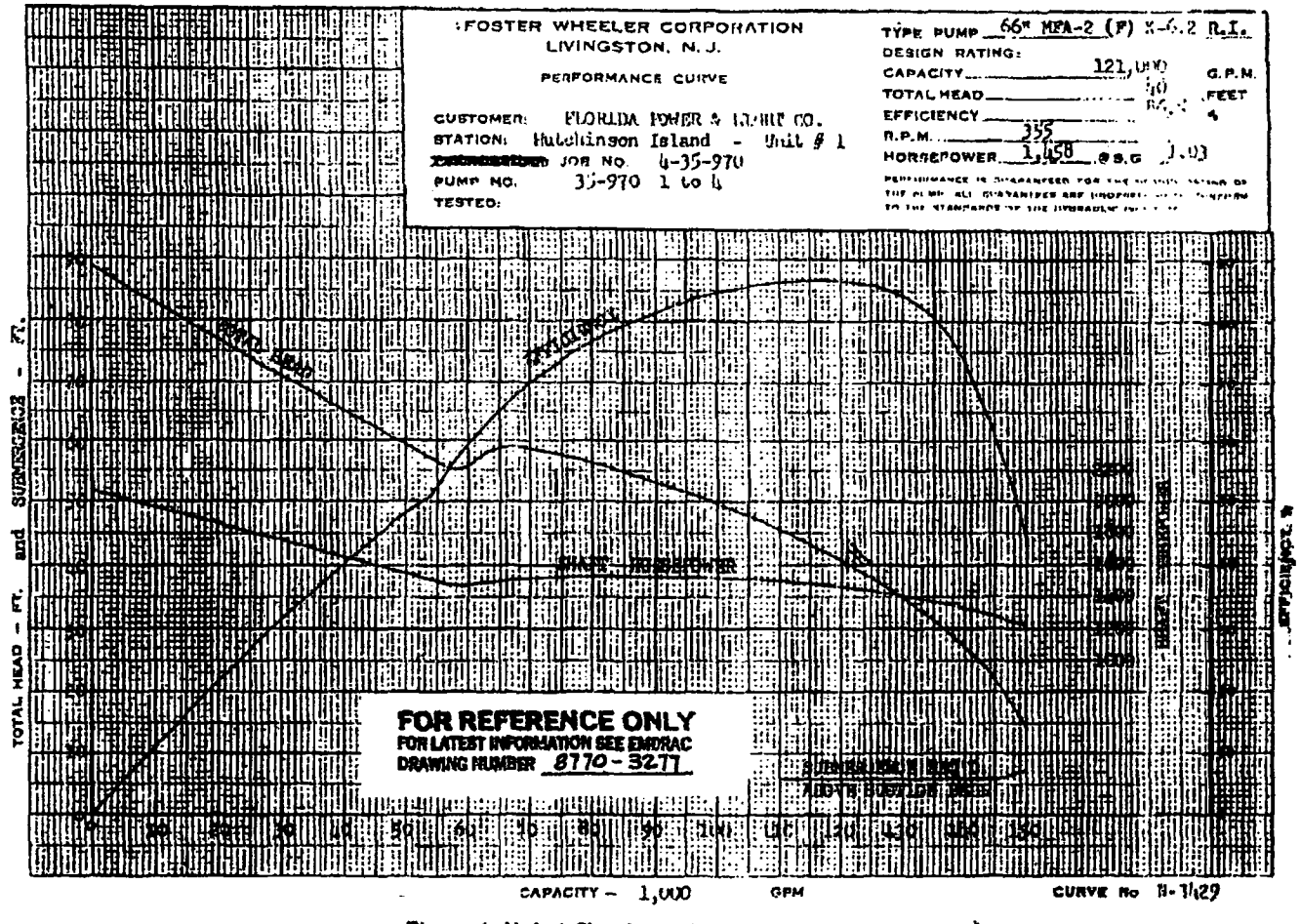


Figure 1. Unit 1 Circulating Water Pump Curves

REFERENCE:
1. FPL, 2008

Golder Associates Atlanta, Georgia

FPL

TITLE

Unit 1 Circulation Water Pump Curves

CLIENT/PROJECT

Florida Power and Light/St. Lucie Plant/ Circulating Water System Flows

DRAWN	MAT	DATE	3-2-08	JOB NO.	07387685
CHECKED	SM	SCALE	As Shown	DWG NO.	REV. NO.
REVIEWED	HF	FILE NO.	Figure 1.cdr	SUBTITLE	FIGURE NO. 1

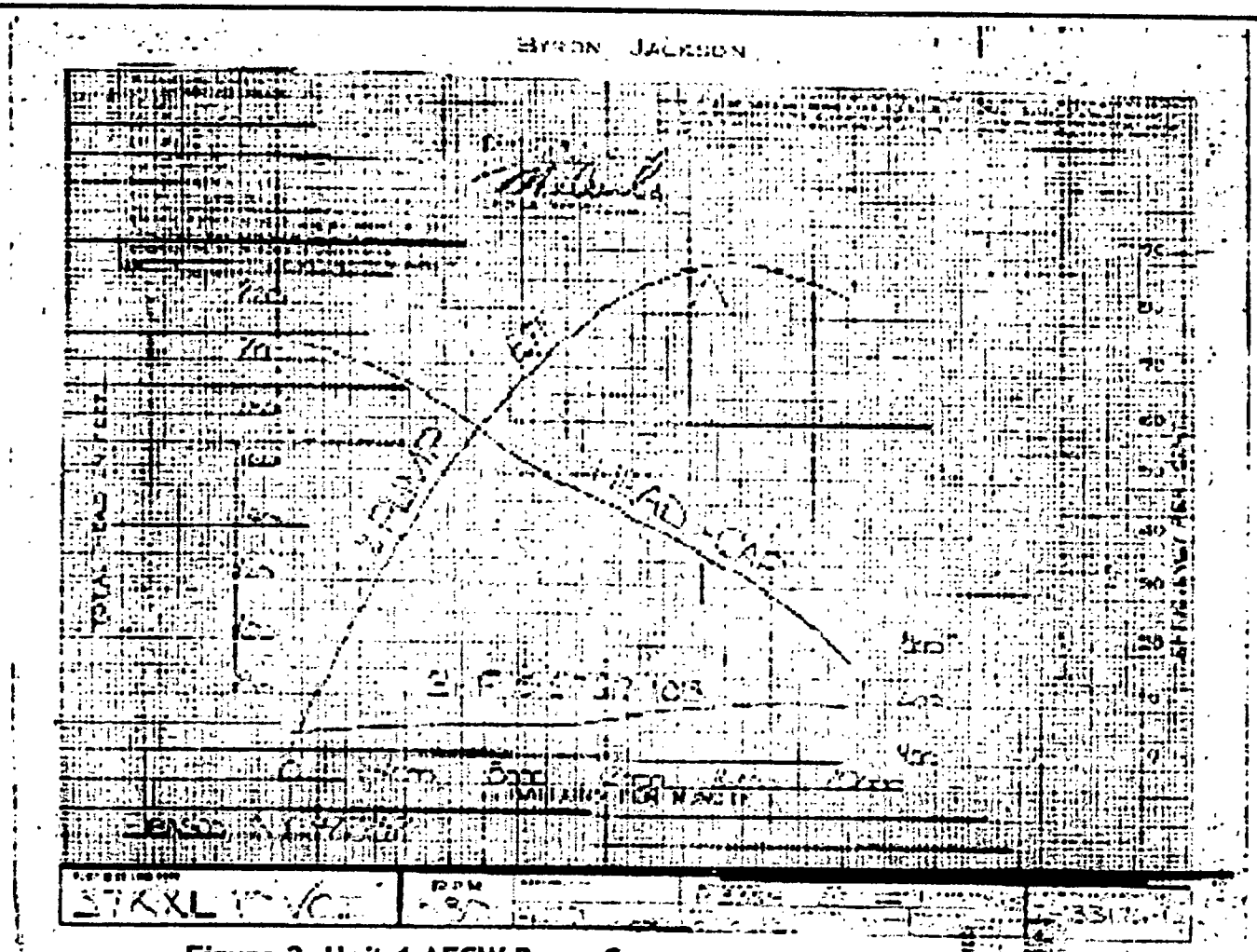


Figure 2. Unit 1 AECW Pump Curves

REFERENCE:
1. FPL, 2008

Golder Associates Atlanta, Georgia

FPL

TITLE

Unit 1 AECW Pump Curves

CLIENT/PROJECT

Florida Power and Light/St. Lucie Plant/ Circulating Water System Flows

DRAWN	MAT	DATE	3-2-08	JOB NO.	07387685
CHECKED	SM	SCALE	As Shown	DWG. NO.	REV. NO.
REVIEWED	HF	FILE NO.	Figure 2.cdr	SUBTITLE	FIGURE NO. 2

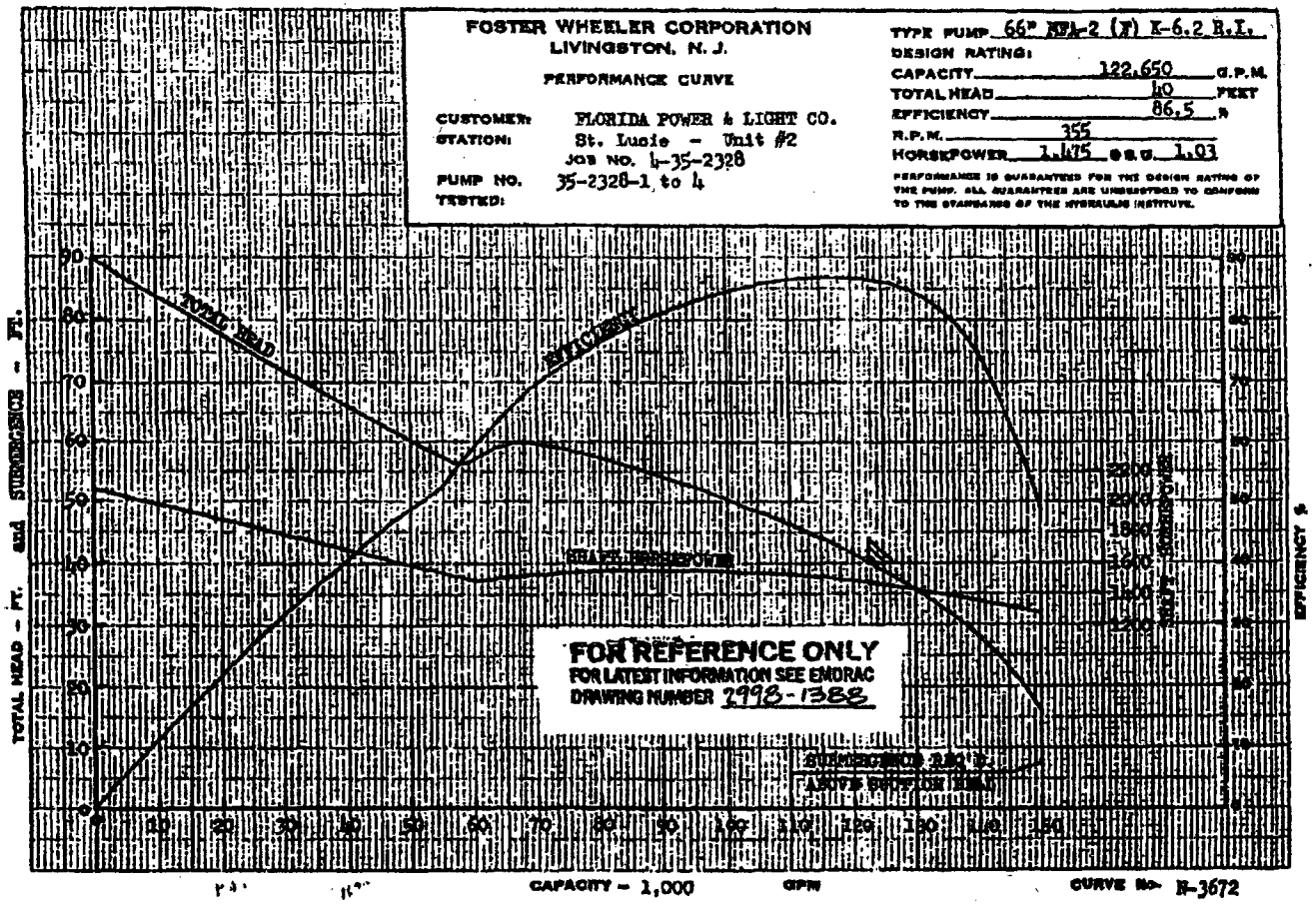


Figure 3. Unit 2 Circulating Water Pump Curves

REFERENCE:
1. FPL, 2008

Golder Associates Atlanta, Georgia

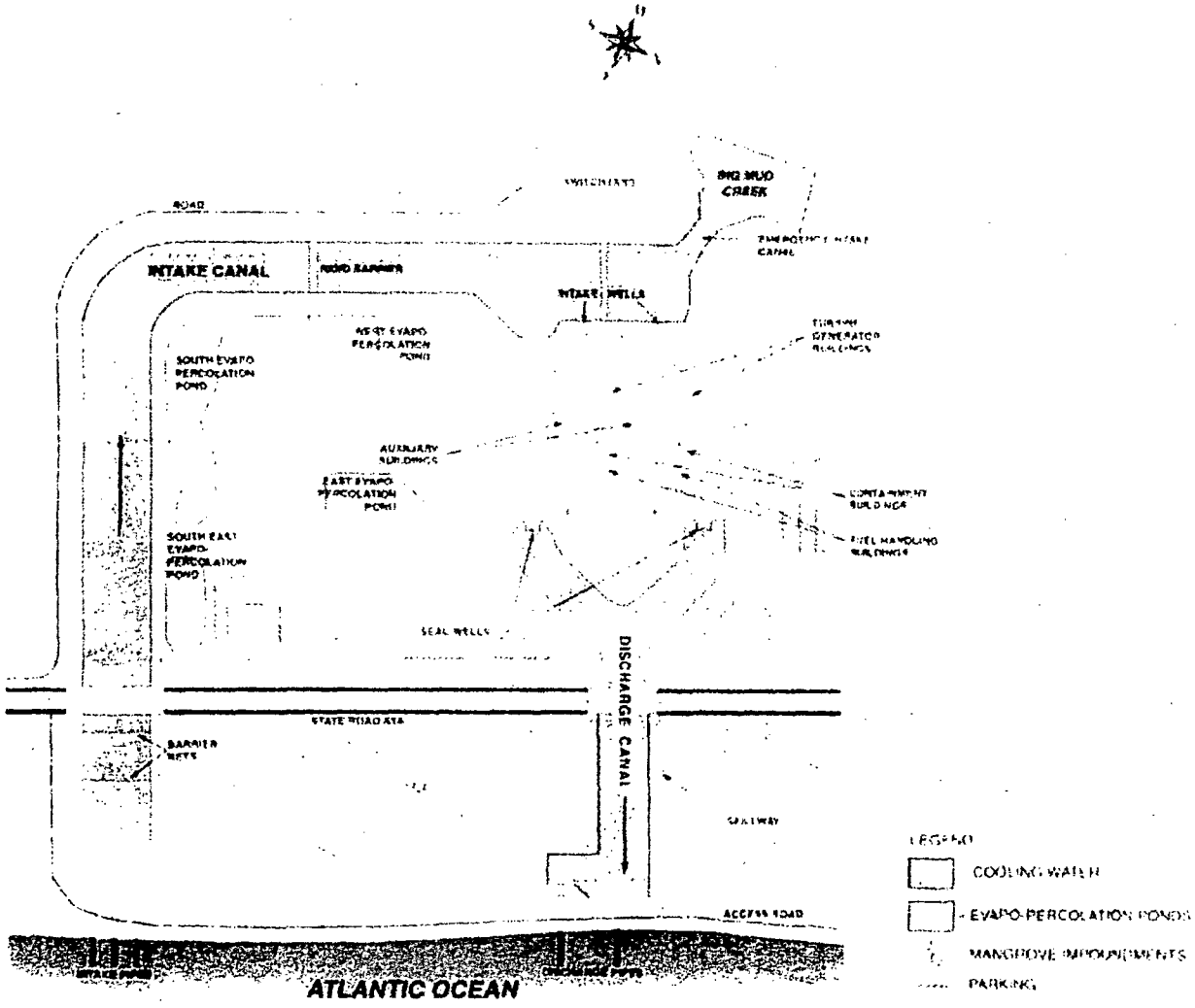
FPL

Unit 2 Circulation Water Pump Curves

CLIENT/PROJECT

Florida Power and Light/St. Lucie Plant/ Circulating Water System Flows

DRAWN	MAT	DATE	3-2-08	JOB NO.	07387685
CHECKED	SM	SCALE	As Shown	DWG. NO.	REV. NO.
REVIEWED	HF	FILE NO.	Figure 3.cdr	SUBTITLE	FIGURE NO. 3



REFERENCE:
1. FPL, 2001

Golder Associates Atlanta, Georgia

FPL

TITLE

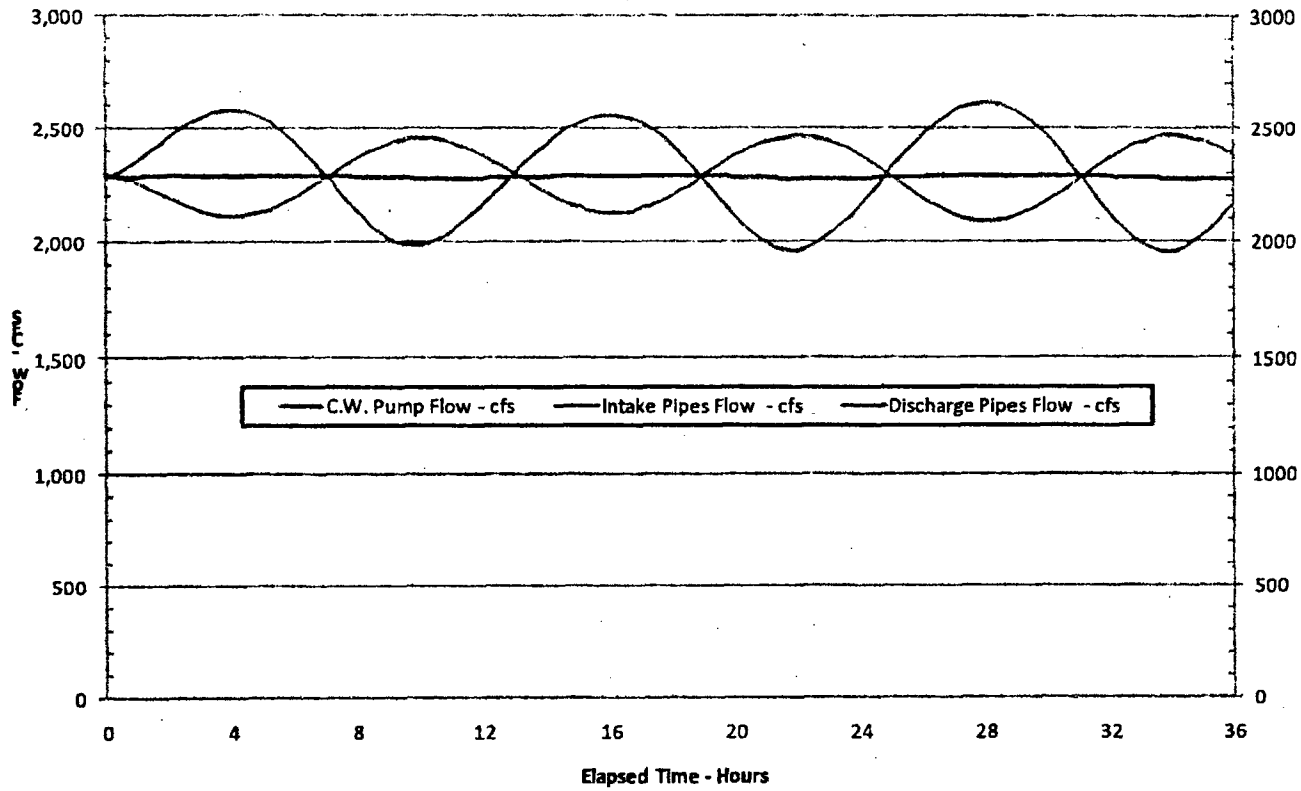
Cooling Water Intake and Discharge System

CLIENT/PROJECT

Florida Power and Light/St. Lucie Plant/ Circulating Water System Flows

DRAWN MAT	DATE 3-2-08	JOB NO. 07387685		
CHECKED SM	SCALE As Shown	DWG. NO.	REV. NO.	
REVIEWED HF	FILE NO. Figure 4.cdr	SUBTITLE	FIGURE NO. 4	

Figure 5. St. Lucie Plant Circulating Water System Flows
Case 1; Intake and Discharge Pipes Both Fouled



REFERENCE:
1. FPL, 2007; Golder, 2008

Golder Associates Atlanta, Georgia

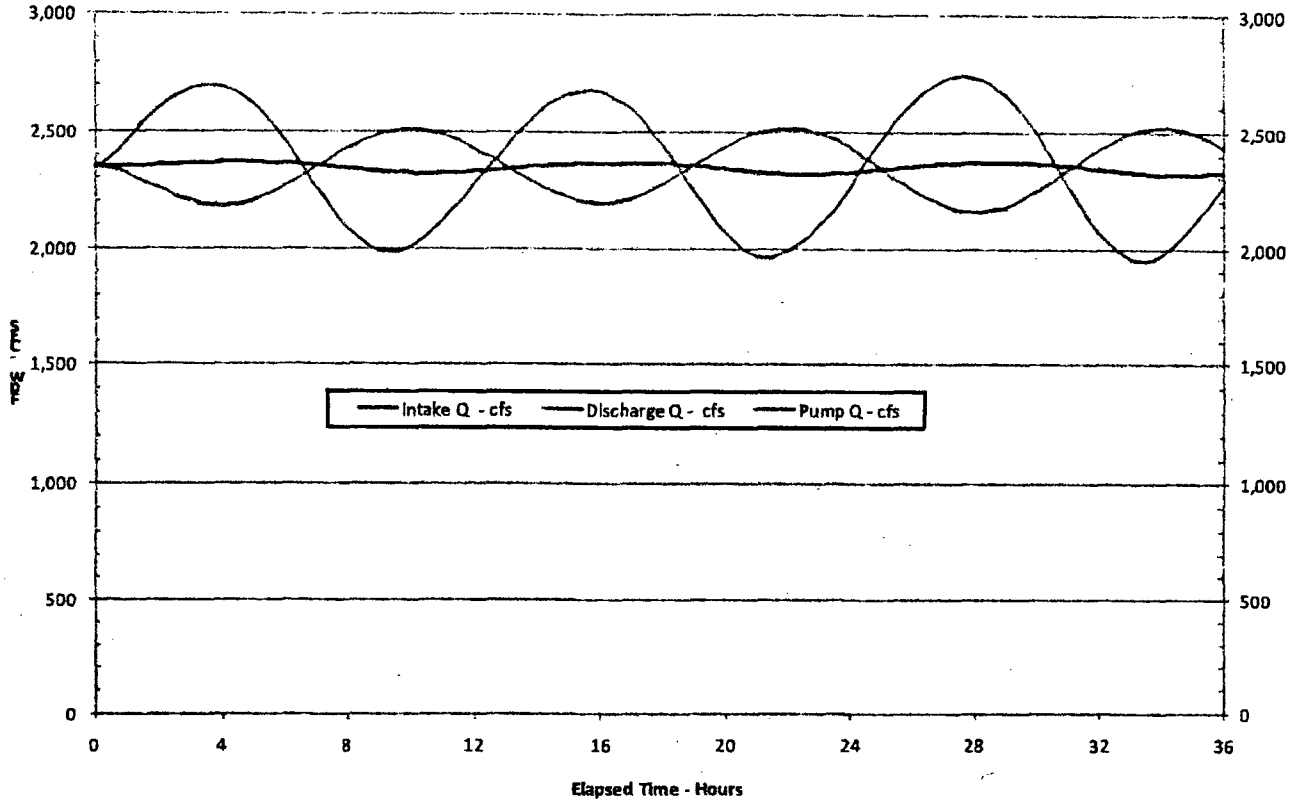
FPL

TITLE
Case 1; Intake and Discharge Pipes both Fouled

CLIENT/PROJECT
Florida Power and Light/St. Lucie Plant/ Circulating Water System Flows

DRAWN MAT	DATE 3-2-08	JOB NO. 07387685		
CHECKED SM	SCALE As Shown	DWG. NO.	REV. NO.	
REVIEWED HF	FILE NO. Figure5.cdr	SUBTITLE	FIGURE NO. 5	

Figure 6. St. Lucie Plant Circulating Water System Flows
Case 2; Intake Pipes Clean, Discharge Pipes Fouled



REFERENCE:
1. FPL, 2007; Golder, 2008

Golder Associates Atlanta, Georgia

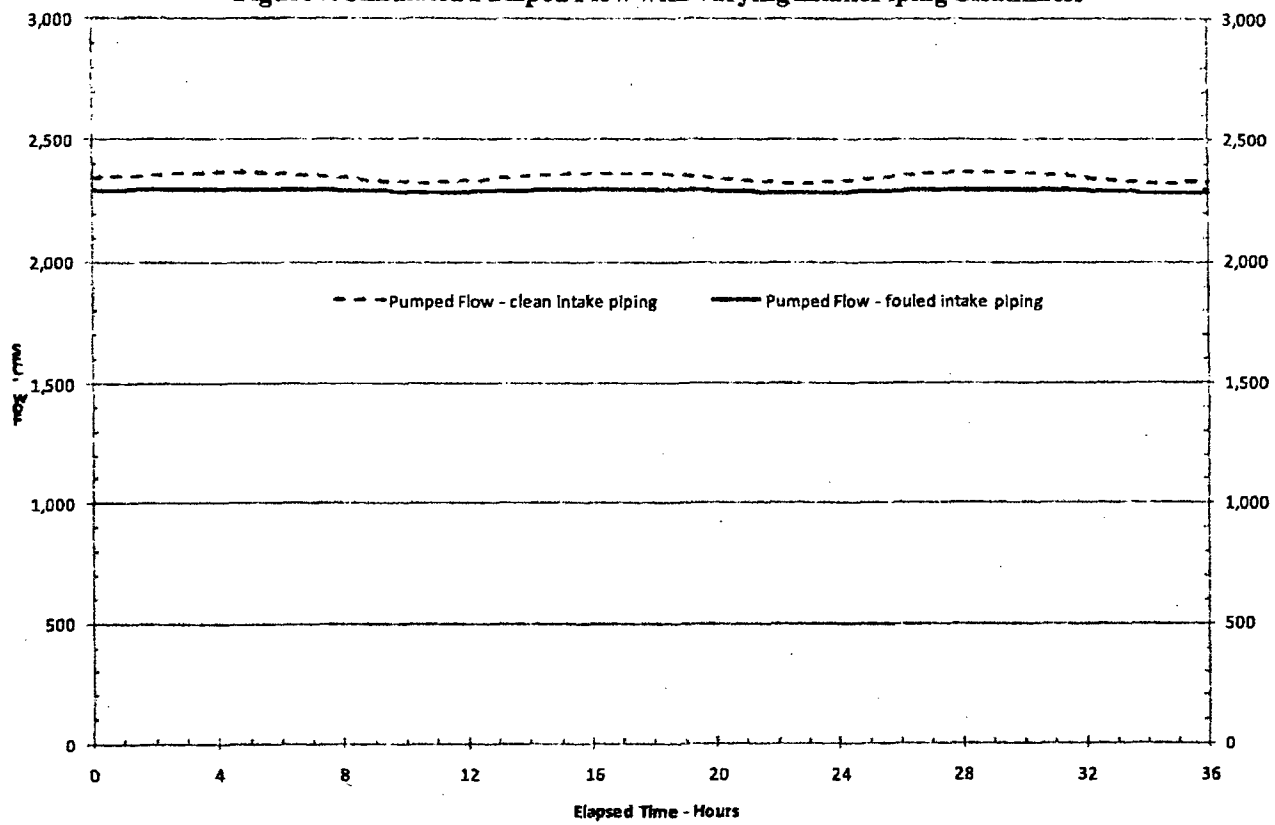
FPL

TITLE
Case 2; Intake Pipes Clean, Discharge Pipes Fouled

CLIENT/PROJECT
Florida Power and Light/St. Lucie Plant/ Circulating Water System Flows

DRAWN	MAT	DATE	3-2-08	JOB NO.	07387685
CHECKED	SM	SCALE	As Shown	DWG. NO.	REV. NO.
REVIEWED	HF	FILE NO.	Figure 6.cdr	SUBTITLE	FIGURE NO. 6

Figure 7. Simulated Pumped Flow with Varying IntakePiping Cleanliness



REFERENCE:
1. FPL, 2007; Golder, 2008

Golder Associates Atlanta, Georgia

FPL

TITLE

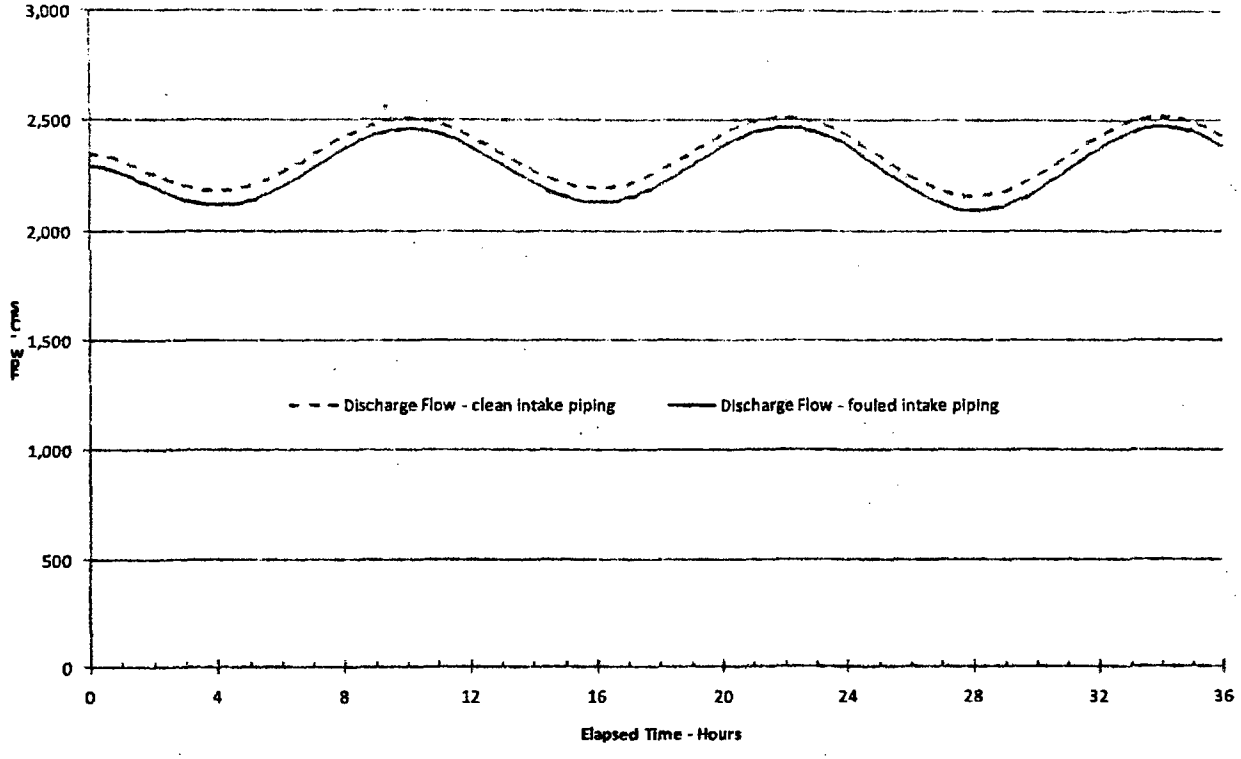
Simulated Pumped Flow with Varying Intake Piping Cleanliness

CLIENT/PROJECT

Florida Power and Light/St. Lucie Plant/ Circulating Water System Flows

DRAWN	MAT	DATE	3-2-08	JOB NO.	07387685
CHECKED	SM	SCALE	As Shown	DWG. NO.	REV. NO.
REVIEWED	HF	FILE NO.	Figure 7.cdr	SUBTITLE	FIGURE NO. 7

Figure 8. Simulated Discharge Flow with Varying Intake Piping Cleanliness



REFERENCE:
1. FPL, 2007; Golder, 2008

Golder Associates Atlanta, Georgia

FPL

TITLE

Simulated Discharge Flow with Varying Intake Piping Cleanliness

CLIENT/PROJECT

Florida Power and Light/St. Lucie Plant/ Circulating Water System Flows

DRAWN MAT	DATE 3-2-08	JOB NO. 07387685		
CHECKED SM	SCALE As Shown	DWG NO.	REV. NO.	
REVIEWED HF	FILE NO. Figure 8.cdr	SUBTITLE	FIGURE NO. 8	

T	Rho(actual)	Rho(est)
30	64.25	64.2420
40	64.20	64.2090
50	64.17	64.1600
60	64.10	64.0950
70	64.02	64.0140
80	63.95	63.9170
90	63.80	63.8040
91		63.7918
92		63.7795
93		63.7670
94		63.7543
95		63.7415
96		63.7285
97		63.7154
98		63.7021
99		63.6886
100	63.70	63.6750
101		63.6612
102		63.6473
103		63.6332
104		63.6189
105		63.6045
106		63.5899
107		63.5752
108		63.5603
109		63.5452
110		63.5300
111		63.5146
112		63.4991
113		63.4834
114		63.4675
115		63.4515
116		63.4353
117		63.4190
118		63.4025
119		63.3858
120		63.3690

Harold Frediani

From: Frediani, Harold [Harold_Frediani@golder.com]
Sent: Friday, May 14, 2010 12:32 PM
To: Hal Frediani
Subject: FW: Simplified Delta-T Calculation - Calc 24A
Attachments: Calc-24A-Writeup-Ian.xls

Regards-
-Hal

Harold A. Frediani, Jr.
(semi-retired, part-time)
Golder Associates, Inc.
3730 Chamblee Tucker Rd.
Atlanta, GA 30341

Phone: 770-992-2533
Fax: 770-934-9476

From: Watters, Ian [mailto:Ian.C.Watters@fpl.com]
Sent: Wednesday, May 12, 2010 1:01 PM
To: Frediani, Harold
Cc: Abbatiello, Tom; Hix, Ron
Subject: Simplified Delta-T Calculation - Calc 24A

Hal

The Table below shows the heat rejected to the Condenser for 8 CW Pumps operating and 6 CW Pumps operating, pre and post EPU from the PEPSE data files.

I have used this total heat rejected for each Unit in Calc 24A. The revised spreadsheet is attached. I don't think that we need the 3050 MWt case since we will never operate at that power due to the licensed power limit.

Let me know if this approach is acceptable.

Results:	Pre-EPU deg F	EPU deg F	Increase deg F
8 CW Pumps	25.50	28.12	2.62
6 CW Pumps	31.33	34.57	3.24

Heat Rejected to Condenser Based on PEPSE Heat Balances

Case: EPU - 8 CW Pumps in Service

Current Heat Rejected to Condenser	Post-EPU Heat Rejected to Condenser

CWIT	Unit 1	Unit 2	Total	Unit 1	Unit 2	Total
90	6.29069E+09	6.22784E+09	1.25185E+10	6.95235E+09	6.85476E+09	1.38071E+10

Case: EPU - 6 CW Pumps In Service

	Current Heat Rejected to Condenser			Post-EPU Heat Rejected to Condenser		
CWIT	Unit 1	Unit 2	Total	Unit 1	Unit 2	Total
90	6.33420E+09	6.26982E+09	1.26040E+10	7.00336E+09	6.90264E+09	1.39060E+10

Golder Associates	SUBJECT: Heat Rates, CW Flows, and ΔTs for Modeling for RFI #1		
	Job No. 07387685 Ref. FPL Uprate PSL Calc 24A	Made By: H. Fredlani Checked Reviewed	Date 5/7/2010 Sheet 1 of 3

Look at two cases: pre-uprate and post-uprate, for both units combined, assuming 8-pump flow:

	pre-uprate	post-uprate	
NSSS thermal power - MWt :	5410.0	6068.0	
gross generation- MWe@90°CWIT	1793.0	1969.6	
waste heat - MWt @90° CWIT	3617.0	4098.4	
4-pump flow rate - gpm	1,032,600	1,032,600	1,032,600
specific heat of fresh water @ 90°	0.998	0.998	
density of water @ 90° - lbs/cu ft (fresh water)	62.105	62.105	
mass flow rate - lbs per hour (fresh water)	513,782,080	513,782,080	499.925 lb/hr per gpm
waste heat - Btu per hour	12,518,500,000	13,807,100,000	
ΔT fresh water- ° F	24.41	26.93	
	for sea water		
specific heat (Btu/lb)	0.930	0.930	
density	63.8	63.8	63.8
mass flow rate - lb/hr	527,804,471	527,804,471	0.13368
ΔT sea water - ° F	25.50	28.12	2.62

Golder Associates	SUBJECT: Heat Rates, CW Flows, and ΔTs for Modeling for RFI #1		
	Job No. 07387685 Ref. FPL Uprate PSL Calc 24A	Made By: H. Frediani Checked Reviewec	Date 5/7/2010 Sheet 2 of 3

Look at two cases: pre-uprate and post-uprate, for both units combined, assuming 6-pump flow:

	pre-uprate	post-uprate	
NSSS thermal power - MWt :	5410.0	6068.0	
gross generation- MWe@90°CWIT	1793.0	1969.6	
waste heat - MWt @90° CWIT	3617.0	4098.4	
3-pump flow rate - gpm	846,000	846,000	
specific heat of fresh water @ 90°	0.998	0.998	
density of water @ 90° - lbs/cu ft (fresh water)	62.105	62.105	
mass flow rate - lbs per hour (fresh water)	420,937,090	420,937,090	
waste heat - Btu per hour	12,604,000,000	13,906,000,000	
ΔT fresh water- ° F	30.00	33.10	
	for sea water		
specific heat (Btu/lb)	0.930	0.930	
density	63.8	63.8	
mass flow rate - lb/hr	432,425,511	432,425,511	
ΔT sea water - ° F	31.33	34.57	3.24

Golder Associates	SUBJECT: Heat Rates, CW Flows, and ΔTs for Modeling for RFI #1		
	Job No. 07387685 Ref. FPL Uprate PSL Calc 24A	Made By: H. Frediani Checked Reviewec	Date 5/7/2010 Sheet 3 of 3

Look at two cases: pre-uprate and post-uprate, for both units combined, assuming 8-pump flow and 3050 MWt for uprate:

	pre-uprate	post-uprate	
NSSS thermal power - MWt :	5410.0	6100.0	
gross generation- MWe@90°CWIT	1793.0	1969.6	
waste heat - MWt @90° CWIT	3617.0	4130.4	
4-pump flow rate - gpm	1,032,600	1,032,600	
specific heat of fresh water @ 90°	0.998	0.998	
density of water @ 90° - lbs/cu ft (fresh water)	62.105	62.105	
mass flow rate - lbs per hour (fresh water)	513,782,080	513,782,080	
waste heat - Btu per hour	~~12,341,713,997~~	~~14,093,507,186~~	No PEPSE Data
ΔT fresh water- ° F	24.07	27.49	
	for sea water		
specific heat (Btu/lb)	0.930	0.930	
density	63.8	63.8	
mass flow rate - lb/hr	528,411,538	528,411,538	
ΔT sea water - ° F	25.11	28.67	

Heat Rejected to Condenser Based on PEPSE Heat Balances

Case: EPU - 8 CW Pumps in Service

	Current Heat Rejected to Condenser			Post-EPU Heat Rejected to Condenser		
CWIT	Unit 1	Unit 2	Total	Unit 1	Unit 2	Total
90	6.29069E+09	6.22784E+09	1.25185E+10	6.95235E+09	6.85476E+09	1.38071E+10

Case: EPU - 6 CW Pumps in Service

	Current Heat Rejected to Condenser			Post-EPU Heat Rejected to Condenser		
CWIT	Unit 1	Unit 2	Total	Unit 1	Unit 2	Total
90	6.33420E+09	6.26982E+09	1.26040E+10	7.00336E+09	6.90264E+09	1.39060E+10

Harold Frediani

From: Frediani, Harold [Harold_Frediani@golder.com]
Sent: Friday, May 07, 2010 4:47 PM
To: Harold Frediani
Subject: FW: Primary, Secondary and Tertiary Cooling
Attachments: U1 ER Sections 4.1.4 &4.1.6 R0 (FINAL) - ICW &UHS.pdf

Regards-
-Hal

Harold A. Frediani, Jr.
(semi-retired, part-time)
Golder Associates, Inc.
3730 Chamblee Tucker Rd.
Atlanta, GA 30341

Phone: 770-992-2533
Fax: 770-934-9476

From: Watters, Ian [mailto:Ian.C.Watters@fpl.com]
Sent: Friday, May 07, 2010 8:35 AM
To: Frediani, Harold; Hix, Ron; Harold Frediani
Cc: Abbatiello, Tom
Subject: RE: Primary, Secondary and Tertiary Cooling

Hal

This is an excerpt from the Shaw Evaluation of the ICW System for EPU. The complete Evaluation is attached for your information.

3.0 EVALUATIONS

3.1 ICW-1 ICW Flow and Heat Removal Capability

Two ICW pumps operate during normal full load power and cooldown. The design capacity and head of each ICW pump is 14,500 gpm at 130 ft TDH (References 7 and 8). The evaluations of the components supplied with intake cooling water determined the minimum required ICW flow rates to confirm their capability is sufficient for EPU conditions. The results of the evaluations indicate that ICW outlet temperature remains bounded by the system design temperature at EPU conditions during normal, cooldown or accident conditions [redacted].

The EPU evaluations of ICW system capability under normal operation, accident, and normal cooldown conditions are summarized as follows:

Normal Operation

Under normal plant operation, the ICW system provides cooling water to the Component Cooling Water (CCW), Turbine Cooling Water (TCW) and Open Blowdown Cooling System (OBCS) heat exchangers.

Reference 23 calculated the minimum required flow rates for each of the heat exchangers cooled by ICW, based on their EPU heat loads, to maintain a bounding outlet temperature of 125°F, with the exception of the CCW heat exchangers which were set to the low flow alarm setpoint of 4,395 gpm. An ICW inlet temperature of 95°F was assumed for these calculations based upon the current pre-EPU maximum ICW inlet temperature contained in References 7 and 8. The following table gives the calculated minimum required ICW flow rates for the Unit 1 CCW, TCW and OBCS heat exchangers for normal operation.

Table 4.1.4-1 – Unit 1 EPU Normal Operation

Components	Minimum Flowrate (gpm)	Heat Load (Mbtu)	ICW Outlet Temp (°F)
CCW HX A	4,395	26.06	106.6
CCW HX B	4,395	26.06	106.6
TCW HX A	1,716	26.4	125
TCW HX B	3,119	48.0	125
OBCS HX A	2,248	34.6	125
OBCS HX B	2,248	34.6	125
TOTAL	18,121		

The minimum required flow shown in the above table is well below the combined design flow rate of 29,000 gpm for two ICW pumps, such that the heat exchangers will remove the EPU heat loads. It is noted the TCW heat exchangers are being replaced at EPU, though the calculated tube side differential pressure only increases from 1.7 psid (Reference 32, Att. B, pg 1) to 2.353 psid (Reference 33, Att. B, Pg. 2) such that the difference is 0.66 psid at the design flow, which will have negligible impact on the ICW flow supply. The current design of the Unit 1 ICW system is acceptable to perform its design basis functions for EPU normal operation.

The Unit 2 evaluation will be performed upon issue of Reference 26. [redacted]

From: Frediani, Harold [mailto:Harold_Frediani@golder.com]
Sent: Thursday, May 06, 2010 11:30 PM
To: Hix, Ron; Harold Frediani
Cc: Abbatiello, Tom; Watters, Ian
Subject: RE: Primary, Secondary and Tertiary Cooling

These are flow rates, can we put a heat load onto the ICW discharge.

Regards-

St. Lucie Circulating Water System
Flow with 2 CW Pumps (1 in each Unit) Out of Service

Determination of Flow Through CW System with 6 CW Pumps Operating

CW Pump Curves:

The Certified Pump Test Curves provide the CW Pump performance head vs. flow characteristic. Curve number N-3429 was used for Unit 1, and Curve number N-3672 for Unit 2. Table 1 shows the pump flows and corresponding heads in the flow range of interest, based on the Certified Pump Test Curves.

Table 1

Pump Flow	Unit 1 Pump Head	Unit 2 Pump Head
100,000 gpm	50 ft	50 ft
110,000 gpm	46 ft	46.5 ft
120,000 gpm	41 ft	41.5 ft
130,000 gpm	35 ft	35.5 ft
140,000 gpm	27.5 ft	28 ft
145,000 gpm	22 ft	23 ft

Combined Pump Curve:

A combined pump curve can be established by adding pump flows at a series of points with the same heads for each pump. Since the Unit 2 CW Pump performance is slightly better than Unit1, the rated flow of the Unit 2 pump at the same head as the Unit 1 pump must be calculated. Table 2 shows the pump heads for the Unit 1 and Unit 2 pumps at the same pump heads.

Table 2

Pump Head	Unit 1 Pump Flow	Unit 2 Pump Flow
50 ft	100,000 gpm	100,660 gpm
46 ft	110,000 gpm	110,273 gpm
41 ft	120,000 gpm	120,783 gpm
35 ft	130,000 gpm	131,182 gpm
27.5 ft	140,000 gpm	140,789 gpm
22 ft	145,000 gpm	145,438 gpm

St. Lucie Circulating Water System
Flow with 2 CW Pumps (1 in each Unit) Out of Service

The combined pump curve for 3 Unit 1 CW Pumps and 3 Unit 2 CW pumps is determined by multiplying the flow for each pump by 3, and then adding these flows to obtain the curve for 6 pumps, as shown in Table 3.

Table 3

Pump Head	Unit 1 3 Pump Flow	Unit 2 3 Pump Flow	Unit 1 & 2 6 Pump Flow
50 ft	300,000	301,980	601,980
46 ft	330,000	330,820	660,820
41 ft	360,000	362,348	722,348
35 ft	390,000	393,546	783,546
27.5 ft	420,000	422,366	842,366
22 ft	435,000	436,314	871,314

CW System Friction Head Loss:

Table 4 is based on the CW System Hydraulic Gradient calculation performed by Ebasco. (Ref. Engineering Evaluation PSL-ENG-SECS-06-040, Rev. 0, Attach. 2, page 4)

Table 4

Intake Loss	6.48	ft
Discharge Loss	6.82	ft
Total Common Loss	13.3	ft
Total System Loss	37	ft
Piping Loss	23.7	ft
Common Flow	2344	cu ft/sec
	1,052,058	gpm
ICW Flow	58,000	gpm
Plant CW Piping Flow	994,058	gpm

Piping friction losses are proportional to the square of the flow. Using the friction losses in Table 4, and dividing by the square of the corresponding flow, the following friction loss factors were determined.

Common Friction Loss Factor (Intake and Discharge)	1.20164E-11	ft/gpm^2
Plant CW Friction Loss Factor (Piping between Intake and Discharge)	2.39842E-11	ft/gpm^2

Determine CW System Operating Point With 6 CW Pumps in Service

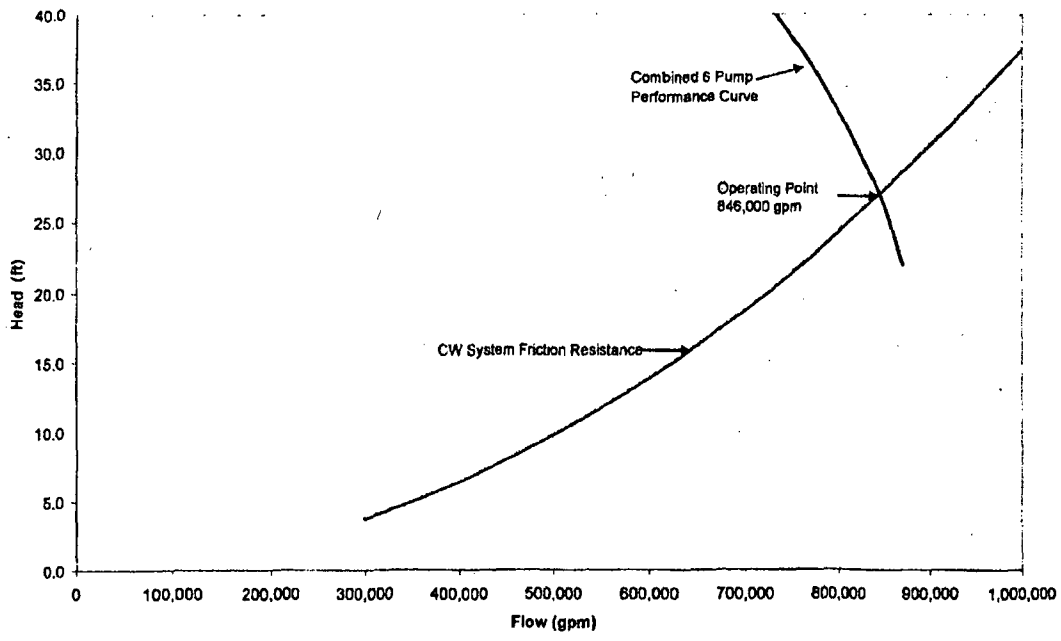
Based on the friction loss factors determined above, the total CW System friction loss was calculated for a range of CW Pump flows. The results are shown in Table 5 below.

St. Lucie Circulating Water System
Flow with 2 CW Pumps (1 in each Unit) Out of Service

Total Plant CW System Flow (gpm)	Plant Piping Head Loss (ft)	Common Head Loss (ft)	Total Head Loss (ft)
300,000	2.2	1.5	3.7
350,000	2.9	2.0	4.9
400,000	3.8	2.5	6.4
450,000	4.9	3.1	8.0
500,000	6.0	3.7	9.7
550,000	7.3	4.4	11.7
600,000	8.6	5.2	13.8
650,000	10.1	6.0	16.2
700,000	11.8	6.9	18.7
750,000	13.5	7.8	21.3
800,000	15.3	8.8	24.2
850,000	17.3	9.9	27.2
900,000	19.4	11.0	30.5
950,000	21.6	12.2	33.9
1,000,000	24.0	13.5	37.4
1,050,000	26.4	14.8	41.2
1,100,000	29.0	16.1	45.1

Figure 1 shows the plot of the combined 6 CW Pump curve and the CW System friction loss curve. The intersection of these two curves is the operating point. At this point the total CW pump flow is 846,000 gpm with a head of 27 ft.

PTN CW System Operation with 6 CW Pumps in Service
Fig. 1



The individual Unit flows are 422,114 gpm in Unit 1, and 423,886 gpm in Unit 2.

Harold Frediani

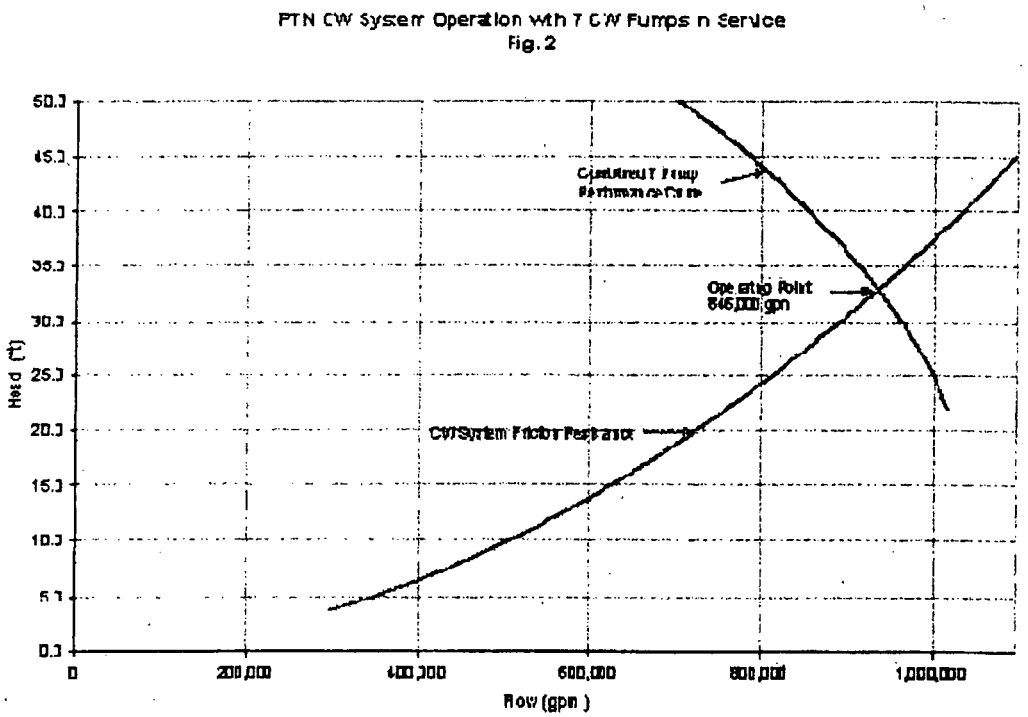
From: Watters, Ian [Ian.C.Watters@fpl.com]
Sent: Wednesday, May 19, 2010 2:18 PM
To: 'Frediani, Harold'; Hix, Ron
Cc: Abbatiello, Tom; Harold Frediani
Subject: 7 CW Pump Case for Saint Lucie Calc 25
Attachments: Determination of Flow Through CW System with 7 CW Pumps Operating.doc

Hal

As discussed, see attached for 7 CW Pump Case.

The total CW pump flow is 935,000 gpm with a head of 33 ft.

The individual Unit flows are 532,663 gpm in Unit 1, and 402,337 gpm in Unit 2.



From: Frediani, Harold [mailto:Harold_Frediani@golder.com]
Sent: Wednesday, May 19, 2010 11:23 AM
To: Hix, Ron; Watters, Ian
Cc: Abbatiello, Tom; Harold Frediani
Subject: RE: Saint Lucie Calc 25

Sorry, bad night. Wasn't up at 10:30

Normal conditions for 2 units, I see a 28 deg delta T and 118 deg CWOT in summer, and 33 deg delta T and 103 deg CWOT in winter.

St. Lucie Circulating Water System
Flow with 1 CW Pump Out of Service

Determination of Flow Through CW System with 7 CW Pumps Operating

CW Pump Curves:

The Certified Pump Test Curves provide the CW Pump performance head vs. flow characteristic. Curve number N-3429 was used for Unit 1, and Curve number N-3672 for Unit 2. Table 1 shows the pump flows and corresponding heads in the flow range of interest, based on the Certified Pump Test Curves.

Table 1

Pump Flow	Unit 1 Pump Head	Unit 2 Pump Head
100,000 gpm	50 ft	50 ft
110,000 gpm	46 ft	46.5 ft
120,000 gpm	41 ft	41.5 ft
130,000 gpm	35 ft	35.5 ft
140,000 gpm	27.5 ft	28 ft
145,000 gpm	22 ft	23 ft

Combined Pump Curve:

A combined pump curve can be established by adding pump flows at a series of points with the same heads for each pump. Since the Unit 2 CW Pump performance is slightly better than Unit1, the rated flow of the Unit 2 pump at the same head as the Unit 1 pump must be calculated. Table 2 shows the pump heads for the Unit 1 and Unit 2 pumps at the same pump heads.

Table 2

Pump Head	Unit 1 Pump Flow	Unit 2 Pump Flow
50 ft	100,000 gpm	100,660 gpm
46 ft	110,000 gpm	110,273 gpm
41 ft	120,000 gpm	120,783 gpm
35 ft	130,000 gpm	131,182 gpm
27.5 ft	140,000 gpm	140,789 gpm
22 ft	145,000 gpm	145,438 gpm

St. Lucie Circulating Water System
Flow with 1 CW Pump Out of Service

The combined pump curve for 4 Unit 1 CW Pumps and 3 Unit 2 CW pumps is determined by multiplying the flow for each pump by the number of operating pumps, and then adding these flows to obtain the curve for 6 pumps, as shown in Table 3.

Table 3

Pump Head	Unit 1 4 Pump Flow	Unit 2 3 Pump Flow	Unit 1 & 2 6 Pump Flow
50 ft	400,000	301,980	701,980
46 ft	440,000	330,820	770,820
41 ft	480,000	362,348	842,348
35 ft	520,000	393,546	913,546
27.5 ft	560,000	422,366	982,366
22 ft	580,000	436,314	1,016,314

CW System Friction Head Loss:

Table 4 is based on the CW System Hydraulic Gradient calculation performed by Ebasco. (Ref. Engineering Evaluation PSL-ENG-SECS-06-040, Rev. 0, Attach. 2, page 4)

Table 4

Intake Loss	6.48	ft
Discharge Loss	6.82	ft
Total Common Loss	13.3	ft
Total System Loss	37	ft
Piping Loss	23.7	ft
Common Flow	2344	cu ft/sec
	1,052,058	gpm
ICW Flow	58,000	gpm
Plant CW Piping Flow	994,058	gpm

Piping friction losses are proportional to the square of the flow. Using the friction losses in Table 4, and dividing by the square of the corresponding flow, the following friction loss factors were determined.

Common Friction Loss Factor (Intake and Discharge)	1.20164E-11	ft/gpm^2
Plant CW Friction Loss Factor (Piping between Intake and Discharge)	2.39842E-11	ft/gpm^2

Determine CW System Operating Point With 7 CW Pumps in Service

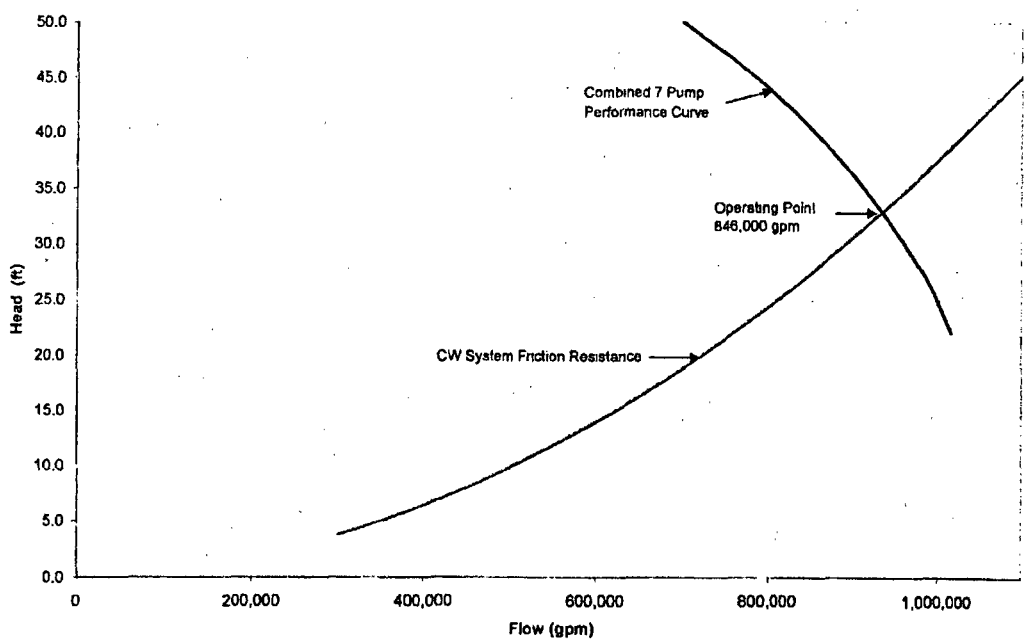
Based on the friction loss factors determined above, the total CW System friction loss was calculated for a range of CW Pump flows. The results are shown in Table 5 below.

St. Lucie Circulating Water System
Flow with 1 CW Pump Out of Service

Total Plant CW System Flow (gpm)	Plant Piping Head Loss (ft)	Common Head Loss (ft)	Total Head Loss (ft)
300,000	2.2	1.5	3.7
350,000	2.9	2.0	4.9
400,000	3.8	2.5	6.4
450,000	4.9	3.1	8.0
500,000	6.0	3.7	9.7
550,000	7.3	4.4	11.7
600,000	8.6	5.2	13.8
650,000	10.1	6.0	16.2
700,000	11.8	6.9	18.7
750,000	13.5	7.8	21.3
800,000	15.3	8.8	24.2
850,000	17.3	9.9	27.2
900,000	19.4	11.0	30.5
950,000	21.6	12.2	33.9
1,000,000	24.0	13.5	37.4
1,050,000	26.4	14.8	41.2
1,100,000	29.0	16.1	45.1

Figure 1 shows the plot of the combined 7 CW Pump curve and the CW System friction loss curve. The intersection of these two curves is the operating point. At this point the total CW pump flow is 935,000 gpm with a head of 33 ft.

PTN CW System Operation with 7 CW Pumps In Service
Fig. 2



The individual Unit flows are 532,663 gpm in Unit 1, and 402,337 gpm in Unit 2.

CALCULATION 26

Golder Associates	SUBJECT : Waste Heat Discharged for Existing Units		
	Job No. 09387687 Ref. FPL PSL NPDES Mod, Calc 26	Made By: H. Frediani Checked: S. Hoschek Reviewed: G. Powell	Date 5/27/2010 Sheet 1 of 5

In response to FDEP's first request for additional information associated with the NPDES Permit FL0002208 Modification Request to increase the permit limit for discharge temperature at Outfall D-001, it is necessary to calculate theΔT for the existing pre-uprate Units. Based on Calc 25, the following cases are addressed;

Case 1. Maximum discharge temperature, both units operating at full load on 4 CW pumps each.

Case 2. Maximum discharge temperature rise, both units operating at full load on 3 CW pumps each.

Case 3. Maximum discharge temperature, one unit operating at full load on 4 CW pumps.

Case 4. Maximum discharge temperature, maintenance mode, Unit 1 operating at full load on 4 CW pumps and Unit 2 operating at full load on 3 CW pumps.

Based on the intake temperature frequency distribution developed in Calculation 20, the highest intake temperature seen in the Period of Record August 2005 through October 2009 was 88.4 deg F. The 90th percentile intake temperature was 70 deg F. In the Unit 2 Final Environmental Statement (FES), it was stated that the maximum ambient water temperature between 1971 and 1978 was 90 deg F. (Unit 2 FES, Page 4-19). Assume the worst-case discharge temperature will occur when the CW Inlet Temperature (CWIT) is at 90 deg F.

Case 1: Normally, four CW pumps operate per unit as follows (see the attached response to FDEP's RFI #1 dated March 5, 2008, for a previous NPDES permit modification, for flow derivation):

Unit 1 CW pumps , four pumps at 121,000 gpm each = 484,000 gpm

Unit 1 also has 2 AECW pumps at 14,500 gpm each = 29,000 gpm

(AECW = ICW) total Unit 1 = 513,000 gpm

Unit 2 has four CW pumps at 122,650 gpm each = 490,600 gpm

Unit 2 has two AECW pumps at14,500 gpm each = 29,000 gpm

total Unit 2 = 519,600 gpm

From PEPSE Heat Balances summarized in FPL's e-mail of 5/12/2010, the heat rejected for each unit with 8 pumps operating and 90 deg F Circulating Water Inlet Temperature (CWIT) for the pre-uprated plant is:

Unit 1 = 6290.69 million Btu per hour

Unit 2 = 6227.84 million Btu per hour

ΔT is calculated as follows: ΔT = heat rejected /(CW flow times specific heat), where CW flow is in lbs per hour

Based on Calculation 27, the specific heat of sea water in the expected range of temperatures is about 0.96 Btu per lb per degree F.

Use the density of sea water relationship developed in Calc 7 and detailed in spreadsheet "Book1.xlsx to determine the density of sea water at the desired temperatures.

In order to obtain the discharge temperature rise, we need to add in the heat load from the ICW systems. Calc 25, Table 4.1.4-1 applies for Unit 1 :

Table 4.1.4-1 – Unit 1 EPU Normal Operation

Components	Minimum Flowrate (gpm)	Heat Load (Mbtu)	ICW Outlet Temp (°F)
CCW HX A	4,395	26.06	106.6
CCW HX B	4,395	26.06	106.6
TCW HX A	1,716	26.4	125
TCW HX B	3,119	48.0	125
OBCS HX A	2,248	34.6	125
OBCS HX B	2,248	34.6	125
TOTAL	18,121		

ICW Heat Rate = 26.06 + 26.06 + 26.4 + 48 +34.6 +34.6 = 196 million Btu/hour = 196,000,000 Btu/hour

This is the Unit 1 value, assume the Unit 2 value is the same.

For Case 1:

Assume that the maximum discharge temperature case (Case 1) occurs with 4 CW pumps operating per unit, and with an inlet CW temperature (CWIT) of 90 deg F. For Unit 1, the 4-pump flow (Case 1):

ΔT_1 = (6,290,690,000 + 196,000,000)Btu/hour/((513,000 gpm / 7.48 gal/cu ft) *ρ *C_p * 60 min/hr)

at CWIT of 90 deg F, ρ = 63.8 pcf.

ΔT_1 = (6,290,690,000+196,000,000)/(513,000 /7.48*63.8*.96*60) = 25.74 deg F.

For Unit 2, Case 1:

ΔT_2= (196,000,000 +6,227,840,000)/((519,600/7.48) * 63.8 *.96 *60) = 25.16 deg F.

For the combined flow of both units:

$\Delta T_{combined}$ = (ΔT_1* Q1 + ΔT_2 * Q2)/ (Q1 + Q2) = 25.45 deg F.

For Case 2

Assume the maximum ΔT occurs when only 3 CW pumps are operating for each unit. Based on the attached document from FPL entitled "Determination of Flow Through CW System with 6 CW Pumps Operating.doc", the CW flows through each unit are as follows:

Unit 1	Unit 2
422,114 gpm	423,886 gpm

Adding in the ICW flow rates, assumed unchanged from Case 1:

Unit 1 CW pumps , three pumps = 422,114 gpm

Unit 1 still has 2 AECW pumps at 29,000 gpm = 29,000 gpm

total Unit 1 = 451,114 gpm

Unit 2 has 3 CW pumps = 423,886 gpm

Unit 2 still has two AECW pumps at 29,000 gpm = 29,000 gpm

total Unit 2 = 452,886 gpm

Assume 3-pump per unit operation can only occur at lower CWIT; otherwise, the units would suffer a backpressure penalty and have to derate. Use the 90% temperature for CWIT of 70 degrees F. From PEPSE Heat Balances summarized in FPL's e-mail of 5/12/2010, the heat rejected for each unit with 6 pumps operating and 90 deg F. Circulating Water Inlet Temperature (CWIT) is:

Unit 1 = 6334.20 Million Btu per hour

Unit 2 = 6269.82 Million Btu per hour

assume these values are still good for the 70 degree F CWIT case.

For Unit 1, Case 2:

ΔT_1 = (6,334,200,000 + 196,000,000)Btu/hour/((451,114 gpm / 7.48 gal/cu ft) *ρ *C_p * 60 min/hr)

at CWIT of 70 deg F, ρ = 64.02 pcf.

ΔT_1 = (6,334,200,000+196,000,000)/(451,114 /7.48*64.02*.96*60) = 29.36 deg F.

For Unit 2, Case 2:

ΔT_2= (196,000,000 +6,269,820,000)/((452,886/7.48) * 64.02 *.96 *60) = 28.96 deg F.

For the combined flow of both units:

$\Delta T_{combined}$ = (ΔT_1* Q1 + ΔT_2 * Q2)/ (Q1 + Q2) = 29.16 deg F.

For Case 3:

For Case 3, which assumes only one unit operating, the highest discharge temperature is expected with a CWIT of 90 deg F and only Unit 1 operating. The parameters for this case have already been established as part of Case 1:

ΔT = 25.74 deg F

CW flow = 513,000 gpm

CWIT = 90 deg F.

CWOT (CW Outlet Temperature , or discharge temperature) = 115.74 deg F.

For Case 4:

For case 4, we assume a Unit 2 CW pump has tripped off , and full load is maintained on both Units. FPL has provided an analysis of the resultant 7-pump flow (see attached document "Determination of Flow Through CW System with 7 CW Pumps Operating") and concludes that the unit flow rates would be as follows:

Unit 1 - 532,663 gpm

Unit 2 - 402,337 gpm

Adding in the ICW flow rates, assumed unchanged from Case 1:

Unit 1 CW pumps ,four pumps = 532,663 gpm

Unit 1 still has 2 AECW pumps at 29,000 gpm = 29,000 gpm

total Unit 1 = 561,663 gpm

Unit 2 has 3 CW pumps = 402,337 gpm

Unit 2 still has two AECW pumps at 29,000 gpm = 29,000 gpm

total Unit 2 = 431,337 gpm

Using the Unit 1 heat rejection rate from Case 1, Unit 1 = 6,486,690,000 Btu/hour

Using the Unit 2 heat rejection rate from Case 2, Unit 2 = 6,423,840,000 Btu/hour

ΔT_1 = (6,486,690,000)Btu/hour/((561,663 gpm / 7.48 gal/cu ft) * ρ *C_p * 60 min/hr)

at CWIT of 90 deg F, ρ = 63.8 pcf.

ΔT_1 = (6,486,690,000)/(561,663 /7.48*63.8*.96*60) = 23.51 degrees F.

For Case 4, Unit 2:

ΔT_2= (6,423,840,000)/((431,337/7.48) * 63.8 *.96 *60) = 30.31 degrees F.

For the combined flow of both units:

$\Delta T_{combined}$ = (ΔT_1* Q1 + ΔT_2 * Q2)/ (Q1 + Q2) = 26.46 degrees F.

In Summary:

	Case 1	Case 2	Case 3	Case 4
CWIT - deg F.	90	70	90	90
ΔT - deg F	25.45	29.16	25.74	26.46
CWOT - deg F.	115.45	99.16	115.74	116.46
CW Flow - gpm	1,032,600	904,000	513,000	993,000

Harold Frediani

From: Frediani, Harold [Harold_Frediani@golder.com]
Sent: Thursday, May 27, 2010 5:05 PM
To: Harold Frediani
Subject: FW: Simplified Delta-T Calculation - Calc 24A
Attachments: Calc-24A-Writeup-Ian.xls

Regards-
-Hal

Harold A. Frediani, Jr.
(semi-retired, part-time)
Golder Associates, Inc.
3730 Chamblee Tucker Rd.
Atlanta, GA 30341

Phone: 770-992-2533
Fax: 770-934-9476

From: Watters, Ian [mailto:Ian.C.Watters@fpl.com]
Sent: Wednesday, May 12, 2010 1:01 PM
To: Frediani, Harold
Cc: Abbatiello, Tom; Hix, Ron
Subject: Simplified Delta-T Calculation - Calc 24A

Hal

The Table below shows the heat rejected to the Condenser for 8 CW Pumps operating and 6 CW Pumps operating, pre and post EPU from the PEPSE data files.

I have used this total heat rejected for each Unit in Calc 24A. The revised spreadsheet is attached. I don't think that we need the 3050 MWt case since we will never operate at that power due to the licensed power limit.

Let me know if this approach is acceptable.

Results:	Pre-EPU deg F	EPU deg F	Increase deg F
8 CW Pumps	25.50	28.12	2.62
6 CW Pumps	31.33	34.57	3.24

Heat Rejected to Condenser Based on PEPSE Heat Balances

Case: EPU - 8 CW Pumps in Service

Current Heat Rejected to Condenser	Post-EPU Heat Rejected to Condenser

CWIT	Unit 1	Unit 2	Total	Unit 1	Unit 2	Total
90	6.29069E+09	6.22784E+09	1.25185E+10	6.95235E+09	6.85476E+09	1.38071E+10

Case: EPU - 6 CW Pumps In Service

	Current Heat Rejected to Condenser			Post-EPU Heat Rejected to Condenser		
CWIT	Unit 1	Unit 2	Total	Unit 1	Unit 2	Total
90	6.33420E+09	6.26982E+09	1.26040E+10	7.00336E+09	6.90264E+09	1.39060E+10

CALCULATION 27

Golder Associates	SUBJECT: Calculate Specific Heat of sea water at varying temperatures		
	Job No. 09387687 Ref: FPL PSL NPDES Mod	Made By: H. Frediani Checked Reviewed	Date: 5/16/2010 Sheet 1 of 1

In order to calculate the temperature rise across each condenser, based on the heat rejection rates provided by FPL, it is necessary to be able to calculate the specific heat (Cp) of sea water at the varying water temperatures.

From Sharqawy, Lienhard, and Zubair, page 9 of Seawater_Property_tables[1].pdf (attached), we can do a table of Cp vs. water temperature at salinities of 30 and 40 PPT. See C-sub-P.xlsx, worksheet Cp.

From the St Lucie Unit 2 Final Environmental Statement (FES), page 4-19, the average salinity of the Atlantic Ocean off Hutchinson Island is 35.5 PPT. Interpolate linearly for C_p at 35.5 PPT on worksheet Cp. Next, convert from metric to useful units as follows:

1 Joule = 0.000948 Btu

1 lb = 0.4535924277 kilograms

1 deg K = 1.8 deg F

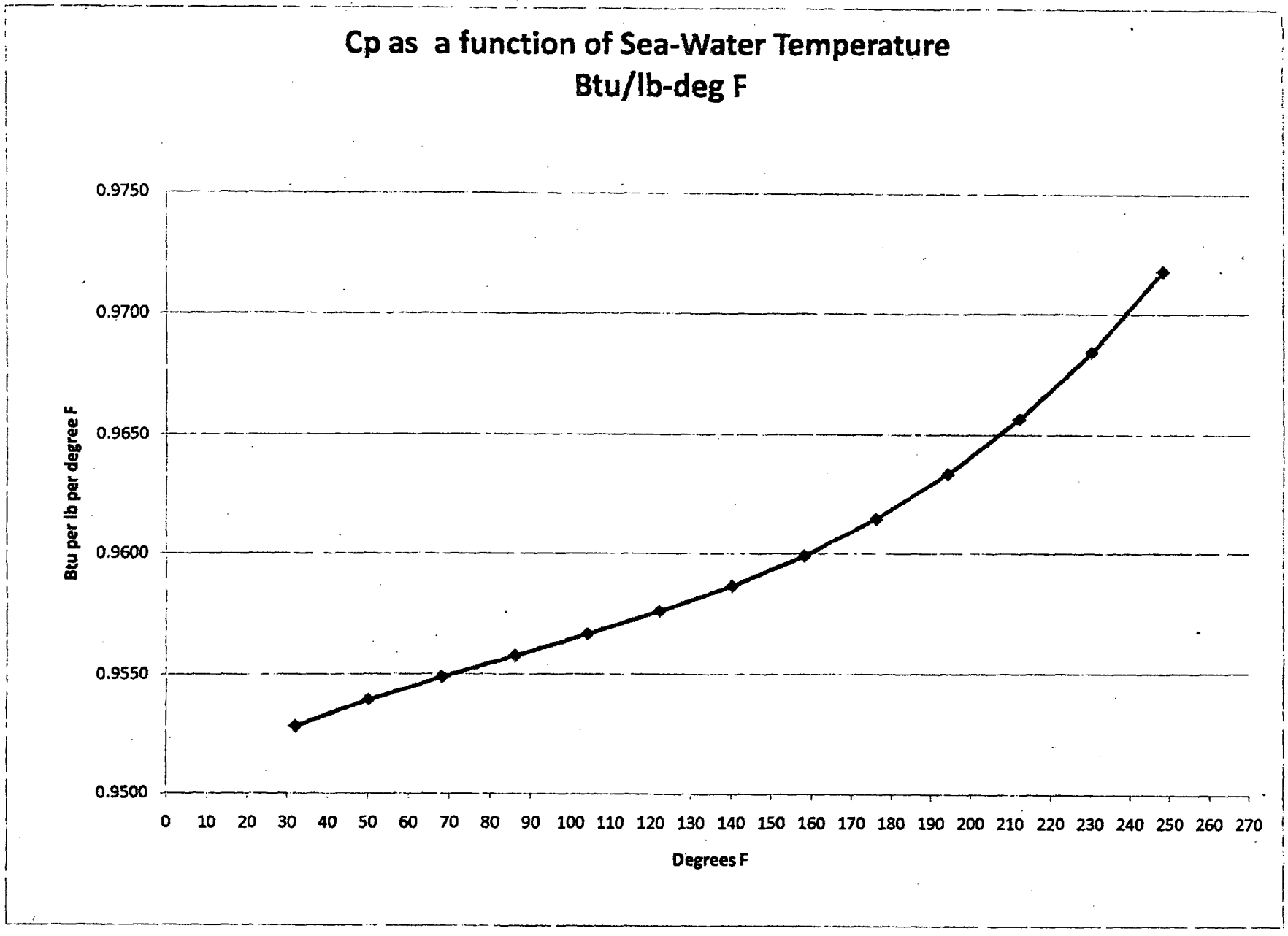
1 Joule per kg per deg K = (.000948 Btu) per (1/.4535924277) lb per (1.8 deg F.)

1 J/kg-degK = 0.000238892 Btu/lb/deg F

Add a column of temperatures in degrees F., then plot specific heat as a function of temperature. See worksheet "Plot". Do a second plot for the temperature range of interest, from 50 to 122 deg F, call it Pllot 2. Add a trend line on Plot2 Linear trend line works, equation is Cp = 0.9514 + .00005 * T (deg F.) and an R^2 of 0.997. Verify the equattion in a table on worksheet "curve fit".

Use this equation in Calc 25 to calculate temperature rises associated with the heat loads to be modeled. Add to worksheet curve fit a table of estimated Cp values from 50 deg F to 130 deg F.

Water Temperature deg F	Actual C_p	Curve-Fit C_p			
50	0.9539	0.9539			
68	0.9549	0.9548			
86	0.9557	0.9557			
104	0.9566	0.9566			
122	0.9576	0.9575			
Water Temperature deg F	Cp	Water Temperature deg F	Cp	Water Temperature deg F	Cp
50	0.9539	77	0.9553	104	0.9566
51	0.9540	78	0.9553	105	0.9567
52	0.9540	79	0.9554	106	0.9567
53	0.9541	80	0.9554	107	0.9568
54	0.9541	81	0.9555	108	0.9568
55	0.9542	82	0.9555	109	0.9569
56	0.9542	83	0.9556	110	0.9569
57	0.9543	84	0.9556	111	0.9570
58	0.9543	85	0.9557	112	0.9570
59	0.9544	86	0.9557	113	0.9571
60	0.9544	87	0.9558	114	0.9571
61	0.9545	88	0.9558	115	0.9572
62	0.9545	89	0.9559	116	0.9572
63	0.9546	90	0.9559	117	0.9573
64	0.9546	91	0.9560	118	0.9573
65	0.9547	92	0.9560	119	0.9574
66	0.9547	93	0.9561	120	0.9574
67	0.9548	94	0.9561	121	0.9575
68	0.9548	95	0.9562	122	0.9575
69	0.9549	96	0.9562	123	0.9576
70	0.9549	97	0.9563	124	0.9576
71	0.9550	98	0.9563	125	0.9577
72	0.9550	99	0.9564	126	0.9577
73	0.9551	100	0.9564	127	0.9578
74	0.9551	101	0.9565	128	0.9578
75	0.9552	102	0.9565	129	0.9579
76	0.9552	103	0.9566	130	0.9579



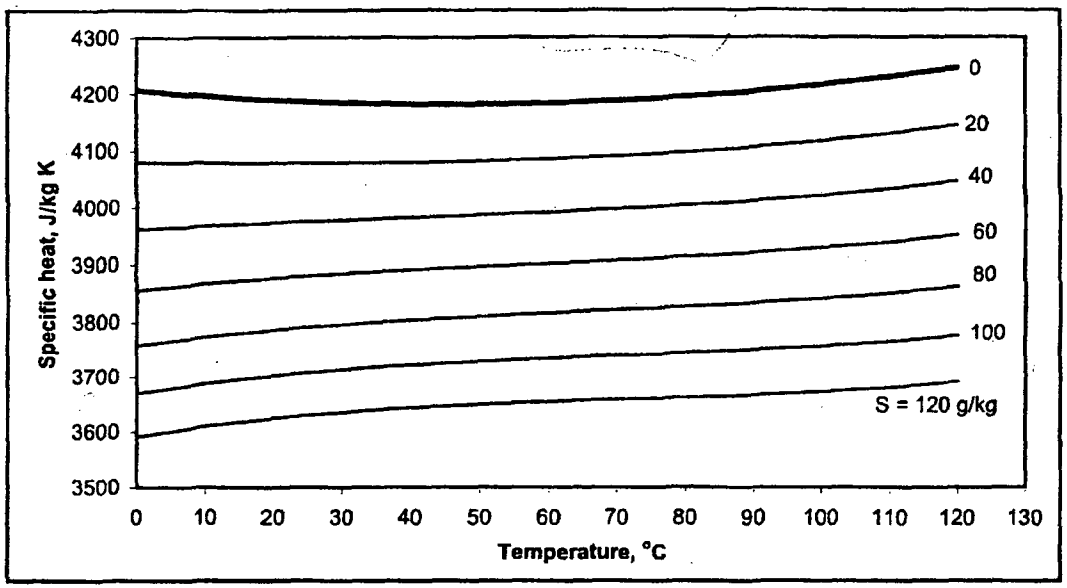
5/16/2010 3:24 PM

C-sub-P.xlsx Plot

Water Temperature deg F	Actual C_p	Curve-Fit C_p
50	0.9539	0.9539
68	0.9549	0.9548
86	0.9557	0.9557
104	0.9566	0.9566
122	0.9576	0.9575

Specific heat at constant pressure, J/kg K

	Salinity, g/kg												
Temp, °C	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
0	4206.8	4142.1	4079.9	4020.1	3962.7	3907.8	3855.3	3805.2	3757.6	3712.4	3669.7	3629.3	3591.5
10	4196.7	4136.7	4078.8	4022.8	3968.9	3916.9	3867.1	3819.2	3773.3	3729.5	3687.7	3647.9	3610.1
20	4189.1	4132.8	4078.2	4025.3	3974.1	3924.5	3876.6	3830.4	3785.9	3743.0	3701.8	3662.3	3624.5
30	4183.9	4130.5	4078.5	4027.8	3978.6	3930.8	3884.4	3839.4	3795.8	3753.6	3712.7	3673.3	3635.3
40	4181.0	4129.7	4079.6	4030.7	3982.9	3936.4	3891.0	3846.7	3803.7	3761.8	3721.1	3681.6	3643.2
50	4180.6	4130.8	4081.9	4034.1	3987.3	3941.5	3896.6	3852.9	3810.1	3768.3	3727.5	3687.8	3649.0
60	4182.7	4133.7	4085.5	4038.3	3992.0	3946.5	3902.0	3858.3	3815.5	3773.7	3732.7	3692.6	3653.4
70	4187.1	4138.5	4090.6	4043.6	3997.3	3951.9	3907.4	3863.6	3820.6	3778.5	3737.2	3696.7	3657.0
80	4194.0	4145.3	4097.3	4050.1	4003.7	3958.1	3913.3	3869.2	3825.9	3783.5	3741.7	3700.8	3660.7
90	4203.4	4154.2	4105.9	4058.3	4011.5	3965.4	3920.2	3875.7	3832.0	3789.1	3746.9	3705.6	3665.0
100	4215.2	4165.4	4116.4	4068.2	4020.9	3974.3	3928.5	3883.6	3839.4	3796.0	3753.5	3711.7	3670.8
110	4229.4	4178.8	4129.1	4080.2	4032.2	3985.1	3938.7	3893.3	3848.6	3804.9	3761.9	3719.9	3678.6
120	4246.1	4194.7	4144.2	4094.6	4045.9	3998.2	3951.3	3905.4	3860.3	3816.2	3773.0	3730.7	3689.4



Accuracy ±0.28%

157 cms (62 in.). Surface runoff, however, is very small at the site because of high soil permeability and evapotranspiration. There are no freshwater streams in the vicinity of the site.

The nearshore bottom of the Atlantic Ocean off the site slopes at a one on 80 gradient to about -10.7 m (-35 ft) MLW. The ocean bottom maintains this depth for about 800 m (0.5 mi) before rising to Pierce Shoal at about -6.4 m (-21 ft) MLW. A slight trough 8 km (5 mi) wide and approximately 15 m (50 ft) deep separates Pierce Shoal from the northward extension of St. Lucie Shoal. The ocean bottom then slopes at a gradient of approximately one in 600 for 19 km (12 mi) across the continental shelf, to a depth of 36 m (120 ft). The slope then increases, resulting in a depth of 183 m (600 ft) approximately 29 km (18 mi) east of the Plant site.

A tide monitoring program undertaken by the applicant from May 1976 to May 1977 showed a mean tidal range of 1 m (3.28 ft). This compares favorably with mean tidal ranges determined from established tide gauges at Miami 0.76 m (2.3 ft), Palm Beach 0.85 m (2.6 ft), and Vero Beach 1.04 m (3.1 ft).

Currents in the nearshore region of the site are affected primarily by winds and tides. The Florida Current, a part of the Gulf stream system, is found farther offshore, beyond the 91 m (300 ft) contour. Ocean currents near the St. Lucie 1 discharge were measured by Continental Shelf Associates (CSA), Tequesta, Florida, from November 1973 through May 1975. Average current speed was found to be 22.5 cm/s (0.74 ft/sec) near the surface and 16.4 cm/s (0.54 ft/sec) near the bottom. The prevailing surface current direction is alongshore toward the north and occurs about 49% of the time. Flow toward the south occurs about 35% of the time. Current speeds were found to range from near zero to 48.8 cm/s (1.6 ft/s). Frequency distributions by month for surface and bottom current directions and speed are provided in the applicant's ER-OL.[16]

Sea water temperatures on the Atlantic Ocean offshore of the site were found to range from about 15°C (59°F) to 32°C (90°F) between 1971 and 1978. The mean temperature for all stations and depths monitored during the period was 25°C (77°F). The average salinity of the Atlantic Ocean off Hutchinson Island is about 35.5 parts per thousand (ppt). A range of 33.0 ppt to 38.5 ppt has been reported with most values between 34.0 ppt and 36.0 ppt. Salinity is generally lowest during fall and winter and increases to a maximum during the summer.

4.3.4 Ground Water Hydrology

Underlying the one to two meters (3 to 6 ft) of surface organic material on Hutchinson Island is the Anastasia Formation. The Anastasia Formation is an unconfined water table aquifer consisting of grey slightly silty fine to medium sand with varying amounts of fragmented shells. The Anastasia Formation extends to a depth of about -41 m (-135 ft) MSL to -47 m (-155 ft) MSL. Below the Anastasia Formation lies the Hawthorne formation. The upper 30 meters of the Hawthorne formation at the site consists of a slightly clayey and silty very fine sand. Below this zone and extending to about -122 m (-400 ft) MSL are sandy clayey silts which form an aquiclude for the underlying Floridian artesian aquifer. The Floridian aquifer, which lies about 210 m below the land surface in St. Lucie County, underlies all of Florida and southern Georgia. The Floridian aquifer is a highly porous limestone formation with an estimated

CALCULATION 28

Golder Associates		SUBJECT MULDIF Run- Y-Nozzle with 123 ° F discharge temperature - Case 2			
		Job No : 09387687	Made by	H Frediani	Date 5/29/2010
		Ref. FPL PSL	Checked	S. Hoschek	Sheet 1 of 2
		PSL Calc 028	Reviewed	G. Powell	

In response to the FDEP RFI#1, Comment 7, we will run the MULDIF model for both St Lucie diffusers assuming 6-pump flow and a discharge temperature of 123°F. The original calculations for the two diffuser runs in support of the 1/21/10 Thermal Discharge Study included Calc 16 for the Y-Nozzle diffuser. This calculation is a revised version of Calc 16 for the Y-Nozzle diffuser at the discharge temperature of 123° F, which is derived from Case 2 in Calculation 25, assuming a 90 deg F CW inlet temperature (CWIT).

Reference Drawings are 8770-G-664-1 for discharge diffuser profile, and 8770-G-66303 for plan view, and are attached to calculation 16.

From Calc 16, we see the Y-nozzle is actually a 45° nozzle with discharge centerline at 34 ft mlw.

From the unit 1 FES (see Calc 16) we have the ports as 7.5 ft diameter .

From Calc 7, we know that the 7.5 foot diameter is the inside diameter (ID) of each port, thus each port has an area of :

A = π R^ 2 = 3.14159 * (7.5/2) * (7.5/2) = 44.18 square feet

Using two ports at 44.18 sq ft each, assume the flow is evenly split:

From Calc 25, flow is 904,0000 gpm for both Units 1 and 2; therefore each port has a flow of 904,000/4 226,000 gpm = 504 cfs

Therefore, the discharge velocity = Q/A = 504/44.18 = 11.40 ft/sec

We will use the near-field model of Koh & Fan (MULDIF) for submerged multiport diffusers.

From MULDIF listing (Attached to Calc 16)

First Data card:

NC = 2 points defining one stratified layer

DO= jet ID 7.5 feet

UO = 11.40 ft/sec

TO is discharge Temp = 123 , from above.

From Calc 7, we have Book1.xlsx defining a curve fit of density of sea water as a function of temperature.

DEN1 = discharge density in g/cc

at 123 deg F , = 1.0147048

ThetaO = angle of discharge = 0°

DJ = Depth of discharge = 34 ft

SPACJ= Jet spacing, call it 115' (because jets are at 45° angle, make them far enough apart so they don't interfere with each other.)

Card 2 and 3: There are 2 cases of ambient depth and density, at the surface and near the bottom.

D = depth = 34 and 0

TA = ambient temperature = 90. degrees F.

Dena = ambient density = 1.02250000

Card 4 GRAVAC = 32.2

BLDR = 50 cfs

RIVR = receiving water flow, = 0 for slack tide / worst case

Tabulate in Worksheet "Input Parameters" and also save as "Y123.DAT" as a Notepad txt file.

Create blank output file Y123.OUT
Using these inputs and output files, run MULDIF.

Open output files in excel and clean up -save as Y123-OUT.xls and plot centerline temperature vertically.

Plot on axis for each of the Y ports on Attachment 1 of Calc 7..
See attachment 1 for results.

T	Rho(actual)	Rho(est)	g/cc
30	64.25	64.2420	1.029519
32	64.25	64.2367	1.029434
40	64.20	64.2090	1.028990
50	64.17	64.1600	1.028205
60	64.10	64.0950	1.027163
70	64.02	64.0140	1.025865
80	63.95	63.9170	1.024311
86.4		63.8465	1.023181
90	63.80	63.8040	1.022500
91		63.7918	1.022305
92		63.7795	1.022107
93		63.7670	1.021907
94		63.7543	1.021704
95		63.7415	1.021498
96		63.7285	1.021290
97		63.7154	1.021080
98		63.7021	1.020867
99		63.6886	1.020651
100	63.70	63.6750	1.020433
101		63.6612	1.020212
102		63.6473	1.019988
103		63.6332	1.019763
104		63.6189	1.019534
105		63.6045	1.019303
106		63.5899	1.019069
107		63.5752	1.018833
108		63.5603	1.018594
109		63.5452	1.018353
110		63.5300	1.018109
111		63.5146	1.017863
112		63.4991	1.017613
113		63.4834	1.017362
114		63.4675	1.017108
115		63.4515	1.016851
116		63.4353	1.016592
117		63.4190	1.016330
118		63.4025	1.016065
119		63.3858	1.015798
120		63.3690	1.015529
121		63.3520	1.015257
122		63.3349	1.014982
123		63.3176	1.014705

MULDIF- Y-Port Diffuser
Input Parameters

Parameter	Y-Port	Units	Definition	Note
NC	2	none	Number of layers	Assume 2 layers at same temp and density
DO	7.5	Ft	Jet diameter	Discharge is through
UO	11.4	Ft/Sec	Discharge velocity per jet	From Calc 6
TO	123	Deg F	Discharge Temperature	From Conference call on 10/19 with Ron Hix
DEN1	1.01470481	g/cm^3	Discharge density	Calculated
THETAO	0	none	Angle of discharge with respect to horizontal	Two scenarios
DJ	34	Ft	Depth of discharge	Depth of discharge
SPACJ	115	Ft	Spacing between jet centers	Only 1 jet
D	0 and 34	Ft	Depth of discharge	Depth of discharge
TA	90	Deg F	Ambient River temperature	
Dena	1.0225	g/cm^3	Ambient River density	
GRAVAC	32.2	Ft/Sec^2	Gravitational constant	Gravitational constant
BLDR	504	cfs	Discharge flow	Calculated
RIVR	0		River flow (0 for slack tide)	Assume slack tide

MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED ENVIRONMENT

AA= 115.00 FEET

1------AA------1 A= 7.50 FEET

1

--A-- * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********* *********

* JET DISCHARGE VELOCITY= 11.40 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 123.00 F

JET DISCHARGE DENSITY= 1.014705 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0			123			90		
46.84	0.00026	15.1577	1.01051	118.4629	1.01578	1.0225	90	28.46292	17
76.59764	2.63063	28.80174	1.93823	104.8394	1.01899	1.0225	90	14.83941	17
91.05657	6.42867	35.18377	2.4087	101.941	1.01968	1.0225	90	11.94097	17
104.8715	12.13786	41.02435	2.88996	99.95247	1.02015	1.0225	90	9.95247	17
117.7805	19.67609	46.25394	3.38778	98.48999	1.02049	1.0225	90	8.48999	17
129.6308	28.79219	50.94408	3.90735	97.36105	1.02076	1.0225	90	7.36105	17
THIS IS FREE SURFACE									
71.88	0.417418			107			90	17	

MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED ENVIRONMENT

```
                    1------AA------1
                                   1
                 *--A--*        *     *
***************     **********     **********
                                            *
                                            *
*******************************************
```

AA= 115.00 FEET

A= 7.50 FEET

JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

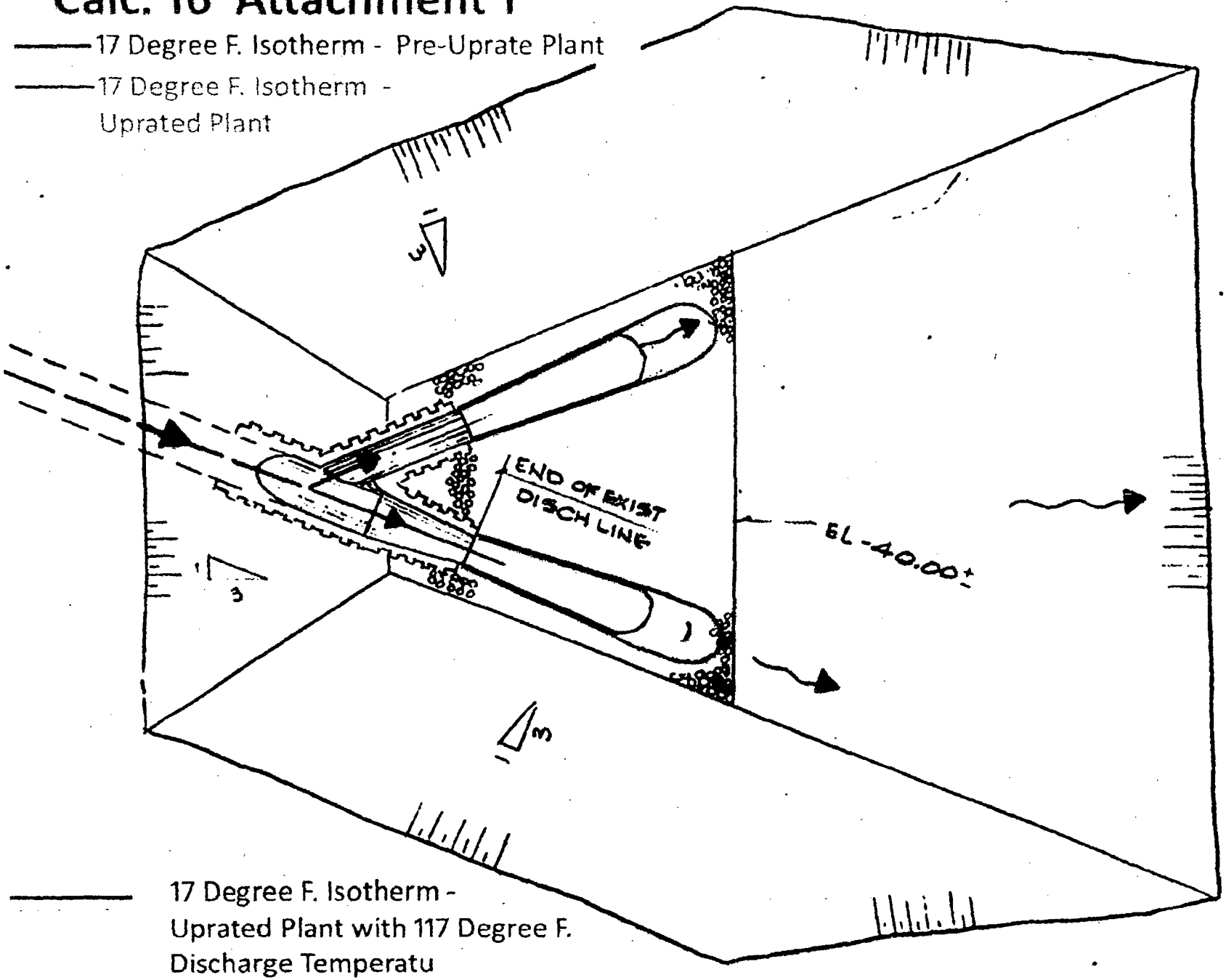
JET DISCHARGE VELOCITY= 11.40 FT/SEC

JET DISCHARGE TEMPERATURE= 123.00 F
JET DISCHARGE DENSITY= 1.014705 GRAM/CC
JET DISCHARGE DEPTH= 34.00 FEET

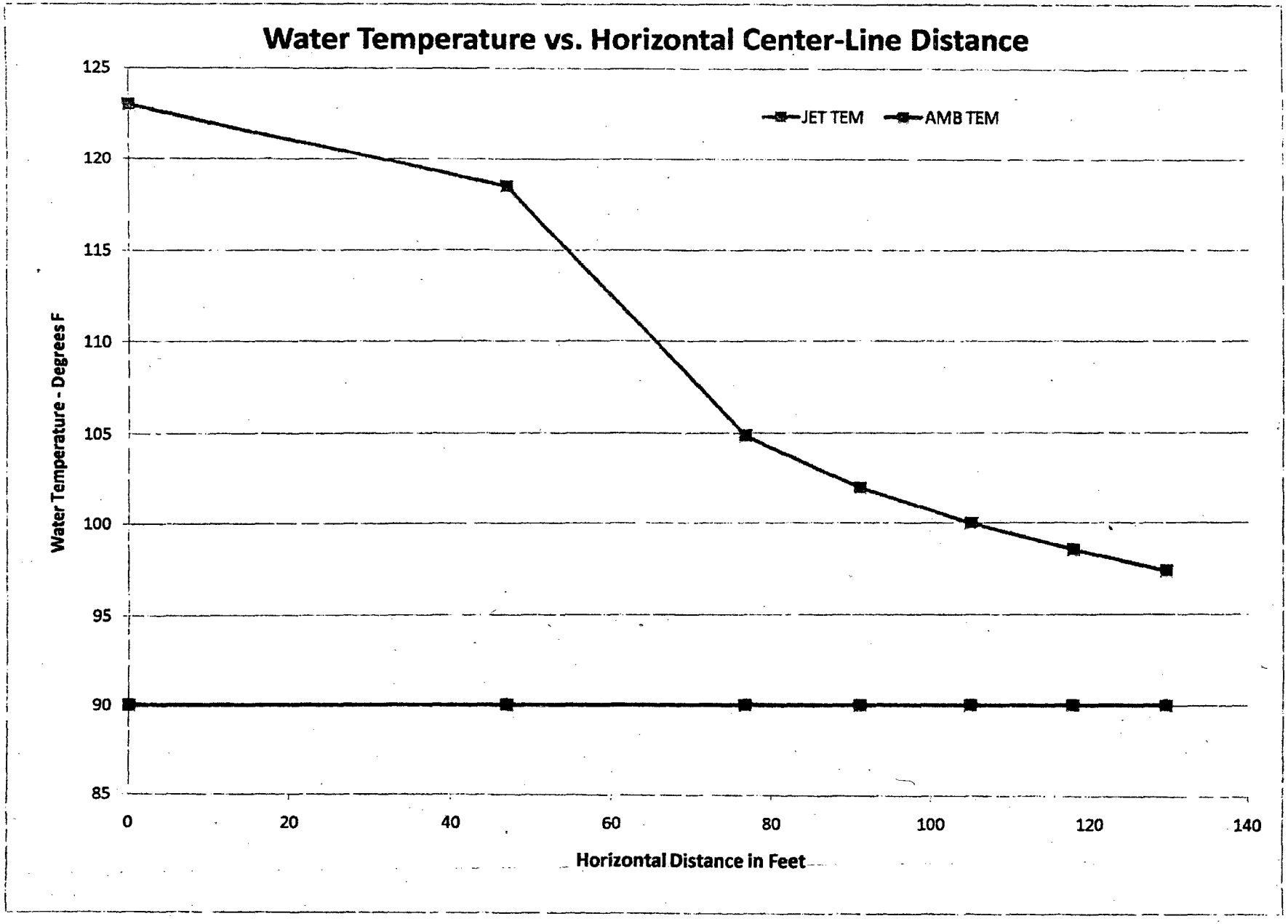
X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
46.84000	.00026	15.15770	1.01051	118.46290	1.01578	1.02250	90.00000	28.46292	17.00000
76.59764	2.63063	28.80174	1.93823	104.83940	1.01899	1.02250	90.00000	14.83941	17.00000
91.05657	6.42867	35.18377	2.40870	101.94100	1.01968	1.02250	90.00000	11.94097	17.00000
104.87150	12.13786	41.02435	2.88996	99.95247	1.02015	1.02250	90.00000	9.95247	17.00000
117.78050	19.67609	46.25394	3.38778	98.48999	1.02049	1.02250	90.00000	8.48999	17.00000
129.63080	28.79219	50.94408	3.90735	97.36105	1.02076	1.02250	90.00000	7.36105	17.00000

THIS IS FREE SURFACE

Calc. 16 Attachment 1



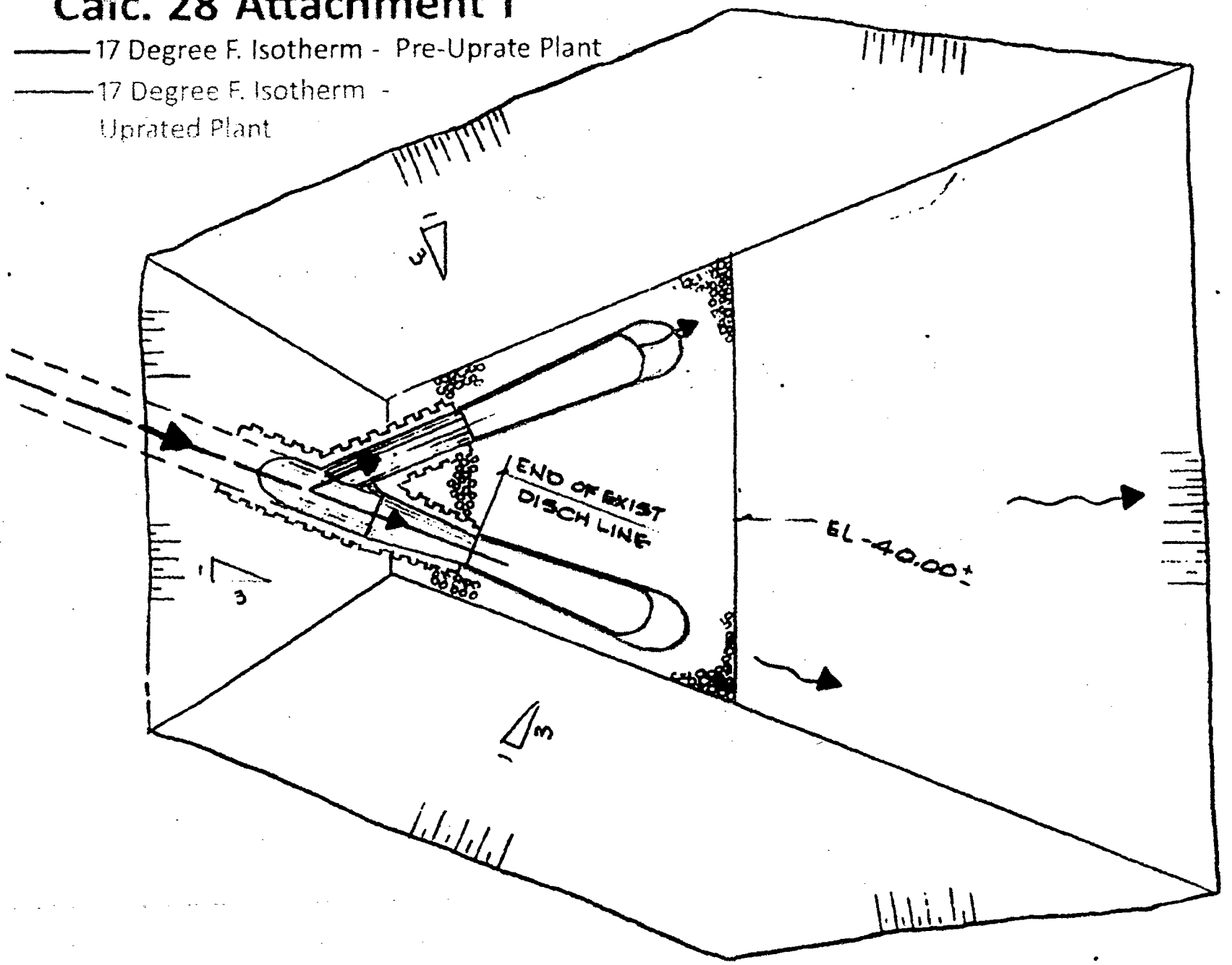
Calc 28


Water Temperature vs. Horizontal Center-Line Distance
JET TEM
AMB TEM
Water Temperature - Degrees F
125
120
115
110
105
100
95
90
85
0
20
40
60
80
100
120
140
Horizontal Distance in Feet

Calc. 28 Attachment 1

17 Degree F. Isotherm - Pre-Uprate Plant

17 Degree F. Isotherm - Uprated Plant



CALCULATION 29

Golder Associates		SUBJECT MULDIF Run- Y-Nozzle with 118 ° F discharge temperature - Case 1			
		Job No : 09387687	Made by	H. Frediani	Date 5/29/2010
		Ref. FPL PSL	Checked	S. Hoschek	Sheet 1 of 2
		PSL Calc 029	Reviewed	G. Powell	

Calc 28 ran the MULDIF model for the St Lucie Y-nozzle diffuser assuming 6-pump flow and a discharge temperature of 123°F. The results indicated that, although Case 2 has the highest discharge temperature, the predicted mixing zone , which is defined by the 17 degree F isotherm, may not have been the maximum sized mixing zone . This calculation is a revised version of Calc 28 for the Y-Nozzle diffuser based on case 1 as described in Calc 25. Case 1 includes 8 CW pumps operating, a temperature rise of 28 deg F, a CW inlet temperature (CWIT) of 90 deg F., and a CW flow of 1,032,600 gpm. The objective is to determine whether Case 2 or Case 1 results in the larger mixing zone.

Reference Drawings are 8770-G-664-1 for discharge diffuser profile, and 8770-G-66303 for plan view, and are attached to calc. 16.

From Calc 16, we see the Y-nozzle is actually a 45° nozzle with discharge centerline at 34 ft mlw.

From the unit 1 FES (see Calc 16) we have the ports as 7.5 ft diameter .

From Calc 7, we know that the 7.5 foot diameter is the inside diameter (ID) of each port, thus each port has an area of :

A = π R^ 2 = 3.14159 * (7.5/2) * (7.5/2) = 44.18 square feet

Using two ports at 44.18 sq ft each, assume the flow is evenly split:

From Calc 25, flow is 1,032,600 gpm for both Units 1 and 2; therefore each port has a flow of 1,032,60(258,150 gpm = 575 cfs

Therefore, the discharge velocity = Q/A = 575/44.18 = 13.02 ft/sec

We will use the near-field model of Koh & Fan (MULDIF) for submerged multiport diffusers.

From MULDIF listing (Attached to Calc 16)

First Data card:

NC = 2 points defining one stratified layer

DO= jet ID 7.5 feet

UO = 13.02 ft/sec

TO is discharge Temp = 118 deg F, from above.

From Calc 7, we have Book1.xlsx defining a curve fit of density of sea water as a function of temperature.

DEN1 = discharge density in g/cc

at 118 deg F , = 1.016065

ThetaO = angle of discharge = 0°

DJ = Depth of discharge = 34 ft

SPACJ= Jet spacing, call it 115' (because jets are at 45° angle, make them far enough apart so they don't interfere with each other.)

Card 2 and 3: There are 2 cases of ambient depth and density, at the surface and near the bottom.

D = depth = 34 and 0

TA = ambient temperature = 90. degrees F.

Dena = ambient density = 1.02250000

Card 4 GRAVAC = 32.2

BLDR = 57 cfs

RIVR = receiving water flow, = 0 for slack tide / worst case

Tabulate in Worksheet "Input Parameters" and also save as "Y118.DAT" as a Notepad txt file.

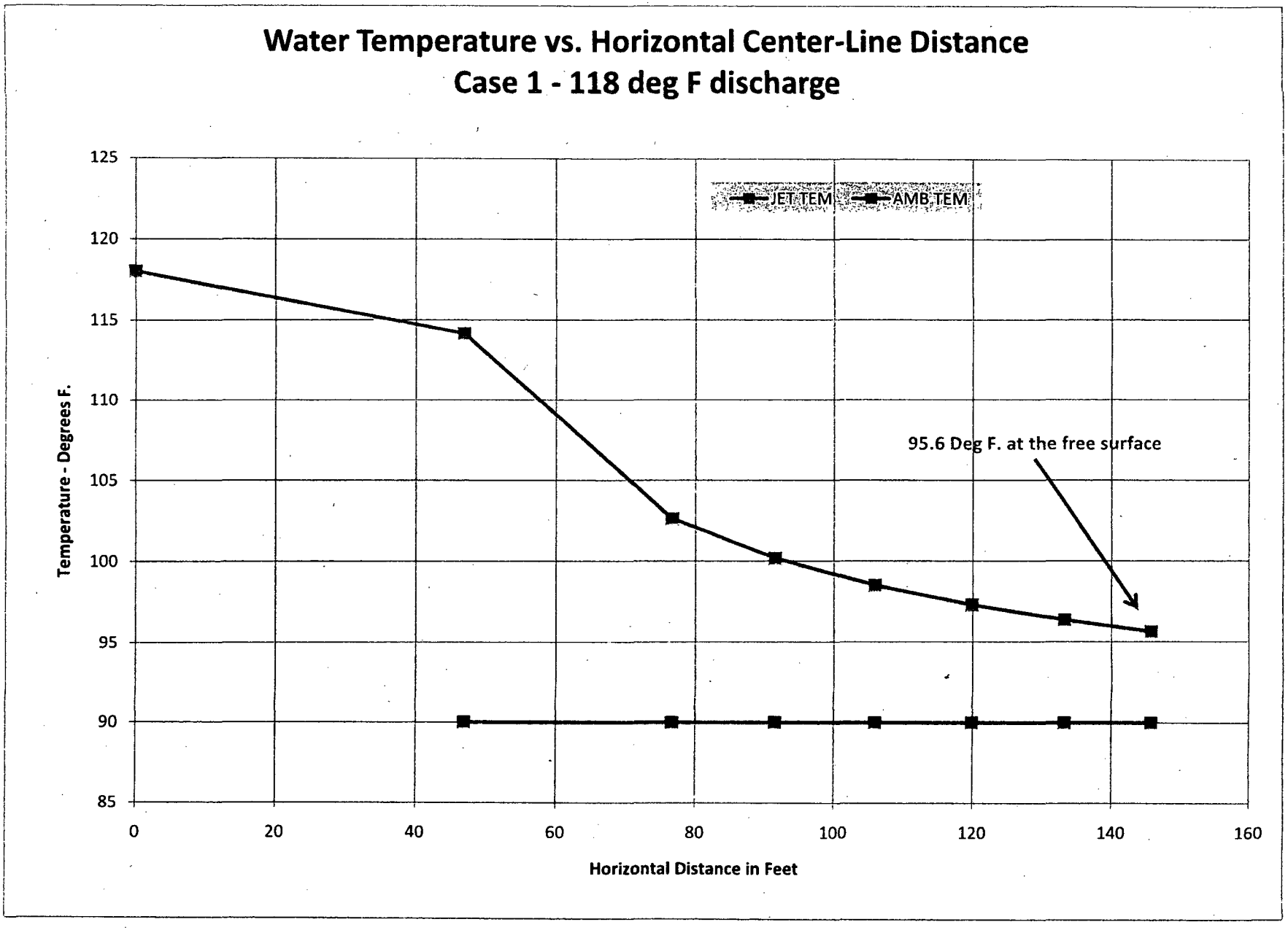
Create blank output file Y118.OUT
Using these inputs and output files, run MULDIF.

Open output files in excel and clean up -save as Y118-OUT.xls and plot centerline temperature vertically.

Plot on axis for each of the Y ports on Attachment 1 of Calc 7..
See attachment 1 for results.

MULDIF- Y-Port Diffuser
Input Parameters

Parameter	Y-Port	Units	Definition	Note
NC	2	none	Number of layers	Assume 2 layers at same temp and density
DO	7.5	Ft	Jet diameter	Discharge is through
UO	13.02	Ft/Sec	Discharge velocity per jet	From Calc 6
TO	118	Deg F	Discharge Temperature	From Conference call on 10/19 with Ron Hix
DEN1	1.01606500	g/cm^3	Discharge density	Calculated
THETAO	0	none	Angle of discharge with respect to horizontal	Two scenarios
DJ	34	Ft	Depth of discharge	Depth of discharge
SPACJ	115	Ft	Spacing between jet centers	Only 1 jet
D	0 and 34	Ft	Depth of discharge	Depth of discharge
TA	90	Deg F	Ambient River temperature	
Dena	1.0225	g/cm^3	Ambient River density	
GRAVAC	32.2	Ft/Sec^2	Gravitational constant	Gravitational constant
BLDR	575	cfs	Discharge flow	Calculated
RIVR	0		River flow (0 for slack tide)	Assume slack tide


Water Temperature vs. Horizontal Center-Line Distance
Case 1 - 118 deg F discharge
JET TEM
AMB TEM
95.6 Deg F. at the free surface
Temperature - Degrees F.
125
120
115
110
105
100
95
90
85
0
20
40
60
80
100
120
140
160
Horizontal Distance in Feet

MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED ENVIRONMENT

AA= 115.00 FEET

1------AA------1 A= 7.50 FEET

1 *--A--* * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 13.02 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 118.00 F

JET DISCHARGE DENSITY= 1.016065 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0	7.5		118				28	
46.84	0.00016	15.15771	1.01051	114.1504	1.01695	1.0225	90	24.15036	17
76.69405	1.67631	28.94036	1.93676	102.6006	1.0196	1.0225	90	12.60056	17
91.44384	4.14679	35.63834	2.40262	100.1573	1.02017	1.0225	90	10.15735	17
105.8959	7.9878	42.05587	2.87322	98.49369	1.02055	1.0225	90	8.49369	17
119.8729	13.30134	48.07619	3.35172	97.28113	1.02083	1.0225	90	7.28112	17
133.2027	20.07683	53.63039	3.84166	96.35253	1.02104	1.0225	90	6.35253	17
145.7549	28.20403	58.72078	4.34653	95.61466	1.02121	1.0225	90	5.61466	17

THIS IS FREE SURFACE

CALCULATION 30

Golder Associates		SUBJECT. MULDIF Run- Y-Nozzle with 119 ° F discharge temperature - Case 3			
		Job No : 09387687	Made by	H. Frediani	Date 5/30/2010
		Ref. FPL PSL	Checked	S. Hoschek	Sheet 1 of 2
		PSL Calc 030	Reviewed	G. Powell	

This calculation will run the MULDIF model for the St Lucie Y-nozzle diffuser for Case 3 as described in Calc 25, assuming only one unit operating at full load. This case is expected to produce the highest surface water temperature of the 4 cases. This calculation is a revised version of Calc 28 for the Y-Nozzle diffuser.

Case 3 includes 4 CW pumps operating for Unit 1 which is at full load, and Unit 2 is shut down. The temperature rise is 29 deg F, rounding up to the next highest whole number. The CW inlet temperature (CWIT) is 90 deg F., and the CW flow is 513,000 gpm.

The objective is to show that Case 3 results in a smaller mixing zone than Case 2 or Case 1, and to determine water temperature at the free surface. Reference Drawings are 8770-G-664-1 for discharge diffuser profile, and 8770-G-66303 for plan view, and are attached to Calc. 16. From Calc 16, we see the Y-nozzle is actually a 45° nozzle with discharge centerline at 34 ft mlw.

From the unit 1 FES (see Calc 16) we have the ports as 7.5 ft diameter .

From Calc 7, we know that the 7.5 foot diameter is the inside diameter (ID) of each port, thus each port has an area of :

A = π R^ 2 = 3.14159 * (7.5/2) * (7.5/2) = 44.18 square feet

Using two ports at 44.18 sq ft each, assume the flow is evenly split:

From Calc 25, flow is 513,000 gpm for Unit 1; therefore each port has a flow of 513,000/4 = 128,250 gpm
= 286 cfs

Therefore, the discharge velocity = Q/A = 575/44.18 = 6.47 ft/sec

We will use the near-field model of Koh & Fan (MULDIF) for submerged multiport diffusers.

From MULDIF listing (Attached to Calc 16)

First Data card:

NC = 2 points defining one stratified layer
DO= jet ID = 7.5 feet
UO = 6.47 ft/sec
TO is discharge Temp = 119 deg F, from above.

From Calc 7, we have Book1.xlsx defining a curve fit of density of sea water as a function of temperature.

DEN1 = discharge density in g/cc
at 119 deg F , = 1.015798

ThetaO = angle of discharge = 0°
DJ = Depth of discharge = 34 ft
SPACJ= Jet spacing, call it 115' (because jets are at 45° angle, make them far enough apart so they don't interfere with each other.)

Card 2 and 3: There are 2 cases of ambient depth and density, at the surface and near the bottom.

D = depth = 34 and 0
TA = ambient temperature = 90. degrees F.
Dena = ambient density = 1.02250000

Card 4 GRAVAC = 32.2
BLDR = 286 cfs
RIVR = receiving water flow, = 0 for slack tide / worst case

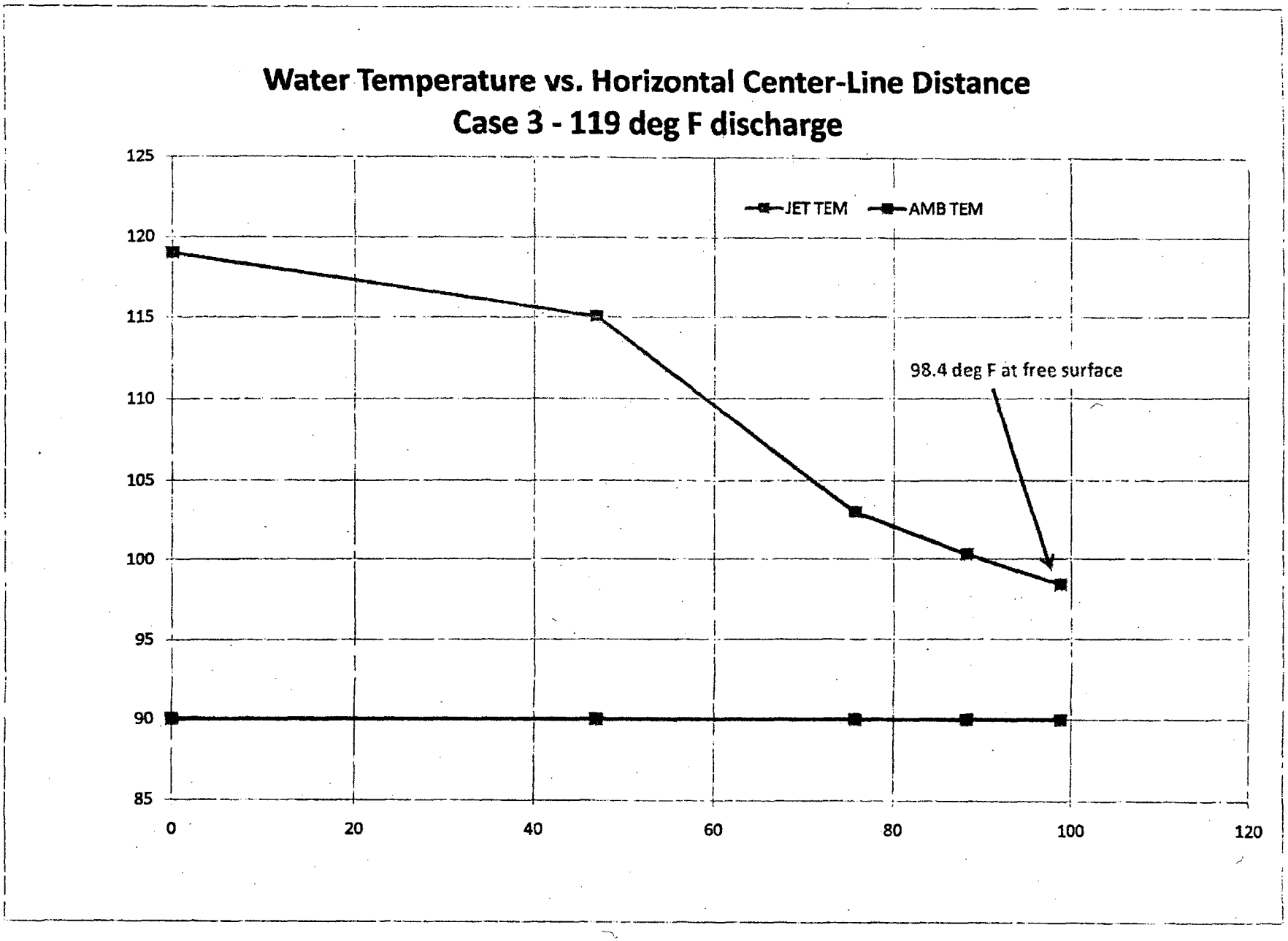
Tabulate in Worksheet "Input Parameters" and also save as "Y119.DAT" as a Notepad txt file.

Create blank output file Y119.OUT
Using these inputs and output files, run MULDIF.

Open output files in excel and clean up -save as Y119-OUT.xls and plot centerline temperature vertically.

MULDIF- Y-Port Diffuser
Input Parameters

Parameter	Y-Port	Units	Definition	Note
NC	2	none	Number of layers	Assume 2 layers at same temp and density
DO	7.5	Ft	Jet diameter	Discharge is through
UO	6.47	Ft/Sec	Discharge velocity per jet	From Calc 6
TO	119	Deg F	Discharge Temperature	From Conference call on 10/19 with Ron Hix
DEN1	1.01579800	g/cm^3	Discharge density	Calculated
THETAO	0	none	Angle of discharge with respect to horizontal	Two scenarios
DJ	34	Ft	Depth of discharge	Depth of discharge
SPACJ	115	Ft	Spacing between jet centers	Only 1 jet
D	0 and 34	Ft	Depth of discharge	Depth of discharge
TA	90	Deg F	Ambient River temperature	
Dena	1.0225	g/cm^3	Ambient River density	
GRAVAC	32.2	Ft/Sec^2	Gravitational constant	Gravitational constant
BLDR	286	cfs	Discharge flow	Calculated
RIVR	0		River flow (0 for slack tide)	Assume slack tide


Water Temperature vs. Horizontal Center-Line Distance
Case 3 - 119 deg F discharge
125
120
115
110
105
100
95
90
85
0
20
40
60
80
100
120
JET TEM
AMB TEM
98.4 deg F at free surface

MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED ENVIRONMENT

AA= 115.00 FEET

1------AA------1 A= 7.50 FEET

1 *--A--* * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 6.47 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 119.00 F

JET DISCHARGE DENSITY= 1.015798 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0			119			90	29	
46.84	0.00069	15.15765	1.01051	115.0129	1.01672	1.0225	90	25.01287	17
75.73824	6.59876	27.65854	1.95197	102.9489	1.01951	1.0225	90	12.94889	17
88.19025	14.83348	32.35958	2.45883	100.2796	1.02012	1.0225	90	10.27962	17
98.78712	25.36724	36.36976	3.0083	98.40205	1.02056	1.0225	90	8.40205	17

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T	Rho(actual)	Rho(est)	g/cc
30	64.25	64.2420	1.029519
32	64.25	64.2367	1.029434
40	64.20	64.2090	1.028990
50	64.17	64.1600	1.028205
60	64.10	64.0950	1.027163
70	64.02	64.0140	1.025865
80	63.95	63.9170	1.024311
86.4		63.8465	1.023181
90	63.80	63.8040	1.022500
91		63.7918	1.022305
92		63.7795	1.022107
93		63.7670	1.021907
94		63.7543	1.021704
95		63.7415	1.021498
96		63.7285	1.021290
97		63.7154	1.021080
98		63.7021	1.020867
99		63.6886	1.020651
100	63.70	63.6750	1.020433
101		63.6612	1.020212
102		63.6473	1.019988
103		63.6332	1.019763
104		63.6189	1.019534
105		63.6045	1.019303
106		63.5899	1.019069
107		63.5752	1.018833
108		63.5603	1.018594
109		63.5452	1.018353
110		63.5300	1.018109
111		63.5146	1.017863
112		63.4991	1.017613
113		63.4834	1.017362
114		63.4675	1.017108
115		63.4515	1.016851
116		63.4353	1.016592
117		63.4190	1.016330
118		63.4025	1.016065
119		63.3858	1.015798
120		63.3690	1.015529
121		63.3520	1.015257
122		63.3349	1.014982
123		63.3176	1.014705

CALCULATION 31

Golder Associates	SUBJECT MULDIF Run- Y-Nozzle with 120 ° F discharge temperature		
	Job No : 09387687	Made by HAF	Date 5/30/2010
	Ref. FPL PSL	Checked	Sheet 1 of 2
	PSL Calc 031	Reviewed	

This calculation will run the MULDIF model for the St Lucie Y-nozzle diffuser for Case 4 as described in Calc 25, assuming both units operating at full load, but with only 7 CW pumps operating. This is the Maintenance case. This calculation is a revised version of Calc 28 for the Y-Nozzle diffuser.

Case 4 includes 7 CW pumps operating for Units 1 and 2, which are both at full load. The temperature rise is 30 deg F, rounding up to the next highest whole number. The CW inlet temperature (CWIT) is 90 deg F., and the CW flow is 993,000 gpm. The objective is to show that Case 4 results in a smaller mixing zone than Case 2 or Case 1, and to determine water temperature at the free surface. Reference Drawings are 8770-G-664-1 for discharge diffuser profile, and 8770-G-66303 for plan view, and are attached to Calc. 16. From Calc 16, we see the Y-nozzle is actually a 45° nozzle with discharge centerline at 34 ft mlw.

From the unit 1 FES (see Calc 16) we have the ports as 7.5 ft diameter .

From Calc 7, we know that the 7.5 foot diameter is the inside diameter (ID) of each port, thus each port has an area of :

A = π R^ 2 = 3.14159 * (7.5/2) * (7.5/2) = 44.18 square feet

Using two ports at 44.18 sq ft each, assume the flow is evenly split:

From Calc 25, flow is 993,000 gpm ; therefore each port has a flow of 993,000/4 = 248,250 gpm

= 553 cfs

Therefore, the discharge velocity = Q/A = 553/44.18 = 12.52 ft/sec

We will use the near-field model of Koh & Fan (MULDIF) for submerged multiport diffusers.

From MULDIF listing (Attached to Calc 16)

First Data card:

NC = 2 points defining one stratified layer

DO= jet ID 7.5 feet

UO = 12.52 ft/sec

TO is discharge Temp = 120 deg F, from above.

From Calc 7, we have Book1.xlsx defining a curve fit of density of sea water as a function of temperature.

DEN1 = discharge density in g/cc

at 120 deg F , = 1.015529

ThetaO = angle of discharge = 0°

DJ = Depth of discharge = 34 ft

SPACJ= Jet spacing, call it 115' (because jets are at 45° angle, make them far enough apart so they don't interfere with each other.)

Card 2 and 3: There are 2 cases of ambient depth and density, at the surface and near the bottom.

D = depth = 34 and 0

TA = ambient temperature = 90. degrees F.

Dena = ambient density = 1.02250000

Card 4 GRAVAC = 32.2

BLDR = cfs

RIVR = receiving water flow, = 0 for slack tide / worst case

Tabulate in Worksheet "Input Parameters" and also save as "Y119.DAT" as a Notepad txt file.

Create blank output file Y120.OUT
Using these inputs and output files, run MULDIF.

Open output files in excel and clean up -save as Y120-OUT.xls and plot centerline temperature vertically.

MULDIF- Y-Port Diffuser
Input Parameters

Parameter	Y-Port	Units	Definition	Note
NC	2	none	Number of layers	Assume 2 layers at same temp and density
DO	7.5	Ft	Jet diameter	Discharge is through
UO	12.52	Ft/Sec	Discharge velocity per jet	From Calc 6
TO	120	Deg F	Discharge Temperature	From Conference call on 10/19 with Ron Hix
DEN1	1.01552900	g/cm^3	Discharge density	Calculated
THETAO	0	none	Angle of discharge with respect to horizontal	Two scenarios
DJ	34	Ft	Depth of discharge	Depth of discharge
SPACJ	115	Ft	Spacing between jet centers	Only 1 jet
D	0 and 34	Ft	Depth of discharge	Depth of discharge
TA	90	Deg F	Ambient River temperature	
Dena	1.0225	g/cm^3	Ambient River density	
GRAVAC	32.2	Ft/Sec^2	Gravitational constant	Gravitational constant
BLDR	553	cfs	Discharge flow	Calculated
RIVR	0		River flow (0 for slack tide)	Assume slack tide

MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED ENVIRONMENT

AA= 115.00 FEET

1-----AA-----1 A= 7.50 FEET

1

--A-- * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 12.52 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 120.00 F

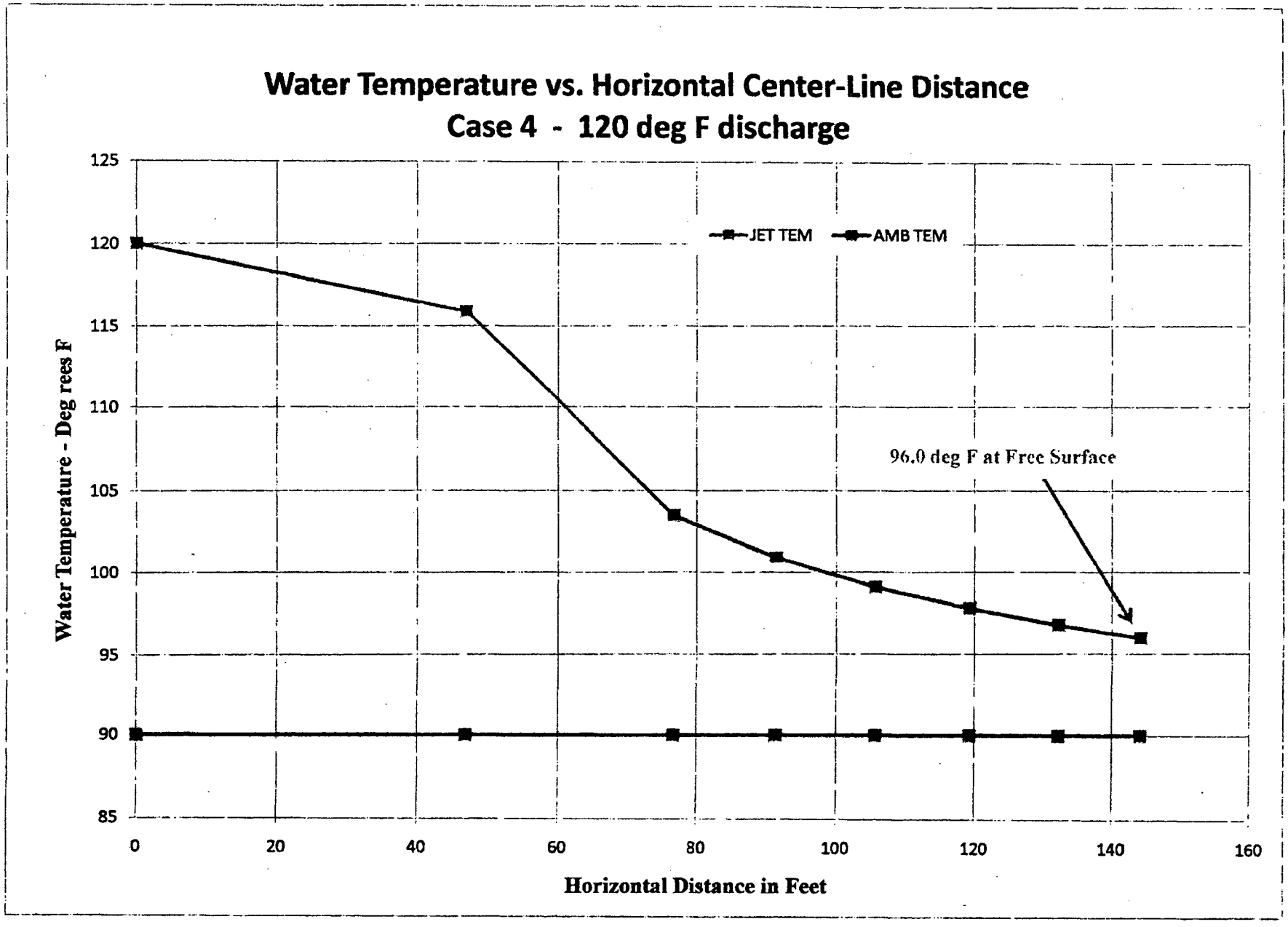
JET DISCHARGE DENSITY= 1.015529 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0			120			90		
46.84	0.00019	15.15771	1.01051	115.8754	1.01649	1.0225	90	25.87539	17
76.66982	1.96048	28.90529	1.93713	103.498	1.01936	1.0225	90	13.49804	17
91.3447	4.83454	35.51991	2.40416	100.8759	1.01997	1.0225	90	10.87591	17
105.626	9.26266	41.77459	2.87754	99.08672	1.02039	1.0225	90	9.08672	17
119.3012	15.30707	47.55079	3.36126	97.77905	1.02069	1.0225	90	7.77905	17
132.1881	22.88941	52.81058	3.85953	96.77477	1.02093	1.0225	90	6.77477	17
144.1751	31.82872	57.6038	4.37615	95.97499	1.02111	1.0225	90	5.97499	17

THIS IS FREE SURFACE

T	Rho(actual)	Rho(est)	g/cc
30	64.25	64.2420	1.029519
32	64.25	64.2367	1.029434
40	64.20	64.2090	1.028990
50	64.17	64.1600	1.028205
60	64.10	64.0950	1.027163
70	64.02	64.0140	1.025865
80	63.95	63.9170	1.024311
86.4		63.8465	1.023181
90	63.80	63.8040	1.022500
91		63.7918	1.022305
92		63.7795	1.022107
93		63.7670	1.021907
94		63.7543	1.021704
95		63.7415	1.021498
96		63.7285	1.021290
97		63.7154	1.021080
98		63.7021	1.020867
99		63.6886	1.020651
100	63.70	63.6750	1.020433
101		63.6612	1.020212
102		63.6473	1.019988
103		63.6332	1.019763
104		63.6189	1.019534
105		63.6045	1.019303
106		63.5899	1.019069
107		63.5752	1.018833
108		63.5603	1.018594
109		63.5452	1.018353
110		63.5300	1.018109
111		63.5146	1.017863
112		63.4991	1.017613
113		63.4834	1.017362
114		63.4675	1.017108
115		63.4515	1.016851
116		63.4353	1.016592
117		63.4190	1.016330
118		63.4025	1.016065
119		63.3858	1.015798
120		63.3690	1.015529
121		63.3520	1.015257
122		63.3349	1.014982
123		63.3176	1.014705


Water Temperature vs. Horizontal Center-Line Distance
Case 4 - 120 deg F discharge
JET TEM
AMB TEM
96.0 deg F at Free Surface
Water Temperature - Deg rees F
Horizontal Distance in Feet
125
120
115
110
105
100
95
90
85
0
20
40
60
80
100
120
140
160

Golder Associates		SUBJECT	MULDIF Run- Y-Nozzle with 120 ° F discharge temperature - Case 4		
		Job No : 09387687	Made by	H. Frediani	Date 5/30/2010
		Ref. FPL PSL	Checked	S. Hoschek	Sheet 1 of 2
		PSL Calc 031	Reviewed	G. Powell	

This calculation will run the MULDIF model for the St Lucie Y-nozzle diffuser for Case 4 as described in Calc 25, assuming both units operating at full load, but with only 7 CW pumps operating. This is the Maintenance case. This calculation is a revised version of Calc 28 for the Y-Nozzle diffuser.

Case 4 includes 7 CW pumps operating for Units 1 and 2, which are both at full load. The temperature rise is 30 deg F, rounding up to the next highest whole number. The CW inlet temperature (CWIT) is 90 deg F., and the CW flow is 993,000 gpm. The objective is to show that Case 4 results in a smaller mixing zone than Case 2 or Case 1, and to determine water temperature at the free surface. Reference Drawings are 8770-G-664-1 for discharge diffuser profile, and 8770-G-66303 for plan view, and are attached to Calc. 16. From Calc 16, we see the Y-nozzle is actually a 45° nozzle with discharge centerline at 34 ft mlw.

From the unit 1 FES (see Calc 16) we have the ports as 7.5 ft diameter .

From Calc 7, we know that the 7.5 foot diameter is the inside diameter (ID) of each port, thus each port has an area of :

A = π R^ 2 = 3.14159 * (7.5/2) * (7.5/2) = 44.18 square feet

Using two ports at 44.18 sq ft each, assume the flow is evenly split:

From Calc 25, flow is 993,000 gpm ; therefore each port has a flow of 993,000/4 = 248,250 gpm
= 553 cfs

Therefore, the discharge velocity = Q/A = 553/44.18 = 12.52 ft/sec

We will use the near-field model of Koh & Fan (MULDIF) for submerged multiport diffusers.

From MULDIF listing (Attached to Calc 16)

First Data card:

NC = 2 points defining one stratified layer
DO= jet ID = 7.5 feet
UO = 12.52 ft/sec
TO is discharge Temp = 120 deg F, from above.

From Calc 7, we have Book1.xlsx defining a curve fit of density of sea water as a function of temperature.

DEN1 = discharge density in g/cc
at 120 deg F , = 1.015529

ThetaO = angle of discharge = 0°
DJ = Depth of discharge = 34 ft
SPACJ= Jet spacing, call it 115' (because jets are at 45° angle, make them far enough apart so they don't interfere with each other.)

Card 2 and 3: There are 2 cases of ambient depth and density, at the surface and near the bottom.

D = depth = 34 and 0
TA = ambient temperature = 90. degrees F.
Dena = ambient density = 1.02250000

Card 4 GRAVAC = 32.2
BLDR = 553 cfs
RIVR = receiving water flow, = 0 for slack tide / worst case

Tabulate in Worksheet "Input Parameters" and also save as "Y119.DAT" as a Notepad txt file.

Create blank output file Y120.OUT
Using these inputs and output files, run MULDIF.

Open output files in excel and clean up -save as Y120-OUT.xls and plot centerline temperature vertically.

MULDIF- Y-Port Diffuser
Input Parameters

Parameter	Y-Port	Units	Definition	Note
NC	2	none	Number of layers	Assume 2 layers at same temp and density
DO	7.5	Ft	Jet diameter	Discharge is through
UO	12.52	Ft/Sec	Discharge velocity per jet	From Calc 6
TO	120	Deg F	Discharge Temperature	From Conference call on 10/19 with Ron Hix
DEN1	1.01552900	g/cm^3	Discharge density	Calculated
THETAO	0	none	Angle of discharge with respect to horizontal	Two scenarios
DJ	34	Ft	Depth of discharge	Depth of discharge
SPACJ	115	Ft	Spacing between jet centers	Only 1 jet
D	0 and 34	Ft	Depth of discharge	Depth of discharge
TA	90	Deg F	Ambient River temperature	
Dena	1.0225	g/cm^3	Ambient River density	
GRAVAC	32.2	Ft/Sec^2	Gravitational constant	Gravitational constant
BLDR	553	cfs	Discharge flow	Calculated
RIVR	0		River flow (0 for slack tide)	Assume slack tide

T	Rho(actual)	Rho(est)	g/cc
30	64.25	64.2420	1.029519
32	64.25	64.2367	1.029434
40	64.20	64.2090	1.028990
50	64.17	64.1600	1.028205
60	64.10	64.0950	1.027163
70	64.02	64.0140	1.025865
80	63.95	63.9170	1.024311
86.4		63.8465	1.023181
90	63.80	63.8040	1.022500
91		63.7918	1.022305
92		63.7795	1.022107
93		63.7670	1.021907
94		63.7543	1.021704
95		63.7415	1.021498
96		63.7285	1.021290
97		63.7154	1.021080
98		63.7021	1.020867
99		63.6886	1.020651
100	63.70	63.6750	1.020433
101		63.6612	1.020212
102		63.6473	1.019988
103		63.6332	1.019763
104		63.6189	1.019534
105		63.6045	1.019303
106		63.5899	1.019069
107		63.5752	1.018833
108		63.5603	1.018594
109		63.5452	1.018353
110		63.5300	1.018109
111		63.5146	1.017863
112		63.4991	1.017613
113		63.4834	1.017362
114		63.4675	1.017108
115		63.4515	1.016851
116		63.4353	1.016592
117		63.4190	1.016330
118		63.4025	1.016065
119		63.3858	1.015798
120		63.3690	1.015529
121		63.3520	1.015257
122		63.3349	1.014982
123		63.3176	1.014705

MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED ENVIRONMENT

AA= 115.00 FEET

1------AA------1 A= 7.50 FEET

1

--A-- * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 12.52 FT/SEC

*

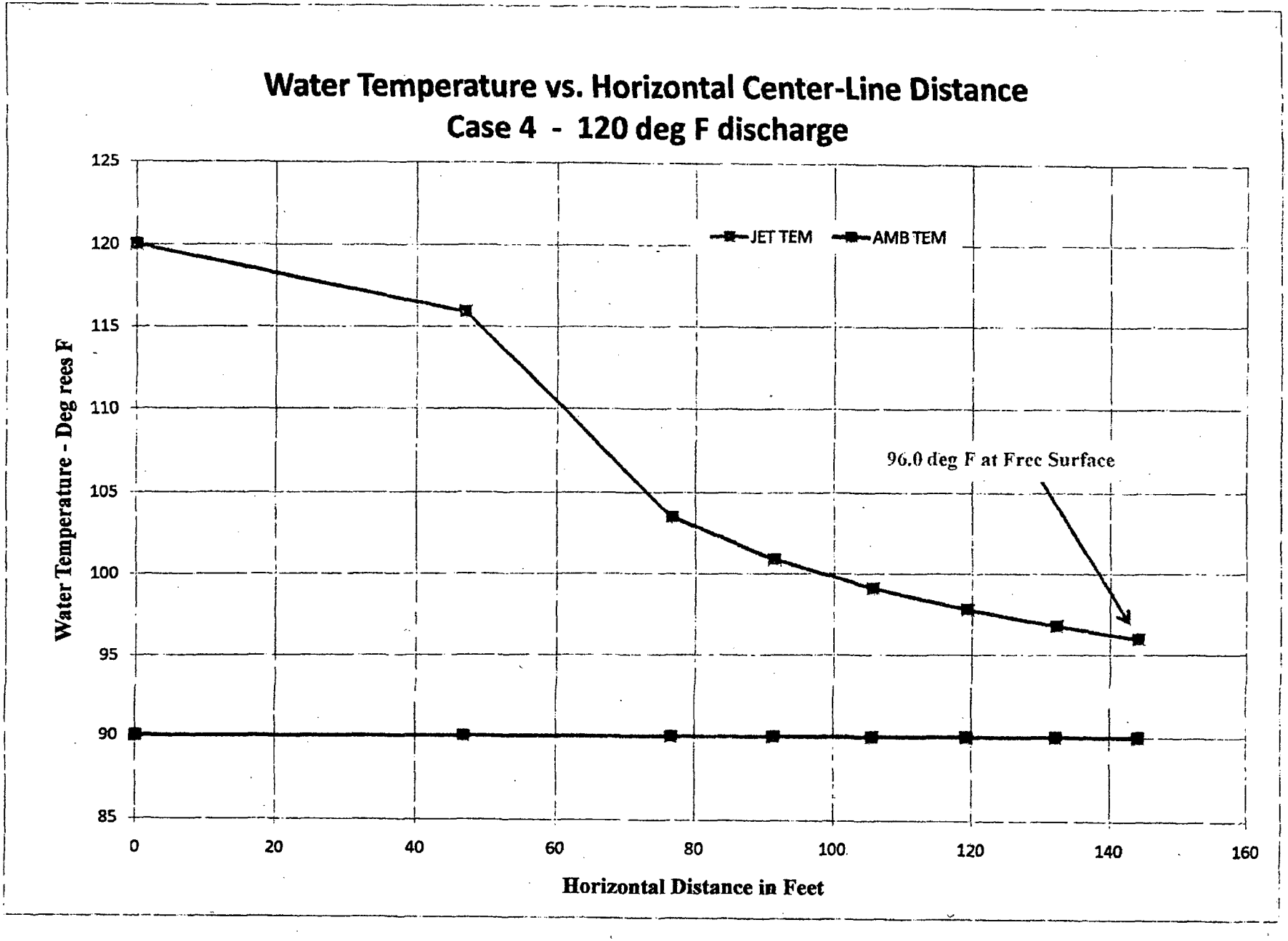
********** JET DISCHARGE TEMPERATURE= 120.00 F

JET DISCHARGE DENSITY= 1.015529 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0			120			90		
46.84	0.00019	15.15771	1.01051	115.8754	1.01649	1.0225	90	25.87539	17
76.66982	1.96048	28.90529	1.93713	103.498	1.01936	1.0225	90	13.49804	17
91.3447	4.83454	35.51991	2.40416	100.8759	1.01997	1.0225	90	10.87591	17
105.626	9.26266	41.77459	2.87754	99.08672	1.02039	1.0225	90	9.08672	17
119.3012	15.30707	47.55079	3.36126	97.77905	1.02069	1.0225	90	7.77905	17
132.1881	22.88941	52.81058	3.85953	96.77477	1.02093	1.0225	90	6.77477	17
144.1751	31.82872	57.6038	4.37615	95.97499	1.02111	1.0225	90	5.97499	17

THIS IS FREE SURFACE


Water Temperature vs. Horizontal Center-Line Distance
Case 4 - 120 deg F discharge
JET TEM
AMB TEM
96.0 deg F at Free Surface
Water Temperature - Deg rees F
Horizontal Distance in Feet
125
120
115
110
105
100
95
90
85
0
20
40
60
80
100
120
140
160

CALCULATION 32

Golder Associates	SUBJECT Mixing Zone Volumes for Cases 1 through 4		
	Job No. 09387687 Ref. St Lucie NPDES Calc : 32	Made By: H. Frediani Checked: S. Hoschek Reviewed: G. Powell	Date 5/30/2010 Sheet 1 of 1

The MULDIF model has been run for the Y-nozzle diffuser for the four cases identified in Calc 25 and documented in the following calculations:

		Output file	Max temp at free surface	
Calculation 29 -	Case 1	Y-118-out	95.6	degrees F
Calculation 28 -	Case 2	Y-123-out	97.4	degrees F
Calculation 30 -	Case 3	Y-119-out	98.4	degrees F
Calculation 31 -	Case 4	Y-120-out	96.0	degrees F

The purpose of this calculation is to calculate the volume enclosed by the 17 deg F above ambient isotherm for each case, because that is the limit of the mixing zone . We will need to determine which of the four cases produces the largest mixing zone.

First, take the tables from the output files from each of Calc 28 through 31 and place as worksheets in Calc32.xlsx

The model predicts a plume with circular cross-section perpendicular to the axis of the plume centerline. Calculate the volume within each model step as the product of the average of the cross-sectional areas and the distance along the centerline. On worksheet5, Calc-32.xlsx, tabulate the x and y coordinates of each time step for each case down to the 17 degree F above ambient temperature at the centerline. Note the 17 degree location along the centerline has been calculated by linear interpolation. Calculate centerline distance S of each time step as square root of sum of squares of X and Y. Tabulate centerline jet delta T at end of step 1. Assume top hat distribution at start of first step; so the 17 degree isotherm is assumed to extend all the way across the discharge port. Next, calculate the jet width to the 17 degree isotherm, first calculate ratio of 17 degrees to delta T at centerline. Then from normal.pdf (normal distribution) calculate corresponding number of standard deviations. (see Calc 18 for an example calc). Next, from the jet width, assuming the full jet is four standard deviations across, multiply by # of SDs divided by 4 to get 17-degree width. Then calculate volume of that step. repeat the proces, at the end of the second step we are at 17 degrees and the area is zero (a point). Add the volumes of the two steps to get the total volume enclosed by the 17 degree isotherm.

Based on the table on sheet 5, the largest 17-degree above ambient isotherm volume is for Case 2, and totals 9,297 cubic feet.

	Case 1	Case 2	Case 3	Case 4
X at start first time step	0	0	0	0
Y at start first time step	0	0	0	0
X at end first time step	46.84	46.84	46.84	46.84
y at end first time step	0.00016	0.00026	0.00069	0.00019
S for first time step	46.840	46.840	46.840	46.840
jet diameter start of first time step	7.500	7.500	7.500	7.500
jet diameter end of first time step	15.158	15.158	15.158	15.158
centerline delta T at start first step	28.000	33.000	29.000	30.000
centerline delta T at end of first step	24.150	28.463	25.013	25.875
ratio of 17 deg to centerline delta T	0.863	0.863	0.863	0.863
from normal distribution, # of SDs	0.540	0.540	0.540	0.540
17 deg jet diameter end of first step	2.046	2.046	2.046	2.046
17 deg volume of first step - cu ft	4,303	4,303	4,303	4,303
x at end second time step	65.322	71.878	66.034	68.230
y at end second time step	1.0378	2.2135	4.3831	1.4058
S for second time step	18.511	25.136	19.688	21.436
jet diameter end second time step	23.690	26.638	23.461	25.016
centerline delta T at end second step	17	17	17	17
17-degree volume of second step	122	165	129	141
Total volume 17-degree isotherm per port	4,425	4,468	4,433	4,444
for two ports (cubic feet) :	8,850	8,937	8,865	8,888

MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED ENVIRONMENT

AA= 115.00 FEET

1-----AA-----1 A= 7.50 FEET

1

--A-- * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 11.40 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 123.00 F

JET DISCHARGE DENSITY= 1.014705 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0			123			90	33	
46.84	0.00026	15.1577	1.01051	118.4629	1.01578	1.0225	90	28.46292	17
71.87829	2.213472	26.6378941						17	
76.59764	2.63063	28.80174	1.93823	104.8394	1.01899	1.0225	90	14.83941	17
91.05657	6.42867	35.18377	2.4087	101.941	1.01968	1.0225	90	11.94097	17
104.8715	12.13786	41.02435	2.88996	99.95247	1.02015	1.0225	90	9.95247	17
117.7805	19.67609	46.25394	3.38778	98.48999	1.02049	1.0225	90	8.48999	17
129.6308	28.79219	50.94408	3.90735	97.36105	1.02076	1.0225	90	7.36105	17

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interpolated linearly for 17 deg

MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED ENVIRONMENT

AA= 115.00 FEET

1-----AA-----1 A= 7.50 FEET

1 *--A--* * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 13.02 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 118.00 F

JET DISCHARGE DENSITY= 1.016065 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0	7.5		118				28	
46.84	0.00016	15.15771	1.01051	114.1504	1.01695	1.0225	90	24.15036	17
65.32233	1.037847	23.69040401						17	
76.69405	1.67631	28.94036	1.93676	102.6006	1.0196	1.0225	90	12.60056	17
91.44384	4.14679	35.63834	2.40262	100.1573	1.02017	1.0225	90	10.15735	17
105.8959	7.9878	42.05587	2.87322	98.49369	1.02055	1.0225	90	8.49369	17
119.8729	13.30134	48.07619	3.35172	97.28113	1.02083	1.0225	90	7.28112	17
133.2027	20.07683	53.63039	3.84166	96.35253	1.02104	1.0225	90	6.35253	17
145.7549	28.20403	58.72078	4.34653	95.61466	1.02121	1.0225	90	5.61466	17

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MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED ENVIRONMENT

AA= 115.00 FEET

1------AA------1 A= 7.50 FEET

1 *--A--* * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 6.47 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 119.00 F

JET DISCHARGE DENSITY= 1.015798 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0			119			90	29	
46.84	0.00069	15.15765	1.01051	115.0129	1.01672	1.0225	90	25.01287	17
66.03415	4.383114	23.4607147						17	
75.73824	6.59876	27.65854	1.95197	102.9489	1.01951	1.0225	90	12.94889	17
88.19025	14.83348	32.35958	2.45883	100.2796	1.02012	1.0225	90	10.27962	17
98.78712	25.36724	36.36976	3.0083	98.40205	1.02056	1.0225	90	8.40205	17

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MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED ENVIRONMENT

AA= 115.00 FEET

1-----AA-----1 A= 7.50 FEET

1

--A-- * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 12.52 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 120.00 F

JET DISCHARGE DENSITY= 1.015529 GRAM/CC

JET DISCHARGE DEPTH= 34.00 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
0	0			120			90	30	
46.84	0.00019	15.15771	1.01051	115.8754	1.01649	1.0225	90	25.87539	17
68.22998	1.405849	25.015647						17	
76.66982	1.96048	28.90529	1.93713	103.498	1.01936	1.0225	90	13.49804	17
91.3447	4.83454	35.51991	2.40416	100.8759	1.01997	1.0225	90	10.87591	17
105.626	9.26266	41.77459	2.87754	99.08672	1.02039	1.0225	90	9.08672	17
119.3012	15.30707	47.55079	3.36126	97.77905	1.02069	1.0225	90	7.77905	17
132.1881	22.88941	52.81058	3.85953	96.77477	1.02093	1.0225	90	6.77477	17
144.1751	31.82872	57.6038	4.37615	95.97499	1.02111	1.0225	90	5.97499	17

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EBASCO SERVICES INCORPORATED

NEW YORK

BY ____ DATE ____ SHEET ____ OF ____

CHKD. BY ____ DATE ____ OFS NO. ____ DEPT. NO. ____

CLIENT Normal Distribution X vs. $e^{-x^2/2}$

PROJECT ____

SUBJECT ____

X	0	2	4	6	8
0.0	1.00000	.99980	.99920	.99821	.99682
0.1	.99503	.99284	.98995	.98729	.98335
0.2	.98020	.97611	.97162	.96726	.96156
0.3	.95601	.95009	.94384	.93726	.93035
0.4	.92312	.91558	.90775	.89961	.89120
0.5	.88251	.87355	.86486	.85488	.84519
0.6	.83527	.82515	.81482	.80429	.79358
0.7	.78272	.77167	.76049	.74916	.73772
0.8	.72615	.71449	.70273	.69080	.67896
0.9	.66699	.65496	.64289	.63078	.61275
1.0	.60653	.59440	.58229	.57019	.55812
1.1	.54608	.53409	.52724	.51028	.49849
1.2	.48675	.47512	.46357	.45213	.44525
1.3	.42956	.41845	.40747	.39661	.38589
1.4	.37531	.36488	.35459	.34446	.33448
1.5	.32466	.31500	.30551	.29618	.28702
1.6	.27804	.26923	.26060	.25214	.24385
1.7	.23575	.22782	.22007	.21251	.20512
1.8	.19790	.19087	.18400	.17732	.17081
1.9	.16448	.15831	.15232	.14649	.14083
2.0	.13534	.13000	.12483	.11982	.11496
2.1	.11025	.10570	.10129	.09703	.09290
2.2	.08892	.08507	.08137	.07778	.07433
2.3	.07101	.06780	.06471	.06174	.05888
2.4	.05613	.05350	.05095	.04854	.04620
2.5	.04395	.04180	.03973	.03776	.03586
2.6	.03405	.03233	.03067	.02908	.02757
2.7	.02612				
2.8	.01984	.01876	.01775	.01675	.01583
2.9	.01507				
3.0					
3.1					
3.2					
3.3					

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.00034

Table 4-1. Requested Instantaneous Maximum Discharge Temperatures and Discharge Temperature Rises Above Ambient

	Pre-Uprate		Post-Uprate	
Case *	Discharge Temperature **	Discharge Temperature Rise Above Ambient **	Discharge Temperature **	Discharge Temperature Rise Above Ambient **
1	116	26	118	28
2	100	30	123	33
3	116	26	119	29
4	117	27	120	30

* Cases 1, 2, and 3 are normal operating cases, Case 4 is the maintenance case.
** All temperatures are in degrees F.

CALCULATION 33

Golder Associates	SUBJECT Revised Multiport Diffuser MULDIF Runs		
	Job No. 09387687 Ref. St Lucie NPDES Calc 33	Made By H. Frediani Checked S. Hoschek Reviewed: G. Powell	Date 5/30/2010 Sheet 1 of 2

Based on Calculation 32, the largest mixing zone for temperature, as defined by the 17-degree F. above ambient isotherm will occur during Case 2 (see calc 25) in which each unit is operating at full load but with only three CW pumps energized. In order to determine the required volume of the total mixing zone, it is necessary to predict its size for the discharge via the multiport diffuser, and then add that volume to the volume calculated in Calculation 32 for the Y-nozzle diffuser.

This calculation follows the procedure used in previous Calculation 13, during the uprate project, to set up and run the computer model MULDIF for the multiport diffuser. The model inputs are tabulated in worksheet "Input" as folllows:
Many of the parameters are the same as was determined in Calc 28, which was the MULDIF run for the Y-nozzle diffuser simulating Case 1.

From Calc 28, the flow rate is 2 * 504 = 1008 cfs
Because there are 58 ports, the individual port flow rate is 1008/58 = 17.38 cfs.

As described in Calc 13, the ports each have a diameter of 17 3/4 inches; therefore, the discharge velocity is calculated as:

V = Q/A = 17.38/(((17.75/12)*(17.75/12))*3.14159/4) = 10.11 feet per second

Port spacing is set at 42 feet.

Input data are put into Notepad file called PSL-M.DAT, and a blank output file called PSL-M.POUT was provided to receive the output.
Results are shown in file PSL-M-out.xlsx. The discharge drops to the 17-degree level between the first and second step.
Calculate the volumes in the same manner as Calc 32. Need to determine the ratio of 17 to the centerline temperature at the end of the first step, which is 28.0396 deg F; therefore ratio = 17/28.0396 = 0.6063 From the normal distribution table (attached to Calc 32), the standard deviations at 0.6063 = 1.00 therefore the jet width to the 17 deg isotherm at the end of the first step = 1/4 * full jet width = 0.25 * 3.03464 = 0.76 feet.

Length of first step = SQRT(((9.33539*9.33539) + (0.00008*0.00008))) = 9.33539 feet
Length of second step = SQRT(((14.17385-9.33539)*(14.17385-9.33539))+((0.10856-0.00008)*(0.10856-0.00008)))= 4.8397 feet

Golder Associates	SUBJECT Revised Multiport Diffuser MULDIF Runs		
	Job No. 09387687 Ref. St Lucie NPDES Calc 33	Made By H. Frediani Checked S. Hoschek Reviewed: G. Powell	Date 5/30/2010 Sheet 2 of 2

Volume of first step = (((1.4792*1.4792*3.14159/4)+(0.76*0.76*3.14159/4))/2)*9.33539 = 10.14 cubic feet

Volume of second step = ((.76*.76*3.14159/4)/2)*4.8397 = 1.10 cubic feet

Total volume for one port = 11.24 cubic feet

For 58 ports volume = 58 * 11.24 = 652 cubic feet.

For both diffusers, total volume of 17-degree isotherm = 9,297 + 652 = 9,949 cubic feet

MULDIF- Multiport Diffuser Case 4
Input Parameters

Parameter	Existing Multiport	Units	Definition	Note
NC	2	none	Number of layers	Assume 2 layers at same temp and density
DO	1.4792	Ft	Jet diameter	Discharge is through
UO	**10.11**	Ft/Sec	Discharge velocity per jet	From Calc 6
TO	**123**	Deg F	Discharge Temperature	From Conference call on 10/19 with Ron Hix
DEN1	**1.01470481**	g/cm^3	Discharge density	Calculated
THETAO	0	none	Angle of discharge with respect to horizontal	Two scenarios
DJ	26.5	Ft	Depth of discharge	Depth of discharge
SPACJ	42	Ft	Spacing between jet centers	
D	34	Ft	Depth of water body	Depth of water body
TA	**90**	Deg F	Ambient River temperature	
Dena	**1.0225**	g/cm^3	Ambient River density	
GRAVAC	32.2	Ft/Sec^2	Gravitational constant	Gravitational constant
BLDR	**17.38**	cfs	Discharge flow	Calculated
RIVR	0		River flow (0 for slack tide)	Assume slack tide

Multiport Diffuser Run - Case 2

MULTIPORT SUBAQUEOUS DIFFUSER IN AN ARBITRARILY DENSITY STRATIFIED ENVIRONMENT

AA= 42.00 FEET

1------AA------1 A= 1.48 FEET

1

--A-- * * JET DISCHARGE ANGLE= .00 DEGREES W/HORIZ

********** ********** **********

* JET DISCHARGE VELOCITY= 10.11 FT/SEC

*

********** JET DISCHARGE TEMPERATURE= 123.00 F

JET DISCHARGE DENSITY= 1.014705 GRAM/CC

JET DISCHARGE DEPTH= 26.50 FEET

X	Y	JET WIDTH	DILUTION	JET TEM	JET DENS	AMB DEN	AMB TEM	DELTA T	ALLOW T
9.33539	0.00008	3.03464	1.02577	118.0396	1.01588	1.0225	90	28.0396	17
14.17385	0.10856	5.27731		107.000			90	17.00	17
15.08585	0.12901	5.70003	1.92787	104.9191	1.01898	1.0225	90	14.91915	17
18.03765	0.32409	7.06454	2.39223	102.0232	1.01966	1.0225	90	12.02316	17
21.1424	0.65643	8.49367	2.88324	99.97565	1.02014	1.0225	90	9.97565	17
24.06521	1.11191	9.82968	3.34985	98.58611	1.02047	1.0225	90	8.58611	17
26.95967	1.72179	11.13949	3.81871	97.53191	1.02072	1.0225	90	7.53191	17
29.65629	2.45174	12.34392	4.26451	96.74454	1.02091	1.0225	90	6.74454	17
32.45942	3.396	13.57593	4.74087	96.06686	1.02107	1.0225	90	6.06686	17
35.19543	4.51993	14.7561	5.22299	95.50685	1.0212	1.0225	90	5.50685	17
37.85149	5.82159	15.8798	5.71226	95.03516	1.02131	1.0225	90	5.03517	17
40.41677	7.29414	16.94586	6.21008	94.63153	1.02141	1.0225	90	4.63153	17
42.88323	8.9269	17.95647	6.71774	94.28152	1.02149	1.0225	90	4.28153	17
45.24585	10.70666	18.91641	7.23641	93.97465	1.02156	1.0225	90	3.97465	17
47.50258	12.61899	19.83208	7.76708	93.70309	1.02163	1.0225	90	3.70309	17
49.65387	14.6493	20.71054	8.31059	93.46091	1.02168	1.0225	90	3.46091	17
51.70213	16.78358	21.5587	8.8676	93.24352	1.02173	1.0225	90	3.24351	17
53.65114	19.00891	22.38289	9.43861	93.04729	1.02178	1.0225	90	3.04729	17
55.50559	21.31367	23.18857	10.024	92.86933	1.02182	1.0225	90	2.86933	17
57.27067	23.68763	23.98033	10.62403	92.70728	1.02186	1.0225	90	2.70728	17
58.95172	26.12184	24.76187	11.23888	92.55917	1.0219	1.0225	90	2.55917	17

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