Prepared for:
Entergy Nuclear Indian Point 2, LLC and
Entergy Nuclear Indian Point 3, LLC
Buchanan, NY

Part 2 of Response to the NYSDEC Staff Review of the 2010 Field Program and Modeling Analysis of the Cooling Water Discharge from the Indian Point Energy Center

ASA Project 09-167 **31 March 2011**

Prepared by:
Craig Swanson
Deborah Crowley
Yong Kim
Nicholas Cohn
Daniel Mendelsohn

Applied Science Associates, Inc.
55 Village Square Drive
South Kingstown, RI 02879

Introduction

Applied Science Associates, Inc. (ASA) submitted a report on 31 January 2011 that documented the 2010 field program and modeling analysis of the cooling water discharge to the Hudson River from the Indian Point Energy Center (IPEC). The New York State Department of Environmental Conservation provided a series of comments (NYSDEC Comments) dated 10 March 2011 on that report. A technical meeting / discussions occurred last Thursday, 24 March, to clarify the comments. The following reflect ASA's response to those NYSDEC Comments, with the NYSDEC Comment first repeated, followed by ASA's Response. NYSDEC has provided nine (9) comments. An earlier response (Part1) submitted on 29 March 2011 addressed six (6) of the nine (9) comments including #3, #4, #5, #6, #8, and #9. This response (Part 2) addresses the remaining three (3) responses (#1, #2, and #7).

NYSDEC (Section 3) Comment #1
Section 3.2.2 (Page 45) Entergy Indian Point needs to provide temperature profiles and temperature distribution (plan view) at “slack before ebb”, “slack before flood” and ebb tidal conditions at the transects indicated in Figure 2-3. The information should also include vertical temperature distribution for the noted transects similar to Figure 3-27.

ASA Response
NYSDEC requested a visual representation of the temperature structure in the river during slack before ebb, slack before ebb, and ebb tidal conditions using the data collected as part of the 2010 field program. A series of plan view and vertical cross section temperature plots were created from the fixed station thermistor data for the requested tidal phases occurring consecutively during a single tidal cycle (11 July and 12 July). A series of transects were chosen for the vertical cross sections based on suggestions by NYSDEC, as shown in Figure 1-1.

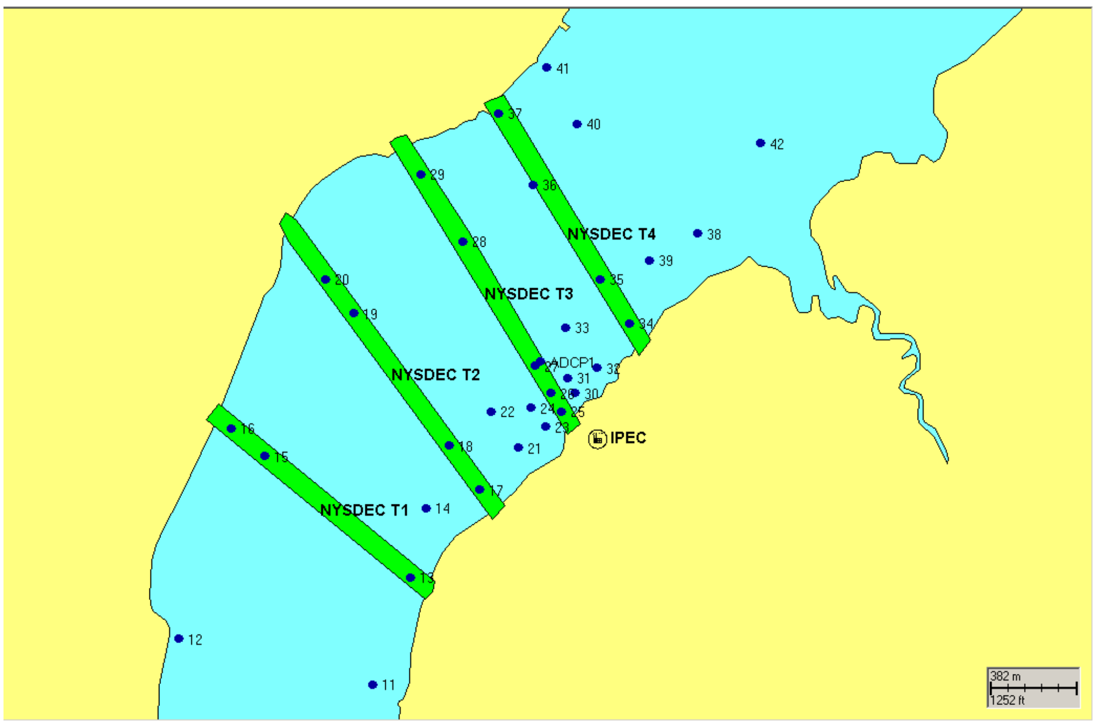

Figure 1-1 Locations of the four NYSDEC transects in the Indian Point area

In order to graphically display the data, a numerical interpolation scheme must be employed. A numerical contouring method was applied by using a Matlab® software routine based on the combination of three interpolation functions (nearest neighbor interpolation, triangle linear interpolation and bilinear (tensor product linear) interpolation) via laplacian regularization to provide a smooth contouring of these results (for details see http://www.mathworks.com/matlabcentral/fx_files/8998/2/content/gridfitdir/demo/html/gridfit_demo.html). It should be noted that, although a sophisticated approach was used, the limitations of the contouring process using irregularly spaced observations (due to the requirement that no thermistor stations be located in the shipping channel) can sometimes result in inaccurate interpolations.

For the vertical cross section profiles, the closest bathymetry points to each transect, as acquired from a 30m resolution bathymetric grid obtained from the NYS GIS Clearinghouse, are displayed to add context of the temperature variability within the river. Note that due to variations in bathymetry and the thermistor station mooring line lengths as recorded from the field survey, the location of all thermistor strings may not always be consistently displayed (normally shown as open circles in the figures), although the data from these thermistors is included in the numerical interpolation scheme.

Only the measured temperatures from the deployed thermistors are shown in the figures. To see the 4°F temperature rise contours due to plant discharge refer to the graphics shown in Comment Response #7.

The first set of contour plots (Figures 1-2 to 1-6) display the river temperature structure during maximum ebb tide on 11 July 2010 at 1800. The first figure in all sets is the surface temperature plan view contours followed by the vertical section contours T1, T2, T3 and T4, which are respectively located from downstream to upstream of IPEC. During this period, the warmest temperatures occur directly near the plant, with the migration of the plume to the south. As the ebbing currents move the warmer plume downstream, cooler water migrates from the north to the area around Indian Point.
The vertical profiles for the same period show that the warmer area is confined to the near surface and close to the eastern (right side of figure) shore. Transects T1 (Figure 1-3) and T2 (Figure 1-4) observe some increase in temperature from the thermal plume, although the increases are relatively small. The T3 (Figure 1-5) and T4 (Figure 1-6) transects observe no discernable impact from the plume during ebb tide, as they are located upstream of the IPEC discharge.

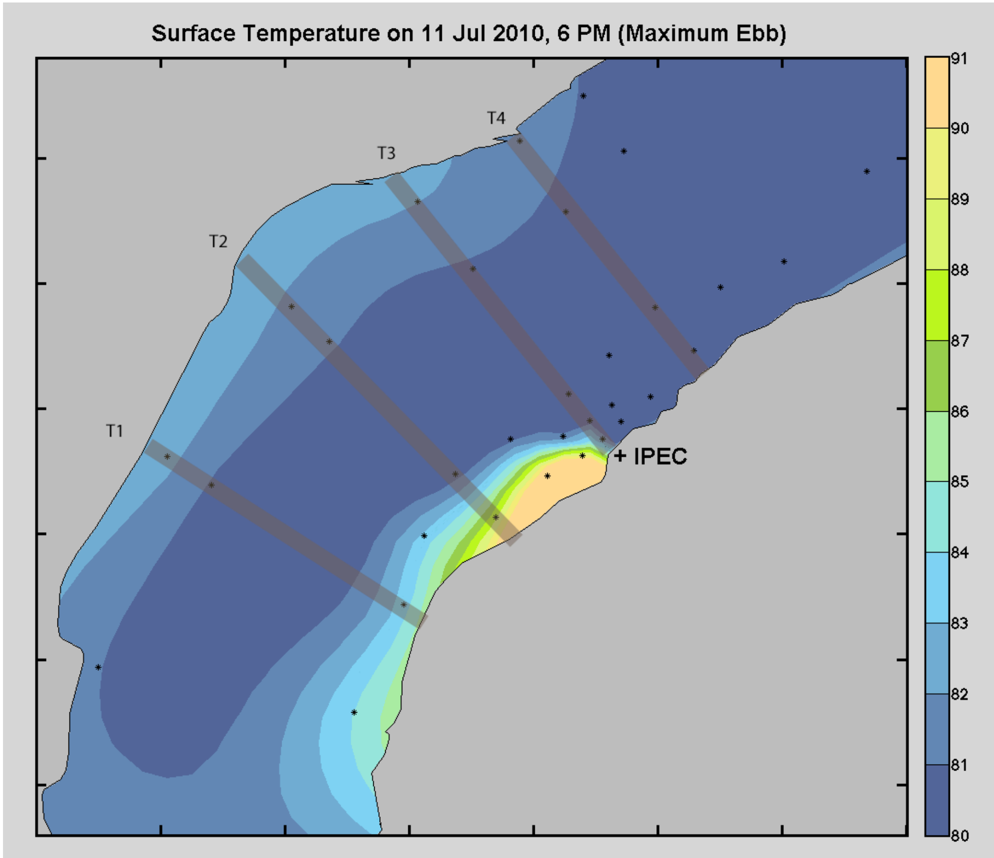

Figure 1-2. Plan view of surface temperatures near IPEC on 11 July 2010 at 1800 during maximum ebb. Color scale (in degrees F) shows the interpolated horizontal temperature distribution.

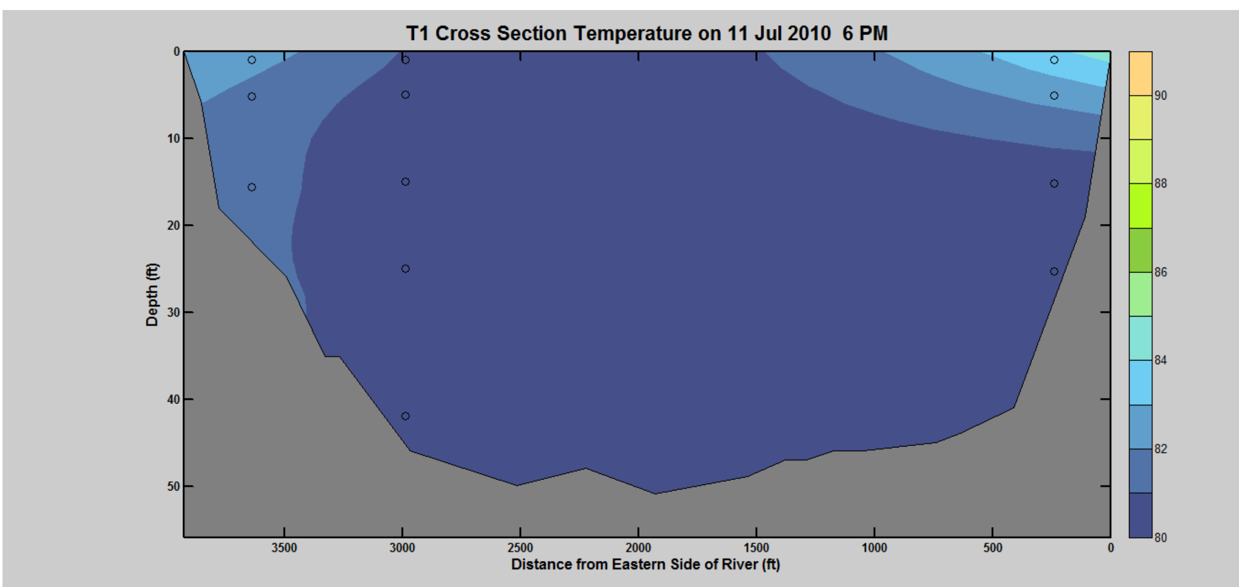

Figure 1-3. Vertical section of temperatures at T1 transect on 11 July 2010 at 1800 during maximum ebb. Color scale (in degrees F) shows the interpolated vertical temperature distribution.

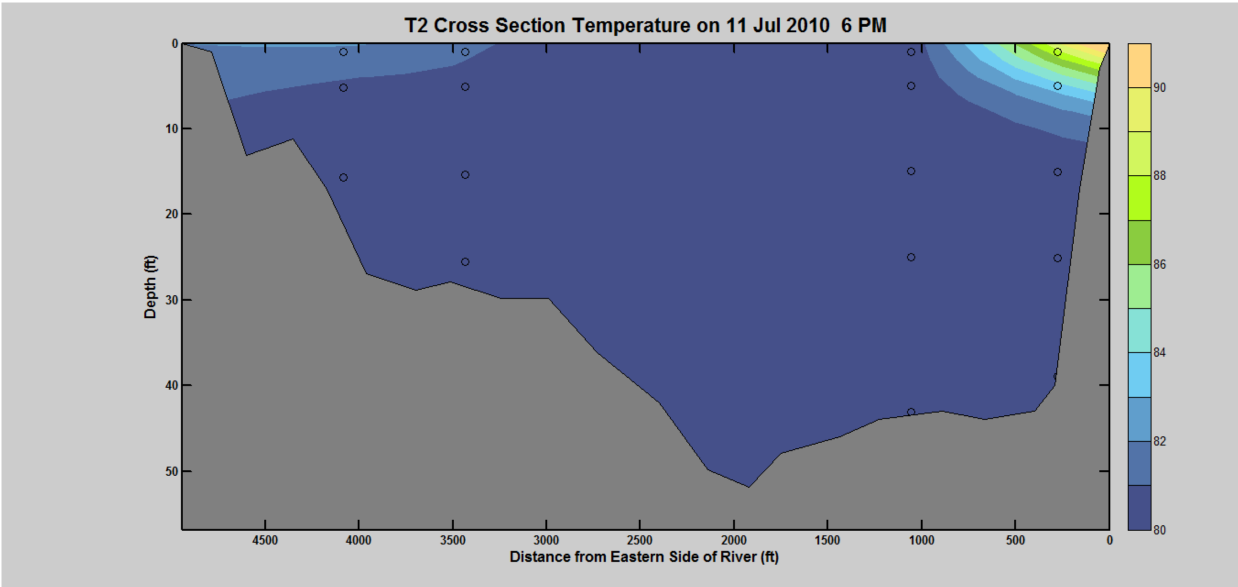

Figure 1-4. Vertical section of temperatures at T2 transect on 11 July 2010 at 1800 during maximum ebb. Color scale (in degrees F) shows the interpolated vertical temperature distribution.

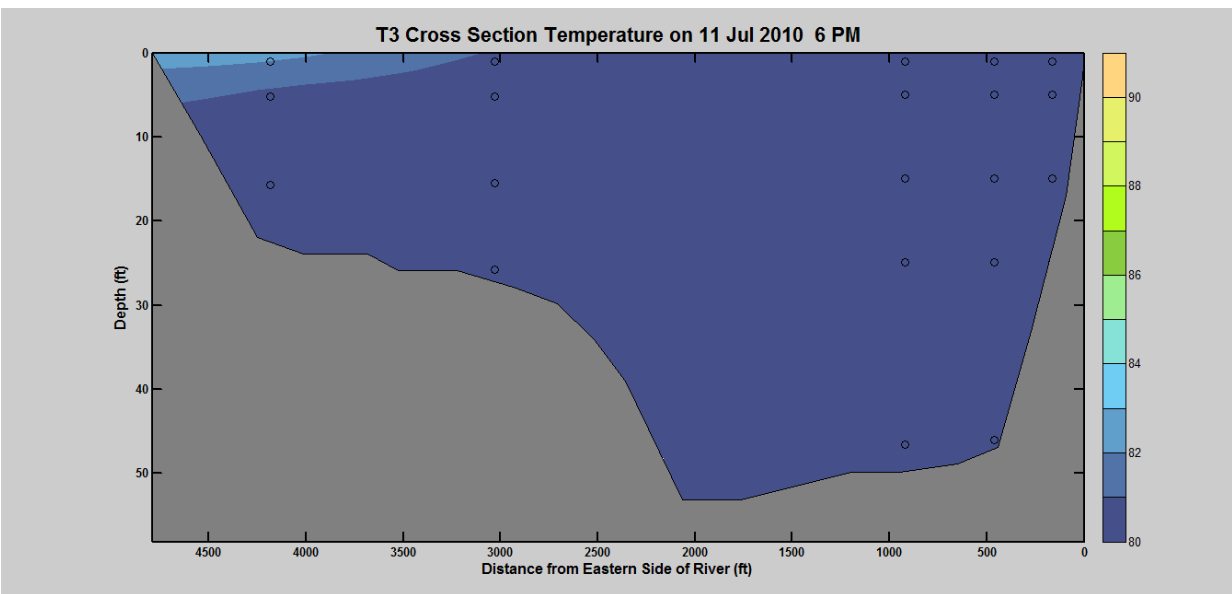

Figure 1-5. Vertical section of temperatures at T3 transect on 11 July 2010 at 1800 during maximum ebb. Color scale (in degrees F) shows the interpolated vertical temperature distribution.

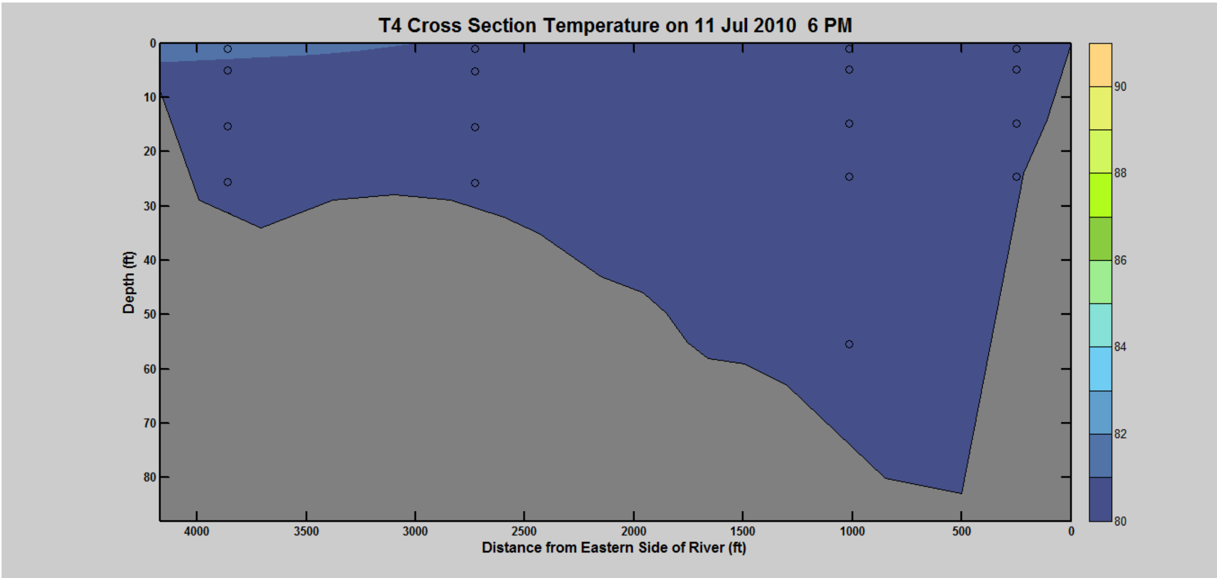

Figure 1-6. Vertical section of temperatures at T4 transect on 11 July 2010 at 1800 during maximum ebb. Color scale (in degrees F) shows the interpolated vertical temperature distribution.

The second set of contour plots (Figures 1-7 to 1-11) display the river temperature structure during the slack before flood on 11 July 2010 at 2000, occurring directly after the period as shown in the previous set of figures (maximum ebb on 11 July 2010 at 1800). Because this time occurs directly after ebb, when waters flow downstream, the temperatures are still slightly warmer downstream of the plant rather than upstream.

The vertical profiles from the same period indicate that the plume from the plant is confined to the near surface and close to the eastern shore (right side of figure). T1 (Figure 1-8) show slight warming in the surface layer, particularly in the western portion of the river, while T2 (Figure 1-9) shows slight warming in the surface layer mostly on the eastern side of the river. As expected, the transect closest to the plant, T3 (Figure 1-10), shows the largest thermal increase from the plant during this slack before flood tide. During this tidal phase, flow has not progressed to the upstream transect and there is no discernible evidence of the plume at T4 (Figure 1-11) anywhere in the water column.

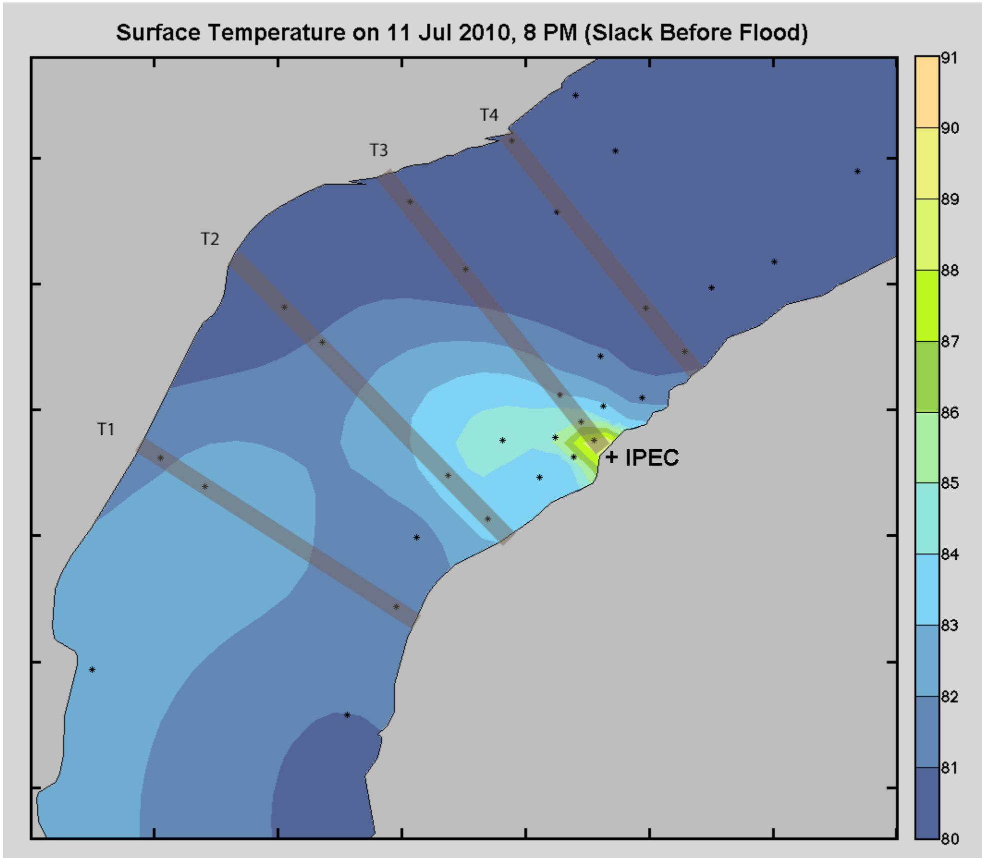

Figure 1-7. Plan view of surface temperatures near IPEC on 11 July 2010 at 2000 during slack before flood. Color scale (in degrees F) shows the interpolated horizontal temperature distribution.

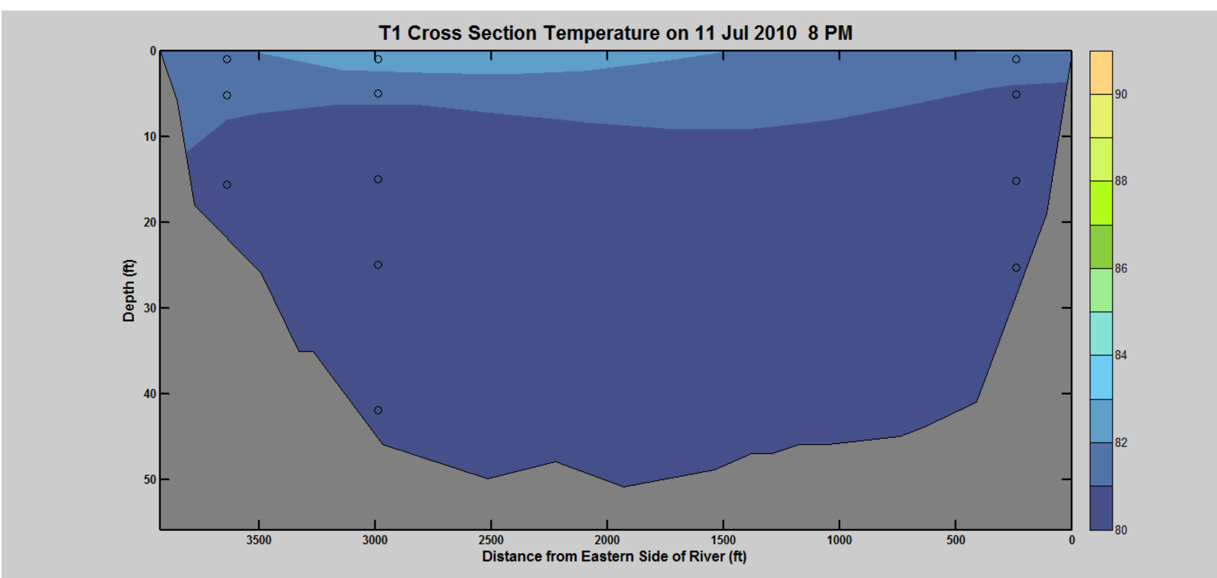

Figure 1-8. Vertical section of temperatures at T1 transect on 11 July 2010 at 2000 during slack before flood. Color scale (in degrees F) shows the interpolated vertical temperature distribution.

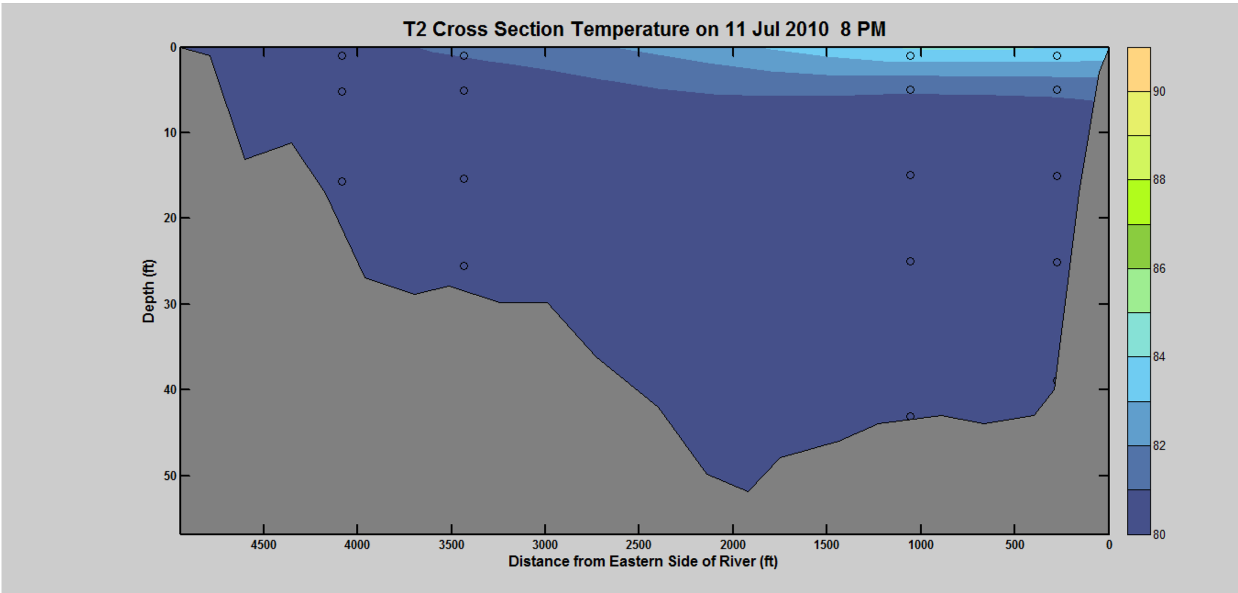

Figure 1-9. Vertical section of temperatures at T2 transect on 11 July 2010 at 2000 during slack before flood. Color scale (in degrees F) shows the interpolated vertical temperature distribution.

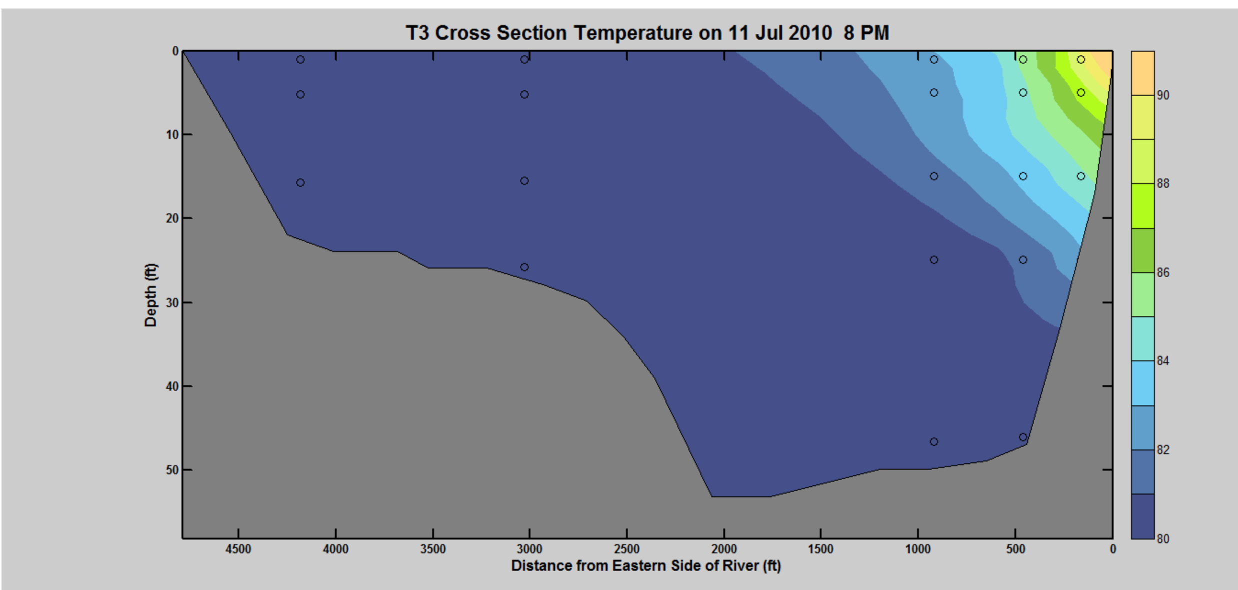

Figure 1-10. Vertical section of temperatures at T3 transect on 11 July 2010 at 2000 during slack before flood. Color scale (in degrees F) shows the interpolated vertical temperature distribution.

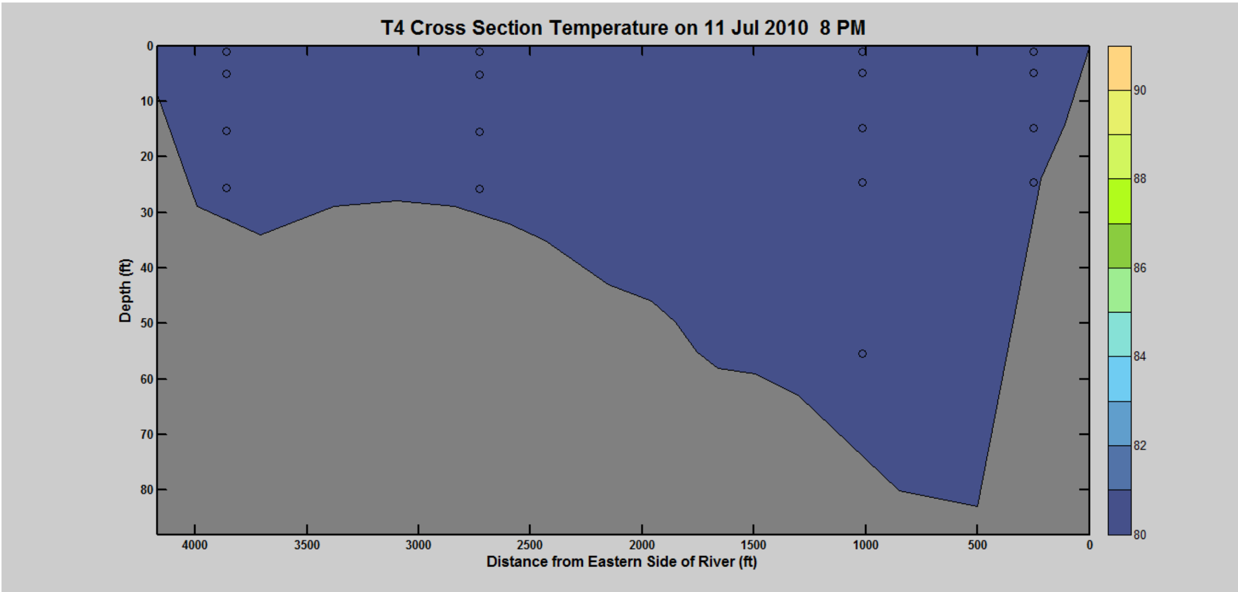

Figure 1-11. Vertical section of temperatures at T4 transect on 11 July 2010 at 2000 during slack before flood. Color scale (in degrees F) shows the interpolated vertical temperature distribution.

The final set of contour plots (Figures 1-12 to 1-16) display the temperature structure in the river during the slack before ebb tide stage on 12 July 2010 at 0200, occurring six hours after the period as shown in the previous five figures (slack before flood on 11 July 2010 at 2000). There is a preference for heating downstream of the plant over upstream, as shown by the elevated temperature tail migrating downstream along the eastern shoreline. The plume does not appear significantly upstream during this tidal current stage because the maximum upstream extent actually occurs approximately one hour earlier.

The vertical profiles taken at the same time show that the warmer waters during this time period are also confined to the near surface and remain close to the eastern shore (right side of figure). T1 (Figure 1-13) is not heated substantially during this period. However, at this time the depth of the 81 °F contour is the deepest of any of the other two tidal stages. This trend is similarly observed at the other three transects. At T2 (Figure 1-14), T3 (Figure 1-15), and T4 (Figure 1-16) there are apparent temperature inversions, whereby waters on the surface are slightly cooler than the waters just below them, and hypothesized to be the effects of radiative heat loss at nighttime. However, the plume only directly affects the T2 transect, just south of the IPEC discharge.

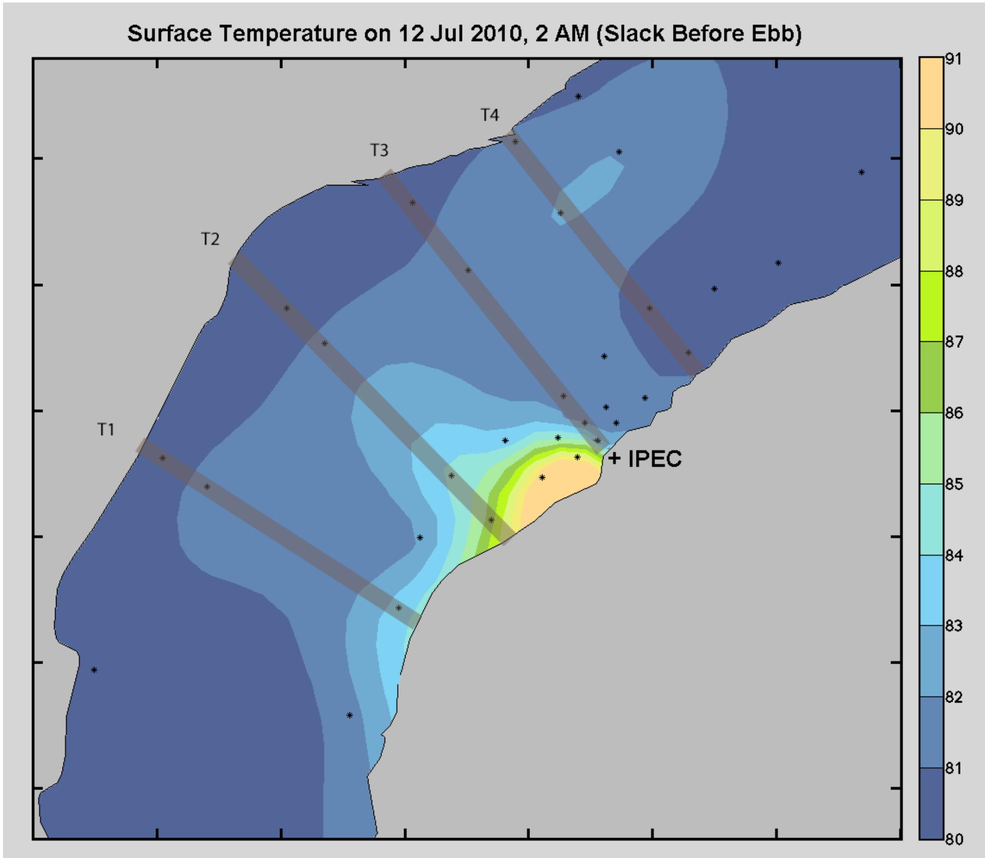

Figure 1-12. Plan view of surface temperatures near IPEC on 12 July 2010 at 0200 during slack before ebb. Color scale (in degrees F) shows the interpolated horizontal temperature distribution.

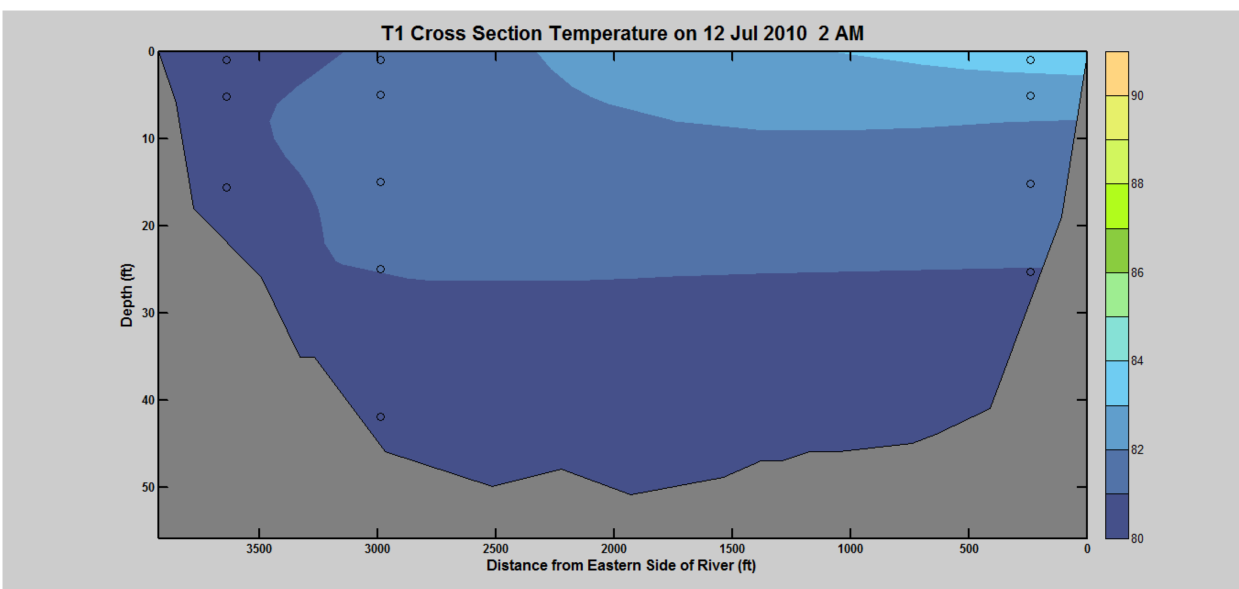

Figure 1-13. Vertical section of temperatures at T1 transect on 12 July 2010 at 0200 during slack before ebb. Color scale (in degrees F) shows the interpolated vertical temperature distribution.

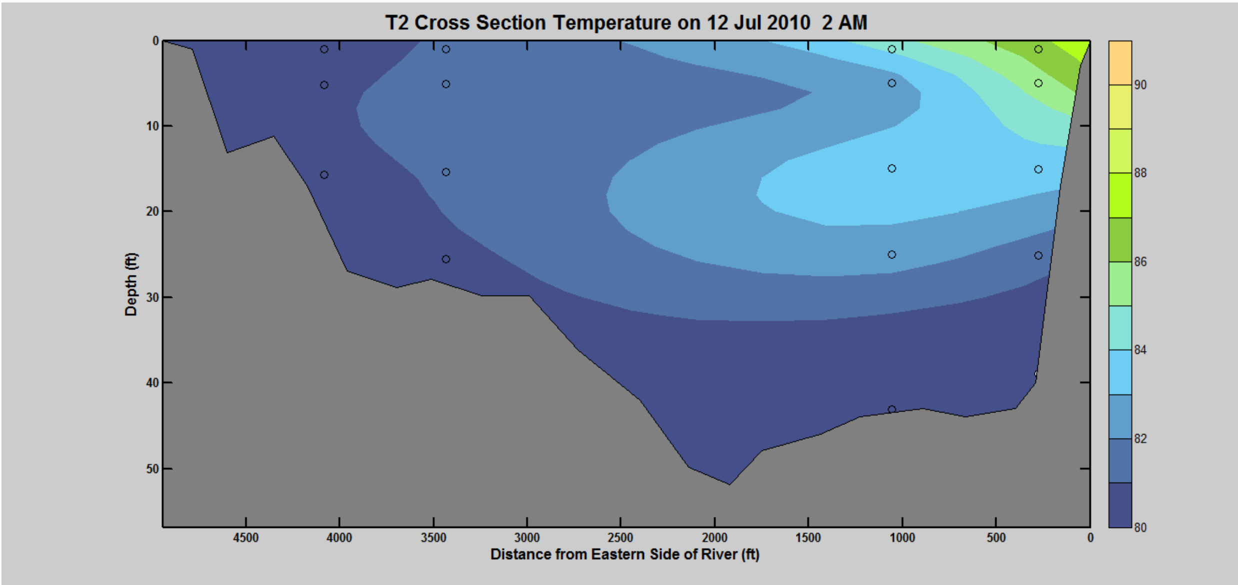

Figure 1-14. Vertical section of temperatures at T2 transect on 12 July 2010 at 0200 during slack before ebb. Color scale (in degrees F) shows the interpolated vertical temperature distribution.

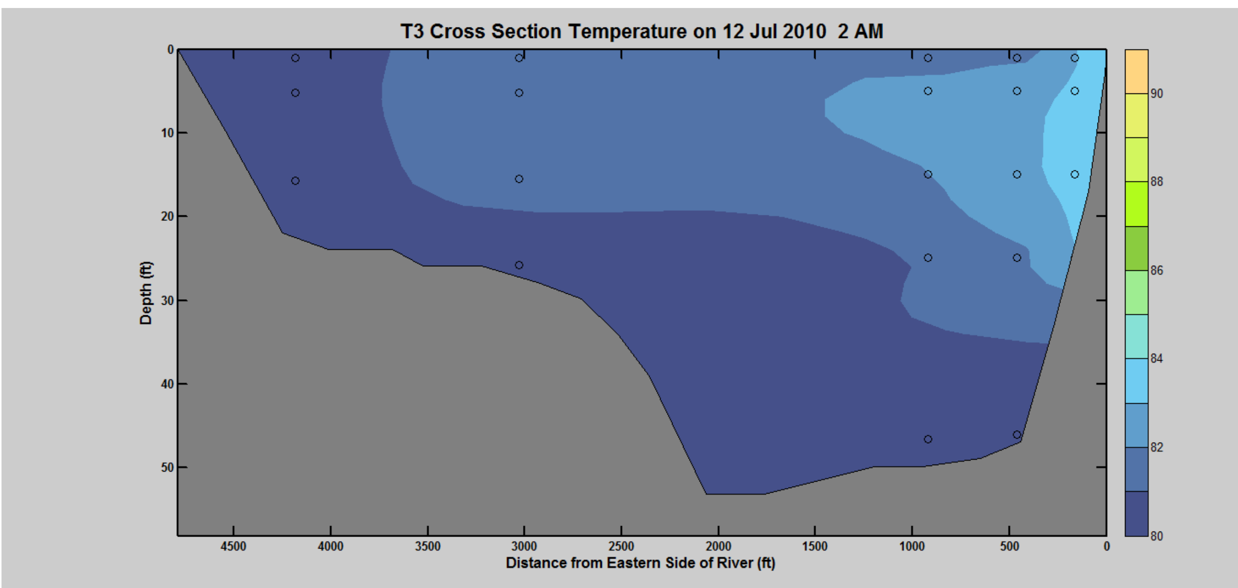

Figure 1-15. Vertical section of temperatures at T3 transect on 12 July 2010 at 0200 during slack before ebb. Color scale (in degrees F) shows the interpolated vertical temperature distribution.

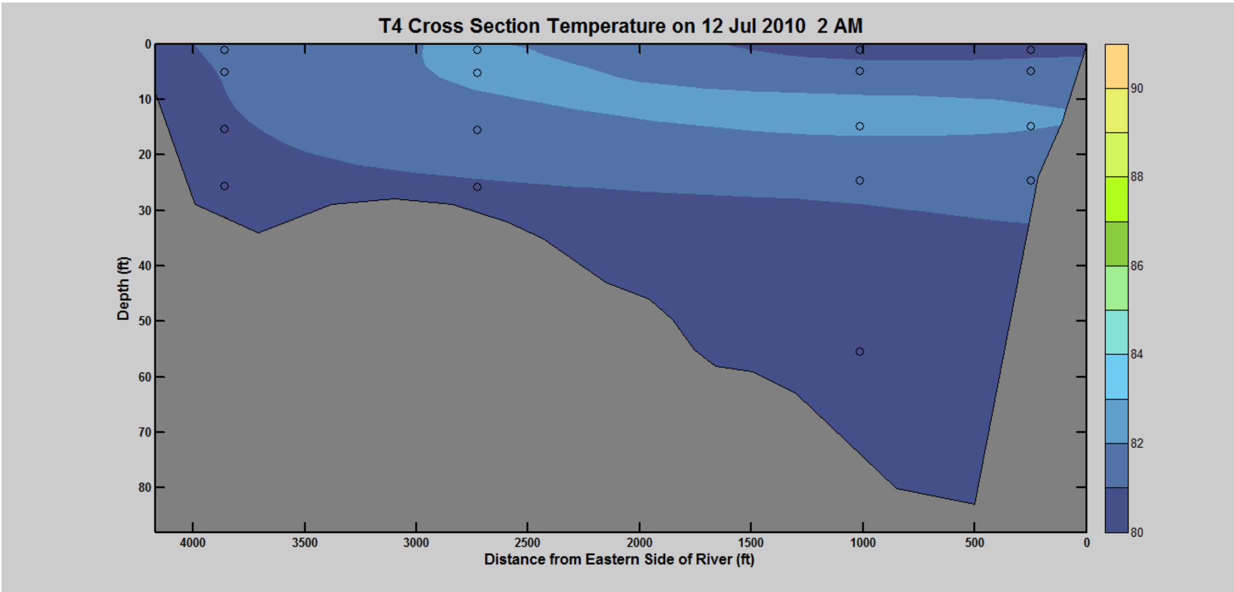

Figure 1-16. Vertical section of temperatures at T4 transect on 12 July 2010 at 0200 during slack before ebb. Color scale (in degrees F) shows the interpolated vertical temperature distribution.

NYSDEC (Section 4) Comment #2

Entergy needs to calibrate the model to more accurately match observed data (modeling protocol/best practice norms/limit, to bring the calculated temperature values to within one-half degree (0.5°F). The variation in criteria temperature is in the range of 1.5-4°F for various sections of 6NYCCR Part 704.2(b)(5). Plots for stations: 17 thru 33 must be updated and submitted with revised sections of the report.

ASA Response

The first portion of the response deals with the correlation between observations and model predictions. During our meeting with NYSDEC on 24 March 2011 it was agreed that a comparison of the difference between model predictions and observations was a good and sufficient statistical measure to establish model validation. This measure can be expressed as the difference between the average of model predictions and the average of observations, which we calculated for each station and then took the average of all stations. Using all 66 surface and 66 bottom thermistors from the 3-week validation period from the 2010 field program and modeling analysis we get values of 1.44°F (0.80°C) at the surface and 0.84°F (0.46°C) at the bottom with an average of 1.14°F (0.63°C).

ASA also has reviewed similar studies under NYSDEC jurisdiction to understand the measures of acceptable approaches/performance. We specifically examined other recent studies available for New York triaxial studies where both a hydrothermal model and a field observation program were utilized to compare their error estimates to the 0.5°F (0.28°C) level suggested by NYSDEC:

- *HydroQual, 2005. Near-Field and Far-Field Modeling Studies for the R. E. Ginna Nuclear Power Plant. Prepared for Constellation Energy, Ontario, NY.* Only a qualitative model / data comparison was made by plotting time series for a 4-day segment of an 11-day field program utilizing four locations with thermistors at surface and bottom. Based on an estimate from the time series, the average of the absolute mean errors for all the stations is approximately 1.8°F (1°C). No quantitative statistics were reported. No model validation was performed.

- *HydroQual, 2009. Near-Field and Far-Field Modeling Studies for the Nine Mile Point Unit 1 and 2. Prepared for Constellation Energy, Ontario, NY.* A quantitative model / data calibration was made for a 3-day segment of an 11-day field program utilizing four locations with thermistors at surface and bottom. The average of the station model / data bias (defined as the difference of the average observed temperature and the average model computed temperature) estimates for the calibration was 0.66°F (0.37°C) at the surface and 0.38°F (0.21°C) at the bottom. There was no validation of the model.

- *Lowe, S.A., F. Schuepfer, and D.J. Dunning, 2009. Case Study: Three dimensional Hydrodynamic model of a power plant discharge. ASCE Journal of Hydraulic Engineering, Vol. 135, No. 4, April 2009.* A quantitative model / data calibration and validation was performed for the Poletti thermal discharge using a data set of eight surveys over two days with data collected at four depths at three stations. The average of the station "mean absolute error" estimates between model and data for calibration was 0.23°F (0.13°C). The average of the station "mean absolute error" estimates between model and data for validation was 1.67°F (0.93°C).

None of these studies showed performance of better than (less than) 0.5°F (0.28°C). Further, the calibration performance for Indian Point exceeded the validation performance as shown by the Lowe study of the Poletti thermal discharge. Indeed, the Indian Point study was significantly better (less) at 1.14°F (0.63°C) than the Lowe study at 1.67°F (0.93°C).

During the March 24 meeting, model accuracy was also discussed relative to the compliance criteria. The model accuracy in terms of predicting absolute temperatures was proven reasonable specifically with respect to the predicted area above 90°F, of which there are multiple observation stations close to the plant which had good model agreement. With respect to determining temperature rise (delta T), it should be noted that since the environmental background results are subtracted out from the actual (with plants) case, the margin of error is reduced for these delta T predictions.

The second portion of the response deals with the presentation of additional time series plots of observations and model predictions. Model to observation graphical comparisons for stations 17 through 33 (except stations 27 and 29 previously provided in the report) follow below in Figure 2-1 through 2 -15 as requested by NYSDEC. Note that, as previously described in Comment Response #8, some of the near field thermistor locations are within the area defining the initial plume distribution (Stations 24, 25, 26 and 30). Therefore, some larger variances in plume signal compared to observed temperatures within the initial plume zone were not considered significant as the stations immediately outside the initial distribution captured the signal well, as represented by Stations 23, 27 and 31. Some of the other differences may be due to the modeled location of the plume being shifted slightly horizontally due to modeled current shear from the physical thermistor location. A choice of an adjacent model grid cell may more closely reflect the observed temperature. For example, Figure 2-16 shows a plot of observed and model predicted at station 33 as well as the model predicted temperatures in the grid cell next to the station 33 location, which shows a better match to observations. In any event the temperature offset seen between model and data at some stations does not affect the determination of modeled temperature rise since the offset is essentially eliminated when the ambient model run (no plant on) is subtracted from the "with plant on" model run to determine the temperature rise.

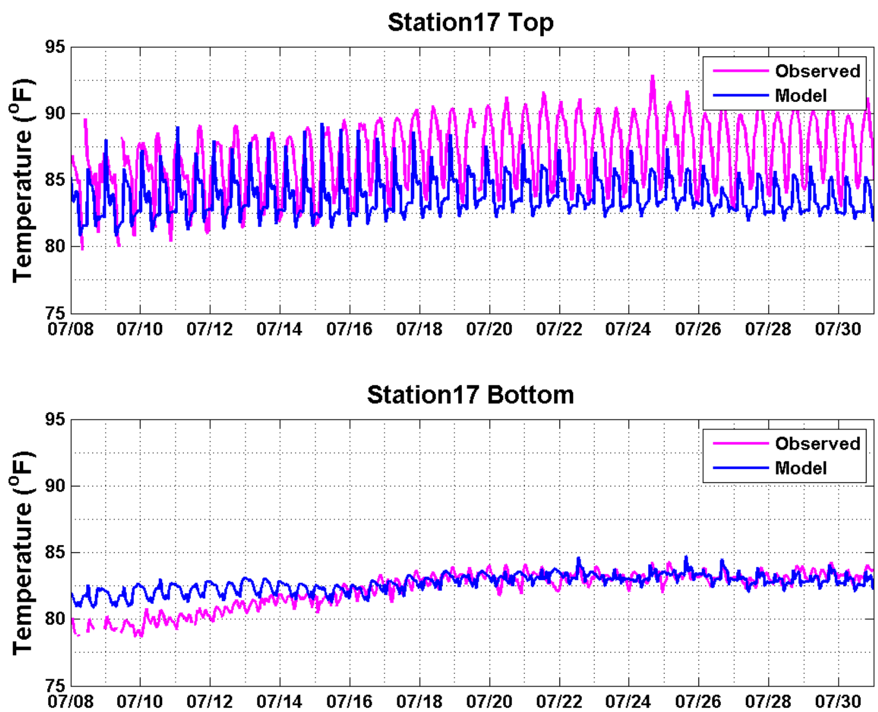

Figure 2-1 Time series of model vs. observed temperatures at station 17 during 2010 validation period

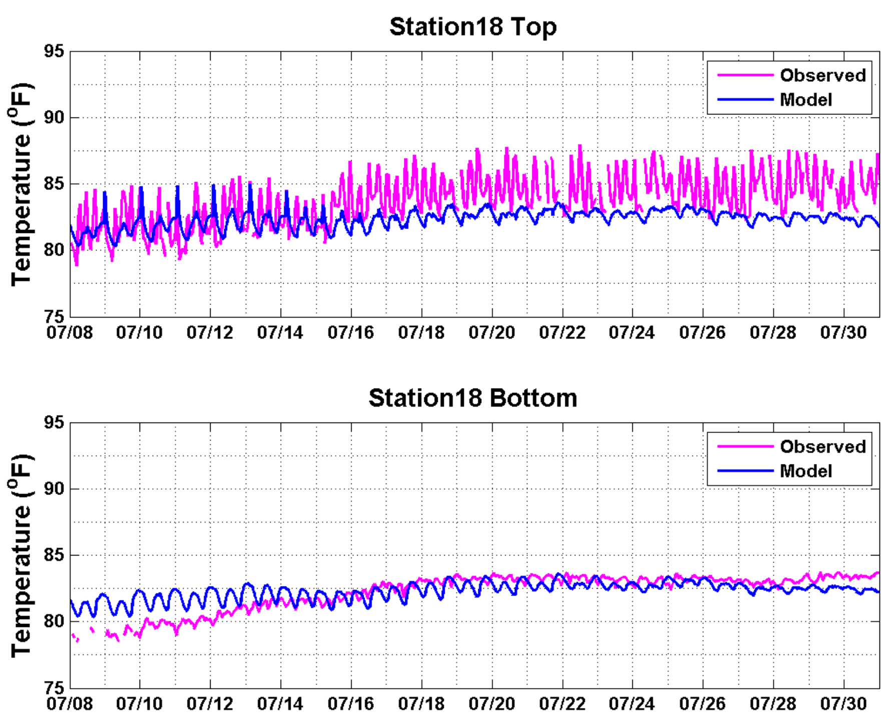

Figure 2-2 Time series of model vs. observed temperatures at station 18 during 2010 validation period

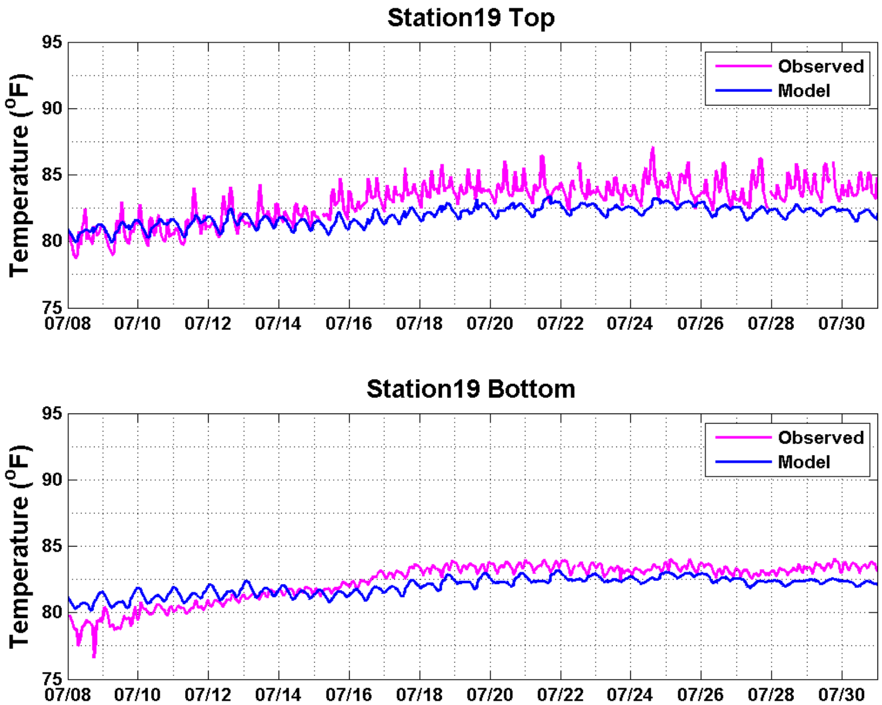

Figure 2-3 Time series of model vs. observed temperatures at station 19 during 2010 validation period

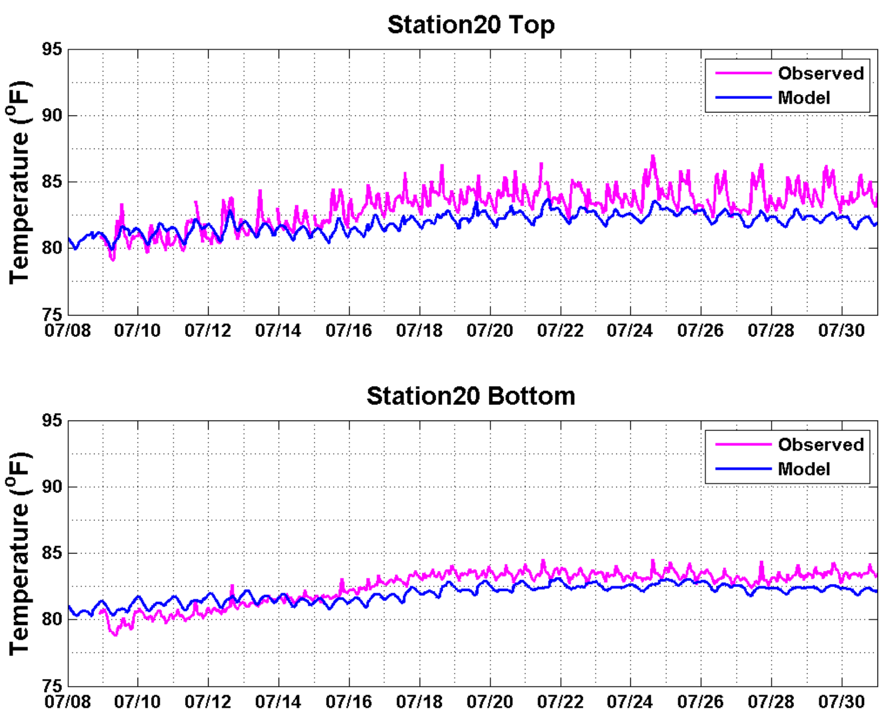

Figure 2-4 Time series of model vs. observed temperatures at station 20 during 2010 validation period

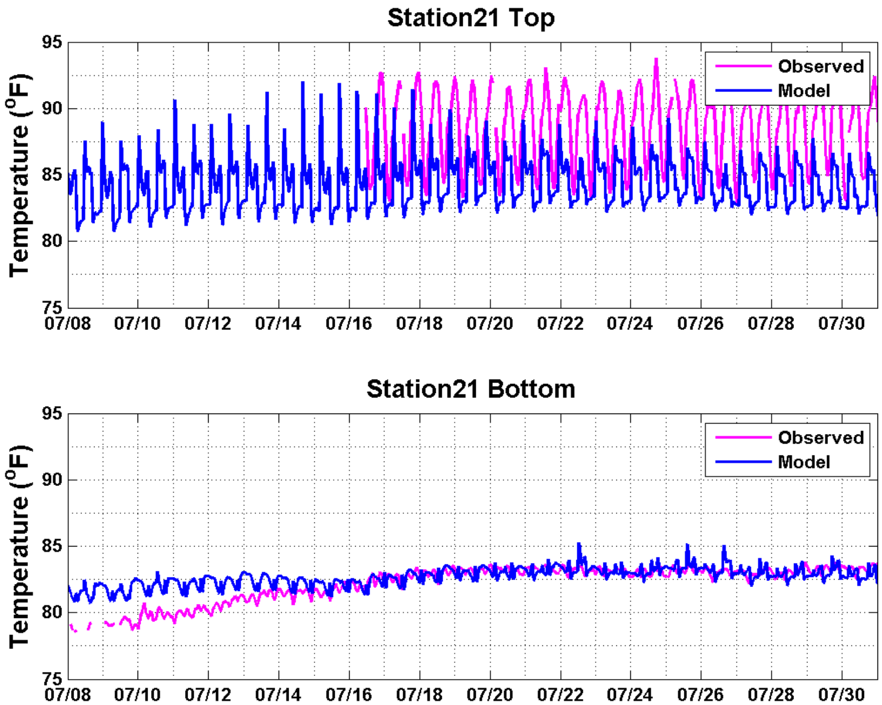

Figure 2-5 Time series of model vs. observed temperatures at station 21 during 2010 validation period

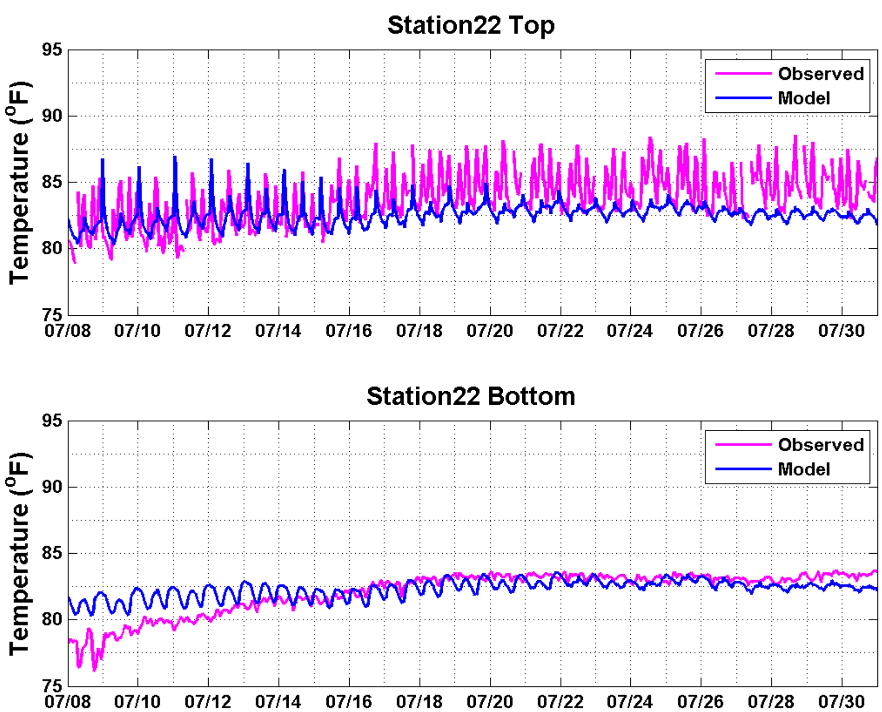

Figure 2-6 Time series of model vs. observed temperatures at station 22 during 2010 validation period

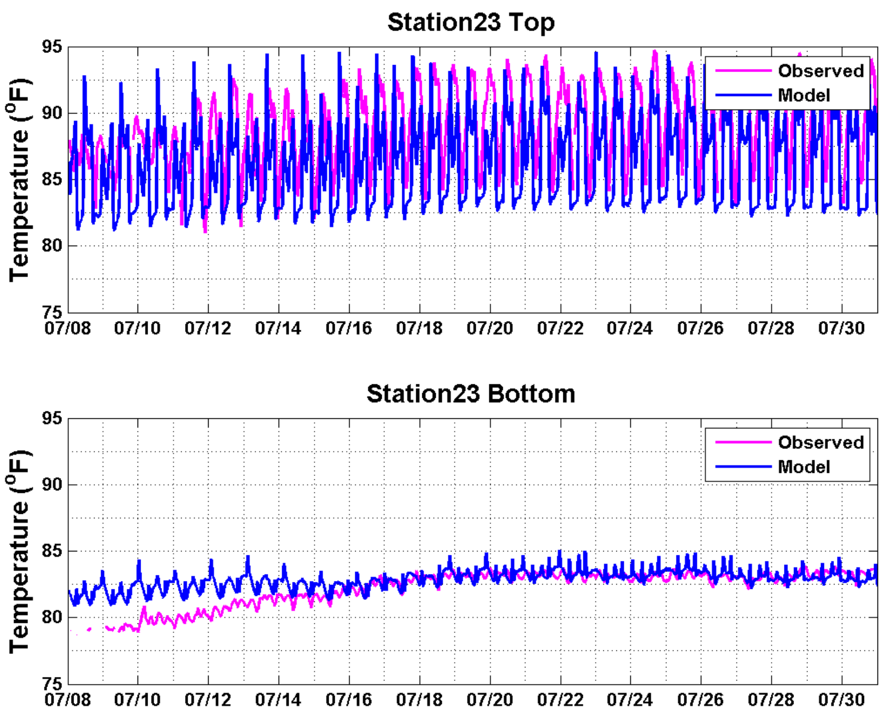

Figure 2-7 Time series of model vs. observed temperatures at station 23 during 2010 validation period

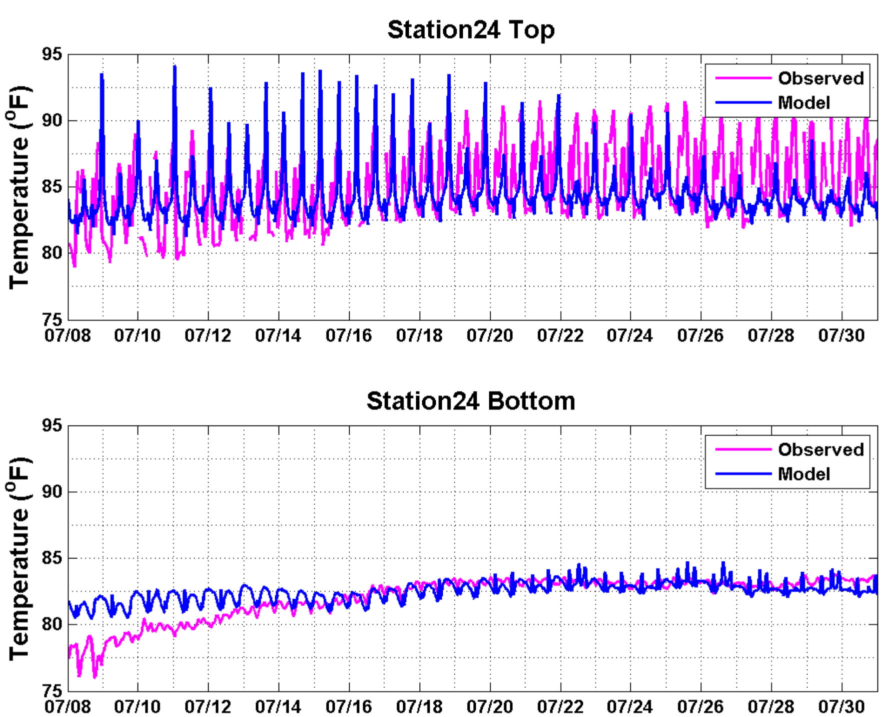

Figure 2-8 Time series of model vs. observed temperatures at station 24 during 2010 validation period

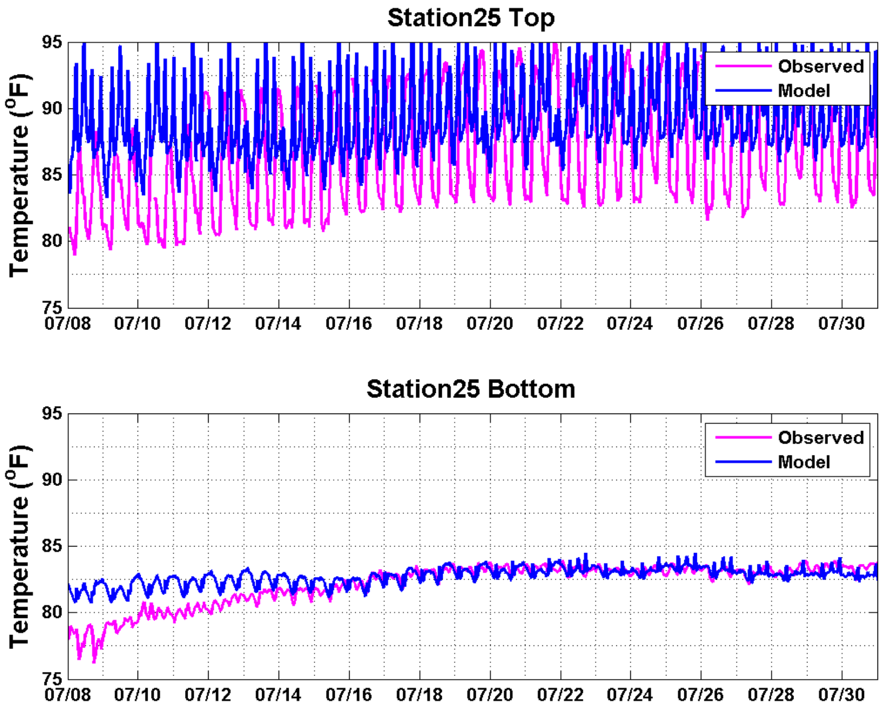

Figure 2-9 Time series of model vs. observed temperatures at station 25 during 2010 validation period

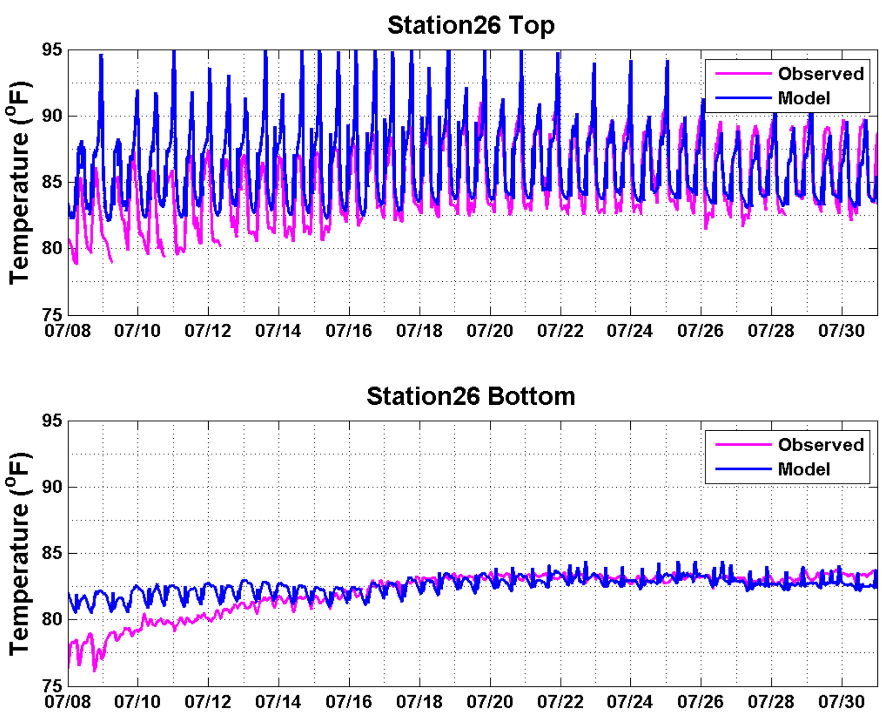

Figure 2-10 Time series of model vs. observed temperatures at station 26 during 2010 validation period

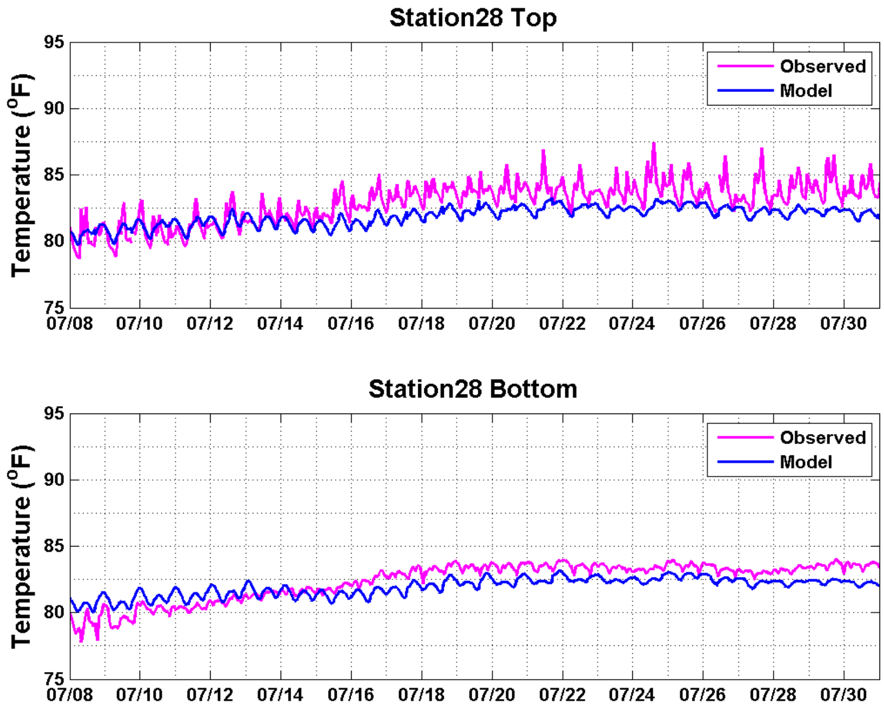

Figure 2-11 Time series of model vs. observed temperatures at station 28 during 2010 validation period

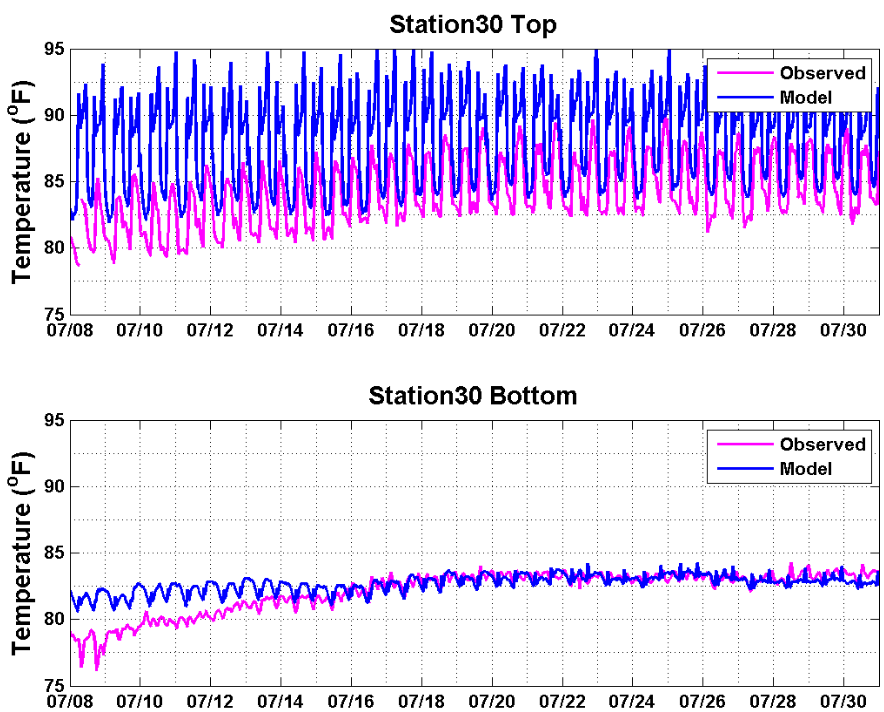

Figure 2-12 Time series of model vs. observed temperatures at station 30 during 2010 validation period

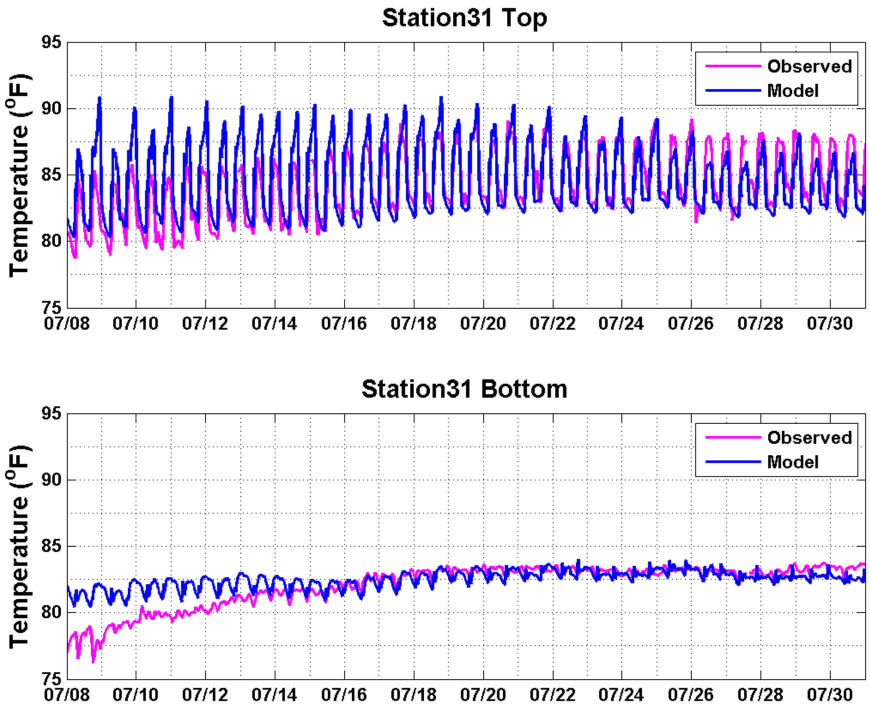

Figure 2-13 Time series of model vs. observed temperatures at station 31 during 2010 validation period

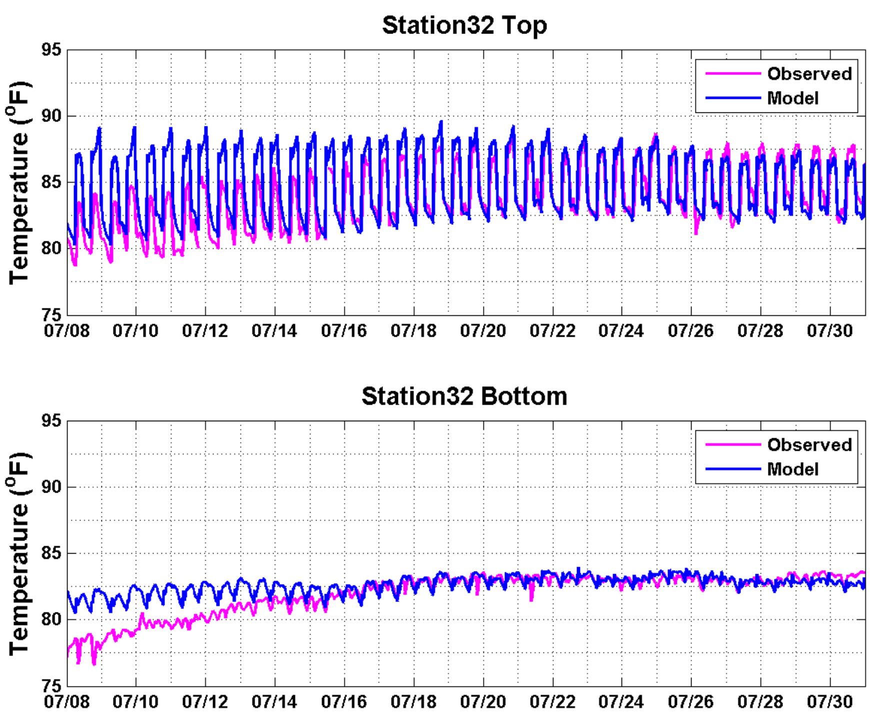

Figure 2-14 Time series of model vs. observed temperatures at station 32 during 2010 validation period

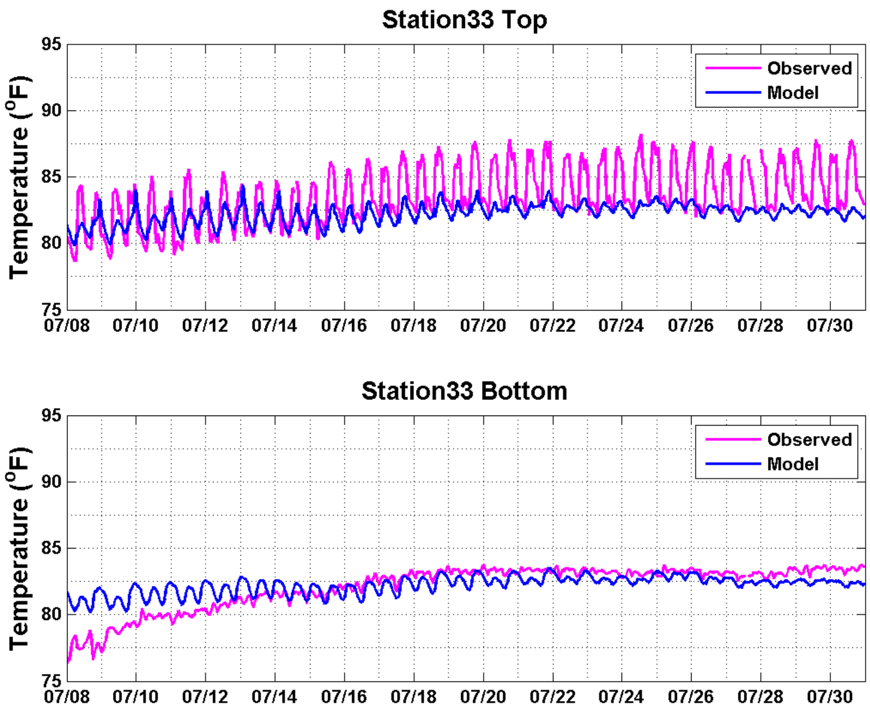

Figure 2-15 Time series of model vs. observed temperatures at station 33 during 2010 validation period

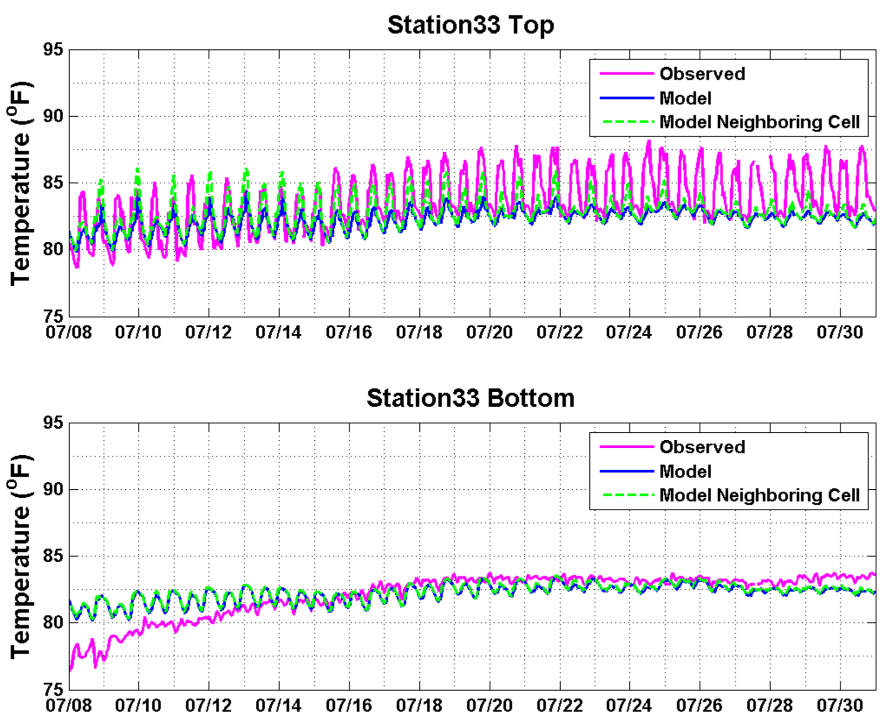

Figure 2-16 Time series of model vs. observed temperatures at station 33 during 2010 validation period that includes the model output at the a grid cell next to station 33

NYSDEC (Additional Comments) Comment #7

DEC staff request the actual aerial delineation of IPEC thermal plume during the field surveys and comparison with the model projected spatial extents of the thermal plume. An explanation should be provided relating to the model reproduction of the dimensional extents of the thermal plume.

ASA Response

The extent of the surface thermal plume is relative to the temperature increase by which it is defined, which in this case is a 4^{o}F increment over ambient. The 4^{o}F plume changes in size and shape depending on the stages of the tide. The 4^{o}F plume was determined for seven different tidal current stages (discrete times) over a tidal cycle to illustrate the variable spatial extent of the 4^{o}F plume. This variable spatial extent is presented for both model predictions and observations over the same tidal cycle using the process described below.

Determination of the model-predicted 4^{o}F plume is based on subtracting the results from an environmental background model run (real tides and other environmental conditions but no plant loads) from the actual model run (real tides and environmental conditions and with plant loads) at every grid cell in the model domain. This differencing results in a delta T representing temperatures in excess of ambient or environmental background. The extent of the model-predicted 4°F plume for seven representative stages of the tidal currents is shown in Figure 7-1.

Determination of the 4^{o}F plume from field observations in areas affected by the plant discharge requires development of an ambient condition (free from plant loads). Since there is only a discrete set of measurements at observation stations, numerical contouring methods (i.e., interpolation and extrapolation) are necessary to resolve the temperature distribution between observation stations. In order to estimate the spatial extent of a 4^{o}F plume based on measurements at the seven representative stages of the tide (similar to the analysis performed on model output discussed above) three steps were followed.

First, the surface modeled ambient temperature at each thermistor location at the appropriated time of tidal current stage was subtracted from the value observed at the same location and time. The thermistors where this subtraction was performed included stations 13, 15, 16, 17, 18, 19, 20, 25, 26, 27, 28, 29, 35, 34, 35, 36 and 37.

Second, a numerical contouring method for filling data gaps among stations was used to generate the spatial distribution of temperature rise over the ambient temperature. A numerical contouring method that is widely used in topographic mapping, which accurately represents the geospatial relationships among irregularly spaced observation locations, was applied by using a Matlab® software routine based on the combination of three interpolation functions (nearest neighbor interpolation, triangle linear interpolation and bilinear (tensor product linear) interpolation) via laplacian regularization (for details see http://www.mathworks.com/matlabcentral/fx_files/8998/2/content/gridfitdir/demo/html/gridfit_demo.html). It should be noted that although a sophisticated approach was used, the limitations of the contouring process using irregularly spaced observations (due to the requirement that no thermistor stations be located in the shipping channel) can sometimes result in inaccurate interpolations, for example extending the thermal plume past its actual dimensions.

Finally, once the spatial data gaps were filled in, the extent of the 4°F plume was drawn as a temperature rise of 4^oF higher than the time varying modeled ambient temperature, as was done for the model predicted temperature rise. Figure 7-2 illustrates the resulting 4^oF plume extent defined by the observations while also showing the locations of the thermistor stations used in the analysis.

As can be seen by comparing Figure 7-1 and 7-2 there is generally good agreement between model predictions and observations in the temporal variability of spatial extent of the 4^oF surface plume. However, there are some differences in the results stemming from some variances in model predictions compared to observations or from limitations of contouring based on irregularly spaced observations. For example, the model predictions show a maximum ebb extent further downstream than the observations. This is likely caused by an overprediction by the model at certain locations downstream of the observed maximum ebb plume (Figure 7-1).

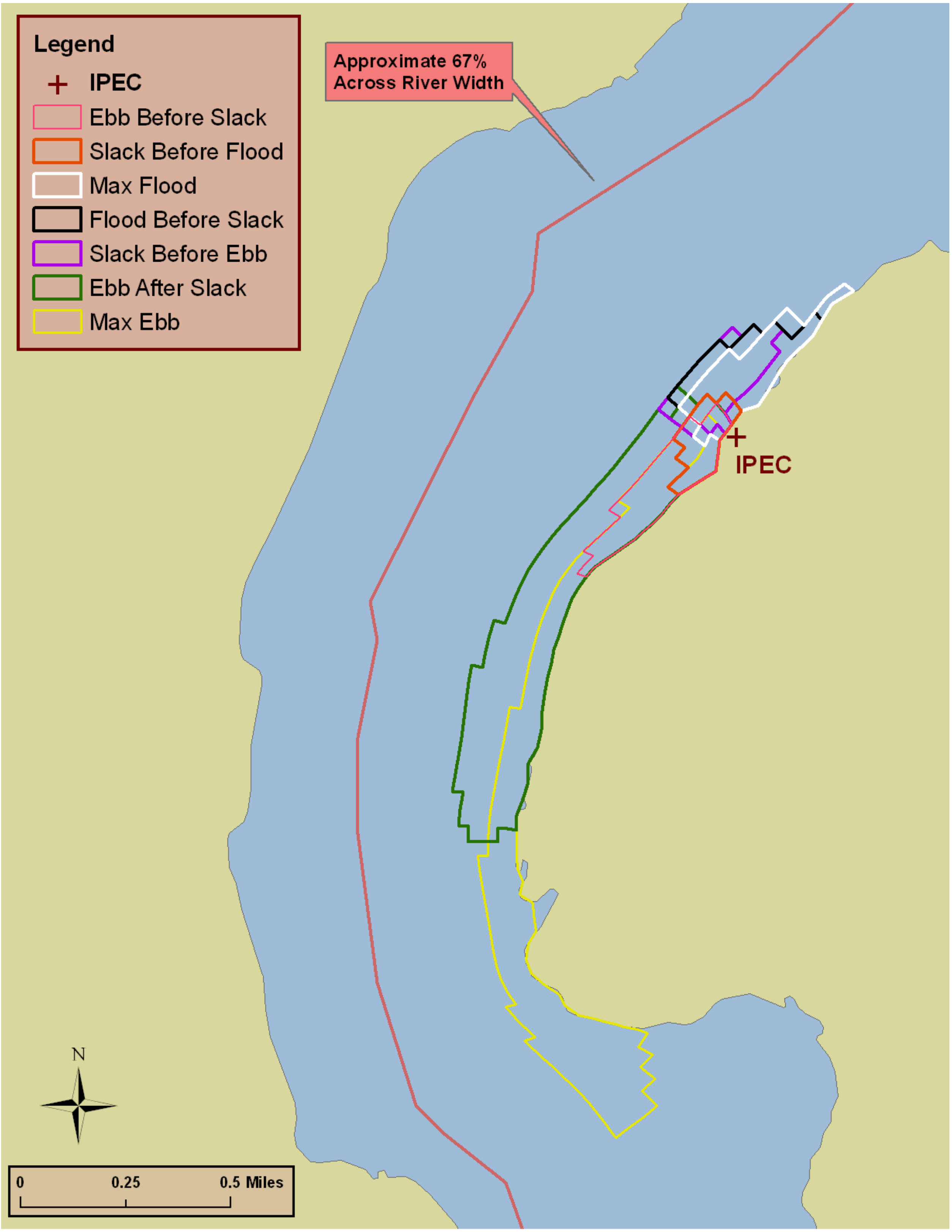

Figure 7-1 Extent of the 4°F plume over a tidal cycle using model predictions

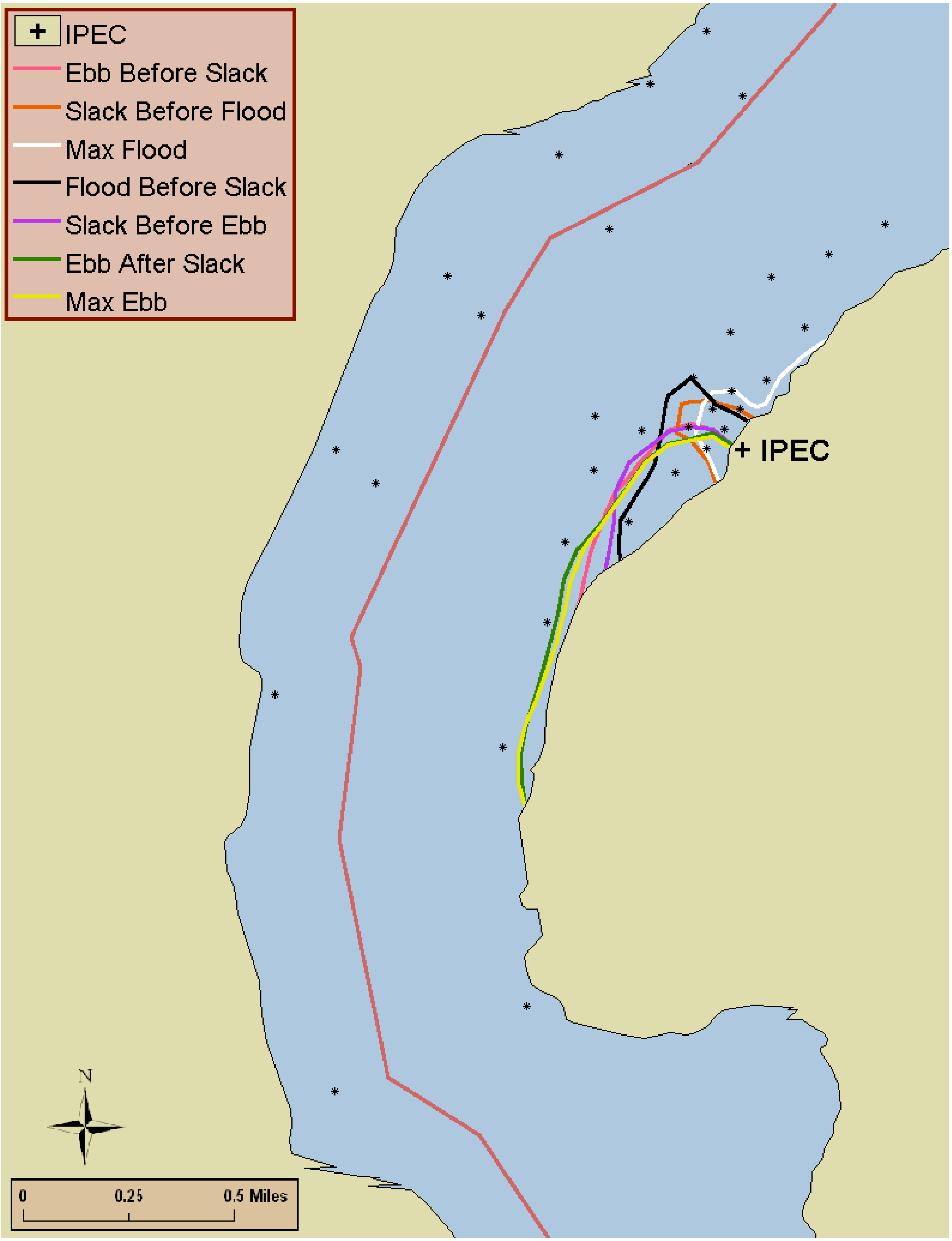

Figure 7-2 Extent of the 4°F plume over a tidal cycle using contoured observed temperatures with modeled ambient subtracted