Enclosure 3

Summer 2011 Compliance Survey for Watts Bar Nuclear Plant Outfall Passive Mixing Zone

TENNESSEE VALLEY AUTHORITY
River Operations

SUMMER 2011 COMPLIANCE SURVEY FOR WATTS BAR NUCLEAR PLANT OUTFALL 113 PASSIVE MIXING ZONE

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EXECUTIVE SUMMARY

The National Pollutant Discharge Elimination System (NPDES) Permit No. TN0020168 for Watts Bar Nuclear Plant (WBN) identifies the discharge of water to the Tennessee River from the Supplemental Condenser Cooling Water (SCCW) System as Outfall 113. Furthermore, the permit identifies that when there is no flow released from Watts Bar Dam (WBH), the effluent from Outfall 113 shall be regulated based on a passive mixing zone extending in the river from bank-to-bank and 1,000 feet downstream from the outfall. Compliance with the requirements for the passive mixing zone is to be achieved by two annual instream temperature surveys–one for winter conditions and one for summer conditions. Summarized in this report are the measurements, analyses, and results for the passive mixing zone survey performed for 2011 summer conditions. The survey was conducted between 21:00 CDT on August 30 and 05:00 CDT on August 31 (eight hours) and included the collection of temperature data at twelve temporary monitoring stations deployed across the downstream end of the passive mixing zone during a period of no flow in the river. The data were analyzed to determine the three instream compliance parameters specified in the NPDES permit for the outfall: the 1-hour average temperature at the downstream end of mixing zone, T_d; the 1-hour average temperature rise from upstream to the downstream end of the mixing zone, ΔT; and the 1-hour average temperature rate-of-change at the downstream end of the mixing zone, TROC. The measured parameters were compared to predicted values from the thermal plume model used by TVA to help determine the safe operation of Outfall 113. The results of the comparisons, in terms of maximum values observed during the no flow event, are as follows:

Compliance Parameter	Model	Measured	NPDES Limit
Maximum T_d	80.8°F	80.6°F	86.9°F
Maximum ΔT	1.5 F°	1.6 F°	5.4 F°
Maximum |TROC|	0.6 F°/hour	0.2 F°/hour	3.6 F°/hr

As shown, both the model and measured values were well below the NPDES limits for all the compliance parameters. Except for the maximum ΔT, values predicted by the model were larger than those measured in the survey. The maximum value of ΔT from the model underpredicted the measured value by 0.1 F°. This difference was caused by unnatural cooling of the upstream ambient temperature from leakage of cold water through Watts Bar Dam. Based on this, as well as the fact that differences of magnitude 0.1 F° easily fall within the factor of safety currently used in performing hydrothermal forecasts, the thermal plume model is yet considered fully adequate for determining the safe operation of the SCCW system. That is, in combination with TVA procedures for predicting the impact of the Outfall 113 effluent, the model continues to provide a high level of confidence that the SCCW system is being operated in a manner that does not exceed the instream limits for T_d, ΔT, and TROC as specified in the WBN NPDES permit.

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INTRODUCTION

Outfall 113 for the Watts Bar Nuclear Plant (WBN) includes the discharge of water to the Tennessee River from the Supplemental Condenser Cooling Water (SCCW) system. Due to the dynamic behavior of the thermal effluent in the river, the National Pollutant Discharge Elimination System (NPDES) Permit No. TN0020168 for the plant specifies two mixing zones for Outfall 113—one for active operation of the river and one for passive operation of the river (TDEC, 2010). The passive mixing zone corresponds to periods when the operation of Watts Bar Dam (WBH) produces no flow in the river (i.e., hydropower and/or spillway releases). The dimensions of the passive mixing zone extend from bank-to-bank and downstream 1,000 feet from the outfall. The active mixing zone applies to all other river flow conditions. The dimensions of the active mixing zone include the right-half of the river (facing downstream) and extend downstream 2,000 feet from the outfall. The passive and the active mixing zones are shown in Figure 1.

Table 1 summarizes the NPDES instream temperature limits for Outfall 113. The limits apply to both the active and passive mixing zones. Compliance for the active mixing zone is monitored by permanent instream water temperature stations situated in the right-half of the river. Due to issues associated with placing permanent stations in the left-half of the river, which contains the navigation channel, a thermal plume model is used to determine the safe operation of Outfall 113 for the passive mixing zone. To verify the thermal plume model, the NPDES permit specifies that two instream temperature surveys shall be conducted each year—one for winter conditions and one for summer conditions. The purpose of this report is to present the results for the passive mixing zone temperature survey performed for summer 2011 conditions. The survey was conducted between 21:00 CDT on August 30 and 05:00 CDT on August 31 (total eight hours). Provided is a brief summary of the survey method, presentations of the measurements and analyses, and discussions of the results and conclusions.

Table 1. NPDES Temperature Limits for Outfall 113 Mixing Zones

Compliance Parameter	Sampling Period	NPDES Limit
Maximum Temperature, Downstream End of Mixing Zone, T_d	Running 1-hr	86.9°F
Maximum Temperature Rise, Upstream to Downstream, ΔT	Running 1-hr	5.4 F°
Maximum Temperature Rate-of-Change, TROC	Running 1-hr	±3.6 F°/hr

INSTREAM SURVEY

The instream survey included the deployment of temporary water temperature stations at twelve locations across the downstream end of the passive mixing zone. Data from these and other monitoring stations were analyzed to obtain measured values for the compliance parameters listed in Table 1. These were then compared with the corresponding values estimated from the SCCW thermal plume model.

The method of conducting the instream survey is the same as that used for the first such survey, performed for winter conditions on May 6, 2005 (McCall and Hopping, 2005). Table 2 provides a summary of the sources of data for the survey. WaterView, a monitoring system for tracking hydroplant operation and performance, was used to obtain measurements for the river discharge from Watts Bar Dam. The WBN Environmental Data Station (EDS) provided measurements from existing permanent monitoring stations for the nuclear plant. These included:

- The river upstream (ambient) water temperature, measured at the EDS Station 30, which is located at the exit of the powerhouse of Watts Bar Dam.
- The river water surface elevation (WSEL) at the EDS Station 30, also known as the tailwater elevation (TWEL) at Watts Bar Dam.
- The SCCW effluent temperature, measured at the EDS Station 32, which is located at the SCCW outfall.
- The SCCW effluent discharge, measured at the EDS Station 32.
- The local air temperature, measured at the EDS meteorological tower.

Table 2. Sources of Data for Passive Mixing Zone Survey

Data	Source	Frequency
River Discharge from Watts Bar Dam	WaterView	1 min
River ambient water temperature	WBN EDS Station 30 (Tailwater at WBH)	15 min
River water surface elevation	WBN EDS Station 30 (Tailwater at WBH)	15 min
SCCW effluent temperature	WBN EDS Station 32 (SCCW Outfall 113)	15 min
SCCW effluent discharge	WBN EDS Station 32 (SCCW Outfall 113)	15 min
Air temperature	WBN EDS Met Tower	15 min
Passive mixing zone water temperature	Temporary HOBO Monitors	1 min

The water temperature at the downstream end of the Outfall 113 passive mixing zone was measured by the aforementioned temporary water temperature stations. Using a global positioning system (GPS) device, the stations were positioned at roughly equal intervals across the river, as shown in Figure 2. The temporary stations recorded water temperatures by using HOBO temperature monitors positioned at depths of 0.5, 3, 5, and 7 feet below the water surface. Shown in Figure 3 is a schematic of the temporary stations. The stations included a string of

HOBO monitors suspended from a tire float, with weights to anchor the station and to keep the sensor string vertical in the water column. The water temperature sensors imbedded in the HOBO monitors have an accuracy of about ±0.4 F° and resolution of about 0.04 F°, which is comparable to the accuracy and resolution of temperature sensors used elsewhere by TVA for NPDES thermal compliance. The HOBO monitors include an internal data acquisition unit that was programmed to collect measurements once per minute. All the temperature probes used in the survey, including both those contained in the HOBO monitors and the thermistors at the permanent EDS monitoring stations, were calibrated by a quality program with equipment accuracies traceable to the National Institute of Standards and Technology (NIST). The calibration procedure is summarized in APPENDIX A. The temporary monitoring stations were deployed several hours before the beginning of the survey, and retrieved several hours after the end of the survey.

RESULTS

River Conditions

Figure 4 shows the measured ambient conditions of the river during the survey. Included are the river discharge, the river tailwater elevation, and river temperature at the exit of Watts Bar Dam. The river temperature at the exit of Watts Bar Dam serves as the upstream ambient river temperature for WBN Outfall 113. To provide a period of no flow in the river, releases from Watts Bar Dam were suspended between about 21:00 CDT on August 30 and 05:00 CDT on August 31, a total of eight hours (nighttime). Leading up to the survey, as the river flow was stepping down, the WSEL below Watts Bar Dam dropped approximately 0.8 feet, from about 681.4 feet msl to about 680.6 feet msl. During the survey, the elevation slowly increased, due to backflow from the surrounding tailwater and leakage through the hydroturbines, returning to about 681.4 feet msl after four hours of no flow in the river. Afterwards, the elevation slowly receded, reaching about 680.9 feet msl at the end of the survey.

The ambient river temperature was 79.3°F at the beginning of the period of no flow, and in a manner similar to the WSEL, increased in the first half of the survey, reaching a maximum of 79.9°F (increase of 0.6 F°). Afterwards, the temperature first receded slowly, only 0.2 F° in the next 2½ hours. However, in the final 1½ hours of the survey, the temperature dropped more rapidly, an additional 0.8 F°, reaching 78.9°F at the end of the period of no flow. A rapid drop in ambient river temperature in this manner is common in the summer when strong thermal stratification exists behind Watts Bar Dam. During periods of no flow, leakage occurs through the hydroturbines at the dam. Previous studies have suggested the amount of leakage to be roughly 50 cfs for each hydro unit, or a total of 250 cfs for the entire powerhouse (Harper et. al, 1998). The leakage flow is from the very bottom of Watts Bar Reservoir, the coldest part of the water column in front of the dam. As the leakage occurs, it slowly fills the bottom layers of the tailrace below the powerhouse, eventually reaching the elevation of the sensors that are suspended in the water (from the surface) to measure the upstream ambient river temperature for WBN. Cooling of the ambient river temperature monitor in this manner falsely increases the measured temperature rise for the SCCW system. That is, the temperature rise is elevated not by warming from the SCCW effluent, but by "unnatural" cooling of the upstream monitor via a process that is beyond the operational control of the SCCW system. In forecasting values for the WBN upstream ambient river temperature, the thermal plume model for the SCCW system does not include cooling that occurs as a result of leakage through the hydroturbines at Watts Bar Dam.

SCCW Conditions

During the survey, the SCCW system at WBN was thermally loaded and operating in "summer" mode. That is, the system was operating in a manner producing the largest possible release of heat to the river. Shown in Figure 5 are the measured conditions of the SCCW system during the survey. Included are the discharge and temperature of the SCCW effluent. During the survey, the average discharge of the SCCW system to the river was about 270 cfs. The root-mean-square variation in the SCCW discharge was only about 2 percent of the average–thus, from the standpoint of mixing processes in the river, the discharge was essentially constant. The SCCW effluent temperature decreased throughout the survey from about 86.3°F at the beginning of the survey to about 83.5°F at the end of the survey. This trend coincides with the falling nighttime air temperature, also shown in Figure 5 (note: the discharge temperature of water from the Unit 1 cooling tower, which provides the source of heat for Outfall 113, varies directly with the temperature of the ambient air that is drawn through the tower). Relative to the upstream ambient river temperature, the temperature rise of the Outfall 113 effluent released from the SCCW system, also shown in Figure 5, decreased from about 7.0 F° at the beginning of the survey to about 4.6 F° at the end of the survey.

Downstream End of Passive Mixing Zone

Shown in Figure 6 are the measurements from the HOBO temperature stations at the downstream end of the passive mixing zone. The stations are labeled consecutively from WB1 to WB12, with WB1 situated near the left-hand shoreline of the river and WB12 situated near the right-hand shoreline of the river (i.e., facing downstream—see Figure 2). In Figure 7, the HOBO data has been analyzed to produce contour plots of the local "instantaneous" water temperature rise (ΔT) relative to the SCCW ambient river temperature (i.e., given in Figure 4). The horizontal (x) axis of each contour plot is the span of the river from WB1 to WB12, and the vertical (y) axis is the water depth from 0.5 feet to 7 feet. In this manner, the plots in Figure 7 represent images of the upper 7 feet of the water column in the river, looking downstream. Note that the depth scale in the plots is very distorted so that the data can be viewed in a meaningful manner—that is, whereas the span of the x-axis is about 1000 feet, the span of the y-axis is only about 7 feet

(0.007 times smaller). Plots are provided at the top of each hour from the beginning of the survey at 21:00 CDT on August 30 to the end of the survey at 05:00 CDT on August 31. The following behaviors are emphasized from Figure 6Figure 7:

- At the beginning of the survey, 21:00 CDT on August 30, heat from the SCCW resides primarily on the right-hand-side of the river. Some heat is found in the left-hand-side of the river, perhaps from river sloshing that occurs as a result of deceleration and cessation of the flow at Watts Bar Dam. The maximum local instantaneous temperature rise is about 1.6 F° and occurs in the upper 3 feet of the water column in the right-hand-side of the river.

- Over the next four hours, the temperature rise at the downstream end of the passive mixing zone decreases, and by 01:00 CDT on August 31, the temperature of water in the upper 7 feet of the water column is at most only about 0.4 F° warmer than the ambient water temperature. There is very little temperature variation across the river.

- By 02:00 CDT on August 31, five hours into the survey, heat from the SCCW effluent has arrived in the left-hand-side of the river at the downstream end of the passive mixing zone. That is, in this survey, it took between four and five hours for the leading edge of the SCCW effluent to spread across the river and reach the downstream end of the passive mixing zone.

- In the remaining three hours of the survey, heat from the SCCW effluent slowly backfills from the left-hand-side of the river to the right-hand-side of the river. The maximum local instantaneous temperature rise is about 1.8 F° and occurs in the upper 3 feet of the water column in the left-hand-side of the river. Overall, however, at the end of the survey, 05:00 CDT on August 31, there again is very little temperature variation across the river—at most about 0.4 F°.

NPDES Compliance Parameters

Since heat from the SCCW effluent is distributed across the full width of the river, data from all of the HOBO stations were used to compute the NPDES compliance parameters, which is consistent with the dimensions of the passive mixing zone (i.e., the passive mixing zone spans the full width of the river). The compliance parameters examined include all those given in Table 1—the temperature at the downstream end of mixing zone, T_d; the temperature rise from upstream to the downstream end of the mixing zone, ΔT; and the temperature rate-of-change at the downstream end of the mixing zone, TROC. The fundamental equations used to compute the compliance parameters are provided in APPENDIX B, based on the criteria specified in the NPDES permit. The temperature at the downstream end of the mixing zone was determined from the HOBO measurements by averaging the readings from the sensors at depths 3, 5, and 7 feet for all twelve HOBO stations. The temperature rise was computed as the difference between the measured temperature at the downstream end of the mixing zone and the upstream temperature measured at Watts Bar Dam (i.e., Station 30). The temperature rate-of-change was determined by the change in the measured temperature at the downstream end of the mixing zone from one hour to the next. The data were averaged over a period of one hour using 15-minute readings, as specified in the NPDES permit, and compared with the WBN thermal plume model. The measurements are presented in Figure 8, along with the results obtained by the thermal plume model. The following behaviors are emphasized:

- Temperature at the downstream end of the passive mixing zone, T_d: The maximum 1-hour average T_d estimated by the thermal plume model was 80.8°F, whereas the maximum measured value was about 80.6°F. Thus, the model overpredicted the maximum measured T_d by 0.2°F. Compared to the measurements, the increase in river temperature due to the no flow event was predicted to occur much more rapidly by the model. This is because the model assumes impacts due to changes in the river and/or Outfall 113 conditions are fully realized as a steady-state episode within one hour (i.e., the model time-step); whereas in reality, the actual time for the thermal plume to evolve is much longer. Both the predictions from the model and measurements from the survey were well below the NPDES limit of 86.9°F.

- Temperature rise, ΔT: The maximum 1-hour average ΔT predicted by the plume model was 1.5 F°, whereas the maximum measured value was about 1.6 F°. Thus, the model underpredicted the maximum measured temperature rise by 0.1 F°. For the reason cited above (i.e., computational time-step of one hour), the model predicted the maximum temperature rise to occur one hour into the no flow event. A close examination of the data reveals that the maximum measured value of the temperature rise occurred at end of the survey, when the impact of leakage at Watts Bar Dam reduced the upstream ambient river temperature relative to the model value (see previous discussion in section entitled "River Conditions"). The model value for the upstream ambient river temperature was 79.3°F, whereas due to leakage of cold water at Watts Bar Dam, the measured ambient temperature was unnaturally lowered to 78.9°F (i.e., 0.4 F° lower than the model value, see Figure 4). Both the predictions from the model and measurements from the survey were well below the NPDES limit of 5.4 F°.

- Temperature rate-of-change, TROC: The maximum 1-hour average TROC predicted by the plume model was 0.6 F°/hour, whereas the maximum measured value was about 0.2 F°/hour (absolute values). Thus, the model overpredicted the temperature rate-of-change by 0.4 F°/hour. Both the predictions from the model and measurements from the survey were well below the NPDES limit of ±3.6 F°/hour.

CONCLUSIONS

The compliance survey for 2011 summer conditions was successful in measuring the NPDES instream water temperature parameters for the Outfall 113. These included the temperature, T_d, temperature rise, ΔT, and temperature rate-of-change, TROC, all at the downstream end of the passive mixing zone. The measurements were compared with values predicted by the thermal plume model that TVA currently uses to determine the safe operation of the SCCW system.

Since 2005, when the first compliance survey was performed for the Outfall 113 passive mixing zone, the model value for the maximum downstream temperature T_d, including that for the survey summarized herein, has always bounded the measured value for the maximum T_d. That is, the model value has always been greater than or equal to the measured value. Such is not the case, however, for ΔT and TROC. In this survey, and for the first time, the model value for the maximum ΔT underpredicted the measured value for the maximum ΔT by 0.1 F°. In the summer survey for 2005, the model value for the maximum TROC underpredicted the measured value for the maximum TROC by 0.3 F°/hour (McCall and Hopping, 2006). These differences are not surprising in light of the fact that the model, like any mathematical representation of an actual complex physical process, contains inherent accuracy limitations. The TVA model for predicting the Outfall 113 thermal plume uses CORMIX, which has a stated accuracy of about 50% of the standard deviation of field measurements (Jirka, et al., 1996). In the survey summarized herein, the difference of 0.1 F° between the model and measured values of the maximum ΔT was not caused by any inadequacy in CORMIX, but by unnatural cooling of the upstream ambient river temperature from leakage of cold water through the hydroturbines at Watts Bar Dam. Based on this, as well as the fact that differences as small as 0.1 F° for ΔT and 0.3 F°/hour for TROC fall within the factor of safety currently used in performing hydrothermal forecasts, the thermal plume model is yet considered fully adequate for determining the safe operation of the SCCW system. That is, in combination with TVA procedures for predicting the impact of the Outfall 113 effluent, the model continues to provide a high level of confidence that the SCCW system is being operated in a manner that does not exceed the instream limits for T_d, ΔT, and TROC as specified in the WBN NPDES permit for the passive mixing zone.

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Harper, Walter L., and Bo Hadjerioua, Mark Reeves, Gary Hickman, and John Jenkinson, "Hydrodynamics and Water Temperature Modeling at Watts Bar SCCW Discharge Structure," TVA Resource Group, Water Management, Report No. WR98-1-85-142, November 1998.

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McCall, Michael J., and P.N. Hopping, "Winter 2005 Compliance Survey for Watts Bar Nuclear Plant Outfall 113 Passive Mixing Zone," TVA River Operations, Report No. WR2005-2-85-151, October 2005.

TDEC, *State of Tennessee NPDES Permit No. TN0020168*, Tennessee Department of Environment and Conservation, Issued June 2010.

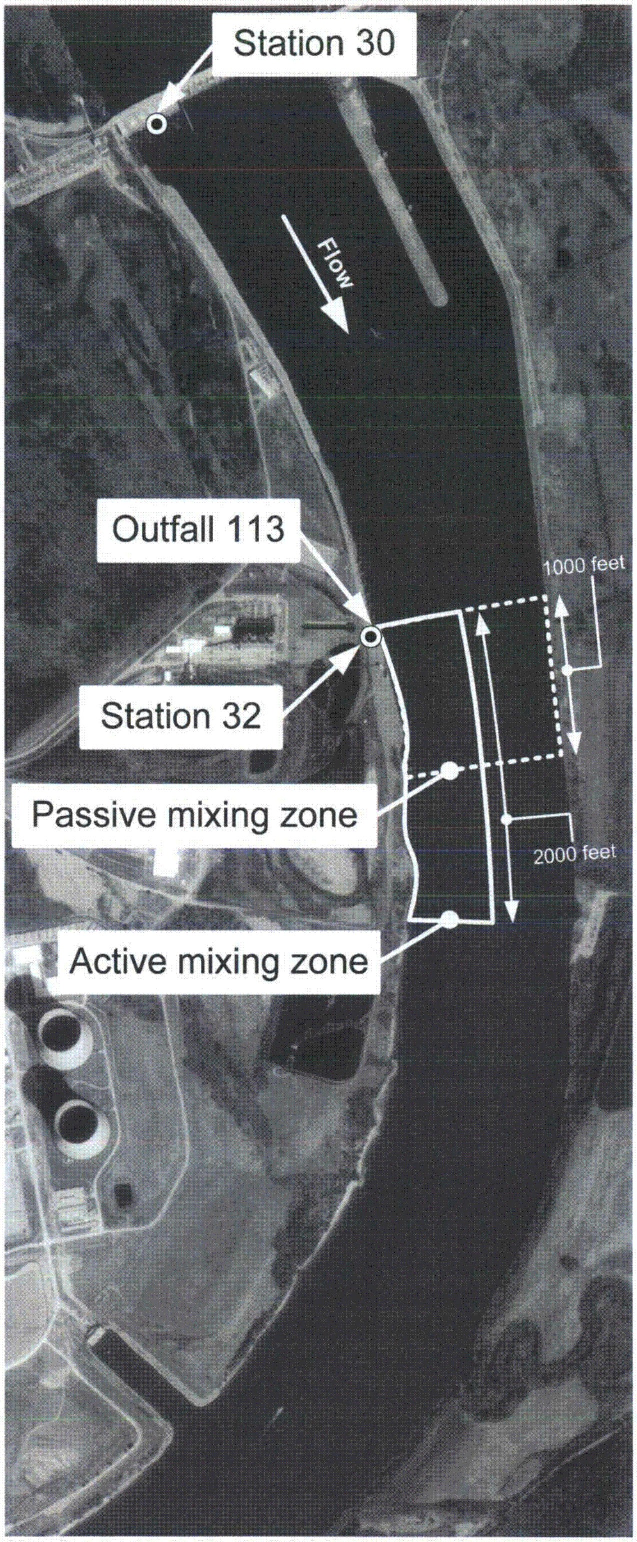


Figure 1. Watts Bar Nuclear Plant Outfall 113 (SCCW) Mixing Zones

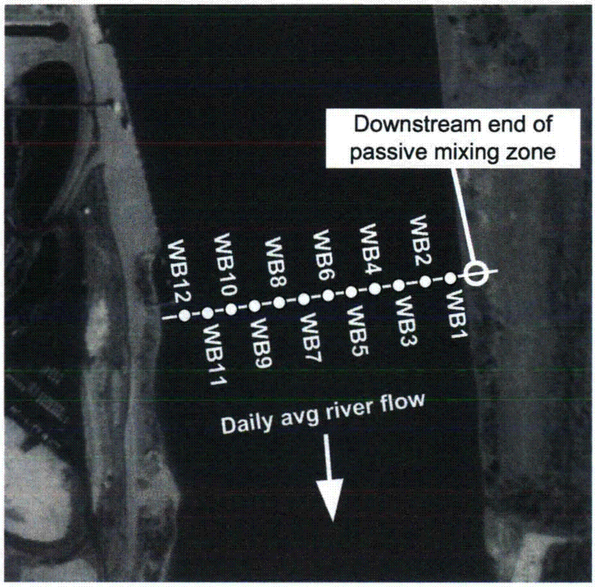


Figure 2. Location of HOBO Monitoring Stations

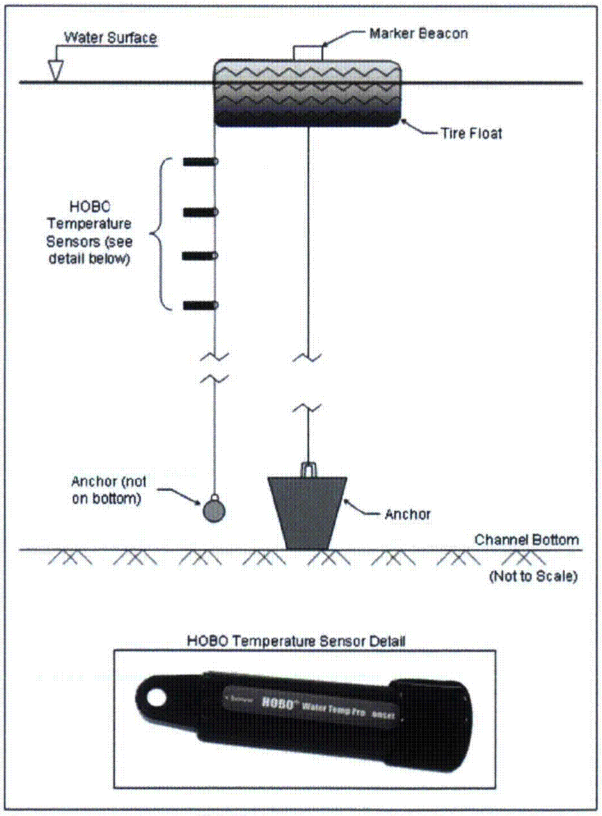


Figure 3. Schematic of HOBO Water Temperature Monitoring Stations

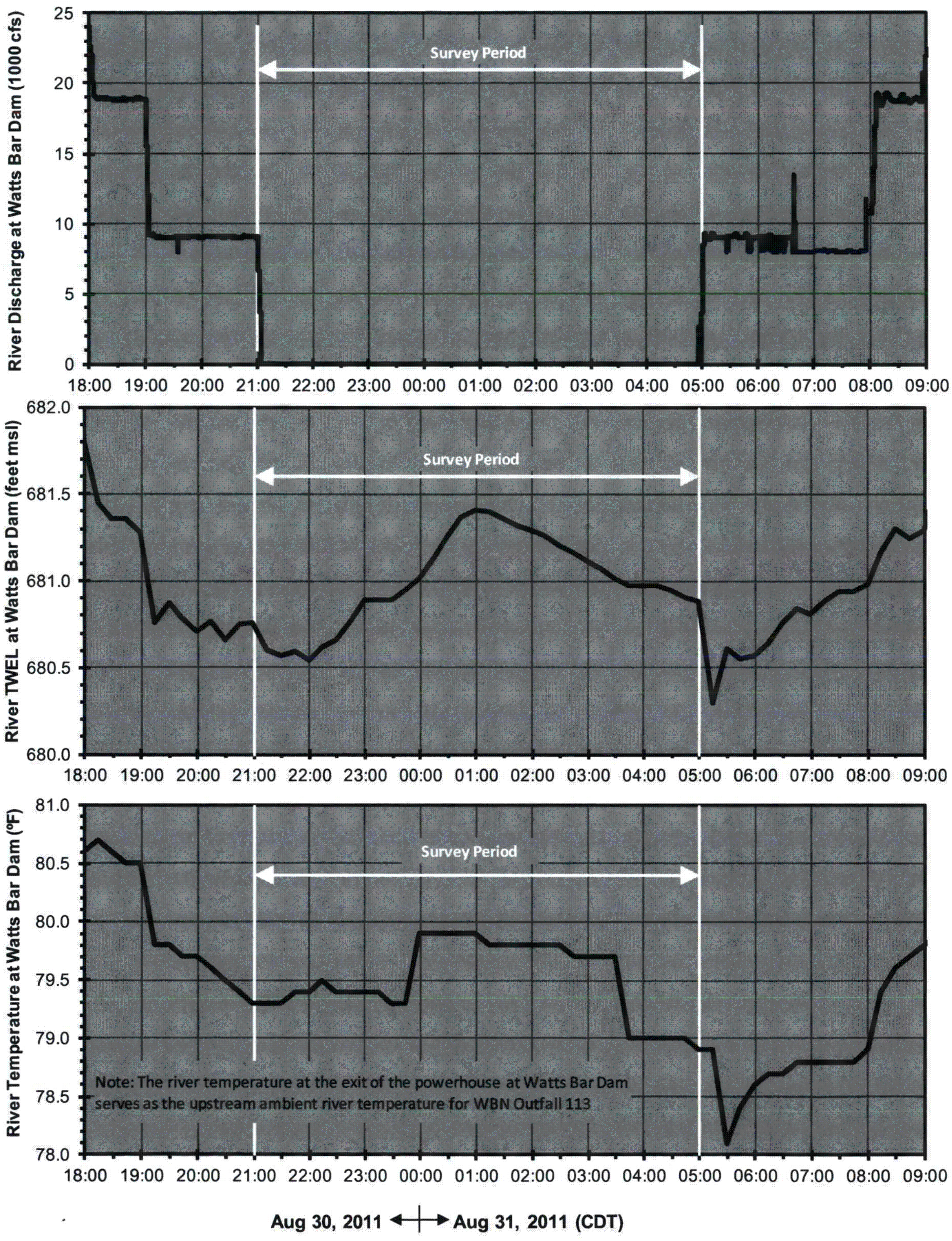


Figure 4. River Conditions

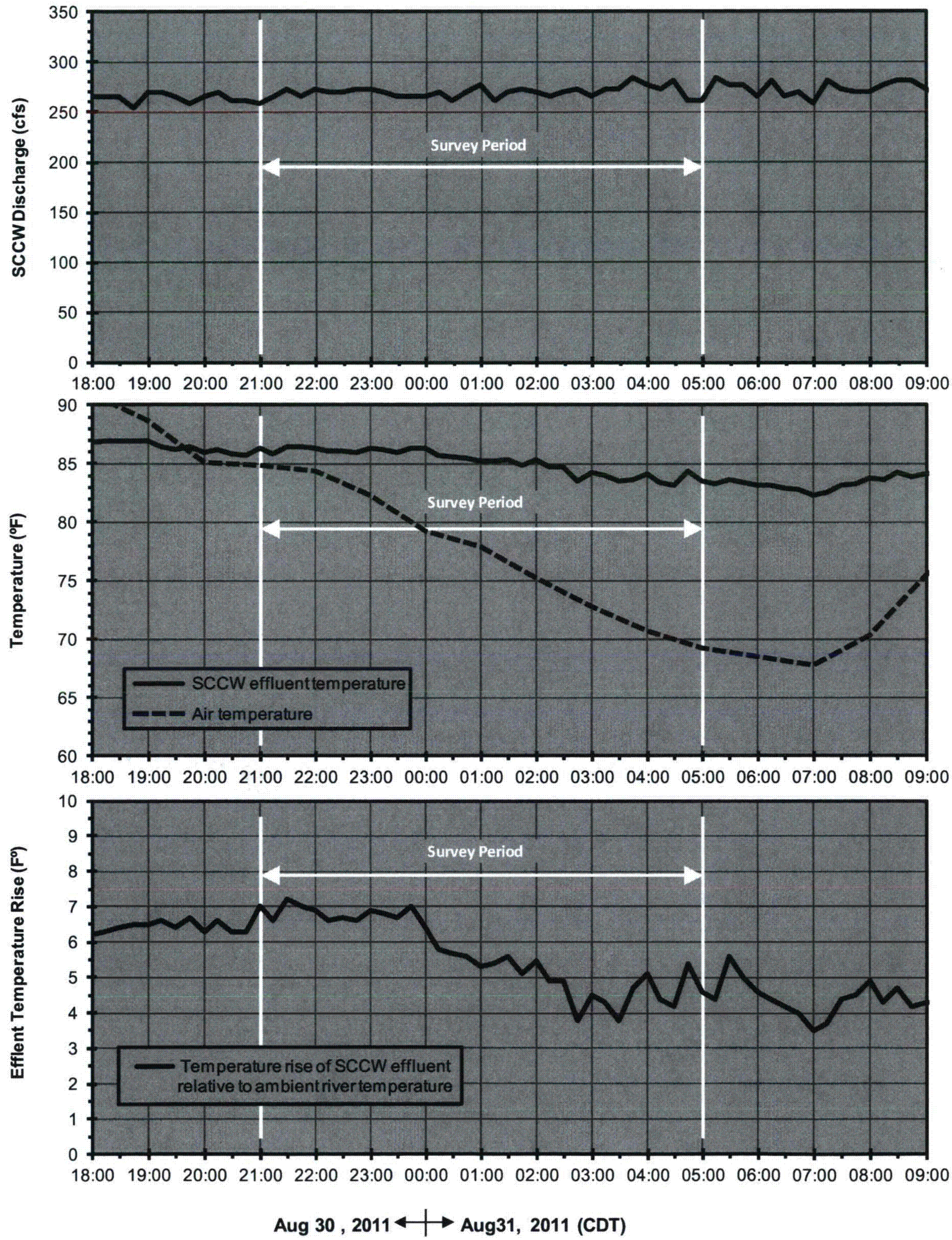


Figure 5. SCCW Conditions

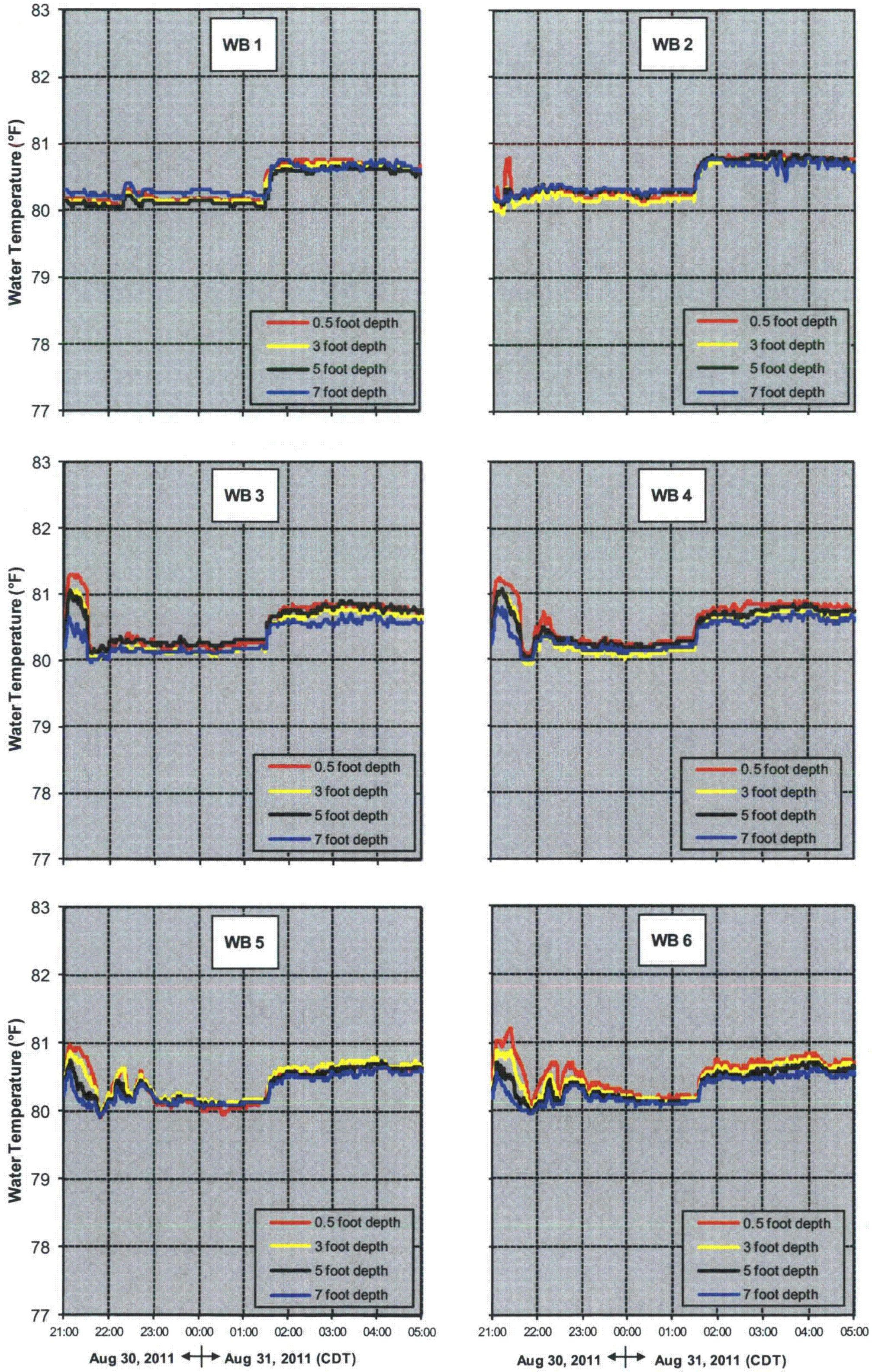


Figure 6. HOBO Water Temperature Measurements

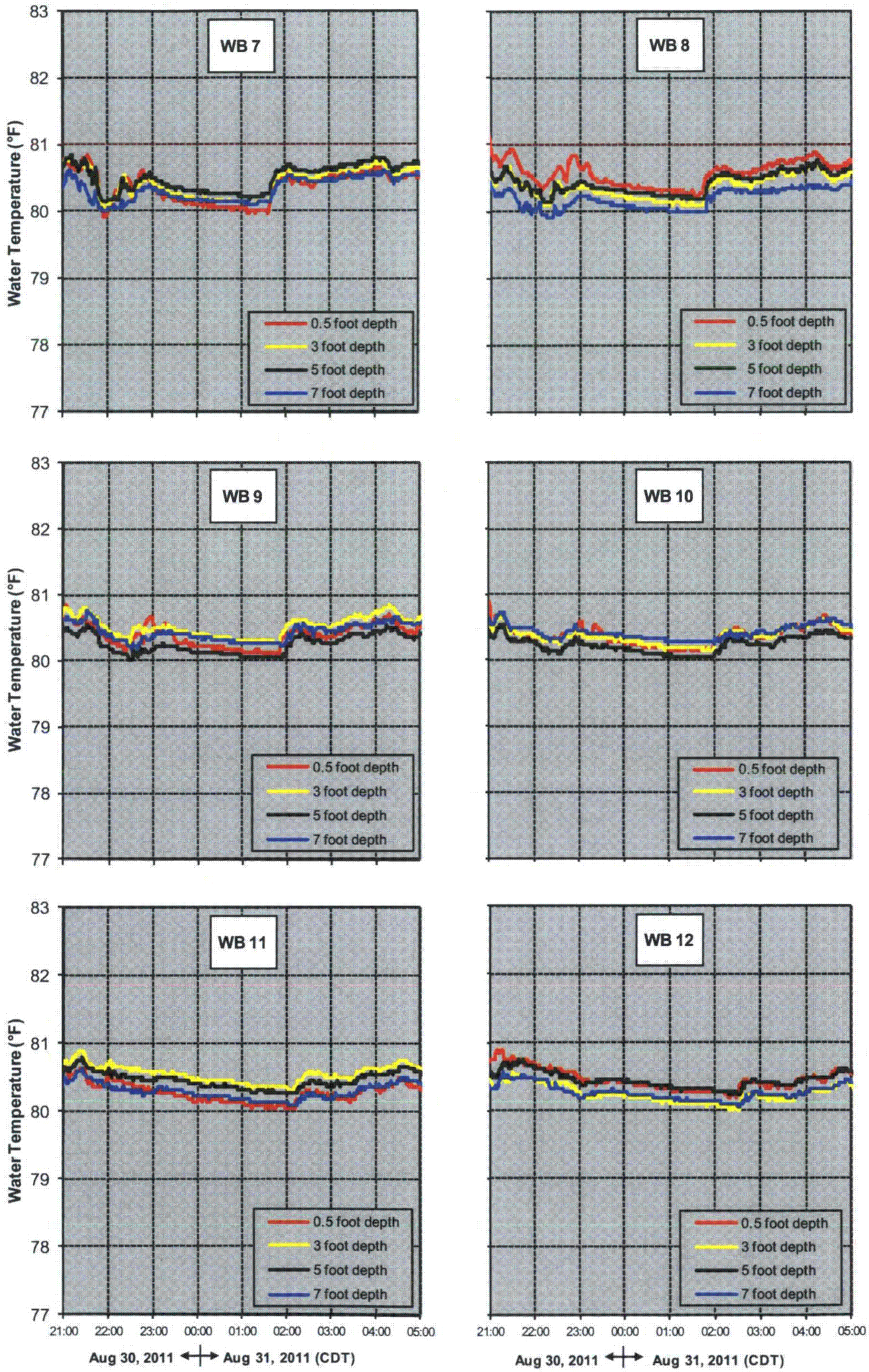


Figure 6 (Continued). HOBO Water Temperature Measurements

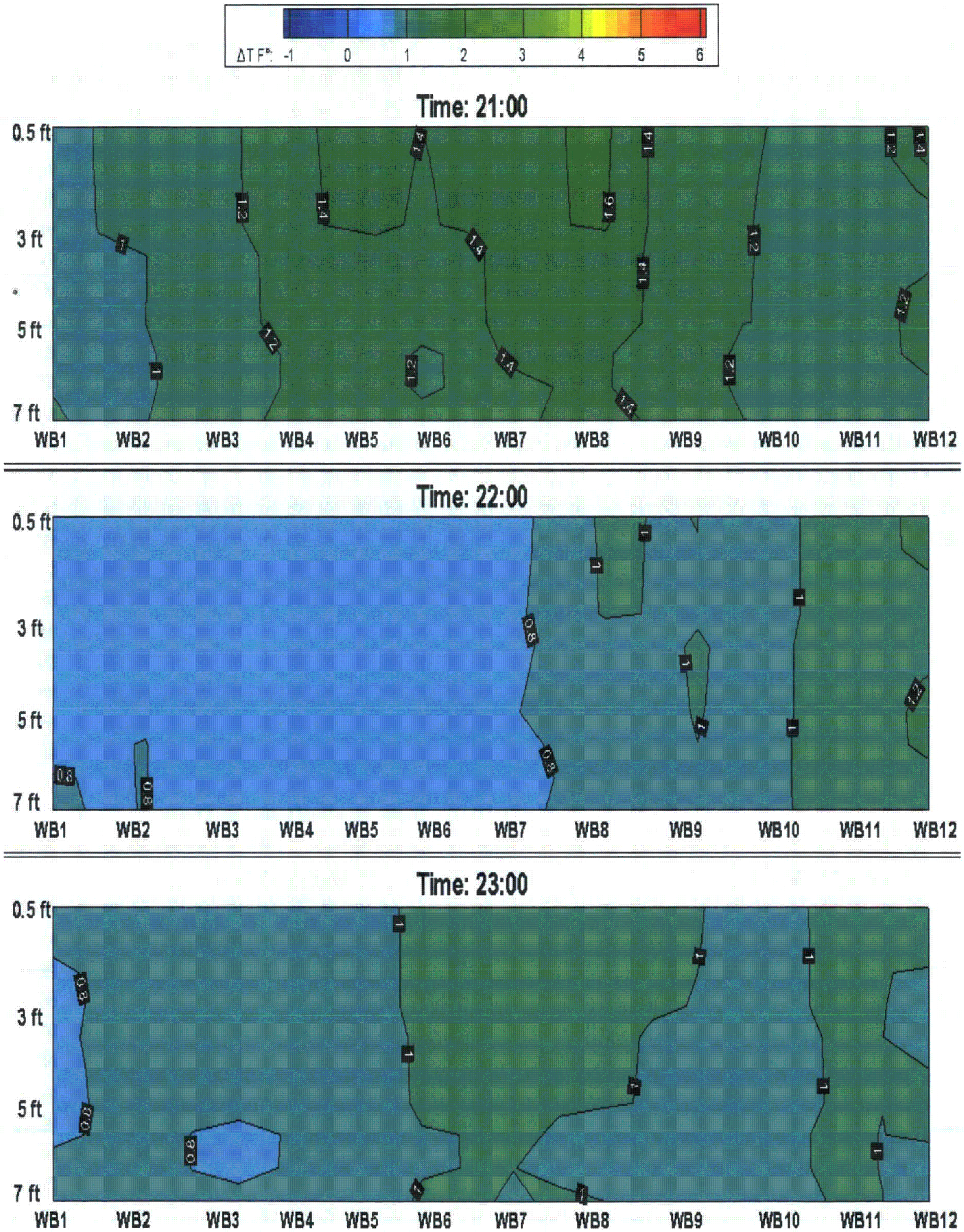
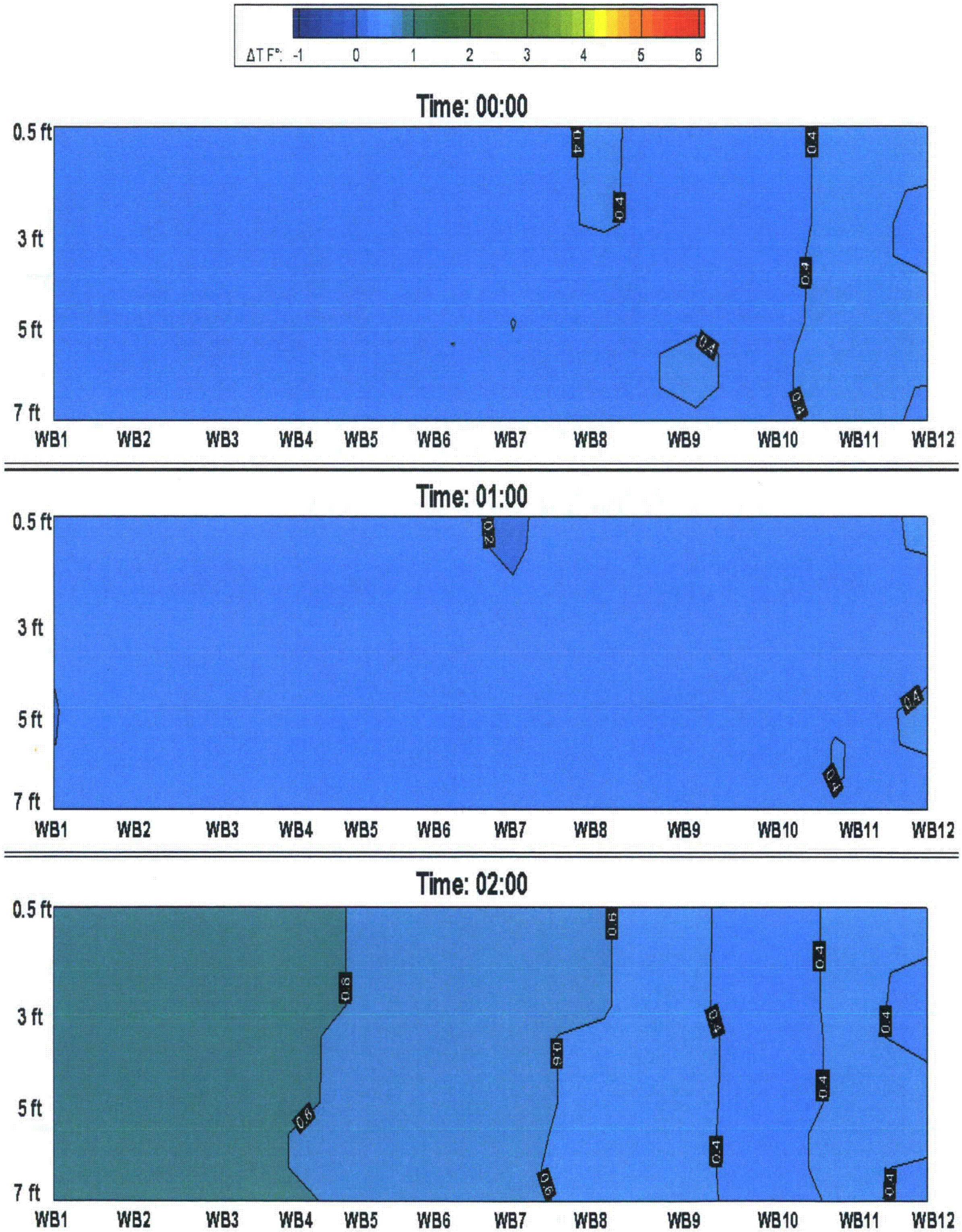


Figure 7. Instantaneous Temperature Rise for HOBO Measurements



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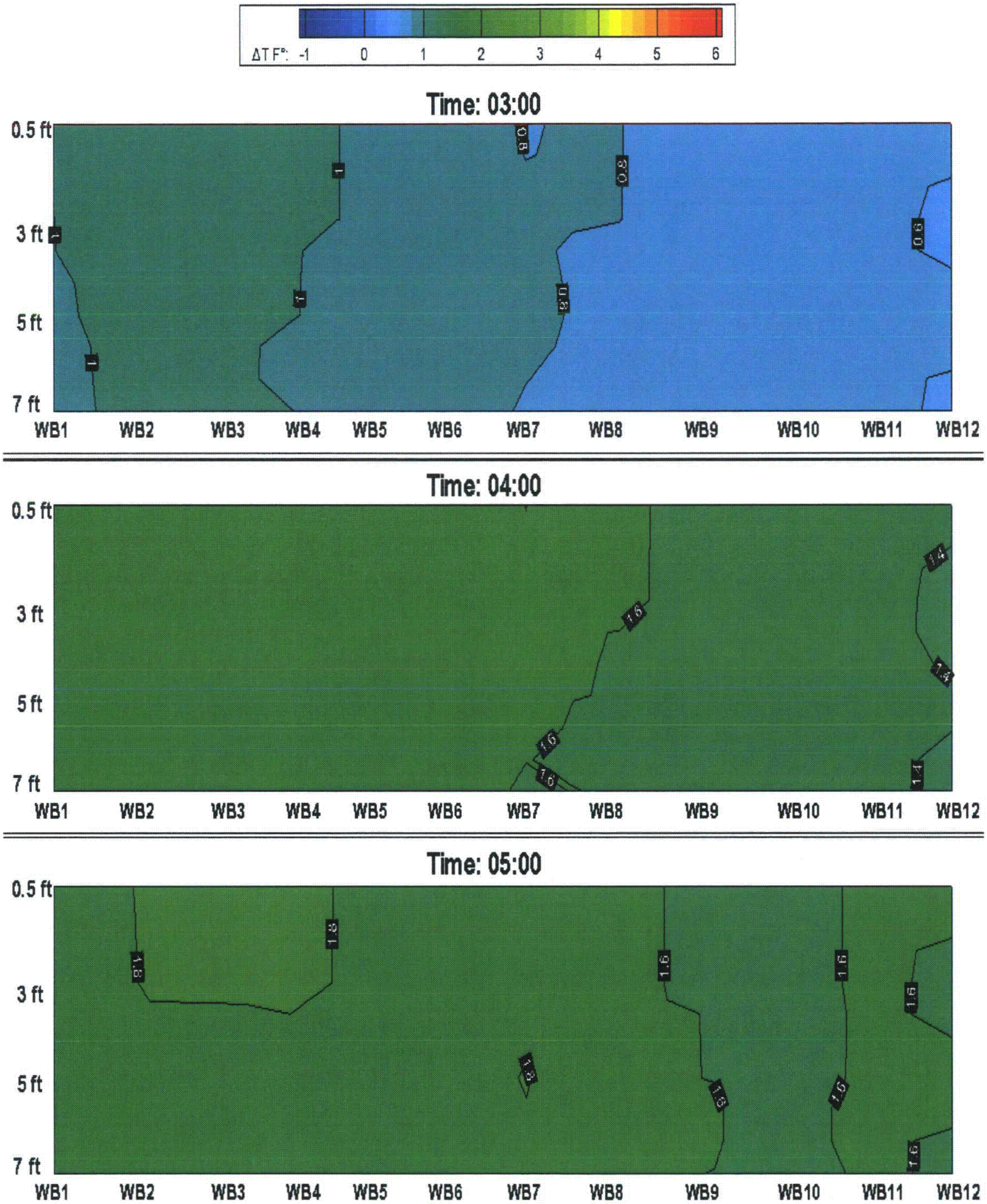

Figure 7 (Continued). Instantaneous Temperature Rise for HOBO Measurements

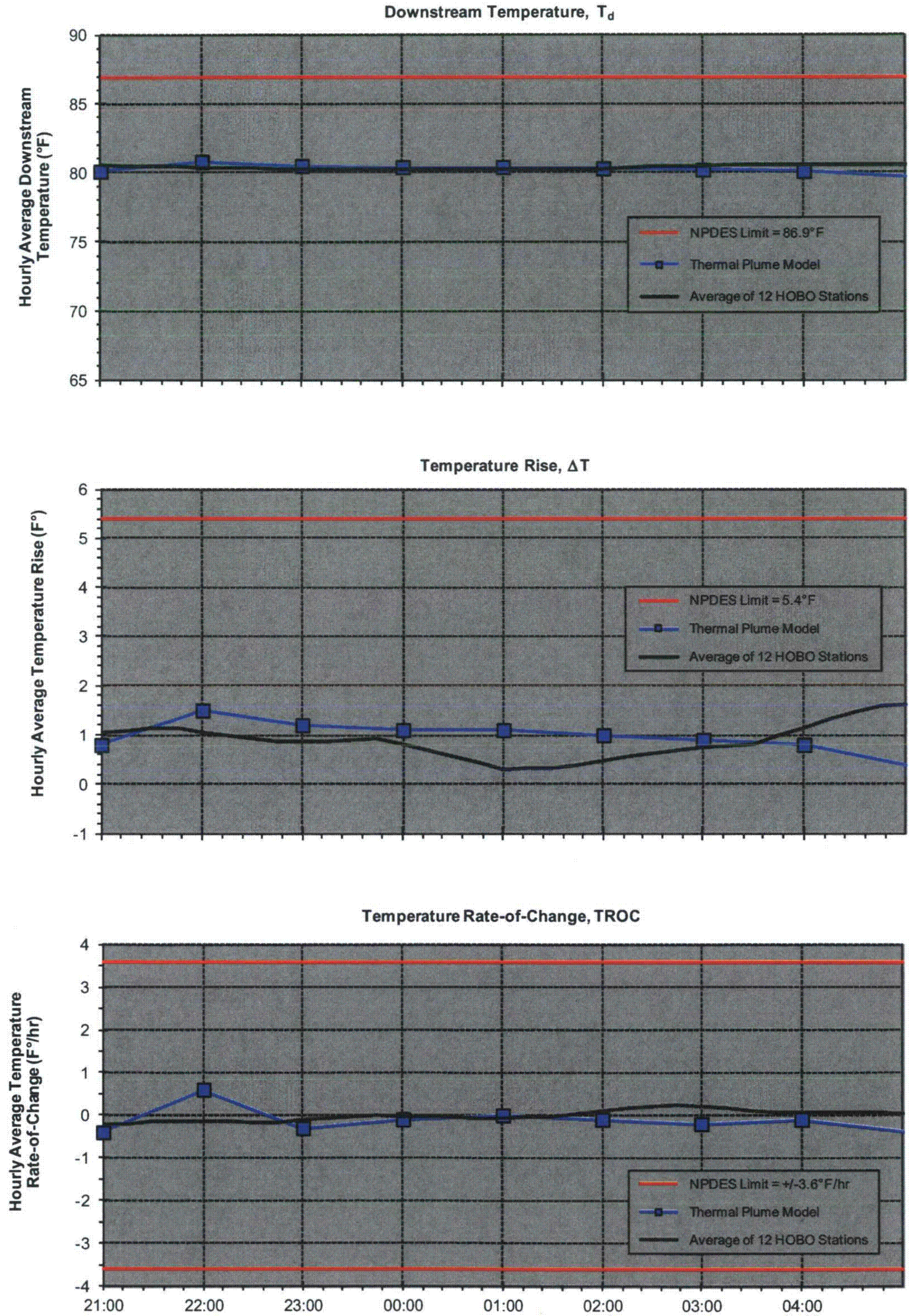

Figure 8. Measured and Computed Compliance Parameters for Passive Mixing Zone

APPENDIX A
Calibration of NPDES Water Temperature Sensors

All sensors used by TVA for monitoring compliance of NPDES water temperature requirements are certified and maintained to meet the following industry and regulatory standards:

- ISO/IEC 17025—Quality assurance requirements for the competence to carry out sampling, testing, and calibrations using standard, non-standard, and laboratory-developed methods (ISO=International Organization for Standardization, IEC=International Electrotechnical Commission).

- 10CFR50 Appendix B—Quality assurance criteria for design, fabrication, construction, and testing of the structures, systems, and components of nuclear power plants (CFR=Code of Federal Regulations).

- 40CFR136—Guidelines establishing test procedures for the analysis of pollutants under the Clean Water Act.

- ANSI N45.2. 1971—Quality assurance requirements for Nuclear Power Plants (ANSI= American National Standards Institute).

- ANSI/NCSL Z540-1-1994—General requirements for calibration laboratories and equipment used for measurements and testing (NCSL=National Conference of Standards Laboratories).

The standard used to certify the thermistors for the permanent EDS stations and the temporary HOBO stations is traceable to the National Institute of Standards and Technology (NIST). The standard includes two pieces of equipment—a platinum resistance temperature detector (RTD) manufactured by Burns Engineering, Inc. and an ohmmeter manufactured by Azonix Inc. The latter is used to measure the resistance of the RTD (i.e., the resistance of platinum varies with temperature). The NTIS traceable calibration certificates for the Burns RTD and the Azonix ohmmeter used to calibrate the HOBO monitors in the field survey summarized herein are available upon request. The overall accuracy of the system for the temperature standard is about ±0.05°F. The tolerance of the thermistors used for the WBN field survey is about ±0.4°F, thus providing a calibration test accuracy ratio (TAR) of about 1:8. That is, the accuracy of temperature standard used for the sensor calibrations is about 8 times greater than the minimum acceptable field accuracy of temperature sensors. This is twice the recommended maximum TAR of 1:4 for sensor calibrations.

The TVA procedure to calibrate the HOBO water temperature monitors, Instruction No. 450.01-020, is provided below. Briefly, the HOBO monitors are immersed in a stirred temperature-

controlled water bath along with the standard (i.e., along with the Burns RTD probe). After the bath stabilizes, temperature readings from the HOBO monitors are compared to the temperature readings from the standard. Experience has shown that in nearly all cases, the readings from both the HOBO monitors and the standard and are essentially constant, so that the 95 percent confidence interval of the readings is diminutive. Under these conditions, the accuracy of each HOBO monitor is recorded simply as the difference between the HOBO reading and that of the standard (negative difference = HOBO reading low/below standard, positive difference = HOBO reading high/above standard). The HOBO monitors are tested at three temperatures between 30°F and 100°F, covering the range of expected water temperature for natural river conditions. The three temperatures are at about the 10 percent, 50 percent, and 90 percent intervals, or 37°F, 65°F and 93°F, respectively. Any HOBO monitor with measured accuracy in excess of the maximum allowable tolerance of ±0.4°F for any one of the three temperatures fails the calibration test and is removed from the field survey inventory. The calibration certificates for HOBO monitors used in this field survey summarized herein are available upon request. All the HOBO monitors passed both the pre-survey and post-survey calibration tests. The mean square error of the HOBO monitors was 0.14 F° for both the pre-survey and post-survey calibrations.

CENTRAL LABORATORIES SERVICES QUALITY PROGRAM INSTRUCTION	TITLE Certification of HOBO Water Temp Pro Data Acquisition SystemsH_2O-001	**Instruction No.** 450.01-020 **Rev. No.** 0 **Page No.** 1 of 7 **Effective Date** 5/19/03

LEVEL OF USE ☐ Continuous ☒ Reference ☐ Information

QA RECORD

Dennis T. Darby	5/19/03
Preparer	Date
Paul B. Loiseau, Jr.	5/19/03
Technical Reviewer	Date
[signature]	6/5/03
Administrative Review	Date

APPROVAL

Jerry D. Hubble	5/19/03
Department Manager	Date

REVISION LOG

Revision Number	Effective Date	Pages Affected	Description of Revision
0	5/19/03	All	Initial Issue.

1.0 PURPOSE

To provide uniform and effective certifications of Hobo Water Temp Pro data acquisition systems meeting the accuracy and performance requirements of TVA's water temperature-monitoring programs. This technical instruction uses the method of comparison with a laboratory standard thermometer.

2.0 SCOPE

This instruction applies to the certification of Hobo Water Temp Pro data loggers manufactured by Onset Computer Corporation of Bourne, Massachusetts. The Hobo Water Temp Pro is a data acquisition system containing a temperature sensor, data logger and battery sealed in a single submersible case. The Hobo Water Temp Pro is programmed and data retrieved by use of an infrared interface located in one end of the case. Hobo Water Temp Pros are certified upon receipt from the manufacturer at no greater than 12 month intervals during use or when requested.

3.0 SUMMARY

In this three-point certification systems are tested as actually used over the historical water temperature range of 30° to 100°F and submerged in water. The three test points are 37°, 65° and 93°F. The systems are required to perform within Onset Computer Corporation tolerances. System conformity at each temperature point is determined by comparing system temperature, logged by the Hobo Water Temp Pro and a laboratory standard thermometer.

Systems are programmed and submerged with a standard thermometer in a stirred, temperature-controlled temperature bath. The systems are read after the test by an infrared interface adapter connected to a computer running Onset Computer Corporation's Boxcar Pro software. Traceability of the certification is through the thermometer.

"As-found" certifications are performed on new systems as an acceptance test and on sensors returned from field service. "As-left" certifications are performed before delivery for field service if more than 12 months has elapsed since the last certification. "As-found" and "as-left" certifications may be combined on the same record if there is clear indication which type each system is undergoing.

Multiple HOBOs may be certified at the same time in the temperature bath.

- Accuracy of ±0.2°C at 25°C (0.33°Flat 70°F)
- Waterproof case, submersible to 100 feet
- Capacity to store up to 21,580 temperature measurements
- Selectable sampling interval from 1 second to 9 hours
- Programmable start time/date
- Two data recording modes: Stop when full or wrap around when full.
- Two data offload modes: Halt then offload or offload while logging.
- Nonvolatile EEPROM memory that retains data even if batteries fail
- Light-emitting diode (LED) operation, indicator, which can be disabled during logging by selecting "Stealth"1 mode
- High-speed IR communications for offloading data; can readout full logger in less than 30 seconds while logging continues
- Battery life of 6 years with typical usage

4.0 PRACTICES/EXCEPTIONS

N/A

5.0 SAFETY

5.1 Standard electrical equipment safety.

6.0 STANDARDS USED

6.1 Laboratory reference thermometer, range 30° to 100°F or greater, 0.01°F resolution, 0.1°F accuracy or better, with current calibration sticker.

7.0 EQUIPMENT/APPARATUS

7.1 Temperature bath, stirred, temperature-controlled.
7.2 Computer with Onset Boxcar Pro software installed (version 4.3 or later)
7.3 IR Base station, Onset Part # BST -IR

8.0 PREREQUISITE ACTIONS

8.1 Turn on temperature bath and set for 37°F.
8.2 Check the IR interface to verify that it is plugged into the correct serial port on the PC. Set the correct time on the PC.
8.3 Align the IR port on the Base station with the HOBO Water Temp Pro communications window. Place the logger no further than 4 to 5 inches away from the Base station (see Figure 2) and make sure the IR windows in both devices point at each other. There is a 30° acceptance angle for the IR beam, so some misalignment is acceptable.

8.4 Start the Onset Box Car Software and select **Logger** then **Hobo Water Temp Pro** and **Launch.**

8.5 The computer will respond with a list of loggers found. The serial number in this list should match the serial number printed on the side of the logger. If these numbers do not match, click the **Refresh** button. Record this serial number on the certification form. Either wait or click the **Stop Searching** button. Using the mouse select the logger and click the **Launch** button.

8.6 After a few seconds the screen will display the status of the HOBO Water Temp Pro. Record the battery percentage on the certification form.

8.7 Verify that the Hobo is set to Fahrenheit and program it to a recording interval of 0:1:0 for a reading once a minute. Verify that the start logging immediately box is checked and that the set data logger clock with host launch is also checked.

8.8 Using the mouse click the **Launch Immediately** button.

8.9 If last HOBO is programmed click the DONE button, else select the **Launch Another** and repeat steps 8.5 through 8.9.

9.0 TEST PROCEDURE/METHOD

9.1 On the certification form record the serial number of the laboratory reference thermometer.

9.2 Place the HOBO Water Temp Pro in the temperature bath, making sure the end opposite the IR windows is submerged, and allow the bath to stabilize at 37°F ±0.5°F on the thermometer. Adjust the bath set point if needed. After the bath reaches the desired temperature allow 20 minutes 'soak time' for the HOBO to reach its final temperature.

9.3 Record the thermometer reading on the certification form and the time. (The time will be needed to get the correct reading from the HOBO.)

9.4 Repeat steps 9.2 and 9.3 for bath settings of 65.0°F ± 0.5°F and 93°F ± 0.5°F.

9.5 Remove the HOBO from the temperature bath and align the IR port on the Base station with the HOBO Water Temp Pro communications window.

9.6 Restart Onset BoxCar Pro if it is not running and select **Logger** then **Hobo Water Temp Pro and Readout.**

9.7 The computer will respond with a list of loggers found. Using the mouse select the logger and click the **Readout** button. The computer will ask to download data and continue logging or the stop logging and offload data. Select the **Stop Logging and Offload data.** After a few seconds the computer will respond with a suggested file name. Select **Save** and allow the HOBO to transfer the data.

9.8 After a successful download click the OK button. The computer will then ask if the data should be displayed in Centigrade or Fahrenheit. Deselect °C and select °F and click **OK.** The computer should display a graph of the collected data. Click the view details button (this is the button just left of the question mark button.)

9.9 Scroll down the displayed list until the time recorded for the 37°F point is found. Record the corresponding temperature on the certification form. Repeat this step for 65° and 93°.

9.10 Close the view details windows and repeat steps 9.6 through 9.9 for additional HOBOs.

9.11 Fill out the rest of the certification form.

10.0 ACCEPTANCE CRITERIA

10.1 Based upon the manufacturer specifications the HOBO Water Temp Pro should be within ±0.4°F over the range of 32°F to 100°F. Any HOBO with an error of greater than ±0.5°F at any of the three measured points shall fail certification.

11.0 POST PROCEDURE ACTIVITY

11.1 Close the BoxCar Software.

12.0 RECORDS

12.1 Completed HOBO Water Temperature Pro Certification form and associated Report of Certification cover sheet is a QA record.

13.0 REFERENCE

13.1 HOBO Water Temp Pro User's Manual, version 1.0 or later

13.2 Onset BoxCar Pro4 Manual Version 1.0 or later

APPENDIX B
WBN Outfall 113 NPDES Compliance Parameters

- Current Instantaneous Upstream Temperature:

  Tu_i (measured at EDS Station 30 by the first sensor below a depth of 5 feet).

- Current 1-Hour Average Upstream Temperature:

  $$Tu1_i = \frac{Tu_i + Tu_{i-1} + Tu_{i-2} + Tu_{i-3} + Tu_{i-4}}{5},$$

  where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of Tu.

- Current Instantaneous Downstream Temperature:

  $$Td_i = \frac{Td3_i + Td5_i + Td7_i}{3},$$

  where $Td3_i$, $Td5_i$, and $Td7_i$ denote the current measurements of river temperature at the downstream end of the mixing zone at water depths 3 feet, 5 feet, and 7 feet, respectively.

- Current 1-Hour Average Downstream Temperature:

  $$Td1_i = \frac{Td_i + Td_{i-1} + Td_{i-2} + Td_{i-3} + Td_{i-4}}{5},$$

  where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of Td.

- Current Instantaneous Temperature Rise:

  $$\Delta T_i = Td_i - Tu_i.$$

- Current 1-Hour Average Temperature Rise:

  $$\Delta T1_i = \frac{\Delta T_i + \Delta T_{i-1} + \Delta T_{i-2} + \Delta T_{i-3} + \Delta T_{i-4}}{5},$$

where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of ΔT.

- Current Temperature Rate-of-Change:

$$TROC_i = \frac{Td_i - Td_{i-4}}{1\ \text{hour}}.$$

- Current 1-Hour Average Temperature Rate-of-Change:

$$TROC1_i = \frac{TROC_i + TROC_{i-1} + TROC_{i-2} + TROC_{i-3} + TROC_{i-4}}{5},$$

where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of TROC.

Enclosure 4

Winter 2011 Compliance Survey for Watts Bar Nuclear Plant Outfall Passive Mixing Zone

TENNESSEE VALLEY AUTHORITY
River Operations

WINTER 2011 COMPLIANCE SURVEY FOR WATTS BAR NUCLEAR PLANT OUTFALL 113 PASSIVE MIXING ZONE

Prepared by

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December 2011

EXECUTIVE SUMMARY

The National Pollutant Discharge Elimination System (NPDES) Permit No. TN0020168 for Watts Bar Nuclear Plant (WBN) identifies the discharge of water to the Tennessee River from the Supplemental Condenser Cooling Water (SCCW) System as Outfall 113. Furthermore, the permit identifies that when there is no flow released from Watts Bar Dam (WBH), the effluent from Outfall 113 shall be regulated based on a passive mixing zone extending in the river from bank-to-bank and 1,000 feet downstream from the outfall. Compliance with the requirements for the passive mixing zone is to be achieved by two annual instream temperature surveys–one for winter conditions and one for summer conditions. Summarized in this report are the measurements, analyses, and results for the passive mixing zone survey conducted for 2011 winter conditions. The survey was conducted between 23:00 CDT on June 2 and 06:00 CDT on June 3 (seven hours) and included the collection of temperature data at twelve temporary monitoring stations deployed across the downstream edge of the passive mixing zone during a period of no flow in the river. The data were analyzed to compute three compliance parameters: the 1-hour average temperature at the downstream edge of mixing zone, T_d; the 1-hour average temperature rise from upstream to the downstream edge of the mixing zone, ΔT; and the 1-hour average temperature rate-of-change at the downstream edge of the mixing zone, TROC. The measured parameters were compared to predicted values from the thermal plume model used by TVA to help determine the safe operation of Outfall 113. The results of the comparisons, in terms of maximum values observed during the no flow event, are as follows:

Compliance Parameter	Model	Measured	NPDES Limit
Maximum T_d	72.5°F	70.8°F	86.9°F
Maximum ΔT	4.0 F°	1.7 F°	5.4°F
Maximum |TROC|	1.0 F°/hour	0.6 F°/hour	3.6 F°/hr

As shown, values predicted by the model were larger than those measured in the survey. Thus, for the conditions of the survey, the plume model was found to be good for enforcing the operation of Outfall 113 at levels of T_d, ΔT, and TROC below the NPDES limits. For T_d and ΔT, these results are consistent with those of all the previous surveys for the passive mixing zone. For TROC, however, previous surveys have revealed that the model is capable of underpredicting measured values for TROC by as much as 0.3 F°/hour (e.g., see McCall and Hopping, 2006). Under these conditions, a factor of safety of 0.3 F°/hour currently is used for tracking TROC in the operation of the SCCW system. That is, for the passive mixing zone, the safe operation of Outfall 113 is evaluated based on a maximum allowable value of TROC from the thermal plume model of ±3.3 F°/hour rather than ±3.6 F°/hour. This practice will continue until further notice.

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WINTER 2011 COMPLIANCE SURVEY FOR WATTS BAR NUCLEAR PLANT OUTFALL 113 PASSIVE MIXING ZONE

INTRODUCTION

Outfall 113 for the Watts Bar Nuclear Plant (WBN) includes the discharge of water to the Tennessee River from the Supplemental Condenser Cooling Water (SCCW) system. Due to the dynamic behavior of the thermal effluent in the river, the National Pollutant Discharge Elimination System (NPDES) Permit No. TN0020168 for the plant specifies two mixing zones for Outfall 113—one for active operation of the river and one for passive operation of the river (TDEC, 2010). The passive mixing zone corresponds to periods when the operation of Watts Bar Dam (WBH) produces no flow in the river (i.e., hydropower and/or spillway releases). The dimensions of the passive mixing zone extend from bank-to-bank and downstream 1,000 feet from the outfall. The active mixing zone applies to all other river flow conditions. The dimensions of the active mixing zone include the right-half of the river (facing downstream) and extend downstream 2,000 feet from the outfall. The passive and the active mixing zones are illustrated in Figure 1.

Table 1 summarizes the NPDES temperature limits for Outfall 113. The limits apply to both the active and passive mixing zones. Compliance for the active mixing zone is monitored by permanent instream water temperature stations situated in the right-half of the river. Due to navigation issues associated with placing permanent stations in the left-half of the river, a thermal plume model is used to determine the safe operation of Outfall 113 for the passive mixing zone. To verify the thermal plume model, the NPDES permit specifies that two instream temperature surveys shall be conducted each year—one for winter conditions and one for summer conditions. The purpose of this report is to present the results for the passive mixing zone temperature survey conducted for winter 2011 conditions. Provided is a brief summary of the survey method, presentations of the measurements and analyses, and discussions for the results and conclusions.

Table 1. NPDES Temperature Limits for Outfall 113 Mixing Zones

Compliance Parameter	Sampling Period	NPDES Limit
Maximum Temperature, Downstream Edge of Mixing Zone, T_d	Running 1-hr	86.9°F
Maximum Temperature Rise, Upstream to Downstream, ΔT	Running 1-hr	5.4 F°
Maximum Temperature Rate-of-Change, TROC	Running 1-hr	±3.6 F°/hr

The survey was conducted between 23:00 CDT on June 2 and 06:00 CDT on June 3 (seven hours). The winter survey usually is conducted in March or April when the ambient river temperature is cool, but when daytime air temperatures can be high. These conditions produce above normal effluent temperatures from Outfall 113. That is, TVA prefers to evaluate the outfall at a time when the effluent from the SCCW system "challenges" the method used by TVA to monitor compliance for the outfall. In 2011, due to high rainfall, TVA was in a flood control operation at Watts Bar Dam during most of March. Under these conditions, river flow could not be discontinued for the purpose of a survey. Then in early April, WBN was removed from service for a routine refueling and maintenance outage. During the outage, Outfall 113 was not thermally loaded. For these reasons, the winter survey was not conducted until early June, when the flood operation had expired and the plant had returned to service with a sustained level of generation.

INSTREAM SURVEY

The instream survey included the deployment of temporary water temperature stations at twelve locations across the downstream edge of the passive mixing zone. Data from these and other monitoring stations were analyzed to obtain measured values for the compliance parameters listed in Table 1. These were then compared with the corresponding values estimated from the SCCW thermal plume model.

The method of conducting the instream survey is the same as that used for the first such survey, performed for winter conditions on May 6, 2005 (McCall and Hopping, 2005). Table 2 provides a summary of the sources of data for the survey. WaterView, a monitoring system for tracking hydroplant operation and performance, was used to obtain measurements for the river discharge from Watts Bar Dam. The WBN Environmental Data Station (EDS) provided measurements from existing permanent monitoring stations for the nuclear plant. These included the upstream (ambient) river temperature, river water surface elevation, SCCW effluent temperature, SCCW effluent discharge, and air temperature.

Table 2. Sources of Data for Passive Mixing Zone Survey

Data	Source	Frequency
River ambient water temperature	WBN EDS Station 30 (Tailwater at WBH)	15 min
River water surface elevation	WBN EDS Station 30 (Tailwater at WBH)	15 min
SCCW effluent temperature	WBN EDS Station 32 (Outfall 113)	15 min
SCCW effluent discharge	WBN EDS Station 32 (Outfall 113)	15 min
Air temperature	WBN EDS Met Tower	15 min
Passive mixing zone water temperature	Temporary HOBO Monitors	1 min

The water temperature at the downstream edge of the Outfall 113 passive mixing zone was measured by the temporary water temperature stations. The stations were positioned at roughly equal intervals across the river, as shown in Figure 2, using a Global Positioning System (GPS) device. The temporary stations recorded water temperatures by using HOBO temperature monitors positioned at depths of 0.5, 3, 5, and 7 feet below the water surface. Shown in Figure 3 is a schematic of the temporary stations. The stations included a string of HOBO monitors suspended from a tire float, with weights to anchor the station and to keep the sensor string vertical in the water column. The water temperature sensors used in the HOBO monitors had an accuracy of about ±0.4 F° and resolution of about 0.04 F°, which is consistent with other temperature sensors used by TVA for tracking hydrothermal compliance. The HOBO monitors include an internal data acquisition unit that was programmed to collect measurements once per minute. All the temperature probes used in the survey, including those contained in the HOBO monitors and the thermistors at the permanent EDS monitoring stations, were calibrated by a quality program with equipment accuracies traceable to the National Institute of Standards and Technology (NIST). The calibration procedure is summarized in Appendix A. The temporary monitoring stations were deployed several hours before the beginning of the survey, and retrieved several hours after the end of the survey.

RESULTS

River Conditions

Figure 4 shows the measured ambient conditions of the river during the survey. Included are the river discharge at Watts Bar Dam, the river water surface elevation (WSEL) at the exit of Watts Bar Dam, and river temperature at the exit of Watts Bar Dam. The river temperature at the exit of Watts Bar Dam serves as the upstream ambient river temperature for WBN Outfall 113. To provide a period of no flow in the river, releases from Watts Bar Dam were suspended between about 23:00 CDT on June 2 and 06:00 CDT on June 3, a total of seven hours (nighttime). Leading up to the survey, as the river flow was stepping down, the water surface elevation below Watts Bar Dam dropped approximately 0.8 feet. During the survey, the elevation slowly increased due to filling (i.e., backflow) from the surrounding tailwater, reaching a value of about 682 feet msl at the end of the survey. The ambient river temperature was 68.5°F at the beginning of the survey and increased to 69.1°F by the end of the survey. In June, the ambient river temperature often increases in this manner because the temperature of the bottom water released through the hydroturbines (before the onset of the no flow event) usually is cooler than that of the surrounding tailwater, which is warmed by daytime solar heating.

SCCW Conditions

During the survey, the SCCW system at WBN was thermally loaded and operating in "summer" mode. That is, the system was operating in a manner producing the largest possible heat load to the river. Shown in Figure 5 are the measured conditions of the SCCW system during the survey. Included are the discharge and temperature of the SCCW effluent. Due to an unexpected outage of data acquisition equipment, the measurement for the SCCW discharge was unavailable between 22:30 CDT on June 2 and 04:00 CDT on June 3. However, since WBN was operating in a near steady manner throughout the survey, it is known that the SCCW discharge, in like manner, was near steady. Based on data collected in the hours immediately before and after the equipment outage, the average SCCW discharge during the survey was estimated to be about 294 cfs. The SCCW effluent temperature decreased throughout the survey from about 87.1°F at the beginning of the survey to about 83.7°F at the end of the survey. This trend coincides with the falling nighttime air temperature, also shown in Figure 5 (note: the discharge temperature of water from the Unit 1 cooling tower, which provides the source of heat for Outfall 113, varies directly with the temperature of the ambient air that is drawn into the tower). Relative to the upstream ambient river temperature, the temperature rise of the Outfall 113 effluent released from the SCCW system, also shown in Figure 5, decreased from about 18.6 F° at the beginning of the survey to about 14.6 F° at the end of the survey.

Effluent Behavior

Individual Temperature Stations

Shown in Figure 6 are the measurements from the HOBO temperature stations at the downstream end of the passive mixing zone. The stations are labeled consecutively from WB1 to WB12, with WB1 situated near the left-hand shoreline of the river and WB12 situated near the right-hand shoreline of the river (i.e., facing downstream—see Figure 2). The following behaviors are noted:

- At the beginning of the survey, between 23:00 CDT and 23:30 CDT on June 2, stations WB2 through WB4 had to be removed from the navigation channel to allow passage of a tow. No data is available from these stations during this time.

- In the first three hours of the survey, temperature undulations at the 0.5 foot depth were more intense than in previous surveys. This perhaps was due to large-scale "swirls" created in the surface layer of the river by the passing tow, as well as water released upstream as part of the operation of the navigation lock. The undulations are attenuated at larger depths.

- It took about three hours for the leading edge of the SCCW effluent to spread across the river and reach the downstream edge of the passive mixing zone. This is observed by the increase in temperature that begins for all stations at about 02:00 CDT on June 3. The increase is more sudden in the left-hand-side of the river than in the right-hand-side of the river (i.e., WB1 through WB6 verses WB7 through WB12). This is because in a no flow situation, the effluent traverses across the river as it transported downstream more rapidly along the left-hand shoreline.

- In the remaining hours of the survey, the temperature at all stations slowly increased–as much as 3 F° at the 0.5-foot depth, and as much as 1.5 F° at the 7-foot depth. The smaller increase at the 7-foot depth suggests that for the prevailing conditions of the river and WBN, most of the thermal effluent from Outfall 113 resided in the surface layer of the water column (i.e., the bottom layer of the river is protected).

Distribution Across The Mixing Zone

At each HOBO station, the instantaneous compliance temperature was determined by averaging the measurements for the sensors at the 3-foot, 5-foot, and 7-foot depths. Plotted in Figure 7 are the resulting temperatures across the downstream end of the passive mixing zone, measured at the top of each hour from 23:00 CDT on June 2 to 06:00 CDT on June 3. The following behaviors are noted:

- As previously stated, between 23:00 CDT and 23:30 CDT on June 2, stations WB2 through WB4 had to be removed from the navigation channel to allow passage of a tow. As such, no data is shown for these stations for 23:00 CDT.

- During the first hour of the survey, the temperatures at WB1 through WB6 decreased about 0.5°F. Then, between 00:00 CDT and 01:00 CDT, the temperature at all the stations remained fairly constant with only small variations, typically between 0.2°F to 0.3°F.

- Between 01:00 CDT and 02:00 CDT, the temperature at WB1 through WB3 increased by about 1.0°F, indicating the arrival of the leading edge of the SCCW effluent at the downstream, left-hand-side of the passive mixing zone.

- By 03:00 CDT, the effluent had spread across the entire width of the river (at the downstream end of the passive mixing zone). Over the remainder of the survey, from 04:00 CDT to 06:00 CDT, temperatures continued to increase, on the average climbing about an additional 0.3°F. The temperature for stations WB3 through WB5 were somewhat higher, suggesting the center of the effluent plume resided in the left-hand-side of the river.

Compliance Parameters

Since heat from the SCCW effluent is distributed across the full width of the river, data from all of the HOBO stations were used to compute the NPDES compliance parameters, which is consistent with the dimensions of the passive mixing zone (e.g., as shown in Figure 1). The compliance parameters examined include those given in Table 1—the temperature at the downstream edge of mixing zone, T_d; the temperature rise from upstream to the downstream edge of the mixing zone, ΔT; and the temperature rate-of-change at the downstream edge of the mixing zone, TROC. The fundamental equations used to compute the compliance parameters are provided in Appendix B, based on the criteria specified in the NPDES permit. The temperature at the downstream end of the mixing zone was determined from the HOBO measurements (i.e., average of sensors at depths 3, 5, and 7 feet for all twelve HOBO stations). The temperature rise was computed as the difference between the temperature at the downstream end of the mixing zone and the upstream temperature measured at Station 30. The temperature rate-of-change was determined by the change in the temperature at the downstream end of the mixing zone from one hour to the next. The data were averaged over a period of one hour using 15-minute readings, as specified in the NPDES permit, and compared with the WBN thermal plume model. The results are presented in Figure 8, along with the results obtained by the thermal plume model. The following comments are provided.

- Temperature at the downstream edge of the passive mixing zone, T_d: The maximum 1-hour average T_d estimated by the thermal plume model was 72.5°F, whereas the maximum measured value was about 70.8°F. Thus, the model overpredicted the maximum measured T_d by 1.7°F. Compared to the measurements, the increase in river temperature due to the no flow event was predicted to occur much more rapidly by the model. This is because the model assumes impacts due to changes in the river and/or Outfall 113 are fully realized within one hour (i.e., the model time-step); whereas in reality, the actual time for the development of these impacts is much longer, at least for events with little or no river flow. Both the predictions from the model and measurements from the survey were well below the NPDES limit of 86.9°F.

- Temperature rise, ΔT: The maximum 1-hour average ΔT predicted by the plume model was 4.0 F°, whereas the maximum measured value was about 1.7 F°. Thus, the model overpredicted the maximum measured temperature rise by 2.3 F°. For the reason cited above (i.e., computational time-step of one hour), the model predicted the temperature rise to occur sooner than that found by the measurements. Both the predictions from the model and measurements from the survey were well below the NPDES limit of 5.4 F°.

- Temperature rate-of-change, TROC: The maximum 1-hour average TROC predicted by the plume model was 1.0 F°/hour, whereas the maximum measured value was about 0.6 F°/hour (absolute values). Thus, the model overpredicted the temperature rate-of-change by 0.4 F°/hour. Both the predictions from the model and measurements from the survey were well below the NPDES limit of ±3.6 F°/hour.

CONCLUSIONS

The survey for 2011 winter conditions was successful in measuring the NPDES water temperature parameters for the Outfall 113 passive mixing zone. The measurements were compared with values predicted by the thermal plume model that TVA currently uses to judge the safe operation of the SCCW system. Overall, for the conditions of the 2011 winter survey, the model was found to be good for estimating the potential impact of Outfall 113 on the temperature, T_d, temperature rise, ΔT, and temperature rate-of-change, TROC, at the downstream end of the passive mixing zone. This is because the model overpredicted, or bounded, the maximum values measured for T_d, ΔT, and TROC. In this manner, for the conditions of the 2011 winter survey, the thermal plume model assured the operation of Outfall 113 at levels of T_d, ΔT, and TROC below the NPDES limits. For T_d and ΔT, these results are consistent with those for all of the previous surveys for the passive mixing zone. The same is not true, however, for TROC. Previous surveys have revealed that the model is capable of underpredicting measured values for TROC by as much as 0.3 F°/hour (e.g., see McCall and Hopping, 2006). Under these conditions, and despite the results summarized herein, a factor of safety of 0.3 F°/hour currently is used for tracking TROC in the operation of the SCCW system. This is accomplished by limiting the operation of Outfall 113 for the passive mixing zone based on a maximum allowable value of TROC from the thermal plume model of ±3.3 F°/hour rather than ±3.6 F°/hour.

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McCall, Michael J., and P.N. Hopping, "Winter 2005 Compliance Survey for Watts Bar Nuclear Plant Outfall 113 Passive Mixing Zone," TVA River Operations, Report No. WR2005-2-85-151, October 2005.

TDEC, *State of Tennessee NPDES Permit No. TN0020168*, Tennessee Department of Environment and Conservation, Issued June 2010.

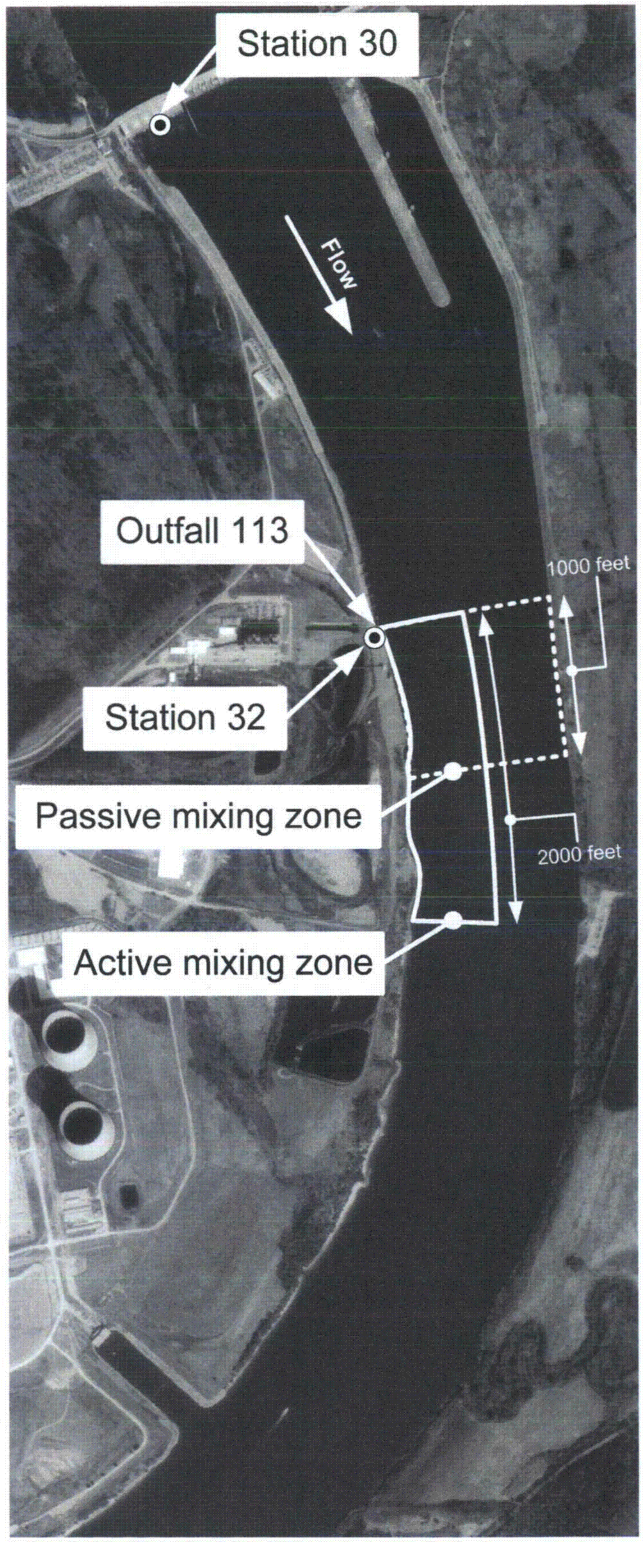

Figure 1. Watts Bar Nuclear Plant Outfall 113 (SCCW) Mixing Zones

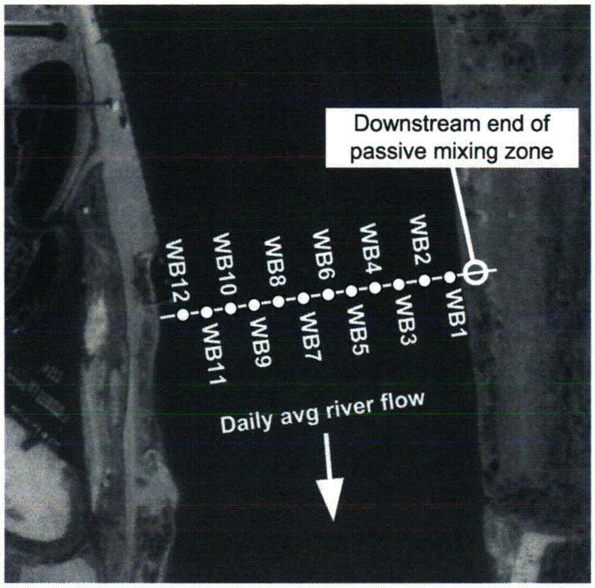

Figure 2. Location of HOBO Monitoring Stations

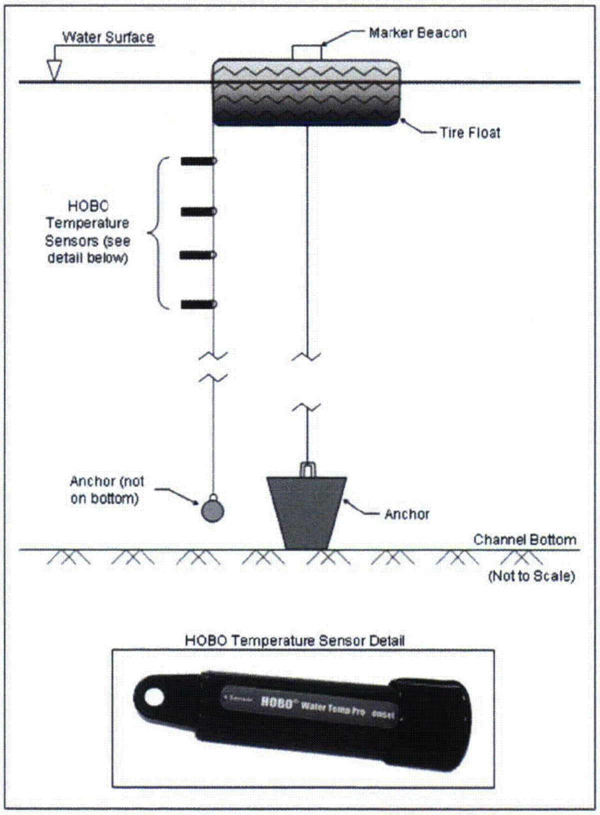

Figure 3. Schematic of HOBO Water Temperature Monitoring Stations

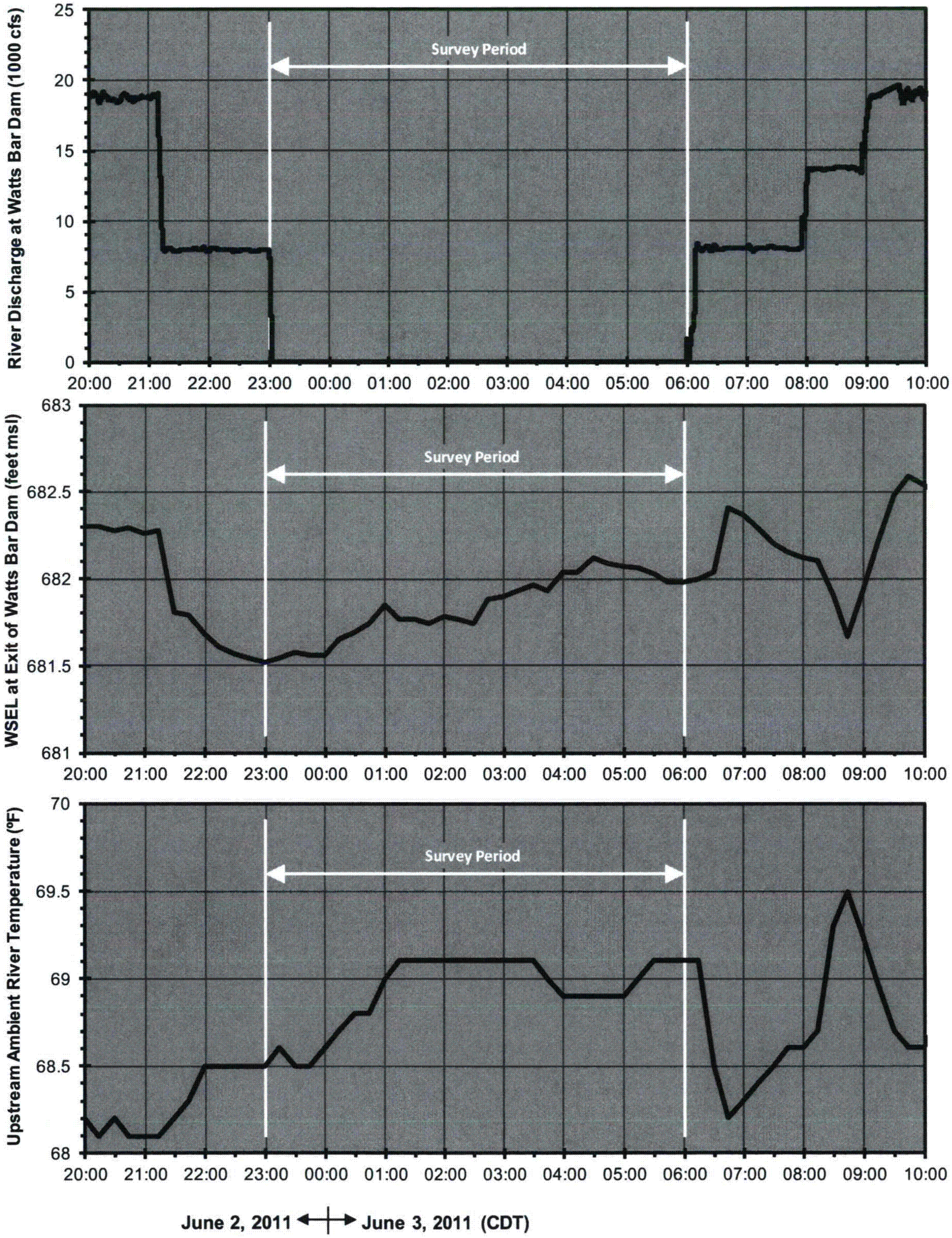

Figure 4. River Conditions

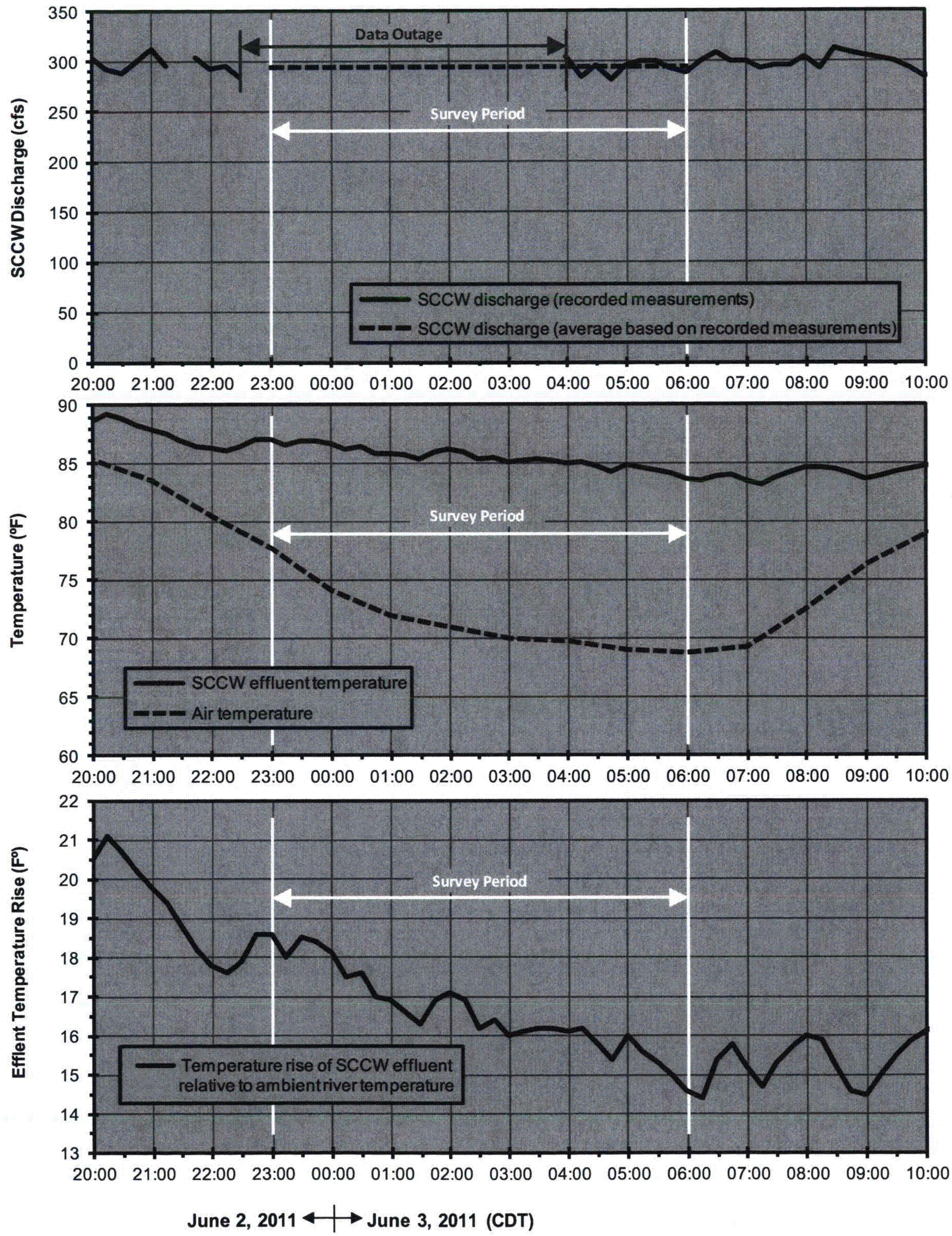

Figure 5. SCCW Conditions

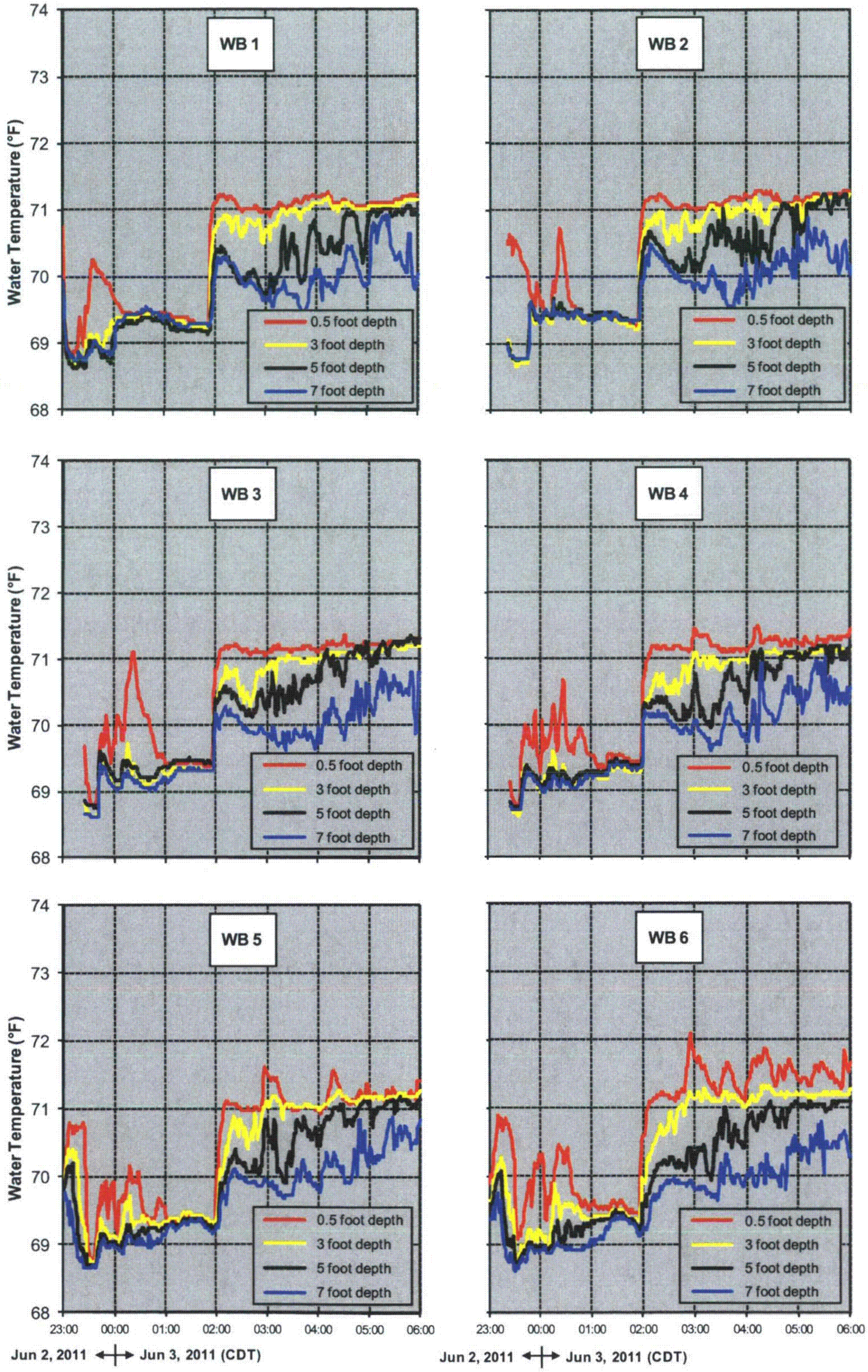

Figure 6. HOBO Water Temperature Measurements During Survey

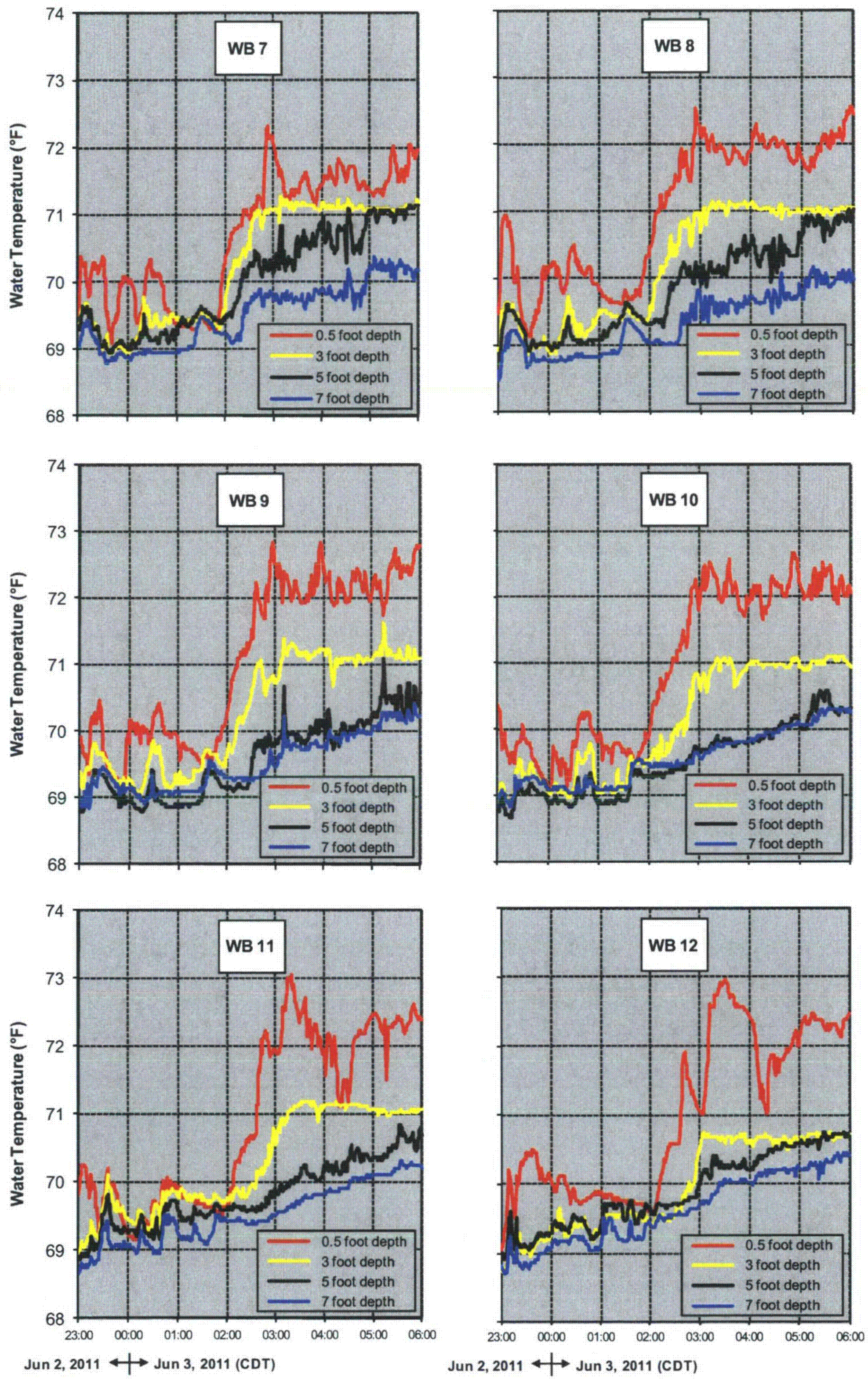

Figure 6 (Continued). HOBO Water Temperature Measurements During Survey

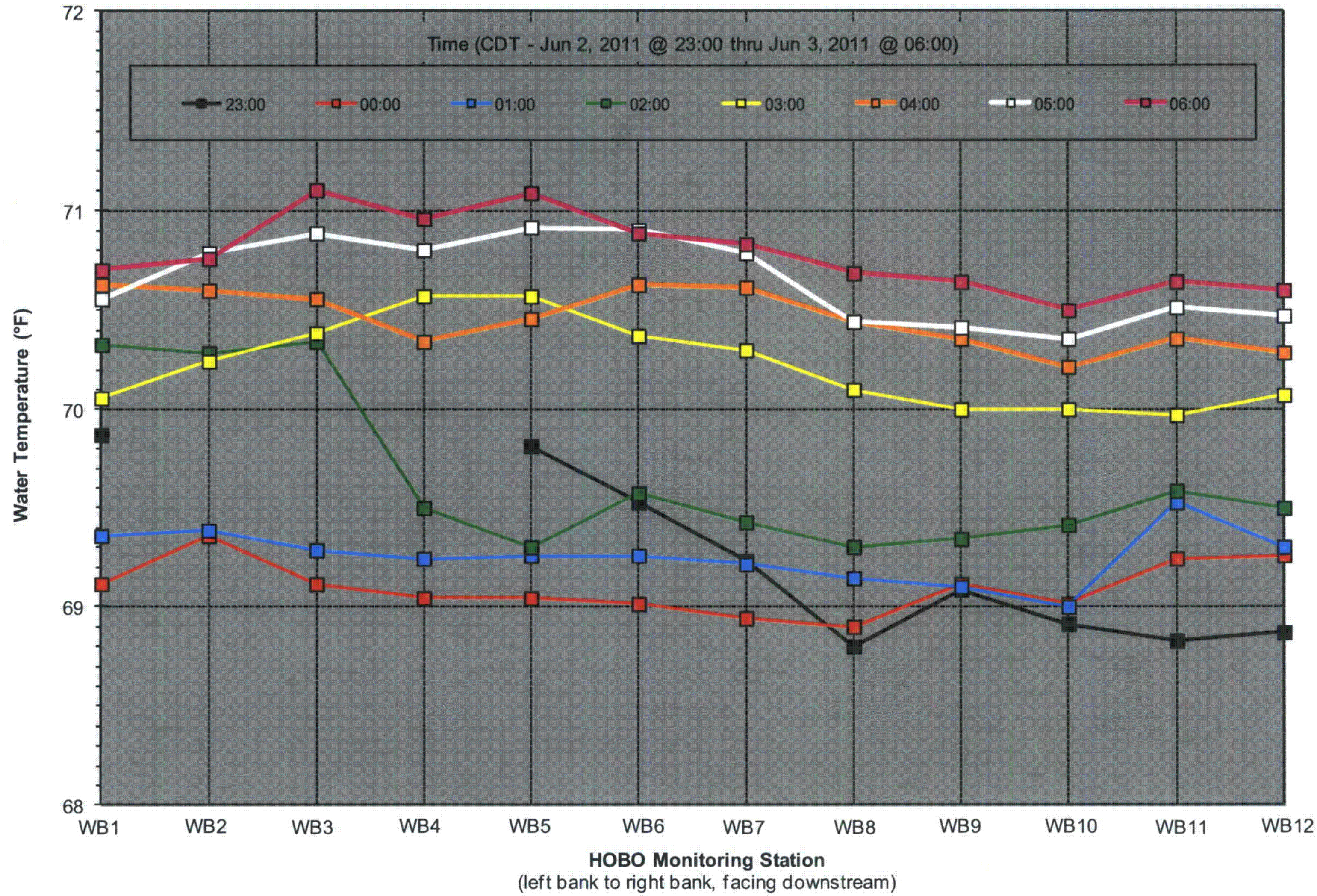

Figure 7. Profiles of Instantaneous Compliance Temperature across Downstream End of Passive Mixing Zone (Average of Readings at 3-Foot, 5-Foot, and 7-Foot Depths)

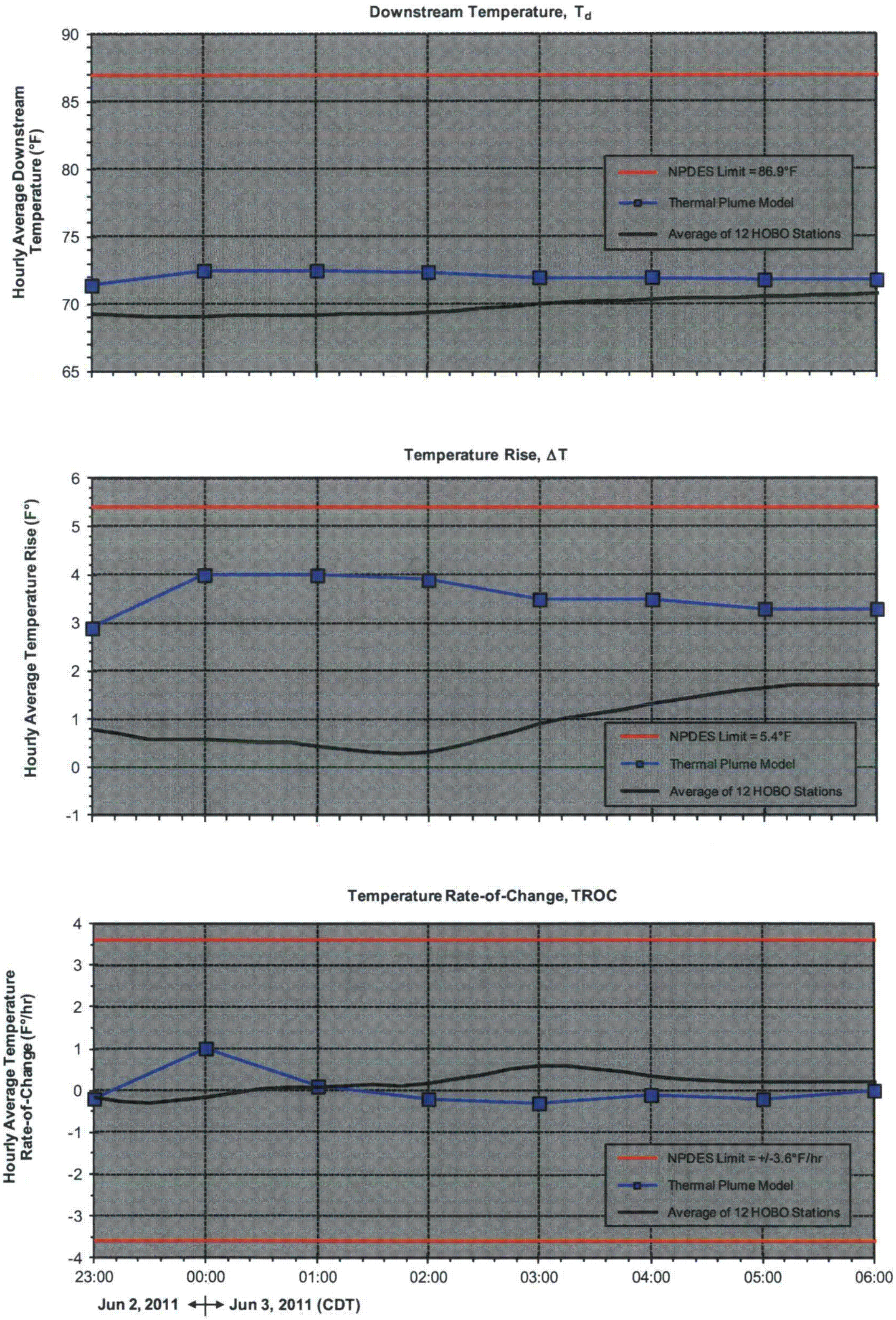

Figure 8. Measured and Computed Compliance Parameters for Passive Mixing Zone

APPENDIX A

(The following information is provided per request of Mike Kelly of TDEC on August 26, 2008)

All sensors used by TVA for monitoring compliance of NPDES water temperature requirements are certified and maintained to meet the following industry and regulatory standards:

- ISO/IEC 17025—Quality assurance requirements for the competence to carry out sampling, testing, and calibrations using standard, non-standard, and laboratory-developed methods (ISO=International Organization for Standardization, IEC=International Electrotechnical Commission).
- 10CFR50 Appendix B—Quality assurance criteria for design, fabrication, construction, and testing of the structures, systems, and components of nuclear power plants (CFR=Code of Federal Regulations).
- 40CFR136—Guidelines establishing test procedures for the analysis of pollutants under the Clean Water Act.
- ANSI N45.2. 1971—Quality assurance requirements for Nuclear Power Plants (ANSI= American National Standards Institute).
- ANSI/NCSL Z540-1-1994—General requirements for calibration laboratories and equipment used for measurements and testing (NCSL=National Conference of Standards Laboratories).

The standard used to certify the thermistors for the permanent EDS stations and the temporary HOBO stations is traceable to the National Institute of Standards and Technology (NIST). The standard includes two pieces of equipment—a platinum resistance temperature detector (RTD) manufactured by Burns Engineering, Inc. and an ohmmeter manufactured by Azonix Inc. The latter is used to measure the resistance of the RTD (i.e., the resistance of platinum varies with temperature). The NTIS traceable calibration certificates for the Burns RTDs and the Azonix ohmmeter that were used to calibrate the HOBO probes are provided below. The end result of the RTD calibration is a set of International Temperature Scale 1990 (ITS 90) coefficients that are used to compute water temperature from the measured RTD resistance. Based on the calibration certificates, the accuracy of the system for the temperature standard is about ±0.05°F. The tolerance of the thermistors used for the WBN field survey is about ±0.4°F, thus providing a calibration test accuracy ratio (TAR) of about 1:8. That is, the accuracy of temperature standard used for the sensor calibrations is 8 times greater than the minimum acceptable field accuracy of temperature sensors. This is twice the recommended maximum TAR of 1:4 for sensor calibrations.

The TVA procedure to calibrate the HOBO water temperature probes, Instruction No. 450.01-020, is provided below. Briefly, the HOBO probes are immersed in a stirred temperature-controlled water bath along with the standard (i.e., along with the Burns RTD probe). After the bath stabilizes, temperature readings from the HOBO probes are compared to the temperature readings from the standard. Experience has shown that in nearly all cases, the readings from both the HOBO probes and the standard and are essentially constant, so that the 95 percent confidence interval of the readings is diminutive. Under these conditions, the accuracy of each HOBO probe is recorded simply as the difference between the HOBO reading and that of the standard (negative difference = HOBO reading low/below standard, positive difference = HOBO reading high/above standard). The HOBO probes are tested at three temperatures between 30°F and 100°F, covering the range of expected water temperature for natural river conditions. Specifically, the three temperatures are at about the 10 percent, 50 percent, and 90 percent intervals, or 37°F, 65°F and 93°F, respectively. Any HOBO probe with measured accuracy (i.e., difference) in excess of the maximum allowable tolerance of ±0.4°F for any one temperature fails the calibration test and is removed from the field survey inventory. In general, based on TVA experience, most HOBO probes that pass the calibration test usually have measured accuracies better than about ±0.25°F for all three temperatures examined in the bath tests. The calibration certificates for HOBO probes used in field survey summarized herein are provided below. Included are certificates for both the pre- and post-survey calibration tests. A close examination of the certificates shows that all the HOBO probes passed the calibration test both before and after the field survey.

Calibration Certificates for Burns Platinum Resistance Thermometer (RTD)

RTD ID No. 906535 was used for both pre-survey and post-survey calibrations.

LAB STANDARD REPORT of CALIBRATION

Asset ID:	906535
Certificate No:	34481
Page 1 of 6	

Tennessee Valley Authority
Central Laboratories Services
Mailing Address: 1101 Market Street, PSC-1B-C, Chattanooga, TN 37402
Shipping Address: 4601 North Access Road, Bldg. A, Chattanooga, TN 37415
Phone: (423) 876-4318 **Fax:** (423) 876-4137

QA RECORD

Customer:
CLS KNOXVILLE
400 W. SUMMIT HILL DR.
KNOXVILLE, TN 37902

Instrument Information:

Description: RTD
Manufacturer: BURNS
Model: 3925
Serial Number:

Calibration Information:

Cal Date: 12/16/2010
Due Date: 12/16/2011
Interval: 12 Months
Cal Instruction: 307.04-004
As Found: In Tolerance
As Left: In Tolerance - Adjusted

Ambient Temperature: 72°F +/- 9°F **Ambient Humidity:** <=80% RH

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10CFR50 Appendix B, ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced, except in full, without the written approval of CLS.

Technical Remarks:
Recalculated coefficients to improve As Left data.

Standards Utilized

TVA I.D.	Mfg.	Model No.	Description	Cal. Date	Due Date
906643	ISOTECH	MERCURY CELL	FIXED POINT CELL	12/08/2009	12/08/2014
906644	HART SCIENTIFIC	WATER TRIPLE CELL	TRIPLE POINT BATH & CELL	12/08/2009	12/08/2014
906645	ISOTECH	GALLIUM CELL	FIXED POINT CELL	12/08/2009	12/08/2014
906646	ISOTECH	TIN CELL	FIXED POINT CELL	12/08/2009	12/08/2014
906647	ISOTECH	ZINC CELL	FIXED POINT CELL	12/08/2009	12/08/2014
906722	GUILDLINE	6622T	TEMPERATURE MEASURING SYSTEM	08/23/2010	08/23/2011
906737	GUILDLINE	9334A	STANDARD RESISTOR	08/20/2010	08/20/2011

Calibrated by:	David R. Bird Sr Metrology Tech	**Approved By:**	Sam Bertram Calibration Supv.	12/20/2010 Date

This report was electronically approved using Edison Mudcats Metrology Suite Ver. 2.2.1.

Tennessee Valley Authority

CENTRAL LABORATORIES SERVICES CHATTANOOGA, TENNESSEE CALIBRATION REPORT	Cust. I.D. No.:	906535
	Page No.:	2 of 6
	Date of Report:	12/16/10

Remarks: **Accuracy = ± 0.02 deg C**

Recalculated coefficients prior to As Left test to improve accuracy.

For As Left data and coefficients refer to page 3 of 6.

AS FOUND TEST

UUT (deg C)	STD (deg C)	Error (deg C)
-38.84	-38.834	-0.0051
0.01	0.010	0.0000
29.75	29.765	-0.0121
231.91	231.928	-0.0199
419.54	419.527	0.0159

As Found ITS 90 Coefficients

Rtpw	100.000221
a5	-4.15854650E-04
b5	-1.55621388E-04
a8	-2.72593907E-04
b8	-2.28004426E-04

Test current 1mA

All meas. ratios between the stds referenced in this instruction and the M&TE calibrated are greater than or equal to 4:1 except as noted.
This instrument was tested and calibrated to prescribed test procedures and the condition of the instrument is indicated.

Report for ITS-90 Coefficients

Model: 3925
Serial: TVA 906535
Date: December 17,2010

TPW:

Reference (°C)	UUT (Ohms)	Residual (°C)
0.0100	100.0002	N/A

Low Range:

Reference (°C)	UUT (Ohms)	Residual (°C)
-38.8344	84.4207	0.0002
29.7646	111.8088	0.0000

High Range:

Reference (°C)	UUT (Ohms)	Residual (°C)
231.9280	189.2353	0.0001
419.5270	256.8059	0.0000

Coefficients:
RTPW = 100.000221

Low Range:
a5 = -4.33797355 E-04
b5 = -1.87516921 E-04

High Range:
a8 = -4.39650984 E-04
b8 = -7.09976322 E-05

°C	Resistance	dr/dT	°C	Resistance	dr/dT	°C	Resistance	dr/dT
-39.00	84.353834	0.4034888	20.00	107.94545	0.3961843	79.00	131.11375	0.3890764
-38.00	84.757322	0.4033577	21.00	108.34164	0.3960630	80.00	131.50283	0.3889566
-37.00	85.160680	0.4032272	22.00	108.73770	0.3959417	81.00	131.89179	0.3888369
-36.00	85.563907	0.4030971	23.00	109.13364	0.3958205	82.00	132.28062	0.3887171
-35.00	85.967004	0.4029674	24.00	109.52946	0.3956993	83.00	132.66934	0.3885974
-34.00	86.369972	0.4028383	25.00	109.92516	0.3955781	84.00	133.05794	0.3884778
-33.00	86.772810	0.4027095	26.00	110.32074	0.3954570	85.00	133.44641	0.3883581
-32.00	87.175520	0.4025812	27.00	110.71619	0.3953359	86.00	133.83477	0.3882385
-31.00	87.578101	0.4024533	28.00	111.11153	0.3952148	87.00	134.22301	0.3881189
-30.00	87.980554	0.4023258	29.00	111.50675	0.3950938	88.00	134.61113	0.3879993
-29.00	88.382880	0.4021987	30.00	111.90184	0.3949728	89.00	134.99913	0.3878797
-28.00	88.785079	0.4020720	31.00	112.29681	0.3948518	90.00	135.38701	0.3877601
-27.00	89.187151	0.4019457	32.00	112.69166	0.3947309	91.00	135.77477	0.3876406
-26.00	89.589096	0.4018198	33.00	113.08640	0.3946100	92.00	136.16241	0.3875211
-25.00	89.990916	0.4016942	34.00	113.48101	0.3944891	93.00	136.54993	0.3874016
-24.00	90.392610	0.4015689	35.00	113.87549	0.3943683	94.00	136.93733	0.3872821
-23.00	90.794179	0.4014440	36.00	114.26986	0.3942475	95.00	137.32461	0.3871627
-22.00	91.195623	0.4013193	37.00	114.66411	0.3941267	96.00	137.71178	0.3870432
-21.00	91.596943	0.4011950	38.00	115.05824	0.3940059	97.00	138.09882	0.3869238
-20.00	91.998138	0.4010709	39.00	115.45224	0.3938852	98.00	138.48574	0.3868044
-19.00	92.399208	0.4009472	40.00	115.84613	0.3937645	99.00	138.87255	0.3866850
-18.00	92.800156	0.4008236	41.00	116.23989	0.3936438	100.00	139.25923	0.3865657
-17.00	93.200979	0.4007003	42.00	116.63354	0.3935232	101.00	139.64580	0.3864464
-16.00	93.601680	0.4005773	43.00	117.02706	0.3934025	102.00	140.03225	0.3863271
-15.00	94.002257	0.4004544	44.00	117.42046	0.3932819	103.00	140.41857	0.3862078
-14.00	94.402711	0.4003317	45.00	117.81374	0.3931614	104.00	140.80478	0.3860885
-13.00	94.803043	0.4002091	46.00	118.20690	0.3930408	105.00	141.19087	0.3859692
-12.00	95.203252	0.4000867	47.00	118.59995	0.3929203	106.00	141.57684	0.3858500
-11.00	95.603339	0.3999645	48.00	118.99287	0.3927998	107.00	141.96269	0.3857308
-10.00	96.003303	0.3998423	49.00	119.38567	0.3926794	108.00	142.34842	0.3856116
-9.00	96.403146	0.3997202	50.00	119.77835	0.3925589	109.00	142.73403	0.3854924
-8.00	96.802866	0.3995981	51.00	120.17090	0.3924385	110.00	143.11952	0.3853733
-7.00	97.202464	0.3994761	52.00	120.56334	0.3923181	111.00	143.50490	0.3852542
-6.00	97.601940	0.3993541	53.00	120.95566	0.3921978	112.00	143.89015	0.3851351
-5.00	98.001294	0.3992321	54.00	121.34786	0.3920774	113.00	144.27529	0.3850160
-4.00	98.400526	0.3991100	55.00	121.73994	0.3919571	114.00	144.66030	0.3848969
-3.00	98.799636	0.3989878	56.00	122.13189	0.3918368	115.00	145.04520	0.3847779
-2.00	99.198624	0.3988656	57.00	122.52373	0.3917166	116.00	145.42998	0.3846588
-1.00	99.597490	0.3987432	58.00	122.91545	0.3915963	117.00	145.81464	0.3845398
0.00	99.996233	0.3986186	59.00	123.30704	0.3914761	118.00	146.19918	0.3844209
1.00	100.39485	0.3984965	60.00	123.69852	0.3913559	119.00	146.58360	0.3843019
2.00	100.79335	0.3983744	61.00	124.08987	0.3912357	120.00	146.96790	0.3841829
3.00	101.19172	0.3982523	62.00	124.48111	0.3911156	121.00	147.35208	0.3840640
4.00	101.58998	0.3981303	63.00	124.87223	0.3909954	122.00	147.73615	0.3839451
5.00	101.98811	0.3980084	64.00	125.26322	0.3908753	123.00	148.12009	0.3838262
6.00	102.38611	0.3978865	65.00	125.65410	0.3907552	124.00	148.50392	0.3837074
7.00	102.78400	0.3977646	66.00	126.04485	0.3906352	125.00	148.88762	0.3835885
8.00	103.18177	0.3976428	67.00	126.43549	0.3905151	126.00	149.27121	0.3834697
9.00	103.57941	0.3975211	68.00	126.82600	0.3903951	127.00	149.65468	0.3833509
10.00	103.97693	0.3973993	69.00	127.21640	0.3902751	128.00	150.03803	0.3832321
11.00	104.37433	0.3972776	70.00	127.60667	0.3901552	129.00	150.42127	0.3831134
12.00	104.77161	0.3971560	71.00	127.99683	0.3900352	130.00	150.80438	0.3829946
13.00	105.16876	0.3970344	72.00	128.38686	0.3899153	131.00	151.18737	0.3828759
14.00	105.56580	0.3969128	73.00	128.77678	0.3897954	132.00	151.57025	0.3827572
15.00	105.96271	0.3967913	74.00	129.16657	0.3896755	133.00	151.95301	0.3826386
16.00	106.35950	0.3966698	75.00	129.55625	0.3895556	134.00	152.33565	0.3825199
17.00	106.75617	0.3965484	76.00	129.94580	0.3894358	135.00	152.71816	0.3824013
18.00	107.15272	0.3964270	77.00	130.33524	0.3893159	136.00	153.10057	0.3822827
19.00	107.54915	0.3963056	78.00	130.72456	0.3891961	137.00	153.48285	0.3821641

°C	Resistance	dr/dT	°C	Resistance	dr/dT	°C	Resistance	dr/dT
138.00	153.86501	0.3820455	197.00	176.20357	0.3750883	256.00	198.13379	0.3682033
139.00	154.24706	0.3819270	198.00	176.57865	0.3749710	257.00	198.50199	0.3680872
140.00	154.62899	0.3818084	199.00	176.95363	0.3748537	258.00	198.87008	0.3679710
141.00	155.01079	0.3816899	200.00	177.32848	0.3747365	259.00	199.23805	0.3678549
142.00	155.39248	0.3815715	201.00	177.70322	0.3746193	260.00	199.60590	0.3677388
143.00	155.77406	0.3814530	202.00	178.07784	0.3745021	261.00	199.97364	0.3676227
144.00	156.15551	0.3813346	203.00	178.45234	0.3743850	262.00	200.34126	0.3675066
145.00	156.53684	0.3812161	204.00	178.82672	0.3742678	263.00	200.70877	0.3673905
146.00	156.91806	0.3810977	205.00	179.20099	0.3741507	264.00	201.07616	0.3672745
147.00	157.29916	0.3809794	206.00	179.57514	0.3740336	265.00	201.44344	0.3671584
148.00	157.68014	0.3808610	207.00	179.94917	0.3739165	266.00	201.81059	0.3670424
149.00	158.06100	0.3807427	208.00	180.32309	0.3737995	267.00	202.17764	0.3669264
150.00	158.44174	0.3806244	209.00	180.69689	0.3736824	268.00	202.54456	0.3668104
151.00	158.82236	0.3805061	210.00	181.07057	0.3735654	269.00	202.91137	0.3666944
152.00	159.20287	0.3803878	211.00	181.44414	0.3734484	270.00	203.27807	0.3665784
153.00	159.58326	0.3802696	212.00	181.81759	0.3733314	271.00	203.64465	0.3664624
154.00	159.96353	0.3801513	213.00	182.19092	0.3732145	272.00	204.01111	0.3663465
155.00	160.34368	0.3800331	214.00	182.56413	0.3730975	273.00	204.37745	0.3662305
156.00	160.72371	0.3799150	215.00	182.93723	0.3729806	274.00	204.74369	0.3661146
157.00	161.10363	0.3797968	216.00	183.31021	0.3728637	275.00	205.10980	0.3659987
158.00	161.48342	0.3796787	217.00	183.68307	0.3727469	276.00	205.47580	0.3658828
159.00	161.86310	0.3795605	218.00	184.05582	0.3726300	277.00	205.84168	0.3657669
160.00	162.24266	0.3794424	219.00	184.42845	0.3725132	278.00	206.20745	0.3656510
161.00	162.62211	0.3793244	220.00	184.80096	0.3723963	279.00	206.57310	0.3655351
162.00	163.00143	0.3792063	221.00	185.17336	0.3722796	280.00	206.93863	0.3654193
163.00	163.38064	0.3790883	222.00	185.54564	0.3721628	281.00	207.30405	0.3653034
164.00	163.75972	0.3789703	223.00	185.91780	0.3720460	282.00	207.66936	0.3651876
165.00	164.13869	0.3788523	224.00	186.28985	0.3719293	283.00	208.03454	0.3650718
166.00	164.51755	0.3787343	225.00	186.66178	0.3718126	284.00	208.39962	0.3649559
167.00	164.89628	0.3786164	226.00	187.03359	0.3716959	285.00	208.76457	0.3648401
168.00	165.27490	0.3784985	227.00	187.40529	0.3715792	286.00	209.12941	0.3647243
169.00	165.65340	0.3783806	228.00	187.77687	0.3714625	287.00	209.49414	0.3646085
170.00	166.03178	0.3782627	229.00	188.14833	0.3713459	288.00	209.85875	0.3644928
171.00	166.41004	0.3781448	230.00	188.51967	0.3712293	289.00	210.22324	0.3643770
172.00	166.78818	0.3780270	231.00	188.89090	0.3711127	290.00	210.58762	0.3642612
173.00	167.16621	0.3779092	232.00	189.26202	0.3709961	291.00	210.95188	0.3641455
174.00	167.54412	0.3777914	233.00	189.63301	0.3708795	292.00	211.31602	0.3640297
175.00	167.92191	0.3776736	234.00	190.00389	0.3707630	293.00	211.68005	0.3639140
176.00	168.29959	0.3775559	235.00	190.37465	0.3706464	294.00	212.04397	0.3637982
177.00	168.67714	0.3774382	236.00	190.74530	0.3705299	295.00	212.40776	0.3636825
178.00	169.05458	0.3773205	237.00	191.11583	0.3704134	296.00	212.77145	0.3635668
179.00	169.43190	0.3772028	238.00	191.48624	0.3702970	297.00	213.13501	0.3634511
180.00	169.80910	0.3770851	239.00	191.85654	0.3701805	298.00	213.49846	0.3633354
181.00	170.18619	0.3769675	240.00	192.22672	0.3700641	299.00	213.86180	0.3632197
182.00	170.56316	0.3768499	241.00	192.59679	0.3699477	300.00	214.22502	0.3631040
183.00	170.94001	0.3767323	242.00	192.96673	0.3698312	301.00	214.58812	0.3629883
184.00	171.31674	0.3766147	243.00	193.33657	0.3697149	302.00	214.95111	0.3628727
185.00	171.69335	0.3764972	244.00	193.70628	0.3695985	303.00	215.31398	0.3627570
186.00	172.06985	0.3763796	245.00	194.07588	0.3694821	304.00	215.67674	0.3626413
187.00	172.44623	0.3762621	246.00	194.44536	0.3693658	305.00	216.03938	0.3625257
188.00	172.82249	0.3761446	247.00	194.81473	0.3692495	306.00	216.40191	0.3624100
189.00	173.19864	0.3760272	248.00	195.18398	0.3691332	307.00	216.76432	0.3622944
190.00	173.57466	0.3759097	249.00	195.55311	0.3690169	308.00	217.12661	0.3621787
191.00	173.95057	0.3757923	250.00	195.92213	0.3689006	309.00	217.48879	0.3620631
192.00	174.32637	0.3756749	251.00	196.29103	0.3687844	310.00	217.85085	0.3619474
193.00	174.70204	0.3755575	252.00	196.65981	0.3686681	311.00	218.21280	0.3618318
194.00	175.07760	0.3754402	253.00	197.02848	0.3685519	312.00	218.57463	0.3617162
195.00	175.45304	0.3753229	254.00	197.39703	0.3684357	313.00	218.93635	0.3616005
196.00	175.82836	0.3752055	255.00	197.76547	0.3683195	314.00	219.29795	0.3614849

°C	Resistance	dr/dT	°C	Resistance	dr/dT
315.00	219.65944	0.3613693	374.00	240.78236	0.3545432
316.00	220.02080	0.3612537	**375.00**	241.13690	0.3544273
317.00	220.38206	0.3611381	**376.00**	241.49133	0.3543114
318.00	220.74320	0.3610224	**377.00**	241.84564	0.3541954
319.00	221.10422	0.3609068	**378.00**	242.19983	0.3540794
320.00	221.46513	0.3607912	**379.00**	242.55391	0.3539634
321.00	221.82592	0.3606756	**380.00**	242.90788	0.3538474
322.00	222.18659	0.3605600	**381.00**	243.26173	0.3537314
323.00	222.54715	0.3604444	**382.00**	243.61546	0.3536154
324.00	222.90760	0.3603288	**383.00**	243.96907	0.3534993
325.00	223.26793	0.3602132	**384.00**	244.32257	0.3533833
326.00	223.62814	0.3600976	**385.00**	244.67595	0.3532672
327.00	223.98824	0.3599820	**386.00**	245.02922	0.3531511
328.00	224.34822	0.3598664	**387.00**	245.38237	0.3530350
329.00	224.70808	0.3597508	**388.00**	245.73541	0.3529189
330.00	225.06784	0.3596351	**389.00**	246.08833	0.3528027
331.00	225.42747	0.3595195	**390.00**	246.44113	0.3526865
332.00	225.78699	0.3594039	**391.00**	246.79382	0.3525704
333.00	226.14639	0.3592883	**392.00**	247.14639	0.3524542
334.00	226.50568	0.3591727	**393.00**	247.49884	0.3523379
335.00	226.86486	0.3590571	**394.00**	247.85118	0.3522217
336.00	227.22391	0.3589415	**395.00**	248.20340	0.3521055
337.00	227.58285	0.3588258	**396.00**	248.55551	0.3519892
338.00	227.94168	0.3587102	**397.00**	248.90749	0.3518729
339.00	228.30039	0.3585946	**398.00**	249.25937	0.3517566
340.00	228.65898	0.3584789	**399.00**	249.61112	0.3516403
341.00	229.01746	0.3583633	**400.00**	249.96276	0.3515239
342.00	229.37583	0.3582477	**401.00**	250.31429	0.3514075
343.00	229.73407	0.3581320	**402.00**	250.66570	0.3512912
344.00	230.09221	0.3580164	**403.00**	251.01699	0.3511748
345.00	230.45022	0.3579007	**404.00**	251.36816	0.3510583
346.00	230.80812	0.3577850	**405.00**	251.71922	0.3509419
347.00	231.16591	0.3576694	**406.00**	252.07016	0.3508254
348.00	231.52358	0.3575537	**407.00**	252.42099	0.3507089
349.00	231.88113	0.3574380	**408.00**	252.77170	0.3505924
350.00	232.23857	0.3573223	**409.00**	253.12229	0.3504759
351.00	232.59589	0.3572066	**410.00**	253.47276	0.3503593
352.00	232.95310	0.3570909	**411.00**	253.82312	0.3502427
353.00	233.31019	0.3569752	**412.00**	254.17337	0.3501261
354.00	233.66716	0.3568595	**413.00**	254.52349	0.3500095
355.00	234.02402	0.3567438	**414.00**	254.87350	0.3498928
356.00	234.38077	0.3566281	**415.00**	255.22340	0.3497762
357.00	234.73740	0.3565123	**416.00**	255.57317	0.3496595
358.00	235.09391	0.3563966	**417.00**	255.92283	0.3495428
359.00	235.45030	0.3562808	**418.00**	256.27237	0.3494260
360.00	235.80659	0.3561651	**419.00**	256.62180	0.3493092
361.00	236.16275	0.3560493	**420.00**	256.97111	0.3491925
362.00	236.51880	0.3559335			
363.00	236.87473	0.3558177			
364.00	237.23055	0.3557019			
365.00	237.58625	0.3555861			
366.00	237.94184	0.3554703			
367.00	238.29731	0.3553544			
368.00	238.65266	0.3552386			
369.00	239.00790	0.3551227			
370.00	239.36303	0.3550069			
371.00	239.71803	0.3548910			
372.00	240.07292	0.3547751			
373.00	240.42770	0.3546592			

Calibration Certificate for Azonix Ohmmeter

Instrument used to read resistance of Burns RTD thermometers.

Azonix Ohmmeter ID No. 906527 was used for both pre-survey and post-survey calibrations.

LAB STANDARD REPORT of CALIBRATION

Asset ID:	**906527**
Certificate No:	**34480**
Page 1 of 2	

Tennessee Valley Authority
Central Laboratories Services
Mailing Address: 1101 Market Street, PSC-1B-C, Chattanooga, TN 37402
Shipping Address: 4601 North Access Road, Bldg. A, Chattanooga, TN 37415
Phone: (423) 876-4318 Fax: (423) 876-4137

QA RECORD

Customer:
CLS KNOXVILLE
400 W. SUMMIT HILL DR.
KNOXVILLE, TN 37902

Instrument Information:

Description: DIGITAL THERMOMETER
Manufacturer: AZONIX
Model: A1011-RS-A0-RT41
Serial Number:

Calibration Information:

Cal Date: 01/07/2011
Due Date: 01/07/2012
Interval: 12 Months
Cal Instruction: 308.02-003
As Found: In Tolerance
As Left: In Tolerance

Ambient Temperature: 72°F +/- 2°F **Ambient Humidity:** <=50% RH

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10CFR50 Appendix B, ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced, except in full, without the written approval of CLS.

Technical Remarks:
Left as found. Certification is limited to channels 1 and 2. Channels 3 and 4 are not certified. Limited certification label is attached.

Standards Utilized

TVA I.D.	Mfg.	Model No.	Description	Cal. Date	Due Date
259303	HONEYWELL	1190	RESISTANCE STANDARD,1 OHM	07/21/2010	07/21/2015
906523	OMEGA	HH 42	DIGITAL THERMOMETER	12/17/2010	12/17/2011
E29099	GUILDLINE	6675A	DC RESISTANCE BRIDGE	11/17/2010	02/10/2011

Calibrated by:	Keith Roberts	**Approved By:**	Sam Bertram	01/11/2011
	Sr Metrology Tech		Calibration Supv.	Date

This report was electronically approved using Edison Mudcats Metrology Suite Ver. 2.2.1.

Tennessee Valley Authority

CENTRAL LABORATORIES SERVICES CHATTANOOGA, TENNESSEE CALIBRATION REPORT	Cust. I. D. No.:	906527
	Page No.:	2 of 2
	Date of Report:	1/7/11

Remarks: Accuracy = 0.004 Ohms

Certification is limited to channels 1 and 2; channels 3 and 4 are not certified.
Limited certification label is attached.

Left as found.

*Denotes out of tolerance.

AS FOUND

Probe	Standard Resistance (Ohms)	UUT Reading (Ohms)	Error (Ohms)
1	89.9995	90.001	0.002
	99.9995	100.002	0.003
	119.9993	120.002	0.003
2	89.9995	90.002	0.003
	99.9995	100.002	0.003
	119.9993	120.002	0.003

TVA Procedure for Calibration of HOBO Water Temperature Probes

TVA CENTRAL LABORATORIES SERVICES QUALITY PROGRAM INSTRUCTION	TITLE Certification of HOBO Water Temp Pro Data Acquisition SystemsH_20-001	Instruction No. 450.01-020 Rev. No. 0 Page No. 1 of 7 Effective Date 5/19/03

LEVEL OF USE ☐ Continuous ☒ Reference ☐ Information

QA RECORD

Dennis T. Darby
Preparer

5/19/03
Date

Paul B. Loiseau, Jr.
Technical Reviewer

5/19/03
Date

[signature]
Administrative Review

6/5/03
Date

APPROVAL

Jerry D. Hubble
Department Manager

5/19/03
Date

REVISION LOG

Revision Number	Effective Date	Pages Affected	Description of Revision
0	5/19/03	All	Initial Issue.

1.0 PURPOSE

To provide uniform and effective certifications of Hobo Water Temp Pro data acquisition systems meeting the accuracy and performance requirements of TVA's water temperature-monitoring programs. This technical instruction uses the method of comparison with a laboratory standard thermometer.

2.0 SCOPE

This instruction applies to the certification of Hobo Water Temp Pro data loggers manufactured by Onset Computer Corporation of Bourne, Massachusetts. The Hobo Water Temp Pro is a data acquisition system containing a temperature sensor, data logger and battery sealed in a single submersible case. The Hobo Water Temp Pro is programmed and data retrieved by use of an infrared interface located in one end of the case. Hobo Water Temp Pros are certified upon receipt from the manufacturer at no greater than 12 month intervals during use or when requested.

3.0 SUMMARY

In this three-point certification systems are tested as actually used over the historical water temperature range of 30° to 100°F and submerged in water. The three test points are 37°, 65° and 93°F. The systems are required to perform within Onset Computer Corporation tolerances. System conformity at each temperature point is determined by comparing system temperature, logged by the Hobo Water Temp Pro and a laboratory standard thermometer.

Systems are programmed and submerged with a standard thermometer in a stirred, temperature-controlled temperature bath. The systems are read after the test by an infrared interface adapter connected to a computer running Onset Computer Corporation's Boxcar Pro software. Traceability of the certification is through the thermometer.

"As-found" certifications are performed on new systems as an acceptance test and on sensors returned from field service. "As-left" certifications are performed before delivery for field service if more than 12 months has elapsed since the last certification. "As-found" and "as-left" certifications may be combined on the same record if there is clear indication which type each system is undergoing.

Multiple HOBOs may be certified at the same time in the temperature bath.

- Accuracy of ±0.2°C at 25°C (0.33°Flat 70°F)
- Waterproof case, submersible to 100 feet
- Capacity to store up to 21,580 temperature measurements
- Selectable sampling interval from 1 second to 9 hours
- Programmable start time/date
- Two data recording modes: Stop when full or wrap around when full.
- Two data offload modes: Halt then offload or offload while logging.
- Nonvolatile EEPROM memory that retains data even if batteries fail
- Light-emitting diode (LED) operation, indicator, which can be disabled during logging by selecting "Stealth"1 mode
- High-speed IR communications for offloading data; can readout full logger in less than 30 seconds while logging continues
- Battery life of 6 years with typical usage

4.0 PRACTICES/EXCEPTIONS

N/A

5.0 SAFETY

5.1 Standard electrical equipment safety.

6.0 STANDARDS USED

6.1 Laboratory reference thermometer, range 30° to 100°F or greater, 0.01°F resolution, 0.1°F accuracy or better, with current calibration sticker.

7.0 EQUIPMENT/APPARATUS

7.1 Temperature bath, stirred, temperature-controlled.
7.2 Computer with Onset Boxcar Pro software installed (version 4.3 or later)
7.3 IR Base station, Onset Part # BST -IR

8.0 PREREQUISITE ACTIONS

8.1 Turn on temperature bath and set for 37°F.
8.2 Check the IR interface to verify that it is plugged into the correct serial port on the PC. Set the correct time on the PC.
8.3 Align the IR port on the Base station with the HOBO Water Temp Pro communications window. Place the logger no further than 4 to 5 inches away from the Base station (see Figure 2) and make sure the IR windows in both devices point at each other. There is a 30° acceptance angle for the IR beam, so some misalignment is acceptable.

8.4 Start the Onset Box Car Software and select **Logger** then **Hobo Water Temp Pro** and **Launch.**

8.5 The computer will respond with a list of loggers found. The serial number in this list should match the serial number printed on the side of the logger. If these numbers do not match, click the **Refresh** button. Record this serial number on the certification form. Either wait or click the **Stop Searching** button. Using the mouse select the logger and click the **Launch** button.

8.6 After a few seconds the screen will display the status of the HOBO Water Temp Pro. Record the battery percentage on the certification form.

8.7 Verify that the Hobo is set to Fahrenheit and program it to a recording interval of 0:1:0 for a reading once a minute. Verify that the start logging immediately box is checked and that the set data logger clock with host launch is also checked.

8.8 Using the mouse click the **Launch Immediately** button.

8.9 If last HOBO is programmed click the DONE button, else select the **Launch Another** and repeat steps 8.5 through 8.9.

9.0 TEST PROCEDURE/METHOD

9.1 On the certification form record the serial number of the laboratory reference thermometer.

9.2 Place the HOBO Water Temp Pro in the temperature bath, making sure the end opposite the IR windows is submerged, and allow the bath to stabilize at 37°F ±0.5°F on the thermometer. Adjust the bath set point if needed. After the bath reaches the desired temperature allow 20 minutes 'soak time' for the HOBO to reach its final temperature.

9.3 *Record the thermometer reading on the certification form and the time.* (The time will be needed to get the correct reading from the HOBO.)

9.4 Repeat steps 9.2 and 9.3 for bath settings of 65.0°F ± 0.5°F and 93°F ± 0.5°F.

9.5 Remove the HOBO from the temperature bath and align the IR port on the Base station with the HOBO Water Temp Pro communications window.

9.6 Restart Onset BoxCar Pro if it is not running and select **Logger** then **Hobo Water Temp Pro** and **Readout.**

9.7 The computer will respond with a list of loggers found. Using the mouse select the logger and click the **Readout** button. The computer will ask to download data and continue logging or the stop logging and offload data. Select the **Stop Logging and Offload data.** After a few seconds the computer will respond with a suggested file name. Select **Save** and allow the HOBO to transfer the data.

9.8 After a successful download click the **OK** button. The computer will then ask if the data should be displayed in Centigrade or Fahrenheit. Deselect °C and select °F and click **OK.** The computer should display a graph of the collected data. Click the view details button (this is the button just left of the question mark button.)

9.9 Scroll down the displayed list until the time recorded for the 37°F point is found. Record the corresponding temperature on the certification form. Repeat this step for 65° and 93°.

9.10 Close the view details windows and repeat steps 9.6 through 9.9 for additional HOBOs.

9.11 Fill out the rest of the certification form.

10.0 ACCEPTANCE CRITERIA

10.1 Based upon the manufacturer specifications the HOBO Water Temp Pro should be within ±0.4°F over the range of 32°F to 100°F. Any HOBO with an error of greater than ±0.5°F at any of the three measured points shall fail certification.

11.0 POST PROCEDURE ACTIVITY

11.1 Close the BoxCar Software.

12.0 RECORDS

12.1 Completed HOBO Water Temperature Pro Certification form and associated Report of Certification cover sheet is a QA record.

13.0 REFERENCE

13.1 HOBO Water Temp Pro User's Manual, version 1.0 or later

13.2 Onset BoxCar Pro4 Manual Version 1.0 or later

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	SN Page Date

WATER TEMPERATURE HOBO WATER TEMP PRO CALIBRATION RECORD

Date of Certification: April 25, 2001

Type of Certification: As-found_____ As-Left X

SENSOR INFO For As-Found List Plant S/N & PLNT	37 deg F BATH TEMP Limits 0.40 degF -0.40 degF	OBSVD ERROR	65 degF BATH TEMP Limits 0.40 degF -0.40 degF	OBSVD ERROR	93 degF BATH TEMP Limits 0.40 degF -0.40 degF	OBSVD ERROR	PASS	FAIL	Battery LIFE
1		0.00		0.00		0.00	✓		
2		0.00		0.00		0.00	✓		
3		0.00		0.00		0.00	✓		
4		0.00		0.00		0.00	✓		
5		0.00		0.00		0.00	✓		
6		0.00		0.00		0.00	✓		
7		0.00		0.00		0.00	✓		
8		0.00		0.00		0.00	✓		
9		0.00		0.00		0.00	✓		
10		0.00		0.00		0.00	✓		

SENSOR TYPE: HOBO Water Temp Pro H20-001

Remarks: ______________________

Calibration Certificates for HOBO Water Temperature Probes

Table of HOBO Probes Used for the WBN Survey Summarized Herein

Station (Figure 3)	Depth (feet)	HOBO Logger (Serial Number)
WB1	0.5	1304864
	3	1304872
	5	1305177
	7	1304860
WB2	0.5	1305152
	3	1304888
	5	1304891
	7	1304874
WB3	0.5	1305159
	3	1305144
	5	1305184
	7	1304867
WB4	0.5	1305192
	3	1304854
	5	1304865
	7	1304889
WB5	0.5	1304882
	3	1305164
	5	1304853
	7	1305182
WB6	0.5	1304883
	3	1304868
	5	1305161
	7	1304863

Station (Figure 3)	Depth (feet)	HOBO Logger (Serial Number)
WB7	0.5	1305136
	3	1305160
	5	1304855
	7	1304890
WB8	0.5	1305139
	3	1304886
	5	1305174
	7	1305143
WB9	0.5	1304866
	3	1305140
	5	1305150
	7	1304870
WB10	0.5	1304861
	3	1305156
	5	1304877
	7	1305179
WB11	0.5	1134040
	3	1305176
	5	1304878
	7	1305153
WB12	0.5	1305141
	3	1304851
	5	1304857
	7	1305155

Pre-Survey Calibrations

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44909 Page 1 of 2 Date 02/07/2011

METEOROLOGICAL MONITORING INSTRUMENTATION
REPORT OF CALIBRATION

Calibrated For: Hydrothermal Compliance

Date of Report: 02/07/2011

Item Description: HOBO WATER PRO

TVA I.D. No.: E44909

Manufacturer: Onset Computer Corporation

Model: U22-001

CLS Instruction No.: 450.01-020

S/N No.: See Attached Sheet

Dispositioned to: CLS Norris Lab

As-Left calibration in tolerance

Standards Used Log:

I.D. No.	Description	Calibration Date	Calibration Due Date
906527	Azonix A1011-RS-XX Therm/Ohmmeter	01/07/2011	01/07/2012
906535	Burns Engineering 12001 PRT	12/16/2010	12/16/2011

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10 CFR 50 Appendix B and ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced except in full, without the written approval of CLS.

Calibrated By: Debra Houser

Approved By: Randy Cooper

Date Approved: 2/9/11

TENNESSEE VALLEY AUTHORITY
CENTRAL LABORATORIES SERVICES
400 W. Summit Hill Drive, Mail Stop SPB BA-K
Knoxville, Tennessee 37902
Phone: (865) 632-2304 Fax: (865) 632-4996

WATER TEMPERATURE HOBO WATER PRO CALIBRATION RECORD

Range 0 to 100°F **Accuracy** ±0.4°F

	Sensor Serial Number	37 deg F BATH TEMP 36.951 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	65 degF BATH TEMP 64.996 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	93 degF BATH TEMP 92.958 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	PASS	FAIL	Battery LIFE
WB11 - ½ ft	1134040	37.04	0.08	65.06	0.06	92.90	-0.05	✓		3.60
WB12 - 3 ft	1304851	36.89	-0.06	65.02	0.02	92.95	-0.01	✓		3.60
WB5 - 5 ft	1304853	36.89	-0.06	65.06	0.06	93.05	0.09	✓		3.57
WB4 - 3 ft	1304854	36.89	-0.06	65.02	0.02	93.05	0.09	✓		3.57
WB7 - 5 ft	1304855	37.08	0.13	65.19	0.19	93.19	0.23	✓		3.60
WB12 - 5 ft	1304857	37.04	0.08	65.19	0.19	93.19	0.23	✓		3.57
WB1 - 7 ft	1304860	36.99	0.03	65.15	0.15	93.19	0.23	✓		3.51
WB10 - ½ ft	1304861	36.94	-0.01	65.10	0.11	93.09	0.13	✓		3.57
WB6 - 7 ft	1304863	36.89	-0.06	65.06	0.06	93.05	0.09	✓		3.57
WB1 - ½ ft	1304864	36.94	-0.01	65.10	0.11	93.05	0.09	✓		3.60

SENSOR TYPE: HOBO Water Temp Pro U22-001

Remarks These Instruments are submerged in water for a long period of time and no calibration label will be attached.

The current calibration report will be in the Instrument Log.

WBN SCCW Testing Pre Cal 2011

Pre-Survey Calibrations (Continued)

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44910 Page 1 of 2 Date 02/07/2011

METEOROLOGICAL MONITORING INSTRUMENTATION
REPORT OF CALIBRATION

Calibrated For: Hydrothermal Compliance

Date of Report: 02/07/2011

Item Description: HOBO WATER PRO

TVA I.D. No.: E44910

Manufacturer: Onset Computer Corporation

Model: U22-001

CLS Instruction No.: 450.01-020

S/N No.: See Attached Sheet

Dispositioned to: CLS Norris Lab

As-Left calibration in tolerance

Standards Used Log:

I.D. No.	Description	Calibration Date	Calibration Due Date
906527	Azonix A1011-RS-XX Therm/Ohmmeter	01/07/2011	01/07/2012
906535	Burns Engineering 12001 PRT	12/16/2010	12/16/2011

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10 CFR 50 Appendix B and ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced except in full, without the written approval of CLS.

Calibrated By: Debbie Hauser

Approved By: Randy Cooper

Date Approved: 2/9/11

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44910 Page 2 of 2 Date 02/07/2011

WATER TEMPERATURE HOBO WATER PRO CALIBRATION RECORD

Range 0 to 100°F

Accuracy ±0.4°F

	Sensor Serial Number	37 deg F BATH TEMP 36.951 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	65 degF BATH TEMP 64.996 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	93 degF BATH TEMP 92.958 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	PASS	FAIL	Battery LIFE
WB4 - 5 ft	1304865	37.04	0.08	65.15	0.15	93.14	0.18	✓		3.57
WB9 - ½ ft	1304866	36.94	-0.01	65.10	0.11	93.09	0.13	✓		3.57
WB3 - 7 ft	1304867	36.89	-0.06	65.06	0.06	93.09	0.13	✓		3.60
WB6 - 3 ft	1304868	36.94	-0.01	65.10	0.11	93.09	0.13	✓		3.57
WB9 - 7 ft	1304870	37.04	0.08	65.19	0.19	93.19	0.23	✓		3.57
WB1 - 3 ft	1304872	36.89	-0.06	65.02	0.02	93.00	0.04	✓		3.60
WB2 - 7 ft	1304874	37.08	0.13	65.19	0.19	93.19	0.23	✓		3.57
WB10 - 5 ft	1304877	36.84	-0.11	64.97	-0.02	93.00	0.04	✓		3.57
WB11 - 5 ft	1304878	37.08	0.13	65.19	0.19	93.19	0.23	✓		3.57

SENSOR TYPE: HOBO Water Temp Pro U22-001

Remarks These Instruments are submerged in water for a long period of time and no calibration label will be attached.

The current calibration report will be in the Instrument Log.

WBN SCCW Testing Pre Cal 2011

Pre-Survey Calibrations (Continued)

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44911 Page 1 of 2 Date 02/08/2011

METEOROLOGICAL MONITORING INSTRUMENTATION
REPORT OF CALIBRATION

Calibrated For: Hydrothermal Compliance

Date of Report: 02/08/2011

Item Description: HOBO WATER PRO

TVA I.D. No.: E44911

Manufacturer: Onset Computer Corporation

Model: U22-001

CLS Instruction No.: 450.01-020

S/N No.: See Attached Sheet

Dispositioned to: CLS Norris Lab

As-Left calibration in tolerance

Standards Used Log:

I.D. No.	Description	Calibration Date	Calibration Due Date
906527	Azonix A1011-RS-XX Therm/Ohmmeter	01/07/2011	01/07/2012
906535	Burns Engineering 12001 PRT	12/16/2010	12/16/2011

This is to certify that all instrumentation, testing methods and personnel used comply with the *requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is* designed to meet the requirements of ISO/IEC 17025, 10 CFR 50 Appendix B and ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced except in full, without the written approval of CLS.

Calibrated By: [signature]

Approved By: [signature]

Date Approved: 2/9/11

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44911 Page 2 of 2 Date 02/08/2011

WATER TEMPERATURE HOBO WATER PRO CALIBRATION RECORD

Range 0 to 100°F **Accuracy** ±0.4°F

	Sensor Serial Number	37 deg F BATH TEMP 36.951 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	65 degF BATH TEMP 64.997 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	93 degF BATH TEMP 92.959 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	PASS	FAIL	Battery LIFE
WB5 - ½ ft	1304882	36.89	-0.06	65.06	0.06	93.05	0.09	✓		3.57
WB6 - ½ ft	1304883	37.13	0.18	65.23	0.23	93.19	0.23	✓		3.57
WB8 - 3 ft	1304886	36.94	-0.01	65.06	0.06	93.05	0.09	✓		3.57
WB2 - 3 ft	1304888	36.94	-0.01	65.06	0.06	93.05	0.09	✓		3.57
WB4 - 7 ft	1304889	37.04	0.08	65.10	0.11	93.09	0.13	✓		3.57
WB7 - 7 ft	1304890	36.94	-0.01	65.06	0.06	93.05	0.09	✓		3.60
WB2 - 5 ft	1304891	36.99	0.03	65.19	0.19	93.19	0.23	✓		3.60
WB7 - ½ ft	1305136	36.84	-0.11	64.97	-0.02	93.00	0.04	✓		3.57
WB8 - ½ ft	1305139	37.08	0.13	65.27	0.28	93.23	0.27	✓		3.60

SENSOR TYPE: HOBO Water Temp Pro U22-001

Remarks These Instruments are submerged in water for a long period of time and no calibration label will be attached.

The current calibration report will be in the Instrument Log.

WBN SCCW Testing Pre Cal 2011

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44912 Page 1 of 2 Date 02/08/2011

METEOROLOGICAL MONITORING INSTRUMENTATION
REPORT OF CALIBRATION

Calibrated For: Hydrothermal Compliance

Date of Report: 02/08/2011

Item Description: HOBO WATER PRO

TVA I.D. No.: E44912

Manufacturer: Onset Computer Corporation

Model: U22-001

CLS Instruction No.: 450.01-020

S/N No.: See Attached Sheet

Dispositioned to: CLS Norris Lab

As-Left calibration in tolerance

Standards Used Log:

I.D. No.	Description	Calibration Date	Calibration Due Date
906527	Azonix A1011-RS-XX Therm/Ohmmeter	01/07/2011	01/07/2012
906535	Burns Engineering 12001 PRT	12/16/2010	12/16/2011

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10 CFR 50 Appendix B and ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced except in full, without the written approval of CLS.

Calibrated By: Debbie Howard

Approved By: Randy Cooper

Date Approved: 2/9/11

TENNESSEE VALLEY AUTHORITY
CENTRAL LABORATORIES SERVICES
400 W. Summit Hill Drive, Mail Stop SPB BA-K
Knoxville, Tennessee 37902
Phone: (865) 632-2304 Fax: (865) 632-4996

ID	E44912
Page	2 of 2
Date	02/08/2011

WATER TEMPERATURE HOBO WATER PRO CALIBRATION RECORD

Range 0 to 100°F **Accuracy** ±0.4°F

	Sensor Serial Number	37 deg F BATH TEMP 36.951 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	65 degF BATH TEMP 64.997 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	93 degF BATH TEMP 92.959 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	PASS	FAIL	Battery LIFE
WB9 - 3 ft	1305140	37.08	0.13	65.23	0.23	93.23	0.27	✓		3.60
WB12 - ½ ft	1305141	36.94	-0.01	65.15	0.15	93.23	0.27	✓		3.57
WB8 - 7 ft	1305143	37.23	0.27	64.97	-0.02	92.95	-0.01	✓		3.60
WB3 - 3 ft	1305144	36.94	-0.01	65.06	0.06	93.05	0.09	✓		3.57
WB9 - 5 ft	1305150	36.84	-0.11	65.02	0.02	93.00	0.04	✓		3.57
WB2 - ½ ft	1305152	36.89	-0.06	65.10	0.11	93.14	0.18	✓		3.57
WB11 - 7 ft	1305153	37.04	0.08	65.06	0.06	93.05	0.09	✓		3.57
WB12 - 7 ft	1305155	36.94	-0.01	65.06	0.06	93.00	0.04	✓		3.57
WB10 - 3 ft	1305156	36.94	-0.01	65.10	0.11	93.09	0.13	✓		3.57
WB3 - ½ ft	1305159	37.04	0.08	65.19	0.19	93.14	0.18	✓		3.60

SENSOR TYPE: HOBO Water Temp Pro U22-001

Remarks These instruments are submerged in water for a long period of time and no calibration label will be attached.

The current calibration report will be in the Instrument Log.

WBN SCCW Testing Pre Cal 2011

Pre-Survey Calibrations (Continued)

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44913 Page 1 of 2 Date 02/09/2011

METEOROLOGICAL MONITORING INSTRUMENTATION
REPORT OF CALIBRATION

Calibrated For: Hydrothermal Compliance

Date of Report: 02/09/2011

Item Description: HOBO WATER PRO

TVA I.D. No.: E44913

Manufacturer: Onset Computer Corporation

Model: U22-001

CLS Instruction No.: 450.01-020

S/N No.: See Attached Sheet

Dispositioned to: CLS Norris Lab

As-Left calibration in tolerance

Standards Used Log:

I.D. No.	Description	Calibration Date	Calibration Due Date
906527	Azonix A1011-RS-XX Therm/Ohmmeter	01/07/2011	01/07/2012
906535	Burns Engineering 12001 PRT	12/16/2010	12/16/2011

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10 CFR 50 Appendix B and ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced except in full, without the written approval of CLS.

Calibrated By: Debbie Howe

Approved By: Randy Cooper

Date Approved: 2/9/11

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44913 Page 2 of 2 Date 02/09/2011

WATER TEMPERATURE HOBO WATER PRO CALIBRATION RECORD

Range 0 to 100°F **Accuracy** ±0.4°F

	Sensor Serial Number	37 deg F BATH TEMP 36.948 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	65 degF BATH TEMP 64.998 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	93 degF BATH TEMP 92.962 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	PASS	FAIL	Battery LIFE
WB7 - 3 ft	1305160	36.94	-0.01	65.10	0.10	93.05	0.08	✓		3.57
WB6 - 5 ft	1305161	36.94	-0.01	65.06	0.06	93.05	0.08	✓		3.57
WB5 - 3 ft	1305164	36.94	-0.01	65.10	0.10	93.09	0.13	✓		3.57
WB8 - 5 ft	1305174	37.04	0.09	65.15	0.15	93.14	0.18	✓		3.60
WB11 - 3 ft	1305176	37.08	0.13	65.27	0.27	93.28	0.32	✓		3.57
WB1 - 5 ft	1305177	36.89	-0.06	65.02	0.02	93.00	0.03	✓		3.57
WB10 - 7 ft	1305179	37.08	0.13	65.19	0.19	93.19	0.22	✓		3.57
WB5 - 7 ft	1305182	36.89	-0.06	65.06	0.06	93.05	0.08	✓		3.60

SENSOR TYPE: HOBO Water Temp Pro U22-001

Remarks These Instruments are submerged in water for a long period of time and no calibration label will be attached.

The current calibration report will be in the Instrument Log.

WBN SCCW Testing Pre Cal 2011

Pre-Survey Calibrations (Continued)

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44914 Page 1 of 2 Date 02/09/2011

METEOROLOGICAL MONITORING INSTRUMENTATION
REPORT OF CALIBRATION

Calibrated For: Hydrothermal Compliance

Date of Report: 02/09/2011

Item Description: HOBO WATER PRO

TVA I.D. No.: E44914

Manufacturer: Onset Computer Corporation

Model: U22-001

CLS Instruction No.: 450.01-020

S/N No.: See Attached Sheet

Dispositioned to: CLS Norris Lab

As-Left calibration in tolerance

Standards Used Log:

I.D. No.	Description	Calibration Date	Calibration Due Date
906527	Azonix A1011-RS-XX Therm/Ohmmeter	01/07/2011	01/07/2012
906535	Burns Engineering 12001 PRT	12/16/2010	12/16/2011

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10 CFR 50 Appendix B and ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced except in full, without the written approval of CLS.

Calibrated By: Debbie Howe

Approved By: [signature]

Date Approved: 2/9/11

TENNESSEE VALLEY AUTHORITY
CENTRAL LABORATORIES SERVICES
400 W. Summit Hill Drive, Mail Stop SPB BA-K
Knoxville, Tennessee 37902
Phone: (865) 632-2304 Fax: (865) 632-4996

WATER TEMPERATURE HOBO WATER PRO CALIBRATION RECORD

Range 0 to 100°F **Accuracy** ±0.4°F

	Sensor Serial Number	37 deg F BATH TEMP 36.948 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	65 degF BATH TEMP 64.998 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	93 degF BATH TEMP 92.962 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	PASS	FAIL	Battery LIFE
WB3 - 5 ft	1305184	37.08	0.13	65.19	0.19	93.19	0.22	✓		3.60
WB4 - ½ ft	1305192	37.04	0.09	65.19	0.19	93.19	0.22	✓		3.60

SENSOR TYPE: HOBO Water Temp Pro U22-001

Remarks These Instruments are submerged in water for a long period of time and no calibration label will be attached.

The current calibration report will be in the Instrument Log.

WBN SCCW Testing Pre Cal 2011

Post-Survey Calibrations

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44909 Page 1 of 2 Date 06/21/2011

METEOROLOGICAL MONITORING INSTRUMENTATION
REPORT OF CALIBRATION

Calibrated For: Hydrothermal Compliance

Date of Report: 06/21/2011

Item Description: HOBO WATER PRO

TVA I.D. No.: E44909

Manufacturer: Onset Computer Corporation

Model: U22-001

CLS Instruction No.: 450.01-020

S/N No.: See Attached Sheet

Dispositioned to: CLS Norris Lab

As-Left calibration in tolerance

Standards Used Log

I.D. No.	Description	Calibration Date	Calibration Due Date
906527	Azonix A1011-RS-XX Therm/Ohmmeter	01/07/2011	01/07/2012
906535	Burns Engineering 12001 PRT	12/16/2010	12/16/2011

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10 CFR 50 Appendix B and ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced except in full, without the written approval of CLS.

Calibrated By: Debbie Houser

Approved By: Randy Lowe

Date Approved: 6/30/11

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44909 Page 2 of 2 Date 06/21/2011

WATER TEMPERATURE HOBO WATER PRO CALIBRATION RECORD

Range 0 to 100°F **Accuracy** ±0.4°F

	Sensor Serial Number	37 deg F BATH TEMP 36.955 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	65 degF BATH TEMP 65.004 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	93 degF BATH TEMP 92.969 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	PASS	FAIL	Battery LIFE
WB11 - ½ ft	1134040	36.99	0.03	65.10	0.10	93.00	0.03	✓		3.60
WB12 - 3 ft	1304851	36.89	-0.06	65.02	0.01	93.00	0.03	✓		3.60
WB5 - 5 ft	1304853	36.94	-0.02	65.06	0.05	93.09	0.12	✓		3.57
WB4 - 3 ft	1304854	36.94	-0.02	65.06	0.05	93.05	0.08	✓		3.57
WB7 - 5 ft	1304855	37.08	0.13	65.19	0.18	93.19	0.22	✓		3.60
WB12 - 5 ft	1304857	37.08	0.13	65.23	0.23	93.19	0.22	✓		3.57
WB1 - 7 ft	1304860	37.04	0.08	65.19	0.18	93.19	0.22	✓		3.57
WB10 - ½ ft	1304861	36.99	0.03	65.10	0.10	93.14	0.17	✓		3.57
WB6 - 7 ft	1304863	36.89	-0.06	65.06	0.05	93.09	0.12	✓		3.60
WB1 - ½ ft	1304834	36.94	-0.02	65.10	0.10	93.09	0.12	✓		3.60

SENSOR TYPE: HOBO Water Temp Pro U22-001

All measurement ratios between the standards referenced in this instruction and the M & TE calibrated are greater than or equal to 4:1 except as noted.

Remarks These Instruments are submerged in water for a long period of time and no calibration label will be attached.

The current calibration report will be in the Instrument Log.

Initial Pre Calibration.

Post-Survey Calibrations (Continued)

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44910 Page 1 of 2 Date 06/21/2011

METEOROLOGICAL MONITORING INSTRUMENTATION
REPORT OF CALIBRATION

Calibrated For: Hydrothermal Compliance

Date of Report: 06/21/2011

Item Description: HOBO WATER PRO

TVA I.D. No.: E44910

Manufacturer: Onset Computer Corporation

Model: U22-001

CLS Instruction No.: 450.01-020

S/N No.: See Attached Sheet

Dispositioned to: CLS Norris Lab

As-Left calibration in tolerance

Standards Used Log.

I.D. No.	Description	Calibration Date	Calibration Due Date
906527	Azonix A1011-RS-XX Therm/Ohmmeter	01/07/2011	01/07/2012
906535	Burns Engineering 12001 PRT	12/16/2010	12/16/2011

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10 CFR 50 Appendix B and ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced except in full, without the written approval of CLS

Calibrated By: Debbie House

Approved By: Randy Cooper

Date Approved: 6/30/11

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44910 Page 2 of 2 Date 06/21/2011

WATER TEMPERATURE HOBO WATER PRO CALIBRATION RECORD

Range 0 to 100°F **Accuracy** ±0.4°F

	Sensor Serial Number	37 deg F BATH TEMP 36.955 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	65 degF BATH TEMP 65.004 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	93 degF BATH TEMP 92.969 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	PASS	FAIL	Battery LIFE
WB4 - 5 ft	1304865	37.04	0.08	65.15	0.14	93.14	0.17	✓		3.57
WB9 - ½ ft	1304866	36.94	-0.02	65.10	0.10	93.14	0.17	✓		3.57
WB3 - 7 ft	1304867	36.94	-0.02	65.10	0.10	93.09	0.12	✓		3.60
WB6 - 3 ft	1304868	36.94	-0.02	65.10	0.10	93.04	0.07	✓		3.57
WB9 - 7 ft	1304870	37.08	0.13	65.23	0.23	93.23	0.27	✓		3.57
WB1 - 3 ft	1304872	36.89	-0.06	65.06	0.05	93.00	0.03	✓		3.60
WB2 - 7 ft	1304874	37.08	0.13	65.23	0.23	93.23	0.27	✓		3.60
WB10 - 5 ft	1304877	36.89	-0.06	65.02	0.01	93.00	0.03	✓		3.57
WB11 - 5 ft	1304878	37.08	0.13	65.23	0.23	93.23	0.27	✓		3.57

SENSOR TYPE: HOBO Water Temp Pro U22-001

All measurement ratios between the standards referenced in this instruction and the M & TE calibrated are greater than or equal to 4:1 except as noted.

Remarks These Instruments are submerged in water for a long period of time and no calibration label will be attached.

The current calibration report will be in the Instrument Log.

Initial Pre Calibration.

Post-Survey Calibrations (Continued)

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44911 Page 1 of 2 Date 06/21/2011

METEOROLOGICAL MONITORING INSTRUMENTATION
REPORT OF CALIBRATION

Calibrated For: Hydrothermal Compliance

Date of Report: 06/21/2011

Item Description: HOBO WATER PRO

TVA I.D. No.: E44911

Manufacturer: Onset Computer Corporation

Model: U22-001

CLS Instruction No : 450.01-020

S/N No : See Attached Sheet

Dispositioned to: CLS Norris Lab

As-Left calibration in tolerance

Standards Used Log:

I.D. No.	Description	Calibration Date	Calibration Due Date
906527	Azonix A1011-RS-XX Therm/Ohmmeter	01/07/2011	01/07/2012
906535	Burns Engineering 12001 PRT	12/16/2010	12/16/2011

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10 CFR 50 Appendix B and ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced except in full, without the written approval of CLS.

Calibrated By: Debbie Houser

Approved By: Randy Cooper

Date Approved: 6/30/11

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44911 Page 2 of 2 Date 06/21/2011

WATER TEMPERATURE HOBO WATER PRO CALIBRATION RECORD

Range 0 to 100°F **Accuracy** ±0.4°F

	Sensor Serial Number	37 deg F BATH TEMP 36.954 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	65 degF BATH TEMP 65.004 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	93 degF BATH TEMP 92.969 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	PASS	FAIL	Battery LIFE
WB5 - ½ ft	1304882	36.94	-0.02	65.06	0.05	93.09	0.12	✓		3.57
WB6 - ½ ft	1304883	37.13	0.18	65.23	0.23	93.19	0.22	✓		3.57
WB8 - 3 ft	1304886	36.94	-0.02	65.06	0.05	93.05	0.08	✓		3.57
WB2 - 3 ft	1304888	36.94	-0.02	65.06	0.05	93.05	0.08	✓		3.57
WB4 - 7 ft	1304889	37.04	0.08	65.15	0.14	93.09	0.12	✓		3.57
WB7 - 7 ft	1304890	36.99	0.03	65.10	0.10	93.05	0.08	✓		3.60
WB2 - 5 ft	1304891	37.04	0.08	65.19	0.18	93.19	0.22	✓		3.60
WB7 - ½ ft	1305136	36.89	-0.06	65.02	0.01	93.00	0.03	✓		3.57
WB8 - ½ ft	1305139	37.08	0.13	65.27	0.27	93.28	0.31	✓		3.57

SENSOR TYPE: HOBO Water Temp Pro U22-001

All measurement ratios between the standards referenced in this instruction and the M & TE calibrated are greater than or equal to 4:1 except as noted.

Remarks These Instruments are submerged in water for a long period of time and no calibration label will be attached.

The current calibration report will be in the Instrument Log.

Initial Pre Calibration.

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44912 Page 1 of 2 Date 06/21/2011

METEOROLOGICAL MONITORING INSTRUMENTATION
REPORT OF CALIBRATION

Calibrated For: Hydrothermal Compliance

Date of Report: 06/21/2011

Item Description: HOBO WATER PRO

TVA I.D. No.: E44912

Manufacturer: Onset Computer Corporation

Model: U22-001

CLS Instruction No.: 450.01-020

S/N No.: See Attached Sheet

Dispositioned to: CLS Norris Lab

As-Left calibration in tolerance

Standards Used Log:

I.D. No.	Description	Calibration Date	Calibration Due Date
906527	Azonix A1011-RS-XX Therm/Ohmmeter	01/07/2011	01/07/2012
906535	Burns Engineering 12001 PRT	12/16/2010	12/16/2011

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10 CFR 50 Appendix B and ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced except in full, without the written approval of CLS.

Calibrated By: Debbie Houser

Approved By: Randy Cooper

Date Approved: 6/30/11

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44912 Page 2 of 2 Date 06/21/2011

WATER TEMPERATURE HOBO WATER PRO CALIBRATION RECORD

Range 0 to 100°F **Accuracy** ±0.4°F

		37 deg F		65 degF		93 degF				Battery
		BATH TEMP 36.954		BATH TEMP 65.004		BATH TEMP 92.969		PASS	FAIL	LIFE
	Sensor Serial Number	Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	Limits 0.40 deg F -0.40 deg F	OBSVD ERROR			
WB9 - 3 ft	1305140	37.13	0.18	65.23	0.23	93.23	0.27	✓		3.60
WB12 - ½ ft	1305141	36.94	-0.02	65.15	0.14	93.23	0.27	✓		3.57
WB8 - 7 ft	1305143	36.84	-0.11	64.97	-0.03	92.95	-0.02	✓		3.57
WB3 - 3 ft	1305144	36.99	0.03	65.10	0.10	93.05	0.08	✓		3.57
WB9 - 5 ft	1305150	36.89	-0.06	65.02	0.01	93.00	0.03	✓		3.57
WB2 - ½ ft	1305152	36.94	-0.02	65.10	0.10	93.19	0.22	✓		3.57
WB11 - 7 ft	1305153	36.89	-0.06	65.06	0.05	93.05	0.08	✓		3.57
WB12 - 7 ft	1305155	36.94	-0.02	65.06	0.05	93.05	0.08	✓		3.57
WB10 - 3 ft	1305156	36.99	0.03	65.10	0.10	93.14	0.17	✓		3.57
WB3 - ½ ft	1305159	37.08	0.13	65.19	0.18	93.19	0.22	✓		3.60

SENSOR TYPE: HOBO Water Temp Pro U22-001

All measurement ratios between the standards referenced in this instruction and the M & TE calibrated are greater than or equal to 4:1 except as noted.

Remarks These Instruments are submerged in water for a long period of time and no calibration label will be attached.

The current calibration report will be in the Instrument Log.

Initial Pre Calibration.

Post-Survey Calibrations (Continued)

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44913 Page 1 of 2 Date 06/21/2011

METEOROLOGICAL MONITORING INSTRUMENTATION
REPORT OF CALIBRATION

Calibrated For: Hydrothermal Compliance

Date of Report: 06/21/2011

Item Description: HOBO WATER PRO

TVA I.D. No.: E44913

Manufacturer: Onset Computer Corporation

Model: U22-001

CLS Instruction No.: 450.01-020

S/N No.: See Attached Sheet

Dispositioned to: CLS Norris Lab

As-Left calibration in tolerance

Standards Used Log:

I.D. No.	Description	Calibration Date	Calibration Due Date
906527	Azonix A1011-RS-XX Therm/Ohmmeter	01/07/2011	01/07/2012
906535	Burns Engineering 12001 PRT	12/16/2010	12/16/2011

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10 CFR 50 Appendix B and ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced except in full, without the written approval of CLS

Calibrated By: Debbie Howard

Approved By: Randy Cooper

Date Approved: 6/30/11

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WATER TEMPERATURE HOBO WATER PRO CALIBRATION RECORD

Range 0 to 100°F

Accuracy ±0.4°F

	Sensor Serial Number	37 deg F BATH TEMP 36.955 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	65 degF BATH TEMP 65.007 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	93 degF BATH TEMP 92.966 Limits 0.40 deg F -0.40 deg F	OBSVD ERROR	PASS	FAIL	Battery LIFE
WB7 - 3 ft	1305160	36.94	-0.02	65.10	0.09	93.09	0.13	✓		3.57
WB6 - 5 ft	1305161	36.94	-0.02	65.10	0.09	93.09	0.13	✓		3.57
WB5 - 3 ft	1305164	36.94	-0.02	65.10	0.09	93.09	0.13	✓		3.57
WB8 - 5 ft	1305174	37.04	0.08	65.19	0.18	93.16	0.19	✓		3.57
WB11 - 3 ft	1305176	37.13	0.18	65.27	0.27	93.28	0.32	✓		3.57
WB1 - 5 ft	1305177	36.94	-0.02	65.02	0.01	93.00	0.03	✓		3.57
WB10 - 7 ft	1305179	37.08	0.13	65.23	0.22	93.19	0.22	✓		3.57
WB5 - 7 ft	1305182	36.94	-0.02	65.06	0.05	93.09	0.13	✓		3.60

SENSOR TYPE: HOBO Water Temp Pro U22-001

All measurement ratios between the standards referenced in this instruction and the M & TE calibrated are greater than or equal to 4:1 except as noted.

Remarks These Instruments are submerged in water for a long period of time and no calibration label will be attached.

The current calibration report will be in the Instrument Log.

Initial Pre Calibration.

TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44914 Page 1 of 2 Date 06/21/2011

METEOROLOGICAL MONITORING INSTRUMENTATION
REPORT OF CALIBRATION

Calibrated For: Hydrothermal Compliance

Date of Report: 06/21/2011

Item Description: HOBO WATER PRO

TVA I.D. No.: E44914

Manufacturer: Onset Computer Corporation

Model: U22-001

CLS Instruction No.: 450.01-020

S/N No.: See Attached Sheet

Dispositioned to: CLS Norris Lab

As-Left calibration in tolerance

Standards Used Log:

I.D. No.	Description	Calibration Date	Calibration Due Date
906527	Azonix A1011-RS-XX Therm/Ohmmeter	01/07/2011	01/07/2012
906535	Burns Engineering 12001 PRT	12/16/2010	12/16/2011

This is to certify that all instrumentation, testing methods and personnel used comply with the requirements of the Central Laboratories Services (CLS) Quality Assurance Program which is designed to meet the requirements of ISO/IEC 17025, 10 CFR 50 Appendix B and ANSI N45.2-1971, and ANSI/NCSL Z540-1-1994. Standards used are traceable to the National Institute of Standards and Technology (NIST), officially recognized agencies, commercially accepted practices or natural physical constants. This report shall not be reproduced except in full, without the written approval of CLS.

Calibrated By: Debbie Houser

Approved By: Randy Cooper

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TENNESSEE VALLEY AUTHORITY **CENTRAL LABORATORIES SERVICES** 400 W. Summit Hill Drive, Mail Stop SPB BA-K Knoxville, Tennessee 37902 Phone: (865) 632-2304 Fax: (865) 632-4996	ID E44914 Page 2 of 2 Date 06/21/2011

WATER TEMPERATURE HOBO WATER PRO CALIBRATION RECORD

Range 0 to 100°F

Accuracy ±0.4°F

		Sensor Serial Number	37 deg F BATH TEMP 36.955 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	65 degF BATH TEMP 65.007 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	93 degF BATH TEMP 92.966 Limits 0.40 deg F / -0.40 deg F	OBSVD ERROR	PASS	FAIL	Battery LIFE
WB3 - 5 ft	1305184	37.08	0.13	65.23	0.22	93.19	0.22	✓		3.57
WB4 - ½ ft	1305192	37.04	0.08	65.19	0.18	93.23	0.27	✓		3.60

SENSOR TYPE: HOBO Water Temp Pro U22-001

All measurement ratios between the standards referenced in this instruction and the M & TE calibrated are greater than or equal to 4:1 except as noted.

Remarks These Instruments are submerged in water for a long period of time and no calibration label will be attached.

The current calibration report will be in the Instrument Log.

Initial Pre Calibration.

APPENDIX B

WBN Outfall 113 NPDES Compliance Parameters

- Current Instantaneous Upstream Temperature:

  Tu_i (measured at EDS Station 30 by the first sensor below a depth of 5 feet)

- Current 1-Hour Average Upstream Temperature:

  $$Tu1_i = \frac{Tu_i + Tu_{i-1} + Tu_{i-2} + Tu_{i-3} + Tu_{i-4}}{5},$$

  where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of Tu

- Current Instantaneous Downstream Temperature:

  $$Td_i = \frac{Td3_i + Td5_i + Td7_i}{3},$$

  where $Td3_i$, $Td5_i$, and $Td7_i$ denote the current measurements of river temperature at the downstream end of the mixing zone at water depths 3 feet, 5 feet, and 7 feet, respectively

- Current 1-Hour Average Downstream Temperature:

  $$Td1_i = \frac{Td_i + Td_{i-1} + Td_{i-2} + Td_{i-3} + Td_{i-4}}{5},$$

  where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of Td

- Current Instantaneous Temperature Rise:

  $$\Delta T_i = Td_i - Tu_i$$

- Current 1-Hour Average Temperature Rise:

  $$\Delta T1_i = \frac{\Delta T_i + \Delta T_{i-1} + \Delta T_{i-2} + \Delta T_{i-3} + \Delta T_{i-4}}{5},$$

where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of ΔT

- Current Temperature Rate-of-Change:

$$TROC_i = \frac{Td_i - Td_{i-4}}{1\,\text{hour}},$$

- Current 1-Hour Average Temperature Rate-of-Change:

$$TROC1_i = \frac{TROC_i + TROC_{i-1} + TROC_{i-2} + TROC_{i-3} + TROC_{i-4}}{5}$$

where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of TROC

Enclosure 5

Summer 2012 Compliance Survey for Watts Bar Nuclear Plant Outfall Passive Mixing Zone

TENNESSEE VALLEY AUTHORITY
River Operations

SUMMER 2012 COMPLIANCE SURVEY FOR WATTS BAR NUCLEAR PLANT OUTFALL 113 PASSIVE MIXING ZONE

Prepared by

Daniel P. Saint
and
Paul N. Hopping

Knoxville, Tennessee
January 2013

TVA

EXECUTIVE SUMMARY

The National Pollutant Discharge Elimination System (NPDES) Permit No. TN0020168 for Watts Bar Nuclear Plant (WBN) identifies the discharge of water to the Tennessee River from the Supplemental Condenser Cooling Water (SCCW) System as Outfall 113. Furthermore, the permit identifies that when there is no flow released from Watts Bar Dam (WBH), the effluent from Outfall 113 shall be regulated based on a passive mixing zone extending in the river from bank-to-bank and 1,000 feet downstream from the outfall. Compliance with the requirements for the passive mixing zone is to be achieved by two annual instream temperature surveys–one for winter conditions and one for summer conditions. Summarized in this report are the measurements, analyses, and results for the passive mixing zone survey performed for 2012 summer conditions. The survey was conducted between 22:00 CDT on August 30 and 06:00 CDT on August 31 (eight hours) and included the collection of temperature data at twelve temporary monitoring stations deployed across the downstream end of the passive mixing zone during a period of no flow in the river. The data were analyzed to determine the three instream compliance parameters specified in the NPDES permit for the outfall: the 1-hour average temperature at the downstream end of mixing zone, T_d; the 1-hour average temperature rise from upstream to the downstream end of the mixing zone, ΔT; and the 1-hour average temperature rate-of-change at the downstream end of the mixing zone, TROC. The measured parameters were compared to predicted values from the thermal plume model used by TVA to help determine the safe operation of Outfall 113. The results of the comparisons, in terms of maximum values observed during the no flow event, are as follows:

Compliance Parameter	Model	Measured	NPDES Limit
Maximum T_d	80.9°F	79.3°F	86.9°F
Maximum ΔT	1.6 F°	1.8 F°	5.4 F°
Maximum |TROC|	0.7 F°/hour	0.2 F°/hour	3.6 F°/hr

As shown, both the model and measured values were well below the NPDES limits for all the compliance parameters. Except for the maximum ΔT, values predicted by the model were larger than those measured in the survey. The maximum value of ΔT from the model underpredicted the measured value by 0.2 F°. This difference was caused by unnatural cooling of the upstream ambient temperature from leakage of cold water through Watts Bar Dam. Based on this, as well as the fact that differences of magnitude 0.2 F° easily fall within the factor of safety currently used in performing hydrothermal forecasts, the thermal plume model is yet considered fully adequate for determining the safe operation of the SCCW system. That is, in combination with TVA procedures for predicting the impact of the Outfall 113 effluent, the model continues to provide a high level of confidence that the SCCW system is being operated in a manner that protects the limits for T_d, ΔT, and TROC specified in the NPDES permit for the passive mixing zone.

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SUMMER 2012 COMPLIANCE SURVEY FOR WATTS BAR NUCLEAR PLANT OUTFALL 113 PASSIVE MIXING ZONE

INTRODUCTION

Outfall 113 for the Watts Bar Nuclear Plant (WBN) includes the discharge of water to the Tennessee River from the Supplemental Condenser Cooling Water (SCCW) system. Due to the dynamic behavior of the thermal effluent in the river, the National Pollutant Discharge Elimination System (NPDES) Permit No. TN0020168 for the plant specifies two mixing zones for Outfall 113—one for active operation of the river and one for passive operation of the river (TDEC, 2010). The passive mixing zone corresponds to periods when the operation of Watts Bar Dam (WBH) produces no flow in the river (i.e., hydropower and/or spillway releases). The dimensions of the passive mixing zone extend from bank-to-bank and downstream 1,000 feet from the outfall. The active mixing zone applies to all other river flow conditions. The dimensions of the active mixing zone include the right-half of the river (facing downstream) and extend downstream 2,000 feet from the outfall. The passive and the active mixing zones are shown in Figure 1.

Table 1 summarizes the NPDES instream temperature limits for Outfall 113. The limits apply to both the active and passive mixing zones. Compliance for the active mixing zone is monitored by permanent instream water temperature stations situated in the right-half of the river. Due to issues associated with placing permanent stations in the left-half of the river, which contains the navigation channel, a thermal plume model is used to determine the safe operation of Outfall 113 for the passive mixing zone. To verify the thermal plume model, the NPDES permit specifies that two instream temperature surveys shall be conducted each year—one for winter conditions and one for summer conditions. The purpose of this report is to present the results for the passive mixing zone temperature survey performed for summer 2012 conditions. The survey was conducted between 22:00 CDT on August 30 and 06:00 CDT on August 31 (total eight hours). Provided herein is a brief summary of the survey method, presentations of the measurements and analyses, and discussions of the results and conclusions.

Table 1. NPDES Temperature Limits for Outfall 113 Mixing Zones

Compliance Parameter	Sampling Period	NPDES Limit
Maximum Temperature, Downstream End of Mixing Zone, T_d	Running 1-hr	86.9°F
Maximum Temperature Rise, Upstream to Downstream, ΔT	Running 1-hr	5.4 F°
Maximum Temperature Rate-of-Change, TROC	Running 1-hr	±3.6 F°/hr

INSTREAM SURVEY

The instream survey included the deployment of temporary water temperature stations at twelve locations across the downstream end of the passive mixing zone. Data from these and other monitoring stations were analyzed to obtain measured values for the compliance parameters listed in Table 1. These were then compared with the corresponding values estimated from the SCCW thermal plume model.

The method of conducting the instream survey is the same as that used for the first such survey, performed for winter conditions on May 6, 2005 (McCall and Hopping, 2005). Table 2 provides a summary of the sources of data for the survey. WaterView, a monitoring system for tracking hydroplant operation and performance, was used to obtain measurements for the river discharge from Watts Bar Dam. The WBN Environmental Data Station (EDS) provided measurements from existing permanent monitoring stations for the nuclear plant. These included:

- The river upstream (ambient) water temperature, measured at the EDS Station 30, which is located at the exit of the powerhouse of Watts Bar Dam.
- The river water surface elevation (WSEL) at the EDS Station 30, also known as the tailwater elevation (TWEL) at Watts Bar Dam.
- The SCCW effluent temperature, measured at the EDS Station 32, which is located at the SCCW outfall.
- The SCCW effluent discharge, measured at the EDS Station 32.
- The local air temperature, measured at the EDS meteorological tower.

Table 2. Sources of Data for Passive Mixing Zone Survey

Data	Source	Frequency
River Discharge from Watts Bar Dam	WaterView	1 min
River ambient water temperature	WBN EDS Station 30 (Tailwater at WBH)	15 min
River water surface elevation	WBN EDS Station 30 (Tailwater at WBH)	15 min
SCCW effluent temperature	WBN EDS Station 32 (SCCW Outfall 113)	15 min
SCCW effluent discharge	WBN EDS Station 32 (SCCW Outfall 113)	15 min
Air temperature	WBN EDS Met Tower	15 min
Passive mixing zone water temperature	Temporary HOBO Monitors	1 min

The water temperature at the downstream end of the Outfall 113 passive mixing zone was measured by the aforementioned temporary water temperature stations. Using a global positioning system (GPS) device, the stations were positioned at roughly equal intervals across the river, as shown in Figure 2. The temporary stations recorded water temperatures by using HOBO temperature monitors positioned at depths of 0.5, 3, 5, and 7 feet below the water surface. Shown in Figure 3 is a schematic of the temporary stations. The stations included a string of

HOBO monitors suspended from a tire float, with weights to anchor the station and to keep the sensor string vertical in the water column. The water temperature sensors imbedded in the HOBO monitors have an accuracy of about ±0.4 F° and resolution of about 0.04 F°, which is comparable to the accuracy and resolution of temperature sensors used elsewhere by TVA for NPDES thermal compliance. The HOBO monitors include an internal data acquisition unit that was programmed to collect measurements once per minute. All the temperature probes used in the survey, including both those contained in the HOBO monitors and the thermistors at the permanent EDS monitoring stations, were calibrated by a quality program with equipment accuracies traceable to the National Institute of Standards and Technology (NIST). The calibration procedure is summarized in APPENDIX A. The temporary monitoring stations were deployed several hours before the beginning of the survey, and retrieved several hours after the end of the survey.

RESULTS

River Conditions

Figure 4 shows the measured ambient conditions of the river during the survey. Included are the river discharge, river water surface elevation, and river temperature, all at the exit of Watts Bar Dam. The river temperature at the exit of Watts Bar Dam serves as the upstream ambient river temperature for WBN Outfall 113. To provide a period of no flow in the river, releases from Watts Bar Dam were suspended between about 22:00 CDT on August 30 and 06:00 CDT on August 31, a total of eight hours (nighttime). Leading up to the survey, as the river flow was stepping down, the WSEL at the exit of Watts Bar Dam dropped approximately 2.7 feet, from about 683.5 feet msl to about 680.8 feet msl. During the survey, the WSEL slowly increased, due to backflow from the surrounding tailwater and leakage through the hydroturbines, returning to about 681.8 feet msl after six hours of no flow in the river. Afterwards, the WSEL slowly receded, reaching about 681.3 feet msl at the end of the survey.

The ambient river temperature was about 77.9°F at the beginning of the period of no flow. The temperature held steady at 77.9°F for the first three hours of the survey, and then began to slowly decrease, reaching 77.4°F at the end of the survey. This drop in ambient river temperature is common when strong thermal stratification exists behind Watts Bar Dam. During periods of no flow, leakage occurs through the hydroturbines at the dam. Previous studies have suggested the amount of leakage to be roughly 50 cfs for each hydro unit, or a total of 250 cfs for the entire powerhouse (Harper et. al, 1998). This leakage comes from the very bottom of Watts Bar Reservoir, the coldest part of the water column in front of the dam. As the leakage occurs, it slowly fills the bottom layers of the tailrace below the powerhouse, eventually reaching the elevation of the Station 30 sensors, which are suspended downward from the water surface. Cooling of the ambient river temperature monitor in this manner falsely increases the measured temperature rise for the SCCW system. That is, the temperature rise is elevated not by warming from the SCCW effluent, but by "artificial" cooling of the upstream monitor via a process that is beyond the operational control of the SCCW system. In forecasting values for the WBN upstream ambient river temperature, the thermal plume model for the SCCW system does not include cooling that occurs as a result of leakage through the hydroturbines at Watts Bar Dam.

SCCW Conditions

During the survey, the SCCW system at WBN was thermally loaded and operating in "summer" mode. That is, the system was operating in a manner producing the largest possible release of heat to the river. Shown in Figure 5 are the measured conditions of the SCCW system during the survey. Included are the discharge and temperature of the SCCW effluent. During the survey, the average discharge of the SCCW system to the river was about 300 cfs. The root-mean-square variation in the SCCW discharge was only about 3.1 percent of the average–thus, from the standpoint of mixing processes in the river, the discharge was essentially constant. The SCCW effluent temperature decreased throughout the survey from about 86.2°F at the beginning of the survey to about 84.8°F at the end of the survey. This trend coincides with the falling nighttime air temperature, also shown in Figure 5 (note: the temperature of the water discharging from the Unit 1 cooling tower, which provides the source for Outfall 113, varies directly with the temperature of the ambient air that is drawn through the tower). The temperature rise of the Outfall 113 effluent relative to the upstream ambient river temperature, also shown in Figure 5, decreased in a similar fashion throughout the survey, from about 8.9 F° at the beginning of the survey to about 7.4 F° at the end of the survey.

Downstream End of Passive Mixing Zone

Shown in Figure 6 are the measurements from the HOBO temperature stations at the downstream end of the passive mixing zone. The stations are labeled consecutively from WB1 to WB12, with WB1 situated near the left-hand shoreline of the river and WB12 situated near the right-hand shoreline of the river (i.e., facing downstream—see Figure 2). In Figure 7, the HOBO data has been analyzed to produce contour plots of the local "instantaneous" water temperature rise (ΔT) relative to the SCCW ambient river temperature (i.e., given in Figure 4). The horizontal (x) axis of each contour plot is the span of the river from WB1 to WB12, and the vertical (y) axis is the water depth, from 0.5 feet to 7 feet. In this manner, the plots in Figure 7 represent images of the upper 7 feet of the water column in the river, looking downstream. Note that the depth scale in the Figure 7 plots is significantly distorted so that measurements can be viewed in a meaningful manner—that is, whereas the span of the x-axis is about 1000 feet, the span of the y-axis is only about 7 feet (0.007 times smaller). Plots are provided at the top of each hour from the beginning of the survey at 22:00 CDT on August 30 to the end of the survey at 06:00 CDT on August 31. The following behaviors are emphasized from Figure 6 and Figure 7:

- At the beginning of the survey, 22:00 CDT on August 30, effluent from the SCCW resides primarily in the right-hand-side of the river. The flow in the river prevents the effluent from spreading across the river; however, the deceleration of flow from Watts Bar Dam appears to have allowed some effluent to move into the middle portion of the cross section. The maximum local instantaneous temperature rise is about 2.0 F°, occurring in the upper 3 feet of the water column.

- Without any significant flow from Watts Bar Dam, outward spreading of the SCCW effluent is unhindered, reaching the left-hand-side of the river and propagating to the downstream end of the passive mixing zone. By 01:00 CDT on August 31, the maximum local instantaneous temperature rise is about 1.6 F° and occurs in the left-hand-side of the river.

- After 01:00 CDT, the effluent continues to spread back across the river, reaching the middle of the river by 02:00 CDT. By 03:00 CDT on August 31, five hours into the survey, the SCCW effluent has returned to the right-hand-side of the river and is fully distributed across the passive mixing zone. At this point, the maximum local instantaneous temperature rise is still about 1.6 F°, occurring at several locations in the cross section, primarily in the upper 3 feet of the water column.

- In the remaining three hours of the survey, heat from the SCCW effluent continues to slowly backfill from the left-hand-side to the right-hand-side of the river. At the end of the survey, the maximum local instantaneous temperature rise is about 2.0 F°, occurring in the upper 3 feet of the water column in the left-hand-side of the river. Overall, however, at the end of the survey, there is very little temperature variation across the river—at most about 0.4 F°.

NPDES Compliance Parameters

Since heat from the SCCW effluent is distributed across the full width of the river, data from all of the HOBO stations were used to compute the NPDES compliance parameters, which is consistent with the dimensions of the passive mixing zone (i.e., the passive mixing zone spans the full width of the river). The compliance parameters examined include all those given in Table 1—the temperature at the downstream end of mixing zone, T_d; the temperature rise from upstream to the downstream end of the mixing zone, ΔT; and the temperature rate-of-change at the downstream end of the mixing zone, TROC. The fundamental equations used to compute the compliance parameters are provided in APPENDIX B, based on the criteria specified in the NPDES permit. The temperature at the downstream end of the mixing zone was determined from the HOBO measurements by averaging the readings from the sensors at depths 3, 5, and 7 feet for all twelve HOBO stations. The temperature rise was computed as the difference between the measured temperature at the downstream end of the mixing zone and the upstream temperature measured at Watts Bar Dam (i.e., Station 30). The temperature rate-of-change was determined by the change in the measured temperature at the downstream end of the mixing zone from one hour to the next. The data were averaged over a period of one hour using 15-minute readings, as specified in the NPDES permit, and compared with the WBN thermal plume model. The measurements are presented in Figure 8, along with the results obtained by the thermal plume model. The following behaviors are emphasized:

- Temperature at the downstream end of the passive mixing zone, T_d: The maximum 1-hour average T_d estimated by the thermal plume model was 80.9°F, whereas the maximum measured value was about 79.3°F. Thus, the model overpredicted the maximum measured T_d by 1.6°F. Compared to the measurements, the increase in river temperature due to the no flow event was predicted to occur much more rapidly by the model. This is because the model assumes impacts due to changes in the river and/or Outfall 113 conditions are fully realized as a steady-state episode within one hour (i.e., the model time-step); whereas in reality, the actual time for the thermal plume to evolve is much longer. Both the predictions from the model and measurements from the survey were well below the NPDES limit of 86.9°F.

- Temperature rise, ΔT: The maximum 1-hour average ΔT predicted by the plume model was 1.6 F°, whereas the maximum measured value was about 1.9 F°. Thus, the model underpredicted the maximum measured temperature rise by 0.3 F°. For the reason cited above (i.e., computational time-step of one hour), the model predicted the maximum temperature rise to occur one hour into the no flow event. A close examination of the data reveals that the maximum measured value of the temperature rise occurred at end of the survey, when the impact of leakage at Watts Bar Dam reduced the upstream ambient river temperature relative to the model value (see previous discussion in section entitled "River Conditions"). The model value for the upstream ambient river temperature was 79.3°F, whereas due to leakage of cold water at Watts Bar Dam, the measured ambient temperature was unnaturally lowered to 77.4°F (i.e., 1.9 F° lower than the model value, see Figure 4). Both the predictions from the model and measurements from the survey were well below the NPDES limit of 5.4 F°.

- Temperature rate-of-change, TROC: The maximum 1-hour average TROC predicted by the plume model was 0.7 F°/hour, whereas the maximum measured value was about 0.2 F°/hour (absolute values). Thus, the model overpredicted the temperature rate-of-change by 0.5 F°/hour. Both the predictions from the model and measurements from the survey were well below the NPDES limit of ±3.6 F°/hour.

CONCLUSIONS

The compliance survey for 2012 summer conditions was successful in measuring the NPDES instream water temperature parameters for the Outfall 113. These included the temperature, T_d, temperature rise, ΔT, and temperature rate-of-change, TROC, all at the downstream end of the passive mixing zone. The measurements were compared with values predicted by the thermal plume model that TVA currently uses to determine the safe operation of the SCCW system.

Since 2005, when the first compliance survey was performed for the Outfall 113 passive mixing zone, the model value for the maximum downstream temperature T_d, including that for the survey summarized herein, has always bounded the measured value for the maximum T_d. That is, the model value has always been greater than or equal to the measured value. Such is not the case, however, for ΔT and TROC. In this survey, the model value for the ΔT undpredicted the value for the maximum ΔT by 0.2 F°. The only other instance when the model underpredicted the actual ΔT was during the summer survey of 2011, when the model value for the maximum ΔT underpredicted the measured value by 0.1 F° (Saint and Hopping, 2011). As for temperature rate-of-change, the model value for the maximum TROC underpredicted the measured value by 0.3 F°/hour in the summer survey of 2005 (McCall and Hopping, 2006). These differences are not surprising in light of the fact that the model, like any mathematical representation of a complex physical process, contains inherent accuracy limitations. The TVA model for predicting the Outfall 113 thermal plume uses CORMIX, which has a stated accuracy of about 50% of the standard deviation of field measurements (Jirka, et al., 1996). Based on this, as well as the fact that differences as small as 0.2 F° for ΔT and 0.3 F°/hour for TROC fall within the factor of safety currently used by TVA in performing hydrothermal forecasts, the thermal plume model is yet considered fully adequate for determining the safe operation of the SCCW system. That is, in combination with TVA procedures for predicting the impact of the Outfall 113 effluent, the model continues to provide a high level of confidence that the SCCW system is being operated in a manner that protects the limits for T_d, ΔT, and TROC specified in the NPDES permit for the passive mixing zone.

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McCall, Michael J., and P.N. Hopping, "Summer 2005 Compliance Survey for Watts Bar Nuclear Plant Outfall 113 Passive Mixing Zone," TVA River Operations, Report No. WR2006-2-85-152, February 2006.

McCall, Michael J., and P.N. Hopping, "Winter 2005 Compliance Survey for Watts Bar Nuclear Plant Outfall 113 Passive Mixing Zone," TVA River Operations, Report No. WR2005-2-85-151, October 2005.

TDEC, *State of Tennessee NPDES Permit No. TN0020168*, Tennessee Department of Environment and Conservation, Issued June 2010.

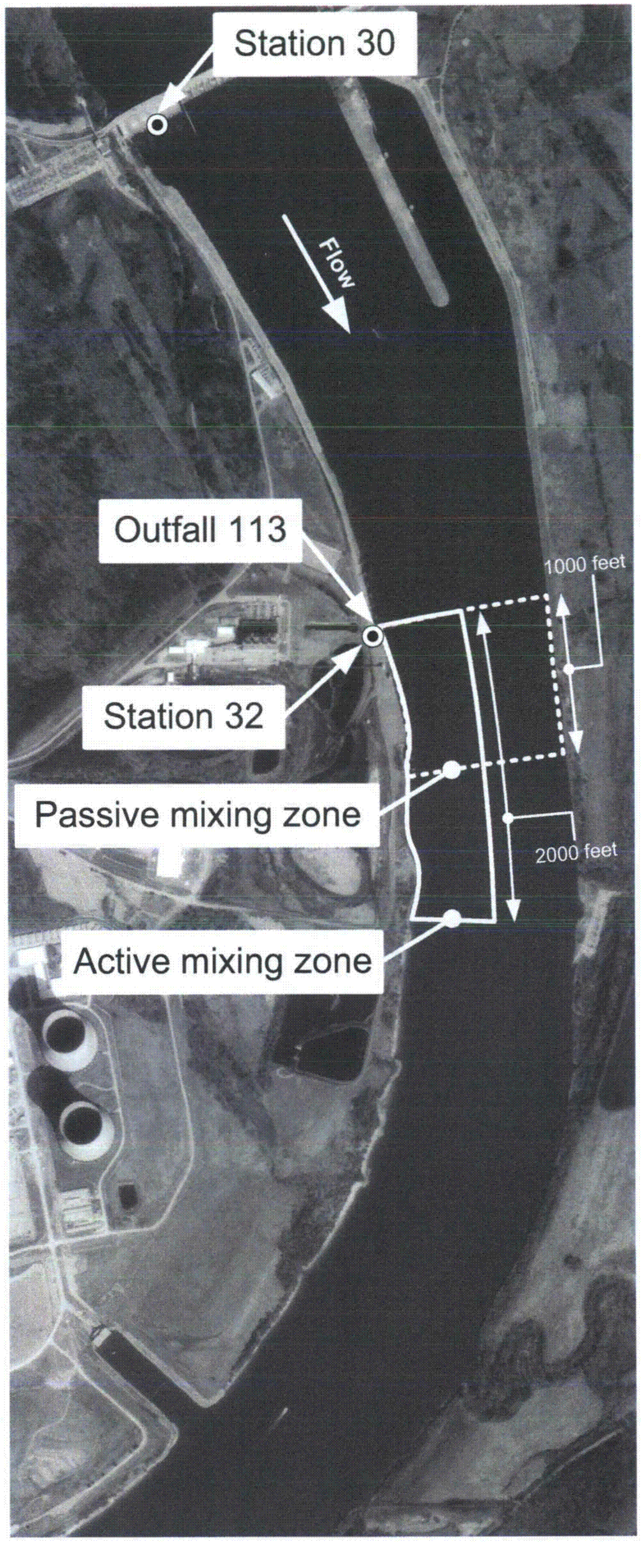

Figure 1. Watts Bar Nuclear Plant Outfall 113 (SCCW) Mixing Zones

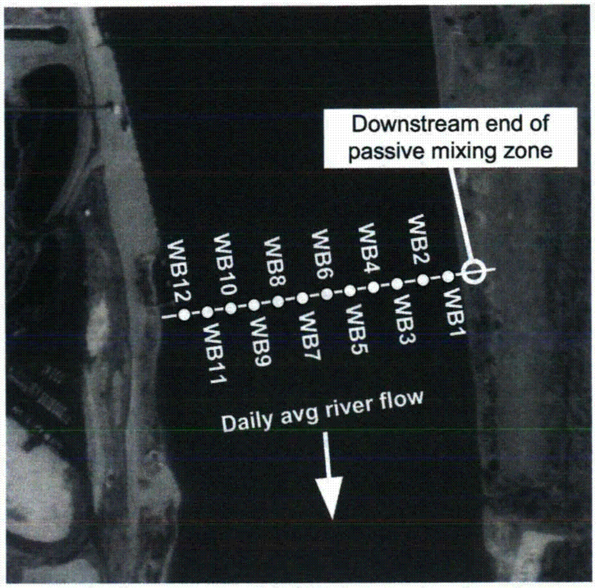

Figure 2. Location of HOBO Monitoring Stations

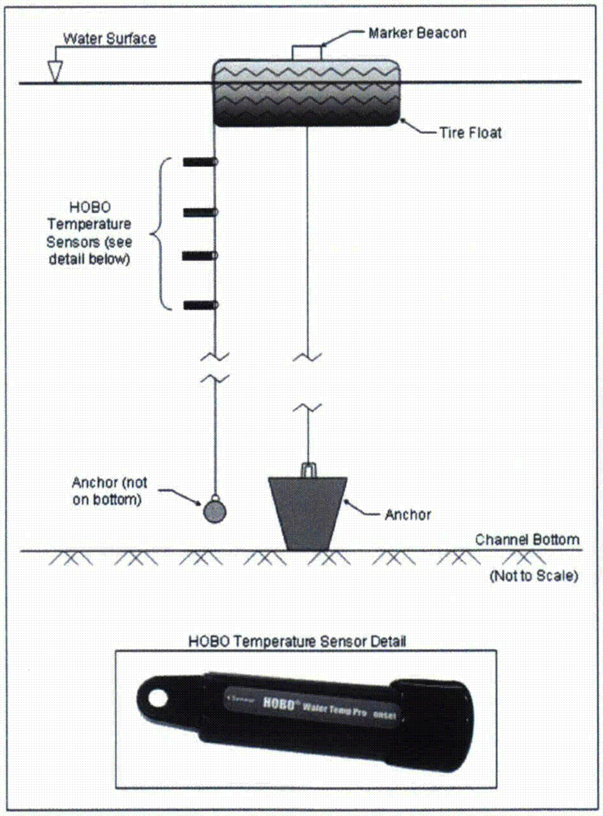

Figure 3. Schematic of HOBO Water Temperature Monitoring Stations

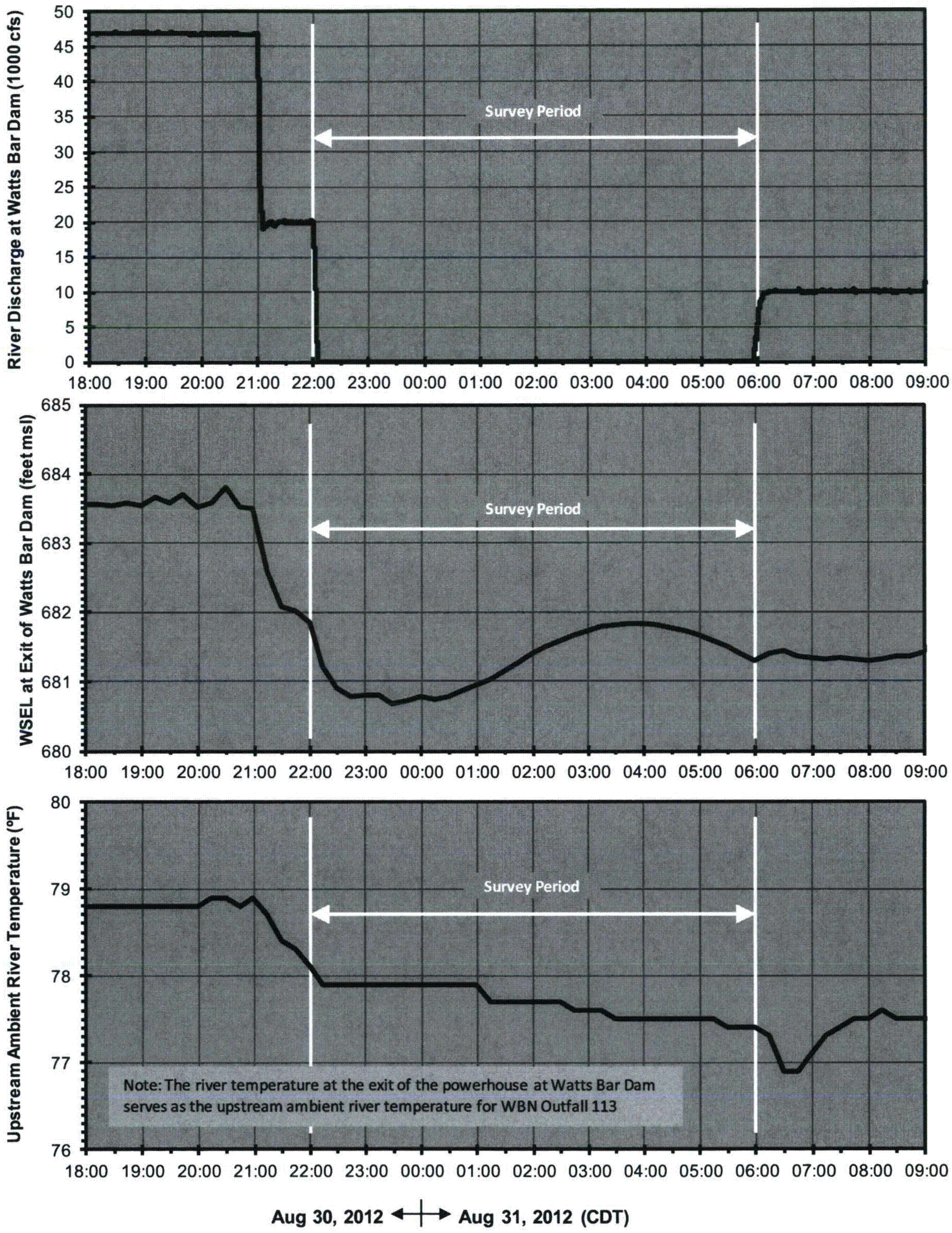

Figure 4. River Conditions

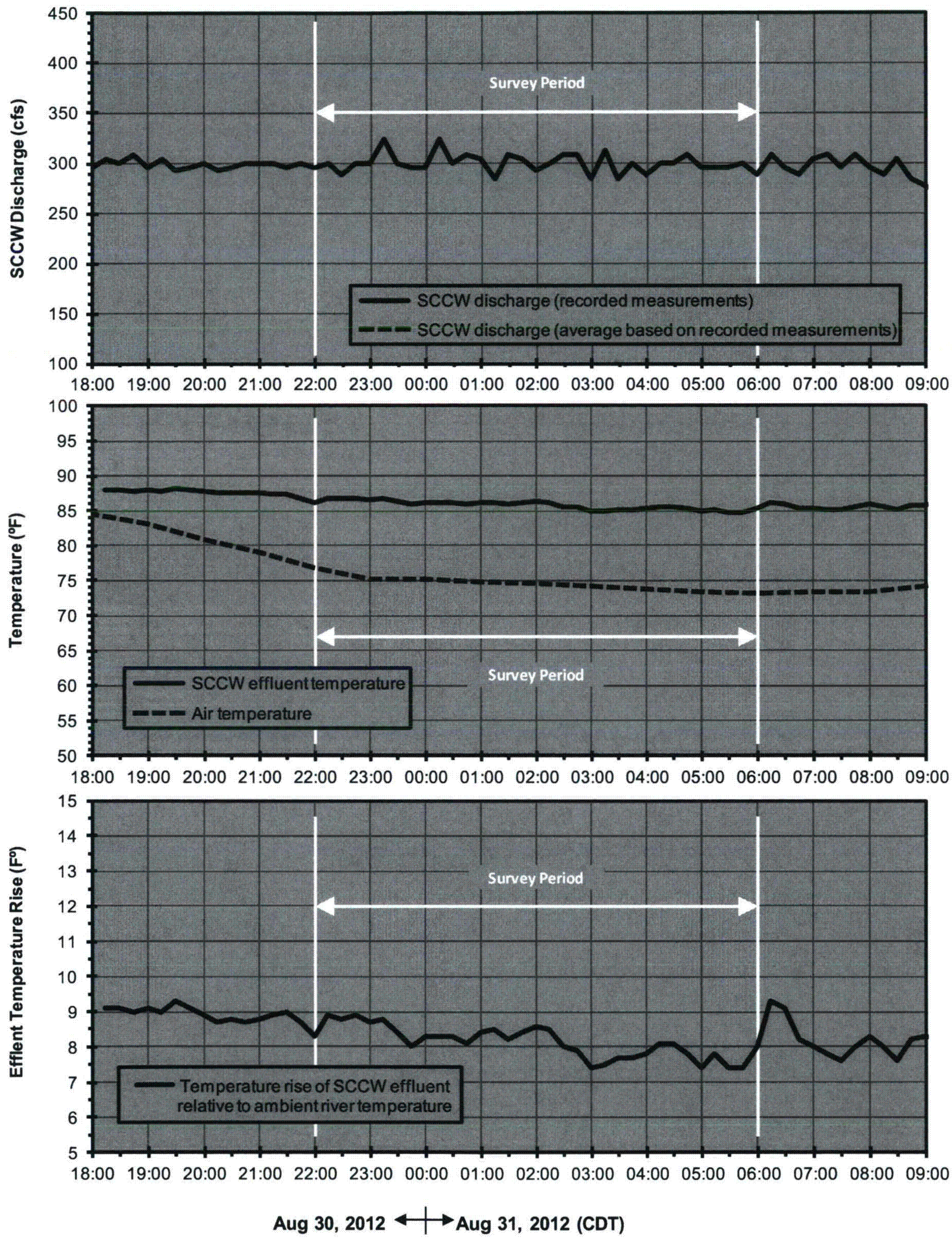

Figure 5. SCCW Conditions

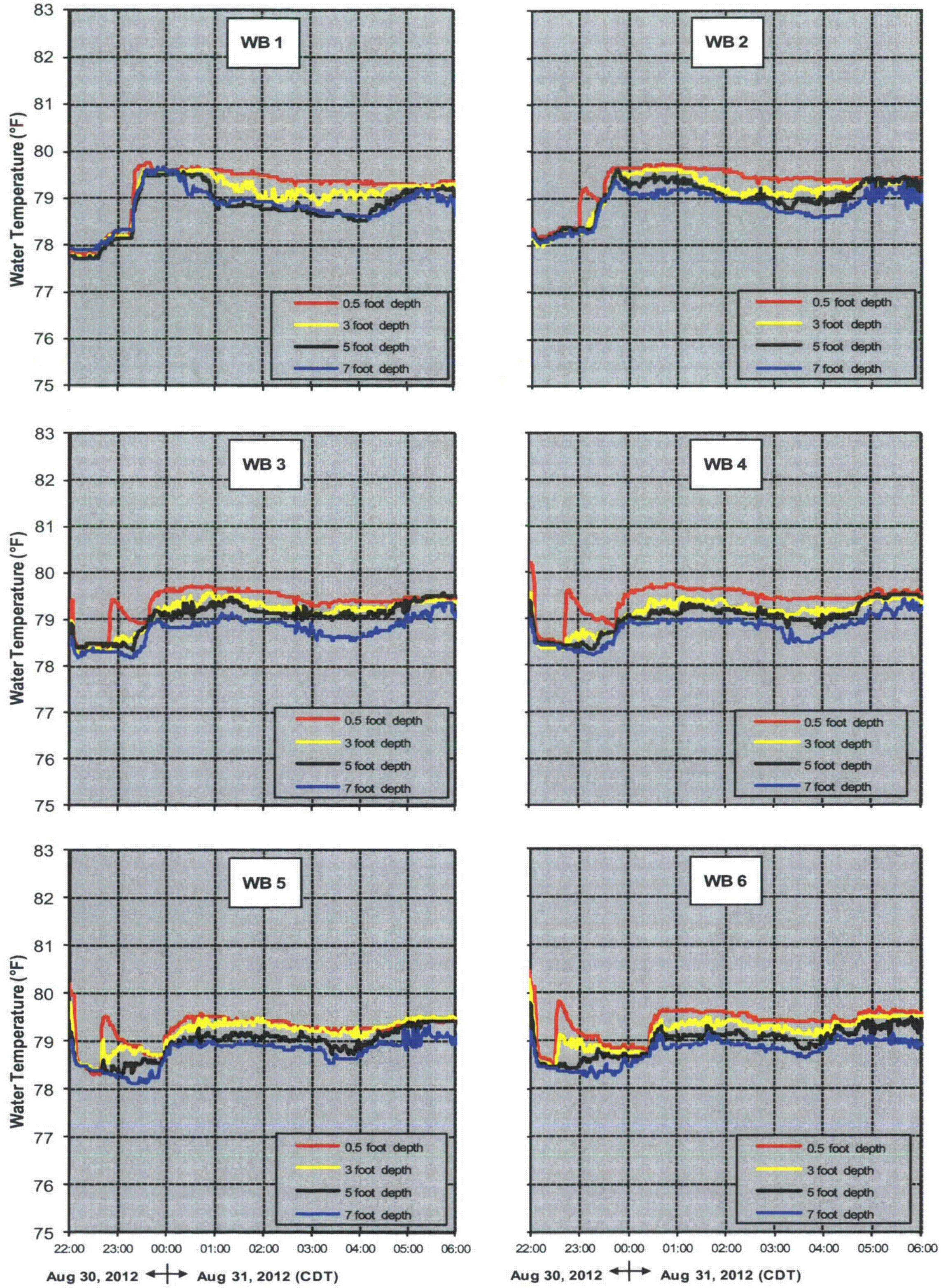

Figure 6. HOBO Water Temperature Measurements

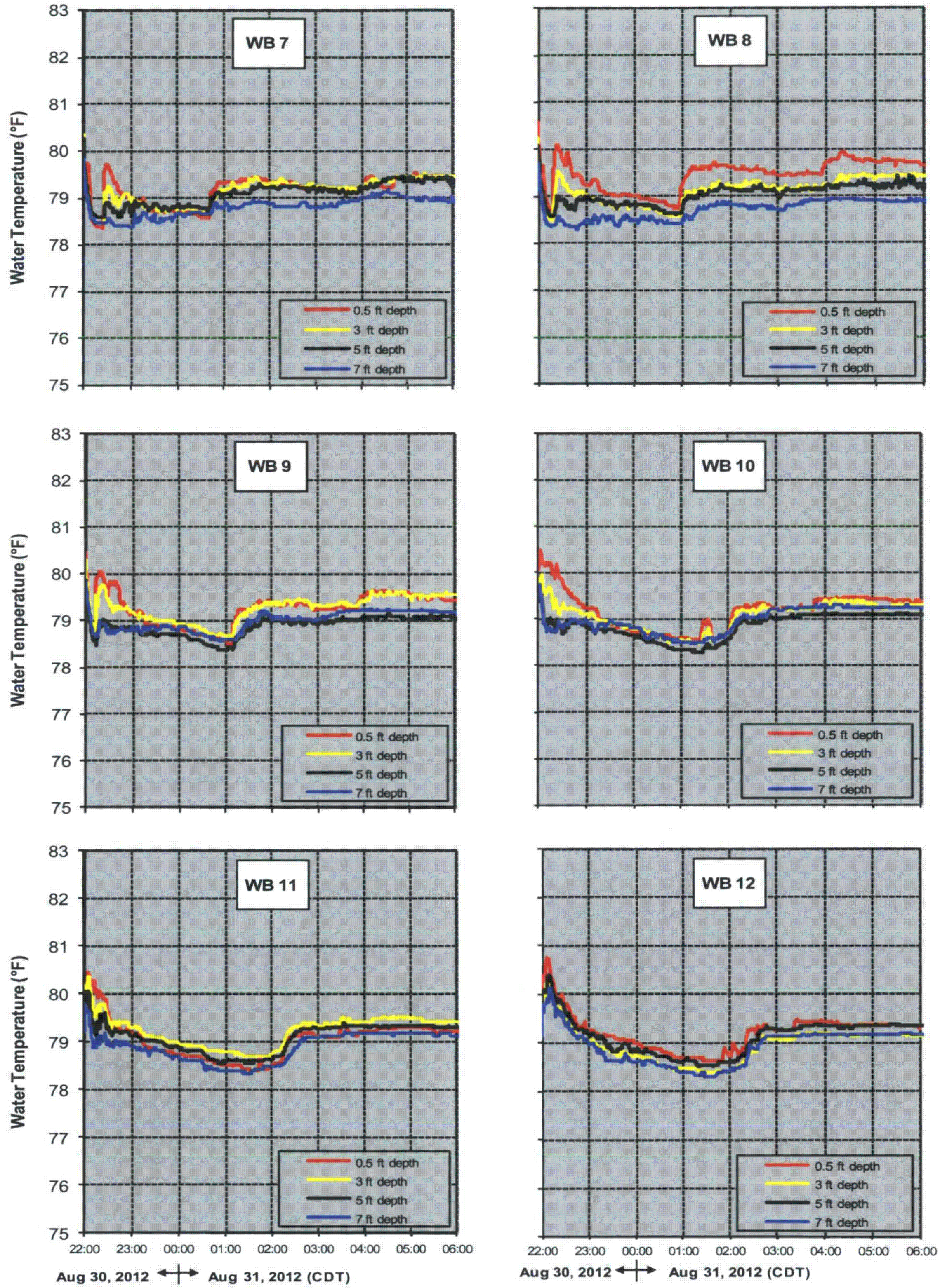

Figure 6 (Continued). HOBO Water Temperature Measurements

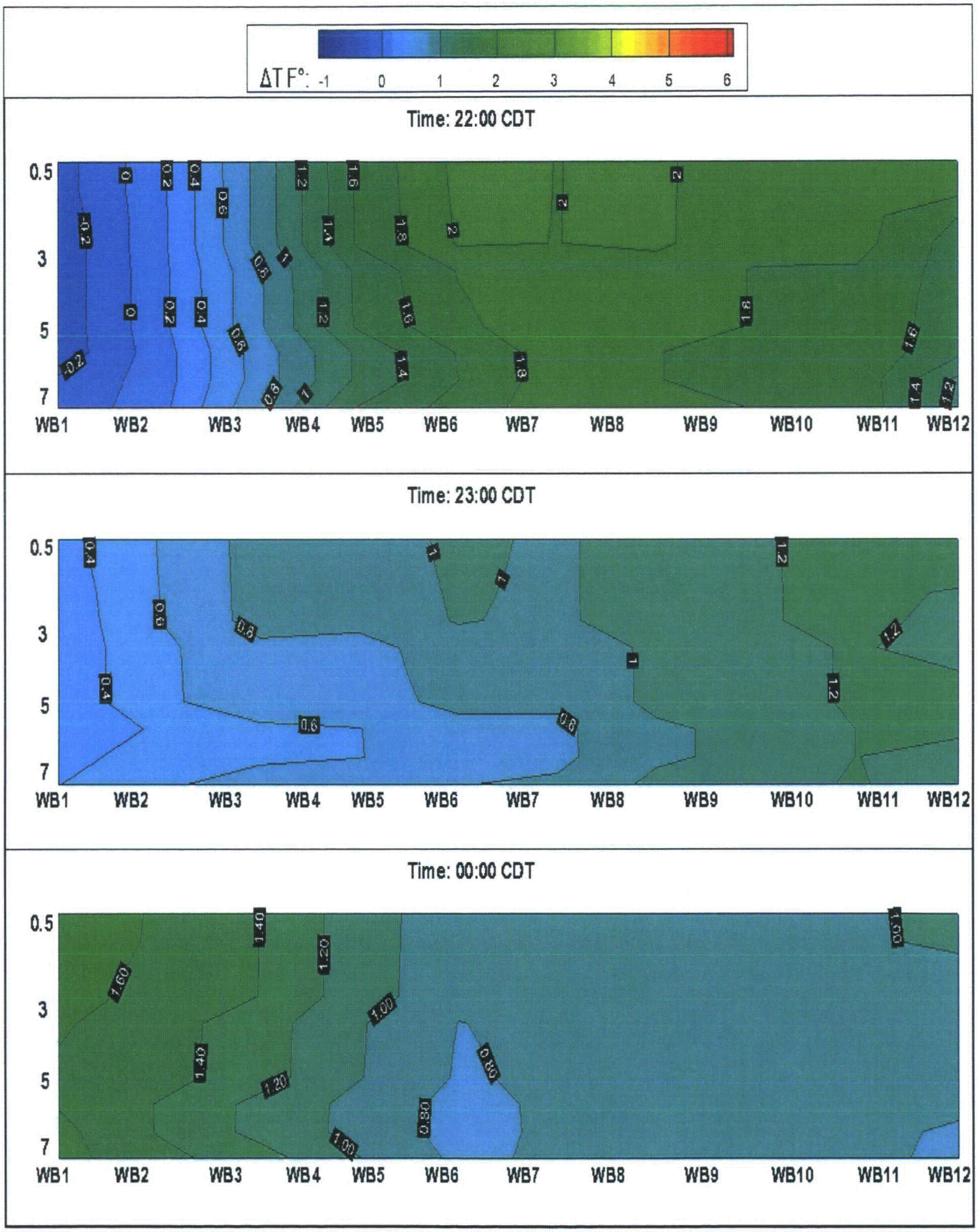

Figure 7. Local Instantaneous Temperature Rise for HOBO Measurements

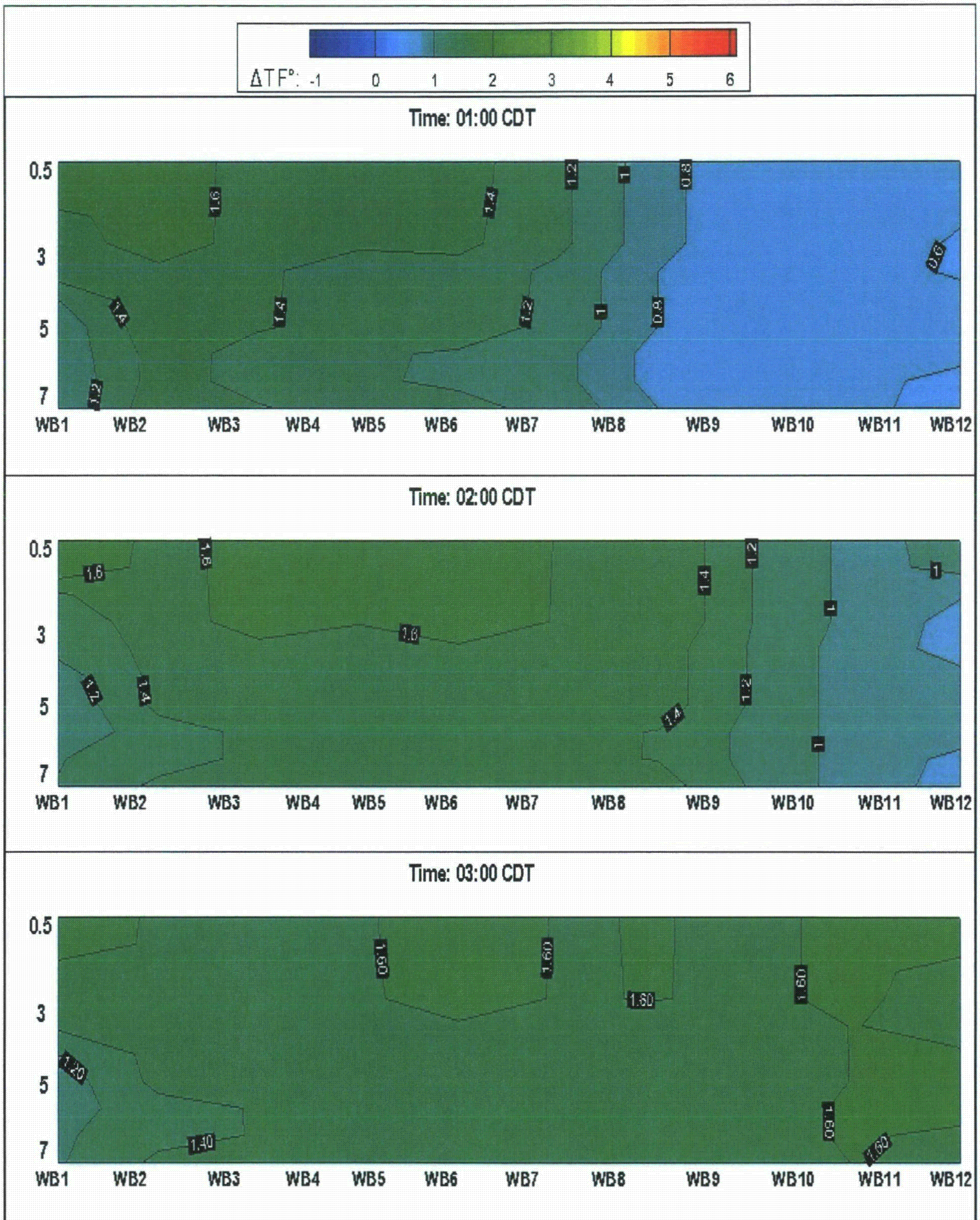

Figure 7 (Continued). Local Instantaneous Temperature Rise for HOBO Measurements

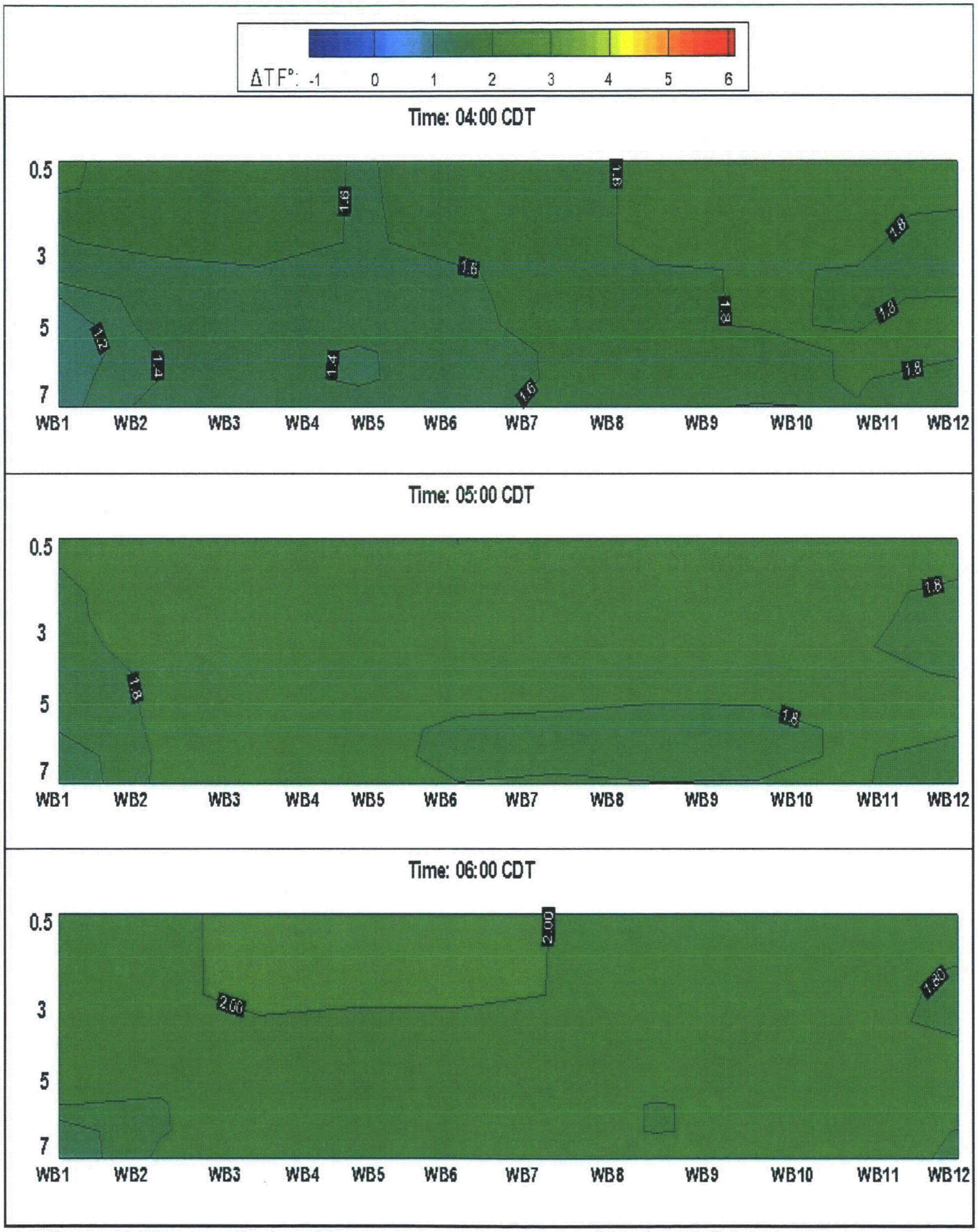

Figure 7 (Continued). Local Instantaneous Temperature Rise for HOBO Measurements

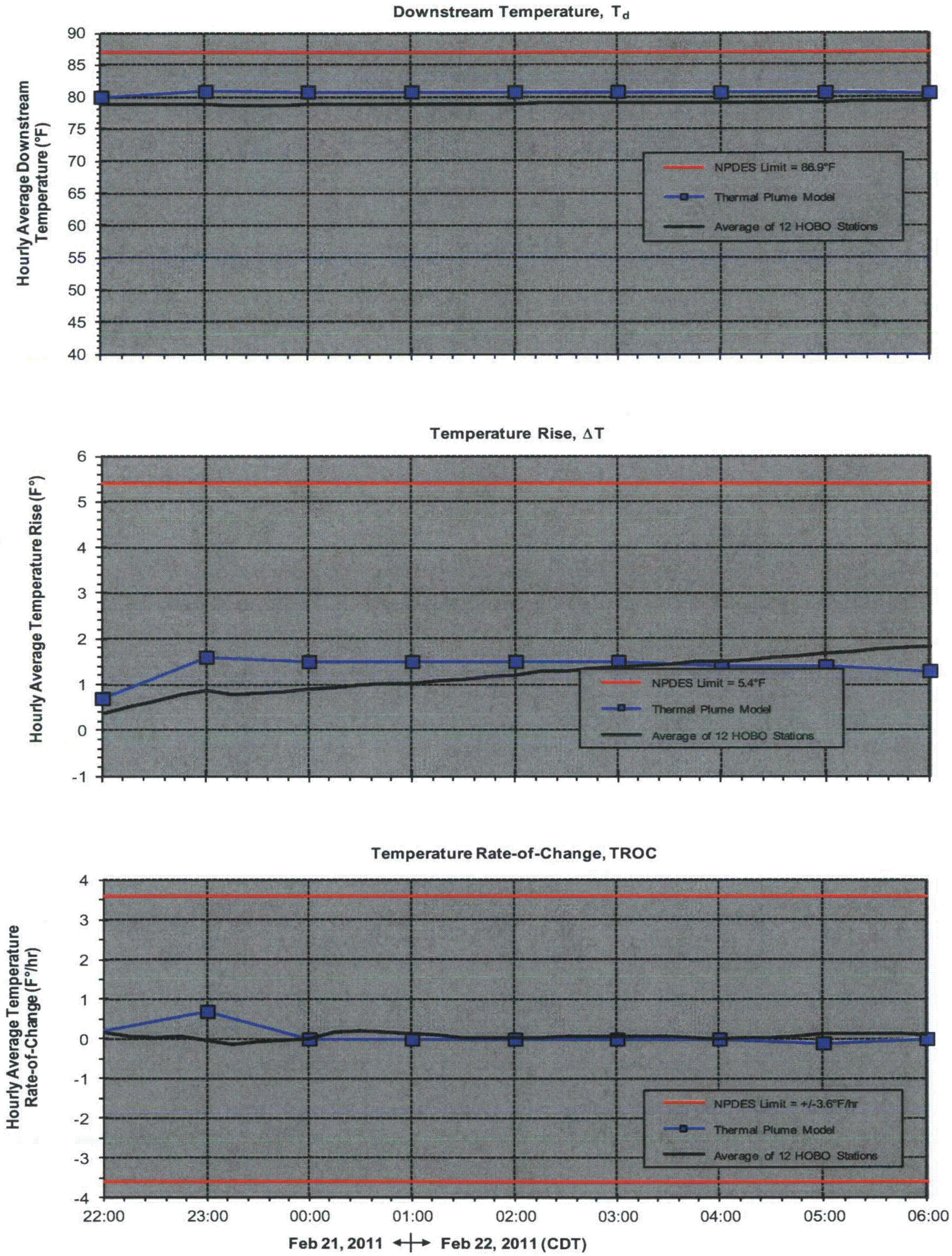

Figure 8. Measured and Computed Compliance Parameters for Passive Mixing Zone

APPENDIX A
Calibration of NPDES Water Temperature Sensors

All sensors used by TVA for monitoring compliance of NPDES water temperature requirements are certified and maintained to meet the following industry and regulatory standards:

- ISO/IEC 17025—Quality assurance requirements for the competence to carry out sampling, testing, and calibrations using standard, non-standard, and laboratory-developed methods (ISO=International Organization for Standardization, IEC=International Electrotechnical Commission).

- 10CFR50 Appendix B—Quality assurance criteria for design, fabrication, construction, and testing of the structures, systems, and components of nuclear power plants (CFR=Code of Federal Regulations).

- 40CFR136—Guidelines establishing test procedures for the analysis of pollutants under the Clean Water Act.

- ANSI N45.2. 1971—Quality assurance requirements for Nuclear Power Plants (ANSI= American National Standards Institute).

- ANSI/NCSL Z540-1-1994—General requirements for calibration laboratories and equipment used for measurements and testing (NCSL=National Conference of Standards Laboratories).

The standard used to certify the thermistors for the permanent EDS stations and the temporary HOBO stations is traceable to the National Institute of Standards and Technology (NIST). The standard includes two pieces of equipment—a platinum resistance temperature detector (RTD) manufactured by Burns Engineering, Inc. and an ohmmeter manufactured by Azonix Inc. The latter is used to measure the resistance of the RTD (i.e., the resistance of platinum varies with temperature). The NTIS traceable calibration certificates for the Burns RTD and the Azonix ohmmeter used to calibrate the HOBO monitors in the field survey summarized herein are available upon request. The overall accuracy of the system for the temperature standard is about ±0.05°F. The tolerance of the thermistors used for the WBN field survey is about ±0.4°F, thus providing a calibration test accuracy ratio (TAR) of about 1:8. That is, the accuracy of temperature standard used for the sensor calibrations is about 8 times greater than the minimum acceptable field accuracy of temperature sensors. This is twice the recommended maximum TAR of 1:4 for sensor calibrations.

The TVA procedure to calibrate the HOBO water temperature monitors, Instruction No. 450.01-020, is provided below. Briefly, the HOBO monitors are immersed in a stirred temperature-

controlled water bath along with the standard (i.e., along with the Burns RTD probe). After the bath stabilizes, temperature readings from the HOBO monitors are compared to the temperature readings from the standard. Experience has shown that in nearly all cases, the readings from both the HOBO monitors and the standard and are essentially constant, so that the 95 percent confidence interval of the readings is diminutive. Under these conditions, the accuracy of each HOBO monitor is recorded simply as the difference between the HOBO reading and that of the standard (negative difference = HOBO reading low/below standard, positive difference = HOBO reading high/above standard). The HOBO monitors are tested at three temperatures between 30°F and 100°F, covering the range of expected water temperature for natural river conditions. The three temperatures are at about the 10 percent, 50 percent, and 90 percent intervals, or 37°F, 65°F and 93°F, respectively. Any HOBO monitor with measured accuracy in excess of the maximum allowable tolerance of ±0.4°F for any one of the three temperatures fails the calibration test and is removed from the field survey inventory. The calibration certificates for HOBO monitors used in this field survey summarized herein are available upon request. All the HOBO monitors passed both the pre-survey and post-survey calibration tests. The mean square error of the HOBO monitors was 0.14 F° for the pre-survey calibrations and 0.13 F° for the post-survey calibrations.

TVA **CENTRAL LABORATORIES SERVICES QUALITY PROGRAM INSTRUCTION**	**TITLE** Certification of HOBO Water Temp Pro Data Acquisition SystemsH_20-001	**Instruction No.** 450.01-020 **Rev. No.** 0 **Page No.** 1 of 7 **Effective Date** 5/19/03

LEVEL OF USE ☐ Continuous ☒ Reference ☐ Information

QA RECORD

Dennis T. Darby — Preparer — 5/19/03 Date

Paul B. Loiseau, Jr. — Technical Reviewer — 5/19/03 Date

[signature] — Administrative Review — 6/5/03 Date

APPROVAL

Jerry D. Hubble — Department Manager — 5/19/03 Date

REVISION LOG

Revision Number	Effective Date	Pages Affected	Description of Revision
0	5/19/03	All	Initial Issue.

1.0 PURPOSE

To provide uniform and effective certifications of Hobo Water Temp Pro data acquisition systems meeting the accuracy and performance requirements of TVA's water temperature-monitoring programs. This technical instruction uses the method of comparison with a laboratory standard thermometer.

2.0 SCOPE

This instruction applies to the certification of Hobo Water Temp Pro data loggers manufactured by Onset Computer Corporation of Bourne, Massachusetts. The Hobo Water Temp Pro is a data acquisition system containing a temperature sensor, data logger and battery sealed in a single submersible case. The Hobo Water Temp Pro is programmed and data retrieved by use of an infrared interface located in one end of the case. Hobo Water Temp Pros are certified upon receipt from the manufacturer at no greater than 12 month intervals during use or when requested.

3.0 SUMMARY

In this three-point certification systems are tested as actually used over the historical water temperature range of 30° to 100°F and submerged in water. The three test points are 37°, 65° and 93°F. The systems are required to perform within Onset Computer Corporation tolerances. System conformity at each temperature point is determined by comparing system temperature, logged by the Hobo Water Temp Pro and a laboratory standard thermometer.

Systems are programmed and submerged with a standard thermometer in a stirred, temperature-controlled temperature bath. The systems are read after the test by an infrared interface adapter connected to a computer running Onset Computer Corporation's Boxcar Pro software. Traceability of the certification is through the thermometer.

"As-found" certifications are performed on new systems as an acceptance test and on sensors returned from field service. "As-left" certifications are performed before delivery for field service if more than 12 months has elapsed since the last certification. "As-found" and "as-left" certifications may be combined on the same record if there is clear indication which type each system is undergoing.

Multiple HOBOs may be certified at the same time in the temperature bath.

- Accuracy of ±0.2°C at 25°C (0.33°F at 70°F)
- Waterproof case, submersible to 100 feet
- Capacity to store up to 21,580 temperature measurements
- Selectable sampling interval from 1 second to 9 hours
- Programmable start time/date
- Two data recording modes: Stop when full or wrap around when full.
- Two data offload modes: Halt then offload or offload while logging.
- Nonvolatile EEPROM memory that retains data even if batteries fail
- Light-emitting diode (LED) operation, indicator, which can be disabled during logging by selecting "Stealth"1 mode
- High-speed IR communications for offloading data; can readout full logger in less than 30 seconds while logging continues
- Battery life of 6 years with typical usage

4.0 PRACTICES/EXCEPTIONS

N/A

5.0 SAFETY

5.1 Standard electrical equipment safety.

6.0 STANDARDS USED

6.1 Laboratory reference thermometer, range 30° to 100°F or greater, 0.01°F resolution, 0.1°F accuracy or better, with current calibration sticker.

7.0 EQUIPMENT/APPARATUS

7.1 Temperature bath, stirred, temperature-controlled.
7.2 Computer with Onset Boxcar Pro software installed (version 4.3 or later)
7.3 IR Base station, Onset Part # BST -IR

8.0 PREREQUISITE ACTIONS

8.1 Turn on temperature bath and set for 37°F.
8.2 Check the IR interface to verify that it is plugged into the correct serial port on the PC. Set the correct time on the PC.
8.3 Align the IR port on the Base station with the HOBO Water Temp Pro communications window. Place the logger no further than 4 to 5 inches away from the Base station (see Figure 2) and make sure the IR windows in both devices point at each other. There is a 30° acceptance angle for the IR beam, so some misalignment is acceptable.

8.4 Start the Onset Box Car Software and select **Logger** then **Hobo Water Temp Pro** and **Launch.**

8.5 The computer will respond with a list of loggers found. The serial number in this list should match the serial number printed on the side of the logger. If these numbers do not match, click the **Refresh** button. Record this serial number on the certification form. Either wait or click the **Stop Searching** button. Using the mouse select the logger and click the **Launch** button.

8.6 After a few seconds the screen will display the status of the HOBO Water Temp Pro. Record the battery percentage on the certification form.

8.7 Verify that the Hobo is set to Fahrenheit and program it to a recording interval of 0:1:0 for a reading once a minute. Verify that the start logging immediately box is checked and that the set data logger clock with host launch is also checked.

8.8 Using the mouse click the **Launch Immediately** button.

8.9 If last HOBO is programmed click the **DONE** button, else select the **Launch Another** and repeat steps 8.5 through 8.9.

9.0 TEST PROCEDURE/METHOD

9.1 On the certification form record the serial number of the laboratory reference thermometer.

9.2 Place the HOBO Water Temp Pro in the temperature bath, making sure the end opposite the IR windows is submerged, and allow the bath to stabilize at 37°F ±0.5°F on the thermometer. Adjust the bath set point if needed. After the bath reaches the desired temperature allow 20 minutes 'soak time' for the HOBO to reach its final temperature.

9.3 Record the thermometer reading on the certification form and the time. (The time will be needed to get the correct reading from the HOBO.)

9.4 Repeat steps 9.2 and 9.3 for bath settings of 65.0°F ± 0.5°F and 93°F ± 0.5°F.

9.5 Remove the HOBO from the temperature bath and align the IR port on the Base station with the HOBO Water Temp Pro communications window.

9.6 Restart Onset BoxCar Pro if it is not running and select **Logger** then **Hobo Water Temp Pro** and **Readout.**

9.7 The computer will respond with a list of loggers found. Using the mouse select the logger and click the **Readout** button. The computer will ask to download data and continue logging or the stop logging and offload data. Select the **Stop Logging and Offload data.** After a few seconds the computer will respond with a suggested file name. Select **Save** and allow the HOBO to transfer the data.

9.8 After a successful download click the **OK** button. The computer will then ask if the data should be displayed in Centigrade or Fahrenheit. Deselect °C and select °F and click **OK.** The computer should display a graph of the collected data. Click the view details button (this is the button just left of the question mark button.)

9.9 Scroll down the displayed list until the time recorded for the 37°F point is found. Record the corresponding temperature on the certification form. Repeat this step for 65° and 93°.

9.10 Close the view details windows and repeat steps 9.6 through 9.9 for additional HOBOs.

9.11 Fill out the rest of the certification form.

10.0 ACCEPTANCE CRITERIA

10.1 Based upon the manufacturer specifications the HOBO Water Temp Pro should be within ±0.4°F over the range of 32°F to 100°F. Any HOBO with an error of greater than ±0.5°F at any of the three measured points shall fail certification.

11.0 POST PROCEDURE ACTIVITY

11.1 Close the BoxCar Software.

12.0 RECORDS

12.1 Completed HOBO Water Temperature Pro Certification form and associated Report of Certification cover sheet is a QA record.

13.0 REFERENCE

13.1 HOBO Water Temp Pro User's Manual, version 1.0 or later

13.2 Onset BoxCar Pro4 Manual Version 1.0 or later

APPENDIX B
WBN Outfall 113 NPDES Compliance Parameters

- Current Instantaneous Upstream Temperature:

  Tu_i (measured at EDS Station 30 by the first sensor below a depth of 5 feet).

- Current 1-Hour Average Upstream Temperature:

  $$Tu1_i = \frac{Tu_i + Tu_{i-} + Tu_{i-} + Tu_{i-} + Tu_{i-}}{5},$$

  where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of Tu.

- Current Instantaneous Downstream Temperature:

  $$Td_i = \frac{Td3_i + Td5_i + Td7_i}{3},$$

  where $Td3_i$, $Td5_i$, and $Td7_i$ denote the current measurements of river temperature at the downstream end of the mixing zone at water depths 3 feet, 5 feet, and 7 feet, respectively.

- Current 1-Hour Average Downstream Temperature:

  $$Td1_i = \frac{Td_i + Td_{i-} + Td_{i-} + Td_{i-} + Td_{i-}}{5},$$

  where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of Td.

- Current Instantaneous Temperature Rise:

  $$\Delta_i = Td_i - Tu_i.$$

- Current 1-Hour Average Temperature Rise:

  $$\Delta 1_i = \frac{\Delta_i + \Delta_{i-} + \Delta_{i-} + \Delta_{i-} + \Delta_{i-}}{5},$$

where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of ΔT.

- Current Temperature Rate-of-Change:

$$TROC_i = \frac{Td_i - Td_{i-}}{1\,\text{hour}} .$$

- Current 1-Hour Average Temperature Rate-of-Change:

$$TROC1_i = \frac{TROC_i + TROC_{i-} + TROC_{i-} + TROC_{i-} + TROC_{i-}}{5} ,$$

where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of TROC.

Enclosure 6

Winter 2012 Compliance Survey for Watts Bar Nuclear Plant Outfall Passive Mixing Zone

TENNESSEE VALLEY AUTHORITY
River Operations

WINTER 2012 COMPLIANCE SURVEY FOR WATTS BAR NUCLEAR PLANT OUTFALL 113 PASSIVE MIXING ZONE

Prepared by

Daniel P. Saint
and
Paul N. Hopping

Knoxville, Tennessee
October 2012

EXECUTIVE SUMMARY

The National Pollutant Discharge Elimination System (NPDES) Permit No. TN0020168 for Watts Bar Nuclear Plant (WBN) identifies the discharge of water to the Tennessee River from the Supplemental Condenser Cooling Water (SCCW) System as Outfall 113. Furthermore, the permit identifies that when there is no flow released from Watts Bar Dam (WBH), the effluent from Outfall 113 shall be regulated based on a passive mixing zone extending in the river from bank-to-bank and 1,000 feet downstream from the outfall. Compliance with the requirements for the passive mixing zone is to be achieved by two annual instream temperature surveys–one for winter conditions and one for summer conditions. Summarized in this report are the measurements, analyses, and results for the passive mixing zone survey performed for 2012 winter conditions. The survey was conducted between 21:00 CDT on February 21 and 05:00 CDT on February 22 (eight hours) and included the collection of temperature data at twelve temporary monitoring stations deployed across the downstream end of the passive mixing zone during a period of no flow in the river. The data were analyzed to determine the three instream compliance parameters specified in the NPDES permit for the outfall: the 1-hour average temperature at the downstream end of mixing zone, T_d; the 1-hour average temperature rise from upstream to the downstream end of the mixing zone, ΔT; and the 1-hour average temperature rate-of-change at the downstream end of the mixing zone, TROC. The measured parameters were compared to predicted values from the thermal plume model used by TVA to help determine the safe operation of Outfall 113. The results of the comparisons, in terms of maximum values observed during the no flow event, are as follows:

Compliance Parameter	Model	Measured	NPDES Limit
Maximum T_d	51.5°F	49.9°F	86.9°F
Maximum ΔT	4.4 F°	3.2 F°	5.4 F°
Maximum |TROC|	1.2 F°/hour	0.8 F°/hour	3.6 F°/hr

As shown, both the model and measured values were well below the NPDES limits for all the compliance parameters. Based on the results, the thermal plume model is considered adequate for determining the safe operation of the SCCW system. That is, in combination with TVA procedures for predicting the impact of the Outfall 113 effluent, the model continues to provide a high level of confidence that the SCCW system is being operated in a manner that does not exceed the instream limits for T_d, ΔT, and TROC as specified in the WBN NPDES permit.

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WINTER 2012* COMPLIANCE SURVEY FOR WATTS BAR NUCLEAR PLANT OUTFALL 113 PASSIVE MIXING ZONE

INTRODUCTION

Outfall 113 for the Watts Bar Nuclear Plant (WBN) includes the discharge of water to the Tennessee River from the Supplemental Condenser Cooling Water (SCCW) system. Due to the dynamic behavior of the thermal effluent in the river, the National Pollutant Discharge Elimination System (NPDES) Permit No. TN0020168 for the plant specifies two mixing zones for Outfall 113—one for active operation of the river and one for passive operation of the river (TDEC, 2010). The passive mixing zone corresponds to periods when the operation of Watts Bar Dam (WBH) produces no flow in the river (i.e., hydropower and/or spillway releases). The dimensions of the passive mixing zone extend from bank-to-bank and downstream 1,000 feet from the outfall. The active mixing zone applies to all other river flow conditions. The dimensions of the active mixing zone include the right-half of the river (facing downstream) and extend downstream 2,000 feet from the outfall. The passive and the active mixing zones are shown in Figure 1.

Table 1 summarizes the NPDES instream temperature limits for Outfall 113. The limits apply to both the active and passive mixing zones. Compliance for the active mixing zone is monitored by permanent instream water temperature stations situated in the right-half of the river. Due to issues associated with placing permanent stations in the left-half of the river, which contains the navigation channel, a thermal plume model is used to determine the safe operation of Outfall 113 for the passive mixing zone. To verify the thermal plume model, the NPDES permit specifies that two instream temperature surveys shall be conducted each year—one for winter conditions and one for summer conditions. The purpose of this report is to present the results for the passive mixing zone temperature survey performed for winter 2012 conditions. The survey was conducted between 21:00 CDT on February 21 and 05:00 CDT on February 22 (total eight hours). Provided is a brief summary of the survey method, presentations of the measurements and analyses, and discussions of the results and conclusions.

Table 1. NPDES Temperature Limits for Outfall 113 Mixing Zones

Compliance Parameter	Sampling Period	NPDES Limit
Maximum Temperature, Downstream End of Mixing Zone, T_d	Running 1-hr	86.9°F
Maximum Temperature Rise, Upstream to Downstream, ΔT	Running 1-hr	5.4 F°
Maximum Temperature Rate-of-Change, TROC	Running 1-hr	±3.6 F°/hr

* R1: Title correction from initial release (initial release contained "2011" rather than "2012").

INSTREAM SURVEY

The instream survey included the deployment of temporary water temperature stations at twelve locations across the downstream end of the passive mixing zone. Data from these and other monitoring stations were analyzed to obtain measured values for the compliance parameters listed in Table 1. These were then compared with the corresponding values estimated from the SCCW thermal plume model.

The method of conducting the instream survey is the same as that used for the first such survey, performed for winter conditions on May 6, 2005 (McCall and Hopping, 2005). Table 2 provides a summary of the sources of data for the survey. WaterView, a monitoring system for tracking hydroplant operation and performance, was used to obtain measurements for the river discharge from Watts Bar Dam. The WBN Environmental Data Station (EDS) provided measurements from existing permanent monitoring stations for the nuclear plant. These included:

- The river upstream (ambient) water temperature, measured at the EDS Station 30, which is located at the exit of the powerhouse of Watts Bar Dam.
- The river water surface elevation (WSEL) at the EDS Station 30, also known as the tailwater elevation (TWEL) at Watts Bar Dam.
- The SCCW effluent temperature, measured at the EDS Station 32, which is located at the SCCW outfall.
- The SCCW effluent discharge, measured at the EDS Station 32.
- The local air temperature, measured at the EDS meteorological tower.

Table 2. Sources of Data for Passive Mixing Zone Survey

Data	Source	Frequency
River Discharge from Watts Bar Dam	WaterView	1 min
River ambient water temperature	WBN EDS Station 30 (Tailwater at WBH)	15 min
River water surface elevation	WBN EDS Station 30 (Tailwater at WBH)	15 min
SCCW effluent temperature	WBN EDS Station 32 (SCCW Outfall 113)	15 min
SCCW effluent discharge	WBN EDS Station 32 (SCCW Outfall 113)	15 min
Air temperature	WBN EDS Met Tower	15 min
Passive mixing zone water temperature	Temporary HOBO Monitors	1 min

The water temperature at the downstream end of the Outfall 113 passive mixing zone was measured by the aforementioned temporary water temperature stations. Using a global positioning system (GPS) device, the stations were positioned at roughly equal intervals across the river, as shown in Figure 2. The temporary stations recorded water temperatures by using HOBO temperature monitors positioned at depths of 0.5, 3, 5, and 7 feet below the water surface. Shown in Figure 3 is a schematic of the temporary stations. The stations included a string of

HOBO monitors suspended from a tire float, with weights to anchor the station and to keep the sensor string vertical in the water column. The water temperature sensors imbedded in the HOBO monitors have an accuracy of about ±0.4 F° and resolution of about 0.04 F°, which is comparable to the accuracy and resolution of temperature sensors used elsewhere by TVA for NPDES thermal compliance. The HOBO monitors include an internal data acquisition unit that was programmed to collect measurements once per minute. All the temperature probes used in the survey, including both those contained in the HOBO monitors and the thermistors at the permanent EDS monitoring stations, were calibrated by a quality program with equipment accuracies traceable to the National Institute of Standards and Technology (NIST). The calibration procedure is summarized in APPENDIX A. The temporary monitoring stations were deployed several hours before the beginning of the survey, and retrieved several hours after the end of the survey.

RESULTS

River Conditions

Figure 4 shows the measured ambient conditions of the river during the survey. Included are the river discharge, the river tailwater elevation, and river temperature at the exit of Watts Bar Dam. The river temperature at the exit of Watts Bar Dam serves as the upstream ambient river temperature for WBN Outfall 113. To provide a period of no flow in the river, releases from Watts Bar Dam were suspended between about 21:00 CDT on February 21 and 05:00 CDT on February 22, a total of eight hours (nighttime). Leading up to the survey, as the river flow was stepping down, the WSEL below Watts Bar Dam dropped approximately 2.8 feet, from about 679.8 feet msl to about 677.0 feet msl. For the first 5 hours of the survey, the tailwater elevation remained steady at about 677.0± feet msl and then for the next three hours, the tailwater elevation slowly receded, reaching about 676.4 feet msl by the end of the survey.

The ambient river temperature was 46.7°F at the beginning of the period of no flow, and remained at this temperature throughout the duration of the study. This behavior is common during the winter months when the water column behind Watts Bar Dam contains little or no stratification. Under these conditions, whether the withdrawal zone from the reservoir is large (e.g., high turbine release) or small (e.g., no flow leakage), the ambient river temperature below the dam remains essentially constant.

SCCW Conditions

During the survey, the SCCW system at WBN was thermally loaded and operating in "summer" mode. That is, the system was operating in a manner producing the largest possible release of heat to the river. Shown in Figure 5 are the measured conditions of the SCCW system during the survey. Included are the discharge and temperature of the SCCW effluent. During the survey, the average discharge of the SCCW system to the river was about 207 cfs. The root-mean-square variation in the SCCW discharge was only about 2.8 percent of the average–thus, from the standpoint of mixing processes in the river, the discharge was essentially constant. The SCCW effluent temperature decreased throughout the survey from about 70.8°F at the beginning of the survey to about 66.0°F at the end of the survey. This trend coincides with the falling nighttime air temperature, also shown in Figure 5 (note: the discharge temperature of water from the Unit 1 cooling tower, which provides the source of heat for Outfall 113, varies directly with the temperature of the ambient air that is drawn through the tower). Relative to the upstream ambient river temperature, the temperature rise of the Outfall 113 effluent released from the SCCW system, also shown in Figure 5, decreased from about 24.1 F° at the beginning of the survey to about 19.3 F° at the end of the survey.

Downstream End of Passive Mixing Zone

Shown in Figure 6 are the measurements from the HOBO temperature stations at the downstream end of the passive mixing zone. The stations are labeled consecutively from WB1 to WB12, with WB1 situated near the left-hand shoreline of the river and WB12 situated near the right-hand shoreline of the river (i.e., facing downstream—see Figure 2). In Figure 7, the HOBO data has been analyzed to produce contour plots of the local "instantaneous" water temperature rise (ΔT) relative to the SCCW ambient river temperature (i.e., given in Figure 4). The horizontal (x) axis of each contour plot is the span of the river from WB1 to WB12, and the vertical (y) axis is the water depth from 0.5 feet to 7 feet. In this manner, the plots in Figure 7 represent images of the upper 7 feet of the water column in the river, looking downstream. Note that the depth scale in the plots is very distorted so that the data can be viewed in a meaningful manner—that is, whereas the span of the x-axis is about 1000 feet, the span of the y-axis is only about 7 feet (0.007 times smaller). Plots are provided at the top of each hour from the beginning of the survey at 21:00 CDT on February 21 to the end of the survey at 05:00 CDT on February 22. The following behaviors are emphasized from Figure 6 and Figure 7:

- At the beginning of the survey, 21:00 CDT on February 21, effluent from the SCCW resides primarily on the right-hand-side of the river. This is due to the flow in the river preventing the effluent from spreading across the river. The maximum local instantaneous temperature rise at the downstream end of the passive mixing zone is about 4.8 F° and occurs in the upper 3 feet of the water column in the very right-hand-side of the river.

- Over the next two hours, the effluent from the SCCW slowly spreads across the passive mixing zone. Since there is no flow in the river, the SCCW effluent is somewhat unrestricted, reaching the left-hand-side of the river and spreading downstream alongside the shoreline. The maximum local instantaneous temperature rise during this period is about 2.8 F° and occurs at 22:00 CDT near the middle of the river.

- By 01:00 CDT on February 22, four hours into the survey, heat from the SCCW effluent is distributed fully across the downstream end of the passive mixing zone. The maximum local instantaneous temperature rise at this point in time is about 4.0 F° and again occurs near the middle of the river.

- Throughout the remaining hours of the survey, the SCCW effluent slowly accumulates across the mixing zone. Due to buoyancy, the heat resides primarily in the upper 3 feet of the water column, with the local instantaneous temperature rise reaching, at places, around 4 F°. Between the depths of 3 feet and 7 feet, a local instantaneous temperature rise in the vicinity of 3 F ° is more common.

NPDES Compliance Parameters

Since heat from the SCCW effluent is distributed across the full width of the river, data from all of the HOBO stations were used to compute the NPDES compliance parameters, which is consistent with the dimensions of the passive mixing zone (i.e., the passive mixing zone spans the full width of the river). The compliance parameters examined include all those given in Table 1—the temperature at the downstream end of mixing zone, T_d; the temperature rise from upstream to the downstream end of the mixing zone, ΔT; and the temperature rate-of-change at the downstream end of the mixing zone, TROC. The fundamental equations used to compute the compliance parameters are provided in APPENDIX B, based on the criteria specified in the NPDES permit. The temperature at the downstream end of the mixing zone was determined from the HOBO measurements by averaging the readings from the sensors at depths 3, 5, and 7 feet for all twelve HOBO stations. The temperature rise was computed as the difference between the measured temperature at the downstream end of the mixing zone and the upstream temperature measured at Watts Bar Dam (i.e., Station 30). The temperature rate-of-change was determined by the change in the measured temperature at the downstream end of the mixing zone from one hour to the next. The data were averaged over a period of one hour using 15-minute readings, as specified in the NPDES permit, and compared with the WBN thermal plume model. The measurements are presented in Figure 8, along with the results obtained by the thermal plume model. The following behaviors are emphasized:

- <u>Temperature at the downstream end of the passive mixing zone, T_d</u>: The maximum 1-hour average T_d estimated by the thermal plume model was 51.5°F, whereas the maximum measured value was about 49.9°F. Thus, the model overpredicted the maximum measured T_d by 0.6°F. Compared to the measurements, the increase in river temperature due to the no flow event was predicted to occur much more rapidly by the model. This is because the model assumes impacts due to changes in the river and/or Outfall 113 conditions are fully realized as a steady-state episode within one hour (i.e., the model time-step); whereas in reality, the actual time for the thermal plume to evolve is much longer. Both the predictions from the model and measurements from the survey were well below the NPDES limit of 86.9°F.

- Temperature rise, ΔT: The maximum 1-hour average ΔT predicted by the plume model was 4.4 F°, whereas the maximum measured value was about 3.2 F°. Thus, the model overpredicted the maximum measured temperature rise by 1.2 F°. For the reason cited above (i.e., computational time-step of one hour), the model predicted the maximum temperature rise to occur one hour into the no flow event. Both the predictions from the model and measurements from the survey were well below the NPDES limit of 5.4 F°.

- Temperature rate-of-change, TROC: The maximum 1-hour average TROC predicted by the plume model was 1.2 F°/hour, whereas the maximum measured value was about 0.8 F°/hour (absolute values). Thus, the model overpredicted the temperature rate-of-change by 0.4 F°/hour. Both the predictions from the model and measurements from the survey were well below the NPDES limit of ±3.6 F°/hour.

CONCLUSIONS

The compliance survey for 2012 winter conditions was successful in measuring the NPDES instream water temperature parameters for the Outfall 113. These included the temperature, T_d, temperature rise, ΔT, and temperature rate-of-change, TROC, all at the downstream end of the passive mixing zone. The measurements were compared with values predicted by the thermal plume model that TVA currently uses to determine the safe operation of the SCCW system. For the results summarized herein, the measured values for each of these parameters were bounded by the model values. That is, the model values were greater than or equal to the actual measured values, assuring compliance with the instream standards for water temperature. Since 2005, when the first compliance survey was performed for the Outfall 113 passive mixing zone, the model value for the maximum downstream temperature T_d has always bounded the measured value for the maximum T_d. The same is not true, however, for the maximum temperature rise ΔT and the maximum temperature rate-of-change TROC. In the summer survey for 2011, the model value for the maximum ΔT underpredicted the measured value for the maximum ΔT by 0.1 F° (Saint and Hopping, 2011), and in the summer survey for 2005, the model value for the maximum TROC underpredicted the measured value for the maximum TROC by 0.3 F°/hour (McCall and Hopping, 2006). These differences are not surprising in light of the fact that the model, like any mathematical representation of an actual complex physical process, contains inherent accuracy limitations.

The TVA model for predicting the Outfall 113 thermal plume uses CORMIX, which has a stated accuracy of about 50% of the standard deviation of field measurements (Jirka, et al., 1996). Based on this, as well as the fact that differences as small as 0.1 F° for ΔT and 0.3 F°/hour for TROC fall within the factor of safety currently used in performing hydrothermal forecasts, the thermal plume model is still considered adequate for determining the safe operation of the SCCW system. That is, in combination with TVA procedures for predicting the impact of the Outfall 113 effluent, the model continues to provide a high level of confidence that the SCCW system is being operated in a manner that does not exceed the instream limits for T_d, ΔT, and TROC as specified in the WBN NPDES permit for the passive mixing zone.

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McCall, Michael J., and P.N. Hopping, "Summer 2005 Compliance Survey for Watts Bar Nuclear Plant Outfall 113 Passive Mixing Zone," TVA River Operations, Report No. WR2006-2-85-152, February 2006.

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TDEC, *State of Tennessee NPDES Permit No. TN0020168*, Tennessee Department of Environment and Conservation, Issued June 2010.

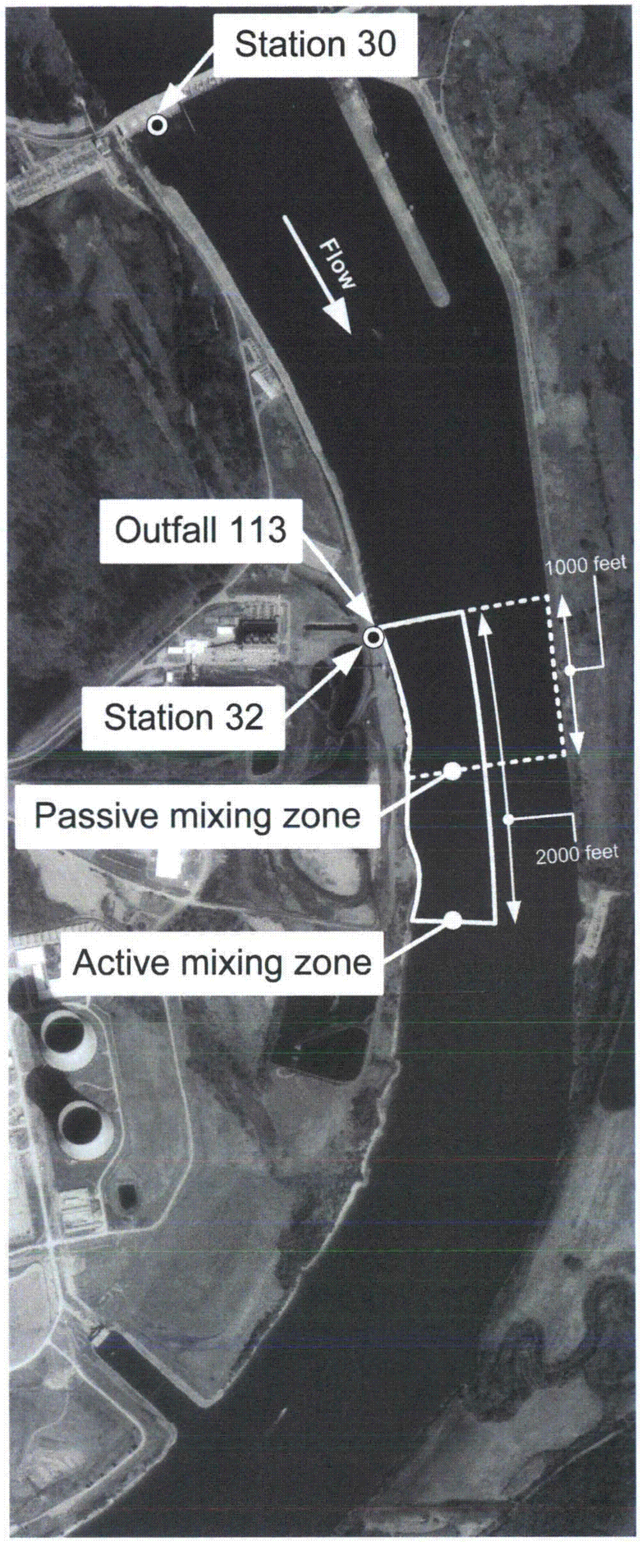

Figure 1. Watts Bar Nuclear Plant Outfall 113 (SCCW) Mixing Zones

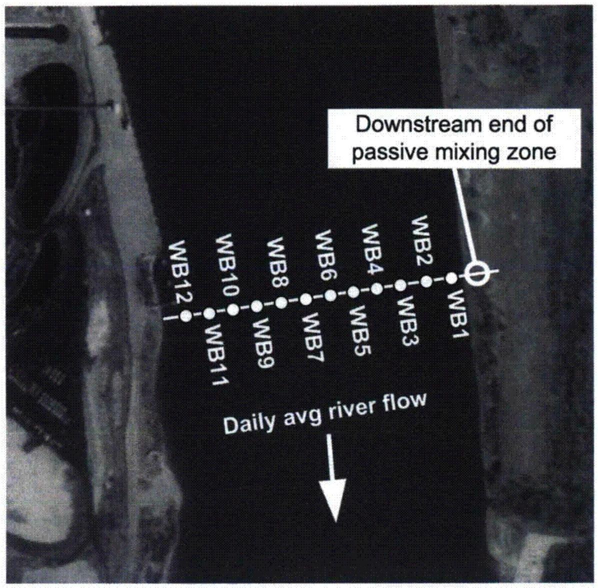

Figure 2. Location of HOBO Monitoring Stations

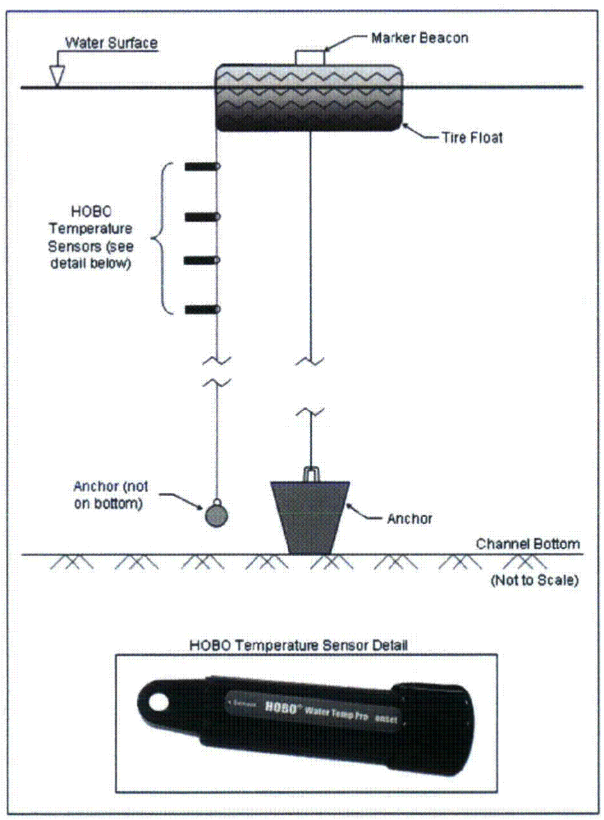

Figure 3. Schematic of HOBO Water Temperature Monitoring Stations

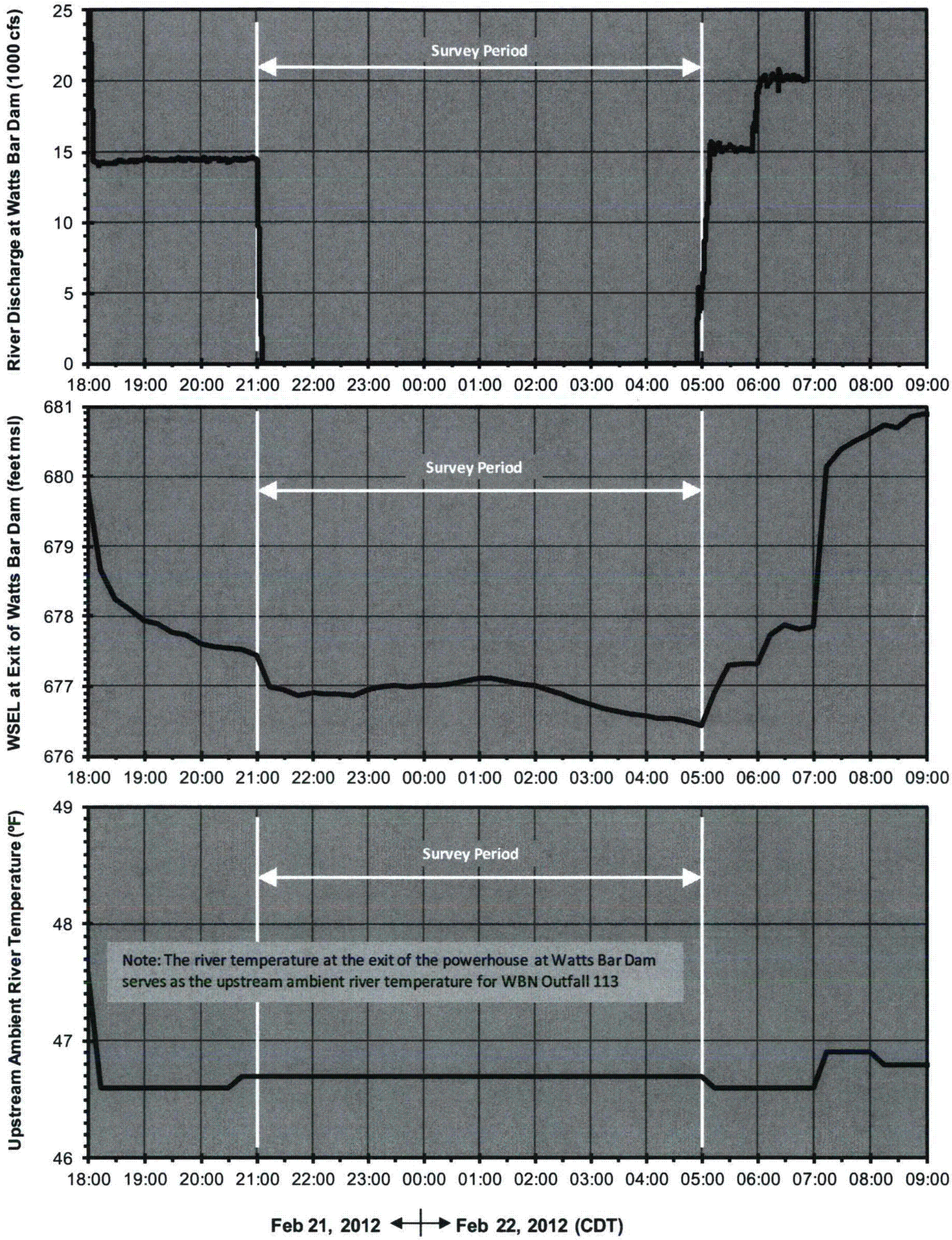

Figure 4. River Conditions

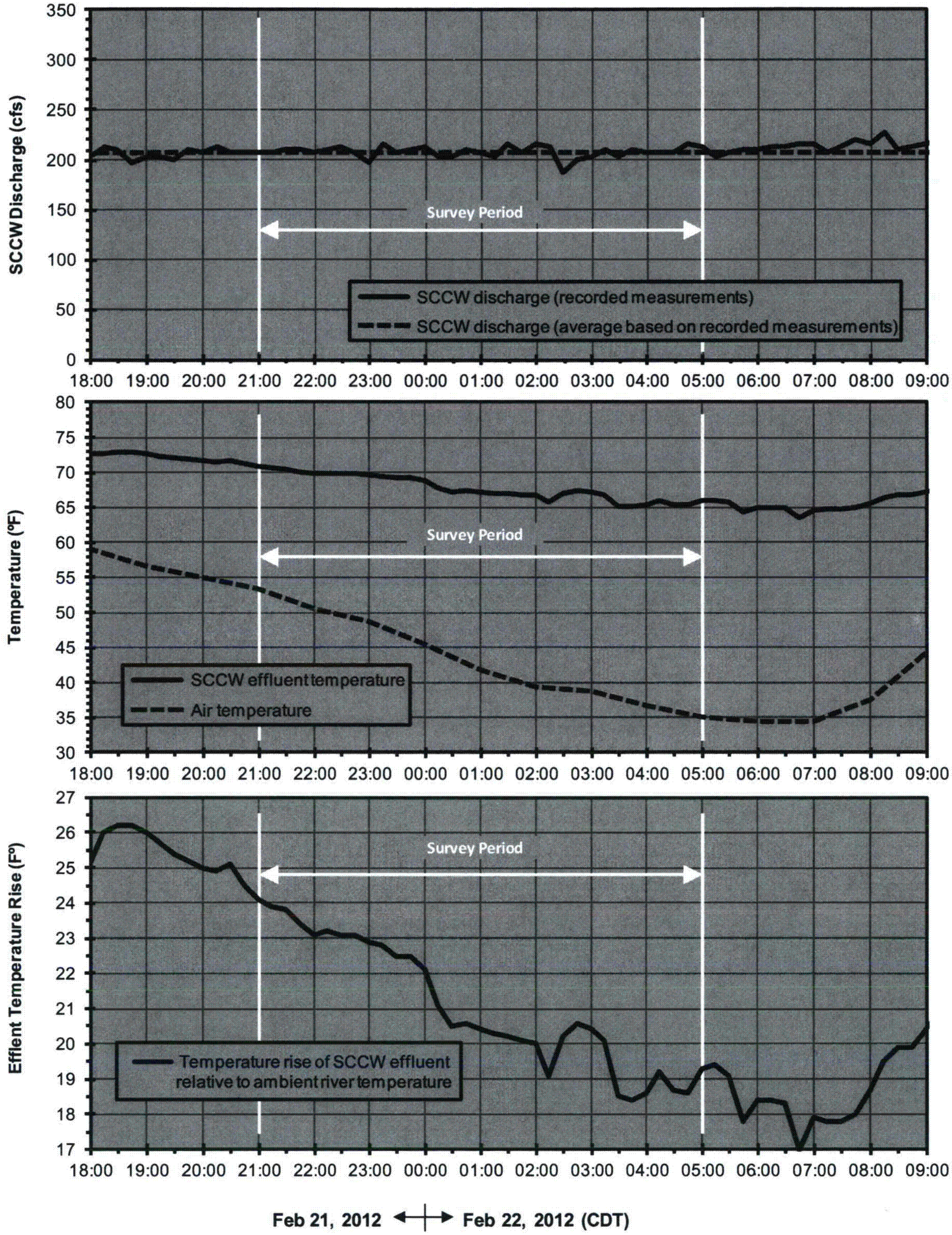

Figure 5. SCCW Conditions

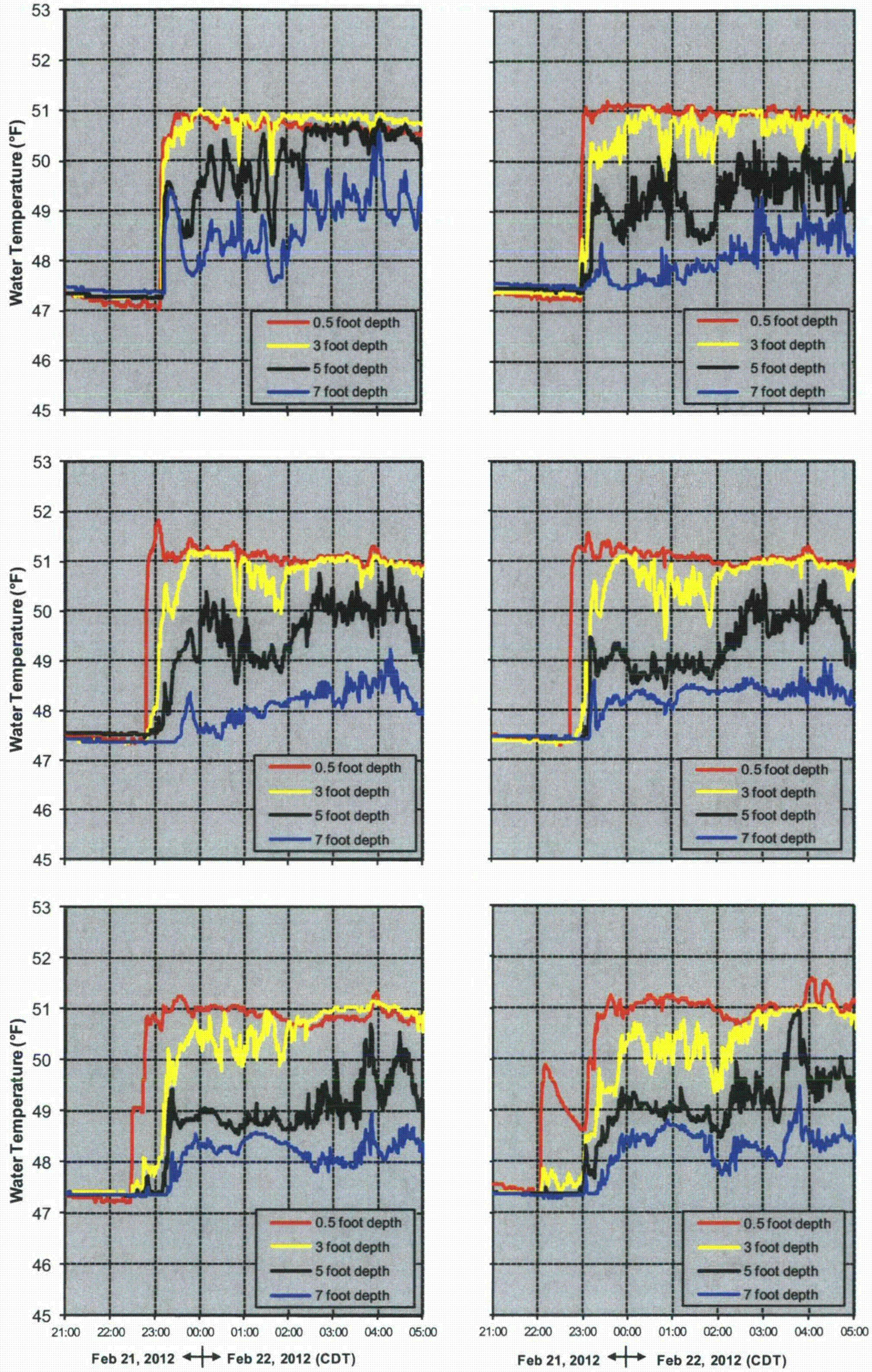

Figure 6. HOBO Water Temperature Measurements

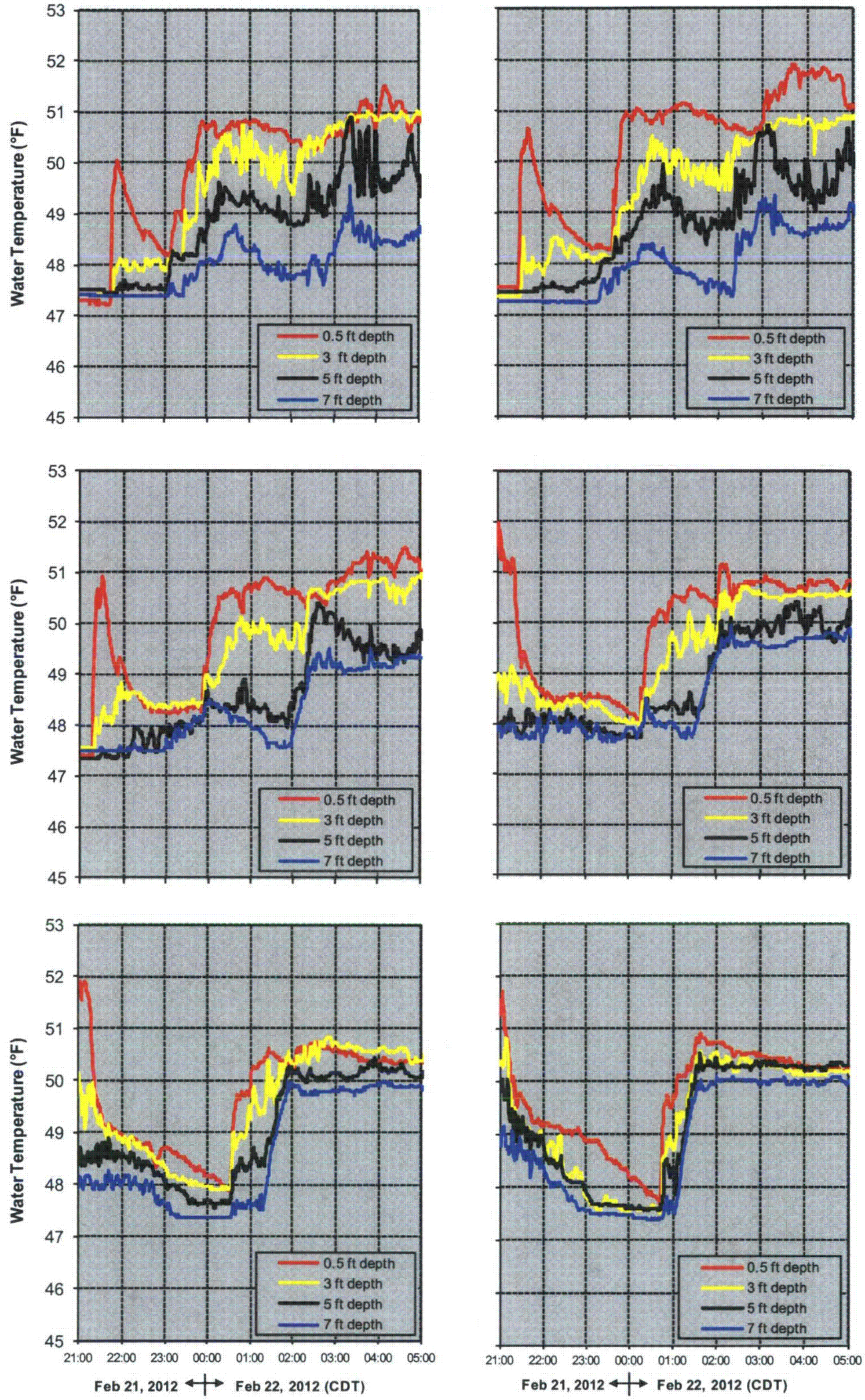

Figure 6 (Continued). HOBO Water Temperature Measurements

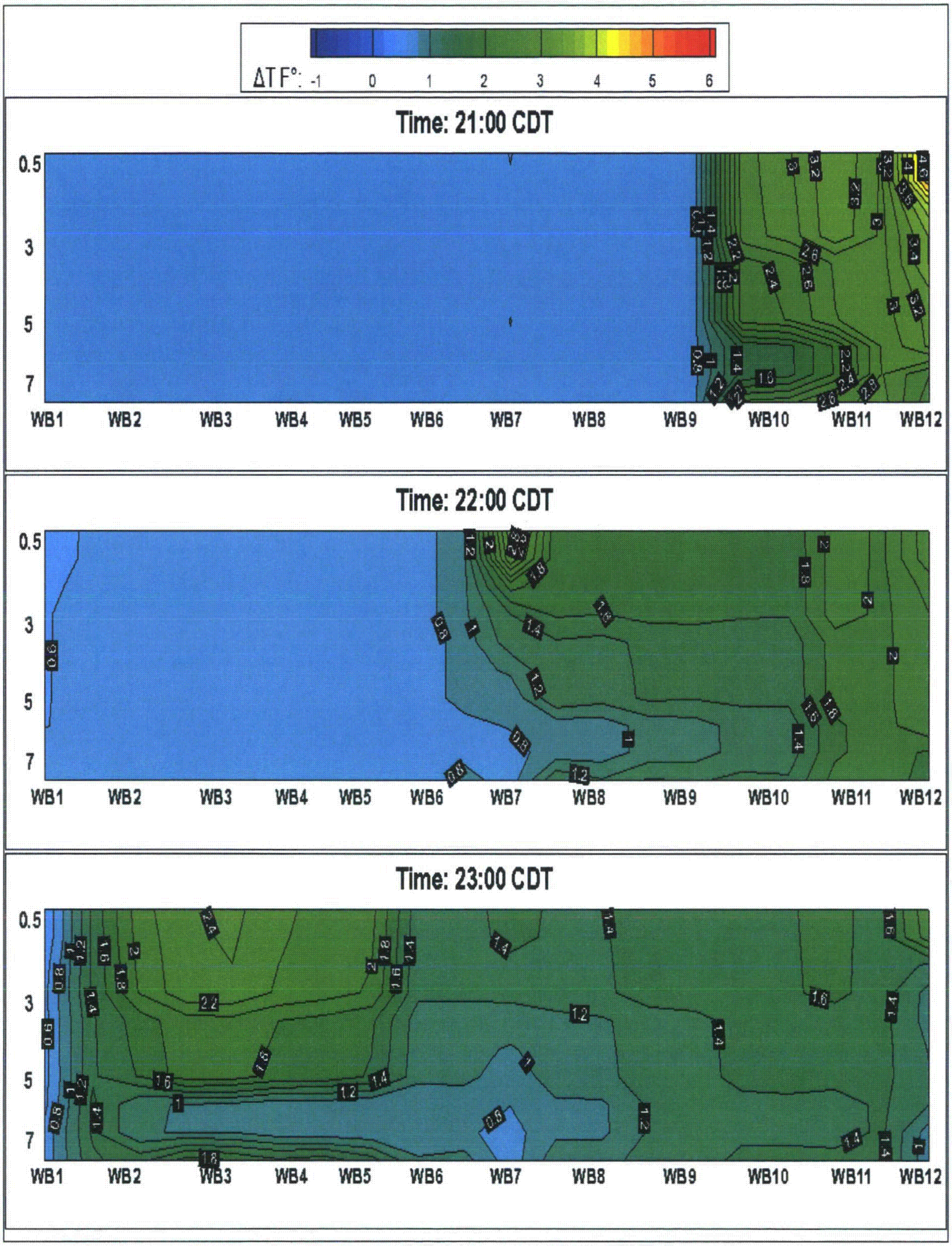

Figure 7. Local Instantaneous Temperature Rise for HOBO Measurements

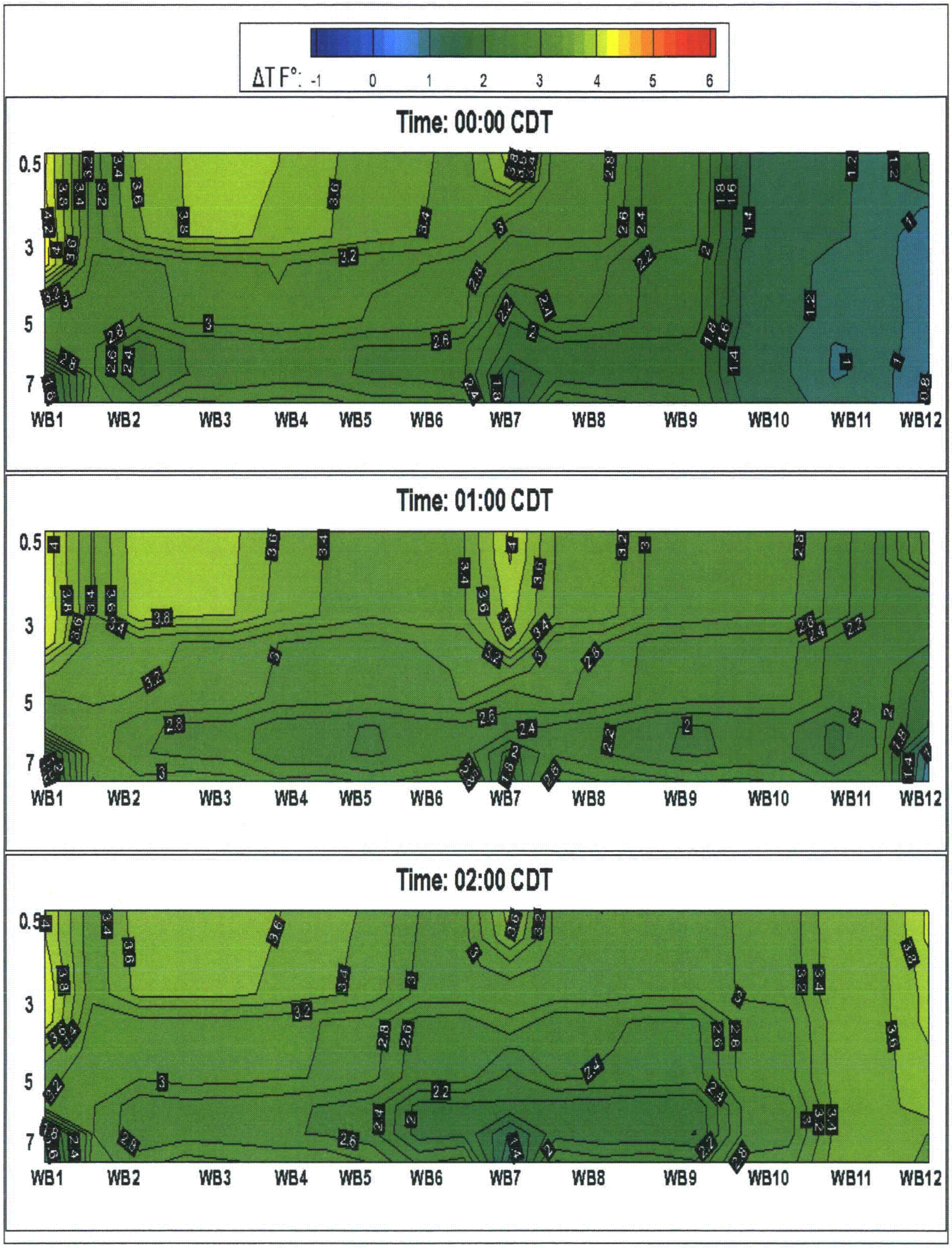

Figure 7 (Continued). Local Instantaneous Temperature Rise for HOBO Measurements

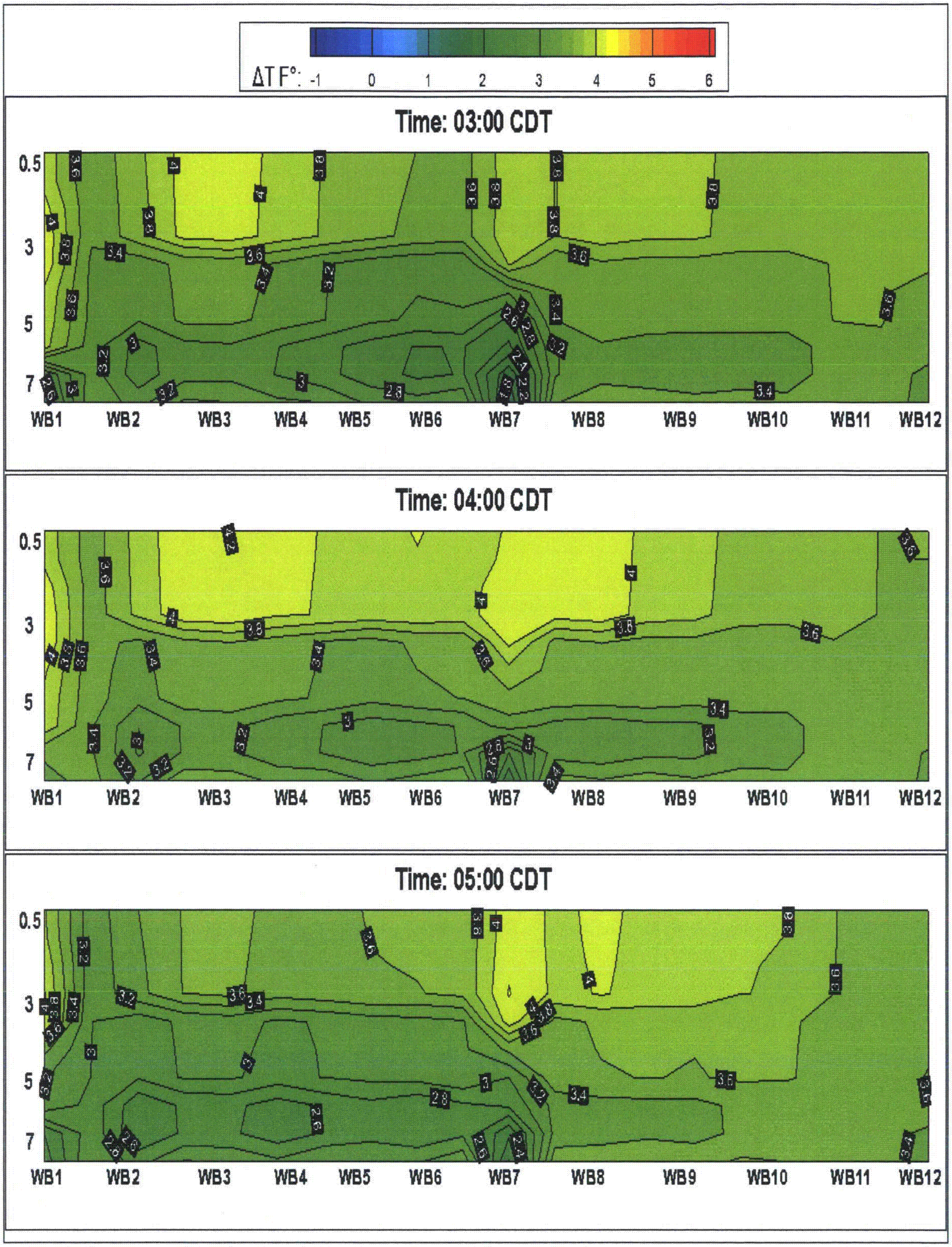

Figure 7 (Continued). Local Instantaneous Temperature Rise for HOBO Measurements

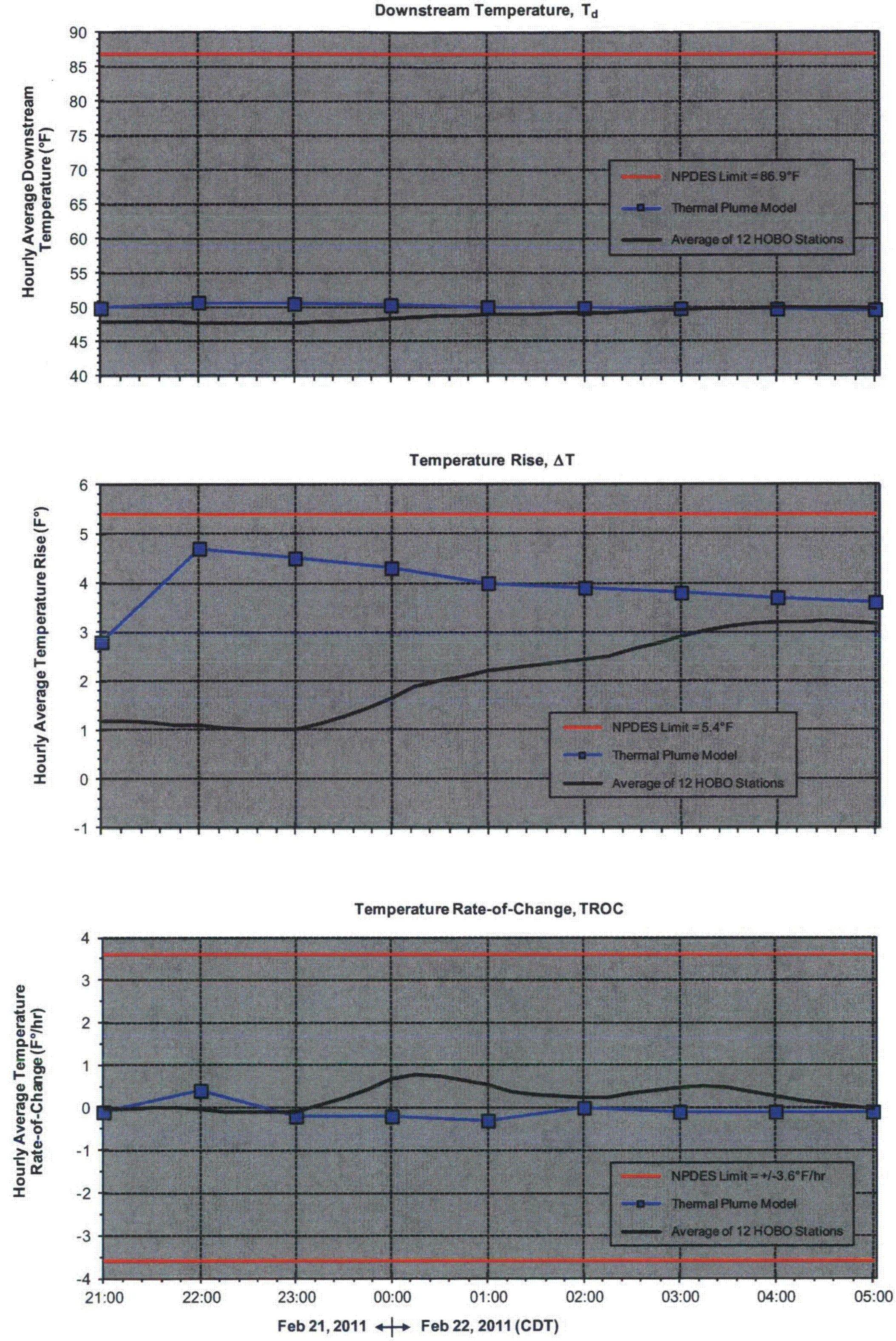

Figure 8. Measured and Computed Compliance Parameters for Passive Mixing Zone

APPENDIX A
Calibration of NPDES Water Temperature Sensors

All sensors used by TVA for monitoring compliance of NPDES water temperature requirements are certified and maintained to meet the following industry and regulatory standards:

- ISO/IEC 17025—Quality assurance requirements for the competence to carry out sampling, testing, and calibrations using standard, non-standard, and laboratory-developed methods (ISO=International Organization for Standardization, IEC=International Electrotechnical Commission).

- 10CFR50 Appendix B—Quality assurance criteria for design, fabrication, construction, and testing of the structures, systems, and components of nuclear power plants (CFR=Code of Federal Regulations).

- 40CFR136—Guidelines establishing test procedures for the analysis of pollutants under the Clean Water Act.

- ANSI N45.2. 1971—Quality assurance requirements for Nuclear Power Plants (ANSI= American National Standards Institute).

- ANSI/NCSL Z540-1-1994—General requirements for calibration laboratories and equipment used for measurements and testing (NCSL=National Conference of Standards Laboratories).

The standard used to certify the thermistors for the permanent EDS stations and the temporary HOBO stations is traceable to the National Institute of Standards and Technology (NIST). The standard includes two pieces of equipment—a platinum resistance temperature detector (RTD) manufactured by Burns Engineering, Inc. and an ohmmeter manufactured by Azonix Inc. The latter is used to measure the resistance of the RTD (i.e., the resistance of platinum varies with temperature). The NTIS traceable calibration certificates for the Burns RTD and the Azonix ohmmeter used to calibrate the HOBO monitors in the field survey summarized herein are available upon request. The overall accuracy of the system for the temperature standard is about ±0.05°F. The tolerance of the thermistors used for the WBN field survey is about ±0.4°F, thus providing a calibration test accuracy ratio (TAR) of about 1:8. That is, the accuracy of temperature standard used for the sensor calibrations is about 8 times greater than the minimum acceptable field accuracy of temperature sensors. This is twice the recommended maximum TAR of 1:4 for sensor calibrations.

The TVA procedure to calibrate the HOBO water temperature monitors, Instruction No. 450.01-020, is provided below. Briefly, the HOBO monitors are immersed in a stirred temperature-

controlled water bath along with the standard (i.e., along with the Burns RTD probe). After the bath stabilizes, temperature readings from the HOBO monitors are compared to the temperature readings from the standard. Experience has shown that in nearly all cases, the readings from both the HOBO monitors and the standard and are essentially constant, so that the 95 percent confidence interval of the readings is diminutive. Under these conditions, the accuracy of each HOBO monitor is recorded simply as the difference between the HOBO reading and that of the standard (negative difference = HOBO reading low/below standard, positive difference = HOBO reading high/above standard). The HOBO monitors are tested at three temperatures between 30°F and 100°F, covering the range of expected water temperature for natural river conditions. The three temperatures are at about the 10 percent, 50 percent, and 90 percent intervals, or 37°F, 65°F and 93°F, respectively. Any HOBO monitor with measured accuracy in excess of the maximum allowable tolerance of ±0.4°F for any one of the three temperatures fails the calibration test and is removed from the field survey inventory. The calibration certificates for HOBO monitors used in this field survey summarized herein are available upon request. All the HOBO monitors passed both the pre-survey and post-survey calibration tests. The mean square error of the HOBO monitors was 0.14 F° for the pre-survey calibrations and 0.13 F° for the post-survey calibrations.

TVA CENTRAL LABORATORIES SERVICES QUALITY PROGRAM INSTRUCTION	TITLE Certification of HOBO Water Temp Pro Data Acquisition SystemsH_20-001	Instruction No. 450.01-020 Rev. No. 0 Page No. 1 of 7 Effective Date 5/19/03

LEVEL OF USE ☐ Continuous ☒ Reference ☐ Information

QA RECORD

Dennis T. Darby Preparer	5/19/03 Date
Paul B. Loiseau, Jr. Technical Reviewer	5/19/03 Date
[signature] Administrative Review	6/5/03 Date

APPROVAL

Jerry D. Hubble Department Manager	5/19/03 Date

REVISION LOG

Revision Number	Effective Date	Pages Affected	Description of Revision
0	5/19/03	All	Initial Issue.

1.0 PURPOSE

To provide uniform and effective certifications of Hobo Water Temp Pro data acquisition systems meeting the accuracy and performance requirements of TVA's water temperature-monitoring programs. This technical instruction uses the method of comparison with a laboratory standard thermometer.

2.0 SCOPE

This instruction applies to the certification of Hobo Water Temp Pro data loggers manufactured by Onset Computer Corporation of Bourne, Massachusetts. The Hobo Water Temp Pro is a data acquisition system containing a temperature sensor, data logger and battery sealed in a single submersible case. The Hobo Water Temp Pro is programmed and data retrieved by use of an infrared interface located in one end of the case. Hobo Water Temp Pros are certified upon receipt from the manufacturer at no greater than 12 month intervals during use or when requested.

3.0 SUMMARY

In this three-point certification systems are tested as actually used over the historical water temperature range of 30° to 100°F and submerged in water. The three test points are 37°, 65° and 93°F. The systems are required to perform within Onset Computer Corporation tolerances. System conformity at each temperature point is determined by comparing system temperature, logged by the Hobo Water Temp Pro and a laboratory standard thermometer.

Systems are programmed and submerged with a standard thermometer in a stirred, temperature-controlled temperature bath. The systems are read after the test by an infrared interface adapter connected to a computer running Onset Computer Corporation's Boxcar Pro software. Traceability of the certification is through the thermometer.

"As-found" certifications are performed on new systems as an acceptance test and on sensors returned from field service. "As-left" certifications are performed before delivery for field service if more than 12 months has elapsed since the last certification. "As-found" and "as-left" certifications may be combined on the same record if there is clear indication which type each system is undergoing.

Multiple HOBOs may be certified at the same time in the temperature bath.

- Accuracy of ±0.2°C at 25°C (0.33°F at 70°F)
- Waterproof case, submersible to 100 feet
- Capacity to store up to 21,580 temperature measurements
- Selectable sampling interval from 1 second to 9 hours
- Programmable start time/date
- Two data recording modes: Stop when full or wrap around when full.
- Two data offload modes: Halt then offload or offload while logging.
- Nonvolatile EEPROM memory that retains data even if batteries fail
- Light-emitting diode (LED) operation, indicator, which can be disabled during logging by selecting "Stealth"1 mode
- High-speed IR communications for offloading data; can readout full logger in less than 30 seconds while logging continues
- Battery life of 6 years with typical usage

4.0 PRACTICES/EXCEPTIONS

N/A

5.0 SAFETY

5.1 Standard electrical equipment safety.

6.0 STANDARDS USED

6.1 Laboratory reference thermometer, range 30° to 100°F or greater, 0.01°F resolution, 0.1°F accuracy or better, with current calibration sticker.

7.0 EQUIPMENT/APPARATUS

7.1 Temperature bath, stirred, temperature-controlled.
7.2 Computer with Onset Boxcar Pro software installed (version 4.3 or later)
7.3 IR Base station, Onset Part # BST -IR

8.0 PREREQUISITE ACTIONS

8.1 Turn on temperature bath and set for 37°F.
8.2 Check the IR interface to verify that it is plugged into the correct serial port on the PC. Set the correct time on the PC.
8.3 Align the IR port on the Base station with the HOBO Water Temp Pro communications window. Place the logger no further than 4 to 5 inches away from the Base station (see Figure 2) and make sure the IR windows in both devices point at each other. There is a 30° acceptance angle for the IR beam, so some misalignment is acceptable.

8.4 Start the Onset Box Car Software and select **Logger** then **Hobo Water Temp Pro** and **Launch.**

8.5 The computer will respond with a list of loggers found. The serial number in this list should match the serial number printed on the side of the logger. If these numbers do not match, click the **Refresh** button. Record this serial number on the certification form. Either wait or click the **Stop Searching** button. Using the mouse select the logger and click the **Launch** button.

8.6 After a few seconds the screen will display the status of the HOBO Water Temp Pro. Record the battery percentage on the certification form.

8.7 Verify that the Hobo is set to Fahrenheit and program it to a recording interval of 0:1:0 for a reading once a minute. Verify that the start logging immediately box is checked and that the set data logger clock with host launch is also checked.

8.8 Using the mouse click the **Launch Immediately** button.

8.9 If last HOBO is programmed click the DONE button, else select the **Launch Another** and repeat steps 8.5 through 8.9.

9.0 TEST PROCEDURE/METHOD

9.1 On the certification form record the serial number of the laboratory reference thermometer.

9.2 Place the HOBO Water Temp Pro in the temperature bath, making sure the end opposite the IR windows is submerged, and allow the bath to stabilize at 37°F ±0.5°F on the thermometer. Adjust the bath set point if needed. After the bath reaches the desired temperature allow 20 minutes 'soak time' for the HOBO to reach its final temperature.

9.3 Record the thermometer reading on the certification form and the time. (The time will be needed to get the correct reading from the HOBO.)

9.4 Repeat steps 9.2 and 9.3 for bath settings of 65.0°F ± 0.5°F and 93°F ± 0.5°F.

9.5 Remove the HOBO from the temperature bath and align the IR port on the Base station with the HOBO Water Temp Pro communications window.

9.6 Restart Onset BoxCar Pro if it is not running and select **Logger** then **Hobo Water Temp Pro and Readout.**

9.7 The computer will respond with a list of loggers found. Using the mouse select the logger and click the **Readout** button. The computer will ask to download data and continue logging or the stop logging and offload data. Select the **Stop Logging and Offload data.** After a few seconds the computer will respond with a suggested file name. Select **Save** and allow the HOBO to transfer the data.

9.8 After a successful download click the **OK** button. The computer will then ask if the data should be displayed in Centigrade or Fahrenheit. Deselect °C and select °F and click **OK.** The computer should display a graph of the collected data. Click the view details button (this is the button just left of the question mark button.)

9.9 Scroll down the displayed list until the time recorded for the 37°F point is found. Record the corresponding temperature on the certification form. Repeat this step for 65° and 93°.

9.10 Close the view details windows and repeat steps 9.6 through 9.9 for additional HOBOs.

9.11 Fill out the rest of the certification form.

10.0 ACCEPTANCE CRITERIA

10.1 Based upon the manufacturer specifications the HOBO Water Temp Pro should be within ±0.4°F over the range of 32°F to 100°F. Any HOBO with an error of greater than ±0.5°F at any of the three measured points shall fail certification.

11.0 POST PROCEDURE ACTIVITY

11.1 Close the BoxCar Software.

12.0 RECORDS

12.1 Completed HOBO Water Temperature Pro Certification form and associated Report of Certification cover sheet is a QA record.

13.0 REFERENCE

13.1 HOBO Water Temp Pro User's Manual, version 1.0 or later

13.2 Onset BoxCar Pro4 Manual Version 1.0 or later

APPENDIX B
WBN Outfall 113 NPDES Compliance Parameters

- Current Instantaneous Upstream Temperature:

  Tu_i (measured at EDS Station 30 by the first sensor below a depth of 5 feet).

- Current 1-Hour Average Upstream Temperature:

  $$Tu1_i = \frac{Tu_i + Tu_{i-1} + Tu_{i-2} + Tu_{i-3} + Tu_{i-4}}{5},$$

  where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of Tu.

- Current Instantaneous Downstream Temperature:

  $$Td_i = \frac{Td3_i + Td5_i + Td7_i}{3},$$

  where $Td3_i$, $Td5_i$, and $Td7_i$ denote the current measurements of river temperature at the downstream end of the mixing zone at water depths 3 feet, 5 feet, and 7 feet, respectively.

- Current 1-Hour Average Downstream Temperature:

  $$Td1_i = \frac{Td_i + Td_{i-1} + Td_{i-2} + Td_{i-3} + Td_{i-4}}{5},$$

  where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of Td.

- Current Instantaneous Temperature Rise:

  $$\Delta T_i = Td_i - Tu_i.$$

- Current 1-Hour Average Temperature Rise:

  $$\Delta T1_i = \frac{\Delta T_i + \Delta T_{i-1} + \Delta T_{i-2} + \Delta T_{i-3} + \Delta T_{i-4}}{5},$$

where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of ΔT.

- Current Temperature Rate-of-Change:

$$TROC_i = \frac{Td_i - Td_{i-4}}{1\ \text{hour}}.$$

- Current 1-Hour Average Temperature Rate-of-Change:

$$TROC1_i = \frac{TROC_i + TROC_{i-1} + TROC_{i-2} + TROC_{i-3} + TROC_{i-4}}{5},$$

where the subscripts i, i-1, i-2, i-3, and i-4 denote the current and previous four 15-minute (0.25 hour) values of TROC.