Tennessee Valley Authority
Office of Natural Resources and Economic Development
Division of Air and Water Resources
Engineering Laboratory

QUALITY PROGRAM FOR VERIFICATION OF SEQUOYAH NUCLEAR PLANT THERMAL COMPUTED COMPLIANCE SYSTEM

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EXECUTIVE SUMMARY

A system of real-time measurements and computer models is used at Sequoyah Nuclear Plant to verify compliance with the instream thermal limits contained in the National Pollutant Discharge Elimination System permit. Seven field studies were used to validate the diffuser mixing model used in the computed compliance system. The field surveys covered a range of ambient conditions (reservoir flowrate and thermal stratification), seasons, and plant operation. These studies showed that the system adequately reproduces laterally-averaged temperatures in the cross section at the downstream edge of the mixing zone.

The State of Tennessee has requested a quality assurance program to include further field verification tests to add confidence to the computed compliance system. Quarterly field surveys are required during the first year after startup and annually thereafter.

A quality program has been developed to meet the State's request. The program identifies a variety of possible combinations of ambient reservoir flowrate and seasonal conditions that can exist and sets priorities for future studies. Additional field surveys are planned that add to the data already taken. The status of Sequoyah Nuclear Plant startup remains uncertain. Therefore, the field verifications cannot be scheduled at this time. Only one unit may operate for the first year. Because the most significant effects of plant operation occur at full two-unit loads, only one survey is suggested during initial one-unit operation. Quarterly studies for a year will be planned after two units are on line. Additional annual field testing will be determined by field and plant conditions and the established priorities. All field measurement equipment will be calibrated using standard procedures.

1.0 INTRODUCTION

The thermal discharge from Sequoyah Nuclear Plant (SQN) is regulated by the water quality standards of the State of Tennessee as implemented in the National Pollutant Discharge Elimination System (NPDES) Permit No. TN0026450. The specific instream permit limitations on the thermal discharge require that: the plant-induced temperature rise should not exceed 5.4°F (3.0°C), the maximum downstream plant-induced water temperature should not exceed 86.9°F (30.5°C), and the maximum rate of water temperature change should not exceed 3.6°F (2.0°C) per hour. These limits are applied at the 5-foot depth outside a mixing zone which is large enough to essentially complete the diffuser-induced mixing.

There are several methods that could be used to verify compliance with the NPDES limits. The effects of power plant thermal discharges can best be studied using a combination of modeling, monitoring and field study techniques. The studies usually concentrate on past operating data (if available) or evaluations of worst-case conditions. Worst-case modeling studies are later validated using field studies. The instream temperature limits are converted to a discharge limit that always keeps the plant below the worst-case instream condition ever studied. Some power utilities continue to conduct periodic field studies to check thermal and biological effects in lieu of real-time monitoring.

Real-time instream monitoring or computed modeling methods for verifying compliance provide flexibility to operate a power plant more in line with the natural ability of a water body to dissipate heat. A discharge limit that is determined by the worst-case conditions ever seen will significantly affect plant operation during periods when the water body can accept more heat without detrimental effects. The ability to change cooling systems (use of cooling towers) provides added plant efficiency by using supplemental cooling only when it is needed.

Instream temperature monitoring has often been used to determine thermal compliance on a real-time basis. There are however several problems with this method. Locating monitors in representative locations is often difficult due to navigation and recreation constraints. For example, no monitors can be located in the navigation channel on the Tennessee River. This can significantly hamper measurements that are needed in the center of a channel, where most of the thermal effluent plume normally goes. The instream monitors can also be significantly affected by natural heating or cooling processes in the water body that produce hotter or cooler temperatures than are actually attributable to the power plant thermal discharge. Natural statistical temperature variations in time and space also require numerous averaging techniques to make sure the measured data is not catching spurious peaks that are not indicative of actual conditions.

In an effort to provide better real-time assessment of the effects of a thermal discharge, a computed compliance method was proposed for SQN. The computed compliance method was seen as providing a more realistic evaluation of the impact of the thermal discharge on downstream temperatures (cross-sectional averages) than a series of instream monitors. The computed compliance method can also be integrated with scheduling needs. The same model can be used to schedule plant cooling tower operation and upstream and downstream dam releases as used to verify compliance. This improves the comparison between scheduling and actual operation, and minimizes the number and duration of thermal noncompliances.

The remaining sections briefly describe the present thermal compliance system, the previous field verification of the system, and the quality program requested by the State of Tennessee. In the State of Tennessee letter (Stewart, 1987), a "quality assurance" program was required. It was decided not to title this document as "quality assurance" since this connotation implies a program with specific strict requirements that are aimed at nuclear safety applications. This document spells out the steps that will be taken to assure a quality thermal compliance system without the level of detail that a nuclear safety "quality assurance" program entails.

2.0 THERMAL COMPLIANCE SYSTEM DESCRIPTION

The computed compliance method is the primary system at SQN for verifying compliance with instream limits on the thermal discharge. The system uses a series of measurements as input to reservoir routing and diffuser mixing computer models that calculate the river flow past SQN and the downstream mixed river temperature. Measurements used as input include: releases from the upstream and downstream dams, the amount of heat being discharged (discharge temperature and flowrate), and the ambient temperature as a function of depth. The calculated downstream mixed river temperature is used to determine compliance with the maximum temperature limit and rate of temperature change limit. The calculated mixed river temperature is also used with the measured ambient temperature at the 5-foot depth to determine compliance with the temperature rise limit. The measurement and calculation process is repeated every 15 minutes for a quasi-continuous real-time demonstration of thermal compliance. A flowchart detailing the thermal compliance system is shown in Figure 1.

In the event the primary computed compliance system is not working, SQN utilizes measured temperature data taken 1,500 feet downstream on the left river bank for the downstream mixed river temperature. This data is also measured ever 15 minutes. If both primary and secondary systems fail, field personnel manually collect upstream and/or downstream reservoir temperatures to demonstrate thermal compliance on a once per day basis. Figure 2 shows the layout of monitoring at SQN.

3.0 PREVIOUS VERIFICATIONS

A number of field studies were done to validate the computed thermal compliance system. The first field verification of one-unit operation occurred during July 1981 (McIntosh, et al., 1982). The study was done at full unit load during a reservoir flowrate of about 27,000 cubic feet per second (cfs). The reservoir was thermally stratified

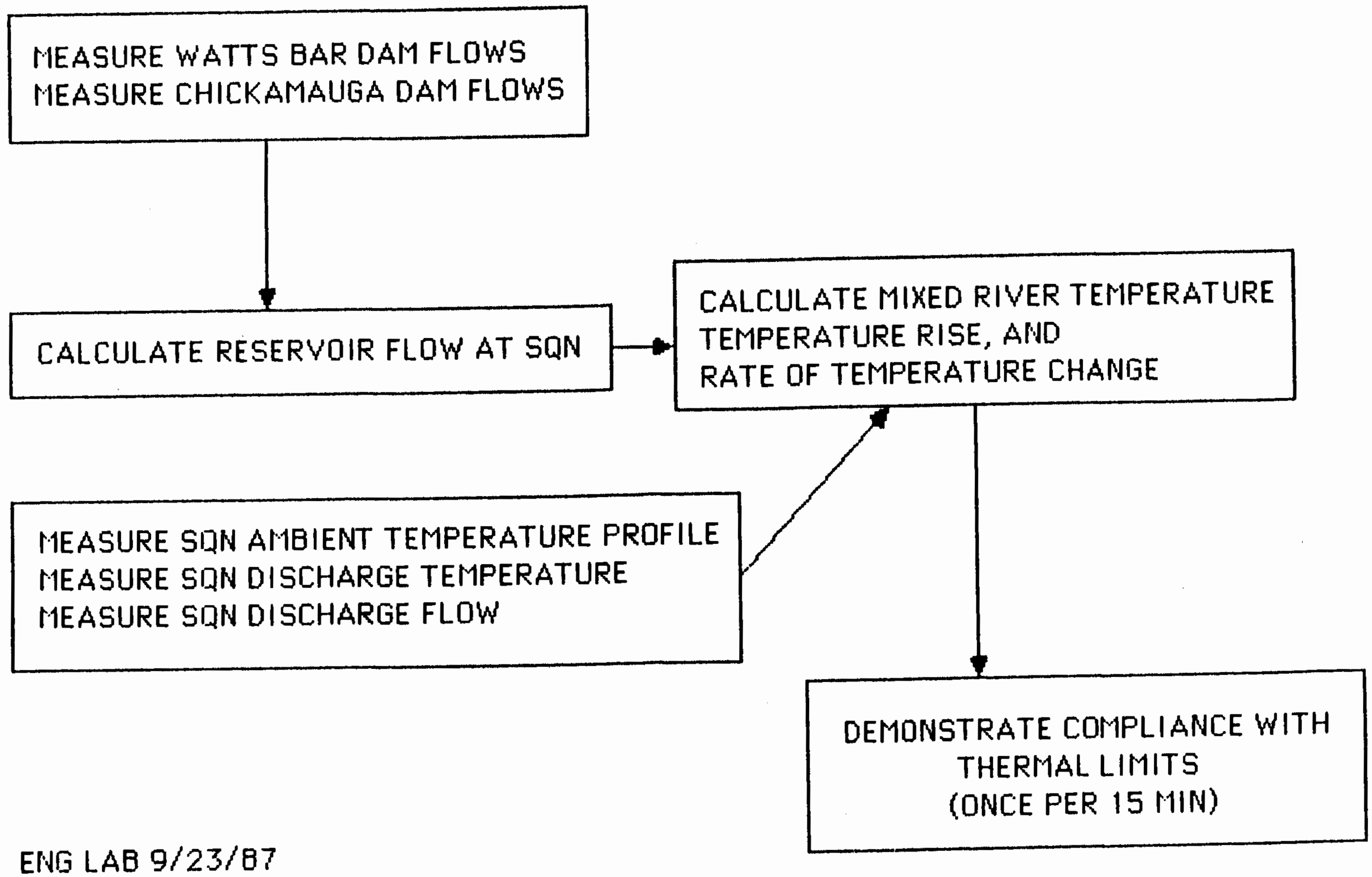

Figure 1. Sequoyah Nuclear Plant Thermal Compliance System.

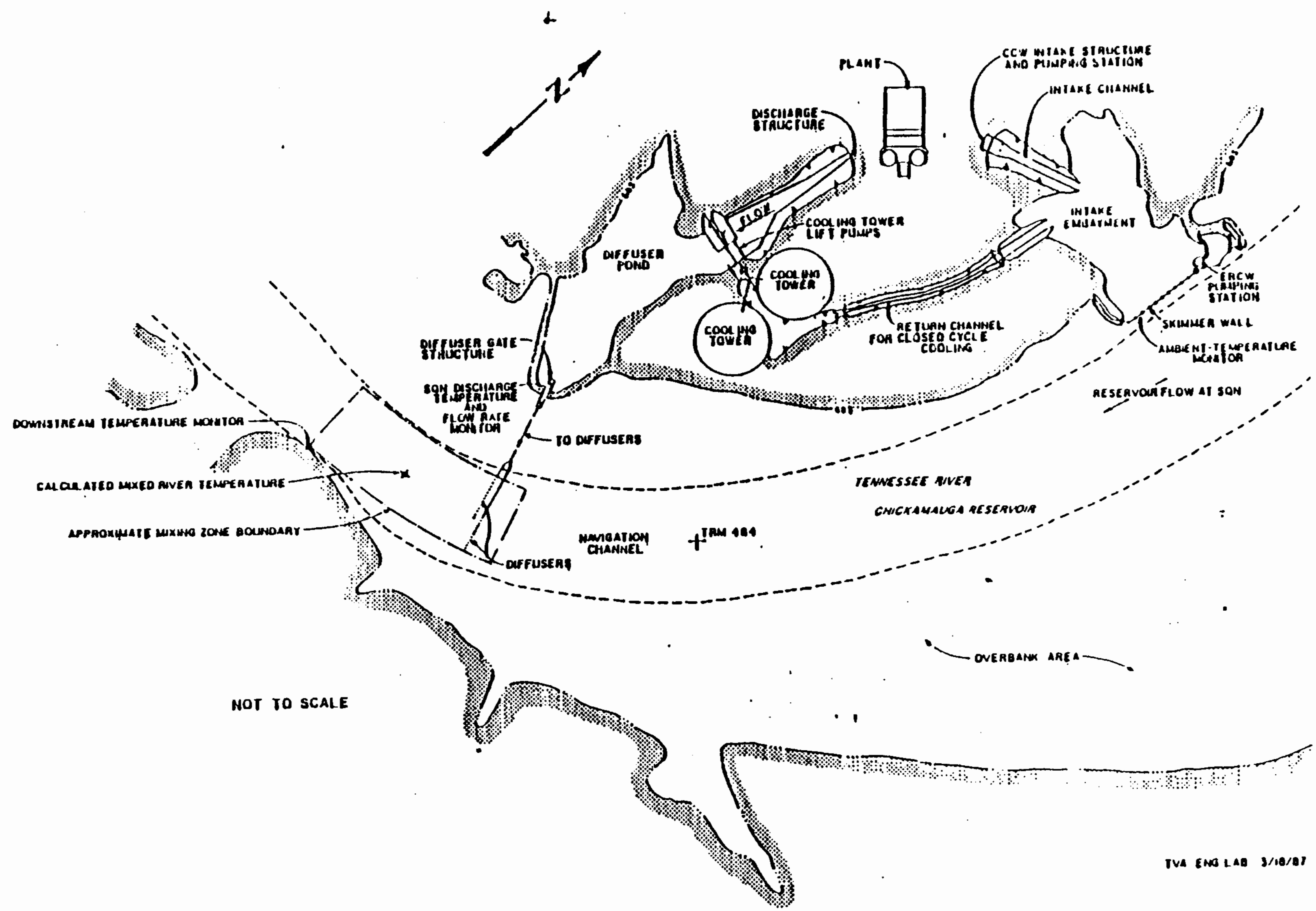

Figure 2. Sequoyah Nuclear Plant - Thermal Compliance System.

during the field survey. The results showed reasonable agreement between the diffuser model and the field data. Any differences were conservative, that is predicted dilutions were less than what was seen in the river.

Further field studies were done in 1982 and 1983 to characterize two-unit operation (McIntosh, et al., 1983). The studies covered a number of seasons and flow conditions as shown in Table 1.

The further surveys indicated that under the conditions studied the instream monitoring or the computed compliance method was adequate for obtaining a representative temperature at the edge of the mixing zone. However, the computed compliance method more favorably compared with laterally-averaged temperatures measured in the reservoir. The added advantages of using the computed compliance method made it the system of choice.

Additional data comparing the instream monitoring with the computed compliance method is available for the period after installation of the computer system until the plant went offline in 1985. This data has been evaluated and a report is in preparation (Ostrowski and Carpenter, in preparation). Comparisons between computed and measured data show good agreement over a wide range of environmental and plant operating conditions. Differences that occur are believed to be primarily due to natural heating and cooling that influences the measured data. The report will also evaluate the years when SQN was not operating (1986 and 1987) to look at differences between upstream and downstream temperature measurements without plant effects.

After a series of meetings with the State of Tennessee, it was agreed that further field studies be done to provide additional confidence in the computed compliance system. As part of the NPDES permit renewal application, the State of Tennessee requested that a "quality assurance" program be submitted which included quarterly field verification during the first year after start-up and annually thereafter (Stewart, 1987).

TABLE 1

Summary of Previous Field Studies of Thermal Compliance at Sequoyah Nuclear Plant

	Date	Units in Operation	Reservoir Flowrate (cfs)	Thermal Stratification
1.	7/24/81	1	27,000	Yes
2.	4/4/82	2	20,000	Yes
3.	5/14/82	2	8,000	Yes
4.	9/2/82	2	37,000	No
5.	11/10/82	1	35,000	No
6.	3/31/83	2	9,000	Yes
7.	5/11/83	2	25,000	Yes

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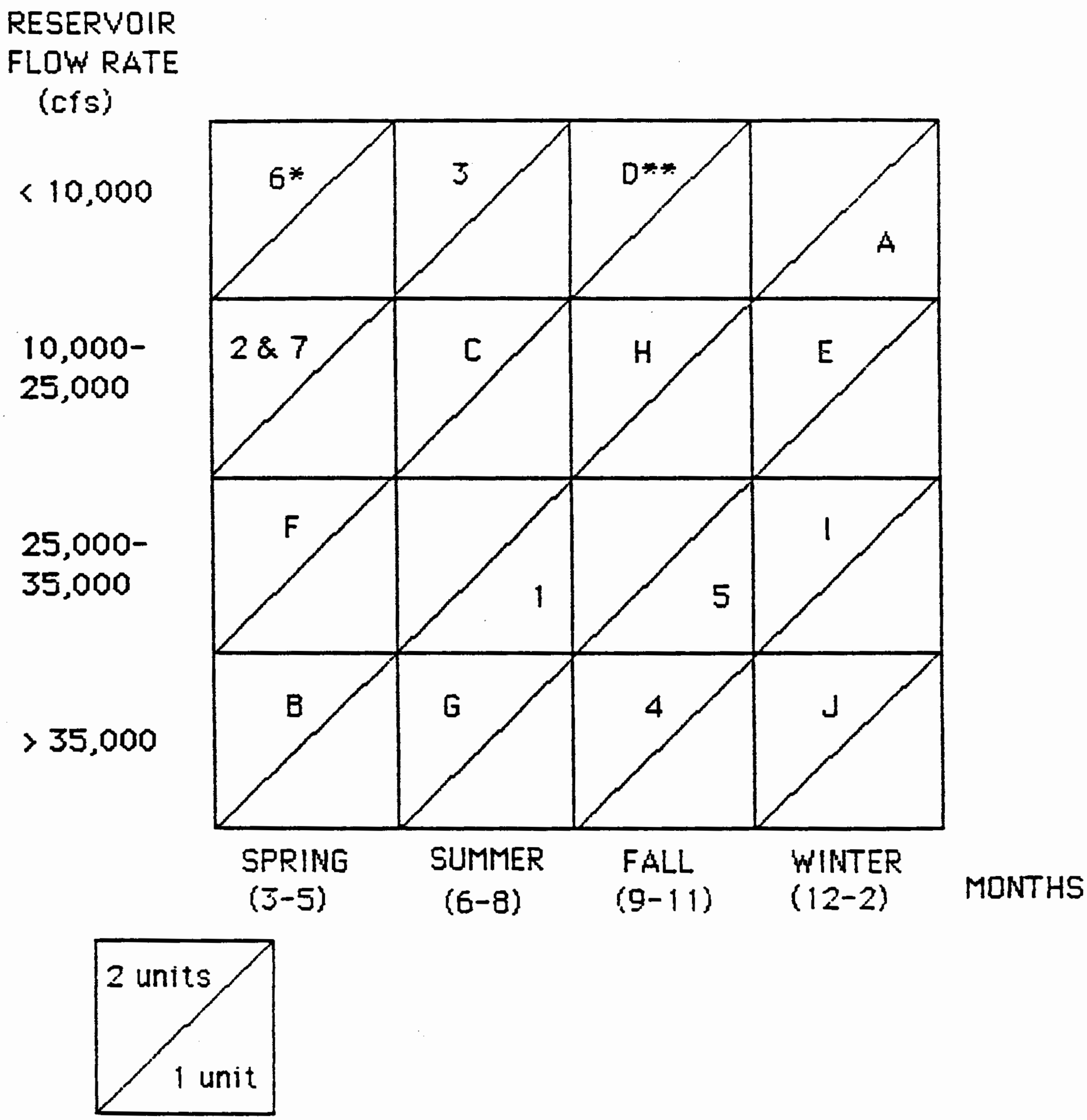
4.0 ADDITIONAL VERIFICATIONS

As described in Section 3.0, seven field surveys were performed during the period from July 1981 to May 1983. These field verifications were done under different ambient conditions, at different times of the year, and with either one or both units in operation. Figure 3 summarizes the background characteristics associated with each field study. The conditions corresponding to each of the previous seven field studies are marked as numbers in the figure. Field studies under this quality program will be arranged in such a way so that each will have different characteristics from those of the previous field studies. The selection of a field study is based on ambient conditions (reservoir stratification and flow) as well as operational constraints of the hydropower system and unit availability of the plant. Figure 3 makes the selection of a field study easier by assuring that the previous field tests are not duplicated. Priorities for future field studies are listed as letters in Figure 3, with "A" as the highest priority. Because two-unit operation is more significant than one-unit operation, several one-unit tests are not deemed necessary where two-unit data exists. Conditions which are not planned appear as blanks in the figure.

The status of SQN startup remains uncertain. Therefore, the field verifications cannot be scheduled at this time. Only one unit may operate for the first year. Because the most significant effects of plant operation occur at full two-unit loads, it is suggested that only one field survey be done during initial one-unit operation. Quarterly studies for a year would be planned after two units are on line. Additional annual field testing would be determined by field and plant conditions and the established priorities. The field studies will be selected with the aim of filling the remaining spots in Figure 3. An end to the field testing will be proposed when adequate data has been gathered.

Figure 3. Summary of Priorities for Field Verification of the Computed Compliance System at Sequoyah Nuclear Plant.

Chickamauga Dam Annual Average Flow Rate (1975-1985) : 33,800 cfs



Note : * Numbers identify a previous field survey as used in Table 1.
** Letters list priority for further field studies.

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4.1 Description of Field Testing

In the previous field studies (McIntosh, et al., 1983), longitudinal water temperature profiles of the mixing zone were measured at depths of 0.5, 3.0, 4.75, and 6.25 feet (0.15, 1.0, 1.5, and 2 meters) below the water surface. The NPDES permit for SQN defines the mixing zone as follows:

> "(1) a maximum length of 1500 feet downstream of the diffusers; (2) a maximum width of 750 feet; and (3) a maximum length of 275 feet upstream of the diffusers. The depth of the mixing zone measured from the surface varies linearly from the surface 275 feet upstream of the diffusers to the top of the diffuser pipes and extends to the bottom downstream of the diffusers. The thermal mixing zone also includes the entire Intake Basin (during closed mode) and Diffuser Pond."

Future field testings will be similar to those of the previous field studies. The longitudinal temperature distribution (mid-channel) will be measured from the upstream edge of the mixing zone (275 feet upstream of the diffusers) to about 1,500 feet downstream of the diffusers at depths of 0.5, 3.0, 4.75, and 6.25 feet (0.15, 1.0, 1.5, and 2 meters) below the water surface. The results of previous field studies indicated that the thermal plume reached the surface very close to the diffusers. Depending on reservoir conditions, this distance varied between about 50 to 500 feet. A vertical string of thermistors is mounted on a rigid frame and towed by a survey boat for these measurements.

In addition to the longitudinal temperature distribution, lateral temperature distributions within the mixing zone will also be measured during the field studies. Cross-sectional (lateral) measurements of temperature distributions will be made at five longitudinal locations (L1, L2, L3, L4, L5) in the mixing zone at the same depths as for the longitudinal surveys. Station L1 is about 50 feet downstream of the diffusers, L2 is approximately 100 feet downstream of the diffusers, L3 is roughly 250 feet downstream of the diffusers, L4 is about 500 feet downstream of the diffusers, and L5 is about 1500 feet downstream (at the location of the fixed monitor on the left river bank). The lateral average of the temperatures at the 3.0-, 4.75-, and

6.25-foot (1.0-, 1.5-, and 2.0-meter) depths is considered to be representative of downstream temperature conditions and is used as the measured downstream mixed river temperature.

Because of the crucial role of temperature stratification on interpreting field data, vertical temperature profiles will be collected at mid-channel at Stations L1, L2, L3, L4, and L5 as well as at the upstream edge of the mixing zone (275 feet upstream of the diffusers). These data, in conjunction with the longitudinal and lateral temperature profiles, will provide information on the vertical extent of the thermal plume as it moves through the mixing zone.

Measurements of plant intake water temperatures and discharge temperatures into the diffuser pond will also be made to check previous estimates of the temperature rise of cooling water across the condenser.

4.2 Equipment Calibration Procedures

To ensure the reliability of the data taken during field surveys, the instrumentation is calibrated prior to and following each field trip. The procedures for calibrating the eqüipment are described in the following paragraphs.

Temperature sensors are calibrated using a constant-temperature bath. The temperature sensors, along with a traceable precalibrated quartz thermometer, are inserted into the bath and the temperature of the bath allowed to reach a steady state. The output voltage from the thermistors circuit and the temperatures measured by the quartz thermometer are used to generate the calibration curves which are inputted to the boat data acquisition system.

The depth measuring sensor is calibrated at Norris Lake since laboratory facilities are not available for calibrating to depths of 60 feet. Prior to calibration, a steel measuring tape is connected to the cable supporting the sensor. Therefore, as the sensor is lowered into the water, known depths could be read from the measuring tape and these values related to the output from the sensor/circuit. This calibration is input directly to the data acquisition system on the boats to be used during field tests.

5.0 REFERENCES

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