EVALUATION OF CHLORINATION PRACTICES

FOR

WATTS BAR NUCLEAR PLANT

TENNESSEE VALLEY AUTHORITY

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ABSTRACT

The Tennessee Valley Authority injects the Raw Cooling Water (RCW) and Essential Raw Cooling Water (ERCW) Systems at Watts Bar Nuclear Plant (WBN) with sodium hypochlorite to control Asiatic clam populations. The National Pollutant Discharge Elimination System (NPDES) Permit for WBN, NPDES No. TN0020168, allows chlorine to be discharged to the Tennessee River continuously; however, total residual chlorine (TRC) shall not exceed a maximum instantaneous concentration of 0.10 mg/L. Additionally, continuous chlorination of the ERCW and RCW systems at a maximum of 30.9 pounds per hour for the purpose of Asiatic clam control is permited when both units are operating and the raw water intake temperature is above 15.6°C (60°F). Part III K. of the permit requires TVA to determine the maximum discharge concentrations of TRC for all discharge flow paths and to evaluate the need to provide dechlorination to comply with the 0.10 mg/L TRC effluent limit under all operational modes and plant conditions.

The TRC concentration in the diffuser discharge (DSN 101) and the emergency overflow from the yard holding pond (DSN 102) varies with the amount of sodium hypochlorite added at the intake pumping station (IPS) and the plant operating status. Ten different scenarios, involving various discharge routes and plant conditions which could affect the TRC concentration in discharges to the Tennessee River, were identified. The scenario in which the two nuclear reactors are in shutdown mode, the two cooling towers are not in operation (water is not being circulated through the condensers), both the RCW and ERCW flow is routed to the cold water channel of the cooling tower, and the diffuser is in operation,

resulted in the highest expected TRC concentration in a discharge to the river. Field investigations showed that for this scenario, a discharge limitation of 0.1 mg/L for TRC could not be met when the TRC averaged 1.0 mg/L at the IPS but could be met when the TRC concentration averaged 0.6 mg/L at the IPS. Field investigations also showed that an instantaneous maximum concentration of 0.8 mg/L for TRC at the IPS could not be met primarily because of the difficulty of controlling the sodium hypochlorite feed system with precision. To allow for these fluctuations, procedures and limitations governing the sodium hypochlorite feed rate should be based on maintaining an average TRC concentration at the IPS station.

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INTRODUCTION

The Tennessee Valley Authority injects the Raw Cooling Water (RCW) and Essential Raw Cooling Water (ERCW) Systems at Watts Bar Nuclear Plant (WBN) with sodium hypochlorite to control Asiatic clam populations. The National Pollutant Discharge Elimination System (NPDES) Permit for WBN, NPDES No. TN0020168, allows chlorine to be discharged to the Tennessee River continuously; however, total residual chlorine (TRC) shall not exceed a maximum instantaneous concentration of 0.10 mg/L. Additionally, continuous chlorination of the ERCW and RCW systems at a maximum of 30.9 pounds per hour for the purpose of Asiatic clam control is permited when both units are operating and the raw water intake temperature is above 15.6°C (60°F). Part III K. of the permit requires TVA to determine the maximum discharge concentrations of TRC for all discharge flow paths and to evaluate the need to provide dechlorination to comply with the 0.10 mg/L TRC effluent limit under all operational modes and plant conditions. The results of this evaluation were originally to be reported to the Environmental Protection Agency (EPA) no later than December 31, 1984; however, the deadline was extended to October 1, 1985 as requested by TVA first on December 27, 1984 and then again on July 29, 1985. The following report gives the results of this evaluation. The report does not consider the scenario in which the condenser cooling water (CCW) system is shock chlorinated. The capability exists for the CCW system to be chlorinated; but at this time TVA does not believe chlorination of the CCW will be necessary.

SYSTEM DESCRIPTION AND OPERATION

Cooling water for WBN is withdrawn from the Tennessee River by the intake pumping station (IPS), where flow is divided into the RCW system and the ERCW system. See figure 1. The intake pumping station consists of two pits. Pit A is equipped with 4 RCW pumps and 4 ERCW pumps while Pit B is equipped with 3 RCW pumps and 4 ERCW pumps. Each RCW and ERCW pump is rated at 5135 gallons per minute (gpm) and 11800 gpm respectively. Plant conditions determine the number of RCW and ERCW pumps that are normally operated. Table 1 shows the maximum number of RCW and ERCW pumps in operation under various operating conditions.

When the temperature of the intake water reaches 60°F, sodium hypochlorite is added to each of the pits in the IPS to control Asiatic clams and to inhibit biofouling on the equipment and components which utilize RCW and ERCW flows. The amount of sodium hypochlorite added at the IPS is controlled by the desired concentration of TRC in the system. The maximum TRC concentration which will avoid oxidation of the resins associated with the makeup demineralizer system is 0.3 mg/L.

After miscellaneous component and equipment cooling, the RCW is discharged into the cold water channel of the cooling tower, where it serves as makeup water for the condenser circulating water (CCW) system.

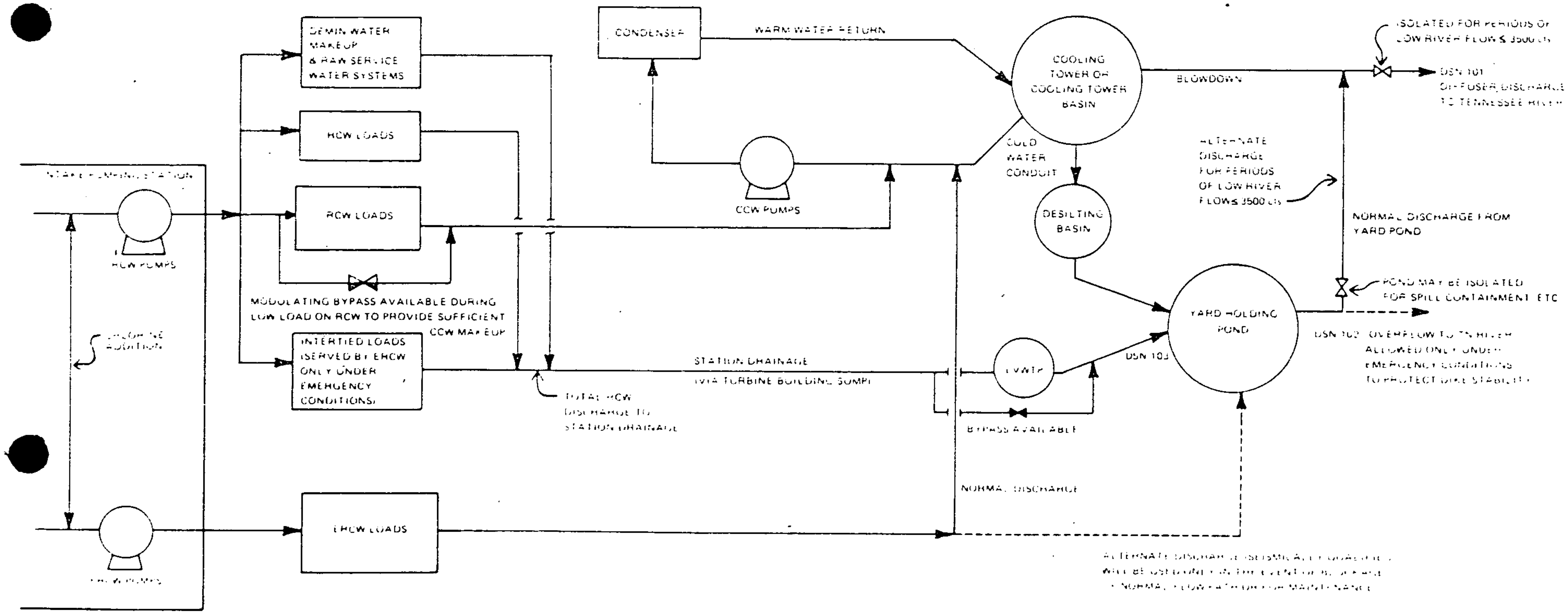

FIGURE 1 CHLORINATED WATER FLOW DIAGRAM

TABLE 1

Maximum RCW and ERCW Makeup Flowrates as a Function of Plant Operation Status

Plant Operation Status	Maximum Number/Type of Pumps in Operation*	Maximum Combined Makeup to CCW** GPM
Both units off line	6 RCW, 2 ERCW	45,735
One unit in operation	6 RCW, 2 ERCW	45,735
Two units in operation	6 RCW, 4 ERCW	61,552

*Fewer pumps could be operated depending on equipment cooling needs.

**RCW pumps rated at 5,135 gpm each; ERCW pumps rated at 11,800 gpm. Discharge flowrate is less than product of number of pumps times rated flow because of miscellaneous water uses.

See figure 2. After safety-related system cooling, the ERCW is discharged into the cold water channel of the cooling tower to serve as makeup for the CCW system or to the yard holding pond. A minimum of 11,000 gpm of makeup per operating unit must be routed at all times to the cold water channel of the cooling tower for makeup. Discharge of the ERCW to the yard holding pond will occur only in the event of blockage of the normal flow path to the cooling tower or for maintenance.

Two closed-cycle natural draft cooling towers will be used to meet cooling requirements at WBN. This will enable the plant to operate with a minimal thermal effect on the Tennessee River, since the CCW system will cycle cool water from the cooling towers through the condensers and discharge the warmer water back to the cooling towers in a closed system. Blowdown is removed from the cold water channel of the cooling tower to limit dissolved solids buildup in the CCW system. The blowdown is then discharged into Chickamauga Reservoir via a specially designed diffuser system.

When the plant is online, water is circulated through the condensers by the CCW pumps and enters the center of the cooling towers where it cascades over the fill material in the tower. The water then leaves the tower via the cold water channel. A portion of this flow discharges over a weir as blowdown and goes out the diffuser. The intake for the CCW pumps is located in the bottom of the end of the cold water channel. The RCW and ERCW flow enters the cold water channel directly over this intake, therefore, during operation of the CCW system, the RCW and ERCW flow are mixed with the CCW flow and pumped through the condensers. When

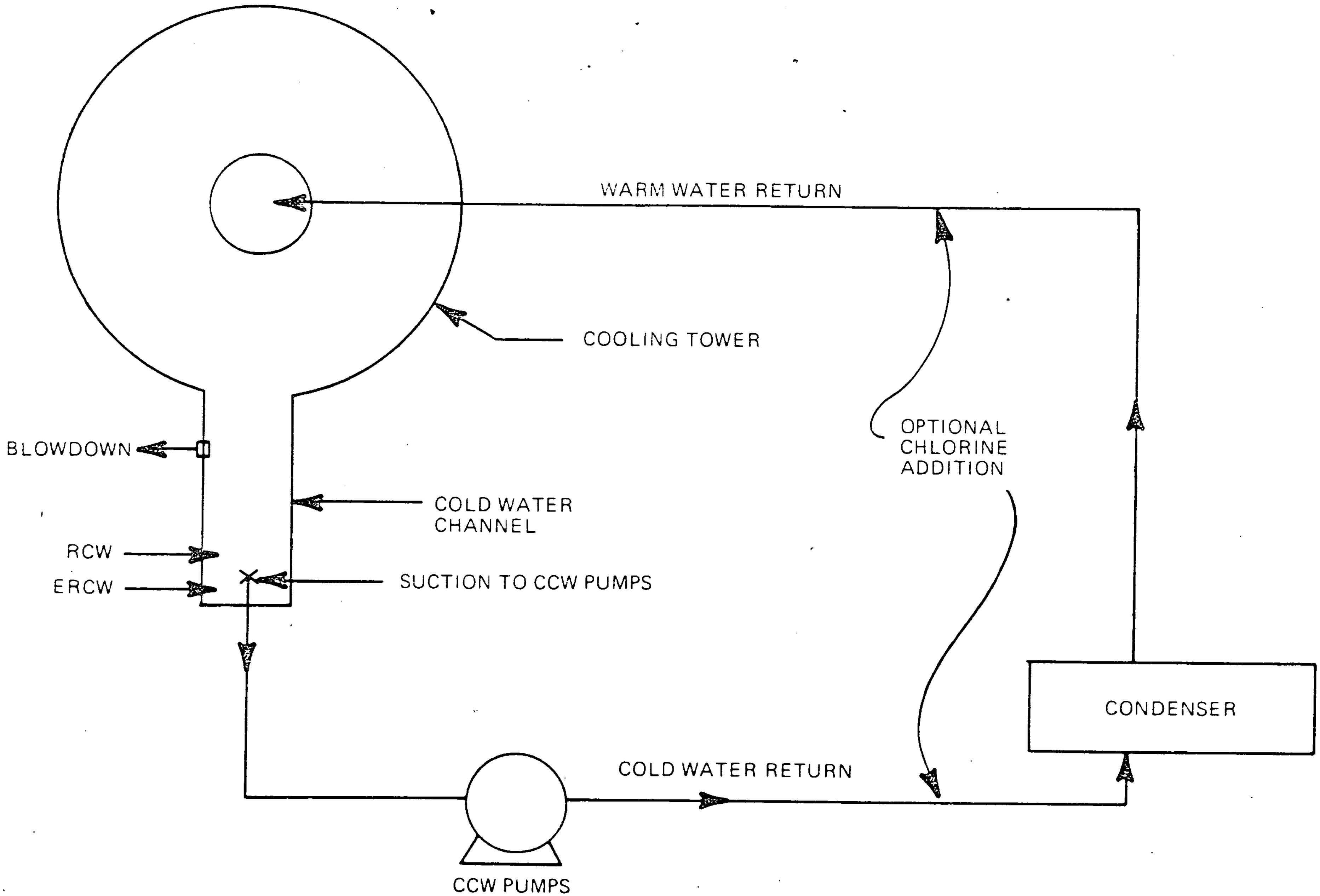

FIGURE 2. CONDENSER CIRCULATING WATER SYSTEM

the plant is off line, water is not circulated through the condensers or cascaded over the fill material and flow in the cold water channel is in the opposite direction from that when the plant is online. Therefore, RCW and ERCW flow enters the cold water channel, flows a short distance through the channel, and discharges over the blowdown weir going to the diffuser.

The TRC concentration in the diffuser discharge (DSN101) varies with the amount of sodium hypochlorite added at the IPS and the plant operating status. The following scenarios summarize discharge routes and plant conditions which can affect the TRC concentration at the diffuser.

Scenario I: The two nuclear reactor units are in shutdown mode, the two cooling towers are not in operation (water is not being circulated through the condensers) and both the RCW and ERCW flow is routed to the cold water channel of the cooling tower. Under this condition, any number of RCW and ERCW pumps could be running with the minimum being one each resulting in a flow of 16,935 gpm. Since water is not circulating through the CCW system, the RCW and ERCW flow would discharge over the weir in the cold water channel and enter the diffuser system with little or no dilution or dissipation of the chlorine from that discharged into the tower.

Scenario II: The two nuclear reactor units are in shutdown mode, the two cooling towers are not in operation, the RCW flow is routed to the cold water channel of the cooling tower, and the ERCW flow is routed to the yard holding pond. Since water is not circulating through the CCW system, the RCW flow would discharge over the weir in the cold water channel and enter the diffuser system with little or no dissipation of the chlorine. The ERCW flow going to the yard holding pond would be retained in the pond for a period of time that would be a function of the number of ERCW pumps operating. This flow would then be discharged to the diffuser system where it would be mixed with the overflow from the cold water channel of the cooling towers. There would be some chlorine dissipation occur in the pond; therefore, the TRC concentration at the diffuser would be expected to be slightly less than that in Case 1.

Scenario III: The two nuclear reactor units are in operation, the two cooling towers are in operation (water is being circulated through the condensers) and both the RCW and ERCW flow is routed to the cold water channel of the cooling towers. Under this condition a maximum of 6 RCW pumps and 4 ERCW pumps would be operating, producing a combined makeup to the CCW system of 61,552 gpm. Since water is circulating through the CCW, the ERCW flow would be diluted with the flow in the CCW system, then cascaded over the fill material in the tower, before discharge to the diffuser system. The CCW flow for each unit is 410,000 gpm, therefore, the makeup flow of 30,776 gpm per unit (61,552 divided by 2) is diluted 13 to 1. Since the cooling towers are not unitized, it is possible for the RCW and ERCW flow to be distributed unequally between the two CCW systems. In the unlikely case when all RCW and ERCW flow is routed to one CCW system, the dilution ratio would still be greater than 6 to 1. Since additional chlorine is not expected to be added to the CCW system, the TRC in the RCW and ERCW discharges will also be diluted. In addition significant chlorine dissipation is expected as the water flows over the cooling tower fill.

Scenario IV: Only one nuclear reactor unit and one cooling tower is in operation and both the RCW and ERCW flow is routed to the cold water channel of the cooling towers. Under this condition, a maximum of 6 RCW and 2 ERCW pumps would be operating producing a combined flow of 45,735 gpm. Portions of this flow could be directed to either CCW system depending on the need for makeup to the operating CCW system. Therefore, the potential exists for some of the chlorine to be diluted with the operating CCW system and dissipated by the cooling tower fill.

Scenario V: The two nuclear units are in operation, the two cooling towers are in operation, the RCW flow is routed to the cold water channel of the cooling tower, and all but 11,000 gpm of ERCW flow is routed to the yard holding pond. Since water is circulating in the CCW, the RCW and ERCW flow routed to the tower will be diluted with the flow in the CCW system, then cascaded over the fill material in the tower, before discharge to the diffuser system. The remaining ERCW flow going to the yard holding pond will be retained in the pond as in Case II. This flow will then be discharged to the diffuser system where it would be mixed with the overflow from the cold water channel of the cooling towers. The TRC concentration at the diffuser would be reduced because of dilution of part of the flow with the CCW system followed by dissipation in the tower and retaining the remaining flow in the pond allowing some dissipation of the chlorine to occur.

In addition to the diffuser discharge, TVA is also permitted to discharge chlorinated water from the yard holding pond (DSN 102) directly to the Tennessee River under emergency conditions to protect dike stability. Under normal operation, the yard holding pond discharges to the diffuser system. When the flow in the river is less than 3500 cubic feet per second (cfs), the diffuser is isolated (shut off) causing the flow to backup in the yard holding pond. With both units in operation, the yard holding pond can store cooling tower blowdown for a minimum of 12 hours before water would spill over the emergency overflow. However, based on historical data, additional flow would be available from Watts Bar Dam immediately upstream of the diffuser, thus reopening the diffuser discharge and lowering the pond prior to overflow.

Should the diffuser have to be isolated during the chlorination season for some other reason, such as maintenance, for longer than 12 hours while both units are operating, there would be a discharge of chlorinated water to the Tennessee River. Although the probability of this occurring is remote, this pathway does exist. Similar to the diffuser discharge, the TRC concentration in the overflow varies with the amount of sodium hypochlorite added and the plant operating status. The following scenarios summarize discharge routes and plant conditions which can affect the TRC concentration at the yard holding pond emergency overflow weir (DSN 102).

Scenario VI: Plant conditions and flow paths would be the same as in Scenario I except that the diffuser would be isolated and the flow would back up into the yard holding pond and then over the emergency overflow weir.

Scenario VII: Plant conditions and flow paths would be the same as in Scenario II except that the diffuser would be isolated and mixing of the ERCW flow and cooling tower blowdown would occur in the pond instead of in the piping system going to the diffuser. Discharge to the river would be over the emergency overflow weir.

Scenario VIII: Plant conditions and flow paths would be the same as in Scenario III except that the diffuser would be isolated and flow would back up into the yard holding pond and then over the emergency overflow weir.

Scenario IX: Plant conditions and flow paths would be the same as in Scenario IV except that the diffuser would be isolated and flow would back up into the yard holding pond and then over the emergency overflow weir.

Scenario X: Plant conditions and flow paths would be the same as in Scenario V except that the diffuser would be isolated and mixing of the ERCW flow and cooling tower blowdown would occur in the pond instead of in the piping system going to the diffuser. Discharge to the river would be over the emergency overflow weir.

The TRC concentration in the diffuser discharge (DSN 101) is expected to be the highest for Scenario I, when the two nuclear reactor units are shutdown, the two cooling towers are not in operation and both the RCW and ERCW flow is routed to the cold water channel of the cooling towers. For the other cases, the chlorine in the RCW and ERCW flow is either diluted with the CCW system and dissipated in the cooling towers or dissipated in the yard holding pond. The TRC concentration in the emergency overflow from the yard holding pond is expected to be the highest for Scenario VI, when the plant conditions and flow paths would be the same as in Scenario I except that instead of discharge through the diffuser, flow would be into the yard holding pond and then over the emergency overflow weir. The TRC concentration in the diffuser discharge for Scenario I is expected to be equal to or greater than that in the emergency overflow from the yard holding pond for Scenario VI. Therefore, in order for TVA to demonstrate compliance with a discharge limitation of 0.1 mg/L for TRC for a given concentration of sodium hypochlorite at the IPS, field studies need only be conducted for Scenario I.

FIELD INVESTIGATIONS

Scenario 1 conditions were simulated during November 1984 and again during May 1985. During both simulations, samples were collected and analyzed for TRC. A description of the methods used during each study and a discussion of the results follows.

Methods - November 1984 Study

The two nuclear reactor units were shut down and the two cooling towers were not in operation and both the RCW and ERCW flow was routed to the cold water channel of the cooling towers for the duration of the study. Two RCW and two ERCW pumps were being operated resulting in a total estimated flow of 33,870 gpm. A 10 percent solution of sodium hypochlorite was being fed at the IPS at a rate that would maintain a TRC concentration between 0.5 and 0.8 mg/L at air compressor B, approximately equivalent to a 0.8 to 1.20 mg/L TRC concentration at the IPS. Air Compressor B is one of the last components inside the plant to utilize ERCW. Two of the four available chlorine pumps were operational for the duration of the study. Grab samples were collected periodically for approximately 5 hours at the following points:

1. At the plant intake pumping station from:

   a. RCW line coming from pit A

   b. RCW line coming from pit B

   c. ERCW line coming from pit A

   d. ERCW line coming from pit B

2. At the cold water channel from the cooling towers:

   a. Tower A

   b. Tower B

3. At the diffuser discharge sample port:

   a. Leg A

   b. Leg B

All samples were 200 ml and were analyzed for TRC concentration in mg/L using the amperometric titration method and Fisher-Porter instruments, Model 17T1010.

Methods - May 1985 Study

Plant operation was the same as for the November 1984 study except sodium hypochlorite was being fed at the IPS by eductors at a rate to maintain a TRC concentration between 0.6 to 0.8 mg/L at the IPS. The pumps used to feed the sodium hypochlorite during the November study were replaced with eductors in an effort to make controlling the feed rate more reliable and accurate. Grab samples were collected periodically for approximately nine hours at the following points.

1. At the plant intake pump station:

   a. RCW line coming from pit A

   b. RCW line coming from pit B

2. At the cold water channel from the cooling towers

   a. Tower B

3. At the diffuser discharge sample port:

   a. Leg A

   b. Leg B

All samples were 200 ml and were analyzed for TRC concentration in mg/L using the amperometric titration method and Fisher-Porter instruments, Model 17T1010.

Results

The results of the November and May studies are given in Tables 2 and 3 respectively. During the November study, the TRC at the IPS varied from 0.3 to 1.5 mg/L and averaged 1.0 mg/L. The diffuser discharge varied from 0.18 to 0.46 and averaged 0.29 mg/L. During the May study, the TRC at the IPS varied from 0.05 to 1.8 mg/L and averaged 0.61 mg/L. The combined diffuser discharge varied from 0.02 to 0.06 mg/L and averaged 0.05 mg/L.

Discussion of Results

As evidenced by the data presented in Table 2, a TRC concentration of less than 0.1 mg/L could not be achieved at the diffuser when the TRC concentration at the IPS averaged 1.0 mg/L. However when the TRC concentration averaged 0.61 mg/L at the IPS, a TRC concentration of less than 0.1 was achieved. Since scenario I conditions represent the worst case with respect to the discharge of chlorine from a permitted discharge for WBN, a TRC concentration of less than 0.1 should be achievable under other plant conditions and flow paths as long as the TRC concentration at the IPS averages 0.6 mg/L. Because of the factors discussed in the previous section, a TRC concentration of less than 0.1 mg/L should be achievable under the other plant conditions at even greater IPS TRC concentrations.

The two studies showed that the instantaneous maximum concentration limitation of 0.8 mg/L for TRC at the IPS could not be met. Although sodium hypochlorite was added at a rate to maintain an average TRC concentration at the IPS between 0.8 and 1.2 during the November study and 0.6 and 0.8 during the May study, instantaneous TRC concentrations as high as 1.8 mg/L were observed. These extraneous values resulted from

TABLE 2

TRC Results (mg/L) - November 1984 Field Investigation

EST	Intake Pumping Station RCW A	Intake Pumping Station RCW B	Intake Pumping Station ERCW A	Intake Pumping Station ERCW B	Cooling Tower A	Cooling Tower B	Diffuser Discharge A	Diffuser Discharge B
1255	1.25							
1300		1.04						
1312			1.04					
1315				0.51				
1325	1.09							
1338	1.11							
1343		1.20						
1353					0.58	0.58		
1355				1.04				
1358			0.57					
1406	1.18							
1410		1.26						
1419							0.24	
1421				1.11				
1424			0.56					
1425								0.19
1429	0.05							
1440							0.24	0.18
1441				1.11				

TABLE 2 (Continued)

TRC Results (mg/L) - November 1984 Field Investigation

EST	Intake Pumping Station RCW A	Intake Pumping Station RCW B	Intake Pumping Station ERCW A	Intake Pumping Station ERCW B	Cooling Tower A	Cooling Tower B	Diffuser Discharge A	Diffuser Discharge B
1447	1.15							
1500					0.74	0.65		
1502				1.34				
1512	1.19							
1513							0.30	
1516								0.20
1527					0.79	0.81		
1532				1.25				
1542	1.30							
1544							0.34	
1550								0.20
1555					0.83	0.83		
1602				1.27				
1607		1.50						
1612	1.37							
1630							0.39	
1632				1.06				
1637								0.22
1647	1.34				0.95	0.88		

TABLE 2 (Continued)

TRC Results (mg/L) - November 1984 Field Investigation

	Intake Pumping Station				Cooling Tower		Diffuser Discharge	
	RCW		ERCW					
EST	A	B	A	B	A	B	A	B
1700				0.30				
1712	0.83							
1713								0.28
1729				0.73				
1730					0.91	0.67		
1742	1.13							
1750							0.46	
1759								0.38
1800	1.0*	1.2*						
1806				1.00				
1812	1.18							
1815	1.10							
Number of Analyses	15	5	3	11	6	6	6	7
Average	1.15	1.24	0.72	0.97	0.80	0.74	0.33	0.24
Minimum	0.83	1.04	0.56	0.30	0.58	0.58	0.24	0.18
Maximum	1.37	1.50	1.04	1.34	0.95	0.88	0.46	0.38

*Analysis by Hach Kit

TABLE 3

TRC Results (mg/L) - May 1985 Field Investigations

	Intake Pumping Station RCW		Cooling Tower	Diffuser Discharge	
EST	A	B	B	A	B
1015	0.5	1.3			
1018	0.43				
1030	0.20	1.2			
1045	0.10	0.9			
1052	0.10				
1058		0.9			
1102	0.20				
1120	0.20	0.75			
1130	0.15	1.10			
1155	0.10				
1145		1.80			
1158	0.20	1.40			
1210		0.50			
1215	0.10	0.30			
1223	0.05				
1235	0.15	0.20			
1242	0.30	0.16			
1252	0.35	0.17			
1300	0.40	0.17			
1315	0.41	0.20			
1320	0.50	0.35			

TABLE 3 (Continued)

TRC Results (mg/L) - May 1985 Field Investigations

EST	Intake Pumping Station RCW		Cooling Tower	Diffuser Discharge	
	A	B	B	A	B
1345	0.56	0.60			
1400	0.51	0.62			
1410	0.88	0.62			
1430	0.72	1.10			
1440			0.16		
1445	0.85	0.98			
1450				0.02	
1500	0.55	0.60	0.15		
1515	0.60	0.40			
1520				0.02	
1525					0.02
1530	0.65	0.53			
1534			0.15		
1545	0.70	0.80		0.03	
1550					0.03
1600	0.60	1.20			
1615	0.70	0.95	0.17		
1620				0.05	
1625					0.05
1630	0.70	0.60			
1633			0.17		

TABLE 3 (Continued)

TRC Results (mg/L) - May 1985 Field Investigations

EST	Intake Pumping Station RCW		Cooling Tower	Diffuser Discharge	
	A	B	B	A	B
1640				0.05	
1645	0.63	0.40			0.05
1650	0.60	0.52	0.18		
1700	0.60	0.90			
1707				0.05	
1712					0.05
1715	0.64	1.50			
1720			0.19		
1725				0.05	
1730	0.70	1.20			
1737					0:05
1740	0.70	0.70			
1745	0.70	0.60	0.15		
1800	0.64	0.43			
1803				0.05	
1805					0.05
1808	0.80	0.70			
1815	0.70	0.85	0.17		
1820					0.06
1825				0.05	
1830	0.50	0.95	0.17		

TABLE 3 (Continued)

TRC Results (mg/L) - May 1985 Field Investigations

EST	Intake Pumping Station RCW A	Intake Pumping Station RCW B	Cooling Tower B	Diffuser Discharge A	Diffuser Discharge B
1845	0.60	0.95			
1848				0.05	
1855	0.7	0.55			
1856			0.18		
1905	0.7	0.30			
1910				0.05	
Number of Samples	45	42	11	11	8
Average	0.48	0.74	0.17	0.04	0.05
Minimum	0.05	0.16	0.15	0.02	0.02
Maximum	0.88	1.80	0.19	0.05	0.06

incomplete mixing of the sodium hypochlorite within the IPS pits and the difficulty of controlling the sodium hypochlorite feed system accurately. These outlying values are dampened out as the water flows through the system, as evidenced by the smaller variability of the TRC concentration in the diffuser discharge compared to the variability in the IPS. Accordingly, internal procedures and limitations governing the sodium hypochlorite feed rate should be based on maintaining an average TRC concentration at the IPS.

CONCLUSIONS

The TRC concentration in the diffuser discharge (DSN 101) and the emergency overflow from the yard holding pond varies with the amount of sodium hypochlorite added at the IPS and the plant operating status. Ten different scenarios, involving discharge routes and plant conditions which could affect the TRC concentration in discharges to the Tennessee River, were identified. The scenario in which the two nuclear reactors are in shutdown mode, the two cooling towers are not in operation (water is not being circulated through the condensers), both the RCW and ERCW flow is routed to the cold water channel of the cooling tower, and the diffuser is in operation, is expected to result in the highest TRC concentration in a discharge to the river. Field investigations showed that for this scenario, a discharge limitation of 0.1 mg/L for TRC could not be met when the TRC averaged 1.0 mg/L at the IPS but could be met when the TRC concentration averaged 0.6 mg/L at the IPS. Therefore, as long as the TRC concentration averages 0.6 mg/L at the IPS, dechlorination equipment is not necessary to meet a discharge limitation of 0.1 mg/L for TRC. Field investigations also showed that the instantaneous maximum concentration limitation of 0.8 mg/L for TRC at the IPS could not be met primarily because of the difficulty in controlling the sodium hypochlorite feed accurately. To allow for these surges in the feed, internal procedures and limitations governing the sodium hypochlorite feed rate should be based on maintaining an average TRC concentration at the IPS station.