

February 6, 1984

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

BRANCH

In the Matter of)

CAROLINA POWER & LIGHT COMPANY)
AND NORTH CAROLINA EASTERN)
MUNICIPAL POWER AGENCY)

(Shearon Harris Nuclear Power Plant,)
Units 1 & 2))

Docket Nos. 50-400 CL
50-401 OL

AFFIDAVIT OF WILLIAM T. HOGARTH IN SUPPORT OF
SUMMARY DISPOSITION OF EDDLEMAN CONTENTION 83/84B

County of Wake)

State of North Carolina)

WILLIAM T. HOGARTH being duly sworn according to law, deposes and says as follows:

1. I am Manager - Environmental Technology Section Carolina Power & Light Company (CP&L) and give this affidavit in support of Applicants' Motion for Summary Disposition of Eddleman Contention 83/84B. I have personal knowledge of the matters set forth herein and believe them to be true and correct to the best of my information, knowledge, and belief. A summary of my professional qualifications and experience is attached as an exhibit to my affidavit included in Applicants' Motion for Summary Disposition of Eddleman Contention 83/84, dated September 1, 1983.

2. In its Memorandum and Order (Ruling on Motions for Summary Disposition of Eddleman Contentions 29/30, 64(f), 75, 80 and 83/84), dated November 30, 1983 ("November 30 Order"), the Atomic Safety and Licensing Board stated at page 27 that my Affidavit included in Applicants' previously filed Motion for Summary Disposition of Eddleman Contention 83/84 did not address the issue of possible effects of "halogenated

8402130246 840207
PDR ADDCK 05000400
PDR

organic compounds that are carcinogenic as a result of the chlorination of cooling waters in the Harris Plant."

3. Since the time of the above referenced Memorandum and Order, on December 21, 1983, the Board of Directors of Carolina Power & Light Company approved the cancellation of Unit 2 of the Shearon Harris Nuclear Power Plant. The cancellation of Unit 2 means that the Cape Fear make-up structure also will not be completed since Cape Fear River water is not needed as make-up for one-unit operation of the Shearon Harris Plant. Therefore, no water whatsoever from the Cape Fear River will be entering the Harris reservoir. Thus, the only possible interaction of Harris plant discharges with Cape Fear River water would be where Harris lake discharges, mixed with and diluted by Buckhorn Creek flow, enter the Cape Fear River downstream of Buckhorn Dam.

4. A study was begun prior to cancellation of Harris Unit 2 to determine the chemical makeup of discharges from CP&L's Cape Fear Plant upstream of the Harris Plant. This study will not conclude until after normal chlorination practices at the plant are studied through the peak summer season, probably in August 1984 (the plant does not chlorinate during the winter under normal operation). The results of this study will be reported at that time but should have absolutely no bearing on this contention since 1) Unit 2 has now been cancelled and no Cape Fear water will enter Harris reservoir, and 2) the analysis of Dr. James A. Fava and Mr. Hans Plugge, included in Applicants' Motion, and summarized below, concludes that discharges of possible carcinogenic compounds from SHNPP will be so extremely minimal that no measurable increase in health risk will be caused regardless of the chemical constituents of the Cape Fear River.

5. In light of the new development as to Harris Unit 2 and in preparation for the environmental hearing previously scheduled in this proceeding for January 1984, Applicants had two further studies conducted of the health effects issue raised by part B of Eddleman Contention 83/84. The purpose of this Affidavit is to demonstrate that

Applicants have now adequately addressed those human health effects, if any, associated with SHNPP discharges. The results of this assessment support the Applicants' Motion for Summary Disposition of Eddleman 83/84B.

6. The first study which Applicants had performed on this issue was one by Lawler, Matusky & Skelly Engineers (LMS) where mathematical modeling was done to determine possible concentrations of chlorine by-products in the plant, in the reservoir, and at the Cape Fear River.

7. In that study, estimates of free available and total residual chlorine concentrations that could be discharged into the Harris reservoir were made. Estimates of total residual chlorine concentrations were done using calculations which incorporated plant design specifications, planned chlorination practices, and lake hydrodynamics and chemistry. These results are presented in Exhibit "A."

8. The LMS study predicts that no free available chlorine, the form of chlorine most likely to react with chemical constituents in a water body, is expected to be discharged to the reservoir or the Cape Fear River.

9. Some concentrations of total residual chlorine are expected to be discharged. Concentrations of total residual chlorine were conservatively estimated to be 4.0 ppb when using a 5 acre mixing zone in Harris reservoir (as referred to by the NRC Staff in the Final Environmental Statement), 1.0 ppb in the 200-acre mixing zone allowed under the Harris Plant NPDES permit, and 0.006 ppb in the Cape Fear River at the confluence of Buckhorn Creek.

10. The second study which Applicants had performed was one in which Dr. James A. Fava, Vice President, and Mr. Hans Plugge, Senior Scientist of Ecological Analysts, Inc., utilized the mathematical models to determine concentrations of possible carcinogenic compounds in the Harris reservoir and Cape Fear River. Using the report of Dr. Roger M. Bean, referred to by the Licensing Board in its November 30 Order, Dr. Fava and Mr. Plugge determined which possibly carcinogenic compounds were most likely

to be discharged from the Harris plant. Relying on mathematical models of LMS and appropriate dilution factors, concentrations of these carcinogens in the Harris reservoir and at the Cape Fear River were calculated. Finally, the possible human health effects of these concentrations was thoroughly analyzed. The conclusion of Dr. Fava and Mr. Plugge was that the concentrations would cause no measurable increase in adverse human health effects. The analysis of Dr. Fava and Mr. Plugge appears as an affidavit included in support of Applicants' Motion for Summary Disposition of Eddleman Contention 83/84B.

11. Therefore, Applicants have now adequately addressed the health effects of chlorinated discharges from SHNPP under the regulations, guidelines, and recommendations of the EPA and NRC and as required by the National Environmental Policy Act.

This is the 6th day of February, 1984

William T. Hogarth
William T. Hogarth

Sworn to and subscribed before
me this 6th day of February, 1984.

Michael D. Howell
Notary Public

My commission expires: 4-6-88

**Lawler,
Matusky
& Skelly
Engineers** Environmental Science & Engineering Consultants

ONE BLUE HILL PLAZA, PEARL RIVER, NEW YORK 10965
(914) 735-8300
TWX: LMSE PERL 710-577-2782

JOHN P. LAWLER, P.E.
FELIX E. MATUSKY, P.E.
MICHAEL J. SKELLY, P.E.
KARIM A. ABOOD, P.E.
PATRICK J. LAWLER, P.E.
FRANCIS M. MCGOWAN, P.E.
THOMAS L. ENGLERT, P.E.

26 January 1984
File No. 340-022

Dr. William T. Hogarth
Manager of Environmental Technology
Carolina Power & Light Company
The Harris E&E Center
Route 1, Box 327
New Hill, NC 27562

Dear Dr. Hogarth:

This letter summarizes the results of Lawler, Matusky & Skelly Engineer's (LMS) studies on the Shearon Harris Nuclear Power Plant. Specifically, we evaluated the effect of chlorination on the cooling reservoir and its subsequent discharge to the Cape Fear River. The fate of residual chlorine and chlorination by-products was investigated, as well as the general effects on the aquatic community.

The important assumptions and results are presented in this letter. Attachment A describes in detail the model development, assumptions, input data, and results. Attachment B summarizes the aquatic effects of chlorination, and Attachment C contains the references.

General Approach

Although several models are in existence to simulate the reaction of free chlorine with ammonia and other nitrogenous compounds, to date none include any of the chlorination by-products, such as trihalomethanes and halogenated phenols. Therefore, we decided to structure the modeling effort to account for total chlorine, and then relate these results to the various by-products, using knowledge of the partitioning of these compounds (Bean 1983a and b).

Three models were developed. The plant, the cooling lake, and the Cape Fear River were analyzed independently so that the results of one model could be used in another, or so that given any chlorine input (lb/day) to a model, results could be obtained.

The plant model is divided into three sections: the cooling tower basin, the circulating water piping, and the cooling tower itself. For a given chlorination schedule, the model computes total chlorine concentrations at the three sections and the poundage that is released through the blowdown. The model accounts for the immediate inorganic demand and other "losses" of chlorine via first-order decay and evaporative removal by the cooling tower. The removal coefficient, which is the least definitive parameter, was determined by calibration to data observed at other plants.

Each plant section is formulated as a completely mixed reactor - conservative for the basin, and conservative in the extreme for the cooling tower and the piping. The latter, particularly the piping, are much closer to plug flow behavior, which will yield lower outlet residual chlorine values. The immediate chlorine demand is simulated in the model and removes some of the chlorination dose. The remaining total chlorine is then modeled using reaction rates based on combined residual chlorine (CRC). This is reasonable for this analysis for several reasons. First, studies have shown that the reaction rates for free available chlorine (FAC) are much faster than for CRC (LMS 1983). Second, few plants with cooling tower systems ever observe FAC in the blowdown (NRC 1983). Third, the immediate demand is assumed to remove FAC (not CRC) only at the point of chlorination; normally, if FAC is maintained through the condenser and into the cooling tower, it will be consumed by the immediate demand in the basin. Fourth, we have not accounted for the removal of chlorine by the slime on the piping walls, i.e., removal due to biocidal action. Fifth, some of the chlorination by-products may be lost in the plant at a faster rate than CRC - volatilization of chloroform, for example (Jolley et al. 1981; Aaberg et al. 1983). Sixth, for the observed chemistry - planned dosage and lake demand - much of the dose will be converted to chloramines by organic nitrogen and ammonia present in the lake water.

The plant model is also conservative in that we maintain a constant and maximum design dose over the chlorination period. In reality, this would be adjusted (from discharge water box measurements) to minimize chlorine use.

The lake model takes the total chlorine output from the plant blowdown (lb/day) and computes an average completely mixed concentration in a specified volume. We have chosen the 200-acre mixing zone as conservatively representative of the mixing volume. The choice of a completely mixed system is overly conservative; a plug flow representation would result in concentrations of effectively zero, because of the long retention time in the mixing zone. If the 72,000 acre-ft lake was used, the concentrations of chlorine would also be zero, even with the completely mixed assumption. Losses during travel time from plant to lake have been considered.

The river model takes the concentration output from the lake, includes losses traveling down Buckhorn Creek, and mixes the flow with the Cape Fear River flow to obtain an incremental total chlorine concentration.

Sources of Data

Plant physical and operating characteristics were taken from three sources: the Shearon Harris Environmental Report - Operating License Stage (CP&L 1982), conversations with CP&L engineering personnel, and the Harris Plant's Final Environmental Statement (NRC 1983). Chlorine information was taken from several sources, including a recent chlorination study (LMS 1983) and the four-volume set of Water Chlorination conferences (Jolley 1978; Jolley et al. 1978; Jolley et al. 1980; Jolley et al. 1983).

Some minor differences in reported flow values were noted in the ER, particularly in the makeup, blowdown, and evaporative flows. In the analysis, we used the flows presented in Table 3.3-1 under maximum power; makeup, blowdown, and evaporation were 50, 27, and 23 cfs, respectively. However, in several locations, the maximum blowdown rate is reported as 23.2 cfs (15 MGD). The higher value was used to be conservative.

The chlorine dose of 3 mg/l is based on the measured lake chlorine demand. This is greater than the maximum capability of the current chlorination system. At 1 hr per day for 309 days per year, the plant would use 112 tons of chlorine per year.

All calculations are done using one unit. The river and lake calculations assume that the plant releases chlorine to the lake every day, and do not account for downtime or reduced load.

Results

A complete discussion is presented in Attachment A. Using all the conservative assumptions mentioned, the following results are obtained:

Total chlorine (TC) used by the plant (when chlorinated at a maximum rate greater than present design)	725	lb/day
TC release to the lake	6.3	lb/day
Average TC concentration over a 5-acre zone (as mentioned in the FES)	2.6	ppb
Average TC concentration over a 200-acre mixing zone (completely mixed model)	0.07	ppb
Average TC concentration discharged to the Cape Fear	0.04	ppb or less
Average incremental TC in the Cape Fear	0.0005	ppb or less

The above levels are indicative of CRC. A conservative estimate for haloforms, using the same decay rate, would be 0.2% of the above CRC concentrations; for halogenated phenols, 0.08%. Note that the above numbers for total chlorine are well below the drinking water standards for total trihalomethanes (100 $\mu\text{g/l}$). Also, the lower limit of detection by amperometric titration is 1.8 ppb in freshwater (Jolley and Carpenter 1982).

If the plant model is ignored, i.e., haloforms as 0.2% of the foregoing no longer applies, and it is assumed that 0.1% of the total plant dose goes to haloforms (TTHM) and is released to the lake, the following results are obtained:

TTHM released to the lake	0.7	lb/day
Average TTHM concentration over a 5-acre mixing zone	0.3	ppb
Average TTHM concentration over a 200-acre mixing zone	0.01	ppb
Average incremental TTHM in the Cape Fear	0.0001	ppb

Biological Effects

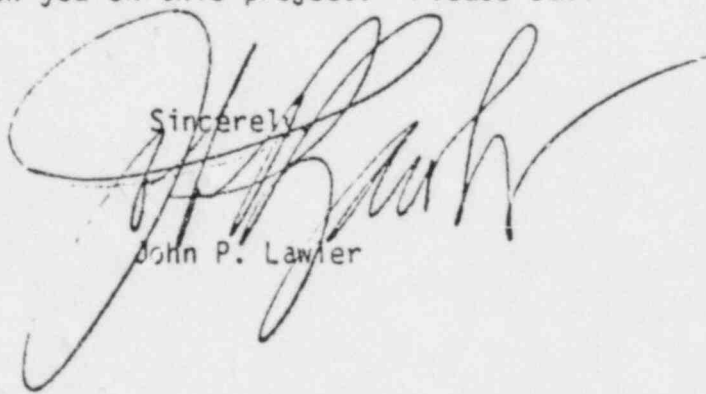
Attachment B presents our summary of the review of the literature. Tables B-1 and B-2 contain selected toxicity, uptake, and depuration data for aquatic organisms. Table B-3 indicates some of the potential human health effects of chlorinated compounds.

The effects of chlorine and its by-products are discussed in Attachment B for specific aquatic species. To summarize the results, the levels of total residual chlorine, free chlorine, chloramines, trihalomethanes, other halo-methanes, and chlorophenols found to cause acute and chronic toxicity to fish species are generally well above the levels of total chlorine predicted to occur in the 5-acre mixing zone (2.6 ppb at maximum chlorination and no initial demand on CRC after discharge).

Closure

The models, results, and biological effects are discussed in detail in the attachments. We have enjoyed working with you on this project. Please call if you require more information.

Sincerely,



John P. Lawler

ATTACHMENT A

MATHEMATICAL FORMULATION OF MODELS

To determine the effect of the Harris plant chlorine use on the Cape Fear River, three mathematical models were developed. The first, and most complex, represents the plant itself. The second model takes the results of the first and computes chlorine levels in the lake. The third takes the results of the lake model and determines chlorine levels in the Cape Fear River (caused by the Harris plant discharge).

Several conservative assumptions incorporated into the above models will be noted in the description of model development. The models do not directly account for the various by-products of chlorination; rather, they are based on total chlorine use. The resulting numbers (whether concentrations or pounds discharged per day) are broken down into various chlorine components by using known fractions (by-products/dose).

The total chlorine (TC) reactions are simulated using combined residual chlorine (CRC) parameters. This is conservative because other reactions that cause the disappearance of by-products (such as the volatilization of chloroform) generally occur at the same rates as the decay of CRC (Jolley et al 1981; Aaberg et al 1983). Thus, the TC results are deemed indicative of CRC and can adequately represent the other by-products.

All of the models begin with a general form of the conservation of mass equation:

$$\text{Accumulation} = \text{Inflow} - \text{Outflow} + \text{Sources} - \text{Sinks} \quad (1)$$

In the case of chlorine, sources include the circulating water dose (in the plant) and the plant to the lake. The service water system, 10% of the circulating water flow, is not considered in this analysis. Sinks of chlorine include the immediate demand, first-order decay, and stripping in the cooling tower.

The conservation of mass equation is rewritten:

$$V \frac{dC}{dt} = \sum Q_{in} C_{in} - \sum Q_{out} C_{out} + (W_C - W_D) - KVC - \text{other sinks} \quad (2)$$

where

V = control volume about which the equation is written

C = average concentration of chlorine in V

Q_{in} = flow into V

C_{in} = chlorine concentration in Q_{in}

Q_{out} = flow out of V

C_{out} = chlorine concentration in Q_{out}

W_C = chlorine dose into V

W_D = immediate chlorine demand on C_D

K = first-order decay rate

Of course, the appropriate units must be maintained in the above equation.

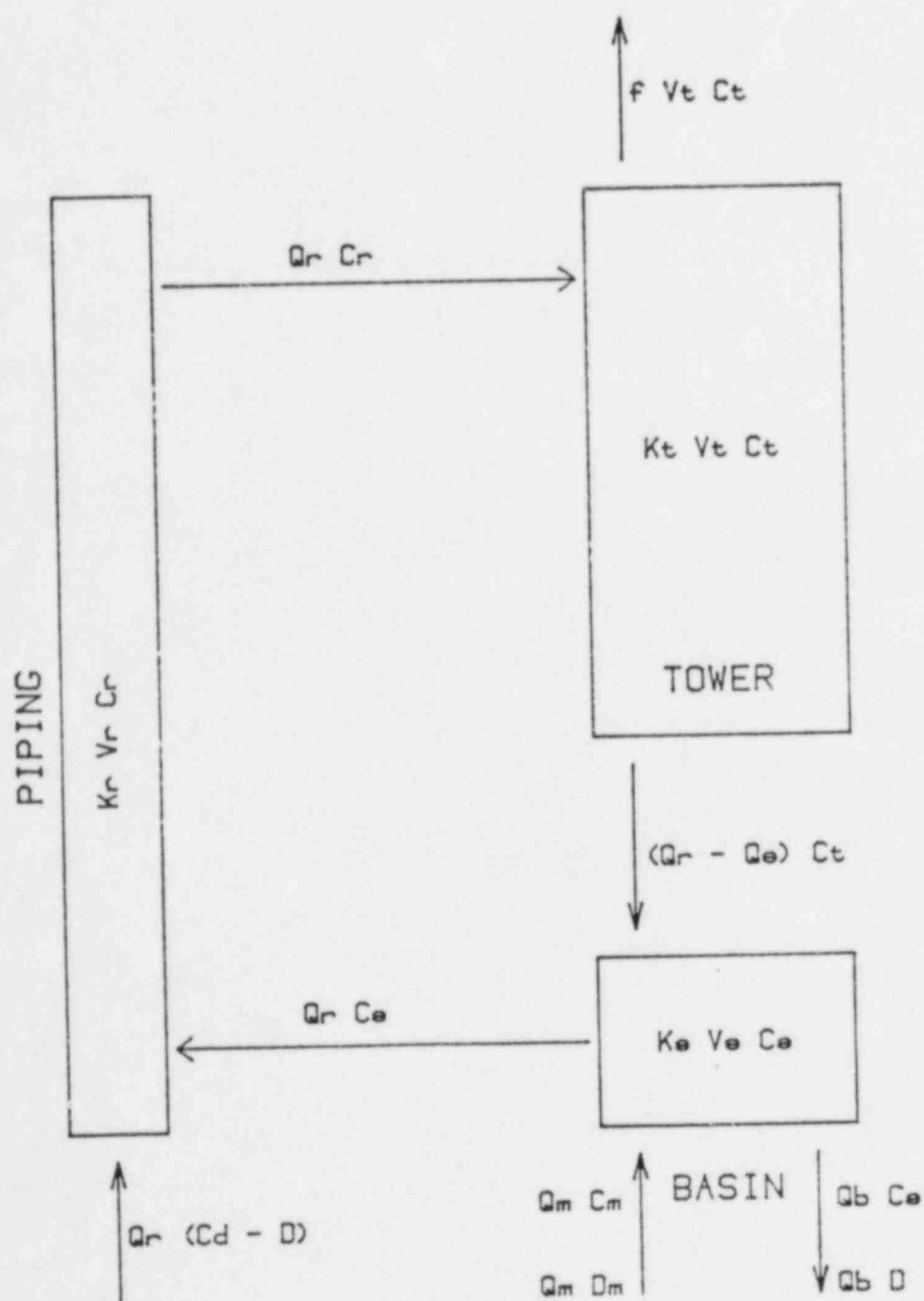
Modeling Chlorine in the Plant

The Harris plant is divided into three zones: the circulating water piping (including condenser tubes), the cooling tower, and the cooling tower basin. Total residual chlorine is modeled separately in each zone, while the demand is modeled considering the system as a whole.

Figure A-1 shows a schematic representation of the plant. The following equations are written:

FIGURE A-1

SCHEMATIC OF HARRIS PLANT CHLORINATION MODEL



For the basin, assuming it is completely mixed:

$$V_S \frac{dC_S}{dt} = Q_m C_m + (Q_R - Q_e) C_T - Q_B C_S - K_S V_S C_S - Q_R C_S \quad (3)$$

where

- V_S = volume of basin (ft³)
- C_S = average concentration of chlorine in basin (mg/l)
- Q_m = makeup flow (cfs)
- C_m = makeup chlorine concentration (mg/l)
- Q_R = circulating water flow (cfs)
- Q_e = evaporative flow (cfs)
- C_T = cooling tower chlorine concentration (mg/l)
- Q_B = blowdown flow (cfs)
- K_S = decay coefficient in basin (sec⁻¹)

For the piping:

$$V_R \frac{dC_R}{dt} = Q_R C_S + Q_R (C_D - D) - Q_R C_R - K_R V_R C_R \quad (4)$$

where

- V_R = volume of piping (ft³)
- C_R = average concentration of chlorine in piping (mg/l)
- C_D = chlorination dose (mg/l)
- D = immediate chlorine demand (mg/l)
- K_R = decay coefficient in piping (sec⁻¹)

For the cooling tower:

$$V_T \frac{dC_T}{dt} = Q_R C_R - f V_T C_T - (Q_R - Q_e) C_T - K_T V_T C_T \quad (5)$$

where

V_T = volume (effective) of cooling tower (ft^3)

C_T = chlorine concentration in tower (mg/l)

f = rate to account for chlorine loss in cooling tower (sec^{-1})

K_T = decay coefficient in tower (sec^{-1})

For chlorine demand in the system:

$$V \frac{dD}{dt} = Q_m D_m - Q_R D - Q_B D \quad \text{during chlorination, and} \quad (6a)$$

$$V \frac{dD}{dt} = Q_m D_m - Q_B D \quad \text{after chlorination.} \quad (6b)$$

where

V = total volume of system (ft^3)

D = chlorine demand of system (mg/l)

D_m = chlorine demand in makeup water (mg/l)

Several points should be addressed about the above equations. All assume complete mixing in each section. This is a valid assumption in the basin and is overly conservative in the piping and cooling tower, where plug flow would result in much lower computed concentrations. The term $Q_R (C_D - D)$ in Equation 4 is used only during the active chlorination procedure; it represents the dose less any immediate demand. This phenomenon appears as $-Q_R D$ in the demand equation; again, it is used only during chlorination. The model makes appropriate adjustments if the dose, C_D , is less than the demand, D . The effective volume, V_T , in the cooling tower is not the total volume; it is computed by multiplying the flow through the tower (Q_R) by the residence time in the tower.

The factor f is used to account for the loss of chlorine as the circulating water flow passes through the cooling tower. This has been described as flashing. The exact mechanism is not known, although it may be vaporization, reaction with cooling tower packing, or some process associated with evaporation. Various authors (Draley 1973; Nelson 1973) have estimated this value to range from 0.3 to 0.5. However, these studies have used the formula $fQ_R C_T$ to account for the loss, meaning it is dependent upon the circulating water rate. This may not be valid as it implies that, as the water flow increases, the loss through the cooling tower increases. It would seem that this loss should be more dependent upon the characteristics of the cooling tower (airflow, packing, etc.). Thus, we have used the formula $fV_T C_T$ and left the value of f subject to calibration. The data used for calibration were those collected by Zielke and Moss (1980), which showed the TRC concentration leaving the cooling tower to be 50% of the concentration entering the cooling tower (also shown by Draley 1973). The Zielke and Moss study was a calibration of a chlorine model to actual data taken at a plant similar to Harris. When $C_T/C_p = 0.5$ during the chlorination period, f is deemed calibrated.

A computer program was written to calculate the solutions of Equations 3-6. The demand equation is solved analytically, with the resulting value used in Equation 4. The remaining chlorine equations are a set of three simultaneous linear differential equations that are solved using a centered finite difference technique. Test cases were run to ensure analytical accuracy and numerical stability.

The following gives estimates of some of the model parameters and their sources:

$$Q_R = 1075 \text{ cfs}$$

$$Q_m = 50 \text{ cfs}$$

$$Q_B = 27 \text{ cfs}$$

$$Q_e = 23 \text{ cfs}$$

Environmental Report (CP&L 1982,
p. 3.3-3), based on maximum power.

$$V_S = 792,000 \text{ ft}^3$$

$$V_R = 287,110 \text{ ft}^3$$

$$V_T = 10,750 \text{ ft}^3$$

Based on telephone conversation
with Roger Stewart, Project Engineer,
CP&L

Based on 10-sec travel time through
cooling tower

Initial chlorine levels in the plant and the makeup water were assumed to be zero. (To see any chlorine in the makeup water, the plant would have to release several tons/day in the blowdown.) Makeup water demand was 1.3 or 2.0 mg/l, from the following CP&L measurements taken for this study (all in mg/l):

DOSE	FAC	CRC	TRC	DEMAND
3.0	0.4	1.3	1.7	1.3
5.0	1.3	1.7	3.0	2.0

Initial demand in the plant water was estimated at 1.85 times makeup demand (the ratio of makeup to blowdown flow).

The dose, C_D , was taken to be 3 mg/l for 30 min, based on the aforementioned demand measurements and a requirement of some FAC to knock out the slime in the system. This is 725 lb of chlorine use for 1 hr of chlorination per day. The current chlorination system is designed for a feed rate of 10,000 lb/day, or 417 lb for 1 hr. This would result in a circulating water dose of 1.7 mg/l, which may not be enough to remove the immediate and nitrogenous demands in the system. To be conservative, this study used the higher rate of 725 lb throughout. In the case of real-world plant operations, the existing chlorination system may be sufficient. If the total demand in the plant at the start of chlorination is 164 lb (1.85 times 1.3 mg/l times the total volume), and 208 lb of chlorine is injected over 30 min, there may be some FAC available for biocidal action.

The decay rate was estimated using a formula by Kim and Lin (1982) that accounts for pH and temperature effects. Using a pH of 7 and a temperature of 30°C, a rate of 4.0/day was computed. This is at the low end of the ranges for both FAC and CRC (LMS 1983). The same decay rate was used in all sections of the plant.

The model was run at both demand levels with a constant, maximum dose of 3 mg/l and varying f from 0.1 to 0.5. The following results were obtained:

CHLORINE CONCENTRATION (mg/l) AT THE END OF CHLORINATION						
f	DEMAND = 1.3			DEMAND = 2.0		
	C_T	C_p	C_T/C_p	C_T	C_p	C_T/C_p
0.1	1.63	3.24	0.50	1.33	2.64	0.50
0.3	0.70	2.78	0.25	0.59	2.34	0.25
0.5	0.44	2.64	0.17	0.38	2.26	0.17

Based on the above results, the model runs using an f of 0.1 were chosen for analysis. In addition to the reasons presented earlier, these runs are conservative because the dose is maintained at 3.0 mg/l. In practice, monitoring equipment is employed so that the residual (FAC) through the condenser is 0.5 mg/l. After the first few minutes of dosing at 3.0, the dose can usually be reduced and still maintain the same residual. Even though the plant specifications ask for FAC residual, studies have shown that CRC can also be an effective biocide, which would enable the dosage to be decreased further.

Using the background demands of 1.3 and 2.0 mg/l and $f = 0.1$ results in a total chlorine discharge in the blowdown of 4.7 and 3.3 lb, respectively, over a 2-hr period (with 75% being discharged in

the first hour after initiation of chlorination). These mass loadings correspond to average 2-hr TC levels in the blowdown stream at the sump of 0.4 and 0.3 mg/l, respectively. This is all presumed to be CRC for several reasons. The FAC, when in the circulating system, will be consumed by the slime on the walls and the remaining immediate demand in the cooling tower basin (ignored in this model). Several studies have validated the lack of FAC in cooling tower blowdown, as noted also by the U.S. Nuclear Regulatory Commission (NRC) staff in the Final Environmental Statement (FES) for this plant (NRC 1983).

Because chlorination occurs twice per day, the above numbers (pounds) should be doubled. The higher value, 9.4 lb/day, will be used for subsequent calculations.

The plant discharge to the lake occurs through a 48-in diameter pipe about 3.5 miles long. Since the discharge port is the point where NPDES permit limitations are applied, the decay during the travel through the pipe should be accounted for. With the discharge of 27 cfs, the travel time is 2.4 hrs. Then, using the same 4 per day decay rate, the discharge to the lake is reduced to 67% of the levels at the plant. This results in a release to the lake of 6.3 lb/day of CRC, or an average 2-hr CRC level of 0.27 mg/l (per 30 min chlorination period), or a daily (24 hr) average CRC of 0.04 mg/l.

The aforementioned CRC level of 0.27 mg/l is more than the value of 0.2 mg/l mentioned in the FES (NRC 1983). This may be due to the fact that previous analyses were based on two units, with the chlorinated discharge being diluted by the unchlorinated discharge. This difference should not be an issue because (1) the lake is providing the dilution instead of the second unit, (2) the total pounds from each unit is still the same, regardless of the concentration, and (3) the discharge to the lake has been cut in half.

Current regulations (EPA 1982) on cooling tower blowdown limit the discharge of FAC to a daily average of 0.2 mg/l for no more than 2-hr per day per unit. For the reasons previously mentioned, there will be no problem in meeting these regulations. There is no limitation on CRC. Even if the same limitation applied to CRC, the standard would be met, based on the 24-hr average level of 0.04 mg/l (6.3 lb/day in a 27 cfs discharge).

Modeling Chlorine Levels in the Lake

Assuming (conservatively) no immediate demand on the chlorine released to the lake, the following equation is written:

$$V_L \frac{dC_L}{dt} = W_L / 5.39 - K_L V_L C_L - Q_L C_L \quad (7)$$

where

- V_L = volume of the lake available for mixing (ft³)
- C_L = lake chlorine concentration (mg/l)
- W_L = amount of chlorine released to the lake (lb/day)
- K_L = lake decay coefficient (sec⁻¹)
- Q_L = lake outflow (cfs)
- 5.39 = unit conversion factor

Assuming complete mixing and steady state, we obtain:

$$C_L = \frac{W_L / 5.39}{Q_L + K_L V_L} \quad (8)$$

W_L has been determined to be 6.3 lb/day. The average discharge from the lake, Q_L , is 43 cfs (CP&L 1982, p. 2.4.2-10). A decay of 4.0 per day will still be used to represent the breakdown of chlorine and chlorinated by-products, although the decay rate increases in the presence of sunlight. The only remaining parameter to estimate is the volume, V_L , used for mixing.

The volume of the lake - 72,000 acre-ft - could be used. However, this would be guaranteed only if the plant discharge were at the upstream end of the lake. The whole lake may take part, but in general, the mixing is only partial, and some short-circuiting may occur. A conservative assumption would be to use the volume of the mixing zone. This not only uses substantially less volume than is available but also enables the prediction of CRC levels at the edge of the zone. Using a depth of 40 ft in the 200-acre mixing zone gives a volume of $3.5 \times 10^8 \text{ ft}^3$. With the parameters already mentioned, Equation 8 can be written as:

$$C_L \text{ (mg/l)} = 0.000011 W_L \text{ (lb/day)} \quad (9)$$

With a 6.3 lb/day plant release, the computed level at the lake discharge or edge of the mixing zone is 0.07 ppb (note the unit change). Equation 9 can be used for any parameter that has a decay rate of 4 per day; for other rates, use Equation 8.

Most of this large decrease is due to residence time and decay. As a sensitivity analysis, the decay coefficient is decreased by a factor of 10. The resulting concentration is then 0.7 ppb. Then, when the mixing zone area is cut down to five acres, the resulting concentration is 14 ppb. Using the original decay rate and a 5-acre zone, the concentration is 2.6 ppb.

The above numbers are conservative for several reasons.

- No sedimentation has been incorporated; several chlorinated by-products have an affinity for particulates that will settle out of the water column, and eventually be buried and removed from active participation in the lake ecosystem.
- No immediate demand in the lake has been considered, which could be exerted on CRC.

- The assumption of complete mixing is very conservative, particularly since steady state is also assumed.

Consider the alternative of plug flow. This is not an unreasonable assumption, given the location and direction of the discharge port, and the use of a 200 acre mixing zone versus the whole lake. Since a small, localized area of the lake is being used as a mixing zone, plug flow is more likely to occur. The lake discharge concentration would be:

$$C_i = C_D e^{-KT} \quad (10)$$

where

C_i = lake discharge concentration (mg/l)

C_D = blowdown concentration (mg/l)

T = travel time ($= V_L/Q_L$)

For a 200-acre mixing zone and a flow of 43 cfs, the travel time is 94 days. A decay rate of 4 per day results in a C_i of effectively zero. A very low decay rate of 0.4 per day and a blowdown concentration of 0.27 mg/l computes to a lake discharge concentration of 1×10^{-17} mg/l.

Modeling Chlorine Levels in the Cape Fear River

The concentrations in the Cape Fear River just downstream of Buckhorn Dam would be:

$$C_{CF} = Q_L/Q_{CF} * C_L * e^{-KT} \quad (11)$$

where

C_{CF} = Cape Fear concentrations (same units as C_L)

Q_{CF} = Cape Fear river flow (cfs)

T = Travel time down Buckhorn Creek

Buckhorn Creek is about 2.5 miles in length. A velocity of 1 fps, a normal stream velocity under pre-impoundment conditions, results in a travel time of 3.7 hr. This velocity is conservative, probably being lower due to the formation of Harris Lake. If the decay rate of 4 per day is still used, the concentrations leaving Buckhorn Creek and entering the Cape Fear are 54% of those leaving Harris Lake.

Q_{CF} has an average value of 3125 cfs at Buckhorn Dam, making Equation 11:

$$C_{CF} = 0.0076 C_L \quad (12)$$

In other words, the river level is less than 1% of the lake concentration. The 0.07 ppb lake level thus reduces to 0.5 parts per trillion (ppt) in the river.

Determination of Chlorine Components

Up until now, total chlorine levels characterized by combined residual reactions have been examined. The following table, taken from Bean (1983a), summarizes the breakdown of chlorine under mild (<20 mg/l) doses:

LOW-LEVEL CHLORINATION OF NATURAL WATERS
(Where Does the Chlorine Go?)

PROCESS	PERCENTAGE OF CHLORINE USED
Haloform formation	0.5-5
Organic oxidation to CO ₂	50-80
Haloacetonitriles	0-5
Nonhaloform organic halogen (e.g., trihalomethane precursors depolymerized organohalogen)	1-6
Halogenated phenols	~0.1

These values were based on laboratory studies and have recently been updated. A newer publication studied actual power plant chlorination. Data were obtained at the following 3 natural draft cooling-tower facilities (Bean 1983b):

FACILITY	CHLORINE ADDED (kg)	(g)	HALOFORMS DISCHARGED (% of dose)	(g)	HALOPHENOLS DISCHARGED (% of dose)
Arkansas Unit 2	57	70	0.12	17	0.03
Beaver Valley Unit 1	114	67	0.06	22	0.02
Trojan	114	120	0.11	75	0.07
Average	95	86	0.10	38	0.04

Using these values, 0.1% of the total dose goes to haloforms. A total dose of 725 lb/day results in a haloform discharge of 0.7 lb/day. Plugging this number into Equation 8 gives a lake level of 0.01 ppb of haloforms for 200 acres and 0.3 ppb over 5 acres. The incremental Cape Fear concentration would then be 0.1 ppt, using Equation 12. This approach is extremely conservative as it accounts

for no losses within the plant (Jolley et al. [1983] observed a loss of 84% through a cooling tower) or the lake. Again, this also assumes that the decay rates for the haloforms are the same at that used for CRC. The levels of halophenols will be lower than the haloforms.

The Bean table can also be used to partition the results from the plant model. However, this table is based on total dose, whereas LMS values include the removal of chlorine by inorganic demand. Since the LMS values are representative of CRC, the highest ratio of haloforms to oxidants in Bean's table ($0.1\%/50\% = 0.2\%$) should be used to be conservative. In other words, since the model results are indicative of CRC, and Bean has a minimum of 50% of the dose as oxidants (CRC), the amount of haloforms, as a fraction of CRC, is double the numbers presented in the table, or 0.2%. Using the computed lake level of 0.07 ppb results in a haloform level of 0.1 ppt in the lake.

Summary

As already mentioned, several conservative assumptions were used in developing the three chlorine models to determine the effect of the Harris plant discharge on the cooling lake and the Cape Fear River. The following results were obtained:

Total chlorine (TC) used (maximum rate)	725	lb/day
Total chlorine released from the cooling tower	9.4	lb/day
Total chlorine released to lake	6.3	lb/day
Average TC concentration over a completely-mixed 5-acre zone	2.6	ppb
Average TC concentration over a completely-mixed 200-acre mixing zone	0.07	ppb
Average TC concentration discharged to Cape Fear	0.04	ppb or less
Average incremental TC concentration in Cape Fear	0.05	ppt or less

The above levels are indicative of CRC. A conservative estimate of haloforms would be 0.2% of the above concentrations; for halogenated phenold, 0.08%.

The current lower detectability limit of residual chlorine in freshwater is 1.8 ppb by amperometric titration (Jolley and Carpenter 1982), which implies an immeasurable value at the edge of the 200 acre mixing zone.

ATTACHMENT B

AQUATIC EFFECTS OF CHLORINE

Tables B-1 and B-2 contain selected toxicity, uptake and depuration data for aquatic organisms. Table B-3 indicates some of the potential human health effects of chlorinated compounds that have been identified from chlorinated waters. The information contained in these tables by no means exhausts the extensive data base concerning the effects of chlorinated compounds on the aquatic environment and human health. Where possible, data for species indigenous to the Cape Fear system or for closely related species were chosen. Data on salmonids were not included except where little or no other information existed. Among fish species, salmonids are the most sensitive to chlorinated water, and because they are cold-water fishes would not be expected to occur in the Cape Fear system.

The levels of total residual chlorine, free chlorine, chloramines, trihalomethanes, other halomethanes, and chlorophenols found to cause acute and chronic toxicity in fish species are above the maximum levels of total chlorine predicted to occur in the 5-acre mixing zone (0.0026 mg/l). The lowest level of any chlorine species causing an effect on fish species was chloramine (Table B-1). Arthur and Eaton (1971) found that at 0.016 mg/l total chloramine reproduction, measured as number of eggs produced, was reduced in fathead minnows (Pimephales promelas). Although not an indigenous species, this was the only long-term chronic test where such a sublethal effect was measured.

For invertebrates, acute toxicity levels for the various chlorine species were above the 0.0026 mg/l total chlorine concentration predicted for the 5-acre mixing zone. However, the chronic no-effect

level for the scud, Gammarus pseudolimnaeus, exposed continuously for 15 weeks to chloramines is estimated to be <0.003 mg/l total chloramine. This result is based on reduced production of young. While the no-effect concentration for this species is the same as the conservatively predicted level for the 5-acre mixing zone, it is greater than the predicted level for the 200-acre mixing zone, the discharge to the Cape Fear River, and the Cape Fear River itself.

Brungs (1973), in a review of the effects of residual chlorine on aquatic life, suggested that, for areas receiving waste treated continuously with chlorine, total residual chlorine should not exceed 0.01 mg/l for the protection of the more resistant organisms or 0.002 mg/l for the protection of most aquatic organisms. As a result, discharge of chlorinated cooling tower blowdown is not expected to have any measurable effect on the aquatic biota beyond the 5-acre mixing zone.

Chlorine interactions with both temperature and metals have been reported. In general, chlorine toxicity increases with temperature. The data presented in Table B-1 reflect the highest temperature tested, with the exception of Heath (1977) for bluegill, where the lowest 96-hr toxicity value was chosen. Chloramine toxicity to golden shiners (Notemigonus crysoleucas) and channel catfish (Ictalurus punctatus) decreased with temperature (Table B-1). These data are an exception to the general trend and no reason is evident. The reported studies on chlorine-metal interactions (Dickson et al. 1974; Crumley et al. 1980) were all conducted at levels well above those predicted for the 5-acre mixing zone, so any synergistic effects between metals and chlorine will probably be negligible.

Data are relatively sparse on bioconcentration factors (BCF) and depuration rates for chlorine species in fish and shellfish. Neither chloroform nor bromoform bioconcentrates much above levels

found in the water (Table B-2). For chloroform, the BCF ranged from 2-6; for bromoform the BCF for molluscs was ~1, indicating little or no accumulation above water concentrations. For shrimp and menhaden, the BCF ranged from 3-50; however, the data indicate a steady-state level of 0.04 $\mu\text{g/g}$ (ppm) in tissue at the higher exposure concentrations, which is similar to that found in organisms exposed to lower water concentrations (Gibson et al. 1981).

The highest BCFs were for chlorophenols (83-1300). However, chlorophenols are expected to be present only at 0.1% of the total chlorine, so any bioaccumulation will be slight.

In all cases depuration rates are rapid. For the trihalomethanes, the half-life is one day or less; for chlorophenols, half-life is on the order of 1-10 days, depending on the organism and form of phenol.

Data on carcinogenic potential also include oncogenecity which is defined as tumor-forming. It should be noted that not all tumors are malignant. Of the compounds listed in Table B-3, only chloroform and 2,4,6 chlorophenol are currently regulated by EPA as carcinogens.

TABLE B-1 (Page 1 of 2)

TOXICITY DATA FOR
CHLORINATED COMPOUNDS^a

COMPOUND	SPECIES	TEST	DURATION	RESULTS (mg/l)	SOURCE ^a
TRIHALOMETHANES					
Chloroform	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	110	Anderson and Lusty 1980
	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	13.3-22.3	
	<u>Micropterus salmoides</u>	acute LC50	96 hrs	45.4-55.8	
	<u>Ictalurus punctatus</u>	acute LC50	96 hrs	>75	
Bromoform	<u>Brevoortia tyrannus</u>	acute LC50	96 hrs	12	Gibson et al. 1981
	<u>Penaeus aztecus</u>	acute LC50	96 hrs	26	
	<u>Mercenaria mercenaria</u>	acute LC50	96 hrs	30-40	Gibson et al. 1981
	<u>Crassostrea virginica</u>				
	<u>Protothaca staninea</u>				
	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	29.3	
	<u>Daphnia magna</u>	acute LC50	96 hrs	46.5	
OTHER HALOMETHANES					
Dichloromethane	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	220	
Methylene chloride	<u>Daphnia magna</u>	acute LC50	96 hrs	224	
	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	224	
Methyl chloride	<u>Cyprinodon variegatus</u>	acute LC50	96 hrs	331	
	<u>Pimephales promelas</u>	acute LC50	96 hrs	193	
	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	550	
	<u>Menidia beryllina</u>	acute LC50	96 hrs	270	
Methylbromide	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	11	
	<u>Menidia beryllina</u>	acute LC50	96 hrs	12	
CHLORAMINES					
Monachloramine	<u>Notropis atherinoides</u>	acute LC50 @ 30°C		0.35 (as total residual chlorine)	Brooks and Seegert 1978
	<u>N. cornutus</u>	acute LC50 @ 30°C		0.45 (as total residual chlorine)	Brooks and Seegert 1978
	<u>N. spilopterus</u>	acute LC50 @ 30°C		0.41 (as total residual chlorine)	Brooks and Seegert 1978
	<u>Lepomis macrochirus</u>	acute LC50 @ 30°C		1.23 (as total residual chlorine)	Brooks and Seegert 1978
	<u>Cyprinus carpio</u>	acute LC50 @ 30°C		1.50 (as total residual chlorine)	Brooks and Seegert 1978
	<u>Gammarus pseudolimnaeus</u>	chronic-life cycle	15 wks	<0.003 ^b	Arthur and Eaton 1971
	<u>Pimephales promelas</u>	chronic-life cycle	21 wks	<0.016 ^b	Arthur and Eaton 1971
	<u>Notemigonus crysoleucas</u>	acute LC50 @ 5°C	96 hrs	0.72	Heath 1978
		@ 24 °C	96 hrs	0.93	Heath 1978
	<u>Ictalurus punctatus</u>	acute LC50 @ 5°C	96 hrs	0.28	Heath 1978
		@ 24°C	96 hrs	0.33	Heath 1978

TABLE B-1 (Page 2 of 2)

TOXICITY DATA FOR
CHLORINATED COMPOUNDS

COMPOUND	SPECIES	TEST	DURATION	RESULTS (mg/l)	SOURCE ^a
<u>CHLOROPHENOLS</u>					
2-chlorophenol	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	8.15 ^c	
	<u>Pimephales promelas</u>	chronic early life stage test	30 days	>3.9	
4-chlorophenol	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	3.8	
	<u>Carassius auratus</u>	acute LC50	24 hrs	9.0	
	<u>Carassius auratus</u>	acute LC54	8 hrs	6.3	
3-chlorophenol	<u>Salmo gairdneri</u>	acute ^d	48 hrs	10.0	
4-chloro- 3-methyl phenol	<u>Pimephales promelas</u>	acute LC50	96 hrs	0.03	
2,4,6-trichloro- phenol	<u>Daphnia magna</u>	acute LC50	96 hrs	2.6	
	<u>Pimephales promelas</u>	acute LC50	96 hrs	9.0	
	<u>Pimephales promelas</u>	chronic early life stage test	30 days	0.7	
	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	0.3	
<u>FREE CHLORINE</u>	<u>Notemigonus crysoleucas</u>	acute LC50 @ 24 °C	96 hrs	0.19 ^e	Heath 1978
	<u>Ictalurus punctatus</u>	acute LC50 @ 24 °C	96 hrs	0.06 ^e	Heath 1978
	<u>Lepomis macrochirus</u>	acute LC50 @ 25 °C	96 hrs	0.39 ^e	Heath 1978
<u>TOTAL RESIDUAL CHLORINE</u>	<u>Alosa aestivalis</u> (egg)	acute LC50	80 hrs	0.33 ^f	Morgan and Prince 1977
	<u>Alosa aestivalis</u> (larvae-1-2-days old)	acute LC50	24 hrs	0.28-0.32	Morgan and Prince 1977
	<u>Alosa aestivalis</u> (larvae-1-2-days old)	acute LC50	48 hrs	0.24-0.25	Morgan and Prince 1977
	<u>Alosa aestivalis</u> (3 day old larvae)	acute LC50	24 hrs	~0.10-0.12	Morgan and Prince 1977

^a All data compiled from 1980 EPA water quality documents unless other wise noted.^b No effect concentration based on reduced production of young.^c Geometric mean of all values for the species.^d Lowest concentration that killed 50% or more.^e Measured as TRC at the peak of the chlorination pulse with free chlorine representing >50%.^f At <0.26 mg/l TRC, 1.6% of larvae that hatched had vertebral abnormalities; at 0.31-0.38 mg/l about 15% were abnormal.

TABLE B-2

BIOCONCENTRATION FACTORS (BCF)
AND DEPURATION RATES FOR
CHLORINATED COMPOUNDS

COMPOUND	SPECIES	BCF	TISSUE	DEPURATION RATE	SOURCE ^a
TRIHALOMETHANES					
Chloroform	<u>Lepomis macrochirus</u>	6	Whole body	t 1/2 <1 day ^b	Veith et al. 1980
	<u>Lepomis macrochirus</u>	2-3	Whole body	t 1/2 <20 hrs ^b	Anderson and Lusty 1980
	<u>Micropterus salmoides</u>	2	Whole body	t 1/2 <4 hrs ^b	Anderson and Lusty 1980
	<u>Tetralurus punctatus</u>	3		t 1/2 < 2 hrs ^b	Anderson and Lusty 1980
Bromoform	<u>Mercenaria mercenaria</u>	1	Whole body		Gibson et al. 1981
	<u>Crassostrea virginica</u>		Whole body		
	<u>Protothaca staminea</u>	3-50	Whole body		Gibson et al. 1981
	<u>Peneus aztecus</u>		Whole body		
	<u>Bravoortia tyrannus</u>		Whole body		
CHLOROPHENOLS					
2-chlorophenol	<u>Lepomis macrochirus</u>	214	Whole body	t 1/2 <1 day	Veith et al. 1980
2,4,5-trichloro-phenol		110 ^c			
2,4,6-trichloro-phenol	<u>Salmo gairdneri</u>			t 1/2 <10 day	Landner et al. 1977
	<u>Mytilus edulis</u>	35-60	Soft body		Geyer et al. 1982
	<u>Aquatic organics</u>	150 ^c	Edible portion		
BROMOORGANICS					
2,4,6-tribromo-phenol	<u>Pimephales promelas</u>	83	Whole body		Kuehl et al. 1978
2,4,6-tribromo-anisole	<u>Pimephales promelas</u>	1300	Whole body		Kuehl et al. 1978

^aAll data compiled from 1980 EPA water quality criteria documents unless otherwise noted.

^bEstimated from data tables.

^cCalculated BCF (EPA 1980)

TABLE B-1 (Page 1 of 2)

TOXICITY DATA FOR
CHLORINATED COMPOUNDS^a

COMPOUND	SPECIES	TEST	DURATION	RESULTS (mg/l)	SOURCE ^a
TRIHALOMETHANES					
Chloroform	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	110	Anderson and Lusty 1980
	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	13.3-22.3	
	<u>Micropterus salmoides</u>	acute LC50	96 hrs	45.4-55.8	
	<u>Ictalurus punctatus</u>	acute LC50	96 hrs	>75	
Bromoform	<u>Brevoortia tyrannus</u>	acute LC50	96 hrs	12	Gibson et al. 1981
	<u>Penaeus aztecus</u>	acute LC50	96 hrs	26	
	<u>Mercenaria mercenaria</u>	acute LC50	96 hrs	30-40	Gibson et al. 1981
	<u>Crassostrea virginica</u>				
	<u>Protothaca staninea</u>				
	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	29.3	
	<u>Daphnia magna</u>	acute LC50	96 hrs	46.5	
OTHER HALOMETHANES					
Dichloromethane	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	220	
Methylene chloride	<u>Daphnia magna</u>	acute LC50	96 hrs	224	
	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	224	
	<u>Cyprinodon variegatus</u>	acute LC50	96 hrs	331	
	<u>Pimephales promelas</u>	acute LC50	96 hrs	193	
	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	550	
Methyl chloride	<u>Menidia beryllina</u>	acute LC50	96 hrs	270	
Methylbromide	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	11	
	<u>Menidia beryllina</u>	acute LC50	96 hrs	12	
CHLORAMINES					
Monachloramine	<u>Notropis atherinoides</u>	acute LC50 @ 30°C		0.35 (as total residual chlorine)	Brooks and Seegert 1978
	<u>N. cornutus</u>	acute LC50 @ 30°C		0.45 (as total residual chlorine)	Brooks and Seegert 1978
	<u>N. spilopterus</u>	acute LC50 @ 30°C		0.41 (as total residual chlorine)	Brooks and Seegert 1978
	<u>Lepomis macrochirus</u>	acute LC50 @ 30°C		1.23 (as total residual chlorine)	Brooks and Seegert 1978
	<u>Cyprinus carpio</u>	acute LC50 @ 30°C		1.50 (as total residual chlorine)	Brooks and Seegert 1978
	<u>Gammarus pseudolimnaeus</u>	chronic-life cycle	15 wks	<0.003 ^b	Arthur and Eaton 1971
	<u>Pimephales promelas</u>	chronic-life cycle	21 wks	<0.016 ^b	Arthur and Eaton 1971
	<u>Notemigonus crysoleucas</u>	acute LC50 @ 5°C	96 hrs	0.72	Heath 1978
		@ 24 °C	96 hrs	0.93	Heath 1978
	<u>Ictalurus punctatus</u>	acute LC50 @ 5°C	96 hrs	0.28	Heath 1978
		@ 24°C	96 hrs	0.33	Heath 1978

TABLE B-1 (Page 2 of 2)

TOXICITY DATA FOR
CHLORINATED COMPOUNDS

COMPOUND	SPECIES	TEST	DURATION	RESULTS (mg/l)	SOURCE ^a
<u>CHLOROPHENOLS</u>					
2-chlorophenol	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	8.15 ^c	
	<u>Pimephales promelas</u>	chronic early life stage test	30 days	>3.9	
4-chlorophenol	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	3.8	
	<u>Carassius auratus</u>	acute LC50	24 hrs	9.0	
	<u>Carassius auratus</u>	acute LC54	8 hrs	6.3	
3-chlorophenol	<u>Salmo gairdneri</u>	acute ^d	48 hrs	10.0	
4-chloro- 3-methyl phenol	<u>Pimephales promelas</u>	acute LC50	96 hrs	0.03	
2,4,6-trichloro- phenol	<u>Daphnia magna</u>	acute LC50	96 hrs	2.6	
	<u>Pimephales promelas</u>	acute LC50	96 hrs	9.0	
	<u>Pimephales promelas</u>	chronic early life stage test	30 days	0.7	
	<u>Lepomis macrochirus</u>	acute LC50	96 hrs	0.3	
<u>FREE CHLORINE</u>	<u>Notemigonus crysoleucas</u>	acute LC50 @ 24 °C	96 hrs	0.19 ^e	Heath 1978
	<u>Ictalurus punctatus</u>	acute LC50 @ 24 °C	96 hrs	0.06 ^e	Heath 1978
	<u>Lepomis macrochirus</u>	acute LC50 @ 25°C	96 hrs	0.39 ^e	Heath 1978
<u>TOTAL RESIDUAL CHLORINE</u>	<u>Alosa aestivalis</u> (egg)	acute LC50	80 hrs	0.33 ^f	Morgan and Prince 1977
	<u>Alosa aestivalis</u> (larvae-1-2-days old)	acute LC50	24 hrs	0.28-0.32	Morgan and Prince 1977
	<u>Alosa aestivalis</u> (larvae-1-2-days old)	acute LC50	48 hrs	0.24-0.25	Morgan and Prince 1977
	<u>Alosa aestivalis</u> (3 day old larvae)	acute LC50	24 hrs	~0.10-0.12	Morgan and Prince 1977

^a All data compiled from 1980 EPA water quality documents unless other wise noted.^b No effect concentration based on reduced production of young.^c Geometric mean of all values for the species.^d Lowest concentration that killed 50% or more.^e Measured as TRC at the peak of the chlorination pulse with free chlorine representing >50%.^f At <0.26 mg/l TRC, 1.6% of larvae that hatched had vertebral abnormalities; at 0.31-0.38 mg/l about 15% were abnormal.

TABLE B-2
BIOCONCENTRATION FACTORS (BCF)
AND DEPURATION RATES FOR
CHLORINATED COMPOUNDS

COMPOUND	SPECIES	BCF	TISSUE	DEPURATION RATE	SOURCE ^a
TRIHALOMETHANES					
Chloroform	<u>Lepomis macrochirus</u>	6	Whole body	t 1/2 <1 day ^b	Veith et al. 1980
	<u>Lepomis macrochirus</u>	2-3	Whole body	t 1/2 <20 hrs ^b	Anderson and Lusty 1980
	<u>Micropterus salmoides</u>	2	Whole body	t 1/2 <4 hrs ^b	Anderson and Lusty 1980
	<u>Tetralurus punctatus</u>	3		t 1/2 < 2 hrs ^b	Anderson and Lusty 1980
Bromoform	<u>Mercenaria mercenaria</u>	1	Whole body		Gibson et al. 1981
	<u>Crassostrea virginica</u>		Whole body		
	<u>Protothaca staminea</u>		Whole body		
	<u>Penceus aztecus</u>	3-50	Whole body		Gibson et al. 1981
	<u>Brevoortia tyrannus</u>		Whole body		
CHLOROPHENOLS					
2-chlorophenol	<u>Lepomis macrochirus</u>	214	Whole body	t 1/2 <1 day	Veith et al. 1980
2,4,5-trichloro-phenol		110 ^c			
2,4,6-trichloro-phenol	<u>Salmo gairdneri</u>			t 1/2 <10 day	Landner et al. 1977
	<u>Mytilus edulis</u>	35-60	Soft body		Geyer et al. 1982
	<u>Aquatic organics</u>	150 ^c	Edible portion		
BROMOORGANICS					
2,4,6-tribromo-phenol	<u>Pimephales promelas</u>	83	Whole body		Kuehl et al. 1978
2,4,6-tribromo-anisole	<u>Pimephales promelas</u>	1300	Whole body		Kuehl et al. 1978

^aAll data compiled from 1980 EPA water quality criteria documents unless otherwise noted.

^bEstimated from data tables.

^cCalculated BCF (EPA 1980)

TABLE B-3

CARCINOGENIC AND ONCOGENIC POTENTIAL OF SOME CHLORINATED COMPOUNDS^a

COMPOUND	CARCINOGENIC	ONCOGENIC	SOURCE
<u>TRIHALOMETHANES</u>			
Chloroform	+		Simmon and Tardiff 1978 Simmon and Tardiff 1978 and EPA 1980
Bromoform	+		
Bromodichloromethane	Suspected		
<u>CHLORAMINES</u>			
Monochloramine	Suspected ^b		
<u>OTHER HALOMETHANES</u>			
Dichloromethane	Suspected ^b		Simmon and Tardiff 1978 and EPA 1980
<u>CHLOROPHENOLS</u>			
2-chlorophenol	+ ^c	+ ^c	Exon and Koller 1983 and EPA 1980
3-chlorophenol		+ ^c	
2,4,5-trichlorophenol		+ ^c	Severn 1980
2,4,6-trichlorophenol	+		

^aAll data compiled from 1980 EPA water quality criteria documents unless otherwise noted.

^bBeing tested.

^cExhibits promoter activity only.

ATTACHMENT C

REFERENCES CITED AND LITERATURE REVIEWED

- Aaberg, R.L., R.A. Peloquin, D.L. Streng, and P.J. Mellinger. 1983. An aquatic-pathways model to predict the fate of phenolic compounds. Pacific Northwest Laboratory Report PNL-4202.
- Anderson, D.R., and E.W. Lusty. 1980. Acute toxicity and bioaccumulation of chloroform to four species of freshwater fish. NUREG/CR-0893.
- Arthur, J.W., and J.G. Eaton. 1971. Chloramine toxicity to the amphipod Gammarus pseudolimnaeus and the fathead minnow (Pimephales promelas). J. Fish. Res. Bd. Canada 28(12):1841-1845.
- Bean, R.M. 1983. Recent progress in the organic chemistry of water chlorination, p. 843-850. In R.L. Jolley, W.A. Brungs, J.A. Cotruvo, R.B. Cumming, J.S. Mattice, and V.A. Jacobs (eds.), Water chlorination: environmental impact and health effects. Vol. 4. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.
- Bean, R.M., C.I. Gibson, and D.R. Anderson. 1981. Biocide by-products in aquatic environments. NUREG/CR-1300.
- Brooks, A.S., and G.L. Seegert. 1978. A preliminary look at the effects of intermittent chlorination on selected warmwater fishes, p. 95-109. In R.L. Jolley, H. Gorchev, and P.H. Hamilton Jr. (eds.), Water chlorination: environmental impact and health effects. Vol. 2. Proceedings of the second conference on the environmental impact of water chlorination, Gatlinburg, TN, October 31-November 4, 1977. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.
- Brungs, W.A. 1973. Effects of residual chlorine on aquatic life. J. Water Pollut. Control Fed. 45(10):2180-2193.
- Buikema, A.L. Jr., M.J. McGinniss, and J. Cairns Jr. 1979. Phenolics in aquatic ecosystems: A selected review of recent literature. Mar. Environ. Res. 2:87-181.
- Carolina Power & Light Company (CP&L). 1982. Shearon Harris Nuclear Power Plant environmental report, operating license stage. Revision 5.
- Crumley, S.C., Q.J. Stober, and P.A. Dinnel. 1980. Evaluation of factors affecting the toxicity of chlorine to aquatic organisms. NUREG/CR-1350.

ATTACHMENT C

REFERENCES CITED AND LITERATURE REVIEWED (Continued)

- Dickson, K.L., A.C. Hendricks, J.S. Crossman, and J. Cairns Jr. 1974. Effects of intermittently chlorinated cooling tower blowdown on fish and invertebrates. *Environ. Sci. Technol.* 8:845-849.
- Draley, J.E. 1973. Chlorination experiments at the John E. Amos Plant of the Appalachian Power Company: April 9-10, 1973. ANL/ES-23.
- Exon, J.H., and L.D. Koller. 1983. Alteration of transplacental carcinogenesis by chlorinated phenols, p. 1177-1188. In R.L. Jolley, W.A. Brungs, J.A. Cotruvo, R.B. Cumming, J.S. Mattice, and V.A. Jacobs (eds.), *Water chlorination: environmental impact and health effects*. Vol. 4. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.
- Geyer, H., P. Sheehan, D. Kotzias, D. Freitag, and F. Korte. 1982. Prediction of ecotoxicological behavior of chemicals: relationship between physico-chemical properties and bioaccumulation of organic chemicals in the mussel Mytilus edulis. *Chemosphere* 11(11):1121-1134.
- Gibson, C.I., F.C. Tone, P. Wilkinson, J.W. Blaylock, and R.E. Schirmer. 1981. Toxicity, bioaccumulation and depuration of bromoform in five marine species. NUREG/CR-1297.
- Haag, W.R., and M.H. Lietzke. 1980. A kinetic model for predicting the concentrations of active halogen species in chlorinated saline cooling water, p. 415-426. In R.L. Jolley, W.A. Brungs, and R.B. Cumming (eds.), *Water chlorination: environmental impact and health effects*. Vol. 3. Ann Arbor Science Publishers Inc., Ann Arbor, MI.
- Hall, L.W., G.R. Helz, and D.T. Burton. 1981. Power plant chlorination: a biological and chemical assessment. Ann Arbor Science Publishers, Inc., Ann Arbor, MI. [EPRI Report EA-1750.]
- Heath, A.G. 1978. Influence of chlorine form and ambient temperature on the toxicity of intermittent chlorination to freshwater fish, p. 123-134. In R.L. Jolley, H. Gorchev, and P.H. Hamilton (eds.), *Water chlorination: environmental impact and health effects*. Vol. 2. Proceedings of the second conference on the environmental impact of water chlorination, Gatlinburg, TN, October 31-November, 1977. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.

ATTACHMENT C

REFERENCES CITED AND LITERATURE REVIEWED
(Continued)

- Jolley, R.L. (ed.). 1978. Water chlorination: environmental impact and health effects. Vol. 1. Proceedings of the conference on the environmental impact of water chlorination, Oak Ridge National Lab., Oak Ridge, TN, October 22-24, 1975. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.
- Jolley, R.L., W.A. Brungs, J.A. Cotruvo, R.B. Cumming, J.S. Matrice, and V.A. Jacobs. 1983. Water chlorination: environmental impact and health effects. Vol. 4. Proceedings of the fourth conference on water chlorination: environmental impact and health effects, Pacific Grove, CA, October 18-23, 1981. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.
- Jolley, R.L., W.A. Brungs, and R.B. Cumming. 1980. Water chlorination: environmental impact and health effects. Vol. 3. Proceedings of the third conference on water chlorination: environmental impact and health effects, Colorado Springs, CO, October 28-November 2, 1979. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.
- Jolley, R.L., and J.H. Carpenter. 1982. Aqueous chemistry of chlorine: chemistry, analysis, and environmental fate of reactive species. Oak Ridge National Laboratory, Oak Ridge, TN. ORNL/TM-7788.
- Jolley, R.L., H. Gorchev, and D.H. Hamilton Jr. 1978. Water chlorination: environmental impact and health effects. Vol. 2. Proceedings of the second conference on the environmental impact of water chlorination, Gatlinburg, TN, October 31-November 4, 1977. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.
- Jolley, R.L., W.W. Pitt, F.G. Taylor Jr., S.J. Hartmann, G. Jones Jr., and J.E. Thompson. 1978. An experimental assessment of halogenated organics in water from cooling towers and once-through systems. In R.L. Jolley, H. Gorchev, and P.H. Hamilton Jr. (eds.), Water chlorination: environmental impact and health effects. Vol. 2. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.
- Katz, B.M. 1977. Chlorine dissipation and toxicity presence of nitrogenous compounds. J. Water Pollut. Control Fed. 49(7): 1627-1635.
- Kim, B.R., and Yin-Sin Lin. 1982. Decay and transport of monochloramine in river. Georgia Institute of Technology, School of Civil Engineering Report SCEGIT-82-103. [Prepared for the Tennessee Valley Authority.]

ATTACHMENT C

REFERENCES CITED AND LITERATURE REVIEWED
(Continued)

- Keuhl, D.W., G.D. Veith, and E.N. Leonard. 1978. Brominated compounds found in waste treatment effluents and their capacity to bioaccumulate, p. 175-194. In Jolley, R.L. (ed.), Water chlorination: environmental impact and health effects. Vol. 1. Proceedings of the conference on the environmental impact of water chlorination, Oak Ridge National Lab., Oak Ridge, TN, October 22-24, 1975. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.
- Landner, L., K. Lindstrom, M. Karlsson, J. Nordin, and L. Sorensen. 1977. Bioaccumulation in fish of chlorinated phenols from Kraft pulp mill bleachery effluents. Bull. Environ. Contam. Toxicol. 18(6):663-673.
- Lawler Matusky & Skelly Engineers (LMS). 1983. Chlorine plume modeling study. Prepared for the Utility Water Act Group. LMSE-83/0091&356/003. April 1983.
- Lietzke, M.H. 1978a. A kinetic model for predicting the composition of chlorinated water discharged from power plant cooling systems, p. 367-378. In R.L. Jolley (ed.), Water chlorination: environmental impact and health effects. Vol. 1. Ann Arbor Science Publishers Inc., Ann Arbor, MI.
- Lietzke, M.H. 1978b. A kinetic model for predicting the composition of chlorinated water discharged from power plant cooling systems, p. 707-716. In R.L. Jolley, H. Gorchev, and D.H. Hamilton Jr. (eds.), Water chlorination: environmental impact and health effects. Vol. 2. Ann Arbor Science Publishers Inc., Ann Arbor, MI.
- Mattice, J.S., and H.E. Zittel. 1976. Site-specific evaluation of power plant chlorination. J. Water Pollut. Control Fed. 48(10):2284-2308.
- Morgan, R.P., II, and R.D. Prince. 1977. Chlorine toxicity to eggs and larvae of five Chesapeake Bay fishes. Trans. Am. Fish. Soc. 106(4):380-385.
- Nelson, G.R. 1973. Predicting and controlling residual chlorine in cooling tower blowdown. EPA-R2-73-273, July 1973.
- Peoples, A.J., C.D. Pfaffenberger, T.M. Shafik, and H.F. Enos. 1979. Determination of volatile purgeable halogenated hydrocarbons in human adipose tissue and blood serum. Bull. Environ. Contam. Toxicol. 23(1/2):244-249.

ATTACHMENT C

REFERENCES CITED AND LITERATURE REVIEWED (Continued)

- Punzi, V.L. 1979. Modelling and predicting free and combined residual chlorine concentrations in cooling tower systems. Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy (Chemical Engineering) at the Polytechnic Institute of New York. June 1979.
- Severn, D.J. 1980. Assessment of human exposure and body burdens of chlorination by-products, p. 55-61. In R.L. Jolley, W.A. Brungs, and R.B. Cumming (eds.), Water chlorination: environmental impact and health effects. Vol. 3. Ann Arbor Science Publishers Inc., Ann Arbor, MI.
- Simmon, V.F., and R.G. Tardiff. 1978. The mutagenic activity of halogenated compounds found in chlorinated drinking water, p. 417-432. In R.L. Jolley, H. Gorchev, and P.H. Hamilton (eds.), Water chlorination: environmental impact and health effects. Vol. 2. Proceedings of the second conference on the environmental impact of water chlorination, Gatlinburg, TN, October 31-November, 1977. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.
- U.S. Environmental Protection Agency (EPA). 1980. Ambient water quality criteria for halomethanes. Environmental Protection Agency, Criteria and Standards Division, Washington, DC. EPA-440/5-80-051.
- U.S. Environmental Protection Agency (EPA). 1980. Ambient water quality criteria for chloroform. Environmental Protection Agency, Criteria and Standards Division, Washington, DC. EPA-440/5-80-033.
- U.S. Environmental Protection Agency (EPA). 1980. Ambient water quality criteria for 2-chlorophenol. Environmental Protection Agency, Criteria and Standards Division, Washington, DC. EPA-440/5-80-034.
- U.S. Environmental Protection Agency (EPA). 1980. Ambient water quality criteria for chlorinated phenols. Environmental Protection Agency, Criteria and Standards Division, Washington, DC. EPA-440/5-80-032.
- U.S. Environmental Protection Agency (EPA). 1982. Steam electric power generating point source category; effluent limitations guidelines, pretreatment standards, and new source performance standards. 47FR52290.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

AM 120

In the Matter of

CAROLINA POWER & LIGHT COMPANY
AND NORTH CAROLINA EASTERN MUNICIPAL
POWER AGENCY

(Shearon Harris Nuclear Power Plant,
Units 1 & 2)

DOCKETING
BRANCH

Docket Nos. 50-400 OL
50-401 OL

CERTIFICATE OF SERVICE

I hereby certify that copies of "Applicants' Motion for Summary Disposition of Eddleman Contention 83/84B," "Applicants' Statement of Material Facts as to Which There is No Genuine Issue to be Heard," "Affidavit of James A. Fava and Hans Plugge" and "Affidavit of William T. Hogarth" were served this 7th day of February, 1984 by deposit in the United States mail, first class, postage prepaid, to the parties on the attached Service List.

This is the 7th day of February.

Hill Carrow

Hill Carrow
Attorney
Carolina Power & Light Company
Post Office Box 1551
Raleigh, North Carolina 27602
(919) 836-6839

Dated: February 7, 1984

SERVICE LIST

James L. Kelley, Esquire
Atomic Safety and Licensing Board
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Mr. Glenn O. Bright
Atomic Safety and Licensing Board
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dr. James H. Carpenter
Atomic Safety and Licensing Board
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Charles A. Barth, Esquire
Myron Karman, Esquire
Office of Executive Legal Director
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Docketing and Service Section
Office of the Secretary
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Mr. Daniel F. Read, President
Chapel Hill Anti-Nuclear
Group Effort
5707 Waycross Street
Raleigh, North Carolina 27606

Dr. Linda Little
Governor's Waste Management Board
513 Albemarle Building
325 Salisbury Street
Raleigh, North Carolina 27611

Ruthanne G. Miller, Esquire
Atomic Safety and Licensing
Board Panel
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

John D. Runkle, Esquire
Conservation Council of North Carolina
307 Granville Road
Chapel Hill, North Carolina 27514

M. Travis Payne, Esquire
Edelstein and Payne
Post Office Box 12643
Raleigh, North Carolina 27605

Dr. Richard D. Wilson
729 Hunter Street
Apex, North Carolina 27502

Mr. Wells Eddleman
718-A Iredell Street
Durham, North Carolina 27705

Thomas A. Baxter, Esquire
John H. O'Neill, Jr., Esquire
Shaw, Pittman, Potts & Trowbridge
1800 M Street, N.W.
Washington, D. C. 20036

Dr. Phyllis Lotchin
108 Bridle Run
Chapel Hill, North Carolina 27514

Bradley W. Jones, Esquire
U. S. Nuclear Regulatory Commission
Region II
101 Marietta Street
Atlanta, Georgia 30303

Robert P. Gruber
Executive Director
Public Staff
North Carolina Utilities Commission
Post Office Box 991
Raleigh, North Carolina 27602