ENCLOSURE

NORTH ANNA POWER STATION

INTAKE FLOW MODIFICATION PROGRAM

ENVIRONMENTAL EVALUATION

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Introduction

This report provides an environmental evaluation of a proposed change of operation at North Anna Power Station Units 1 & 2. Specifically, it is proposed that during the cooler months of the year we would reduce the circulating water flow through the station by removing circulating water pumps from service and by throttling the discharge valves of the circulating water pumps that remain in service. This modification is being made in order to increase the back pressure in the condenser which will help reduce condenser tube vibration and improve the operating efficiency of the station. As a result of this modification, the delta T across the condensers will increase above existing levels with a subsequent increase of water temperatures to the Waste Heat Treatment Facility environment. The BTU licensed discharge limit at outfall 010 in our NPDES permit, No. VA 0052451, will not be exceeded as there will be no increase in thermal output (BTU) from the station and water temperatures at that location are expected to be equal to or less than those that currently exist. As described in the subsequent sections of this report, it has been concluded that this modification should not result in a significant adverse environmental impact. Virginia Power tentatively plans to implement this proposed change of operation during December of 1985 following the scheduled outage of Unit 1.

Site Description

In 1972, Virginia Power impounded the North Anna River creating Lake Anna, resulting in a 3885 hectare (9600-acre) reservoir that provides condenser cooling water for its North Anna Power Station, and a 1376 hectare (3400-acre) Waste Heat Treatment Facility (WHTF) that receives the cooling water and trans-

fers the heat from the water to the atmosphere before discharge into the reservoir (Figure 1). The discharge from Dike 3 of the WHTF into the Lake Anna reservoir is regulated by the National Pollution Discharge Elimination System (NPDES) Permit No. VA 0052451 issued by the Virginia Water Control Board.

The North Anna Power Station is located in Louisa County, Virginia and consists of two nuclear units, each with a total design rating of 2910 Mwt. Commercial operation for Unit 1 began in June, 1978 and Unit 2 was declared commercial in December, 1980. Four circulating water pumps (CWP) per unit, each rated at 13.9 m^3/s, are located at the intake structure. The once-through cooling water system is filtered by a single rotating traveling screen (9.5 mm mesh) in front of each pump. The current nominal temperature change across the condensers with 4 CWP's operating per unit is 7.6°C (13.7°F).

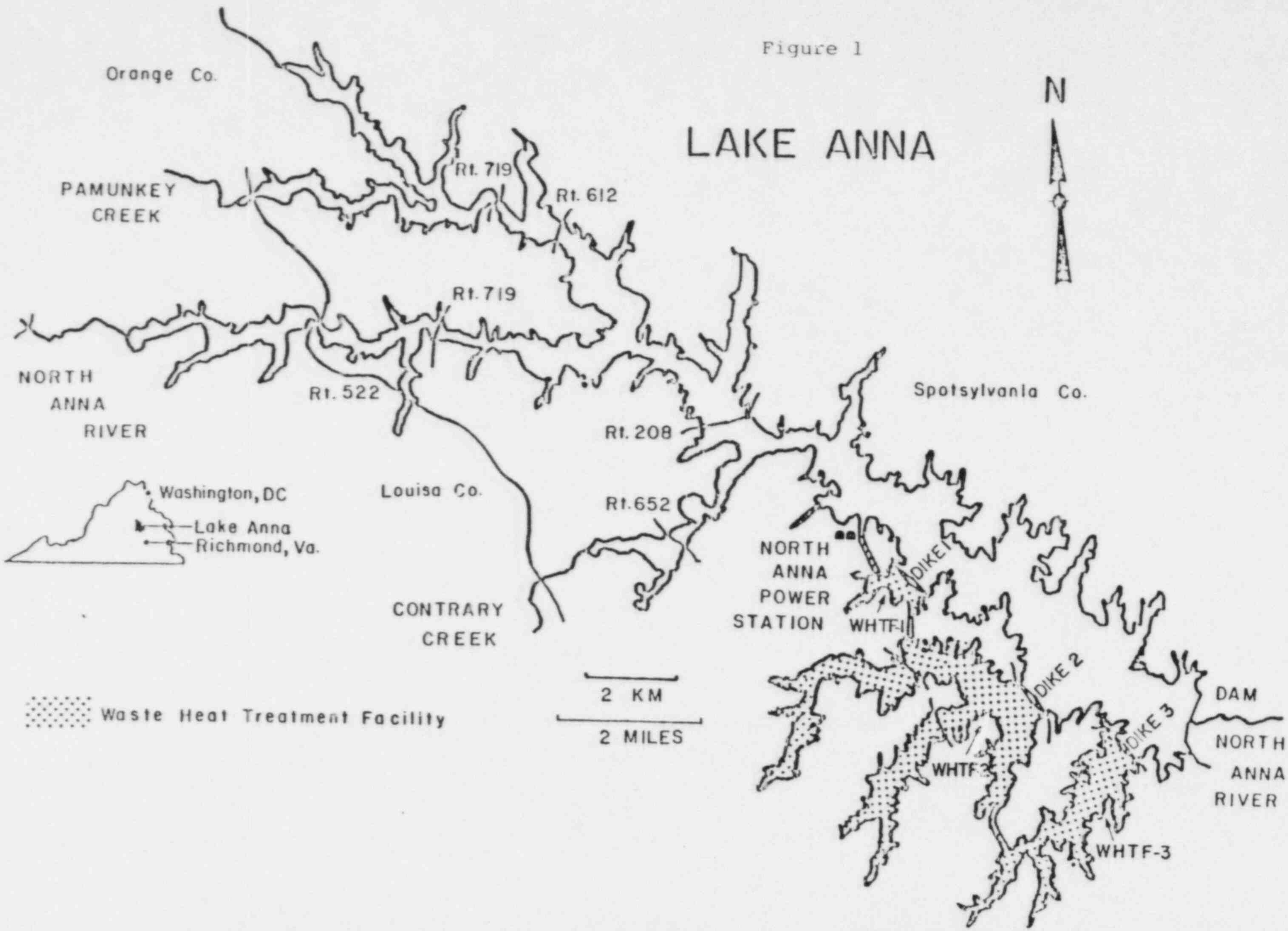
Statement of Problem and Proposed Resolution

The North Anna Power Station Units 1 and 2 condensers have experienced tube leaks requiring frequent waterbox entries to locate leaks and plug tubes. A Virginia Power Condenser Task Force examined this problem in some detail and found that the incidence of tube leaks was much greater during the winter months. The Task Force concluded that high condenser vacuum resulting from cold circulating water was contributing to tube-to-tube vibration damage and may also be aggravating tube-to-tubesheet joint leakage problems.

The condenser tube leaks allow circulating water to leak into the condenser steam space chemically altering the condensate and feedwater systems. Out-of-specification water chemistry results in power level limitations and station outages as well as contributing to steam generator tube corrosion.

Virginia Power has decided that this problem must be addressed and has identified the following benefits for resolution of the problem. The primary benefit would be that reducing condenser tube degradation would improve conden-

Figure 1



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Waste Heat Treatment Facility
WHTF-2
WHTF-3

sate water chemistry, with resultant reduction in secondary system corrosion and possibly fewer steam generator tube leaks. A secondary benefit of reducing cooling water flow in cold weather months is the gain in net power generation resulting from the removal of circulating water pumps (2,000 hp motors) from service and operation of the turbine at or near the backpressure which corresponds to the turbine's optimum heat rate.

Virginia Power has evaluated several approaches to correcting overcooling in the condenser during winter months. These include: 1) reduction of total circulating water flow through a combination of shutting down one or two of the four circulating water pumps and throttling the pump discharge valves on the operating pumps, 2) recirculation of a percentage of the heated condenser discharge to the inlet piping, and 3) bypassing a percentage of the circulating water around the condenser. Because of the large quantities of water either to be recirculated or bypassed to achieve the desired effects, major modifications to the circulating water pipe system would be required for either of the last two alternative approaches. As a result, these options are considered economically impractical. The practical alternative is to reduce flow through the condenser by shutting down one or two pumps and throttling the pump discharge valves. Modifications are required to the circulating water system control circuitry to allow throttling of pump discharge valves and to satisfy the steam dump permissive interlock; however, no pump or piping modifications are required. The reduction of cooling water flow in the winter season is not considered unique to the utility industry as it is known that many power stations practice this modification for various reasons (i.e., improve operating efficiency, reduce condenser tube vibration, reduce screen impingement rates). A fourth option of modifying the air ejector system to increase turbine back pressure was not considered since a resulting increase of dissolved oxygen in the condensate would contribute to steam generator tube degradation.

Since the recommended modification of reducing the number of operating circulating water pumps and throttling the discharge valves on the operating pumps in the cooler seasons of the year results in a higher temperature rise across the condenser, an evaluation of the environmental impact was performed and is included herein.

Temperature Modeling and Delta T Simulation

Dr. E. Eric Adams from the Department of Civil Engineering of Massachusetts Institute of Technology, where a cooling lake model for the North Anna Power Station was developed (Wells et al. 1982; Ho and Adams 1984), simulated condenser temperature rises at various proposed condenser flows (Table 1). Cooler weather throttling would occur starting in the fall (approximately October) when intake water temperatures declined below 18.9°C (66°F) and would be gradually increased through March, depending on intake water temperature, when delta T's across the condensers would approach 15.5°C (28°F). Intake flow would then be gradually increased in the spring to reach current operating levels when water temperatures approach 24°C (75°F). The delta T would remain at present operating levels during the summer months (approximately June - September).

The proposed schedule of condenser operation would result in higher water temperatures in the near field of the WHTF and lower temperatures in the far field of the WHTF (Table 2). Decreasing the condenser cooling water flow with a subsequent delta T increase would result in a lower temperature rise from current operating levels at our permitted discharge into the reservoir. Water temperatures in the lower reservoir are projected to be 0.2°C to 1.0°C less than previously experienced during the months that the proposed change in operation would be in effect. Water temperatures in the WHTF would be higher in WHTF-1 and WHTF-2 and lower in WHTF-3 near the permitted discharge. There are two reasons for this condition: 1) the higher delta T across the condenser results in a

TABLE 1. SIMULATED CONDENSER TEMPERATURE RISE (C) AT VARIOUS INTAKE WATER TEMPERATURES AND FLOWS.

INTAKE TEMPERATURE F (C)		CONDENSER FLOW/UNIT (GPM)	% OF FULL FLOW	CONDENSER TEMP RISE F (C)	APPROXIMATE MONTHS
T > 75 (23.9)	BASELINE CASES	952,800	100	13.7 (7.6)	JUNE-SEPT
T < 75 (23.9)	BASELINE CASES	796,000	83.5	16.4 (9.1)	MAY
T > 75 (23.9)	TEST CASES	952,800	100	13.7 (7.6)	JUNE-SEPT
66 < T < 75 (18.9) (23.9)	TEST CASES	787,000	82.6	16.6 (9.2)	MAY
61 < T < 66 (16.1) (18.9)	TEST CASES	625,000	65.6	20.9 (11.6)	OCT-NOV
55 < T < 61 (12.8) (16.1)	TEST CASES	525,000	55.1	24.9 (13.8)	NOV
50 < T < 55 (10.0) (12.8)	TEST CASES	470,000	49.3	27.8 (15.4)	APR
T < 49.6 (9.8)	TEST CASES	466,000	48.9	28.0 (15.5)	DEC-MAR

TABLE 2. SIMULATED MONTHLY MEAN WATER TEMPERATURE INCREASES (C) RESULTING FROM FLOW MODIFICATIONS ON A 30-DAY SCHEDULE, AVERAGED BY MONTH FOR FIVE YEARS (1978 - 1983).

	DISCHARGE CANAL	WHTF2	WHTF3	LOWER LAKE
JUNE	0	0	0	0
JULY	0	0	0	0
AUG	0	0	0	0
SEP	0	0	0	0
OCT	0	0	0	0
NOV	1.6	0.2	-0.1	-0.2
DEC	4.1	0.4	-0.2	-0.6
JAN	5.0	0.7	-0.1	-0.9
FEB	5.1	1.0	-0.1	-1.0
MAR	5.2	1.1	0	-0.8
APR	5.1	0.9	-0.2	-0.7
MAY	2.9	0.5	-0.2	-0.5

higher temperature at the upstream end of the WHTF which will cause increased heat dissipation by evaporation to the atmosphere; 2) the reduced condenser cooling water flow rate increases the residence time for the heated water in the WHTF, thus allowing more time for the heat dissipation process.

Environmental Assessment

Due to the increased water temperatures in the WHTF, an environmental assessment was conducted and includes:

1) potential for cold shock to fish after a unit trip
2) potential for gas supersaturation in the receiving water and subsequent fish gas bubble disease
3) potential for increased atmospheric fogging
4) seasonal water temperature pattern alteration

Cold Shock

It is well documented that during the cooler seasons of the year fish will tend to congregate near thermal discharges where temperatures approach their preferred or optimum range (Barkley and Perrin 1972; Gibbons et al. 1972; Gammon 1973; Landry and Strawn 1973; Marcy and Galvin 1973; Neill and Magnuson, 1974). It is anticipated that during the winter season at North Anna fish will be attracted to the discharge since temperatures will probably be above 20°C (68°F) during two unit operation. This temperature is within the seasonal temperature range where fish tend to be the most active. As delta T's are increased across the condensers the potential for cold shock to fish increases following a unit trip. Many other factors, of course, may also play a large role in whether a fish kill would occur. Some of these may be location of fish in the discharge area, species present, pump volume, duration of pumping, and mixing characteristics in the discharge area. Planned outages typically involve a gradual reduction in power level that gradually reduces the delta T across the condensers.

Although many factors may be involved in determining the potential for cold shock, the fish that are congregated in the canal could, to some extent, be subjected to a rapid temperature decline which increases the risk of cold shock. Cold shock has been observed at other power stations (American National Standards Institute, 1975). Coutant (1977) provides an excellent description of cold shock and the consideration of power station siting, design and operation.

During winter operation at North Anna Power Station, three possible situations could occur which would involve a potential for cold shock to fish:

1) Two units, eight or six pumps operating, and both units trip
2) Two units, eight or six pumps operating, and one unit trips
3) One unit, four or three pumps operating, and unit trips

The first condition, although possible, is considered highly unlikely to occur and has never occurred at North Anna. If both units did trip simultaneously in the winter then, given the conservative assumptions made on the magnitude and rate of temperature drop, a fish kill would likely occur only in the immediate discharge area of WHTF-1 as fish would be able to seek out waters of ever-decreasing temperatures within the WHTF system. The second condition, which has occurred four times during the winter months since commercial operation of both units, should have no significant impact as the actual discharge temperature would be tempered by the continued discharge of heated water from the unit still operating. The mixing of both cool and warm waters should significantly reduce the risk of cold shock to levels that currently exist with only one unit operating. Under present operating conditions, no fish kills have been reported subsequent to a unit trip. Actual water temperature data following several unit

trips at maximum station operation levels are shown in Table 3. When two units were operating and one unit tripped, the delta-T at the condenser exit was 9.5°C (17.1°F) while the actual maximum hourly delta-T in the discharge canal was only 2.3°C (4.1°F). The third condition has occurred five times during the winter months since commercial operation. The observed maximum temperature drop in the discharge canal was approximately 7.3°C (13.1°F) and no adverse effects on fish life were observed.

Under the proposed modification, with one unit operating with a condenser average delta-T greater than 20°F (Nov. - Apr.) and the other unit inoperable, the inoperable unit will keep at least two circulating water pumps running or the operating unit will reduce its condenser average delta-T to 20°F or less. The water in the discharge canal and WHTF 1 would be a maximum of approximately 14.0°F above ambient, a level which experience has shown to have no adverse effect after a unit trip. Figure 2 shows a generalized chart for protection from cold shock for all freshwater species. Data from the nomograph indicate that the risk of cold shock under the proposed operating conditions is minimal or within acceptable limits.

Mortality associated with cold shock may be considered significant if it primarily affects the sizes and reproductive capacities of local populations (Coutant 1977). One species of fish which probably will concentrate in the canal during an operating winter period will be the threadfin shad, Dorosoma petenense. If a cold kill does occur for this species in the canal, the numbers affected would be offset by the high reproductive potential of the species (Baker and Schmitz 1971). Also, intake impingement rates have historically been highest (up to 75% of annual total) at North Anna during colder periods (Virginia Power 1985). Due to the reduced intake flow during the winter season, impingement rates for several species would be less and help to offset any reduction in the

TABLE 3. WATER TEMPERATURE DATA (C) SUBSEQUENT TO SELECTED ACTUAL UNIT TRIPS AT NORTH ANNA POWER STATION.

	PLANT CONDENSER EXIT WATER MAX HOURLY DELTA T	DISCHARGE CANAL* TEMPERATURE RECORDER				DISCHARGE CANAL* MAXIMUM HOURLY DELTA T
		HR 1	HR 2	HR 3	HR 4	
DATE:2/21/82 2 UNITS 100% 1 UNIT TRIPS # PUMPS=3+3	9.5 (17.1F)	15.1	12.8	12.8	12.9	2.3 (4.1F)
		//////////	//////////			
DATE:2/3/81 1 UNIT 100% 1 UNIT TRIPS # PUMPS=3+0	10.6 (19.1F)	12.3	12.3	12.2	5.3	6.9 (12.4F)
				//////////	//////////	
DATE:1/22/81 1 UNIT 100% 1 UNIT TRIPS # PUMPS=3+0	10.8 (19.4F)	11.3	11.4	11.0	3.7	7.3 (13.1F)
				//////////	//////////	

* RECORDER LOCATED AT END OF THE DISCHARGE CANAL.

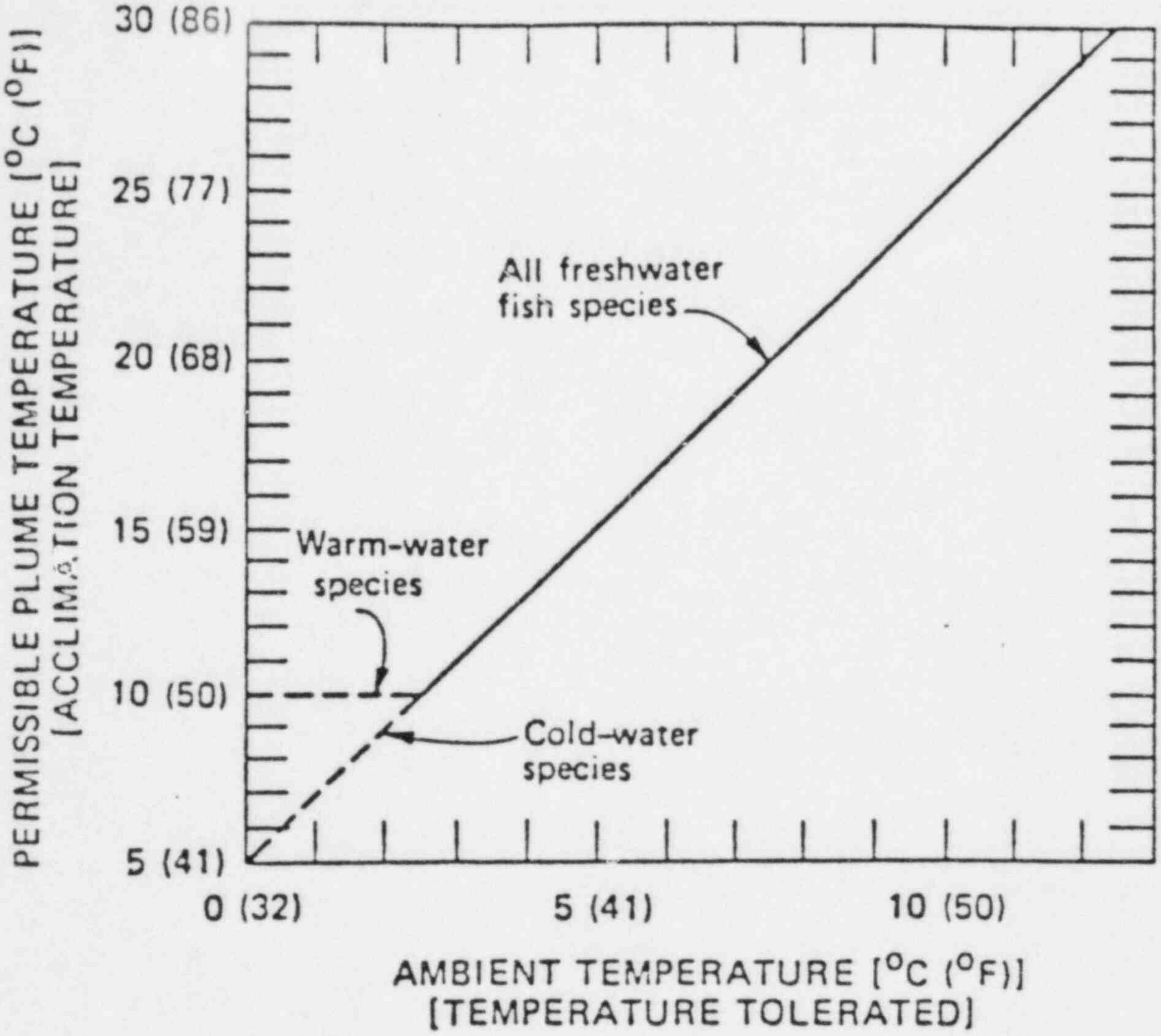

Figure 2. Nomograph developed from available cold-shock data for all freshwater fish which may be used when species specific data have not been obtained. (Environmental Protection Agency, 1976).

population due to cold shock. Recruitment from other areas in the WHTF would quickly compensate for the reduction in stock. Dr. Eric Adams of MIT (personal communication) also has indicated that some stratification would occur in WHTF-1 after a unit trip and possibly there may be warm surface refuge areas for fish to avoid the colder water at lower depths.

The potential for cold shock is dependent upon many site specific characteristics. Based on the low probability of both units tripping simultaneously, the rapid compensation for the reduction in stock from other areas in the WHTF should a simultaneous trip of both units occur and a fish kill also occur, the proposed mitigation measures to reduce the delta-T in the canal during one unit operation, the localized effect of any potential cold kill and the dynamics of certain temperature stratification patterns, it is concluded that the increased risks of cold shock are considered minimal and will not result in a significant adverse environmental impact.

Gas Supersaturation and Gas Bubble Disease

Gas bubble disease (G.B.D.) in fish is caused when inhabited waters become supersaturated with atmospheric gases. Conditions causing potential supersaturation occur primarily below the spillways of dams, by entrapment of air in falling water, and in power plant discharges when saturated intake cooling waters are warmed and gas solubility reduced. Supersaturation can also occur under natural conditions. Spring and well waters are frequently supersaturated; and photosynthesis, in conjunction with rising water temperature, can cause supersaturation in reservoirs.

Bouck (1980) defined gas bubble disease as a non-infectious, physically induced process caused by total dissolved gas pressure greater than normal atmospheric pressure, which produces primary lesions in the blood (emboli) and in tissues (emphysema) with subsequent physiological dysfunctions. Under these

conditions gas bubbles form in the fish's blood. As they accumulate and grow larger, blood circulation is stopped. External diagnostic signs of G.B.D. are gas bubbles under the skin, between and at the base of fin rays, in the mouth and gills and in the eyes.

Resistance of fishes to G.B.D. varies between species (Gray et al. 1982; Nebecker et al. 1980; Bouck et al. 1976; Dawley et al. 1976). However, individuals which normally inhabit the shallower waters can be the first to exhibit symptoms of G.B.D. since hydrostatic pressure below about two meters usually prevents formation of gas bubbles. Fish exposed to supersaturated conditions and showing symptoms of G.B.D. can sound and recover completely. The longer they remain at depth the longer the survival time when subsequently re-exposed to surface supersaturation (Knittel et al. 1980). However, even traditionally bottom species can contract the disease if gas supersaturation persists long enough (Crunkilton et al. 1980). Certain fish species can also detect and laterally or vertically avoid supersaturated conditions (Stevens et al. 1980).

Gas bubble disease in the effluent of power plants has been observed (DeMont and Miller 1971; Marcello and Strawm 1973; Marcello and Fairbanks 1976; and others). Gas bubble disease in power plant discharges usually occurs during winter months, especially from February through April (Crunkilton et al. 1980).

The proposed condenser upgrade project at the North Anna Nuclear Power Station will increase the condenser delta-T, during the winter months, up to 15.5°C which could produce supersaturated conditions in the discharge canal. However, in the proposed operation plan, the discharge valve of the circulating water pump will be partially closed. This in conjunction with condenser vacuum priming will reduce the pressure on the circulating water and the reduced flow of water through the system will allow a longer period of time for gases to escape

as the water is warmed. These gases would otherwise be held in solution physically by pressure eventually causing relatively higher levels of supersaturation in the discharge canal. As a result of these proposed changes, supersaturation levels in the discharge canal are expected to be less than the levels under current operation. Saturation levels will be monitored in the discharge canal to determine if supersaturation occurs. Under supersaturation conditions, the occurrence of G.B.D. would be a dependent on fish species habitat preferences, resistance to G.B.D. and ability of some species to detect and avoid high levels of supersaturation.

Fog Potential

As a result of the discharge of condenser cooling water from operations at the North Anna Power Station, a thermal heat load is placed upon the WHTF and Lake Anna water system. Under certain conditions, fog (steam fog) develops as a result of evaporation from the warm lake waters into the surrounding air. Up until this time, fog/icing development has not created any special problems nor has it been considered a nuisance.

Meteorological data and water temperatures are continuously monitored at the plant site and on the lake. Using these data, and comparative meteorological data from other locations, a review of regional fogging potential was made which involved the development of wind speed, temperature, and dew point frequency distributions. Additionally, the local interaction of air fogging potential and actual water temperatures was reviewed. Finally, an additional thermal impact (increased water temperature) was artificially introduced to test the sensitivity of fogging potential.

As a result of the meteorological data review pertaining to fogging/icing potential at Lake Anna as related to operations at the North Anna Power Station, the following conclusions were reached:

1) There is no indication that the occurrence of fog on a regional basis at the North Anna meteorological tower is any different from other locations in central Virginia. Consequently, any enhancement of pre-existing regional fog or creation of steam fog is very localized to lake waters only.

2) Current operations are now creating a high potential for fog (steam fog) enhancement and creation above the surface waters on the WHTF side of Lake Anna. The closer to the station discharge point, the greater the fog potential. The fog layer appears to be limited to the lake surface area with no quantifiable fog potential increase at the nearby meteorological tower. Fog development historically has not created any special problems nor has it been considered a nuisance.

3) The sensitivity of fog potential to increased WHTF water temperatures was evaluated (Table 4). Increased water temperatures within WHTF-1 will have minimal impacts due to already high fogging potential. The increased water temperatures in WHTF-2 will increase fogging potential a small amount but remain less than the potential of WHTF-1. No increased fogging potential is expected for WHTF-3 due to anticipated water temperatures being similar to those of the current case.

(4) Localized icing may occur in the vicinity of the facilities but this is expected to be minor. Typically, icing is related to situations where a warm vapor plume is injected into a cold atmosphere and then transported by surface layer winds toward some type of natural or man-made barrier. At North Anna, no mechanical moisture injection system is used. The fogging condition that does form is steam fog, which is associated with light winds and very little lower atmospheric transport. The steam fog should be constrained to just above the lake surface with little apparent transport.

TABLE 4

Fog Potential Sensitivity to Increased Water Temperatures

	Location		
	Dike 1	**Dike 2**	**Dike 3**
Base Case - Enhancement of Natural Fog Potential, % of Time Water T Exceeds Air T:			
Original	100%	98.93%	98.36%
Water T + 5°F	100%	99.70%	99.40%
Water T + 10°F	100%	100%	100.00%
Strong Enhancement of Natural Fog Potential, % of Time Water T Exceeds Air T by 10°F			
Original T	96.33%	88.00%	81.99%
Water T + 5°F	99.84%	95.62%	92.15%
Water T + 10°F	100%	98.94%	98.36%
Base Case - Fog Potential Creation, % of Time Water T Exceeds Air T			
Original T	98.41%	96.99%	94.97%
Water T + 5°F	99.68%	98.81%	98.25%
Water T + 10°F	99.90%	99.47%	99.13%
Strong Potential of Fog Creation, % of Time Water T Exceeds Air T By 10°F			
Original T	87.01%	73.53%	61.68%
Water T + 5°F	94.87%	91.07%	84.50%
Water T + 10°F	98.41%	96.99%	94.97%

Seasonal Pattern Alteration

Due to increasing the water temperature during cooler months of the year, a change will occur in seasonal water temperature patterns, primarily in WHTF-1. Historical low temperatures in WHTF-1 have been near 10°C (50°F) during maximum operating conditions. It is estimated that water temperatures in WHTF-1 would not fall below approximately 18°C (64°F) in the winter season during two unit station operation. One concern of increased potential impact may be associated with fish reproduction. The success of reproduction by fish is governed by many extrinsic factors such as photoperiod, seasonal temperature change, water currents and sex ratios (Lagler et al. 1962; Schwassmann 1971; Kaya and Hasler 1972). The period of gonadal development coincides with increasing day length and water temperature. It is generally assumed that photoperiod is a controlling factor in gonadal development and that water temperature is the primary stimulus that triggers spawning. Observations at Lake Anna suggest that some factor(s) other than water temperature, probably photoperiod, is the primary determinant of largemouth bass spawning times (Virginia Power 1985). In Parr Pond, South Carolina (Clugston 1973) where water temperatures rarely fall below 25°C (77°F), successful spawning of bass and sunfish has occurred almost year round. It is anticipated that within WHTF-1 any modification to fish reproduction patterns will be more than compensated for by fish reproduction in the remainder of the WHTF.

The seasonal emergent and winter diapause patterns for benthic aquatic insects may also be modified. These insects would probably emerge earlier in the season and this could place the emerging adults in an unfavorable environment with cooler air temperatures. It has been documented in previous environmental reports (Vepco 1983); however, that aquatic insects have historically emerged one month earlier in WHTF-1 with no apparent harmful effects to the community. Any

change in seasonal emergence patterns resulting in higher adult mortality in colder winter air temperatures would likely be limited to WHTF-1 and repopulation from other areas will inevitably reduce any local impacts should they occur. The variation in temperature tolerance and subsequent response depends on many factors such as the species of insect, and the relationship between temperature, food sources (phytoplankton and zooplankton) and predators (fish). Other factors such as photoperiod and/or behavioral adaptations may act as the determining variable(s) with respect to benthic community response.

Natural seasonal shifts in the phytoplankton community generally involve a dominance of the community by diatoms in cooler seasons followed by a dominance of the community by green and blue-green algae during the warmer periods. As a result of increased winter temperatures in WHTF-1, a slight shift in the community composition could occur favoring the green and blue-green algae. In the zooplankton community, reproduction may be stimulated as a result of the increased water temperatures. Also, the reduced current during the winter may have a positive effect on the zooplankton community, enabling organisms to better maintain their position in the water column. Any community compositional change that may occur to the plankton in the WHTF is considered not to cause a significant adverse environmental impact and should not significantly affect the ecosystem of Lake Anna.

General Summary

Virginia Power is proposing to throttle the intake water flow at North Anna Power Station during cooler months of the year to improve station operation efficiency and reduce degradation of the condenser system. The environmental assessment indicates that no significant adverse environmental impact is expected and that any effect that may occur as a result of this project would be limited to the WHTF and would be of a relatively short duration and not in the Lake Anna

reservoir. To mitigate the potential for cold shock during one unit operation, we propose to control the condenser delta-T such that no adverse environmental impact would be expected. The assessment for gas supersaturation, increased fogging and seasonal pattern alteration indicates that there should be no significant adverse impact to the ecosystem of Lake Anna. If any adverse environmental or biological condition is evident from the results of ongoing monitoring programs, appropriate action will be taken upon final evaluation. Implementation of this project is tentatively scheduled for December 1985.

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