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May 4, 1989

Mr. Robert D. Kelsey
Fish and Wildlife Biologist
U. S. Fish and Wildlife Service
Department of the Interior
1825-B Virginia Street
Annapolis, Maryland 21401

Dear Mr. Kelsey:

Please find enclosed for your review a report detailing results of the fish passage study Virginia Power conducted relative to the North Anna Hydroelectric Project. The data indicate that fish passage through the hydroelectric facility occurs at a low rate (0.6-3.1 fish/day). Bluegill (Lepomis macrochirus) was the most frequently captured species in passage samples. Operation of the hydroelectric facility had minimal effect on river temperatures and dissolved oxygen levels.

The North Anna Hydroelectric Project is expected to have no noticeable or deleterious effects on Lake Anna fish populations or North Anna River biota. The results of fish passage studies indicate that further screening of the hydroelectric facility's intake would be an unnecessary installation and maintenance expense. Should you have any questions, please contact me at (804) 273-2990 or Mr. J. W. Bolin, III at (804) 257-4777.

Sincerely,

B. M. Marshall, P.E.
Manager
Water Quality

Enclosure

bc: Mr. G. E. Kane - enclosure
Mr. W. R. Cartwright - enclosure
Mr. J. W. Bolin, III - enclosure
Mr. M. F. Kadlubowski
Mr. J. W. White - enclosure
Mr. J. E. Tripp - enclosure
Mr. R. J. Graham - enclosure

FISH PASSAGE STUDY
FOR
LAKE ANNA DAM
1986-1988

Prepared by:
Water Quality Section
Corporate Technical Services
Virginia Power

April 1989

Introduction

The North Anna Hydroelectric Project is owned and operated by Virginia Power, a subsidiary of Dominion Resources, Incorporated. The facility is located in Louisa County, Virginia, on the North Anna River at the base of the Lake Anna Dam. Two Ingersoll-Rand vertical turbines are operated at the facility. As part of the hydroelectric facility's exemption from licensing by the Federal Energy Regulatory Commission (FERC), the United States Fish and Wildlife Service (USFWS) requested that Virginia Power perform pre-operational and operational fish passage studies to evaluate the need for intake screening. This report presents results of studies conducted during 1986, 1987, and 1988 and an assessment of possible turbine-induced mortality.

Background and Project Description

In response to expected growth in electrical power demands, Virginia Power initiated studies of conventional and alternative energy sources in 1981. Construction of a small-scale, run-of-the-river hydroelectric facility utilizing water from Lake Anna was deemed a feasible project. An Exemption From Licensing was filed with FERC in March 1984 and an Order Granting the Exemption was issued in September 1984. Virginia Power filed for a License and Certificate of Public Convenience and Necessity with the State Corporation Commission in April 1986. On June 5, 1986, the Final Order from the State Corporation Commission granting a Certificate of Public Convenience and necessity was received stating the previous license for the Lake Anna Dam itself was applicable to the hydroelectric facility. Construction activities for the hydroelectric facility began in March of 1986. Initial testing of the turbines occurred in July 1987, and commercial operations commenced in December 1987.

The hydroelectric facility consists of two separate generating units (Unit 5A and Unit 5B). Each unit possesses a single stage, open runner-type vertical water turbine. An induction-type generator is mounted on top of each unit's turbine support column. Peak operational design efficiency is at a flow of 40 cfs for Unit 5A and 133 cfs for Unit 5B (Table 1). The control console for units 5A and 5B is housed in a switchgear building approximately 500 feet southeast of the dam.

The water source for the hydroelectric facility is Lake Anna. Water from near the lake's surface (depths $<$ 7 feet) passes through skimmer gate trash racks to a sluice pipe. The skimmer gate opening measures 8.5 feet wide and extends 7 feet below the lake's surface at normal lake elevation (250 fmsl). Two trash racks are employed to filter the water before it enters the turbines. The first is constructed of steel bars with 6-inch by 24-inch openings and covers the entire skimmer gate opening. The second rack was installed in 1987 to prevent floating debris from entering the sluice pipe. It is composed of 3/4-inch steel mesh and extends approximately 5 feet below the lake's surface.

A 5-foot diameter penstock leading to the turbine receives water flowing from the sluice pipe. Upstream of the turbines, flow is directed through 24-inch and 48-inch conduits to Units 5A and 5B, respectively, by a bifurcation piece. Flow is controlled by the control console via the inlet valves. Entering the main turbine chamber, water passes through stationary stator vanes that reduce turbulence to spinning runner vanes. There is approximately 1 inch of clearance between stator vanes and runner vanes. Passing through the turbine runners (minimum aperture distance approximately 3 inches), flow is discharged directly to the North Anna River through draft tubes.

A minimum discharge of 40 cfs from the lake to the river is maintained at all times as required by the North Anna Power Station NPDES Permit. Prior to construction of the hydroelectric facility, at lake elevations less than 250.1 feet, Lake Anna surface waters were discharged directly to the North Anna River through a skimmer gate located at the north abuttment of the dam. At lake elevations greater than 250.1 feet a skimmer gate located at the south abuttment of the dam was opened to allow spillover of surface waters. Discharge was controlled by lowering or raising skimmer gates within the range of 1.2 (minimum flow setting; 40 cfs) to 7.0 feet (550 cfs). At lake elevations greater than 250.2 feet, one to three radial gates were opened to discharge water directly to the river from depths of approximately 30 feet.

With construction of the hydroelectric facility, all flow from the lake to the river is directed through the south skimmer gate opened full at 7.0 feet at lake elevations less than 250.1 feet. At lake elevations less than 250.0 feet, all flow is directed through Unit 5A turbine. Whenever lake elevations exceed 250.0 feet, water is also directed through Unit 5B until such point that the lake elevation reaches 250.1 feet, when the north skimmer gate is opened. Radial gates are opened at lake elevations greater than 250.15 feet. At lake elevations equalling or exceeding 250.5 feet, both units are tripped automatically as North Anna River levels then approach flooding.

Fish Passage Studies

Methods

In July 1986, Virginia Power submitted a proposal for fish passage studies at the Lake Anna Dam to the USFWS. The plan was approved in September 1986. The purpose of these studies was to determine the extent of fish passage from Lake Anna to the North Anna River under pre-operational and operational conditions.

Pre-operational sampling was initiated in November 1986, on a twice per month basis and continued until August 1987. An aluminum frame basket with 3/8-inch steel wire mesh measuring 8.7 feet long x 2 feet wide x 2 feet deep was used to sample fish passage. The basket was submerged just below the lake's surface in front of the north skimmer gate trash rack. During the first experimental 24-hour sampling period the basket was submerged for time periods ranging from 15 minutes to 6 hours. Between each submersion the basket was checked for fish. No fish were collected during the initial 24-hour sampling period; therefore, after consultation with and approval from the USFWS, the remaining pre-operational samples were to be of 24-hour duration. At the beginning and end of each sampling period water temperature and dissolved oxygen levels were measured at the lake's surface near the sampling basket and in the dam tailwaters near the point of discharge.

In May 1987, Virginia Power personnel met with Mr. Robert D. Kelsey of the USFWS for a site visit to the North Anna Hydroelectric Project. At this meeting a proposed operational fish passage study plan was discussed. It was agreed to modify the pre-operational fish passage study methods for operational conditions.

North skimmer gate sampling was discontinued and south skimmer gate sampling was begun following commencement of 2-unit operations in September 1987. Sampling continued for a period of one year until August 1988. South skimmer gate sampling was performed on a monthly basis and consisted of three consecutive 24-hour collections. Three depths (surface, midwater, and bottom) were sampled during each month, each depth being sampled for one 24-hour period. The sampling basket used during pre-operational studies was also used for operational studies. At the beginning and end of each 24-hour sample, water temperature and dissolved oxygen levels were measured at the lake's surface near the sampling basket and in the hydroelectric facility discharge.

Passage rates for fish passing through the north skimmer gate to the North Anna River and the south skimmer gate to the hydroelectric facility were estimated separately for pre-operational and operational sampling periods, respectively. Pooled catch and sampling effort data for each sampling period were used. Two methods to estimate passage rates were employed for comparative purposes.

The first method of estimating passage rates was based on sampling duration. Passage rates (fish/hour) were calculated by dividing the number of fish caught in the sampling basket by the number of hours the basket was submerged. Passage rates for pre-operational and operational periods were extrapolated to one-year periods by multiplying hourly passage rates by 8760 hours (365 days).

The second method used to estimate passage rates was based on estimates of the volume of water filtered during pre-operational and operational sampling. Velocities at the north and south skimmer gate openings were estimated for different gate openings and discharge rates (Appendix 1). The volume of water filtered on each sampling day (Appendix 2) was then estimated by multiplying hourly velocity estimates, based on gate openings and discharge, by the cross-sectional area of the sampling basket (17.0 sq ft) and 24 hours (86400 s). Passage rates (fish/cu ft). were estimated by dividing the number of fish collected during pre-operational and operational periods by the summed values of water filtered during each period.

Annual passage at the north skimmer gate and south skimmer gate for pre-operatonal and operational periods, respectively, was estimated for two discharge conditions: continuous release of 40 cfs for one full year and continuous release of 170 cfs. These conditions reflect the lowest level of fish passage through the hydroelectric facility expected (Unit 5A operation alone: 40 cfs) and the highest level of passage possible (Unit 5A and

Unit 5B operation: 170 cfs) under continuous operation. Annual passages were calculated by multiplying passage rates for pre-operational and operational periods by discharge (cfs) and extrapolated to 365 day (3.1536×10^7 s) periods.

Results

Forty-eight separate 24-hour samples were collected during the course of the Lake Anna dam fish passage studies. Sixteen 24-hour pre-operational samples and 32 24-hour operational samples were obtained. Four pre-operational samples and two operational samples were not collected due to several factors (Appendix 3).

Pre-operational samples were collected at the north skimmer gate at discharges ranging from approximately 40 to 300 cfs (Table 2). Lake surface water temperatures ranged from 7.0 to 29.2°C and dissolved oxygen levels from 6.3 to 13.0 ppm. Tailrace water temperatures ranged from 6.2 to 29.0°C and dissolved oxygen levels from 6.3 to 12.4 ppm. Water temperatures and dissolved oxygen levels at the lake's surface and in the tailrace were very similar. Only five fish representing four species, threadfin shad (*Dorosoma petenense*); bluegill (*Lepomis macrochirus*); white perch (*Morone americana*); and satinfin shiner (*Notropis analostanus*), were collected during pre-operational sampling (Table 3). Fish ranged in size from 57 to 97 mm total length.

Operational samples were collected at the south skimmer gate at discharges ranging from approximately 40 to 170 cfs (Table 4).

Lake surface water temperatures ranged from 6.0 to 30.1°C and dissolved oxygen levels from 5.9 to 11.8 ppm. Tailrace water temperatures ranged from 6.0 to 30.1°C and dissolved oxygen levels from 6.6 to 12.0 ppm. Passage of Lake Anna surface water through the hydroelectric facility had negligible effects on tailrace water temperatures and dissolved oxygen levels. Twenty fish representing four species, threadfin shad; bluegill; white perch, and golden shiner (<u>Notemigonus crysoleucas</u>), were collected during operational sampling (Table 5). Fish ranged in size from 42 to 185 mm. Nine of the twenty fish were collected in 11 surface samples, seven in 11 midwater samples, and four in 10 bottom samples. Bluegill was the most frequently caught species (14 of 20 fish).

The passage rate for fish at the north skimmer gate during the pre-operational sampling period was estimated at 0.013 fish/hour (one fish every 3.2 days) by the sampling duration method. Extrapolation to a one-year period yielded an estimate of 114 fish/year passing through the north skimmer gate. The passage rate for fish at the south skimmer gate during the operational sampling period was estimated at 0.026 fish/hour (one fish every 1.6 days) which extrapolates to an estimate of 228 fish/year.

The passage rate for fish passing through the north skimmer gate during the pre-operational period estimated by the volumetric method was 4.478×10^{-8} fish/cu ft of discharge. Extrapolation to a one-year period yielded an estimate of 56 fish/year passing through the north skimmer gate at a continuous discharge of 40 cfs and 240 fish/year at 170 cfs. The passage rate for fish passing through the south skimmer gate during the operational period was estimated at 2.115×10^{-7} fish/cu ft of discharge. Extrapolation to a one-year period yielded an estimate of 267 fish/year passing through the south skimmer gate at a continuous discharge of 40 cfs and 1134 fish/year at 170 cfs.

Conclusions

Pre-operational and operational studies indicate that passage of fish from Lake Anna to the North Anna River is minimal. The extrapolated estimates of annual fish passage obtained by the sampling duration and volumetric methods, respectively, are 56 to 240 fish through the north skimmer gate prior to operation of the hydroelectric facility and 128 to 1134 fish through the south skimmer gate during the first year of operation. These estimates are a very small portion of the total fish populations inhabiting Lake Anna and the North Anna River.

Cove rotenone surveys conducted by the Virginia Commission of Game and Inland Fisheries indicate standing crops of fishes for Lake Anna in the vicinity of the dam have ranged from 81.73 to 220.80 kg/hectare for the period 1975-1985 (Virginia Power, 1986). In the most recent cove rotenone survey conducted in 1985, an estimate of 102.05 kg/hectare was obtained. Bluegill, the most frequently collected species in fish passage samples, comprised 17.66 kg/hectare of the 1985 total. Assuming an average weight of 25 g per bluegill, this approximates 706 bluegill/hectare inhabiting Lake Anna in the vicinity of the dam.

It should be noted that the annual passage estimate of 1134 fish/year calculated for continuous, 2-unit operation of the hydroelectric facility at 170 cfs is presented as a worst case condition that will likely never occur. During most years, the period June-October is characterized by minimum or near minimum flow releases during which operation of the hydroelectric facility at full capacity would not be possible. Additionally, scheduled and unplanned unit outages were not accounted for in the calculation of passage rates. As such, the annual passage of fish through the south skimmer gate and hydroelectric facility probably falls somewhere between the estimates of 128 and 1134 fish/year calculated for continuous releases of 40 and 170 cfs, respectively.

Statistical analyses of catch data for comparison of passage rates during pre-operational and operational periods and seasonal trends are not valid due to the low numbers of fish collected. However, the numbers of fish collected during fish passage sampling, calculated passage rates, and estimates of annual fish passage indicate greater fish passage has occurred at the south skimmer gate during the operational period than at the north skimmer gate during the pre-operational period. Field observations made during sampling and the effect of variable hydroelectric unit operations in part account for this condition.

During sampling, fishes, particularly bluegill, were frequently observed in the vicinity of the north and south skimmer gate trash racks. During times of minimum flow release, these fish appeared to have no difficulty in maintaining position around the trash racks. It is hypothesized that when releases were increased above minimum flow, the increase in flow rate and consequent water velocity was gradual at the north skimmer gate, as the gate opening was gradually increased. This allowed fish to shift their positions from the trash racks to areas of lower water velocities as flow increased. However, with operation of the hydroelectric facility, a sudden shift in flow from 40 cfs to 170 cfs occurs that may not provide adequate time for fish to clear the trash rack area, resulting in greater entrainment. Samples collected on 4, 5, and 6 April 1988 and 21, 22, and 23 June 1988 support this hypothesis. Both of these samples were collected during times of highly variable unit operation, due to changes in lake elevations and several unscheduled unit trips. Together these two monthly samples account for one-half (10) of the total number of fish collected during operational sampling. Recent adjustments to Unit 5A turbine runners and the hydroelectric facility's control console are expected to reduce the frequency of unscheduled trips, and consequently, incidence of fish entrainment.

Operation of the North Anna Hydroelectric Project is not expected to have any deleterious effect on the biotic communities of Lake Anna or the North Anna River. Changes in water temperatures and dissolved oxygen levels as water passes from the lake to the river are minimal. The number of fish expected to be entrained is small in comparison to the total numbers of fish inhabiting Lake Anna and the North Anna River. Quarterly electrofishing collections at two sampling locations on Lake Anna near the dam yielded averages of 74 and 104 fish/100 m of shoreline in 1987 (Virginia Power, 1988). For the North Anna River, an average of 242 fish/70 m of stream was collected at Rt. 601, located approximately one mile downstream from the dam, during May, July, and September 1987 (Virginia Power 1988).

Electrofishing collections conducted from 1981 through 1988 indicate that Lake and North Anna River fish assemblages have remained relatively unchanged in recent years (Figure 1). Given the total areas, numbers of fish present, and apparent stability of the Lake Anna and North Anna River ecosystems, losses of fish due to entrainment by the hydroelectric facility are expected to have negligible impact. In summary, operation of the North Anna Hydroelectric units is expected to have no noticeable effect on the total fish populations of Lake Anna or the North Anna River. The results of the pre-operational and operational studies indicate that further screening of the intake water for the hydroelectric units is not necessary.

Table 1. North Anna Hydroelectric Project turbine characteristics.

Unit	Flow Rating (cfs)	Design Speed (rpm)	Efficiency	Rated Output (kw)
5A	40	124	92.0%	222
5B	133	727	91.5%	740

Table 2. Sampling dates and physical conditions for North Anna Hydroelectric Project pre-operational studies.

Date	Basket Location	Sampling Period (hours)	Discharge* (ft/sec)	SET Lake Temp. (°C)	SET Lake D.O. (ppm)	SET Tailrace Temp. (°C)	SET Tailrace D.O. (ppm)	PULL Lake Temp. (°C)	PULL Lake D.O. (ppm)	PULL Tailrace Temp. (°C)	PULL Tailrace D.O. (ppm)
861120	Surface	0.25-6	40	16.0	8.8						
861203	Surface	24	40	13.8	9.2	13.8	9.6	15.9	8.9		
861218	Surface	24	40	11.5	10.3	11.2	10.8	13.5	9.6	13.2	10.2
861230	Surface	24	280	10.1	10.5	10.2	10.6	10.8	10.7	10.7	11.2
870113	Surface	24	40	9.9	10.6	9.9	11.2	10.0	10.8	10.2	10.4
870204	Surface	24	280	8.2	11.4	7.8	12.9	10.0	10.4	10.0	10.6
870217	Surface	24	40	7.2	12.1	7.7	12.6	7.0	11.4	6.2	12.4
870317	Surface	24	40	10.9	11.2	10.6	12.1	7.9	11.4	7.8	11.6
870330	Surface	24	40	14.1	13.0	14.0	12.6	11.8	10.8	11.8	11.9
870518	Surface	24	120-300	22.9	8.2	22.5	8.3	13.8	10.4	13.5	10.0
870528	Surface	24	40	23.8	8.0	22.2	8.4	20.0	8.0	19.6	8.7
870615	Surface	24	40	M	M	M	M	27.5	8.1	23.0	8.5
870623	Surface	24	40	26.0	6.5	25.3	7.8	26.8	7.0	25.8	7.8
870706	Surface	24	40	26.2	7.1	26.2	7.7	25.3	6.8	25.1	7.9
870723	Surface	24	40	29.2	6.3	28.9	7.2	29.0	6.4	27.8	7.4
870825	Surface	24	40	26.5	6.6	26.9	6.7	29.0	7.4	29.0	7.8
								26.3	6.3	26.0	6.5

* Approximate.

M Equipment malfunction

Table 3. Fish collected during pre-operational fish passage studies.

Date	Basket Location	Species Collected	Number of Fish	Total Length (mm)
861120	Surface		0	
861203	Surface		0	
861218	Surface	Notropis analostanus	1	73
861230	Surface		0	
870113	Surface		0	
870204	Surface		0	
870217	Surface		0	
870317	Surface	Morone americana	1	62
870330	Surface		0	
870518	Surface	Lepomis macrochirus	1	57
		Dorosoma petenense	2	97, 96
870528	Surface		0	
870615	Surface		0	
870623	Surface		0	
870706	Surface		0	
870723	Surface		0	
870825	Surface		0	

Table 4. Sampling dates and physical conditions for North Anna Hydroelectric Project operational studies.

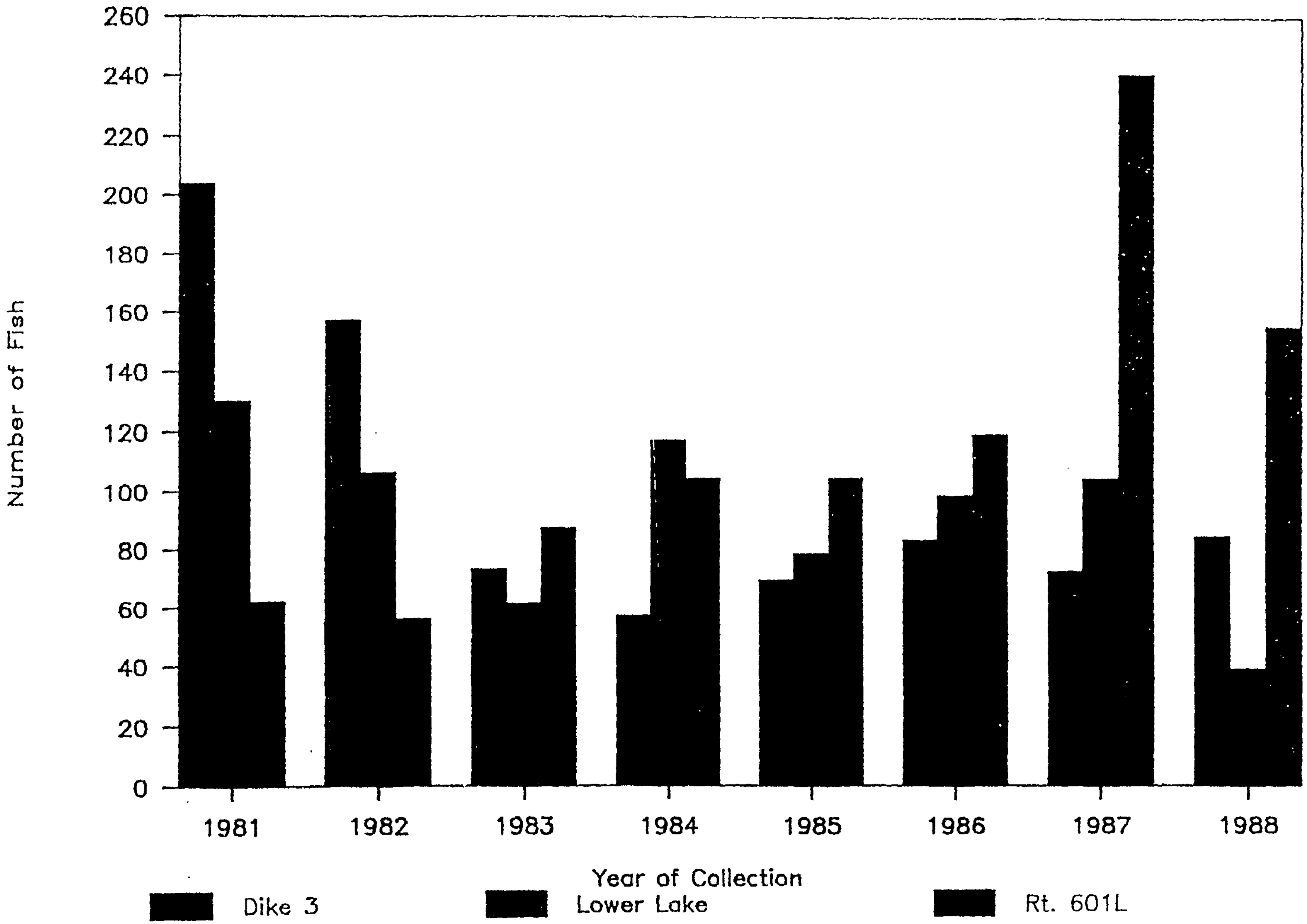
				SET				PULL			
				Lake		Tailrace		Lake		Tailrace	
Date	Basket Location	Sampling Period (hours)	Discharge* (ft/sec)	Temp. (°C)	D.O. (ppm)	Temp. (°C)	D.O. (ppm)	Temp. (°C)	D.O. (ppm)	Temp. (°C)	D.O. (ppm)
870901	Surface	24	40	26.8	6.9	26.8	7.5	26.5	6.9	26.5	6.9
870902	Mid	24	40	26.5	6.9	26.5	6.9	25.1	6.5	25.5	6.7
870903	Bottom	24	40	25.1	6.5	25.5	6.7	24.9	6.6	24.9	6.6
871020	Bottom	24	40	17.8	8.2	17.8	8.5	17.4	8.7	17.4	8.8
871021	Mid	24	40	17.4	8.7	17.4	8.8	17.0	8.5	17.0	8.8
871022	Surface	24	40	17.0	8.5	17.0	8.8	16.5	8.6	17.0	9.8
871109	Bottom	24	40	15.2	9.8	15.0	9.8	14.9	9.8	14.9	9.8
871110	Mid	24	170	14.9	9.8	14.9	9.8	14.0	9.7	14.0	9.7
871111	Surface	24	40	14.0	9.7	14.0	9.7	13.5	9.6	13.4	9.7
871214	Surface	24	170	11.1	9.1	11.0	9.3	11.0	10.2	10.8	10.8
871215	Mid	24	170	11.0	10.2	10.8	10.8	11.0	9.6	10.9	9.8
871216	Bottom	24	170	11.0	9.6	10.9	9.8	10.5	10.2	10.4	10.4
880118	Bottom	24	170	6.1	11.0	6.0	11.4	6.2	11.0	6.2	11.3
880119	Surface	24	170	6.2	11.0	6.2	11.3	6.1	11.2	6.1	11.8
880120	Mid	24	170	6.1	11.2	6.1	11.8	6.9	11.0	6.8	12.0
880215	Mid	24	170	6.0	10.9	6.0	11.5	6.5	10.4	6.5	11.3
880216	Bottom	24	170	6.5	10.4	6.5	11.3	6.5	11.8	6.4	11.9
880217	Surface	24	170	6.5	11.8	6.4	11.9	7.8	10.4	7.4	11.2
880314	Bottom	24	170	12.0	10.4	11.9	10.5	11.7	10.7	11.8	10.8
880315	Mid	24	170	11.7	10.7	11.8	10.8	11.9	10.2	11.8	10.3
880316	Surface	24	170	11.9	10.2	11.8	10.3	11.8	10.1	11.7	10.0
880404	Surface	24	170	15.9	9.1	15.9	9.4	16.2	9.8	16.2	9.9
880405	Mid	24	170	16.2	9.8	16.2	9.9	16.9	9.4	16.8	9.8
880406	Bottom	24	170	16.9	9.4	16.8	9.8	16.5	10.1	16.4	10.1
880502	Mid	24	40	19.0	8.4	19.0	8.6	18.9	8.4	18.9	8.6
880503	Bottom	24	40	18.9	8.4	18.9	8.6	19.1	8.6	19.0	8.6
880504	Surface	24	40	19.1	8.6	19.0	8.6	19.5	8.5	18.4	8.8
880621	Surface	24	40-170	28.0	8.2	27.5	8.2	28.2	7.6	27.2	7.6
880622	Mid	24	40-170	28.2	7.6	27.2	7.6	28.2	7.2	27.2	7.6
880623	Bottom	24	40-170	28.2	7.2	27.2	7.6	28.8	6.8	27.2	7.2
880823	Surface	24	130	29.9	5.9	29.9	7.1	29.9	5.9	29.9	7.0
880824	Mid	24	130	29.9	5.9	29.9	7.0	30.1	5.9	30.1	7.1

* Approximate

Table 5. Fish collected during operational fish passage studies.

Date	Basket Location	Species Collected	Number of Fish	Total Length (mm)
870901	Surface		0	
870902	Mid		0	
870903	Bottom		0	
871020	Bottom		0	
871021	Mid		0	
871022	Surface	Lepomis macrochirus	1	179
871109	Bottom		0	
871110	Mid	Morone americana	1	139
871111	Surface		0	
871214	Surface		0	
871215	Mid	Lepomis macrochirus	1	50
871216	Bottom		0	
880118	Bottom		0	
880119	Surface	Dorosoma petenense	1	90
		Notemigonus crysoleucas	1	103
880120	Mid		0	
880215	Mid		0	
880216	Bottom		0	
880217	Surface		0	
880314	Bottom		0	
880315	Mid		0	
880316	Surface		0	
880404	Surface	Lepomis macrochirus	3	62,56,58
880405	Mid	Morone americana	1	150
		Lepomis macrochirus	1	131
880406	Bottom	Lepomis macrochirus	2	62,64
880502	Mid	Lepomis macrochirus	1	174
880503	Bottom	Morone americana	1	185
880504	Surface		0	
880621	Surface	Lepomis macrochirus	2	146,112
880622	Mid		0	
880623	Bottom	Lepomis macrochirus	1	108
880823	Surface	Morone americana	1	139
880824	Mid	Lepomis macrochirus	2	42,53

Figure 1. Average number of fish collected per electrofishing survey of 100 m of Lake Anna shoreline (Dike 3 and Lower Lake) and 70 m of the North Anna River (Rt. 601L).



Appendix 1. Velocity estimates calculated for the north skimmer gate during the pre-operational period and south skimmer gate for the operational period based on the equation Discharge (cfs) = Velocity (f/s) x Area (sq ft).

North Skimmer Gate				South Skimmer Gate			
	Gate Area (sq ft)				Gate Area (sq ft)		
Discharge (cfs)	Depth	Width	Velocity (ft/s)	Discharge (cfs)	Depth	Width	Velocity (ft/s)
40	1.2	8.0	4.17	40	7.0	8.0	0.71
120	2.5	8.0	6.00	130	7.0	8.0	2.32
280	4.5	8.0	7.78	170	7.0	8.0	3.04
300	5.0	8.0	7.50				

Appendix 2. Estimated volumes of water filtered during 24-hour fish passage samples.

NORTH SKIMMER GATE

Date	Discharge (cfs)	Estimated Velocity (ft/s)	Sampling Duration(s) (24 hours)	Area (sq ft)	Sample Volume (cu ft)
861120	40	4.17	86400	17.0	6124896
861203	40	4.17	86400	17.0	6124896
861218	40	4.17	86400	17.0	6124896
861230	280	7.78	86400	17.0	11427264
870113	40	4.17	86400	17.0	6124896
870204	280	7.78	86400	17.0	6124896
870217	40	4.17	86400	17.0	11427264
870317	40	4.17	86400	17.0	6124896
870330	40	4.17	86400	17.0	6124896
870518	120-300	6.00-7.50	86400	17.0	6124896
870528	40	4.17	86400	17.0	9180000*
870615	40	4.17	86400	17.0	6124896
870623	40	4.17	86400	17.0	6124896
870706	40	4.17	86400	17.0	6124896
870723	40	4.17	86400	17.0	6124896
870825	40	4.17	86400	17.0	6124896

20 hours at 120 cfs, 4 hours at 300 cfs

SOUTH SKIMMER GATE

Date	Discharge (cfs)	Estimated Velocity (ft/s)	Sampling Duration(s) (24 hours)	Area (sq ft)	Sample Volume (cu ft)
870901	40	0.72	86400	17.0	1048723
870902	40	0.72	86400	17.0	1048723
870903	40	0.72	86400	17.0	1048723
871020	40	0.72	86400	17.0	1048723
871021	40	0.72	86400	17.0	1048723
871022	40	0.72	86400	17.0	1048723
871109	40	0.72	86400	17.0	1048723
871110	170	3.04	86400	17.0	4465152
871111	40	0.72	86400	17.0	1048723
871214	170	3.04	86400	17.0	4465152
871215	170	3.04	86400	17.0	4465152
871216	170	3.04	86400	17.0	4465152
880118	170	3.04	86400	17.0	4465152
880119	170	3.04	86400	17.0	4465152
880120	170	3.04	86400	17.0	4465152
880215	170	3.04	86400	17.0	4465152
880216	170	3.04	86400	17.0	4465152
880217	170	3.04	86400	17.0	4465152
880314	170	3.04	86400	17.0	4465152
880315	170	3.04	86400	17.0	4465152
880316	170	3.04	86400	17.0	4465152
880404	170	3.04	86400	17.0	4465152
880405	170	3.04	86400	17.0	4465152
880406	170	3.04	86400	17.0	4465152
880502	40	0.72	86400	17.0	1048723
880503	40	0.72	86400	17.0	1048723
880504	40	0.72	86400	17.0	1048723
880621	40-170	0.72-3.04	86400	17.0	2472235*
880622	40-170	0.72-3.04	86400	17.0	1618128**
880623	40-170	0.72-3.04	86400	17.0	1059984***
880823	130	2.32	86400	17.0	3407616
880824	130	2.32	86400	17.0	3407616

* 14 hours at 40 cfs, 10 hours at 170 cfs
** 20 hours at 40 cfs, 4 hours at 170 cfs
*** 20 hours at 40 cfs, 1 hours at 170 cfs, 3 hours off-line

Appendix 3. Listing of missed fish passage samples and reason for missing sample.

Pre-operational Sampling Period

Month	Year	Missed	Reason for Missing Sample
January	1987	1 of 2	Icing
April	1987	2 of 2	Icing and flooding
August	1987	1 of 2	Sampling delayed due to turbine tests

Operational Sampling Period

Month	Year	Missed	Reason for Missing Sample
July	1988	Surface Midwater Bottom	Units off-line due to lightning strike; servicing of turbines by manufacturer
August	1988	Bottom	Servicing of turbines by manufacturer