UNITED STATES ATOMIC ENERGY COMMISSION

IN THE MATTER OF:

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

(Indian Point Station, Unit No. 2)

DOCKET NO. 50-247

Place - Washington, D. C. Vol. I

Date - Monday, 5 March 1973 **Pages** 9388 - 9400

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UNITED STATES OF AMERICA

ATOMIC ENERGY COMMISSION

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(Indian Point Station, Unit No. 2)

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Federal Office Building # 7
726 Jackson Place
Washington, D. C.

Monday, 5 March 1973

The above-entitled matter came on for further hearing, pursuant to notice, at 9:00 a.m.

BEFORE:

SAMUEL W. JENSCH, Esq., Chairman, Atomic Safety and Licensing Board.

DR. JOHN C. GEYER, Member.

MR. R. B. BRIGGS, Member.

APPEARANCES:

(As heretofore noted.)

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P R O C E E D I N G S

CHAIRMAN JENSCH: We will please come to order.

This proceeding is a hearing in the matter of Consolidated Edison Company, and is convened here in accordance with an order setting this time and place for the further evidentiary session in this proceeding.

Due to a change in the accommodations available, and in accordance with the notice given to the attorneys for all parties on March 2, 1973, this hearing will recess, to reconvene in Hearing Room C of the Interstate Commerce Commission at Twelfth and Constitution, Washington, D. C., at 10:15 a.m.

It may be noted that in accordance with the notice, no parties or their attorneys have appeared here. However, three persons did arrive at 9:00 o'clock and they have been informed of the change in the location of this proceeding.

At this time we will recess, to reconvene at 10:15 in Hearing Room C of the Interstate Commerce Commission, Twelfth and Constitution, Washington, D. C.

(Whereupon, at 9:05 a.m., the hearing was recessed, to reconvene at 10:00 a.m., this same date, at Hearing Room C, Interstate Commerce Commission, Washington, D.C.)

CHAIRMAN JENSCH: We will please come to order.

This proceeding is a further evidentiary session of hearings in the matter of Consolidated Edison Company of

New York, Incorporated, as reflected by Docket No. 50-247 in reference to Indian Point Station Unit No. 2, Atomic Energy Commission.

This hearing is convened in accordance with an order for further sessions of evidentiary hearings which was entered at the last evidentiary session on January 19, 1973, setting this date and time for the reconvening of the further evidentiary hearing.

The order which was entered on January 19, 1973 was supplemented by an additional notice setting forth that a further session of evidentiary hearings would be held on March 5, 1973; that notice was similar to the one given on January 19, 1973, which provided that the hearings would be held, however, at the Atomic Energy Commission Auditorium in Germantown, Maryland.

This additional notice was given general public distribution which included publication in the Federal Register as reflected by the publication on February 27, 1973, as reflected in Volume 38 of the Federal Register at Page 5278.

Since the time of those two notices, that is, the one given on January 19, 1973, and the published notice which was issued on February 21, 1973, but published on February 27, 1973, it has been ascertained that there has been a change in the accommodations as available for a public hearing jrb 3

at the auditorium of the Atomic Energy Commission in Germantown, Maryland, in that the facilities are no longer available for a public hearing, and in accordance with that recognized fact, consideration was given to a change in location for this hearing, and arrangements were made to hold the hearing in this room, Hearing Room C of the Interstate Commerce Commission at Twelfth and Constitution Avenue, Washington, D. C.

All parties were notified through their attorneys orally by my secretary to each of the counsel, and also a telegraphic notice was sent to the attorneys for the parties on March 2, 1973. That notice given by telegram provided that, since adequate time did not permit publication of the change of the notice of hearing, a call to the hearing would occur at 9:00 o'clock, a.m., on March 5, 1973, at the Auditorium of the Atomic Energy Commission in Germantown, Maryland.

This was done. At 9:00 o'clock this morning a call of the hearing occurred at the Autitorium, and as indicated in the telegram, a recess was taken immediately to then reconvene this proceeding at 10:15 a.m., on March 5, 1973, in this hearing room -- Hearing Room C.

Three persons did arrive at the hearing, however, all of whom were informed of the change of location; and I note that two of the three are here now. No other person jrb 4

has appeared. A notice is being placed on the door at the Autitorium in Germantown to notify people of the change as well as the Public Information Section being informed.

With that, the appearances for the Applicant, I note, are Messrs. Trosten, Cohen, and Sack, and accompanied by Mr. Woodbury, the Executive Vice President of Consolidated Edison.

The Regulatory Staff is represented by Myron Karman.

The Hudson River Fishermen's Association by Mr. Angus Macbeth.

I believe that constitutes all of the appearances.

We, the Board, have sent to the parties some communications in reference to several of the matters which are related to this session of the hearing, and perhaps, -- maybe there will be another session; I do not know, of evidentiary hearings, -- by letter dated March 1, 1973, the Board submitted its views to the parties in reference to radiological matters that await development at some session of evidentiary hearings, and in addition, the Board indicated the desire to have further discussion on the record in reference to a motion that has been submitted by the Hudson River Fishermen's and the Environmental Defense Fund in reference to indications which have been given in proposed technical specifications for testing of the thermal plume.

The Board is anxious to have that matter developed somewhat for its further consideration before ruling on the motion and the comments of the Board are reflected in the letter of March 1, 1973, transmitted by the Board to the attorneys for all the parties.

Before we convened this morning, the attorneys indicated they desired to discuss, perhaps, this motion further, and at this time, the Board will receive those further discussions that the parties desire to present.

I think the Applicant spoke first.

MR. TROSTEN: Mr. Chairman, shortly after the last session of the hearings, I contacted counsel for the Regulatory Staff and discussed with him the matter of the proposed technical specifications for thermal model testing.

It is the Applicant's position that if, and I expressed this to Mr. Karman at the time, that if the Staff determined that it would not be necessary that this proposed technical specification be included in the testing license, the Applicant would not object; and the Applicant therefore would not be performing the thermal model testing under the proposed -- under the testing license.

Mr. Karman took this matter under consideration, and I believe is prepared to address this matter today.

This, fundamentally, is our position, Mr. Chairman, that if the Staff feels that the condition should be deleted in light of the expressions of concern by the Board, that the Applicant would simply not oppose the deletion of that condition and the testing would not take place. We would simply perform the testing that was characterized in the evidence before the Board with respect to radiological health and safety, the evidence which is fully before the Board in the testimony in this proceeding.

I do have one point that I would like to make, however, Mr. Chairman, and that is that I would hope that we correctly interpreted the Board's decision with regard to the matter of 100 days.

As I mentioned at the last session of the hearings, it seems to me that the evidence in the proceeding indicates that although we expect and hope to have the testing completed in 49 days, and we certainly anticipate that it will be completed within 100 days, which is a simple doubling of this period, there is, of course, no absolute guarantee that the testing, radiological health and safety testing, will be completed within 100 days; and we think the evidence before the Board expressed that point.

Accordingly, we would hope that the proposed license that was suggested by the Staff, which allows for a period of nine months as a matter of the administrative period ofthe license would be allowed to remain, because we feel that it is important that there be a certain measure of flexibility here and that we not have to return with new motions or new considerations in the event that the testing of the reactor for radiological health and safety purposes should for some reason go beyond 100 days.

This is the position of the Applicant on this matter.

CHAIRMAN JENSCH: Before we hear from the Regulatory Staff and the other attorneys, I wonder if you could tell us, what is the situations about the testing license?

I think Mr. Cahill at one of our last sessions indicated that you expected to have the plant ready for criticality about April.

MR. TROSTEN: Yes.

CHAIRMAN JENSCH: Is that still holding?

MR. TROSTEN: Yes, the criticality is expected in April, Mr. Chairman; and if the Board wishes a further report on this, I requested this morning that I be given the latest information. It is expected in April.

CHAIRMAN JENSCH: I think, unless some members of the Board indicate otherwise, I think your report is adequate for us.

The reason I ask is that the Board has indicated a desire to perhaps visit the site again and the plant, and I just wanted to know how the situation was developing. We appreciate the fact that you have brought Mr. Cahill down, or asked him to come down at the last session. I don't think the Board would ask that you do that again. We will accept your statement or Mr. Woodbury's statement in that regard.

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MR. TROSTEN: Thank you. In this respect, all the fuel has been loaded back into the facility, Mr. Chairman, and as I say, criticality is expected in April.

MR. KARMAN: Mr. Chairman, and Members of the Board, when the Regulatory Staff submitted its proposed technical specifications for the testing license, it was with the intent that if, during the course of this testing period which the Applicant had proposed and which the Board had authorized, the Applicant commences some of the thermal modeling and get that much ahead of the future thermal modeling which we would certainly recommend for a full power license. This would be fine. But under no circumstances was it the intent of the Regulatory Staff to extend any testing license predicated upon the thermal modeling.

We would not oppose the deletion of that thermal modeling requirement during the testing license itself. With respect to the duration of the license which the Regulatory Staff proposed in its proposed license, this was, again, as Mr. Trosten indicated, selected on an administrative basis, figuring that if something did go wrong during the testing, it would not be necessary for the Applicant to come back and request extensions or for us to come to the Board for an extension of any testing license.

But it did not mean that the Regulatory Staff was intending to have testing for nine months. It was still

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within the confines of the proposal which the Applicant submitted and which we discussed during the testimony in this particular hearing.

MR. MACBETH: The interest of the fishermen is the total testing that goes on and the effect on the biota of the river. The heart of that is really additional time for thermal modeling. We don't view the hundred days as a sacrosanct period. I think I would like to reduce to writing the statements that we have had from the Applicant and the Regulatory Staff this morning, and put that into a stipulation to present to the Board simply so that it is clear that we are talking about the radiological testing that was described in, I think it is the October 19, 1971 testimony, which is the basis of the original stipulation between the Applicant and the Hudson River Fishermen's Association.

As long as that is perfectly clear and there can be no error about it, then the Hudson River Fishermen's Association does not feel that 100 days has to be the time. Should there be some lull in the middle when no activity is going on at the plant, which requires the total period to go 105 days, or something of that sort, that would not upset our basic understanding, which was on the total amount of operation testing that the plant would undergo rather than the exact time sequence in which the testing could be done.

MR. TROSTEN: Mr. Chairman, I would like to make

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one observation just to be sure we are all clear on this. I think the record already reflects that, but in any event, the 100 days represents 100 days of testing. It is not necessarily 100 consecutive days. I think we are all clear on that point.

MR. MACBETH: I thought it was more accurately 49 days of testing spread over a more realistic schedule.

MR. TROSTEN: That is not really the case. What we were talking about was 49 days of testing, which, to be conservative, might take 100 days of testing. It is not strictly a calendar period, Mr. MacBeth. Macbeth Every single day would not necessarily be -- it is not a consecutive period of 49 days, or a consecutive period of 100 days.

MR. MACBETH: When you say 100 days of testing, are you talking about 100 days with the plant at some power level? I understand it to be 49 days with the plant at some power level which might be spread over 100 or more calendar days. Is that correct?

MR. TROSTEN: The number of days that the plant would be at a specific power level is set forth in our testimony, and this is the position we are taking. There is no deviation from that.

CHAIRMAN JENSCH: Well, the Board will withhold any ruling until the stipulation would be proposed for our consideration.

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MR. MACBETH: Thank you.

CHAIRMAN JENSCH: Very well.

I believe there have been indications from several of the parties that further evidence would be adduced. Which party desires to proceed first?

MR. TROSTEN: Mr. Chairman, we have a number of documents which we would like to offer into evidence at this time.

CHAIRMAN JENSCH: Very well. Proceed.

MR. TROSTEN: The first set of documents consists of the 19 redirect-rebuttal ~~redirect, rebuttal~~ testimony documents, which were submitted to the Board and the parties on February 5, 1973.

I will identify them for the record.

CHAIRMAN JENSCH: Do you have sufficient copies for inclusion in the record?

MR. TROSTEN: Yes, we do have copies for inclusion in the record.

CHAIRMAN JENSCH: Proceed.

MR. TROSTEN: They are the testimony by Dr. James T. McFadden and Mr. Carey ~~Dr. Harry~~ Woodbury entitled, "Indian Point Studies To Determine the Environmental Effects of Once-Through Cooling" and so forth. All these documents are dated February 5, 1973.

The second is the testimony of Dr. James T. Mc-fadden, entitled, "The Effects of Indian Point Units 1 and 2

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on Hudson River Fish Populations."

The third is the testimony of Dr. John P. Lawler entitled "Mathematical Model Used By the Staff To Estimate the Effect of Indian Point Units 1 and 2 Entrainment on Hudson River Striped Bass."

The fourth is the testimony of Dr. John T. Lawler, "Responses to Questions on the Sensitivity of the Model Presented in the Testimony of October 30, 1972, On the Effect of Entrainment and Impingement at Indian Point ~~On Hudson~~ on the Population River Striped Bass."

The fifth is the testimony of Dr. John P. Lawler entitled "Answers to Questions on The Statistical Data Analysis of Table 19 of the October 30, 1972 Testimony on the Effect of Entrainment and Impingement at Indian Point On the Population of the Hudson River Striped Bass."

The sixth is the testimony of Dr. John P. Lawler entitled "Effect of Indian Point Units 1 and 2 Operation On Hudson River Dissolved Oxygen Concentrations."

The seventh is the testimony of Dr. Lawler entitled "Effect of Indian Point Unit 2 ~~Chlorination."~~ Chlorination on the Aquatic Biology of the Hudson River"

The eighth is the testimony of Dr. John P. Lawler entitled "Thermal Effects of Indian Point Cooling Water on the Hudson River."

The ninth is the testimony of Dr. John P. Lawler entitled "Behavior of the Indian Point Thermal Effluent

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During Winter Conditions and Its Effect on Hudson River Striped Bass."

The tenth is entitled, "Contributions of the Hudson River to the Middle Atlantic Striped Bass Fishery."

The eleventh is Dr. Lauer's testimony on "Striped Bass."

CHAIRMAN JENSCH: That is Dr. Lawler or Dr. Lauer?

MR. TROSTEN: Dr. Lauer.

Twelve is Dr. Lauer's testimony entitled "Expected Water Temperature." Thirteen is Dr. Lauer's testimony entitled "New York University Seine Fish Data on Hudson River Fishes."

Fourteen is Dr. Lauer's testimony on the "Effects of Entrainment on Striped Bass and [illegible] Perch) Eggs and Larvae at Indian Point."

Fifteenth is Dr. Lauer's testimony on "Studies of the Effects of Rapid Pressure Changes on Striped Bass Eggs and Larvae by New York University."

The sixteenth is Ronald A. Alevras "The Estimation of Fish Impingement At Indian Point Units 1 and 2."

The seventeenth is Dr. Edward C. Raney's testimony entitled "Striped Bass."

The eighteenth is the testimony of Mr. Carl L. Newman, Mr. Bertram Schwartz, and Mr. Harry Woodbury entitled "Restricted Operation of Indian Point 2."

Nineteen is Mr. Carl Newman's testimony entitled

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"Alternative Closed Cycle Cooling Systems at Indian Point 2."

This consists of the first collection of testimony, Mr. Chairman.

By stipulation with the parties, Mr. Chairman, the authors of several of these documents are not here. These documents are being offered as the sworn testimony of the individuals in question. All of them have previously been sworn and I ask that these documents be received in evidence in this proceeding and included in the transcript as if read.

(The documents follow.)

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CHAIRMAN JENSCH: Is there any comment any party desires to make with reference to that statement by the Applicant's counsel?

MR. MACBETH: No objection.

MR. KARMAN: No objection.

CHAIRMAN JENSCH: VEry well, the request is granted, and the ~~document~~ documents identified by Applicant's counsel may be physically incorporated in the transcript as if read, and shall constitute evidence on behalf of the Applicant.

MR. TROSTEN: Thank you, Mr. Chairman.

CHAIRMAN JENSCH: It is understood that sufficient copies will be made available to the reporter for inclusion in the transcript.

MR. TROSTEN: Yes, sir.

(Document follows.)

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of	)	
Consolidated Edison Company of New York, Inc.	)	Docket No. 50-247
(Indian Point Station, Unit No. 2)	)	

Testimony of

Dr. James T. McFadden, Dean

School of Natural Resources

University of Michigan

and

Harry G. Woodbury, Executive Vice President

Consolidated Edison Company

of New York, Inc.

on

Indian Point Studies to Determine the Environmental Effects

of

Once Through vs. Closed Cycle Cooling at Indian Point Unit No. 2

February 5, 1973

INTRODUCTION

The Atomic Energy Commission Staff's Environmental Impact Statement for Indian Point Unit No. 2 recommends that Con Edison be required to provide closed cycle cooling for the plant by Jaunary 1, 1978. This recommendation is based on limited data and speculation concerning the effect of once through cooling. Con Edison has provided extensive testimony to show that the effects of operating Indian Point 2 with once through cooling until September 1981, when the Hudson River Ecology Study is completed and a closed cycle cooling system could be in operation, would not cause substantial or irreversible damage.

The AEC staff's recommendation to provide a closed cycle cooling system imposes additional study requirements to determine the environmental design requirements of a closed cycle cooling system and its impact. Con Edison has underway or planned studies which are to provide comparative estimates of the long range environmental impact of Indian Point No. 2 for A) the existing once through cooling system and B) an alternative closed cycle cooling system. It is axiomatic that such studies will require additional time and Con Edison urges that it be allowed the time to complete these studies before a regulatory agency makes any decisions to require closed cycle cooling.

The AEC staff recommended in Item 8 on page viii that: "Whenever the applicant believes it has accumulated information which can clearly demonstrate that the operation of Unit #2 in conjunction with Unit #1 with the once through cooling system will not result in an unacceptable, long-term, irreparable damage to aquatic biota, the applicant may file an appropriate application for amendment of the operating license." This statement acknowledges the tenuousness of the Staff's conclusions on biological damage and recognizes that with proper study evidence might be developed which could well show that the social and economic costs of a closed cycle cooling system exceeded the benefits therefrom. Nevertheless, the staff recommendation provides inadequate time in which to make an adequate study before requiring substantial financial commitment to the closed cycle system.

Con Edison's position on cooling towers, as previously stated, is that:

> "Should Con Edison conclude on the basis of information gathered during the five-year study period that the need has been demonstrated for modification of the once-through cooling system for Indian Point 2, Con Edison

would on its own initiative propose such a modification to the appropriate governmental agencies. In any event, the data would be made available to the agencies having jurisdiction and they would have the information needed to determine what changes in the system were required."[1]

The need for further study to determine the contribution of the Hudson River stock of striped bass to the Atlantic Coastal Fishery is demonstrated by a recent cooperative study agreement between the Department of Commerce and the New York State Department of Environmental Conservation. The object of this three-year study is described in the attached "Project Proposal" dated August 15, 1972 (Appendix C) and we are advised that the Department of Environmental Conservation has received a Federal Grant for the study. As indicated in the "Attachment to Project Proposal", "very little is known about the contribution of the Hudson River stock to the coastal fishery." The results of this study, together with the results of Con Edison's research program as described in this testimony, will provide information required before a rational decision can be made concerning the need for an alternative cooling system for Indian Point 2.

The purpose of this testimony is to present the studies to be made, time required and the dates when results will be available for review and evaluation. The studies are in four general fields:

A) Meteorological

B) Botanical

C) Noise

D) Biological

The meteorological, botanical and noise studies are associated with a determination of effects of a closed cycle natural draft wet cooling tower. If additional studies were to include mechanical draft as well as natural draft wet cooling towers, or other alternatives, additional work would be required beyond that described here. The biological studies relate primarily to the effects on the aquatic ecosystem of once-through cooling on the Hudson River although there

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[1] Opening statement of Mr. Leonard Trosten, attorney for the applicant, on October 30, 1972 when the Environmental Hearing reconvened in Crugers, New York.

effects on the aquatic ecosystem of once-through cooling on the Hudson River although there are biological considerations in closed cycle cooling systems as well.

Meteorological Study

The meteorology study has the following objectives:

1) Determine meteorological design parameters for cooling towers.

2) Determine frequency of formation of visible cooling tower plumes, fogging, icing, dew and cloud formations.

3) Predict the geographical increase in ambient salts resulting from the carryover of entrained water droplets (drift).

4) Determine impact of tower on micro-meteorology of Indian Point site for radioactive release calculations.

5) Determine the effect of a cooling tower on the dispersion of pollutants from Indian Point No. 1 stack.

6) Determine the effect of closed cycle operations on radiological emissions.

The investigation will require the erection of instrumentation towers at Indian Point and the collection of data for a period of 1 year. This is considered to be an absolute minimum for data collection as it will provide one set of observations for each season at the required elevations. A period of three months is needed for the analysis of data and preparation of final report.

Botanical Study

The botanical study has two basic objectives:

1) Determine the threshold values for physiological damage to the most susceptible species of plants in Westchester, Putnam, Orange and Rockland Counties to the deposition of salt and other compounds contained in drift.

2) Establish design criteria for cooling towers (including drift eliminators) to minimize damage to vegetation in the Indian Point area.

This is primarily a laboratory type test where indigenous plants are selected and exposed to a saline aerosol in green houses under controlled conditions. A period of 1 year is considered essential to set up the experiment and to gather data to determine the exposure threshold which will produce damage in the more sensitive species. Environmental damage threshold information is considered necessary before the tower is designed. The study will continue for one additional year to determine the threshold of growth damage and to confirm the first year's results.

Noise Study

Selecting the natural draft cooling tower, and its location on a site are factors that determine property line noise level. Engineering data on cooling tower resonance and noise emissions are required before locating cooling towers, if the Village of Buchanan property line noise levels are not to be exceeded.

Natural draft cooling towers have been used for many years, but in locations where noise was not a concern. Scant information is available on the subject of natural draft cooling tower noise and further information is required in order to accurately predict far field noise levels. Unlike some mechanical equipment, where additional noise control treatments can added after start-up to reduce property line noise, additive noise suppression treatments for natural draft cooling towers would be extremely expensive, and perhaps not even feasible.

In order to predict compliance with property line noise requirements with any degree of certainty, it will first be necessary to develop noise estimating procedures for natural draft cooling towers. Engineering studies for this purpose would include: (a) evaluating the magnitude and frequency distribution of noise emitted by alternate types of towers, (b) sound radiation and resonance characteristics of large towers, (c) audible emanations induced through ground vibrations caused by power plant operations, and (d) attenuation versus distance characteristics of the noise from towers.

Biological Study

The aquatic biological studies are the most time consuming. A part of the work relates to a determination of the effect of cooling tower blowdown on the biology of the river.

The physical and chemical characteristics of the cooling tower blowdown will be established and the resulting three dimensional configuration of the discharge concentrations will be estimated. Additional bioassays will be run as required to determine the expected impact of the various chemical discharge concentrations on the ecosystems of the river to insure proper design and control of discharges.

The aquatic biology studies associated with once-through cooling are the most "time critical". The purpose of these studies is to evaluate the effects of the operation of Indian Point 1, 2 and 3 once through cooling systems on the ecosystem of the river and to devise means and methods for minimizing adverse effects within the guidelines of the National Environmental Policy Act. The study was started in June 1969 under the surveillance of the Hudson River Policy Committee, when the Raytheon Company undertook to identify the various forms of biological life in the river, at Indian Point. This survey determined the presence and relative abundance of some of the species. The field work was accomplished over a period of approximately one and one-half years. The scope of work was modified and the present biological studies being accomplished under contract with New York University, Quirk, Lawler and Matusky and Texas Instruments were initiated in 1971 and early 1972. These study responsibilities are as follows:

1) Texas Instruments, Inc. - Effects of plant operation on screenable organisms.

2) New York University - Effects of plant operation on non-screenable organisms (entrainment).

3) Quirk, Lawler and Matusky - Development and use of a mathematical model to predict the effects of entrainment and impingement on the population of striped bass in the light of known water uses in 1974.

4) Texas Instruments - Integrate the results of 1, 2 and 3 above.

Additional studies planned but not yet under contract include studies to mitigate impingement and entrainment losses by stocking of striped bass fish behavior studies in the presence of alternate screening concepts, the use of a common intake structure for all three Indian Point plants and the use of air curtains.

The Texas Instruments Study has five major objectives which are as follows:

1) Determine the biological significance on the Hudson River ecosystem of impingement of screenable fishes at the intake of Indian Point Units 1, 2 and 3.

2) Determine the biological significance on the Hudson River ecosystem of thermal and chemical additions from Indian Point Units 1, 2 and 3.

3) Determine the biological significance on the Hudson River ecosystem of aquatic organisms passing through or being attracted to the thermal plume and/or into the effluent canal or intake.

4) Determine the acute and chronic effects of temperature on life stages and migrating habits of key fish species, on the behavior of these organisms, the upper and lower temperature tolerance of these organisms, and relate these data to plant operations.

5) Develop and test concepts of protective measures for minimizing adverse biological effects and ascertain biological benefits and costs of such measures.

To be able to quantify the long range effects on a Hudson River population, it is essential that data be collected both before and after start-up of the plant. This study was originally scheduled to measure river conditions before start up of Unit 2 and continue for two years after start up of Indian Point 3.

A study schedule in the form of a time phase and logic diagram is presented as Appendix A attached. Also attached as Appendix B is a diagram which integrates the ecological studies schedules with the schedules for the design and construction of an alternate cooling system indicating an earliest availability date of September 1, 1981 for operational natural draft cooling.

I. SCHEDULING OF BIOLOGICAL TASKS AND GENERAL ANALYTICAL FRAMEWORK

Appendix A contains a presentation of various biological tasks and the times necessary to complete them. Approximately one year was provided to develop and field test the methodology to be used in the population estimates. Interaction occurs between types of sampling gear, tags, and survival of tagged fish with seasons. Thus, these must be determined on a seasonal basis. This work was started in April 1972 and was terminated on January 1, 1973.

This phase of field work will be followed by a period of data analysis and completion of a report on sampling and marking methods. The results of this phase will provide methodology for mark-recapture estimation of the population of striped bass and white perch in the Hudson River.

The methodology developed will provide guidance for field sampling as shown on the diagram. This sampling will provide input data to be used in such related study tasks as estimating population size, sub-populations of major species, ecological characteristics and health of fish populations and the physical-chemical correlates of biological parameters.

A key part of the study is the determination of the population dynamics of striped bass and white perch. Basically, this will consist of estimation of abundance of fish of different ages, their survival, growth, and reproductive rates, and the ways in which these population parameters change under (a) the influence of natural environment conditions (freshwater flow rates, temperature, water chemistry, availability of food, etc.) and (b) impacts caused by man (entrainment and impingement at power plants; thermal and chemical effluents, etc.).

Two closely related perspectives, which, together embody the dynamics of striped bass, and which are the basis for our assessment of the impact of Indian Point Unit #2, are presented in Tables 1 and 2. Similar data syntheses are being carried out for white perch as well. Table 1 is the standard demographic analysis used for populations of living organisms, including actuarial work on human population. It traces by age in years (x) the age specific survivorship (L_x) and age specific fecundity rate (M_x) for a year class of striped bass. For example, one year after the year class is spawned (X= 1), 20,064 fish survive for every billion eggs produced by the parental stock (L_1 = .000020064), and ~~many~~ none of these fish are sexually mature ($M_1 = 0$). At age X = 5, for every billion eggs produced by the parental stock 5 years previously, 836 fish survive and these produce an average of 329,000 eggs per female (M_5 = 329,000). This egg production at age 5 is 27.5 percent of the parental egg complement from which this years class arose ($L_5 M_5$ = .2750). The basic data on reproductive rates are from the testimony of John Lawler (April 5, 1972, TR 4831). Similar use of these data in Dr. McFadden's previous testimony of October 30, 1972, page 29, included minor computational errors which are corrected here. Table 1 represents a striped bass year class in a stationary state - i.e., one which exactly replaces in the course of reproductive

Table 1. - Life table and age specific fecundity rates for a stationary population of striped bass. Based upon sexual maturity and fecundity data from testimony of John Lawler; and assumed annual survival of 30% from Age Group 0-I (12th to 24th month of life), and 50% annually thereafter

X = Age in years measured from the egg stage X = 0;

L_x = fraction of the initial egg complement alive at age 4;

M_x = age specific fecundity rate, the total number of eggs produced by all females at age 4.

X	$L_x \times 10^3$	$M_x \times 10^{-3}$	$L_x M_x$
0	1000.000000	0	0
1	.020064	0	0
2	.006688	0	0
3	.003344	0	0
4	.001672	86	.1438
5	.000836	329	.2750
6	.000418	585	.2445
7	.000209	752	.1572
8	.000105	820	.0861
9	.000053	909	.0482
10	.000026	910	.0237
11	.000013	964	.0125
12	.000007	1136	.0080
13	.000003	908	.0027
			1.0017

Table 2. - Movement of a year class of striped bass through the population of the Hudson River. Survivorship and reproductive rate data from Table 1 for a hypothetical stationary 1969 year class. The lower left quadrant shown for the 1973 and subsequent year classes the spread of Impingement and Entrainment (E) effects from Unit #2 through the age group of the population Horizontal arrows (◄--e) indicate reproduction by the 1969 class.

Year	Eggs	Immatures			Spawners			
	0	1	2	3	4	5	6	7
1969	10^9							
1970		2.0×10^4						
1971			6.7×10^3					
1972				3.3×10^3				
1973					1.7×10^3 $e = 1.4 \times 10^8$			
1974		I				0.8×10^3 $e = 2.8 \times 10^8$		
1975		E + I	I				0.4×10^3 $e = 2.4 \times 10^8$	
1976		E + I	E + I	I				0.2×10^3 $e = 1.6 \times 10^8$

life the number of eggs from which it was originally produced. Thus it exemplifies an equilibrium situation. The $L_x M_x$ column gives the fraction of the lifetime egg production by this year class which is spawned at each age. Age groups V and VI account for half the egg production, and age groups IV through VII account for some 80 percent. The sum of the $L_x M_x$ column is set in this example at unity (differing here by rounding error), reflecting equilibrium with the size of the spawning from this year class arose ($L_o = 1.0$, unit parental egg complement).

Table 2 shows how successive year classes of striped bass move through the population of the Hudson river in real time. The survivorship and fecundity rates of Table 1 operate along a diagonal through Table 2, as shown for a hypothetical 1969 year class. The top numerical entry in each cell of the table is the number of survivors at each successive age from the initial spawning of one billion eggs. For example, the 1969 year class is present in 1972 as age 3 fish, which number $3.3 \cdot 10^3$. In 1973, the 1969 year class first contributes to spawning, producing $1.4 \cdot 10^3$ eggs, as indicated by the horizontal arrow (←---e). The balance of the eggs produced in 1973 would come from the 1968 year class spawning at age 5, the 1967 year class spawning at age 6, etc. Figures 1 and 2 embody essentially the same approach as the population model of John Lawler.

In the lower left quadrant of Table 2 are indicated the paths along which postulated impingement (I) and entrainment (E) effects caused by operation of Indian Point Unit #2 would spread through the age groups of the striped bass population. While all age groups of striped bass and white perch accessible for sampling are included in the Indian Point Ecological Study, the critical stages in terms of power plant impact are those of the first 12 months of life. During the first year of life:

(a) density independent environmental factors which dramatically influence year class strength are strongly operative;

(b) compensatory processes, which increase growth or survival when population density is low and decrease growth or survival when population density is high, are likely to be most effective;

(c) entrainment and impingement of striped bass and white perch have their greatest impact.

On the average, about 80 percent of the annual egg complement of striped bass is produced by Age Groups IV, V, VI, and VII, with V and VI by themselves accounting for 50 percent. By 1969, when the first data on relative abundance of striped bass near Indian Point were collected in the Raytheon study, all four of the principal age groups in the spawning stock had originated from year classes exposed to the impact of Indian Point Unit #1, which began operation in 1962. Thus the effect of Unit #1 is incorporated in the baseline data from 1969, 1970, 1972, and 1973 against which data reflecting the impact of Unit #2 will be contrasted. Exceptions to this condition are noted at appropriate points later in this testimony. It now appears improbable that Unit #2 will be fully operational early enough in 1973 to significantly affect the striped bass and white perch populations through entrainment; therefore its effects in 1973 are assumed here to be limited to impingement of juveniles during the latter part of the year.

It is predicted by the AEC Staff that operation of Indian Point Units 1 and 2 will reduce year class size in striped bass by 30 to 50 percent, and the intervenors predict drastic reductions in striped bass and white perch populations. Based upon: (a) generally applicable principles of animal population dynamics which state that compensatory processes will offset in whole or in part population reduction due to a new increment of mortality; (b) integration of available data on the Hudson River Estuary into a simulation model by QLM; and (c) recent experimental data from NYU studies which demonstrate that a significant proportion of living organisms exposed to the stress of entrainment will survive, Con Edison considers that Staff and Intervenor predictions of fish population reduction are greatly exaggerated. Con Edison contends that solid grounds exist for believing that operation of Unit #2 will not cause serious damage to fish populations. Further, Con Edison considers that ecological studies underway at Indian Point would detect impending irreversible damage to fish populations, and the estuary ecosystem in general, in ample time to implement corrective measures, such as closed cycle cooling towers.

Using data from studies completed in 1969-70 and from the Indian Point Ecological Study now underway and planned for completion in 1976, the following fish population parameters will be monitored for striped bass and white perch:

Population Density

Survival

Age Composition

Growth Rate

Age at Sexual Maturation

Sex Ratio

Identification of Sub-Populations

These parameters change in predictable ways as a result of serious exploitation: population density and survival rates decrease; reduced recruitment causes a predictable decline in the relative abundance of certain age groups in subsequent years reflected in age frequency distribution data; growth rate increases; sexual maturity may be attained at young ages; and aberrations in sex ratio may appear. A data base exists from which each of these parameters can be contrasted before and after activation of Indian Point Unit #2. The data base and analytical methods to be used for each population parameter in assessing the impact of Unit 2 are detailed in the following sections of this testimony.

II. POPULATION DENSITY

Five different measures of fish population density are available:

Catch/Effort Trawl data - relative abundance

Catch/Effort Seine data - relative abundance

Mark-Recapture population estimates - absolute abundance

Egg Deposition estimates - absolute abundance

Pelagic larvae estimates - absolute abundance

In addition, work is underway to develop echo-sounding techniques which would be calibrated against trawl catch/effort data, and which would allow much broader collection of catch/effort data. It will be possible, if this technique is successful, to follow changes in abundance and seasonal movements to different locations in the estuary more closely than is possible through trawling techniques alone.

IIA. CATCH EFFORT

The number of fish caught in a standardized amount of fishing effort using standardized collecting gears is an index of relative abundance of the fish population. Such indices are one of the longest established and most widely used types of data in the study and management of fish populations. Catch per unit of fishing effort - or catch/effort, the term used here - has been used to monitor changes in abundance from year to year and place to place in such widely differing situations as the great high seas fisheries of the world and local, hook and line, sport fisheries.

Catch/effort data have been collected for striped bass, white perch and other species in the vicinity of Indian Point by the use of trawls and beach seines. In the Indian Point Ecological Study now underway stations have been established from Ossining to Denning Point. These sampling stations are distributed among three study regions, as shown in Figure 1, the most important being Region I, extending from Haverstraw Bay to the Bear Mountain Bridge, with a concentration of stations near the Indian Point power plant. The sampling effort is distributed as follows:

	Region I	Region II	Region III	Ossining
Boundaries	Haverstraw Bay Bear Mt. Bridge	Bear Mt. Bridge Storm King Mt.	Storm King Mt. Beacon Newburgh Bridge	See Fig. 1
Number Trawl Stations	10	3	3	5
Number Seine Stations	8	4	3	3

This sampling effort continues in intensified form the fish population monitoring begun in the Raytheon Study in June 1969. Because of the continuity in sampling, site, and methods from the Raytheon Study to the present Indian Point Ecological Study, it will be possible to contrast data from 1969, 1970, and 1972 - years free of Unit #2 effects - with data from 1973, 1974, and 1975, when Unit #2 is operative. At present it appears that Unit #2 may not go on line early enough in 1973 to affect fish populations significantly by entrainment, so the 1973 data may reflect either "pre-operational" or "operational" status of Unit #2, depending upon date of activation of the Unit and the nature of the fish population contrast being made.

The Raytheon data extend from June 1969 through October 1970. Sampling was limited in winter and spring, with the main data being from summer and autumn of 1969 and 1970. Seven major and 9 minor trawling stations were maintained, along with 6 major and 3 minor seining locations. The major trawling and seining stations are of greatest importance in

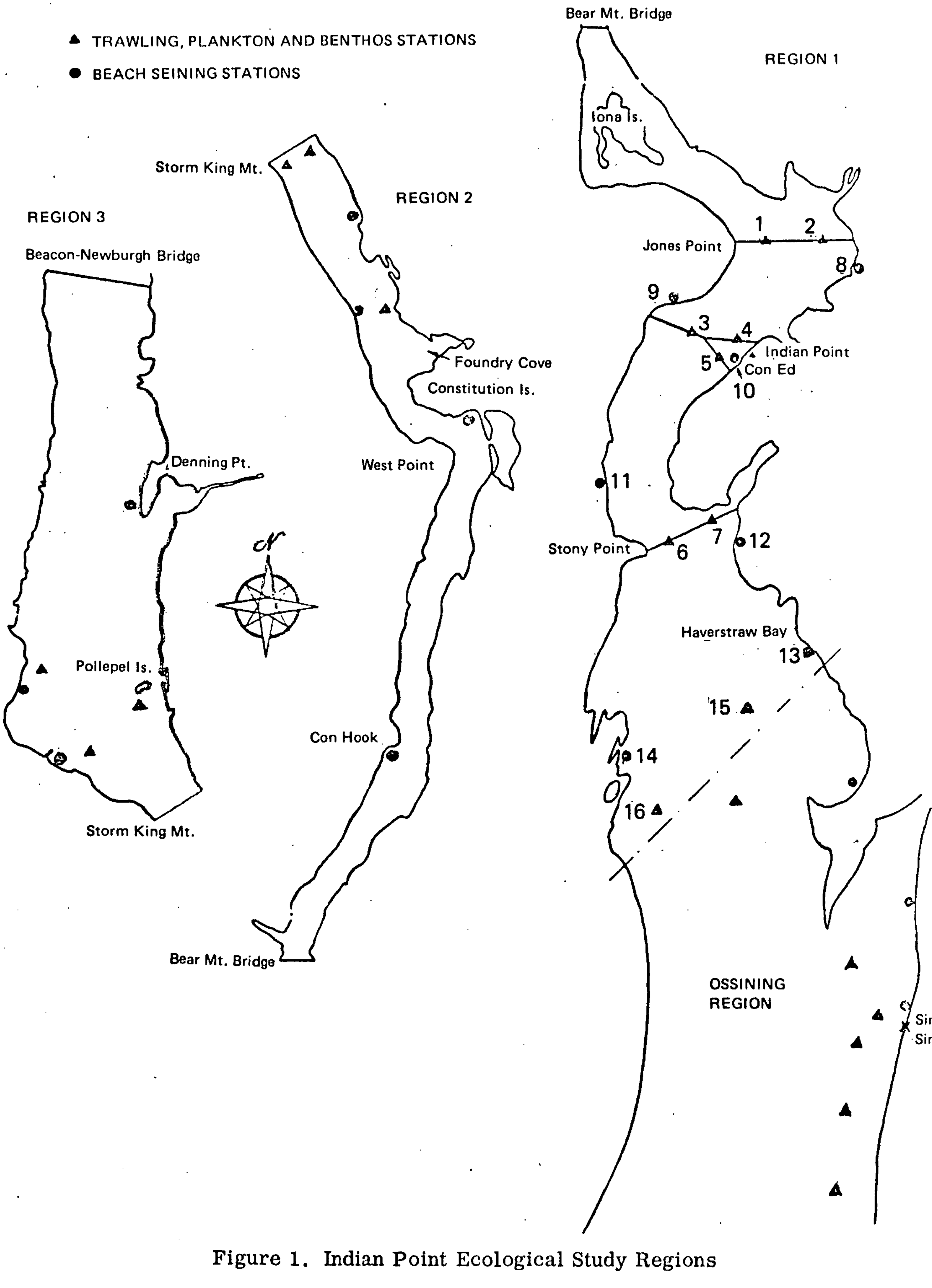

Figure 1. Indian Point Ecological Study Regions

comparisons of data from 1969 - 1970 with subsequent data collected by Texas Instruments in the Indian Point Ecological Study.

Bottom trawling was begun in June 1969. Samples were taken 3 times monthly at major stations and at least once monthly at minor stations, with occasional night samples. From March through May 1970 major stations were sampled at least once monthly and minor stations only occasionally. From June through October 1970 major stations were sampled weekly in daytime and monthly at night; minor stations were sampled three times each month, but only once in October.

Surface trawling was begun in autumn 1969. Samples were taken twice each month, both day and night, at major stations, and once monthly, both day and night, at minor stations. During April and May 1970 sampling was reduced to once monthly at selected stations. From June through October 1970, major stations were sampled biweekly, both day and night, and minor stations monthly, both day and night.

From June 1969 through October 1970 beach seining was carried out weekly, both day and night at major stations; and monthly, day and night, at minor stations except as prevented by winter weather conditions.

A gap in trawl and seine catch/effort data exists from November 1970 through March 1972. Data from the Indian Point Ecological Study began in April 1972 and will continue into 1975, except for the seven Ossining stations which began in June 1972 and will be sampled through 1973. Samples are taken weekly in daytime and biweekly at night. Seining is carried out on a 24 hour basis with the biweekly sampling.

Through this entire data set, catch/effort indices are being calculated separately for age groups 0-I, I-II, and II+ in white perch; and for age groups 0-I, I-II, and II-III for striped bass based on length frequency data. Verification of this age specific breakdown of catch effort data, and possible extension of identification to older age groups of white perch will be effected through scale sample age data.

Much of the data can be subjected to factorial analysis of variance in balanced designs which provide powerful discrimination of changes in relative abundance of the fish populations. Although the inherent variability of the data is high, sample sizes are large, several important sources of variability are accounted for in the sampling design, and a number of physical and chemical parameters of the environment have been measured concurrent with the fish catch/effort data.

The importance of sample size and sources of variability accounted for in the sampling design can be considered simultaneously by examining the form of variance analysis to which the data will be subjected. Catch effort indices of abundance of 0-I age fish, for example, could be assembled according to the analytical design shown in Table 3. This table assumes the availability of data from 6 years, (1969, 1970, 1972, 1973, 1974, 1975), from 7 standardized stations, sampled during 25 different weeks (seasonal effects) at surface and bottom, utilizing 2100 different trawl samples in total. It should be noted that such an analysis is only one of many possible, and that the number of catch/effort samples will be much greater than 2100 by the conclusion of the Indian Point Ecological Study. The analysis is a formal statistical device for partitioning the total variation among catch/effort data into components attributable to years, different sampling locations (stations), different seasons of the year (weeks), and different depths in the estuary. Also partitioned out are the components of variation attributable to interactions among these four main effects (e.g. Y x S = interaction between Years and Stations). An example of an interaction between years and stations would be an upward trend in catch/effort values over a period of years at some stations, accompanied by stable values or a downward trend from year to year at other stations. If no interaction is present, the year to year trends would be the same for all stations even though the average values of catch/effort might be very different from one station to another.

All the main effects and interactions are of value in understanding the fish populations of the Hudson estuary and the impact of the power plant upon them. The changes in catch/effort among years is of greatest significance, however, in assessing the impact of Indian Point Unit #2. Note that variance analysis clearly separates the changes from year to year from other sources of variation, and also removes the variation due to the main effects and interactions listed in Table 3 from our sampling error. Sampling error may be thought of as the background "noise" in the data. If the "noise" level is high (large sampling error), it is difficult to detect real changes in the fish populations, such as those due to any added impact by Unit #2. As the "noise" in the data is reduced, it becomes possible to detect smaller differences in catch/effort attributable to identifiable causes, such as years or

Table 3. - General form of variance analysis of catch/effort data for Hudson River fish populations. Example based upon data from 6 years x 7 stations x 25 weeks x 2 depths.

Source of Variance	Degrees of Freedom	$F_{.05}$
Years	5	2.22
Stations	6	2.11
Weeks	24	1.53
Depths	1	3.85
Y x S	30	1.48
S x W	144	1.24
Y x W	120	1.27
Y x D	5	2.22
S x D	6	2.11
W x D	24	1.53
Y x S x W	720	1.14
Y x S x D	30	1.48
S x W x D	144	1.24
Y x W x D	120	1.27
Error	720	—
Total	2099	

sampling locations. The form of the data being obtained at Indian Point allows extensive refinement of the sampling error and sensitive discrimination of changes in the fish populations. Experience in treating quantitative samples from populations of stream dwelling invertebrates - among the most notoriously variable of biological field data - with similar analysis of variance designs has shown that sampling error can be adequately controlled and population changes large enough to be of practical significance can be readily detected. In the case of the striped bass population of the Hudson River, a sudden decrease of 30 to 50 percent in year class strength has been predicted by the AEC Staff and Intervenors as a result of operation of Indian Point Unit #2. Thus it is not a small and subtle change which the biological monitoring must be able to detect.

Various physical and chemical parameters are measured at each of the catch/effort sample stations. These may affect the abundance of fish in predictable ways, allowing still further refinement of sampling error through analysis of covariance, and further identification of significant causes of variation in fish populations. For example, year to year variations in salinity might cause changes in abundance of fish which could be confused with changes due to initiation of operation of Unit #2. Through analysis of covariance, it would be possible to remove effects due to salinity from other effects (such as power plant operation) associated with years.

Table 3 summarizes the example variance analysis discussed above. The "degrees of freedom" are a measure of the number of observations relevant to each source of variance. The column $F_{.05}$ gives the ratio of variance caused by a particular identifiable source (Years, Weeks, Y x S, etc.) to variance due to sampling error, as required for statistical significance at the .05 probability level. For example, variance among years must be at least 2.22 times as great as sampling error to be judged significant at the .05 probability level.

Estimates of sampling error from trawl and seine catch/effort data collected during 1972 indicate that the standard deviation for a single haul approximates the value of the mean (Table 4). Because critical comparisons of catch/effort data in evaluating the impact of Unit #2 will be based upon large numbers of samples, drawn from different sampling stations, weeks, etc., the precision with which means for individual years will be estimated will be high. For example, a mean catch/effort of 10, with a standard deviation of 10, and based on a sample size of 100 trawl hauls, would have a standard error of 1.0.

Table 4. - Estimates of sampling error for catch/effort data for August - September 1972 from the Indian Point Ecological Study. n = sample size; $\bar{x}$ = mean catch/effort; $S_{\bar{x}}$ = standard error of the mean; S = standard deviation.

	Striped Bass				White Perch			
Gear	n	$\bar{x}$	$S_{\bar{x}}$	S	n	$\bar{x}$	$S_{\bar{x}}$	S
Beach Seine	20	8.25	1.69	7.55	20	8.25	3.01	13.45
	8	8.00	3.63	10.27	8	19.38	7.89	22.33
	20	6.85	1.51	6.75	20	19.05	3.71	16.58
	5	2.40	0.00	0.00	5	6.20	0.00	0.00
Bottom Trawl	14	0.29	0.11	.41	14	2.21	0.34	1.27
	14	0.59	0.13	.49	14	6.42	0.58	2.17
	7	0.00	-	-	7	0.67	0.00	0.00
Surface Trawl	14	0.00	-	-	14	0.07	0.03	0.11

$$S_{\bar{x}} = \frac{S}{\sqrt{n}} = \frac{10}{\sqrt{100}} = 1.0$$

A conservatively small sample size is chosen for this example to emphasize that precision will be high even for means calculated within subsets of the overall matrix of catch/effort data. In the example given here the true mean catch/effort may be inferred to lie within the range $\bar{x} \pm 1.98\ S_{\bar{x}}$ or 10 ± 1.98 unless a 1 in 20 chance event has occurred in sampling. Another way of expressing the precision of the data is to say that a 95 percent probability exists that the true mean catch/effort lies within the range 8.02 and 11.98.

Catch/Effort data are known to be biased in such a way that comparisons of abundance among all size groups or different species of fish cannot be made directly. The mark-recapture work carried out in 1972, 1973, 1974, and 1975 will provide a basis for correcting the Catch/Effort data for these biases, with the result that the relative abundance of different size and age groups of white perch can be determined, and within the younger age groups the relative abundance of white perch and striped bass can be accurately determined.

In addition to the main body of data treated in some detail above, two additional sources of information which provide some comparison of past conditions within the fish populations of the Hudson River exist. First, trawling stations have been established in the current Indian Point Ecological Study which correspond to some of the stations sampled in the Cornwall study in 1965 - 1968. Secondly, ancillary information is available from fishery studies on the lower Hudson by biologists from QLM, Vassar College, Dutchess Community College, Boyce-Thompson Institute, and New York Department of Environmental Conservation. While relevant to our assessment of fish stocks in the Hudson, this second group of studies does not integrate directly with the design of the Indian Point Ecological Study.

IIB. Mark-Recapture Population Estimate

Unlike the catch/effect data which are indices of relative abundance, the mark-recapture methods provide estimates of absolute numbers in the population. This method of estimating population size by marking some members, distributing them among the body of the population, and subsequently withdrawing a sample to determine the proportion of the population marked, dates back to the latter years of the 19th Century in fishery work (Petersen, 1896). It has been applied to fish populations in almost every conceivable situation - small streams, large rivers, ponds, lakes, high seas. The same method is used to estimate the North American continental duck population, and has been applied to insect and mammal populations.

The basic method has been elaborated and adapted to a variety of complex situations, including the occurrence of mortality, emmigration, and recruitment within the population being estimated (Ricker, 1958; Delury, 1947, 1951, 1958; Chapman, 1952, 1954). The same principles underlie the technique in the many forms used today. For example, assume that 1000 Age Group O striped bass are marked and released alive in the Hudson estuary in the vicinity of Indian Point. In subsequent trawling operations 2000 striped bass of the same age are collected, of which 32 are recaptures of the previously marked fish. We then reason:

(1) 1000 marked fish are at large in the population

(2) our subsequent sample indicates that 32/2000 = 1.6% of the total population are marked fish

(3) therefore the total population in the locality under study must consist of 2000 ÷ 016 = 125,000 fish

The basic assumptions underlying the valid application of this method are given by Ricker (1958 p. 86). These have been examined during the fish collecting, marking, and field trial work of 1972 at Indian Point in preparation for full scale mark-recapture estimates of the white perch and striped bass populations in 1973 and succeeding years. The only basic assumption which has been problematic is that marked fish be distributed at random in the population. However, by reintroducing marked fish to the population in proportion to the abundance of the population in different habits (as determined from trawling data and possibly from echo-sounding) and by distributing recapture fishing effort proportionally across all segments of the population, this requirement for the valid use of the mark-recapture method can be fulfilled.

The developmental work of 1972 has already proven that large numbers of young white perch and striped bass can be successfully marked and released in healthy condition in the Hudson River estuary to provide a basis for estimates of population size. Tentative plans are to proceed with this method full-scale in 1973.

Separate population estimates will be made for different age groups and size groups of fish, and for zones extending various distances from the Indian Point power plant.

Through use of differential marking in different zones of the estuary, the origin of fish collected on intake screens at Indian Point can be determined. At present it is not known whether a very local area or an extensive area of the estuary is affected. Until reliable estimates of the absolute abundance of fish during the first twelve months of life are available, no accurate basis for assessing the importance of impingement losses is available. The absolute numbers of fish collected from intake screens of the Indian Point plant have been determined with suitable accuracy. What proportion of the stock from the estuary this loss represents can be directly determined from the population estimate data collected in the ongoing ecological study.

Collection of data from three successive years (1973, 1974, 1975) is important for two reasons:

(a) The first year will represent the influence of Unit #1 plus no influence or minimal influence of Unit #2 (depending upon the date of its activation); the second and third years will reflect full influence of Units #1 and #2.

(b) Survival rates can be calculated for those year classes of fish included in two or more successive years' population estimates. Not only abundance of fish, but also their survival rates (an important component of population turnover rate) are important in assessing an increment of mortality, such as expected from operation of the Indian Point power plant. In addition to their direct use in assessing ecological impacts, these survival rate estimates will be most useful in "tuning" the parameters of the population dynamics model developed by QLM.

Because of greater abundance and vulnerability to collecting gear, the most precise population estimates will be obtained for the younger age groups of fish. It is planned to estimate the number of Age Group O and of Age Group I striped bass and white perch present in areas of the Hudson River adjacent to Indian Point. The best estimates will be for Age Group O in the fall. We anticipate being able to discriminate a 25 percent change in abundance of these fish at the 5 percent probability level.

Estimates of absolute abundance of the fish stocks of the Hudson estuary are considered to be of great importance in assessing the ecological impact of the Indian Point power plant. Accordingly, during the initial planning of the Ecological Study an alternative to the mark-recapture method — the catch-removal method of estimating absolute population size — was defined for use in the event that mark-recapture procedures were unworkable. The catch-removal alternative is incorporated in the time flow-diagram of Appendix A. It consists of intensively fishing representative habitat types in the Hudson estuary with experimental gear and commercial gear under contract and removing all fish caught during a short interval of intensive fishing effort. The decline in catch-per-unit effort is plotted against cumulative catch and the regression line fit to the data is extrapolated to 0 catch-per-unit-effort, at which point the corresponding value for cumulative catch is an estimate of total population size for the area fished. The estimates for a selected set of "typical" Hudson estuary sampling plots would then be expanded to an estimate of fish population size for the entire estuary, or major regions thereof.

Developmental work on population estimation techniques indicates that the mark-recapture method will yield usable data, and the use of the catch-removal alternative is not now envisioned.

IIC. Combined Use of Catch/Effort Data and Mark-Recapture Population Estimates

During 1973, 1974, and 1975, catch/effort data will be collected in the same time periods and localities in which the mark-recapture population estimates are made. A relationship between these two types of population data can be developed where the two are collected in parallel, and this relationship can be applied to the catch/effort data of earlier years (1969, 1970, 1972) to calculate approximate values for absolute abundance of fish.

IID. Egg Deposition and Pelagic Larvae Estimates

Additional estimates of the size of white perch and striped bass populations, completely independent of the mark-recapture work described above, will be made by estimating total egg deposition and abundance of the pelagic larvae for each species, and reconstructing (with the use of age structure, sex ratio, sexual maturation, and fecundity data) the adult population size required for the spawning observed. While the promise of success of mark-recapture population estimates rising from work to date makes these estimates based upon egg deposition less critical, they nevertheless will constitute a valuable independent check on the mark-recapture work, and increase overall confidence in our assessment, of fish population size. Evaluation of our present development of methods indicates that in 1973 a good estimate of the white perch population can be obtained through the egg deposition method. A preliminary estimate will be obtained for striped bass in 1973, and refined estimates of the size of the striped bass population would be expected in 1974, and 1975.

The estimate of striped bass eggs, and both striped bass and white perch larvae will be made using improved collecting gear and appropriate stratification of samples in time and space to provide population estimates applicable to the Indian Point region in particular, and the entire main spawning area of striped bass in the Hudson estuary.

Egg densities of striped bass and white perch will be corrected to daily deposition rates/m^2 (see Edmondson, 1960) and summed over the season for 10 stations spanning river miles 40 to 59. The areal deposition rates (eggs/m^2/day) will be compared for a first approximation of the importance of the various areas for spawning of both species. The striped bass densities will be derived from plankton data due to the pelagic nature of their eggs, while benthic grabs will be used to obtain the demersal white perch eggs. The white perch egg data will then be applied to population parameters (sex ratio, age structure, and mean eggs per female) to derive an estimate of the total population in this area by an application of "backwards" population dynamics. Because mature females go into the breeding season with their full compliment of eggs and no rejuvenation of ovaries or eggs occurs during the breeding season, the observed decrease in mean female eggs per female from time t_o to t_1 in the population is a direct estimate of m_x (the mean number of female eggs produced by a female in a unit of time). A unity sex ratio is assumed, and the m_x value is multiplied by two and divided by the number of days between sampling for an estimate of the daily egg production rate (eggs/female/day). Parts of the two ratios cancel to yield females/m^2 (eggs/m^2/day and eggs/female/day).

The Computational methods for working back from a given egg complement — through intermediate data on age at sexual maturity, sex ratio, fecundity, and age frequency distribution — to estimate the size of fish population required to produce the observed spawning, can be readily deduced from the data array of Table 1.

In addition to their use in estimating total fish population size, estimates of eggs and pelagic larvae are of prime importance in calculation of survival rates as explained in Section IV.

IIE. Summary of Estimates of Population Density

The temporal sequence of the various population density estimates discussed above and the life history stages to which they pertain are summarized in Table 5. Four years of observation prior to activation of Indian Point Unit #2 and two years following activation are included in the data. Five different life history stages during the first 15 months of life, plus some data from Age Groups II, III, and IV are represented.

For striped bass estimates of eggs spawned would be made during the period May 9 - June 17; the Juvenile II's — screenable fish between 2.0 and 3.3 inches in length — would be estimated between midsummer and fall; Juvenile III's, overwintering fish 3-4 inches in length, would be estimated in spring. The best estimates for older fish would be obtained in summer and fall.

Table 5. Population Data for Assessment of Impact of Indian Point Unit #2 Upon Population Density of Striped Bass and White Perch in Hudson Estuary

	Power Plant Impact		Data on Fish Populations						
					Age Group 0				Age Group
Year	Unit #1	Unit #2	Eggs	Larvae	Juvenile I	Juvenile II	Juvenile III	Age Group I	II III IV
1969	Entrainment Impingement	None	—	—	—	△1 ○1	△1 ○1	△1 ○1	△1 ○1
1970	Entrainment Impingement	None	—	—	—	△1 ○1	△1 ○1	△1 ○1	△1 ○1
1971	Entrainment Impingement	None	—	—	—	—	—	—	—
1972	Entrainment Impingement	None	—	—	—	△1 ○1	△1 ○1	△1 ○1	△1 ○1
1973	Entrainment Impingement	Impingement	◇1	◇1	—	△1 ○1 □1	△1 ○1	△1 ○1 □1	△1 ○1
1974	Entrainment Impingement	Entrainment Impingement	◇2	◇2	—	△2 ○2 □2	△2 ○2	△2 ○2 □2	△2 ○2
1975	Entrainment Impingement	Entrainment Impingement	◇2	◇2	—	△2 ○2 □2	△2 ○2	△2 ○2 □2	△2 ○2

Legend for Table 5

△ 1′	Raytheon — Trawl Catch/Effort — Unit 1 effect only
△ 1	Texas Instruments — Trawl Catch/Effort — Unit 1 effect only*
△ 2	Texas Instruments — Trawl Catch/Effort — Unit 1 + Unit 2 effect
○ 1′	Raytheon — Seine Catch/Effort — Unit 1 effect only
○ 1	Texas Instruments — Seine Catch/Effort — Unit 1 effect only*
○ 2	Texas Instruments — Seine Catch/Effort — Unit 1 + Unit 2 effect
□ 1	Texas Instruments — Mark Recapture population estimate — Unit 1 effect only
□ 2	Texas Instruments — Mark Recapture population estimate — Unit 1 + Unit 2 effects
◇ 1	Texas Instruments — Population estimate eggs and larvae — Unit 1 effect only
◇ 2	Texas Instruments — Population estimate eggs and larvae — Unit 1 + 2 effects

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* Impingement effects of Unit #2 if operational during last half of 1973.

The appropriate contrasts of fish abundance before and after activation of Unit #2 are obvious from Table 5. In statistical analysis, variability among the "before Unit #2" years and among the "after Unit #2" years can be separated from density changes associated with the activation of Unit #2. The potential problem in using density changes alone lies in the large variations in year class size typical of striped bass and white perch. Fluctuations in population density caused by natural environmental variation, could, if not accounted for in the data, obscure or be confounded with effects of Unit #2. However, in the Indian Point Ecological Study a large number of physical, chemical, and biological parameters are being measured along with the fish population estimates. Examples are salinity, temperature, freshwater flows, turbidity, water currents, dissolved oxygen, pH, carbon content, plankton populations, benthic invertebrate populations, and indices of abundance of other species of fish. Among these environmental variables it is expected that one or more will be important predictors of year class strength in striped bass and white perch.

Freshwater flows have been shown to account for 85 percent of the variation in year class strength of the San Francisco Bay striped bass population over a six year period (Sommani, 1972). Reduction of suitable spawning areas, low egg and larval survival rate, decline in food availability, or some combination of these are believed to be the proximate causes of low striped bass production in years of low freshwater flow. Similar relationships with these or other environmental variables will be established for the fish populations of the Hudson River. These components of variability will be differentiated from that caused by the operation of Indian Point Unit #2 through regression analysis. This will substantially reduce the tendency for naturally occuring variations in year class strength to obscure real impacts upon fish populations by the power plant, or to create spurious indications of adverse effects of plant operation through the chance occurrence of adverse natural conditions, coincident with start up of Unit #2.

Some important relationships among the different population data being collected for the Hudson Estuary fishes, are:

1. catch/effort data extend over the longest span of years; include the largest number of age groups of striped bass and white perch; and include comparative indices of

relative abundance for other fish species. For maximum value catch/effort data must be corrected for size and species selectivity by utilizing data collected during mark-recapture studies.

2. catch/effort data for all years can be used to calculate approximate values for absolute size of fish populations by the use of conversion factors developed from those years in which catch/effort data were collected concurrently with mark-recapture population estimates.

3. mark-recapture data provide direct estimates of absolute abundance of fish. These estimates will be available from the three study regions and from 1973, 1974, 1975. The recapture on the water intake screens of the Indian Point power plant of fish differentially marked in zones of increasing distance from the plant will provide direct estimates of the fraction of the fish population in each zone which is impinged.

4. estimates of the numbers of eggs spawned in the Hudson by the striped bass and white perch populations will provide a basis for calculation of the size of the parental stocks, and associated age groups of immatures. This reconstruction of population size will be used to verify the mark-recapture estimates.

5. measurements of important environmental variables concurrently with fish population estimates will be used to account for the naturally occuring fluctuations in fish population size which tend to obscure the true effects of power plant operation.

III. ENTRAINMENT STUDIES

New York University is responsible for entrainment studies at Indian Point.

The biological significance of aquatic organisms being drawn or attracted into the intake canal is being quantitatively determined by measuring the horizontal and vertical distribution of planktonic organisms on a diel basis, applying these densities to the actual water mass subject to entrainment on a diel basis, comparing these theoretical entrainment values to observed densities of entrained organisms, and finally establishing the immediate and delayed effects of entrainment (passage) of non-screenable organisms through the condensor system of the plant. Quantitative sampling is being done in the river, intake bays and discharge canal during all seasons of the year. Survivorship and behavior of zooplankton and fish larvae are immediately compared to see if any statistically significant differences are observed between the control group (intake bays) and the treated group (discharge canal) which passed through the condensor coils. In addition, a series of experimental laboratory studies are keyed to combinations of ΔT, chemical discharges, and residence times through the system produced by various plant operational schemes. Effects measured are lethal, behavioral, and reproductive for zooplankton; lethal and behavioral for fish larvae; and photosynthetic capability, chlorophyl concentration, and cell damage for phytoplankton. Studies include sequential trials, trials of different size groups of key species, and multi-species trials. When possible, all life history stages of each organism are studied

IV. MORTALITY AND SURVIVAL RATES

Collections of white perch and striped bass obtained from the standard trawl and seine stations are separated into four size groups (<50, 50-125, 125-250, >250 mm) and 15 individuals of each size (if available) are randomly picked for age determination by scale analysis. Both species show clear annuli and can be aged quickly and reliably so that relative age structure can be determined.

Both data on relative abundance of successive age groups, as obtained from catch/effort study; and data on absolute abundance, as obtained from mark-recapture, egg deposition, and fish larvae estimates, can be used as a basis for calculating mortality rate, and its complement, survival rate.

For striped bass the life history stages upon which survival rates are based are those defined in the October 30, 1972 testimony of John P. Lawler. The egg stage is defined as lasting 1.5 days and eggs are present in the Hudson estuary from May 9 to June 17. The larval stage lasts about 28 days (from hatching to a length of 3/4 to 1.0 inches) and larvae are present in the Hudson from May 10 to July 8. The Juvenile I non-screenable stage (J_I) lasts 30 days. J_I striped bass are present from May 31 to August 7. The Juvenile II stage (J_{II}) includes fish from 2.0 to 3.3 inches long, present between June 30 and December 1, and subject to impingement. The Juvenile III stage includes overwintering fish, 3 to 4 inches in length, present between December 1 and May 9. Survival rates available from the different life history stages are summarized in Table 6.

Table 6. - Survival rate estimates available for striped bass and white perch in Hudson estuary. See Table 5 for summary of methods of estimation.

Life History Stage	Year of Survival Estimate				
Egg - Larvae			1973	1974	1975
Larvae - J_{II}			1973	1974	1975
J_{II} - J_{III}			1973	1974	1975
J_{III} - Age Group I	1969 - 70	1972 - 73	1973 - 74	1974 - 75	

Taking the data from the entrainment studies together with the survival data based on population estimates, the following sequence of calculations will be carried out:

(1) the number of eggs spawned in the estuary;

(2) the size of the larval population;

(3) from the entrainment study, the density of eggs and larvae in the immediate vicinity of the power plant water intake;

(4) from (1), (2), and (3) the fraction of the population of eggs and larvae subjected to the influence of the water intake;

(5) from the entrainment study, the number of fish entrained and the number passing alive through the cooling system - hence the survival rate for entrained fish; these data will be integrated with those from laboratory studies of the impact of the physical-chemical conditions of entrainment upon young fish;

(6) from (1), (2), and (5) the fraction of the population killed during early life history stages by entrainment;

(7) from (1), (2), and estimates of J_{II}, J_{III}, and Age Group I fish obtained from mark-recapture and catch/effort studies, the total mortality rates for each

successive stage of the early life history; development of a survivorship curve will allow some useful interpolations, as for the J_I stage;

(8) from (6), and (7) by the use of standard actuarial calculations for survival under exposure to competing risks of death, the survival rate for each early life history stage in the absence of the operation of the power plant (note that Unit #1 and Unit #2 effects can be treated separately here and both can be differentiated from background natural mortality);

(9) from (7), and (8) the decrease in survival during the early life history due to operation of Indian Point Units #1 and #2.

These calculations of the fraction of the year class affected by entrainment are not sensitive to the natural fluctuations in year-class strength which complicate interpretation of population density changes. Entrainment affects a certain proportion of the fish population and is primarily a function of the fraction of the estuarine water withdrawn by the power plant cooling system. Appropriate allowance for non-random distribution of the fish and avoidance capability of the juveniles must be made, but again these phenomena are not believed to change because of year-class size.

The magnitude of natural mortality varies from year to year in the early life history stages, but is always quite high. The variations do influence the combined natural and power plant induced mortality, but the relationship can be predicted as in step (8) above for any observed or postulated natural mortality rate.

The spatial distribution of spawning and surviving young fish may vary, especially as a function of volume of freshwater discharge in the Hudson, and correlated physical and biological conditions. Such phenomena are causally related to variations in year-class size. The spatial distribution of early stages of striped bass and white perch would influence the fraction of each year-class exposed to entrainment. By utilizing the population data discussed above in the model of the Hudson estuary striped bass population developed by John Lawler of QLM, the effects of any observed or postulated change in spatial distribution of spawning fish and early life stages of the progeny on the entrainment phenomenon can be readily predicted.

In fact, the most meaningful way to evaluate the impact upon fish populations of the Indian Point power plant is to integrate the data from the Indian Point Ecological Study and the studies of New York University and Quirk, Lawler and Matusky in a dynamic simulation model of the ecosystem. The second generation model will not be deterministic as is the present Lawler model - that is it will not be restricted to exploring the performance of the fish population in an assumed "unchanging" environment. Rather, the fish population parameters will change in response to environmental variables which are represented in the model. The functions which translate environmental changes into changes in fish population parameters are being described in present field studies. The natural pattern of variability in environmental factors to be represented in the model is being determined from current field studies and from past studies of the Hudson estuary and similar estuarine environments.

The simulation model is simply a device for assessing the outcome of joint operation of the many population phenomena described individually through the field studies. This comprehensive assessment of an integrated biological system to impact is complementary to assessments of the individual population phenomena empirically studied in the field.

Criteria for Assessing Impacts on Fish Populations

Based upon the population data detailed in this testimony, the following criteria for assessing the impact of Indian Point Units #1 and #2 upon populations of striped bass and white perch are established. Each criterion is stated in terms of the symptoms of adverse impact.

(1) Decline in density of Juvenile II, Juvenile III, and Age Group I fish coincident with startup of Unit #2 and not accounted for by changes in egg production by parental stock or by natural environmental fluctuations.

(2) Large fraction of the population of eggs, larvae, or Juvenile I fish entrained.

(3) High mortality rate of entrained organisms.

(4) Substantial reduction in survival rate from egg stage to Juvenile II, etc. accounted for by entrainment.

(5) Substantial percentage of stock from significant area of estuary impinged on intake screens.

(6) Lack of compensatory increase in survival rate among Juvenile II and Juvenile III fish following fulfillment of criterion (4).

(7) Lack of compensatory increase in survival rate among Juvenile III to Age Group I fish following fulfillment of criterion (5).

(8) Increase in growth rate of fish. Note that increased growth rate is both a classical indicator of a substantial decrease in stock density (hence an indicator of adverse impact) and a compensatory response to reduction in density (hence an indicator of some capability of the fish stock to sustain itself in the face of increased mortality).

(9) Attainment of sexual maturity at an earlier average age. The note in (8) above identifying the criterion as an indicator of both adverse impact and compensatory capability of the population applies here as well.

(10) Continuing decline in population size or stabilization at an undesirably low level following a period of decline, as predicted by a simulation model of the fish population which integrated the empirical data from the ecological studies.

V. BIOLOGICAL CHARACTERISTICS OF FISH POPULATIONS

Racial Composition

Food Habits

Age Composition

Growth Rate

Reproductive Rate

Identification of sub-populations and study of ecological relationships of major fish species will be completed by April 1, 1973 and October 1973, respectively. These two studies will provide additional information on the resident or migrating nature of the sub-populations (vital to estimates of population size) and their respective food habits. The report on this phase of work is to be completed by May 1, 1974.

The study of biological characteristics and health of fish populations will reach full scale in April 1973 and continue until January 1, 1976. This is a continuation of efforts begun in 1972, which will provide information as to the age and growth of fishes in the area, sexual maturation, sex rate, fecundity and any possible effects by the once through cooling employed at Indian Point. Data of very high precision are being obtained in this part of the study. Many of the important uses of these data in reconstructing the dynamics of the fish populations have been described in the preceding sections.

Changes in age composition, growth rate, age at first sexual maturation, and fecundity are classical indicators of important changes in the mortality experience of fish stocks. The first two of these tend to have a historical character, often being detectable in the fish population for some time after their first occurrence. Additional comparative data on age composition and growth rates predating 1969 is available from New York University studies and from the New York Conservation Survey of 1936. All of these population parameters, when closely monitored, are useful in predicting population decline in advance of critical depletion. The first report of this phase of the work will be completed by May 1, 1975. The data are being collected and analyzed in such a way as to provide continuous monitoring of the fish populations with minimal lag time between field collection and examination against previous population trends.

VI. IMPACT OF THERMAL AND CHEMICAL EFFLUENTS ON ESTUARY

Measurements of the physical-chemical correlates of biological parameters are being made starting with April 1972 and continuing until January 1, 1976. It is essential that this information be gathered as supporting data relating to the condition, behavior and distribution of fish life. This information will be analyzed and factored into the final report issued from the study.

Thermal studies, attraction of fish to the discharge canal, infra-red mapping of thermal plume, acute and chronic effects of temperature on survival and behavior of fish and benthic invertebrates will be investigated during the period from April 1, 1972 to October 1, 1975. These studies are important to the success of the overall program but are not considered as critical in time as the population estimation part of the program. Studies of thermal preferences and the impact of thermal shocks on fish and invertebrates can be carried out simultaneously in the facilities available, and are planned for completion in 1973. They require a full year of effort due to seasonal changes in reactions of the organisms. The temperature avoidance study, which also required one year to complete, will be carried out in calendar year 1974. Assay of chronic temperature effects through study of biological energetics will require two full years for completion. This work will extend through 1974 and 1975.

The biological significance of thermal and chemical discharges from the plants will be determined by establishing the rate, quantity, and distribution of these discharges, and comparing these to the densities and distributions of zooplankton, phytoplankton, fishes, and benthos in the study area on a seasonal basis. The population dynamics, turnover rates, productivity, and species diversity of plankton organisms are being determined and will be used to evaluate the significance of any observed effects on the ecosystem. Energy budgets will also be used to evaluate the effect of predicted thermal discharges on secondary production rates of selected fish and benthos. These rates will be determined through laboratory experiments. Additional laboratory experiments will be performed to determine the acute and chronic effects of temperature on the life stages of key aquatic species, the effect of temperature on the behavior of these organisms, the upper and lower temperature tolerances of these organisms, and the relationship of these data to plant operations. Finally, the significance of attraction of fish into the effluent canal will be evaluated.

Computer simulation, hydraulic modeling, aerial infrared measurements at all tidal stages (correlated with control measurements in the river), and a 25 station thermal grid are being used to derive the intensity and extent of thermal discharges (Units 1 & 2 and a prediction of values for Units 1, 2 and 3). Thermal infrared imagery will be collected during four overflights to coincide as close as possible to the major phases of the tidal cycle (e.g. high and low slack, maximum ebb and flood). These overflights will be replicated with Unit 1 operating alone, Units 1 and 2 together, and Units 1, 2, and 3 as a battery. The thermal imagery will be used to compile isothermal maps with 1°C contour intervals from Stony Point to Annsville Creek and to verify the hydraulic and mathematical model predictions (along with the thermal grid data). Plant production records provide data on the frequency of chlorination, concentrations and durations by season as related to organic build-up in various water passages, and efficiency losses in order to establish the minimum amounts of chlorination that are absolutely necessary. Physical and chemical parameters are being measured in the intake bays and effluent canal and also at three transects (Figure 1.): one from Verplanck southwest to Stony Point, one from Jones Point to Peekskill, and the third, a Y-shaped transect, at Indian Point. Each transect includes a main channel (deep) and a bay area (shallow) which allows for evaluations in different habitats. The northern transect serves as the control and the southern will show the effects of passing through the plant's influence. The middle transect is designed to sample close to the nuclear facility itself. The physical-chemical measurements (along with previous data) will define those physical and chemical properties of the estuary which have important influences on the biota. The end result of this measurement program will be an atlas, which presents a multidimensional picture of the pertinent variables in the Indian Point area of the lower Hudson River. This reference will serve as a data base, in a readily usable format, which will allow investigators to quickly recognize the onset of unusual conditions of water quality. Current velocity (as a function of season and wind conditions) is being measured with depth for six tidal cycles spanning one lunar month. Dissolved ion ratios are being measured to ascertain the location of the migratory "salt-wedge" which is a critical factor in several species' distributions. These data, along with temperature and specific conductivity, are used to define "salinity". Dissolved oxygen is measured to assist in the identification of water inputs that degrade water quality and will be included in the atlas via a grid system as will pH. Turbidity is also included because of its relationship to photosynthesis. Inorganic and organic carbon are monitored as indicators of organic pollution and because of their relationship to secondary production of filter feeders and dissolved oxygen levels. Chlorine demand, residual chlorine concentrations, and organo-chlorines are also measured as a direct chemical perturbation.

Fish density and distribution data come from the standard stations, catch per unit effort program (beach seines, bottom and surface trawls) and are supplemented by the sonar echo integration studies. If the latter technique proves reliable, a very thorough small scale dispersion analysis will be made. The benthos densities are being enumerated via replicated Petersen bottom grabs while macro and microplankton densities are derived from appropriate sized plankton nets.

Laboratory experiments will be performed to establish the influence of ambient and elevated water temperatures on the physiology of key fish species. The temperature at which these species suffer equilibrium loss and death will be defined (i.e. thermal tolerance studies).

The effects of short term exposure to "shock" temperatures (above or below ambient) will also be determined. A bioenergetic budget (see Warren and Davis, 1967) will be determined to define the chronic effects of temperature on key fish species. Measurements of internal energy transfers and utilization at specific temperatures will be used (food consumption, assimilation, active respiration, and growth).

Key benthic invertebrates will also be subjected to temperature tolerance and shock experiments and will be used to determine the long term effect of temperatures experienced in the effluent canal and discharge area on life table processes and growth rates. In addition these species will be used for in situ cage experiments comparing long term survivorship in the intake and effluent canals. Laboratory findings from temperature preference and avoidance experiments of white perch and striped bass will be compared with field results (fish and temperature distributions). Pertinent temperatures for these experiments have been chosen from actual or predicted temperatures for the Ind ian Point area of the Hudson River (ambient and changed by plant operations).

The significance of attraction into the effluent canal and plume area is primarily directed at fish species. Fish traps, beach seines and electro-shocking are used to provide data on species composition, abundance, size, age, fecundity, and general condition in these areas. These are supplemented by the sonar studies. Temperature profiles are determined to verify the extent and location of the thermal plume itself. Similar data from Objective 1 (catch per unit effort) are used for comparative purposes. The results of the laboratory experiments on temperature preference and avoidance will be compared to aggregations of fish found in the effluent canal and plume area. A fish tagging program in the discharge canal and plume area will be used to determine residency periods and local dispersal. Tagging procedures will follow those found most efficient in the population dynamics studies.

Survival experiments will test the immediate effects of chlorine dosages routinely added by plant operations to fish residing in the effluent canal.

VII. FEASIBILITY OF STOCKING PROGRAM

The feasibility of stocking juvenile striped bass to mitigate losses caused by plant operations will be determined by thoroughly investigating the technology and economics of existing hatchery programs. The federal striped bass hatchery at Edenton, North Carolina will be used in this analysis as will the Washington State salmonid hatchery system that presently replaces salmonid losses due to public hydroelectric dams with hatchery reared fish.

A cost-benefit analysis will then be made that will also include developmental, engineering, siting and operational costs of a striped bass hatchery on the Hudson River. If this analysis shows that such a hatchery would be feasible, a test hatchery would first be built to discover possible unforeseen problems and to prove the technological feasibility, followed by the actual hatchery upon completion of satisfactory testing. Such a system would be scientifically advantageous in providing an excellent source of markable fish for total population estimates of the striped bass in the entire Hudson River estuary, migration patterns, survivorship, etc.

VII. REPORT COMPLETION AND IMPLEMENTATION SCHEDULE

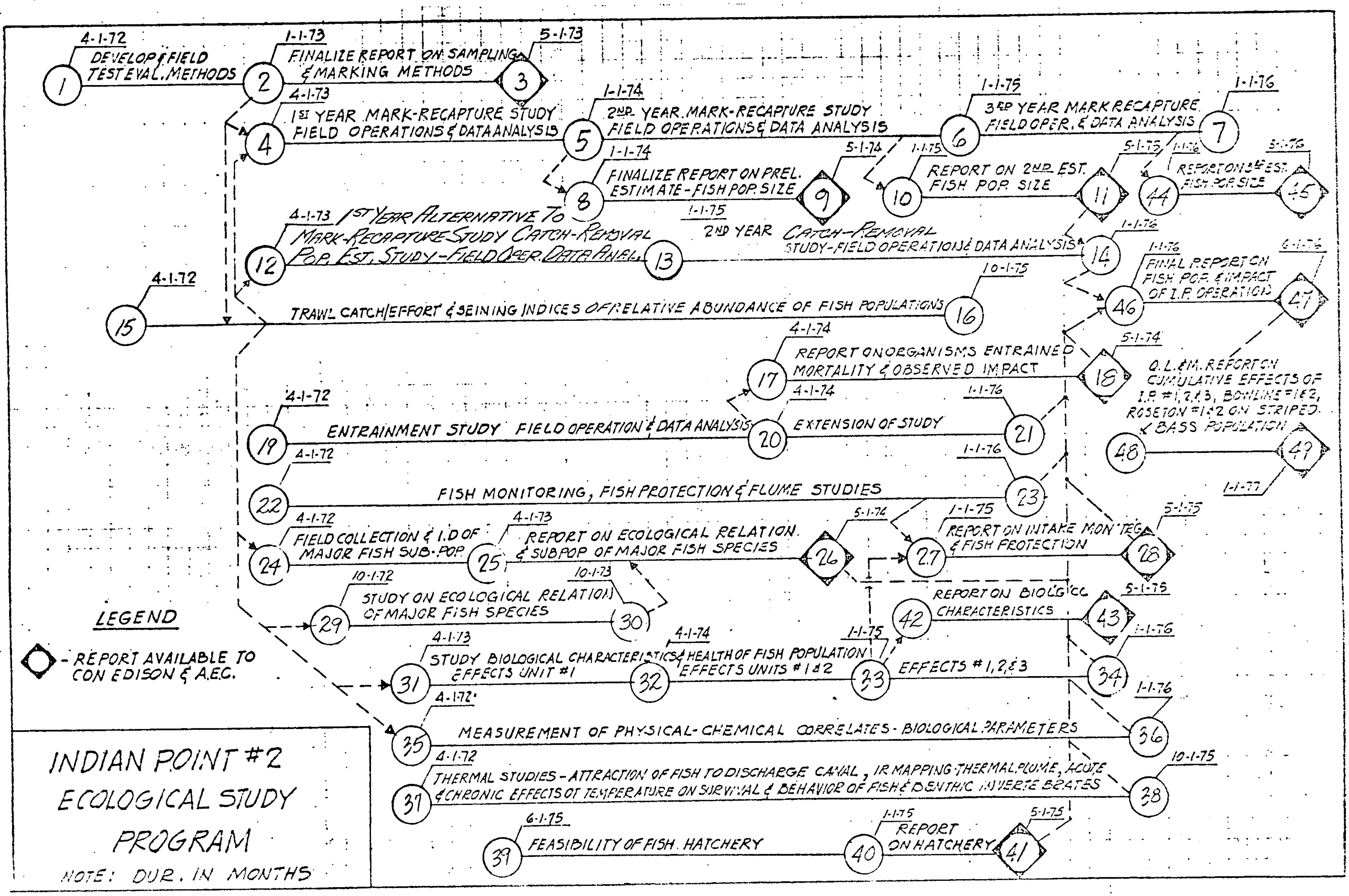
All of the foregoing phases of the study program will be integrated into a final report on fish populations and impact of once-through cooling. This latter report is to be issued in June 1976. This integrated report will then be made available to the consulting engineering firm of Quirk, Lawler and Matusky Engineers, for further evaluation and preparation of a report on cumulative effects of Indian Point Units 1, 2 and 3, Bowline Units 1 and 2 and Roseton Units 1 and 2 on the striped bass population of the Hudson River. This latter report is scheduled for completion on January 1, 1977 and would complete the biological program evaluating the impact on the Hudson River fishes of once-through cooling at Indian Point and other indicated generating stations.

Appendix B contains a schedule of tasks and times for completion of various phases of work relating to the design and construction of cooling towers. This diagram shows the ecological study integrated with the closed cycle cooling tower studies. These environmental studies associated with cooling towers include botanical, meterological, water quality, noise and land use evaluations. The most critical in time is the meterological study which provides a short period for development of study and setup of instrumentation followed by a twelve month period for the collection of data. This would then be followed by data analysis and integration of results with the botanical study. This is considered a very tight schedule. The water quality, noise and land use studies are of a shorter duration and are not critical in establishing an overall completion date. These investigations would then be presented to the regulatory agencies for their review.

The Indian Point ecological study program results will be completed on January 1, 1977 and presented to the control agencies for evaluation. A period of four months is allowed for the agency review after which time it would be determined whether to proceed with the installation of cooling towers for Indian Point or the company would be allowed to continue with once-through cooling. The date for this decision would be May 1, 1977 and would be made under this alternative prior to the release for bids by Con Edison for construction work on cooling towers. If the decision is that cooling towers must be built for Indian Point Unit No. 2, this critical path of activity would continue and would lead to the final cutover to cooling tower operation by September 1, 1981.

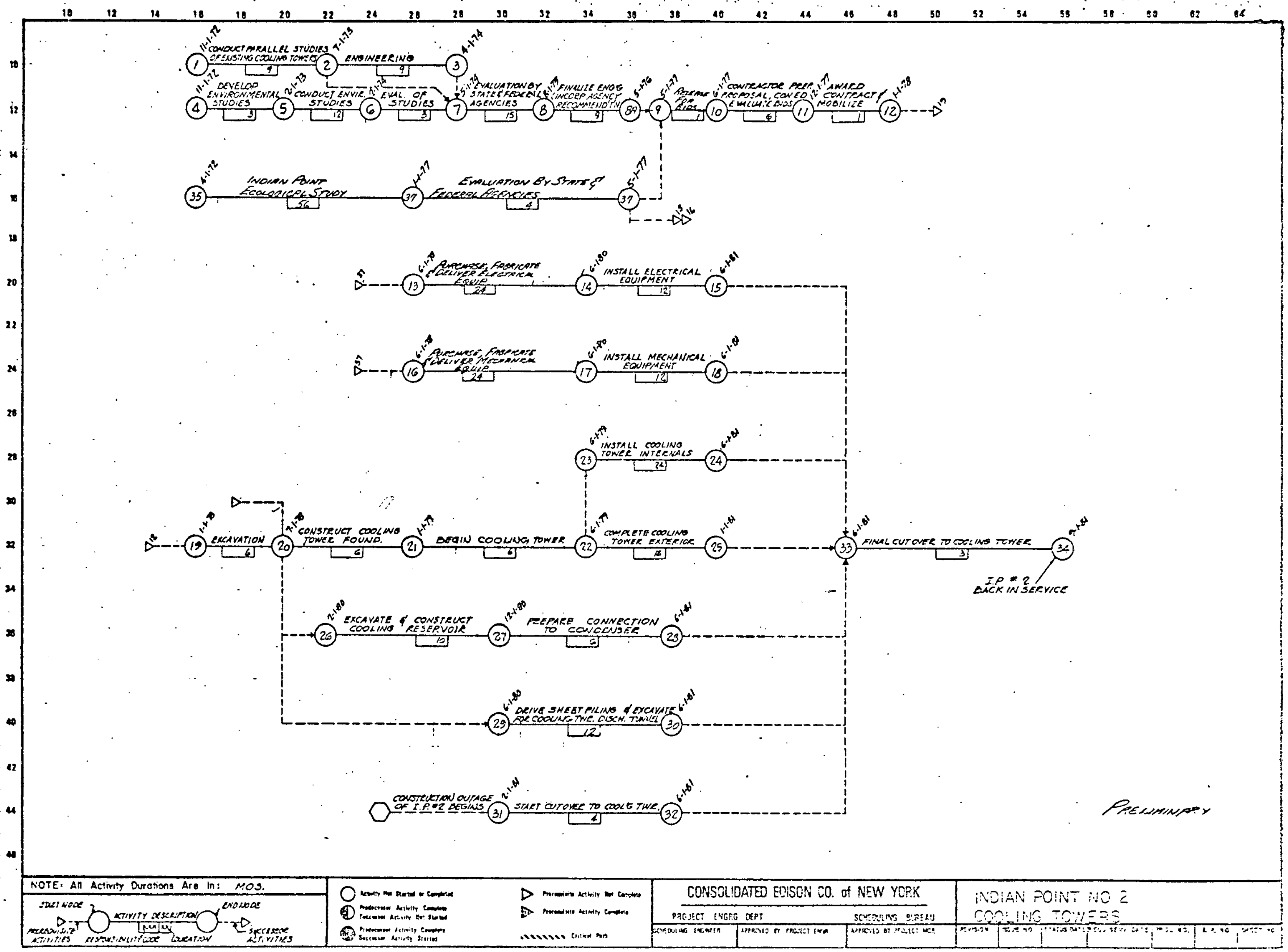
APPENDIX A

Indian Point No. 2 Ecological Study Program


INDIAN POINT #2
ECOLOGICAL STUDY
PROGRAM
NOTE: DUR. IN MONTHS
LEGEND
REPORT AVAILABLE TO CON EDISON & A.E.C.
4-1-72 DEVELOP & FIELD TEST EVAL. METHODS
1-1-73 FINALIZE REPORT ON SAMPLING & MARKING METHODS
5-1-73
4-1-73 1ST YEAR MARK-RECAPTURE STUDY FIELD OPERATIONS & DATA ANALYSIS
1-1-74 2ND YEAR MARK-RECAPTURE STUDY FIELD OPERATIONS & DATA ANALYSIS
1-1-75 3RD YEAR MARK RECAPTURE FIELD OPER. & DATA ANALYSIS
1-1-76
1-1-74 FINALIZE REPORT ON PREL. ESTIMATE - FISH POP. SIZE
5-1-74
1-1-75 REPORT ON 2ND EST. FISH POP. SIZE
5-1-75
1-1-76 REPORT ON 3RD EST. FISH POP. SIZE
5-1-76
4-1-73 1ST YEAR ALTERNATIVE TO MARK-RECAPTURE STUDY CATCH-REMOVAL POP. EST. STUDY - FIELD OPER. DATA ANAL.
1-1-75 2ND YEAR CATCH-REMOVAL STUDY - FIELD OPERATION & DATA ANALYSIS
1-1-76
1-1-76 FINAL REPORT ON FISH POP. & IMPACT OF I.P. OPERATION
6-1-76
4-1-72 TRAWL CATCH/EFFORT & SEINING INDICES OF RELATIVE ABUNDANCE OF FISH POPULATIONS
10-1-75
4-1-74 REPORT ON ORGANISMS ENTRAINED MORTALITY & OBSERVED IMPACT
5-1-74
Q.L.&M. REPORT ON CUMULATIVE EFFECTS OF I.P. #1,2 & 3, BOWLINE #1 & 2, ROSETON #1 & 2 ON STRIPED BASS POPULATION
1-1-77
4-1-72 ENTRAINMENT STUDY FIELD OPERATION & DATA ANALYSIS
4-1-74 EXTENSION OF STUDY
1-1-76
4-1-72 FISH MONITORING, FISH PROTECTION & FLUME STUDIES
1-1-76
4-1-72 FIELD COLLECTION & I.D. OF MAJOR FISH SUB-POP.
4-1-73 REPORT ON ECOLOGICAL RELATION & SUBPOP OF MAJOR FISH SPECIES
5-1-74
1-1-75 REPORT ON INTAKE MON'TRG & FISH PROTECTION
5-1-75
10-1-72 STUDY ON ECOLOGICAL RELATION OF MAJOR FISH SPECIES
10-1-73
REPORT ON BIOLOG'CL CHARACTERISTICS
5-1-75
4-1-73 STUDY BIOLOGICAL CHARACTERISTICS & HEALTH OF FISH POPULATION EFFECTS UNIT #1
4-1-74 EFFECTS UNITS #1 & 2
1-1-75 EFFECTS #1, 2 & 3
1-1-76
4-1-72 MEASUREMENT OF PHYSICAL-CHEMICAL CORRELATES - BIOLOGICAL PARAMETERS
1-1-76
4-1-72 THERMAL STUDIES - ATTRACTION OF FISH TO DISCHARGE CANAL, IR MAPPING THERMAL PLUME, ACUTE & CHRONIC EFFECTS OF TEMPERATURE ON SURVIVAL & BEHAVIOR OF FISH & BENTHIC INVERTEBRATES
10-1-75
6-1-75 FEASIBILITY OF FISH HATCHERY
1-1-75 REPORT ON HATCHERY
5-1-75

APPENDIX B

Ecological Studies Integrated With The Indian Point No. 2 Schedule for Design and Construction of A Closed Cycle Cooling System


CONDUCT PARALLEL STUDIES OF EXISTING COOLING TOWERS
ENGINEERING
DEVELOP ENVIRONMENTAL STUDIES
CONDUCT ENVIR. STUDIES
EVAL. OF STUDIES
EVALUATION BY STATE & FEDERAL AGENCIES
FINALIZE ENGG (INCORP AGENCY RECOMMEND'TN)
CONTRACTOR PREP. PROPOSAL, CON ED EVALUATE BIDS
AWARD CONTRACT & MOBILIZE
INDIAN POINT ECOLOGICAL STUDY
EVALUATION BY STATE & FEDERAL AGENCIES
PURCHASE, FABRICATE & DELIVER ELECTRICAL EQUIP
INSTALL ELECTRICAL EQUIPMENT
PURCHASE, FABRICATE & DELIVER MECHANICAL EQUIP
INSTALL MECHANICAL EQUIPMENT
INSTALL COOLING TOWER INTERNALS
EXCAVATION
CONSTRUCT COOLING TOWER FOUND.
BEGIN COOLING TOWER
COMPLETE COOLING TOWER EXTERIOR
FINAL CUT OVER TO COOLING TOWER
I.P. # 2 BACK IN SERVICE
EXCAVATE & CONSTRUCT COOLING RESERVOIR
PREPARE CONNECTION TO CONDENSER
DRIVE SHEET PILINGS & EXCAVATE FOR COOLING TWR. DISCH. TUNNEL
CONSTRUCTION OUTAGE OF I.P. #2 BEGINS
START CUTOVER TO COOL'G TWR.
PRELIMINARY
NOTE: All Activity Durations Are In: MOS.
START NODE
ACTIVITY DESCRIPTION
END NODE
PREREQUISITE ACTIVITIES
RESPONSIBILITY CODE
LOCATION
SUCCESSOR ACTIVITIES
Critical Path
CONSOLIDATED EDISON CO. of NEW YORK
PROJECT ENGRG DEPT
SCHEDULING BUREAU
INDIAN POINT NO. 2
COOLING TOWERS

APPENDIX C

Project Proposal
August 15, 1972

APPENDIX C

UNITED STATES
DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Division of Federal Aid

State	New York
Project No.	AFC-8

PROJECT PROPOSAL

To be Filled in by Applicant

1. Federal Aid Program
   Act: Anadromous Fish Act — Regulation: 84 Stat 214

2. Project Title
   A study of striped bass in the Marine District of New York.

3. Project Objectives To evaluate the recruitment of young striped bass spawned in the Hudson River and their contribution to the fisheries of New York, other Middle Atlantic States and the New England States.

4. Project Duration
   From: September 15, 1972 To: March 31, 1975

5. Estimated Cost

1st Year	2nd Year	3rd Year	Additional Year(s)	Total	U.S. Share
$45,000	$45,000	$ 30,000	$	$ 120,000	$ 60,000

6. Applicant (Name and Address) Department of Environmental Conservation
   Building #40 - State University of New York
   Stony Brook, New York 11790

Signature: Albert C. Jensen Title: Director of Division of Marine & Coastal Res. Date: 8/15/72

For Use of Approving Official

7. Special Project Conditions

For Use by Department of Commerce Only

8. Approved for the Secretary of Commerce

Signature Title: Date:

Form No. 2-238
Rev. 10/3/70

ATTACHMENT TO PROJECT PROPOSAL

Objectives

To evaluate the recruitment of young striped bass spawned in the Hudson River and their contribution to the fisheries of New York, other Middle Atlantic States and the New England States.

Location

Marine District of New York, including Hudson River and Long Island waters.

Justification

The spawning of striped bass in the Hudson River is well documented but little is known of the fate of the young bass that result from the spawning. Adult bass have been tagged in the Hudson and recaptures of tagged fish suggest they contribute to the commercial catch in the coastal waters of New England and Middle Atlantic States, including New York. It is believed that young bass spawned in the Hudson may also contribute to these fisheries. These fisheries are of major importance; in 1968, New York's commercial fishermen landed 1.5 million pounds of striped bass and several times that amount were taken by sportsmen. The results of this study would pave the way for management of Hudson River stocks of striped bass.

Procedures

Background Information:

Although there have been numerous studies of the striped bass in New York waters, many important aspects of its biology and the fishery remain unknown. The surf fishery has been investigated from Jones Inlet to Shinnecock Inlet, but there is little information available about the fishery in other waters of Long Island. Furthermore, the rate of exploitation of striped bass tagged in Long Island waters has not been investigated. Very little is known about the contribution of the Hudson River stock to the coastal fishery. To obtain knowledge needed to better manage the striped bass, the Department of Environmental Conservation proposes to undertake a research program which will involve separate concurrent studies.

1. A study of the contribution of the Hudson River stock of striped bass to the coastal fishery. During each of the annual segments of the project, an attempt will be made to tag 5,000 juvenile fishes which will be obtained by capture utilizing a 500 foot haul seine. All marking and/or tagging will be accomplished using standard techniques. Additional information on growth and survival of young-of-the-year and juvenile bass will be obtained.

2. The second phase of the program will involve a study of the rate of exploitations of striped bass in the coastal waters of Long Island, with more emphasis being placed in the greater production areas at the eastern end of Long Island. In each year, an attempt will be made to tag 3,000 adult striped bass in catches of commercial haul seiners.

3. Estimates of the catch of striped bass by sports fishermen in Long Island waters will be made using techniques specifically designed to include surf anglers and those utilizing boats.

4. Although not collected through direct effort of the project, all information relative to the commercial landings of striped bass will be collated with that gathered for the sports fishery. These comparisons will assist in placing the striped bass fishery in better perspective and could thus help in providing the background information required for making administrative decisions on this important marine resource.

Publications

Project findings will be published through timely press releases, articles in departmental magazines, other popular periodicals and technical journals.

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of	)	
	)	
Consolidated Edison Company of	)	Docket No. 50-247
New York, Inc.	)	
(Indian Point Station, Unit No. 2)	)	

Rebuttal Testimony of
Dr. James T. McFadden, Dean
School of Natural Resources
The University of Michigan

on

Effects of Indian Point Units #1 and #2
on Hudson River Fish Populations

February 5, 1973

Introduction

This Testimony consists of two main parts:

I. A brief criticism of the arbitrarily narrow focus which has been adopted by Staff and Intervenors in evaluating the impact of the Indian Point nuclear power plant.

II. Within the focus adopted in the hearings, comments countering testimony by Staff and Intervenors are offered in the following areas:

(a) operation of compensatory processes in marine fish;

(b) below average growth rates in Hudson River fish;

(c) discrepancies in estimates of striped bass abundance;

(d) deficiencies in analysis and interpretation of commercial fishery data by Staff;

(e) population response to increments of mortality and examples of recuperation of heavily exploited fish stocks;

(f) exaggeration of mortality estimates of young striped bass due to entrainment and impingement.

I. CRITICISM OF BASIS FOR ASSESSMENT OF ENVIRONMENTAL IMPACTS

The impact upon the fish populations of the Hudson River resulting from the operation of Indian Point Units #1 and #2 has been evaluated by the AEC Staff and the Intervenors from an arbitrarily narrow focus. Seven different levels at which the impact could be assessed are identified as follows:

1. Death of individual fish.
2. Decrease in survival of fish populations as a result of (1) above.
3. Compensatory responses of the population through changes in growth or survival which take place within the period of the environmental impact and within the particular group of fish affected (e.g. an increase in survival of juvenile striped bass offsetting removals due to impingement).
4. Compensatory response by the fish population taking place within the group of fish affected by the impact but at a later stage of the life cycle (e.g. a decrease in survival of early juveniles caused by power plant operation being offset by subsequent increase in survival of over-wintering juveniles due to their reduced density).
5. Compensation in the population taking place in a year class subsequent to the one which received the impact (e.g. a decrease in the number of juveniles produced is caused by operation of the power plant and results in a decrease in the size of the spawning stock when this juvenile group has matured. The survivors from the spawning of this reduced year class experience lower mortality rates due to their reduced density).
6. Compensation effected at the ecosystem level rather than the population level through shifts in the relative abundance of species.
7. Complete replacement of a reduced or destroyed species through natural processes or managerial intervention by man.

Assessment of the impact of Indian Point Units #1 and #2 has been focused by the AEC Staff and Intervenors largely at the first and second levels above: with assessment levels 3 through 5 being discounted in testimony by the Staff and intervenors and impact levels 6 and 7 scarcely being considered at all. The impact assessment has focused on the existing assemblage of species, apparently assuming that these are of high or irreplaceable value by virtue of their current occupancy of the Hudson River Estuary. This veiw ignores the ephemeral status of the present species assemblage even under natural conditions. The present ecological community is of relatively recent, post-glacial origin and is undoubtedly subject to substantial natural shifts in relative abundance of different species. From time to time new species may be introduced into the system through completely natural processes and drastically alter the present balance. In attaching paramount value to the present state of the Hudson Ecosystem, impact evaluations have not taken sufficient cognizance of the highly disturbed state of the ecosystem. A management focus is adopted which assumes that maintenance of the biological status quo is in the best interest of society and therefore that status quo should be preserved even at great cost. The full potential for considering the estuarine ecosystem and the technological developments of man as a single integrated system and devising optimal management approaches has not been given adequate consideration in the testimony presented to date.

Considering the substantial costs of alternatives to once-through cooling -- such as evaporative cooling towers -- a wide range of feasible management alternatives exists which has not been given adequate consideration, largely because of lack of necessary data. For example, a systems management plan could be devised which allowed for disposal of waste heat originating from power production and at the same time assured a productive fishery made up of commerically or recreationally desirable species. This would be possible by investment of part of the cost associated with such alternatives as evaporative cooling towers into intensive management of fish populations. This management might take the form of reduction of competitive species of low value and supplementation (as through hatchery production) of more desirable species. The striped bass are clearly a high value fish. It is ironical, however, that mortalities of the companion species, white perch, in the Hudson Estuary are viewed with such alarm. During the past year, fishery experts cited potential danger to sport fish populations from introductions of white perch into other natural waters, due to their tendency to prey on eggs and larvae of other species; and to overpopulate and stunt from excessive food competition (reference to white perch seminar at Annual Meeting of American Fisheries Society reported in The Newsletter of The American Fisheries Society, Vol. 16 No. 78, September - October, 1972, page 14). The Hudson River Ecology Study described in the Woodbury - McFadden testimony of February 5, 1973 is designed to obtain the information needed in order to evaluate properly the feasible management alternatives which exist.

II. Rebuttal to Specific Points Raised in Testimony of Staff and Intervenors

This rebuttal is directed towards the following composite argument by AEC Staff and Intervenors. It is claimed in the testimony of John Clark (page 49 and transcript 8323-8324) that the phenomenon of overcrowding in fish populations (equivalent to a compensatory reduction in growth in the face of high population density) has not been demonstrated for large open water systems such as estuaries and oceans. It is stated that Hudson River fish exhibit average growth rates (Clark transcript 8417); that there is no evidence of crowding and depressed growth rate; and that the fish stock is sparse for a productive environment such as an estuary (John Clark testimony page 50). It is maintained by the staff that the predatory influence of the fishery controls the striped bass population and that the compensatory reserve of this population has been exhausted (AEC Environmental Statement V-56). It is further maintained (John Clark testimony page 52, 58 and AEC Environmental Statement V-61) that removals of striped bass by operation of the Indian Point Power Plant will result in a proportional reduction to the adult fish stock. This reduction is estimated at 39% (entrainment and impingement) by John Clark (Testimony page 44) and in the neighborhood of 30 to 50% by the AEC Staff (Environmental Statement V-61).*

This testimony responds to the composite arguments of staff and intervenors as sketched above through the following points:

- o Compensatory processes have been shown to be operative in estuarine and high seas fish populations including striped bass and indeed are operative in all animal populations. This argument is based on an extensive review of the ecological literature.

- o Contrary to testimony introduced so far in this hearing, data from the Indian Point Ecological Study shows that striped bass and white perch in the Hudson River are below average in growth rate and that the white perch population can accurately

*See also Tr. 9137-9138, January 18, 1973.

be characterized as stunted. These fish populations possess a potential for faster growth which constitutes a compensatory reserve permitting faster growth rate at reduced population densities.

- Back calculating from the combined sport and commercial catch cited in the testimony of John Clark produces estimates of the young-of-the-year striped bass in the Hudson Estuary which are much higher than those reflected elsewhere in Clark's testimony and, in fact, suggest that striped bass are abundant rather than sparse in the Hudson Estuary.

- The staff analysis of commercial fishery data, which provides the basis for the assertion that the fishery controls the striped bass population and that the compensatory reserve of the population has been exhausted, is invalid on methodological and logical grounds.

- An explanation is advanced for the way in which increments of mortality impact a fish population in such a way as to drive the stock to a new (usually lower) level of equilibrium from which the population recovers when the mortality is relaxed. Principles and examples of recovery of fisheries are presented.

- An argument is advanced, based upon standard acturial computations, to show that even without invoking the operation of compensatory populations processes, estimates of the impact of the Indian Point Power Plant upon the striped bass population are exaggerated. The data of the testimony of John Clark are used in an alternative calculation recognizing exposure of the fish population to competing risks from natural causes of death and the nuclear power plant.

IIa. Operation of Compensatory Processes in Fish Populations and Animal Populations in General.

Thirteen examples of fish populations in which the operation of compensatory processes has been demonstrated are summarized in Table 1. Of these examples, the ten which are asterisked are species which spend part or all of their life cycle in salt water situations —

Table 1. Published examples of the operation of compensatory processes in fish populations. Asterisks indicate populations which spend part or all of their life histories in marine "open systems."

* Atlantic Salmon	Allee et al. 1949
* Sockeye Salmon	Forester 1944
* Menhaden	Schaff & Huntsman 1972
* Pacific Sardine	Radovich 1962
* Striped Bass	Sommani 1972
* Plaice	Beverton 1962
* Haddock	Beverton & Holt 1957
* Herring	Tester 1948
* Coho Salmon	Pritchard 1947
* Pink Salmon	Pritchard 1947
Northern Pike	Smith & Krefting 1954
Yellow Perch	Smith & Krefting 1954
Walleye	Pycha 1961

estuaries or high seas. The list includes the striped bass population of San Francisco Bay which has been convincingly shown to be controlled by compensatory processes. Many more examples could be extracted from the fishery literature. It is clear, however, from even this limited sample that major fish populations in open systems such as estuaries and the high seas commonly (it is argued here, universally) are influenced by the operation of compensatory survival or reproductive processes.

In a major review of the literature, Tanner (1966) has summarized data for 71 different species of animals from 111 different populations showing that of the 71 species, 47 showed statistically significant evidence of the operation of compensatory processes; and an additional 15 showed evidence of compensatory processes but not at a high statistical level of confidence.

The populations reviewed included insects, micro (crustaceans), fish, birds, and mammals. Tanner's summary conclusion was that populations of vertebrate species (excepting man) are, in general, regulated by the production of adult individuals being a decreasing function of population density.

IIb. Growth Rates of Hudson River Striped Bass and White Perch

Data collected during 1972 in the Indian Point Ecological Study clearly demonstrate that striped bass in the vicinity of Indian Point (Table 2) and white perch in the vicinity of Indian Point (Table 3) grow at substantially slower rates than the same species in other waters for which published data are available. The most plausible explanation for these relative growth data is that the populations of striped bass and white perch in the Hudson River are fairly abundant in relation to their food supply, with the result that growth is slower than average. From this, it can be argued that these fish possess a substantial growth potential which could well be realized through a growth rate increase in response to reduced population density. This potential represents one type of compensatory reserve. Compensatory growth responses are not limited to fish populations in closed systems such as small lakes or ponds. An example of the occurrence of compensatory growth response in a marine fish population is presented in the work of Beverton and Holt (1957).

IIc. Estimate of Young Striped Bass Based on Fishery Catch

In the testimony of this hearing, Staff has estimated that one-half to one million striped bass of Hudson River origin are caught annually by commercial fishermen. If we take the figure of one million for the commercial catch and conservatively assume that the sport catch is twice this level, we arrive at an estimated total catch of three million fish annually. This is within the range of the Staff and the intervenors' estimates (Tr. 9182-9183, 9194).

Assume further that this catch of three million fish is made up of age groups III, IV and V and assume further that the exploitation rate is 30%. The combined stock of striped bass of ages III, IV and V would then be 3 million divided by 0.3 = 10 million.

Table 2. A Comparison of Calculated Total Length (mm) at Annulus Formation of Striped Bass[1,2]

Age	Maryland Mansueti, R. (1961) [3]a = N. A. [4]n = 224 Males	Maryland Mansueti, R. (1961) [3]a = N. A. [4]n = 520 Females	California Robinson (1960) [3]a = N. A. [4]n = N. A.	Massachusetts Fitzpatrick & Cookson (1958) [3]a = N. A. [4]n = N. A.	South Carolina Scruggs (1957) [3]a = N. A. [4]n = N. A.	New England States Merriman (1941) [3]a = N. A. [4]n = N. A.	[5]Hudson River Lower Hudson River (1936) [3]a = N. A. [4]n = 70	Hudson River Miles 40-60 Present Study (1972) a = 31.9 n = 342
I	145	134	112	244	172	134	70	119.7
II	321	315	269	307	384	252	159	241.6
III	411	420	420	343	502	395	325	333.6
IV	466	505	538	411	571	486	379	431.7
V	540	601	628	483	647	573	467	509.9
VI	642	697	705	546	707	683	488	585.0
VII	760	782	765	601	776	741	512	649.0
VIII	815	845	820	634	834	809	-	731.5
IX	897	924	886	661	886	886	-	805.6
X	946	971	-	689	-	-	-	799.2
XI	979	1,009	-	710	-	-	-	871.6
XII	-	-	-	738	-	-	-	900.3
XIII	-	-	-	754	-	-	-	927.0

[1]Calculated total length (mm) at annulus formation for combined sexes, unless otherwise indicated.

[2]Fork length converted to total length by the conversion factor of 1.08, derived from a study of Hudson River striped bass.

[3]a = Y-intercept of scale-total length regression. When a value not available, a = N. A.

[4]n = sample size. When n value not available, n = N. A.

[5]Observed total length (mm) for ages 0+ — 6+.

Table 3. A Comparison of Calculated Total Length (MM) at Annulus Formation of White Perch[1,2,3]

Age	Delaware River Wallace, D. (1971) [4]a = 22.45 [5]n = 3,469	Quabbin Reservoir Taub, S. (1964-65) [4]a = 19.2 [5]n= 2,737	North Carolina Canover (1958) [4]a = N. A. [5]n = 720	Maryland Mansueti (1961) [4]a = 16.7 [5]n = 8,447	Delaware Miller (1963) [4]a = N. A. [5]n = 1,012	Oneida Lake Alsop & Forney (1962) [4]a = N. A. [5]n = 1,767	Maine AuClair, R. (1964) [4]a = N. A. [5]n = N. A.	Hudson River Miles 40-46 Present Study 1972 [4]a = 27.2 [5]n = 1,184
I	92.7	91	71	93	93	87	-	76.5
II	147.3	154	110	142	147	189	160	133.3
III	172.8	207	151	170	173	225	175	164.1
IV	190.3	234	183	189	191	244	190	181.2
V	203.5	253	210	205	208	257	210	192.9
VI	214.2	269	234	227	226	269	230	201.4
VII	224.4	282	254	247	240	307	240	210.0
VIII	229.3	304	271	261	254	-	255	216.9
IX	-	319	-	276	308	-	275	240.2
X	-	330	-	301	319	-	285	-
XI	-	-	-	-	-	-	295	-
XII	-	-	-	-	-	-	305	-
XIII	-	-	-	-	-	-	-	-

[1]Calculated total length (mm) at annulus formation for combined sexes.

[2]Fork length converted to total length by the conversion factor of 1.11, derived from a study of Hudson River white perch.

[3]Standard length converted to total length by the conversion factor of 1.28, derived from a study of Hudson River white perch.

[4]a = Y-intercept of scale-total length regression. When a value not available, a = N. A.

[5]n = sample size. When n value not available, n = N. A.

Assume now that successive year classes are reduced in abundance through mortality by one-half and that, therefore, the ratio of age group III to age group IV to age group V is 4:2:1. The population of 10 million fish of ages III, IV, V is then broken down as shown in Table 4. The numbers of age group II fish and age group I fish are then calculated by doubling the number of age III's and re-doubling again to yield an estimate of 2.3×10^7 age I fish.

If we assume that these 23 million young striped bass occupy an area of 20 square miles in the estuary (12,800 acres) then the population of striped bass at the end of the first year of life numbers 1,770 per acre on the average. This figure would represent a substantial population density of striped bass and stands in marked contrast to the figure in the testimony of John Clark (page 50) of 200 to 300 small fishes per acre attributed to the trawling data of the Carlson-McCann Report. This crop of young striped bass would also greatly exceed the figure of 1.9 pounds per acre for striped bass alone quoted by Clark on page 50 of his testimony.

As an interesting aside which reflects the inconsistencies in the data presented in the testimony of Clark, the population structure of striped bass can be extrapolated through ages VI, VII and VIII by assuming that the abundance of fish is halved at each successive age. This has been carried out in Table 4. If it is further assumed that all fish of ages IV through VIII are sexually mature and that the sex ratio is 1:1, the population would consist of 2.7×10^6 female spawners which, at an average egg complement of 600,000, would produce 16×10^{11} eggs. This estimated egg production for striped bass in the Hudson of one trillion, six hundred billion stands in stark contrast to the estimate of 1.3 billion used in Clark's testimony. Clark's figure represents fertilized and viable eggs only, whereas the figure calculated here represents all eggs produced by females in the population. Nevertheless, the discrepancy is a gross one.

Table 4. Reconstruction of the striped bass population of the Hudson River based on assumptions set forth in the text.

Age Group	I	II	III	IV	V	VI	VII	VIII
Numbers	2.3×10^7	1.1×10^7	5.7×10^6	2.9×10^6	1.4×10^6	7.0×10^5	3.3×10^5	1.7×10^5

IId. Staff Analysis of Commercial Fishery Data for Hudson River

It was agreed by Staff that the observations included in Figure V-12 of the Final Environmental Statement were not independent observations but were serially correlated (Tr. 6829). It was further agreed by Staff that independence in the set of observations is a requirement in order for statistical regression to be valid (Tr. 6832-6833). These data were used despite their inherent serial correlations in the regressions of Figures V-13 and V-14. It was argued by staff that while "strictly speaking" the regression of Figure V-13 was invalid, for "practical sense" it was not necessarily so (Tr. 6838). It was further stated by staff (Tr. 6845) that the invalidity of the procedure does not necessarily alter the accuracy of the prediction made from the regression. It was further stated (Tr. 6847) that Figure V-13 implied a cause and effect relationship. This treatment in Figure V-13 is a basis for the conclusions that variability in recruitment to the Atlantic population can be attributed to the abundance of mature fish in the Hudson; and that increased mortality of larvae and juveniles is very likely to cause proportionally reduced recruitment.

The appropriate regression model for the data used in the staff analysis is the bivariate normal distribution, which assumes that the observations are independent, normally distributed variable (Brownlee, 1960 page 353). The violation of the assumption of independence -- such as caused by serial correlation -- is not a trivial matter. The consequences of such problems in regression data are discussed by Johnston (1963) who shows that they may be very serious, indeed. Estimates of the regression parameters may be seriously biased and conclusions based upon the analysis may be very misleading. The requirements set forth for the valid use of statistical regression are not conditions applicable only to theoretical explorations but are conditions which must be met where regression is used in assessing practical problems if the assessment is to have reliability. The tests of significance through which the reality of a regression relationship is judged are seriously affected by serial correlation in the data. Even where the regression equation is useful for purposes of prediction, it could not validly be used to establish a cause and effect relationship. Still more serious problems in the use of regression analysis arise where serial correlation exists in combination with other problems commonly encountered in time series data (Orcutt and Cochrane, 1949). Considering that the commercial fishery data of Figure V-12 are used in regression analyses with the intent of establishing cause and effect relationships; and considering further, the substantial economic consequences of drawing wrong conclusions in the problem at hand; the use of regression in analysis of the commercial fishery data is completely unjustified.

It is clear from the work of Koo (1970) that many of the striped bass stocks of the Atlantic coast have undergone steady increases in abundance in recent history. Because the striped bass landings from the various regions of the Atlantic coast all trend generally upward during the period from 1930 onward, the data from a number of statistical regions could be paired and the landings would be seen to increase in parallel. Regression analyses could be carried out on such sets of statistics with results similar to those obtained in the Staff analysis. A wide range of possibilities for offsetting the landing from one district by several years in making comparisons with landings from another district would all yield interesting looking scatter diagrams showing strong evidence of correlation. This is true because of the powerful effect of the overall yearly trend towards parallel increases in all the stocks. These trends, in no way, prove cause and effect relationships among the different stocks, however.

Another factor which produces similarity in the catch values for different statistical districts is the tendency for fishing effort to be similar in relative value in adjacent districts in any particular year. For example, fishing effort in the Hudson River is fairly closely correlated with fishing effort in the Atlantic region five years later (Figure 1.). This is one of the reasons why the landings in the Hudson are correlated with landings in the mid-Atlantic five years later. The data used in this and all following analyses are those supplied by the National Marine Fisheries Service and those extracted from the paper by Koo (1970).

The pervasiveness of correlations along historical catch records for striped bass from different areas of the Atlantic coast gives rise to an almost unlimited number of possible correlations. In the Staff analysis, tag return data for striped bass are the basis for the hypothesis that Hudson River spawning supports the bulk of the mid-Atlantic fishery. Arguing from the same set of tag return data, Applicant's consultant has concluded that fish of Chesapeake Bay origin supply the bulk of the mid-Atlantic catch (testimony of E. C. Raney). The Staff's hypothesis is tested through the regression of Figure V-13 in the Final Environmental Statement. Setting aside, for the moment, the objections to the use of regression analysis raised here and concentrating only on the scatter diagram for catches from one

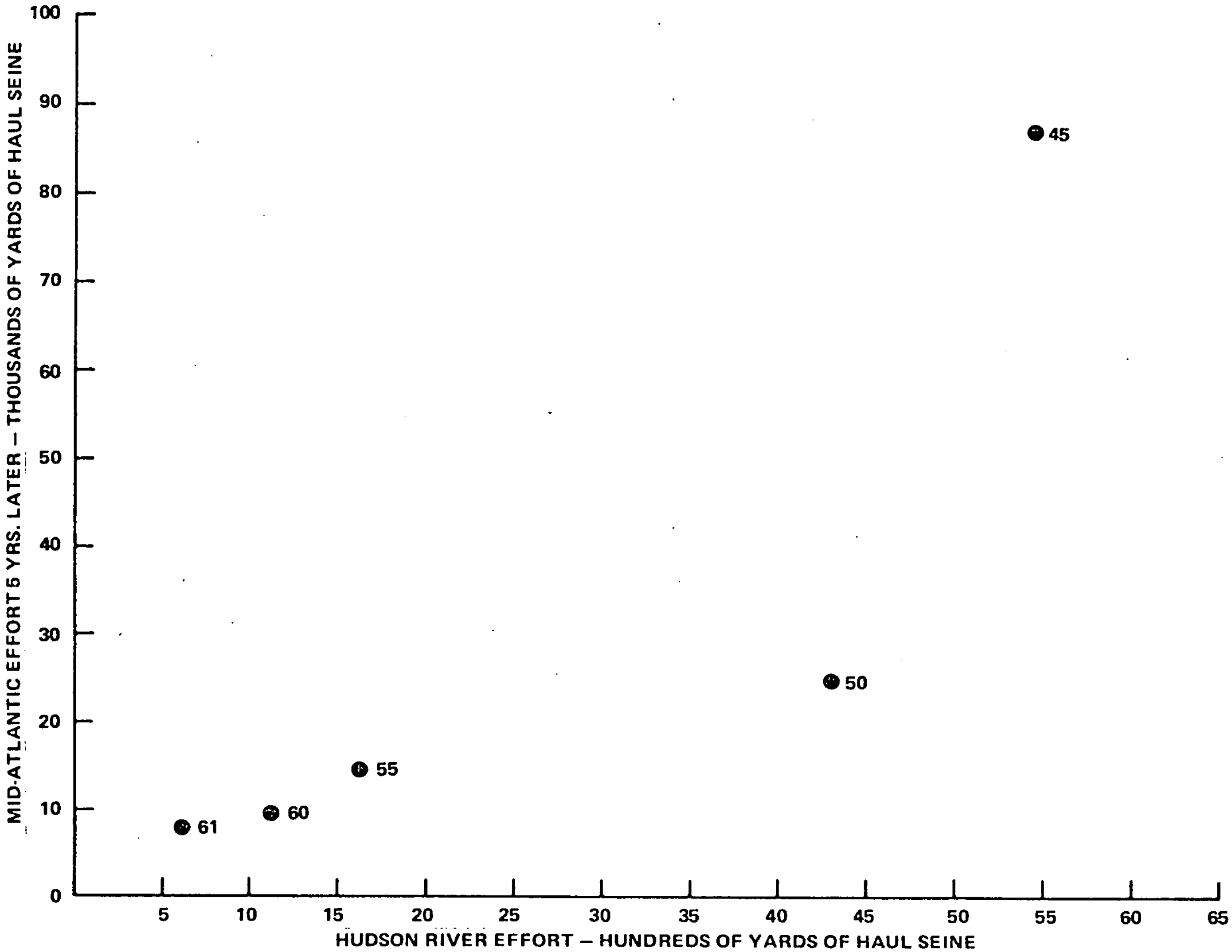


Figure 1. - Relationship between commercial fishing effort in The Hudson and in the mid-Atlantic five years later. Years for the Hudson effort data are given on each point plotted.

district versus catches from another, it can be seen in Figure 2 that a similar relationship exists between Hudson River landings and Chesapeake Bay landings five years later. Of course, no one has postulated that the Hudson River stock is the origin of striped bass caught in Chesapeake Bay. In fact this would be considered a ridiculous hypothesis in the light of the tagging data and general experience with Atlantic coast striped bass, but a scatter diagram not unlike that used in the Staff analysis can be produced, none-the-less. A similar diagram of catch data could be produced to support the hypothesis held by the Applicant's consultant, that mid-Atlantic landings consist largely of Chesapeake Bay fish, and in fact the staff has performed such an analysis (Tr. 9196). A number of additional possible hypotheses, some plausible and some ridiculous, could be similarly supported by regression analysis of commercial catch data.

The summary conclusion is that the analysis of Figure V-13 in the Final Environmental Statement provides no basis whatsoever for inferring a cause and effect relationship between landings of striped bass in the Hudson and those in the mid-Atlantic. This conclusion is based upon both invalid statistical methodology and reasons of logic.

Another serious effect of the analysis of time series data is exposed by Figure 3 in which the same data as used in Figure V-15 of the Final Environmental Statement are plotted, along with additional points available from fishery statistics but not used in the Staff analysis. Figure V-15 in the Final Environmental Statement shows a strong negative relationship between fishing effort and catch and this relationship is in part the basis for the conclusion that "the fishery itself is fluctuating because of over-exploitation during periods of high fishing intensity" (page V-56). The scatter diagram of Figure 3 in this testimony identifies the observations by year. Four distinct temporal clusters of observations are shown. The four observations which combine high fishing effort and low catch all come from the four oldest years in the data set. When this cluster is plotted along with the 1959-60 cluster and the 1955-58 cluster, without identification of the observation by the year, it produces a plausible looking negative correlation relationship. However, one can just as plausible argue that the four earliest years were years in which effort was high and catch was low, the low catch likely being attributable to lower population density unrelated to fishing effort. This argument is consistent with the general increase in size of Atlantic coast striped bass stocks since 1930. Populations available to the fishery in earlier years of this period were

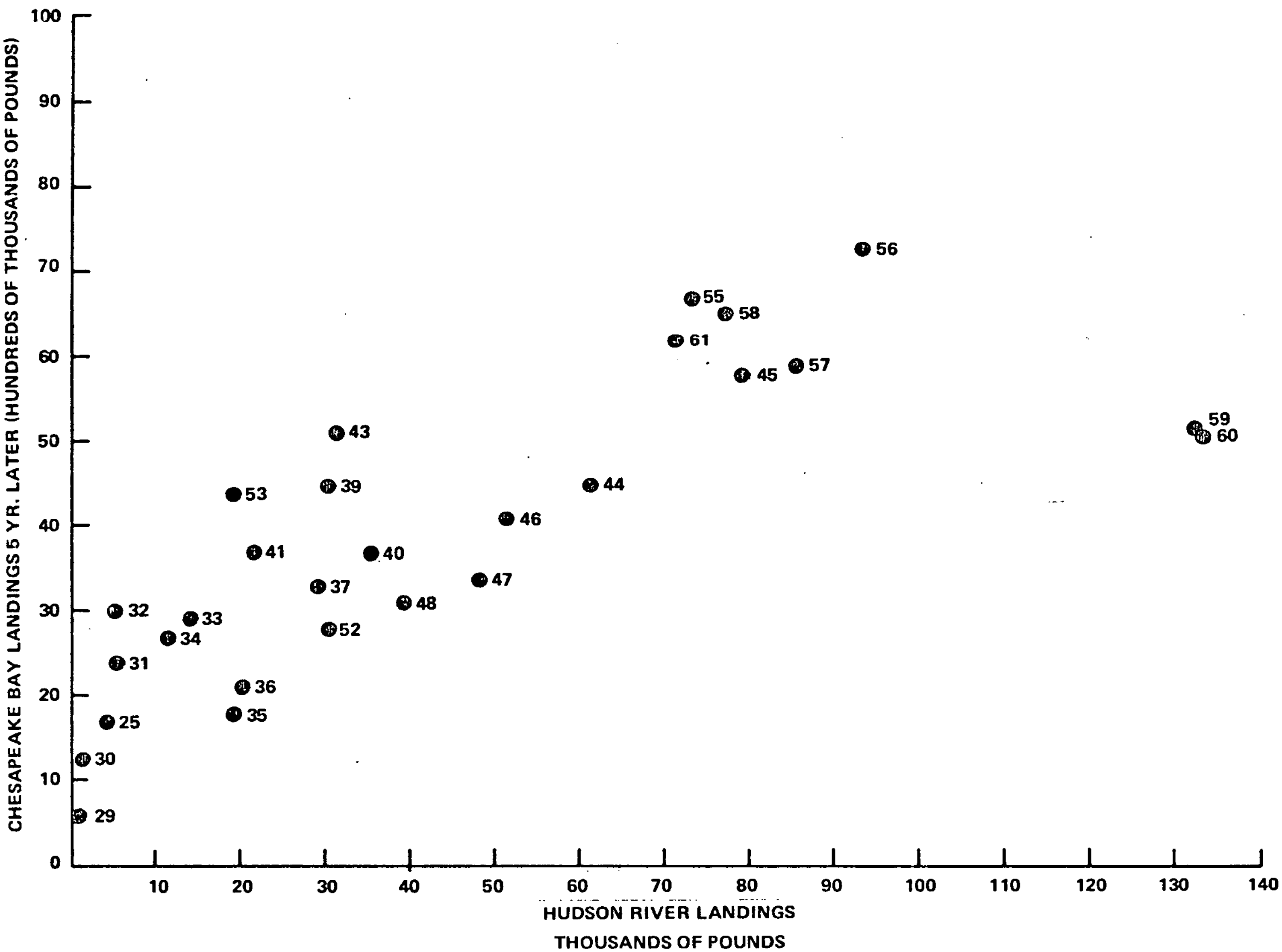


Figure 2. - Chesapeake Bay landings of striped bass vs. landings in the Hudson River based on data from National Marine Fisheries Service.

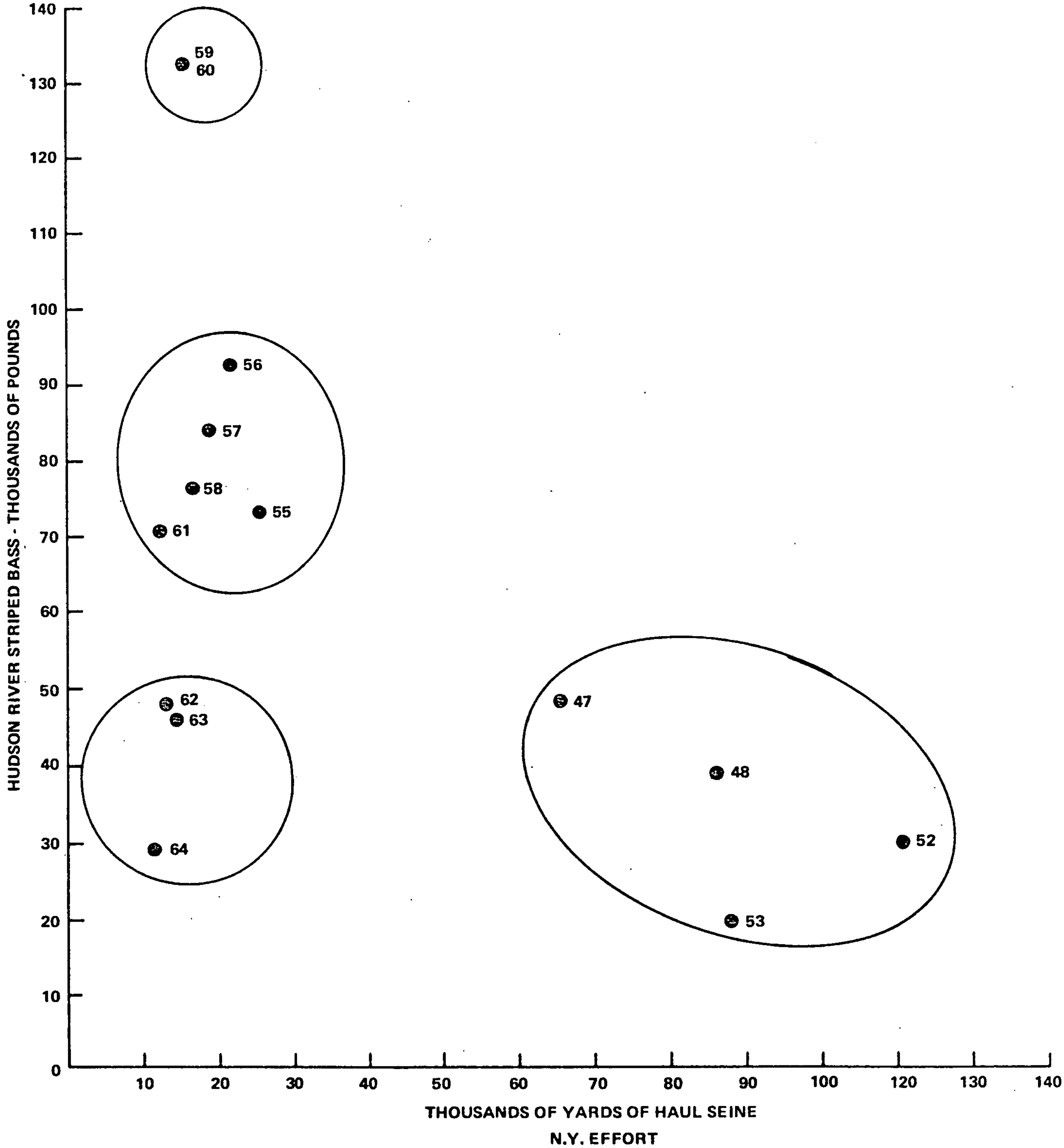


Figure 3. - Striped bass catch in the Hudson River as a function of New York fishing effort. Plot similar to Fig. V-15 of Final Environmental Statement but including all available data points. Temporal clusters of observations are encircled.

smaller, and catches from more recent years are higher than the earlier catches despite the lower fishing effort because striped bass stock size has increased substantially (Koo 1970). The temporal clustering in Figure V-15 of the Final Environmental Statement casts serious doubts upon the validity of the regression analysis used there and on the reality of the negative relationship between striped bass catch and fishing effort which is deduced therein.

The Staff has argued that the commercial fishery catch controls the size of the striped bass population and hence the population has exhausted its compensatory reserve. This is based on the argument that as catch increases population declines. However, it has been clearly established that the striped bass population and the commercial catch have both increased steadily since 1930 and that the total catch including the sport fishery shows an even sharper upward trend because the sport catch is greater in recent years than the commercial catch (Tr. 9080). If both total catch and population size for striped bass have been increasing over the last 30 to 40 years, one cannot logically conclude that the commercial catch is controlling population size in striped bass.

A summary objection to the structure of the Staff analysis of the commercial fishery data for the Hudson and mid-Atlantic regions is as follows:

1. From analysis of tag returns the hypothesis that Hudson River spawning is the major source of the mid-Atlantic striped bass catch is developed.

2. Through regression analysis of the hypothesis in (1) above the hypothesis is subjected to test.

3. The regression analysis was used to establish a cause and effect relationship between Hudson River catches and mid-Atlantic catches (Tr. 6847) - but the data available are not usable for regression analysis from which cause and effect inference may validly be drawn because of the statistical methodological problems cited in detail in this testimony.

IIe. Population Response to New Increment of Mortality - Principles and Examples

Some basic principles of fish population dynamics can be set forth in simplified form through the use of standard diagrams called reproduction curves in a way which will clarify the reaction of a fish population to added increments of mortality such as caused by fisheries or power plant operations. Consider a parental stock of fish and the stock of progeny which it produces, with both parents and progeny expressed in the same units of measurement. If the relationship between parental stock and progeny were described by a 45 degree diagonal line as shown in Figure 4 (replacement reproduction) we would have a density-independent relationship between parents and progeny. If environmental conditions allowed the survival of a very large parental stock, that stock would produce a generation of progeny equal in size to itself. By the same token if unfavorable environmental conditions reduced the parental stock to some very low density, it would produce again a generation of progeny equal to itself. Under this hypothetical situation, the size of the population would vary at random toward an infinitely expanding condition or towards dwindling to extinction. There is no negative feedback operating to increase the rate of population growth at low levels of density, thus deflecting it from decline to extinction, and to decrease the rate of population growth at very high levels of population density, thus deflecting it from unlimited expansion. In order to persist within some more or less well defined limits of abundance a fish stock must have some negative feedback processes operating synonymous with density-dependent processes. The curve of Figure 4 represents a density dependent relationship between parental and progeny stocks. At very low levels of parental stock the population tends to increase several fold in the progeny generation. At point "R" the parental stock is replaced by exactly the same size of progeny stock (the reproduction curve intersects the 45 degree diagonal) and this density is the equilibrium point or replacement level of reproduction. If no environmental fluctuation occurred which deflected the stock from point "R" it would remain perpetually at that density, exactly replacing itself over each succeeding generation. Population statistics for a striped bass stock at equilibrium density are developed in Table I of the February 5, 1973 testimony by Woodbury and McFadden. At densities above replacement reproduction the parental stock fails to replace itself and the population declines back toward equilibrium level. If stock density is deflected by environmental conditions below the equilibrium level, the parental stock more than replaces itself, that is, the population tends to increase back towards replacement level over succeeding generations. Note that at replacement level the parental stock exactly replaces itself in the face of baseline natural mortality, with no surplus progeny being produced as a buffer against removal by a fishery or environmental impact such as power plant operation.

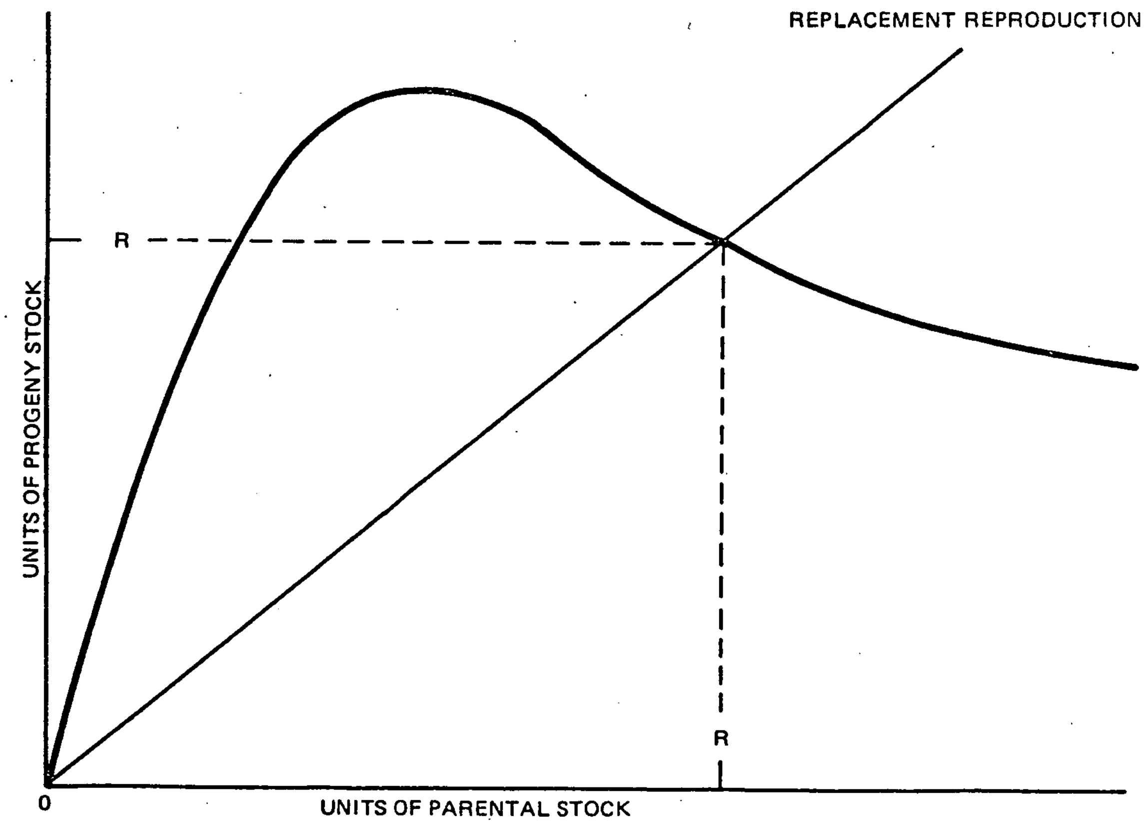


Figure 4. Possible relationship between parental and progeny stock size for a fish population.

In Figure 5 is explored the situation where an increment of mortality is imposed on the population of Figure 4, thus deflecting it away from the replacement level of parental stock. Let us say, for example, that an amount of stock equal to the line segment "cR" is removed from the population before reproduction. The parental stock now consists of "Oc" units and this parental stock produces "ca" units of progeny. Note that at this stock density the parents produce "cb" units of offspring (sufficient to replace themselves) plus a surplus "ab" which may be removed by the fishery or killed by power plant operation and still leave the population equalibrated at a density "Oc". Note that for this situation the removal from the population "ab" is about 28 percent of the total stock "ac".

If an additional increment of removal is imposed upon the stock, say a total of "de" units of parental stock, the removal rate will be 60 percent (de ÷ df) and the population will sustain this level of removal, equalibrating at density "of". In order to hold the stock at this reduced density a 60 per cent average removal must be sustained. If this rate of removal is reduced the parental stock will more than replace itself and succeeding generations will tend to increase until the population equalibrates once again at a higher level of density.

A still higher percentage removal, say 70 percent (gh ÷ gi), if sustained would reduce the population to a density "Oi".

Two important points emerge from these principles. First, an additional increment of removal imposed upon a fish stock drives the stock to a lower average parental density at which the population once again equalibrates. The increment of mortality imposed and sustained does not drive the population into a steady downward spiral leading to severe depletion or extinction. Secondly, in order to hold a stock at a reduced level of abundance the rate of removal must be sustained from generation to generation. Increasingly higher percentage removals are required in order to drive the stock to successively lower levels of density.

These principles of fish population dynamics underlie observed increases in stocks in which the rate of removal has been deliberately decreased. A classical case is the Pacific halibut stock (Fukuda, 1962). The Pacific halibut stock density declined steadily until 1930 when a closed season was imposed. Subsequently the stock density increased steadily. Similar examples are reported for the whitefish of Lake Wabamun (Miller, 1949) and for lake trout of Lake Oteongo (Fry, 1949). Murphy (1967) was able to calculate that a Pacific sardine population would have been 8 times larger than actual after the end of a seven year period had fishing been stopped at the beginning of the interval.

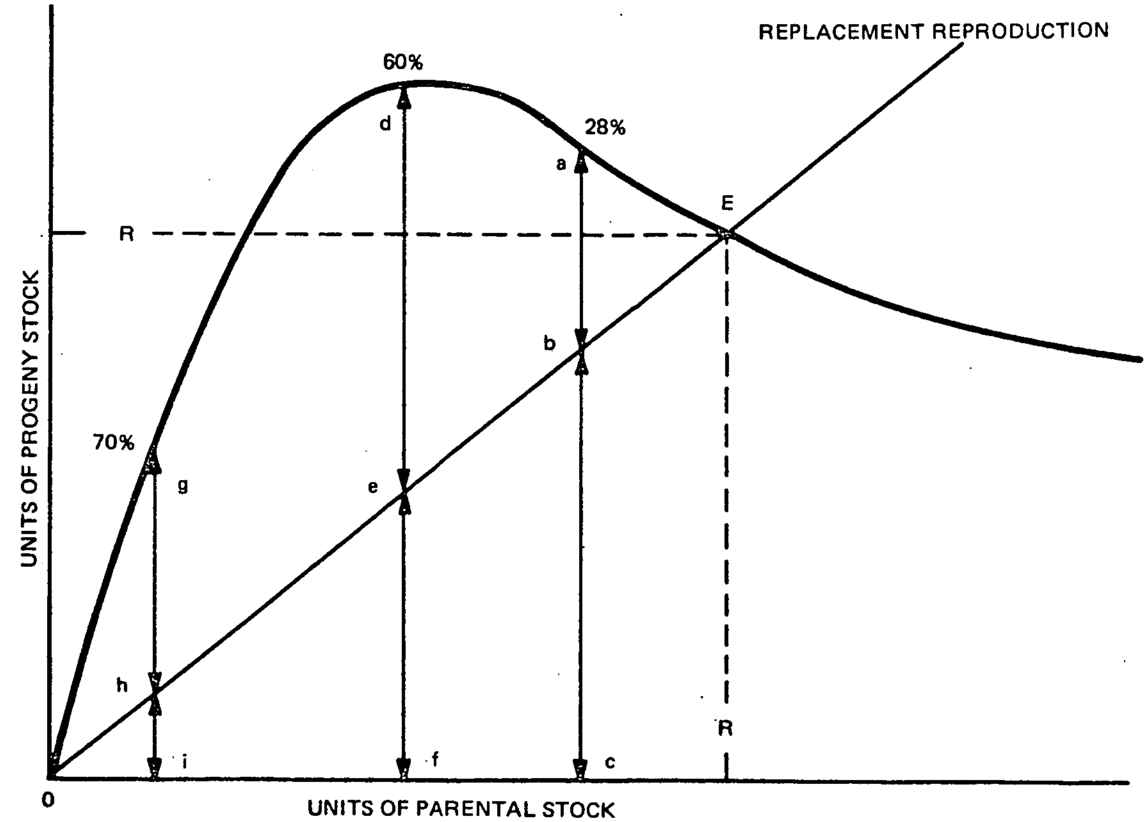


Figure 5. - Possible relationship between parental and progeny stock size for a fish population as developed in Figure 4, with increments of mortality (ab ; de ; gh) imposed so as to reduce the stock below equilibrium level E.

IIf. Estimates of Power Plant Impact Upon Survival of Young Striped Bass

When an additional probability of death, "p", (for example from operation of a power plant) is imposed upon a population which is already exposed to a probability of natural death, "d", the probability of death from both causes operating simultaneously, "a", is:

$$a = p + d - pd$$

That is to say, the probability of death from both causes combined is clearly not the sum of the individual probabilities. The relationship set forth above is well known from actuarial work where living organisms are exposed to risks of death from several sources simultaneously. Estimates of the reduction of the young-of-the-year striped bass as a result of operation of the Indian Point power plant appear to be exaggerated because this basic actuarial relationship has been overlooked. An example of the operation of this phenomenon under natural conditions is presented in Figure 6, drawn from studies of brook trout populations. The phenomenon may reasonably be inferred to operate with other species because it is simply a matter of risk probabilities.

To demonstrate the error generated by failure to recognize the operation of competing risks from natural death and death caused by operation of the Indian Point power plant, the data set forth in the testimony of John Clark is analyzed here by appropriate mathematical methods. To carry forth the calculations two instaneous rates of mortality, "n" and "m", are defined as follows:

$$d = 1 - e^{-n}$$

where n equals the instaneous natural mortality rate;

$$p = 1 - e^{-m}$$

where m equals the instantaneous rate of death caused by the Indian Point power plant.

Using these instaneous rates along with the assumptions and base data used in John Clark's testimony, new calculations have been carried out to accurately predict the reduction in abundance in young-of-the-year striped bass resulting from operation of the Indian Point power plant. For purposes of these calculations the assumptions about the magnitude of mortality and population abundance at various life history stages as set forth in Clark's testimony are used. This does not imply substantive agreement with the figures set forth in his testimony.

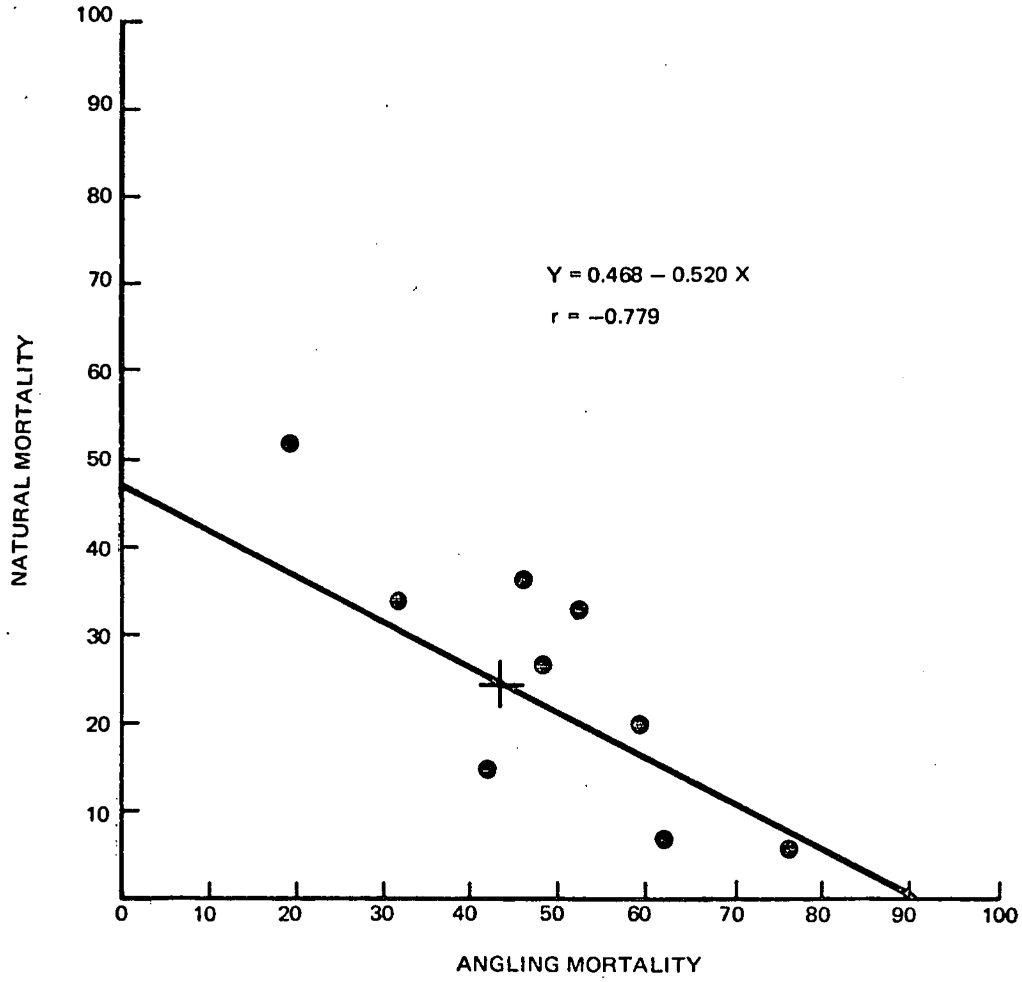


Figure 6. An example of reduction of natural mortality with increasing angling mortality as a result of exposure of the fish to competing risks of death from the two causes. Based on studies of a brook trout population under natural conditions (McFadden, 1961).

For purposes of this analysis of Clark's data I accept (a) his estimates of abundance of striped bass at successive stages in the life history under natural conditions; (b) his description of life history stanzas and their duration; (c) his estimates of number of striped bass entrained or impinged at each stage; (d) the assumption that all striped bass intercepted by Indian Point Power Plant Units 1 and 2 are killed.

It is further assumed that within each life history stage all individuals are exposed to the same probability of death from natural causes and the same probability of death due to entrainment or impingement, even though different fish pass through a given development stage on different calendar dates due to the protracted spawning period of adult striped bass. This assumption treats the year class of fish as though all had been spawned on the same day.

The duration of each developmental stage as used here differs from certain of Clark's statements because of minor inconsistencies in his testimony in this regard. No difficulties in interpretation are caused.

The basic data, derived from Clark's testimony and summarized in Table 5 represent striped bass abundance under natural conditions, that is, without removal by Indian Point Units 1 and 2. For purposes of my calculations Clark's estimate of 1.8×10^6 juveniles at age 240 is replaced by the more realistic value of 1.6×10^6. On page 23 Clark uses Pearcy's survival figure of 41 percent for 10 months to interpolate an 18 week survival of 75 percent by simple proportion. To maintain an assumption of constant mortality rate I calculate from Pearcy's 10 month survival of 41 percent an instantaneous weekly mortality rate of .022, and from this survival of 67 percent for an 18 week period instead of Clark's figure of 75 percent.

The data for abundance of fish at successive development stages, as given in Table 5, are plotted to give the survival curve of Figure 7, which represents natural conditions in the Hudson River. This interpretation is generally consistent with that of Clark's Figure 2.

From Figure 7 the numbers of fish present at the beginning of each life history stage is determined and entered in Table 6. The estimates of fish killed by the operation of Indian Point Units 1 and 2, as developed by Clark, are entered also (column C). The remaining calculations of Table 6 are based on the assumption that during each life history

Table 5. Basic Data on Hudson River Striped Bass from testimony of John Clark

Age in Days	Stage	Number	Description
0	I	1.3×10^9	Eggs (viable, fertilized)
2	II	112×10^6	Early larvae
23	III	62.5×10^6	Larvae/pre-juveniles
44	III	16.0×10^6	
51	III	10.0×10^6	
76	IV	—	Early juveniles
104	V	—	
114	V	2.4×10^6	Late juveniles
240	V	1.8×10^6*	

*A more realistic figure 1.6×10^6 is calculated by McFadden and used in this analysis.

stage the fish are exposed to competing exponential risks of death from natural causes and from entrainment or impingement by the Indian Point plant. Under this assumption:

$$N_t' = N_o e^{n+m}$$

where

N_t' = number of fish surviving to the end of a life history stage during which natural and power plant mortalities were operative.

N_o = number of fish present at the beginning of a life history stage.

e = base of natural logarithms.

n = instantaneous natural mortality rate.

m = instantaneous death rate due to Indian Point Units 1 and 2.

The older larval stage (V) was considered variously by Clark as lasting through mid-February of the calendar year after hatching (158 day duration) or through May 28 (260 day duration). Calculations for each are presented in Table 6.

If the impact of operation of Indian Point Units 1 and 2 upon the young-of-the-year striped bass is assessed as of mid-February of the year following hatching, the year class is seen to be reduced to

$$N_t' / N_t = \frac{1.25 \times 10^6}{1.60 \times 10^6} = 78\% \text{ of the level expected under natural conditions.}$$

If the assessment is made as of May 28, the year class is reduced to

$$N_t' / N_t = \frac{1.03 \times 10^6}{1.20 \times 10^6} = 86\% \text{ of natural abundance.}$$

These reductions, 22 percent at the earlier date and 14 percent at the later date, are greatly at variance with Clark's assertion on page 44 of his testimony that,

> "The effect of full time operation of Indian Point No. 2 along with Indian Point No. 1, with both using once-through cooling, would be to remove from the Hudson 39 percent of the striped bass in their first year of life . . ."

The discrepancy arises from Clark's method of adding removals (due to power plant mortality) in sequence order. This method generates statistics which exaggerate the ecological impact of the Indian Point power plant. The ecologically significant figure is the estimate of reduction of young fish reaching the advanced juvenile stage, and approaching the age at which migration seaward, with attendant increase in growth potential takes place.

It should be noted that the preceding discussion does not invoke any compensatory decrease in natural mortality or increase in growth rate among the striped bass. It merely recognizes that the fish are exposed to competing risks of death due to natural causes and due to power plant operation.

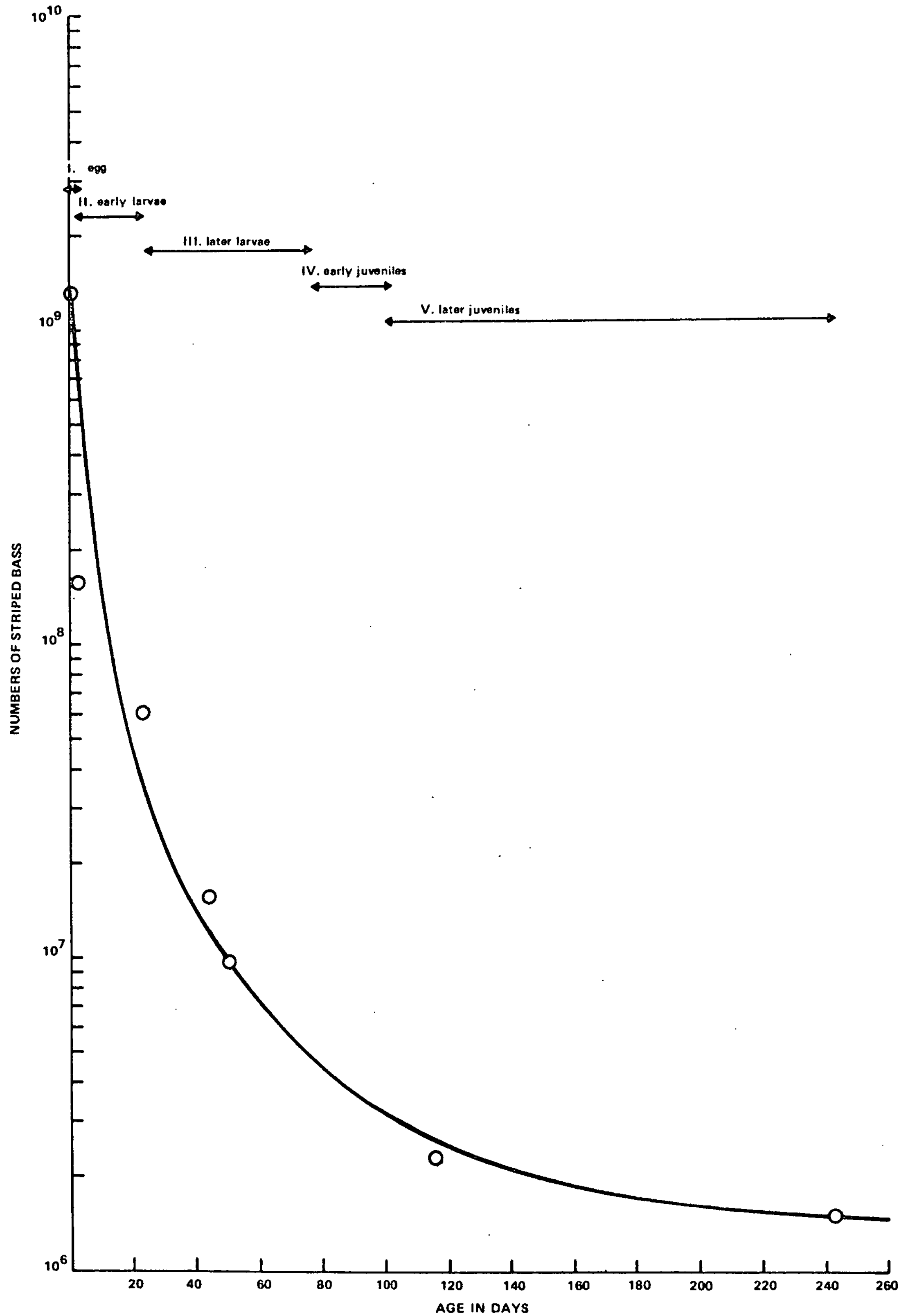


Figure 7. Natural survivorship curve for striped bass in Hudson River Estuary based on testimony of John Clark, Oct. 30, 1972

Table 6. Mortality and Survival Statistics for Striped Bass in the Hudson River During the First Year of Life

Stage	Initial Number N_o	Final Number Under Natural Conditions N_t	Number Killed By Power Plant C	Number of Natural Deaths D $(N_o - N_t)$	% Killed By Power Plant C/N_o	% Natural Deaths D/N_o
II	112×10^6	54×10^6	5.7×10^6	58×10^6	.051	.518
III	54×10^6	2.7×10^6	1.6×10^6	51.5×10^6	.0296	.950
IV	2.7×10^6	2.48×10^6	0.10×10^6	0.22×10^6	.037	.0815
V (158 days)	2.48×10^6	1.60×10^6	0.27×10^6	0.88×10^6	.1089	.355
V (260 days)	2.48×10^6	1.20×10^6	0.35×10^6	1.28×10^6	.141	.515

Stage	Natural Death Rate n	Death Rate Due To Power Plant m	Total Instantaneous Mortality Rate i = n+m	Survival s	Final Number With Power Plant Operative N_t'
II	.73	.053	.783	.457	51.2×10^6
III	3.00	.030	3.03	.0483	2.47×10^6
IV	.085	.038	.123	.8843	2.18×10^6
V (158 days)	.44	.115	.555	.5741	1.25×10^6
V (260 days)	.724	.153	.877	.4161	1.03×10^6

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BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the matter of	)	
	)	
CONSOLIDATED EDISON COMPANY OF	)	
NEW YORK, INC.	)	DOCKET NO. 50-247
	)	
(Indian Point Station, Unit 2)	)	

Redirect-Rebuttal Testimony
of

John P. Lawler, Ph.D.

QUIRK, LAWLER & MATUSKY ENGINEERS

on the

Mathematical Model Used by the Staff to
Estimate the Effect of Indian Point Units 1 & 2
Entrainment on Hudson River Striped Bass

February 5, 1973

I. INTRODUCTION

The purpose of this testimony is to show that the entrainment mathematical model used by the AEC Staff oversimplifies a complex system. The Staff's model does not adequately represent the actual interrelationship between the hydrodynamic characteristics of the Hudson River and behavior of young striped bass during their entrainable stage. Moreover, the results presented in the Final Statement have extended the influence of the plant across the entire river cross-section at Indian Point. In reality, however, due to its location, the intake will influence only a portion of the upper layer.

In order to make comparisons between results of the model used by the Staff and the Applicant's model, the terms which each use are defined below.

The percent reductions computed by the Staff's Model reflect the reduction in the young of the year up to the point at which they are no longer considered to be entrainable, i.e., it computes the effect of entrainment only. Impingement losses are included in the Applicant's model.

The Applicant's model computes the percent reductions of the year one class as well as the percent reductions on the total adult striped bass population for years of plant operation as well as the per cent reductions of the intermediate stages of the egg, larval, and juvenile striped bass within any one year.

The Applicant's model includes a compensatory mechanism (i.e., variation of survival with the striped bass concentration) whereas the Staff's model does not.

In most of the runs presented in the Staff's Final Statement (Table A-V-16, pg. A-V-85), an "f" factor of one was used.

Exceptions are cases 52, 53, 54 and 55 of Table A-V-16 of the Final Statement, where an "f" factor of .6 is used.

The Staff used 100% mortality through the condenser in the entrainable stage excepting cases 6 and 7 of Table A-V-16 of the Final Statement. For these cases, the Staff employed a 50% inplant mortality factor.

"f" factors used by the Applicant are different for each entrainable stage (eggs, larvae and juvenile I's) and are presented in Table 20 of the Applicant's testimony of October 30, 1972*.

It must be realized at this point, that the assumptions and hypotheses behind the numerical values used in many of the cases considered by the Staff are not explained in the Final Statement or in this proceeding. On the evening of January 18, 1973, at the AEC offices in Bethesda, Maryland, the Staff met with Applicant representatives to clarify some of the details of the Staff's model as well as many of the assumptions used by the Staff to generate the results presented in the Final Statement. I believe that many of the interpretations presented by the Staff during the January 18, 1973 meeting to support its selection of model input values represent hypothetical conditions that have not been supported by field observations.

Additional material clarifying the Staff's position as discussed at the meeting on January 18, 1973, and in this proceeding (TR.9221 & 9222) has not been made

*Testimony of John P. Lawler, Ph.D., Quirk, Lawler & Matusky Engineers on the Effect of Entrainment and Impingement at Indian Point on the Population of the Hudson River Striped Bass, October 30, 1972.

available in its entirety as of the date of submission of this testimony. Therefore, further rebuttal of the Staff's model and results may be submitted after receipt of the requested information.

This testimony will show that when the hydrodynamic characteristics of the Hudson River behavior of the early stages of striped bass and plant intake location are more realistically considered in the Staff's model, the previously reported 30 to 50% reduction in striped bass population (Tr.9221) will be significantly lower.

However, I do not imply that inclusion of the more realistic values and events in the Staff's model will make it capable of reproducing actual striped bass behavior or of estimating the impact of the plant. This testimony takes the Staff's conceptual notion as the point of departure and simply introduces more representative hydrodynamics into that portion of the Staff's model wherein river hydrodynamics are called for by the Staff.

The format of this testimony consists of first presenting a theoretical discussion of the mechanisms active in the Hudson River estuary, followed by modifications to the Staff's model. Two sample runs are then made to illustrate the influence of these modifications on the final results. Comments of model verification and concluding remarks are given in Sections III and IV, respectively.

Two appendices have been included to provide the details of the Staff's model and the modifications performed by the Applicant.

II. REBUTTAL OF STAFF'S MODEL

1. Introduction via Reference to the Record

The following statements, taken from the January 18 and 19, 1973 Hearing Record are reproduced below to illustrate the general characteristics and dominating mechanisms considered in the Staff's model.

On January 19, 1973 (Tr. 9292 to 9304), I asked Dr. Goodyear of the AEC a series of questions which were designed to summarize the previous day's cross examination on the model (TR.9205 to 9278) as well as to include information developed during the previous evening's discussion with Dr. Goodyear and other Staff personnel.

"Q. Dr. Goodyear, you have stated in the paragraph entitled "Estimate of Entrainment," on page A-V-81, in the last sentence after commenting on the comparison with the field data, that the "most obvious result of these comparisons was that the longitudinal distribution was more sensitive to variations in assumed magnitudes of the density-induced flows than were the estimates of entrainments."

Now I ask you, are you saying that regardless of the conditions modeled, the entrainment loss is still essentially the same?

A. Within a factor of two, yes.

Q. Dr. Goodyear, is it not true that your model continually brings larvae back from a point below the plant into a position above the plant?

A. Yes.

Q. And do these larvae not then pass the plant a number of times before the end of the eight-week period of vulnerability?

A. Yes.

Q. You have then an endless belt in which organisms are constantly flowing past the plant, dropping into the lower layer, and then returning and repassing the plant, would you not agree?

A. Yes.

Q. Dr. Goodyear, will not the changing of conditions of flow and/or migration factors speed up or slow down the rate at which this rotating or circulating belt functions?

A. Yes.

Q. Dr. Goodyear, is not the insensitivity of your estimate of entrainment to variation in the input parameters due to this endless belt concept?

A. Yes.

Q. In other words, as long as you keep Indian Point located within the belt, you will get approximately the same results regardless of input changes?

A. Yes.

Q. The range in results will be related to how fast a given set of input parameters makes the belt circulate, would you not agree?

A. Yes.

Q. Dr. Goodyear, on page V-53 you have presented a series of observed field observations of larval distribution or longitudinal larval distribution in the river, and also the results from several *selected model runs. So the verification in terms of a comparison of the model results, the field observations, then, appears to be given on page V-53.*

My question to you is are you not simply showing that the shape of the longitudinal distribution of larvae as generated by the model is similar to the shape of the distribution as observed in the field?

A. Yes.

Q. And the time represented by the runs depicted in figure V-11, that is to say the model runs, is four weeks. Is that not correct?

A. That is correct.

Q. And the time represented by the field runs in figure V-11 covers several periods after spawning. Is that not correct?

A. That is correct."

"Q. Now the model receives all of the spawn at one point in time; is that correct?

A. Yes.

Q. The spawn in the field occurs over a period of several weeks; is that correct?

A. Yes.

Q. The magnitude of the larval concentrations from the model has not been compared to the magnitude of the larval concentrations in the field. Is that not correct?

A. From an absolute sense?

Q. The magnitude.

A. That is true"

√

The following discussion occurred during the afternoon of January 18, 1973, (TR.9255 to 9256) and deals with the notion of introducing time variable behavior into the model, rather than using static 24 hour averages to describe organism behavior.

"Q. Is it not true that in making a given run in the model you used for the saline intruded section the same migration split in all segments or compartments?

A. Yes.

Q. Does it seem resonable to you that the same split should apply to all segments when in fact your model over any 24-hour period will yield a net vertical downward movement in some segments-- as we described a moment ago -- and a net vertical upward movement in other segments?

A. Yes.

Q. It does?

A. Yes.

Q. It is logical to you that the split should be the same for all segments, even though the vertical transportation may be in one direction over a 24-hour period, which these splits refer to now, in one segment, and in the opposite direction in another segment?

A. Yes.

Q. Would you not think that a better approach in evaluating this phenomena would have been to introduce the known time variable behavior of the migrating organism into the model?

A. Yes.

Q. Might this not give a substantially different result *than the results you have reported?*

A. I doubt it. It would be different, but the degree of difference should not be too great.

Q. But you don't know whether or not it would be?

A. Not without some additional thought."

Again on the afternoon of January 18, 1973, following a lengthy discussion of the role of longitudinal mixing in models of this type (TR. 9257-9269), I then asked Dr. Goodyear for his opinion of the relative merits of introducing time dependent vertical and longitudinal transport mechanisms into the model and of averaging on a three hour or a one hour basis rather than on a 24 hour basis.

"Q. Dr. Goodyear, do you think that rather than averaging upper and lower layer flows and larval vertical movements over a 24-hour period, as we have discussed earlier, that averaging over a three-hour period would be a more accurate representation of the system you have described?

Let me add to that, I would add to that by introducing an average over a three-hour period, I would also propose introducing into the model the actual vertical time-dependent transport that takes place in the organism and its actual horizontal time-dependent transport that takes place due to the tide?

A. What was the question itself?

Q. My question is that were I to introduce those two time-dependent mechanisms explicitly, and evaluate in terms of a three-hour average, or one hour, for that matter, but let's just take the three-hour average, would you not agree *that this would give a more accurate representation of the physical system we are trying to describe?*

A. It would, of the physical system, yes.

Q. And biological system?

A. Only if the data you use are sufficiently precise.

Q. Would you agree that this procedure as I have described, the introduction of the time-dependent mechanisms and the three-hour averaging technique, could result in translating the organisms at a lower rate?

A. A slower rate?

Q. Yes.

A. Yes."

" Q. If the three-hour averaging technique translates organisms at a slower rate downstream and upstream than a 24-hour averaging process would, would not the plant reduction, as computed via that "three-hour model" be less than the plant reduction computed with a similar set of conditions, but using the 24-hour model?

A. Somewhat."

On the basis of these statements and the discussion given in Appendix V-3 of the Staff's Final Statement, I believe that the Staff's model represents an unrealistic over-estimate of the plant entrainment effect on the Hudson River striped bass due to Indian Point Unit 1 and 2 operation.

This over-estimate is mainly due to the following two factors:

1. the averaging technique used in the model, resulting in the elimination of explicit treatment of the tidal and vertical transport mechanisms .

2. the use of the segment average concentration in the Indian Point segment for plant withdrawal. Questioning of Dr. Goodyear on this topic appears in Tr. 9294-9298.

2. Influence of Averaging Techniques on Model Results

In order to illustrate the effect of averaging, a simple numerical example is presented below.

Assume that the tidal flow in the upper layer of a segment is represented as shown in Figure 1. It has a period of 12 hours and on ebb, the flow is 50,000 cfs and on flood, the flow is 40,000 cfs. Over a 12 hour period, the net (average) upper layer flow downstream is 5000 cfs $(= \frac{50,000x6 - 40,000x6}{12})$. Since the behavior is cyclic, and the diurnal cycle is closely twice the tidal cycle, the 5000 cfs average applies over 24 hours as well. Assume also that the vertical migratory behavior moves a number of larvae into the upper layer as shown in Figure 1, i.e. for the first 15 hours (sunlight hours) all of the larvae are in the lower layer and for the next 9 hours (nighttime hours) the larvae distribute themselves between the upper and lower layer so as to give 50 larvae in the upper layer.

The daily average number of larvae in the upper layer is then 18.75 $(= \frac{0x15 + 50x9}{24})$. If these averages are used to compute the "daily average transport" downstream, it is computed as....average flow x average larvae = 5000 cfs x 18.75 = 93,750 cfs-larvae.*

---

*These units (cfs-larvae) simply represent larval transport. Had larval concentrations been used, rather than simply numbers, and volume and time conversions made, units would have been larvae per day (moving downstream).

However, if the actual variation about the average values are used, (i.e., if the actual time dependent behavior in the river is modeled) the computation of larval transport will produce a different result.

Consider a typical early summer (entrainment period) case of ebb beginning at 6 am at the Battery* and daylight extending from 6 am to 9 pm. Using the numbers presented above, upper layer larval transport is calculated as follows:

$$\text{Upper Layer Larval Transport} = \frac{\left[\begin{array}{l} \text{Ebb Flow x Larval Concentration x Ebb Day Period (6 am - 12 noon)} \\ \text{-Flood Flow x Larval Concentration x Flood Day Period (12 noon - 6 pm)} \\ \text{+Ebb Flow x Larval Concentration x Ebb Day Period (6 pm - 9 pm)} \\ \text{+Ebb Flow x Larval Concentration x Ebb Night Period (9 pm - 12 midnight)} \\ \text{-Flood Flow x Larval Concentration x Ebb Flood Night Period (12 midnight - 6 am)} \end{array}\right]}{\text{24 hours}}$$

$$= \frac{\left[\begin{array}{l} 50{,}000 \times 0 \times 6 \\ -40{,}000 \times 0 \times 6 \\ +50{,}000 \times 0 \times 3 \\ +50{,}000 \times 50 \times 3 \\ -40{,}000 \times 50 \times 6 \end{array}\right]}{24}$$

$$= -187{,}500 \text{ cfs-larvae}$$

---

*Mouth of the Hudson River

Therefore, for this example,use of the average values produces a result which is twice the "true" average transport downstream and in the opposite direction.

The Staff's transport model is based on using the daily average tidal flows* in the upper and lower layers and the daily average distribution of larvae between the upper and lower layer. It does not include any terms to represent deviations from these averages within the 24 hour period.

When one uses time-averaged values of products of variables to represent a system in which those variables undergo time fluctuations, and does not introduce terms to account for these fluctuations, a series of real effects is lost in the system presentation. Such is the case in question, tidal variation and vertical larval migratory activity appear as products in the representation of larval transport, so a series of terms representing the transport of the material (larvae) above and below the values computed as simple products of time average flows and concentrations are lost. These additional terms may or may not be significant depending on the averaging period and the nature of the fluctuations.**

---

*The tidal period was implicitly assumed to be 12 hours (as opposed to ~12.42 hours) so the daily average tidal flow = 12 hour average tidal flow. Also note that tidal flow, in this context, includes river fresh water flow. Sensitivity analysis (presented in Appendix 2) using 12 and 12.42 hour durations showed virtually identical results.

**These facts are brought home most clearly when one constructs a transport model from first principles; i.e., when use of the three dimensional time variable equations of mass, momentum and energy transport in a fluid system are used as the point of departure in constructing the model. This point is discussed, in slightly more detail, in the record (Tr. 9271-9274). This notion, for example, is what generates the existence of the longitudinal dispersion coefficient in the one dimensional estuarine transport equation.

In tidal estuaries when averages are taken over a tidal period and over a cross-section, both laterally and vertically, these fluctuations are significant and are represented by a dispersion term as was done in the Applicant's transport model.

When averages are taken over a tidal period and over segments of a cross-section, i.e. averaged in the upper layer and averaged in the lower layer as was done in the Staff's transport model, the additional terms generated due to the averaging process are also significant.

The effect of the 24 hour averaging in the Staff's model can be estimated by constructing a model which includes splitting the system into two layers, and explicitly including the larval vertical migration and upper layer and lower layer flows using a small time scale* (1 to 3 hours).

Both the original Staff's transport model (abbreviated as Model 24) and the model as modified by the above considerations (abbreviated as Model 1) on a 1-hour averaging basis were programmed for computer solution.**

For similar input conditions (See Table 1), the Staff's transport model predicts a reduction of the larvae throughout the estuary of 25% and Model 1 predicts a reduction of 18%. For this case, simply by not properly time averaging, the Staff's model overestimates its own concept of the entrainment effect by 39% $\left[\frac{(25-18)}{18} \times 100\%\right]$.

---

*See hearing record Tr. 9271, January 18, 1973 (page 9, this testimony)

**See Appendix 1 and 2

TABLE 1

RUN CONDITIONS USED FOR COMPARISON OF
24-HOUR (MODEL 24) AND 1-HOUR (MODEL 1)
AVERAGING MODELS+

Segment	Spawn * (# of organisms initially in a segment)	24 hour Average Flow **		24 Average Fraction Of Population ***	
		Downstream Flow Upper Layer (Downstream-end)	Upstream Flow Lower Layer (Downstream-end)	In Upper Layer	In Lower Layer
1	.08	4000	- 4000	.2	.8
2	10.55	4000	- 4000	.2	.8
3	10.55	4000	- 4000	.2	.8
4	4.20	4000	- 4000	.2	.8
5	11.23	4000	- 4000	.2	.8
6	11.23	4000	- 4000	.2	.8
7	6.00	4000	- 4000	.2	.8
8	6.00	4000	- 4000	.2	.8
9	6.70	4000	- 4000	.2	.8
10	6.70	11000	3000	.2	.8
11	10.00	16000	8000	.2	.8
12	10.00	29000	21000	.2	.8
13	3.44	30000	22000	.2	.8
14	3.33	32000	24000	.2	.8
15	0.	34000	26000	.2	.8
16	0.	37000	29000	.2	.8
17	0.	43000	35000	.2	.8
18	0.	54000	46000	.2	.8
19	0.	54000	46000	.2	.8

* Based on Table A-V-19, P. A-V-93 of the Final Statement

** Based on Table A-V-20, P. A-V-94 of the Final Statement

*** Based on Results of Model 1 (See Appendix 2)
($\mu = 2 \times .2 = .4$, $\ell = 2 \times .8 = 1.6$)

\+ Model 1 = Staff's model modified to reflect influence of smaller averaging time (1 hour)

Model 24 = Staff's model as used in the Final Statement

The reasons for the differences in the percentage reductions stem from the absence of actual tidal flow and vertical migration behavior from the Staff's transport model which produces a quicker movement of organisms to the salt front (segment 9) at which time they enter a circulation belt as described in the January 18, 1973 testimony.* This belt is illustrated numerically in Figures 3 and 4.

Figure 3 shows all circulation (advection or convective transport and vertical transport) at a point 8 weeks in time with Indian Point** Units 1 and 2 operating (Run 1).

Comparable results computed using Model 1 are not shown in this figure, since the numerical magnitudes of the transport terms are time dependent within each day.

This makes direct numerical comparison of Model 24 results (which represent averages over a 24 hour period) with Model 1 results (which are indicative of average hourly behavior with a 24 hour period) incommensurate.

However, the overall characteristics, averaged over a common time base, of both models may be compared. The overall characteristics of Model 1 are discussed later in this section.

The circulation zone is entirely contained within segments 10 to 19. Sub-zones (sub-belts) exist between segments 10 and 12, 10 and 13.... to 10 and 19 and between segments 11 and 19.

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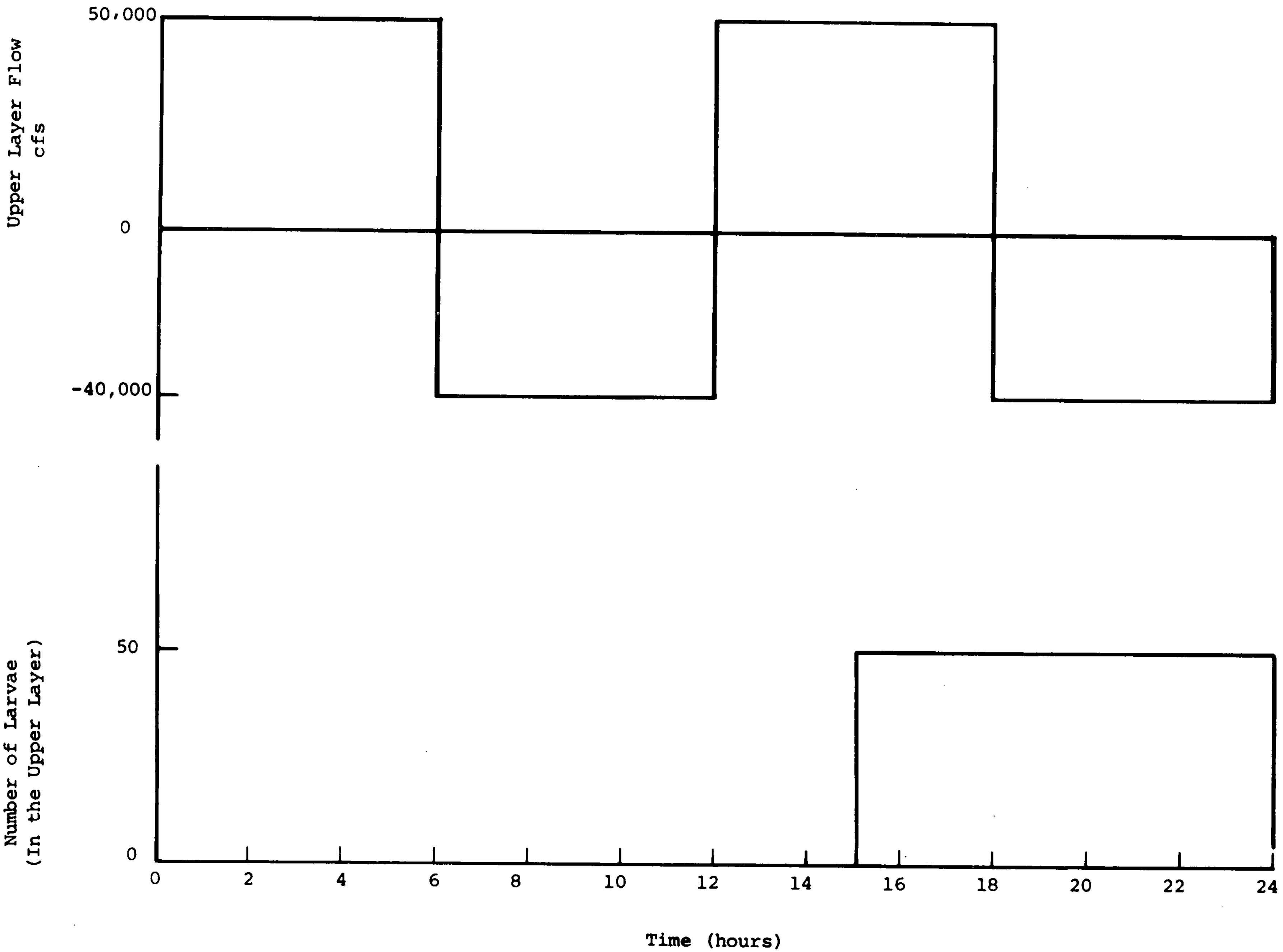
*The figures drawn on the blackboard by Dr. Lawler during cross-examination on January 18, 1973 are enclosed here as Figure 2.

**Indian Point is in segment 12.



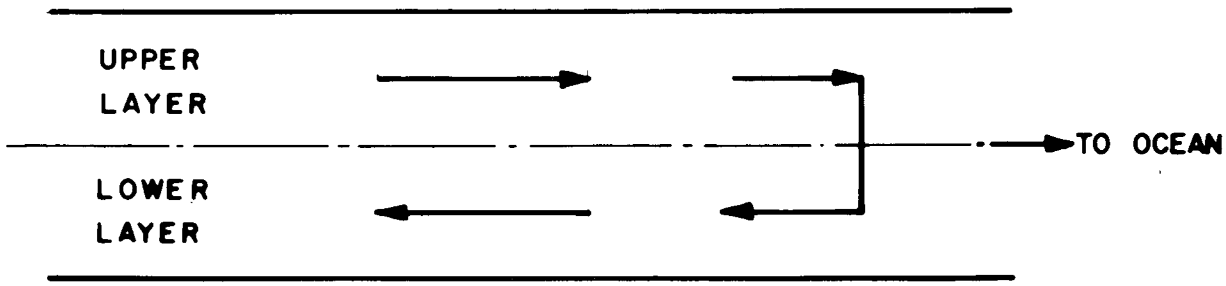
UPPER LAYER FLOWS AND LARVAL NUMBERS USED IN EXAMPLE CASE PRESENTED IN THE TEXT

FIGURE 1

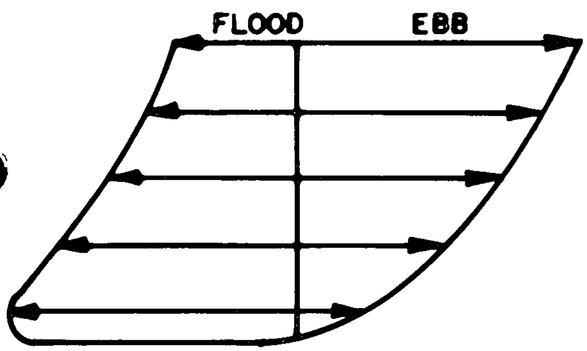
FIGURE 2

SKETCHES DRAWN BY DR. JOHN P. LAWLER ON JAN. 18, 1973 IN CONJUCTION WITH CROSS EXAMINATION OF DR. PHIL GOODYEAR OF THE A.E.C.

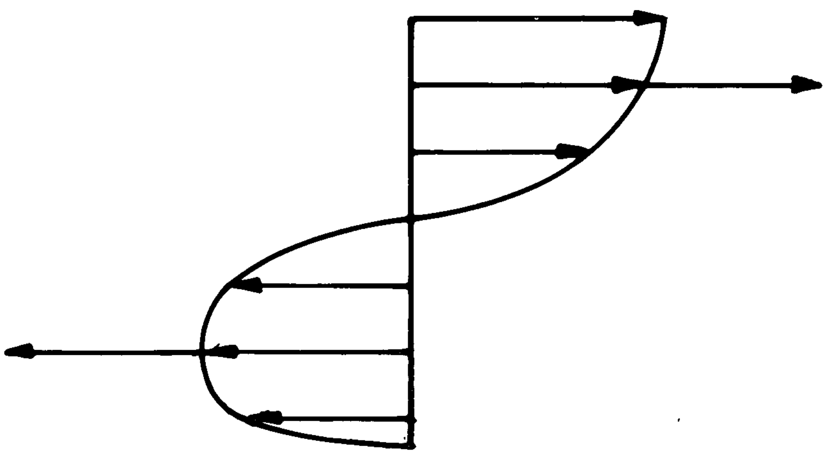
(1) 1:40 PM



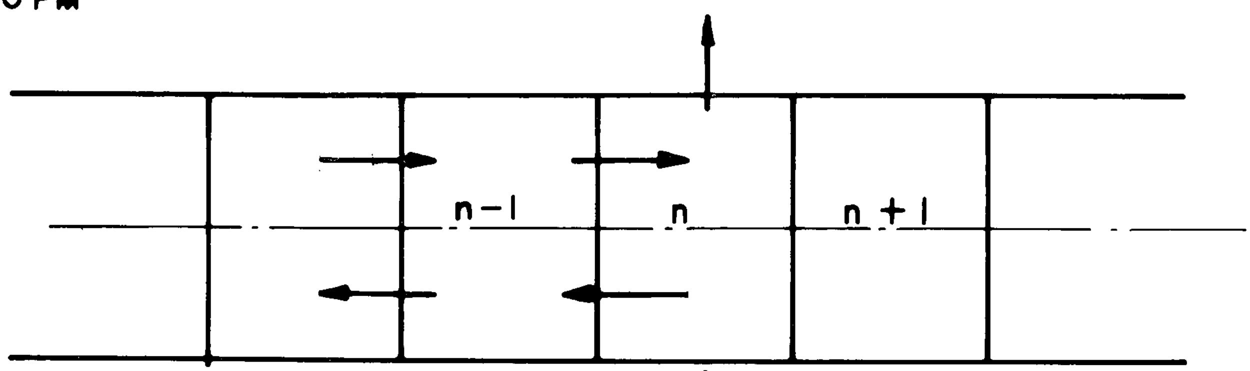
(2) 1:45 PM



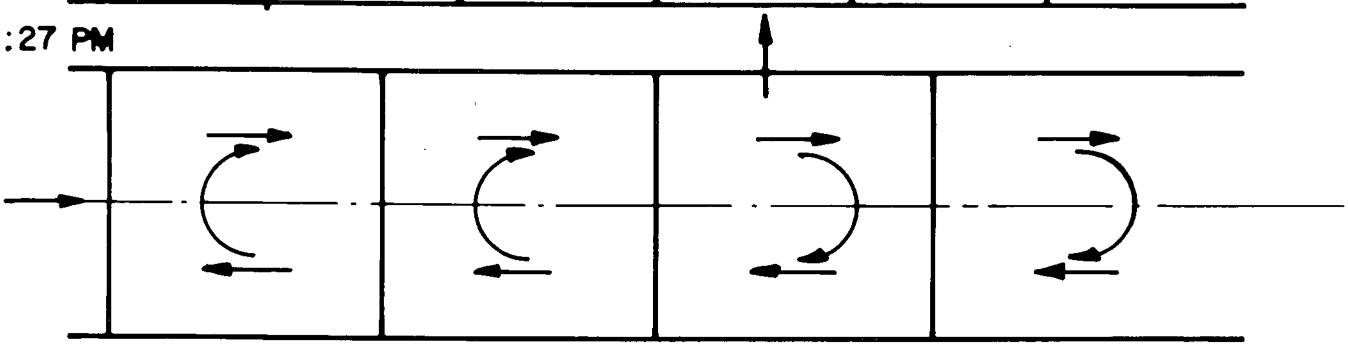
(3) 1:50 PM AVG. MOTION



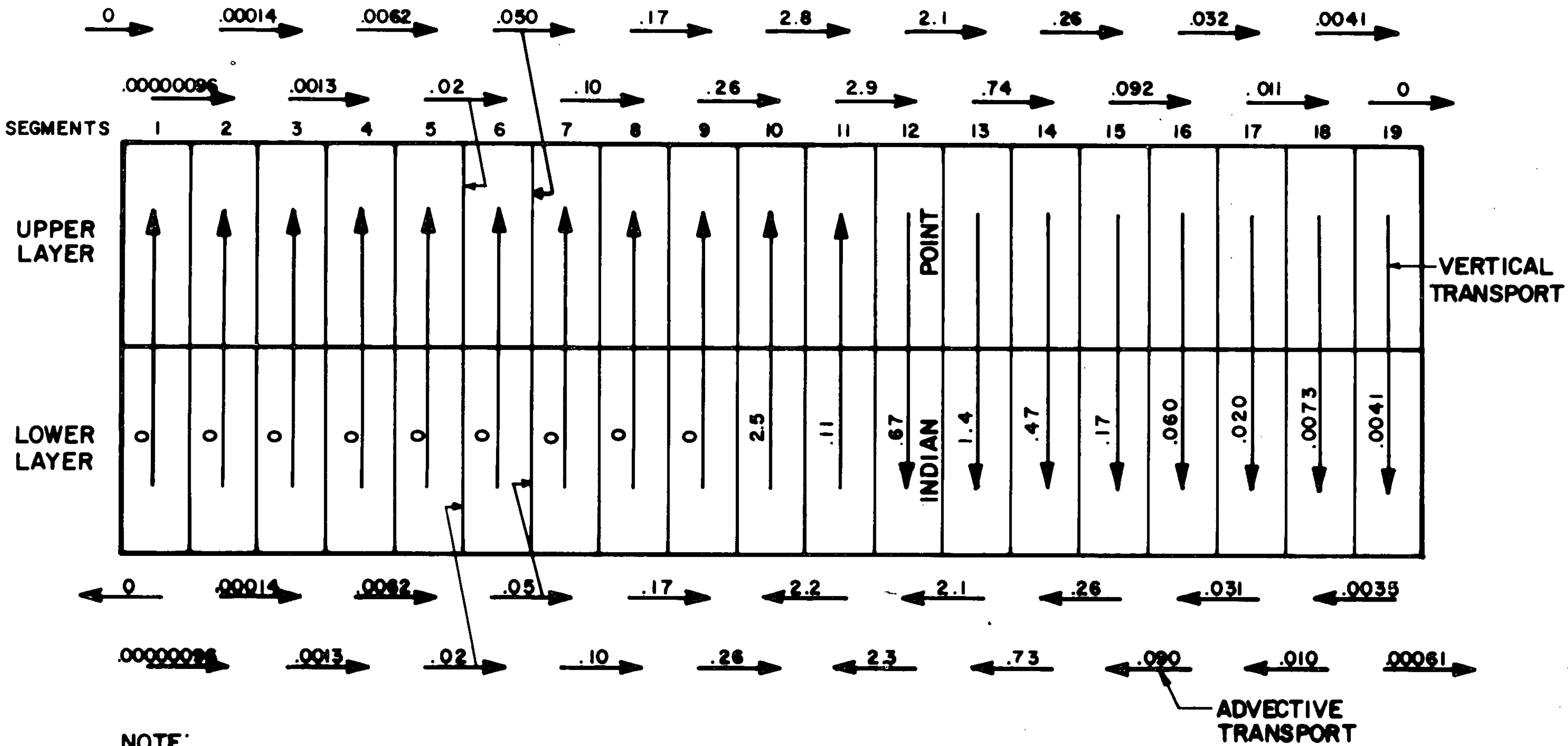
(4) 2:20 PM



(5) 2:27 PM



CIRCULATION BELTS GENERATED BY RUN I OF THE STAFF TRANSPORT MODEL



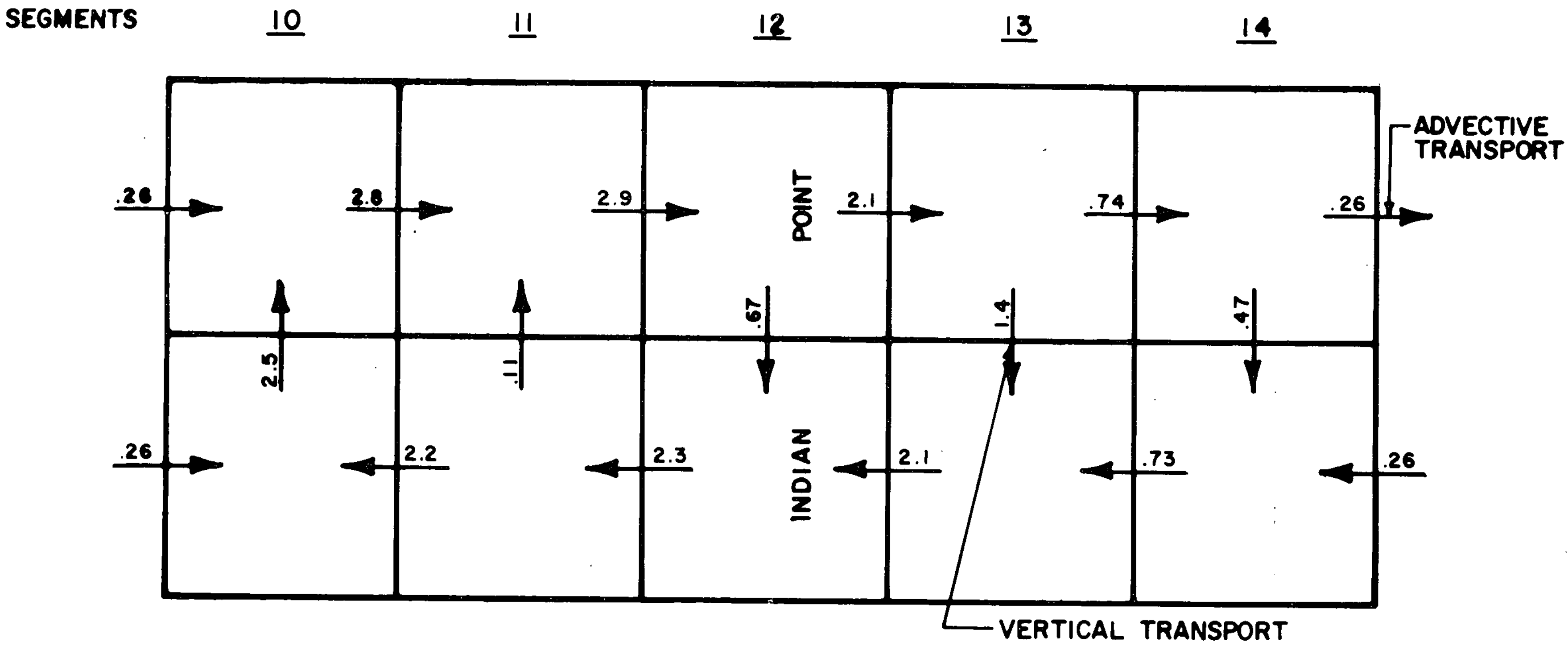
NOTE:

1.) NUMERICAL VALUES ARE PRESENTED IN NO. OF LARVAE / DAY AND ARE ROUNDED TO TWO SIGNIFICANT DIGITS.

2.) RESULTS ARE BASED ON RUN I OF THE STAFF TRANSPORT MODEL AT THE END OF THE 8th WEEK WITH INDIAN POINT IN OPERATION.

FIGURE 3

SCHEMATIC OF MAJOR CIRCULATION BELTS



NOTE:

1.) NUMERICAL VALUES ARE PRESENTED IN NO. OF LARVAE / DAY AND ARE ROUNDED TO TWO SIGNIFICANT DIGITS.

2.) RESULTS ARE BASED ON RUN I OF THE STAFF TRANSPORT MODEL AT THE END OF THE 8th WEEK WITH INDIAN POINT IN OPERATION.

FIGURE 4

However, all (100%) of the upward (vertical) transport is contained in segments 10 and 11 and 79% of the downward (vertical) transport is contained in segments 12 and 13 (97% in segments 12, 13 and 14).* Therefore, most** of the circulation is contained with the four segments surrounding Indian Point (segments 10 to 13).

As indicated earlier, when Model 1 is used for similar input conditions (Run 1) circulation belts are also generated but with different characteristics. Circulation is not limited to the salt water zone (segments 10 to 19) but occurs throughout the system (segments 1 to 19) to different degrees.

The larvae are "spread-out" more over the estuary (since hourly averaged tidal flows are used) since part of the "dispersion" above the 24-hour average tidal flows has been accounted for. This produces a "longer" circulation belt which has a "more even" circulation within its sub-belts; i.e. most of the organisms are not circulated within the innermost sub-belts.

This reduces to having the average time between passes of an organism past the Indian Point plant being increased and, therefore, the per cent reduction for a fixed period of time being reduced (since the number of passes has been reduced).

3. <u>Influence of Using Segment Average Rather than Upper Layer Concentrations</u>

The effect of using the segment average concentration in the Indian Point segment for plant withdrawal as opposed to the upper layer concentration, can be estimated by comparing the results of the two respective runs. The input

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*Similar results are obtained for all nine weeks with or without the plant operating.

**More than 75%

parameters used were the same as those shown in Table 1, excepting that the plant withdrawal is from the upper layer, and are considered to be more representative run conditions than many of the other conditions considered by the Staff.

The Staff's transport model (Model 24) and Model 1 results are shown in Table 2 and plotted in Figure 5.

Model 24 predicts an 8 week per cent reduction of 12% and Model 1 predicts an 8 week reduction of 6%.

TABLE 2

Comparison Between Results Obtained Using Model 24 and Model 1 with Plant Withdrawal from the Upper Layer

Week No.	Run 2 Model 1* % Reduction Total	Run 2 Model 1* % Reduction Nursery	Run 2 Model 24** % Reduction Total	Run 2 Model 24** % Reduction Nursery
1	.69	1.86	1.18	5.93
2	1.35	2.95	2.18	9.38
3	2.01	3.87	3.19	11.39
4	2.67	4.69	4.31	12.67
5	3.33	5.44	5.57	13.68
6	3.99	6.15	6.98	14.67
7	4.64	6.83	8.55	15.73
8	5.30	7.49	10.24	16.90
9	5.94	8.14	12.02	18.20

*Staff's model modified to reflect influence of smaller averaging time

**Staff's model as used in the Final Statement

COMPARISON BETWEEN RESULTS OBTAINED USING MODEL 24 AND MODEL 1 WITH PLANT WITHDRAWAL FROM THE UPPER LAYER

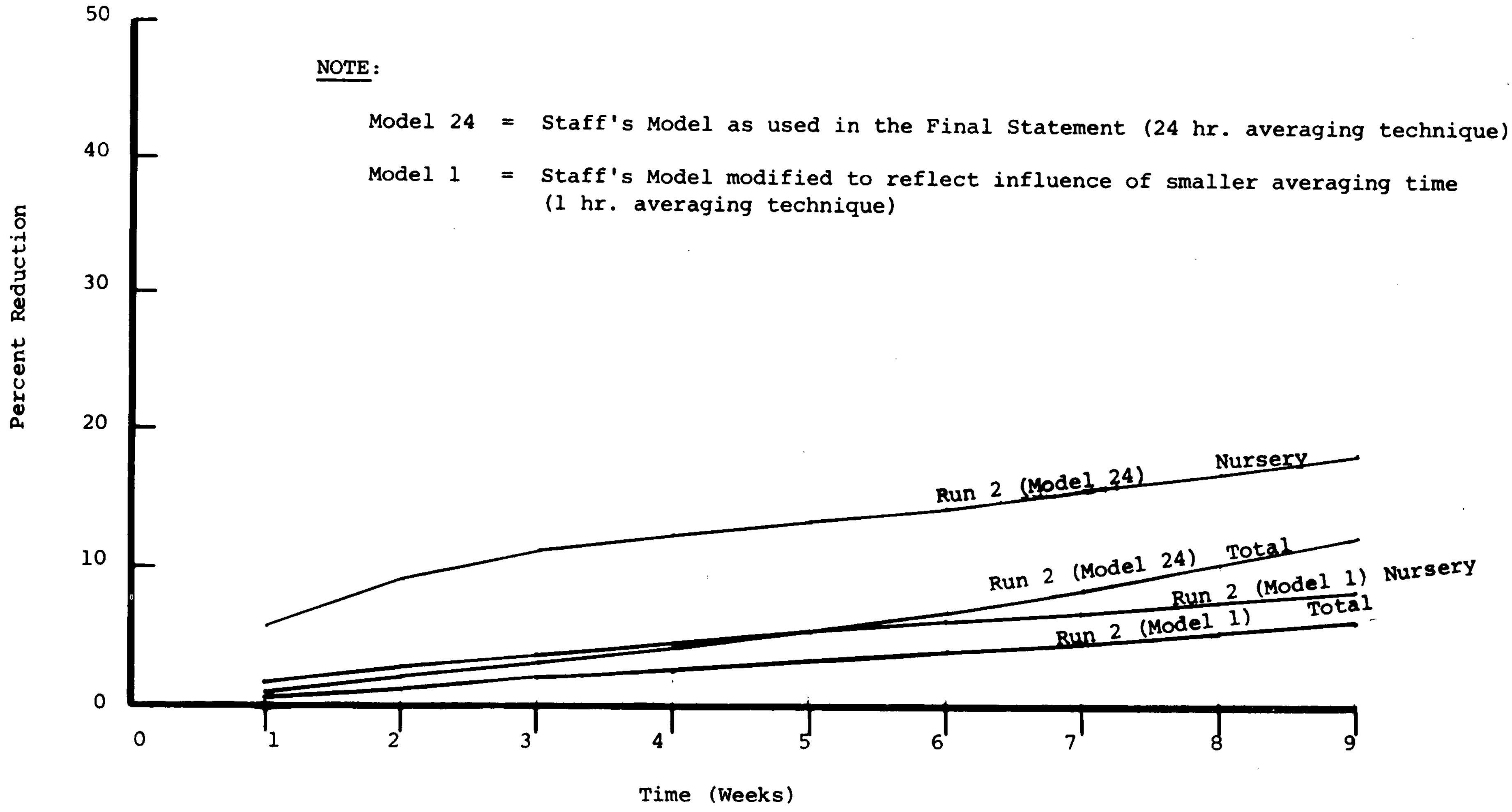

FIGURE 5

III. VERIFICATION OF STAFF'S MODEL

The verification of the Staff's model was accomplished by comparing the shape of the distributions of previous field surveys averaged over several weeks to the fourth week results of the Staff's model (Tr. 9303-9304). No attempt was made to compare the magnitudes of the results of the Staff's model to the magnitudes of the field observations nor is there any indication of an attempt to compare the shape of the results of the Staff's model to the field observations on a week by week basis.

In addition and unlike actual larval behavior, neither natural mortality nor time variable production of larvae was accounted for in the verification cases presented in the Final Statement.

Further rebuttal of the Staff's verification may be submitted since the intermediate weekly results of those cases* which the Staff has included in its verification figure (Figure V-11, p. V-53 of the Final Statement) were received too late (February 2, 1973) to be analyzed by the Applicant.

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*Cases 1, 13, 61, 62 and 67.

IV. CONCLUDING REMARKS

1. Due to neglect of terms which should have arisen in translating its conceptual model into mathematical terms, the computational procedure chosen by the Staff for use in its model yields an over-estimate of the impact of the Indian Point plant on the % reduction of entrainable striped bass.

2. For the set of Staff conditions considered by the Applicant to be representative of River conditions, this over-estimate was 39%; i.e., proper treatment of time-averaging of the River mechanisms influencing transport yielded a total year class one recruit reduction of 18%, versus the Staff's result of 25%.

3. Furthermore, although the Staff clearly recognizes the existence of upper and lower layer flows, and vertical diurnal migration back and forth into these layers, plant entrainment was computed on the basis of the section average concentration and not on the upper layer concentration.

I maintain that Applicant's testimony of October 30, 1972 (that of both Dr. Lawler as well as of Dr. Lauer) shows clearly that the existing plant is drawing from primarily the upper layer and the new plant, based on its similar intake location,can also be expected to withdraw from this upper layer.

Operation of the Staff's model and the Applicant's revision of that model to account for time variable behavior of flows and diurnal migrations yields further substantial reductions in the computed entrainment loss, when intake location is taken into account. When the plant draws from the upper layer only, for the representative River conditions under which both models were run, the total year class one recruitment reduction drops to 12% using the Staff's computational procedure and to 6% using the Applicant's revision of this computational procedure.

4. Considering the influence of both time averaging and intake location, the 25% reduction computed using the Staff's model without modification reduces to 6% or a reduction of more than 300% in the Staff's results. Application of this combined reduction in Staff's results, reduces the Staff's 30 to 50% reduction in year class one recruitment to 7 to 12%.

5. The Staff has presented no evidence in its Final Statement that any of its runs reduce the computed total year class one recruitment by more than 40% (Tr. 9211 to 9222). On the basis of the foregoing analysis, I maintain the 30 to 40% year class one reduction should be decreased to 7 to 10%.

6. The Staff's model was run for the case of existing plant operation (Danskammer, Lovett and Indian Point 1). For the case of all units operating, the situation on the River since 1969, a 26% reduction in the year class one recruits is predicted. This is shown to lead to unsupportable natural growth rates in another segment of the Applicant's testimony.* Use of the time averaging and upper layer entrainment computational procedures postulated above would yield a reduction of about 6%.

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*Responses to Questions by John P. Lawler, Ph.D. on the Sensitivity of the Model Presented in the Testimony of October 30, 1972 (Submitted February 5, 1973).

7. Use of condenser mortality data in the Staff's model in line with the testimony presented on February 5, 1973 by Dr. Lauer will reduce the above percentages by at least 50%, into the range of 3 to 6%.

8. The Staff's model does not consider compensation nor is it capable of computing long term population reductions. It also does not include tidal exchange (longitudinal dispersion). These considerations should be introduced before it can be considered to be a representative means of evaluating the broad range of contentions that have been the subject of this proceeding.

9. The Staff's conceptual model pictures intense movement of larval organisms back and forth past the Indian Point plant during an estimated eight week period of vulnerability to entrainment. Since substantive evidence exists regarding the tendency of later larvae and early juvenile striped bass to seek shallow water, a lateral shoal and shoreward directed mechanism should also be incorporated into this model.

10. Until these considerations are introduced into the Staff's model, it is my position that this model is inadequate to support the Staff's contention that cooling system modifications must be agreed to at this time. I contend that the model accuracy required for the magnitude of the decision involved requires model development time of the same order proposed by the Applicant for development of a satisfactory data base. In fact, the Applicant's five year study plan envisions mutual dependence of model and data base development. The model provides insight toward the type of data collection program necessary, and the data obtained will permit continuing model refinement, of the type described above.

and

$$C_{N_{t+\Delta t}} = aC_{Nu_{t+\Delta t}} + (1-a)\, C_{N\ell_{t+\Delta t}} \tag{8}$$

Substitution of (8) into (7) gives:

$$\mu_N = \frac{C_{Nu_{t+\Delta t}}}{aC_{Nu_{t+\Delta t}} + (1-a)\, C_{N\ell_{t+\Delta t}}} \tag{9}$$

Finally, substitution of (5) and (6) into (9) yields an equation with all values at time t which can be rearranged to solve for V_{T_N} at time t. It is functionally equivalent to:

$$V_{T_N} = V_{T_N}\Big(K_{N_t},\ R_{Nu_t},\ R_{N\ell_t},\ a,\ b,\ m,\ r,\ V_N,\ \Delta t,\ C_{N-1u_t},\ C_{Nu_t},\ C_{N\ell_t},\ C_{N+1\ell_t},\ Q_{C_N},\ Q_{N-1u_t},\ Q_{Nu_t},\ Q_{N\ell_t},\ Q_{N+1\ell_t},\ \mu_N\Big)$$

Table A-1-1 lists the output from a sample run of the Staff's model as well as the results from the same model * as implemented by the applicant for the same input conditions; the results agree exactly.

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* The Staff's model was originally written in a programming language called "FOCAL" for the PDP-8 computer; the Applicant's version is written in FORTRAN IV language for the GE-430 computer.

upper and lower layers and applying the material balance to each layer.

In separating the two layers, a vertical transport term is generated which is assumed to be from the lower to the upper layer.

In a manner similar to the development of the Staff's model, the resulting two equations are:

UPPER LAYER:

$$C_{Nu_{t+\Delta t}} = \left[C_{Nu_t} \left(1 - K_{N_t} \Delta t\right) a \cdot V_N + \left\{ R_{N_{ut}} + Q_{N-1_{ut}} \cdot C_{N-1_{ut}} + V_{T_N} - Q_{N_{ut}} \cdot C_{Nu_t} - m \cdot r \cdot b Q_{C_N} C_{Nu_t} \right\} \Delta t \right] \frac{1}{a \cdot V_N} \qquad (5)$$

LOWER LAYER:

$$C_{N_{\ell t+\Delta t}} = \left[C_{N_{\ell t}} (1 - K_{N_t} \Delta t)(1-a) \cdot V_N + \left\{ Q_{N+1_{\ell t}} \cdot C_{N+1_{\ell t}} + R_{N_{\ell t}} - V_{T_N} - Q_{N_{\ell t}} \cdot C_{N_{\ell t}} - m \cdot r \cdot (1-b)\, Q_{C_N} \cdot C_{N_{\ell t}} \right\} \Delta t \right] \frac{1}{(1-a) V_N} \qquad (6)$$

Since:

$$\mu_N = \frac{C_{Nu_{t+\Delta t}}}{C_{N_{t+\Delta t}}} = m_{N_t} = m_{N_{t+\Delta t}} \qquad (7)$$

With $S_{N_t} = 1 - K_{N_t} \Delta t$ and $b = .5$, equation (5) is analogous to the Staff's model equation on p. A-V-82 of the Final Statement.

RELATIONSHIP BETWEEN μ & ℓ

The relationship between the μ & ℓ parameters can be derived as follows:

Assume that the fraction of the total segment volume in the upper layer is a; the fraction in the lower layer is 1-a. If C_{N_u} is the upper layer concentration, C_{N_ℓ} is the lower layer concentration and C_N is the segment average concentration, then by definition:

$C_{N_u} = \mu_N \cdot C_N$ and $C_{N_\ell} = \ell_N C_N$, therefore:

$$\ell_N = \frac{C_{N_\ell}}{C_N} = \frac{\text{Numbers in lower layer}/[(1-a) \cdot V_N]}{\text{Numbers in segment}/V_N}$$

$$= \frac{(\text{Numbers in segment - numbers in upper layer})/(1-a)}{\text{Numbers in segment}}$$

$$= \frac{(V_N C_N - aV_N \quad (\mu_N C_N))/(1-a)}{V_N C_N}$$

Therefore $\ell_N = (1 - a\mu_N)/(1-a)$

When the volumes of the upper and lower layer are equal (a = .5), then:

$$\ell_N = (1 - .5\mu_N)/.5 \text{ or}$$

$$.5\,\ell_N = 1 - .5\mu_N, \text{ therefore } \ell_N + \mu_N = 2$$

COMPUTATION OF IMPLICIT VERTICAL TRANSPORT

The rate of vertical transport between the upper and lower layers which occurs in the Staff's model can be computed by separating the segment into the r = Coefficient of susceptibility to condenser flow

K_{N_t} = The rate of decay of organisms in segment X as a function of time (per time)

R_{N_t} = Rate of reproductive addition of organisms in segment N (organisms/day)

b = Fraction of the plant flow withdrawn from the upper layer.

If the volume of all segments are equal and are assumed constant, then:

$$\frac{dV_N \cdot C_{Nt}}{dt} = V_N \frac{dC_{Nt}}{dt} \qquad (2)$$

If, additionally, the first derivative is assumed constant within a time interval Δt, then:

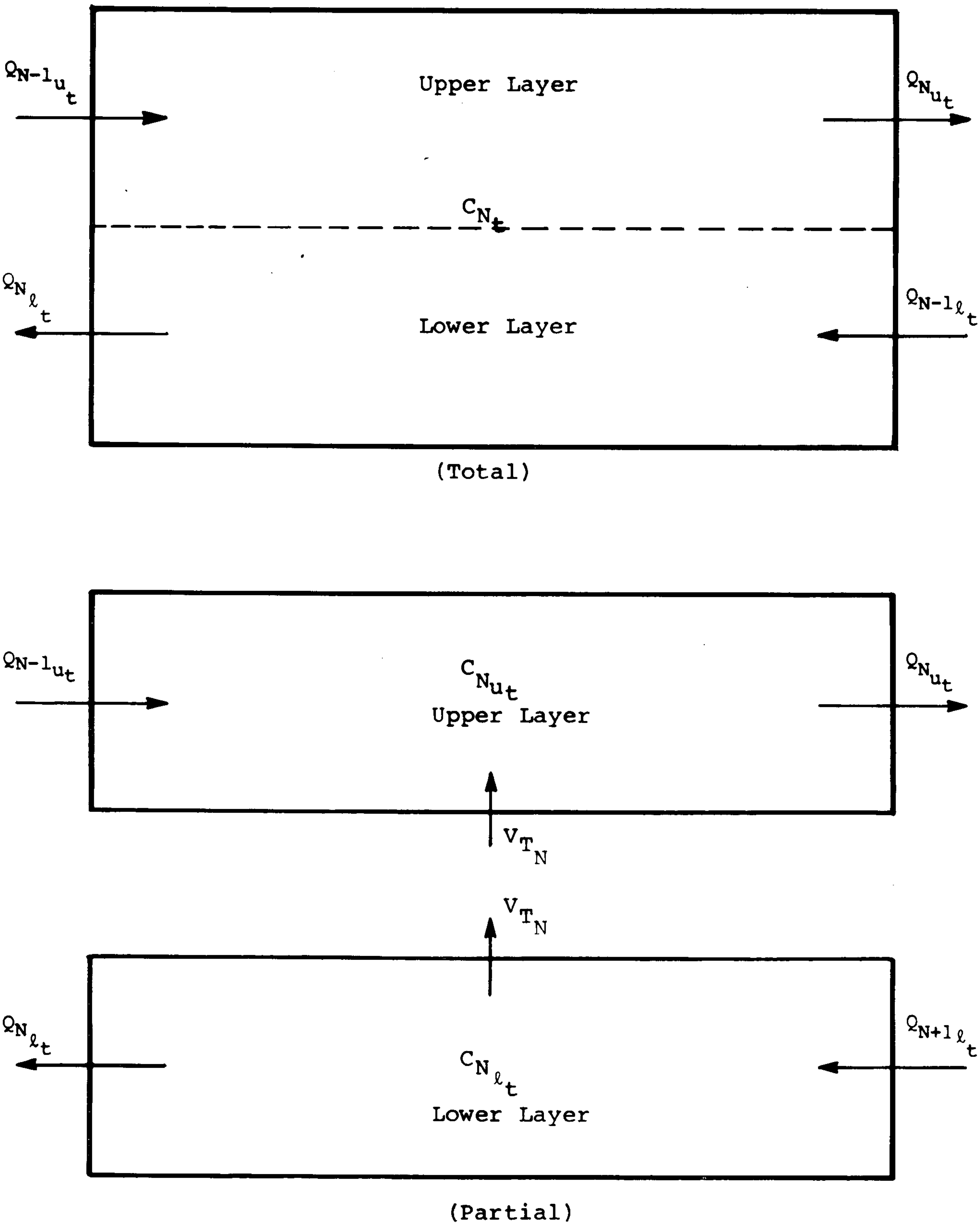
$$V_N \frac{dC_N}{dt}_t = V_N \frac{\Delta C_{Nt}}{\Delta t} = \frac{V_N}{\Delta t}\left(C_{N_{t+\Delta t}} - C_{N_t}\right) \qquad (3)$$

Substitution of equations (2) and (3) into equation (1) yields:

$$C_{N_{t+\Delta t}} = \Bigg[C_{Nt} \;(1 - K_{Nt}\Delta t)\; V_N + \Big\{ R_{Nt} + \mu_{N-1_t} \cdot Q_{N-1_{u_t}} \cdot C_{N-1_t} + \ell_{N+1_t} \cdot Q_{N+1_{\ell_t}} \cdot C_{N+1_t} - C_{Nt} \Big(\mu_{N_t} Q_{N_{u_t}} + \ell_{N_t} \cdot Q_{N\ell t} + m \cdot r \cdot Q_{cN} \,[b \cdot \mu_{N_t} + (1-b) \cdot \ell_{N_t}] \Big) \Big\} \Delta t \Bigg] \frac{1}{V_N} \qquad (4)$$

FIGURE A-1-1

SCHEMATIC OF MATERIAL BALANCE ON
SEGMENT N TOTAL AND PARTIAL



APPENDIX 1

DERIVATION OF STAFF TRANSPORT MODEL

The Staff's transport model can be derived in the following manner:

Considering Figure A-1-1, a material balance is applied to segment N:

Rate of Accumulation = (Rate of Input)-(Rate of Output)-(Rate of Decay)-(Rate of Plant Withdrawal)+(Rate of Production)

$$\frac{dV_N \cdot C_{N_t}}{dt} = \mu_{N-1_t} \cdot Q_{N-1_{u_t}} \cdot C_{N-1_t} + \ell_{N+1_t} \cdot Q_{N+1_{\ell_t}} \cdot C_{N+1_t} - \mu_{N_t} \cdot Q_{N_{u_t}} \cdot C_{N_t} - \ell_{N_t} \cdot Q_{N_{\ell t}} \cdot C_{N_t} - K_{N_t} \cdot V_N \cdot C_{N_t} - m \cdot r \cdot Q_{C_N}\left[b \cdot \mu_N \cdot C_{N_t} + (1-b) \cdot \ell_N \cdot C_{N_t}\right] + R_{N_t} \quad (1)$$

where:

V_N = Volume of segment N

t = Time

C_{X_t} = Average concentration in segment X at time t (organisms/volume)

μ_{X_t} = Ratio of the average concentration in the upper layer to the average concentration in the segment X

ℓ_{X_t} = Ratio of the average concentration in the lower layer to the average concentration in segment X

$Q_{X_{\ell_t}}$ = Average flow in the lower layer (moving upstream) and located at the upstream boundary of segment X (volume/time)

$Q_{X_{u_t}}$ = Average flow in the upper layer (moving downstream) and located at the downstream boundary of segment X (volume/time)

m = Average fraction killed by entrainment through the condenser

TABLE A-1-1

COMPARISON BETWEEN RESULTS OF STAFF'S TRANSPORT MODEL
AS PRESENTED IN THE FINAL STATEMENT AND
APPLICANT'S IMPLEMENTATION OF STAFF'S MODEL*

Week Number	Staff's Version % Reduction Total	Staff's Version % Reduction Nursery	Applicant's Reconstruction of Staff's Model % Reduction Total	Applicant's Reconstruction of Staff's Model % Reduction Nursery
1	4.33	13.17	4.33	13.17
2	7.95	20.33	7.95	20.33
3	11.54	25.26	11.54	25.26
4	15.27	29.06	15.27	29.06
5	19.17	32.31	19.17	32.31
6	23.20	35.30	23.20	35.30
7	27.31	38.20	27.31	38.20
8	31.45	41.09	31.45	41.09
9	35.55	44.00	35.55	44.00

*Susceptibility to intake = 100%

Condenser mortality = 100%

Natural mortality = 0%

Plant flow = 2650 cfs

Computation interval = 6 hours

Migration Factors: μ = .5, ℓ = 1.5

See Tables A-1-2 and A-1-3 for flow and spawn conditions

APPENDIX 2

MODIFIED STAFF'S TRANSPORT MODEL (MODEL 1)

The Staff's transport model was modified to include intra-daily larval vertical migratory behavior and intra-tidal behavior by splitting each segment into two layers and using equations, (5) and (6) of Appendix 1, and using the vertical transport (V_{T_N}) and tidal flow (Q_{N_u} and Q_{N_ℓ}) averaged over a small time increment*. The larval (vertical) migratory behavior was modeled as shown in Figure A-2-1.

For the first 15 hours (daytime hours) all of the larvae were in the lower layer (V_{T_N}=0); for the next 1 hour (sunset) a transport rate was computed so as to allow R%**of the larvae to be in the upper layer and (1-R)% in the lower layer; for the next 7 hours (nighttime) the vertical transport was set to zero and for the remaining hour of the day (sunrise) the vertical transport was again recomputed so as to move the upper layer larvae into the lower layer for the start of the next daily cycle.

The flow variation within a tidal cycle was modeled as shown in Figure A-2-2. Both the upper layer and lower layer are split into two sine components (Ebb Component and Flood Component).

The upper layer equations are:

Ebb Component

$$Q_{NU} = E_{U_N}\left[\sin\left(\frac{\pi t}{TE_{U_N}}\right)\right]$$

---

* 1 hour was used for comparison runs

** R = 50% was used in the comparison runs.

TABLE A-1-3

FLOW CONDITIONS FOR
SAMPLE COMPARISON RUN OF
STAFF'S TRANSPORT MODEL

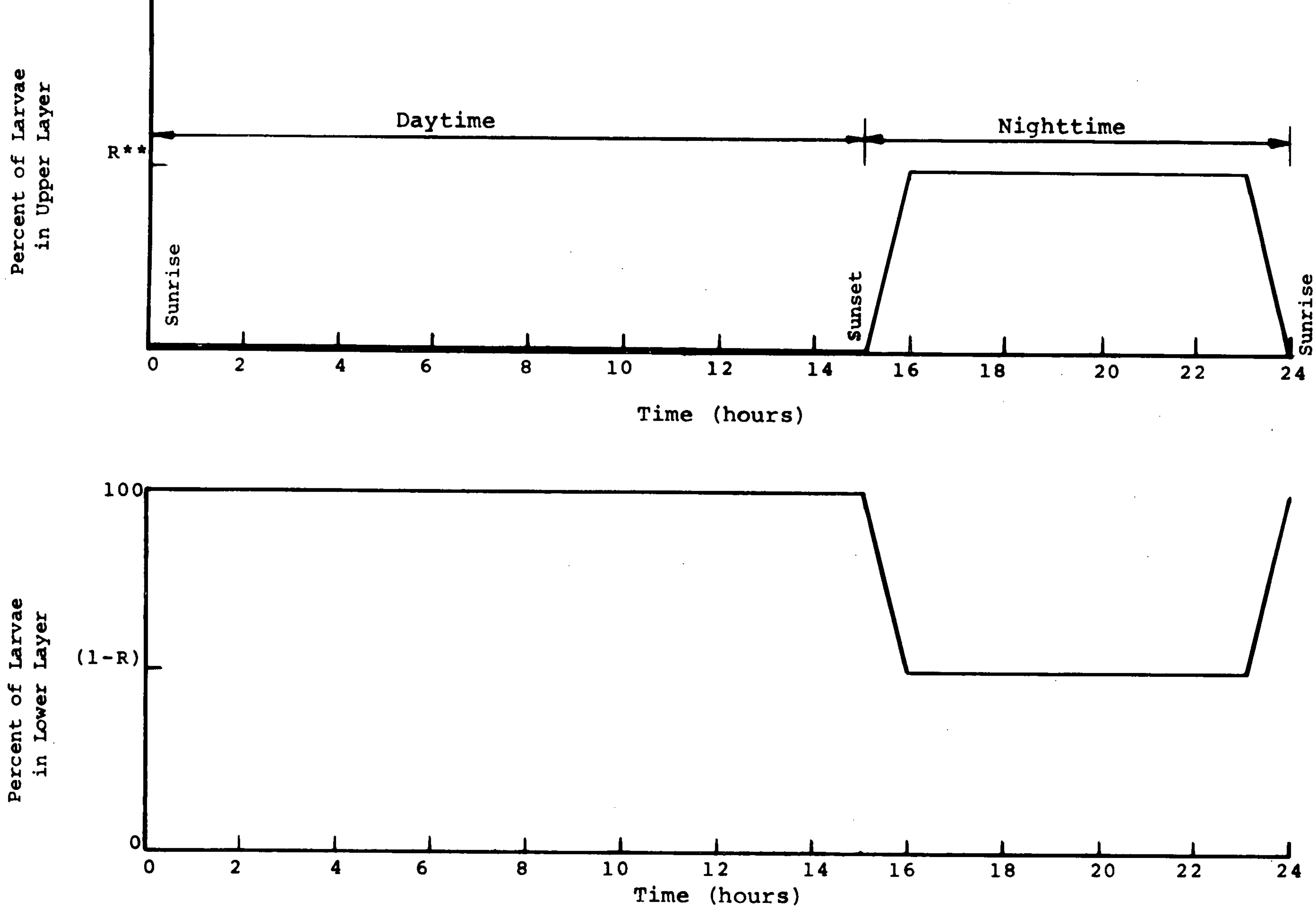
Segment	Upper Layer Flow Downstream (At Downstream Boundary) (cfs)	Lower Layer Flow Upstream (At Upstream Boundary) (cfs)
1	4000	-4000
2	4000	-4000
3	4000	-4000
4	4000	-4000
5	4000	-4000
6	4000	-4000
7	4000	-4000
8	4000	-4000
9	4000	-4000
10	11000	-4000
11	16000	3000
12	29000	8000
13	30000	21000
14	32000	22000
15	34000	24000
16	37000	26000
17	43000	29000
18	54000	35000
19	54000	46000

TABLE A-1-2

SPAWN CONDITIONS FOR
SAMPLE COMPARISON RUN OF
STAFF'S TRANSPORT MODEL

Segment	No. of Larvae in Segment
1	0.08
2	5.00
3	5.00
4	4.20
5	5.23
6	5.23
7	6.70
8	6.70
9	6.55
10	6.55
11	15.00
12	15.00
13	3.44
14	3.33
15	0.00
16	0.00
17	0.00
18	0.00
19	0.00

VERTICAL DISTRIBUTION OF LARVAE USED IN RUNS OF MODEL 1*



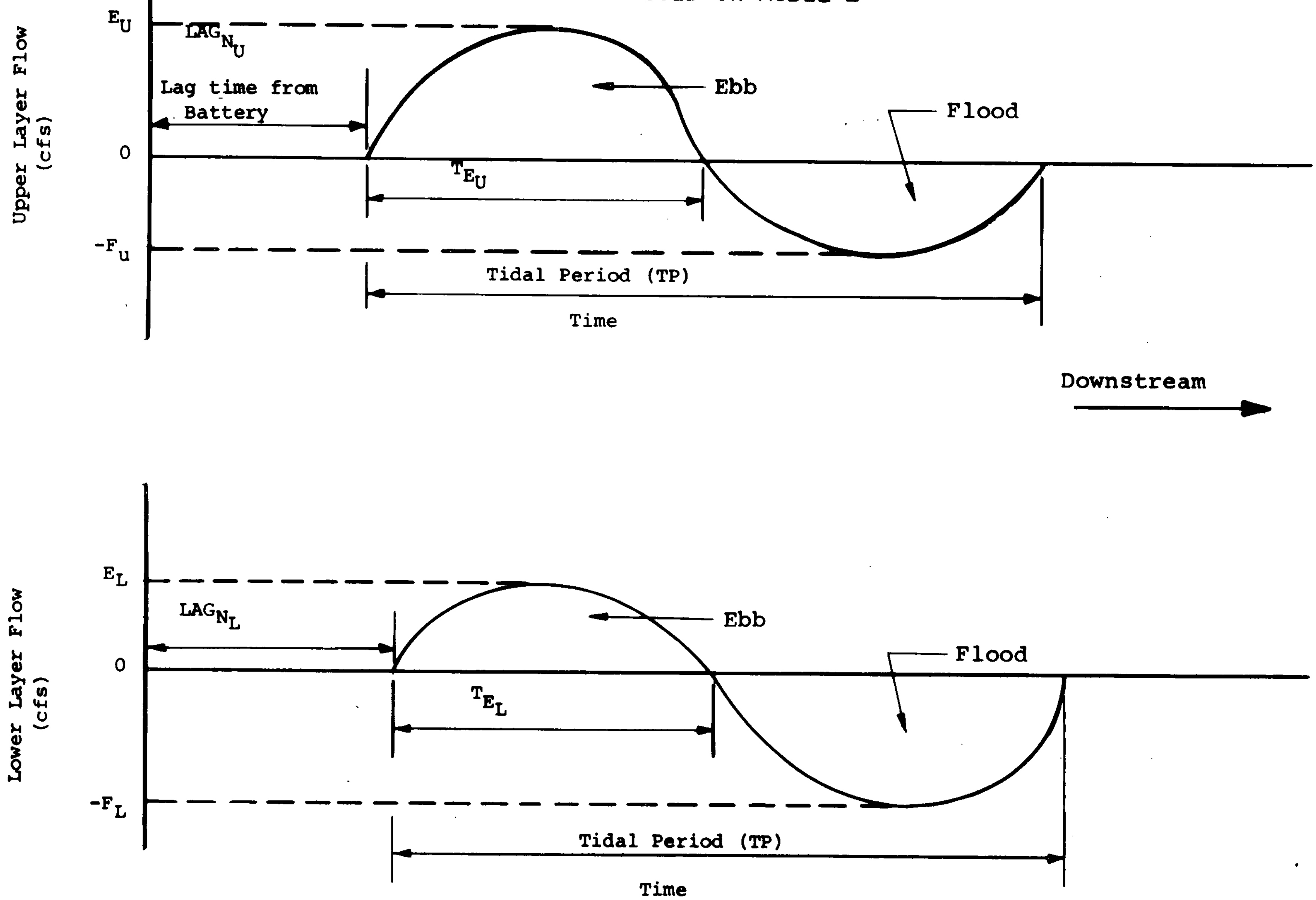
*Staff's model modified to reflect influence of smaller averaging time (1 hour)

** R = per cent of organisms in the upper layer during nighttime

FIGURE A-2-1

SCHEMATIC OF UPPER AND LOWER LAYER FLOWS

USED IN MODEL 1*+



*Staff model modified to reflect influence of smaller averaging time (1 hour)

+Zero time is beginning of ebb phase at Battery

FIGURE A-2-2

Flood Component

$$Q_{N_U} = F_{U_N}\left[\sin\left\{\pi + \pi\frac{(t - TE_{U_N})}{(TP - TE_{U_N})}\right\}\right]$$

Analogously the lower layer equations are:

Ebb Component

$$Q_{N_L} = E_{L_N}\left[\sin\left(\frac{\pi t}{TE_{L_N}}\right)\right]$$

Flood Component

$$Q_{N_U} = F_{L_N}\left[\sin\left\{\pi + \pi\frac{(t - TE_{L_N})}{(TP - TE_{L_N})}\right\}\right]$$

Where:

Q_{N_U} = Flow downstream in the upper layer at the downstream end of segment N.

LAG_{N_U} = Lag time of the ebb flow (from the ebb wave at the Battery) in the upper layer (downstream end) of segment N.

E_{U_N} = Amplitude of the ebb wave in the upper layer of segment N.

F_{U_N} = Amplitude of the flood wave in the upper layer of segment N.

TP = The tidal period

TE_{U_N} = Time from the start of the ebb wave in the upper layer at which the flood wave occurs.

Q_{N_L} = Flow downstream in the lower layer, at the downstream end of segment N.

E_{L_N} = Amplitude of the ebb wave in the lower layer of segment N.

F_{L_N} = Amplitude of the flood wave in the lower layer of segment N.

TE_{L_N} = Time from the start of the ebb wave in the lower layer at which the flood wave occurs.

For the cases where the modified Staff's transport model (Model 1) was compared to the results of the original Staff's transport model (Model 24), the flow functions used are shown in Table A-2-1.

TABLE A-2-1

UPPER AND LOWER LAYER SINUSOIDAL FLOW FUNCTION PARAMETERS USED IN MODEL 1 *

Segment (Downstream Boundary)	Upper Layer E_{N_U} (cfs)	Upper Layer F_{N_U} (cfs)	Upper Layer LAG_{N_U} (hours)	Upper Layer TE_{N_U}/TP	Upper Layer Net Flow Downstream Over 1 Tidal Period (cfs)	Lower Layer E_{N_L} (cfs)	Lower Layer F_{N_L} (cfs)	Lower Layer LAG_{N_L} (hours)	Lower Layer TE_{N_L}/TP	Lower Layer Net Flow Downstream Over 1 Tidal Period (cfs)	Upper and Lower Net Flow Downstream Over 1 Tidal Period (cfs)
(0)	57,500	50,600	5.55	0.5262089297	4,000	57,500	50,600	5.55	0.5262089297	4,000	8,000
1	78,200	62,100	5.05	0.4874068803	4,000	78,200	62,100	5.05	0.4874068803	4,000	8,000
2	11,900	87,500	4.43	0.4541558610	4,000	119,000	87,500	4.43	0.4541558610	4,000	8,000
3	145,000	120,000	3.88	0.4765403219	4,000	145,000	120,000	3.88	0.4765403219	4,000	8,000
4	132,000	121,000	3.40	0.5030955941	4,000	132,000	121,000	3.40	0.5030955941	4,000	8,000
5	132,000	120,000	3.09	0.5011237512	4,000	132,000	120,000	3.09	0.5011237512	4,000	8,000
6	119,700	113,400	2.80	0.5134413784	4,000	119,700	113,400	2.80	0.5134413784	4,000	8,000
7	142,500	127,500	2.62	0.4954932789	4,000	142,500	127,500	2.62	0.4954932789	4,000	8,000
8	130,900	115,500	2.45	0.4942499403	4,000	130,900	115,500	2.45	0.4942499403	4,000	8,000
9	119,000	105,000	2.25	0.4967999344	4,000	119,000	105,000	2.25	0.4967999344	4,000	8,000
10	120,300	97,500	2.00	0.5269915499	11,000	123,500	123,500	2.00	0.4809215021	-3,000	8,000
11	174,000	130,500	1.89	0.5111091665	16,000	165,300	165,300	1.89	0.4619891996	-8,000	8,000
12	234,000	156,000	1.58	0.5168028037	29,000	156,000	175,500	1.58	0.4299043052	-21,000	8,000
13	163,200	144,000	1.40	0.6221480786	30,000	96,000	129,600	1.40	0.4212875924	-22,000	8,000
14	195,500	138,000	1.20	0.5645141901	32,000	155,300	155,300	1.20	0.3786248815	-24,000	8,000
15	281,000	232,000	0.96	0.5563490742	34,000	194,000	194,000	0.96	0.3947404524	-26,000	8,000
16	238,000	168,000	0.63	0.5569444927	37,000	175,000	175,000	0.63	0.3698483045	-29,000	8,000
17	223,700	138,600	0.25	0.5689876952	43,000	182,700	157,500	0.25	0.3013584028	-35,000	8,000
18	296,000	192,000	0.10	0.5672602491	54,000	216,000	232,000	0.10	0.3565700202	-46,000	8,000
19	409,500	262,500	0	0.5168497047	54,000	262,500	315,000	0	0.4203343382	-46,000	8,000

* Staff's model modified to reflect influence of smaller averaging time (1 hour)

both the tidal period and the start of the ebb flow at the Battery with respect to sunrise were varied in Model 1 under both comparison runs (Run 1 and Run 2) with the Staff's transport model (Model 24) with resultant minor differences in the percent reductions. The summary of the results is presented in Table A-2-2.

Runs of Model 1 using the larval migratory behavior during the day resulted in weekly averaged values of the fraction of the population in the upper and lower layer of about .18 and .82, respectively. These fractional values were rounded to .2 and .8 and were used as the daily average values (in Model 24) of the larvae in the upper and lower layer, respectively, for the comparison runs (Run 1 and Run 2).

TABLE A-2-2

INFLUENCE OF APPROXIMATING THE 12.42 HOUR TIDAL PERIOD BY 12 HOURS AND INITIAL CONDITIONS AT BATTERY

	MODEL 1												MODEL 24			
	Run 1 (1) % Reduction		Run 1 (2) % Reduction		Run 1 (3) % Reduction		Run 2 (4) % Reduction		Run 2 (5) % Reduction		Run 2 (6) % Reduction		Run 1 % Reduction		Run 2 % Reduction	
Week No.	Total	Nursery	Total	Nursery	Total	Nursery	Total	Nursery	Total	Nursery	Total	Nursery	Total	Nursery	Total	Nursery
1	2.30	5.88	2.18	5.60	2.24	6.39	.69	1.86	.68	1.95	.78	2.56	2.79	13.90	1.18	5.93
2	4.36	9.24	4.32	9.59	4.25	9.72	1.35	2.95	1.42	3.40	1.51	3.85	4.98	21.21	2.18	9.38
3	6.39	11.98	6.23	11.76	6.20	12.34	2.01	3.87	2.05	4.11	2.24	4.87	7.13	25.13	3.19	11.39
4	8.39	14.36	8.24	14.64	8.09	14.55	2.67	4.69	2.79	5.29	2.95	5.75	9.46	27.46	4.31	12.67
5	10.36	16.50	10.08	16.15	9.93	16.51	3.33	5.44	3.42	5.70	3.66	6.54	12.05	29.24	5.57	13.68
6	12.29	18.47	11.98	18.59	11.73	18.31	3.99	6.15	4.14	6.85	4.36	7.28	14.93	30.96	6.98	14.67
7	14.18	20.34	13.78	19.90	13.49	20.01	4.64	6.83	4.77	7.12	5.06	7.99	18.06	32.82	8.55	15.73
8	16.03	22.12	15.56	22.05	15.21	21.65	5.30	7.49	5.47	8.25	5.75	8.67	21.40	34.87	10.24	16.90
9	17.84	23.84	17.31	23.34	16.90	23.23	5.94	8.14	6.10	8.48	6.43	9.35	24.85	37.11	12.02	18.20

(1) Plant withdrawal at average segment concentration
Ebb flow at Battery at sunrise
(i.e. Lag time at Battery = 0)
Tidal period = 12 hours

(2) Same as (1) except tidal period = 12.42 hours

(3) Same as (1) except ebb flow at Battery is 6.45 hours after sunrise

(4) Plant withdrawal at upper layer concentration
Ebb flow at Battery at sunrise
Tidal period = 12 hours

(5) Same as (3) except tidal period = 12.42 hours

(6) Same as (3) except ebb flow at Battery is 6.45 hours after sunrise.

Notes: Other run conditions for Run 1 and Run 2 are shown in Table 1, Table A-2-1 and Figure A-2-1

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the matter of	)	
	)	
CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.	)	DOCKET NO. 50-247
	)	
	)	
(Indian Point Station, Unit 2)	)	

Responses to Questions
by
John P. Lawler, Ph.D.
QUIRK, LAWLER & MATUSKY ENGINEERS

on the
Sensitivity of the Model Presented in the
Testimony of October 30, 1972

on the
Effect of Entrainment and Impingement
at Indian Point on the Population of
the Hudson River Striped Bass

February 5, 1973

I. INTRODUCTION

This presentation is in response to a request by Dr. Geyer to Dr. Lawler (Friday, December 15, 1972, Tr. 7782) for an expansion of Table 24 of the October 30, 1972 testimony of Dr. Lawler. Dr. Lawler indicated, in response to Dr. Geyer, that additional computer runs were being made, to test the sensitivity of the model to the various control parameters (f factors, migration preferences, compensation,dispersion.) This presentation is divided into three sections.

Section II deals with the effects on the striped bass population by the plant when no compensation[1], several levels of compensation[1], several migration preferences, differential larval survival (a different larval survival is used for each segment or reach of the Hudson River), differential migrations (variable migrations within a stage and for several stages within a single computer run), several levels of total spawn, several sets of f factors and several dispersion coefficients are considered. A variety of combinations of each of the aforementioned are considered.

Section III is concerned with the effect which has occurred in the striped bass population from 1949 to present day. It considers the effect due to the existing River stations (Lovett, Danskammer, and Indian Point) operating on the Hudson during that period.

Section IV summarizes the foregoing and presents a variety of items, developed since presentation of the earlier testimony, which I consider to be relevant and important to proper interpretation and application of the Applicant's model.

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(1) Equation 1, page 23, October 30, 1972 Testimony

II. SENSITIVITY ANALYSIS

The results of the runs made to test the transport model sensitivity are presented in Table 1. Percentage reduction in the year class one recruitment, as well as in the total adult population (ages 1-13 years) are given in this table.

Tables $1K_E$, 1M, and 1F, respectively, display the early stage rates, migrations, and f-factors considered. The table notation ($1K_E$, 1F, 1M) was selected to provide easy recognition of the major parameters (K_O/K_E, M, F) being varied, when examining the Run Conditions column in Table 1.

Discussion of several individual sets of runs listed in Table 1 follows. Each set was designed to test the sensitivity of the model to a particular control parameter (compensation, f-factors, etc.) or to a combination of parameters (high compensation with high f-factors, low compensation with low f-factors, etc.)

1. Effect of Low Compensation and High Migration @ "Current Best Estimate" f-Factors

Clark and Goodyear both estimate migration past Indian Point to be extensive during the stages supposedly vulnerable to entrainment. Clark estimates 75% of the early stage fish pass Indian Point by the period mid-August to mid-October, and Goodyear estimates 85% pass the plant by early August. We have used these percentages as indicative of high downstream migration preferences at the end of the J_I stage.

These migration preferences are considered to be quite conservative, since the median fish leaves the J_I stage before mid-July, and all of them leave

Table 1

Results of Computer Runs of QL&M Model

Case Number	Run Names	Run* Conditions	Percent Reduction in Production of: Larvae	J-I	J-II	J-III	Percent Reduction Year 1 Adult 1	Year 1 Total Adult	Year 5 Adult 1	Year 5 Total Adult	Year 10 Adult 1	Year 10 Total Adult	Comments
1	CLKEI CLKEEI	1F-31 $1K_E$-1d 1M-1	0.11	2.47	3.80	0.76	2.26	1.58	3.16	2.88	5.01	4.90	75% migration to segments 7 and 8 occurs. $K_o = K_E/2$. Not projected for a 20-year run.
2	CLKFI CLKFFI	1F-32 $1K_E$-1d 1M-1	0.11	0.92	1.19	0.25	2.07	1.45	2.71	2.52	4.01	3.93	75% migration to segments 7 and 8 occurs. $K_o = K_E/2$. Not projected for a 20-year run.
3	CLKEI1 BLKEI1	1F-30 $1K_E$-1a 1M-1	0.11	2.25	4.16	4.35	5.92	4.15	9.46	8.39	18.79	17.93	75% migration to segments 7 and 8 occurs. $K_o = K_E$.
4	CLKEI8 BLKEI8	1F-29 $1K_E$-1c 1M-1	0.11	2.44	4.15	3.07	3.54	2.48	5.68	4.93	7.48	9.74	75% migration to segments 7 and 8 occurs. $K_o = 0.8K_E$.
5	CLKEI9 BLKEI9	1F-28 $1K_E$-1b 1M-1	0.11	2.23	4.22	3.90	4.70	2.97	7.35	6.59	13.83	13.32	75% migration to segments 7 and 8 occurs. $K_o = 0.9K_E$.
6	CLKFI1 BLKFI1	1F-25 $1K_E$-1a 1M-1	0.11	0.83	1.33	1.52	3.13	2.20	5.55	4.82	12.00	11.39	75% migration to segments7 and 8 occurs. $K_o = K_E$.
7	CL8E1 BL8E1	1F-24 $1K_E$-1a 1M-2	0.11	2.24	4.10	4.30	5.87	4.12	9.42	8.35	18.77	17.91	85% migration to segments 7 and 8 occurs. $K_o = K_E$.
8	CL8E8 BL8E8	1F-26 $1K_E$-1c 1M-2	0.11	2.44	4.10	2.81	3.42	2.40	5.40	4.80	9.98	9.64	85% migration to segments 7 and 8 occurs. $K_o = K_E$.
9	CL8E9 BL8E9	1F-27 $1K_E$-1b 1M-2	0.11	2.38	4.16	3.74	4.59	3.22	7.24	6.44	13.75	13.20	85% migration to segments 7 and 8 occurs. $K_o = 0.9K_E$.

*Run Conditions 1F are found in Table 1F, conditions $1K_E$ in Table $1K_E$ and 1M in Table 1M.

Table [illegible]
(Continued)

Case Number	Run Names	Run* Conditions	Percent Reduction in Production of: Larvae	J-I	J-II	J-III	Percent Reduction Year 1 Adult 1	Year 1 Total Adult	Year 5 Adult 1	Year 5 Total Adult	Year 10 Adult 1	Year 10 Total Adult	Comments
10	LAR550	1F-45 $1K_E$-3a 1M-8	0.11	2.87	2.90	3.00	3.33	2.26	3.06	2.98	2.73	2.75	Larval survival of 5%. A total egg production of 21 billion used throughout spawning season.
11	LAR515	1F-44 $1K_E$-3a 1M-8	2.69	3.00	2.97	3.11	3.51	2.44	3.47	3.42	4.07	4.04	Larval survival of 5%. A total egg production of 6 billion used throughout spawning season.
12	AEC1 CAEC1	1F-10 $1K_E$-2a 1M-11, 12	0.11	2.94	2.94	0.32	2.40	1.68	3.14	2.91	4.79	4.71	Interesting migrations.
13	CLKINT	1F-61 $1K_E$-2a 1M-1	0.11	2.94	3.19	0.80	2.34	1.64	-	-	-	-	
14	CLKA CLKAA	1F-35 $1K_E$-1a 1M-1	0.26	5.27	13.80	14.00	15.41	10.81	22.08	20.08	38.73	37.29	$K_o = K_E$ for all stages. Impingement. No compensation.
15	CLKB CLKBB	1F-36 $1K_E$-1d 1M-1	0.26	5.84	13.16	3.41	3.28	2.30	5.08	4.53	8.71	8.52	With compensation. Impingement. Compensation.
16	CLKC CLKCC	1F-37 $1K_E$-1d 1M-1	0.26	5.27	13.80	13.85	13.85	9.71	19.23	17.59	33.06	31.83	$K_E = K_o$ for all stages. No impingement.
17	CLKD CLKDD	1F-38 $1K_E$-1d 1M-1	0.26	5.85	13.16	3.36	1.32	0.93	2.75	2.32	5.58	5.43	Compensation. No impingement
18	CLKE CLKEE	1F-39 $1K_E$-1d 1M-1	0.11	2.48	3.80	0.72	0.28	0.19	0.72	0.58	1.61	1.56	Compensation. No impingement.

*Run Conditions 1F are found in Table 1F, conditions $1K_E$ in Table $1K_E$ and 1M in Table 1M.

Table 1
(Continued)

Case Number	Run Names	Run Conditions*	Percent Reduction in Production of: Larvae	J-I	J-II	J-III	Percent Reduction Year 1 Adult 1	Year 1 Total Adult	Year 5 Adult 1	Year 5 Total Adult	Year 10 Adult 1	Year 10 Total Adult	Comments
30	KE75 KE7575	1F-4 $1K_E$-2c 1M-8	0.11	3.25	3.24	3.37	3.74	2.63	4.91	4.56	6.80	6.63	$K_o = 0.75K_E$ in larval stage.
31	BEST6 BEST66	1F-2 $1K_E$-2d 1M-8	0.11	3.37	4.26	4.64	6.63	4.63	8.03	7.59	13.11	12.72	$K_o = K_E$.
32	BEST5 BEST55	1F-1 $1K_E$-2a 1M-8	0.11	2.94	3.02	3.01	3.20	2.25	3.78	3.61	4.39	4.34	$K_o = 0.25\ K_E$ in larval stage.
33	CLKH CLKHH	1F-63 $1K_E$-1d 1M-1	-	-	-	-	2.91	2.04	4.42	4.19	7.47	7.31	With compensation.

*Run Conditions 1F are found in Table 1F, conditions $1K_E$ in Table $1K_E$ and 1M in Table 1M.

Table
(Continued)

Case Number	Run Names	Run Conditions*	Percent Reduction in Production of: Larvae	J-I	J-II	J-III	Percent Reduction Year 1 Adult 1	Year 1 Total Adult	Year 5 Adult 1	Year 5 Total Adult	Year 10 Adult 1	Year 10 Total Adult	Comments
19	CLKF CLKFF	1F-40 $1K_E$-1d 1M-1	0.01	0.93	1.19	0.20	0.08	0.05	0.25	0.21	0.54	0.53	Compensation. No impingement.
20	CLKG CLKGG	1F-41 $1K_E$-1a 1M-1	0.20	4.06	10.72	10.92	12.39	8.69	18.01	16.30	32.44	31.15	No compensation. Impingement.
21	RAM1 CRAM1	1F-5 1M-3 $1K_E$-2	0.11	2.94	3.06	0.98	2.25	1.58	2.96	2.80	4.34	4.33	Differential survival in the larval stage.
22	RAM2 CRAM2	1F-6 1M-4 $1K_E$-2	0.11	2.94	3.17	1.00	2.30	1.61	3.01	2.83	4.40	4.36	Differential survival in the larval stage.
23	RAM3 CRAM3	1F-7 1M-5 $1K_E$-2	0.11	2.94	3.24	0.97	2.32	1.63	3.04	2.88	4.45	4.43	Differential survival in the larval stage.
24	RAM4 CRAM4	1F-8 1M-6 $1K_E$-2	0.11	2.94	3.27	0.88	2.34	1.64	3.39	2.95	4.50	4.52	Differential survival in the larval stage.
25	RAM5 CRAM5	1F-9 1M-7 $1K_E$-2	0.11	2.94	3.26	0.77	2.35	1.65	3.07	2.86	4.52	4.46	Differential survival in the larval stage.
26	LS05 CLS05	1F-11 $1K_E$-3a 1M-8	0.11	2.26	2.49	2.65	3.28	2.31	3.54	3.47	3.89	3.87	$K_o = 0.25K_e$.
27	LSIO CLSIO	1F-12 $1K_E$-4a 1M-8	0.11	2.35	2.49	2.58	2.95	2.07	3.38	3.24	3.81	3.79	
28	DIFMIG	1F-62 $1K_E$-2a 1M-9	0.11	2.94	2.96	2.91	3.17	2.23	-	-	-	-	Differential migrations. Differential larval survival.
29	KE5 KE55	1F-3 $1K_E$-2b 1M-8	0.11	3.10	3.13	3.22	3.51	2.47	4.14	3.95	4.92	4.85	$K_o \doteq 0.5K_E$.

*Run Conditions 1F are found in Table 1F, conditions $1K_E$ in Table $1K_E$ and 1M in Table 1M.

TABLE 1F

"f" FACTORS CHOSEN FOR SENSITIVITY ANALYSIS RUNS

Case	Entrainable Stages f_e	f_l	f_{J_1}	Impingement f_{J_2}	f_{J_3}
1	0.41	0.39	0.09	0.00374	0.01249
2	0.41	0.39	0.09	0.00727	0.02469
3	0.41	0.39	0.09	0.00412	0.01367
4	0.41	0.39	0.09	0.00458	0.01510
5	0.41	0.39	0.09	0.00580	0.07439
6	0.41	0.39	0.09	0.00470	0.07589
7	0.41	0.39	0.09	0.00414	0.07756
8	0.41	0.39	0.09	0.00392	0.07954
9	0.41	0.39	0.09	0.00400	0.08181
10	0.41	0.39	0.09	0.1008	0.09401
11	0.41	0.39	0.09	0.00533	0.01686
12	0.41	0.39	0.09	0.00408	0.01301
24*	0.40	0.40	0.20	0.00691	0.10008
25*	0.03	0.15	0.05	0.00647	0.10017
26*	0.40	0.40	0.20	0.00585	0.08758
27*	0.40	0.40	0.20	0.00638	0.09322
28*	0.40	0.40	0.20	0.00638	0.09350
29*	0.40	0.40	0.20	0.00548	0.08668
30*	0.40	0.40	0.20	0.00647	0.10017
31*	0.40	0.40	0.20	0.00435	0.07799
32*	0.03	0.15	0.05	0.00435	0.07799
35*	1.00	1.00	1.00	0.00647	0.10017
36*	1.00	1.00	1.00	0.00435	0.07799
37	1.00	1.00	1.00	0	0
38	1.00	1.00	1.00	0	0
39	0.40	0.40	0.20	0	0
40	0.03	0.15	0.05	0	0
41*	0.75	0.75	0.75	0.00647	0.10017
44*	0.41	0.39	0.09	0.00452	0.01470
45*	0.41	0.39	0.09	0.00419	0.01360
57	1.00	1.00	1.00	0	0
58	0.41	0.55	0.30	0	0
59	0.41	0.39	0.11	0	0
61	0.41	0.39	0.09	0.00440	0.08115
62	0.41	0.39	0.09	0.00605	0.02922
63	0.75	0.75	0.75	0.00435	0.07799

f_{J_2}, f_{J_3} were computed on the basis of the expected total numbers impinged and the predicted population for that stage. Generally impingement in stage J_2 was 16,000 striped bass, and in stage J_3, 30,000 bass.

TABLE 1K_E

MINIMUM MORTALITY RATE COEFFICIENTS, "K_o",
SELECTED FOR SENSITIVITY ANALYSIS RUNS

Run Condition	Transport Model Early Life Stage: Eggs	Larvae	J-I	J-II	J-III
1*	0.153506E+1[+]	0.677543E-1	0.536479E-1[+]	0.5134422E-2[+]	0.1065090E-1
1a	$K_o=K_E$	$K_o=K_E$	$K_o=K_E$	$K_o=K_E$	$K_o=K_E$
1b	$K_o=K_E$	$K_o=0.9K_E$	$K_o=0.9K_E$	$K_o=0.9K_E$	$K_o=0.9K_E$
1c	$K_o=K_E$	$K_o=0.8K_E$	$K_o=0.8K_E$	$K_o=0.8K_E$	$K_o=0.8K_E$
1d	$K_o=K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$
2	$K_o=K_E$	Segment 1 – Differential Survival** 0.99	$K_o=K_E$	$K_o=K_E$	$K_o=K_E$
		Segment 2 – 0.1492045			
		Segment 3 – 0.9743760			
		Segment 4 – 0.7004865E-1			
		Segment 5 – 0.5517498E-1			
		Segment 6 – 0.5820145E-1			
		Segment 7 – 0.7304865E-1			
		Segment 8 – 0.5096844E-1			
2a	$K_o=K_E$	$K_o=0.25K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$
2b	$K_o=K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$
2c	$K_o=K_E$	$K_o=0.75K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$
2d	$K_o=K_E$	$K_o=K_E$	$K_o=K_E$	$K_o=K_E$	$K_o=K_E$
3***	$K_o=K_E$	0.10699	$K_o=K_E$	$K_o=K_E$	$K\ =K_E$
3a	$K_o=K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$	$K_o=0.5K_E$
4***	$K_o=K_E$	0.822352E-1	$K_o=K_E$	$K_o=K_E$	$K_o=K_E$
4a	$K_o=K_E$	$K_o=0.25K_E$	$0.5K_E$	$0.5K_E$	$0.5K_E$

*This gives the value of K_E, the first order mortality rate for all run conditions with the exception of the larval stages in run conditions 3 and 4. In those stages, the chosen value of K_E is given and $K_o=K_E$.

**Differential survival in larval stage by segment. The values given are the K_E values, $K_o=K_E$.

[+] E+1 = 10, E-1 = 10^{-1}, E-2 = 10^{-2}

TABLE 1M

MIGRATION PREFERENCES SELECTED FOR SENSITIVITY ANALYSIS RUNS

Case	Segment 1	2	3	4	5	6	7	8	Stage
1	0	0.00083	0.00166	0.00666	0.01832	0.24854	0.22689	0.49709	J1
2	0.025	0.025	0.025	0.025	0.025	0.025	0.2125	0.6375	J1
3	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	J1
4	0.02649	0.05563	0.08344	0.11126	0.13907	0.16689	0.19470	0.22252	J1
5	0.00412	0.01784	0.04034	0.07350	0.11812	0.17486	0.24430	0.32692	J1
6	0.00043	0.00363	0.01340	0.03617	0.07995	0.15438	0.27065	0.44140	J1
7	0.00003	0.00046	0.00310	0.01358	0.04413	0.11705	0.26855	0.55309	J1
8	0.04406	0.07573	0.07819	0.09281	0.17146	0.18005	0.10089	0.25681	J1
	0.00630	0.01083	0.03458	0.04105	0.06463	0.06787	0.21852	0.55623	J2
9	0.03468	0.05960	0.16997	0.20175	0.15857	0.16652	0.05892	0.14998	J11
	0.04406	0.07573	0.07819	0.09281	0.17146	0.18005	0.10089	0.25681	J12
	0.05214	0.08961	0.07453	0.08847	0.18275	0.19191	0.09042	0.23017	J13
	0.05214	0.08961	0.07453	0.08847	0.18275	0.19191	0.09042	0.23017	J21
	0.06160	0.10587	0.08030	0.09532	0.21485	0.22562	0.06105	0.15539	J22
	0.05227	0.08984	0.06405	0.07602	0.22215	0.23329	0.07400	0.18837	J23
	0.04223	0.07257	0.05794	0.06878	0.22524	0.23653	0.08369	0.21303	J24
	0.02531	0.04349	0.05209	0.06183	0.15577	0.16357	0.14045	0.35750	J25
	0.00630	0.1083	0.03458	0.04105	0.06463	0.06787	0.21852	0.55623	J26
10	0	0	0	0	0	0	0	0	J3
11	0	0.00108	0.00544	0	0.00046	0.05651	0.01486	0.92165	J1
12	0	0	0.00095	0	0.00153	0.25037	0.17799	0.56917	J1

before the end of August. Clark's analysis, for example, shows that this level of migration has occurred by mid-August to mid-October, but not necessarily before.

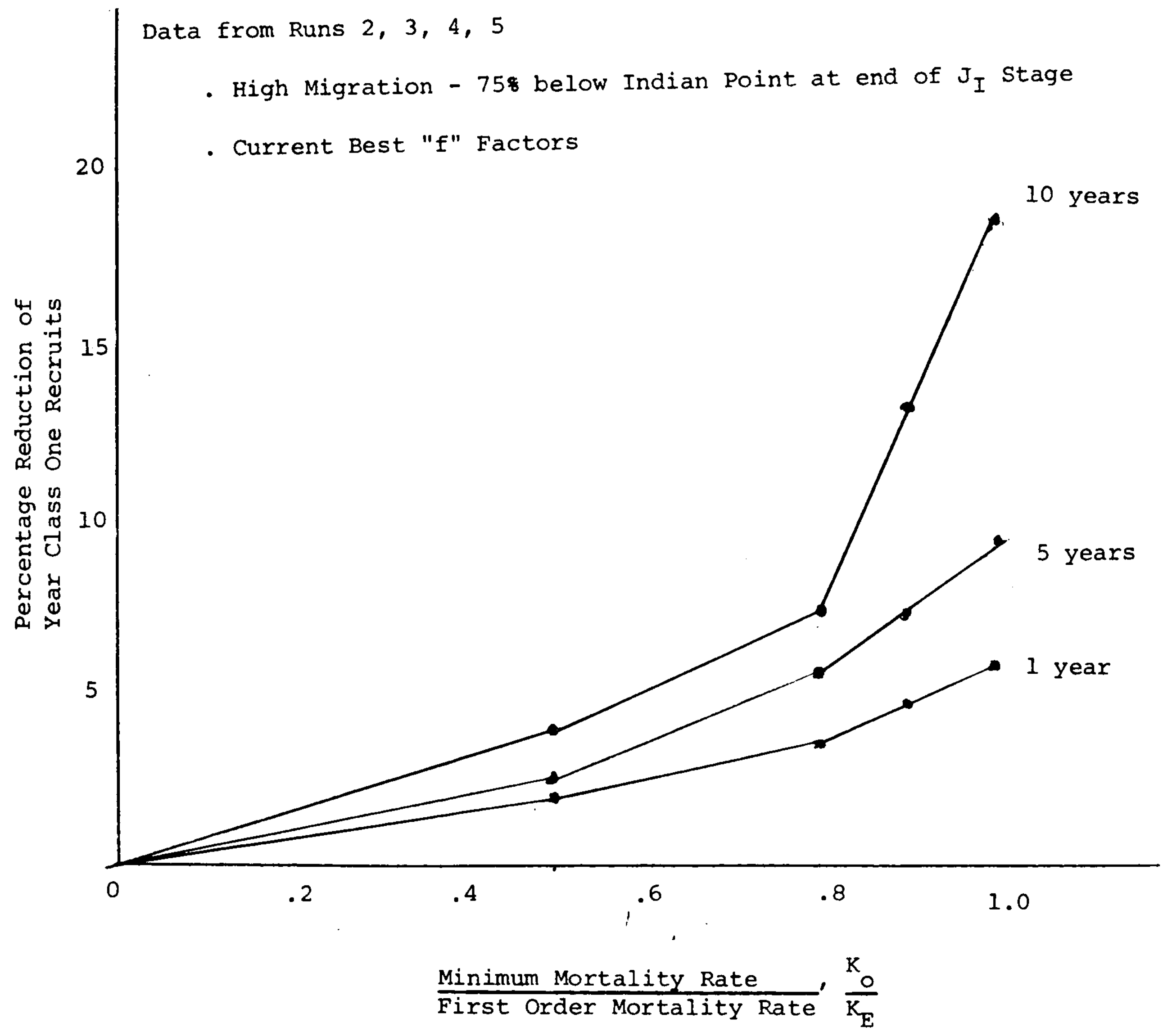
This set of runs, in which downstream migration is conservatively high, maximum compensation potential is set quite low and supportable "f" factors are employed is considered to be relatively conservative. Results are shown below.

High Migration, Low Compensation, Best "f" Factor Estimate

Run #	Entrainment "f" Factors f_E	f_L	f_{J_I}	Ratio of Minimum Mortality Rate to First Order Rate (K_O/K_E)	% Fish below Indian Point at End of J_I Stage (Migration Preference)	% Reduction: Young of the Year Recuits at Year 1	% Reduction: All Adults 10 Year
4	.4	.4	.2	.8	75	3.5	9.7
8	.4	.4	.2	.8	85	3.4	9.7
5	.4	.4	.2	.9	75	4.7	13.8
9	.4	.4	.2	.9	85	4.6	13.2
3	.4	.4	.2	1.0	75	5.9	17.9
7	.4	.4	.2	1.0	85	5.9	17.9
2	.4	.4	.2	0.5	75	2.1	3.9

These results show that even in the presence of high migration, population reduction can be controlled, provided some compensation is occurring. Actually, it appears likely that even if an early strong downstream migration occurs, as is postulated here, the plant effect will probably have been substantially less than is shown here. Dr. Lauer's testimony of today indicates that larvae greater than 3/4" long were not observed in his discharge canal samples. Dr. Raney's testimony of today indicates the preference for shallow water of such early forms. Both of these observations would reduce the J_I "f" factor still further, and Raney's observations suggest the downstream migration may not be so strong as used in the foregoing runs.

Further examination of these results indicates, as discussed by Dr. Lawler on December 13 and 15, 1972, that a relatively small compensation potential appears to be all that is needed to protect the population. The figure below, which is a plot of the 75% migration runs for various compensatory ratios, shows that a compensation ratio of about 0.8 appears to be sufficient to keep the plant effect to a minimum. This is significant, because it does not seem unreasonable to judge that nature can provide at least this relatively minimal compensation requirement.



2. Differential Mortality, Variable J_I Migrations and Larval Compensation

This set of runs employed different survival rates in each segment. This possibility was discussed in the October 30, 1972 testimony as being a possible means of explaining the larval concentration curves developed by Carlson and McCann. Only migration rates were varied in this set of runs. It can be seen that, due to the relatively high levels of compensation, the model is insensitive to migration rates.

Differential Mortality, Variable J_I Migrations and Larval Compensation

Run #	Entrainment "f" Factors			Compensation Ratio, K_O/K_E		J_I Migration Percent in Segments 7 & 8	% Reduction	
	f_E	f_L	f_{J_I}	Larvae	J_I, J_{II}, J_{III}		Young of Year Recruits at Year 1	All Adults 10 Year
21	.41	.39	.09	.25	.5	25	2.25	4.33
22	.41	.39	.09	.25	.5	42	2.30	4.36
23	.41	.39	.09	.25	.5	56	2.32	4.43
24	.41	.39	.09	.25	.5	71	2.34	4.52
25	.41	.39	.09	.25	.5	82	2.35	4.46

These runs represent behavior, at least as far as percentage reductions are concerned, that may well be the case once the plant is operating on a long term basis. Compensation may possibly be high in the larval stage, but the probable existence of lower f factors, particularly in the J_I stage, may still effect these low reductions.

3. Differential Intra-stage Migrations and Differential Larval Survival

This run looked at varying the migrations on a bi-weekly basis. It demonstrates the ability of the model to accept weekly (and even daily) distributional data, when such becomes available. Moderate levels of compensation (0.25 for larvae, 0.5 for juvenile stages) hold the percentage reduction at relatively low levels.

Differential Intra-stage Migrations and Differential Larval Survival

Run #	Entrainment "f" Factors			Migrations		% Reduction	
	f_E	f_L	f_{J_I}	J_I Percent Migrations to Segments 7 & 8	J_{II} Percent Migrations to Segments 7 & 8	Young of Year Recruits at Year 1	All Adults 10 Year
28	.41	.39	.09	20	31	3.2	2.2
				35	21		
				32	25		
					30		
					50		
					77		

4. Variable "f" Factors, High Migration, Moderate to No Compensation

These runs show clearly that without compensation and with the assumption that the plant sees and destroys organisms at the area-average River concentration at Indian Point (all "f" factor set to unity), substantial reductions can occur.

Variable "f" Factors, High Migration, Moderate to No Compensation

Run #	Entrainment "f" Factors			Impingement	Compensation Ratio	% Reduction	
	f_E	f_L	f_{J_I}		(K_o/K_E)	Young of Year Recruits at Year 1	All Adults 10 Years
14	1	1	1	Yes	1.0	15.41	37.3
15	1	1	1	Yes	0.5	3.28	8.52
16	1	1	1	No	1.0	13.85	31.8
17	1	1	1	No	0.5	1.32	5.43
18	.4	.4	.2	No	0.5	0.28	1.56
19	.03	.15	.05	No	0.5	.08	0.53
20	.75	.75	.75	Yes	1.0	12.39	31.2

With moderate levels of compensation, however, entrainment losses, if they occur, will be controlled. Furthermore, when current minimum estimates of f factors are used, reduction is virtually negligible.

5. Reduced Larval Survival, Increased Egg Production

These runs look at what is considered to be a more probable estimate of the "real" egg production and larval survival than the Carlson and McCann data yield. The likelihood of larger egg production and reduced natural larval survival is discussed in the October 30, 1972 testimony.

The impact of the plant for reduced larval survival, increased total eggs, a 76 percent migration to segments 7 and 8, with a compensation ratio of K_O/K_E of .5 shows in run 10 and 11, respectively, a 3.3 and 3.5 percent reduction to the young of the year at end of one year and, for the adults at the end of 10 years, a percentage reduction of 2.75 and 4.04. The total eggs for run 10 is 21 billion and for run 11, six billion. The larval survival is 5 percent. In both cases, compensation controls and holds the reduction to a minimum.

6. Variation of the Longitudinal Dispersion Coefficient

In response to Staff and Board suggestions, (December 15, 1972), the model was operated using a variety of dispersion coefficients in segments 7 and 8 (Bear Mountain Bridge to below the Tappan Zee Bridge).

All previous runs were made with dispersion coefficients given in the October 30, 1972 testimony. In those runs for segments 7 and 8, a value of 12 square miles per day was used throughout June and July.

Values of 8, 10, and 14 square miles/day were tested. Virtually no difference, as had been expected, occurred for the base case of no plant operation. As of today, we have not yet tested the case of plant operation, due to computer facility difficulties beyond our control. Although we expect no more than negligible differences for this range of dispersion, even with the plant operating, we will submit the results for the case of plant operation as soon as they become available.

III. COMPARISON TO EXISTING PLANTS

The model was tested by simulating the operation of electric generating stations that have been operating on the River over the past 25 years. These include the Lovett, Danskammer and Indian Point Unit 1. Location and operating characteristics of these stations are given in previous testimony (Table 1, October 30, 1972).

Modeling was accomplished by starting operation of the life cycle model in 1948, the year before the first unit at Lovett went on line and then bringing each unit into operation in the model in the year it actually went on line. Table 2 lists the year each unit went on line, the period over which a given total flow is being withdrawn from the River, unit identification, circulating water system flow for each unit and the total flow being withdrawn from the River during any interval of operation.

Data on Hudson River striped bass landings over the period 1930-1968 shows approximately a 5% per year increase in catch. For the sake of the ensuing analysis, we have assumed population growth has paralleled the landing statistics and have used a 5% per year growth rate in the life cycle model.

During the period of plant operation, then, the River striped bass population is assumed to increase at a 5% yearly rate. To determine the impact of plant operation on the River, we first ran the model to generate this growth rate in the presence of operating plants, and then, without plant operation, computed the rates of "natural" population increase.

Table 2

Cumulative Plant Intakes 1949-1973

Year Plant First on Line and Interval of Operation of the Given Cumulative Flow	Plant	Unit Flow (cfs)	River Withdrawal (cfs)
49-51	Lovett #1	57.40	57.40
52-54	Lovett #2	57.40	
	Danskammer #1	100.26	
		157.66	215.06
55-59	Lovett #3	95.64	
	Danskammer #2	100.26	
		195.90	410.96
60-62	Danskammer #3	200.52	611.48
63-65	Indian Point #1	695.13	1306.61
66-67	Lovett #4	236.84	1543.45
68	Danskammer #4	316.38	1859.83
69-73	Lovett #5	273.28	2133.11

Conditions comparable to those given in the previous testimony ("apparent best estimate" and "apparent maximum") for f factors, as well as the maximum f factor case (all entrainment f factors = 1.0) were employed. Compensation was not employed. Results are shown below for the period of operation between 1963 and 1973, the period during which Indian Point Unit 1, and the last Lovett and Danskammer units began operation.

Condition	Percent Reduction in 10 Years	Computed Natural Growth Rate	Computed Natural Population Growth	
			% Increase	N-Fold
Maximum	24	1.078	112	2.12
Apparent Maximum	11	1.062	82	1.82
Best Estimate	6	1.057	74	1.74
No Plant	0	1.050	63	1.63
Staff Model	80	1.230	714	8.14
Staff Model	60	1.150	307	4.07

For each condition, the 10 year adult population reduction is shown in column 2. Column 3 gives the computed natural growth rate; i.e., the growth rate that would have occurred, had the plants not been in operation. Columns 4 and 5 give the increase in population that would have occurred in the absence of plant operation.

The Staff's model was also run under similar conditions. Operation of this model yielded reductions between 60 and 80% in the 10 year adult population; i.e., the adult population that would be present in 1973 after 10 years of staggered plant operation.

These results show clearly the superiority of the applicant's model, in that the Staff's model shows almost runaway growth rates in the absence of plant operation, i.e., 4 fold to 8 fold population increases in 10 years. These border on the preposterous, particularly when one considers that continued operation, say for 20 years, would simply yield continued exponentially increasing growth.

This last comment is clear evidence of the fact that some compensation is required in any of these models, to properly simulate expected fish growth behavior. Operation of the Applicant's model with compensation will prevent unlimited growth just as it has been previously shown to prevent unlimited decay.

IV. SUMMARY

1. A sensitivity analysis of the QL&M transport model has been performed and presented in the foregoing. This analysis shows that the presence of compensation is important, but shifts in natural mortality rates need not be major to keep the percentage reduction in the population to a minimum. Such shifts appear to be no greater than the natural fluctuations in mortality rates which occur in a bio-system of this type, and which may simply be reflecting the system's own innate ability to compensate in a natural environment.

2. Consideration of actual early stage distributions in the Indian Point vicinity is also important, as is a knowledge of the actual plant-induced mortality as the organism passes through the circulating water system. Evaluation of all available data suggests strongly that these effects, translated into computational terms as "f" factors, cannot be ignored, i.e., "f" factor values are substantially less than unity.

3. Results of the sensitivity analysis, for uses when major migration is assumed to have occurred past Indian Point by the end of the assumed entrainable stage, and which cover the ranges of minimal to moderate compensation and moderate to maximum "f" factors, are given below:

Compensation Ratio (maximum mortality rate / density independent rate)	"f" Factor Estimate			Percent Reduction in		
	Eggs	Larvae	Juveniles	1 Year Year Class One Recruitment	10 Year Adult Population	Reference Run # (Table 1)
minimal (0.8)	0.4	0.4	0.2	3.5	9.7	8
moderate (0.5)	0.4	0.4	0.2	2.1	3.9	2
moderate (0.5)	1.0	1.0	1.0	3.3	8.5	15

These results suggest that year class one recruitment, after one year of operation, may be expected to be reduced by 2 to 4%, and percentage reduction in the 10 year total population may vary between 4 and 10%. On the basis that the migration effect on entrainable stages has probably been overestimated in this analysis, and that entrainment vulnerability and mortality may not be as severe as is estimated herein, I consider the low end of these ranges to be closer to what may eventually occur after long term plant operation.

4. The effect of the Danskammer, Lovett and Indian Point Unit 1 stations on the River striped bass population was evaluated in the model. A 6% plant reduction effect was computed (no compensation, current best f-factor estimate) and reflects a conservative estimate of the effect of these stations over the past 10 years.

Evaluation of the existing plant effect was also made using the Staff's model. A 20 to 25% reduction effect was computed. This reduces to the order of 6% when refinements are introduced into the Staff's model, as discussed in other testimony of this date.

In making these evaluations, a 5% per year increase was used to represent the apparent growth rate of the Hudson River striped bass population in recent years. When the plant operation is lifted, the model then yields a natural growth rate of about 5.7% per year, and an increase in the population over 10 years of about 6%.

Two conclusions are drawn from this. First, the computed effect of Unit 2 at Indian Point would have a similar effect on the growth rate, since the projected percentage reductions are about the same.

Secondly, and more importantly, these calculations again show clearly that some type of compensatory action must take place. Unlimited growth cannot occur in reality, but presumed large percentage removals by the plants in the presence of actual population growth lead to the untenable position of unlimited growth when the plant effect is lifted from the system.

5. A number of additional considerations suggest the actual effect of Indian Point Unit 2 may be less than that computed by the transport model. In particular, these include migration behavior and condenser mortality.

6. Striped bass longer than 3/4" were not found in either intake or discharge samples by Dr. Lauer. This suggests that they were either not present (avoided the intake) or not damaged (if present, avoided the discharge canal nets).

   This translates to the possibility that the composite f factor for the early juvenile stage (J_1) is zero or very nearly so. The result is elimination of the early juveniles as subject to entrainment, and reduction of the period of entrainment by about 4 weeks. This will result in a substantial decrease in the computed population reductions.

7. Dr. Raney's testimony suggests the abundance of these early forms all along the River, and also that they tend to seek shallow water. The former observation suggests a less rapid downstream migration than has been employed in most of the computations presented. The latter suggests they would not be in the intake vicinity, in keeping with Dr. Lauer's observation of their absence in the intake samples.

Our own observations tend to show that substantial migration downstream does not occur until into September. Prior to that time, catch-effort yields essentially similar densities from Kingston to Haverstraw Bay, whereas afterward, up river populations fall off and Haverstraw Bay populations increase markedly.

8. These observations all suggest that longitudinal migration downstream does not occur as rapidly as has been postulated, and that lateral shallow-water directed migration, which has not been seriously taken into account, does occur.

They further suggest the actual period of entrainment is on the order of 4 to 5 weeks, not 8 to 9, and that the numbers of organisms subject to entrainment in these earlier weeks is lower than used in most of the estimates made to date.

9. These observations are made to place perspective on the use of the model. At this stage of their development, the various models employed in this proceeding have been useful in defining the issues, and in placing a variety of previously qualitative statements into a quantitative framework.

However, the mistake should not be made of allowing the models to appear as "gospel." The River will behave of its own accord, and the models can only help to define what that accord is.

The model, of course, has great utility and continues to lend itself to evaluation of the type of observations described above. For example, in evaluating the notion introduced above that early juveniles may not be subject to entrainment, the data collection program design should be guided by the model's requirements to evaluate this hypothesis conclusively.

Therefore, as also stated in my concluding remarks on our evaluation of the Staff's model, I contend that the model accuracy required for the magnitude of the decision involved requires model development time of the same order proposed by the Applicant for development of a satisfactory data base. In fact, the Applicant's five year study plan envisions mutual dependence of model and data base development. The model provides insight toward the type of data collection program necessary, and the data obtained will permit continuing model refinement, of the type described above.

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the matter of	)	
	)	
CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.	)	DOCKET NO. 50-247
	)	
	)	
(Indian Point Station, Unit 2)	)	

Answers by
John P. Lawler, Ph.D.
QUIRK, LAWLER & MATUSKY ENGINEERS
to Questions on the
Statistical Analysis of Table 19
of the October 30, 1972 Testimony
on the
Effect of Entrainment and Impingement at
Indian Point on the Population of the
Hudson River Striped Bass

February 5, 1973

During the course of Cross Examination of Dr. Lawler by Dr. Geckler, the AEC Staff posed the following two related questions pertaining to statistical analysis of data on Table 19 of the October 30th testimony (pages 7767 and 7768).

> *DR. GECKLER: The question deals with Table 19, which follows page 60 and was corrected two days ago.*
>
> *What would be your conclusion, Dr. Lawler, if the statistical comparison which you intent to carry out would -- indicated there were no significant differences among the various numbers and, therefore, no reason for believing them to be different?*

Response by Dr. Lawler to this question was directed toward defining the procedure by which the proper tests of significance would be chosen. Dr. Geckler, apparently desirous of clarifying what he had in mind then asked:

> *DR. GECKLER: Would an adequate technique be to take the means and standard deviations and make the comparison according to ordinary statistical tests?*

Table 19 presents data from which the "f_2" factor, the ratio of the daily average intake concentration of early fish forms to the daily average "upper east quadrant" concentration of these forms, is computed.

This written response to Dr. Geckler's question begins with a clear definition of the various means employed to compute "f_2", discusses the statistical procedures used, presents the results of the statistical analyses and draws conclusions on the range of probable f_2 values.

The factor defined by the term "f_2" as presented in Table 19 is expressed in four different ways.

Viz:

FORMULA: (1)

$$f_2 = \frac{\frac{I_N + I_D}{2}}{\frac{E_N + E_D}{2}}$$

East Shore Unweighted

FORMULA: (2)

$$f_2 = \frac{1/3\ I_N + 2/3\ I_D}{1/3\ E_N + 2/3\ E_D}$$

East Shore Weighted

FORMULA: (3)

$$f_2 = \frac{\frac{I_N + I_D}{2}}{\frac{Q_N + Q_D}{2}}$$

East Quadrant Unweighted

FORMULA: (4)

$$f_2 = \frac{1/3\ I_N + 2/3\ I_D}{1/3\ Q_N + 2/3\ Q_D}$$

East Quadrant Weighted

In the above expressions, I, E, and Q represent concentrations in the Intake, in the upper East Shore and in the upper East Quadrant (0' to 20' depth for both the East Channel and the East Shore), respectively, with the subscripts N and D denoting Night and Day.

It is originally stated on page 61 of the October 30, 1972 testimony, and is reiterated here, that the East Quadrant concentration is the correct value to use in computing f_2, since this is how f_2 is defined. The East Shore cases were inserted in Table 19 for illustrative purposes. More specifically, defining formula #4, above, is considered to represent the definition of f_2 best.

Since the data were obtained by sampling at the appropriate locations during several times over a 24 hour period, means for each of the terms in the expression for f_2 can be calculated. A value of f_2 can then be calculated based on the sampling means of each term. This procedure yields the f_2 values presented in Table 19.

It is quite possible that the true value of f_2 might be quite different from that computed on the basis of sample means. One estimate of the possible range of f_2 within which the true f_2 may fall might be obtained by developing confidence limits for each of the terms (I_N, I_D, etc.) in the f_2 formulae.

The confidence limits for each of these concentration parameters would define, for a particular chosen level of certainty, over what range of values the true population mean of that concentration would be contained. The question might then be answered in terms of whether or not the population means for the intake and upper east quadrant fall within the same range (no significant difference), overlap to some degree (possible significant difference, depending on degree) or don't overlap at all (demonstrated significant difference.

It must be recognized that each of the parameters in the f_2 formulae actually consists of the mean of a distribution of that variable and that, by nature of the methods of sampling, the maximum likelihood estimates of the population means are the sample means. This produces an unbiased estimate and should be considered as the best point estimate. This is what Table 19, as presented and later corrected, represents. The method of calculating confidence limits allows for obtaining a range in which the population mean could be contained following which, inferences such as those described above about the population may be drawn.

Rather than simply compare ranges of intake and upper east quadrant concentrations to determine significance, another possibility would be to estimate the probable range of f_2 by computing Lower and Upper Confidence Limits for each of the concentration terms. Then, using all the Lower Confidence Limits of the terms, compute an f_2 value, and again, using all the Upper Confidence Limits of the terms, compute another f_2 value.

It must be stated that these two operations would produce neither "worst case" nor "best case" estimates as the effect is to change both the numerator and denominator of the expression in a similar direction. Thus, these computed f_2 values might not be too different from the f_2 mean value, although some change in f_2 should be expected, since $\frac{X + A}{Y + B}$ and $\frac{X - A}{Y - B}$ are different from $\frac{X}{Y}$ even if $A = B$.

The results of performing the above operations are shown in Tables 1a and 1b. Table 1a shows the upper and lower limits on the east shore and east channel values, for a selected confidence interval of 95%. This means that there is a 95% probability that the true mean of each parameter's population will fall within the range given by the upper and lower confidence limits.

TABLE 1a

SIGNIFICANCE OF "f_2" FACTOR FOR EARLY JUVENILES

All Sampling Data Reported as Numbers of Total Serranids per Thousand Cubic Feet

Data of July 25, 1972
Means as Given in Table 19 as Corrected (Tr.7371-7374) [1]

	Day Sampling		Night Sampling	
	East	East Channel	East	East Channel
Mean	3.03	4.82	5.32	7.10
UCL	4.70	11.31	10.43	13.18
LCL	1.36	0.00	0.00	1.02

		LCL*	MEAN	UCL*
Quadrant Average	- Day	0.80	3.93	7.06
	- Night	2.06	6.21	10.36
Intake Concentration	- Day	0.00	1.50	3.06
	- Night	0.00	1.01	14.67

*LCL = Lower Confidence Limit
UCL = Upper Confidence Limit

Note: A 95% Confidence Level has been chosen for this analysis.
[1]See Footnote 1, page 5, this testimony.

TABLE 1b

ESTIMATION IN RANGE OF "f_2" VALUES
USING INTAKE & QUADRANT AVERAGE CONFIDENCE LIMIT APPROACH

	Unweighted		
Basis for Analysis	Using LCL's	Using MEANS	Using UCL'S
East Shore	.00	.30	1.17
East Quadrant	.00	.30	1.02
	Weighted		
East Shore	.00	.35	1.04
East Quadrant	.00	.29	.85

Considering the first approach suggested for determining significance, it can be seen that, for the day sampling, there is some overlap between the intake concentration ranges and the quadrant average concentration ranges. In this case, the intake range begins and ends at substantially lower values than does the quadrant average concentration. This suggests that, depending on the level of significance chosen, a significant difference between the two concentrations can be postulated, and for such, any given intake concentration will be significantly lower than its upper east quadrant counterpart.

For the night concentrations, simple examination of the data shows that the intake range encompasses the quadrant values. This would normally be interperted as showing no significant difference. However, the problem here is the small sample size of the intake which is reflected in the high value of the Upper Confidence Limit. The Lower Confidence Limit is constrained to be no less than zero on physical grounds.

Table lb shows values of f_2 calculated first using only the Lower Confidence Limits shown in Table la, then using means[1] shown in Table la and finally the Upper Confidence Limits in Table la.

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1 Intake mean concentrations in Table 1 are slightly different than those reported in Table 19, since individual intake sample concentrations were used in the Table 1 analysis, whereas, in developing Table 19, the intake concentration was computed by dividing the sum of all fish taken at the intake by the sum of all volume passed. Furthermore, as stated on cross-examination (Tr. 7373) only one fish was observed in the intake at night, although 2 were arbitrarily used in Table 19. In order to perform the statistical analysis correctly, the actual observation of one fish in one sample and zero fish in five other samples was used. It should be borne in mind that the absence of fish is as valid a sample as any other and simply demonstrates our contention that very few fish appear in the intake.

The above table shows possible values of f_2 using consistent criteria but does not provide for a true measure of the actual confidence limits on the mean f_2 itself. This technique, while it allows for a measure of some possible values f_2 can take, uses essentially only point values of the individual concentrations and it therefore becomes desirable to abandon the previous approaches and employ a methodology directed at developing proper confidence limits on the "f_2" value itself.

Observation of the various formulae given for f_2 on page 2 shows that f_2 is not a linear combination of the individual terms. Since this is so, the standard approach to taking confidence limits on functions of random variables cannot be applied. A valid procedure is to perform a Monte Carlo technique of statistical analysis on the observed data. The reasons for the use of Monte Carlo methods and the methodology consist of the following.

As described above, an attempt to obtain confidence limits on the mean value of f_2 or a deterministic description of the distribution of f_2 values as a function of the individual terms is not possible due to the non-linear relationship of the terms. Additionally, the actual distribution of the individual terms is not precisely known.

Monte Carlo makes use of the fact that given random samples from different independent distributions (the individual concentration parameters) and some operating function (in this case f_2), the distribution of the operating function can be closely approximated by taking randomly selected possible

These results suggest that the true mean "f_2" value should fall within a relatively narrow band around the sample mean value. Note that the mean values on a quadrant average basis obtained via this procedure are only slightly higher than those presented above in Table la.

Based on the foregoing analyses, all of which suggest the presence of an "f_2" effect, and on the fact that the mean value still represents the best estimate of f_2, I believe our original best estimate of 0.5 for the f_2 factor for the early juvenile stage is still valid. Furthermore, the probable range in f_2, presented on page 61 may be tightened to between 0.4 and 0.6, rather than up to 0.8, the previously reported "apparent maximum."

II. SPECIFIC ITEMS TO BE CONSIDERED

An examination of the overall effect of Indian Point Unit 2 on the dissolved oxygen concentration in the Hudson River requires the study of both the cooling system dissolved oxygen and the dissolved oxygen regime to be expected in the Hudson River mainstream. Studies by QL&M relating to these two items are as follows:

(a) Cooling system mathematical model

- Determination of the effects of changes in temperature and atmospheric pressure on cooling water oxygen concentrations.

- Field study of the Unit 1 cooling system to confirm the model.

(b) Hudson River mathematical model

- Thermal studies to determine expected temperature rise characteristics.

- Use of the Hudson River dissolved oxygen model to analyze the effects of thermal discharges which include biochemical oxygen consumption and reaeration, both of which are temperature-dependent and are so used in the model.

- Field studies by QL&M to verify the effect of Indian Point Unit 1 on the Hudson River dissolved oxygen.

values of each independent parameter and calculating a particular value of the operating function. If this is done, a large number of times the distribution of the particular values obtained simulates the distribution of the operating function.

In reference to the data used in constructing Table 19, the following procedure was used. The raw data were averaged (0', 10', and 20' depth values) for each particular sampling time at the East Shore and also for the East Channel. Intake surface, mid-depth and bottom values for each particular sampling time were also calculated.

This gave six sets of concentrations; i.e., East Channel-Night, East Channel-Day, East Shore-Night, East Shore-Day, Intake-Night, and Intake-Day, with each number in a set being the average of three depths. The pairs of East Shore and East Channel readings were then averaged to yield upper east quadrant values. Using a random number generator, a group of random numbers was obtained with the random number for each set being contained within the range of the number of values available in each set.

The particular values of the terms were then taken and a possible f_2 value for each definition of f_2 was calculated. This procedure was performed successively 300 times. Results of this procedure are given below:

Item	FORMULA FOR "f_2" (page 2) (1)	(2)	(3)	(4)
Mean	0.51	0.52	0.32	0.39
Upper Confidence Limit (95%)	0.58	0.59	0.38	0.46
Lower Confidence Limit (95%)	0.43	0.45	0.27	0.33

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit 2)	)))))	Docket No. 50-247

Redirect-Rebuttal Testimony of John P. Lawler, Ph.D. Quirk, Lawler & Matusky Engineers on the Effect of Indian Point Units 1 and 2 Operation on Hudson River Dissolved Oxygen Concentrations

February 5, 1973

I. INTRODUCTION AND SUMMARY

This testimony presents redirect-rebuttal testimony on the AEC Regulatory Staff's evaluation of the effect of Indian Point Units 1 & 2 operation on Hudson River dissolved oxygen (DO) concentrations as presented in the Final Environmental Statement for Indian Point 2 ("Final Statement") and statements made by Mr. John R. Clark on January 10, 1973 in this proceeding (Tr. 7940).

In addition to this testimony, the Applicant has submitted the following documents on this topic:

- Testimony by John P. Lawler in this proceeding on January 11, 1972, (Tr. 4428-4430).
- A QL&M report entitled, "Effect of Indian Point Plant on Hudson River Dissolved Oxygen", February 1972 together with Appendix C (Generalized Comments on Dissolved Oxygen) to which it was attached. These were introduced into evidence in this proceeding (follows Tr. 6256).

Oxygen gas, which is necessary for survival of desirable aquatic organisms, is sparingly soluble in water. Since the amount of oxygen which can be dissolved in water decreases as the temperature of the water rises, and pressure decreases, concern has developed regarding the possible losses of dissolved oxygen from water heated by 'once-through' power plant cooling systems. Another potential route for loss of dissolved oxygen is through heat-enhanced metabolic oxygen use. It is my opinion that these effects will not occur to an environmentally harmful level as a result of two unit operation at Indian Point at any time during the year including late summer and early fall.

III. PRESENTATION OF DATA

A. COOLING SYSTEM DISSOLVED OXYGEN

In February 1972, Quirk, Lawler & Matusky Engineers presented a report to Con Edison which described the dissolved oxygen changes to be expected in the cooling water system of Indian Point Unit 2. Factors affecting dissolved oxygen that were considered in this study were:

- The change in dissolved oxygen saturation with temperature
- The change in dissolved oxygen saturation with decreased atmospheric pressure caused by the siphoning effect used to reduce pumping head.
- Present and possible future Hudson River dissolved oxygen concentrations

Table 1 summarizes the results of this modeling study. To test the model for Unit 1 operation, field examination of intake and discharge dissolved oxygen concentrations was done in December 1971. The resulting samples, taken hourly over a 26-hour period, showed an average reduction through the condenser of 0.18 mg/l of dissolved oxygen, which is less than 2% of the intake concentration.

B. HUDSON RIVER DISSOLVED OXYGEN

To test the effect of the Indian Point inplant loss of dissolved oxygen on the Hudson River oxygen levels, a previously developed mathematical model was employed. This model was presented in the January 1968 report by QL&M titled "Effect of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution" and is described below.

TABLE 1

EFFECT OF INPLANT DISSOLVED OXYGEN LOSS ON HUDSON RIVER DISSOLVED OXYGEN DISTRIBUTION AT INDIAN POINT

- TWO UNIT OPERATION -

Item	Present DO Conditions			Future DO Conditions		
	Summer	Winter		Summer	Winter	
River Parameters						
River ambient temperature, °F	79	33	50	79	33	50
Freshwater flow, cfs	4,000	12,500		4,000	12,500	
River ambient D.O. concentration at I.P., mg/l	6.5	11.3	9.0	7.5	11.7	9.7
Plant Parameters						
Intake temperature, °F	79	33	50	79	33	50
Plant cooling water temperature rise, °F	14.8	24.7	24.7	14.8	24.7	24.7
Discharge temperature (rounded), °F	94.0	58.0	75.0	94.0	58.0	75.0
Cooling water flow, cfs	2,500	1,500*	1,500*	2,500	1,500*	1,500*
D.O. saturation, mg/l						
- at intake	8.2	14.4	11.3	8.2	14.4	11.3
- at discharge	7.2	10.3	8.5	7.2	10.3	8.5
Inplant Loss of D.O. from the Cooling Water						
Intake D.O. concentration, i.e., ambient conditions, mg/l	6.5	11.3	9.0	7.5	11.7	9.7
Discharge D.O. concentration (rounded), mg/l	6.3	10.9	8.6	7.2	11.2	9.3
Inplant loss of D.O. mg/l	0.17	0.42	0.31	0.26	0.47	0.40
Effect on Hudson River D.O. Distribution						
River ambient D.O. concentration at I.P., mg/l	6.5	11.3	9.0	7.5	11.7	9.7
River D.O. concentration at I.P. including plant operation (rounded), mg/l	6.48	11.27	8.88	7.47	11.67	9.67
Decrease in river D.O. concentration at I.P.						
- mg/l (rounded)	0.02	0.03	0.02	0.03	0.03	0.03
- percent of ambient concentration	0.30	0.26	0.24	0.35	0.28	0.28
Percent of total Lower Hudson River content	0.07	0.06	0.06	0.07	0.06	0.06

*The cooling water flow throttled to about 60% of full during winter months.

The mathematical modeling of the river dissolved oxygen concentrations included: (a) transport mechanisms by advection and dispersion, (b) first-order bio-oxidation, (c) reaeration, (d) benthic oxygen intake, and (e) constants (zero-order) to account for other mechanisms such as addition of B.O.D. due to river organism mortality, addition of dissolved oxygen by algal photosynthesis, etc.

The Hudson River was divided into 28 segments of varying lengths between the Troy Dam and the Battery. A material balance of B.O.D. was developed for each segment and a set of 56 simultaneous equations was generated by inverting the segment B.O.D. and dissolved oxygen solutions into the appropriate boundary conditions. The simultaneous equations were solved using matrix inversion on a digital computer.

The effect of the Indian Point plant was introduced to the model as a direct withdrawal of oxygen from the river segments adjacent to the plant.

The computer runs were made for summer and winter conditions. The summer conditions were characterized by a Hudson River freshwater drought flow of 4,000 cfs, a maximum river ambient temperature of 79°F, and cooling water flow of 2,500 cfs (in view of the low levels of oxygen depletion found, the use of the AEC's staff Figures for maximum ambient River temperature would not produce a change in any of the conclusions). For winter runs, fresh water flow of 12,500 cfs and cooling water rate of 1,500 cfs (flow throttled to 60% of full flow) were used. To estimate the wintertime effect, two winter ambient temperatures of 32° and 50°F were used in the analysis. In general, this temperature range coincides with cooling water flow reduction period.

The final results of the analysis are shown in Table 1 and indicate that passage of cooling water through the plant will decrease the Hudson River dissolved oxygen concentration at Indian Point by about 0.3% or 0.02 mg/l during summer months and by 0.25% or 0.03 mg/l during winter conditions. At the estimated future (1990) levels of river dissolved oxygen, the decrease is expected to be about 0.03 mg/l. In terms of the total lower Hudson River (between the Battery and Troy) dissolved oxygen content, the above mentioned values correspond to a decrease of 0.07% during summer months and of 0.06% during winter months.

These effects are insignificant by comparison with other deoxygenation processes and are below the minimum detectable dissolved oxygen concentrations. In conclusion, therefore, the cooling water passage through the plant will have an immeasurable effect on the distribution of dissolved oxygen in the Hudson River.

Considering, then, the effect of the heated effluent combined with the reduction in dissolved oxygen through the plant, a second model study was conducted. QL&M calculated the effect of the plant-induced river temperature rise on river dissolved oxygen concentrations for two-unit operation.

The model results indicated that the dissolved oxygen concentrations for the heated conditions corresponding to two-unit operation at Indian Point could be expected to be 0.1 mg/l lower than that for the unheated conditions. The present diurnal variation in the Hudson River is approximately 0.2 mg/l.

Field studies of the effect on the river of Indian Point Unit 1 were conducted on August 17, 1972. Two replicates were collected at each sampling section and were fixed immediately for laboratory titration using the Azide modification of the Winkler method for dissolved oxygen. Water temperature of each sample was taken using a mercury thermometer calibrated to 0.1°C. Sampling stations shown in Figure 1 were chosen to delineate the change in dissolved oxygen through the cooling system and the change in dissolved oxygen in the parallel reach of the river. Results of this survey are shown in Table 2 and Figure 2.

Conditions which prevailed during the survey period were:

(a) Unit 1 aerator was not in operation during the survey.

(b) Cooling water flow was partially throttled. Unit 1 condenser temperature rise was about 15° F.

(c) Run #1 was conducted during late ebb (maximum ebb was at 10:50).

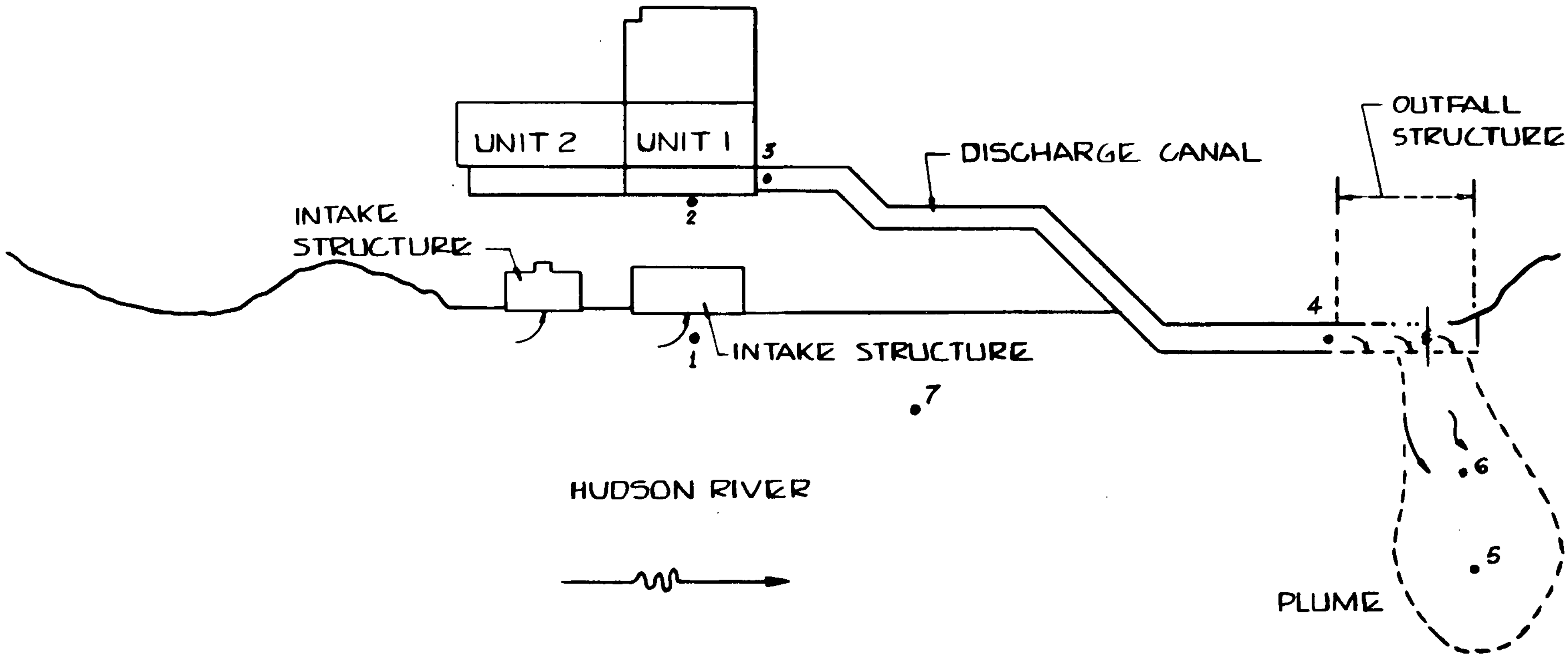
(d) Run #2 was done at low water slack (14:31).

(e) Weather during the survey was cool (21.3° C), overcast, and there was no significant wind.

INDIAN POINT PLANT INTAKE AND DISCHARGE

DISSOLVED OXYGEN SAMPLING POINTS

SAMPLES TAKEN AUGUST 17, 1972



• - SAMPLE POINTS

FIGURE 1

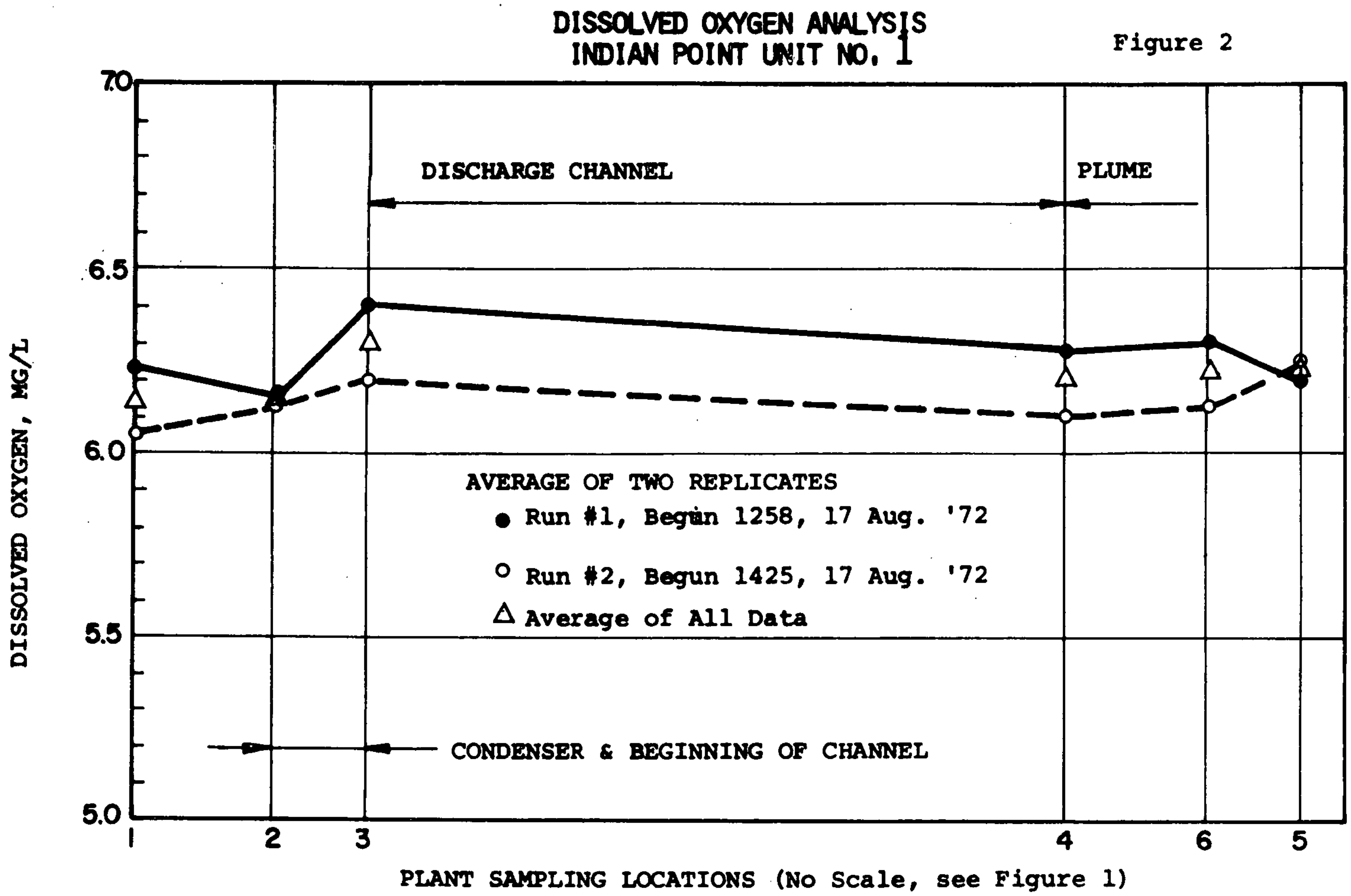
TABLE 2

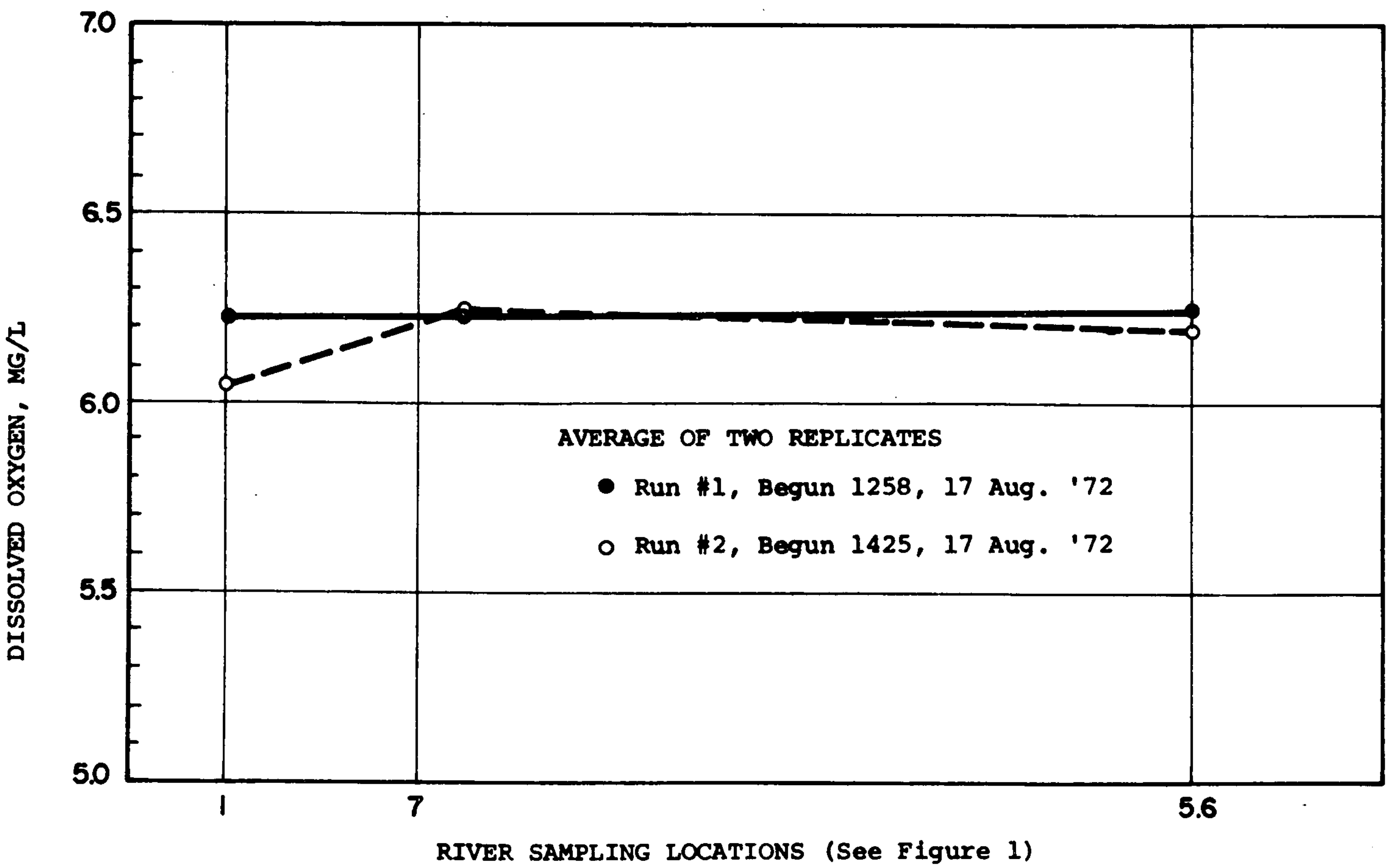
DISSOLVED OXYGEN MEASUREMENTS AT INDIAN POINT
AUGUST 17, 1972

Sample Location*	Depth, ft.	Run #1 Temperature, °C	Run #1 Time EDST	Run #1 D.O., mg/l		Run #2 Temperature, °C	Run #2 Time EDST	Run #2 D.O., mg/l	
Point 1	10	24.1°	12:58	6.2	6.25	24.2°	14:25	6.0	6.1
Point 2	10	24.1	13:04	6.25	6.05	24.3	14:29	6.1	6.15
Point 3	7	32.6	13:11	6.55	6.25	32.4	14:41	6.2	6.2
Point 4	9	32.6	13:28	6.3	6.25	32.5	14:54	6.1	6.1
Point 5	10	24.8	13:40	6.4	6.15	24.9	15:06	6.25	6.3
	0-2	24.1	13:40	6.0	6.25	26.4	15:10	6.25	6.2
Point 6	0-2	28.3	13:46	6.1	6.55	28.8	15:03	6.1	6.15
Point 7	0-2	24.2	13:50	6.25	6.2	27.2	15:14	6.25	

*See Figure 1.

Figure 2


DISSOLVED OXYGEN ANALYSIS
INDIAN POINT UNIT NO. 1
7.0
6.5
6.0
5.5
5.0
DISSOLVED OXYGEN, MG/L
DISCHARGE CHANNEL
PLUME
AVERAGE OF TWO REPLICATES
Run #1, Begun 1258, 17 Aug. '72
Run #2, Begun 1425, 17 Aug. '72
Average of All Data
CONDENSER & BEGINNING OF CHANNEL
1
2
3
4
6
5
PLANT SAMPLING LOCATIONS (No Scale, see Figure 1)


7.0
6.5
6.0
5.5
5.0
DISSOLVED OXYGEN, MG/L
AVERAGE OF TWO REPLICATES
Run #1, Begun 1258, 17 Aug. '72
Run #2, Begun 1425, 17 Aug. '72
1
7
5.6
RIVER SAMPLING LOCATIONS (See Figure 1)

IV. INTERPRETATION OF DATA

As previously mentioned, the expected dissolved oxygen reduction through the condenser section is about 0.3 mg/l. The probable cause for the small size of the reduction may be found by examining the mechanisms of oxygen transfer. Each of the expected mechanisms for dissolved oxygen loss due to increased temperature and decreased pressure operates by lowering the saturation value of oxygen.

The temperature increase through the condenser lowers the saturation value, but the reduced saturation value caused by temperature alone is still greater than the expected dissolved oxygen concentration under either winter or summer conditions. The presssure decrease reduces the saturation value below the expected oxygen concentration, but this effect is of short duration.

The predicted average decrease (3%) in dissolved oxygen concentration in cooling water will be experienced by water organisms only during a short travel time between the condensers and outfall structure. This travel time amounts to several minutes during two-unit operation at Indian Point. Once the cooling water is discharged through the submerged discharge outfall structure, it will quickly be mixed with ambient water and the drop in dissolved oxygen will be reduced to an unobservable level. Therefore, the metabolic components were not included in our February 1972 analysis of the inplant changes in dissolved oxygen.

Concerning the dissolved oxygen in the Hudson River, the effect of the plant if only the material balance is considered will be minor, about 0.02 mg/l during summer conditions. However, the combined temperature effects, which reflect influence on metabolic components, and oxygen loss in the condensers will lower the average dissolved oxygen concentration by 0.1 mg/l under the most severe conditions of temperature and flow.

Examining the results shown in Table 2 and Figure 2, it can be seen that no reduction in plume dissolved oxygen in comparison to river D.O. was observed during Unit 1 operation in August 1972. A minor rise in dissolved oxygen is seen in the profile of the cooling water system after the condensers. No mechanism has been found which would explain this increase. An insignificant decrease in dissolved oxygen concentrations was observed through the discharge canal in both runs, but the average D.O. level at the end of the canal is equal to the dissolved oxygen concentration in the river. These results, except for the rise in dissolved oxygen at Station #3, agree with conclusions drawn in this and previous QL&M documents, i.e., insignificant changes in D.O. levels.

In addition, the "late summer" measurements of river dissolved oxygen concentrations in the vicinity of Indian Point presented in this testimony, as well as observations made by QL&M in the Summers of 1969 and 1970 at Lovett and Bowline (see the Final Environmental Statement, Volume II, Appendix C, page 223), indicate that typical summer concentrations of the river dissolved oxygen in the vicinity of Indian Point are in excess of 5.0 mg/l. The only data contradictory to the conclusions herein is that obtained by the Raytheon Company. These data were contrary to our experience extending over a period of years. Investigation revealed that Raytheon has used improperly calibrated instruments. This was described in Testimony before the Board on January 11, 1972. (Tr. 4428-30). The AEC staff in the Final Statement agrees that there "...credence to the Applicant's opinion that the Raytheon data were in error" (V-13-14). Nevertheless, the Staff concludes relying solely on the Raytheon data, "The dissolved oxygen concentration in the thermal plume on occasion may be reduced to levels detrimental to aquatic life, principally in late summer and early fall" (p. iii). Mr. John Clark also continues to place emphasis on the repudiated Raytheon data. Since these data have now been thoroughly contradicted by the analysis and measurements described herein, we do not believe that the Board can rely on them to any extent whatsoever.

The expected decrease of dissolved oxygen concentrations by about 0.1 mg/l will not have significant effect on Hudson River biota. I believe that Clark's Statement* that fish migration can be stopped due to a lack of oxygen, as it is in the Delaware River (Tr. 7940) is irrelevant as far as the Hudson River is concerned.

Late spring and summer concentrations of D.O. in the Delaware River have been markedly lower than those in the Hudson River at Indian Point. The observed weekly average levels of D.O. in the Delaware River have been as low as 1.0 mg/l, i.e., levels which have never been observed in the vicinity of Indian Point.

Such low D.O. concentrations and associated interference with fish occur in the Delaware River when, during periods of prevailing low D.O. levels, intense storm precipitation over the Delaware watershed produces sharp increases of runoff in the estuary. The excessive fresh water runoff disturbs and resuspends the anaerobic bottom sediments which almost instantaneously exert high chemical oxygen demand in the estuary, resulting in further D.O. reduction.

*Clark's Statement (lines 12 through 14, Tr. 7940) is reproduced in this footnote "We know that it [migration] can be stopped, as it is in the Delaware River, by things that will repel the fish, in that case a lack of oxygen."

During such occasions, resident fish species have been killed by short-term oxygen deprivation. During such transient periods of DO depletion, migration of fish through the affected sections of the estuary may be blocked.

Such conditions have never been observed in the vicinity of Indian Point, mainly, because of the substantially higher ambient DO levels in the Hudson River. In addition, the effect of high runoff on any bottom sediments in the Hudson River at Indian Point is insignificant because the River at Indian Point is deeper than the Delaware River (mean Hudson River depth of 40 ft. vs. mean Delaware River depth of 21 ft.) and is a partially stratified waterbody while the Delaware is a completely mixed estuary. Furthermore, the existence of putrescible bottom sediments at Indian Point has not been observed.

V. FINDINGS AND CONCLUSIONS

In light of the material presented in the preceding sections, the following conclusions can be drawn:

1. Dissolved oxygen reduction in the Indian Point Unit 1 and 2 cooling water system (inplant loss) under present conditions will be minor, approximately 0.4 mg/l and 0.2 mg/l under winter and summer conditions, respectively.

2. Future improvements in Hudson River quality will result in condenser dissolved oxygen reduction (inplant loss) no greater than 0.5 mg/l and 0.3 mg/l under winter and summer conditions, respectively.

3. The effect of this reduction through the condenser on the dissolved oxygen concentration in the Hudson River at Indian Point will be negligible by itself, less than 0.03 mg/l.

4. Heating effects, together with the oxygen loss in the condensers, will, under the least favorable ambient conditions of flow and temperature, cause a reduction in river dissolved oxygen at Indian Point of approximately 0.1 mg/l below the unheated condition.

5. This change in dissolved oxygen represents a change significantly smaller than changes in River DO that occur naturally throughout the day, from top to bottom and from side to side.

REFERENCES

1. Quirk, Lawler & Matusky Engineers, "Effect of Indian Point Plant on Hudson River Dissolved Oxygen," February 1972. (follows TR. 6256).

2. Quirk, Lawler & Matusky Engineers, "Hudson River Water Quality and Waste Assimilation Capacity," December 1970.

3. Quirk, Lawler & Matusky Engineers, "Effect of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution," January 1968.

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of	)	
	)	
Consolidated Edison Company of New York, Inc.	)	Docket No. 50-247
	)	
(Indian Point Station, Unit 2)	)	

Redirect-Rebuttal
Testimony of
John P. Lawler, Ph.D.
Quirk, Lawler & Matusky Engineers
on the
Effect of Indian Point Unit 2
Chlorination on the Aquatic Biology
of the Hudson River

February 5, 1973

I. INTRODUCTION AND SUMMARY

Once-through cooling systems generally require the control of slime formation on the surfaces on the condenser and auxiliary cooling water systems. These slimes are colonies of fungi and bacteria which coat the heat transfer surfaces and which trap particulates in the cooling water, further reducing heat transfer.

In order to prevent reduced heat transfer and flow caused by this slime, chlorine is introduced into the cooling water on some periodic schedule. Although chlorination has previously been considered only from the standpoint of its beneficial effects, recent environmental research has disclosed the possible adverse effects which chlorine may have on aquatic organisms. Among these are:

- Suppression of algal photosynthesis and respiration
- Damage to zooplankton
- Damage to fish, both juvenile and adult

The potential effects of chlorine are based on two factors: concentration and time of exposure. By limiting either or both of these factors, the adverse effects associated with chlorine can be reduced or eliminated. It should be noted that there are several forms of chlorine of interest: hypochlorous acid (HOCl), hypochlorite ion, chloramines (NH_xCl_{3-x}) and organic chlorine compounds. Hypochlorous acid may be removed from the aquatic environment more rapidly than chloramines. Formation of chloramines from hypochlorous acid depends on the concentrations of ammonia and of hypochlorous acid, pH, and temperature. Removal of hypochlorous acid may be accomplished by satisfaction of "chlorine demand," a measure of the amount of substances in the water which can be oxidized by the chlorine present. In the process of satisfaction of this demand, the chlorine is reduced to chloride (Cl^-) ion, a biologically inactive form which occurs naturally at an annual average of about 750 mg/l in Hudson River water at Indian Point (Reference 1, p. V-16). In addition to the reduction of chlorine concentration resulting from chlorine demand, cooling water flows from other condensers and river mixing have diluting effects.

Studies with relevance to chlorination that have been undertaken by QL&M and others are:

- Laboratory studies of chlorine reactions
- Laboratory determinations of chlorine demand of Hudson River water
- Field determinations of chlorine demand of cooling water
- Field determinations of actual chlorine concentrations from Unit No. 1
- Laboratory studies on chlorine toxicity

Hudson River water from Indian Point and chlorine in the form used at Indian Point, sodium hypochlorite solution, were used in these studies. These chlorine data, in conjunction wit- plant operating and design data, allow predictions of the concentration-exposure time at Indian Point and its effect on aquatic species to be made.

Predictions of expected chlorine and chloramine concentrations from Unit No. 2 are required to predict possible effects on Hudson River biota, both those entrained in the cooling water and those exposed to the active chlorine which enters the river. These predictions will include the effects of demand by river water and condenser slimes, decay of chlorine to chloride ion, and conversion of ammonia to chloramine.

II. SPECIFICS TO BE CONSIDERED

Specific items to be considered in this testimony are the expected chlorine and chloramine concentrations from Indian Point Unit 2, the effects of chlorine demand and dilution on these concentrations, and the effects of this concentration-duration relationship on the types of organisms found in the Hudson River. Clarification and rebuttal of the data presented by Mr. John R. Clark and the AEC staff in its Final Environmental Impact Statement will also be presented.

Rebuttal of Clark's data will include refutation of his hypothetical chlorine concentrations presented in his July, 1972 testimony and refutation of his expectations regarding the effect of chlorine on Hudson River organisms. Rebuttal presented regarding the staff Final Statement will include clarification of the reactions of chlorine and ammonia, discussion of the toxic effects of chlorine, and refutation of their assumptions of discharge chlorine concentrations.

III. ANALYTICAL CONSIDERATIONS

INTRODUCTION

In those cases where circulating water condensers are not self-cleaning because of natural silt in condenser cooling water, some method of slime control is required for maintenance of efficient heat transfer. Chlorination is among the methods currently in use for control of condenser slimes. As discussed previously, studying the effect of chlorination on the life forms in the cooling water system and in the river requires some knowledge of the concentration and contact time. To determine the chlorine concentrations throughout the discharge canal, plume and river, it is necessary, in lieu of testing under all possible conditions, to develop, verify, and apply a mathematical model which accounts for the known chlorine reactions.

REACTIONS OF CHLORINE

In order to predict the discharge canal concentrations of chlorine species, it is necessary to develop the reactions which occur in chlorinated natural waters. For this purpose, the relevant reactions are:

1. Hydrolysis of sodium hypochlorite and dissociation of hypochlorous acid

2. Immediate chlorine demand by alkalinity and organic and inorganic non-nitrogenous reducing substances

3. Formation of chlorinated ammonia compounds

4. Ultraviolet-activated reduction of hypochlorous acid and hypochlorite ion (free chlorine)

5. Reduction of chlorinated ammonia compounds (combined chlorine) to chlorides and nitrogen compounds.

Reactions in each of these groups, when taken together, control the relative and absolute concentrations of the various chlorinated compounds and their precursors, and are summarized in Figure 1.

Reactions in Group 1, hydrolysis and dissociation of sodium hypochlorite, are:

$$NaOCl + H_2O \rightarrow NaOH + HOCl \text{ ....(1)}$$

$$HOCl \rightleftarrows H^+ + OCl^- \text{ ....(2)}$$

Reaction 1 is extremely rapid, and can be expected to be complete as soon as the hypochlorite is added to water. Hypochlorous acid is the exclusive product of Reaction 1 pH >4 and hypochlorite <1,000 mg/l. Reaction 2 is a pH-controlled reversible reaction (50% HOCl at pH 7.6), and is of primary interest because the ionized form will not react with ammonia compounds, and because the un-ionized form is a more efficient slimicide.

Reactions of Group 2, reduction of immediate demand, are generally:

$$HOCl + RH \rightarrow RCl + H_2O \text{ ....(3)}$$

$$OCl^- + RH \rightarrow RCl + OH^- \text{ ....(3a)}$$

where RH is any reduced organic carbon compound. Similar reactions occur with non-nitrogenous inorganic forms. According to Morris (22), this demand is virtually instantaneous, and because of its rapidity, occurs before the reactions of chlorine with nitrogenous species, at least in the case of amino acids, where decarboxylation precedes deamination. This reduction is generally a function of the initial chlorine concentration, possibly because of variations in the redox potential of the reducing species. After

CHLORINE REACTIONS OF INTEREST

Chlorination at Indian Point*

(R = Electron donating carbon compound)

$H_2O + RCl$ $\qquad$ $RCl + OH^-$

(Group 2) $\qquad \uparrow \qquad \uparrow$

$RH \qquad RH$ $\qquad$ Reduction of Free Chlorine

(UV Activated Breakdown) $\qquad + \qquad +$

$1/2\ O_2 + Cl^- + H^+ \leftarrow HOCl \rightleftarrows H^+ + OCl^-$ $\qquad$ Dissociation of Hypochlorous Acid

(Group 4) $\qquad +$

$H_2O + NH_3 \rightleftarrows NH_4^+ + OH^-$

$\downarrow$

$NH_2Cl + H_2O$ $\qquad$ Monochloramine Formation

(Group 3) $\qquad +$

$HOCL \leftrightarrows H^+ + OCl^-$

$\downarrow$

$NHCl_2 + H_2O$ $\qquad$ Dichloramine Formation

*Excludes hydrolysis of NaOCl and chloramine breakdown satisfaction of this 'instantaneous demand,' the long-term reduction of hypochlorous acid and hypochlorite ion (free chlorine) by non-nitrogenous reducing agents to chloride ion (Cl^-) is rather slow, one exception being demand in the condenser section.

Group 3 reactions, those of ammonia and chlorine, are of the following types:

$$NH_3 + H_2O \rightleftarrows NH_4^+ + OH^- \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$NH_3 + HOCl \rightarrow NH_2Cl + H_2O \quad \ldots\ldots\ldots\ldots\ldots (5)$$

$$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O \quad \ldots\ldots\ldots\ldots (6)$$

$$\text{(low pH only)} \quad NHCl_2 + HOCl \rightarrow NCl_3 + H_2O \quad \ldots\ldots\ldots\ldots (7)$$

These reactions describe the so-called 'breakpoint' phenomenon. Their rates and equilibria are controlled generally by the pH of the medium, and compete with the slower chlorine reduction reactions. Reaction rates for these reactions have been experimentally determined, primarily by Morris and several coworkers (3).

The ultraviolet (UV) activated reduction of hypochlorous acid and hypochlorite ion (Group 4) has been studied by Hancil and Smith (17). These reactions have rates dependent on the absorption of UV by hypochlorite.

$$HOCl \rightarrow H^+ + Cl^- + \frac{1}{2} O_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

$$OCl^- \rightarrow Cl^- + \frac{1}{2} O_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

In the absence of UV, rates are much slower than with UV, but the reaction does occur.

Several routes have been proposed for reduction of chlorinated ammonia compounds (Group 5) as follows:

$$NH_2Cl + NHCl_2 + H_2O \rightarrow N_2 + 3\ HCl + H_2O \quad \text{.........(10)}$$

$$NH_2Cl + NHCl_2 + HOCl \rightarrow N_2O + 4\ HCl \quad \text{.............(11)}$$

$$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O \quad \text{.....................(12) (low pH)}$$

Of these routes, the most probable pathway is dependent on initial chlorine to ammonia mole ratios, pH, and concentrations (3). Note that the reactions 10-12 will require either 1.5, 2 or 3 moles of chlorine for each mole of ammonia. Because of the differences in quantities required, no attempt was made to model these reactions rigorously. Limited work has been done on determining rate data for these reactions, and for this investigation, results of batch studies conducted at the National Water Quality Laboratory (NWQL) in Duluth, Minnesota, have been used to approximate the reduction of chloramines with time. More detailed work is currently being performed by Morris and Wei at Harvard University.

REACTIONS OF BROMINE

In the Final Environmental Statement, the Staff introduced the question of reactions between bromide ion and chlorine compounds. These reactions have been reported by Johanneson and others (14, 18). Bromine is a more powerful oxidant than chlorine, and will displace chlorine in the +1 oxidation state as follows:

$$HOCl + Br^- \rightarrow HOBr + Cl^- \quad \text{......................(13)}$$

According to Johnson and Overby (12), the reactions of bromine and ammonia are similar to those of chlorine and ammonia, except that the bromamines are less stable than are the chloramines. For this reason, bromine reactions were not separately investigated, since the less stable bromine compounds will be reduced more rapidly and completely to the -1 oxidation state by satisfaction of chlorine demand, and the assumption of bromide-free conditions is more conservative than any other assumption concerning bromine. The relative toxicities of bromine and chlorine will be discussed in the section on interpretation of results, page 19.

DEVELOPMENT OF THE CHLORINE MODEL

To account for the Staff objection to application of Unit No. 1 chlorine data to Unit No. 2, based on differences in channel residence time between the two units (1), it is necessary to develop a mathematical model for the reactions of chlorine in which channel residence time is a variable. Because the rates of chlorine reactions are known with respect to the breakdown of chlorine and chloramine formation with time and because field data are available on the overall reaction in the Indian Point discharge channel, it is possible to develop this model. The model developed is suitable for prediction of free and combined chlorine concentrations through the discharge canal.

Considering the channel length is sixty times its average width and depth, the assumption of plug flow conditions in the channel was made, to be tested later in the verification step. Because of weak points in the body of knowledge concerning chlorine chemistry, it is necessary to make certain assumptions at various points during model operation. These assumptions will be discussed at the relevant point in model development. Because the initial chlorine demand is essentially instantaneous, no differential equations were written for it. Its effect was determined by mass balance at the points where some immediate demand was introduced.

General differential equations which are applied to the system of interest are:

$$\frac{dc_{HOCl}}{dt} = -K_1 \, C_{HOCl} - K_2 \, C_{HOCl} \, C_{NH_3} - K_3 \cdot C_{HOCl} \, C_{NH_2Cl} \qquad \text{.......... (14)}$$

$$\frac{dc_{NH_3}}{dt} = -K_2 \, C_{HOCl} \, C_{NH_3} \qquad \text{.............................. (15)}$$

$$\frac{dc_{NH_2Cl}}{dt} = K_2 \, C_{HOCl} \, C_{NH_3} - K_3 \, C_{HOCl} \, C_{NH_2Cl} - K_o \qquad \text{............ (16)}$$

$$\frac{dc_{NHCl_2}}{dt} = K_3 \, C_{HOCl} \, C_{NH_2Cl} \qquad \text{.............................. (17)}$$

Where:

C_{HOCl} = Hypochlorous acid concentration

C_{NH_3} = Ammonia concentration

C_{NH_2Cl} = Monochloramine concentration

C_{NHCl_2} = Dichloramine concentration

t = Travel time in seconds

K_o = Pseudo-zero order breakdown rate for monochloramine

The equations shown above describe the reactions given in Section III as follows:

Equation 14 describes the removal of hypochlorous acid by reaction with ammonia, by consumption in satisfying the residual chlorine demand of as yet unoxidized organics and UV activated breakdown. The latter two mechanisms are both modelled as irreversible first order reactions, and give rise to the term $K_1 \cdot C_{HOCl}$ in Equation 14.

Equation 15 describes ammonia removal by conversion to monochloramine.

Equation 16 describes the formation of monochloramine, its conversion to dichloramine, and chloramine breakdown.

Equation 17 describes the formation of dichloramine.

Equations 14 through 17 have four unknowns, namely, C_{HOCl}, C_{NH_3}, C_{NH_2Cl}, and C_{NHCl_2}. Numerical solution of the four simultaneous differential equations was accomplished by applying Adams' predictor-corrector technique.[19,20]

Reaction rate constants for the above equations are as follows:

Constant	Value	Source
K_1	$2x10^{-4}$ sec^{-1}	determined by model calibration run, using field data
K_2	$5.1x10^{6}$ liter/mol-sec	Morris (3)
K_3	$3.37x10^{2}$ liter/mol-sec	Morris (3)
K_o	$1.67x10^{-11}$ mol/sec	NWQL Duluty (13)

Although Draley[14] reports a value for the rate of breakdown of chlorine in the absence of UV, this rate is not supported by references and the range between low and high estimates is too great to be of use. In the process of calibration of the model, a value for K_1 of .0002 sec^{-1} was found. This includes the actual UV and residual unoxidized organic effects.

DATA REQUIRED FOR MODEL APPLICATION

Application of the model requires the use of data on ambient river concentrations of ammonia, hydrogen ions (pH), and immediate chlorine demand, condenser chlorine demand, discharge canal temperatures during the chlorination period (ambient river temperature greater than 45°F) and the chlorine application rate. Data on ammonia and pH were obtained from the NYSDEC monitoring station at Verplanck, New York. This station, in operation since April 1969, has experienced average chlorination period values of 0.196 mg/l of ammonia (0.161 mg/l as NH_3-N) and a pH of 7.34 as shown in Figure 2. The average discharge canal temperature during the chlorination period was 77°F as measured by NYU personnel during 1972. Therefore, reaction constants developed at 25°C (77°F) were used for the model.

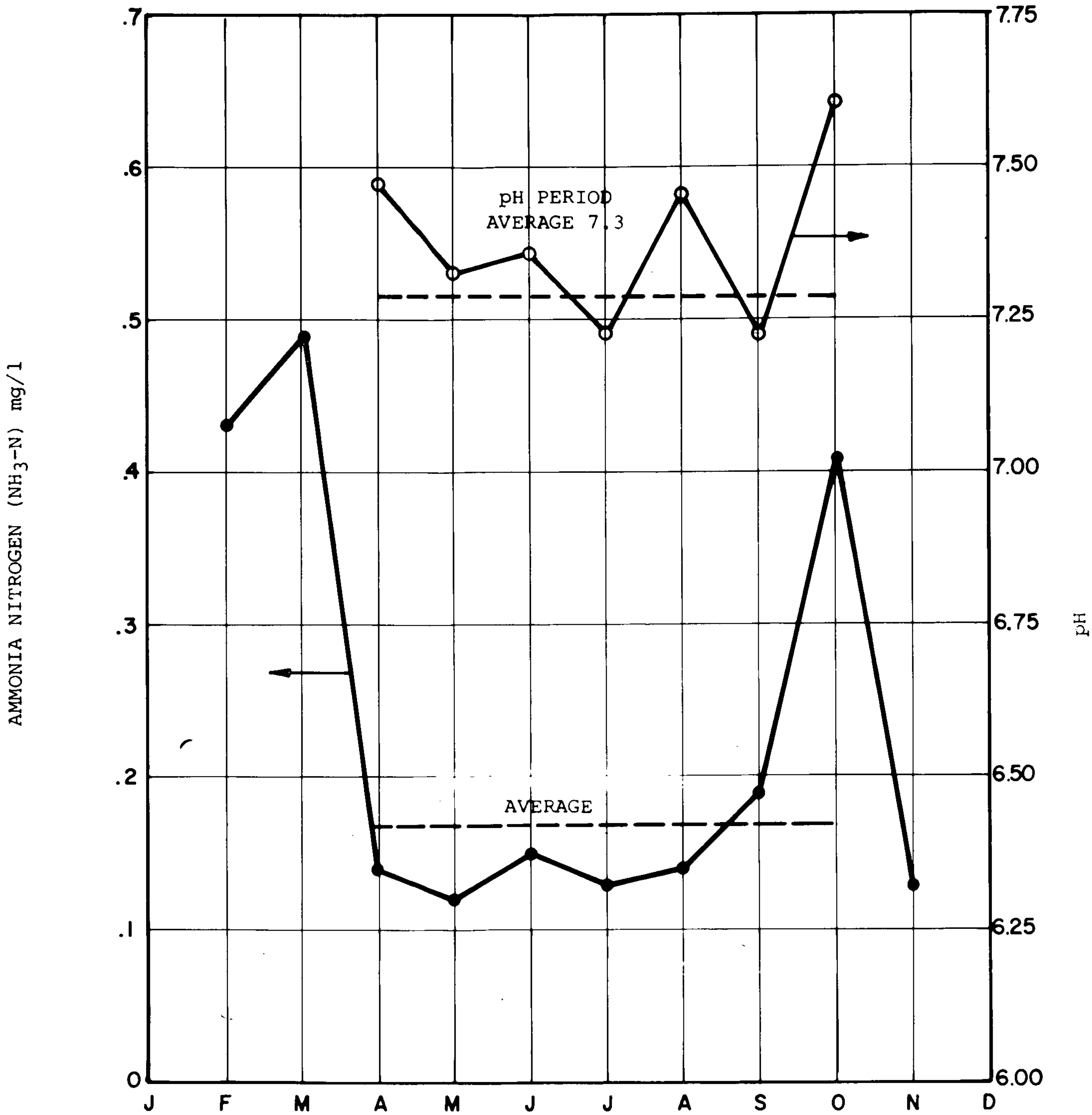
Immediate chlorine demand is a characteristic of natural waters. This value is determined periodically by Indian Point operating personnel using iodometric titration. This method uses potassium iodide, which displaces free chlorine and monochloramine at neutral pH, and which displaces free chlorine, monochloramine and dichloramine at acid pH, followed by titration with sodium thiosulfate. Because of the lower redox potential of iodine, the demand reaction is effectively quenched by potassium iodide addition. The average value for immediate river demand during 1971 and 1972 has been 0.8 mg/l as chlorine at an initial laboratory test concentration of 2.5 mg/l chlorine.

A linear relation of chlorine demand to initial chlorine concentration, in the ratio of 0.8/2.5, has been assumed to apply over a range of initial concentration of 0 to 2.5 mg/l. This assumption is supported by both Con Edison and QL&M laboratory testing at various levels of initial concentration up to 2.5 mg/l.

FIGURE 2

MONTHLY AVERAGE AMMONIA AND pH
HUDSON RIVER AT VERPLANCK, N.Y.
(APRIL 1969-OCTOBER 1972)

Source: NYSDEC Monitoring Station



IV. MODEL CALIBRATION AND APPLICATION

MODEL CALIBRATION

In order to control slime growth in the condenser and auxiliary cooling water system, sodium hypochlorite is fed into one-half of the Unit 1 condenser so as to produce an intended condenser concentration at the condenser outlet box of 1.0 mg/l of available chlorine for thirty minutes three times a week in the late spring, summer, and fall (ambient river temperatures greater than 45°F). The other half is then subsequently chlorinated in a similar manner. This procedure, including dilution by the unchlorinated side of the condenser, results in a maximum condenser effluent concentration of 0.5 mg/l. Since additional breakdown and demand satisfaction occurs downstream of the condenser, this procedure insures that discharge concentrations are always below the maximum allowable discharge level permitted by the New York State Department of Environmental Conservation. The same procedure is to be employed for chlorination of Unit 2.

Before application of the model to determine probable values for Unit 2 discharge concentrations, calibration using data from Unit 1 was performed. This calibration allowed determination of several values which were required for Unit 2 modeling, including evaluation of the overall discharge canal consumption coefficient, K_1 introduced in equation 15. The initial conditions on June 8, 1972 during the field testing for calibration were:

- Initial chlorine concentration (before immediate cooling water demand) = 1.0 mg/l as Cl
- Immediate chlorine demand - 0.7 mg/l at 2.5 mg/l initial chlorine (test value)
- pH and ammonia nitrogen concentrations in the river of 7.2 and 0.25 mg/l, respectively
- Discharge canal temperature of 78° F

Two values which were obtained from the calibration run were the value for the chlorine demand in the condenser (as opposed to the demand of the river water) and the reaction rate for the breakdown of free chlorine to chloride ion. In the absence of ultraviolet (UV) light, the breakdown rate constant (K_1) has been reported to be as high as 0.0025 sec^{-1} was obtained for use in further analysis. This order of magnitude difference will be discussed in the section on interpretation of results.

Figure 3 shows the system in operation at Indian Point Unit 1 and the results of the calibration run. Data for calibration were obtained on June 8, 1972 by QL&M personnel using amperometric titration. As can be seen in Figure 3, by making Point 2 a point of control, the condenser chlorine demand upstream and the breakdown rate of free chlorine downstream can be estimated. That calibration has been effected can be seen from the comparison of field-determined total chlorine values at Points 4, 5, and 6 with the total chlorine value from the model.

Average NYU data, determined by amperometric titration, from 1972 are also shown in Figure 2. These data show the same pattern of chlorine reduction. Combined chlorine values from the model are an order of magnitude below field measurements. This may be caused by the testing errors of extremely low combined chlorine levels, because the concentrations of chloramines found in field testing are at the lower limit of detectability, averaging 10 to 15 percent of the free chlorine concentration.

INDIAN POINT CHLORINE MODEL
CALIBRATION OF MODEL

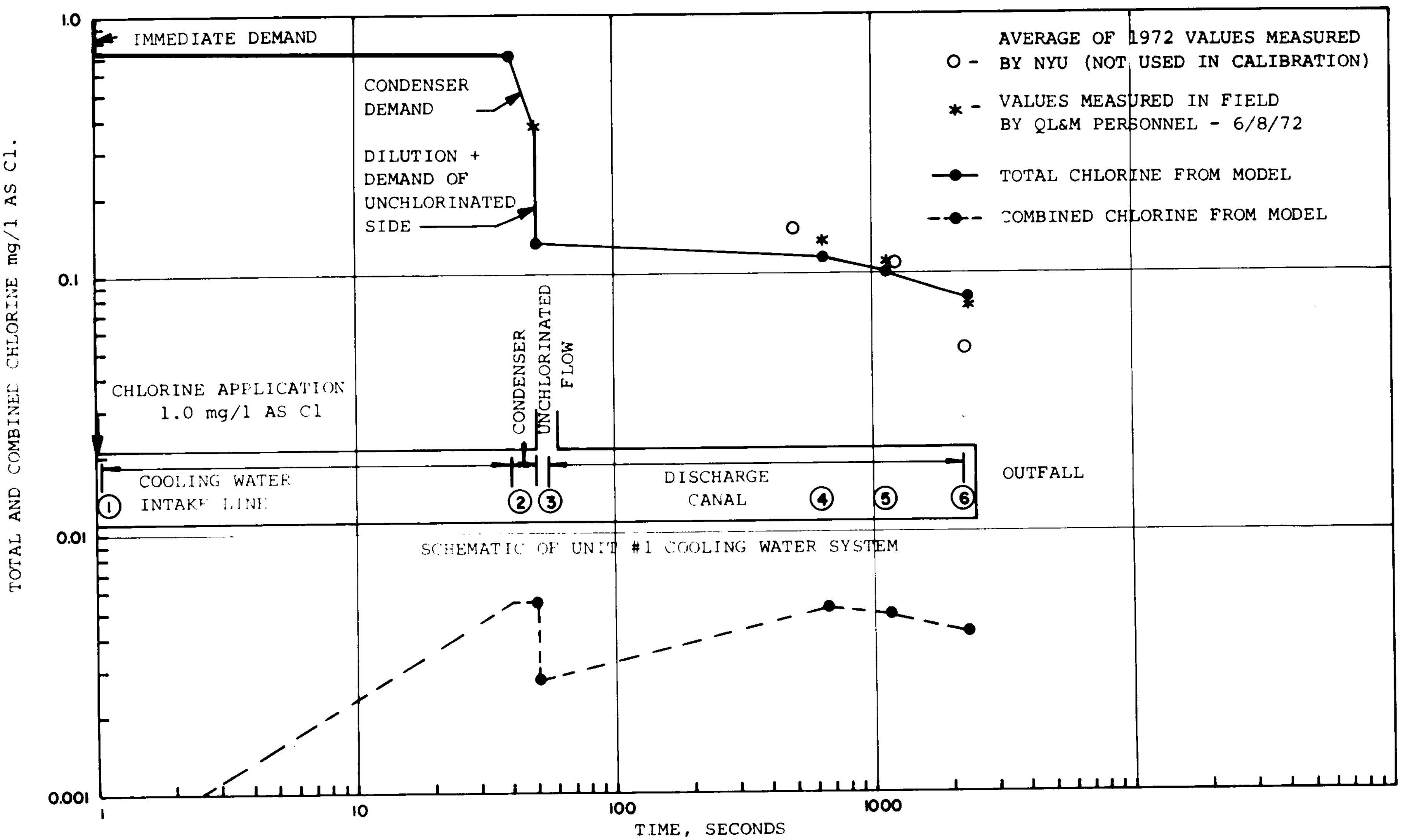


FIGURE 3

MODEL APPLICATION

After the model calibration is completed, the next step is application of the model to determine probable chlorine values at Indian Point Unit 2. A schematic of the Indian Point Unit 2 cooling water system is shown in Figure 4. Sodium hypochlorite is fed into one-half of the Unit 2 condenser so as to produce a maximum condenser concentration at the outlet box of 1.0 mg/l of available chlorine for thirty minutes three times a week in the late spring, summer, and fall (ambient river temperatures greater than 45°F). The other half is then subsequently chlorinated in a similar manner. This procedure will be such that the dilution by the unchlorinated cooling water reduced the maximum total chlorine level to 0.5 mg/l, before the effects of further demand and chlorine breakdown, are considered. The reactions of interest in each segment are:

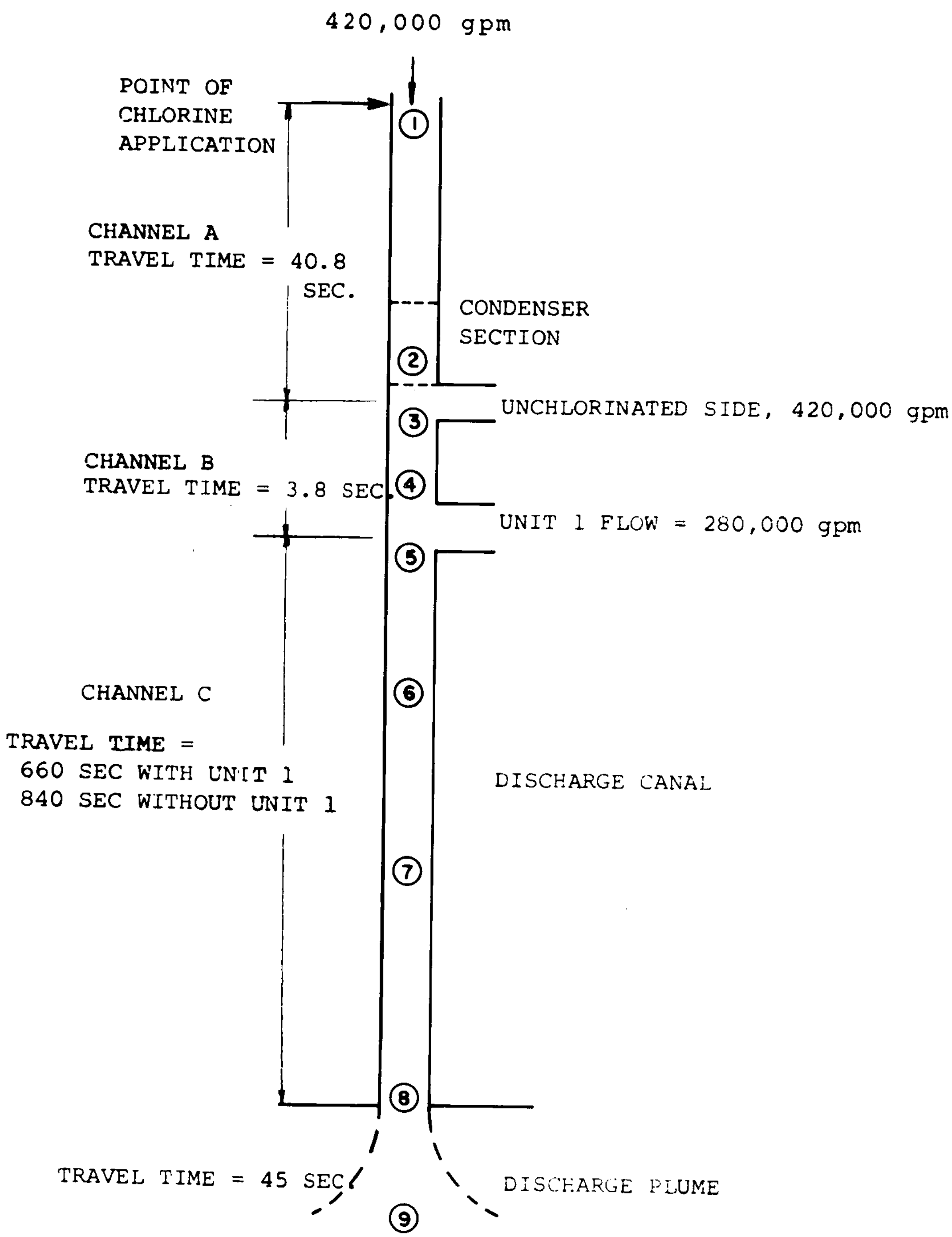
a. Channel A (after chlorine addition)

In accordance with plant operating procedures, chlorine is introduced upstream from the condenser section. This chlorine is subject to the initial demand of the river water, followed by chloramine formation in the section upstream from the condenser. As the condenser section is entered, chlorine demand by the condenser slime begins. Because the chloramine formation rate is dependent on the initial chlorine concentration, the highest initial chlorine concentration employed during the 1972 chlorination period, 2.2 mg/l initial chlorine, was used in Model 2 calculations. The control point for the model is that to be used at Indian Point, namely, the outlet water box. The condenser chlorine concentrations for these conditions can be calculated as follows:

Initial chlorine concentration	=	2.2 mg/l
Immediate demand	=	0.8 mg/l
Chlorine available to the condenser	=	1.4 mg/l
Chlorine concentration at outlet water box	=	1.0 mg/l
Condenser chlorine demand	=	0.4 mg/l

FIGURE 4

SCHEMATIC OF COOLING WATER SYSTEM INDIAN POINT UNIT NO.2



Note that control at the discharge water box simply recognizes that both river immediate demand, and condenser immediate demand, may vary.

b. Channel B (after mixing with the unchlorinated side)

Initial conditions in this segment are based on dilution of 50%, followed by immediate chlorine demand, which reduces the free chlorine according to the assumed linear relationship between chlorine feed and demand. Reduction of free chlorine (Reaction 3) continues at the same rate as in Channel A.

c. Channel C (after mixing with the unchlorinated flow from Unit 1)

At this point, another increment of free chlorine is removed according to the immediate demand relationship used previously in Channel B. Because this channel segment is exposed to sunlight, a higher rate of free chlorine breakdown may be used by since the actual amount of absorbed UV is not known, the value used is that developed in the model calibration. Monochloramine reduction during this period is approximated by using the previously discussed NWQL data to determine a pseudo-zero order reaction rate.

d. Discharge Plume

For computational purposes, no immediate demand was assumed to be exerted in the plume. This is conservative, as NYU plume measurements indicate that chlorine demand does occur in the plume. The plume dilution value recommended by the Staff was used for this calculation.

Results of the model analysis for two conditions, with and without Unit 1 operation, are given in Tables 1 and 2.

EFFECT OF pH VARIATION

Because the pH values obtained at Indian Point have varied between 6.8 and 7.8 over the period since 1967, it was deemed necessary to test the effect of pH on total chlorine and chloramine using the model. Considering the section immediately after chlorine addition, it can be seen in Table 3 that the total chlorine varies less than 1.5% in the pH range 7.0-7.6. The total chloramines, however, show a threefold increase. This increase is to be expected because of the dependence of chloramine formation rate on pH.

Note that the initial ammonia concentration will control the total amount of chloramines formed. Morris' analysis of data by Palin (24) indicates that the breakpoint reaction which removes both ammonia and chlorine goes most rapidly at a pH near 7.2-7.4, the range observed at Verplanck.

CHLORINE TOXICITY DATA

Toxicity values from literature research by the Staff are shown in Figure 5. The plotted points are the 50% tolerance limits (TL 50 or TLM) for several fish species common to the Hudson River (25) and may be considered the only ones relevant to this discussion. The chronic and short-term toxicity curve shown in Figure 5 is that proposed by the Staff (Ref 1, p V-17). Other data collected by the Staff were not used in the figure, either because the test organisms were not native to the Hudson River or because the limits and conditions used in the original test were vague primarily regarding Point 6 on the Staff plot.

TABLE 1

INDIAN POINT UNIT 2 CHLORINE CONCENTRATIONS
(WITH UNIT 1 DISCHARGE)
pH = 7.34

Point***	HOCl + OCl$^-$ (mg/l as Cl)	NH_4^+ + NH_3 (mg/l as N)	NH_2Cl (mg/l as Cl)	$NHCl_2$ (mg/l as Cl)
1	1.400	0.161	0	0
2*	0.995	0.000	0.004	0.001
3	0.338	0.081	0.002	0.001
4	0.334	0.000	0.004	0.001
5	0.170	0.040	0.003	0.000
6 (t** = 174 sec. from Point 5)	0.161	0.000	0.004	0.001
7 (t** = 314 sec. from Point 5)	0.156	0.000	0.003	0.001
8	0.144	0.000	0.002	0.002
9	0.036	0.121	0.001	0.001

*Including effect of condenser demand.
**t = Travel time.
***See Figure 4.

TABLE 2

INDIAN POINT UNIT 2 CHLORINE CONCENTRATIONS
(WITHOUT UNIT 1 DISCHARGE)
pH = 7.34

Point*	$HOCl + OCl^-$ (mg/l as Cl)	$NH_4^+ + NH_3$ (mg/l as N)	NH_2Cl (mg/l as Cl)	$NHCl_2$ (mg/l as Cl)
1	1.400	0.161	0	0
2**	0.995	0.000	0.004	0.001
3	0.338	0.081	0.002	0.001
4	0.334	0.000	0.004	0.001
5	0.334	0.000	0.004	0.001
6 (t***= 221 sec. from Point 5)	0.317	0.000	0.003	0.002
7 (t***= 398 sec. from Point 5)	0.315	0.000	0.002	0.003
8	0.277	0.000	0.001	0.004
9	0.069	0.121	0.000	0.001

* See Figure 4.
** Including effect of condenser demand.
*** t = Travel time.

TABLE 3

EFFECT OF pH ON CHLORINE RESIDUALS AT POINT 2 OF CHANNEL A

pH	Chlorine Residuals* as mg/l Cl		
	Free	Combined	Total
7.00	1.385	0.002	1.387
7.34	1.378	0.005	1.383
7.60	1.363	0.009	1.372

*Not considering condenser demand.

COMPARISON OF TOXICITY VS. CONCENTRATION-DURATION

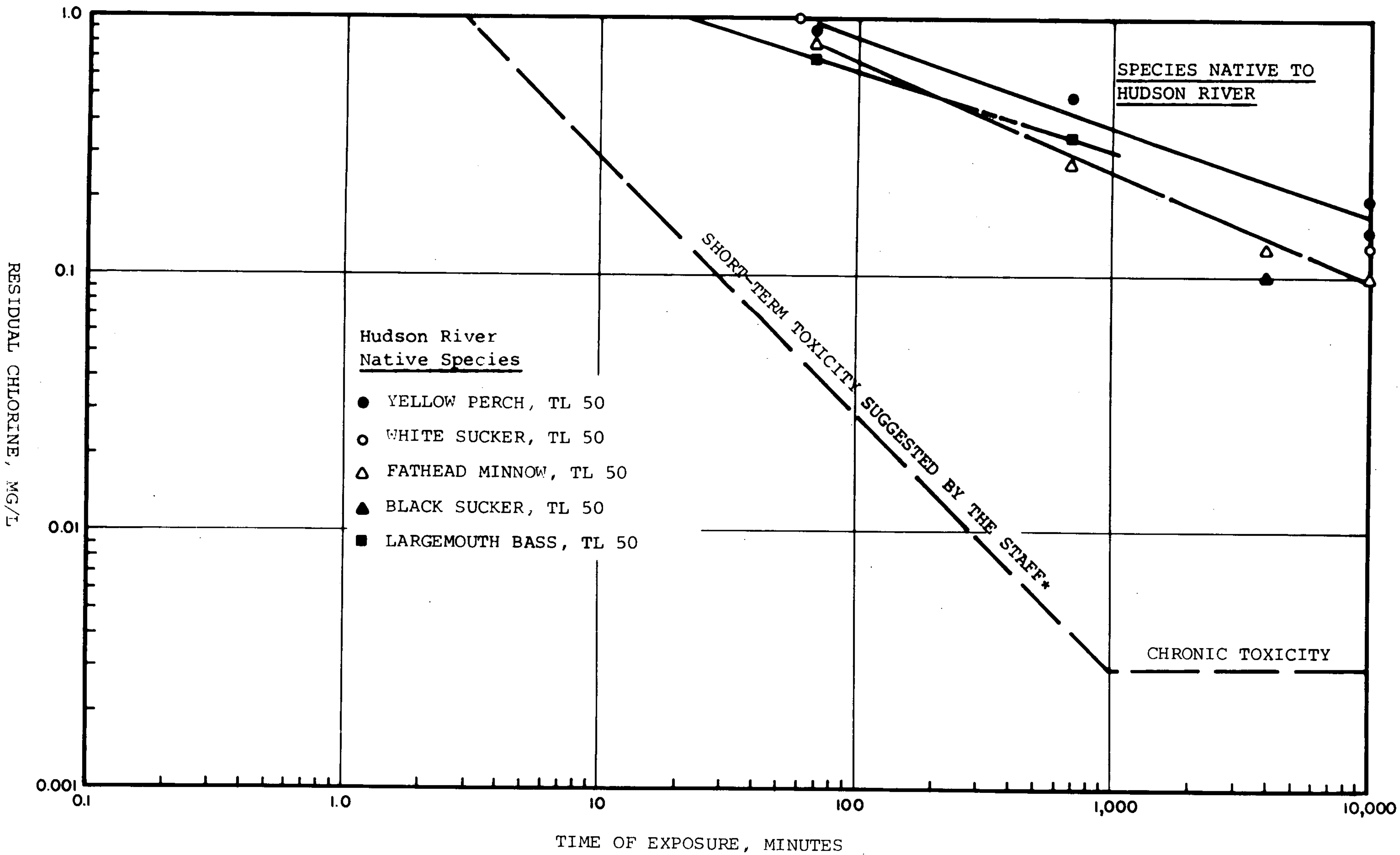


FIGURE 5

*Curve developed using data which included species not resident in the Hudson River

Considering that the relationship between the Staff toxicity curve and the actual data is vague (no toxicity level is given for the Staff curve), that the slope of the curve appears to be arbitrary and not related to the slope of the toxicity duration relationship for selected species as given in the data, and that the majority of the data used by the Staff does not apply to Hudson River biota, it may be concluded that the curve suggested by the Staff should be modified to reflect actual conditions in the Hudson River at Indian Point.

Although an occassional trout has been caught during the River sampling program, this is an extremely rare occurrence and in no way should be interpreted as suggesting that the Hudson River in the vicinity of Indian Point supports a trout population. Trout are simply not resident in the Hudson. Their rare appearance may be explained by the occassional carriage or movement of small numbers of these species into the Hudson from some of its tributaries. For example, the one or few brown trout caught in the vicinity of Indian Point could have come from Cedar Pond Brook in Stony Point, a waterway which does support a brown trout population.

Concerning the question of toxicity of bromine compounds to aquatic species, the only comparative research is that of Kott (23), who compared the effects of chlorine and bromine at 0.18 mg/l and 0.4 mg/l on Chlorella pyrenoidosa, finding their effects to be similar at the 0.18 mg/l level and the 0.4 mg/l level.

V. INTERPRETATION OF RESULTS

EVALUATION OF THE MODEL CALIBRATION RESULTS

The calibration results, with further confirmation by NYU data, are shown in Figure 3. The breakdown rate for free chlorine which fits the model results (0.0002 sec^{-1}) may be conservatively low because chlorinating for testing purposes was done at night to accommodate the NYU biological investigations. Actually all general chlorination is planned for the daytime shift. This means that some additional decay can be expected via the UV mechanism. Some additional investigation would be necessary to tie down the actual increase in rate. UV is absorbed in the near surface water, but this would be offset to some extent by the rapid rate of surface renewal in the turbulent discharge channel.

EVALUATION OF THE UNIT 2 TEST RESULTS

Tables 1 and 2 above show the expected concentration at several points through the system. These values have been converted to concentration-duration relationships in Figures 6 and 7 by plotting the cumulative average exposure to total chlorine with and without Unit 1. These cumulative average concentrations are obtained by dividing the total exposure in mg/l seconds by total elapsed time in seconds. Note that with Unit 1 operation, the cumulative average exposure is not above the curve suggested by the Staff at any point in the channel. Note, also, that with Unit 1 not operating, the average exposure is below the values obtained by the Staff which apply to Hudson River biota.

CUMULATIVE AVERAGE CHLORINE CONCENTRATION VS. TIME
UNIT #2 CHLORINATION WITH UNIT #1 OPERATING

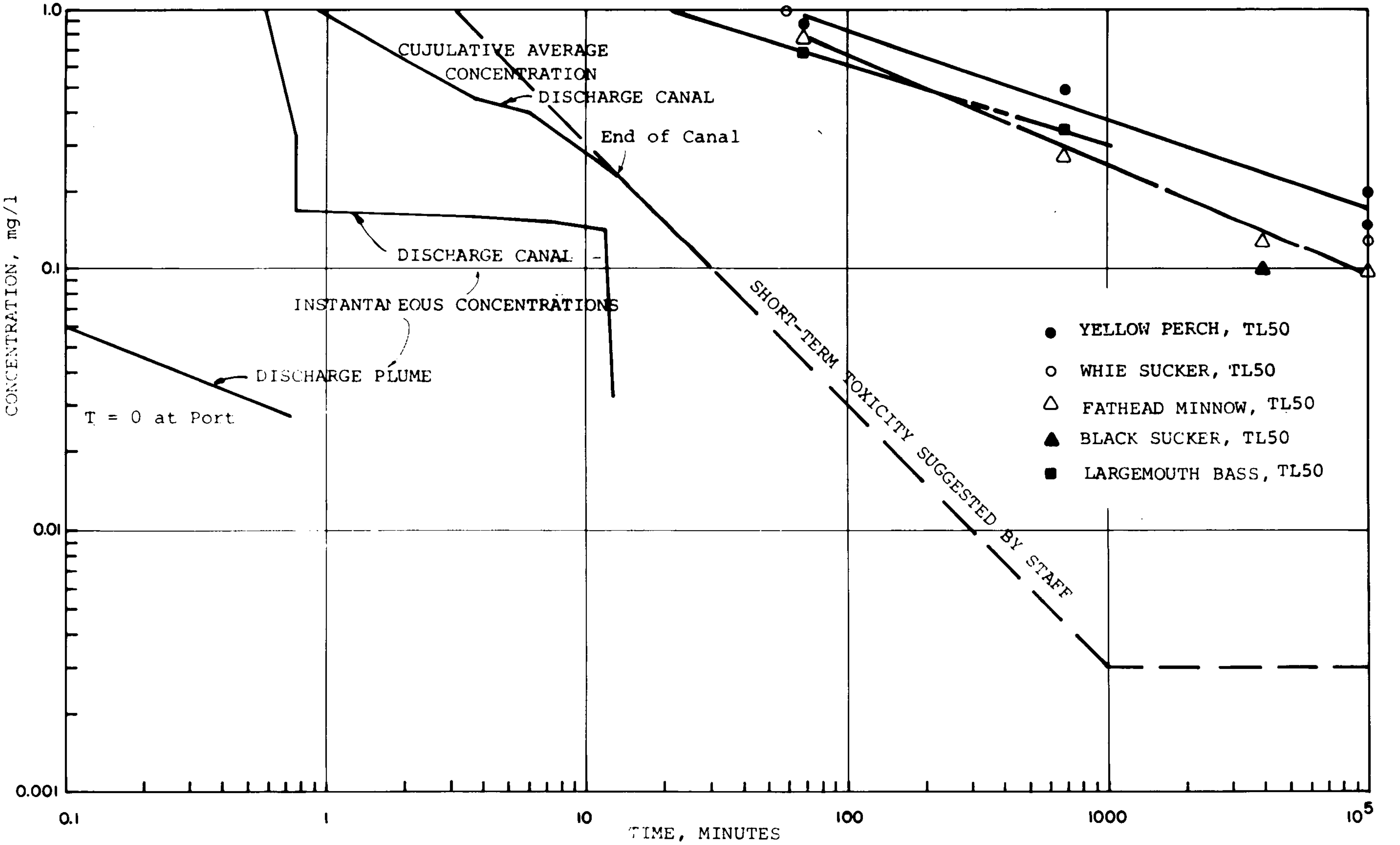


FIGURE 6

CUMULATIVE AVERAGE CHLORINE CONCENTRATION vs. TIME
UNIT #2 WITHOUT UNIT #1

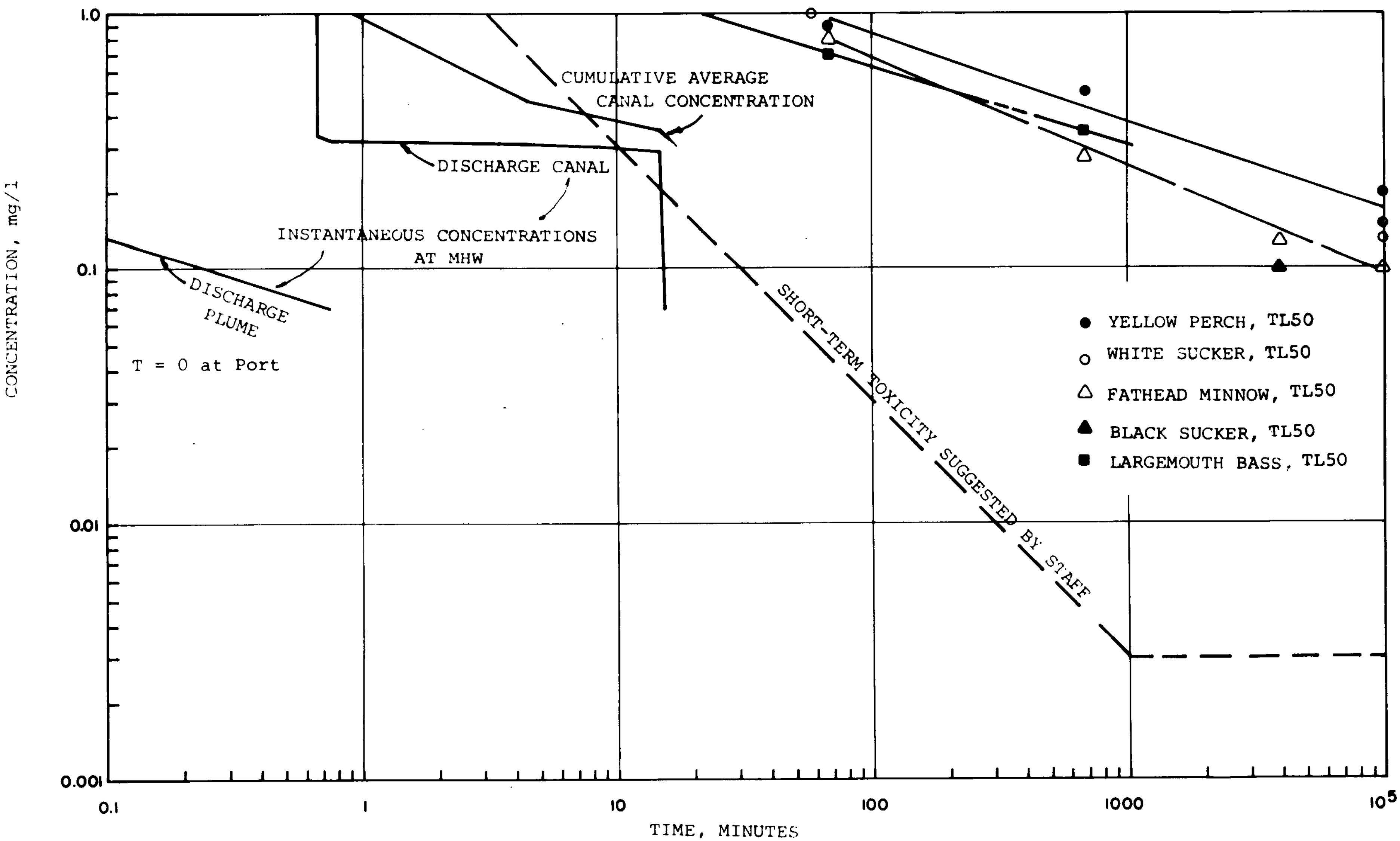


FIGURE 7

Instantaneous chlorine concentrations are also shown in Figures 6 and 7. These figures show the rapid reduction of chlorine in the plume. Because NYU field data fail to show any detectable chlorine in the plume, the actual plume concentrations may be less than those shown in Figures 6 and 7. One possible reason might be the chlorine demand of the water entrained in the plume.

Although the 1.0 mg/l value used for outlet water box concentration of chlorine used in the test runs was selected on the basis of supposed plant operating procedures, observation of actual discharge water box concentrations show that historically the values have been lower. For this reason the residual chlorine concentration values reported above may be in excess of the average concentration which would be experienced during Indian Point Unit 2 chlorination.

EXPECTED CHLORINE LEVELS IN THE HUDSON

After leaving the discharge plume (Point 9), the chlorine concentration would be further reduced by river dilution and chlorine demand. Even without including the effects of dispersion and decay, the long-term steady-state river concentration would be at least two orders of magnitude below the discharge concentration. These values are well below the level suggested by the Staff for chronic toxicity. Once dispersion and decay are included, long-term River chlorine is totally negligible.

REBUTTAL OF PREVIOUS TESTIMONY

Reviewing Mr. Clark's testimony of July 14, 1972 and January 10, 1973, the major areas where misinformation should be corrected are:

a. Expected chlorine concentrations in discharge canal and plume.

b. Lack of consideration of River chlorine demand and ultraviolet-activated decay in the surface layer.

c. Avoidance levels as given not specific to Hudson River species.

The first point, expected chlorine concentrations, are described as follows by Mr. Clark in response to questioning on his support for the chlorine concentrations appearing in his testimony:

"THE WITNESS (JOHN R. CLARK): I neither did nor did not. I merely assumed that -- I set up a hypothetical case, where there would be a half part per million of chlorine associated with a discharge temperature of 5 or 6 degrees.

How it got to be five or six degrees, I don't know. Or in fact whether that would be probable in terms of the amount of chlorine action (sic) you are going to have to use at different times of the year and so on. I don't know. I am just setting that up as a hypothetical case.

If that were the prevailing situation in the discharge, what kind *of spread you might get across the river."* (TR #7930)

Mr. Clark appears to have associated his surface river concentration of 0.5 mg/l as being the level permitted by the NYSDEC. In fact, the State Standard refers to the discharge and not river concentration. Clark's assertion does not consider the previously discusssed factors which reduce chlorine in the canal to less than 0.15 mg/l, or the dilution in the plume, which would be of 3:1 dilution at the five degree isotherm. When these considerations are introduced, the concentration at the surface should be 0.05 mg/l or less instead of the 0.5 mg/l according to Clark. This does not include the chlorine demand of the entrained river water, which has been discussed in a previous section.

The second point, lack of consideration of the effects of river chlorine demand is seen in the following testimony: (TR #7929)

"Q. (By Mr. Trosten): Just before we adjourned, Mr. Clark, I believe you indicated that you did not take into account the chlorine demand of the river water in drawing these comparative distributions of chlorine and the heat in the river. Is that correct?

A. Yes, that is correct."

The concept of chlorine demand by Hudson River water has the support of weekly measurements by Indian Point operating personnel. During the previous five years of operation of Unit #1, this demand has not fallen below 0.3 mg/l at a dosage of 2.5 mg/l, and has been as high as 1.8 mg/l at 2.5 mg/l dosage. Although this demand is dosage-related, some demand should be felt at all dosage levels, however small. A second consideration is the UV activated breakdown of chlorine, which will occur more rapidly after the discharge plume has spread across the surface.

The third point, that of avoidance of chlorine by marine forms, is shown as follows. (TR #7937)

"Q. Mr. Clark, what data support the hypothesis stated in Figure 3 that intermittent exposure to chlorine in the amount of one 100th part per million would repulse mobile forms which are found in the river?

A. You are asking for a reference to this?

Q. Yes.

Is this McKee and Wolf?

A. No. The information repulsion is from another source.

In trying to check this through myself, I got a little bit confused, and I am going to have to clarify that later. I have somehow not carried through into this the suitable reference for that particular value. I rather anticipated the question, so in trying to check it out, I find I had a missing item in my bibliography, which I will try to rectify for you.

But in the meantime, in a book called "Biological Aspects of Thermal Pollution," page 173, there is a statement of research done by Trembley showing that chlorinated plumes had somewhat less fish in them, less fish of each species, but not a lesser number of species.

Q. You will supply then the data reference for the repulsion, is that correct?

A. I will try to find the one that relates specifically to a numerical estimate.

Let me give it to you now and still check it later and make sure, but I think it is Sprig and Drury (sic).

Q. Sprig and Drury?

A. Yes. Would you like me to read it?

Q. Yes, please.

A. It is Sprig, J.B., if you have the EIS in front of you, it it also listed in page B-95. This is Item 28.

That will avoid having to spell it out.

Q. All right.

Now, Mr. Clark, if, in fact, fish were repulsed by concentrations of one 100th part per million, wouldn't this fact safeguard them against exposure to higher concentrations of chlorine?

A. Yes."

Reference 28, listed on page V-95 of the Staff Final Statement is in fact:

> Sprague, J.B. and Drury, D.E. "Avoidance Reactions of Salmonid Fish to Representative Pollutants "Advances in Water Pollution Research, Proc. 4th Int'l Conf., 1969

As discussed above, data obtained for salmonid fish is less applicable than is data for native Hudson River species. Since the toxic levels of chlorine for salmonids are an order of magnitude below that of non-salmonids, it might be expected that avoidance levels of salmonids are also lower than those of non-salmonids.

The final contentions of this rebuttal with respect to Mr. Clark's testimony are: first, that his assumptions regarding chlorine concentrations are in error by at least one order of magnitude, and second, that his conclusion regarding chlorine blockage of migrating fish is in error.

Reviewing the Staff's Final Statement dated September 1972, several points require correction.

- Although river ammonia concentrations of 0.5 mg/l have been reported, the average during the chlorination period is 0.16 mg/l as NH_3-N. This implies that the levels of chloramine to be expected are not as high as though by the Staff.

- Mono and dichloramine do not exhibit an equilibrium relationship as shown on page A-V-23. Rather, their relative concentration is governed by their respective formation rates. This has been determined by Morris (24).

VI. FINDINGS AND CONCLUSIONS

The foregoing analysis has described the expected concentrations of biologically active forms of chlorine in the discharge channel and in the cooling water discharge jet for two conditions of Indian Point operation, with and without Unit 1. Review of the data presented and their interpretation as well as of the literature discloses the following:

1. The model developed by QL&M and calibrated using field data obtained by QL&M includes the important time dependent reactions affecting chlorine, and the non-time dependent reactions are included by mass balance.

2. Application of this model to Indian Point Unit 2 results in cumulative exposures to total chlorine in the discharge canal which do not rise above those proposed by the Staff when Unit 1 is operating, and which are below those of the data applicable to Hudson River biota obtained by the Staff when Unit 1 is not operating.

3. Variation in hydrogen ion concentration (pH) will be of less importance with respect to chloramine formation than will the ammonia concentration. This is because of the low level (0.2 mg/l) of ammonia found in the Hudson during the chlorination period. Note that the total chlorine concentration falls as the pH rises, indicating that the increase in chloramine, due to pH, would be more than balanced by a decrease in free chlorine (in terms of concentration).

4. The chlorine toxicity curve suggested by the Staff would be made more applicable to the Hudson River in the vicinity of Indian Point by consideration of only those biota actually present at and native to Indian Point.

5. Concentrations of chlorine found in the river, under all conditions, will be below the chronic toxicity level proposed by the Staff, even after disregarding reduction by decay and dispersion. This is further supported by discharge plume measurements by NYU, with river chlorine concentrations below the level of detectability.

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BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit 2)	)))))	Docket No. 50-247

Redirect-Rebuttal Testimony of John P. Lawler, Ph.D. Quirk, Lawler & Matusky Engineers on the Thermal Effects of Indian Point Cooling Water on the Hudson River

February 5, 1973

I. INTRODUCTION

This document presents redirect-rebuttal testimony on the AEC Regulatory Staff's evaluation of the thermal effects of Indian Point Unit 2 on Hudson River temperature distribution as presented in the Final Environmental Statement for Indian Point 2 ("Final Statement") and the December 7, 1972 transcript (Tr. 6883-6926).

QL&M has been analyzing the thermal effects of the Indian Point project on the Hudson River since 1967. The results of these analyses appear in the Applicant's Environmental Report as Appendices A, I, J, M and N. Some of these analyses are referenced in the Final Statement (pages III-77 through III-81). These studies have been reviewed for Indian Point 2 and summarized in a report dated February 1972 (Reference 1)* and in the testimony introduced into evidence on April 5, 1972 (follows Tr. 4831). In addition, comments, including supplemental studies (Reference 2), have been submitted to the Staff by Consolidated Edison on the Draft Detailed Statement for Indian Point 2 issued on April 13, 1972 (Reference 4). These comments have also been introduced into evidence in this proceeding (follows Tr. 5797).

This testimony addresses itself to certain statements and conclusions made by the Regulatory Staff ("the Staff") in the Final Statement for Indian Point 2, in a letter of November 10, 1972 from the staff revising previous predictions which were based upon an error in the Staff's model and in statements made by the Staff in this proceeding (Tr. 6891-6926). The Staff's conclusions

*See references listed in Appendix A attached hereto.

are either in disagreement with the results of Applicant analyses referenced above or in error.

For convenience, the following tabulation correlates the topics relating to thermal effects of Indian Point cooling water on the Hudson River with the References set forth in the attached Appendix A.

Topic	Reference
1. Far-Field Thermal Models	1,3,6,7,10,14
2. Near-Field Thermal Models	1,2,3,8,13
3. Hydraulic Models	6,7,8,15,16
4. Hydrodynamic Characteristics of the Hudson River	1,3,5,6,7,9,10,11,12,14, 17
5. Density-Induced Circulation or Net Non-Tidal Flow in the Hudson River	1,3,9,10,12,13,14
6. Evaluation of the Influence of Intake Recirculation on Temperature Distribution	1,3,15,16
7. Selection of River Dispersion Coefficients	1,3,5,6,10,11,18
8. Selection of Thermal Stratification Factors	1,3,7,13,14
9. Selection of River Freshwater Flow Volumes	1,3,6,7,10,12
10. Evaluation of Submerged Jet Dilution Values	1,2,3,8
11. Evaluation of Surface Heat Exchange Coefficient	1,3,6,14
12. Evaluation of Intra-Tidal Temperature Distribution (Variation within Tidal Cycle)	1,3
13. Field Studies Used To Select System Parameter Values	1,3,12
14. Applicability of the Far-Field Models to Thermal Discharges	1,3

II. RIVER SURFACE AND CROSS-SECTIONAL TEMPERATURE DISTRIBUTION

I disagree with the Staff's conclusion (pages ii and III-48) that the New York State thermal discharge criteria relative to surface width and cross-sectional area bounded by temperature rises of 4°F will probably not be met during two-unit operation at Indian Point. This conclusion has been based on the Staff parametric study which included significant errors as demonstrated later in this testimony.

Although it is stated in the Final Statement (page III-41) that the Staff parametric study was based on QL&M's dispersion model presented in Reference [7], the Staff misinterpreted the basic equations of the model:

$$\Delta \bar{T}_o = \frac{H}{\rho \; C_p \; Q \sqrt{1 + 4K'E/U^2}} \quad \ldots\ldots\ldots(1)$$

where:

$\Delta \bar{T}_o$ = average cross-sectional temperature rise at plane of discharge, °F

H = heat load, BTU/day

ρ = water density, lb/ft^3

C_p = water heat capacity, BTU/lb °F

Q = river freshwater flow, ft^3/day

K' = temperature decay coefficient, day^{-1}

E = longitudinal dispersion coefficient, square miles/day

U = freshwater velocity, miles/day

and

$$K' = \frac{\bar{K} \; B}{\rho \; C_p \; A} \; (TSF) \quad \ldots\ldots\ldots(2)$$

where:

$\overline{K}$ = surface heat transfer coefficient, BTU/ft^2 - °F-day

B = river width, ft

A = river cross-sectional area, ft^2

TSF = thermal stratification factor

First, the recirculation of heated water between the discharge and intake will not affect the value of the net heat load (BTU/day) rejected to receiving water bodies by a power plant. The river at steady-state will respond only to the net heat discharged to the river:

$$H = Q_c \rho C_p \Delta T_p$$

where: H = heat load discharge to the river, BTU/day

Q_c = cooling water flow, ft /day^3

ΔT_p = temperature rise of cooling water in condensers, °F

The values of cross-sectional average as well as surface average temperature rises should, therefore, be exactly the same for all those cases which reflect the same conditions except the factor of recirculation. For such cases, however, Table III-5a of the Final Statement as well as its revised version submitted on December 4, 1972 indicates different values (for example, see cases 1, 2,and 3 and cases 25, 26, and 27). A higher discharge temperature only affects the relative temperature distribution over cross-sectional area and surface width.

The Staff erroneously increased the cross-sectional average temperature rise with an increased factor of recirculation (Staff's computer program line 0070), as follows:

$$\Delta\overline{T}_r = \Delta\overline{T}_o (1 + R) \quad ....(3)$$

where:

$\Delta\overline{T}_r$ = cross-sectional average temperature rise under conditions of recirculation, °F

$\Delta\overline{T}_o$ = cross-sectional average temperature rise without recirculation, °F

R = recirculation factor, temperature rise of intake above ambient temperature (ΔT_r) divided by condenser temperature rise (ΔT_c) = $\Delta T_r / \Delta T_c$

As indicated by Equation 1 of this testimony, and confirmed by the Staff in this proceeding (line 10, Tr. 6912), this increase in cross-sectional average temperature rise corresponds to an increase in heat load by the same factor, i.e.:

$$H = Q_c \rho C_p \Delta T_p (1.0 + R) \quad ....(4)$$

As mentioned before and confirmed by the Staff in this proceeding (line 5, Tr. 6914), the incorporation of the influence of recirculation as shown in Equation 4 is incorrect. Therefore, recirculation does not affect the heat rejection rate from the plant to the river. Furthermore, since net heat rate does not vary with the degree of recirculation, the area average and surface-average temperature rises, which are indicators of the far-field effect, also do not vary, provided TSF is held constant. This was confirmed by the Staff in this proceeding (see lines 16 and 17, Tr. 6913).

Moreover, the Staff's conclusions as presented in the Final Statement on pages ii and III-48 were derived using the Staff's computer program which included an additional error. This additional error was recently discovered by the Staff and revised versions of Tables III-5a and III-5b were introduced into evidence in this proceeding on December 4, 1972.

However, since the Staff's conclusions have not been amended and since, as it will be shown later, that elimination of this error from the Staff's analysis results in a significant difference in the final results, a brief description of this additional error and its significance is given below.

The Staff erred in its computer program development in that the heat rate H, substituted in Equation (1), was calculated as follows:

(a) No recirculation

$$H_0 = \rho C_p Q_c \Delta t$$

(b) Recirculation factor $R_1 = 0.075$

$$H_1 = H_0 (1 + R_1) = 1.075 H_O$$

(c) Recirculation factor $R_2 = 0.100$

$$H_2 = H_1 (1 + R_2) = H_0 (1 + R_1) (1 + R_2) = 1.183 H_O$$

(d) Recirculation factor $R_3 = 0.125$

$$H_3 = H_2 (1 + R_3) = H_0 (1 + R_1) (1 + R_2) (1 + R_3) = 1.330 H_O$$

As an illustration, Cases 25, 26, and 27 in Table III-5a in the Final Statement represent exactly the same conditions, except for the factor of recirculation; therefore, the area-average as well as surface-average temperature rises should be the same for all three cases, i.e., $\Delta\overline{T} = 1.82°F$ and $\Delta\overline{T}_s = 3.64°F$ (TSF = 2.0). However, in the analysis presented in the Final Statement, the Staff calculated these temperature rises as follows:

Case 25: Recirculation factor $R_1 = 0.075$

$$\Delta\overline{T} = 1.82 \times (1 + 0.075) = 1.96 \simeq 2.0\ °F$$

$$\Delta\overline{T}_s = 1.96 \times 2.0 = 3.92 \simeq 3.9\ °F$$

or 11% in excess of the properly computed values of 1.8 °F and 3.6 °F

Case 26: Recirculation factor $R_2 = 0.100$

$$\Delta\overline{T} = 1.82 \times 1.075 \times 1.100 = 2.16 \simeq 2.2\ °F$$

$$\Delta\overline{T}_s = 2.16 \times 2.0 = 4.32 \simeq 4.3\ °F$$

or 22% in excess of the properly computed values of 1.8 °F and 3.6 °F

Case 27: Recirculation factor $R_3 = 0.125$

$$\Delta\overline{T} = 1.82 \times 1.075 \times 1.100 \times 1.125 = 2.42 \simeq 2.4\ °F$$

$$\Delta\overline{T}_s = 2.42 \times 2.0 = 4.84 \simeq 4.8\ °F$$

or 33% in excess of the properly computed values of 1.8 °F and 3.6°F

The above comments also apply to the Staff's use of the density-induced circulation model and its accompanying results as presented in Table III-5b. The same errors in principle and computations were made. In addition, the second column in the table, labeled river freshwater flow, should be upper layer flow; otherwise the model is incorrectly used. Further discussion of these results appears on pages 12 and 13 of this testimony.

The above-presented discussion concerned itself with improper use by the Staff of the recirculation factor and does not imply that one must not consider recirculation effects. In fact and as indicated in previously submitted documents (1, 2, 3, and 7) as well as in this proceeding (Tr. 6925), the Applicant did consider recirculation effects in determining the near-field thermal effects of two-unit operation on the Hudson River, as shown below.

1. In establishing compliance with the New York State maximum surface temperature rise criterion of 90° F, the Applicant added 1° F to the predicted maximum surface temperature rise (computed using QL&M's submerged discharge near-field model presented in References 2 and 7) to account for the recirculation effects. (See items 3 and 4 on page S-2 of the April 5, 1972 testimony, Reference 3.) As shown in Reference 3 (last paragraph on page 18), employment of 1° F rise to represent recirculation effects throughout the tidal cycle is an extremely conservative assumption.

2. As mentioned before, intake recirculation results in an increase in the discharge canal temperature. This increase only affects the relative temperature distribution over river cross-sectional area and surface width, and does not affect the overall river temperature rises, i.e., recirculation does not affect the area and surface average temperature rise ($\Delta\overline{T}$ and $\Delta\overline{T}_S$) in the river since these parameters are only affected by the net heat load rejected to the river.

To incorporate the influence of an increase in discharge canal temperature rises due to recirculation, the Applicant increased the maximum temperature rise experienced by the river (ΔT_m) and maximum surface temperature rise (ΔT_{sm}) by an appropriate temperature rise above ambient conditions due to recirculation (ΔT_r) and kept the overall river rises ($\Delta \overline{T}$ and $\Delta \overline{T}_s$) unaffected by recirculation, i.e.:

ΔT_m = $\Delta T_c + \Delta T_r = \Delta T_c\ (1+R)$ ....(5)

ΔT_{sm} = $\Delta T_m/\text{Dil.}$ ....(6)

$\Delta \overline{T}_o$ = Equation 1 for plane of discharge ....(7)

$\Delta \overline{T}_s$ = $\Delta \overline{T}_o \times \text{TSF}$ ....(8)

in which:

ΔT_m = maximum temperature rise experienced by the river or plant discharge temperature rise, °F

ΔT_{sm} = maximum river surface temperature rise above ambient conditions, °F

Dil = Submerged jet dilution ratio

Equations 5 through 8 were used in conjunction with the exponential decay models (References 1, 3, and 7) to determine the plant thermal effects on the river and, therefore, the recirculation effects were incorporated in the Applicant's analysis.

On the other hand, the equations used in the Staff's model may be expressed as follows:

$$\Delta T_m = \Delta T_c + \Delta T_r = \Delta T_c\ (1+R) \quad (9)$$

$$\Delta T_{sm} = \Delta T_m/Dil \quad (10)$$

$$\Delta\overline{T}_{AEC} = \Delta\overline{T}_o\ (1 + R) = \Delta\overline{T}_o\ \left(1 + \frac{\Delta T_r}{\Delta T_c}\right) \quad (11)$$

$$\Delta\overline{T}_{s_{AEC}} = \Delta\overline{T}_o \times TSF \times \left(1 + \frac{\Delta T_r}{\Delta T_c}\right) \quad (12)$$

Notice that the Staff did apply the effect of recirculation properly in Equations 9 and 10, but not in Equations 11 and 12. Equations 9 and 10 are exactly the same as Equations 5 and 6. However, Equations 11 and 12 cannot be used to determine parameters capable of describing the response of a waterbody to a known net plant heat load. Employment of Equations 11 and 12 is tantamount to inserting the near-field phenomenon of recirculation in a far-field model. As confirmed by the Staff in this proceeding (line 5 of Tr. 6914), this insertion results in an invalid evaluation of the near-field effects.

The Applicant evaluated the near-field and plane of discharge effects using Equations 5 through 8, the exponential decay models (References 1, 3, and 7), hydraulic models (References 6, 7, 8, 15, and 16), and mathematical submerged discharge models (References 1, 2, 3, and 8). It is to be stressed at this point that the exponential decay models were developed using actual near-field as well as far-field temperature data (Tr. 6923).

I disagree with the statement indicating that the Applicant's model is not capable of predicting thermal effects under the most severe tidal conditions (page III-48) and similar statements made by the Staff in this proceeding (Tr. 6898 and 6899) to justify use of the above-described invalid method. The empirical factor (CTP/TA) was introduced to the model to allow conversion of the tidal average effects in terms of percent surface width and cross-sectional area bounded by 4°F to conditions reflecting critical tidal phase (see pages 16 through 19 of the April 5, 1972 testimony, [Reference 3]). The factor CTP/TA is based on numerous measurements conducted by QL&M in the Hudson River at different locations. These measurements also indicate a high stability of this factor at a value of 1.3.

III. SIGNIFICANCE OF ELIMINATION OF THE RECIRCULATION ERRORS FROM THE STAFF'S ANALYSIS

This section compares the results presented in the original as well as updated Tables III-5a and III-5b of the Final Statement with their properly computed counterparts. The results given in the Final Statement included both of the above-described errors, i.e., insertion of the recirculation factor in the far-field model error and the loop error in the Staff's computer program development discussed on pages 4 through 7. The revised results presented in the updated Tables III-5a and III-5b included the improper use of the recirculation effect but not the loop error. The properly computed results eliminate both errors from the analysis.

For convenience of presentation, these three sets of results have been designated the original Staff, revised Staff and properly computed results, respectively.

Table 1 compares the revised staff results presented in the updated Table III-5a with their properly computed counterparts. Tables 2 and 3 present and compare properly computed values with the updated Table III-5b values.

The staff incorrectly used the Applicant's density-induced circulation model (Table III-5b) and did not recognize the difference between the incipient salt flow (ISF) and upper layer flow conditions. A detailed description of this difference and of applicability of the ISF model and upper layer model to Indian Point is given on pages 6 through 12 of the April 5, 1972 testimony, Reference 3. As indicated in References 3 and 12, the ISF model cannot be used in the Indian Point case when the fresh water flow in the river is less than about

TABLE 1

FRACTIONS OF SURFACE WIDTH AND CROSS-SECTIONAL AREA WITHIN 4°F TEMPERATURE RISE CALCULATED BY AEC AND QL&M FOR PLANE OF DISCHARGE AT INDIAN POINT*

SUMMER CONDITIONS (HEAT TRANSFER COEFFICIENT = 130 BTU/FT^2/°F/DAY)
SUBMERGED JET DILUTION RATIO = 3

Case**	River Freshwater Flow, cfs	Dispersion Coefficient sq. mi./d	Thermal Stratification Factor	Intake Recirculation Factor	Fraction of Total Width Within 4°F Isotherm		Fraction of River Area Within 4°F Isotherm	
					AEC	QL&M	AEC	QL&M
1	4,000	4.0	1.0	0.075	0.52	0.40	0.36	0.33
2	4,000	4.0	1.0	0.100	0.56	0.40	0.37	0.33
3	4,000	4.0	1.0	0.125	0.59	0.40	0.37	0.33
4	4,000	4.0	1.5	0.075	2.38	1.22	0.30	0.28
5	4,000	5.0	1.0	0.075	0.39	0.31	0.33	0.30
6	4,000	5.0	1.0	0.125	0.45	0.32	0.34	0.30
7	4,000	5.0	1.5	0.075	0.94	0.66	0.27	0.25
8	4,000	6.0	1.0	0.125	0.37	0.27	0.31	0.27
9	4,000	6.0	1.5	0.075	0.62	0.47	0.25	0.23
10	4,000	6.0	1.5	0.100	0.66	0.46	0.25	0.22
11	4,000	6.0	2.0	0.075	1.63	0.98	0.22	0.20
12	4,000	6.0	2.0	0.100	1.76	0.90	0.22	0.20
13	4,000	7.0	1.0	0.125	0.33	0.24	0.29	0.25
14	4,000	7.0	1.5	0.075	0.49	0.37	0.23	0.21
15	4,000	7.0	1.5	0.100	0.52	0.38	0.23	0.21
16	4,000	7.0	1.5	0.125	0.56	0.39	0.24	0.21
17	4,000	7.0	2.0	0.075	0.93	0.65	0.20	0.19
18	4,000	7.0	2.0	0.100	1.00	0.63	0.20	0.19
19	4,000	8.0	1.5	0.100	0.43	0.28	0.22	0.19
20	4,000	8.0	1.5	0.125	0.46	0.32	0.22	0.20
21	4,000	8.0	2.0	0.075	0.67	0.50	0.19	0.18
22	4,000	8.0	2.0	0.100	0.72	0.49	0.19	0.17
23	4,000	8.0	2.5	0.075	1.36	0.86	0.17	0.16
24	4,000	10.0	1.5	0.125	0.36	0.26	0.20	0.18
25	4,000	10.0	2.0	0.075	0.46	0.36	0.17	0.16

TABLE 1

(continued)

Case**	River Freshwater Flow, cfs	Dispersion Coefficient sq. mi./d	Thermal Stratification Factor	Intake Recirculation Factor	Fraction of Total Width Within 4°F Isotherm		Fraction of River Area Within 4°F Isotherm	
					AEC	QL&M	AEC	QL&M
26	4,000	10.0	2.0	0.100	0.49	0.36	0.17	0.16
27	4,000	10.0	2.0	0.125	0.52	0.36	0.17	0.16
28	4,000	10.0	2.5	0.075	0.69	0.51	0.15	0.14
29	4,000	10.0	2.5	0.100	0.75	0.44	0.15	0.13
30	4,000	10.0	3.0	0.075	1.22	0.79	0.14	0.13
31	4,000	12.0	1.5	0.125	0.31	0.22	0.18	0.16
32	4,000	12.0	1.5	0.150	0.32	0.22	0.19	0.16
33	4,000	12.0	2.0	0.100	0.39	0.29	0.16	0.14
34	4,000	12.0	2.0	0.125	0.42	0.30	0.16	0.14
35	4,000	12.0	2.0	0.150	0.44	0.30	0.16	0.14
36	4,000	12.0	2.5	0.075	0.50	0.38	0.14	0.13
37	4,000	12.0	2.5	0.100	0.54	0.38	0.14	0.13
38	4,000	12.0	2.5	0.125	0.57	0.39	0.14	0.13
39	4,000	12.0	3.0	0.075	0.71	0.53	0.13	0.12
40	4,000	12.0	3.0	0.100	0.76	0.52	0.13	0.12
41	7,000	4.0	1.5	0.075	0.88	0.62	0.27	0.25
42	7,000	4.0	1.5	0.100	0.94	0.61	0.27	0.25
43	7,000	5.0	1.5	0.075	0.60	0.45	0.25	0.23
44	7,000	5.0	1.5	0.100	0.65	0.45	0.25	0.23
45	7,000	6.0	1.5	0.075	0.47	0.36	0.23	0.21
46	7,000	6.0	1.5	0.100	0.51	0.37	0.23	0.21
47	7,000	6.0	2.0	0.075	0.99	0.69	0.20	0.19
48	7,000	6.0	2.0	0.100	1.06	0.65	0.21	0.19
49	7,000	7.0	1.5	0.100	0.43	0.32	0.22	0.20
50	7,000	7.0	2.0	0.750	0.70	0.52	0.19	0.18

TABLE 1

(continued)

Case**	River Freshwater Flow, cfs	Dispersion Coefficient sq. mi./d	Thermal Stratification Factor	Intake Recirculation Factor	Fraction of Total Width Within 4°F Isotherm		Fraction of River Area Within 4°F Isotherm	
					AEC	QL&M	AEC	QL&M
51	7,000	7.0	2.0	0.100	0.75	0.51	0.19	0.18
52	7,000	8.0	1.5	0.100	0.38	0.28	0.21	0.19
53	7,000	8.0	1.5	0.125	0.40	0.28	0.21	0.19
54	7,000	8.0	2.0	0.075	0.55	0.42	0.18	0.17
55	7,000	8.0	2.0	0.100	0.59	0.42	0.18	0.17
56	7,000	8.0	2.5	0.075	1.02	0.70	0.16	0.15
57	7,000	10.0	1.5	0.100	0.31	0.23	0.19	0.17
58	7,000	10.0	1.5	0.125	0.33	0.23	0.19	0.17
59	7,000	10.0	2.0	0.075	0.41	0.32	0.16	0.15
60	7,000	10.0	2.0	0.100	0.44	0.33	0.17	0.15
61	7,000	10.0	2.0	0.125	0.47	0.33	0.17	0.15
62	7,000	10.0	2.5	0.075	0.61	0.46	0.15	0.14
63	7,000	10.0	2.5	0.100	0.65	0.46	0.15	0.14
64	7,000	12.0	1.5	0.100	0.27	0.20	0.17	0.16
65	7,000	12.0	1.5	0.125	0.29	0.21	0.18	0.16
66	7,000	12.0	2.0	0.100	0.36	0.27	0.15	0.14
67	7,000	12.0	2.0	0.125	0.38	0.28	0.16	0.14
68	7,000	12.0	2.5	0.075	0.46	0.35	0.14	0.13
69	7,000	12.0	2.5	0.100	0.49	0.36	0.14	0.13
70	7,000	12.0	2.5	0.125	0.52	0.36	0.14	0.12
71	7,000	12.0	3.0	0.075	0.65	0.48	0.12	0.12
72	7,000	12.0	3.0	0.100	0.70	0.48	0.13	0.12

*Based on a full-capacity two-unit heat load of 200 BTU/day as used by the Staff and a 15°F condenser temperature rise.

**Case numbers correspond to numbers in Table III-5a of the Final Environmental Statement.

TABLE 2

FRACTIONS OF SURFACE WIDTH AND CROSS-SECTIONAL AREA WITHIN 4°F TEMPERATURE RISE CALCULATED BY AEC AND QL&M FOR PLANE OF DISCHARGE AT INDIAN POINT*

INCIPIENT SALT FLOW CONDITIONS (HEAT TRANSFER COEFFICIENT = 90 $BTU/FT^2/°F/DAY$)
SUBMERGED JET DILUTION RATIO = 3

Case**	Incipient Salt Flow cfs	Dispersion Coefficient sq. mi./d	Thermal Stratification Factor	Intake Recirculation Factor	Fraction of Total Width Within 4°F Isotherm AEC	Fraction of Total Width Within 4°F Isotherm QL&M	Fraction of River Area Within 4°F Isotherm AEC	Fraction of River Area Within 4°F Isotherm QL&M
18	20,000	0	1.00	0.150	0.18	0.12	0.18	0.16
19	20,000	0	1.50	0.150	0.31	0.22	0.18	0.16
20	20,000	0	2.00	0.075	0.49	0.37	0.17	0.16
21	20,000	0	2.00	0.100	0.52	0.38	0.18	0.16
22	20,000	0	2.00	0.125	0.56	0.38	0.18	0.16
23	22,500	0	1.00	0.150	0.16	0.11	0.16	0.14
24	22,500	0	1.50	0.150	0.25	0.18	0.16	0.14
25	22,500	0	2.00	0.100	0.38	0.28	0.16	0.14
26	22,500	0	2.00	0.125	0.41	0.29	0.16	0.14
27	22,500	0	2.00	0.150	0.43	0.29	0.16	0.14
28	25,000	0	1.50	0.150	0.22	0.16	0.14	0.13
29	25,000	0	2.00	0.125	0.33	0.24	0.14	0.13
30	25,000	0	2.00	0.150	0.34	0.24	0.14	0.13
31	25,000	0	2.50	0.075	0.49	0.37	0.14	0.13
32	25,000	0	2.50	0.100	0.52	0.38	0.13	0.13
33	25,000	0	2.50	0.125	0.56	0.38	0.13	0.13
34	27,500	0	1.50	0.150	0.20	0.14	0.13	0.11

TABLE 2

(continued)

Case**	Incipient Salt Flow cfs	Dispersion Coefficient sq. mi./d	Thermal Stratification Factor	Intake Recirculation Factor	Fraction of Total Width Within 4°F Isotherm AEC	Fraction of Total Width Within 4°F Isotherm QL&M	Fraction of River Area Within 4°F Isotherm AEC	Fraction of River Area Within 4°F Isotherm QL&M
35	27,500	0	2.50	0.100	0.40	0.30	0.13	0.12
36	27,500	0	2.50	0.125	0.43	0.30	0.13	0.12
37	30,000	0	1.50	0.150	0.18	0.12	0.12	0.11
38	30,000	0	2.00	0.150	0.25	0.18	0.12	0.11
39	30,000	0	2.50	0.125	0.35	0.25	0.12	0.11
40	30,000	0	2.50	0.150	0.37	0.26	0.12	0.11
41	30,000	0	3.00	0.075	0.49	0.37	0.11	0.11
42	30,000	0	3.00	0.100	0.52	0.38	0.12	0.11
43	30,000	0	3.00	0.125	0.56	0.38	0.12	0.11
44	35,000	0	1.50	0.100	0.14	0.10	0.10	0.09

*Based on a full-capacity two-unit heat load of 200 BTU/day as used by the Staff and a 15°F condenser temperature rise.

**Case numbers correspond to numbers in Table III-5b of the Final Environmental Statement.

TABLE 3

FRACTIONS OF SURFACE WIDTH AND CROSS-SECTIONAL AREA WITHIN 4°F TEMPERATURE RISE CALCULATED BY QL&M FOR PLANE OF DISCHARGE AT INDIAN POINT*

TWO LAYER FLOW CONDITIONS (HEAT TRANSFER COEFFICIENT = 90 $BTU/FT^2/°F/DAY$)
SUBMERGED JET DILUTION RATIO = 3

Case**	Upper Layer Flow cfs	Dispersion Coefficient sq. mi./d	Thermal Stratification Factor	Intake Recirculation Factor	Fraction of Total Width Within 4°F Isotherm		Fraction of River Area Within 4°F Isotherm	
					AEC +	QL&M	AEC +	QL&M
18	20,000	0	1.00	0.150		0.06		0.16
19	20,000	0	1.50	0.150		0.09		0.16
20	20,000	0	2.00	0.075		0.11		0.16
21	20,000	0	2.00	0.100		0.11		0.16
22	20,000	0	2.00	0.125		0.12		0.16
23	22,500	0	1.00	0.150		0.05		0.14
24	22,500	0	1.50	0.150		0.08		0.14
25	22,500	0	2.00	0.100		0.10		0.14
26	22,500	0	2.00	0.125		0.10		0.14
27	22,500	0	2.00	0.150		0.11		0.14
28	25,000	0	1.50	0.150		0.07		0.13
29	25,000	0	2.00	0.125		0.09		0.13
30	25,000	0	2.00	0.150		0.10		0.13
31	25,000	0	2.50	0.075		0.11		0.13
32	25,000	0	2.50	0.100		0.11		0.13
33	25,000	0	2.50	0.125		0.12		0.13
34	27,500	0	1.50	0.150		0.06		0.11

TABLE 3

(continued)

Case**	Upper Layer Flow cfs	Dispersion Coefficient sq. mi./d	Thermal Stratification Factor	Intake Recirculation Factor	Fraction of Total Width Within 4°F Isotherm		Fraction of River Area Within 4°F Isotherm	
					AEC	QL&M	AEC	QL&M
35	27,500	0	2.50	0.100		0.10		0.12
36	27,500	0	2.50	0.125		0.11		0.12
37	30,000	0	1.50	0.150		0.06		0.11
38	30,000	0	2.00	0.150		0.08		0.11
39	30,000	0	2.50	0.125		0.10		0.11
40	30,000	0	2.50	0.150		0.10		0.11
41	30,000	0	3.00	0.075		0.11		0.11
42	30,000	0	3.00	0.100		0.11		0.11
43	30,000	0	3.00	0.125		0.12		0.11
44	35,000	0	1.50	0.100		0.05		0.09

*Based on a full-capacity two-unit heat load of 200 BTU/day as used by the Staff and a 15°F condenser temperature rise.

**Case numbers correspond to numbers in Table III-5b of the Final Environmental Statement.

+The Final Statement does not contain such two layer results.

20,800 cfs since a two-layer flow system exists in the Hudson River under such flow conditions. In addition, the upper layer flow model cannot be employed to evaluate the thermal effects at Indian Point when the fresh-water flow in the river is in excess of about 20,800 cfs since a one-layer system exists in the Hudson River under such flow conditions. River flow conditions resulting in a one- or two-layer flow system at Indian Point are depicted in Figure 5 of the April 5, 1972 testimony, Reference 3.

In addition, when the upper layer flow model is used, a different thermal stratification factor describing the distribution within the upper layer only must be used. This factor is about one-half of the total cross-sectional area factor.

Therefore, Table 2 presents only the cases that describe an incipient salt flow condition. The properly computed upper layer flow conditions are given in Table 3.

The following tabulation has been prepared to show the influence of the two recirculation errors on the conclusions derived by the Staff. This tabulation covers all the 72 cases presented in Table III-5a and its revised version and 27 realistic or possible cases out of the 44 cases given in Table III-5b and its revised version.

	Original Staff Table	Corrected Staff Table	Properly Computed Values
Number of cases given in Table III-5a corresponding to a fraction of surface width equal to or in excess of 0.67 bounded by 4° F	39 (54% of cases)	22 (30% of cases)	7 (10% of cases)
Same, but in Table III-5b (incipient salt flow conditions)	10 (37% of cases)	0	0
Same, but upper layer flow conditions	-	-	0

In all 116 cases (72 and 44 cases in Tables III-5a and III-5b, respectively) the fraction of total cross-sectional area bounded by 4°F is significantly less than 0.5.

In presenting its results in Chapter III of the Final Statement, the Staff selected 11 cases for a more elaborate discussion of its findings. These cases were referred to by the Staff as "likely values" of parameters (cases 10, 12, 15, and 18) and "also possible" values (cases 19, 22, and 26) for a summer flow of 4,000 cfs and "the more reasonable assumptions" for an average low summer flow of 7,000 cfs (cases 46, 48, 49, and 50). Table 4 compares the original and revised results corresponding to these 11 cases with their properly computed counterparts. A summary of these findings is given in the following tabulation:

	Original Staff Table	Revised Staff Table	Properly Computed Values
Number of cases corresponding to a fraction of surface width equal to or in excess of 0.67 bounded by 4° F	7 (64% of cases)	5 (45% of cases)	1 (9% of cases)

It should be recognized, in this connection, that the important point is not the number of cases subjected to treatment (even if it is 5,000 as indicated by the Staff in Tr. 6925), but rather the physical meaning behind the numerical values employed in the analysis. In its parametric study, the staff employed values that are neither representative of the Hudson River hydrodynamic characteristics nor applicable to the Indian Point outfall design. A brief description of the values used by the Staff which are in disagreement with those employed by the Applicant is given in the next item of this testimony.

TABLE 4

COMPARISON OF THE STAFF'S AND QL&M'S CALCULATIONS OF %A AND %B+ FOR CASES INDICATED BY STAFF AS FRACTIONS OF SURFACE WIDTH AND CROSS-SECTIONAL AREA WITHIN 4°F TEMPERATURE RISE CALCULATED BY AEC AND QL&M FOR PLANE OF DISCHARGE AT INDIAN POINT

SUBMERGED JET DILUTION RATIO = 3

					Fraction of River Width Within 4°F Isotherm			Fraction of Total Area Within 4°F Isotherm		
Case	River Flow cfs	Dispersion Coefficient sq. mi./d	Thermal Stratification Factor	Intake Recirculation Factor	Final Statement*	Revised Staff Values**	QL&M Values***	Final Statement	Revised Staff Values**	QL&M Values***
A. Cases termed "likely values of parameters," page III-45, 1st paragraph, line 9										
10	4,000	6.00	1.50	0.100	0.94	0.66	0.46	0.27	0.25	0.22
12	4,000	6.00	2.00	0.100	7.81	1.76	0.90	0.24	0.22	0.20
15	4,000	7.00	1.50	0.100	0.67	0.52	0.38	0.25	0.23	0.21
18	4,000	7.00	2.00	0.100	1.75	1.00	0.63	0.22	0.20	0.19
B. Cases termed "also possible - more favorable," page III-45 1st paragraph, line 17										
19	4,000	8.00	1.50	0.100	0.54	0.43	0.28	0.24	0.22	0.19
22	4,000	8.00	2.00	0.100	1.05	0.72	0.49	0.21	0.19	0.17
26	4,000	10.00	2.00	0.100	0.63	0.49	0.36	0.19	0.17	0.16
C. Cases termed "more reasonable assumptions," page III-45, 1st paragraph, line 23										
46	7,000	6.00	1.50	0.100	0.65	0.51	0.37	0.25	0.23	0.21
48	7,000	6.00	2.00	0.100	2.01	1.06	0.65	0.22	0.21	0.19
49	7,000	7.00	1.50	0.100	0.53	0.43	0.32	0.24	0.22	0.20
50	7,000	7.00	2.00	0.075	0.70	0.70	0.52	0.19	0.19	0.18

*Table III-5a of the Final Statement.
**Table III-5a Revised by the Staff.
***Values without the recirculation errors discussed in the text, but with the recirculation effect properly included.
+% A, % B = percent cross-sectional area and surface width bounded by 4°F.

IV. HUDSON RIVER HYDRODYNAMICS AND OTHER SYSTEM PARAMETERS

As discussed in the previous item, I do not fully agree with those Staff conclusions and interpretations dealing with net non-tidal flow or density-induced circulation (DIC) in the Hudson River. For example, values of upper layer flow calculated by the Staff and presented in Table III-3 of the Final Statement should be calculated using tidal and cross-sectional average salinity gradient data presented in Reference [4] of Chapter III (page III-77) rather than data corresponding to the high water slack and mid-channel conditions, since DIC is a tidal average phenomenon.

The Final Statement does not employ or even refer to all survey data used to support the qualitative and quantitative evaluations of Hudson River density-induced circulation.. The surveys were listed on pages 96 and 97 in Reference [4] of Chapter III (page III-77). These surveys are, for convenience, reproduced on Tables 5 and 6 of this testimony.

I cannot accept the Staff's statement that dispersion coefficient values of 10 to 12 square miles per day "seem to be too high" (page III-35), since the Staff does not offer any theoretical or physical information to support it. QL&M used salinity data obtained from comprehensive measurements and an estuarine one-dimensional steady-state mass transport equation to compute these values. Salinity data are normally the best data available for evaluation of dispersion coefficients in estuaries. Use of the estuarine steady-state mass transport equation was fully justified since the thermal models employing these coefficients were based on this equation.

TABLE 5

INVENTORY OF HUDSON RIVER
SALINITY SURVEYS

Survey	Year
USC&GS density observations	1929
NYS Conservation Department	1936
USGS Surveys	1949 and 1951
Corps of Engineers	1957
NYC DH & NYS	1959
Indian Point Measurements	1958 - 1966
Danskammer Point Measurements	1958 - 1966
USGS Surveys	1962 and 1963
ISC Bay Measurements	1964
QL&M Kyma Survey	1964
FWPCA Survey	1965
NYCDWS Chelsae Measurements	1965
Michigan State University Survey	1966
QL&M Copter Survey	1966
QL&M Salinometer Survey	1966
NYSDH Copter Survey	1967
NYSDH Boat Survey	1967
USGS Intrusion Front Surveys	1968 and 1969
NYU Indian Point Measurements	1968 and 1969
QL&M Lovett, Danskammer and Bowline Surveys	1969 and 1970

TABLE 6

INVENTORY OF HUDSON RIVER VELOCITY DATA

Year	Conducted or Reported by	Survey Duration	River Section Covered (miles above Battery)	Reference Number*
1919	Winston	Aug. 25-Nov. 4	0 to 14	1
1922	Denson	July 16-Aug. 30	1 to 16	1
1929	Finnegan	Aug. 29-Sept. 14	15 to 153	1
1932	Rittenburg	June 29-Aug. 31	5 to 15	1
1932	Corps of Engineers			
1952	Stewart	May 24-June 23	15 and 55	2
1957	Corps of Engineers			
1958-59	Marmer	Oct. 7-16 April, June	35 and 50 35 and 50	3 3
1965	USGS		75	

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*1. USC¢GS, "Tides and Currents in Hudson River,". Special Publication No. 180, 1934.

2. Stewart, H.B.,Jr. "Upstream Bottom Currents in New York Harbor," Science, 127:1113-1115, 1958.

3. Pritchard, D.W., Akira Okubo and Emanuel Mehr. "A Study of the Movement and Diffusion of an Introduced Contaminant in New York Harbor Waters." Technical Report #31, The Chesapeake Bay Institute, The John Hopkins University, October, 1962.

Although I agree with the need for more investigation and field data as recommended by the Staff, I do believe that sufficient field information exists to establish supportable and consistent values of certain system parameters, particularly the one-dimensional longitudinal dispersion coefficient. The method used in the QL&M reports to determine this coefficient has been successfully employed by many investigators to describe one-dimensional mass transport in numerous water bodies. Investigators who used or reported similar equations include Harleman and Ippen*and their colleagues at MIT, Fischer, Hansen, Bowden, Kent,***, Okubo, Pritchard** at CBI.

It seems that Staff based its "seem to be too high" statement upon its review of Reference 11 of Chapter III of the Final Statement. The Staff did not indicate, however, that in general the specific examples cited in that Reference apply to the Delaware and Potomac Rivers as well as non-tidal rivers. The Final Statement does not address itself to the differences between these rivers and the Hudson in terms of gain in potential energy, mixing, and tidal power dissipation characteristics.

In addition, pages 12 through 14 of the April 5, 1972 testimony present a detailed discussion showing that, in thermal discharge studies, dispersion coefficient values derived from mass transfer equations are conservative.

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* Ippen, Arthur I. "Estuary and Coastline Hydrodynamics", McGraw Hill Book Company, Inc., 1966.

** Pritchard, D.W., Akira Okubo and Emanuel Mehr. "A Study of the Movement and Diffusion of an Introduced Contaminant in New York Harbor Waters", Technical Report #31, The Chesapeake Bay Institute, The John Hopkins University, October, 1962.

*** Kent, R.F., "Turbulent Diffusion in a Sectionally Homogeneous Estuary", Proc. ASCE, Vol. 86, S.A.2, March 1960.

Therefore, on the basis of the above presented statements and discussions given in previously submitted reports (References 1, 3, 5, 6, 10, 11 and 18), the Applicant concludes that dispersion coefficient values on the order of 10 to 12 square miles per day represent a more accurate description of transport under summertime conditions.

Similarly, the estimates of the thermal stratification factor (TSF) used in the QL&M reports were based not only on interpolation between a minimum value of 1.0 and the value of 3.0 observed for surface discharge of Unit 1 as suggested by the Staff on Page III-45, but also on measurements conducted on thermal discharges at other plants (Albany, Danskammer, Lovett, Astoria) as well as on the results of available hydraulic model studies.

As indicated on pages 14 through 15 of the April 5 testimony, Reference 3, the heat transfer coefficient values used by the Applicant and the Staff are conservative. In addition, all of the values listed in the Applicant's environmental report and quoted in the Final Statement on Page III-8 indicate that full flow licensed two unit operation at Indian Point will result in a plant temperature rise of 13.94°F (see Table 7) rather than the 15°F used by the Staff in its parametric study. The lower plant temperature rise may result in somewhat reduced thermal effects.

TABLE 7

INDIAN POINT UNITS
I & II PLANT CHARACTERISTICS

Parameter	Indian Point Units I	Indian Point Units II	Indian Point Units I+II
MW(e)	265	873	1138
HEAT LOAD (10^6 $\frac{Btu}{hr}$)			
(a) Condenser	1,765	6,250	8,015
(b) Service	150	100	250
(c) Total	1,915	6,350	8,265
flow (10^3 gpm)			
(a) Condenser	280	840	1,120
(b) Service	38	30	68
(c) Total	318	870	1,184
Temperature Rise (^oF)			
(a) Condenser	12.59	14.86	14.29
(b) Service	7.88	6.66	7.34
(c) Weighted Average	12.03	14.58	13.94

V. CONCLUSIONS

The "reasonable" values for freshwater flow, thermal stratification factor, recirculation, and submerged jet dilution factors indicated by the Staff on page III-45 of the Final Statement are used in Table 8 of this testimony to demonstrate the influence of the errors incorporated in the analysis made by the Staff. Only the cases corresponding to applicable dispersion coefficients are used in this table.

As shown in Table 8, when the errors are eliminated from the Staff's analysis, the Staff's conclusion that "satisfying the two-thirds (river width) criterion is in doubt" (page III-45) is not valid. The properly computed results shown in Table 8 clearly indicate that predictions of the 4° F temperature rise surface width (between 21% and 36%) and cross-sectional area (between 13% and 19%) are substantially less than the New York State criteria of a maximum of 67% and 50%, respectively. Under critical tidal phase conditions, use of a CTP/TA ratio of 1.3 results in a maximum surface width percentage ranging from 27% to 47%.

The original incorrect analysis presented in Table III-5a of the Final Statement shows computed surface width percentages ranging from 31% to 136% and cross-sectional area percentages ranging from 16% to 25%. The revised, but still incorrect, analysis made by the Staff shows computed surface width percentages ranging between 27% and 52% and cross-sectional area percentages between 15% and 20%.

TABLE 8

FRACTIONS OF SURFACE WIDTH AND CROSS-SECTIONAL AREA WITHIN 4°F TEMPERATURE

RISE CALCULATED BY AEC+ AND QL&M FOR PLANE OF DISCHARGE AT INDIAN POINT**

SUMMER CONDITIONS (HEAT TRANSFER COEFFICIENT = 130 BTU/FT^2/°F/DAY)

Case*	River Fresh Water Flow cfs	Dispersion Coefficient sq. mi/d	Thermal Stratification Factor	Intake Recir. Factor	Submerged Jet Dilution Ratio	Temperature Rise of Cross-Sectional Area ***		Surface Temperature Rise***		Fraction of Total Area Within 4°F Isotherm	Fraction of River Width Within 4°F Isotherm	Source
						Average °F	Maximum °F	Average °F	Maximum °F			
24			1.5	0.125	3.0	2.1	16.9	3.1	5.6	0.18	0.26	QL&M
						2.4		3.5		0.20	0.36	AEC
25			2.0	0.075	3.0	1.8	16.1	3.6	5.4	0.16	0.36	QL&M
		10.0				2.0		3.9		0.17	0.46	AEC
26			2.0	0.100	3.0	1.8	16.5	3.6	5.5	0.16	0.36	QL&M
						2.0		4.0		0.17	0.49	AEC
27			2.0	0.125	3.0	1.8	16.9	3.6	5.6	0.16	0.36	QL&M
						2.1		4.1		0.17	0.52	AEC
31			1.5	0.125	3.0	1.9	16.9	2.9	5.6	0.16	0.22	QL&M
	4,000					2.2		3.2		0.18	0.31	AEC
32			1.5	0.150	3.0	1.9	17.3	2.9	5.7	0.16	0.22	QL&M
						2.2		3.3		0.19	0.32	AEC
33		12.0	2.0	0.100	3.0	1.7	16.5	3.3	5.5	0.14	0.29	QL&M
						1.8		3.7		0.16	0.39	AEC
34			2.0	0.125	3.0	1.7	16.9	3.3	5.6	0.14	0.30	QL&M
						1.9		3.8		0.16	0.42	AEC
35			2.0	0.150	3.0	1.7	17.3	3.3	5.7	0.14	0.30	QL&M
						1.9		3.8		0.16	0.44	AEC
57			1.5	0.100	3.0	2.0	16.5	3.0	5.5	0.17	0.23	QL&M
						2.2		3.3		0.19	0.31	AEC
58			1.5	0.125	3.0	2.0	16.9	3.0	5.6	0.17	0.23	QL&M
						2.2		3.4		0.19	0.33	AEC
59		10.0	2.0	0.075	3.0	1.8	16.1	3.5	5.4	0.15	0.32	QL&M
						1.9		3.8		0.16	0.41	AEC
60			2.0	0.100	3.0	1.8	16.5	3.5	5.5	0.15	0.33	QL&M
						1.9		3.9		0.17	0.44	AEC
61	7,000		2.0	0.125	3.0	1.8	16.9	3.5	5.6	0.15	0.33	QL&M
						1.9		3.9		0.17	0.47	AEC
64			1.5	0.100	3.0	1.8	16.5	2.7	5.5	0.16	0.20	QL&M
						2.0		3.0		0.17	0.27	AEC
65			1.5	0.125	3.0	1.8	16.9	2.7	5.6	0.16	0.21	QL&M
		12.0				2.1		3.1		0.18	0.29	AEC
66			2.0	0.100	3.0	1.6	16.5	3.2	5.5	0.13	0.26	QL&M
						1.8		3.6		0.15	0.36	AEC
67			2.0	0.125	3.0	1.6	16.9	3.2	5.6	0.14	0.28	QL&M
						1.8		3.6		0.16	0.38	AEC

*Case numbers correspond to numbers in Table III-5a of the Final Environmental Statement
**Based on a full capacity two unit heat load of 200 BTU/day as used by the Staff
***Values employed by the Staff based on a 15°F condenser temperature rise.
+As presented in the revised Table III-5a.

PEFERENCES

1. Quirk, Lawler & Matusky Engineers, "Effects of Indian Point Units 1 and 2 Cooling Water Discharge on Hudson River Temperature Distribution," Summary Report, February 1972.

2. Quirk, Lawler & Matusky Engineers, "Supplemental Study of Effect of Submerged Discnarge of Indian Point Cooling Water on Hudson River Temperature Distribution," Report to Con Edison, May 1972.

3. Testimony of John P. Lawler, Ph.D., Quirk, Lawler & Matusky Engineers, on the Thermal Effects of Indian Point Cooling Water on the Hudson River, April 5, 1972.

4. U.S. Atomic Energy Commission, "Final Environmental Statement, Docket No. 50-247," September 1972.

5. Quirk, Lawler & Matusky Engineers, "Effect of Contaminant Discharge at Indian Point on Hudson River Water Intake at Chelsea, New York," Report to Consolidated Edison Company of New York, Inc., May 1966 (Appendix A of the Environmental Report).

6. Quirk, Lawler & Matusky Engineers, "Effect of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution," Report to Consolidated Edison Company of New York, Inc., January 1968 (Appendix I of the Environmental Report).

7. Quirk, Lawler & Matusky Engineers, "Effect of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution," Report to Consolidated Edison Company of New York, Inc., February 1969 (Appendix J of the Environmental Report).

8. Quirk, Lawler & Matusky Engineers, "Effect of Submerged Discharge of Indian Point Cooling Water Discharge on Hudson River Temperature Distribution," Report to Consolidated Edison Company of New York, Inc., October 1969 (Appendix M of the Environmental Report).

9. Quirk, Lawler & Matusky Engineers, "Influence of Hudson River Net Non-Tidal Flow on Temperature Distribution," Report to Consolidated Edison Company of New York, Inc., October 1969 (Appendix N of the Environmental Report).

10. Quirk, Lawler & Matusky Engineers, "Hudson River Water Quality and Waste Assimilative Capacity Study," Report to the State of New York Department of Environmental Conservation, Division of Pure Waters, December 1970.

11. Quirk, Lawler & Matusky Engineers, "Hudson River Assimilation Capacity Study," Report to the New York State Department of Health, March 1970.

12. Abood, Karim A., "Circulation in the Hudson Estuary," The Hudson Estuary Colloquium, February 23, 1972, The City College of the University of New York.

13. Abood, Karim A. and John P. Lawler, "Evaluation of Estuarine Thermal Discharges Using Mathematical, Hydraulic and Ecological Models," Presented at the Fourth Mid-Atlantic Industrial Waste Conference, University of Delaware, Newark, Delaware, November 18-20, 1970.

14. Lawler, John P. and Karim A. Abood, "Thermal State of the Hudson River and Potential Changes," Presented at the Second Symposium on Hudson River Ecology, Sterling Forest Conference Center, Tuxedo, New York, October 28-29, 1969.

15. Alden Research Laboratories, "Indian Point Model Studies," March 1969 (Appendix O of the Environmental Report).

16. Alden Research Laboratories, "Indian Point Cooling Water Studies: Model No. 2," May 1969 (Appendix P of the Environmental Report).

17. Alden Research Laboratories, "Hydraulic Survey of Hudson River: The Haverstraw Bay Area," February 1970 (Appendix Q of the Environmental Report).

18. Abood, K. A., J. P. Lawler and M. D. Disco, "Utility of Radioisotope Methodology in Estuary Pollution Control Studies - Longitudinal Dispersion Coefficient," USAEC, Division of Technical Information Report No. NYO-3961-1, August 1969.

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit 2)	)))))	Docket No. 50-247

Redirect-Rebuttal Testimony of John P. Lawler, Ph.D. Quirk, Lawler & Matusky Engineers on the Behavior of the Indian Point Thermal Effluent During Winter Conditions and its Effect on Hudson River Striped Bass

February 5, 1973

I. INTRODUCTION

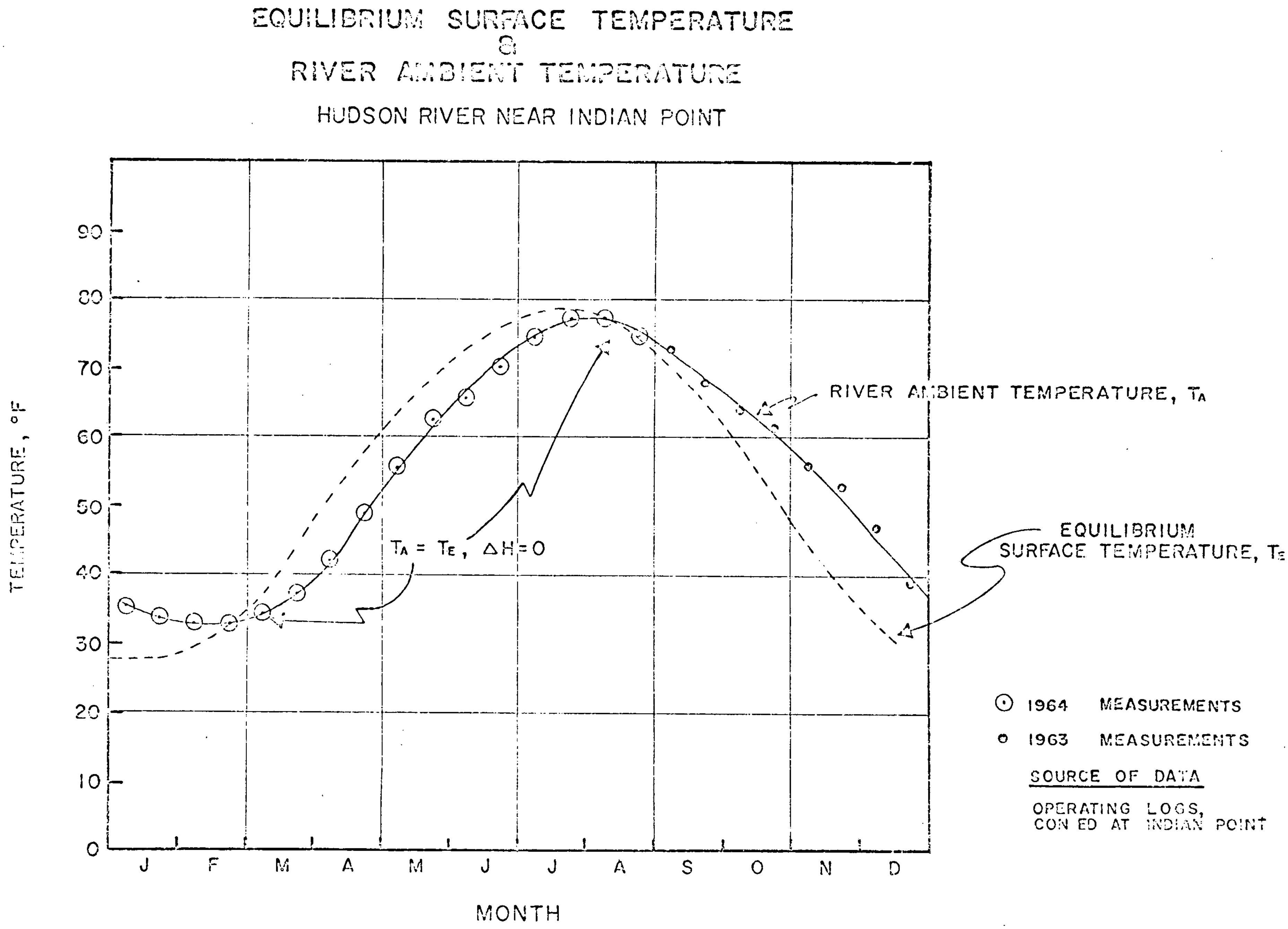
This testimony addresses itself to the discussion of the behavior of the Indian Point thermal effluent under conditions of low ambient temperatures occurring during the winter season, and its effect on Hudson River striped bass. These items were mentioned in Clark's October 30, 1972 Testimony (Final) (Reference 1) in a section entitled "Effect of Winter Conditions" on page 39.

I will be particularly concerned with Clark's statement that "in winter the heated plume does not remain buoyant; to the contrary, it tends to sink beneath the surface and to spread toward the bottom when the water temperature goes below 39.2°F", and with Clark's subsequent conclusions on the attraction of fish to the sinking plume.

II. HUDSON RIVER CONDITIONS AND THE INDIAN POINT PLANT OPERATION DURING WINTER

The Hudson River ambient temperature at Indian Point is usually below 39.2°F (4°C) at the end of December, and reaches its minimum of 32 to 33°F in February. From about the beginning of March, the river ambient temperature increases and reaches the level of 39.2°F approximately at the beginning of April (see Figure 1). During the years of extremely high fresh water flows in January or February, the river ambient temperature at Indian Point may drop close to 32°F, since generally ocean waters do not reach Indian Point under these extreme conditions.

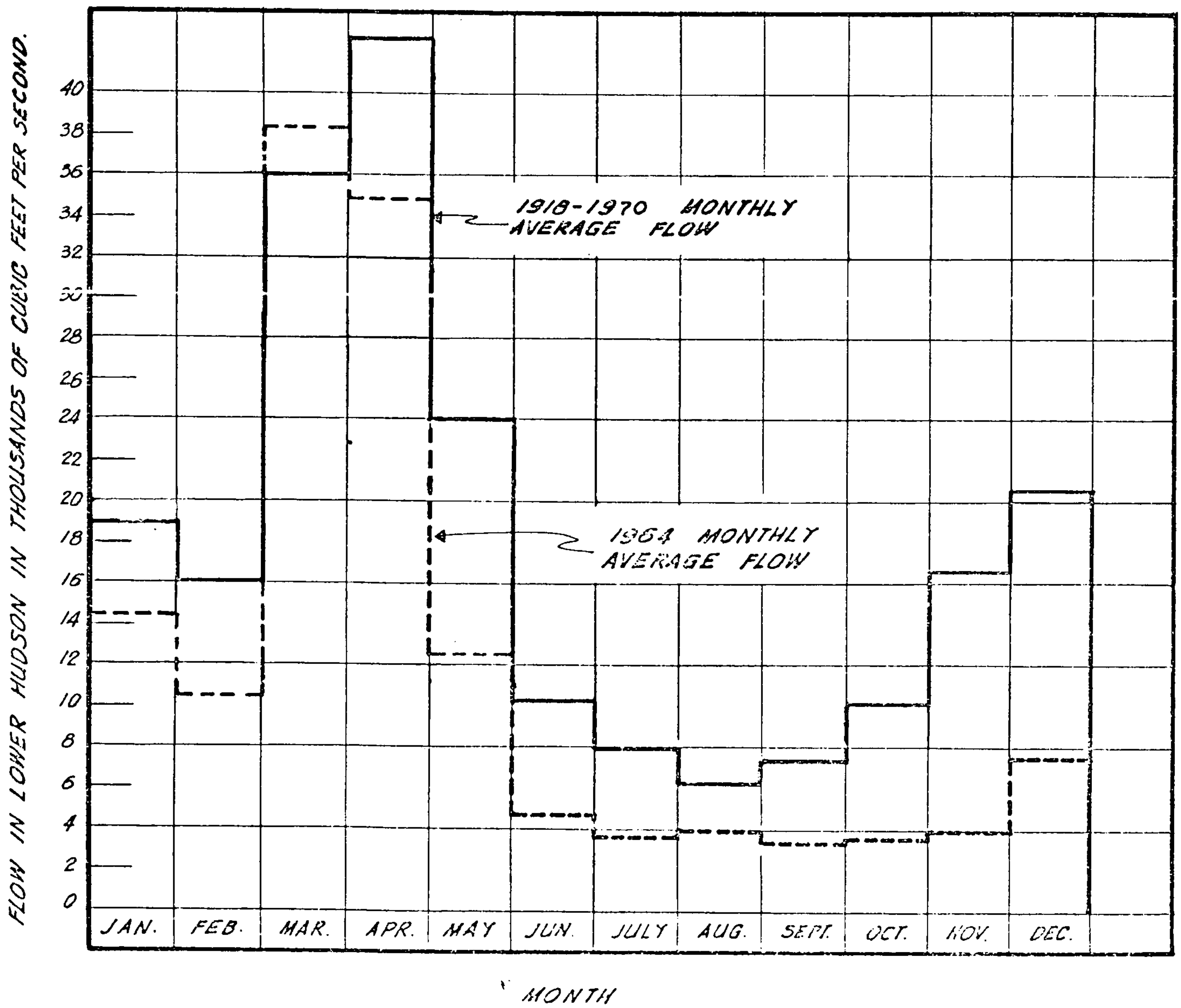
The three-month period of the river's lowest ambient temperatures, i.e., the period of January, February and March, is characterized by variable fresh water flows. Long-term monthly average flows are about 19,000 cfs in January, 16,000 cfs in February, and about 36,000 cfs in March (see Figure 2). Flows



EQUILIBRIUM SURFACE TEMPERATURE
&
RIVER AMBIENT TEMPERATURE
HUDSON RIVER NEAR INDIAN POINT
TEMPERATURE, °F
90
80
70
60
50
40
30
20
10
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
RIVER AMBIENT TEMPERATURE, T_A
EQUILIBRIUM SURFACE TEMPERATURE, T_E
$T_A = T_E$, $\Delta H = 0$
1964 MEASUREMENTS
1963 MEASUREMENTS
SOURCE OF DATA
OPERATING LOGS, CON ED AT INDIAN POINT

FIGURE 1

LOWER HUDSON RIVER MONTHLY AVERAGE FRESH WATER FLOWS



of these three months also vary from year to year, as indicated in Figures 3, 4 & 5. These figures depict the frequency distributions of the Lower Hudson River monthly average fresh water flows in January, February and March, respectively.

Fresh water flow is the major factor affecting salt concentrations in the Hudson River estuary. Figure 6 depicts the relationship between the fresh water flow and Hudson River mean salinity at Indian Point. This relationship was previously presented in Reference 2 and is based on the analysis of a number of salinity measurements conducted in the Hudson River. Figure 6 indicates that the salinity at Indian Point decreases with an increasing fresh water flow. When the fresh water flow in the Lower Hudson River is about 21,000 cfs, the salt front (salinity of 0.1 ppt) is located just at Indian Point.

Due to the incomplete mixing of fresh and salt waters in the Hudson River, salinity is not uniformly distributed over a river cross-section, but increases from the surface to the bottom. Figure 7 shows vertical salinity distributions as observed in the Hudson River during November 19 - November 24, 1964. All Hudson River salinity surveys indicate that, at the locations close to the front of the salt intrusion, the vertical mixing of salt and fresh waters is more intensive, and the distribution of low salinity concentrations is practically uniform at these locations.

Figure 8a correlates the difference in bottom and surface salinities with the mean salinity at Indian Point under normal winter conditions. This approximate relationship is based on several river salinity measurements, including:

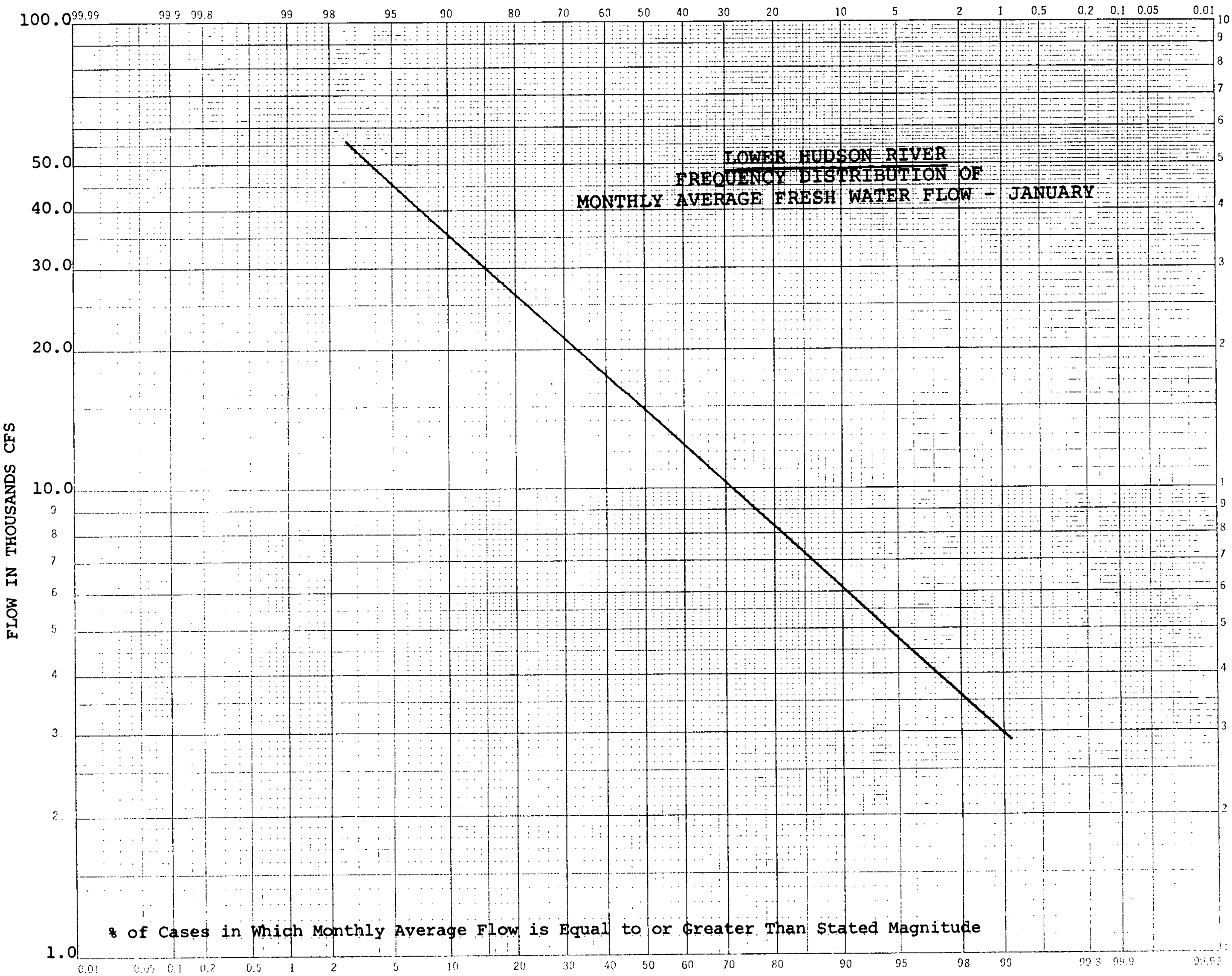
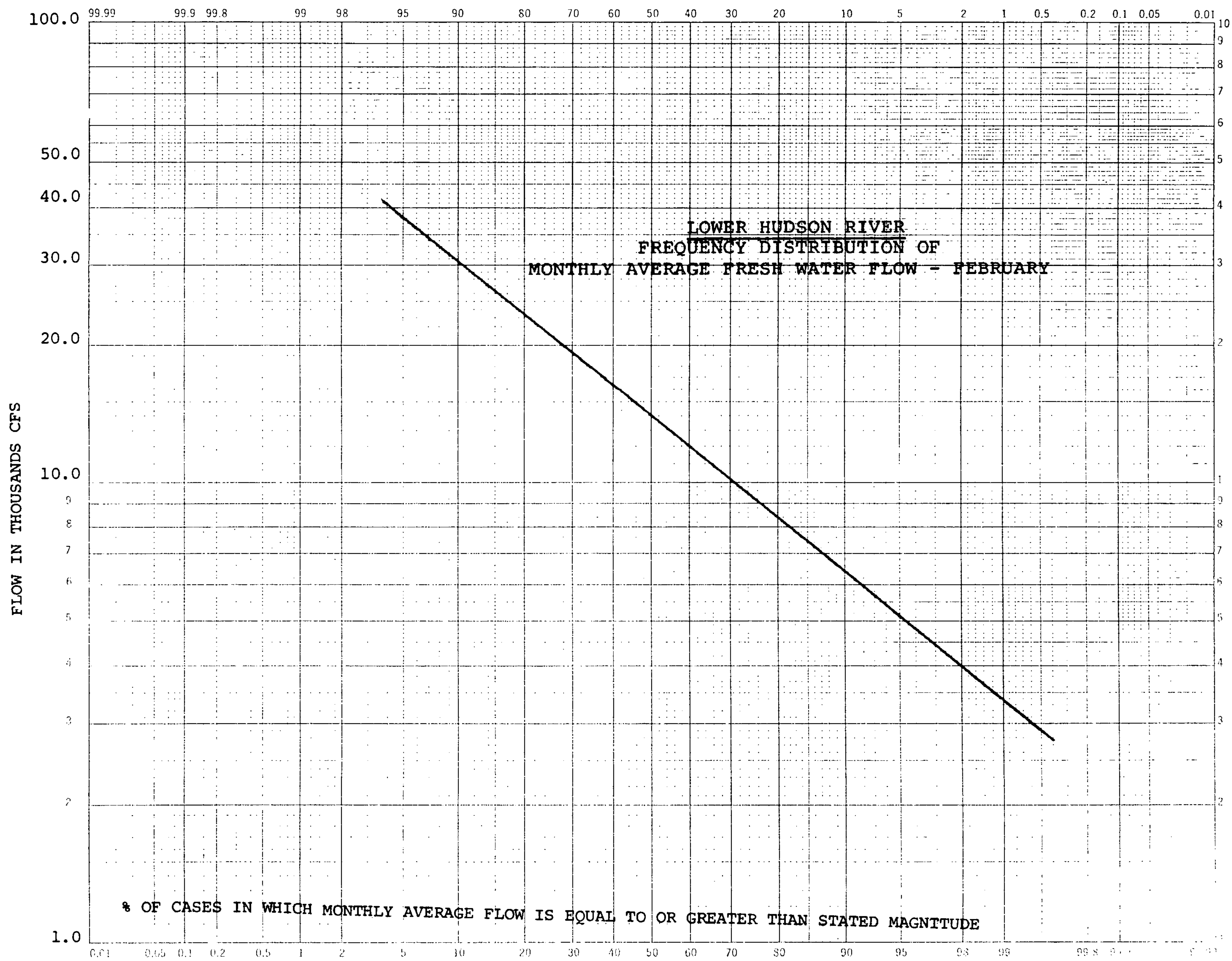

LOWER HUDSON RIVER
FREQUENCY DISTRIBUTION OF
MONTHLY AVERAGE FRESH WATER FLOW - JANUARY
FLOW IN THOUSANDS CFS
100.0
50.0
40.0
30.0
20.0
10.0
% of Cases in Which Monthly Average Flow is Equal to or Greater Than Stated Magnitude
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99

FIGURE 3



LOWER HUDSON RIVER
FREQUENCY DISTRIBUTION OF
MONTHLY AVERAGE FRESH WATER FLOW - FEBRUARY
FLOW IN THOUSANDS CFS
% OF CASES IN WHICH MONTHLY AVERAGE FLOW IS EQUAL TO OR GREATER THAN STATED MAGNITUDE
100.0
50.0
40.0
30.0
20.0
10.0
1.0
99.99
99.9
99.8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01

FIGURE 4

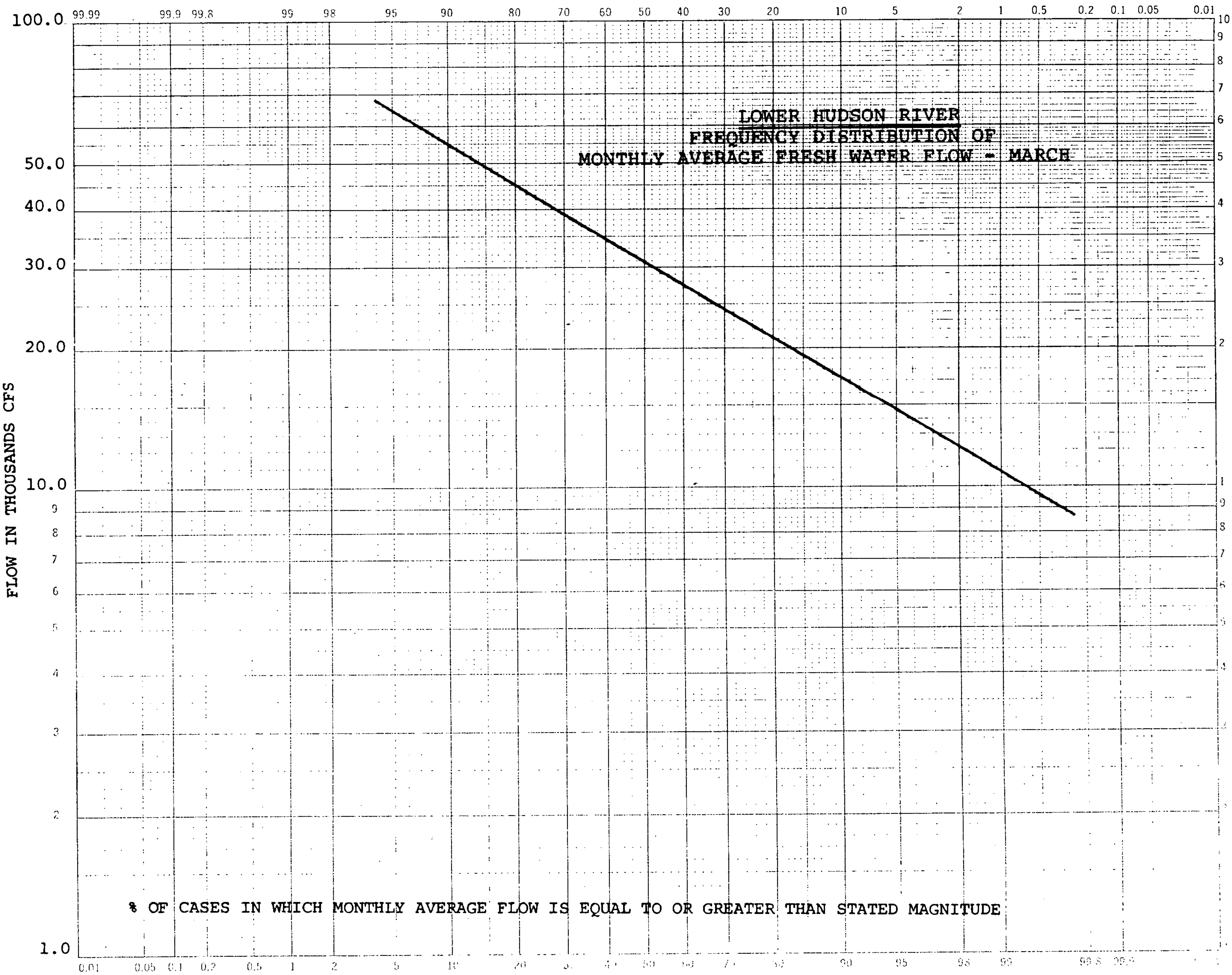

LOWER HUDSON RIVER
FREQUENCY DISTRIBUTION OF
MONTHLY AVERAGE FRESH WATER FLOW - MARCH
FLOW IN THOUSANDS CFS
% OF CASES IN WHICH MONTHLY AVERAGE FLOW IS EQUAL TO OR GREATER THAN STATED MAGNITUDE
100.0
50.0
40.0
30.0
20.0
10.0
1.0
99.99
99.9
99.8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01

FIGURE 5

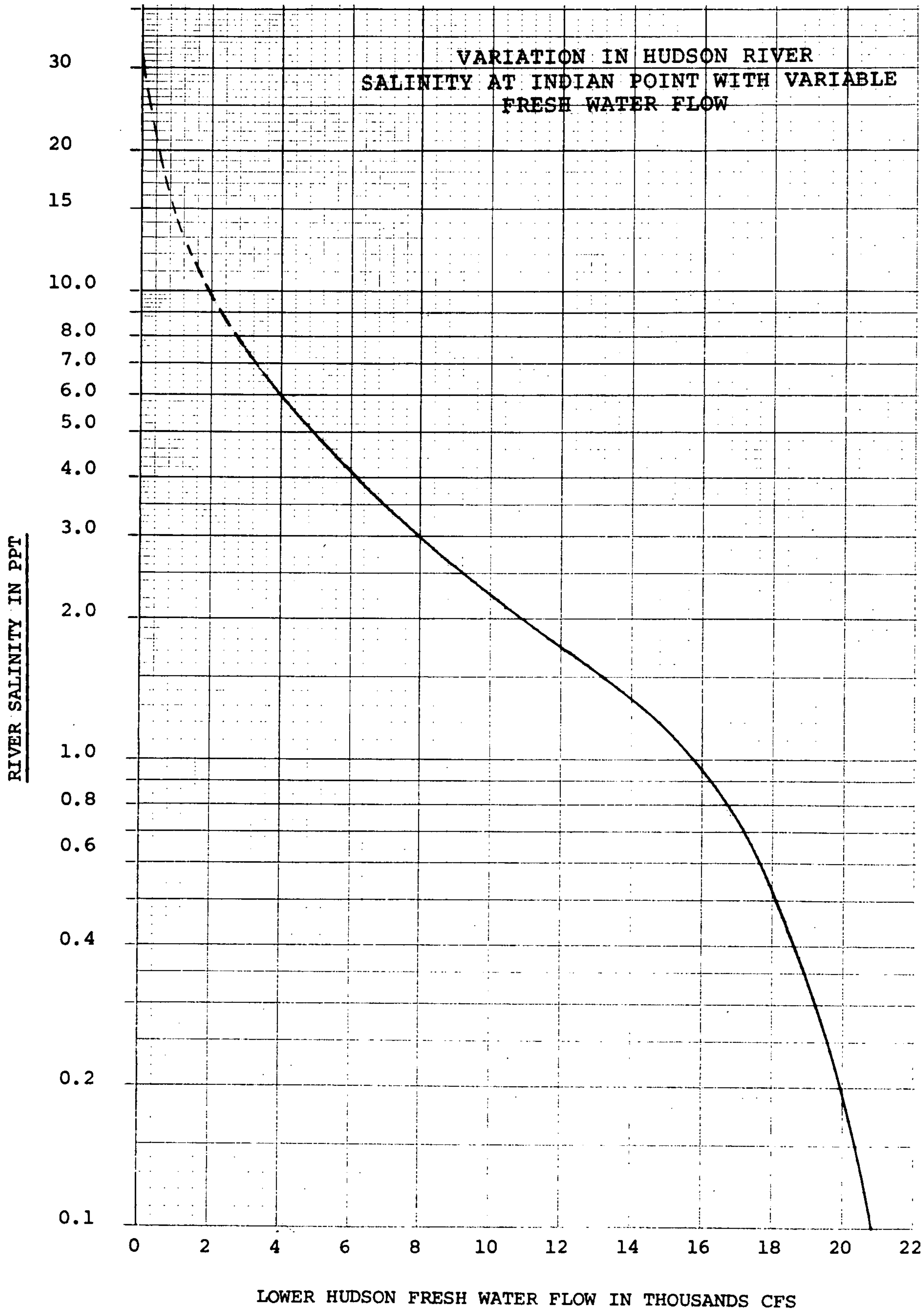
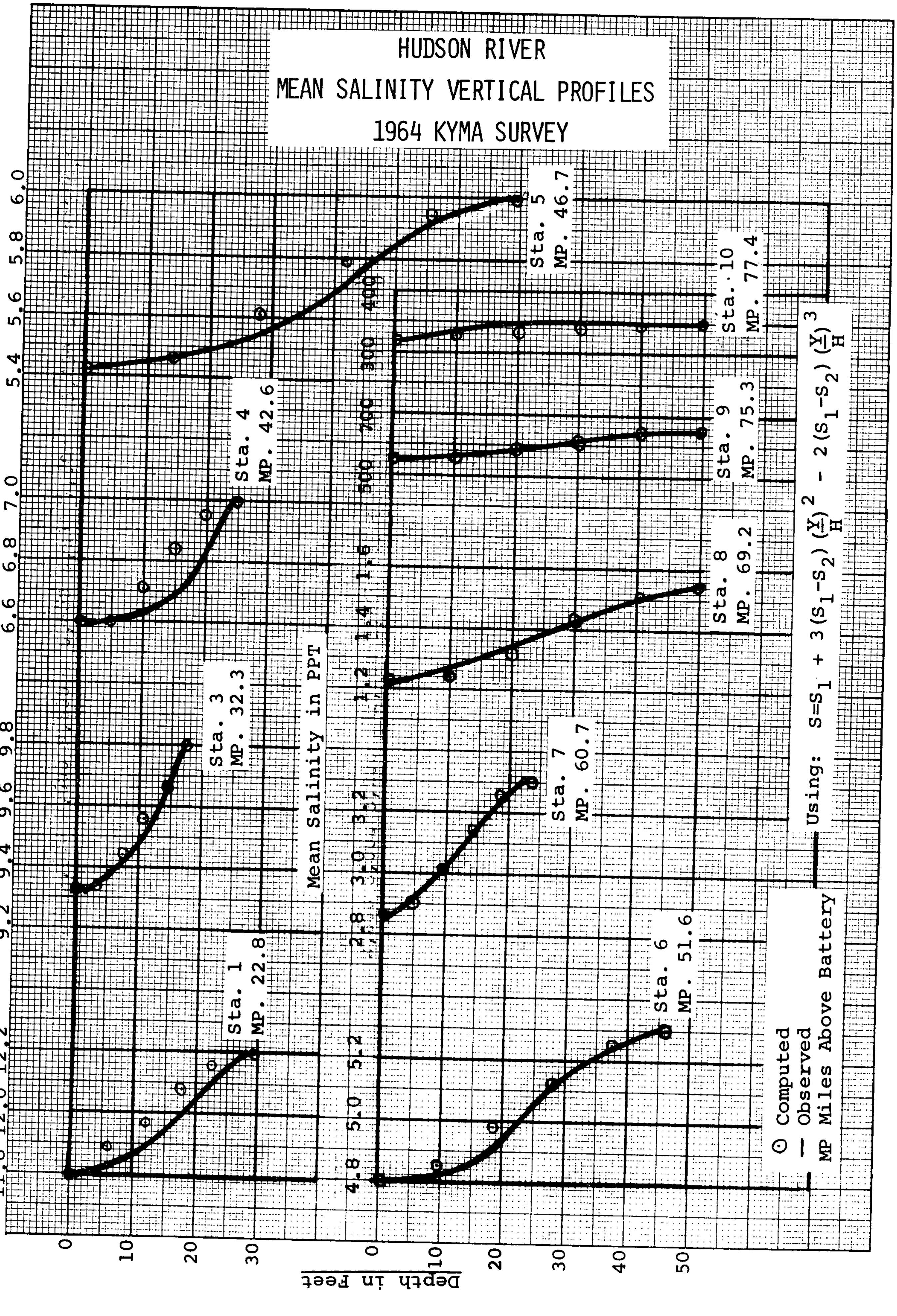

VARIATION IN HUDSON RIVER SALINITY AT INDIAN POINT WITH VARIABLE FRESH WATER FLOW
RIVER SALINITY IN PPT
30
20
15
10.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.8
0.6
0.4
0.2
0.1
0
2
4
6
8
10
12
14
16
18
20
22
LOWER HUDSON FRESH WATER FLOW IN THOUSANDS CFS

FIGURE 7


HUDSON RIVER
MEAN SALINITY VERTICAL PROFILES
1964 KYMA SURVEY
Mean Salinity in PPT
Depth in Feet
Sta. 1
MP. 22.8
Sta. 3
MP. 32.3
Sta. 4
MP. 42.6
Sta. 5
MP. 46.7
Sta. 6
MP. 51.6
Sta. 7
MP. 60.7
Sta. 8
MP. 69.2
Sta. 9
MP. 75.3
Sta. 10
MP. 77.4
Using: $S=S_1 + 3(S_1-S_2)(\frac{Y}{H})^2 - 2(S_1-S_2)(\frac{Y}{H})^3$
⊙ Computed
— Observed
MP Miles Above Battery

(a) Kyma survey (November 19-24, 1964), (b) the September 1967 survey, and (c) several salinity measurement- conducted during February and May of 1966 in the vicinity of Indian Point. The above relationship and the relationship between the mean river salinity and the fresh water flow from Figure 6 were used to correlate the difference between bottom and surface salinities with the Lower Hudson fresh water flow as shown in Figure 8b.

Using the above information, the winter conditions in the Hudson River at Indian Point relating to river ambient temperature, fresh water flow, and salinity, are summarized in Table 1.

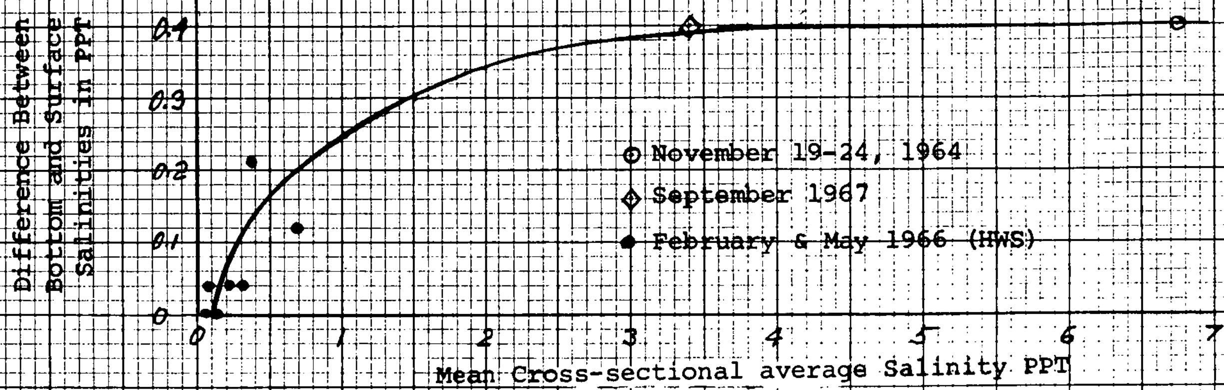
The operation of the Indian Point power plant (Units 1 & 2) during winter conditions is characterized by a reduction in the cooling water flow to about 60% of the full flow capacity of the system. Provisions for the reduction in the cooling water flow were made in order to reduce the intake velocity and, thus, protect juvenile fish against excessive impingement upon the intake screens. Reduced cooling water flow rates result in an increase in the cooling water temperature rise to about 25°F.

III. EVALUATION OF THE BEHAVIOR OF THERMAL EFFLUENT DURING WINTER CONDITIONS AT INDIAN POINT

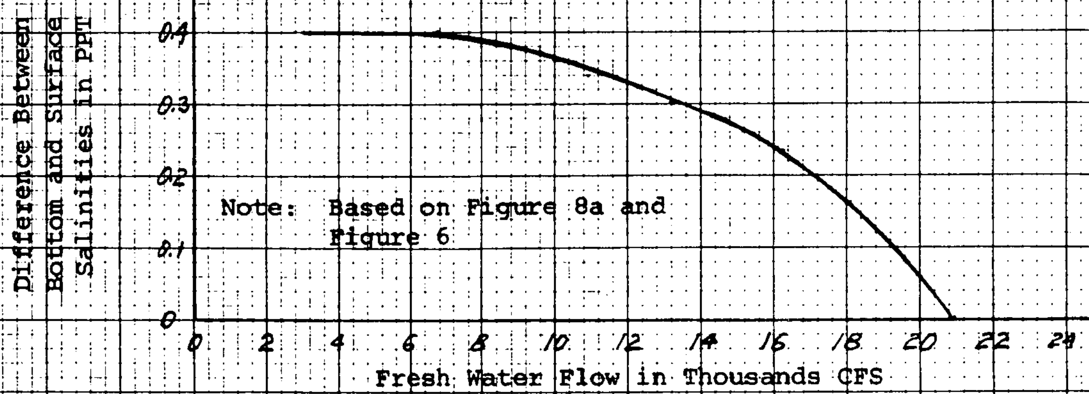
One of the physical properties of water is the dependency of its density on water temperature. As shown in Figure 9, the density of fresh water reaches its maximum of 1.0gm/ml when the water temperature is 39.2°F (4°C). Higher or lower water temperatures result in a decrease in the water density. Figures 9A & 9B depict the relationship between water density, salinity and temperature.

FIGURE 8

HUDSON RIVER AT INDIAN POINT DIFFERENCE BETWEEN BOTTOM AND SURFACE SALINITIES
(Under Normal Flow Conditions)

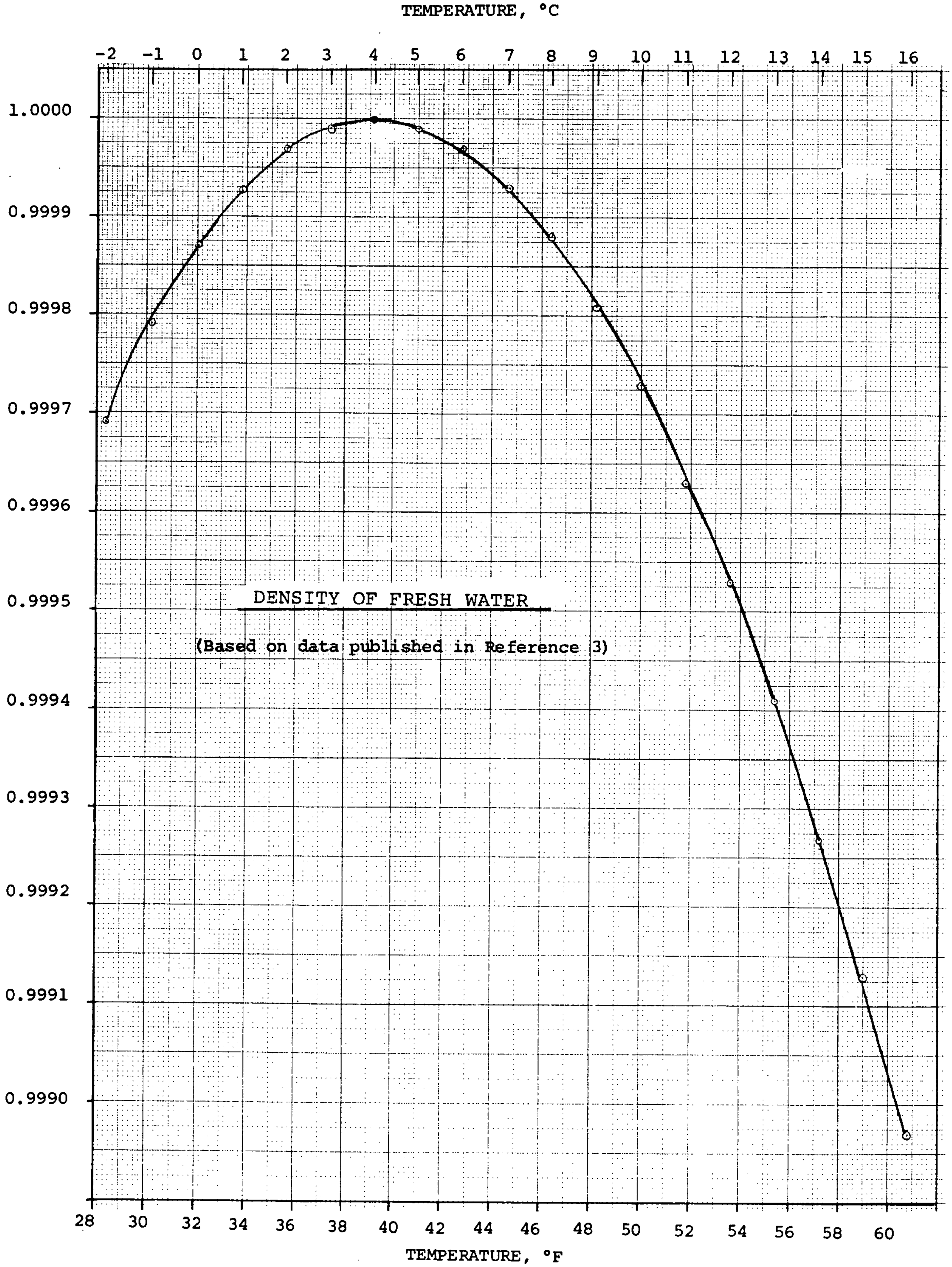


a) Difference Between Bottom and Surface Salinities vs. Mean Salinity



b) Variation in Difference Between Bottom and Surface Salinities With Variable Fresh Water Flow

FIGURE 9



TEMPERATURE, °C
-2
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
1.0000
0.9999
0.9998
0.9997
0.9996
0.9995
0.9994
0.9993
0.9992
0.9991
0.9990
DENSITY, GM/ML
DENSITY OF FRESH WATER
(Based on data published in Reference 3)
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
TEMPERATURE, °F

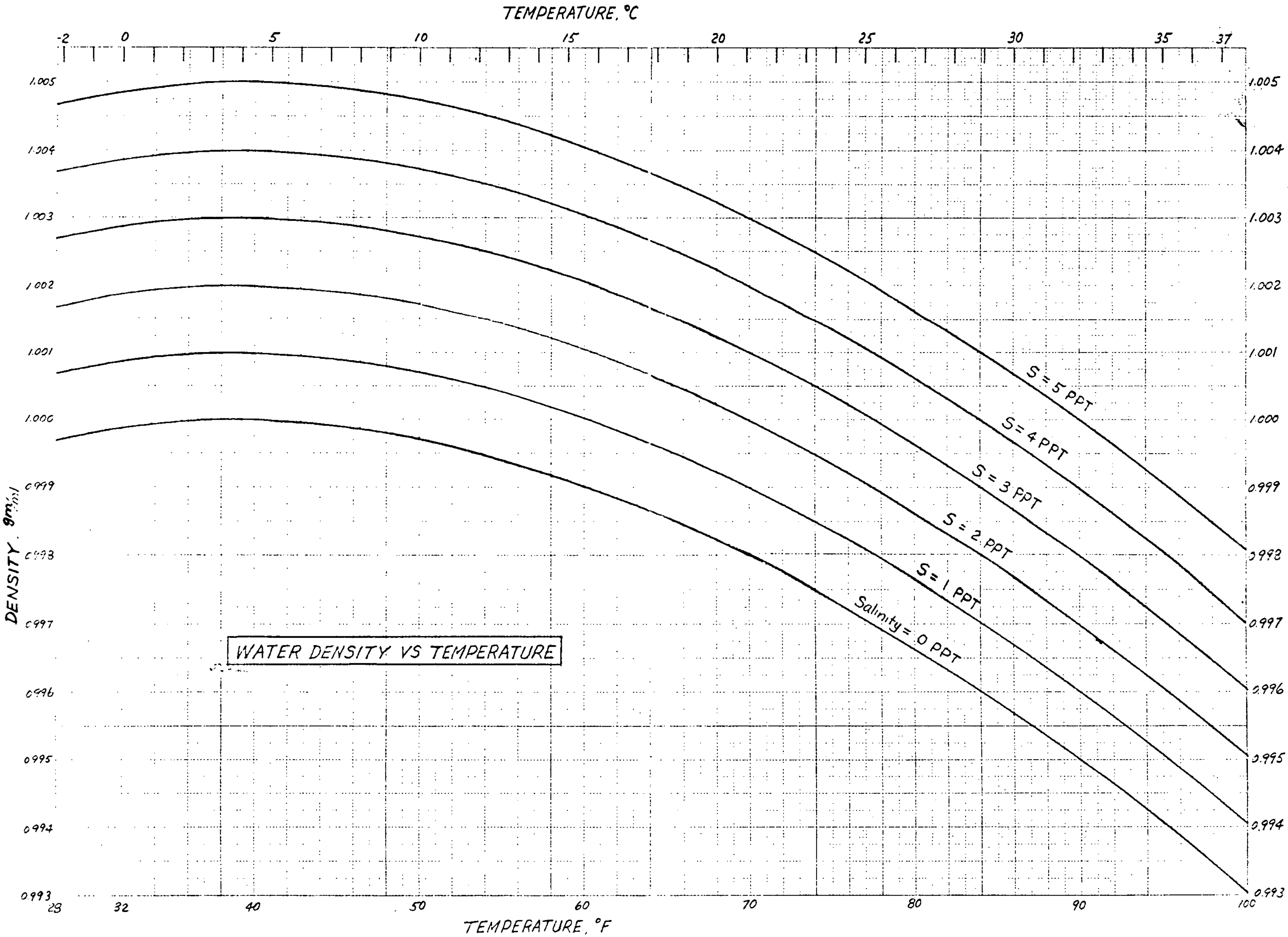
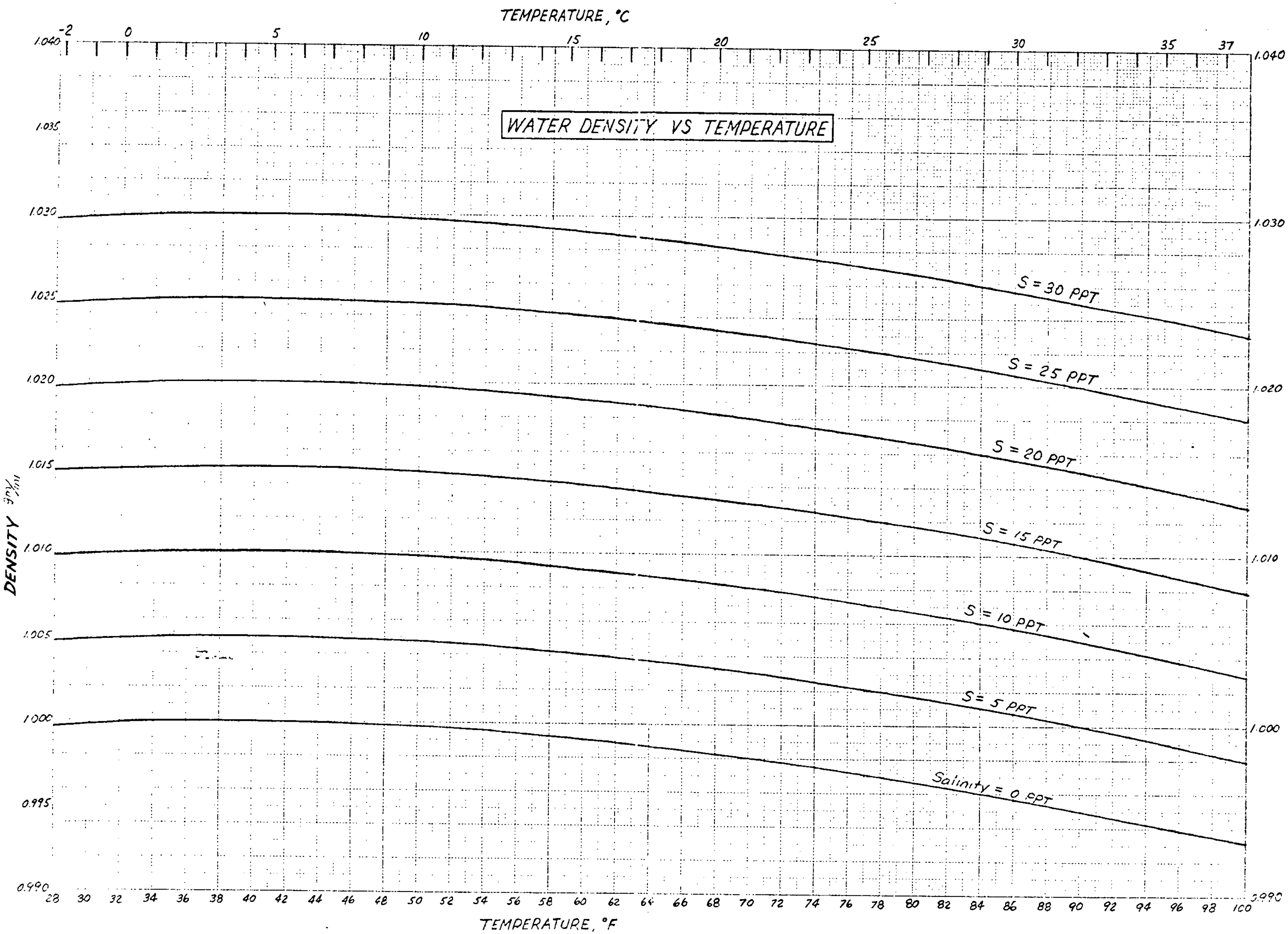

TEMPERATURE, °C
-2
0
5
10
15
20
25
30
35
37
1.005
1.004
1.003
1.002
1.001
1.000
0.999
0.998
0.997
0.996
0.995
0.994
0.993
DENSITY, gm/ml
S = 5 PPT
S = 4 PPT
S = 3 PPT
S = 2 PPT
S = 1 PPT
Salinity = 0 PPT
WATER DENSITY VS TEMPERATURE
28
32
40
50
60
70
80
90
100
TEMPERATURE, °F

FIG. 9-A



WATER DENSITY VS TEMPERATURE
TEMPERATURE, °C
-2
0
5
10
15
20
25
30
35
37
1.040
1.035
1.030
1.025
1.020
1.015
1.010
1.005
1.000
0.995
0.990
DENSITY
S = 30 PPT
S = 25 PPT
S = 20 PPT
S = 15 PPT
S = 10 PPT
S = 5 PPT
Salinity = 0 PPT
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
80
82
84
86
88
90
92
94
96
98
100
TEMPERATURE, °F

FIG. 9-B

TABLE 1

HUDSON RIVER AT INDIAN POINT

SUMMARY OF WINTER CONDITIONS

<table>
<tr><th rowspan="2">Month</th><th rowspan="2">Range of River Ambient Temperature °F</th><th colspan="3">Probability that the Monthly Average Fresh Water Flow will be Less than Stated Magnitude</th><th colspan="4">Range of River Mean Salinity (ppt)
Difference Between Bottom & Surface Salinities (ppt)
for Indicated Ranges in Lower Hudson
River Fresh Water Flow:</th></tr>
<tr><th>21,000 cfs</th><th>15,000 cfs</th><th>10,000 cfs</th><th>Greater than 21,000 cfs</th><th>From 15,000 cfs to 21,000 cfs</th><th>From 10,000 cfs to 15,000 cfs</th><th>From 3,500 cfs* to 10,000 cfs</th></tr>
<tr><td>January</td><td>33-35</td><td>70</td><td>50</td><td>30</td><td rowspan="4">0 - 0.1

0.0</td><td colspan="2">RANGE OF MEAN SALINITY</td><td rowspan="4">2.3 - 6.7

0.4</td></tr>
<tr><td>February</td><td>~33</td><td>75</td><td>55</td><td>30</td><td>0.1 - 1.2</td><td>1.2 - 2.3</td></tr>
<tr><td rowspan="2">March</td><td rowspan="2">33-39</td><td rowspan="2">20</td><td rowspan="2">Less Than 1</td><td rowspan="2">Less Than 1</td><td colspan="2">APPROXIMATE DIFFERENCE BETWEEN BOTTOM AND SURFACE SALINITIES:</td></tr>
<tr><td>0.15</td><td>0.3</td></tr>
</table>

*Minimum of monthly average fresh water flow in lower Hudson River is approximately equal to 3,500 cfs.

During most of the year, the river ambient temperature is above 39.2°F. The warmer effluent from the Indian Point power plant will be lighter than the ambient water and, therefore, it will spread into the upper layers of the river, where it will tend to reach the surface. During the winter conditions, when the river ambient temperature is less than 39.2°F, the diluted thermal effluent of the Indian Point plant will have, under certain circumstances, greater density than the ambient water. This may cause an increase in temperature with depth, particularly within the upper layer, but the plume may not spread toward the bottom and remain in the lower layer.

First of all, there is a relatively high probability of the presence of salt in the river at Indian Point during the winter months. Referring back to Table 1, the probability of the occurrence of salt at Indian Point can be summarized as follows:

Average Range of Mean Cross-sectional Salinity (ppt)	Approx. Difference Between Bottom and Surface Mean Salinities (ppt)	Frequency of Occurrence of River Salinity Within Stated Range (%)		
		January	February	March
6.7 - 2.3	0.4	30	30	Less than 1
2.3 - 1.2	0.3	20	25	Less than 1
1.2 - 0.1	0.27 - 0	20	20	~19
0.1 - 0	0	30	25	80

The vertical difference in density due to salt vertical distribution, under conditions of the presence of salt at Indian Point, is usually in excess of the increase in the density of the thermal plume, due to its temperature rise above the minimum ambient temperature of about 33°F. In other words, the salt-induced density difference is sufficient enough to overcome the plant-induced density difference and, therefore, will act against plume sinkage.

The conditions under which buoyancy or sinkage occur therefore depend on the prevailing River ambient temperature and salinity. To illustrate typical possibilities, Figures 10 and 11 have been prepared. These Figures compare the depth-variable density of the ambient water with the density of the thermal plume for river ambient temperatures of 33°F and 37°F, respectively. In Figures 10 and 11, the density of ambient water was calculated for four possible conditions of river salinity at Indian Point as follows:

Case	Mean Cross-Sectional Average Salinity ppt	Difference Between Bottom and Surface Mean Salinities, ppt
a	5.0	0.4
b	1.7	0.3
c	0.6	0.15
d	0	0

The vertical salinity distribution was assumed to follow the generalized distribution derived from numerous salinity measurements and expressed by an equation (Reference 2) as follows:

$$S = S_1 + 3d\eta^2 - 3d\eta^3$$

where: S_1 = mean salinity at given depth, ppt

S = mean surface salinity, ppt

d = $S_1 - S_2$, where S_2 is bottom salinity, ppt

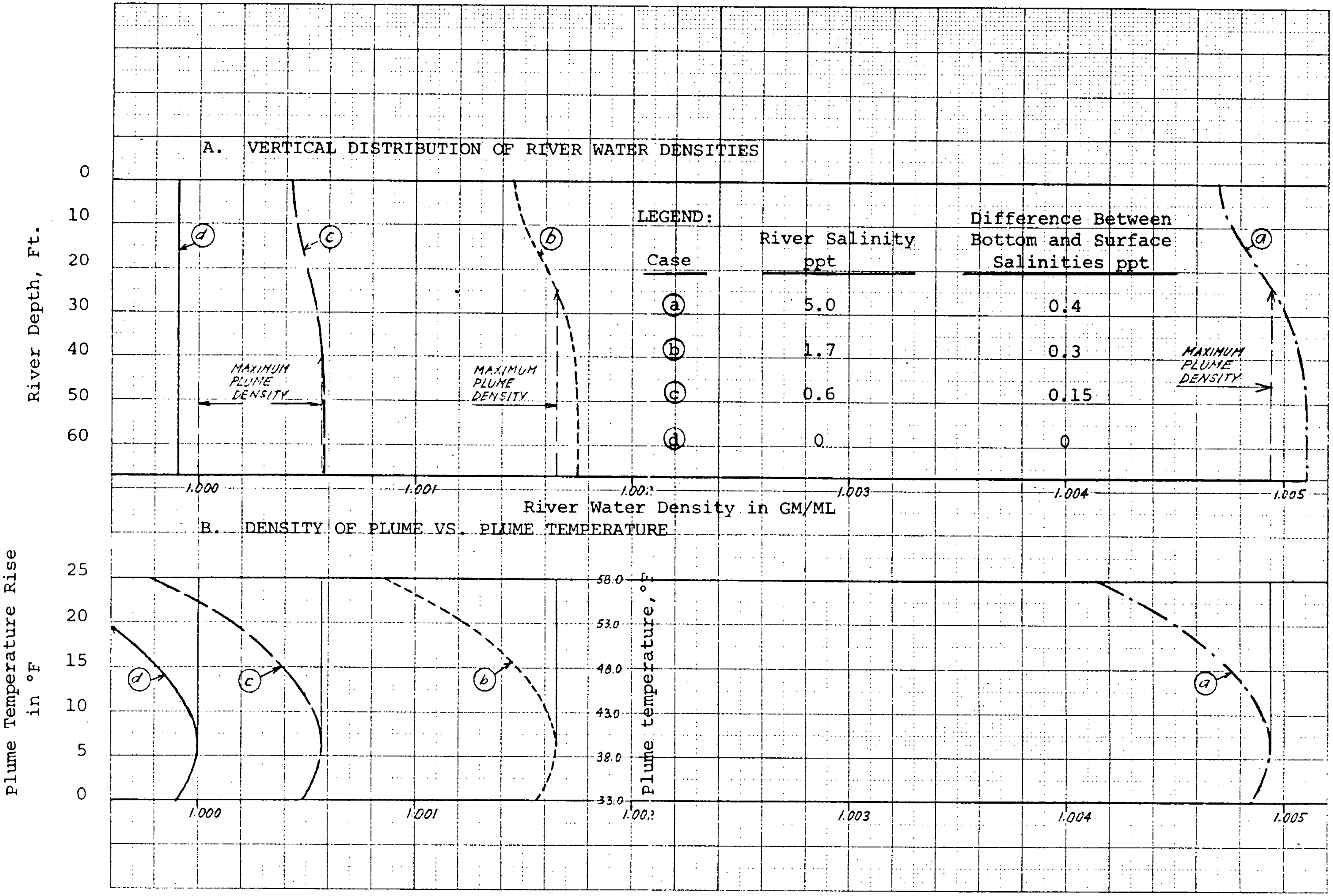
η = $\frac{y}{H}$

y = depth below the water surface, ft

H = mean depth, ft

In order to calculate the density of the thermal plume, the salinity of the thermal effluent was calculated as the average salinity of the cooling water withdrawn from a depth ranging from 0 ft to 30 ft.

HUDSON RIVER AT INDIAN POINT
COMPARISON OF THE PLUME AND RIVER WATER DENSITIES
FOR RIVER AMBIENT TEMPERATURES OF 33°F



LEGEND:

Case	River Salinity ppt	Difference Between Bottom and Surface Salinities ppt
a	5.0	0.4
b	1.7	0.3
c	0.6	0.15
d	0	0

FIGURE 10

HUDSON RIVER AT INDIAN POINT
COMPARISON OF THE PLUME AND RIVER WATER DENSITIES
FOR RIVER AMBIENT TEMPERATURE OF 37°F

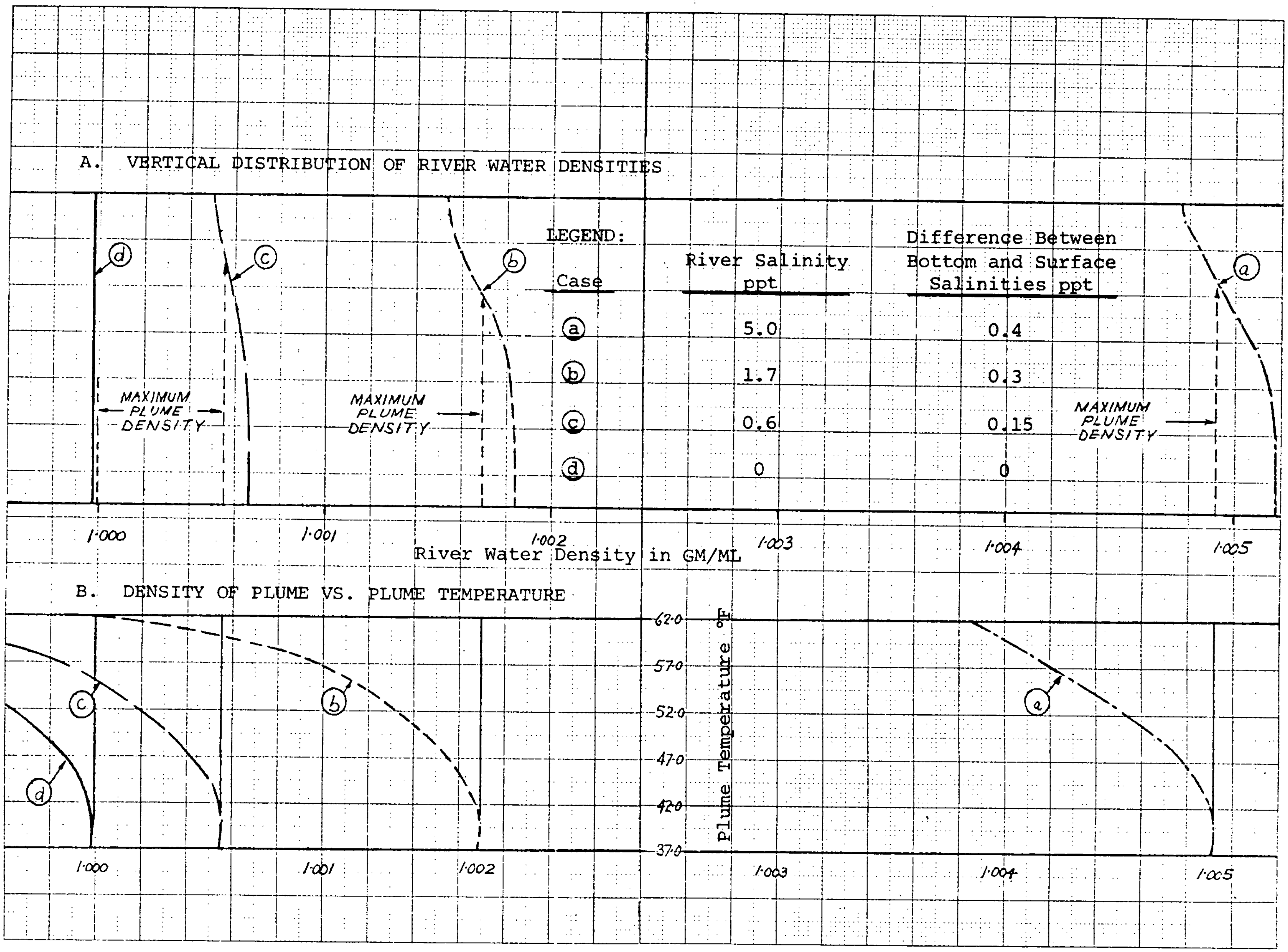


FIGURE 11

To show the depth to which temperature increases from the surface may be observed, vertical lines corresponding to the maximum plume density for each condition have been extended into the upper graph on each Figure. The intersection of this extension with the depth-density profile will locate the depth to which increasing temperature may extend.

Figures 10 and 11 indicate that, during conditions under which river ambient temperatures are 33°F and 37°F and river salinities are greater than 1.7 and 0.6 ppt, respectively, the thermal plume discharged from the Indian Point power plant remains buoyant. Therefore, the plume will not spread toward the bottom but will remain in the upper layer of the river.

The diluted plume at certain temperatures will not be buoyant only when the river salinity is less than the limits stated above for the two river ambient temperatures of 33°F and 37°F.

In summary, considering the observed occurrence of flows and ambient temperatures during January, February and March, rising temperatures are not expected to extend below mid-depth more than about 25% of the time for the January-February period. In March, although monthly fresh water flow frequency is high, this generally will be due to snow melt and subsequent runoff in the northern reaches of the Basin, a phenomena which generally occurs late in March. At this point, River ambient temperatures are approaching, if not already exceeding the critical temperature of 39.2°F.

The behavior of the non-buoyant plume, however, is not entirely opposite to that of the buoyant plume resulting from the discharge of the thermal effluent into ambient water of high temperatures.

The driving force of buoyancy, or of sinkage of the plume, is related to the difference between the plume and river water densities. Figure 12 compares the driving forces of the buoyancy and sinkage of two plumes under the following conditions:

a) Thermal effluent is discharged at a temperature of 85°F into the river water at a temperature of 70°F (jet initial temperature rise 15°F). These conditions correspond to the conditions which exist at Indian Point during summer.

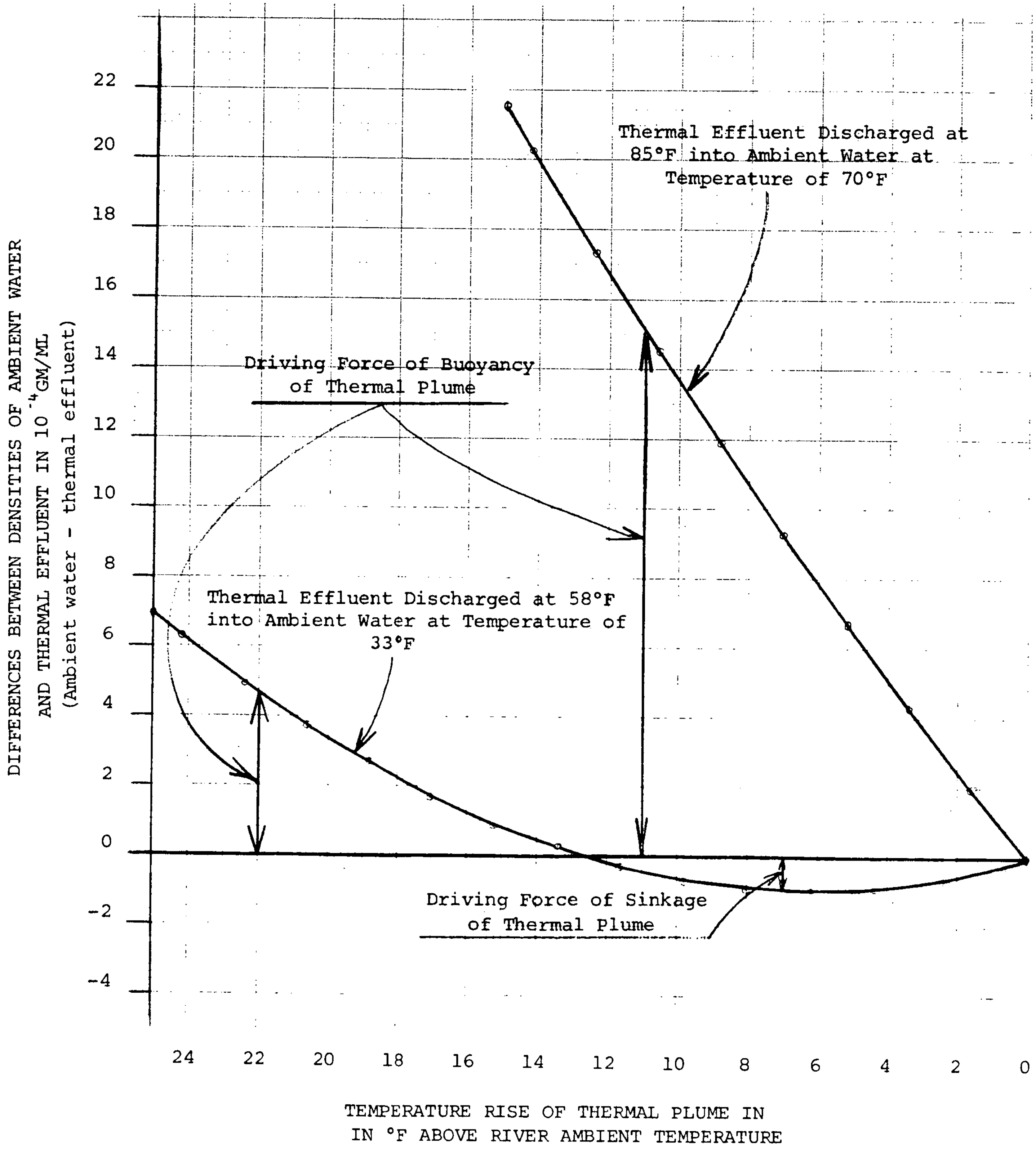
b) Thermal effluent is discharged at a temperature of 58°F into the river water at a temperature of 33°F (jet initial temperature rise of 25°F). These conditions may exist at Indian Point during winter.

In both cases, zero salinity of river water was assumed.

Figure 12 indicates that the thermal effluent discharged at a temperature of 58°F into the river water at an ambient temperature of 33°F (under condition "d" - winter) remains buoyant until the plume temperature is decreased, due to heat dissipation, to about 45.5°F (a temperature rise of 12.5°F above the river ambient temperature). The plume becomes non-buoyant as its temperature decreases below 45.5°F. Note that jet horizontal momentum is still significant and ambient water entrainment and dilution of temperature will continue.

Figure 12 also indicates that the driving force of the sinkage of the plume during winter conditions is at least one order of magnitude less than the driving force of the buoyancy of the plume during summer conditions. Therefore, the thermal plume discharged into the river from the Indian Point near-surface discharge should not be expected to sink toward the river bottom in the same way that it

COMPARISON OF DRIVING FORCES OF BUOYANCY AND SINKAGE OF THERMAL PLUME
(Zero Salinity Condition)



reaches the surface during summer conditions. Due to this significantly weaker stratifying force, turbulence of the river water can be expected to be a more important factor affecting the behavior of the thermal plume during winter than it is under summer conditions. This turbulence may tend to spread the plume in the river and to result in more uniformly distributed temperatures during winter than are usually observed during other periods of the year.

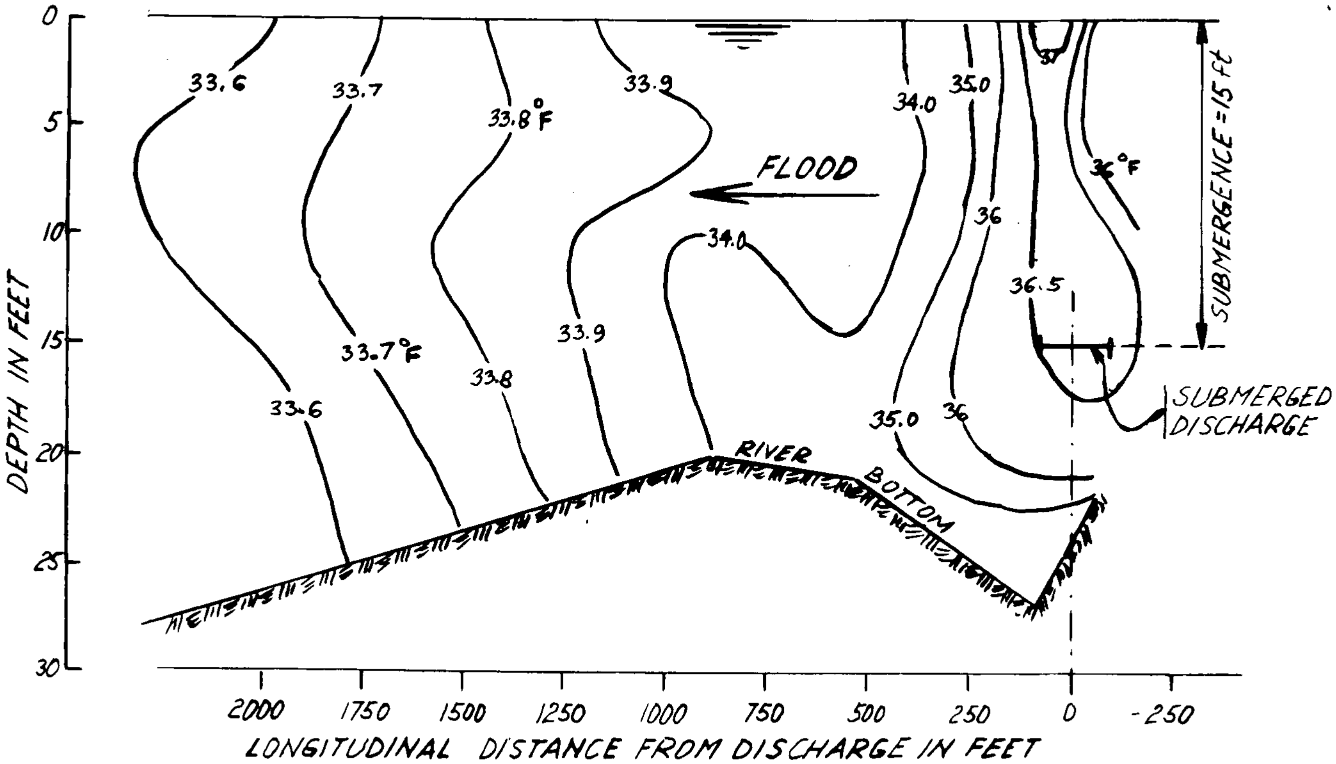
QLM Laboratories, Inc., conducted temperature measurements in the vicinity of the Bowline power plant multiport submerged jet discharge on January 10, 1973. Conditions during the survey were as follows:

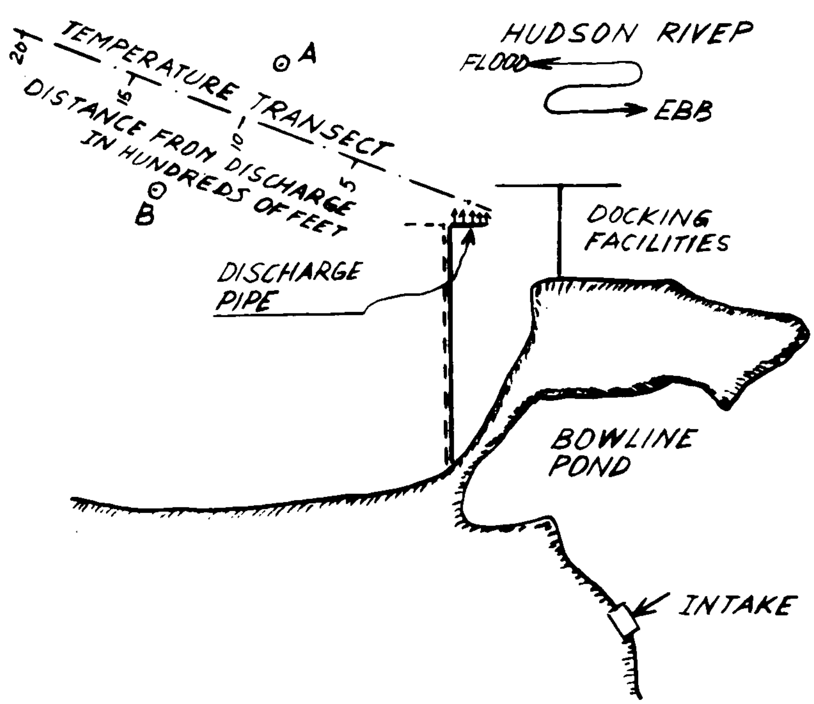
River ambient temperature	32.0°F - 32.5°F
River salinity	less than 0.1 ppt
Plant temperature rise above river ambient temperature	~ 13°F
Tidal phase	Flood

Excluding the plant temperature rise, these conditions are generally the same as those listed under the above item "d" and represent a set of severe sinkage conditions due to absence of vertical salt gradients during the survey. Lack of ocean-derived salt gradients in this reach during the survey is due to the unusually high fresh water flow in the Hudson River this year.

Figure 13 presents the observed temperature distribution in a vertical section approximately at the centerline of the plume. The figure indicates that no consistent tendency of the plume to sink toward the bottom was observed.

VERTICAL DISTRIBUTION OF TEMPERATURE
IN VICINITY OF THE BOWLINE PLANT
SUBMERGED DISCHARGE
(Measured by QL&M on January 10, 1973)





The vertical distribution of the temperature was found to be unstable and to fluctuate with time indicating existence of turbulent conditions. Figure 14 compares two sets of temperature measurements taken at the same locations, but at different times (20 to 30 minutes apart). This figure indicates that existence of positive temperature profiles, i.e., temperatures increasing with depth, is an unstable phenomenon and cannot persist for a long period of time. Due to turbulence, the vertical gradients are weak, i.e. variations about the mean are less than $\pm$ 0.5°F.

In general, similar conclusions may also apply in the case of the Indian Point plume under the most severe set of sinkage conditions.

As indicated earlier more stable plume conditions exist during normal winter conditions, characterized by presence of ocean-derived salt. This is due to existence of natural forces (increasing vertical density gradients from surface to bottom) acting against plume sinkage. Under these conditions, the Indian Point plume will tend to stay in the upper layer and, therefore, the upper layer temperatures would be in excess of their lower layer counterparts.

The vertical salinity gradients presented and used earlier in this testimony are indicative of normal flow conditions in the river. However, stronger vertical salinity gradients have also been reported; for example, a vertical salinity difference of 4.6 mg/l presented by Clark (Reference 1) and observed during the Dolphin cruise on March 6-8, 1968.

Such strong vertical gradients may result from transient flow conditions, i.e., after a period of low flows, the fresh water inflow into the estuary experiences a sudden and significant increase. Under these conditions, the waters in upper layers of the river are diluted by increased fresh water flow

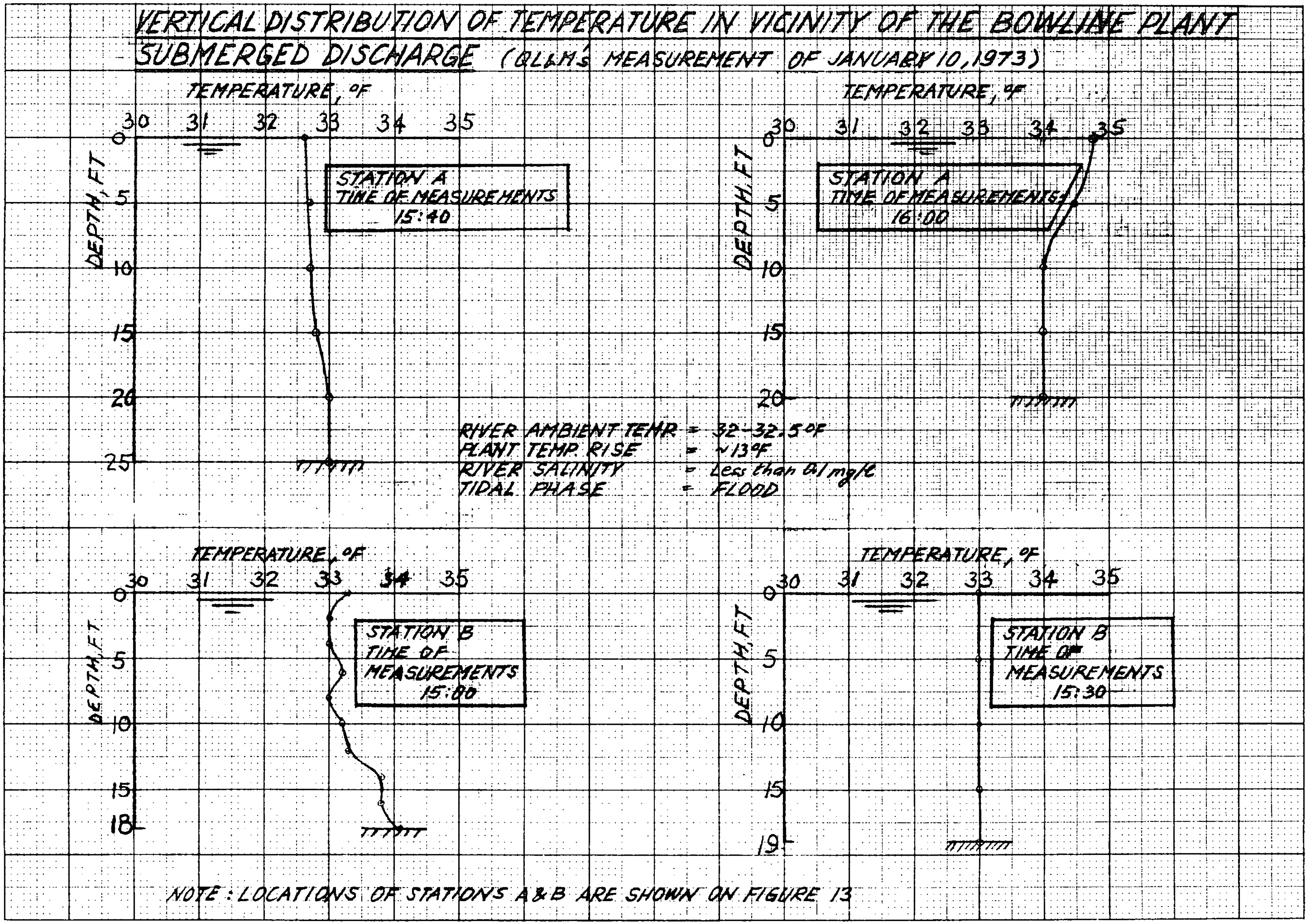

VERTICAL DISTRIBUTION OF TEMPERATURE IN VICINITY OF THE BOWLINE PLANT
SUBMERGED DISCHARGE (QL&M's MEASUREMENT OF JANUARY 10, 1973)
TEMPERATURE, °F
30 31 32 33 34 35
DEPTH, FT
0 5 10 15 20 25
STATION A
TIME OF MEASUREMENTS
15:40
TEMPERATURE, °F
30 31 32 33 34 35
DEPTH, FT
0 5 10 15 20
STATION A
TIME OF MEASUREMENTS
16:00
RIVER AMBIENT TEMP. = 32-32.5°F
PLANT TEMP. RISE = ~13°F
RIVER SALINITY = Less than 0.1 mg/l
TIDAL PHASE = FLOOD
TEMPERATURE, °F
30 31 32 33 34 35
DEPTH, FT
0 5 10 15 18
STATION B
TIME OF
MEASUREMENTS
15:00
TEMPERATURE, °F
30 31 32 33 34 35
DEPTH, FT
0 5 10 15 19
STATION B
TIME OF
MEASUREMENTS
15:30
NOTE: LOCATIONS OF STATIONS A & B ARE SHOWN ON FIGURE 13

FIGURE 14

more rapidly than waters in lower layers which results in somewhat stronger vertical gradients. Greater differences between bottom and surface salinities and, therefore, greater vertical density gradients of river water during such transient flow conditions, will result in a greater stability and stronger buoyancy of the thermal plume, i.e., the forces resisting plume sinkage are stronger. For example, in the case cited by Clark, no plume sinkage would be possible regardless of ambient River temperature and plant temperature rise.

IV. EFFECT OF THE INDIAN POINT WINTER OPERATION ON STRIPED BASS

Echo sounder records have shown striped bass to stay mostly within 8 ft of the river bottom during winter conditions (Ref. 5). As shown in the previous item of this testimony, the Indian Point thermal plume will not remain in the lower layers of the river. Therefore, striped bass would not be expected to be especially attracted to the area of the intake by the thermal plume temperatures.

Furthermore, a collection of striped bass made by QLM Laboratories, Inc., during the months of January and February 1972 indicated the possibility that the bulk of striped bass does not overwinter in fresh water in the Hudson River, but maintains a definite position in waters of greater salinities. Therefore, under the most severe conditions in respect to the sinkage of the plume at Indian Point, i.e., during conditions of zero or low salinities (see Item III of this testimony), striped bass juveniles will probably not be present in the vicinity of the Indian Point plant.

I also do not agree with Clark's statement that "one might expect those fish resident in the plume in winter to be suddenly driven into adjoining cold water when chlorine added to the cooling water reaches the plume". Present experience with the Indian Point Unit 1 operation has indicated that no chlorination of the cooling water system will be needed during winter months (when ambient temperatures are greater than 45°F).

Even if the Unit 2 cooling water system were to be chlorinated according to the proposed non-winter chlorination procedure during winter months, the concentration of chlorine residual would be reduced at the end of the discharge canal to less than 0.15 mg/l (Reference 4). Approximately 130 ft out of the discharge and beyond, the chlorine concentration is expected to be essentially zero or immeasurable.

LIST OF REFERENCES

1. Testimony of John R. Clark on Effects of Indian Point Units 1 & 2 on Hudson River Aquatic Life, October 30, 1972 (Final).

2. Quirk, Lawler & Matusky Engineers, "Environmental Effects of Bowline Generating Station on Hudson River," Report submitted to Orange & Rockland Utilities and to Consolidated Edison Company of New York, Inc. March 1971.

3. "Handbook of Chemistry and Physics" 51st Edition, editor Robert C. Weast, Ph.D., published by the Chemical Rubber Company, Cleveland, Ohio 1970-71.

4. Redirect-Rebuttal Testimony of John P. Lawler on the Effect of Indian Point Unit 2 Chlorination on the Aquatic Biology of the Hudson River, February 5, 1973.

5. John R. Clark "Seasonal Movements of Striped Bass Contingents of Long Island Sound and the New York Bight, Reprint from Transactions of the American Fisheries Socieyt, Vol. 97, No. 4, October 31, 1968, pp 320-343.

BEFORE THE UNITED STATES
ATOMIC ENERGY COMMISSION

In the matter of CONSOLIDATED EDISON COMPANY OF NEW YORK, INC. (Indian Point Station Unit 2)	))))))	DOCKET NO. 50-247

Redirect-Rebuttal Testimony
of
John P. Lawler, Ph.D.
QUIRK, LAWLER & MATUSKY ENGINEERS

on the

Contribution of the Hudson River
to the Middle Atlantic Striped
Bass Fishery

February 5, 1973

I. INTRODUCTION

The purpose of this section of testimony is to refute the conclusion stated by Clark and Goodyear that the Hudson River contributes 80% of the striped bass population in the Middle Atlantic region.

Approach

1. To place the striped bass spawning areas which contribute to the Mid-Atlantic fishery into their correct geographic perspective.

2. To present an analysis of the commercial fishery statistics in order to clarify the relationship of the Mid-Atlantic striped bass catch to the total Atlantic coast catch.

3. To refute the notion of an 80% contribution of the Hudson River to the Mid-Atlantic fishery by demonstrating the fallacies in the following:

   a. Dr. Goodyear's and Mr. Clark's belief that the fact that only a small percentage of striped bass less than four years old migrate out of Chesapeake Bay demonstrates that the Chesapeake does not make a substantial contribution to the fishery in the Mid-Atlantic region.

   b. Mr. Clark's use of tagging data to demonstrate that the Hudson River is the principal spawning area for striped bass inhabiting the Mid-Atlantic region.

These are discussed under the following chapter headings:

II. Geographic Perspective

III. Commercial Fishery Statistics

IV. Per Cent Contribution of the Chesapeake

V. Tagging Studies: Clark, Alperin, Schaefer.

II. GEOGRAPHIC PERSPECTIVE

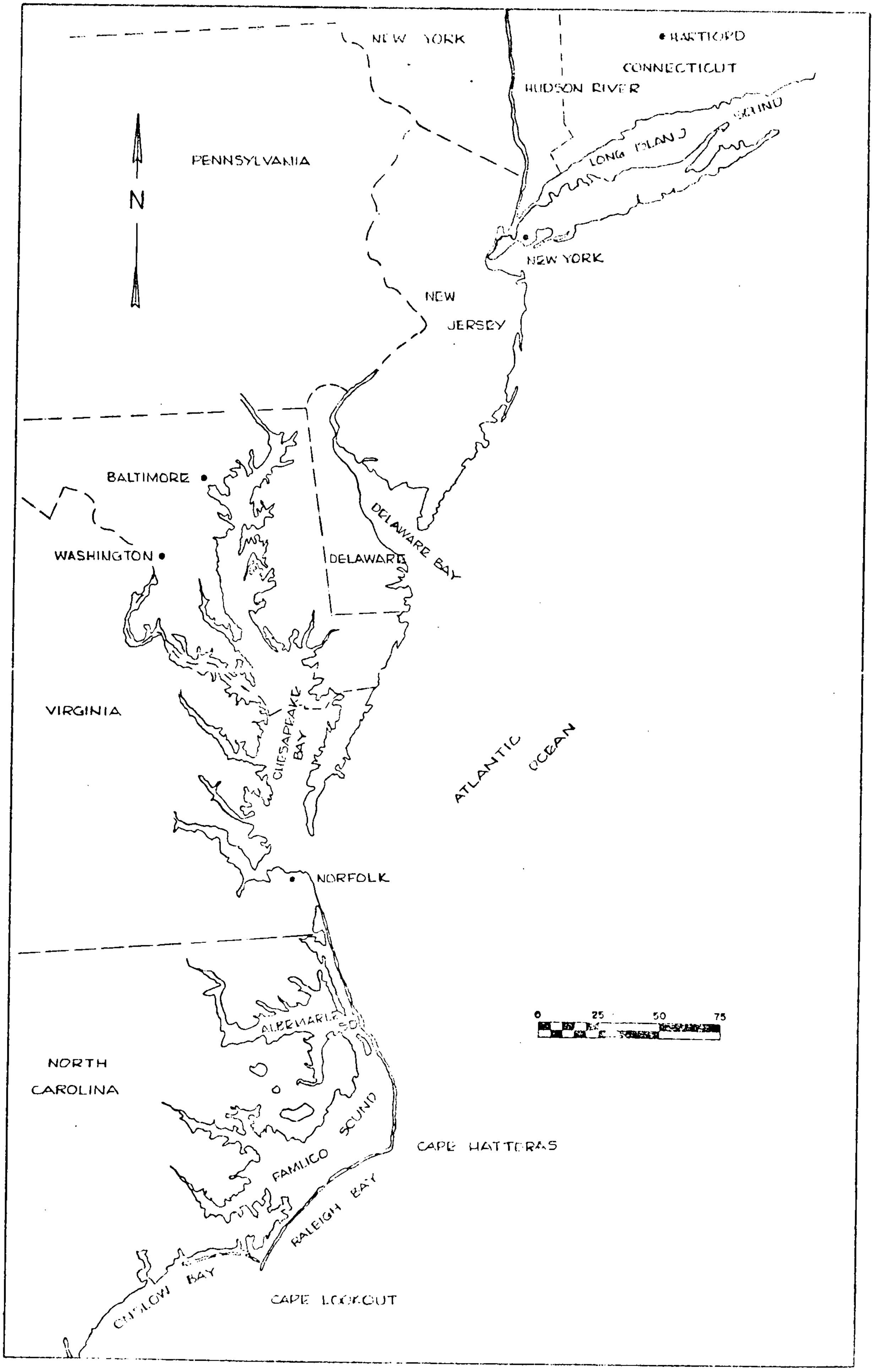
There are four major spawning areas for striped bass along the Atlantic Coast of the United States: the Hudson River, Chesapeake Bay, Delaware Bay, and the Albemarle Sound - Pamlico Sound systems. There are no rivers to the north of the Hudson or to the south of Pamlico Sound which make significant contributions to the striped bass population.

As can be seen from Figure 1, the various spawning rivers including the Hudson empty into a large shallow bay which can be utilized by the young striped bass as a feeding area throughout their first years of life. It is our belief that for bass spawned in the Hudson, the feeding area of young striped bass, at least in their first two years of life, encompasses the lower portion of the Hudson, New York Bay including the portion of New Jersey bordering on the Bay, and the western end of Long Island. The young fish would move into these area in spring and remain through the summer and fall, then return to the Hudson to overwinter. These areas appear to play the same role with respect to the Hudson River as that played by Chesapeake and Delaware Bays to the variety of Rivers that empty into these bays.

Clark agrees with this concept as he indicated in cross-examination (Tr. 8211. ln. 1-21) but he expands this area to extend from Barnegat Bay to the Connecticut-Rhode Island border. There is no evidence, however, to support the existence of such an extensive juvenile feeding range.

Some question has been raised as to the role of the Delaware as a striped bass spawning area.

FIGURE 1


NEW YORK
CONNECTICUT
HUDSON RIVER
PENNSYLVANIA
N
NEW YORK
NEW
JERSEY
BALTIMORE
WASHINGTON
DELAWARE
DELAWARE BAY
VIRGINIA
CHESAPEAKE
BAY
ATLANTIC
OCEAN
NORFOLK
0
25
50
75
NORTH
CAROLINA
PAMLICO
SOUND
CAPE HATTERAS
RALEIGH BAY
CAPE LOOKOUT

Clark in his October 30, 1972 testimony, (p. 4) states that the Delaware is too polluted to support a significant nursery area. When asked on January 11, 1973 (Tr. 8187. ln. 3-14) what data caused him to form this opinion, which represented a change from his position in his 1968 paper (7), he replied that his present belief was based on the study performed by Walter Murawski of the New Jersey Division of Fish and Game.

An examination of Murawski's publication (1) has failed to confirm Clark's conclusions. Murawski indicates that striped bass eggs were collected from river mile 58, at Oakwood Beach, New Jersey to mile 79 at Bridgeport, New Jersey. Neither eggs nor larvae were found from mile 79 to 107 (Riverton, New Jersey). Above this area from mile 118 (Burlington, New Jersey) to 125 (Newbold Island) only larvae were collected. (River mile 0 is at Cape May at the mouth of the Bay.)

He further states:

> *"That 1964 was a year of serious drought and thus represents unusually bad conditions. Unfortunately, comparable data for the entire geographic area in question is not available for the years prior to the drought of the 1960's."*

It is therefore possible that in years of good river flow the effects of Philadelphia pollution would be mitigated and allow for spawning over a greater stretch of the river.

It should also be noted that in years of greater river flow, the salt front would be moved down river, thereby providing a longer stretch of fresh water for spawning in the river below Philadelphia.

Murawski also collected eggs and/or larvae of the striped bass in various tributaries of the Delaware Bay. These included Oldman's Creek, Racoon Creek, Salem River and the Chesapeake and Delaware Canal.

In addition Hamer (2) has stated that the Maurice River, one of the main tributaries to Delaware Bay is known to produce fair numbers of striped bass and in 1961 tagged 88 "running ripe" adults in the Maurice which he believed to be of the local spawning stock. The Delaware Bay itself provides extensive nursery and feeding areas for young striped bass. In the light of the above information, Clark's conclusions of October 30, 1972, p. 4, must be rejected and the Delaware Bay and its tributary Rivers considered as a contributor of striped bass to the Atlantic Coast population.

Chesapeake Bay and the rivers tributary to it

It is well documented that Chesapeake Bay is a major contributor to the Atlantic Coast Striped Bass population. Mansuetti & Hollis (3) provided a good summary of striped bass spawning areas in Chesapeake Bay. The attached list taken from

Mansuetti and Hollis describes these areas.

"*Striped Bass Spawning Areas in Chesapeake Bay*

Head of Chesapeake Bay - *Includes the Bay proper above Worton Point and such tributary rivers as the Susquehanna, Elk, Bohemia, Northeast, and Sassafras, as well as the Chesapeake and Delaware Canal.*

Potomac River - *Upper Cedar Point to Whitestone Point (51 miles to 81 miles above the river mouth).*

Choptank River - *Bow Knew Point to one mile above Williston (23.5 miles to 41.5 miles above river mouth). Spawning also occurs in Tuckahoe Creek up to Route 328.*

Nanticoke River - *Newfoundland Point to Sharptown (6 miles to 26 miles above river mouth). Spawning also occurs in first two miles of Marshhope Creek.*

Patuxent River - *Deep Landing to 2 miles above Lyons Creek Wharf (26 miles to 38 miles above river mouth).*

Wicomico River - *Pine Beach to Rockawalking Creek (4 miles above river mouth).*

Blackwater River - *Snake Island to Little Blackwater (mouth to 14 miles above river mouth).*

Pocomoke River - *Mouth of river to Pocomoke City (mouth to 14 miles above river mouth).*

Transquaking River - *Mouth to Beaverdam Pond (mouth to 10 miles above the mouth). Spawning also occurs in the lower 2 miles of the Chicamacomico River.*

Chester River - *Piney Grove to Crumpton (22 miles to 30 miles above the mouth).*

Manokin River - *A small area above 12 miles above mouth.*

In addition the Rappahannock, Mattiponi, Pamunkey, Chickahominy, and James Rivers in Virginia are known to support spawning populations of striped bass.

Rivers South of Chesapeake Bay

All testimony in this hearing has restricted itself to striped bass spawned and captured in the area from Chesapeake Bay northward. No real consideration has been given to fish occuring in the southern regions. Although it is not stated in the testimony, this neglect is apparently based upon the prevalent belief that striped bass spawned in these areas contribute little or nothing to the population of striped bass occurring off the Middle and North Atlantic States.

Some confusion, however, enters into the picture as a result of the varying definitions of the region under consideration. If the definition of the Middle Atlantic States used in commercial statistics and by Goodyear (Tr. 9030 ln. 4-16) is taken to include only New Jersey, Delaware, and New York, then the statement is correct. If it is taken to include Maryland and Virginia as well, the statement still is true. But if the definition utilized by the Salt Water Angling Surveys (4) and consequently by Clark in his analysis of sport catches is utilized, then some additional information must be taken into account.

The Salt Water Angling Surveys define the Middle Atlantic region as the Atlantic Coast from New Jersey to Cape Hatteras. Using this definition it is apparent that striped bass caught in the areas of Albemarle and Pamlico Sounds will be included in these surveys and that it is likely these fish spawned in the rivers tributary to these sounds.

For the purpose of our analysis, we will utilize the definition employed in the commercial fishery statistics and by Goodyear and the rivers south of Chesapeake Bay will be considered to contribute nothing to the fishery in the Middle Atlantic area.

Using this definition we will be concerned with only three major areas of striped bass production in the North and Middle Atlantic States, the Hudson, the Delaware, and the Chesapeake. Of these three, the Chesapeake

Bay and its tributaries provides by far the greatest amount of suitable habitats for striped bass to utilize as spawning, nursery, and feeding areas.

Table 1 gives a comparison of the various physical characteristics of the three spawning areas.

TABLE 1

PHYSICAL CHARACTERISTICS OF MAJOR STRIPED BASS SPAWNING AREAS

Water Body	Drainage Area (miles^2)	Monthly Average Freshwater Flow (1,000cfs)	Length of the Estuary (Miles)	Width of the Mouth (Miles)	Length of Saline Water Region (Miles)	Spawning Area
Hudson River	13,000 (1)	18.0 (1)	165 (1)*	8 (1)	50 (1)	Peekskill (M.P.43) to Saugerties (M.P. 102)
Delaware River	13,000 (3)	21.0 (3)	140	12 (3)	60 (3)	Oakwood Beach (M.P. 58 to Bridgeport N.J. (M.P.79)
Chesapeake Bay	67,200 (2)	77.8 (2)	210 (main channel) +180 (Tributaries)	12	-	See Text, pages 7 & 8
Total	93,200	116.8	695	-		
% Hudson River / Total	13.9%	15.4%	23.7%	-		

* Includes 15 miles from Sandy Hook to the Battery + 150 miles from the Battery to Troy.

1. QL&M, "Environmental Effects of Bowline Generating Station on Hudson River," March 1971

2. "The Nation's Water Resources", U. S. Water Resources Council, Washington, D.C. 1968

3. "Report on Utilization of Waters of Delaware River", The Interstate Commission on Delaware River Basin, August, 1950

III. COMMERCIAL FISHING STATISTICS

The AEC staff has based some of its conclusions regarding the contribution of the Hudson River to the Atlantic coast striped bass population on the records of the commercial catches from the Hudson River and the Middle Atlantic states.

Table 1 presents the records of commercial catches of striped bass in the various regions along the coast and the percentage of the catch taken in Chesapeake Bay, the Middle Atlantic region, and the Hudson River. These data are taken from Koo's (5) Table 2. Percentages were calculated to facilitate analysis.

From Table 1 it can be seen that the commercial catch of striped bass undergoes periodic cyclical fluctuations, but that the general trend has been upward from a low point of 1,097 million pounds in 1934 to 9,076 million in 1966. It is also apparent that in every year, the commercial catches from the Chesapeake Bay have been greater than 58% of the catch from the entire Atlantic Coast with the average being 69%.

A possible explanation of the dramatic increase in striped bass is presented by Pearson (6) who states the following:

> *"It is surprising to note that after an extended period of lean years the catch of striped bass in Maryland waters increased from 332,000 pounds in 1934 to 928,000 pounds in 1935. This increase of nearly threefold cannot be definitely explained in the absence of field observations but a likely cause for the greater abundance of fish is suggested. In 1932 the use of the purse seine was forbidden in Maryland. This type of net*

TABLE 2

COMMERCIAL CATCHES OF STRIPED BASS
(listed in thousands of pounds)

Year	New England	Mid-Atlantic (N.Y., N.J., Del.) Total	Hudson Only	Chesapeake	South Atlantic	Total	% of Atlantic Catch Taken From Chesapeake Bay	Mid-Atlantic	Hudson River
1930	89	205	1	1,653	457	2,404	68.8	8.5	.04
1931	90	135	5	1,116	327	1,668	66.9	8.1	.2
1932	42	52	4	1,028	507	1,629	63.	3.2	.2
1933	61	40	13	833	-	(1,369)[1]	60.8	2.9	.9
1934	-	-	10	642	362	(1,097)	58.5	-	.9
1935	22	62	19	1,302	-	(1,951)	66.7	3.2	1.0
1936	-	-	20	2,383	768	(3,621)	65.8	-	.5
1937	450	405	29	3,016	713	4,584	65.8	8.8	.6
1938	301	311	25	2,869	523	4,004	71.6	7.8	.6
1939	285	446	30	2,692	340	3,763	71.5	11.8	.8
1940	147	382	35	1,839	540	2,908	63.2	13.1	1.2
1941	-	-	21	2,089	-	(3,213)	65.0	-	.7
1942	219	-	-	3,286	-	(4,464)	73.6	9.4	-
1943	216	514	31	-	-	(5,186)	-	9.9	.6
1944	341	799	61	4,545	540	6,225	73.0	12.8	1.0
1945	317	782	79	3,664	610	5,373	68.2	14.6	1.4
1946	406	963	-	3,699	-	(5,772)	64.1	16.7	-
1947	119	413	48	4,063	-	(5,299)	76.7	7.8	.9
1948	151	758	39	5,102	-	(6,715)	76.0	11.3	.6
1949	162	902	-	4,542	-	(6,310)	72.0	14.3	-
1950	167	897	-	6,834	797	7,695	75.8	11.7	-
1951	265	981	-	4,140	702	6,088	68.0	14.3	-
1952	179	1,141	30	3,413	647	5,380	63.4	11.7	.6
1953	193	1,023	19	3,106	757	5,079	61.2	16.1	.4
1954	184	636	-	3,059	1,122	5,001	61.2	21.2	-
1955	106	629	73	3,466	736	4,937	70.2	20.14	1.4
1956	98	473	93	3,145	764	4,480	70.2	12.7	2.1
1957	80	701	84	2,788	597	4,166	66.9	9.8	2.0
1958	95	479	77	4,422	1,097	6,093	72.6	16.8	1.3
1959	120	746	133	6,446	872	8,184	78.8	7.9	1.6
1960	211	870	133	6,687	783	8,551	78.2	9.1	1.6
1961	397	1,252	71	7,262	551	9,462	76.8	10.2	.8
1962	682	1,259	48	5,923	747	8,611	68.8	13.2	.6
1963	582	1,474	47	6,496	737	9,289	69.9	14.6	.5
1964	632	2,022	29	5,189	7;7	8,560	60.6	15.9	.3
1965	531	1,533	-	5,162	486	7,712	66.9	23.6	-
1966	843	1,429	-	6,150	654	9,076	67.8	19.9	-
							Avg.	68.6%	Avg. 12.2%

1. Figures in parentheses were interpolated by Koo (5) by adding the mean of two adjacent years for the missing statistic.

had accounted for about 25 percent of the annual catch for several years prior to 1931. Although the catch remained low from 1932 to 1934, it is significant that the striped bass do not generally attain commercial size until their third summer. Hence, fish which were spawned in 1933 did not appear in the catch until 1935. It might be assumed that enough adult striped bass 3 years old or older were spared by the abolition of the purse-seine fishery in 1932 to aid greatly in spawning production in the spring of 1933. Many fish spawned in 1933 undoubtedly reached the commercial catch during 1935. If such a condition actually occurred then a heavy production of young also occurred in 1934, making possible a large commercial catch in 1936. Field reports again indicate that the striped bass was as abundant in 1936 as in 1935, and that most catches were composed of small fish."

Pearson's work was published in 1938 and apparently he did not have available to him the records for commercial catches made after 1935.

Table 1 indicates that Pearson's deduction was correct; striped bass were again plentiful in the Chesapeake in 1936. It is of interest to note that while fishing improved in the Chesapeake in 1935, three years after the end of purse seining, the records also show an improvement in fishing in the Middle Atlantic in 1937. This is consistent with the idea that these fish originated in Chesapeake Bay since members of a year class would first appear in the commercial catches near their spawning area and then in the following years in areas further away as the fish grow older and undertake more extensive migrations.

If this is indeed the correct explanation then this is a strong indication that fish of Chesapeake Bay origin are directly responsible for the abundance of striped bass along the entire coast, since an alteration in the fishery in that region directly affected the level of abundance of striped bass in the North and Middle Atlantic regions.

It is also apparent that despite the high level of exploitation by both commercial and sports fishermen the population of striped bass, as reflected by commercial fishery statistics, has been increasing for over thirty years. There is no indication from more recent fishery statistics that this trend has not continued to the present.

The rapid increase in the number of striped bass caught by commercial fishermen between 1934 and 1937 may well be an indication of the speed with which population of these fish can recover once sources of mortality are removed. If this is actually the case this would tend to indicate that if the operation of the Indian Point power plants was demonstrated to have an adverse effect on the striped bass population and if the plants consequently converted to alternate cooling methods, the population of bass might well be able to recover to its former level in a very short space of time.

The following analysis is provided to illustrate the range of values which might be obtained for the impact of operation of the Indian Point power plants upon the East Coast striped bass commercial fishery.

1. From Table 2 the average contributions of the Middle Atlantic commercial fishery to the total commercial catch is 12%.

2. From the statements of Clark and Goodyear, as previously mentioned in this testimony, the level of contribution of Hudson River striped bass to the total population in the Middle Atlantic is set at 80%.

3. From the AEC staff analysis, as previously mentioned, the level of reduction of Hudson River striped bass is set at 40%.

The percent reduction in the East Coast fishery would then equal

$$.12 \times .8 \times .4 = 4.8\%$$

This reduction of 4.8% assumes that the plant will have a linear effect upon the fishery, a conclusion which cannot be conclusively demonstrated at this time.

An alternate calculation may be made utilizing other values for the factors involved.

1. The contribution of the Mid-Atlantic remains set at 12%.

2. Although it is our contention that there is insufficient data at this time to select any number as the contribution of the Hudson to the mid-Atlantic fishery, the contribution of the Hudson to the striped bass population in the mid-Atlantic is left at the 80% value selected by the Staff.

3. The level of reduction of Hudson River striped bass is set at 7% in line with previous QL&M testimony.

The reduction then would equal

$$.12 \times 0.8 \times 0.07 = .7\%$$

Once again these calculations assume a linear effect of the plant on the fishery. These calculations show clearly that the effect of Indian Point operation on the Atlantic commercial striped bass fishery can be expected to be negligible. We suggest the phrase "mid-Atlantic" is clearly a misnomer when used in the manner it has been in this proceeding. The implication of due happenings to the East Coast fishery is unfounded.

IV. PERCENT CONTRIBUTION OF THE CHESAPEAKE

Goodyear has stated that his major support for allocating 80% of the mid-Atlantic catch to the Hudson is the fact that less than 1% of Chesapeake Bay two year olds leave the Bay. This argument is specious for the following reasons:

1. All investigators appear to agree the Chesapeake population is much larger than any other. If commercial fishing data are used as an index of abundance, the Chesapeake population is 3 to 10 times larger than the entire area reported as "mid-Atlantic" and 30 to 200 larger than the Hudson. (These figures are on a pound basis - consideration of minimum legal limits which apply in both areas suggest higher numbers on a count basis - for the latter, age differences therefore also exist, additionally complicating the population comparison.)

2. A 1 or 2% movement out of the Chesapeake Bay would represent a much larger contribution to the mid-Atlantic region, therefore, than will a comparable percent movement out of the Hudson or Delaware.

3. Two year olds are not generally caught in the Middle Atlantic, because of legal size limitations, with the possible exception of Delaware Bay. Ten inch fish in this waterbody obviously should be considered of Delaware origin. Where these fish are when they are legal size, and therefore where caught, is not addressed by concerning oneself with the percent of two year olds moving out.

4. No attention is given to the 4,5,6 etc. year olds which may be moving out of Chesapeake Bay and contributing to the mid-Atlantic fishery. The New York and New Jersey legal limit of 16" suggests the majority of New York and New Jersey catches, the only catches which can be assumed to be made up to any significant degree of Hudson River fish, are fish 4 years old and more.

5. Statements on the part of many investigators, summarized by Goodyear in the Staff's Final Environmental Statement, are to the effect that two year olds are expected to stay in the system of their origin; i.e., Chesapeake system fish would be expected, by and large, to stay in the Chesapeake area, and Hudson system fish in the Hudson area, including Jamaica Bay, Lower New York Harbor, and the western quarter of Long Island Sound. After 4 years, they are all expected to undergo some migration.

V. TAGGING STUDIES: CLARK, ALPERIN, SCHAEFER

In cross-examination Clark was asked how he arrived at his conclusion that 80% of the striped bass population from Delaware Bay to the Connecticut-Rhode Island Border were spawned in the Hudson. He replied: (Tr. 8561-8562)

> *"The AEC Staff has reported calculations in the Final Environmental Statement for Indian Point No. 2, page Roman 12-36 and 38, from which it might be estimated that up to 79 to 93 percent of the mid-Atlantic stock of striped bass -- those caught from New York to Delaware -- may be of Hudson origin.* In my study, the seasonal movements of striped bass contingents of Long Island Sound and the New York Bight, Table 4, shows that 52 of 65 fish taken inspawning situations, that is during spring in the Hudson, or tidal rivers to the south.***
>
> *Consequently, one might conclude that 80 percent of the tagged stock resorted to the Hudson to spawn. One might further conclude that 18 percent went to the Delaware and New Jersey Rivers, and 2 percent to the Chesapeake, since recaptures were 16 and 1 fish respectively.*
>
> *Numerically the sample is weak. Taggings were concentrated along the Connecticut, New York and New Jersey coats adjacent to the Hudson estuary. Delaware is not represented in the tagging. There are other shortcomings. Still, this agrees rather closely with the Staff opinion.*
>
> *Thus, one might take this 80 percent as representing the best present measure of the Hudson contribution."*

---

* Dr. Goodyear later testified that Mr. Clark apparently had misinterpreted the Staff's testimony-Tr. 9175-9177.

** Phraseology subsequently corrected.

It would appear therefore, that Clark arrived at his conclusion regarding the 80% simply by dividing his 52 fish captured in the Hudson in spring by the total 65 fish captured in rivers in spring to arrive at 80%.

In the first place, virtually all of the fish recaptured in the Hudson, as well as anywhere else, were originally tagged in the shores and shallows of western Long Island and Lower New York Bay and the vicinity of Jamaica Bay, the very area that previously has been shown to be the juvenile feeding and overwintering area for Hudson River striped bass. So naturally a large percentage of this fish can be expected to return to the Hudson River.

In the second place, it should be noted that in the study referred to a total of 78 bass were recovered in rivers in spring. This is shown in the following table from that paper.

Table 4

RECAPTURES FROM RIVERS IN THE SPRING SEASON

Recapture location	Number of recaptures
Chesapeake Bay rivers	1
Delaware Bay rivers	4
South Jersey rivers	4
North Jersey rivers	4
Hudson River	52
Connecticut rivers	7
Rhode Island rivers	1
Massachusetts rivers	4
St. John River	1
Total	78

The very fact that the 52 recaptures represent 60% of the total spring recaptures, and not 80%, refutes Clark's statement:

> *"Consequently, one might conclude that 80 percent of the tagged stock resorted to the Hudson to spawn."*

Finally, aside from the fact that Clark's conclusion is based on a very small sample size, which he admits, there is a basic error in that Clark assumes that every striped bass captured in a river in spring is in a spawning situation and that they had resorted to the Hudson to spawn. This assumption cannot be supported since no record is available at the age, sex, or spawning condition of the fish in question. One would certainly expect spawning fish to be present in the Hudson in spring, but one would also expect large numbers of immature, non spawning fish from the New York Harbor area to be also present.

The following two tables are from Clark's 1968 tagging paper (7).

Table 5

LENGTH COMPOSITION OF SPRING RECAPTURES
FROM THE HUDSON RIVER

Length group (inches)	Number of fish
11-12	4
13-14	7
15-16	7
17-18	25
19-20	5
21-22	2
23-24	2
Total	52

Table 6

LENGTH, SEX, AND MATURITY STAGE FOR 65
STRIPED BASS TAKEN IN THE HUDSON RIVER
AT HAVERSTRAW BAY ON 3 MAY, 1967

Length in inches	Male		Female	
	Imm.	Mat.	Imm.	Mat.
16	2	1	-	-
17	1	4	3	-
18	1	8	6	-
19	-	5	4	-
20	2	5	3	-
21	1	2	2	1
22	-	1	2	-
23	-	1	-	1
24-33	-	5	-	4
Total	7	32	20	6

It can be seen from a comparison of the two tables that of the 52 fish recaptured in the Hudson 11 fish were in the size range from 11-14 inches. At this size it is improbable that either males or females would have been mature. 34 bass fell in the size range from 15-20 inches, at which size most males but no females could be expected to be mature. Only 4 fish fell within the size range where females might be expected to mature.

Considering this information and the fact that Clark has no record of the sex of the 52 fish captured in the Hudson it would appear that terming these fish spawners is at least highly questionable.

When Clark was cross examined on this subject he replied as follows (Tr. 8732-8733)

> *"Q Would you say the simple presence of striped bass in a river in the spring is evidence of spawning?*
>
> *A No, it works the other way around. If they are not there, they can't possibly spawn. If they are, they may.*

Q Wouldn't you agree that you would also have to know the age and the sexual maturity of the fish involved?

A Yes.

Q If you look at table five on page 340, which is right next to table four on page 340 of your 1968 paper, you give a breakdown of the 52 spring recaptures in the Hudson in terms of the length. And these ranged from 11 to 24 inches. Is that correct?

A Yes

Q Now, would you not also agree that the majority, 25 of the 52, fall into the 17 to 18 inch length group?

A True.

Q Is it not possible then that many of the fish which occurred in the Hudson in the spring were not sexually mature?

A Yes, you can see that from table six where I tried to carry this all of the way through and I provided specific data on the lengths and the maturity of both male and female fish which you can see that your point is well taken.

There is a gradually increasing maturity of these fish over the area between 12 inches and 22 inches."

In cross-examination Clark stated that the data reported in the studies of Schaefer (8) and Alperin (9) support his opinion regarding the proportion of striped bass spawned in the Hudson. Clark stressed the fact that the data, not the conclusions of these authors supported his beliefs. In regard to this he said: (Tr. 8740-8741)

> A *The several taggings that were done, if analyzed in this fashion, will show you that the areas that the fish tagged by Schaeffer and Albrin went to, to spawn, the primary area was the Hudson River, regardless of their conclusions, these guys have this data in front of them to look at, they come out with some rather strange conclusions from it, and it puzzles me that nobody has analyzed these tag records in this fashion, that you have to look and see where they were, at spawning period; now, (probably should be "not") where they spent the winter.*

Since Clark relies for support on the work of these authors, yet disregards their conclusions, it is of interest to note precisely what Alperin and Schaefer did conclude from their studies.

Alperin states in a section entitled "ORIGINS"

> *"The origins of the striped bass that frequent Great South Bay are not readily descernible from the information collected during this investigation. Returns from the fish tagged in 1960 and 1961 do not, however, suggest a Hudson River origin, although this river contains the nearest important spawning grounds. Of the 149 tag returns from within New York waters, only three (2.0 percent) came from the main body of the Hudson. Even when all adjacent areas were included*

(i.e., Jamaica Bay, Upper and Lower New York Bays, Staten Island and western Long Island Sound) the returns totalled only 11 (7.4 per cent). In contrast, much higher rates of recovery in the Hudson River resulted from the small samples tagged in1956 and 1959. Of the six returns for fish tagged in 1956, all in New York waters, one (16.6 percent) was taken in the lower Hudson River in 1958. For the fish tagged in 1959, recoveries from the Hudson River totalled four (18.1 percent) of the 22 from State waters. Also, as shown in Table 5, none of the striped bass tagged in 1959 was recovered south of New Jersey although some did reach New England.

These data (summarized in Table 7), meager as they are, lead to the conclusion that the fish marked in 1956 and 1959 were of more local nature and may have originated in the Hudson River, while those marked in 1960 and 1961 bass, which appeared in great numbers, probably originated elsewhere. In the years when migrants from the south are not abundant in Great South Bay, fish of Hudson River origin may be the principal source of supply. On the other hand, Raney et al. (1954), after examining 792 tag returns from 9,320 striped bass marked in the years 1948 through 1952, concluded that Hudson River stock did "not" often go further east along the south shore of Long Island than Jones Beach."

Table 7

RELATION OF RETURNS FROM HUDSON RIVER TO TOTAL RETURNS
FROM NEW YORK FOR STRIPED BASS TAGGED IN GREAT SOUTH BAY

Year	Number tagged	Total returns	Returns from New York		
			Total	From Hudson River	
				Number	Percent
1956..............	34	6	6	1	16.6
1959..............	69	29	22	4	18.1
1960-1961.........	1,814	246	149	3	2.0
1960-1961.........	1,814	246	149	11*	7.4*

*Includes all New York Harbor, Jamaica Bay and western Long Island Sound.

It can be seen from the above table that only 8 fish in the entire study were recaptured in the Hudson River proper. Even if all New York Harbor, Jamaica Bay and western Long Island are considered, only 16 fish were recovered from that area.

In interpeting these data Clark again takes the simplistic view that any striped bass which occurs in the Hudson in spring is spawning.

Since no data are presented by Alperin for the age or size of the fish recovered in the Hudson, and since the majority of fish tagged in this study were small, there is no basis for concluding that any of the fish caught in the Hudson in spring represented spawning adults.

Schaefer concludes from his study,

> *"It would appear that, for the most part, the abundance of striped bass inhabiting the south shore surf areas of Long Island is directly dependent upon the contribution of stocks produced in more southern*

waters, most probably Chesapeake Bay. Apparently only in years when this contribution is low does the influence of Hudson River stock on the south shore population become evident."

He bases this conclusion on the following:

"The number of recoveries from the Hudson River for fish tagged during the 1954-1956 period, for example, is striking when compared with that from the same location for fish tagged between 1961 and 1963. For fish tagged during the earlier period 14 (28.0 percent) of the 50 recoveries came from the Hudson River, but only one (1.0 percent) of the 100 recoveries for both small and large fish tagged during the later period came from this stream. A test indicated a highly significant difference (.01 probability level) between the two proportions (t = 100, d.f. = 148). Of the 14 Hudson River returns for fish tagged during the 1954-1956 period, 12 represented spring recoveries of which 11 were taken by commercial gill netting in the Haverstraw-Nyack area and one was caught by a sport fisherman on hook and line in New York Harbor. Each of the other two was made by hook and line in New York Harbor, one in the early fall (October 7) and the other in late winter (March 6)."

It is clear from these statements and from others in the papers quoted, that the authors did consider where the fish were located in spring and after careful analysis arrived at conclusions other than those drawn by Clark. These papers may well be interpeted as indicating that some striped bass enter the Hudson in spring to spawn, but they in no way support Clark's notion that the Hudson supplies 80% of the striped bass population from the Maryland-Delaware line to Rhode Island.

Substantially more information on the question of the contribution of the Hudson River to the "Mid-Atlantic" Fishery should be provided by the planned three year tagging study to be executed jointly by New York State Department of Environmental Conservation and the U.S. Department of Commerce, referred to in other testimony presented today by the applicant (Woodbury-McFadden).

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BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit No. 2)	))))	Docket No. 50-247

Rebuttal Testimony of
Gerald J. Lauer, Ph. D.
New York University

on

The Temperature Tolerance of Striped Bass Eggs and Larvae Relative to Their Seasonal Occurrence and Expected Indian Point Plant Discharge Temperatures

February 5, 1973

In making its prediction as to the entrainment effects of Indian Point Unit No. 2 on the population of striped bass the United States Atomic Energy Commission's regulatory staff indicated that substantial mortality of entrained striped bass larvae could result from exposure to temperatures above 90°F, based on studies reported by Chadwick; and, that the Indian Point plant discharge temperature would reach 90°F around mid-June.

The results of New York University studies reported in my October 30 testimony indicate that the temperature tolerance of different development stages of striped bass differ, and that the temperature tolerance increases with decrease in exposure time. The New York University data on temperature tolerance of larvae larger than 8 mm substantially agree with Chadwick's finding that these larvae can tolerate temperatures up to 90°F with little or no mortality. The New York University results also indicate that eggs and smaller larvae of striped bass have lower temperature tolerances.

The AEC staff's statement that the Indian Point discharge temperatures will begin to exceed 90°F by mid-June is refuted by analyses of available temperature data by Quirk, Lawler and Matusky Engineers.[1]

At rated capacity operation organisms passed through the Indian Point plant will be exposed to a ΔT of approximately 15°F for a calculated passage (exposure) time of about 11 minutes.

The degree of possible risk to entrained striped bass eggs and larvae during 1971 based upon their times of occurrence, the ambient temperatures that existed during those times, and temperature tolerance data from laboratory studies was discussed in detail on pages 42-49 of my October 30 testimony.

The possibility exists that both the time of occurrence of striped bass eggs and larvae and seasonal ambient temperatures of the Hudson River may vary from the 1971 conditions in other years. Therefore more detailed analyses of these variables is warranted.

The times of occurrence of striped bass eggs and larvae in collections from the Indian Point vicinity relative to ambient river temperatures for years of record are summarized in Table 1.

Table 1. Reported Time of Occurrence Relative to Ambient River Temperature

Striped bass eggs

Year	Time of Occurrence and Temperature			
	Total	Temperature (°F)	Peak Abundance	Temperature (°F)
1966[1]	5/15-6/11	51-66	5/22-6/11	58-66
1967[1]	5/14-6/10	52-62	5/21-6/10	55-62
1971[2]	5/10-6/7	50-64	5/20-6/3	54-60
1972[2]	5/8-6/8	53-67	5/18-6/5	53-67

Year	Time of Occurrence and Temperature			
	Total	Temperature (°F)	Peak Abundance	Temperature (°F)
1971[2]	5/10-6/14	50-68	5/24-6/7	57-67
1972[2]	5/8-6/15	53-67	5/30-6/8	62-67

Striped bass larvae

Year	Time of Occurrence and Temperature			
	Total	Temperature (°F)	Peak Abundance	Temperature (°F)
1966[1]	5/29-7/9	61-76	6/5-7/2	66-74
1967[1]	6/4-7/22	62-75	6/11-7/8	65-72
1971[2]	6/2-7/19	62-76	6/7-7/6	57-69
1972[2]				

[1] Carlson, McCann Cornwall Study.
[2] New York University studies.

An analysis of expected water temperatures during entrainment at the Indian Point plant is contained in the attached report by Quirk, Lawler, and Matusky Engineers. (1) Figure 13 of the report which summarizes the results of the analysis is the foundation for the following interpretations.

Figure 17 of my October 30 testimony is reproduced here to provide the necessary information on temperature tolerance of the striped bass eggs, yolk-sac larvae and post yolk-sac larvae.

Striped bass egg occurrence in the vicinity of Indian Point during the four years of record has covered a span of time from about May 8 through June 11 (Table 1). Peak abundance of eggs has occurred during the period from about May 18 through June 11.

The 18 to 22 hour egg stage is the most sensitive to temperature, with a maximum safe temperature requirement of about 76 to 77°F. Ninety percent of the expected discharge canal temperatures are expected to be below this maximum 60 minute exposure safe limit through about May 27. Thereafter live eggs in this particular stage of development which pass through the plant will be exposed to temperatures which begin to exceed their 60-minute safe limit. By the end of the egg season (June 7-11) approximately ninety percent of the expected discharge canal temperatures will exceed the 60-minute safe temperature limit. The sixty-minute safe temperature limit for 0-4 hour and 44 hour eggs (78°F) would relate to the expected discharge temperatures in similar fashion, but the portion of a given season during which their safe temperature would be exceeded would be slightly shorter.

The eggs during approximately 32 hours of their 48 hour development time have a 60-minute exposure maximum safe temperature limit of from 80°F up to 89°F. During years when the egg season terminates early (such as in 1971 and 1972), the expected discharge canal temperatures would be less than the upper safe limit for almost the entire year's crop of these developmental stages. In years of later occurrence up to June 11, about 50% of the expected discharge canal temperatures would exceed 80°F.

In summary, approximately 16 hours of the 48 hour developmental stages of eggs which are entrained through the plant during rated capacity operation, only in the later part of the

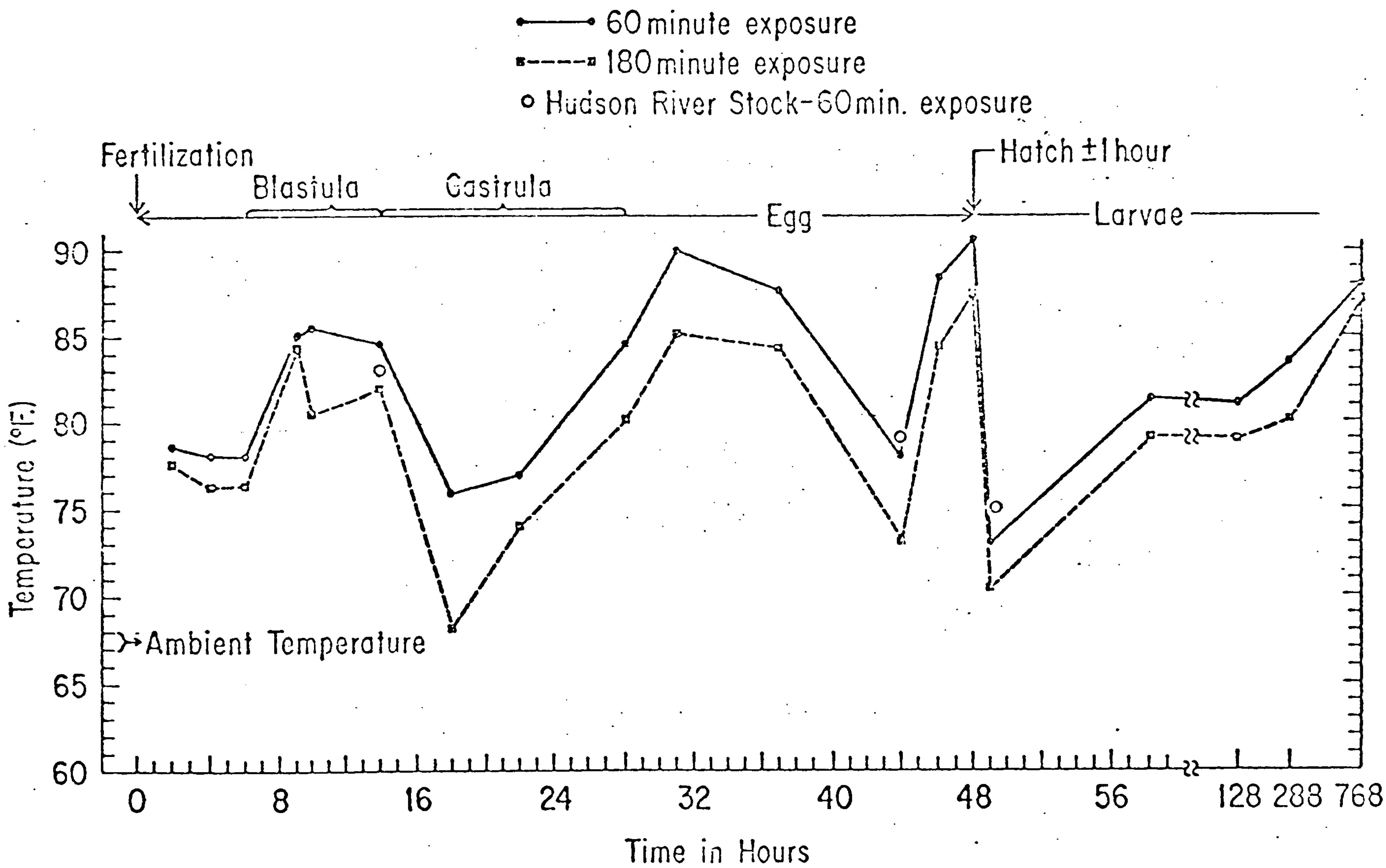

Figure 17. Maximum Safe Temperature[1] for Striped Bass Eggs and Larvae from Monks Corner, S. C. Hatchery Stock

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[1] Safe temperature is the maximum temperature of exposure which did not result in increased mortality or abnormal development compared to controls.

egg season, would experience temperatures in excess of their 60 minute maximum temperature tolerance. The remaining 32 hours of developmental stages would not experience such excesses over their safe temperature limit.

The season of yolk-sac larvae occurrence in the vicinity of Indian Point extended from May 8 to May 15 during 1971 and 1972 (Table 1). The peak abundance occurred between May 24 and June 8.

The newly hatched yolk-sac larvae have a 60 minute exposure maximum safe temperature limit of about 73°F. This temperature is expected to be exceeded in the discharge canal during most of the yolk-sac larvae season. The 60-minute exposure maximum temperature tolerance of the yolk-sac larvae is increased to 81°F by the time the larvae are 9 hours old. Ninety percent of the expected discharge canal temperatures are less than 81°F through June 6, which includes most of the yolk-sac season of occurrence (Table 1).

It is concluded that striped bass yolk-sac larvae between 0 and 9 hours old which are entrained through the plant during rated capacity operation will be exposed to temperatures in excess of their 60-minute safe tolerance, with the amount of excess decreasing as the larvae grow from 0 to 9 hours of age. Entrained yolk-sac larvae from 9 hours up to about two weeks of age would not experience temperatures in excess of their safe temperature limit.

The seasonal occurrence of striped bass larvae in the vicinity of Indian Point during the 3 years of record extends from about May 29 to July 22. The peak abundance occurred during periods ranging from June 5 through July 8.

The 60-minute exposure maximum temperature tolerance of the larvae is about 88°F. Ninety percent of the expected discharge canal temperatures are less than 88°F up until about July 4, which includes most of the period of peak abundance. Larvae entrained through the plant after July 4 will be exposed to higher percentages of discharge canal temperatures that exceed their 60-minute maximum temperature tolerance.

In summary, most larvae entrained through the plant will not experience temperatures above their 60-minute exposure maximum tolerance limit. Only those larvae from the later part of the seasonal crop which pass through the plant during rated capacity operation would be exposed to such excesses.

The use of 60 minute temperature toler ance limits for this testimony is quite conservative, considering that the expected transit time through the Indian Point plant is about 11 minutes. The temperature tolerances of the eggs and larvae for an 11 minute exposure are on the order of 2 to 3^{o}F higher than for the 60-minute exposure.

The term temperature tolerance limit as used here refers to temperatures that cause no mortality, and in the case of eggs, no abnormal development, or reduction in hatching success.

The statements here-in that safe temperature will be exceeded does not imply that the organisms involved would experience 100% mortality. The percent mortality which would result would depend both upon the amount of temperature excess over the safe limits and the duration of exposure to the excess.

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BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the matter of	)	
	)	
Consolidated Edison Company of	)	Docket No. 50-247
New York, Inc.	)	
(Indian Point Station, Unit 2)	)	

Redirect-rebuttal testimony of
John P. Lawler, Ph.D
Quirk, Lawler & Matusky Engineers
on
Expected Water Temperature at Indian Point
During Entrainment Period

February 5, 1973

Introduction

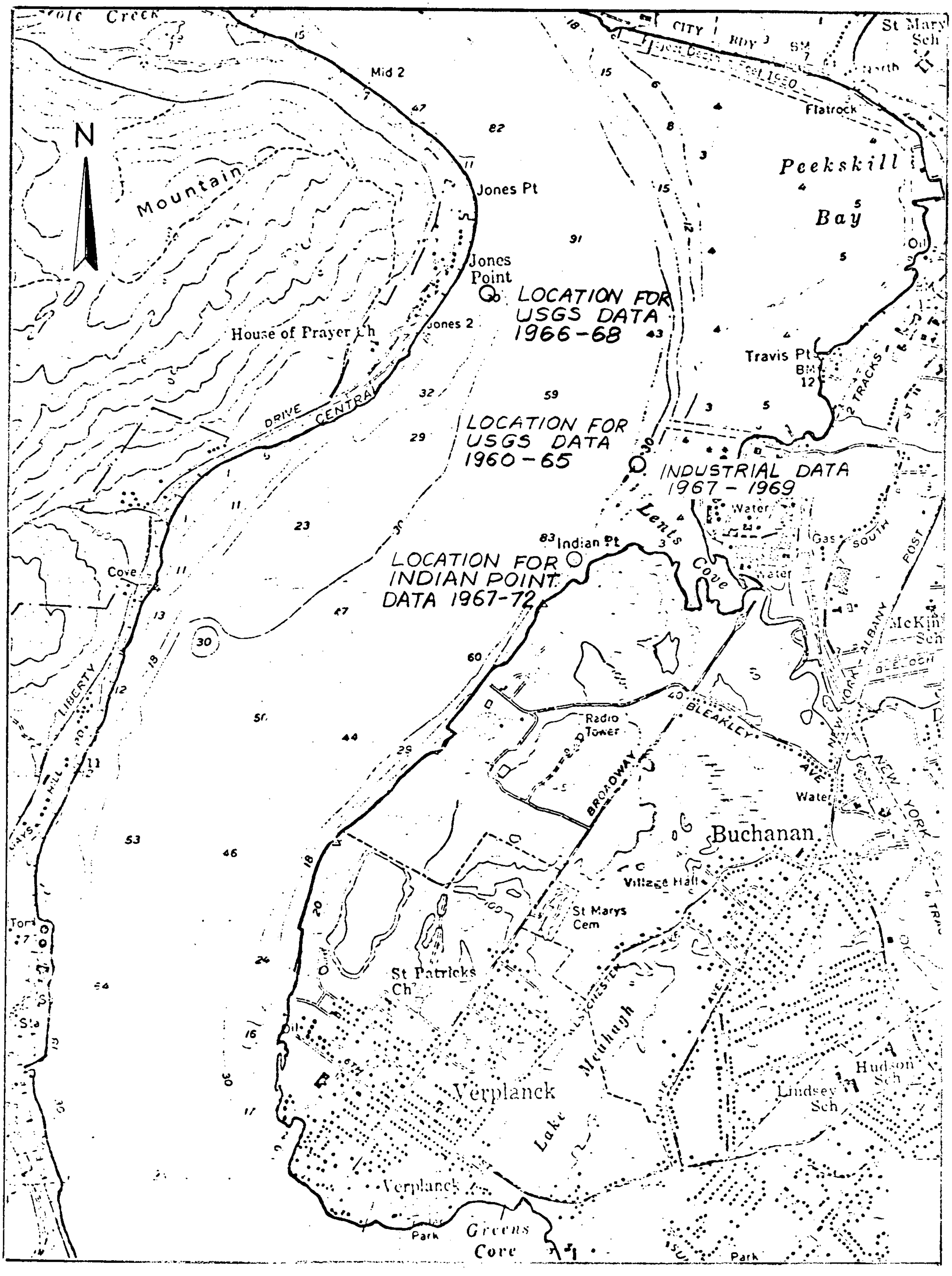
Because of the sensitivity of entrained larval fish to temperature, it has become necessary to know the probable intake and discharge canal temperatures at Indian Point. Records available for determination of intake temperatures were of two general types: Historical records covering a number of years, and short term or periodic records. The first group of records, those of several years standing, proved to be amenable to statistical methods of analysis, including determination of ranges and frequency distributions. The second general class of records serve primarily to confirm the first group. Records from Raytheon, which are in the second group, have been previously analyzed for differences between the 0800, daily mean, and daily maximum values. These data are vital in comparing the data from continuous records, which show generally the same relationship. Significantly, the data from the Raytheon analysis show the daily mean temperature to be less than one degree Fahrenheit greater than the value at 0800.

Determination of probable canal temperatures will be based on predicted temperature rise through the condensers, probable effects of recirculation, and the expected intake temperatures.

Long Term Temperature Data

Daily water temperatures in the Indian Point area over a period of several years have been collected by the U. S. Geological Survey, the operating personnel at Indian Point, and at a local industrial plant. Locations of these analyses are shown in Figure 1. These records are tabulated as follows:

LOCATION OF LONG TERM TEMPERATURE DATA



LONG TERM TEMPERATURE DATA

SOURCE	Period of Record	Location & Depth	Value Recorded*	Method
1. a. U.S.G.S.	1960-1965	Main Channel at Charles Pt. at 7' (bottom)	Daily temp. at 0900	Thermometer
b. U.S.G.S.	1966-1968	Reserve Fleet at Jones Pt. at 5' depth in 30'	Daily Maximum	Continuous Recording Thermistor
2. Con Edison	1967-1972	Intake Forebay	Daily (no time set)	Thermometer
3. Local Industry	1967-1969	Same as USGS 1960-1965	Daily at 0900	Thermometer

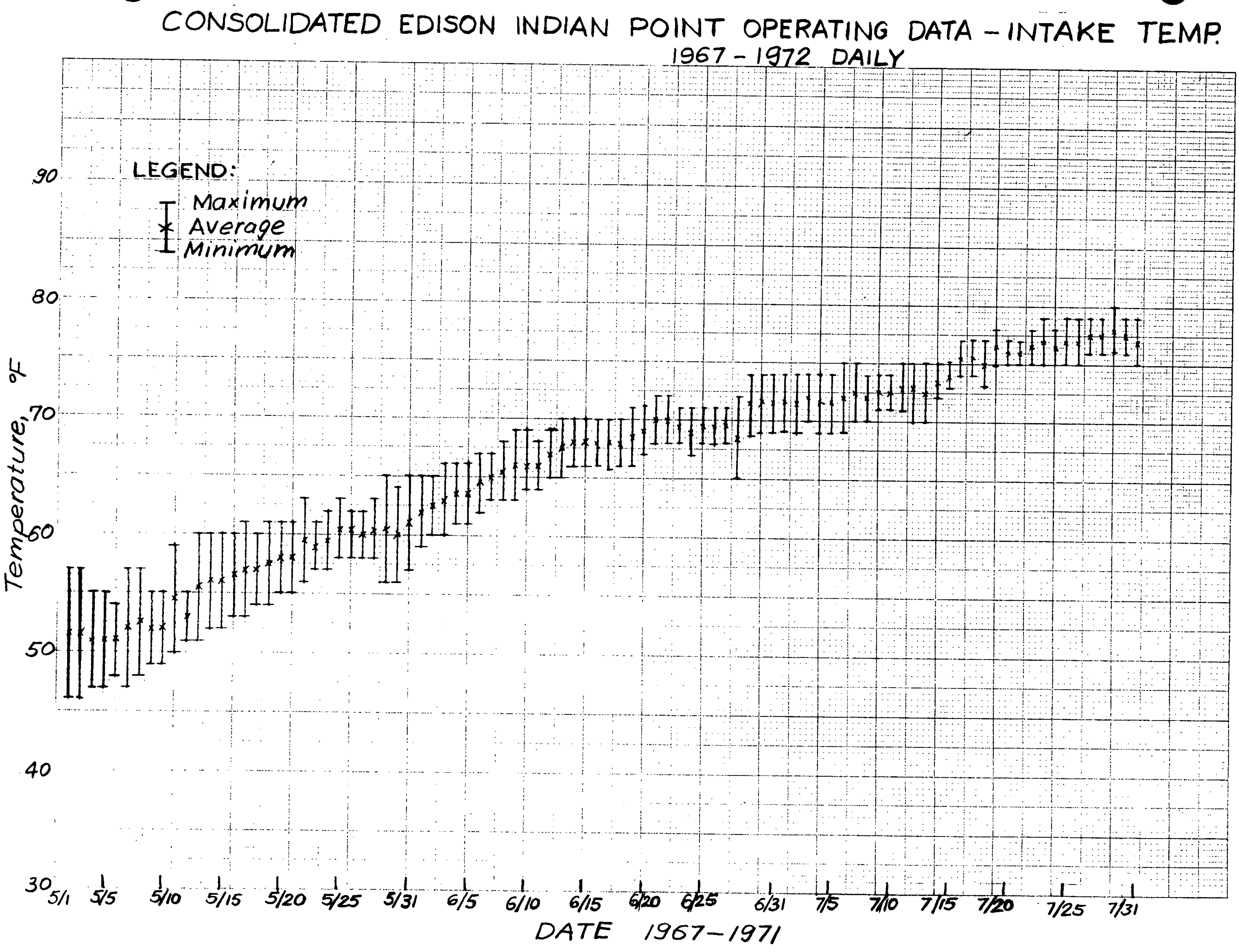
* All recorded to nearest degree Fahrenheit.

Average, minimum and maximum daily values from these records over the period from May 1 to July 31 are shown in Figures 2 and 3. The earlier U.S.G.S. data and the industrial data are grouped together, because they were collected at the same location and in the same way over a period of several years. Frequency distributions for these data by 15 day periods are shown in Figures 4 through 9. Frequency distributions for the Indian Point intake temperature measurements by 7 day periods are summarized in Figure 10.

Short Term Records and Survey Data

Short term records and survey data in the Indian Point area have been collected by QL&M, Orange and Rockland Utilities, New York University, and Raytheon.

Source	Period of Record	Method of Measurement	Frequency	Location
1. a. QL&M	May 1971-Sept '72	Thermistor	Periodic	Bowline
b. QL&M	May 1970-Aug '70	Thermistor	Periodic	Lovett
2. O.& R. U.	May-July 1972	Thermometer	Daily Mean	Lovett Intake
3. N.Y.U.	April-Sept. 1972	Thermometer	Periodic	Indian Pt. Intake
4. Raytheon				
a. Biological	April-Aug. 1970	Thermistor	Monthly Mean	I.P. Intake
b. Temp. Sensor	April-Aug.1970	Thermistor	Continuous	In Hudson above Discharge
c. A.E.S.	Jan-Oct. 1970	Thermistor	Continuous	I.P. Intake



CONSOLIDATED EDISON INDIAN POINT OPERATING DATA - INTAKE TEMP.
1967 - 1972 DAILY
LEGEND:
Maximum
Average
Minimum
Temperature, °F
90
80
70
60
50
40
30
5/1
5/5
5/10
5/15
5/20
5/25
5/31
6/5
6/10
6/15
6/20
6/25
6/31
7/5
7/10
7/15
7/20
7/25
7/31
DATE 1967-1971

FIGURE 2

USGS STATION, TEMPERATURE DATA AT PEEKSKILL, N.Y. (CHARLES PT.)

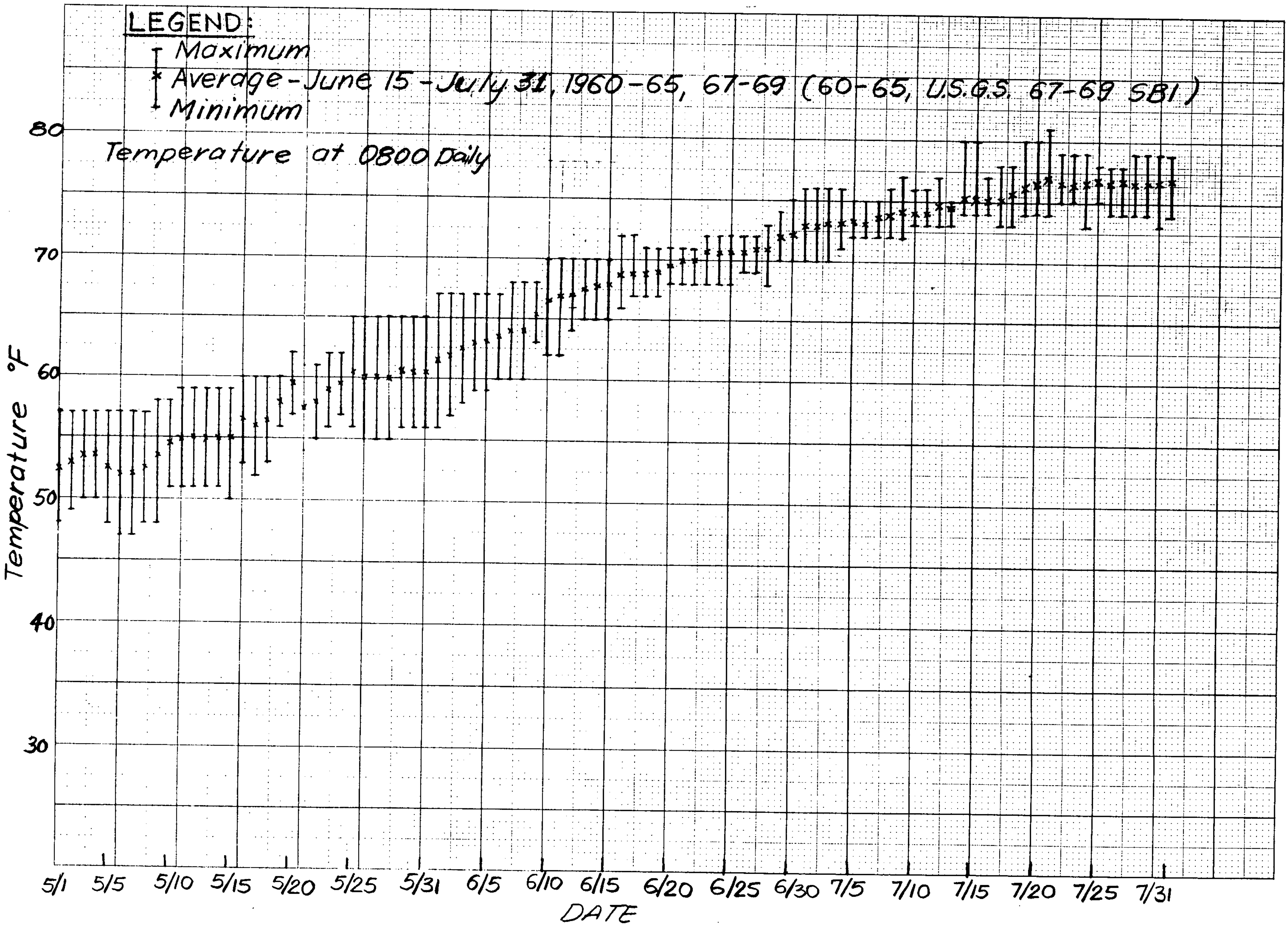


FIGURE 3

DAILY TEMPERATURE DISTRIBUTION, INDIAN POINT AREA
1-15 MAY 1960-1972

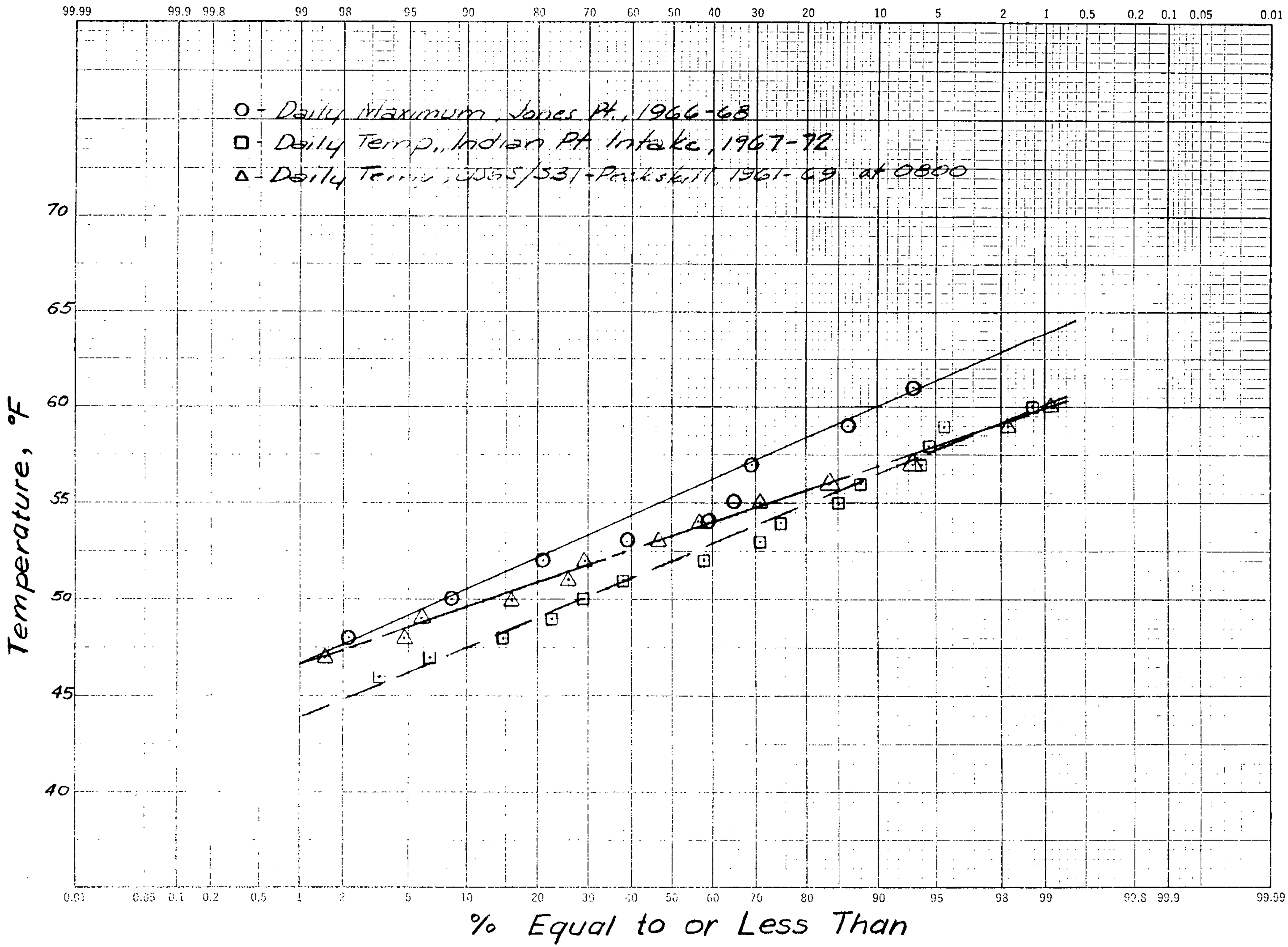


FIGURE 4

DAILY TEMPERATURE DISTRIBUTION, INDIAN POINT AREA
16-31 MAY 1960-1972

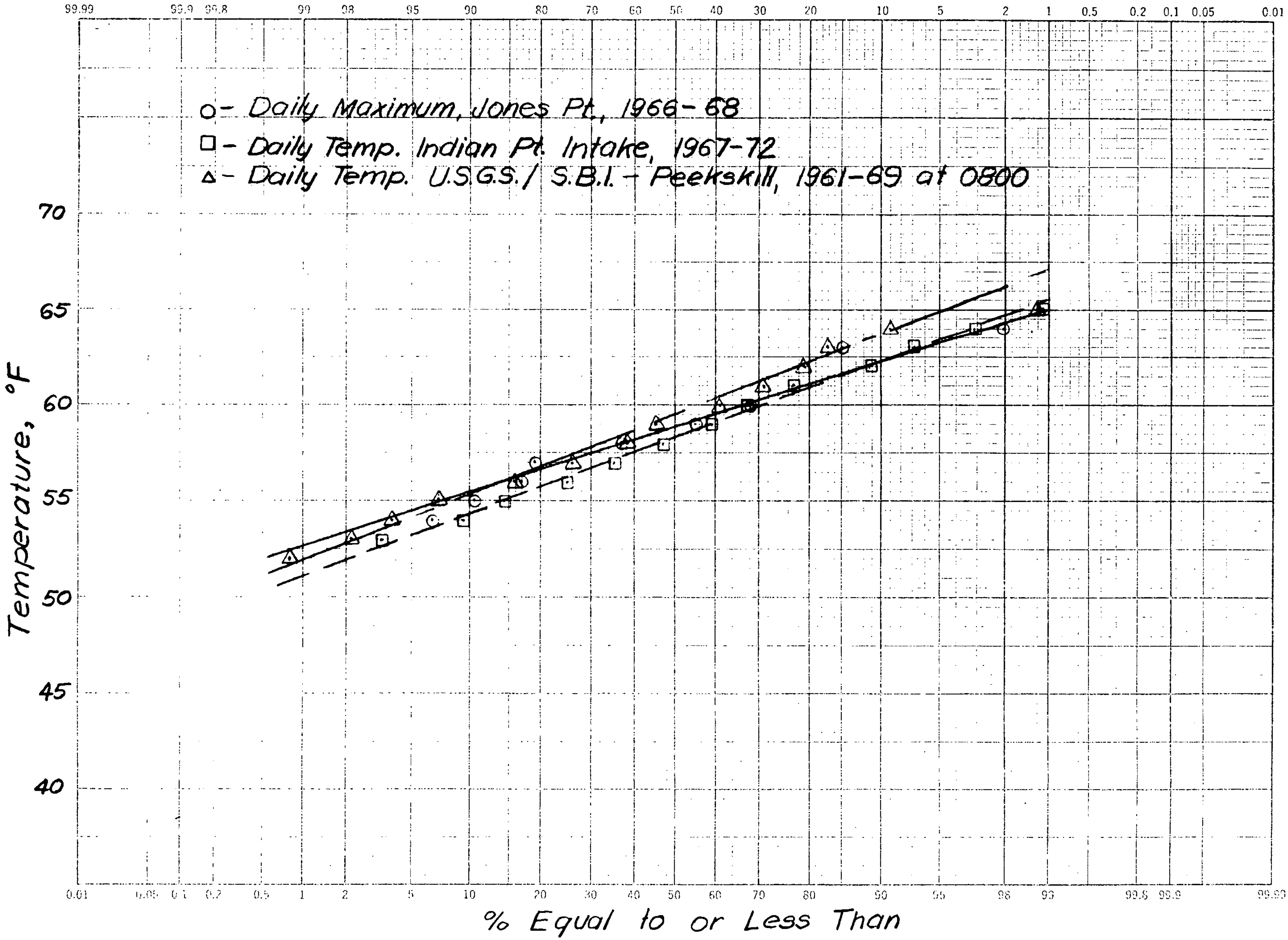


FIGURE 5

DAILY TEMPERATURE DISTRIBUTION INDIAN POINT AREA
1-15 JUNE 1960-1972

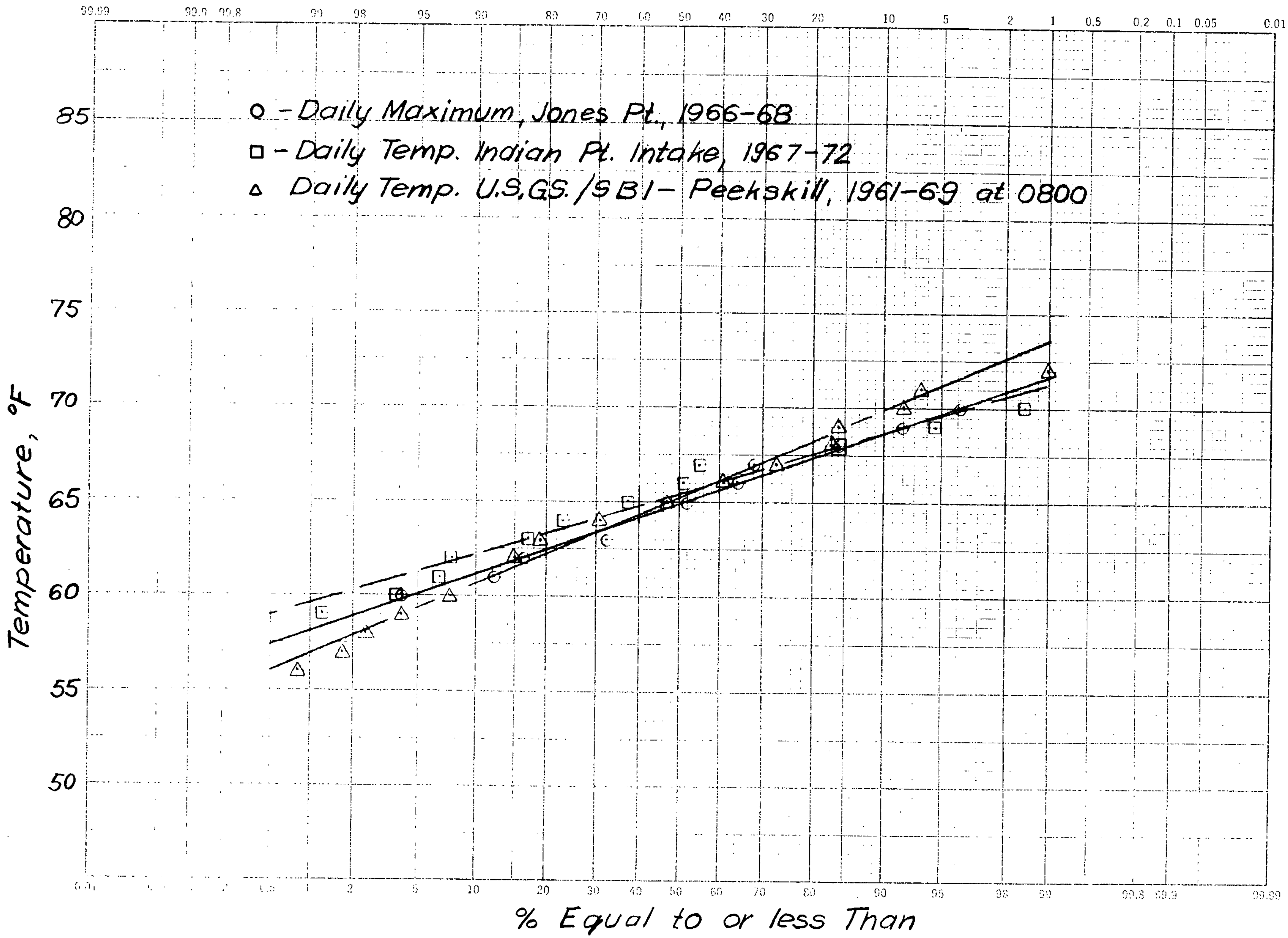


FIGURE 6

DAILY TEMPERATURE DISTRIBUTION, INDIAN POINT AREA
16 – 30 JUNE 1960 – 1972

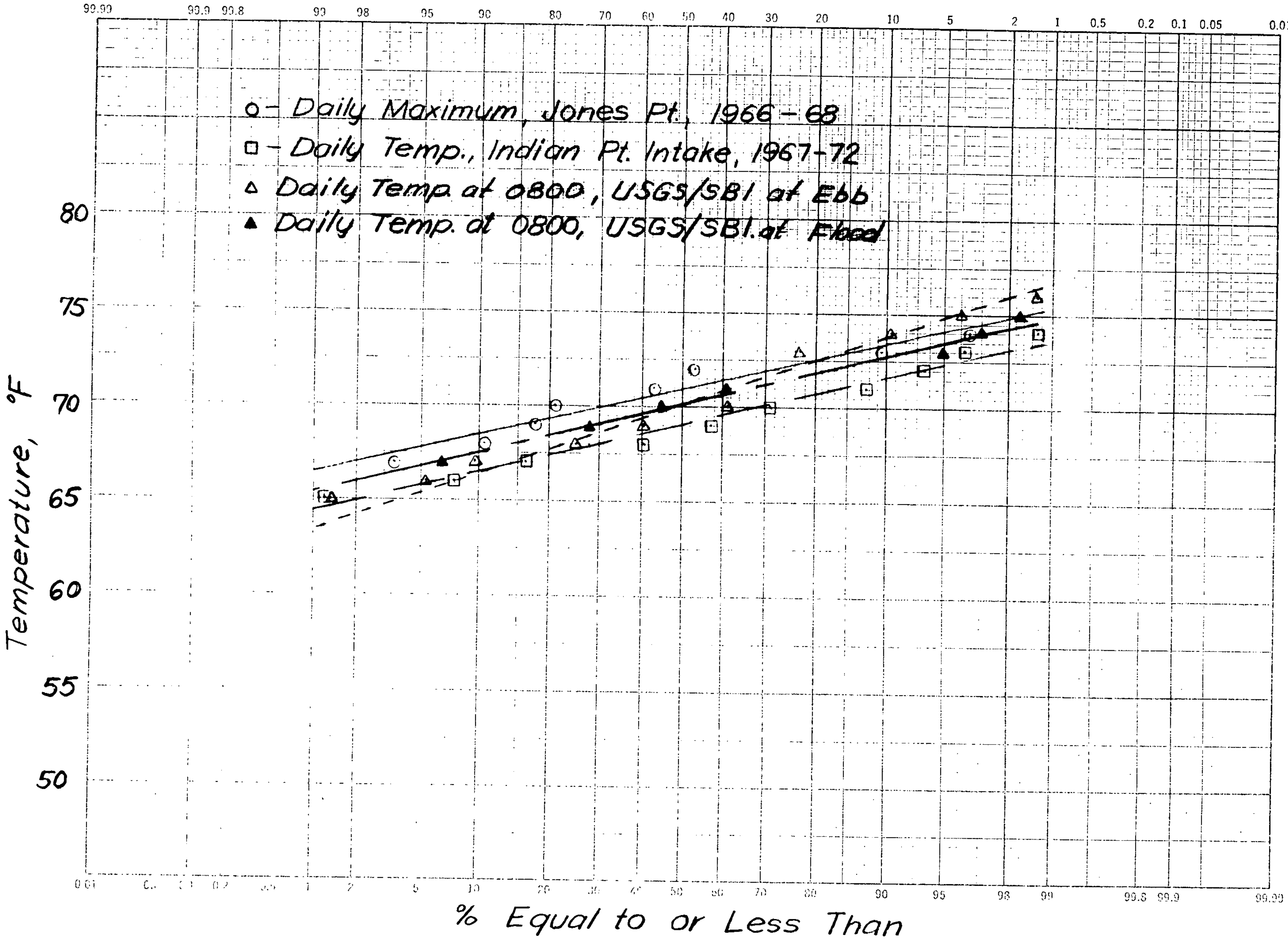


FIGURE 7

DAILY TEMPERATURE DISTRIBUTION, INDIAN POINT AREA
1-15 JULY 1960-1972

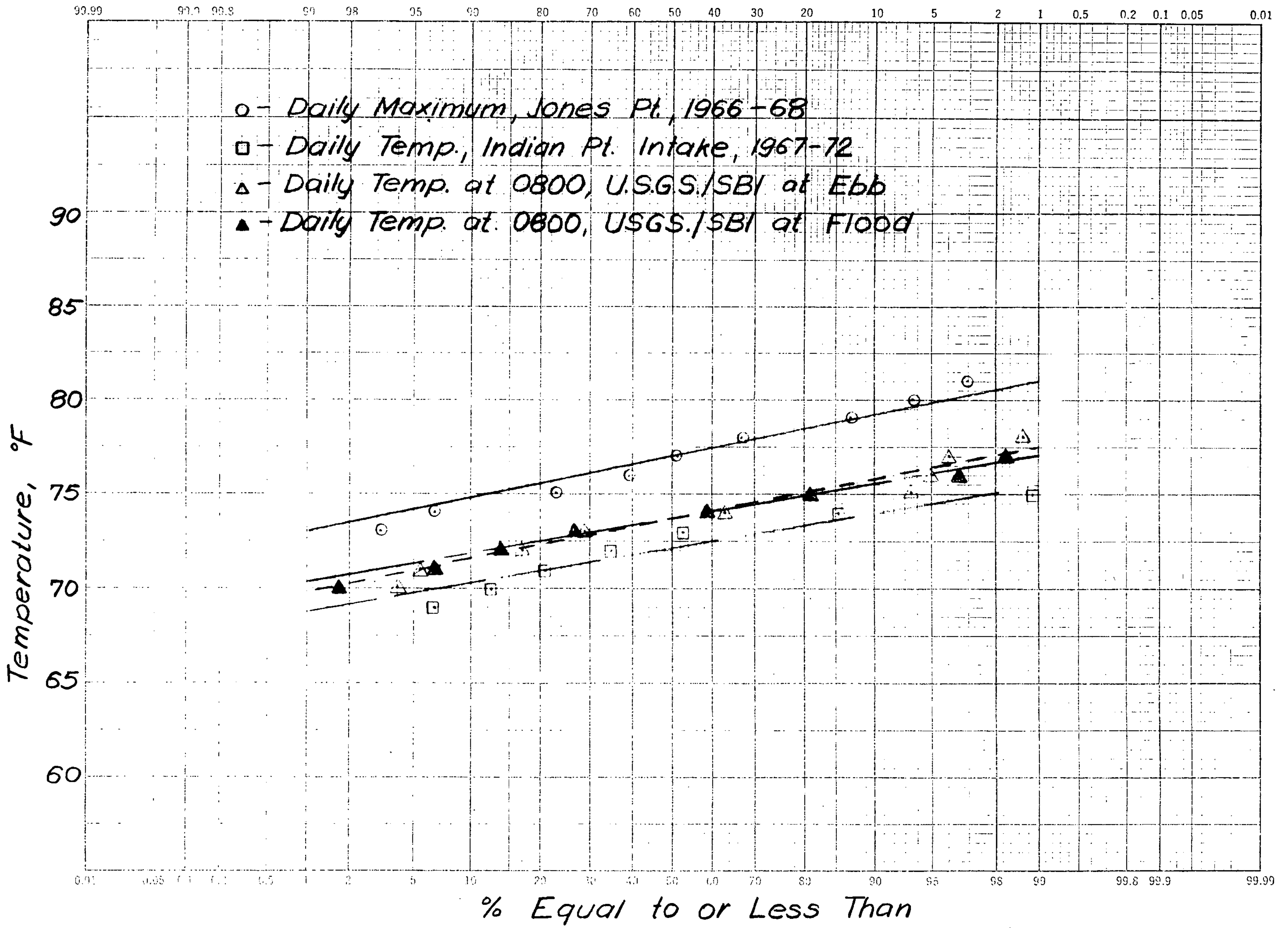


FIGURE 8

DAILY TEMPERATURE DISTRIBUTION, INDIAN POINT AREA
16-31 JULY 1960-1972

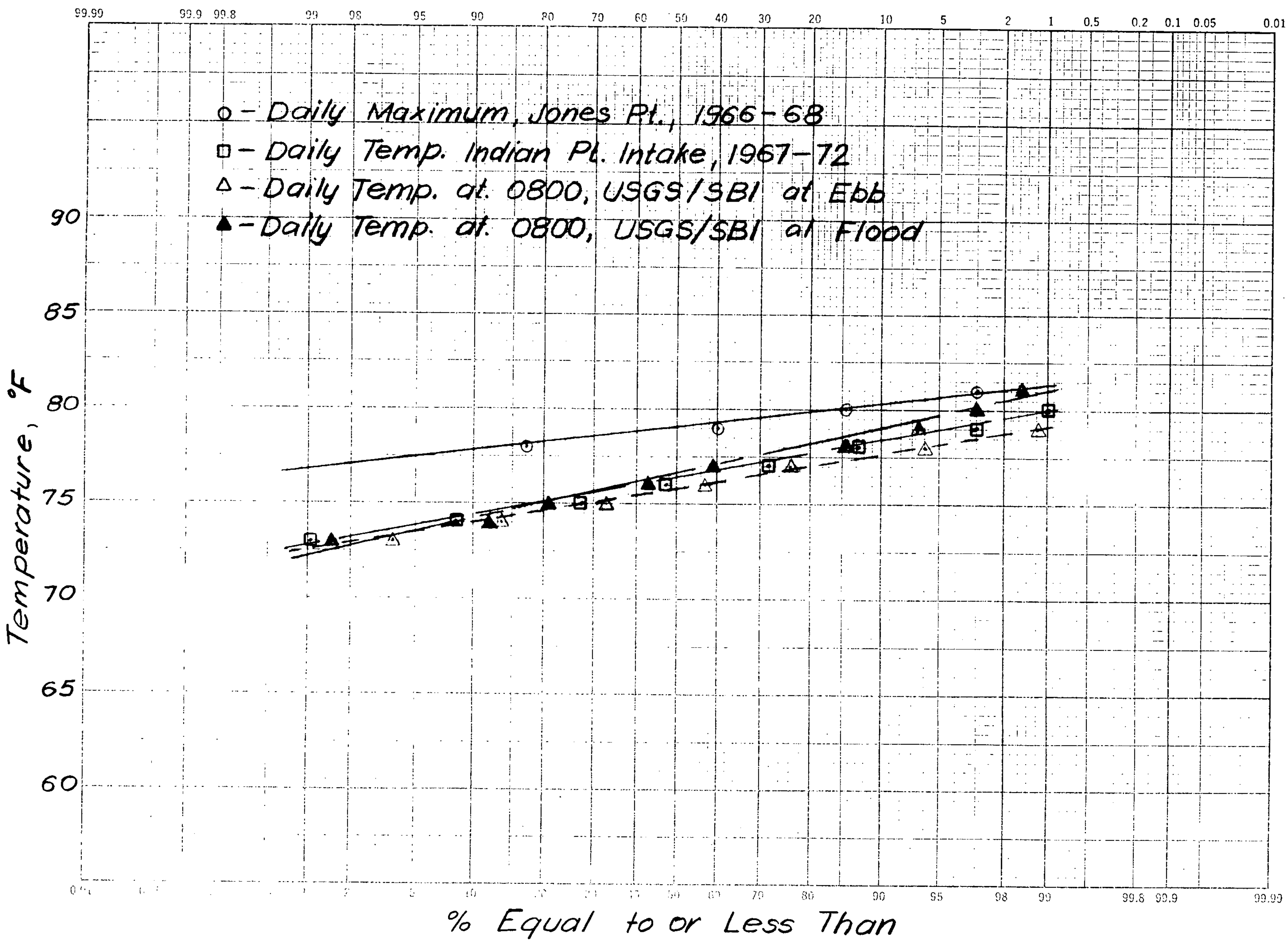


FIGURE 9

WEEKLY TEMPERATURE PROBABILITY
INDIAN POINT INTAKE, 1967-72

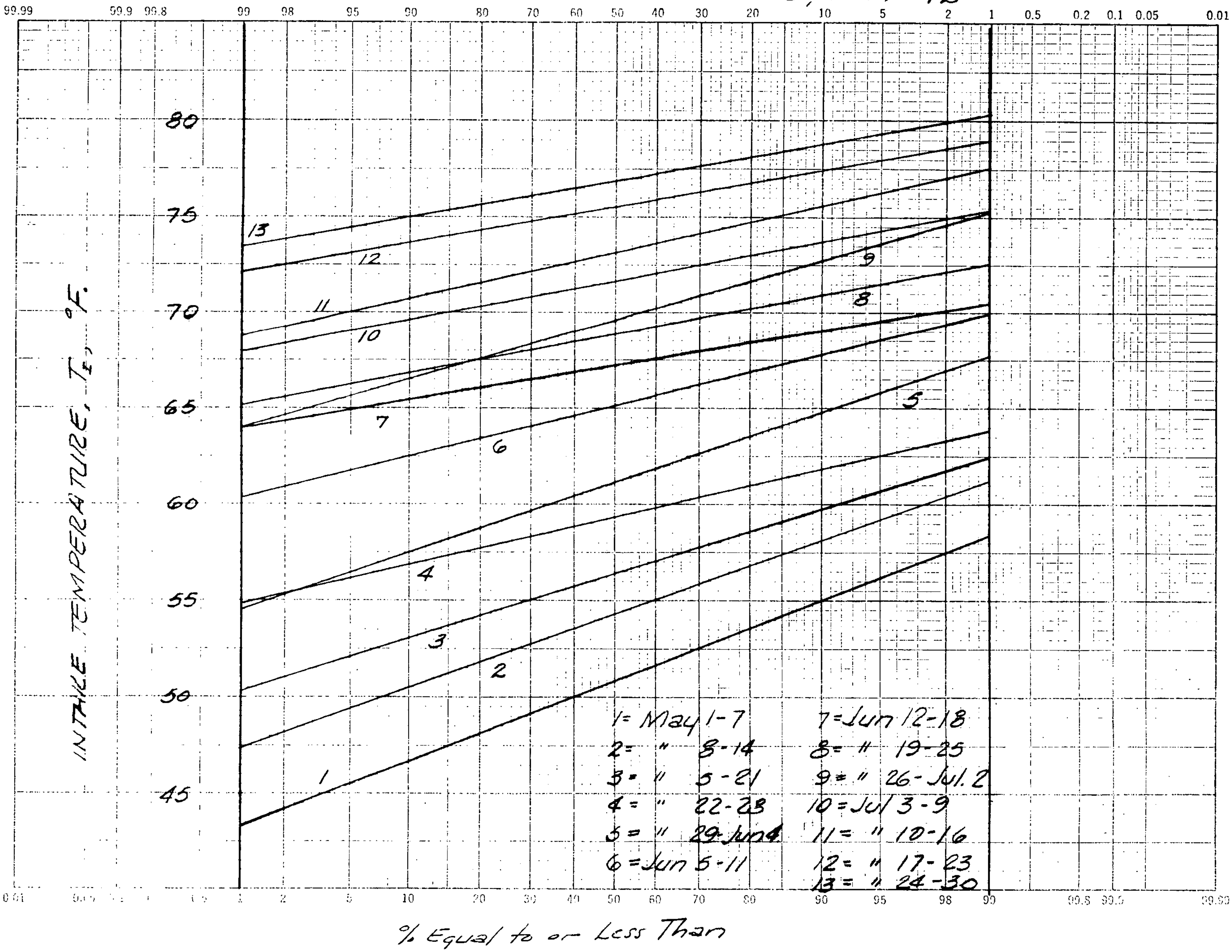


FIGURE 10

Data from these sources for the period May 1 to July 31 are given in Figure 11. Additional analyses of continuous sensor data by Raytheon showed that for 48 readings, the difference between the average 0800 value and the average daily mean was - 0.4°F, and that for the same group of readings, the average daily maximum was 2°F higher than the average value at 0800.

As can be seen in Figure 11, these short term data correspond to the ranges of continuously recorded data. Bathythermograph data from Raytheon (not shown) indicated a small thermal gradient from surface to bottom during the summer months. Analysis of long term temperatures indicates a differentiation between ebb and flood values at Charles Point. If these data showed that flood values were consistently higher than ebb values, recirculation might be a possible cause. However, the relationship between ebb and flood value varies according to the time of year. This may indicate that the difference between ocean and river temperatures is more important than is recirculation at Charles Point.

The above presented values may not be representative of ambient temperature conditions in the river channel since some of these measurements were either made in shallows or include the recirculation effects resulting from Indian Point Unit 1 operation. They do, however, represent conservative estimates of instantaneous intake conditions.

In order to construct a temperature histogram for the Indian Point intake, the maximum weekly temperature (obtained from Figure 10) was plotted against the last day of the week under consideration. Three histograms corresponding to the 10, 50 and 90 percentile values for the period of interest to this testimony are shown in Figure 12. This plotting procedure is valid since the previously presented data show that river temperatures increase with calendar

SHORT TERM RECORDS AND SURVEYS

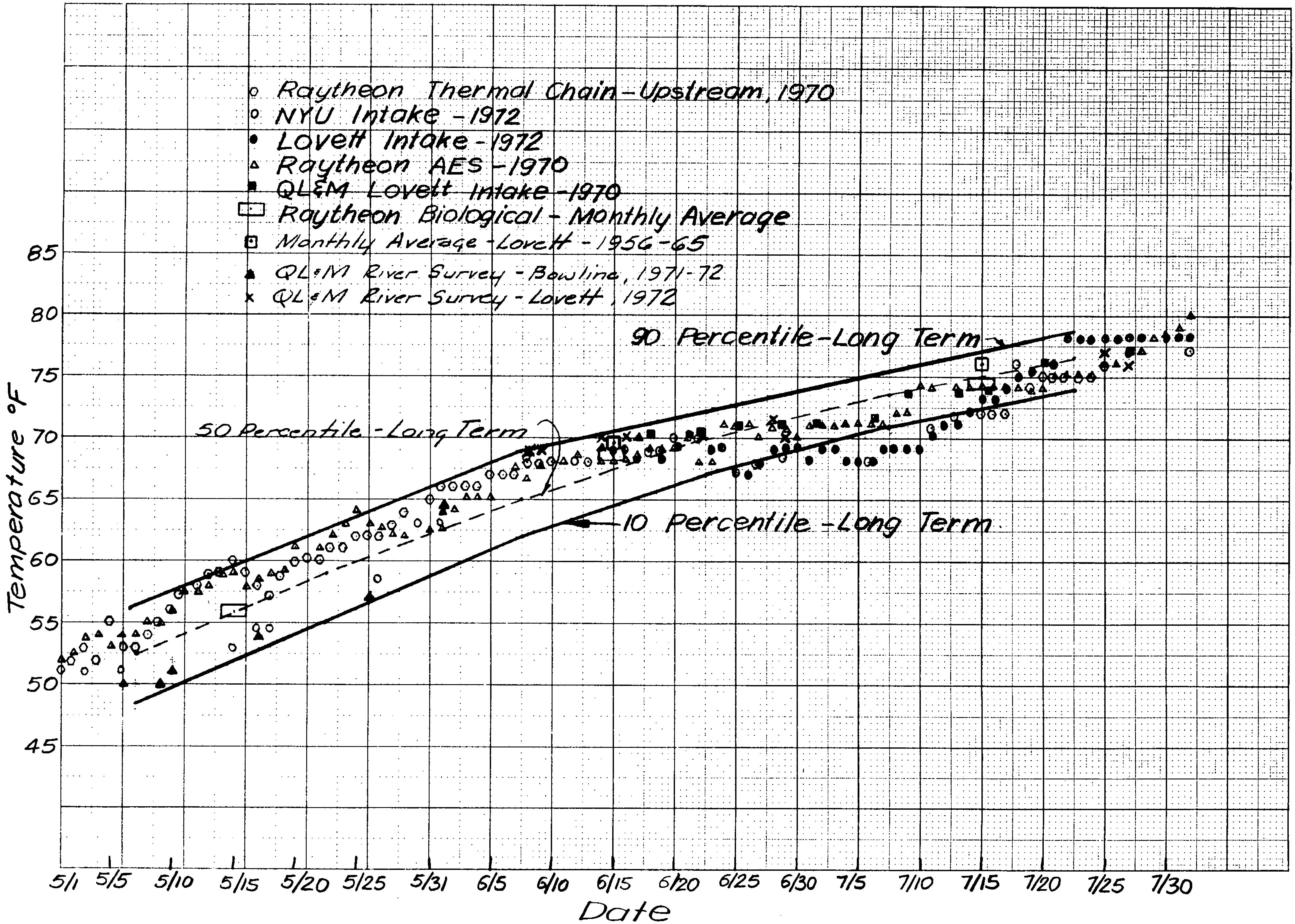
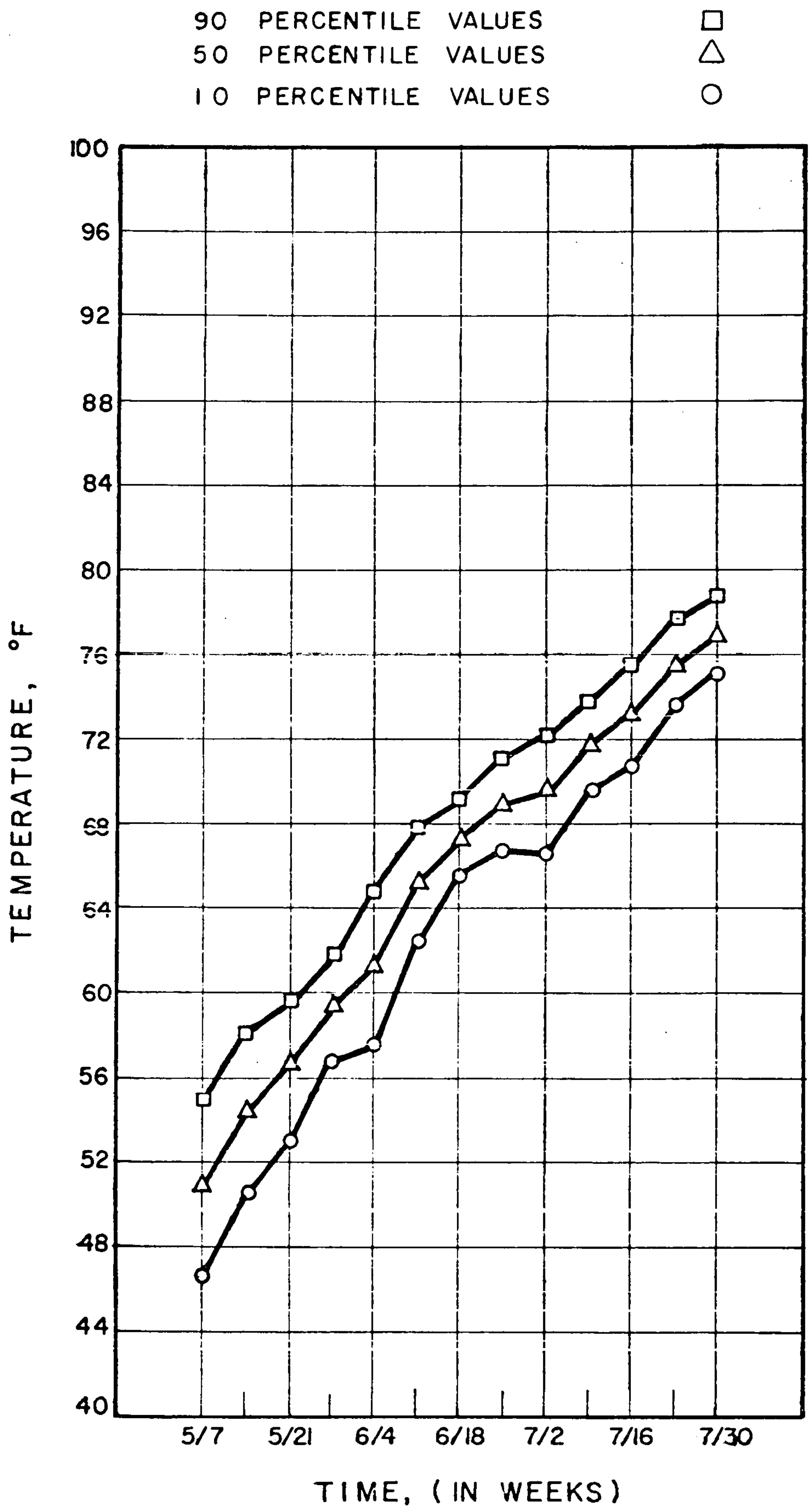


FIGURE 11

INDIAN POINT INTAKE TEMPERATURE WEEKLY MAXIMA 1967 – 1972



time during this period. This is probably due to the fact that the ambient temperature histogram in the Hudson River lags its equilibrium surface temperature counterpart by several days during this period.*

Expected Discharge Canal Temperatures

The critical temperature with regard to survival of entrained organisms is the discharge canal temperature. This temperature, rather than the condenser outlet temperature, is critical because the condenser outlet temperature is experienced by the organism for a few seconds before entering the discharge canal. Based on full power production the discharge canal temperature elevation is predicted to be 13.94°F above the temperature entering the condenser.** This value combines the temperature rise of Units 1 and 2, both cooling and service water.

Condenser temperature rise is directly related to cooling water flow. Conservative head loss assumptions on Unit 1 have resulted in increased cooling flow, and decreased condenser temperatures through the Unit 1 condenser. The head loss in Unit 2 was calculated with fewer conservative assumptions, but may be expected to result in a flow that is somewhat higher than the design flow, resulting in lower condenser temperatures, hence, lower canal temperatures. A possible five to ten percent increase in actual flow over design flow would result in a canal temperature rise of 13.25°F to 12.55°F as opposed to 13.94°F. However, to make the analysis conservative, the design value of 13.94°F was used in this testimony.

*See Figure 1 of Redirect-rebuttal testimony of John P. Lawler on the behavior of the Indian Point Thermal Effluent During Winter Conditions and Its Effect on Hudson River Striped Bass, Feb. 5, 1973.

**Redirect-rebuttal testimony of John P. Lawler on the Thermal Effects of Indian Point Cooling Water on the Hudson River, Feb. 5, 1973.

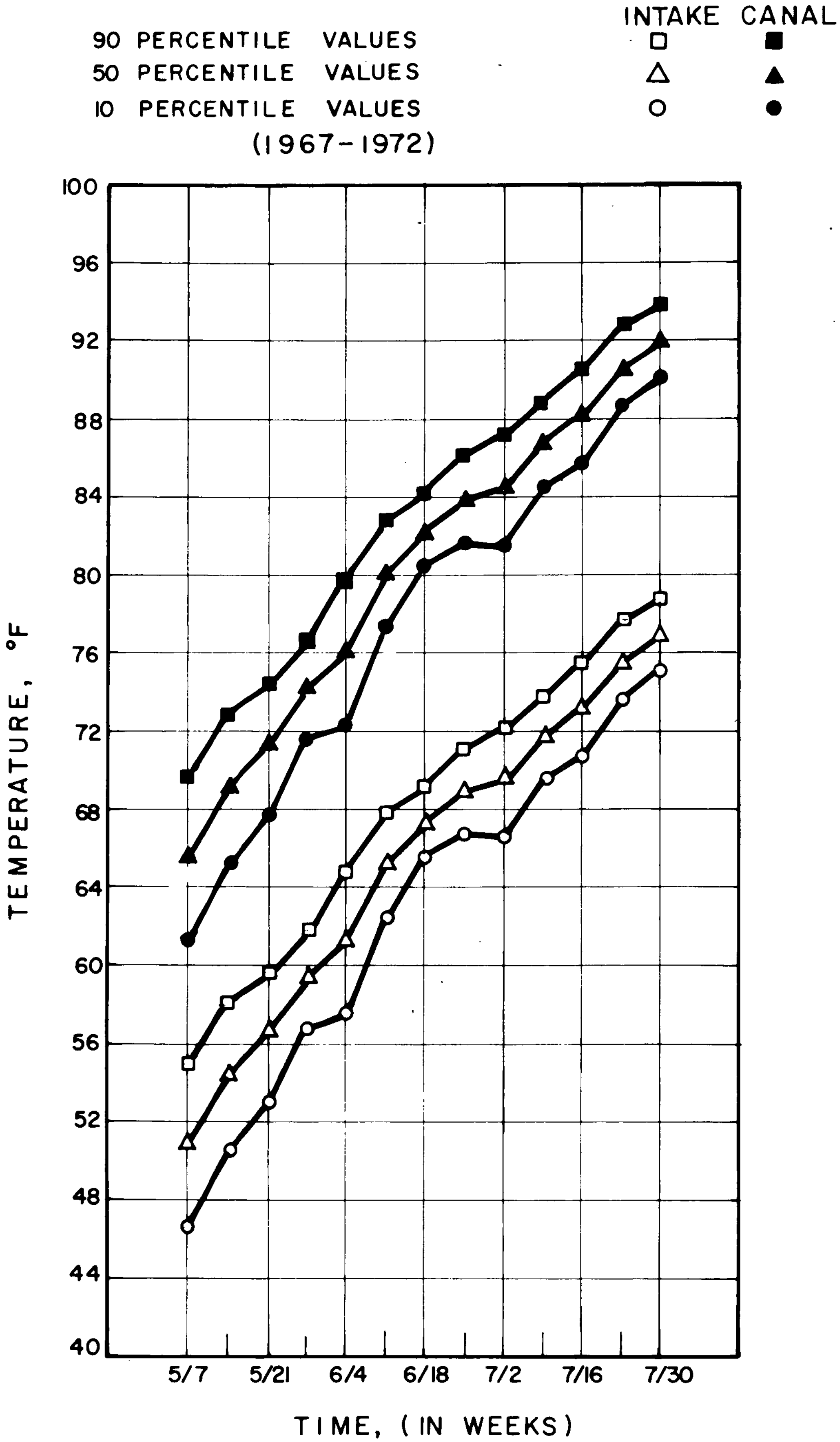
To predict canal temperatures during the entrainment season, the effect of recirculation of heated water must also be considered. The April 5, 1972 testimony by John P. Lawler, on thermal effects, has indicated that employment of 1°F rise to represent recirculation effects throughout the tidal cycle represents a conservative assumption. Combining the temperature rises between the condenser and service water heating and the 1°F rise due to recirculation, the expected average rise above ambient would be 14.94°F.

Concern with long-term plant effects would indicate that the long-term 50 percentile, or median, temperatures represent a more stable measure of canal conditions. Therefore, the long-term median canal temperatures are shown in Figure 13 based on the long-term median. For comparison, however, the 10 and 90 percentile weekly maxima values at Indian Point are also shown in Figure 13

A third factor in mortality of entrained organisms is the expected plant down-time. During this period, which is estimated to be twenty percent of the total time, organisms will not be entrained, or if entrained, will not be subject to thermal effects.

EXPECTED DISCHARGE CANAL TEMPERATURE AT INDIAN POINT

FIGURE 13



BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of)
Consolidated Edison Company of)
New York, Inc.) Docket No. 50-247
(Indian Point Station, Unit No. 2))

Rebuttal Testimony of
Gerald J. Lauer, Ph.D.
New York University

on

New York University Seine Fish Data
on Hudson River Fishes

February 5, 1973

The United States Atomic Energy Commission Final Environmental Statement on the Indian Point Nuclear Generating Plant Unit No. 2 states on page V-61, "Furthermore, the 1965-1969 New York University fish collection data [12-15] indicate that the high mortality of white perch which has resulted from entrainment and impingement at Indian Point Unit No. 1 could be adversely affecting the white perch in the Hudson (Fig. V-16) and is supported by Raytheon Company data[18-46] which indicate that the downward trend continued into 1970".

The above statement is missleading and erroneous in several respects. First, it could be erroneously interpreted to mean that New York University fish collection data establish that high mortality of white perch has resulted from entrainment and impingement. The number of white perch impinged on the Indian Point Unit 1 intake screens is a matter of record in these proceedings, but these data were not generated by New York University studies.

New York University is studying the effects of entrainment on fish eggs and larvae. However, there was not then nor is there now information existant to substantiate the AEC staff conclusion that white perch experience high mortality due to entrainment by Indian Point Unit 1. This was an assumption on the part of the staff.

The staff's use of the 1965-1969 New York University fish collection data as support for their conclusion that mortalities related to operation of Indian Point Unit 1, "could be adversely affecting the white perch in the Hudson", is an invalid use of the New York University data.

New York University biologists under the direction of Dr. Alfred Perlmutter collected fish by seine at nine shore sites on the west side of the Hudson River during June, July and August of each of the years 1965 and 1968,[1,2,3] and at eight of those same sites during 1969[4]. The sampling stations were located between mile points 26 and 105 from the Battery in New York City.

A fifty foot long seine made of 3.8 inch nylon mesh was used to collect the fish. Both ends of the seine were taken offshore, and with the seine parallel with the shoreline, both ends were drawn toward the shore simultaneously. The area seined at a given station and date depended upon the tide, the topography of the bottom, and the individuals handling the seine. The area seined was estimated, and the catch per haul was multiplied by a factor appropriate to express all catch data in numbers of fish per 100,000 square feet. The areas estimated to have been seined during each sample ranged from 1250 to 5000 square feet.

The data from the five year's summer collections were statistically analyzed in 1969[4].

The calculated average catch of a species among sampling sites during the same year and among years was extremely variable. The abundance of white perch at a single sampling site varied an order of magnitude, and for some species abundance ranged over two orders of magnitude.

Statistical analyses of the seine data did not reveal any significant differences in the catch of fish during the years (1965-1969) of collection. Analyses of variance failed to reveal any significant change from year to year in the fish populations. Comparison of each of the five means with the other four resulted in no "t" values that were significant at the 0.05 level (critical value 3.20). It was concluded that, "there was no significant observable change in the population, against the background of natural flucturations of populations, which might be attributed to natural or other causes".

Intensive sampling by the same method during twenty-four-hour periods at two stations was done in 1969 in an effort to determine the source of the variability[5]. The number of species caught and their total abundance were found to vary greatly during any twenty-four-hour period, but there was no apparent consistant relationship between catch and time of day or tide.

The New York University researchers concluded that shore seining alone was totally inadequate for determining whether fish populations in the Hudson River estuary were increasing, decreasing or remaining the same over a period of years. It was apparent that a much expanded effort utilizing a variety of collection gear and marking techniques would be necessary to determine fish population abundance. New York University recommended that its seine collections be replaced by such an expanded program, which was part of the stimulus leading first to the studies by Raytheon, and now by Texas Instruments.

Raytheon used a 75 ft x 8 ft x ¼ inch square mesh seine without a bag until September, 1969, and then changed to a 100 ft x 10 ft x 3/8 inch square mesh seine with a ¼ inch square mesh bag[6]. They placed one end of the seine at the shoreline and the other out into the water perpendicular to the shoreline. The one end in the water was then pulled toward the shoreline in an arc covering approximately ¼ the area of a circle with radius equal the length of the seine. The Raytheon data for 1970 were thus obtained by different gear, methods, personnel and some different locations than data collected by New York University during 1965-69. It is therefore inappropriate to compare the two sets of data for the purpose of drawing conclusions about trends in white perch population abundance.

In summary, the AEC staff used New York University and Raytheon seine data on white perch to draw conclusions about trends in white perch population abundance; although the New York University study had been discontinued in 1969 because statistical analyses of the data by New York University clearly showed the data collected by seining alone to be so variable as to be useless for judging whether the Indian Point plant operation was affecting population size.

The AEC staff (Dr. Goodyear) agreed that the data are inadequate but said that the data cannot be ignored (Tr9285). The data are inadequate for the purpose for which they were used by the staff. Correct scientific use of data dictates that one not form intrepretations and conclusions beyond the adequacy and reliability of that data.

It is worthy of mention that commercial fish catch statistics,[7] if used in the manner that the AEC staff used the New York University seine data, would have lead one to conclude that the population trend was one of increase during 1966-69, rather than decrease. The commercial catch of white perch from the Hudson River during the period 1965-69 was as follows[6]:

Year	Pounds
1965	3,600
1966	1,600
1967	1,490
1968	1,700
1969	2,600

Similarly, the increases in annual catch of striped bass from the Hudson River since 1964 could, if used in the manner of the AEC staffs use of the seine data, be interpreted as an indication that operation of Indian Point Unit 1 has been beneficial to the striped bass population. The recorded commercial catch for those years were reported as follows:

Year	Pounds
1964	29,500
1965	26,700
1966	44,342
1967	54,642
1968	60,800
1969	77,155

The commercial catch statistics are probably about as inadequate as the seining data for measuring trends in population size, hence the need for the multifaceted sampling and mark-recapture program now being conducted by Texas Instruments.

REFERENCES

1) New York University, "Ecological Survey of the Hudson River," Progress Report No. 2 (1966).

2) New York University, "Ecological Survey of the Hudson River", Progress Report No. 3 (1968).

3) New York University, "Ecological Survey of the Hudson River," Progress Report No. 4 (1969).

4) Perlmutter, A., R.F. Heller, and H. Hermo. 1970. Fluctuations of Fish Populations. Part 1. As a Monitor of Environmental Changes in the Hudson River. Proceeding of 2nd Symposium on Hudson River Ecology. Edited by G. Howells, and G.J.Lauer.

5) Heller, Richard F., and H. Hermo. 1970. Fluctuations of Fish Populations. Part II. Observed by 24-hour Sampling. Proceeding of 2nd Symposium on Hudson River Ecology. Edited by G. Howells and G.J. Lauer.

6) Raytheon Company. 1971. Indian Point Ecological Survey, Report II. January-June 1970. Raytheon Co., Submarine Signal Division, Portsmouth, Rhode Island.

7) Hudson River Fishery for Anadramous, Catadromous and Brackish Water Species, 1913-1969 (Bureau of Commercial Fisheries).

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of	)	
	)	
Consolidated Edison Company New York, Inc.	)	Docket No. 50-247
	)	
(Indian Point Station, Unit No. 2)	)	

Rebuttal Testimony of
Gerald J. Lauer, Ph.D.
New York University

on

Effects of Entrainment
on <u>Morone sp</u>. (striped bass and white perch) eggs and larvae
at Indian Point

February 5, 1973

In making its prediction as to the entrainment effects of Indian Point Unit No. 2 on the population of striped bass, the United States Atomic Energy Commission's regulatory staff assumed that 100% of the striped bass entrained through the Indian Point plant would likely be killed (Page V-48)[1]. The assumption appeared to be based in part on the erroneous belief that normal operation would produce Indian Point discharge canal temperatures above 90°F beginning about mid June (Page XII-28); and, on unfounded statements on the effects of pressure changes on the entrained larvae (Page XII-28 and Page XII-29).

Mr. John Clark, witness for the Hudson River Fisherman Association, also assumed that 100% of the striped bass larvae entrained through the Indian Point plant would be killed[2]. He appeared to base his assumption on results of an entrainment study at the Connecticut Yankee power plant by Barton Marcy[3]; although no striped bass were involved in that study.

New York University conducted studies during 1972 to determine the effects of entrainment on fish eggs and larvae at Indian Point Unit 1. Sampling stations used for this purpose are indicated in Figure 1. These included a station in the intake bay I-1, a station (D-1) in the discharge canal approximately 60 ft. downstream of the emergence of the canal from under the Unit 1 building, and another (D-2) in the discharge canal approximately 350 feet downstream of station D-1 and 100 feet from the first submerged discharge port.

Metered 0.5 meter diameter, 500μ mesh nets were used to collect the specimens. Most samples collected prior to June were taken at a depth just below the water surface.

Installation of sampling devices to permit taking of near-simultaneous samples from the bottom, mid-depth and just beneath the surface was completed for use after June 15.

Samples collected from the nets were placed in plastic pails containing water taken from the station and were brought immediately to the wet-lab on the dock at Unit 1. The samples were gently poured into flat pyrex dishes for sorting. These sorting dishes were positioned in a shallow wooden trough supplied with flowing water from the plant intake to avoid temperature changes during sorting.

Each fish larvae in the samples was characterized as being live, stunned, or dead according to the following definitions:

Live - swimming vigorously, no orientation problems, behavior normal. Many of the live larvae were held in aquaria in the laboratory. They

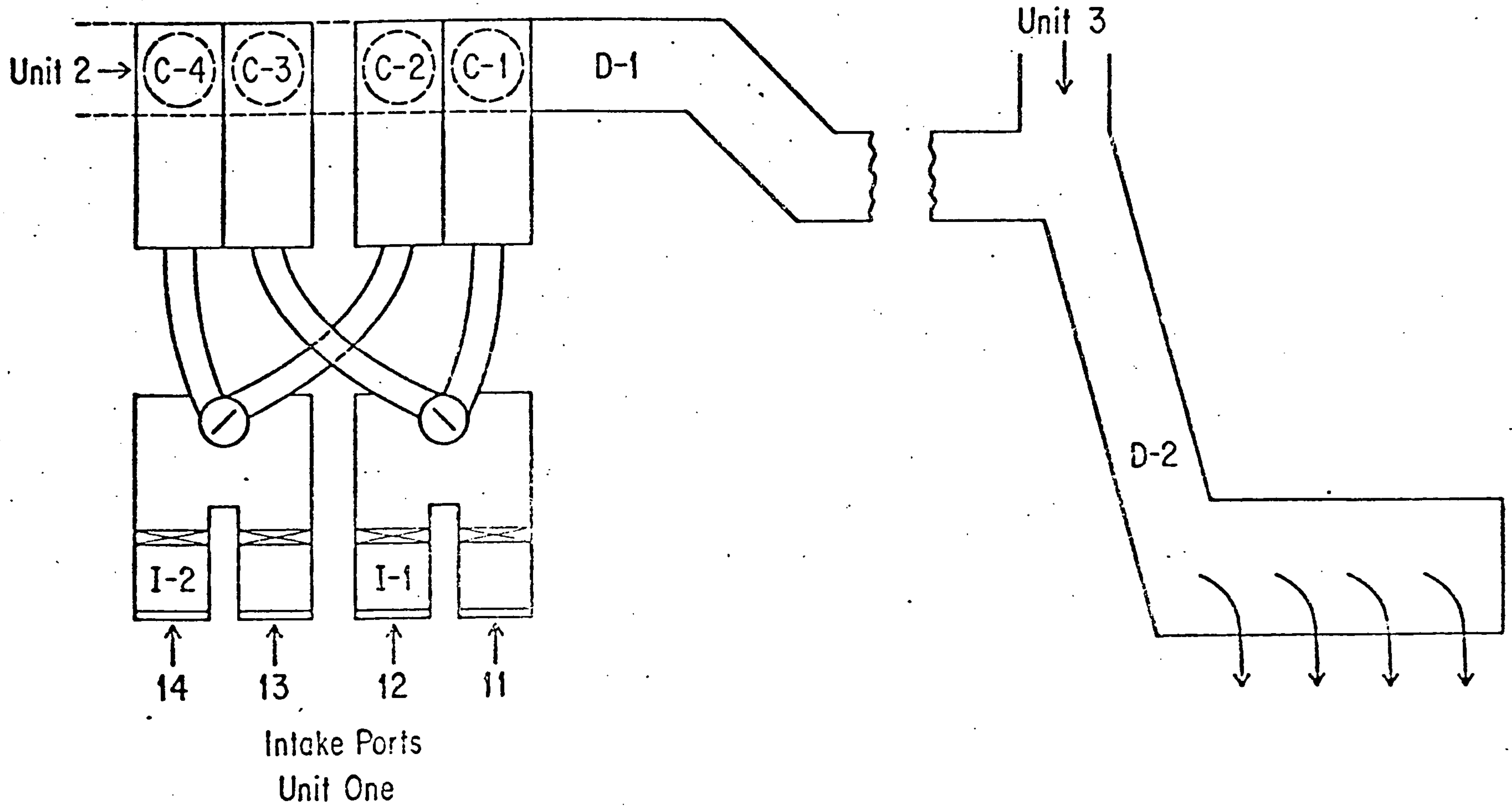


Figure 1. - Schematic of Indian Point Cooling Water System

fed well on natural foods offered them and were maintained in the laboratory for variable time periods up to one-month after collection. These larvae were used for temperature tolerance and pressure tolerance studies.

Stunned - swimming erratically, struggling, swimming on side, some twitching but mobile.

Dead - no vital life signs including heart beat, body or opercular movements.

Marcy[3] reported the majority of fish larvae collected from the Connecticut Yankee plant discharge canal to be mangled. Questions were raised during the 13 December, 1972 hearings (Transcript pages 7394, 7398, 7400-07) about the possibility of a majority of larvae being mangled or chopped up during passage through the Indian Point plant.

New York University researchers collected well over one-thousand samples from the Indian Point Unit 1 cooling water system during the period June through November, 1972. Only occasional larvae in a mangled condition were observed both in intake and discharge samples. This was attributed to collection damage. Moreover, the average concentration of larvae per unit volume of water filtered did not differ significantly in pooled intake and discharge samales (Table 1). Thus there was no significatn portion of larvae unaccounted for in the discharge canal samples.

The calculation of mean concentrations given in Table 1 does not include dates on which no Morone sp. were collected: Therefore, the mean concentrations in Table 1 are biased upward and do not reflect total abundance estimates for the time period in question.

The results of these on-site studies indicate that the mortality of entrained Morone sp. (striped bass and white perch) is considerably less than 100%.

My October 30 testimony included a first approximation estimate that 54% of Morone (striped bass and white perch) larvae survived passage through Indian Point Unit 1. This was computed by the formula:

$$\% \text{ survival} = \frac{\text{Number of live larvae in discharge samples}}{\text{Number of live larvae in intake samples}} \times 100$$

Table 1

Concentration of Morone sp. larvae (#/1000 m^3)

Plant Operation Condition	Temperature Intake-Discharge	Sample Station I-1	D-1	D-2	D-1 & D-2
A	63-69°F				
	$\bar{X}$(1)	87	83	234	160
	SE	62	42	155	80
	n	5	9	9	18
B	69-69°F				
	$\bar{X}$	214	287	263	280
	SE	43	87	97	67
	n	85	44	19	63
C	68-79°F				
	$\bar{X}$	344	143	209	165
	SE	66	40	54	34
	n	56	23	5	28
D	78-88°F				
	$\bar{X}$	27	25	87	46
	SE	19	15	31	14
	n	12	4	2	6
E	79-94°F				
	$\bar{X}$	222	376	275	326
	SE	113	119	178	107
	n	3	6	6	12
Pooled Statistics	$\bar{X}$	242	221	243	228
	SE	32	47	63	39
	n	161	86	41	127

(1) $\bar{X}$ Mean; SE = Standard error of the mean; n = number of samples

Significant differences: 63-69 None, 69-69 None, 68-79 (i-1)-(D-1); (I-1)-(D-1 & D-2), 78-88 None, 79-94 None, Pooled Statistics None.

This approach was similar to the method used by Marcy[3], except that Marcy used concentrations/unit volume of water rather than the absolute numbers of larvae observed. The New York University data analyses had not at the time of preparation of my October 30 testimony, included calculations of concentrations, so associated with the use of the method at that time were the assumptions that the collection efforts had been the same in the Indian Point intake and discharge; and, that all of the difference between numbers of live larvae from the intake and discharge was due to the plant. Data from all plant operating conditions were combined for this approach. It was indicated that this first approximation was subject to revision upward or downward as further data analyses were completed.

Further analyses have now been completed with the following results:

Occurrence

Morone sp. larvae were taken in Indian Point Unit 1 intake and discharge samples from June 4 through August 19, 1972 (Figure 2). There were two peaks of abundance, the first during the period June 11-24, and the second between July 23 and July 29. Very few *Morone* larvae were present during the time (June 25-July 23) between the two peaks.

Size Distribution

The longest striped bass larvae collected in the intake and discharge canal samples was 19 mm (≡0.8 inches) long. Seventy seven percent of the striped bass were 12 mm (≡0.5 inches) or less in length. This indicates either that larger larvae were not passed through the cooling system; or, that if larger larvae did pass through, they were in sufficiently good health to avoid the collection nets.

Chadwick and Stevens[4] reported that in the Sacramento and San Joaquin river striped bass larvae 0.8 inches or less in length concentrated in shallow water habitat less than 5 feet deep within 10 to 20 feet off shore. If the Hudson River striped bass larvae behave in the same manner and Dr. Raney's testimony of February 5, 1973 suggests this is the case[5], this could explain the reduced abundance of larvae between 10 and 19 mm long and the absence of larvae longer than 19 mm in samples of the cooling water system at Indian Point.

In any case the absence of striped bass larvae larger than 0.8 inches in over 1000 samples from the Unit 1 intake and discharge canals contrasts with previous testimony by others in this proceeding that striped bass up to 1.5 inches long are susceptible to entrainment, and that all of those entrained will be killed.

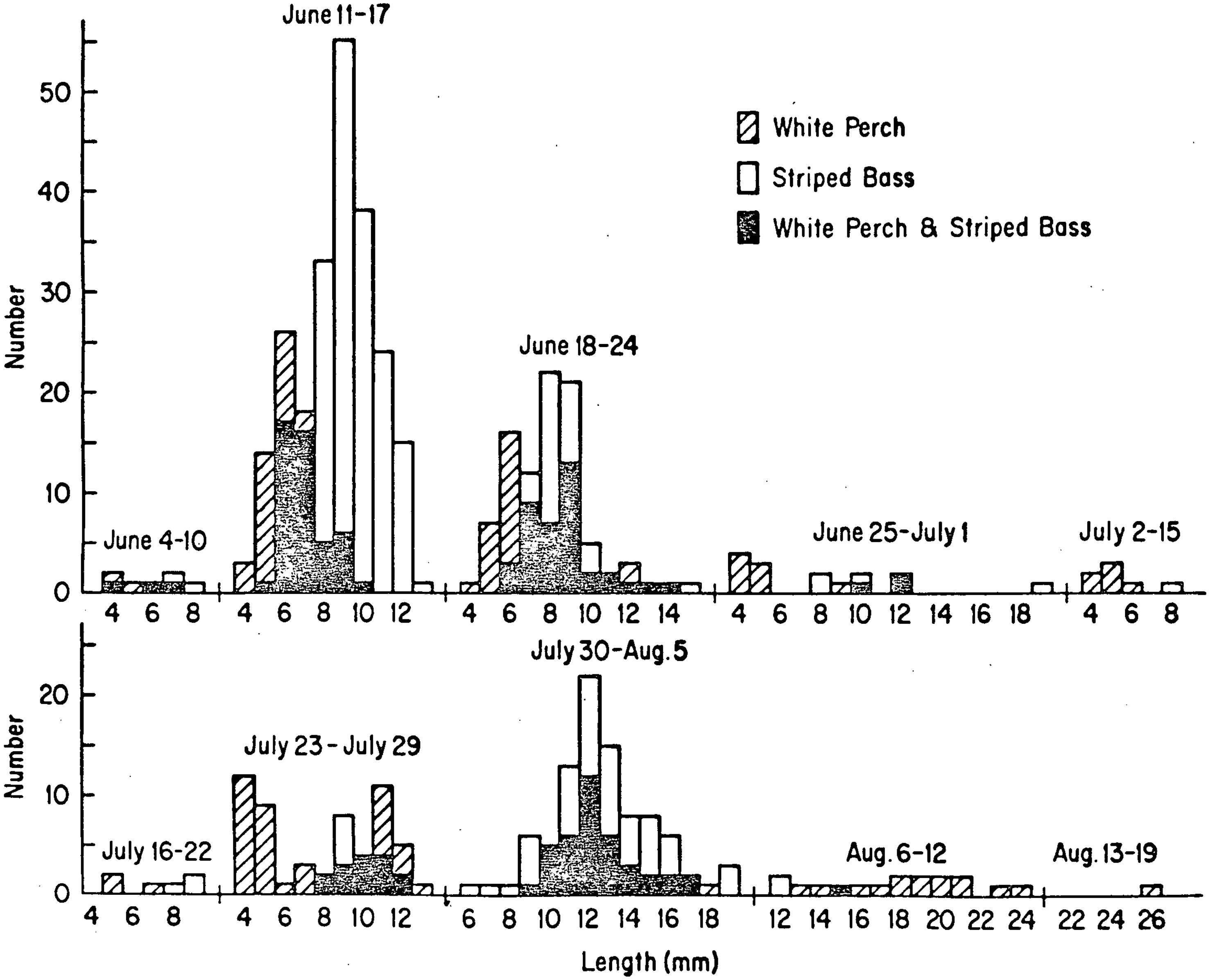

June 11-17
White Perch
Striped Bass
White Perch & Striped Bass
Number
June 18-24
June 4-10
June 25-July 1
July 2-15
July 30-Aug. 5
July 23 - July 29
July 16-22
Aug. 6-12
Aug. 13-19
Length (mm)

Figure 2

The length frequency distribution of striped bass larvae collected from the Unit 1 cooling system in 1972 presents a rather curious pattern (Figure 2). An expected increase in size with passage of time was not found. Instead, the mode for striped bass larvae in the July 30 - August 5 collections was only about 2 mm longer than for the June 11-17 and June 18-24 collections. Moreover, a few larvae 6 to 8 mm long were observed in the July 30 - August 5 collections. One would expect that eggs would have to have been spawned about two weeks earlier to produce larvae of this size. However, no striped bass eggs were collected in the vicinity of Indian Point after June 8. The larvae could have come from eggs spawned outside of the New York University sampling area.

A possible explanation could be that white perch larvae were mis-identified as striped bass, although the smaller size larvae of these two species are easier to distinguish than the larger larvae. The identifications are being re-checked.

Condition of Entrained Larvae

Having established that there was no significant difference in average concentrations of Morone sp. (striped bass and white perch) larvae in intake and discharge canal samples, it was then possible to make a more refined estimate of the effects of entrainment on the larvae.

The condition of the larvae collected from the Unit 1 intake and discharge canals were characterized as live, stunned or dead as defined on page 1.

Intake samples contain stunned and dead larvae along with live ones. The dead and stunned larvae in the intake samples consist of those coming into the intake already in those conditions and those damaged by collection.

The condition of larvae in intake samples was used as the control. Comparison of larvae condition in discharge canal samples with the intake was used to estimate the effects of entrainment on the larvae.

Unit 1 operation varied during the time of Morone sp. occurrence in the cooling system such that there was no temperature elevation (ΔT) during the time when the largest number of larvae were taken, and a $15^{\circ}F$ ΔT was present only briefly late in the season when there were few larvae present (Table 1). This circumstance reduces the amount of useful information as relates to thermal effects which might otherwise have been derived from the data.

Mean values, e.g. of percent alive, can be compared at the intake and discharge in order to determine any reduction by the power plant. Data derived from plankton catches are variable, consequently mean values for such data are variable. It is clear that, since mean values for intake and mean values for discharge will both vary as a result of factors not related to the power plant, there will be differences between the means which are caused by factors not related to the power plant, i.e. chance.

In order to determine if the difference between two means could be the result of chance variation it is necessary to know how reliable each mean is, i. e. what values would be expected if the experiment were repeated under identical conditions.

The reliability of a mean value (confidence limits) can be calculated and is, among other things, a function of the variability of the numbers and the number of samples taken.

The 95% confidence limits of a mean are the values between which the mean would vary as a result of chance in 95% of repeated experiments.

Since the confidence limits are a function of the number of samples taken, i.e. means made up of a large number of samples will have narrower confidence limits than means made up of a small number of samples, the sensitivity of any comparison between two means will be improved if the number of samples is increased. One consequence of this is that if one is comparing two means both of which are made up of a small number of samples, their confidence limits will be so wide that they will overlap thus indicating that the difference between the means could be accounted for by chance alone; a seemingly large difference between the means could be accounted for by chance alone.

Since the number of samples taken during periods when there was a ΔT (Table 1-A, C, D, E) is relatively small, particularly for the discharge stations. The means and standard errors have been pooled for comparing alive, dead and stunned organisms in the intake and discharge, when the plant was operating (Tables 2, 3 and 4). The effect of combining these data is to make tests for significant differences between intake and discharge as sensitive as possible.

Tables 2, 3 and 4 show mean percents alive, dead and stunned respectively. Each mean is represented with its 95% confidence interval, thus, for Table under the heading intake without ΔT, the mean percent alive was 49%±12. This indicates that if the experiment were repeated under identical conditions one would expect 95% of the means thus obtained to lie between 37% and 61%. Likewise, again in Table 2, under the heading discharge without T it can be seen that the mean percent alive was found to be 26%±10. As in the case of A, the mean at the intake, the mean at the discharge would be expected to take on any value between 16% and 36% if chance variation were operating alone. The means at both the intake and at the discharge, then, could be expected to take on a range of values as a result of chance variation.

There are now two sets of circumstances to be considered.

1. The mean at the intake and discharge could be nothing more than measurements of duplicate circumstances, e.g. the difference between the two means is caused by chance variation. If this were true the range of values which could be taken on by

Table 2

Morone sp. larvae entrainment 1972
Confidence Intervals: Percent Alive

95% confidence interval of the mean percent alive at:

	Intake	Discharge	With Cl_2 Discharge
Without ΔT	49%±12	26%±10	15%±28
With ΔT	65%±10	44%±12	11%±10
Pooled Average	56%±8	34%±8	11%±5

95% confidence interval of the difference between the mean percent alive at intake and mean percent alive at discharge

	Intake-Discharge	With Cl_2 Discharge-Discharge
Without ΔT	7 ≤ difference ≤ 39*	0 ≤ difference ≤ 37
With ΔT	5 ≤ difference ≤ 37*	17 ≤ difference ≤ 49*
Pooled Average	10 ≤ difference ≤ 33*	4 ≤ difference ≤ 42*

*Indicates a significant difference at the 95% confidence level: the difference cannot be accounted for by chance alone. The absence of an asterisk indicates that there is no significant difference.

Table 3

Morone sp. larvae entrainment 1972
Confidence Intervals: Percent Dead

95% confidence interval of the mean percent dead at:

	Intake	Discharge	With Cl_2 Discharge
Without ΔT	43%±12	51%±12	44%±28
With ΔT	29%±10	48%±12	87%±12
Pooled Average	36%±8	49%±8	76%±12

95% confidence interval of the difference between the mean percent dead at intake and mean percent ~~alive~~ DEAD at discharge

	Intake-Discharge	With Cl_2 Discharge-Discharge
Without ΔT	0 ≤ difference ≤ 25	0 ≤ difference ≤ 34
With ΔT	4 ≤ difference ≤ 35*	22 ≤ difference ≤ 56*
Pooled Average	2 ≤ difference ≤ 24*	13 ≤ difference ≤ 41*

*Indicates a significant difference at the 95% confidence level: the difference cannot be accounted for by chance alone. The absence of an asterisk indicates that there is no significant difference.

Table 4

Morone sp. larvae entrainment 1972
Confidence Intervals: Percent Stunned

	95% confidence interval of the mean percent stunned at:		
	Intake	Discharge	With Cl_2 Discharge
Without ΔT	8%±6	23%±10	42%±32
With ΔT	6%±6	8%±4	4%±8
Pooled Average	7%±4	16%±9	13%±10

95% confidence interval of the difference between the mean percent stunned at the intake and the mean percent stunned at discharge

	Intake-Discharge	With Cl_2 Discharge-Discharge
Without ΔT	$3 \leq$ difference ≤ 27*	$0 \leq$ difference ≤ 49
With ΔT	$0 \leq$ difference ≤ 9	$0 \leq$ difference ≤ 13
Pooled Average	$2 \leq$ difference ≤ 16*	$0 \leq$ difference ≤ 15

*Indicates a significant difference at the 95% confidence level: the difference cannot be accounted for by chance alone. The absence of an asterisk indicates that there is no significant difference.

one mean would be expected to include some of the values which could be taken on by the other mean, i. e. their confidence limits overlap.

2. The second condition is that the confidence limits of the two means include no values in common, in which case it would be concluded that the difference between the mean could not be accounted for by chance alone, i. e. there would be a significant difference between the means.

In the example given, the mean percent alive in the intake could be from 37% to 61% and the mean percent alive in the discharge could be from 16% to 36%. Since these two ranges contain no values in common, it can be concluded that the difference between the means is significant at the 95% confidence level.

Even though the difference is significant, there still exists the element of chance variation: the difference can be expected to vary from experiment to experiment even though the experiments are identical. For this reason 95% confidence intervals have been calculated for the differences between the means under consideration.

In the second half of each Table (Tables 2, 3 and 4) the confidence intervals for differences have been reported. For instance in Table 2 under the heading Intake-Discharge, without ΔT the difference is $7 \leq \text{difference} \leq 39$; the difference is less than or equal to 39% and greater than or equal to 7%. Another way of saying this for the example given is that if 100 percent of the Morone sp. were found alive in the intake one would expect to find between 93% and 61% alive in the discharge. The asterisk next to the inequality in the Table indicates that this is a significant difference.

In summary, the above results provide information on effects of pressure changes, turbulence, mechanical stress and the ΔT conditions described in Table 1 on striped bass and white perch larvae entrained through Indian Point Unit 1. The larvae incurred considerably less than the 100% mortality projected by the AEC staff and the Hudson River Fishermen's Association.

As indicated in my October 30 testimony, laboratory temperature tolerance data indicate that entrained striped bass larvae should be able to tolerate a $15^{o}F\ \Delta T$ except possibly in the later portion of the season when ambient river water temperatures exceed 73 to $75^{o}F$.

Unfortunately the effects of a full $15^{o}F\ \Delta T$ on entrained larvae throughout the season could not be thoroughly studied because the plant was not operational during part of the time and did not produce a $15^{o}F\ \Delta T$ during much of the time it was operational.

Entrainment studies will continue in 1973 in order to acquire this $15^{o}F\ \Delta T$ information and to improve the precision of the estimates of entrainment effects for larvae of striped bass and other fish species. These studies will continue to include assessment of the condition of the larvae immediately after collection, and live and stunned larvae will be held in the laboratory and examined for delayed effects.

Concurrently, intensive sampling of the larvae will be done throughout a 24-hour-day once per week in the plant intake and the river to improve estimates on the relationship of spatial distribution of larvae in the river to the abundance of larvae that enter the plant.

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BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit. No. 2	)))))	Docket No. 50-247

Rebuttal Testimony of
Gerald J. Lauer, Ph.D.
New York University

on

Studies of the Effects of Rapid Pressure Changes
on Striped Bass Eggs and Larvae
by New YOrk University

February 5, 1973

The final environmental statement of the United States Atomic Energy Commission for Consolidated Edison's Indian Point nuclear generating plant (Unit 2) contains a discussion of the potential damage from pressure changes due to entrainment (XII-28).

During the cross examination of Dr. Goodyear of the A.E.C. staff concerning the potential for damage due to pressure, Dr. Goodyear indicated that the information provided by Dr. G.J. Lauer in his October 30, 1972 testimony, page 46, on the effects of pressure on striped bass eggs and larvae as presented raised certain questions concerning the applicability of these data.

The questions posed by Dr. Goodyear on pages 6633-34 of the transcript for December 6, 1972.

(1) were the eggs and larvae used in the experiments exposed to negative pressures (i.e., pressures less than ambient) as well as pressures greater than ambient?

(2) were the organisms exposed to thermal stress at the same time they were being exposed to pressure changes?

(3) were the organisms exposed to turbulence at the same time they were exposed to pressure and temperature.

The following paragraphs attempt to answer these questions.

My October 30, 1972 testimony states the striped bass eggs, and larvae were exposed to abrupt changes of pressure ranging from +5 to =100 psi. Since the experimental organisms were acclimated to ambient pressure of approximately 14.7 psi, this means that experiments did include exposure of eggs and larvae to pressures approximately 10 psi below ambient, or in Dr. Goodyear's terminology, "negative from acclimation." The experiments also included exposures to higher than acclimation pressure (100 psi) relative to acclimation at 14.7 psi.

The larvae and eggs used in these studies were exposed to pressure changes and temperature increases at the same time. Each striped bass life history stage used (from 3 hour old eggs to larvae 30 days old and older) was exposed to temperature alone, pressure alone, and temperature and pressure in combination. The initial analysis of the results of these studies indicate that the mortality observed as a results of the combined stresses of temperature and pressure are not significantly different from that which would be predicted due to temperature alone (page 45, figure 17, Oct. 30 testimony.)

Turbulence was not included as a variable in the studies conducted by New York University. To our knowkedge there have not been any studies conducted on fish larvae which suggests that turbulence in conjunction with rapidly dropping pressures increases the rate of gaseous exchange between the blood stream and tissues of fish over that expected due to pressure alone.

The reference by the staff to Doroshev's (1971) work concerning the appearance and vitality of striped bass with abnormal gas bladders (page XII-29) is somewhat misleading when viewed in context of the effects of pressure changes, gas disease, and the potential for damage as a result of these stresses. Doroshev used these terms in describing a pathological condition (cause unknown) resulting from the failure of the gas bladder to fill with air prior to the closing of the ductus pneumaticus (a duct leading from the gas bladder to the esophagus, essential to the initial filling of the bladder. Once the bladder has been filled the organ becomes functional as a hydrostatic organ capable of volume changes within as yet certain undescribed limits of exposure time and volume.

The pressure studies conducted by New York University coupled with the apparent lack of any external clinical diagnostics (popped eyes, accumulation of gas bubbles around fins) of gas disease in live or dead larval fish collected from various depths in the intakes and discharge canal would indicate that the effects due to pressure are not significant.

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of	)	
	)	
Consolitated Edison Company of New York, Inc.	)	Docket No. 50-247
	)	
(Indian Point Station, Unit No. 2)	)	

Testimony of
Ronald A. Alevras
Biologist
Consolidated Edison Company
of New York, Inc.

on

The Estimation of Fish Impingement at
Indian Point Units 1 and 2

February 5, 1973

SUMMARY

All the estimates of the number of fish that will be impinged on the intake screens of Indian Point Units 1 and 2 should be considered preliminary and subject to error. Little confidence is placed in the present projections because the major factors believed to affect the number of fish collected are presently unquantified or unpredictable. The following factors could have the effect of substantially decreasing or increasing the total annual collections:

1. The influence of the air bubble curtain.
2. The different rates of fish impingement per unit volume of cooling water at Unit 2 and Unit 1.
3. Biological or physical factors which influence the number, distribution, movements and health of the fish populations in the river.
4. Frequency and timing of start-up and shut-down of units.
5. Intake velocity distributions significantly different from the modelled velocities.

With respect to the question of the ecological significance of fish withdrawal, the data on previous fish collections is useful for establishing trends in fish impingement. With allowance for the limitations of the data, there appears to have been a substantial reduction in fish impingement at Unit 1 since 1970. If the present "best available projection" of fish impingement rate is reasonably accurate the numbers of fish impinged with Units 1 and 2 combined are expected to be no greater than the numbers of fish impinged at Unit 1 prior to 1970.

INTRODUCTION

The data on fish collected from the intake screens at Unit 1, from October 1962 to the present is limited in its usefulness for makingpredictions because of the conditions under which it was collected, by the method of sampling and by the existence of unquantified biological and physical factors known to influence fish collections. This paper will characterize the existing data and describe its usefulness for prediction purposes. It will also present a "best method" for making predictions and describe the limitations of that method. Finally, this paper will review the methods of predicting fish impingement presented by intervenor's witness, Mr. Clark, and by the AEC Staff.

THE CHARACTER OF THE DATA

Observations and counts of fish collected at the intakes of the power units at Indian Point have been made sporadically since 1962 when Unit 1 began operation. Data is available from Unit 1 from 1962 to the present and from Unit 2 sporadically from January of 1971. With respect to the Unit 1 data, the time period from 1962 to the present can be broken down into smaller time periods for which the data can be characterized.

October 1962 to March 24, 1965

No known physical counts of fish are available for this time period. Estimates, based on visual observations, by various parties differ widely in terms of numbers of fish collected. General agreement exists for the fact that many large striped bass were collected and that the collections were most prevalent during the winter months. It is reasonable to assume that many small fish were also probably collected at this time.

March 25, 1965 to August 30, 1967

Counts were made at irregular intervals during this period. Major changes in intake-discharge configuration, to reduce fish impingement, occurred during this period (Table 1). The technique of collecting and counting for the period, is not recorded, but visual counts of fish in the sluice water were used part of the time. Observations of species composition and size of fish were made but no species counts or measurements were made. The modifications made to the plant at that time, as set forth in Table 1, eliminated the collection of large fish and were thought to have solved the problem.

September 1967 to September 28, 1969

No Counts or observations of fish collected on intake screens were recorded.

September 29, 1969 to January 11, 1970

Raytheon, a contractor for Con Edison, made 11 counts during this time period. The techniques used were not standardized and no data on species composition or size were recorded. (See Stipulation on fish impingement, dated November 9, 1972.)

TABLE 1. - Major changes in intake-discharge configuration at Indian Point Unit 1.

DATE	MAJOR CHANGE
June 1965	moved point of injection of sodium hypochlorite from riverward side to landward side of traveling screen
August 1965	removed sheet piling around wharf
April 1966	intake openings enlarged (reducing intake approach velocities)
Spring 1966	discharge extended from 320 to 540 feet from intake
November 1967	removed discharge extension because of construction of Unit No. 3, returning discharge to 320 feet from intake
December 1967	completed installation of fixed fine screens on all intakes
Fall 1969	fixed fine screens blocked in fully open position to eliminate clogging by detritus
December 1969	fixed fine screens partially lowered
January 28, 1970	fixed fine screens fully lowered
February 1970	holes under screen plugged

TABLE 1. - (Continued)

DATE	MAJOR CHANGE
February 6, 1970	discharge moved 960 feet from intake
February 24, 1970	back up fixed screens installed
April 1970	changed procedure for disposal of dead fish to minimize reimpingement
April 1970	tested reduced flow operation
December 29, 1970	discharge moved 1,155 feet from intake
January 1971	commenced operation with flow at 60% of normal flow and continued until April and thereafter reduced flow on days when the numbers of fish collected appeared unusual
June 1972	ports completed for submerged discharge, with adjustable gates design for an exit velocity of approximately 10 fps

January 12, 1970 to April 2, 1970

Collections were made by Raytheon biologists and technicians at request of Con Edison. Frequent changes were made in screen position and cleaning procedure during this time. Fixed screens were not functioning properly during the beginning of this period. Data was recorded on species composition and size (length and weight) of fish. Collection procedure was standardized but counting and recording was not continuous. From January 28 to April 2, fish were netted from in front of the fixed screens by plant personnel in addition to the collections made daily from the traveling screens.

It was during this period that the March 6 and 7 collections mentioned by Mr. Clark on page 8814 of the testimony and later questioned by Mr. Jensch on page 8820 of the testimony, were made with hand nets from a rowboat by plant personnel from in front of the fixed screens. A day to day log of the fixed screen positioning was kept during the winter of 1970 (Attachment 1).

The build up of fish which was collected on March 6 and 7 apparently began on March 1 when the plant returned to service after a short outage. The fixed screens were not cleaned on March 1 and 2, but on March 3 a 14 in. differential across fixed screens 12 and 13 required cleaning of #12 & #13. At that time with the circulators running a total of 6,000 fish were netted in front of the screens and an estimated 18,000 were sluiced from the traveling screens 12 and 13. All four fixed screens were raised and cleaned on March 4 with the circulators off and 15,000 fish were netted in front of the screens. On March 5 a 2 ft. differential developed on the fixed screens and the circulators were shut off and the screens were raised and over 30,000 fish were netted. When the fixed screens were lowered after cleaning and the circulators turned on an 18 in. differential developed almost immediately, indicating that many fish were reimpinged on the fixed screens.

A fixed screen cleaning began on March 6 and when it was realized that there was an exceptional number of fish, the screens were raised slowly while the fish were netted. The fixed screen cleaning continued into March 7 when the plant was taken off line. A total of approximately 120,000 fish were netted and 388 sluiced on March 6 and 7.

April 4, 1970 to November 16, 1970

Collections were made by a combination of contractor and company employees (including plant personnel) under the direction of the Office of Environmental Affairs (then the Environmental Engineering Bureau) for specific test purposes. The reactor was down during this period. Some collection intervals were quite short. Collecting was standardized. Data was recorded on species composition and length and weight of fish. Data was also recorded on plant operating conditions.

December 7, 1970 to Present

Collections were made by trained personnel under direction of the Office of Environmental Affairs. The collection technique was standardized. Data was recorded on species composition, length and weight, and relative condition of fish. Data was also recorded on plant operations. Tests of the effect of plant factors such as intake velocities, air bubble curtains and traveling vs fixed screens on fish impingement were done during this period.

Data Availabe from Indian Point Unit 2

Counts of fish collected from the intake screens at Unit 2 are available generally for whenever the circulator pumps were running (See Stipulation on fish impingement, dated November 9, 1972). In addition to the data in the stipulation, collections were made at Unit 2 from August 19, 1972 to October 10, 1972 (Table 2). These collections were made by trained technicians using standardized procedures. Data was recorded on species composition, length and weight and relative condition of fish. Data was also recorded on plant operating conditions.

TABLE 2. - Number of fish collected at Unit 2 from August 19, 1972 to October 10, 1972

DATE	Screen 21	Screen 22	Screen 23	Screen 24	Screen 25	Screen 26
8/19/72	21		151			140
8/20/72						
8/21/72	0		19			0
8/22/72	1					3
8/23/72						
8/24/72	5					6
8/25/72						
8/26/72						
8/27/72						
8/28/72						0
8/29/72	0		0			
8/30/72						
8/31/72	19					59
9/1/72	53					125
9/2/72	138					88
9/3/72	68					100
9/4/72	5					6
9/5/72	29					6
9/6/72	0					2
9/7/72	56					31
9/8/72	195					231
9/9/72	52					106
9/10/72	23					13
9/11/72	95					69
9/12/72	21					24
9/13/72						
9/14/72						
9/15/72	2					1
9/16/72	2					1
9/17/72	3					5
9/18/72	1					0
9/19/72	18					9
9/20/72	20					4
9/21/72	122					8
9/22/72	398					47
9/23/72	313					19
9/24/72	732					28
9/25/72	257					230
9/26/72	109					23
9/27/72	53					6
9/28/72	156					4

TABLE 2. - (Continued)

DATE	Screen 21	Screen 22	Screen 23	Screen 24	Screen 25	Screen 26
9/29/72	48					5
9/30/72	346					78
10/1/72	41					4
10/2/72	269					131
10/3/72	381					95
10/4/72	122					8
10/5/72	456					65
10/6/72	301					28
10/7/72	183					15
10/8/72						
10/9/72	129					51
10/10/72	231					

THE SUITABILITY OF THE DATA FOR MAKING PREDICTIONS

The operating conditions at the plant have been shown to affect the number of fish collected. When the plant is operated at reduced flow (and thereby reduced intake velocity) the number of fish collected is significantly reduced (Table 3). Reduction of flow raises the temperature increase (Δt) across the condensers and thus could have other biological effects.

TABLE 3. - Number of fish collected at Unit 1 during October and November 1971

Month	REDUCED FLOW (84,000 GPM EST.) No. of Sample Days	REDUCED FLOW (84,000 GPM EST.) Mean No. of Fish/Day	FULL FLOW (140,000 GPM EST.) No. of Sample Days	FULL FLOW (140,000 GPM EST.) Mean No. of Fish/Day
Oct.	12	117	10	2190
Nov.	8	930	19	3958

In selecting data to be used for estimating future fish collections data should be selected which was collected under conditions as similar to the proposed operating conditions as possible. Relative to fish protection at Units 1 and 2, the proposed operating conditions are:

1. Fixed fine screens in place at all times

2. Fixed fine screens cleaned daily
3. Plant operated at full flow (140,000 gpm per main pump) from April 1 to September 30
4. Plant operated at reduced flow (84,000 gpm per main pump) from October 1 to March 31
5. Air bubble curtain in front of fixed screens in use when ambient river temperature is less than 40°F
6. Chlorination of each condenser in three 1/2 hour periods per week

Data from estimates made visually (specimens not actually collected and hand counted) are not suitable for prediction purposes because they are subject to very great error. This limitation applies to data collected prior to 1965 and to an unquantified number of collections made from March 1965 to August 1967.

The data collected between March 1965 and December 1967 is not suitable for making predictions of future fish collections in my opinion because it was during this time that changes were being made in the intake-discharge arrangement which significantly affect the number of fish impinged (Table 1). It was at the end of this period when fixed screens were installed across the outer intake openings of all bays. No collecting and reporting of fish occurred after the installation of these screens until the Fall of 1969. Data collected in 1972 indicate that the fixed screens significantly reduced the number of fish collected on the traveling screens at Unit 1 (Table 4).

The intake velocity has been shown to be an important factor influencing the number of fish collected at the plant. The 1965 collections were made under velocity conditions significantly greater than the velocities that now exist at Unit 1 and are therefore not suitable for predictions. In addition, for the period October 1 to March 31 the intake velocity will be significantly less than the velocities in existence between 1966 and 1970. This severely limits the usefulness of data collected between 1966 and 1970, particularly during the winter months when most of the fish are collected.

The data collected between March 1965 and August 1967 could be used to estimate annual fish collections under the conditions that existed at that time but the data is not useful for making predictions under existing conditions.

TABLE 4. - Number of Fish Collected at Indian Point Unit 1 With and Without Fixed Screens During August 1972

	Without Fixed Screen		With Fixed Screen	
Date	Bay 11	Bay 12	Bay 13	Bay 14
August 4	60	189	15	8
5	118	318	5	10
6	101	337	7	8
11	66	822	16	3
13	113	491	6	0
Total	458	2157	49	29

The data collected by Raytheon from September 1969 to March 1970 is not suitable for prediction purposes because the fixed screens were either raised in their slots, rendered ineffective because of holes, or were not raised and cleaned on a daily basis (and [redacted] thus no fish could enter and be counted). During the period when the fixed screens were not raised daily, fish were netted from in front of the fixed screens. Only rough visual estimates were made of the fish netted and there is no basis for estimating the number lost in the netting process.

The collections from April 1970 to November 1970 were made during specific test intervals when the plant was not producing power. The fixed screen arrangement was altered from the standard operating procedure for some of these tests and many of the test intervals were very short. For these reasons, this data is not suitable for prediction purposes.

Beginning in December 1970, regular monitoring of the number of fish collected at Unit 1 began. From December 1970 to the present, the Unit 1 intake has operated in a manner similar to the proposed operating mode except that the complete air bubbler system is not yet installed. The fixed screens at Unit 1 have been in use almost continuously and raised and cleaned daily. Unit 1 has operated at reduced flow for the bulk of the winters of 1970-1971 and 1971-1972, but it did not operate at reduced flow on a regular basis during October and November of those years. Test data at reduced flow are available, however, for October and November and this data is useful for making predictions.

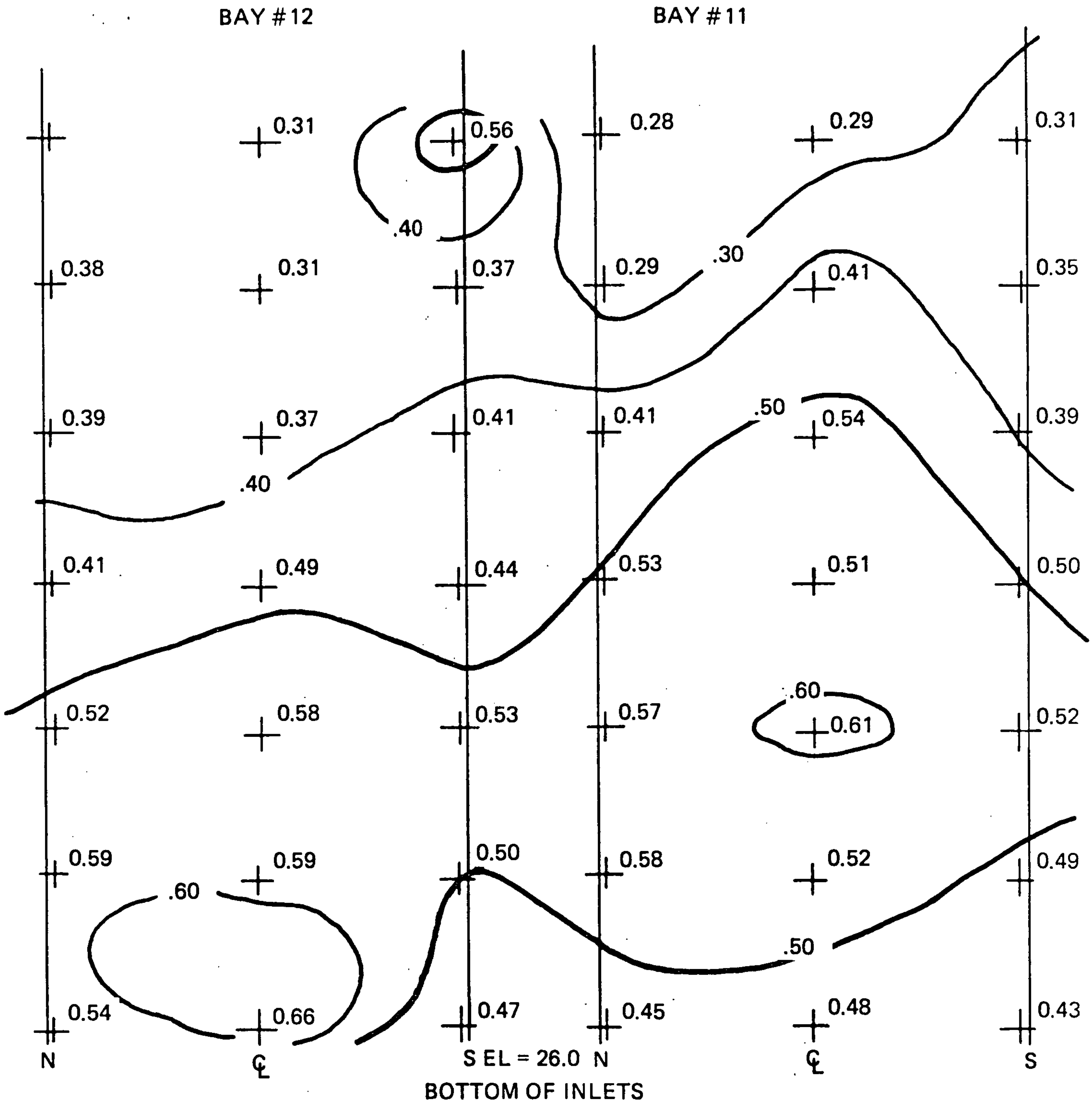
Since February of 1971 an air bubble curtain has been installed in front of fixed screen #12 and operated intermittently for test purposes to the present. This device has provided preliminary data on the effect of an air bubble curtain on fish impingement. To date the results have been inconclusive; a reduction in number of fish collected was found during tests in February, but tests during the summer resulted in increases in fish collected at the bay with the test device.

The data collected from December 1970 to the present is the most suitable data for predicting future fish collections without regard to the air curtain primarily because it was collected under conditions that are the closest to the proposed operating conditions at Units 1 and 2. This data is also the longest series of data for which the sampling technique was standardized and data on plant operating conditions are known.

The data collected at Unit 2 is very fragmentary (all 6 main pumps have never operated simultaneously) and much of it was not collected under the flow conditions which will be standard operating procedure during the winter months. The Unit 2 data can be used to qualify the predictions for Unit 2 based on Unit 1 data.

A METHOD FOR USING THE EXISTING DATA TO PREDICT FISH COLLECTIONS AT UNITS 1 AND 2

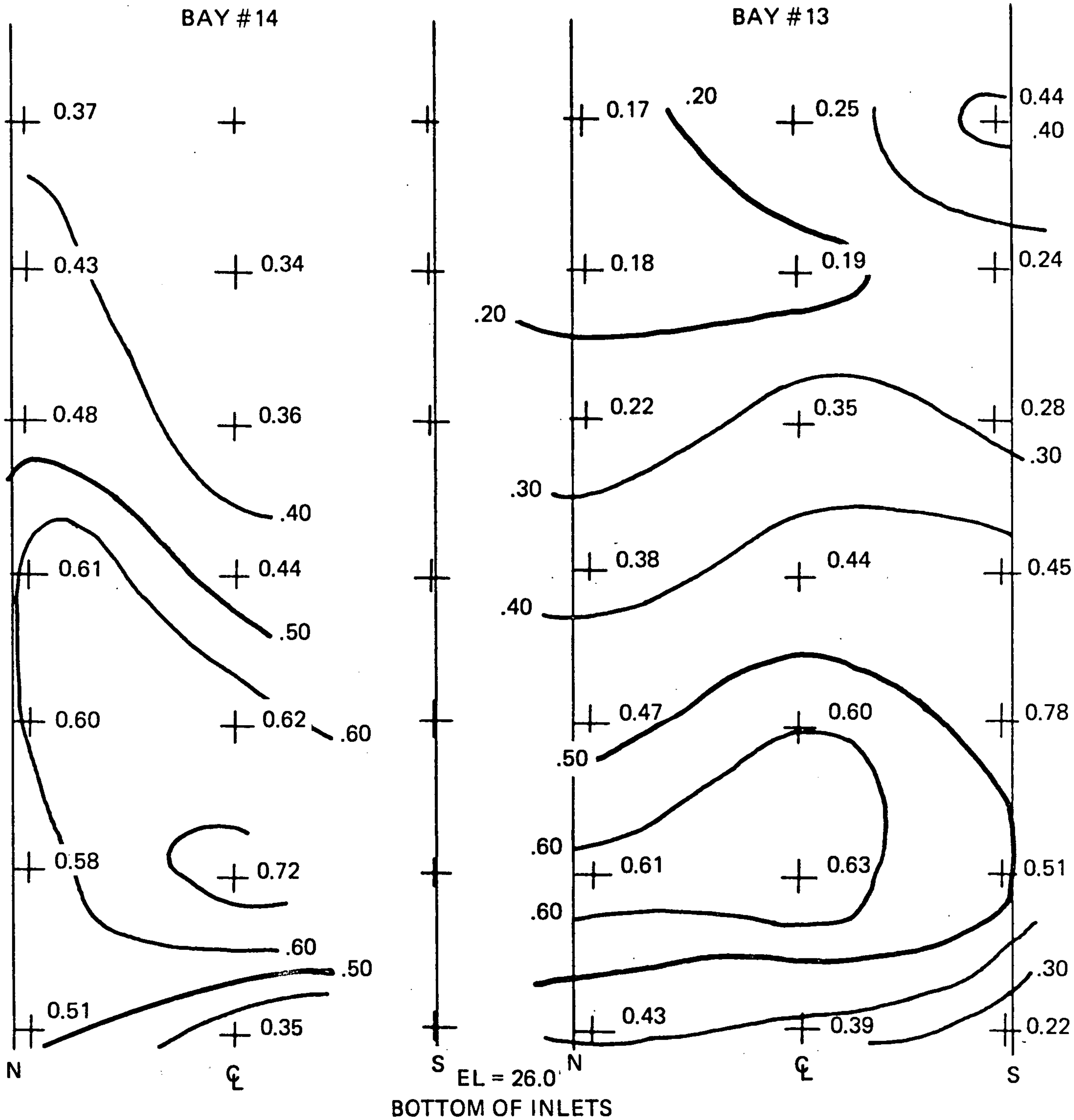
In the previous section the data collected at Unit 1 from December 1970 to the present was established as the most suitable for predicting future fish collections. This data must be used with caution because there are two basic limitations for which adjustments must be made. First, there are losses of fish in the collection process. The fixed screens are raised and cleaned one at a time. The wash water hits the screen from behind above the water level spraying some fish away from the screen. Most of these fish fall back into the water but do not escape the influence of the intake flow (see Figures 1 and 2). These fish may not be collected until subsequent screen cleanings and may be collected from an intake bay other than the one where they were originally impinged. The spray from the cleaning process also deposits some fish on the steel supporting structure of the screens and these fish



FRONT VIEW OF SCREENED INLETS LOOKING EAST

READINGS TAKEN BETWEEN 2:20–4:15
AVERAGE TIDE – +1.7

FIGURE 1. INDIAN POINT STATION
FLOW VELOCITY MEASUREMENTS AT SCREENED INLETS
4/10/70 NO. 11 PUMP 100% OPEN THROTTLE
GUSTY SOUTH WEST WIND



FRONT VIEW OF SCREENED INLETS LOOKING EAST

READINGS TAKEN BETWEEN 9:42–10:10
AVERAGE TIDE—+1.5

FIGURE 2. INDIAN POINT STATION
FLOW VELOCITY MEASUREMENTS AT SCREENED INLETS
4/10/70

are not collected. Fish may also be lost if they become impaled on the traveling screen and if they are not removed by the cleaning spray they are carried over the screen and are dislodged into the pump flow and not collected. The above losses are unquantified but are estimated to be a small portion of the total collected.

In collecting fish washed from the traveling screens, a screen basket is placed in the sluice which carries the screen wash water. When debris (leaves, seaweed, plastic bags and other garbage) is heavy the sampling screen becomes clogged and a clean basket is put in the sluice and the existing one removed. In the exchange of screens fish are lost down the sluice. In November 1971 a screen basket was placed in the sluice downstream of the regular sampling point to collect fish lost in the collection process. This screen was relieved of the debris load by the upper screens and therefore collected very efficiently. Table 5 gives the percentage of fish lost on four occasions when the fish and debris load was very heavy, which occurs a small percent of the time.

TABLE 5. Percentage of fish lost during sampling in sluice under conditions of heavy debris.

Date	Time	T-Screen No.	No. of Fish on Upper Screens	No. of Fish on Lower Screen	Total	% Passed Upper Screens
11/11/71	1200	11	1294	214	1508	14.2
11/11/71	1200	12	2055	522	2577	20.3
11/22/71	1200	11	2615	289	2904	10.0
11/22/71	1200	12	2321	295	2616	11.3
					Mean	14.0

In an attempt to compensate for the losses in the collecting process a factor of 25% increase was agreed to with Mr. Clark representing the Hudson River Fishermans Assn. and has been applied to the data. This factor includes the losses occurring in the sluice and all other unquantified losses described above. The factor has been applied to the data on an annual basis. The factor overestimates the actual total loss because the debris load is heavy only during the fall of the year. When the debris load is light collecting from the sluice is very efficient.

The second basic limitation on the data is the fact that the plant, equipment (screens and pumps) is not designed for controlled, systematic sampling of fishes and therefore, a high degree of precision in sampling is not possible. Changes in plant operating mode due to plant outages, severe weather conditions (icing of screens), mechanical breakdown of equipment, lack of manpower for screen cleanings and other problems result in interruptions in the data series. These interruptions are manifest in the data as missed samples, either for the intake as a whole or for one or more of the individual intake bays.

The data collected at Unit 1 since April 1970, includes information on operating problems at the plant that might have influenced the data collection. Using this information it is possible to select representative series of days during which sampling was done in a consistent manner and without interruption. Selecting representative samples is preferable to trying to apply an arbitrary factor to compensate for missed sampling. The long data series provides adequate representative sample days for all seasons.

PROJECTION OF THE NUMBER AND WEIGHT OF FISH EXPECTED TO BE IMPINGED AT I.P. 1 AND 2 COMBINED

The following estimate of the number and weight of fish expected at Indian Point Units 1 and 2 is considered the best estimate possible with the data available. This projection excludes consideration of an increased thermal discharge velocity or air curtains and will need to be adjusted to reflect those operating changes as soon as they are placed in operation and further data obtained.

Method for projection of number and weight of fish expected at Indian Point Unit 1 and 2 based on Indian Point Unit 1 data from December 1970 to March 1972:

1. Compute mean number of fish/day by months for days with complete or nearly complete counts (full flow and reduced flow separately, Table 6).
2. Multiply (1) by number of days/month (assumption: plant operates all days per month).
3. Multiply (2) by 3 for each month to get monthly totals at Unit 2 (assumption: collections at Unit 2 will be directly related to flow rate and follow a similar annual pattern of abundance).
4. Sum (3) for annual total.
5. Multiply (4) by 1.25 for annual total adjusted for specimens lost.
6. Apply annual per cent composition for Unit 1 to (5) to get annual species totals for Unit 2 (assumption: annual per cent composition will be similar at Units 1 and 2, Table 7).
7. Apply annual mean weight for each species at Unit 1 to (6) to get total weight of each species at Unit 2 (assumption: fish collected at Unit 2 will be similar in weight to fish collected at Unit 1).
8. Sum species values from (7) to get annual poundage of fish expected at Unit 2.

A summary of the estimated number and weight of fish for Indian Point Units 1 and 2 is presented in Table 8.

The assumption that the plant operates all days per year is used because it is impossible to predict accurately plant outages. An annual refueling cycle occurs at Indian Point which is of known duration but which will not occur at the same time each year. Because

TABLE 6. Projected Number of Fish Per Month at Units 1 and 2

Month	Mean No. of Fish/Day Unit 1	Projected Total/ Month For Unit 1	Projected Total/ Month for Unit 2
Jan.	756R	23,436	70,308
Feb.	3843R	107,604	322,812
March	473R	14,663	43,989
April	497F	14,910	44,730
May	181F	5,611	16,833
June	141F	4,230	12,690
July	51F	1,581	4,743
August	814F	25,234	75,702
Sept.	1217F	36,510	109,530
Oct.	117R	3,627	10,881
Nov.	930R	27,900	83,700
Dec.	1064R	32,984	98,952
Totals		298,290	894,870
Adjusted Totals		372,863	1,118,588

R = Reduced Flow
F = Full Flow

TABLE 7. Projected Composition and Weight of Fish Collected at Unit 2

Percent Composition At Unit 1		Total of Each Species Expected Annually At Unit 2	Mean Weight For Unit 1 (oz)	Total Annual Poundate Exp. Unit 2 (lb)
W. Perch	70.7	790,842	.13	6,426
S. Bass	3.1	34,676	.22	477
Tomcod	8.3	92,843	.25	1,451
Herrings	12.8	143,179	.20	1,790
Bay Anchovy	2.2	24,609	.06	92
Other	2.9	32,439	1.0	2,263
		1,118,588		12,263

TABLE 8. Estimated Annual Number and Weight of Fish Impinged at Indian Point, Units 1 and 2

SPECIES	Unit 1 Weight (lbs)	Number	Unit 2 Weight (lbs)	Number
White Perch	2124	263,614	6426	790,842
Striped Bass	159	11,559	477	34,676
Atlantic Tomcod	484	30,948	1451	92,843
Herrings	597	47,726	1790	143,179
Bay Anchovy	31	8,203	92	24,609
Other	676	10,813	2027	32,439
Total	4089	372,863	12263	1,118,588
Adjustment for refueling		-57,232		-171,640
Estimated total annual collections		315,631		946,948

the monthly fish counts vary significantly the effect of a refueling outage on number of fish impinged cannot be accurately predicted for any given year. The effect of a refueling outage, however, can be factored in for the long term operation of the plants by computing the annual mean number of fish collected daily and multiplying this value by the average length of a refueling outage. For Indian Point Units 1 and 2 a refueling outage is 56 days. This results in an average annual reduction in fish impingement of 51,631 fish for Unit 1 and 171,640 fish for Unit 2 (Table 8).

LIMITATIONS OF THE PROJECTION METHOD

Following is a list of limitations which apply to the above best estimate and how these limitations may effect the estimate.

1. The method is not based on the biological and physical factors which underlie the problem and probably determine in my opinion, to an overwhelming degree, the number of fish collected. The use of actual fish counts from an operating intake incorporates the biological and physical factors as they influenced previous collections. The method of estimation used assumes that the effect of the important biological and physical factors will be the same in future as they were in the past. Certainly the effect of biological and physical factors will vary significantly from

year to year and thereby cause differences in annual collections. The influence of biological and physical factors on fish collections is not yet well quantified and these factors must be presently considered unpredictable.

2. The method does not factor in the available fish collection data from Unit 2. The data available from Unit 2 is fragmentary in that the sampling covers short intervals of time and no collections have been made with all six main pumps running simultaneously. Also, no collections have been made during the winter months under the flow and velocity conditions which will be used at the plant. The method used assumes that there is a direct relationship between fish collections and flow rate. This relationship is not well established; the existing data indicates that collections at Unit 2 may exceed the Unit 1 collections by more than three times during the winter months, but may be less than three times the Unit 1 rate during other parts of the year. Because fish collections are at an annual high during the winter, if the Unit 2 collections exceed three times the Unit 1 rate, then the projection will be low.

3. The method used does not factor in the short duration, large fish collections which have occurred at Unit 2, The collection of large numbers of fish over a short period of time has occurred twice at Unit 2; during January 1971 and February 1972 (in both cases, small white perch comprised the majority of the fish collected). The occurrence of a large collection is presently impossible to predict, although it would probably occur in the winter months. The specific reasons for such an incident, as opposed to the much lower daily withdrawal of fish, are presently unknown. Since no large collections have occurred at Unit 1 during the past two winters, such an incident is not factored into the estimate. The occurrence of such an incident would have the effect of increasing the total annual collection. On the other hand, the large collections may have been associated with initial start-up of the circulators and may not be experienced in a continuous operation.

4. The method does not take into account the fact that the intake velocities at Unit 2 are slightly higher than the comparable velocities at Unit 1. Although the flow rate per main pump is the same at Units 1 and 2, the intake openings are slightly

smaller at Unit 2, thereby, giving slightly higher velocities in front of the screens. The higher velocities can be expected to increase the number of fish impinged but there is at present no basis to quantify this estimate.

5. The method assumes that Indian Point Units 1 and 2 will operate all days in a year (except for the adjustment for refueling outages). This assumption is made, because it is impossible to predict the occurrence and duration of all outages and represents the "worst" biological condition. If a prolonged outage occurred at either unit during the winter months the total annual collection would be reduced accordingly. An outage during the spring, when fish collections are at a seasonal low, would have a small effect on the annual total.

A REVIEW OF FISH IMPINGEMENT PREDICTIONS BY MR. CLARK AND THE AEC STAFF

Both Mr. Clark and the AEC Staff used Con Edison data on fish collections for projecting collections at Indian Point Units 1 and 2. Therefore, all the limitations of the data described previously in this paper also apply to the projection methods of Mr. Clark and the Staff and severely limit the validity of these estimates. The difference between the numerical estimate presented in this paper (Table 8) and the estimates of impingement of Mr. Clark and the Staff are the result of the way in which the available data was used.

Estimate of Mr. Clark

The primary difference between the estimate presented here and the estimate of Mr. Clark is the use by Mr. Clark of the data collected at Unit 1 from April 1966 to March 1967 and an attempt to include the fragmentary data from Unit 2. As stated previously, the data from March of 1965 to March of 1970 is not suitable for estimation purposes because the operating conditions that existed at that time no longer exist at Unit 1 and will not be used in the future at Unit 1 or Unit 2.

The usefulness of the available data for making estimates of future collections can be judged, in part, by how good an estimate the available data would have provided for the most recent experience.

For example, if the data from the period April 1966 to March 1967 is used to project the total fish collected in 1972 at Unit 1 using Mr. Clark's method (Table 9) it can be seen that the 1966/67 data over-estimates the actual number collected by almost 6 times. If the data from 1971 is used to project a total for 1972 at Unit 1 the estimate is slightly more than 2 times the actual total. Therefore, it is not reasonable to use the 1966/67 data for projecting future collections as Mr. Clark has done, particularly since the plant will not return to the operating conditions that existed during 1966/67. A better method of estimating would be to combine the 1971 and 1972 data and project future collections from them.

Mr. Clark uses the data collected at Unit 2 to estimate that collections at Unit 2 will exceed the Unit 1 collections by four times rather than three times as used in this paper's estimate. The collections made at Unit 2 are of short duration and they show that at times Unit 2 exceeds the Unit 1 collections by more than a factor of three and at other times by less than a factor of three. The Unit 2 data is also limited in that it was not always collected under operating conditions comparable to Unit 1. Nor was it always collected under the operating condition that will be followed at Unit 2. Much more data from Unit 2 is needed before the relationship between Unit 1 and Unit 2 collections, made under similar operating conditions, can be established.

Mr. Clark assumes that 5.0% of the fish collected at Units 1 and 2 will be striped bass. From April 1970 to February 1972, 252,709 fish were collected at Unit 1 and identified to species with striped bass making up 3.1% of the total collected (3.1% is the mean of the percentage of striped bass from each of the four intake bays at Unit 1).

The result of the method used by Mr. Clark to predict fish impingement at Units 1 and 2 combined is that the total number collected and total number of striped bass collected is grossly overestimated.

Estimate of AEC Staff

The AEC Staff estimates that 2 to 5 million fish 1 to 2 inches in length will be impinged on the intake screens at Unit 2. The Staff's Final Environmental Statement provides the method used for deriving the figure of 5 million, but it does not clearly state a methodology for the 2 million figure which is the low side of its estimate.

Table 9. Comparison of estimates of fish collection at Unit 1 for 1972

Month	Mean No. of Fish/Day for 1966 to 1967	Projected Monthly Totals from 1966 to 1967 Data	Mean No. of Fish/ Day for 1971	Projected Monthly Totals From 1971 Data	Actual Monthly Totals for 1972
Jan.	7200	223200	453	14043	19689
Feb.	4300	120400	4853	135844	35865
March	4400	136400	333	10323	27015
April	500	15000	497	14910	6747
May	700	21700	181	5611	933
June	600	18000	141	4230	1990
July	1600	49600	51	1581	694
August	1000	31000	814	25234	16559
Sept.	900	27000	1217	36510	33249
Oct.	1300	40300	2190[2]	67890	24716
Nov.	1400	42000	930	27900	6306
Dec.	4600	142600	1127	34937	3299
Total		867200		379053	177062
Annual Adjusted Total		1300800[1]		473816[3]	221328[4]

1. Total adjusted 25% for missed sampling and 25% for undersampling

2. Mean at full flow used because Unit 1 operated at full flow in October 1972 for test purposes

3. Total adjusted 25% for undersampling; representative sample days selected to avoid missed sampling periods

4. Total adjusted 25% for undersampling

We are advised by the Staff that their estimate of 5 million is based on an estimate of impingement at Unit 2 prepared by Con Edison and presented in "Testimony of Applicant in Support of Its Motion for Issuance of a License Authorizing Limited Operation" submitted to the AEC on October 19, 1971. At that time an estimated impingement of 437 lb/day was made for Unit 2 operating six main pumps at 105,000 gpm per pump during the winter months. This estimate was based on only 7 days of data and was under conditions of higher flow rates and velocities than will now be in use at Unit 2, because pump by-passes have been installed to reduce winter flows from 105,000 gpm to 84,000 gpm per screen.

The Staff states that "present evidence indicates that a reduction in the water velocity may greatly reduce the fish kill problem." The by-passes at Unit 2 will permit a 40% reduction in flow rate and thereby a significant reduction in intake velocity. Each main pump will withdraw 84,000 gpm with an intake approach velocity of 0.5 ft/sec. A substantial reduction in fish impingement is expected at the lower velocities.

The Staff states that 4% of the fish collected will be striped bass. As stated previously the percentage of striped bass in collections from April 1970 to February 1972 is 3.1%.

ECOLOGICAL IMPACT OF FISH IMPINGEMENT

The ecological impact of fish impingement at Indian Point has not been clearly established. The AEC Staff recognized the difficulty in forecasting the impact on river populations in their Final Environmental Statement on page V-32 when they stated, "From the experience of Unit No. 1, the staff cannot reasonably estimate the percentage reduction of fish populations which will occur as a result of impingement at Unit 2, because the proportions of the various populations which will be present and susceptible to the intake are unknown."

Up to the present time, it was assumed that the intakes function as predators on the fish populations of the river. To date, we have been unable to establish the percentage of the total fish collected which are dead prior to impingement and the percentage which are alive when impinged. Recent studies have been made of the occurrence of a gill parasite on fishes and the length to weight relationship of white perch and striped bass.

The studies show that the impinged fish carry a statistically significant higher gill parasite load then "normal" river fish (Table 10). Impinged white perch and striped bass were found to have a statistically significant lower condition factor (length to weight relationship) than normal river fish of the same species (Figures 3 and 4). This means that the impinged fish are thinner than the river fish. Impinged white perch weigh, on the average, 22.6% less than river fish of the same length and striped bass weigh, on the average, 27.3% less than river fish of the same length.

Table 10. A comparison of the gill parasite load of fish caught in the Indian Point region of the Hudson River and impinged at the intake screens of Consolidated Edison's nuclear power plant at Indian Point.

INDIAN POINT AREA 10/2-10/19	
327 Adult White Perch Col.	62 Bluefish Col.
1 with Isopod	45 with Isopod
0.3% SE = 0.017	72.6% SE = 0.73
OSSINING 10/1-10/18	
573 Adult White Perch Col.	31 Bluefish Col.
3 with Isopod	15 with Isopod
0.5% SE = 0.013	48.4% SE = 1.64
INTAKE UNIT I 9/25-10/18	
533 Adult White Perch Col.	Bluefish not quantitatively monitored for this character during this period.
31 with Isopod	
5.8% SE = 0.04	

This data suggests that the intake may function as a scavenger on fish populations or as a selective predator on weaker individuals in the populations. It is probable that the intake functions as both predator (at times selective) and scavenger and that further study is needed to determine the "ecological" role of the intake. If the intake is functioning primarily as a scavenger or selective predator on weaker individuals in the population, the ecological impact of impingement should be assessed in light of this situation. Since the weaker individuals may have a lower probability of survival than healthy individuals, the weaker individuals may contribute less to the reproductive potential of the population.

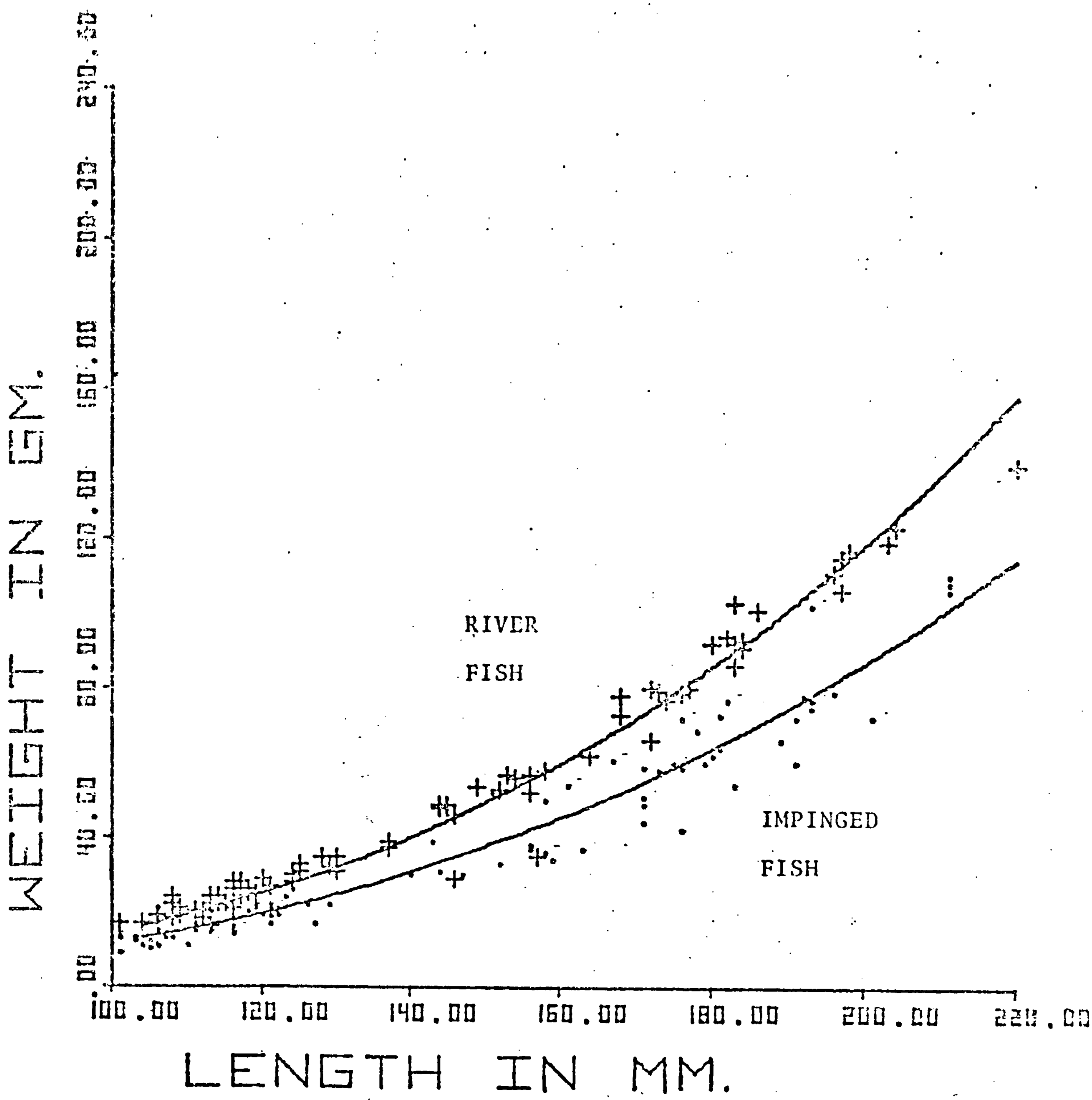


Figure 3. Length to weight relationship for white perch captured by conventional techniques in the Indian Point region of the Hudson River and impinged at the intake screens of Consolidated Edison's nuclear power plant at Indian Point for October 1972.

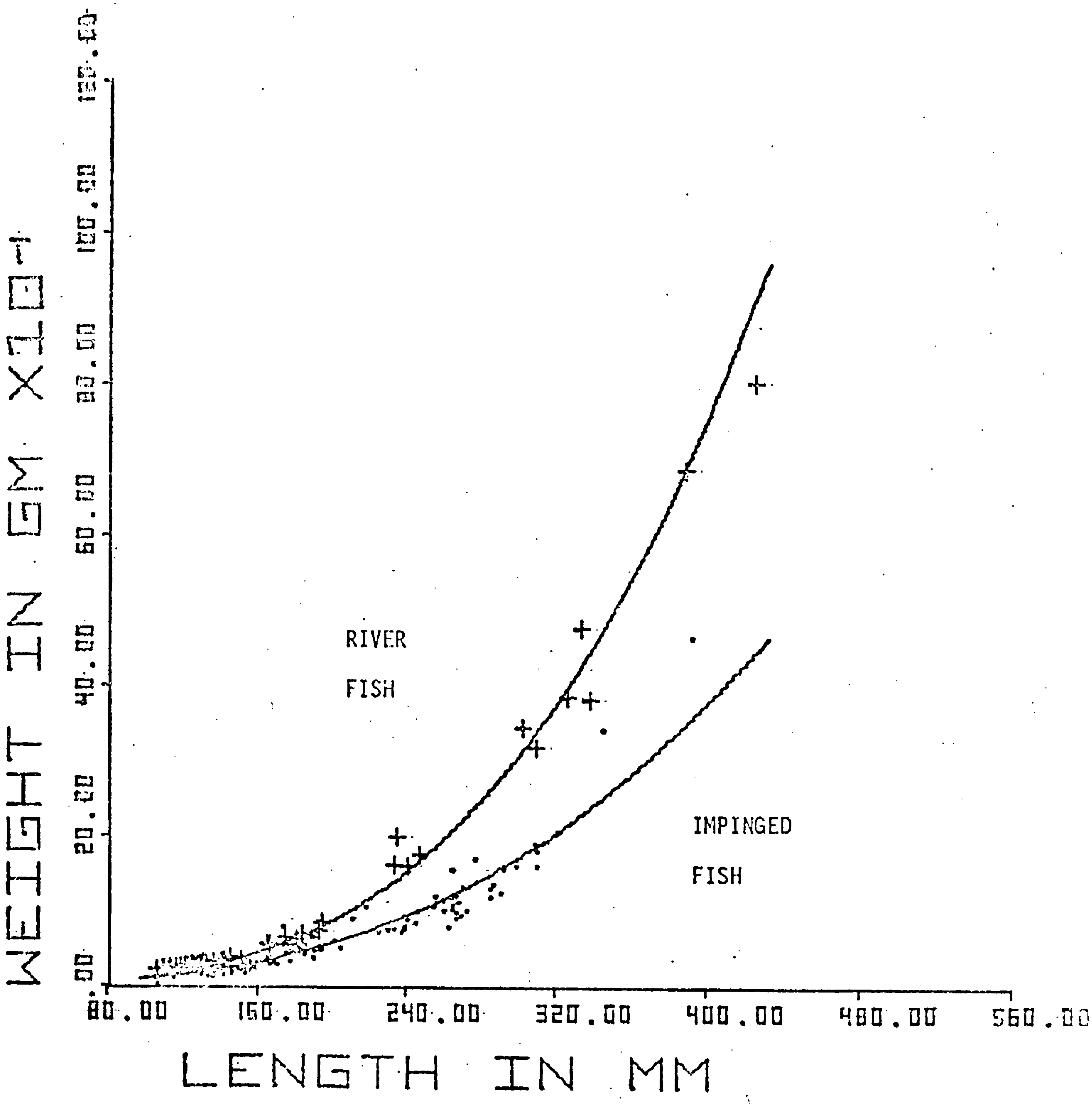


Figure 4. Length to Weight relationship for striped bass captured by conventional techniques in the Indian Point region of the Hudson River and impinged at the intake screens of Consolidated Edison's nuclear power plant at Indian Point for October 1972.

ATTACHMENT 1

CHRONOLOGY OF INDIAN POINT FISH SITUATION - 1970

January 28th	-	Decision made to operate with fine mesh screens in place at all times.
January 28th to February 23rd	-	All four screens cleaned daily by jetting in place with respective circulators shut down one at a time. Average number of fish netted from in front of screens - 3,000 to 5,000 total.
February 23rd	-	Differential across fine mesh screens gradually climbed over past month to point where jet in place no longer effective. Differential about 28". All four screens lifted and cleaned with circulators shut down one at a time. Total of about two barrels of fish netted as a result of accumulation on screens over past month.
February 24th through 26th	-	Outer screens lifted and cleaned on 24th, 25th and 26th with back-up screens in place but not fully bottomed and with circulators shut down one at a time. Average number of fish netted as a result of this method of screen cleaning continued in neighborhood of 3,000 to 5,000 per day. No significant increase in number of fish picked up on revolving screens as a result of back-up screens not being fully bottomed.
February 27th	-	Screens Not Cleaned
February 28th	-	Screens cleaned with plant out of service. Approximately 3,000 fish collected. Back-up screens bottomed this date.
March 1st	-	Plant returned to service but screens not washed.
March 2nd	-	No differential requiring screen washing.

March 3rd	-	Raised and cleaned Nos. 12 and 13 outer screens due to 14" differential across those screens with circulators in service. Netted about 6,000 fish from in front of Nos. 12 and 13 screens. Raised back-up screens due to observed differential and sluiced about 18,000 fish from revolving screens.
March 4th	-	With circulators removed from service one at a time, raised all four outer screens and netted about 15,000 fish.
March 5th	-	4 to 12 Watch - Differential across outer screens about 2 feet. With circulators out of service one at a time, cleaned outer screens by raising and netted two drums totalling over 30,000 fish. Almost immediately after returning screens to position 18" differential appeared.
March 6th	-	Early on 8 to 4 Watch - started to lift No. 11 outer screen and with screen lifted, only 4 to 5 feet, approximately 10,000 fish tumbled into the water from the screen. Netting of fish proceeded as screens were gradually lifted so as to not transfer the burden directly to back-up screens. For the rest of the day, continued cleaning screens in this manner.
March 7th	-	Continued screen cleaning operation as commenced on the 6th. Unit removed from service late afternoon because of fish problem. Total quantity of fish netted as a result of screen cleaning on the 6th and 7th approximately eight barrels, or 120,000 fish.
March 8th	-	Netted fish from discharge canal and under dock accumulated a little over one barrel. Placed both circulators in service with unit off line at 9:00 P. M. with outer screens down and back-up screens up. Operated in this mode until 7:00 P. M. on the 9th reaching maximum differential of about 3".

March 9th - At about 7:00 P.M., raised outer screens of 11, 12 and 13 bays with back-up screens in place and netted 500 - 600 fish. With back-up screens down and outer screens up, placed air bubbler system in service.

March 10th - Continued as commenced on the 9th until about 7:00 P.M. and observed maximum differential of 8" on back-up screens. Dropped outer screens and raised inner screens. Flushed approximately 2,500, 1,000 and 500 fish into revolving screens during 8:00 PM, midnight and 4:00 AM on the 11th washings.

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of	)	
	)	
Consolidated Edison Company of New York, Inc.	)	Docket No. 50-247
	)	
(Indian Point Station, Unit No. 2)	)	

Testimony of
Edward C. Raney, Ph.D.
Ichthyological Associates
Ithaca, New York 14850

on

Striped Bass

February 5, 1973

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INTRODUCTION

The most comprehensive study of the distribution of spawning grounds of the striped bass in the Hudson River was done in 1954 and 1955 by Rathjen and Miller (1957:43). This study was done as part of a cooperative striped bass study. It was a cooperative study between the U. S. Fish and Wildlife Service and the State of New York Conservation Department. Copies of field notes which list number and size of young striped bass taken with 1/2 inch stretched mesh seines in shoal areas during the period from June to October 1954 were deposited with me and the specimens were deposited in the Fish Collection of Cornell University.

These data on young striped bass have been restudied. The results indicate the nature of the distribution and growth of young striped bass in the Hudson River during their first summer of life and is discussed below in reference to the AEC Staff inference that passive drifting of eggs and larvae of striped bass would permit on the order of 70 percent of the surviving portion of the total annual production in the Hudson River to pass the Indian Point plant by sometime in July (TR 9138). In my opinion this contention is untenable and is refuted by the data presented in this proceeding.

The reproductive success of the striped bass is known to vary greatly from year to year in a given river. For the Hudson the 1954 year class seems to have been very successful in terms of the survival of young through their first summer. To my knowledge, and unfortunately, there has been no continued effort through the years which would have given the proper data required to evaluate the strength of various year classes in the Hudson River. Such a study combined with marking by tagging or other means of large numbers of young and yearling bass which are known to have been spawned in the Hudson, together with a comprehensive study of tag returns by season and geographical locality, will furnish solid data with regard to the contribution of the Hudson to the striped bass fishery of the Middle Atlantic area.

The studies of Raney, et al (1954) and Clark (1968) have confirmed that the Hudson race of striped bass (described by Raney and deSylva, 1953) contributes importantly to the fishery of the western quarter of Long Island Sound, the New York Bay area and the Hudson River. To a lesser extent it contributes to the fishery in waters off northern New Jersey and southwestern Long Island.

Developmental Stages of the Striped Bass

The egg is pelagic, buoyant and slightly heavier than freshwater. It is spherical, transparent, non-adhesive and relatively large when compared to that of other estuarine and anadromous fishes. When unfertilized they are approximately 1.3 mm in diameter and are approximately 3.4 mm when they are fertilized and fully water hardened. The granular yolk-sac is green in live eggs.

The eggs hatch into prolarvae in 36 to 48 hours in an average water temperature of about 63°F. It ranges from 2.9 to 3.7 mm in total length.

When it is about 5 to 6 mm long the yolksac and oil globular are partly or wholly assimilated and at this stage they are known as postlarvae.

The postlarvae transform to the young stage (called juveniles by some workers) at a length of between 7-10 mm.

When the postlarvae have reached a length of between 10-20 mm, they have completed their metamorphosis and at a length of 20-30 mm they are scaled and have almost a full complement of fin rays. For details see Mansueti (1958).

An examination of the data in Table 1 shows that at a length of 18 mm the young have reached a stage where they are NOT drifting passively with the current but have moved toward shore and are found near the bottom where they can be seined with 1/4 inch mesh nets.

The data in Table 1 are those compiled from the original data of Rathjen and Miller arranged in length frequency distributions by locality. Those listed first are from the up-river station at Coxsackie. All fish listed are young (often referred to as young-of-year).

The data in Table 1 indicate the general growth pattern during the summer of 1954.

The data in Table 1 show that young bass were present at each of the stations sampled along the Hudson River. Those striped bass which are spawned upriver enter nearby nursery grounds in the Hudson. These young are not in a geographic position which would have made them susceptible to entrainment at Indian Point.

In Table I a vertical line has been drawn between lengths of 38 and 39 mm which approximates 1 1/2 inch in fork length (length measured from tip of snout to fork of tail).

Table I Length Frequency Distribution and Percentage of Screenable Striped Bass Caught in the Hudson River in 1954 by Rathjen and Miller. (Arranged North to South.) Fork length measured in millimeters. Screenable size is over 1.5 inches (38mm).

LENGTH IN MM

LOCATION	DATE	COLL. #	15-17	18-20	21-23	24-26	27-29	30-32	33-35	36-38	39-41	42-44	45-47	48-50	51-53	54-56	57-59	60-62	63-65	66-68	69-71	72-74	75-77	78-80	81-83	84-86	87-89	90-92	93-95	96-98	99-101	102-104	105-107	108-110	TOTAL	MEAN	% OVER 1.5"
Coxsackie	7/20/54	106						1																											1	29	0%
Coxsackie	7/29/54	116									1	1		1																					3	43.7	100%
Coxsackie	8/4/54											2	1	1																					4	45.5	100%
Coxsackie	8/5/54	131											1	1		1																			3	49.3	100%
Coxsackie	8/18/54	150										1		7	4	8	7	5	5	6	1	1	1												46	58.5	100%
Coxsackie	8/24/54	153										1			1	2	1			1															6	54.7	100%
Coxsackie	8/30/54	161														3	1																		4	56.5	100%
Coxsackie	9/15/54	170															3	1		2	1	1			1										9	66.2	100%
Coxsackie	9/29/54	180																1	1	3					1										6	68	100%
Coxsackie	10/14/54	189&190															1	1	1	3	2		2		2						1	1	1		15	76.5	100%
Middleground Is.	7/27/54	117&118					1			3	2	8	3																						21	42.4	61.8%
Alsen	7/20/54	107			1		2	5	6	3	1	3																							21	34.0	19.0%
Alsen	7/26/54	115							3	2	1			3	1																				10	41.2	50%
Alsen	8/5/54	132										1																							1	42.0	100%
Alsen	8/31/54	162										1				2	2	6	7	1	3	2	2				1								27	64.9	100%
Mills St. Pk.	7/19/54	103				1		1	1	2		2	2	2																					11	39.7	54.7%
Mills St. Pk.	7/28/54	121								1	1	1	2	2																					7	44.6	85.7%
Mills St. Pk.	8/4/54	129									2	2	5	11	6	2	1																		29	48.7	100%
Mills St. Pk.	8/18/54	149												2	5	1	5	7																	20	56.6	100%
Mills St. Pk.	8/30/54	160															2	4	1			1													8	62.4	100%
Mills St. Pk.	9/29/54	178																	1																1		100%
Newburgh	7/20/54	108							1	4	2	5	2	4	4	1																			23	44.6	78.2%
Newburgh	7/26/54	114					1	1		1	2	1	2	2																					10	41.4	70%
Newburgh	8/5/54	133								1		1	4	4	6	3	6	6	4																35	54.5	97.1%
Newburgh	8/31/54	163												2	1	4	1	3	3	4	1	4		1	2	2									28	66.0	100%
Newburgh	9/13/54	169																	3		2	1	1		1										8	70.8	100%
Newburgh	9/30/54	183																				2		1											3	74.7	100%
Denning	7/19/54	102								2	2	2	4	4	1				1																16	46.1	87.5%
Denning	7/28/54	122									1		3	5	3	7	4	1																	24	50.2	100%
Denning	8/4/54	128									1				2	2	4	1	1	1	1		1												14	58.2	100%
Denning	8/17/54	148												1				1	1																3	57.7	100%
Denning	8/30/54	159												1			1	2	2		4	1			1			1							13	68.0	100%
Denning	9/29/54	177														1	3	4	2		1		1	2	2	2	2	3	3	2	3	1			32	80.4	100%
Roa Hook	7/19/54	101							2	1	1		1																						5	36.3	40%
Roa Hook	7/26/54	113												1		1																			2	51.0	100%
Greens Cove	7/14/54	94				4	3	21	14	11	8	3	1	1																					66	34.2	19.6%
Greens Cove	7/21/54	112						1	7	4	1		3	1	1																				18	39.1	33.3%
Greens Cove	7/29/54	127								1		5	4	6	1	4	2	1	1																25	49.6	96%
Greens Cove	8/6/54	136								1	1	1	1	3	2	2																			11	48.2	90.9%
Greens Cove	8/16/54	147												1		3	6	4	4	3	2	1		1	1		1								27	63.4	100%
Greens Cove	8/27/54	156																		1															1	67	100%
Stoney Pt.	7/15/54	100			1	4	4	3	3	7	1																								23	30.2	4.3%
Grassy Pt.	8/13/54	144																	1																1	64	100%
Haverstraw	7/29/54	126									6	14	15	18	12	6	4	2	1																78	48.5	100%
Haverstraw	8/6/54	135												1	1	5	6	4	2	2		1													22	58.9	100%

Table I Continued

Length Frequency Distribution and Percentage of Screenable Striped Bass Caught in the Hudson River in 1954 by Rathjen and Miller. (Arranged North to South.) Fork length measured in millimeters. Screenable size is over 1.5 inches (38mm).

LOCATION	DATE	COLL. #	15-17	18-20	21-23	24-26	27-29	30-32	33-35	36-38	39-41	42-44	45-47	48-50	51-53	54-56	57-59	60-62	63-65	66-68	69-71	72-74	75-77	78-80	81-83	84-86	87-89	90-92	93-95	96-98	99-101	102-104	105-107	108-110	TOTAL	MEAN	% OVER 1.5"
Haverstraw	8/13/54	143													1		1		1	1	1	1													6	64.2	100%
Haverstraw	8/19/54	151												1			1		2	1		2			1										9	64.6	100%
Haverstraw	9/10/54	165																					1												1	77	100%
Haverstraw	9/21/54	175														1			2	2	3	5	7		1			2							23	73.5	100%
Haverstraw	9/30/54	184															1	1	1	4	5	5	8	2	3	4									34	74.0	100%
Haverstraw	10/20/54	192															1	1	1	1	4	3	2	3	5	2	1	2	1		2				30	77.9	100%
Harmon	6/28/54	76&77	1		1	2	6	1																											12	26.3	0%
Harmon	7/6/54	82&83		7	19	43	23	14	7	8	1	4																							126	27.6	3.9%
Harmon	7/14/54	92&93				1		2	4	2	8	4	10	1	2																				34	41.2	73.5%
Harmon	7/21/54	111						2	5	16	13	17	5	1																					59	40.0	61.0%
Harmon	7/28/54	123							1		2	4	2	3	1																				13	44.4	92.3%
Harmon	8/6/54	137													1	2	2			1															6	58.0	100%
Harmon	8/16/54	146														2		4	3			1		1											12	63.3	100%
Harmon	8/27/54	155											1	2			2	2	3	1	3	2	2	1			1								20	65.6	100%
Harmon	9/10/54	164															1		1	1	1	1	1	2	1										9	72.1	100%
Harmon	9/21/54	174														1			1	2	1	5	4	5	5	4									28	76.2	100%
Croton	7/21/54	110						1	1	3	4	8	3		2																				22	42.2	77.7%
Croton	8/16/54	145																				1													1	72	100%
Croton	10/8/54	187																		1				1	3	1	2	14	4	1					27	89.3	100%
Croton	10/20/54	191																	2			1	1		1	7	11	17	6	2	1			1	50	88.7	100%
Nyack	7/15/54	97			1	1	4	9	12	14	6	6	4																						57	35.8	28.0%
Nyack	7/29/54	125													1																				1	53	100%
Nyack	8/19/54	152														1	8	7	5	5	3	2													31	63.4	100%
Nyack	8/27/54																1		1	3				1			1								7	69.7	100%
Piermont	7/15/54	95&96				2		1	1	3	2																								9	33.8	22.2%
Piermont	7/20/54	109										1		2																					3	47	100%
Piermont	7/29/54	124										3	3	7	3	2	2	2																	22	51.7	100%
Piermont	8/13/54	142															1	3	2	1	1	1	1												10	65.3	100%
Piermont	8/27/54	158																1	1		1		1	3		1									8	74.1	100%
Palisades St.Pk.	9/10/54	168																2	2	2	2	4		1		1									14	70.1	100%
Palisades St.Pk.	9/21/54	176									1							1		2	3	3		3	4	2				1					20	74.5	100%
Palisades St.Pk.	9/30/54	185												1		1	2		1	1	2	1	5	4	5	5	4	5	1	1	4		1		44	79.1	100%
Palisades St.Pk.	10/20/54	193															2	1	1		2	1	3	1	1	3	3	1			1				20	77.2	100%

4

It is at a length of 1 1/2 inch or more (fork length) that young striped bass are not vulnerable to entrainment in cooling waters protected by a 3/8-inch mesh screen which is the size used at Indian Point.

Contribution of the Delaware

I.A. personnel have determined for certain areas in the upper Chesapeake Bay and for the Delaware River near the Chesapeake and Delaware Canal that there was virtually no production of young striped bass in 1972. This presumably was caused by the tremendous amount of silt which was carried during and after hurricane Agnes in June. In 1970 in these same areas there was a very large year class of striped bass. This was determined by our studies at Augustine Beach near river mile 55 in Delaware Bay. See William H. Bason, "Ecology and Early Life History of the Striped Bass, Morone saxatilis, in the Delaware Estuary", Ichthyological Associates Bulletin No. 4, October 1971.

Studies on the Racial Status of Populations of Striped Bass Found on the Atlantic Coast

Such studies need samples of young (young-of-year) striped bass taken in the river of their birth. A sample of 25 specimens collected from a locality at one time is adequate.

These samples are not to be confused with those which are required in a marking and recovery program which is designed to determine the size of a population of striped bass in a river or a section thereof.

A knowledge of the origin of the stock or stocks exploited in a fisheries is basic to sound management. As used here the term "race" implies a lower level of differentiation than that of a subspecies.

The major reports concerning racial structure and migration are as follows: Merriman (1937 and 1941), Vladykov and Wallace (1938 and 1952), Tiller (1950), Raney and deSylva (1953), and Raney, Woolcott and Mehring (1954), Raney and Woolcott (1955), Raney (1957), Lewis (1957), Lund (1957), Murawski (1958) and deSylva (1961).

The studies are on samples of young striped bass; the assumption is that young have not yet made extensive migrations. Fin ray, scale and gill raker counts, proportional measurements and serology have been investigated.

The problem can be stated as follows: Are all Atlantic Coast striped bass a freely intermingling group drawing their characters from a single large gene pool? The answer is negative. The main Atlantic Coast migratory stock is derived from the several rivers tributary to Chesapeake Bay. The Chesapeake race consists of several subraces, some of which may migrate little or not at all. Some Chesapeake bass, two years and older, undertake a non-spawning coastal migration northward in the spring. In the fall they return to Chesapeake Bay by approximately the same route although some migrants may enter and winter over in northern coastal rivers. These migrating stocks are largely responsible for the coastal striped bass fishery from Virginia and Maryland northward to Massachusetts and Maine.

Stocks in Nova Scotia, New Brunswick and the St. Lawrence River seem to be semi-endemic but were obviously drawn from post Pleistocene northward migrants of the Chesapeake race.

Small and as yet inadequate samples from the Delaware River (deSylva, 1961) and the coastal rivers of New Jersey are closely related to the Chesapeake race.

The Hudson River race differs from the Chesapeake race at a level of 70 to 80% based on a character index combining dorsal, anal, and total pectoral soft ray counts. The dorsal soft ray count is modally 11 in the Hudson race and is 12 in all other stocks investigated to date. The Hudson race migrates to the western quarter of Long Island Sound and the region near the mouth of the Hudson River, including the northeastern New Jersey shore and the south shore of Long Island east to Jones Beach where it is an important local fishery (Raney, et al, 1954).

South of Chesapeake Bay striped bass stocks seem not to make extensive coastal migrations. However, some concentrations of large striped bass have been taken off North Carolina in midwinter.

The Albemarle Sound (including the Roanoke River) population is similar to the Chesapeake race in fin ray and scale counts but the rather compact distribution pattern seems to indicate an endemic group. Previous scanty returns from tagging imply a similar conclusion.

MIGRATIONS OF STRIPED BASS, *Morone saxatilis* (WALBAUM), TAGGED ALONG THE ATLANTIC COAST FROM 1971-1972

by

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INTRODUCTION

The American Littoral Society has been conducting a tagging program on Atlantic Coast striped bass since 1967 and lists of the recaptured fish have been published in Underwater Naturalist (Vol. 4, No. 2; Vol. 5, No. 2; Vol. 6, No. 2; and Vol. 7, No. 3). An analysis of these returns was reported by Edward C. Raney in his testimony of October 30, 1972, pp. 69-88.

The following is an analysis of the most recent tagging reports published in Underwater Naturalist (Vol. 7, No. 4). Generally, the results are in accord with the previous report.

SPATIAL DISTRIBUTION (Tables 2, 3, 4 and Figures 1-6)

1. The 1 striped bass tagged off Ocean, New Jersey in the fall was recaptured at a point further south (off Cumberland County, New Jersey in Delaware Bay) the following spring.

2. Of the 3 striped bass tagged off Monmouth, New Jersey, the 1 tagged in August, was recaptured off Monmouth, in late spring. The other 2 striped bass were recaptured at more southerly locations, Delaware Bay and Worchester, Maryland. These recaptures were in the late winter and early spring.

3. Of the 11 striped bass tagged off Richmond, New York, 10 (90.9%) were tagged in the spring or fall. They were recaptured as far south as Dare, North Carolina and as far north as the Tappan Zee Bridge in the Hudson River. Seven (63.6%) of the recaptures were at points farther south than Richmond, and all of these were in the winter or spring of the following year. The 4 remaining fish were also recaptured in the spring in the New York area. Generally, the fish which occur off Richmond, New York, are part of the Atlantic Coast migratory stock which migrate southward in the fall and northward in the spring. The results of these data do not indicate if these fish over-summer in the New York area or if they travel further northward. The results of the previous report are more extensive and suggest that Richmond, New York, is not an over-summering area.

4. The 1 striped bass caught off the north shore of Queens was caught in the fall of 1969 and was recaptured two years later in the summer off Essex, Massachusetts.

5. The 1 striped bass caught off South Nassau was tagged in the summer and was recaptured the following winter off York, Virginia.

6. The 1 striped bass caught off South Suffolk was tagged in the spring and was recaptured in the same area a few days later.

TABLE 2. SITES OF TAGGING AND RECAPTURE

Date Tagged	Location Tagged	Location Recovered	Date Recovered
	Ocean, New Jersey		
Oct. 71		Cumberland Co. (Del. Bay)	April 72
	Monmouth, New Jersey		
May 71		Worchester, Maryland	March 72
Aug. 71		Monmouth, New Jersey	June 72
Sept. 71		Cumberland Co. (Del. Bay)	April 72
	Richmond, New York		
April 71		Charles, Maryland	Feb. 72
April 72		Richmond, New York	June 72
April 71		Dare, North Carolina	Feb. 72
April 72		Richmond, New York	April 72
May 71		Chesapeake Bay, Virginia	May 72
July 71		Kent, Delaware	April 72
Oct. 71		Kings, New York	June 72
Nov. 71		Atlantic, New Jersey	Jan. 72
Nov. 71		Rockland, New York (Hud. R.)	April 72
Nov. 71		James City, Virginia	April 72
Dec. 71		Worchester, Maryland	March 72
	Queens, New York		
Oct. 69		Essex, Massachusetts	July 71
	South Nassau, New York		
Aug. 71		York, Virginia	Jan. 72
	North Suffolk, New York		
April 71		Atlantic, New Jersey	May 72
April 72		South Barnstable, Mass.	June 72
May 71		Fairfield, Connecticut	May 72
May 72		North Nassau, New York	June 72
July 71		Atlantic, New Jersey	April 72
Aug. 71		Sussex, Delaware	March 72
Sept. 71		Northeast Suffolk, New York	March 72
Jan. 72		North Suffolk	April 72
	South Suffolk, New York		
April 72		South Suffolk, New York	April 72
	Northeast Suffolk, N. Y.		
July 70		Northeast Suffolk, New York	June 72
Oct. 71		Northeast Suffolk, New York	May 72
Oct. 70		Southeast Suffolk, New York	May 71
Nov. 71		Northeast Suffolk, New York	June 72
Nov. 70		Dare, North Carolina	Feb. 72
Nov. 71		Worchester, Maryland	Feb. 72
	Southeast Suffolk, N.Y.		
Oct. 71		Southeast Suffolk, New York	Nov. 71
	Rockland, N.Y. (Hud. R.)		
May 71		Westchester, New York (Hud. R.)	June 72
May 72		Rockland, New York (Hud. R.)	May 72

(Continued)

TABLE 2. SITES OF TAGGING AND RECAPTURE (Cont'd.)

Date Tagged	Location Tagged	Location Recovered	Date Recovered
	Fairfield, Connecticut		
May 70		Worchester, Maryland	March 72
May 71		Fairfield, Connecticut	May 72
June 70		Fairfield, Connecticut	June 72
June 71		Virginia (Ches. Bay)	Jan. 72
June 71		Northeast Suffolk, N. Y.	June 72
July 70		Southeast Suffolk, New York	June 71
July 71		Dare, North Carolina	March 72
July 71		Worchester, Maryland	Feb. 72
Aug. 71		Talbot, Maryland	April 72
Aug. 71		Cumberland Co. (Del. Bay)	April 72
Aug. 70		Cumberland Co. (Del. Bay)	April 72
Sept. 71		Worchester, Maryland	March 72
Sept. 71		Worchester, Maryland	March 72
Sept. 71		Dare, North Carolina	Jan. 72
Oct. 71		Westchester, N. Y. (Hud. R.)	May 72
Oct. 71		Fairfield, Connecticut	May 72
Nov. 72		Fairfield, Connecticut	June 72
	New Haven, Connecticut		
July 71		New Haven, Connecticut	May 72
July 71		Dorchester, Maryland	April 72
Aug. 71		New Haven, Connecticut	May 72
Sept. 71		Dare, North Carolina	Jan. 72
	New London, Connecticut		
May 70		New London, Connecticut	June 72
	Washington, Rhode Island		
Nov. 71		Talbot, Maryland	April 72
	Newport, Rhode Island		
June 71		Ocean, New Jersey	May 72
June 70		Northumberland, Virginia	April 72
July 71		Washington, Rhode Island	Dec. 71
	North Plymouth, Mass.		
Oct. 71		Ocean, New Jersey	May 72
	South Barnstable, Mass.		
Sept. 71		Northumberland, Virginia	April 72
	Dukes, Massachusetts		
Sept. 70		Virginia (Ches. Bay)	Jan. 72
Oct. 71		Atlantic, New Jersey	May 72
Oct. 71		Westmoreland, Virginia	March 72
	Essex, Massachusetts		
May 72		Essex, Massachusetts	June 72
July 71		Worchester, Maryland	April 72
	York, Maine		
June 72		York, Maine	June 72

TABLE 3. LOCATION AND SEASON OF TAGGING

Season / Location	Winter 1	2	3	Spring 4	5	6	Summer 7	8	9	Fall 10	11	12	TOTAL
Dare, N. C.													
James City, Va.													
York, Va.													
Northumberland, Va.													
Westmoreland, Va.													
Charles, Md.													
Talbot, Md.													
Dorchester, Md.													
Worchester, Md.													
Chesapeake Bay, Va.													
Sussex, Del.													
Kent, Del.													
Cumberland (Del.Bay)													
Atlantic, N. J.													
Ocean, N. J.					1			1	1	1			4
Monmouth, N. J.													
Richmond, N. Y.				4	1		1			1	3	1	11
Kings, N. Y.													
Queens, N. Y.							1						1
N. Nassau, N. Y.													
S. Nassau, N. Y.								1					1
N. Suffolk, N. Y.	1			2	2		1	1	1				8
S. Suffolk, N. Y.				1									1
NE Suffolk, N. Y.							1			2	3		6
SE Suffolk, N. Y.									1				1
Westchester, N. Y.													
Rockland, N. Y.					2								2
Fairfield, Conn.					2	3	3	3	3	2	1		17
New Haven, Conn.							2	1	1				4
New London, Conn.					1								1
Washington, R. I.											1		1
Newport, R. I.						2	1						3
N. Plymouth, Mass.										1			1
S. Barnstable, Mass.									1				1
Dukes, Mass.					1		1						2
Essex, Mass.					1		1						2
York, Maine						1							1
TOTAL	1			7	10	6	11	7	8	10	8	1	69

TABLE 4. CAPTURE LOCATIONS

1.	Dare, North Carolina
2.	James City, Virginia
3.	York, Virginia
4.	Northumberland, Virginia
5.	Westmoreland, Virginia
6.	Charles, Maryland
7.	Talbot, Maryland
8.	Dorchester, Maryland
9.	Worchester, Maryland
10.	Chesapeake Bay, Maryland
11.	Sussex, Delaware
12.	Kent, Delaware
13.	Cumberland Co., New Jersey (Delaware Bay)
14.	Atlantic, New Jersey
15.	Ocean, New Jersey
16.	Monmouth, New Jersey
17.	Richmond, New York
18.	Kings, New York
19.	Queens, New York
20.	North Nassau, New York
21.	South Nassau, New York
22.	North Suffolk, New York
23.	South Suffolk, New York
24.	Northeast Suffolk, New York
25.	Southeast Suffolk, New York
26.	Westchester, New York
27.	Rockland, New York
28.	Fairfield, Connecticut
29.	New Haven, Connecticut
30.	New London, Connecticut
31.	Washington, Rhode Island
32.	Newport, Rhode Island
33.	North Plymouth, Massachusetts
34.	South Barnstable, Massachusetts
35.	Dukes, Massachusetts
36.	Essex, Massachusetts
37.	York, Maine

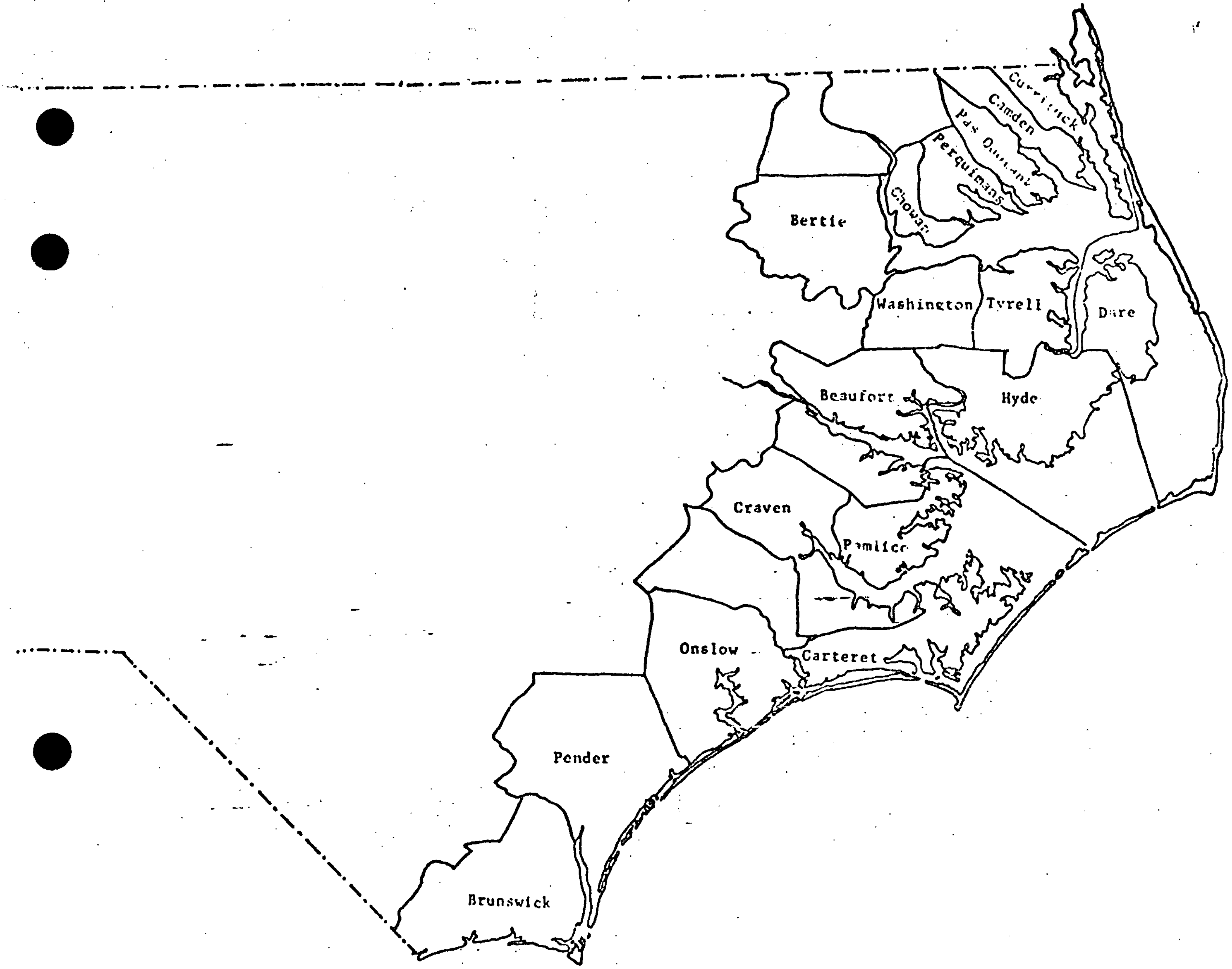

Figure 1. Coastal Counties of North Carolina.

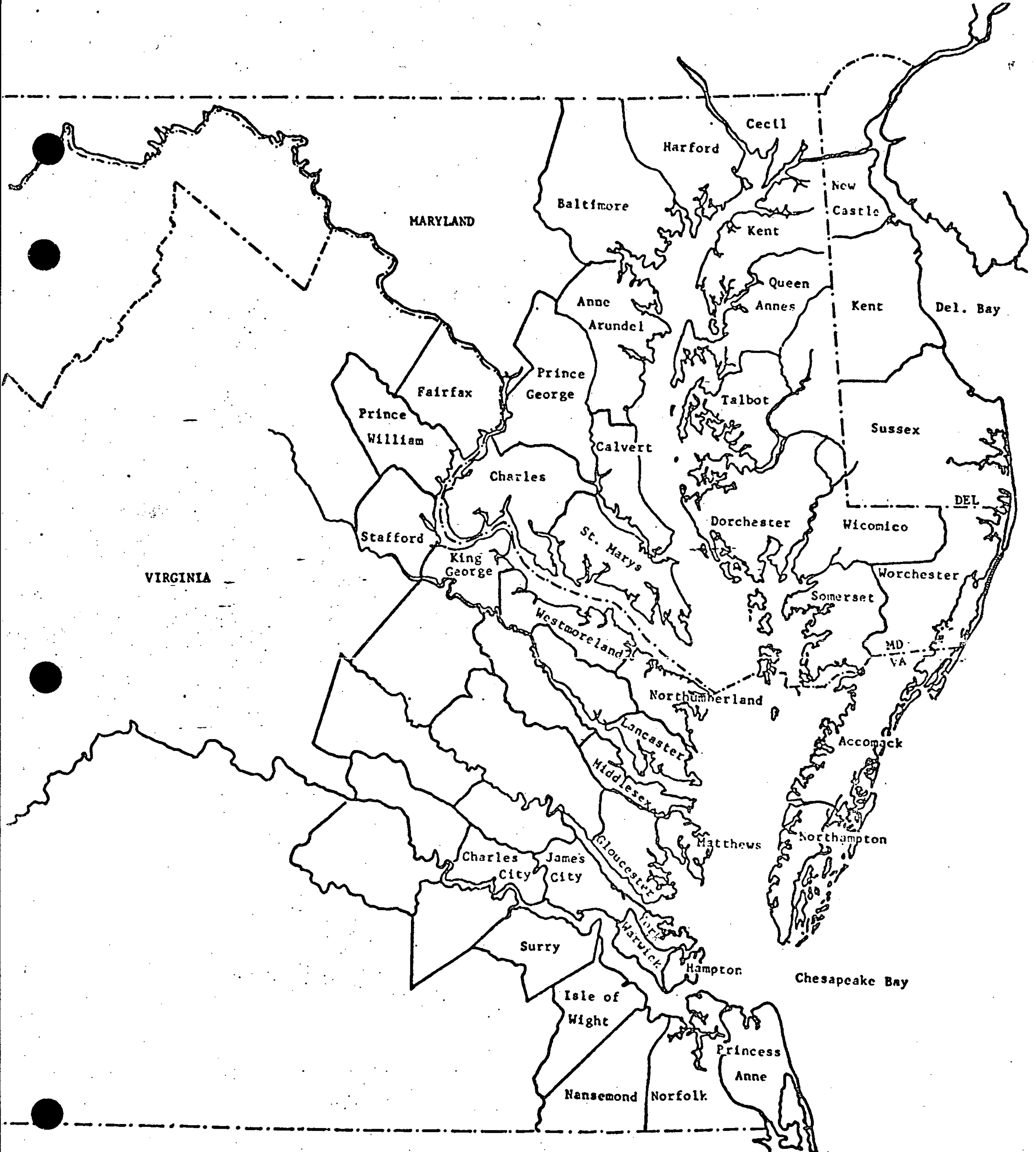

Figure 2. Coastal Counties of Virginia, Maryland and Delaware.

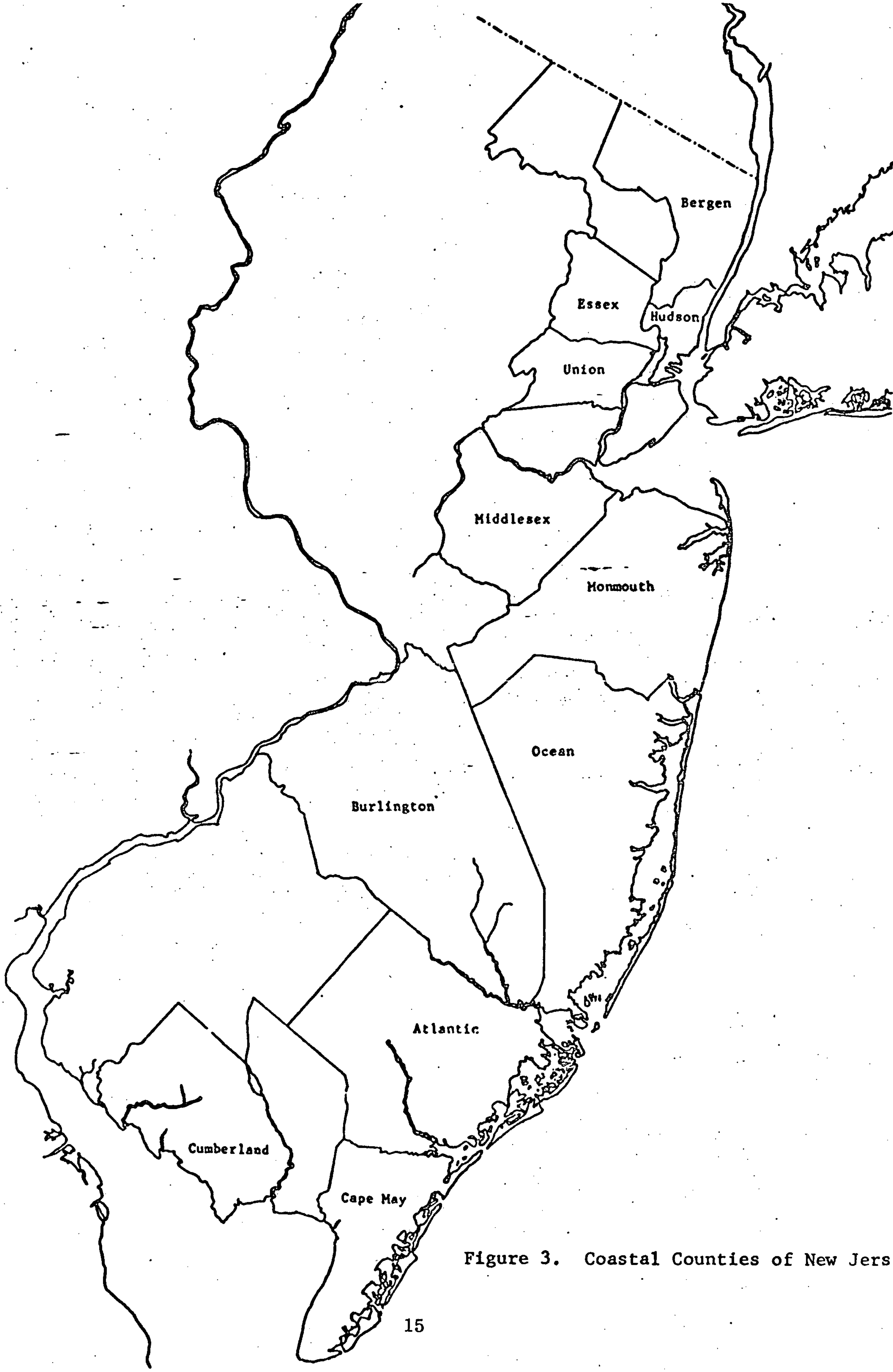

Figure 3. Coastal Counties of New Jersey.

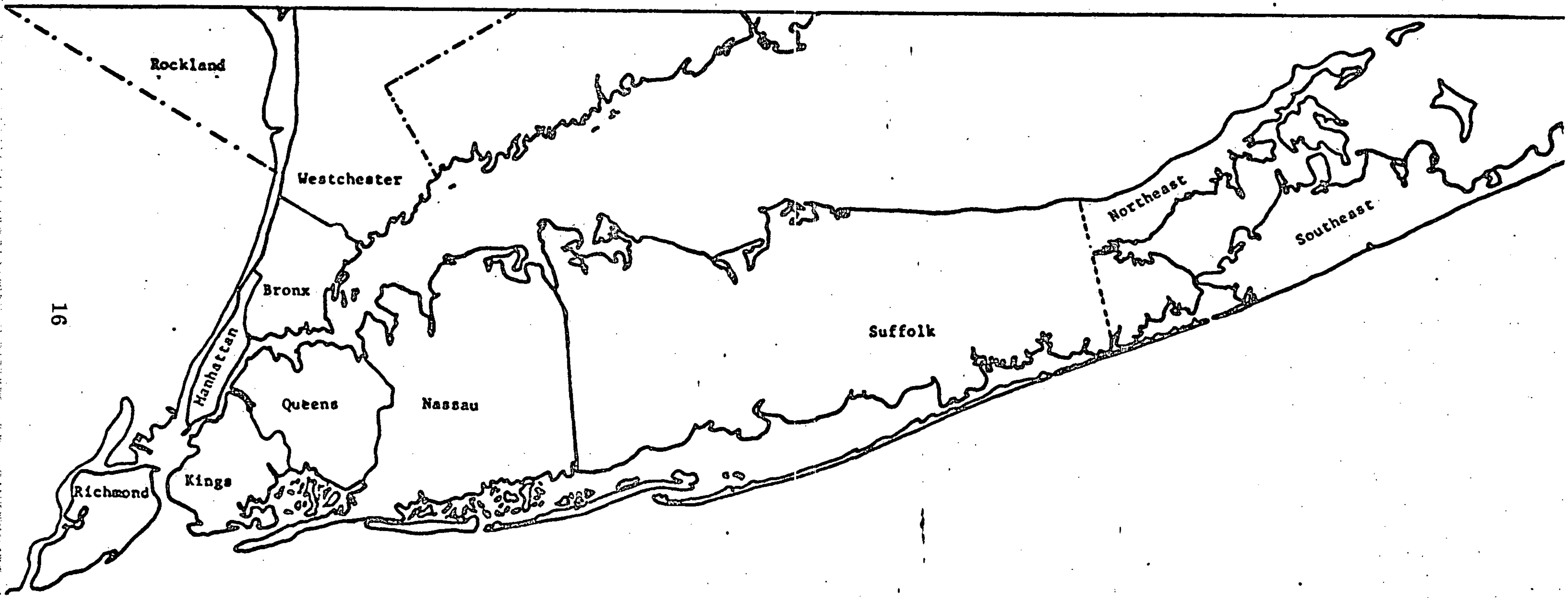

Figure 4. Coastal Counties of New York.

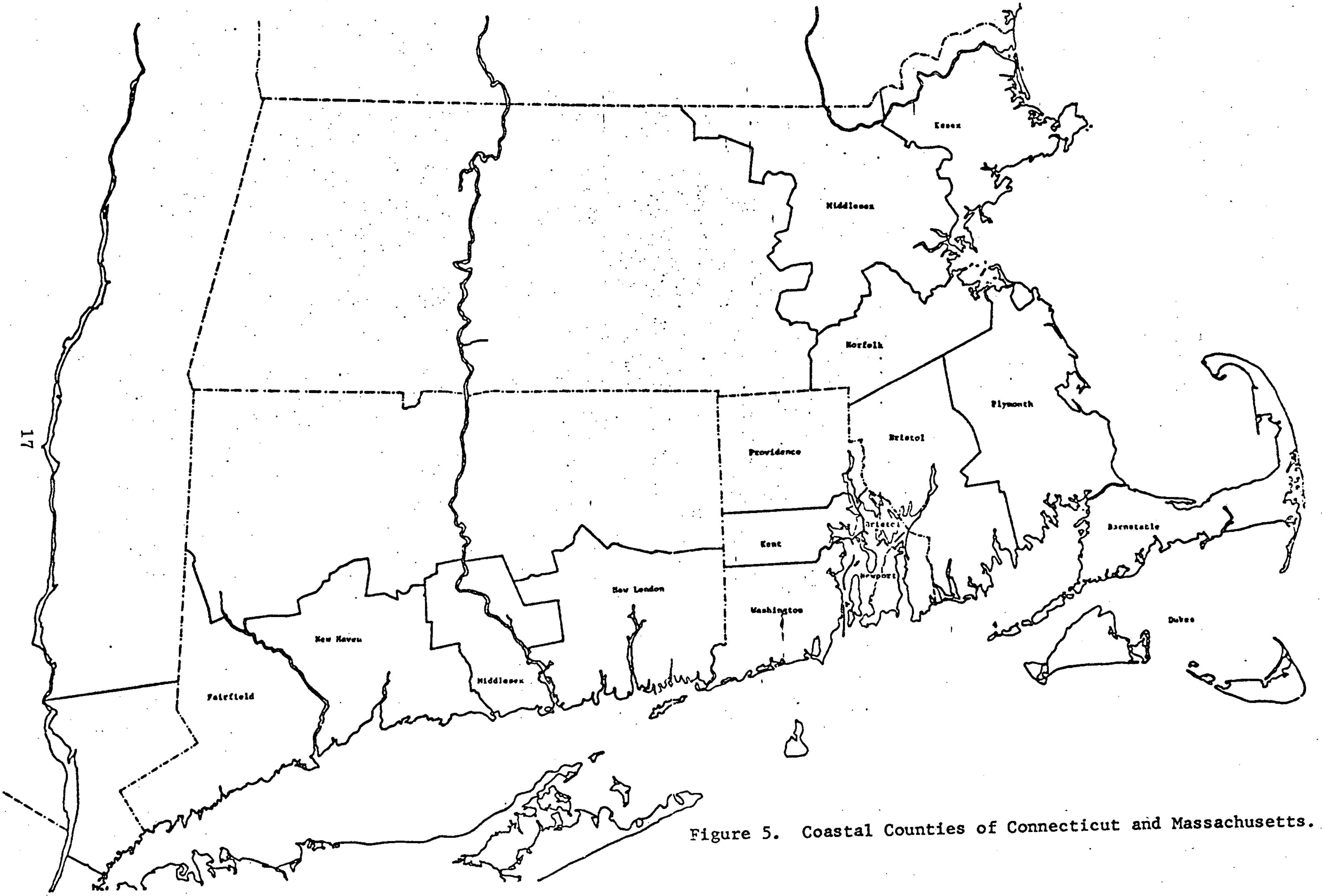

Figure 5. Coastal Counties of Connecticut and Massachusetts.

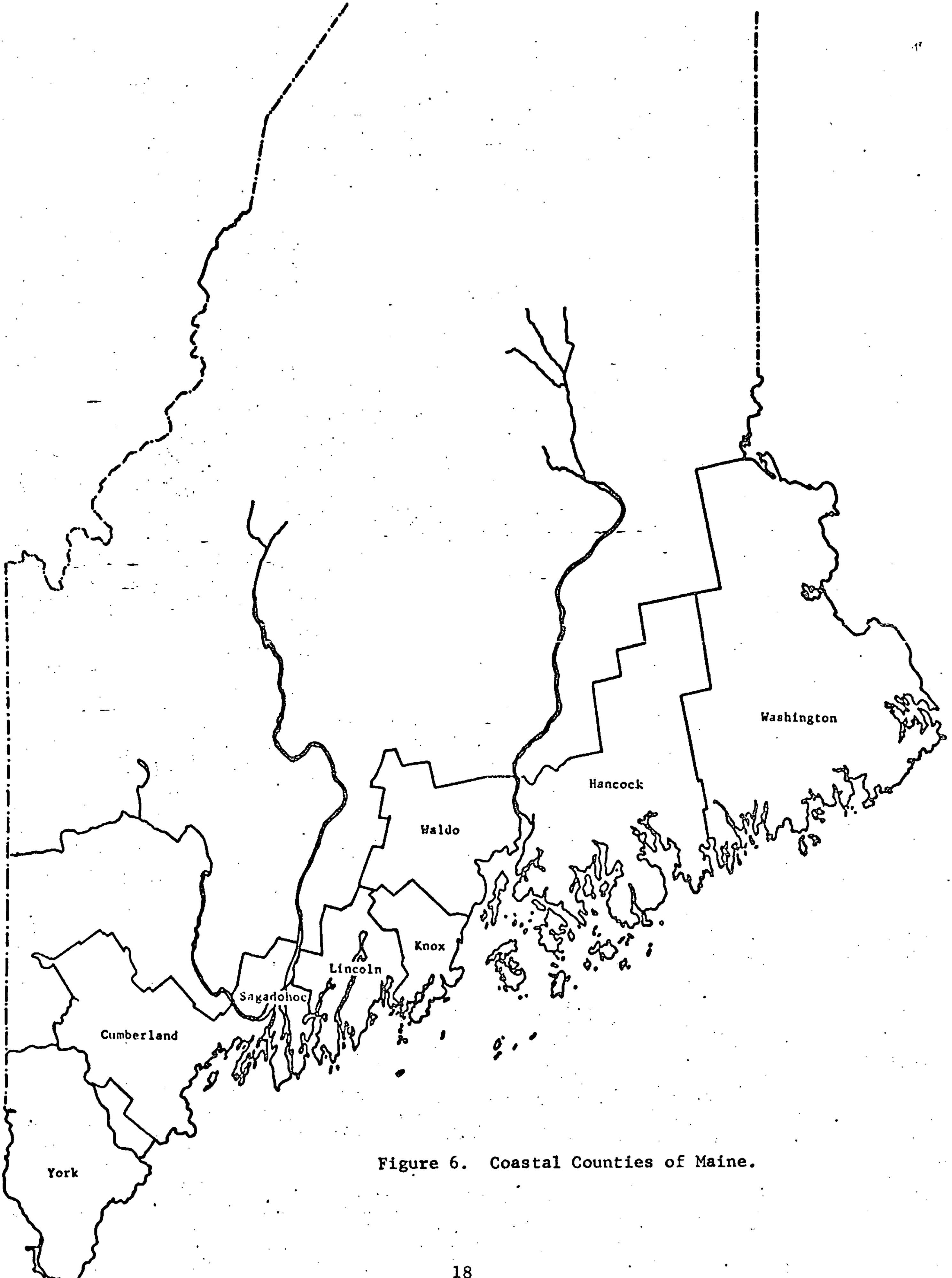

Figure 6. Coastal Counties of Maine.

7. A total of 7 striped bass were caught off the extreme eastern end of Long Island (1 off Southeast Suffolk and 6 off Northeast Suffolk). Six (35.7%) of these were tagged in the fall and only 1 was tagged in the summer. Five striped bass were recaptured off the extreme eastern end of Long Island, all of them in the spring or fall. The remaining 2 were caught at points farther south, off Maryland and North Carolina, in the winter. The striped bass caught off the tip of Long Island are part of the migratory stock which travels up and down the Coast.

8. Of the 8 striped bass caught off North Suffolk, New York, 4 were tagged in the spring, 3 in the summer and 1 in the winter. One of those tagged in the spring was caught at a point farther north that same year, (off South Barnstable, Massachusetts). Three additional fish were recaptured at a distance from the Long Island sound area in the spring; 2 were taken off Atlantic, New Jersey and one off Sussex, Delaware. Two of these migrating fish were originally tagged off North Suffolk in the summer. The bass tagged in the winter was recaptured in the same area in the spring.

It is possible that this part of Long Island Sound has a resident population, an over-summering population which migrates to this area, and a transient population which migrates to points farther north in the summer.

9. The 17 striped bass tagged in Long Island Sound, off Fairfield, Connecticut, were tagged from May to November. A total of 10 (58.8%) were recaptured at more southerly points, all south of Delaware Bay. Furthermore, 8 of the 9 striped bass tagged in the summer off Fairfield were recaptured the following winter and spring at southerly points from Dare, North Carolina to Delaware Bay. The one remaining fish tagged in the summer off Fairfield was recaptured the following spring off the southeastern tip of Suffolk County. It seems clear from these data that the western end of the Sound supports both the resident West Sound Contingent and part of the migratory Atlantic Stock. It is also evident that part of the Atlantic Stock actually over-summers in the western end of the Sound. These results are in accord with

those reported previously in Raney's testimony of Oct. 30, 1972 but the percentage of fish recaptured outside of the Sound (58.8%) is substantially higher in these returns than in those previously reported (26%).

10. The 5 striped bass tagged off New Haven and New London, Connecticut, were caught in the spring and summer. Two were recaptured at southerly points, one off Dare, North Carolina in the winter and one off Dorchester, Maryland in the spring. The remaining 3 were recaptured in the same area the following spring.

11. The 12 striped bass tagged north of Washington, Rhode Island were caught in the late spring, summer and fall. All of the fish were recaptured south of Ocean, New Jersey in the winter or early spring. Generally, these northerly sectors seem to be the over-summering location of the Atlantic Coast migratory stock which over-winters in the southern sectors.

SEASONAL DISTRIBUTION (Table 5)

1. Striped bass were found in the most southerly sectors (Dare, North Carolina to Kent, Delaware) mostly in the winter and early spring (January to April). Only 1 (3.7%) of the 27 fish caught south of Kent, Delaware was caught as late as May.

2. Striped bass occurred in New Jersey from January to October, but out of the 15 fish caught in New Jersey, only 1 (6.6%) was caught as early as January. A total of 12 (80%) was caught in the spring (April to June).

3. Of the 15 striped bass caught off Richmond, Kings and Queens, only 1 was caught in the summer. The remainder (93.3%) were caught in the spring and fall. These areas seem to be only stop-overs for migratory striped bass. There was a higher percentage (31.6%) of summer residents in the previous report (Weller, December 3, 1972).

4. The striped bass caught off Nassau and Suffolk counties, both on the north and south shores, were all caught in the spring and summer.

TABLE 5. TOTAL SEASONAL DISTRIBUTION

Season / Location	Winter 1	2	3	Spring 4	5	6	Summer 7	8	9	Fall 10	11	12	TOTAL
Dare, N. C.	2	2	1										5
James City, Va.				1									1
York, Va.	1												1
Northumberland, Va.				2									2
Westmoreland, Va.			1										1
Charles, Md.		1											1
Talbot, Md.				2									2
Dorchester, Md.				1									1
Worchester, Md.		2	5	1									8
Chesapeake Bay, Va.	2				1								3
Sussex, Del.			1										1
Kent, Del.				1									1
Cumberland (Del. Bay)				4									4
Atlantic, N. J.	1			1	2								4
Ocean, N. J.					3			1	1	1			6
Monmouth, N. J.						1							1
Richmond, N. Y.				5	1	1	1			1	3	1	13
Kings, N. Y.						1							1
Queens, N. Y.										1			1
North Nassau, N.Y.						1							1
South Nassau, N.Y.								1					1
North Suffolk, N.Y.	1			3	2		1	1	1				9
South Suffolk, N.Y.				2									2
NE Suffolk, N. Y.			1		1	3	1			2	3		11
SE Suffolk, N. Y.					1	1				1	1		4
Westchester, N. Y.					1	1							2
Rockland, N. Y.				1	3								4
Fairfield, Conn.					5	5	3	3	3	2	1		22
New Haven, Conn.					2		2	1	1				6
New London, Conn.					1	1							2
Washington, R. I.											1	1	2
Newport, R. I.						2	1						3
N. Plymouth, Mass.										1			1
S. Barnstable, Mass.						1			1				2
Dukes, Mass.									1	2			3
Essex, Mass.					1	1	2						4
York, Maine						2							2
TOTAL	7	5	9	24	24	21	11	7	8	11	9	2	138

5. Out of the 15 striped bass caught east of Riverhead, off the southeast and northeast arms of Long Island, 13 (86.6%) were caught in the spring and fall. Only 1 fish was caught in these areas in the winter (March) and only 1 in the summer (July).

6. The 6 occurrences of striped bass in the Lower Hudson River (Rockland and Westchester counties) were all in the spring.

7. Of the 30 striped bass caught off the Connecticut coast, 27 (90%) were caught in the late spring and summer.

8. Of the 16 striped bass caught north of Washington, Rhode Island, 13 (81.2%) were caught between June and October. None were caught in the winter (January through March) or in December. It is clear that these northern areas support only a summer population.

DISCUSSION

The results reported herein generally confirm the trends discussed in the previous report. The Atlantic Coast migratory stock travels northward in the spring and southward in the fall. Only 5 (3.1%) out of a total of 138 fish were caught as far south as North Carolina. This supports Merriman's (1941) contention that North Carolina contributes little to the Atlantic Coast fishery.

The striped bass which occurred in the Hudson River were recaptured in New York Bay and Long Island Sound. The existence of a Hudson-Atlantic contingent could not be proven or disproven from these results. There is very limited fishing for striped bass in the Hudson, and the number captured is meager.

Contrary to the previous results, the West Sound contingent was not stationary. A total of 11 (61.1%) of the 18 fish which occurred off Fairfield, Connecticut were caught out of the Sound.

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

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In the Matter of

Consolidated Edison Company	)	
of New York, Inc.	)	
	)	Docket No. 50-247
(Indian Point Station, Unit No. 2)	)	

Redirect-Rebuttal Testimony of

Carl L. Newman, Vice President
Bertram Schwartz, Vice President
Harry G. Woodbury, Executive Vice President
Consolidated Edison Company of New York, Inc.

on

Restricted Operation of Indian Point 2

February 5, 1973

INTRODUCTION

In a document filed by HRFA on November 13, 1972 and entitled, "Intervenors' Statement of Contention and Matters in Controversy Concerning Environment Issues" HRFA proferred the following condition to be included in a full-power, full-term operating license for Indian Point 2:

> "During the period before a closed cycle cooling system is installed and operating, the operation of Indian Point Unit No. 2, and in particular the pumps, will be minimized during the periods between December 15 and March 1 and between June 1 and July 31. The minimizing of plant and pump operation shall be achieved by (i) scheduling all shutdowns and maintenance for the periods of restricted operation and/or (ii) restricting the operation of the plant during the periods of restricted operation to hot shutdown except when, after all other available Con Edison plants are operating at full capacity and a good faith effort has been made to purchase power from other utilities, the production of power is essential to Con Edison consumers. Such essential operation shall be limited to the minimum period and amount of power necessary to meet the needs of Con Edison consumers. Reports on each such essential operation shall be filed daily with the Commission with service on the Intervenors in this proceeding."

The peak demand on the Consolidated Edison System is likely to occur within the periods* December 15 through

*The summer peak demand occurs during June 15 through September 15 and the winter peak demand occurs during mid-December.

March 1 and June 1 through July 31. By suggesting that operation of Indian Point 2 be restricted during these periods except for the generation of essential power, HRFA has suggested that the Board license Indian Point 2 as a "peaking unit" as long as it operates with a once-through cooling system.

Consolidated Edison has conducted an analysis to determine not only the feasibility but also the consequences of operating Indian Point 2 as a peaking unit during the periods set forth by HRFA. This testimony contains the results of such analysis as well as a discussion of HRFA's suggestion to require the scheduling of "all shutdowns and maintenance for the periods of restricted operation."

The conclusion reached is that an experimental excursion into the novel operation of Indian Point 2 as a peaking unit would not only be technologically impractical but also would result in a less reliable system for Consolidated Edison and its consumers, while at the same time resulting in an economic cost of at least $70,000,000 and an environmental cost of increased air pollution.

In addition, such operation would not result in any long term nor substantial short term environmental benefits.

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Scheduled Outage

Outages for Indian Point 2 are scheduled to permit refueling and maintenance. The life of the nuclear core in the reactor is a determining factor in scheduling such outages.* If the time for the refueling outage is to be determined by a requirement in the operating license rather than by the requirements of the operation of Indian Point 2, such refueling may not correspond to the time that the core would be depleted. The result would be refueling prior to the time that it might be necessary. The economic cost of such untimely refuelings would be reflected in additional reprocessing of the fuel for the Indian Point 2 core.

Furthermore, to restrict Consolidated Edison to a firm schedule for refueling or maintenance would unduly constrain the Consolidated Edison System. The scheduling for maintenance and refueling must remain flexible and take into consideration the planned and scheduled outages of other units in the System. If other units or purchased

* Refueling and maintenance outage requires an eight-week period.

power were not available to meet demand, then Consolidated Edison would be required to reduce voltage throughout its System or curtail energy distribution on part of its System. If Consolidated Edison is required to adhere to a definite outage schedule for Indian Point 2, the necessary flexibility of its System will be curtailed.

Restricted Mode of Operation

Indian Point 2 was designed to be a base load plant. HRFA, however, has suggested that rather than Indian Point 2 being the first unit on the line and the last unit off the line, that Indian Point 2 be the last unit on the line and the first unit off the line, thus operating as a "peaking unit" to meet demand during the suggested periods. HRFA's suggestion not only results in an inefficient use of resources, expensive power generation, additional costs to the consumer and a less reliable System for Consolidated Edison (and thus for its consumers) but also the use of Indian Point 2 as a peaking unit introduces a new element into this proceeding, the operation of Indian Point 2 in an untried manner contrary to its intended design resulting perhaps in the inoperability of Indian Point 2 itself. HRFA's suggestion, although couched in terms of environmental protection, results in no substantial environmental benefit but rather in environmental detriment.

As a peaking unit Indian Point 2 would be held at hot standby during the periods of December 15 through

March 1 and during June 1 through July 31.* Actual daily power demands for the Indian Point 2 peaking unit could vary from none to continuous daily operation. When power is needed from Indian Point 2, however, the need will most likely occur during a period of rapidly increasing demand. Consolidated Edison has estimated that as a peaking unit Indian Point 2 would be required to operate the equivalent of approximately two hours per day at near rated power (and hot standby for 18 hours per day) during the suggested period of restricted operation. This is an average based on projected electric power demand, available power from planned generating capacity and planned firm power purchases.

During the hot standby mode, steam generated by the Indian Point 2 reactor (approximately three percent of the gross thermal capacity) will be discharged to one of the condensers. Consequently, one circulator pump will be

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* Since Indian Point 2 will remain at hot standby or operate at power throughout the entire period of restricted operation, such operation will not change the time nor the cost required for the cut-over outage necessary for the implementation of a cooling tower system at Indian Point.

required to operate continuously. Before Indian Point 2 increases load from hot standby, the number of pumps operating will be increased to maintain condenser vacuum. Three pumps will be in full operation before load is increased to approximately 50% of full power. Before power increases above 50%, six pumps will be in full operation. Pump startup, including evacuation of lines and clearing of inlet screens, takes approximately one hour. Therefore, it would take about one hour for pump startup to meet an instantaneous demand for power with the operation of Indian Point 2. A schedule for pump operation, condenser flow and cooling water temperature rise for an average day of peaking operation is given in Table 1.

Plant Operating Limitations

Operation of Indian Point 2 as a peaking unit with frequent ascensions to power from hot standby is limited and may be precluded by several factors. These include the buildup of xenon concentration in the fuel, the mechanical interaction between the zircaloy fuel rod clad and the oxide fuel pellets and the thermal stress limitations on the steam turbine.

Actual daily power demands requiring the use of Indian Point 2 in accordance with the restraints of restricted operation proposed by HRFA may vary from none to continuous daily operation. If the plant is needed for several days of operation at near rated power and is thereafter placed at hot standby, there will be, depending upon fuel life, a time period within which the core could not be returned to high power levels for peaking purposes due to the buildup of xenon concentration in the fuel. Xenon poisons the fuel and prevents the reactor from attaining required power level as needed. Xenon decays and is burned up with time and eventually its level and poisoning effect are reduced. For example, during the winter months of 1975 through 1979 a minimum of 19 hours after shutdown would be required before the reactor could be brought back to full power at the designed let down (or boron dilution rate) of 75 gpm. This "incapacitated period" increases with cycle burnup. The following table lists the requisite number of hours before Indian Point could be used to generate substantial power after the facility has been operated near rated power and thereafter placed at hot standby.

Period of Restricted Operation*	Incapacitated Period (hours after return to hot standby)
Dec., 73 through Feb., 74	7
June, 74 through July, 74	8
Dec., 74 through Feb., 75	10
June, 75 through July, 75	13
Dec., 75 through Feb., 76	19
June, 76 through July, 76	10
Dec., 76 through Feb., 76	19
June, 77 through July, 77	10
Dec., 77 through Feb., 78	19
June, 78 through July, 78	10
Dec., 78 through Feb., 79	19
June, 79 through July, 79	10
Dec., 79 through Feb., 80	19

*If any of these incapacitated periods were to occur at the same time that consumer demand was high or that there was a need for additional power due to unexpected outages of other equipment, the unavailability of Indian Point 2 might make necessary the curtailment of system loads by means of appeals to the public, voltage reduction, and if necessary, by interruption of service.

After the Indian Point 2 fuel has accumulated burnup, mechanical interaction between the zircaloy fuel rod clad and the oxide fuel pellets may also limit the rate at which power can be increased. Mechanical interaction does not normally compromise clad integrity unless power cycling causes rapid thermal expansion of the pellet, in which case high, localized strains in the clad may initiate failure. The operation of Indian Point 2 as a peaking unit (as suggested by HRFA) might cause sufficient pellet-clad interaction so as to compromise the mechanical integrity of the clad. However, Indian Point 2 can be operated as a load-follow unit in accordance with the provisions of its radiological technical specifications.

The steam turbine installed at Indian Point 2 was designed for base load operation; therefore, peak load operation of Indian Point 2 will be restricted by the time required for turbine loading and unloading and by the extent of thermal stress caused by cyclic operation.

When Indian Point 2 would be normally operating as a base load plant, the following restrictions would be imposed on turbine loading and unloading:

1. During cyclic load operation, changes of load and steam condition should be controlled to limit the rate of change of impulse chamber steam temperature to 125°F/hr..

2. The temperature difference between the horizontal flange and the bolts of the H.P. cylinder should not exceed 250°F.

3. The temperature difference between the horizontal flange inner surface and the inner surface at the bottom of the H.P. cylinder should not exceed 100°F.

4. Turbine exhaust hood temperature should not exceed 175°F for continuous operation. This unit is equipped with exhaust hood sprays with a temperature controller set to automatically control exhaust hood temperatures at 160°F maximum. It is suggested by the manufacturer the the use of these sprays be kept to a minimum and that proper exhaust hood temperatures be obtained by maintaining as high a vacuum as possible to the main condenser.

5. The minimum load for normal operation is 5% of the rated load. However, operation at extremely light loads for any considerable period of time is not recommended.

6. The air removal equipment should not be operated without sealing steam on the turbine glands to avoid air being drawn through them.

7. Undue heating of the low pressure portion of the turbine beyond what is required for operating under vacuum should be avoided. This is to avoid necessary stress due to expansion of parts of the exhaust chamber and possible misalignment of the L.P. Inner Cylinder and Rotor.

Empirical data from the steam turbine manufacturer indicates that the approximate first stage turbine temperature after 18 hours off the line would be 200°F. Maximum recommended rate of loading for the steam turbine up to 90% of power from this temperature is 120 minutes:

1. Accelerate turbine to synchronous speed: 10 minutes
2. Hold five percent load: 30 minutes
3. Increase load to 90 percent of full load: 80 minutes

Therefore, before Indian Point 2 could go from hot standby to substantial power to meet an essential, instantaneous demand for power two hours would be required for loading the turbine.

In addition to time restrictions for ascent to power because of design parameters of the steam turbine, turbine fatigue must also be considered. Turbine life is a function of load change and rate of load change. Although consistent with maximum recommended rate of load changes, operation of Indian Point 2 as a peaking unit, will increase the thermal stresses in the turbine and will decrease the life of turbine components. It is obvious that if the unit is run without rapid changes in temperature the life of the components will be maximized. Using the maximum recommended rate of change as distinguished from normal recommended load changes results in increased stresses which consequently would ultimately result in a reduction in the number of times the turbine could be cycled (no load to full load to no load) from 10,000 cycles to less than 2,000 cycles. If the turbine were loaded or unloaded more rapidly than the maximum recommended rate, the turbine cycling capacity would be further reduced. In addition it should be noted that thermal stress considerations preclude operation of the turbine with less than six circulating pumps except for low load conditions when three pump operation is permitted as indicated in Table 1.

System Reliability

Operation of Indian Point 2 in the manner suggested by HRFA will reduce the reliability with which Consolidated Edison can meet the power requirements of its service area. HRFA's mode of operation creates significant inflexibility in the dispatch of Indian Point 2, results in power unavailability when most needed due to xenon considerations, and jeopardizes plant components by excessive cycling. Furthermore, operation of the plant at any power level with less than six circulating pumps decreases plant reliability.

Economic Cost

If HRFA's suggestion were adopted, Consolidated Edison would be required to invert the use of Indian Point 2 in order to provide sufficient power to its service area. As a result, gas turbines which have high fuel and operating costs would be dispatched before Indian Point 2 and were be required to operate for many more hours than they were designed. Indian Point 2, which was designed as a base load unit with low operating costs, would be used as a peaking facility. Consequently, operation of Indian Point 2 as a peaking unit results not only in a misallocation of investment on behalf of the consumer but also results in a substantial incremental cost to the consumer. While Indian Point 2 remained at hot standby, replacement power would be provided by gas turbines and fossil fired steam generators in New York City and vicinity. Approximately 40 percent of the replacement power would be from additional use of gas turbines and increased use of old less efficient facilities. The remainder would be provided by operating more efficient fossil fueled steam generators. The levelized annual economic cost for replacement fuel and operation alone would be $8,600,000 or approximately $70,000,000 for an eight year period. This figure is based on an eight week maintenance and refueling schedule during the period of restricted operation. In the event, however, that power demand on the Consolidated Edison System prevented scheduled maintenance and refueling from occurring during the period of restricted operation so that such maintenance would have to occur when the unit was otherwise base loaded, the annual levelized cost would increase to $13,400,000 or $107,200,000 over an eight year period.

The costs stated are based on incremental fuel and operating costs for replacing power from one source with power from other units on the Consolidated Edison System. In the event that daily purchases of power were available from other utilities, it might be possible to further restrict the use of Indian Point 2 than had been anticipated in this analysis, but the cost of replacement power would be even more expensive. When purchasing power Consolidated Edison would not only be paying an incremental fuel cost but also would be paying an allocation for amortization of plant cost. Such daily purchases, however, cannot be anticipated at this time.

Environmental Considerations

If refueling and maintenance of Indian Point 2 occurs during December 15 to March 1, the increased operation of gas turbines and fossil-fuel fired steam generators will impose additional air pollutants to the environment. The pollutant increase will be on the order of 4,800 tons of particulate, 13,000 tons of sulfur dioxide and 21,000 tons of nitrogen, depending upon the specific dispatch over an eight year period. If maintenance and refueling of Indian Point 2 occurs during other than the peaking interval, additional use will have to be made of gas turbines and fossil fired plants. This will increase the discharge of pollutants to 6,960 tons of particulate, 18,977 tons of sulfur dioxide, and 30,280 tons of nitrogen oxide.

By operating Indian Point 2 as a peaking unit the number of fish impinged and the number of organisms entrained during the suggested periods of restricted operation would be decreased. In an attempt to quantify the decrease in fish impingement, we have assumed that Indian Point 2 would operate as set forth in Table 1. Thus using the statistics set forth in reference 1 we can apply relative cooling water flows to quantify relative effects. Six pumps operating for 24 hours or 144 pump hours per day was the basis for the estimated impingements in reference 1. The peaking mode of operation as described in Table 1 produces 48 pump hours per day. Since each pump has the same flow rate and intake velocity, the number of fish impinged with Indian Point 2 as a peaking unit might be expected to be 1/3 of the base condition. Based on these factors, the comparative number of fish impinged during June through July would be*:

Month	mean #/day at full flow (6 pumps) Base Loaded	mean #/day as peaking unit
June	423	141
July	153	51

The same method of computation can be applied to estimate the comparative number of fish impinged during December 15 through March 1.

*HRFA also suggests that the scheduled outage for refueling and maintenance should be required to be scheduled during the periods of restricted operation. Since the exact timing of the outage within the periods of restricted operation cannot be predicted, the exact reduction in impingement also cannot be predicted. The reduction for any postulated eight week refueling outage, however, can be computed from the mean number of fish per day per month. Reduction in fish impingement based on a refueling and maintenance outage, however, would occur whenever such outage was scheduled and impingement rates in reference 1 took cognizance of this reduction but on an average basis.

Month	mean #/day at reduced flow (6 pumps) Base Loaded	mean #/day as peaking unit
December 15-31	3192	1064
January	2268	756
February	11529	3843

The numbers of organisms entrained would also be decreased if Indian Point 2 were operated as a peaking unit. Based on the Table 1 mode of operation, Indian Point 2 would operate with one main pump (1/6 of total condenser flow) twenty-four hours a day and with other circulators on for approximately 8 hours per day and only in the daytime. In this mode the number of entrainable organisms passed through the plant would be substantially reduced. The reduction applied to striped bass larvae probably would exceed 80% (Reference 2 and 3).

While a decrease in impingement and entrainment can be expected, we should also expect an increased potential for thermal shock to fish in the discharge canal when Indian Point 2 is operating as a peaking unit. Although laboratory studies indicate that the potential for thermal shock exists, a thermal shock kill of fish has never actualy been observed at Indian Point. However, this effect is a consideration in deliberating the impact of cyclic operation on river biota.

Consolidated Edison has introduced substantial evidence in this proceeding which demonstrates that the impact of base load operation of Indian Point 2 is not expected to be substantial or irreversible. The testimony demonstrates that the impact of entrainment and impingement on the striped bass population with Units 1 and 2 operating as base load plants is expected to be no more than three percent after five years of base load operation. Therefore, while operation of Indian Point 2 as a peaking unit can be expected to decrease impingement and entrainment during restricted operation, the benefit is not considered substantial and the increase in discharge of air pollutants is considered environmentally detrimental. The operating, environmental and economic disadvantages of the proposed operating mode clearly exceed any potential, limited environmental benefits.

TABLE I

ASSUMED AVERAGE DAILY OPERATION OF INDIAN POINT 2

AS A PEAKING UNIT

OPERATION	TIME, HRS.	NO. OF PUMPS	FLOW, %	CONDENSER ΔT, °F
June 1 to July 31		--		
Hot Standby	18	1	17	3
Part Load < 50%	2	3	50	15
Part Load > 50%	2	6	100	7
Full Load	2	6	100	15
Dec. 15 to March 1				
Hot Standby	18	1	10	5
Part Load < 50%	2	3	30	23
Part Load > 50%	2	6	60	12
Full Load	2	6	60	24

Note: This chart of assumed average daily operation is based on anticipated plant load factors. Actual daily peaking operation will demand the unit operate anywhere from zero to full load and from no operation to continuous operation on any given day. Plant load factors at 90 percent of full load are expected to decrease non-linearly from 10 percent in 1973 to 2 percent in 1980. This represents the equivalent operation of 2.4 hours per day at 90 percent of full load in 1973 to 0.48 hours per day in 1980. In this table an average of 2 hours per day at 90 percent full load was assumed in order to facilitate the analysis presented in this testimony. During winter operation, water inlet flow is reduced by recirculating 40 percent of the cooling water through the pump and by-pass and return system. No water recirculation is used in the summer in order to keep the temperature rise of the water passing through the condenser below 15°F to insure meeting state thermal discharge criteria.

REFERENCES

1. "The Estimation of Fish Impingement at Indian Point Units 1 and 2." Testimony of Ronald A. Alevras in the matter of Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit No. 2) Docket No. 50-247, February 5, 1973.

2. "Effects of Operations of Indian Point Units 1 and 2 on Hudson River Biota." Testimony of Gerald J. Lauer, Ph.D. in the matter of Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit No. 2) Docket No. 50-247, October 30, 1972 and February 5, 1973.

3. "Effect of Entrainment and Impingement at Indian Point on the Population of the Hudson River." Testimony of John P. Lawler, Ph.D. in the matter of Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit No. 2) Docket No. 50-247, April and October 1972, February 5, 1973.

4. "A Supplementary Report on Temperature Shock Studies with White Perch (Morone Americana) and Striped Bass (Morone Saxatilis)." Ichthyological Associates Report to Con Edison, February 17, 1972.

5. "Temperature Preference, Avoidance and Shock Experiments with Estuarine Fishes." Ichthyological Associates, Bulletin 7, November 1971.

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit No. 2)	)))))	Docket No. 50-247

Redirect-Rebuttal Testimony Of
Carl L. Newman, Vice President
Consolidated Edison Company Of
New York, Inc.

On

Alternative Closed-Cycle Cooling Systems
At Indian Point 2

February 5, 1973

I. Introduction

This document presents additional technical information to supplement my testimony of October 30, 1972 on alternative closed-cycle cooling system at Indian Point 2 (follows Tr. 6254) and at Tr. 7724-39. It also responds to requests for additional information concerning implementation of cooling towers at the Indian Point site addressed to Con Edison during the recent hearing sessions. I have also attached to this document as Exhibit 4 the contour for the cooling tower described in my testimony of December 15, 1972 (Tr. 7746).

Specifically, my testimony addresses the following areas:

1. Further discussion on the construction schedule for implementing a natural draft cooling tower system at Indian Point, including engineering, hardware procurement and outage. Information on schedules at Vermont Yankee, Palisades and Michigan City No. 12 (Northern Indiana Public Service Co.) was analyzed and compared with the schedule for Indian Point 2.

2. Further discussion on direct costs for implementing a natural draft cooling tower system at Indian Point. Data from Vermont Yankee, Palisades and Northern Indiana were analyzed and compared with the cost estimates for Indian Point 2.

3. Discussion on meteorological and topographical features. Data from the Keystone and Indian Point sites were compared.

II. Schedule Details for Implementing a Closed-Cycle Cooling System at Indian Point

Table A in my October 30, 1972 testimony sets forth an approximate schedule for implementation of an alternative closed-cycle cooling system at Indian Point 2 (for convenience, Table A is attached hereto as Exhibit 1). The time requirements to "Finalize Engineering" (activity 8-9 in Exhibit 1), "Release for Bids" (activity 9-10), "Contractor Prepare Proposal and Con Edison Receive and Evaluate Bids" (activity 10-11), "Award Contracts" (activity 11-12), "Start Cut Over to Cooling Towers" (activity 31-32), and "Final Cut Over to Cooling Towers" (activity 33-34) are estimated to be, respectively, 9, 1, 6, 1, 4 and 3 months.

The first four tasks cited above would be divided into different sub-task activities as depicted in Exhibit 2. The heavy slashed line in Exhibit 2 delineates the sub-tasks representing the critical path which is equivalent to 73 weeks or approximately 17 months as indicated in Exhibit 1.

The last two "cut over" tasks, which represent the outage or downtime, would be as described in the detail shown in Exhibit 3. The critical path spans 29 weeks or approximately 7 months during which time final pipe connections, structural work and component and system testing would occur. Exhibit 3 indicates the considerable number of system rearrangements involved in making the final cut over and presents the basis for the need for a seven month outage.

The Board has requested information on actual time spent for implementing the cooling towers at Vermont Yankee (Tr. 8939-40), Palisades (Tr. 8953) and Northern Indiana (Tr. 8960). The information presented in the following paragraphs was obtained by personal communication with personnel of these utilities.

The Northern Indiana cooling tower is a hyperbolic tower designed for Michigan City Unit 12, which is a new 521 MW fossil plant. The tower, with a base diameter of 355 feet and height of 362 feet (as compared to a base diameter of 450 feet and height of 450 feet for Indian Point 2) is to be completed by the end of February 1973 as originally scheduled. The tower foundation is built on relatively flat sand-clay ground. The time requirement for site preparation is only 4 to 5 weeks (as compared to the 6-month rock excavation estimate for Indian Point). The actual construction time will be 19 months as compared to the 36 months requirement of Indian Point. The gross size difference in tower structure and extreme differences in ground conditions between Northern Indiana and Indian

Point explain the difference in construction time required for these two sites. Since the Michigan City Unit 12 station will not be ready for operation until after the complete construction of its hyperbolic cooling tower, no outage costs for installation of a tower system are expected to be incurred.

The outage time for the cut over for cooling towers at Palisades was three months. This three month outage coincided with the annual plant maintenance downtime. The three-month period was an expedited schedule utilizing two 10-hour shifts daily and 6 work days per week. This approach is not considered feasible at Indian Point due to labor productivity factors. On the basis of a standard work week the Palisades downtime would cover four and one-half months and can be reconciled with the downtime needed at Indian Point when the effort indicated in Exhibit 3 is considered. Exhibit 3 shows the scope of activities involved in the cut over, a situation peculiar to Indian Point because of the arrangement of the plant on the site.

Vermont Yankee is a new nuclear plant with a nominal rating of 514 MWe. The plant was originally designed for once-through cooling but was backfitted with two (2)

11-cell mechanical draft cooling towers. The time requirement for tower construction was approximately fourteen (14) months. Upon the completion of cooling towers, the power plant itself was still not ready for operation, therefore, no plant downtime costs were incurred.

It is difficult to make a direct comparison of the 14 month construction time of the mechanical draft cooling tower at Vermont Yankee with the 36 month construction time of a hyperbolic cooling tower system for Indian Point. The basic structural characteristics of mechanical draft cooling towers and of hyperbolic towers are different. Generally, it would take twice the time to erect a hyperbolic tower due to extent of concrete work involved as to erect a mechanical draft tower. This factor, together with the difficult site preparation situation at Indian Point and the arrangement of the Indian Point plant on its site basically reconcile the construction time differences.

III. Direct Capital Costs of An Alternative Closed-Cycle Cooling System

Capital cost comparisons among Vermont Yankee, Palisades, and Indian Point were presented during the December 15, 1972 hearing session (Tr. 7724-45). The cost adjustment reconciled the various direct capital expenditures so that they could be compared to each other on an identical basis. Five (5) adjusting indices, representing escalation, labor cost differential, power ratio, cooling element cost differential, and site preparation (excavation) cost differential were used.

For the site preparation cost adjustment, $9,000,000 representing the cost estimate for excavation at Indian Point was added to the costs of Vermont Yankee and Palisades. I have reviewed this gross site preparation cost adjustment and it is appropriate.

Palisades is a sand foundation with little or no excavation. No special structural features, such as steel piling, were required at Palisades. The exact site preparation cost differential between Palisades and Indian Point is essentially the cost of excavation at Indian Point.

Vermont Yankee has a relatively flat earthen rock foundation with virtually no excavation. No steel piling was required to install the cooling towers. The site preparation cost was less than $100,000 compared to the $9,000,000 cost of excavation at Indian Point.

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IV. Topographical and Meteorological Features at Indian Point Site

Preliminary analyses of topographic and meteorological data available at the Indian Point and Keystone sites indicate the significant peculiarities of each of these two sites. I do not agree with Dr. Aynsley's remarks that "the overall general meteorological conditions" at the Homer City and Keystone plants are "not significantly different." (Tr. 8915)

Keystone, for example, is located near Shelocta, Pennsylvania, approximately 47 miles east-northeast of Pittsburgh, Pennsylvania. Keystone is situated in a rural shallow valley with undulating terrain and gently rolling hills rising 300 to 600 feet above the nominal site terrain. The most significant topographical feature in the area is Chestnut Ridge, located about 14 miles southeast of Keystone, oriented in a NE-SW direction. Plum Creek and Crooked Creek are the major tributaries in the vicinity of the site, having a nominal width of 150 feet. NOAA meteorologist F.A. Schiermeir (1970) stated, "Influences of large-scale topography are not evident from past ground-level measurements of Keystone emissions ...."*

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* Schiermeir, F.A., 1970, Large Area Power Plant Effluent Study (LAPPES); Volume 3-Instrumentation, Procedures, and Data Tabulations, Office of Air Programs Publication APTD-0735, Environmental Protection Agency, Research Triangle Park, North Carolina.

Indian Point, on the other hand, is situated on the east bank of the Hudson River, 35 miles north of New York City, New York. The site is surrounded by high ground ranging from 600-1000 feet MSL. Immediately west of the site is the Hudson River, having a nominal width of 5000 feet. The western bank rises very steeply with maximum elevations in excess of 1000 feet MSL at Dunderberg and West Mountains, while Buckberg Mountain extends to 740 feet MSL. Two miles north of the site the Manitou peaks extend to 700 feet MSL. Toward the east, terrain rises less abruptly to 300-400 feet MSL, where Blue Mountain peaks to 600 feet MSL and Spitzenberg 560 feet MSL. Five miles downriver South Mountain peaks to 827 feet MSL. The Hudson River runs NE-SW at Indian Point and two miles north bends sharply to the northwest. South of the site the river bends southeast and widens past Croton and Haverstraw. River width ranges from 0.5 miles to 2.5 miles within a several mile radius of the site. Proximity of the surrounding elevated terrain to the river creates a distinct valley wind circulation directed along the valley axis.

Analysis of on-site meteorological conditions indicate that the effect of topography on wind direction is significant at Indian Point. The valley orientation will create a preferential wind direction as compared to wind directions over flat terrain in the area. During periods of weak pressure gradients distinct diurnal reversal of wind direction occurs.

Upvalley winds prevail during daylight hours, distinctly reversing downvalley at night. Maximum frequencies of N-NNE, S-SSE, and WNW-NW winds are observed at the Indian Point site. Also, in summer months with a light pressure gradient, offshore winds are observed simultaneously on both banks of the river during nighttime hours. Topographic features surrounding the Hudson River deflect and channel the air flow, extending vertically hundreds of feet above the valley floor.

A meteorological comparison between Keystone and Indian Point indicates that the sites are influenced by synoptic regimes of different origin. Keystone is considered to have a humid continental type of climate, partly influenced by the proximity of the Great Lakes. Indian Point has a modified continental-maritime climate, significantly influenced by the proximity of the Atlantic Ocean.

Therefore, any statement implying that the environmental impact of hyperbolic towers at Indian Point, based on local meteorological conditions, would be similar to the impact of towers at the Keystone site is highly misleading. Terrain induced meteorological effects and synoptic regimes are different at the two sites and any attempt to relate tower impact on the basis of similar conditions is not valid.

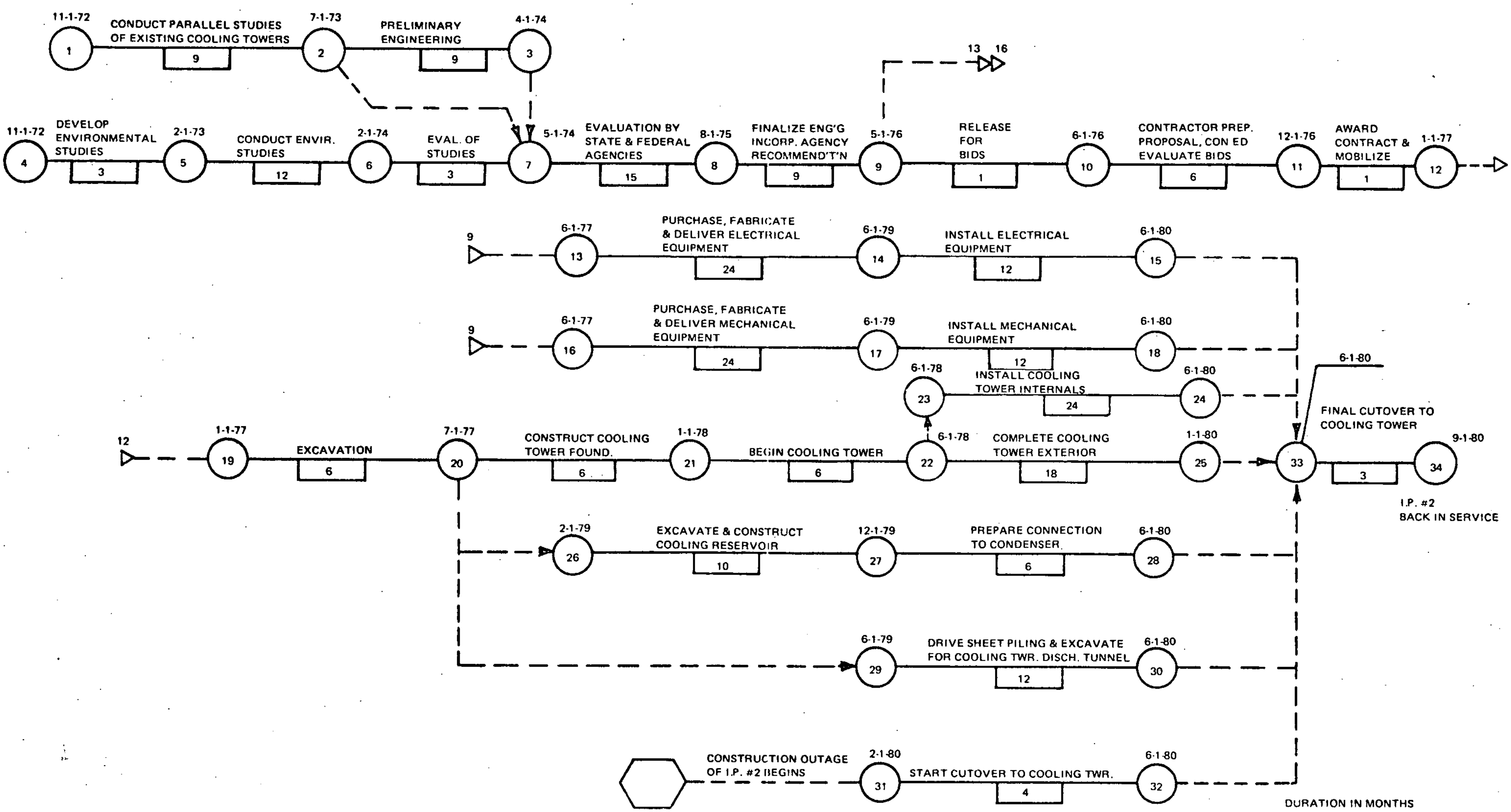
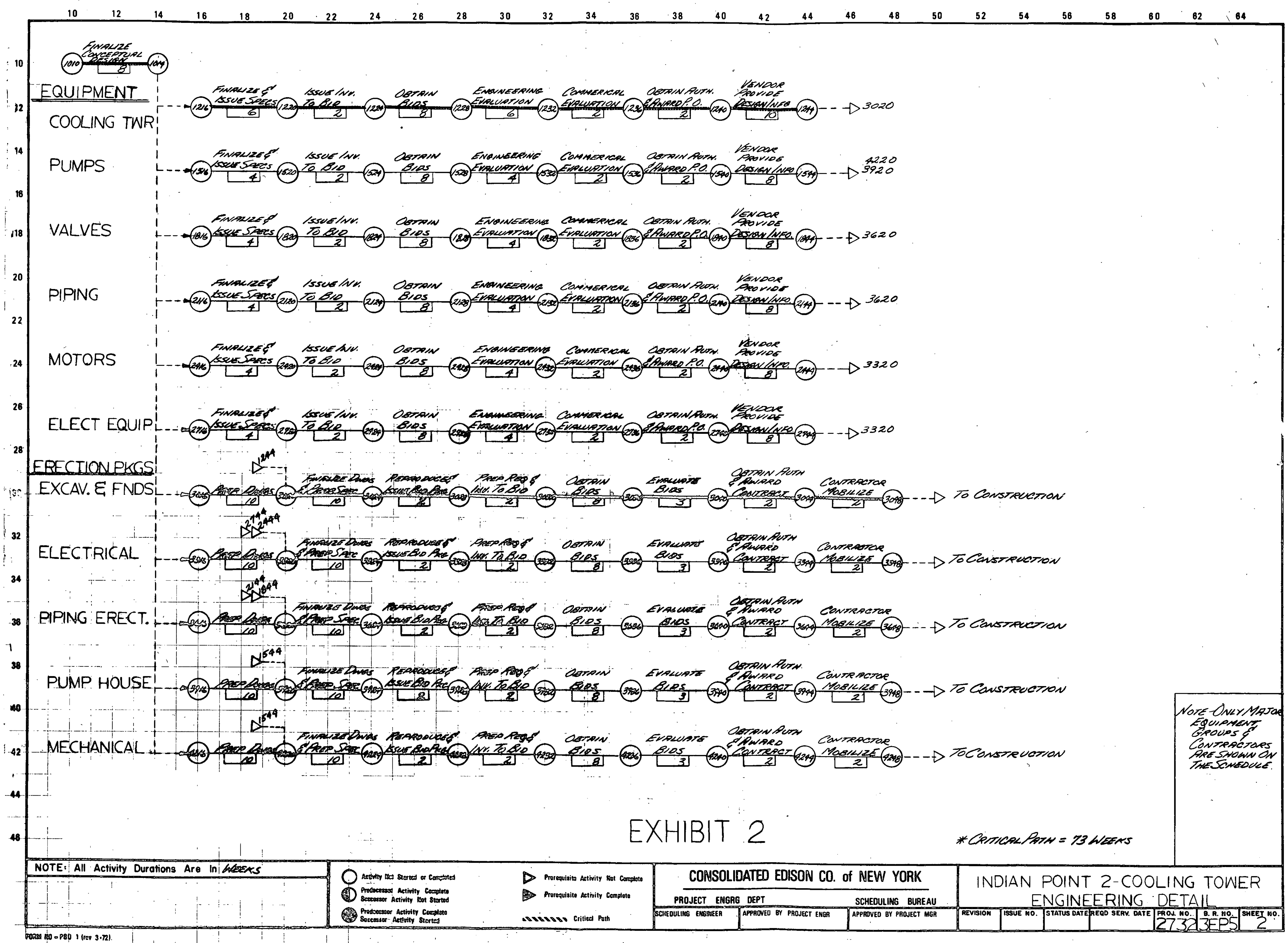
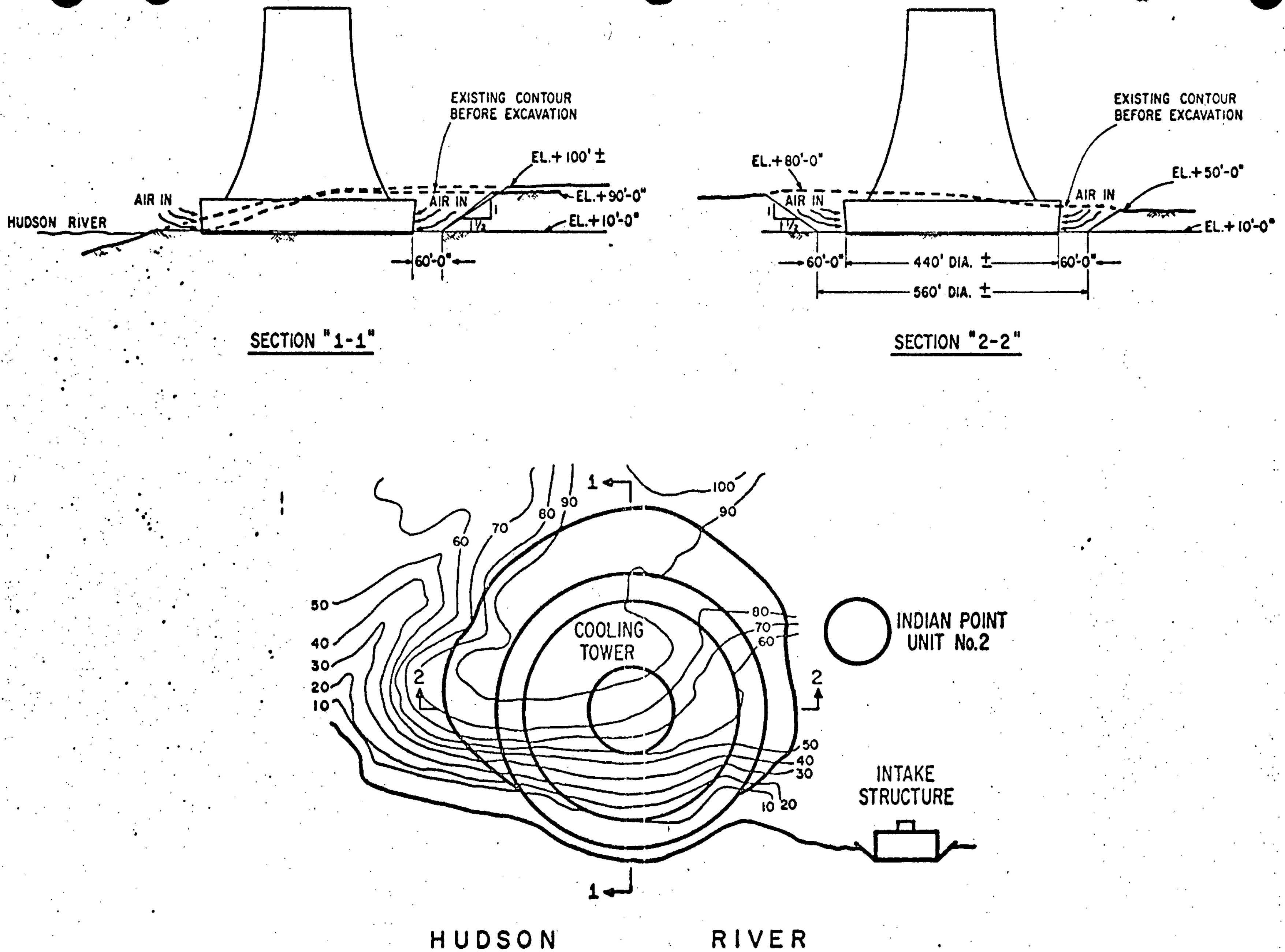


EXHIBIT 1 INDIAN POINT NO. 2 COOLING TOWER


FINALIZE CONCEPTUAL DESIGN 8
EQUIPMENT
COOLING TWR
PUMPS
VALVES
PIPING
MOTORS
ELECT EQUIP
FINALIZE & ISSUE SPECS
ISSUE INV. TO BID
OBTAIN BIDS
ENGINEERING EVALUATION
COMMERICAL EVALUATION
OBTAIN AUTH. & AWARD P.O.
VENDOR PROVIDE DESIGN INFO
3020
4220
3920
3620
3320
ERECTION PKGS
EXCAV. & FNDS
ELECTRICAL
PIPING ERECT.
PUMP HOUSE
MECHANICAL
PREP DWGS
FINALIZE DWGS & PREP SPEC
REPRODUCE & ISSUE BID PKG
PREP REQ & INV. TO BID
OBTAIN BIDS
EVALUATE BIDS
OBTAIN AUTH & AWARD CONTRACT
CONTRACTOR MOBILIZE
TO CONSTRUCTION
NOTE-ONLY MAJOR EQUIPMENT GROUPS & CONTRACTORS ARE SHOWN ON THE SCHEDULE.
EXHIBIT 2
* CRITICAL PATH = 73 WEEKS
NOTE: All Activity Durations Are In WEEKS
Activity Not Started or Completed
Predecessor Activity Complete Successor Activity Not Started
Predecessor Activity Complete Successor Activity Started
Prerequisite Activity Not Complete
Prerequisite Activity Complete
Critical Path
CONSOLIDATED EDISON CO. of NEW YORK
PROJECT ENGRG DEPT
SCHEDULING BUREAU
SCHEDULING ENGINEER
APPROVED BY PROJECT ENGR
APPROVED BY PROJECT MGR
INDIAN POINT 2-COOLING TOWER ENGINEERING DETAIL
REVISION
ISSUE NO.
STATUS DATE
REQD SERV. DATE
PROJ. NO. 2732
B. R. NO. 3EP5
SHEET NO. 2
FORM RO-PBD 1 (rev 3-72)



Natural Draft Cooling Tower
Single Tower System
Indian Point Unit 2

EXHIBIT 4

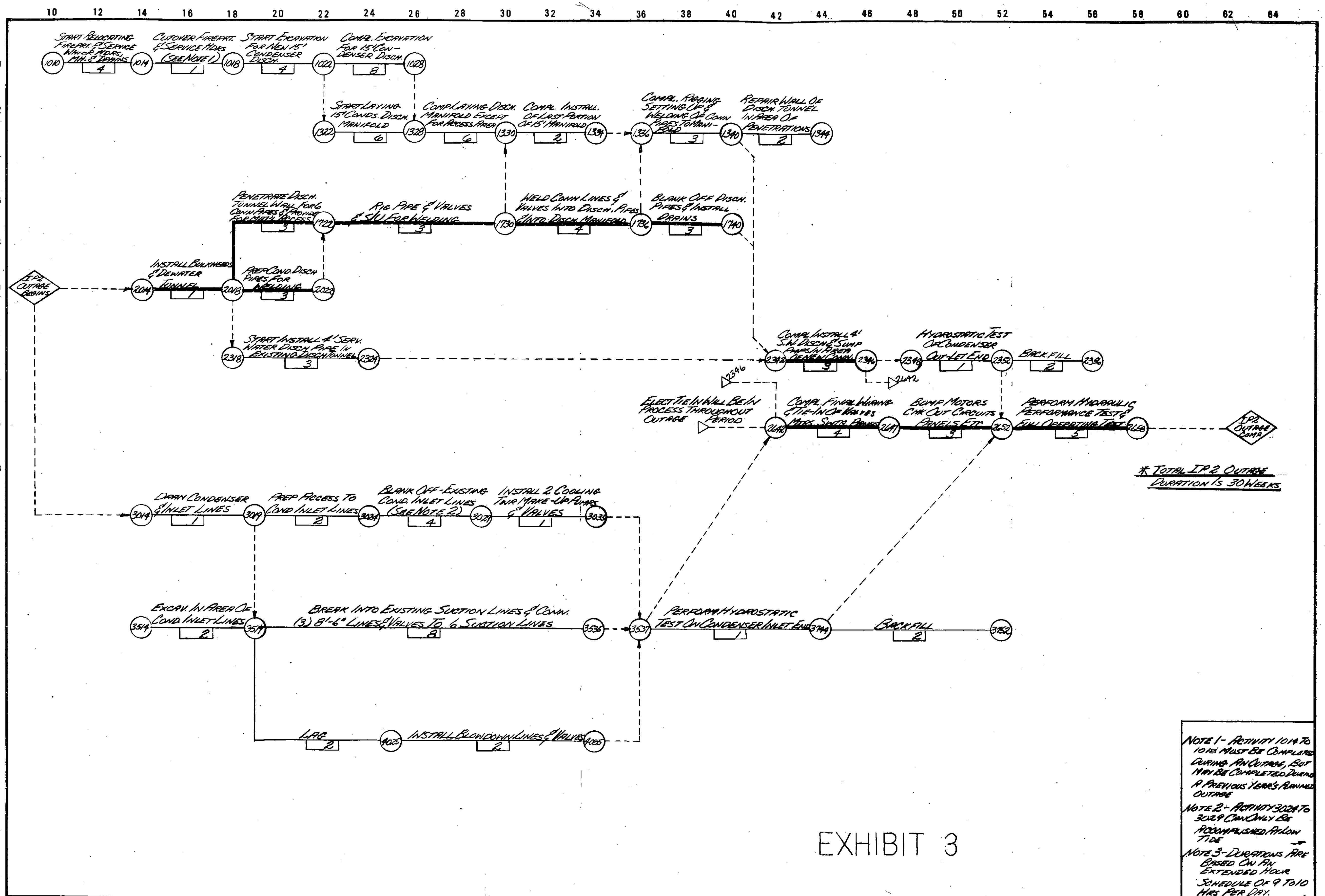


EXHIBIT 3

NOTE: All Activity Durations Are In *Weeks*

- Activity Not Started or Completed
- Predecessor Activity Complete / Successor Activity Not Started
- Predecessor Activity Complete / Successor Activity Started
- Prerequisite Activity Not Complete
- Prerequisite Activity Complete
- Critical Path

CONSOLIDATED EDISON CO. of NEW YORK

PROJECT ENGRG DEPT — SCHEDULING BUREAU

INDIAN POINT 2 - COOLING TOWER CUTOVER DETAIL

SCHEDULING ENGINEER	APPROVED BY PROJECT ENGR	APPROVED BY PROJECT MGR	REVISION	ISSUE NO.	STATUS DATE	REQD SERV. DATE	PROJ. NO.	B. R. NO.	SHEET NO.
							2732	3EP5	1

FORM NO - PSD 1 (rev 3-72)

mm2

MR. TROSTEN: The second collection of documents is additional rebuttal testimony.

There are five documents, and I will list them. All of them are dated February 20, 1973.

The first is the additional rebuttal testimony of Dr. Lauer. It is listed just as such. It has no specific title.

The second is entitled "Rebuttal Testimony of Ronald A. Alevras, Biologist, Consolidated Edison Company of New York, Inc., on The Estimation of Fish Impingement at Indian Point Units 1 and 2."

The third is additional rebuttal testimony of John Lawler on the"Mathematical Model Used by the Staff to Estimate the Effect of Indian Point Units 1 and 2 Entrainment on Hudson River Striped Bass."

The fourth is"Addendum to Responses to Questions by John P. Lawler, Ph.D., Quirk, Lawler & Matusky Engineers, on the Sensitivity of the Model Presented in the Testimony of October 30, 1972 on the Effect of Entrainment and Impingement at Indian Point on the Population of the Hudson River Striped Bass."

The fifth document is entitled, Additional Rebuttal Testimony of John P. Lawler, Ph.D., Quirk, Lawler & Matusky Engineers on the Economic Evaluation of the Impact of Indian Point Unit 2 Operation on the Middle Atlantic Fishery."

(8)